Annex 6

Report of the Working Group on
Ecosystem Monitoring and Management
(Warsaw, Poland, 6 to 17 July 2015)

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Report of the Working Group on
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Opening of the meeting

1.1 The 2015 meeting of WG-EMM was held at the Ministry of Agriculture and Rural Development, Warsaw, Poland, from 6 to 17 July 2015. The meeting was convened by Dr S. Kawaguchi (Australia). The meeting was opened by Dr M. Kaniewska-Krolak (Ministry of Agriculture and Rural Development) and Prof. P. Jonczyk (Institute of Biochemistry and Biophysics, PAS) who welcomed the Working Group to Warsaw.

1.2 Dr Kawaguchi welcomed participants (Appendix A) and reviewed the current work of WG-EMM. He also outlined the meeting's agenda that focused on the krill-centric ecosystem and issues related to the development of the feedback management (FBM) of the krill fishery.

Adoption of the agenda and organisation of the meeting

1.3 The Working Group discussed the provisional agenda. While there was no specific agenda item dealing with climate change, WG-EMM reiterated the importance of climate change in its work. The Working Group agreed to note the discussion points that were relevant to climate change for further consideration by the Scientific Committee. The agenda was adopted (Appendix B). Subgroups were formed to address detailed aspects of the agenda.

1.4 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.

1.5 In this report, paragraphs that provide advice to the Scientific Committee and its other working groups have been highlighted; these paragraphs are listed in Item 4.

1.6 The report was prepared by T. Brey (Germany), A. Constable (Australia), R. Currey (New Zealand), C. Darby (UK), O.R. Godø (Norway), S. Grant and S. Hill (UK), B. Krafft (Norway), J. Melbourne-Thomas (Australia), D. Ramm, K. Reid and L. Robinson (Secretariat), C. Reiss (USA), M. Santos (Argentina), C. Southwell (Australia), P. Trathan and J. Watkins (UK) and G. Watters (USA).

The krill-centric ecosystem and issues related to management of the krill fishery

Issues for the present

Fishing activities

Krill Fishery Report

2.1 The Working Group reviewed the draft krill fishery report (WG-EMM-15/30) noting that:

- (i) in 2013/14:
  - (a) 12 vessels fished in Subareas 48.1, 48.2 and 48.3
  - (b) Subarea 48.1 was closed on 17 May 2014 when the catch of krill in that subarea reached the apportioned limit of 155 000 tonnes
  - (c) the total catch of krill was 293 814 tonnes (WG-EMM-15/30, Appendix 3, Table 3, see also *CCAMLR Statistical Bulletin*)
  - (d) the total catch and the catch in Subarea 48.3 (75 169 tonnes) were the highest catches reported in the fishery and in that subarea since 1990/91 (WG-EMM-15/30, Appendix 3, Table 3).
- (ii) in 2014/15 (to 10 June 2015):
  - (a) 13 vessels fished in Subareas 48.1 and 48.2
  - (b) Subarea 48.1 was closed on 28 May 2015 (total catch of krill: 153 946 tonnes)
  - (c) vessels were currently fishing in Subarea 48.3
  - (d) the total catch of krill reported in catch and effort reports was 175 240 tonnes.

2.2 The Working Group noted that in 2013/14 and 2014/15 fishing occurred in Subarea 48.1 in December and January, particularly in the southern part of Bransfield Strait (Gerlache Strait). The pattern for February and March was also similar in both seasons with a focus towards Bransfield Strait in April and May prior to the closure of Subarea 48.1.

2.3 The Working Group noted that only 17 100 tonnes of krill had been taken to date from Subarea 48.2 in 2014/15 compared with 72 455 tonnes in 2013/14. Sea-ice charts for 1 May 2014 and 2015 (see gis.ccamlr.org) indicated that the northern extent of sea-ice in Subarea 48.2 was greater in 2015 than in 2014, with sea-ice extending to the South Orkney Islands in May 2015. Sea-ice extent along the Antarctic Peninsula (Subarea 48.1) was also greater in 2015 than in 2014.

2.4 The Working Group agreed that trends in sea-ice extent on the krill fishing grounds should be included in the Krill Fishery Report, noting that a routine had been developed for time series analysis of sea-ice extent in exploratory fisheries for toothfish (SC-CAMLR-XXXIII, Annex 7, paragraphs 3.18 to 3.23).

2.5 The Working Group noted that the data available to date for 2014/15 revealed discrepancies between the amounts of by-catch reported in observer and fishery (C1) data. Two vessels did not appear to be reporting by-catch in their C1 data (WG-EMM-15/30, Table 4); the observers on those two vessels had reported by-catch in 65–75% of the hauls observed.

2.6 The Working Group reiterated that the reporting of fish by-catch, other than the by-catch in the 25 kg samples collected by observers, was a vessel responsibility and should be reported in the C1 data (SC-CAMLR-XXXIII, Annex 6, paragraph 2.37).

2.7 The Working Group also noted the advice from WG-SAM-15 related to discrepancies in the reporting of by-catch in the fishery (C2) data from the Ross Sea toothfish fishery (Annex 5, paragraph 2.27). WG-SAM had requested that the Secretariat correspond with those Members that had participated in that fishery to obtain information in order to develop a better understanding of how by-catch data are collected and reported on the C2 forms.

2.8 WG-EMM agreed that the information sought by WG-SAM would also be useful in understanding discrepancies in the reporting of by-catch in krill fisheries. The Working Group requested that the Secretariat extend its correspondence on this matter (Annex 5, paragraphs 2.27i and ii) to Members involved in krill fisheries.

2.9 The Working Group thanked the Secretariat for further developing the structure and content of the draft Krill Fishery Report. The Working Group noted that:

(i) catch maps were included in an appendix, pending a decision by the Commission on the publication of such maps in fishery reports

(ii) spatial shifts in fishing areas could be illustrated in a figure that does not require maps pending the decision of the Commission in (i).

2.10 The Working Group agreed that the length frequencies for krill in Subarea 48.1 would be better represented if grouped into northern small-scale management units (SSMUs) (Antarctic Peninsula West (APW), Drake Passage West (APDPW), Drake Passage East (APDPE), Elephant Island (APEI)) and southern SSMUs (Bransfield Strait West (APBSW), Bransfield Strait East (APBSE), Antarctic Peninsula East (APE)).

2.11 The Working Group provided further editorial suggestions during the course of the meeting, and requested that the Secretariat submit a revised version of the Krill Fishery Report to SC-CAMLR-XXXIV.

Redevelopment of the CCAMLR database

2.12 The Working Group noted the Secretariat's work in redeveloping the CCAMLR database and supporting infrastructure (WG-SAM-15/33). The new structure follows an

Enterprise Data Model and will simplify the database architecture, improve data-quality assurance and modernise the workflow. As a result, data quality and database documentation should substantially improve for users from late 2015 onwards. The Working Group welcomed these developments and the resulting improved integration, inter alia, of fishery and observer data. The Working Group also noted the advice from WG-SAM on this matter (Annex 5, paragraph 2.51).

Green weight estimation

2.13 The Working Group reviewed the methods and data reported by fishing vessels in 2014/15 for the direct estimation of the green weight of krill caught (WG-EMM-15/19; see also Conservation Measure (CM) 21-03, Annex 21-03/B). Fishing vessels used five methods for directly estimating green weight: codend volume, holding tank volume, flow meter (method 2), flow scale and meal conversion. Two vessels had each used two methods concurrently.

2.14 WG-EMM-15/58 reported on a comparative analysis of data from the *Betanzos* which had used the codend volume method and flow meter method 2. The Working Group recalled that the flow meter method 2 was documented in 2014 (SC-CAMLR-XXXIII, Annex 6, paragraph 2.18), and that this was a valid method for estimating green weight. This method provided a more accurate estimate of product-to-green weight ratio than the codend method.

2.15 The Working Group considered methods used in other fisheries where small-sized fish were caught, and noted that the krill fishery differed from these fisheries in the range of methods of on-board processing. The development of methods for the direct estimation of the green weight of krill caught aimed to get precise estimates of the total amount of krill brought on board.

2.16 The Working Group considered the use of strain gauges to measure the weight of the codend as it is winched on board and tasked a small group coordinated by Dr Krafft to further investigate the feasibility of using strain gauges to measure the weight of the codends and, if feasible, to develop a protocol for trial use in 2015/16.

Fishery notifications

2.17 The Working Group reviewed notifications for krill fisheries in 2015/16 which were submitted in accordance with CM 21-03 (WG-EMM-15/30, see also www.ccamlr.org/en/fishery-notifications/notified/krill). Prior to the meeting, the Secretariat had been advised that Russia had withdrawn its notifications for the vessel *Viktoriya*, and Poland had withdrawn the *Saga*'s notifications for Subareas 48.3 and 48.4 and Divisions 58.4.1 and 58.4.2. The remaining notifications for krill fisheries in 2015/16 were considered during the meeting: Chile (2 vessels), China (8 vessels), Republic of Korea (3 vessels); Norway (3 vessels), Poland (1 vessel) and Ukraine (1 vessel) (Table 1). A total of 18 vessels had notified, with a total expected catch level of 574 000 tonnes. All vessels had notified for fishing in Subarea 48.1, and most vessels had also notified for fishing in Subareas 48.2 and 48.3. In addition, two vessels had notified for fishing in Subarea 48.4.

2.18 The Working Group noted that 16 vessels notified the use of conventional trawling and two vessels notified the use of the continuous fishing method (Table 1). WG-EMM-15/01 to 15/03, 15/08, 15/49 and 15/60 provided diagrams of trawl nets and marine mammal exclusion devices for each of the notified vessels. Codend mesh size ranged from 11 to 20 mm. Some trawl nets were made up of the same mesh in all net panels, while other trawl nets used coarse mesh in the mouth of the net with decreasing mesh sizes towards the codend. Two general types of marine mammal exclusion devices were notified for use: a panel across the mouth and a panel in the net (in front of the codend) with an escape window. Panel mesh size in these exclusion devices ranged from 125 to 300 mm (Table 1).

2.19 The Working Group also noted that (Table 1):

(i) six methods had been notified for the direct estimation of green weight of krill caught (see also paragraphs 2.13 to 2.16)

(ii) vessels used either Simrad or Furuno echosounders and 38 kHz was the most common frequency in use; some vessels used multiple frequencies ranging up to 200 kHz

(iii) vessels used either Simrad or Furuno sonars.

2.20 The Working Group recalled that the instruction manual developed by SG-ASAM for the collection of fishing-vessel-based acoustic data (Annex 4, Appendix D) was currently limited to Simrad (ES60, ES70 and EK60) echosounders. The Working Group noted that 13 of the 18 vessels notified in 2015/16 used these types of echosounder, and one vessel (*Insung Ho*) was considering installing a Simrad echosounder during the next refit.

2.21 The Working Group encouraged Members with vessels using other types of echosounders to develop data collection procedures for inclusion in the instruction manual. The Working Group also noted that further work is required before acoustic data from sonars could be used in an FBM strategy.

2.22 The Working Group noted that the expected level of catch provided in the notifications was of limited use to its work, and recommended that, instead, Members notify each vessel’s daily processing capacity (in tonnes of green weight).

2.23 The Working Group also reviewed its requirements for information on fishing gear configuration, and agreed that the following net information was essential in developing estimates of stock assessment parameters:

(i) net-mouth opening height (m)
(ii) net-mouth opening width (m)
(iii) total net length (m) (including codend, measured along the centreline of the net)
(iv) codend-mouth opening height (m)
(v) codend-mouth opening width (m)
(vi) codend length (m)
(vii) codend mesh size (mm) (stretched mesh).

2.24 The Working Group recommended that the notification pro forma in CM 21-03, Annex 21-03/A, be revised and that the parameter listed in the net configuration table be replaced with the parameters above (paragraph 2.23).

Fishing gear library

2.25 The Working Group noted the ongoing development of the CCAMLR fishing gear library (WG-EMM-15/35; see also www.ccamlr.org/node/74407). The fishing gear library is a candidate for future work to continue the Secretariat's efforts to improve the utility and functionality of the website, and the Secretariat was seeking advice in relation to:

(i) the utility, structure, function and information content of the current gear library in relation to its application in CCAMLR

(ii) possible future requirements of a gear-related resource on the CCAMLR website. For example, if future work on fishing gear selectivity is anticipated, are additional parameters that characterise specific gear-types required?

2.26 The Working Group agreed that information on fishing gears and exclusion devices was important in developing estimates of total removals from krill fisheries and estimating stock assessment parameters. Gear parameters essential to this work were identified in paragraph 2.23.

2.27 The Working Group encouraged the Secretariat to further develop the website and online forms for fishery notification, and archive gear parameters identified in paragraph 2.23 and associated diagrams of trawl nets and marine mammal exclusion devices using the gear library and vessel registry where appropriate.

Scientific observation

2.28 WG-EMM-15/06 presented a photographic reference guide to fish species of the by-catch species of the Southern Ocean. Photographs were taken by the author on board a trawler targeting Antarctic krill (*Euphausia superba*) and a longliner targeting *Dissostichus* spp. in Areas 48, 58 and 88. Dr S.-G. Choi (Republic of Korea) noted that the author would like to continue his work during the next year in other areas and would like to collaborate with other Members to progress the work. The Working Group commented on the high quality of the photographs and the format of the guide; there were a few minor identification problems noted which will be communicated to the author. It was also noted that the translations used in the guide were very useful.

2.29 The Working Group noted that a series of guides for each CCAMLR area had been developed by other Members and that there was a need to coordinate their reviews and development such that CCAMLR could make use of them as a standardised reference series. The Working Group referred WG-EMM-15/06 to WG-FSA for review and requested that WG-FSA and the Scientific Committee consider how this series of guides that are becoming available for different regions are reviewed and made available as a library to observers to facilitate their work.

2.30 WG-EMM-15/16 evaluated the spatial and temporal patterns of the length of Antarctic krill in Subarea 48.1 recorded by scientific observers. Generalised additive models (GAM) and generalised additive mixed models (GAMM) indicated that median krill length showed a complex pattern and varied significantly with fishing location, fishing depth, season, month and vessel. The paper recommended that the current sampling strategy to observe krill length in SSMUs in Subarea 48.1 needs to be modified in order to gain a comprehensive understanding of the temporal and spatial variability in krill length distribution and to determine the scale of observer coverage in the longer term. The paper also recommended that krill length measurements should be conducted on all vessels in every fishing season to reduce the likelihood of potential biases in the overall krill length estimates. In order to develop and evaluate alternative observer sampling strategies for measurements of particular properties of a krill population, the paper also proposed a simulation approach.

2.31 The Working Group agreed that evaluating the current sampling strategy for the krill observer program and modifying the design to meet the data requirements for management would be valuable and that simulation approaches would provide a useful method by which to develop and evaluate schemes. However, it noted that the analysis in WG-EMM-15/16 had been calculated on a haul-by-haul basis, whereas sampling was actually specified on a daily basis due to the use of the continuous fishing system and considered that the analysis and simulations should be conducted using this sampling approach. It also noted that the analysis in WG-EMM-15/16 had pooled the data collected by the conventional and continuous fishing systems to simulate the variability of length distribution, which would mix the effect of monitoring the different fishing patterns on the krill catch. The effect of mesh size that potentially impact on the length distribution was also excluded in the analysis. However, WG-EMM-15/16 indicated that trawl type and mesh size were highly correlated with vessel.

2.32 The Working Group noted that using fishing vessels to collect information on the krill stock, for instance for FBM, would require consideration of the fishing strategy and mesh size required by the vessel and the sampling scheme associated with it. This was noted in the review of data fitted within the integrated model (WG-EMM-15/51 Rev. 1), in which it was difficult to determine year-class strength from the observer data, potentially due to the variation in fishing behaviour. Furthermore, changes in behaviour which alter the selectivity of the fishery will also influence the dynamics of the recorded catch-per-unit-effort (CPUE) in terms of variability and trends and this was also considered within WG-EMM-15/26.

2.33 WG-EMM-15/57 Rev. 1 reviewed the observer coverage within the krill fishery which remains the only fishery within the CAMLR Convention Area that does not require 100% scientific observer coverage (i.e. having an observer on a vessel for all of the time that it was engaged in fishing for krill). The coverage in the observer scheme for the krill fishery in Area 48 during 2013 and 2014 was evaluated in terms of the spatial and temporal pattern of the fleet, by subarea and season and the composition and abundance of by-catch species.

2.34 The Working Group noted that in fisheries where 100% observer coverage was not mandatory, there was no standard metric to describe the actual level of observer coverage and, therefore, requested that the Scientific Committee develop such a metric.

2.35 A total of 15 vessels fished for krill during the 2013 and 2014 seasons, with a total fishing effort of 2 978 days and 511 500 tonnes of krill caught. Considering all vessels combined, the fleet had 65% or more observer coverage across both years, with a minimum of 58% in summer and 63% in winter. The observer coverage of the fleet across both years was 80%, equivalent to 2 382 days at sea.

2.36 The deployment of scientific observers on board krill vessel has increased significantly from 2010 onwards since the first adoption of CM 51-06 in 2009. This increase is lower in the conventional trawl fleet, while the continuous trawl fleet had very high observer coverage rates (in terms of the number of days of fishing during which an observer was on board).

2.37 The Working Group noted that, while the fishery overall fulfilled the requirement for greater than 50% coverage across the fleet, there are three vessels that had an observer coverage level below the minimum 50% requirement (CM 51-06) for 2013 and 2014. The Working Group, therefore, recommended that the Secretariat provide a review of the information to the Scientific Committee.

2.38 The authors of WG-EMM-15/57 Rev. 1 recommended that the requirements for systematic observer coverage within CM 51-06 should be applied to all subareas and that achieving the required coverage should be a requirement for a one-year rather than a two-year period. In addition, they recommended the number of by-catch samples taken during a season should be increased by increasing the minimum requirement for observer coverage and/or the number of samples taken by observers.

2.39 The Working Group agreed that there was a need to increase the observer sampling frequency for fish by-catch and that improving the sampling capability should be accompanied by increased training in the collection of the data and in the identification of fish to family level.

2.40 The Working Group noted that management advice could be provided as to the likely impact of the level of by-catch at the family level as in WG-EMM-12/28 and 12/29. These papers had estimated the likely scale of the impact of the krill fishery on fish stocks in Area 48 using data from a single vessel fishing with the continuous fishing method and the Working Group encouraged further considerations and observations to address this issue for all vessels.

2.41 The Working Group recalled the discussions at the Scientific Committee in 2014 regarding CM 51-06; there was general acknowledgement that 100% coverage (i.e. having an observer on a vessel for all of the time that it was engaged in fishing for krill) was scientifically desirable (SC-CAMLR-XXXIII, paragraph 7.16). In 2014, some Scientific Committee Representatives stressed that increasing the quality of data collected by observers was a higher priority than an increase in observer coverage. The Working Group considered this view and noted that analyses presented to this Working Group (WG-EMM-15/16, 15/51 Rev. 1, 15/57 Rev. 1) indicated that the quality is adequate, but that sampling frequency and design of the observer coverage need further development; however, it was noted that there was also a need to improve the quantity and quality of the fish by-catch sampling as well as observer training in fish identification (paragraph 2.39; WG-EMM-15/57 Rev. 1; SC-CAMLR-XXXIII, Annex 6, paragraph 2.43).

2.42 The Secretariat indicated that when each set of observer data was received, a routine data-quality report was sent to the data providers. The Working Group recommended that the number of issues identified by this process could be used as a metric to measure improvements in data quality.

2.43 Given the increase in the amount of observer data coming from the krill fishery, and the ongoing discussion on the level of coverage required, the Working Group recommended that the Scientific Committee should consider establishing a working group focussed on the CCAMLR Scheme of International Scientific Observation (SISO) to:

(i) review the krill observer coverage for the fishery and finfish by-catch
(ii) recommend sampling schemes and levels of coverage
(iii) identify where there may be a need to improve data quality
(iv) clarify the objectives of the observer data collection in different subareas and seasons.

Should such a group be established, the Working Group recommended that it coordinate with WG-FSA to determine the best temporal and spatial coverage of the finfish by-catch sampling and with WG-EMM to ensure that the data required for FBM is collected.

Krill biology, ecology and management

2.44 WG-EMM-15/05 reported on the results of a series of cruises to investigate the abundance and distribution of Antarctic krill around the Antarctic Peninsula by the US AMLR Program in winters with contrasting ice conditions.

2.45 Krill biomass and density was extremely low in offshore waters during winter compared to summer. Krill biomass was an order of magnitude higher (~5 500 000 tonnes in 2014) in Bransfield Strait compared to the summer average biomass (520 000 tonnes), and this winter concentration represents 79% of the mean summer biomass (6.9 million tonnes) in the larger (124 000 km^2) study area averaged over 19 years of surveys.

2.46 The authors argued that krill overwinter in coastal basin environments independent of ice and primary production. This overwintering occurs in areas that are becoming more frequently ice free, increasing their availability to autumn and winter krill fisheries.

2.47 The Working Group noted that the same seasonal pattern of changes in krill abundance between inshore waters in winter and offshore waters during summer had been observed in other areas along the Peninsula. The Working Group noted that estimates of krill biomass could potentially be determined more efficiently if surveys were conducted during winter when krill were concentrated in a smaller area.

2.48 The Working Group also noted that the at-sea distribution of two species of seal, crabeater (*Lobodon carcinophagus*) and Antarctic fur (*Arctocephalus gazella*) seal, was examined in this study and indicated that analysis of the at-sea distribution of other species, including birds and whales, could be useful in examining predator overlap with the krill fishery.

2.49 The Working Group also noted that the reported low ice concentrations, which could make areas accessible to the fishery in some years, highlight the importance of considering climate change in providing advice to the Scientific Committee on the future spatial distribution of the fishery.

2.50 WG-EMM-15/13 reported on the quality and quantity of acoustic data collected by Norwegian fishing vessels involved in krill fisheries and the kinds of research questions that might be addressed using acoustics on krill fishing vessels. Using data from the 2011 fishing season, the authors described standardised surveys to estimate krill biomass trends, compare the biomass patterns between the standardised survey and the fishery, and examine information on changes in vertical and horizontal distribution patterns of krill over a range of time and space scales from diel changes to longer-term (seasonal) trends.

2.51 The paper highlighted several important patterns observed in the acoustic data. Diel migration of krill to the surface was more pronounced in the fishing area than outside the fishing areas and the mean krill depth increased over the season. The paper showed that krill biomass in the fishing area is variable over the season and there is no apparent trend. The paper indicated that fishing vessel data can be used to study a variety of phenomena important for science and management, and can provide data for use in FBM approaches that might be developed.

2.52 The Working Group agreed that this paper provided a good introduction to the vast amount of data that can be collected and the types of analyses that can be conducted using data collected by fishing vessels. The Working Group encouraged the authors to continue to analyse these data and present the results at future working group meetings.

2.53 WG-EMM-15/17 Rev. 1 reported on the results of an acoustic survey for krill biomass conducted around the Balleny Islands during the 2015 austral summer. The acoustic data were analysed using two parameterisations of the stochastic distorted-wave Born approximation (SDWBA) target strength (TS) model (i.e. orientation distributions $\theta = N(11,4)$ and $\theta = N(-20,28)$) which resulted in two different estimates of krill biomass. The biomass estimated with $\theta = N(-20,28)$ was 13 750 tonnes (CV = 0.14).

2.54 The Working Group noted that the two krill orientation parameterisations resulted in similar spatial distributions of krill biomass and that the differences in total abundance arose primarily as a result of the inclusion of a small number of additional high-density swarms. Noting its previous discussions about the sensitivity of interannual variation in mean krill density estimates to the number and density of the densest krill swarms detected (SC-CAMLR-XXXII, Annex 5, paragraphs 2.39 and 2.40), and the large impact of the parameterisations of krill orientation (which is generally inferred rather than observed) on survey results, the Working Group encouraged further work to better understand krill orientation.

2.55 The Working Group emphasised that SC-CAMLR-XXIX, Annex 5, paragraphs 2.13 to 2.19, described a series of issues in the model code used to generate the original $\theta = N(11,4)$ orientation distribution. In addition, it was noted that the standard deviation of the orientation distribution should be corrected for the sample-averaging effect of orientation variance as described in SC-CAMLR-XXIX, Annex 5, paragraphs 2.27 to 2.29. Given these issues, the Working Group reiterated the SG-ASAM advice that the parameters presented in WG-EMM-11/20, Table 1, were currently the best estimates for each variable used in the SDWBA.

2.56 The Working Group further noted that, while the $\theta = N(-20,28)$ orientation distribution was the CCAMLR recommended distribution, the krill identification dB-difference window for 200–120 kHz used in WG-EMM-15/17 Rev. 1 was much smaller than the CCAMLR recommended windows provided in WG-EMM-11/20, Table 2.

2.57 Dr Constable corresponded with the authors of WG-EMM-15/17 Rev. 1 to determine whether a revision to the calculations could be progressed and completed for review by the Working Group meeting. The authors gratefully acknowledged the feedback on the paper and the issues raised with respect to the calculation.

2.58 The authors clarified that the dB-difference windows used in WG-EMM-15/17 Rev. 1 were based on the minimum and maximum dB difference range that occurred between the 2.5% and 97.5% length quantiles, but were based on the simplified SDWBA model rather than the full SDWBA model. The WG-EMM-11/20 procedure does not calculate the minimum and maximum dB difference between the 2.5% and 97.5% length quantiles, but rounded down the lower 2.5% quantile and rounded up 97.5% quantile to the nearest 10 mm (as described in SC-CAMLR-XXIX, Annex 5, paragraph 2.30).

2.59 The Working Group agreed that it was not easy to understand and implement the current protocol because different elements are distributed in different reports and publications over a series of years. In addition, there were published papers that are no longer consistent with the present protocol that are still frequently cited. The Working Group, therefore, agreed that to facilitate the implementation and citation of the current acoustic protocol, SG-ASAM should be requested to document the full protocol together with associated code in one single publication.

2.60 WG-EMM-15/21 reported on the 60th Russian Antarctic Expedition during the 2014/15 austral summer on board the research vessel *Akademik Fedorov*. The study was conducted off East Antarctica (the Cosmonauts Sea, the Commonwealth Sea and the Davis Sea). The cruise conducted studies on the plankton community structure in this region and data were collected along a cruise track that sampled from near shore to the open ocean. Samples were also collected for genetic and laboratory study.

2.61 The Working Group welcomed this contribution and noted its importance in light of the lack of data in this region compared to other areas of the Southern Ocean (e.g. Area 48). The authors were encouraged to work with other Members, including Australia and Japan, that are initiating or continuing studies in this region, and with other international programs like the Southern Ocean Observing System (SOOS).

2.62 WG-EMM-15/22 presented preliminary information regarding an opportunistic marine science survey conducted by the Australian Antarctic Division off East Antarctica during the 2015 austral summer. The study investigated the spatial variability of the prey field for penguins, flying seabirds and marine mammals in East Antarctica using three frequencies of acoustics and net tows in a series of survey boxes at the shelf slope. Additional data on small-scale variability of prey in key foraging locations near to land-based colonies of penguins and flying seabirds were also collected. The paper indicated the utility of opportunistic cruises to undertake ecosystem monitoring and research.

2.63 The Working Group noted the importance of using ships of opportunity, or of using all opportunities to collect data in the Southern Ocean in support of basic science, assessments and for data collection in support of monitoring efforts for marine protected areas (MPAs). In particular, participants noted that the ability to design and manage a survey with little advance notice was important given current funding constraints.

2.64 WG-EMM-15/14 reported on a current study into fishing net selectivity and escape mortality. This study will use field experiments, modelling and analysis to develop a prediction method for trawl selectivity and escape mortality, intended to enable the industry to optimise trawl design. The Working Group looked forward to field results, noting that an understanding of size selectivity will help with the interpretation of length-frequency data from commercial trawls. The Working Group noted the importance of this and recent studies (e.g. WG-EMM-14/14) and looked forward to seeing a completed analysis in future years.

2.65 WG-EMM-15/23 presented a histological study of krill collected in the Scotia Sea. The resulting histological atlas of healthy krill is a baseline for future research into krill pathogens. The most common pathogen identified in the study was the protozoan gut parasite gregarine, *Cephaloidophora pacifica*. There was also evidence of possible viral infection in the hepatopancreas.

2.66 The Working Group agreed with the authors that future warming may affect the susceptibility of krill to infection by disease agents which require specific temperatures for survival. Krill experience a wide range of habitats over their life span and, therefore, have complex exposure to the effects of climate change, including those mediated through pathogens. The Working Group further noted that such baseline work could be usefully developed into a long-term monitoring tool to understand how climate change could alter the distribution and occurrence of these and other diseases in krill populations. The Working Group recommended that the Scientific Committee consider how this could be progressed.

2.67 WG-EMM-15/26 reported an analysis of a standardised CPUE index and a CPUE index for each national fleet that operated in Area 48 between 2008 and 2014. The authors identified a period of high CPUEs from 2008 to 2010 followed by low CPUEs in 2011/12. CPUE then increased in 2013/14. Despite the increase, CPUE over the last two years was lower than in the period from 2006 to 2010. This pattern is apparent in the CPUE dynamics in each subarea (Subareas 48.1, 48.2 and 48.3) and SSMU analysed, regardless of the fishing method used.

2.68 The pattern was most clear in the CPUE index in Subarea 48.1, where most of the catch was from three SSMUs in Bransfield Strait. This was also the location of the highest CPUEs. CPUE varies between vessels, fishing methods, months and years. The mean SSMU-scale CPUE index for conventional trawls was higher than the corresponding index obtained using the continuous fishing method. The variability between vessels operating at the same fishing grounds is often greater than the temporal variability in CPUE. There was no effect of fishing method on vessel location. The authors proposed to analyse the effect of on-board krill processing technology on CPUE to improve understanding of the krill fishery.

2.69 The Working Group encouraged submission of further information on standardisation and model diagnostics. CPUE is a potentially useful index of fishable biomass, which could be used in conjunction with acoustic data and predator data to study krill abundance, distribution and demography. Fishers make active choices about which krill densities they fish and information about these preferences is important in the interpretation of CPUE data.

2.70 WG-EMM-15/28 presented an index of krill biomass in Area 48 based on krill abundance and size data from scientific nets (the Krillbase database, Atkinson et al., 2009). This index, together with three indices from local acoustic surveys, shows no evidence of a systematic change in krill biomass since 2000 (the year of the CCAMLR synoptic survey). The study also suggested that the trigger level is less than 2% of krill biomass estimated in any year 2000 to 2011.

2.71 Subarea surveys cover less than 25% of each subarea (48.1 to 48.3) but generally detect substantially more krill biomass than would be taken if the relevant subarea catch limits specified in CM 51-07 were to be achieved. The paper suggested that at the area scale the trigger level is appropriate for achieving the Commission's Article II objectives for the krill stock, but recalled that neither the trigger level nor the subarea catch limits are intended to manage localised fishery impacts on krill predators.

2.72 The Working Group agreed that if catches at the subarea trigger level were to be taken in a few SSMUs, as is gradually occurring with concentrated fishing, then the Commission's objectives may not be achieved. Catch-to-survey-biomass ratios exhibit high values when krill biomass is low in extreme years and in such cases spatial management of the krill fishery at the SSMU scale is likely to be required to ensure precautionary management at such scales.

2.73 WG-EMM-15/28 also assessed catches and catch limits relative to the lowest biomass observed in a time series. The Working Group supported this approach, noting that the single available B_0 estimate, from the CCAMLR-2000 Survey, gives limited information on the pre-exploitation state of the krill stock.

2.74 The Working Group agreed that current levels of catches are not observed to cause a trend in krill biomass and noted that the paper's comparison of catch and catch limits to krill biomass indices is useful for providing advice. It is important to maintain the current suite of time series to indicate krill abundance and the local processes that influence its variability. Early detection of systematic changes to krill abundance may be difficult with these relatively short and highly variable time series, but the probability of reliable detection will increase with the length of the time series, especially if the spatial replication is maintained.

2.75 WG-EMM-15/45 demonstrated that it may be possible to use annular growth bands in krill eye stalks to age krill. Studies demonstrate that the number of growth bands is consistent with the known age of laboratory-reared krill. The nominal age-at-length based on krill growth models is also consistent with the age indicated by annular rings in wild-caught krill.

2.76 The Working Group agreed that the ageing of krill is important and encouraged the authors to continue their work.

2.77 WG-EMM-15/P08 reported an analysis of the salp species *Salpa thompsoni* in the Drake Passage. This species competes with krill for food, has a very patchy distribution and can use two contrasting reproductive strategies. The dominant sexual reproductive strategy was found in both the north and south of the Drake Passage, while the more efficient asexual strategy was found only in the warmer conditions in the north of the Drake Passage. Development was also more advanced in the north. The paper concluded that climate change is likely to lead to increasing populations of *S. thompsoni*.

2.78 The Working Group noted that WG-EMM-15/P08 and 15/23 highlight the importance of considering the potential effects of climate change on all components of marine ecosystems, including in the planktonic community, as some of these are likely to drive changes in krill and dependant and related species.

2.79 WG-EMM-15/24 reported on research to understand the relative importance of the advection of krill by the prevailing geostrophic currents around South Georgia as an example of the importance of water replacement to the catch rates of krill. The authors calculated that the full volume of the water, and thus krill, in each SSMU is replaced between six and eight times during the fishing season. Some evidence of the significant krill flux in Subarea 48.3 was illustrated from the fluctuations of krill density over the fishing grounds in different months from 1988 to 1990 from multiple acoustic surveys in the local area. The authors concluded that the harvest-rate indicators should be estimated against krill biomass available in subarea/SSMUs during a year or fishing season and krill catch limits based on single surveys can underestimate the total biomass of krill available to krill-dependent predators and the fishery. The authors further argued that the FBM must properly account for this water replacement when developing conservation measures.

2.80 The Working Group noted that the calculation of flux and the relationship with the replacement rate of krill biomass in fishing areas is a source of uncertainty in the management of the krill fishery and determining fishery impacts on krill-dependent predators.

2.81 The Working Group noted that the geostrophic method for determining replacement is potentially useful, however, newer oceanographic models that can examine onshore and offshore flows and eddies and can include biological processes like vertical migration (see for example WG-EMM-14/08) could ultimately provide more precise and accurate calculations for most areas where fishing occurs. The Working Group also noted that acoustic data collected by the fishery may also provide a method for estimating the flux of krill in fishing areas.

2.82 WG-EMM-15/40 examined catch among subareas over the last four fishing seasons and argued that, while CM 51-07 has been effective in redistributing krill catch in a manner envisaged by the Commission, the closure of the krill fishery in some subareas early in the season is inflexible and has the potential to impact the economics of the fishery. The authors proposed that catch percentages be modified for all subareas, including an increase in Subarea 48.1 to 50%. Additionally, the authors argued that catch limit percentages should be re-examined biennially.

2.83 The Working Group noted that there was no scientific basis provided by the authors to support the changes to the conservation measure. The ultimate determination of catch limits or allocations is an item for the Commission to decide, and the Working Group, therefore, referred the paper to the Commission.

Role of fish in the ecosystem

2.84 WG-EMM-15/52 documented long-distance movements and site fidelity of Type C killer whales moving between the southern Ross Sea (74–77°S) and subtropical New Zealand waters (31–35°S), with tagged whales moving from Terra Nova Bay to the Kermadec Trench and photo identification matches between southern McMurdo Sound and the northeastern coast of New Zealand's North Island. Scars consistent with cookiecutter shark (*Isistius brasiliensis*) bites that are considered to have occurred north of 50°S were observed on more than one-third of individuals photographed in the southern Ross Sea, indicating such movements may be relatively common. The whales show evidence of site fidelity between years in both regions, with photographic matches of individuals up to a decade apart. The authors noted that the annual retreat and break-up of coastal sea-ice in the southern Ross Sea permits Type C killer whales to forage in areas of relatively shallow bathymetry where they can target prey such as silverfish in Terra Nova Bay or the large sub-adult and adult toothfish found in McMurdo Sound (e.g. WG-EMM-14/52).

2.85 The Working Group noted the value of odontocete distribution studies, given most cetacean tagging studies conducted in the Southern Ocean have focused on mysticetes. It encouraged stable isotope analysis to help elucidate trophic relationships as well as genetic comparisons between areas and with sympatric killer whale ecotypes. Dr Watters noted similar tagging studies had been conducted by US scientists and these studies yielded similar results. A combined analysis of the data from the New Zealand, Italian and US efforts would be powerful.

2.86 The Working Group noted the importance of monitoring the availability of Type C killer whale prey in McMurdo Sound and Terra Nova Bay. It recalled that toothfish monitoring in these areas was an objective of the proposed Ross Sea shelf survey (WG-SAM-15/45) considered at WG-SAM (Annex 5, paragraphs 4.23 to 4.26), while acoustic monitoring of silverfish in Terra Nova Bay was an objective of the New Zealand–Australia Antarctic Ecosystems Voyage (WG-EMM-15/56) discussed below (paragraph 2.93).

2.87 The Working Group recalled the discussion of papers on killer whale depredation (WG-SAM-15/27 and 15/28) at WG-SAM (Annex 5, paragraphs 2.56 to 2.61). The Working Group agreed that there was a risk that depredation by killer whales could occur in the southern Ross Sea in the future, given observed killer whale depredation behaviour in other CCAMLR fisheries. The movements of Type C killer whales from the Ross Sea may also mean that they encounter longline fisheries outside the Convention Area. The Working Group recommended that depredation mitigation and management options for the Ross Sea be considered by the intersessional group formed by WG-SAM, led by Drs M. Belchier and M. Söffker (UK), and be presented for consideration by WG-FSA and the Scientific Committee.

2.88 The Working Group recalled the suggestion of WG-SAM that WG-EMM and WG-FSA consider the process by which the three parts of the depredation issue (mitigation, impacts on stock assessments and ecosystem effects) might be addressed in the coming years so that recommendations can be made to the Scientific Committee (Annex 5, paragraph 2.60). The Working Group requested that the Scientific Committee consider the best mechanism to address all aspects of the depredation issue. It noted that one mechanism might be a group to consider top–down structuring mechanisms for ecosystems, which would be a broad topic of interest to SC-CAMLR, not just in relation to killer whales.

2.89 WG-EMM-15/53 examined the hypothesis that predation release of Antarctic silverfish (*Pleuragramma antarctica*) due to fishing of Antarctic toothfish (*Dissostichus mawsoni*) could have contributed to the large increase in the number of breeding pairs of Adélie penguins (*Pygoscelis adeliae*) at breeding colonies in the southern Ross Sea. However, as the mass of silverfish estimated as being released from predation by fishing was equivalent to only about 2% of the amount of silverfish consumed annually by Adélie penguins in this region, the authors concluded that the increase in penguins is inconsistent with the predation-release hypothesis. The authors encouraged the development of further specific testable hypotheses on fishing effect mechanisms that could affect Adélie penguins in the Ross Sea.

2.90 The Working Group noted there had been a previous diet study in 1978, 1979 and 1981 that indicated toothfish in midwater in the southern McMurdo Sound may have a greater proportion of silverfish in their diet compared to those at the bottom (Eastman, 1985). It noted that sensitivity analyses may be insightful to assess the proportion of silverfish in the diet of toothfish that would be required to generate the observed increases in the number of Adélie penguin breeding pairs. At the request of the Working Group, the authors of WG-EMM-15/53 have completed additional sensitivity analyses for presentation to WG-FSA.

2.91 The Working Group noted that the diet samples used in the analysis in WG-EMM-15/53 were obtained from 422 *D. mawsoni* stomachs collected over the Ross Sea shelf using bottom longlines as part of dedicated systematic surveys between 2011/12 and 2013/14 (WG-FSA-12/41, WG-SAM-13/32, WG-FSA-14/51). It noted the importance of diet samples being obtained over the relevant spatial and temporal scales. The Working Group recommended that research be conducted using vertical longlines to sample large neutrally buoyant *D. mawsoni* over the Ross Sea shelf to obtain information on their vertical distribution and associated diet in midwater.

2.92 The Working Group noted the value of studies that test hypotheses of importance for management. It recommended the consideration of alternative hypotheses to explain the observed increases in the number of Adélie penguins breeding in the southern Ross Sea. It noted the importance of identifying mechanisms driving population trends, irrespective of their direction, and recommended that future analyses consider intrinsic factors such as breeding success and recruitment, extrinsic factors such as ice conditions, and alternative model structures such as metapopulation models.

2.93 WG-EMM-15/56 provided an overview of the New Zealand–Australia Antarctic Ecosystems Voyage to the Ross Sea on the New Zealand research vessel *Tangaroa* that undertook ecological studies of marine food webs of importance to top predators to help quantify key structural and functional components of the Ross Sea ecosystem to further develop ecosystem models. The objectives of the voyage were to: (i) determine factors influencing the abundance and distribution of humpback whales around the Balleny Islands; (ii) assess habitat characterisation of blue whale foraging 'hotspots' in the northern Ross Sea; (iii) conduct a demersal trawl survey of the Ross Sea slope; (iv) deploy a moored echosounder to study Antarctic silverfish spawning in Terra Nova Bay during winter; and (v) undertake oceanographic and atmospheric observations of the Southern Ocean. Data collection for all five science objectives was successfully completed. Analyses are ongoing and results will be presented to CCAMLR in the coming years.

2.94 The Working Group recognised the value of this collaborative research cruise and noted that the first results from the voyage were presented in WG-EMM-15/17 Rev. 1 (paragraph 2.53). The Working Group also welcomed the clarification that the data obtained from the survey would be made available to Members either on request or via the International Whaling Commission's Southern Ocean Research Partnership.

Feedback management (FBM)

2.95 Dr Kawaguchi introduced the topic of FBM for the krill fishery, noting:

(i) the adoption of the staged approach (SC-CAMLR-XXXII, paragraph 3.15) and the need to move towards stage 2 of that approach

(ii) that stage 2 involves increasing catches from the trigger level (CM 51-01) to a higher interim catch limit and/or changes in the spatial distribution of catches that are adjusted based on decision rules that take account of results from the existing CCAMLR Ecosystem Monitoring Program (CEMP) and other observation series

(iii) possible tools for developing stage 2 include increasing the frequency of krill surveys and expanding the number of CEMP sites or sites where predator monitoring compatible with CEMP is conducted, and use of land-based and at-sea monitoring combined in space and time

(iv) at-sea monitoring and CEMP need to be undertaken in a practical and feasible way, with documented standards and protocols, and in areas relevant to managing krill harvesting

(v) the implementation of stage 2 will require managing the risks with an appropriate level of confidence, while using any opportunity to learn about the regional ecosystem to improve CCAMLR's ecosystem approach to harvesting (SC-CAMLR-XXX, Annex 4, Figures 3 and 4)

(vi) that the conservation measure for exploratory krill fisheries (CM 51-04), includes the concept of the data collection plan, together with agreed catch limits, which could also be used to enable further development of FBM approaches, particularly if there are research requirements to test different views on what is needed.

2.96 Dr Kawaguchi encouraged the Working Group to examine the strengths, gaps and limitations of the different approaches tabled for discussion (WG-EMM-15/04, 15/10, 15/11, 15/33, 15/36, 15/55 Rev. 1) and to consider the possible synergies between candidate approaches, particularly with regard to their principles and properties and proposed decision rules, assessment methods and data requirements. He also encouraged the Working Group to consider how CCAMLR might begin implementing any of the approaches.

2.97 The Working Group agreed that a written history documenting the development of CCAMLR's approaches to managing the krill fishery would be useful in order to keep both scientists and managers abreast of methods, issues and resolutions considered in the past. It recalled the discussion on this topic last year (SC-CAMLR-XXXIII, Annex 6, paragraph 2.7) and agreed to discuss this under future work (paragraphs 5.16 and 5.17).

2.98 To help provide some general background for discussions at the Working Group, Dr C. Jones (USA) presented the talk he delivered to the Commission in 2014 (CCAMLR-XXXIII, paragraphs 5.11 and 5.12), which covered the following points:

(i) the concept and general processes of FBM

(ii) the Commission's conclusion of FBM as the best approach to achieve Article II of the CAMLR Convention, and the interim precautionary approach as FBM is developed

(iii) the spatial footprint of the krill fishery becoming increasingly constricted from the entire Convention Area to very limited regions within Area 48

(iv) a historical summary of the Scientific Committee's progress toward approaches to FBM

(v) recent developments and adoption of the current staged approach.

2.99 The Working Group noted that fisheries may affect krill predators through a number of mechanisms, including, inter alia:

(i) removal of krill
(ii) disturbing feeding behaviour of predators
(iii) disrupting distributions of krill
(iv) enhancing foraging success of predators.

2.100 The Working Group agreed to structure the reporting of its discussions in the following manner:

(i) Submitted approaches, considering the submitted approaches and how to progress them:

(a) FBM in Subarea 48.1 (paragraphs 2.102 to 2.110)

(b) development of FBM in Subarea 48.2 (paragraphs 2.111 to 2.120)

(c) a general approach to FBM at the SSMU scale (paragraphs 2.121 to 2.126)

(d) general points for developing these approaches (paragraphs 2.127 to 2.132).

(ii) General considerations for management of the krill fishery, considering current issues, developing stage 2 and FBM generally:

(a) state of the krill-based food web at present (paragraphs 2.133 to 2.141)

(b) precautionary requirements for predators at SSMU-scales (paragraphs 2.142 to 2.145)

(c) using existing data and monitoring (paragraphs 2.146 to 2.148)

(d) further development of at-sea monitoring and CEMP sites (paragraphs 2.149 to 2.153)

(e) structured fishing to further FBM (paragraphs 2.154 and 2.155)

(f) implementation of FBM (paragraphs 2.156 to 2.158).

(iii) Future work to progress stage 2, considering the next steps in developing FBM (paragraph 2.159):

(a) current state of the krill-based ecosystem and the fishery (paragraphs 2.160 and 2.161)

(b) stage 2 subdivision of catch and/or update of trigger level (paragraphs 2.162 and 2.163)

(c) precautionary requirements for predators at SSMU scales (paragraph 2.164)

(d) krill surveys and CEMP in stage 2 (paragraphs 2.165 to 2.173)

(e) general (paragraphs 2.174 to 2.178).

2.101 The Working Group noted that terms used to describe the different spatial scales of the krill-based ecosystem can be confusing. In this respect, the Working Group adopted the following terms as part of its discussion:

(i) area scale – the scale approximated by the size of the CCAMLR-2000 Survey (Trathan et al., 2001)

(ii) subarea scale – the scale approximated by the size of subareas in Area 48; pelagic SSMUs are close in scale to the subarea scale

(iii) SSMU scale – the scale approximated by the size of coastal small-scale management units but noting that actual locations of interest may be within one or among more than one SSMU depending on the location.

Submitted approaches

FBM in Subarea 48.1

2.102 Dr Watters presented details on two FBM approaches that were proposed for implementation in Subarea 48.1. The first of these approaches is outlined in WG-EMM-15/04, the second in WG-EMM-15/33. Neither approach was designed to include structured fishing (in this context, where the spatial distribution of catches would be pre-specified with the objective of learning how fishing might impact krill-dependent predators) or reference areas (areas that might be closed to fishing to facilitate comparisons with areas that are open to fishing). The proposed implementation of both approaches would follow a common time line:

(i) A ‘base’ catch limit would be established for Subarea 48.1 on 1 December. The base catch limit would be determined using an integrated assessment model and decision rules that are analogous to the current decision rules for krill.

(ii) Monitoring data (CEMP data and data collected from the fishery) would be collected from approximately October to March and submitted to the Secretariat by 15 March. The Secretariat would process these monitoring data and determine whether to adjust the catch limit using new decision rules. The adjustment would occur on 15 April and apply for the remainder of the fishing season.

(iii) The catch limit would reset to its base on 1 December, and the process would repeat for four fishing seasons. After the fifth fishing season, the base catch limit would itself be reset.

2.103 WG-EMM-15/04 outlined an approach to increase catches from the base catch limit. The upward adjustment would occur if a suite of CEMP observations indicated that krill-dependent predators were successful during the breeding season and standardised monthly surveys conducted by krill fishing vessels indicated stable or increasing biomass of krill. The upward adjustment would apply at the subarea scale and the approach is intended to allow the fishery to capitalise on favourable conditions.

2.104 WG-EMM-15/33 outlined an approach to decrease catches from the base catch limit. The base catch limit would be distributed among groups of SSMUs (e.g. to the Bransfield Strait SSMUs and Drake Passage SSMUs) based on agreed ‘allocation fractions’ that would be specified in advance. Downward adjustments from these default allocations would be based on CEMP observations of penguin fledging mass and age at crèche. Data collected at Cape Shirreff and Copacabana indicate that both fledging mass and age at crèche are related to survival during the birds’ first one or two years of independence, and previous work (e.g. Hinke et al., 2007) has demonstrated that overwinter survival of newly independent birds is a primary driver of trends in penguin abundance. Catch limits would be adjusted according to the lower catch limit of those determined from application of decision rules based on observed fledging masses and ages at crèche respectively. This is intended to reduce catches when penguin survival is expected to be below a critical threshold during the forthcoming austral autumn and winter. The downward adjustments would apply to groups of SSMUs and be determined by species-specific decision rules. For example, if the fledging mass of Adélie penguins was below its threshold, the catch limit might only be reduced in the two Bransfield Strait and the Antarctic Peninsula East SSMUs. The authors of WG-EMM-15/33 used data from winter tracking studies to suggest groups of SSMUs relevant to each of the three Pygoscelid penguins and noted that a new network of remote cameras being installed within Subarea 48.1 would provide increased monitoring of age at crèche.

2.105 The Working Group noted that the FBM approaches proposed in WG-EMM-15/04 and 15/33 could be combined. A hybrid approach that allows for increased catches when conditions are favourable and decreased catches when poor conditions are predicted from leading indicators of predator success would capitalise on useful elements of both approaches. Similarly, the approaches proposed for Subarea 48.1 could be harmonised with that proposed in WG-EMM-15/55 Rev. 1 by using krill density, rather than krill biomass or predator success, as an indicator. Harmonisation with the approach proposed in WG-EMM-15/10 could be accomplished by including a reference area in the design for Subarea 48.1.

2.106 The Working Group also noted that in-season adjustments to catch limits like those proposed for Subarea 48.1 might be difficult to implement and be problematic in an Olympic fishery (e.g. the base catch limit might be taken before the desired data could be collected or the adjustment could be made). An alternative that could work in both cases would be to delay starting the fishing season in Subarea 48.1 until March or April, after some monitoring data were already collected.

2.107 Some participants questioned whether CEMP data could be used in decision rules to adjust catch limits for the krill fishery, at least during stage 2 while uncertainties about functional relationships between krill and krill predators are large. It was, therefore, suggested that available data from Subarea 48.1 be used to explore functional relationships. It was further suggested that future work to evaluate candidate feedback approaches (paragraphs 2.109 and 2.110) include analyses that compare the effects of using and omitting CEMP data from decision rules that adjust catch limits.

2.108 Several topics need to be addressed to advance the approaches presented in WG-EMM-15/04 and 15/33 (or a hybrid of them) during the coming intersessional period so that an FBM strategy could be considered for implementation in Subarea 48.1. Specific issues are identified in Table 2, and general issues are outlined below.

2.109 To advance implementation of the approaches proposed for Subarea 48.1, it will be necessary to parameterise candidate decision rules for each approach, or for a hybrid approach, and evaluate the expected consequences for krill, predators and the fishery of applying these candidates. Parameterisation of decision rules includes specifying thresholds, acceptable probabilities that these thresholds are exceeded and the nature and level of adjustment that would occur through application of the rules. The expected consequences of applying candidate decision rules should be quantified in terms of risks, mean effects and variability in the effects.

2.110 Candidate decision rules would be evaluated with simulation models, empirical analyses of time-series observations, and/or other methods, depending on the complexity in understanding the relative effects of the rule on krill, predators and the fishery. Using simulation models might take several years and delay implementation of stage 2. Retrospective analyses using, or based on, data already available from Subarea 48.1 could be undertaken relatively easily in the coming year and allow implementation of stage 2 to progress in the near term. These latter efforts should aim to fill the blanks in statements like 'if decision rule __ had been implemented in year __, catches might have been __ and predator success might have changed by __'. Potential impacts on predator success could be evaluated over the short (e.g. foraging-trip durations), medium (e.g. survival from fledging to first breeding) and long term (e.g. trends in breeder abundance), each of which may have different implications for parameterisation and implementation of the candidate decision rules.

Development of FBM in Subarea 48.2

2.111 WG-EMM-15/10 presented an outline proposal for a structured experimental framework for managing krill in Subarea 48.2. Dr Trathan referred to WG-EMM-14/04 which concluded that movement towards stage 2 in Subarea 48.2 would be highly improbable based on the current level of ecological knowledge; he indicated that the experimental framework described in WG-EMM-15/10 was therefore intended to improve levels of relevant management information. He emphasised that the framework would develop over time, based on advice from WG-EMM and the Scientific Committee. He indicated that WG-EMM-15/10 does not attempt to answer all questions, as he foresaw that part of the process of implementing a structured experimental approach would depend on scientific, logistical and analytical contributions from many different Members. The object of WG-EMM-15/10 was therefore to initiate a discussion about how CCAMLR might proceed in Subarea 48.2.

2.112 Dr Trathan suggested that a complete experimental framework would need to encapsulate a number of clearly articulated hypotheses, an ordered and well-designed research strategy, a list of expected outcomes and an appropriate risk analysis. All of these should form the focus of community effort and could be led by an appropriately qualified task-team. He suggested that without an appropriate level of community involvement, the necessary level of scientific information might not be available, and therefore the catch limit in CM 51-07 would be unlikely to change in Subarea 48.2 such that the krill fishery would remain under-developed.

2.113 WG-EMM-15/10 proposed that, given the highly localised nature of the krill fishery in Subarea 48.2, it is plausible the fishery could be managed using acoustic information collected by the fishery in order to assess whether the stock is likely to fall below some previously agreed threshold.

2.114 WG-EMM-15/10 suggested that the experimental framework should focus on the relationships between oceanography, krill abundance and predator populations, and determine how krill fishing might modify these relationships. The proposed framework includes the use of CEMP sites, remote cameras at important land-based predator breeding colonies, oceanographic moorings with acoustic sensors, acoustic data capture during fishing operations and repeated acoustic surveys. The paper proposed that the experiment should be evaluated after five years in order to explore initial results and to determine if the experimental framework should be continued.

2.115 WG-EMM-15/10 proposed that there should be two temporal phases to the experiment: an initial phase of two years, with a fixed catch limit, and a second phase of five years with a variable catch limit. The purpose of the first phase would be to collect information on inter- and intra-annual variability in krill biomass and baseline information on predator (penguins and cetaceans) populations. The purpose of the second phase would be to test and refine a management strategy for maintaining krill biomass above an agreed reference level. Phase two of the experiment is potentially a complete FBM approach which modifies catch limits in response to information about the krill stock and uses information about krill predators to assess and control impacts. However, Dr Trathan indicated that at the moment, it is premature to predict the outcomes of the experiment and the form of the eventual long-term management strategy.

2.116 WG-EMM-15/10 identified that the spatial framework for the experiment includes two areas with contrasting levels of fishing. Currently most harvesting already occurs within the South Orkney West (SOW) SSMU, so most fishing vessels could participate in the proposed experiment. If the South Orkney North East SSMU and/or the South Orkney South East SSMU were to be closed to harvesting, this would represent a risk to the fishery. However, 95% of the historical harvest in Subarea 48.2 has taken place in the SOW SSMU, so the risk to the fishery would be small while the potential increases in management information could be significant. The trade-off between risk to the fishery and increase in management information will need to be evaluated.

2.117 The two areas with contrasting levels of fishing should each have land-based predator monitoring, at-sea predator monitoring and acoustic surveys to assess ecological status. The design of the monitoring system will need to be evaluated to ensure that observed differences between the contrasting areas help provide evidence to enable scientific advice as to whether the fishery is having an impact upon krill-dependent predators.

2.118 WG-EMM-15/10 included a proposed set of restrictions and rules that elucidate how the candidate FBM approach could work. These identify catch limits for the two areas of contrasting harvest, details of how the phased approach might develop into the future, proposed harvesting limits and how these might change and a default catch limit should the proposed experiment fail to deliver useful information (see paragraph 2.131). Each of the restrictions and rules will need to be evaluated as the proposed approach develops.

2.119 WG-EMM-15/11 highlighted how the spatial harvesting footprint within Area 48 varies from year to year. It noted that potential impacts arising from increased spatial overlap between the fishery and krill-eating penguin colonies are plausible but not yet investigated at scales smaller than the SSMU-scale, e.g. at the scale of krill swarms or aggregations of swarms (paragraph 2.143). As such, WG-EMM-15/11 suggested that it is appropriate to explore functional overlap further as part of an experimental approach, in order to gather data to test the hypothesis that functional overlap occurs. Determining krill critical density thresholds for predators will be vital for FBM approaches.

2.120 The Working Group thanked Dr Trathan and his group for their work in developing their proposal. In subsequent discussion, the Working Group identified key issues that need to be addressed (Table 3).

A general approach to FBM at the SSMU scale

2.121 In introducing WG-EMM-15/36 and 15/55 Rev. 1, Dr Constable indicated that the FBM system for krill needed to include methods to:

(i) determine a catch limit for the krill population

(ii) divide that catch limit into smaller areas at a scale relevant to predators in order to avoid inadvertent disproportionate impacts on some predators over others

(iii) minimise effects on predators when available food is at critical levels

(iv) account for changing productivity and relationships in the system

(v) validate/check the management system.

2.122 WG-EMM-15/36 proposed methods that could achieve the first two parts of the management system – catch level and division of that catch into smaller areas. It draws together past experience in CCAMLR and provides (i) an empirical ecosystem assessment model, (ii) a decision rule for determining SSMU-scale catch limits based on a designated spatial harvest strategy and a single-species assessment of yield, and (iii) a method for implementing the procedure. The decision rule for setting catch limits for a given harvest strategy has a straightforward expression of the target conditions to be achieved for krill, krill predators and the fishery and the uncertainties that need to be managed. It is a natural extension of the current precautionary approach of CCAMLR for krill and can utilise existing datasets, including B_0 surveys, local-scale monitoring of krill densities, local-scale monitoring of predator performance, monitoring of predator foraging locations and time series of catches from the fishery. The procedure developed in the paper:

(i) enables the spatial harvest strategy to be determined by fishers and then set SSMU-scale catch limits according to the uncertainties in food-web status and dynamics

(ii) provides a common framework for inserting data, assessment methods and candidate modelling approaches for assessing catch limits

(iii) has a formalism that provides for the development of a fishery, enabling advice to be updated as improvements are made in any component of the procedure, including the provision of data, implementation of new assessment or projection models or a revision of the decision rule

(iv) formalises the decisions that need to be made in dealing with uncertainty across an ensemble of plausible food-web models and dynamics

(v) provides the primary expectation for managing uncertainty, either by obtaining better estimates of parameters for the projection models and/or by altering the harvest strategy

(vi) is able to respond to trends in the status of the ecosystem, including trends arising from climate change.

2.123 WG-EMM-15/55 Rev. 1 extended the management system to minimise effects on predators when available food is at critical levels. The paper indicated how this management system can be made operational in the early phases of a fishery in SSMU-scale areas. A decision rule for adjusting catch limits at SSMU scales when krill density is near critical levels for predators is proposed. This rule uses an estimate of krill biomass density (e.g. g m^{-2}) and recruitment strength in a given year to determine an adjustment of the long-term annual catch for the area in the following year. This decision rule is designed to keep the probabilities of low reproductive performance by predators at acceptable levels in the long term. The process for undertaking the assessment using a population projection model and its application is demonstrated in the paper. Lastly, the paper outlines a process for testing the management system in the early phases of the fishery by concentrating the fishery in some SSMUs and testing whether the reproductive performance of predators is maintained at acceptable levels.

2.124 Dr Constable concluded his presentation by indicating that progress could be made in the coming year by assembling available krill and predator data to estimate critical biomass densities of krill in SSMUs and for progressing the implementation of a population projection model, which could be based on the generalised yield model (GYM). It would also include further modelling of the properties of the decision rule and the management system as a whole.

2.125 The Working Group thanked Dr Constable and his group for their work in developing these proposals. The Working Group noted that:

(i) the decision rule for short-term adjustments of the long-term catch limit in an SSMU is based on estimates of krill biomass and recruitment strength, which could be obtained from surveys or fishing data

(ii) shifts in the ecosystem, or changes in the food web, can be included in this approach if needed

(iii) the empirical ecosystem assessment may need to factor in time lags in predator responses

(iv) the short-term adjustment approach derives from predator–prey theory and requires empirical data on the links between the reproductive performance of predators, their foraging activities and krill availability to identify critical prey densities (data will need to be assembled to identify critical krill densities)

(v) the one-year projection model may need to include parameters for krill flux; the sensitivity of the approach to different levels of flux could be explored

(vi) the effect of the decision rule for adjusting catch limits on variability of catches will need to be explored in order to minimise volatility in catches, noting that this approach is only for adjusting catches in SSMUs rather than the whole of the area

(vii) the method for adjusting catch limits at the SSMU scale is consistent with the approach being developed for Subarea 48.2 and encouraged the proponents of the two approaches to consider how they may be combined.

2.126 The key issues identified by the Working Group to be addressed in developing these approaches are given in Table 4.

General

2.127 The Working Group thanked Members for submitting candidate proposals for progressing FBM towards stage 2. It agreed that the approaches and supporting papers submitted (WG-EMM-15/04, 15/10, 15/11, 15/33 15/36, 15/55 Rev. 1), had a number of common elements and similar data requirements. It also agreed that different parts of the CAMLR Convention Area may need different approaches because of the nature of the ecosystem in different regions, as well as the different levels of data and monitoring capability currently available. The Working Group recognised that a common framework would be desirable across all of the krill fishery, with a means of learning about the ecosystem and testing the management system during the development of the fishery. However, the Working Group noted that achieving a common framework may take some time. The Working Group encouraged the proponents to continue to progress their proposals in the coming year, taking account of the points in Tables 2, 3 and 4. The Working Group recommended that the progress on FBM be highlighted to the Scientific Committee and the Commission.

2.128 The Working Group agreed that work to address the approaches and evaluate candidate decision rules could be advanced by holding a workshop in 2016. Compiling relevant datasets in advance of this workshop would facilitate the workshop and, since all approaches to FBM are likely to utilise the same types of data, it was noted that additional feedback approaches could be submitted to the workshop or WG-EMM-16 and potentially be evaluated at these meetings. It was agreed that submission and evaluation of additional approaches would not delay implementation of stage 2; new ideas could be implemented in a revision to stage 2 or during advancement to stage 3, noting that consideration might need to be given as to how such proposals may impact on existing implementations.

2.129 Ultimately, decision rules applied in FBM approaches need to be understood by policy-makers and stakeholders and minimise risks to achieving the objectives in Article II. The Working Group agreed that a submission of an approach needed to be accompanied by suitable documentation to understand the basis and implementation of the approach as well as how it would result in conservation measures. The Working Group recommended that the pro forma adopted by SC-CAMLR in 2014 be amended to include the following:

(i) public summary: a simple and concise explanation that is accessible to a range of potential stakeholders that describes how this specific FBM approach would be implemented

(ii) rationale and implementation summary: a summary for appending to the WG-EMM report that describes the rationale and implementation of the approach suitable for the Scientific Committee.

2.130 The Working Group also agreed that implementation of all stage 2 approaches need to be reviewed after a trial period with clear courses of actions to be taken, if needed, given positive and/or negative outcomes of the review. Review of stage 2 approaches is needed to balance CCAMLR's precautionary approach with a need to improve FBM through an active learning process (see also SC-CAMLR-XXXII, Annex 5, paragraph 2.89).

2.131 The Working Group agreed that until stage 2 can be implemented, or if stage 2 is implemented and the reviews identified in paragraph 2.130 indicate that the implemented approaches are not successful, the risks to achieving the objectives in Article II could be minimised by maintaining the subarea catch limits currently established in CM 51-07.

2.132 The Working Group noted that, given the current approach to the management of the krill fishery, implementing an FBM approach in one subarea might have broader implications for management of the krill fishery in other subareas. Furthermore, any changes to the implementation of the decision rules may have implications for other fisheries more generally.

General considerations for management of the krill fishery

State of the krill-based food web at present

2.133 The Working Group considered the potential effects that krill fishing might currently be having on krill and its predators. It noted that the last area-scale survey within Area 48 took place in 2000, but that there was currently no evidence for a recent trend in krill biomass (WG-EMM-15/28), density (g m^{-2}; e.g. Fielding et al., 2014), or abundance (individuals caught by research nets; e.g. Atkinson et al., 2014; Steinberg et al., 2015) in Subareas 48.1 to 48.3.

2.134 The Working Group agreed that the subarea-scale catch limits established in CM 51-07 may risk failure to achieve the Commission's objectives at the SSMU scale. In this regard, it was noted that:

(i) results from surveys conducted by the US AMLR Program demonstrate that, at the SSMU scale, interannual differences in krill biomass within Subareas 48.1 can span two orders of magnitude, and annual biomass estimates in the Bransfield Strait and north of the South Shetland Islands have periodically been less than the subarea-scale catch limit established for Subarea 48.1 in CM 51-07 (WG-EMM-11/26)

(ii) fishing activity has become more concentrated into some SSMUs, with particular focus on Bransfield Strait in Subarea 48.1 (WG-EMM-14/11)

(iii) given points (i) and (ii) above and catch limits that are only resolved to the subarea-scale, it is not possible to rule out SSMU-scale harvesting impacts that would result in failure to achieve management objectives. In some years, SSMU-scale harvest rates may inadvertently be higher than would be expected from application of the krill decision rules at the SSMU scale.

2.135 The Working Group agreed that:

(i) Catch is currently at about 48% of the trigger level and 5% of the precautionary catch limit; catches are currently less than 0.5% of the biomass estimate from the CCAMLR-2000 Survey.

(ii) Interannual trends in SSMU-scale biomass are not evident (with only limited information on seasonal or monthly cycles of SSMU-scale biomass). However, given the observed variation described above (paragraph 2.134i), it is not possible to rule out small-scale harvesting impacts because fishing activity has become more concentrated into some SSMU-scale areas and local harvest rates in some years may be higher than expected by gamma.

(iii) A consideration in interpreting CEMP data is that the different CEMP parameters integrate across different time and space scales. For example, foraging trip duration may be affected by conditions in the foraging area at the time of foraging, while breeding success and fledging weight integrate conditions in the foraging areas over several months during the breeding season. Breeding population size integrates conditions at the scale of years. Thus, CEMP and subsequent analyses need to be organised in such a way that they detect the spatial and temporal effects intended to be observed. Within-season effects of fishing will need to be detected using parameters that indicate conditions at locations and times where there is coincidence between foraging and fishing area and the months of fishing.

(iv) At present, the effects of current fishing activities on krill-dependent predators monitored at breeding colonies are uncertain. Noting that different sets of indices are recorded at each CEMP site, it is also unclear whether variation in the set of indices that have been recorded at each site can be attributed to fishing activity. This is an important research topic, and investigating this issue will, inter alia, require attention to the amounts of bias and observation error in each CEMP index, the time and space scales over which each index integrates, covariation among indices and the amount of fishing activity that occurred within the time–space frame to which the monitored indices are relevant.

2.136 The Working Group agreed that the spatial distribution of the trigger level in CM 51-07 should be continued in order that harvesting is further not concentrated and does not impact adversely upon predators. A realistic work program for establishing stage 2 is being progressed and CM 51-07 should ultimately be revised to reflect stage 2.

2.137 The Working Group agreed the following points:

(i) Krill biomass is not homogeneously distributed within the subareas. Consequently, an increase in catch may be possible if the catch for a subarea is subdivided into smaller spatial units that take account of predator needs, or other safeguards to predators are put in place.

(ii) The fishery has become concentrated in some SSMU-scale areas in recent years (WG-EMM-15/30, Appendix 3, Table 3).

(iii) There is a need to avoid harvesting impacts upon the ecosystem at the SSMU scale.

(iv) During certain time periods, particularly during the breeding season, krill beyond a critical distance from land are not accessible to land-based predators. Similarly, the fishery also preferentially targets krill in some locations. The krill readily available to breeding land-based predators is likely to be the main focus of the fishery, although the degree of overlap will depend on, inter alia:

(a) the time of year

(b) the individual constraints on foraging of the breeding and non-breeding parts of the predator populations at that time

(c) the aggregation/distribution of krill.

(v) Fishing in areas distant from land may not affect land-based predators but could affect pelagic predators such as whales, pack-ice seals, fish and other predators foraging in those areas.

(vi) Full implementation (i.e. stage 4) of FBM requires that CCAMLR is able to estimate the ecosystem effects of fishing; CEMP currently only includes land-based predators, making these the best opportunity for detecting such effects at present. Detecting effects in pelagic areas may need monitoring of krill predators utilising those areas, such as cetaceans, ice seals and fish.

(vii) The trigger level (CM 51-01) was based on the highest aggregate catch in the historical time series. No information is available on whether that catch had an effect on the ecosystem or whether sustained catches at that level would or would not have an effect. Kinzey et al. (2013) concluded that better information is required about krill recruitment variability and natural mortality before increasing catches much beyond the trigger level. Watters et al. (2013) also indicated in simulations that sustained catches at the trigger level would increase the risks of CCAMLR not meeting the objectives of Article II, including by failing to facilitate the restoration of depleted predator populations.

(viii) Krill consumption by predators within different SSMUs could be used as a basis for distributing catch limits. An approach for undertaking these calculations is available in Everson and de la Mare (1996). Estimates are also available in Hill et al. (2007).

(ix) If the existing spatial distribution of the trigger level (CM 51-07) was removed, precautionary management would still be required. This is because more concentrated fishing might then occur in subareas or SSMU-scale areas, and CCAMLR would only be able to detect the effects of fishing, if the fishing occurred in areas where monitoring exists.

2.138 The Working Group agreed that a future revision of CM 51-07 should consider how the fishery is arranged within subareas in order to avoid impacts on predators within some SSMU-scale areas.

2.139 The Working Group agreed that consideration should be given as to whether it is more precautionary for the subareas in Area 48 to be managed separately. A task for the intersessional period considered in future work is to review and evaluate whether it is more precautionary to manage subareas independently or within a regional context (paragraph 2.161vii).

2.140 The Working Group noted the following points were raised in relation to the task in paragraph 2.139:

(i) There is a need to consider connectivity between subareas as well as whether subareas are sources or sinks for krill. A key issue is whether the flux of krill is sufficiently high that the subareas are closely connected or relatively independent.

(ii) Oceanographic modelling indicates that a high volume of water moves between subareas and that some subareas have multiple sources (e.g. Subareas 48.1, 48.2 and 48.3). This needs to be taken into account in relation to the behaviour of krill. The management implications of different scenarios for ocean connectivity will need to be considered.

(iii) Krill can move actively, not simply drifting as particles in the water – they can swim at speeds equivalent to current flows and can migrate vertically and horizontally taking them into different water masses; they can also associate and move with sea-ice. Their capacity to move actively may allow them to migrate small distances, but this can then have important consequences for distribution. The implications of krill behaviour are therefore important for krill transport (paragraphs 2.79 and 2.80).

(iv) The mobility of predators, where they forage and the degree to which they might be affected across subareas, will need to be considered.

(v) Results presented by Watters et al. (2013) indicate that in modelling scenarios with no oceanographic connectivity, risks to the ecosystem are higher than in scenarios where oceanographic movement occurs. If movement of krill between subareas is limited, then management at subarea scale may be more precautionary.

2.141 The Working Group agreed that facilitating fisheries research that contributes towards development of FBM was important; e.g. requirements for fishing vessels to conduct acoustic surveys (paragraph 2.169), might necessitate careful consideration of temporal/seasonal catch limits. The Working Group noted that the Secretariat could notify fishing vessels at key times during the fishing season (e.g. at different levels of catch relative to the catch limit) so that acoustic observations can be collected at suitable times before the season closes.

Precautionary requirements for predators at SSMU-scales

2.142 The Working Group noted that extreme events occur naturally in the marine environment. These events are known to have important impacts upon components of the natural ecosystem and safeguarding against the consequences of harvesting exacerbating the impacts, or increasing the frequency, of these extreme events will be necessary in any approach to FBM.

2.143 The Working Group recognised that at the SSMU scale, approaches for taking precaution for predators will be important, particularly during the interim period while new monitoring CEMP sites and new methods are established. The Working Group noted the following:

(i) The aim of any SSMU-scale decision rule might be to help avoid exacerbating problems in critical years. Such rules could be used in conjunction with a shift or increase in catch in subareas. Such rules might contribute towards the future development of CM 51-07.

(ii) The need to consider the critical krill density for predators in order to apply any such SSMU-scale decision rule and the need for other data for providing the annual adjustment.

(iii) Information to help elucidate critical krill densities for penguins include:

   (a) comparisons between fished and non-fished areas

   (b) information from habitat models (WG-EMM-15/09) that help improve understanding about necessary levels of krill density

   (c) estimates of critical krill densities across different sites.

(iv) Data available for determining the critical krill density might include CEMP data combined with SSMU-scale krill surveys. To further such analyses:

   (a) the Secretariat should compile available data and make them accessible to Members for analyses

   (b) WG-EMM should establish an e-group to facilitate the development of these analyses from all the subareas and for the communication between data holders and analysts

   (c) there will be a need to include factors that might impact upon the use of CEMP data, such as sea-ice and oceanography

(d) there will be a need to look at variables at the right spatial scale; foraging scales for predators are often season-specific

(e) a CEMP workshop would help progress this program of work, although there is a need to define questions that are relevant to FBM.

2.144 The Working Group noted that some areas may already be affected at current fishing levels, e.g. Bransfield Strait (SC-CAMLR-XXXIII, Annex 6, paragraph 2.121). The creation of precautionary no-take buffer zones around predator colonies or foraging areas would help provide safeguards for predator needs. The Working Group recognised that new tracking data collected since 2002 could help progress these safeguards, noting previous discussions on critical distances from predator colonies (Agnew and Phegan, 1995; see also WG-EMM-15/09 and 15/11).

2.145 The Working Group also noted that protecting krill nursery areas would be a precautionary approach to help protect krill that will eventually recruit to predator foraging areas and fishing grounds.

Using existing data and monitoring

2.146 The Working Group noted that estimates of variability and trends in recruitment could be obtained from existing datasets. Integrated stock assessments (e.g. WG-EMM-15/51 Rev. 1) might provide such estimates as well as assisting with drawing inferences about the dynamics of krill generally.

2.147 The Working Group also noted that CPUE analyses may be able to help identify whether fishing effects krill at SSMU scales. However, CPUE can be hyperstable and also may be determined by vessel factory requirements rather than characteristics of the stock. Such analyses will need to take these considerations into account when estimating the relationship of CPUE with krill density.

2.148 The Working Group noted several points related to the use of CEMP indices in FBM:

(i) CEMP indices can describe conditions at a range of scales. Combining indices across CEMP sites, SSMUs and subareas can respectively describe conditions at the SSMU, subarea and area scales

(ii) the scale at which CEMP indices should be combined (or not) should be determined by the specific question of interest

(iii) additional work is needed to understand whether and how variations in some CEMP indices (e.g. arrival mass and chronology) affect abundance over the long term. Predator population models could be used to examine such effects (paragraph 2.160)

(iv) habitat modelling can provide information on the spatial locations and scales for which CEMP indices are applicable indicators of foraging conditions and krill availability. Work to progress such modelling has already begun for penguins (paragraph 2.195).

Further development of at-sea monitoring and CEMP sites

2.149 The Working Group noted a number of issues related to FBM and possible future area-scale krill surveys (WG-EMM-15/28); these included:

(i) how an area-scale survey relates to SSMU-scale surveys and how krill becomes concentrated in predictable ways

(ii) a series of area-scale surveys would help address area-scale questions, potentially including with respect to possible impacts of climate change; those Members interested in pursuing this may wish to establish a design process to:

(a) determine how area-scale surveys will help understand the effects of climate change

(b) determine how these surveys may provide context for variability between and within subareas and SSMUs and how such surveys could be linked to subarea- and SSMU-scale surveys.

2.150 The Working Group noted that the effects of fishing on SSMU-scale densities of krill will be critical to understand. It recognised that use of fishery acoustics may help in monitoring of seasonal and monthly cycles in SSMU-scale biomass, or trends over longer time scales. The Working Group noted that:

(i) use of fishery acoustics will need consideration of vessel acoustic calibrations (Annex 4, paragraphs 3.13 and 3.14). However, use of the same vessel may provide indices of data without the need to calibrate acoustic equipment. The use of different vessels would need intercalibration/standardisation across vessels

(ii) surveys of areas before, during and after fishing should help determine if there are SSMU-scale effects on krill density or swarm structure

(iii) repeat sampling within season in areas without fishing will help improve understanding about seasonal variation

(iv) it will be necessary to critically review survey results because multiple mechanisms may explain changes in surveys over time

(v) the spatial and temporal design of surveys will be important as a change in biomass between acoustic surveys may not just be because of harvesting but could be because of flux or predator consumption

(vi) seasonal patterns in krill biomass have been documented, including during the Elephant Island experiment (Kim et al., 1998); seasonal patterns in biomass should be taken into account within FBM

(vii) it would be desirable to trial some transects for a year to look at data and then determine how it might be scaled up (see paragraphs 2.229 to 2.232)

(viii) China, the Republic of Korea and Norway have indicated a willingness to collect acoustic data from fishing vessels. To develop FBM, the proposed program of work in paragraphs 2.229 to 2.232 will be important. Observers could usefully be involved in the collection of acoustic and ancillary data, such as length-frequency data, for generating indices of abundance or enabling estimation of abundance from acoustic data.

2.151 The Working Group noted the following in using CEMP indices and encouraged further development of CEMP for FBM:

(i) parameters and species should be chosen to signal change in different parts of the ecosystem affected by fishing or reflect dynamics and change in the ecosystem overall (e.g. calving of whales – Leaper et al., 2006)

(ii) sub-lethal parameters (e.g. foraging, diet, reproductive success) may help determine interactions in advance of seeing population changes

(iii) cameras will help automate the collection of some CEMP data but the methods require further development and standard procedures (paragraph 2.185)

(iv) given the resources available for CEMP, there may be trade-offs between the number of CEMP parameters measured at a site and the number of sites. This will be less likely as more Members become involved and CEMP parameters are identified on which efforts should be concentrated. Linked at-sea work needs to be spatially and temporally coordinated with monitoring at CEMP sites:

    (a) Bransfield Strait may be an area of high priority for additional monitoring given the concentration of the fishery there

    (b) design of CEMP should aim to have contrasting sites to understand the effects of fishing, e.g. control sites to fishing would be useful, or perhaps vary fishing intensity between areas

    (c) the performance of CEMP should be regularly reviewed in order to maintain the contrasting design

    (d) use of habit models to examine the utility of existing CEMP sites will help with some of the questions being posed

    (e) the monitoring design could utilise the deployment of cameras and other sampling in a way that has the parameters sampled for species at appropriate sites but not requiring all species be monitored for all parameters at all sites, e.g. akin to a latin-square statistical design

(v) the location of new sites could be evaluated for their utility to CEMP using locations of land-based predators (e.g. WG-EMM-15/32) coupled with habitat models.

2.152 The Working Group noted that indicators of the performance of the fishery will be useful to develop. It noted the following suggestions and asked the authors to develop papers for future meetings of WG-EMM:

(i) Dr K. Demianenko (Ukraine) proposed one such indicator that could relate to accessibility of the fishery to the stock. Such an indicator could be derived from satellite data of ice cover in a region along with survey data. He proposed that the accessibility index would be calculated as the sum across areas within a region of the index for an individual area. The index for an area would be the proportion of the year that an area is accessible multiplied by the proportion of the krill stock in the area. He also indicated that the accessibility index for the region can be readily adapted to include the management arrangements for an area, such as whether it is open or closed to fishing.

(ii) Dr S. Kasatkina (Russia) proposed to estimate krill flux between subareas and across individual SSMUs in Area 48 using the reanalysed CCAMLR-2000 Survey data. It was also proposed to analyse interannual and monthly dynamics of CPUE by SSMUs using time series of standardised CPUE as well as CPUE index by national fleets derives from the CCAMLR database. She proposed to undertake the above said analysis in the coming intersessional period for WG-EMM-16. The Working Group noted that these analyses may provide additional information to determine how krill biomass may have varied in Area 48 since 2000.

(iii) Dr Kasatkina noted it is necessary to clarify the understanding of the threshold to trigger the application of the precautionary approach to krill fishery management. There is not scientific-based argument that trigger level should be established at the level of 620 000 tonnes and used as the precautionary catch limit for Area 48. She recalled that trigger level does not reflect the status of krill stock and predators in the times past as well as the current status of krill stock and predators. The trigger level has remained the same magnitude despite significant increased estimates for krill biomass B_0 and allowable catch in Area 48 during recent years, particularly the allowable catch increased from 4 million tonnes (2007) to 5.61 million tonnes (since 2011). The trigger level needs scientific justification. Moreover, there is a need for additional substantiated reference points for krill fishery management.

2.153 The Working Group noted that the SISO could be used to collect data for FBM. For example, other than krill data considered elsewhere (paragraph 2.41), wildlife observations could be collected. For example, sightings of cetacean and other krill predators reported with the amount of time spent making wildlife observations could be obtained by observers on krill vessels. When possible, photos of cetaceans could help with identification and mark-recapture programs based on photos. In addition, if scientists can participate in voyages, they could collect biopsy samples or deploy tracking tags or other devices. This is similar to what occurs in other CCAMLR fisheries. Cetacean data could be managed by the International Whaling Commission Southern Ocean Research Partnership (IWC SORP) as one of the few multinational cetacean data repositories. Other wildlife could also be observed, such as penguins and seals.

Structured fishing to further FBM

2.154 The Working Group noted that structured fishing refers to designing where and when fishing should be undertaken. It has been discussed over many years and as a general term it has been used in various ways, including the following examples:

(i) where fishing is undertaken in specific locations or concentrated there, possibly at different catch densities in different areas, to answer specific questions about, say, the effects of fishing on predators and/or krill in those areas

(ii) having fishing avoid areas in order to estimate species or food web parameters or their status in the absence of fishing

(iii) concentrate fishing in some areas early in the fishery in order to achieve catch densities at the scale expected of a fully developed fishery to test the management system

(iv) have fishing vessels undertake survey or other work to collect data needed in assessments.

2.155 These examples of structured fishing may all contribute to assessments and/or the acquisition of data for use in decision rules on catch limits.

Implementation of FBM

2.156 The Working Group noted that the timeline for implementation of FBM will depend on the development and implementation of various technologies. These include the continuing development of fishing vessel acoustic methods (Annex 4) and remote cameras. For remote cameras, important issues include the length of time series required to establish a baseline (SC-CAMLR-XXII, Annex 4, Appendix D). Proxy data, or appropriate links to data from other sites, may facilitate the incorporation of data from a new monitoring site into long-term series already in existence. Without such data, a new monitoring site may take five to 10 years to achieve a sufficient base line.

2.157 The Working Group agreed that the development of written materials to document the value of CEMP to FBM, including the establishment of CEMP sites and long-term field activities to support them, would be useful.

2.158 The Working Group also agreed that interactions with the fishing industry and Members to promote monitoring would be essential. This could be through a workshop or some other mechanism such as a subgroup that involved industry.

Future work plan to progress stage 2

2.159 The Working Group agreed that significant progress has been made in developing options for stage 2. It noted that a number of topics will need to be addressed in the coming years in developing FBM and encouraged Members to participate in this work. For the coming year, the Working Group recommended that the following topics are a high priority on which progress needs to be made:

(i) the current state of the krill-based ecosystem and managing the effects of fishing (paragraphs 2.160 and 2.161)

(ii) stage 2 subdivision of catch and/or update of trigger level (paragraphs 2.162 and 2.163)

(iii) precautionary requirements for predators at SSMU scales (paragraph 2.164)

(iv) krill surveys and CEMP at SSMU scales in stage 2 (paragraphs 2.165 to 2.173).

General points are also made in paragraphs 2.174 to 2.178.

Current state of the krill-based ecosystem and the fishery

2.160 In order to have available the best scientific evidence for deliberations on stage 2, the Working Group encouraged Members to continue work on the current state of the krill-based ecosystem and possible effects of fishing, and, if possible, provide updates in the coming year on the following:

(i) the krill biomass relationships between SSMUs and subareas within areas to determine the connectivity of krill between these areas for management, including:

  (a) whether SSMU-scale surveys could be used to determine the proportion of krill biomass in SSMUs at any one time and the proportion vulnerable to the fishery at that time (e.g. WG-EMM-11/20 provided this for approximately the subarea scale using the reanalysed CCAMLR-2000 Survey data)

  (b) the percentage of the stock (and the catch limit) that is vulnerable to the fishery in the areas where it operates, both historically and with the current fishing spatial distribution

(ii) whether the area-scale survey from the CCAMLR-2000 Survey can be related to subarea-scale surveys to determine how krill may have varied in Area 48 since 2000, including consideration of temporal trends

(iii) the availability of krill to the fishery and to predators and what spatial and temporal overlap there may be

(iv) the response of predators to krill density, including identifying and comparing CEMP sites that have been potentially exposed to the effects of fishing with those that have not been exposed, noting that not all krill predators are monitored, including fish, whales and pack-ice seals

(v) using predator population models to understand the properties of CEMP parameters, taking account of various scenarios for krill and the environment

(vi) whether competition between different predators is able to be determined from these data.

2.161 The Working Group requested Members to undertake the following work on this issue in the coming year:

(i) review the variability and trends of krill at SSMU scales for use in developing stage 2 management approaches

(ii) assess the current harvest rates of krill at SSMU scales

(iii) assess whether CPUE data from the krill fishery is useful for quantifying variability and trends in SSMU-scale krill biomass, while recognising that acoustic data collected during krill fishing operations might provide higher temporal resolution information (paragraphs 2.67 to 2.69)

(iv) review whether acoustic data collected continuously during fishing may serve as the basis for a spatial–temporal index of abundance/biomass/density at SSMU scale (WG-EMM-15/13)

(v) evaluate SSMU-scale relationships between krill density, predators and the fishery, giving appropriate consideration to, inter alia:

    (a) the overlap of predator foraging areas with fishery harvesting areas

    (b) whether penguins may be attracted to fishing vessels for feeding (WG-EMM-15/25)

    (c) the relative importance of different locations to predators and the fishery and the lengths of krill revealed by diet studies and SISO data

    (d) determining the level of foraging success in relation to the density of krill and intensity of functional overlap with the fishery (paragraphs 2.190 and 2.191)

    (e) considering wildlife observations at sea for estimating predator–fishery overlap

    (f) taking note of the role that flux may have on SSMU-scale dynamics e.g. Bransfield Strait

    (g) taking account of prey switching

(vi) evaluate whether the effects of fishing can be detected at present, including whether CEMP indices suggest such effects

(vii) review and evaluate whether it is more precautionary to manage subareas independently or within a regional context.

Stage 2 subdivision of catch and/or update of trigger level

2.162 The Working Group noted the different approaches for stage 2 aimed at updating CM 51-07 and/or revising the trigger level (paragraphs 2.102 to 2.132). It requested proponents of these approaches to continue work in the year as indicated in Tables 2, 3 and 4 and take account of relevant issues in paragraphs 2.160 and 2.161. The Working Group also requested Members work on evaluating the likely performance of proposed approaches with respect to krill, krill predators and the fishery.

2.163 The Working Group noted the consideration of multinational surveys of Area 48 (paragraph 2.149). It encouraged interested Members to continue to plan for this work.

Precautionary requirements for predators at SSMU scales

2.164 The Working Group requested Members to consider precautionary requirements for predators at SSMU scales in stage 2, including work on SSMU-scale decision rules. In that respect, the Working Group requested this work to consider:

(i) the likely performance, with respect to krill, krill predators and the fishery, of the decision rules, including the consequences for catches over time, e.g. the mean and variability of the catch levels, and how the catch may be optimised in the context of Article II and taking account of uncertainties

(ii) the requirements for implementation, such as through work identified in Tables 2, 3 and 4 and paragraphs 2.160 and 2.161

(iii) the roles that fishing vessels and observers may play in collecting data, including undertaking krill surveys.

Krill surveys and CEMP in stage 2

2.165 The Working Group congratulated CCAMLR Members on bringing together this long-standing time series and noted that the data can, once standardisation is achieved, be used as the basis for the development of FBM, harvest control rules and associated advice for the Scientific Committee and the Commission.

2.166 The Working Group agreed that the approaches considered for managing the krill fishery at subarea and SSMU scales are dependent on the continuation of subarea krill surveys and the maintenance of time series of data from CEMP. The Working Group recommended that the Scientific Committee highlight the importance of these surveys and CEMP data collection to the Commission so that Members may consider ways to ensure their continuation and expansion.

2.167 The Working Group requested the Scientific Committee consider the mechanisms that may be needed to sustain these monitoring activities into the future. It noted that decision rules and assessments will need to take account of the spatial and temporal frequency of monitoring able to be achieved, and that advice will need to account for the uncertainties arising from that monitoring.

2.168 The Working Group requested Members to continue to develop and design a capability for undertaking surveys by fishing vessels to assess within-season dynamics of krill, including depletion by fishing and/or predators and the flux of krill in an area, including:

(i) considering the design and instructions provided by SG-ASAM

(ii) commitment to do the research by fishing vessels

(iii) consideration of when during the season those surveys need to be undertaken and the role that the Secretariat may play in coordinating those times

(iv) calibration of vessel equipment as considered by SG-ASAM.

2.169 With respect to the design of within-season surveys, the Working Group agreed that it would be desirable for fishing nations to collect acoustic data on the SG-ASAM transects as much as possible during the coming season and then for SG-ASAM to analyse data in the coming year. This work would form the pilot for designing regular within-season surveys for the future by allowing a test of the potential utility of such data in estimating depletion and flux and for use in FBM. The Working Group agreed that these data should be reviewed next year in order to evaluate the requirements for inter- and intra-annual surveys by fishing vessels to obtain the data necessary for FBM.

2.170 The Working Group requested Members to evaluate for next year what the spatial and temporal requirements might be for CEMP to facilitate the implementation of the management approaches, including the species and parameters to be monitored in space and time and the costs and timeliness of implementation.

2.171 The Working Group recommended to the Scientific Committee that priority be given to the following tasks for the Secretariat:

(i) assist with assembling data for work by Members on FBM in the coming year, including helping prepare time series of data on krill, CEMP parameters and the fishery and validating those data and providing details on the quality of records as appropriate

(ii) assist with developing and making available metadata records for (i) and for providing a conduit between data owners and data users

(iii) document the spatial and temporal scales of CEMP parameters in different SSMUs in Area 48

(iv) in consultation with the e-group (paragraphs 2.143(iv) and 2.172), analyse the relationships between those parameters at subarea and area scales.

2.172 The Working Group agreed that this work should be facilitated through an e-group, including coordination and access to datafiles and data extractions. It noted that notifications to data owners under the Rules for Access and Use of CCAMLR Data should be made when such data are posted to the e-group site. It encouraged Members to submit other data useful for this work and to engage in facilitating contributions from the broader scientific community.

2.173 The Working Group agreed that the development of different candidate approaches for FBM would require a number of different data sources. It noted that access to CEMP data and catch data were already governed under the Rules for Access and Use of CCAMLR Data (www.ccamlr.org/node/74296). It agreed that these rules would also provide the necessary security for owners of other data not currently held by the CCAMLR Data Centre, but which may be needed in the development of FBM. The Working Group recognised that it was essential to develop positive collaborations with the wider scientific community, and so agreed that the Rules for Access and Use of CCAMLR Data should be highlighted when seeking external data.

General

2.174 The Working Group agreed that the following topics will need to be progressed in the coming year:

(i) advise on CM 51-07, the trigger level and/or precautionary measures for krill predators at SSMU scales

(ii) consider critical densities for krill predators, according to the work plan in paragraph 2.143(iv)

(iii) mechanisms for monitoring krill and CEMP parameters

(iv) status and uncertainties in the krill-based ecosystem and interactions with, and effects of, the fishery.

2.175 The Working Group advised the Scientific Committee that in order to progress to stage 2, the Scientific Committee will require advice from the following groups on the following topics:

(i) SG-ASAM on acoustic surveys using fishing vessels

(ii) WG-SAM on assessment methods and decision rules and their evaluation

(iii) WG-EMM on the status and uncertainties in the krill-based ecosystem and precautionary approaches for krill predators at SSMU scales.

2.176 The Working Group also agreed it would be desirable to have workshops in some form to:

(i) engage with stakeholders on what is being undertaken with respect to stage 2 and to communicate and discuss the need for surveys from fishing vessels, amongst other research activities

(ii) facilitate work and discussions on the three topics in paragraph 2.174.

2.177 The Working Group agreed to establish an e-group to develop the proposed work plan for FBM and timeline for consideration by the Scientific Committee, noting:

(i) the need to engage with stakeholders and the wider scientific community

(ii) the need to be realistic on what can be achieved in the coming year, given existing commitments

(iii) the cost of bringing experts to multiple meetings within one year, including working group meetings.

2.178 The Working Group requested that the Scientific Committee be flexible in its management of the agenda and priorities for working groups next year in order that sufficient consideration of FBM can be achieved.

CEMP and WG-EMM-STAPP

CEMP data submission

2.179 In 2014/15, CEMP data were submitted by nine Members for 12 CEMP parameters from 15 sites (WG-EMM-15/07 Rev. 1). In addition to ongoing annual submissions, the Secretariat reported on submissions from New Zealand on historical breeding population size (A3) data for penguins at Ross Island, and Norway on historical data for penguins and seals at Bouvet Island. Italy has resumed collection and submission of CEMP data collected at Edmonson Point. The Working Group welcomed these additional data submissions.

New methods and tools for CEMP

2.180 The Working Group has previously recognised the utility of remotely operating cameras for increasing the spatial and temporal extent of monitoring in a cost-effective and non-invasive manner. The cost-effectiveness of camera monitoring is demonstrated in WG-EMM-15/P03, where camera monitoring is shown to be cheaper than direct observation by a factor of 10 under a scenario of monitoring at 20 sites in three regions over 10 years in the east Antarctic.

2.181 WG-EMM-15/31 and 15/P03 outlined the extent of current camera deployments at penguin colonies in Subareas 48.1, 48.2 and 48.3 and Divisions 58.4.1 and 58.4.2 (21 cameras, one species) and focused attention on the task of processing the growing number of images. The papers described three processing methods currently being developed or investigated:

(i) manual processing using custom-made software (WG-EMM-15/P03)

(ii) ‘citizen science’ processing through the PenguinWatch site on the Zooniverse platform (WG-EMM-15/31)

(iii) machine learning and computer vision techniques to develop automated image recognition algorithms (WG-EMM-15/31).

2.182 The Working Group noted that development of automated image analysis methods is being finalised intersessionally through the CEMP Methods e-group and recognised that such methods could enhance the utility of camera monitoring for FBM if shown to be successful.

2.183 The Working Group noted that the data from cameras can be used to count the number of birds in the colony through the season as well as to collect detailed observations of nests for measurement of breeding success and phenology. An alternate use of cameras is for them to be located at an elevated vantage point further from the colony, to count breeding population size over some or all of a colony.

2.184 An emerging issue is the management of large volumes of images and data produced from the growing camera networks in CCAMLR areas. This issue is common to camera network initiatives across other disciplines and regions and data management procedures developed for these initiatives may be suitable or adapted for CCAMLR's needs.

2.185 The Working Group agreed that prior to the incorporation of data from camera studies into management processes, validation of the time series of data and derived estimates will be required. This would include a full description of the methods applied to collect the data and a full description of the data analysis to derive time series of estimates and their associated uncertainty. As the data collected from camera networks would be eventually considered in conjunction with data collected for CEMP, the Working Group noted that it was important to ensure a similar standardisation approach across sites to that applied to the CEMP data collection.

2.186 Three papers reported on applications or evaluations of unmanned aerial vehicle (UAV) technology for predator populations. WG-EMM-15/48 described the use of two different UAVs (PW-ZOOM, CryoWing) in 2014/15 at two protected areas with penguin colonies (ASPA No. 128 – Western Shore of Admiralty Bay and ASPA No. 151 – Western Shore of King George Bay (Lions Rump) on King George Island, as well as Chabrier Rock and Shag Islands, South Shetland Islands). In total, eight colonies were surveyed. The use of the UAVs reduced the time to survey the colonies from 14 days by manual methods to five hours and the authors plan to extend the research area to include colonies not accessible by foot.

2.187 WG-EMM-15/50 investigated the potential effects of wildlife disturbance by UAVs with electric or combustion engines. During 2014/15, UAV overflights at the altitude of 300−350 m AGL were conducted in the Adélie penguin colony at Pt. Thomas (Western Shore of Admiralty Bay, King George Island, Subarea 48.1). Electric UAVs had no impact on penguin behaviour. During the overflight by a UAV powered by combustion engine, symptoms of vigilance were noticed, similar to those observed when skuas flew over a penguin colony without trying to attack nesting birds. These observations fed into formulation of preliminary guidelines for UAV use.

2.188 WG-EMM-15/P06 presented results from the first use of vertical take-off and landing (VTOL) aircraft for estimating abundance, colony area and density of krill-dependent predators in Cape Shirreff, Livingston Island, South Shetland Islands, during January and February of 2011 and 2013. Several characteristics of small battery-powered VTOLs make them particularly useful in wildlife survey applications (portability, stability in flight, limited launch area requirements, safety and limited sound when compared to fixed-wing and internal combustion engine aircraft). The paper also reported on the utility of VTOLs for missions other than abundance and distribution, namely to estimate size of individual leopard seals (*Hydrurga leptonyx*).

2.189 The Working Group agreed that UAVs offer great potential for efficient monitoring of land-breeding predator populations, especially at inaccessible sites and over larger spatial scales. The Working Group also noted the concerns about the potential for UAVs to disturb wildlife, an issue that had also been considered by the Committee for Environmental Protection (CEP) at its meeting in 2015. During the discussion it was also pointed out that special attention should be paid to the issue of safety, particularly in the coordination of manned and UAV flight operations in the region. The Working Group noted that this is an area of mutual interest between CCAMLR and the CEP and requested the Scientific Committee to consider who would be the appropriate body to lead the development of guidelines.

2.190 WG-EMM-15/25 reported on preliminary results of using vessel acoustics to detect diving patterns of krill foraging predators. Echogram data and direct-observation data on seabirds and marine mammals during active commercial fishing and during pre-set cruise lines of scientific surveys were collected and an automated detection procedure was compared against manual processing by experienced analysts. The study showed that some form of automatic acoustic detection of diving predators is possible. However, the automatic method missed many dives that were detected manually, so there is significant room for improving the simple algorithm. The results highlighted possibilities of using fishery-derived data to study predator–prey interactions and to provide information on the extent of conflict between fisheries operations and predator foraging behaviour.

2.191 The Working Group noted that the detection of predators in the acoustic data used to estimate krill biomass may potentially provide a means to study the relationship between at-sea density of krill predators and the abundance and distribution of krill. The Working Group welcomed these advances in the use of acoustic data and noted the potential to study swarm dynamics and how these might change in response to the presence of predators and fisheries.

2.192 WG-EMM-15/P01 described the principles underlying a marine ecosystem acoustics (MEA) concept, which combines acoustic sensor technologies, advanced operational capabilities and tailored modelling to answer scientific questions in marine ecology and management. Noting that operational matters could constraint the use of acoustics, the paper described some novel operational solutions for expanding acoustics and discussed the role of modelling to secure the integrity and consistency of ‘big data’ collected from acoustic technology. It concluded with a common frame of reference for multidisciplinary work taking place under the MEA concept.

2.193 WG-EMM-15/P05 assessed the accuracy of very high frequency (VHF) radio telemetry data for monitoring the foraging trip duration of Antarctic fur seals (CEMP Standard Method C1) by comparing VHF and time-depth recorder (TDR) data collected concurrently at Bouvet Island. The study found that VHF data overestimated attendance duration by around nine hours compared with TDR data and that errors were not systematic. The authors concluded that VHF is not an appropriate way of collecting attendance data.

2.194 The Working Group agreed that reviewing the suitability of CEMP methods is an important element of its work and suggested that the reported inaccuracies in VHF data may be location dependent. The Working Group agreed that collecting foraging trip duration using TDR technology may become a viable alternative to VHF technology as it becomes cheaper, however, a potential alternative and practical solution may be to combine VHF technology with a wet/dry sensor to detect when seals come ashore.

CEMP monitoring in Area 48

2.195 WG-EMM-15/09 reported on a workshop, which was held in Cambridge, UK, from 11 to 15 May 2015 and convened by the British Antarctic Survey (BAS), BirdLife International and US AMLR. The aim was to bring together researchers working with penguin tracking data to discuss methodologies and approaches for using tracking data in habitat use modelling.

2.196 Penguin tracking data for five species (gentoo (*Pygoscelis papua*), Adélie, chinstrap (*P. antarctica*), king (*Aptenodytes patagonicus*) and macaroni (*Eudyptes chrysolophus*) penguins) collected at 22 different colonies in Area 48 were compiled before the workshop in the BirdLife International Seabird Tracking Database (www.seabirdtracking.org). The datasets covered different breeding stages.

2.197 The Convener of the workshop (Dr Trathan) thanked data contributors and the Working Group congratulated Dr Trathan for successfully organising the workshop.

2.198 WG-EMM noted the recommendations from the workshop, in particular that:

(i) using tracking data to develop at-sea preferred habitat use models for krill-dependent predators has the potential to provide valuable management information for CCAMLR, particularly as part of the future development of FBM approaches for the krill fishery as well as for marine spatial planning and the possible future designation of marine protected areas

(ii) there are a number of different modelling approaches that might be used to develop penguin habitat preference models. It noted that any such models were only part of the information needed to make management decisions, but that they could form an important component

(iii) identifying preferred penguin habitats and determining how interference from fisheries takes place within these habitats is complex; in general there are insufficient data available to determine the degree of competition

(iv) competitive effects are more likely to occur at certain times of year, particularly when animals are highly constrained and fisheries operate close to their foraging locations (e.g. during brood and crèche)

(v) habitat preference models would be valuable for the development of candidate FBM proposals, particularly for where the spatial overlap of penguins and fisheries occur and where available monitoring data are not available.

WG-EMM recognised that competitive effects are likely to occur, but are difficult to document; nevertheless, habitat models could be useful for identifying the times and locations where competition potentially occurs and this will be important for the implementation of FBM.

2.199 WG-EMM-15/12 summarised penguin research efforts conducted by the Korean Antarctic Program in Barton Peninsula (ASPA No. 171), King George Island, where colonies of chinstrap and gentoo penguins occur. The size of breeding populations has been monitored occasionally from 1989/90 to 2006/07 and annually from 2006/07 in accordance with CCAMLR standard methods. Other research involves camera-based monitoring and behaviour studies using different types of loggers and recorders. In the future, the authors intend to continue research at this site, develop international collaborations with other research groups working in the area and contribute to CCAMLR science in a more committed and systematic fashion.

2.200 The Working Group welcomed this work by the Korean research program and encouraged the continued engagement of Korean scientists in the work of WG-EMM. The Working Group also noted that the Secretariat was in discussion with scientists from the Korea Polar Research Institute (KOPRI) about the submission of the monitoring data to CEMP.

2.201 WG-EMM-15/37 reported on season variation in the diet of Antarctic fur seal at 25 de Mayo/King George Island from scats collected in the 2004 winter and 2004/05 summer on the coasts of Stranger Point. For the total study period, krill was the main prey taxon, followed by fish, cephalopods and penguins. For fish, myctophids (*Gymnoscopelus nicholsi* and *Electrona antarctica*) and the nototheniid *P. antarctica* constituted the dominant fish prey species during summer, while *P. antarctica* was dominant in winter and myctophids were absent. The only squid species present in the diet was *Slozarsykowia circumantarctica*. The paper concluded that fur seals centred their foraging activity on a krill community and fish associated with krill aggregations.

2.202 The Working Group recognised the value of data that provided information on non-krill (alternate) food webs and noted that the data from fur seal scats provide information on the occurrence and size frequency of myctophids and other fish species and that diet data of this type could be useful in a broader ecosystem monitoring program.

2.203 WG-EMM-15/47 provided an update on the project ‘Admiralty Bay as a model for the long-term marine monitoring program’. The first comprehensive concurrent analyses of biotic and abiotic elements of the environment of Admiralty Bay and adjacent waters occurred in the 1980s and 1990s, when the effects of climate change were less evident than now. Collection of biotic and abiotic data under this new project, which commenced in 2014/15, will allow an assessment of changes over the past 30 years, and create the possibility for future predictions. The biological, chemical and geological samples collected in 2014/15 are currently being analysed.

Spatial correlation of CEMP parameters

2.204 WG-EMM previously agreed that an analysis of spatial correlations between CEMP parameters was important for determining those parameters that might reflect local- and regional-scale changes in krill abundance (SC-CAMLR-XXXI, Annex 6, paragraph 2.122). WG-EMM-15/07 Rev. 1 presented an analysis of the spatial correlation in A3 data from the CEMP database and concluded that the level of correlation between colonies of the same species in the same subarea and division was quite variable. The Working Group agreed that the level of correlation in the A3 data between colonies was important in determining how such data should be aggregated, but also noted that it is important to consider the overall population trajectories of those colonies, even if the year-to-year variability was poorly correlated.

2.205 The Working Group thanked the Secretariat for the correlation analyses in WG-EMM-15/07 Rev. 1. It noted that such correlations are difficult because other factors may impact on the ability to achieve correlations and that further work in that regard would be beneficial (paragraph 2.171).

2.206 The Working Group noted that the A3 data used in the correlation analysis varied in the level of aggregation over sub-colonies or colonies within individual CEMP sites and reiterated its advice from 2012 (SC-CAMLR-XXXI, Annex 6, paragraph 2.123) 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. The Secretariat was requested to help assemble data to enable Members to assess the most appropriate aggregation of sub-colonies or colonies within individual CEMP sites to allow the correct interpretation of time series of penguin populations.

2.207 WG-EMM-15/P04 reported on spatial variability in A3 data for Adélie penguin populations in the east Antarctic where populations have shown consistent regional increases over the past 30 years, suggesting a common large-scale driver notwithstanding variability within regions related to local processes. The Working Group had no comments on this paper.

Standardisation

2.208 WG-EMM-15/44 provided an overview of the importance of standardising new methods against existing methods to maintain the robustness of time series from work presented in the following papers.

2.209 WG-EMM-15/P02 used data from remotely operating cameras to reassess historical abundance estimates for Adélie penguins in the east Antarctic and found there was a general trend for reconstructed estimates to be higher (20–30%) and more uncertain than published estimates. WG-EMM-15/P04 compared recent Adélie penguin population estimates at 99 sites across the east Antarctic with count data from the same sites 30 years ago. The historical and recent data were standardised to a common metric using the same correction data and process. The paper concluded that increases in Adélie penguin populations across the east Antarctic were regionally consistent, a conclusion that differs from a recent comparison of contemporary satellite estimates and historical published data, which concluded that populations in the east Antarctic had increased in some areas, decreased in others and remained stable in others. The differing conclusions may be due to aspects of non-standardisation in the satellite study, which used ground-based estimates from the Antarctic Peninsula and Ross Sea to calibrate satellite estimates for the east Antarctic. These regions could differ in a number of factors that could affect calibration, including differing colony structures, diets and their effects on guano reflectance, background substrate affecting detection, or density-dependent changes in nesting density as populations increase.

2.210 Finally, WG-EMM-15/P03 presented an evaluation of how well camera-derived observations compare with direct observations consistent with current CEMP standard methods. The work showed that cameras can provide unbiased estimates of breeding success (A6) and that, while breeding phenology (A9) events can be more difficult to observe from cameras than from direct observation, it may be possible to develop proxy observations from cameras that can effectively monitor some A9 events.

2.211 The Working Group noted that CEMP is defined by its objectives rather than by the current set of standard methods. There is scope to increase the number of CEMP parameters, based on standard methods, particularly relevant to FBM of krill.

2.212 The Working Group agreed that technological advances are increasingly leading to new and improved methods for ecosystem monitoring and it is important to ensure that existing time series remain robust as new methods are developed. Therefore, it is important to determine a minimum set of standards to be considered in accepting and using new methods for ecosystem monitoring. In particular, there was a need to understand the methods by which data had been collected in order to allow an evaluation of how that data could be used in providing advice.

2.213 The Working Group recognised that in the future of CEMP development there will be a need to make better use of existing CEMP data, data from other sources and initiatives outside of CCAMLR such as the Scientific Committee on Antarctic Research (SCAR) Horizon Scan, Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) and SOOS in order to develop a better system-level understanding through improved population and ecosystem models. The Working Group considered that this could be achieved by holding a workshop in the near future to consider these issues and noted that there have been many methodological developments and additional data sources since a previous CEMP review workshop in 2003. It may be possible to fund such a workshop through a proposal to the CEMP Special Fund in 2016.

2.214 Dr T. Ichii (Japan) recalled that a variety of CEMP indices has been collected for more than 25 years, but so far none of them have been assessed whether they are useful for krill fishery management. He indicated that existing CEMP indices should be thoroughly assessed at the CEMP review workshop and that, if their usefulness is uncertain, WG-EMM should be careful with the use of the CEMP indices in stage 2 of FBM.

2.215 WG-EMM-15/32 highlighted the value of a new inventory of important bird areas (IBAs) in Antarctica as a scientific resource for WG-EMM and SC-CAMLR. The effort to compile an IBA inventory for Antarctica was first initiated by BirdLife International and SCAR in 1998 and its recent completion was aided with further support from Australia, New Zealand, Norway, UK, USA, the Pew Charitable Trust and the British Birdwatching Fair. Australia, New Zealand, Norway, UK and the USA jointly submitted a working paper and information paper on the IBA report to the CEP meeting in Bulgaria in June 2015. The Working Group agreed that this was a valuable resource for CCAMLR and thanked the authors and contributors for this significant work. The full report is available for free download from the websites of BirdLife International (www.birdlife.org) or Environmental Research and Assessment (www.era.gs/resources/iba/Important_Bird_Areas_in_Antarctica_2015_v5.pdf). Future work is planned to link terrestrial IBAs with important marine areas identified from tracking data.

WG-EMM-STAPP

2.216 The Working Group discussed the progress of WG-EMM-STAPP towards its goal of developing spatially explicit prey consumption estimates for air-breathing predators within CCAMLR subareas around Antarctica. An update of progress in 2011 (WG-EMM-11/30) outlined a five-year program of work from 2011 to 2016 and indicated it would take at least five years to achieve a number of critical milestones (SC-CAMLR-XXX, Annex 4, paragraph 2.199). The Working Group encouraged WG-EMM-STAPP to document and report on its progress over this period, identify any further work required after this period and indicate how any further work might proceed, at WG-EMM-16.

Integrated assessment model

2.217 WG-EMM-15/51 Rev. 1 summarised recent work to develop an integrated modelling framework to estimate krill population dynamics in Subarea 48.1. The model uses statistical fits to catch and length-composition data from the krill fishery, together with biomass indices and length compositions from research surveys, to estimate parameters and then project future stock dynamics at pre-specified catch levels. The model is used to compare predicted krill spawning biomass under projected future catches to the CCAMLR decision rules. Alternative decision rules, which are based on comparing krill spawning biomass expected under projected future catch levels to spawning biomass expected without any fishing during the same future period, are also evaluated. In particular, the model suggests that if observers collect twice as much length-frequency data as they have collected to date, and those data have the same characteristics as existing data, estimates of stock status from the model would not change appreciably. By contrast, changing the precision of total estimated removals does seem likely to impact assessments of stock status. Results from this paper have implications for scientific observation of the krill fishery.

2.218 WG-EMM-15/P07 provided more details on the model and data assimilation framework and evaluated the effects of fitting to different combinations of survey data and also using two forms of selectivity.

2.219 The Working Group acknowledged the importance of developing a suite of diagnostics for evaluating the performance of assessment models, and that this had also been a topic of discussion at WG-SAM-15 (Annex 5, paragraphs 2.34 to 2.37). It suggested that the authors of WG-EMM-15/51 Rev. 1 and 15/P07 should routinely provide equivalent diagnostics such that model fits can be evaluated, especially as this model is a modification to that previously reviewed at WG-SAM-14. The Working Group suggested that model and diagnostics should be reviewed by WG-SAM-16 and that its development could also be progressed via an e-group. An overlapping meeting of WG-EMM and WG-SAM might also be an appropriate venue for a review of the model (paragraph 5.4).

2.220 Dr Watters noted that the Center of Independent Experts in the USA is scheduled to review the model in March 2016. If possible, the report from this review will be tabled to the appropriate SC-CAMLR working group (WG-SAM-16).

2.221 The Working Group also discussed the following points in relation to variability and uncertainty in the context of integrated assessment models:

(i) the spatial scale at which an assessment model is applied has implications for the degree of variability in model outputs, particularly given that observational data at subarea and local scales are highly variable

(ii) as the number of parameters in an assessment model increases, it may become difficult to interpret structural versus observational uncertainty. This is especially the case in this model where selectivity, catchability, natural mortality, B_0 and steepness are being estimated simultaneously – parameters which are confounded in integrated models and, therefore, diagnostic output is critical to understanding the model fit before stock projections can be evaluated.

2.222 The Working Group noted that estimated high levels of variation in krill recruitment have implications for the CCAMLR decision rules; a projection framework, as is used for mackerel icefish (*Champsocephalus gunnari*), might be suitable to account for this, or one similar to that proposed in de la Mare et al. (1998). It also noted that application of the current decision rules to krill would result in relatively stable catches over time as intended, but that an F-based rule based on short-term projections, like those used for mackerel icefish, could potentially result in highly variable catch limits that are not easy to manage. Importantly, any changes to the decision rule as part of the staged approach to FBM should take account of environmental change. An evaluation of the properties of different decision rules could be part of the work plan for FBM (paragraph 2.132).

2.223 The Working Group concluded that integrated assessment models could potentially be used within FBM strategies for krill. It also acknowledged the value of ensemble approaches for ecosystem integrated assessments and noted the contribution of the assessment model presented in WG-EMM-15/36 in this regard.

Collection of fishing vessel acoustic data

2.224 A summary of the 2015 meeting of SG-ASAM was provided by Dr Watkins. SG-ASAM-15 noted the submission of a paper entitled ‘The use of fishing vessels to provide acoustic data on the distribution and abundance of Antarctic krill and other pelagic species’ written by scientists involved in SG-ASAM and describing the proof of concept study undertaken by SG-ASAM. Dr Watkins reported during the present meeting that this paper had just been accepted for publication in a special issue of *Fisheries Research* on ‘Fishing vessels as scientific platforms’.

2.225 The Working Group recognised that the present focus of SG-ASAM on the use of acoustic data from fishing vessels to provide qualitative and quantitative information on the distribution and abundance of krill is an important component for the ongoing discussions of FBM.

2.226 An instruction manual detailing acoustic data collection protocols, instrument set up and metadata requirements for use by krill fishing vessels had been provided as Appendix D of the SG-ASAM-15 report (Annex 4). The Working Group recognised that this was a very clear and concise document that could now be used by fishing vessels to collect acoustic data in the coming season.

2.227 SG-ASAM-15 noted the key role of a SISO observer in the collection of acoustic data. The Working Group agreed that observers on board fishing vessels had an important role in the collection of acoustic data and the associated metadata as detailed in Annex 4, Appendix D.

2.228 The Working Group agreed that information on the length-frequency distribution of krill was necessary to generate estimates of krill density from acoustic data collected on fishing vessels. While sampling of the krill catch for length measurements is regularly undertaken by the observers, it would be important to ensure that any selectivity in the size of krill in the catch was taken account of in the generation of krill TS.

2.229 The Working Group noted the recommendation of SG-ASAM-14 and agreed that collecting acoustic data on CCAMLR transects was a priority activity (SC-CAMLR-XXXIII, Annex 4, Table 2). SG-ASAM-15 selected a subset of transects from each subarea on the basis of their biological and oceanographic interest. The Working Group agreed with these recommendations and also that, in order to use the data collected along these nominated transects to investigate temporal variation in krill abundance, the transects should be sampled as frequently as possible during the fishing season.

2.230 The Working Group noted that for the development of FBM procedures, a focus on repeated within-season occupations of these nominated transects (possibly by different appropriately equipped vessels) would be more valuable than single occupations of other transects.

2.231 The Working Group recommended that acoustic data collected by fishing vessels along these nominated transects should be submitted to the CCAMLR Secretariat and then analysed jointly by participants at the next SG-ASAM meeting. The results of this joint analysis should be presented to the next meeting of WG-EMM (paragraph 2.150). The Working Group noted that this process would also help with broadening the use, development and dissemination of the recommended analysis protocols.

2.232 The Working Group noted that providing information to the CCAMLR Secretariat on when transects were undertaken in near-real time could facilitate scheduling of repeated transects. This could also provide positive publicity for fishing companies engaged in providing acoustic data for use in the FBM process.

Scientific surveys undertaken from fishing vessels

2.233 WG-EMM-15/54 described the analysis of five annual krill surveys undertaken between 2011 and 2015 in Subarea 48.2 using two fishing vessels. The five surveys were undertaken at the same time each year over the same nominal transect lines, however, the differing quantities of sea-ice present in the survey area led to very different areas of survey coverage each year. The fishing vessels were equipped with similar echosounder systems but the available frequencies varied by vessel and year such that there was no single frequency that could be used in every year to generate a coherent series of krill biomass estimates. A substantial proportion of the survey area is south of the South Orkney Islands, which was frequently covered in sea-ice at the time of the survey. In order to avoid variability due to different areas of coverage between years, a stratum covering the transect sections on the northern side of the South Orkney Islands covered in all years except 2013, was defined.

2.234 The Working Group noted that future work planned as part of the joint UK–Norway studies to be undertaken in January/February 2016 would provide additional sampling in this region and in particular the distribution, abundance and potential flux of krill through the main fishing region on the northwest side of the South Orkney Islands.

2.235 The Working Group noted that 70 kHz had not been used previously within CCAMLR either as part of the target identification process or as the frequency at which krill density was estimated. WG-EMM-15/54 raised a series of issues around the use of this frequency as well as other issues (paragraph 2.233) that were very relevant to the work of SG-ASAM and the Working Group recommended submission to that Subgroup.

2.236 WG-EMM-15/54 presented krill length-frequency distributions collected during the acoustic surveys that showed a strong year class in 2012 (detectable as 25 mm cohort). The Working Group noted that this cohort was detected in winter surveys undertaken in Subarea 48.1 by the US AMLR Program and also in the length-frequency distributions provided by scientific observers on board fishing vessels and in the Krill Fishery Report (WG-EMM-15/30). Furthermore, a compilation of all summer and winter survey data collected by Germany, Peru and the USA from 2012 to present was being undertaken and it was possible to see the progress of this year class through this cohort over a three-year period. Importantly, it was also noted that there was no sign of any other significant recruitment in this time period.

2.237 The Working Group noted that the data in the Krill Fishery Report (WG-EMM-15/30) showed that over a longer time scale strong recruitment peaks occurred episodically (for instance in 2008 and 2012). The Working Group reiterated that such extreme variability in annual recruitment had implications for management strategies as these would be very different from those required if there was a consistently low level of recruitment every year.

2.238 The Working Group noted that understanding the fishing strategies used by fishing vessels was important, for instance in determining critical krill densities required for fishing, or what signals might be used to choose fishing regions. Recalling the workshop organised by the Association of Responsible Krill harvesting companies (ARK) in Punta Arenas, Chile (June 2014), it was agreed that this had been a very valuable forum for direct communication with fishing masters and others directly involved in deciding fishing strategy. However, the Working Group noted that not all fishing companies were presently represented in ARK and that mechanisms by which formal dialogue with all fishers might be established should be considered by SC-CAMLR.

Proposals for future krill surveys

2.239 WG-EMM-15/43 presented Japan's outline plan for surveys in East Antarctica.

2.240 Two kinds of survey are proposed:

(i) An annual survey undertaken from a dedicated cetacean sighting vessel equipped with a scientific echosounder system, a vertical net and conductivity temperature depth probe (CTD) system. These surveys would be carried out for 12 years using a zigzag stratified survey design optimised for sighting whales. The aims of these surveys include obtaining an index of relative krill abundance.

(ii) A dedicated krill survey carried out from a trawler-type research vessel equipped with a multifrequency scientific echosounder system, research net such as RMT8 or IKMT and a full CTD/multi-bottle water sampler. These surveys would be carried out once in each of two six-year periods using a survey design compatible with CCAMLR survey protocols and an area of coverage similar to those used in previous surveys carried out in the region (BROKE in 1996 and BROKE West in 2006). The main aim of these surveys is to obtain an index of absolute krill abundance.

2.241 The Working Group noted that survey design was important for determining whether outcomes of such work would be relevant to WG-EMM and CCAMLR.

(i) The survey undertaken from the whale sighting vessel was primarily designed for work outside of CCAMLR. The collection of data on the krill ecosystem, other than whale sightings, was also proposed. However, the proposed whale sighting survey design is not consistent with survey designs established by CCAMLR for monitoring krill.

(ii) In this regard it was noted that this whale sighting survey would consist of a zigzag design of alternating phases of independent observer and closing modes. This raised two potential issues that would need to be considered in the context of a krill ecosystem survey: (i) the survey will involve approaching the sighted whales to confirm identification, determine school size and, in some cases, to take samples (biopsy and photo-id), (ii) zigzag surveys result in an uneven sampling effort that needs to be taken into account.

(iii) The Working Group noted that the whale sighting surveys would cover areas where there had been little oceanography data collected previously. Therefore, deploying expendable CTDs regularly during these surveys would be valuable. In this regard the Working Group was informed that oceanographic data from the previous 24 years of whale sighting surveys was now available for use by the scientific community (http://icrwhale.org/pdf/oceanographicdata.pdf). The Working Group also noted that in this area there was a sparse coverage from surface drifting meteorological buoys and the possibility of deploying such drifters on behalf of the relevant international programs could be considered.

(iv) WG-EMM-15/43 proposed that the two dedicated krill surveys would be carried out in two separate regions of the east Antarctic, over the survey areas covered by BROKE and BROKE West surveys in the past. The Working Group recommended that, given that there would be two such surveys within a 12-year period, it would be more valuable to undertake the two surveys in the same region using the same survey design. This would provide a better temporal coverage for one area.

(v) The Working Group noted that different net sampling gear and protocols were proposed for the two types of survey: a small vertically hauled net with an attached light/strobe in the whale sighting surveys in contrast to an obliquely hauled krill research trawl in the CCAMLR-endorsed design surveys. Given these differences, the Working Group encouraged conducting comparisons between the nets and also on the effect of using a light to fish for krill.

(vi) The Working Group encouraged submission of details of the broader objectives of the research program in order to aid the interpretation of the survey design. Recognising that WG-EMM-15/43 was a preliminary proposal, and taking into account the different time frames for the two types of survey, the Working Group recommended that a more detailed paper on the proposal for the dedicated krill survey should be submitted to the next meeting of WG-EMM. With regard to the whale sighting-type survey, it was noted that the first survey would take place next season. However, the Working Group is not currently able to assess the utility of data from surveys of this design. It was agreed that detailed information on survey design would be submitted with data from the first of these surveys to the next meetings of SG-ASAM (to consider the utility of the acoustic data for estimating relative and absolute krill abundance), WG-SAM (to assess the survey design, in particular the trade-offs between the primary goal of gathering information on cetaceans versus the secondary goal of gathering information on krill) and WG-EMM (to review the results).

Multinational coordination

2.242 The Working Group realised that this agenda item is much broader than suggested by the submission of a single paper (WG-EMM-15/27). It noted that SG-ASAM-15 (Annex 4) demonstrated the potential of coordinated effort from the fishing fleet. Other papers suggested utilising coordinated fishing vessel effort from several nations to achieve the observation requirements for FBM (WG-EMM-15/04, 15/10, 15/33). The Working Group agreed that multinational coordination should be considered as a regular agenda item for WG-EMM to ensure progress in the data collection for FBM.

2.243 WG-EMM-15/27 discussed requirements for carrying out a new area-scale survey covering Subareas 48.1 to 48.4. The paper refers to Article II of the Convention requiring that harvest does not negatively impact the goal of ensuring a spawning population that supports stable recruitment. The authors recommended that WG-EMM consider the need for such surveys and, if such surveys are likely to be important, establish a planning process which will allow an efficient response to future requests for area-scale surveys.

2.244 The paper underlined that the existing subarea-scale surveys show high variability without trend and that there are major uncertainties associated with the impact of flux within and between regions that are not resolved through the current monitoring. An area-scale survey should support better understanding of these uncertainties in present assessments. The FBM requires subarea-scale stock assessments but another paper (WG-EMM-15/10) also suggested that these have to be combined with area-scale surveys carried out at intermittent or regular intervals.

2.245 WG-EMM-15/27 introduced practical considerations for planning an area-scale krill survey by reference to the CCAMLR-2000 Survey and provided the basis for discussions within WG-EMM to establish a planning process. The paper suggested that many of the procedures behind the CCAMLR-2000 Survey be followed, although advances in e.g. data management and processing of acoustic data need to be included. The paper emphasised that it is not only realistic, but probably the only viable option, to include fishing vessel effort as a major contribution if such a survey should be carried out. Thus, as the planning will be time-consuming and demanding, it will have to start now if a survey is to be carried out in the near future.

2.246 The Working Group welcomed the initiative. The CCAMLR-2000 Survey was a complicated task and the Working Group realised that a new survey involving more vessels will cost time and effort in coordination and planning. The Working Group agreed that such a process could learn from experience gained in complex coordination tasks in other parts of the Convention Area. It also agreed that cross-reference to other activities in the Antarctic should be taken into account to secure temporal and spatial coordination with these activities without complicating the planning and execution of the survey. For example, some coordination with activities with SOOS could be useful in this regard (WG-EMM-15/61).

2.247 China, the Republic of Korea and Norway confirmed the interest of their industries to participate in multinational coordinated subarea-scale surveys which underline the potential of using multinational fishing vessel effort for area-scale surveys in the future. A particular challenge will be to manage combining the completion of the subarea-scale surveys in the same year as CCAMLR carries out the area-scale survey. Success of similar coordinated effort within the International Council for the Exploration of the Sea (ICES) demonstrates the potential of such coordinated effort. The Working Group emphasised that definition of the basic scientific questions is required as a basis for the planning and execution of an area-scale survey.

2.248 The Working Group requested that Members that undertake krill fishing activities liaise with their industry representatives to determine whether their krill fishing vessels are willing to participate in these research activities.

2.249 The Working Group recalled its advice from last year (SC-CAMLR-XXXIII, paragraph 3.39) that absolute estimates of krill biomass in the whole of Area 48 are unlikely to be available on a regular basis and there will be a need to have management approaches that are not dependent upon data that are unlikely to be available at the spatial and temporal scales required for a particular management approach. However, the Working Group agreed that large-scale surveys provide essential data related to variability and trends in the subarea-scale surveys and krill distribution, abundance and the impacts of climate change.

Spatial management

Marine protected areas (MPAs)

MPA Planning Domain 1 (Western Antarctic Peninsula and southern Scotia Sea)

3.1 WG-EMM-15/34 reported on a domestic workshop to identify US stakeholders' objectives and protection priorities for one or more MPAs in Planning Domain 1. The workshop was held in La Jolla, USA, in March 2015, and hosted by scientists from the US AMLR Program. The USA has substantive interests within the boundaries of Planning Domain 1, and the aim of the workshop was to develop background information and to provide a basis for future collaborations and discussions on MPA planning in this region.

3.2 Key outputs from the workshop included:

(i) list of specific objectives for MPAs in Domain 1

(ii) map of priorities for spatial protection, based on the list of objectives. This was done using an expert opinion approach, where groups of participants were asked to assign varying levels of priority to areas across the planning domain, in an effort to achieve all of the defined objectives

(iii) estimates of conservation targets inferred from these priorities, for application in decision-support tools such as Marxan

(iv) stakeholders' views on MPA size and duration, the management tools (e.g. no-take areas, gear restrictions and seasonal closures) that may be required to achieve various MPA objectives, and the future research and monitoring efforts needed to underpin one or more MPAs.

3.3 The workshop also reviewed a range of newly compiled data layers on the spatial distributions of zooplankton, fish and upper-level predators, the physical environment and the distributions of fishing, tourism and research activities in Domain 1. Much of this data was subsequently made available as GIS shapefiles for use at the Second International Workshop on identifying MPAs in Domain 1 (see paragraphs 3.8 to 3.11).

3.4 Participants at the workshop prioritised protection of the continental shelf and inshore waters along the western coast of the Antarctic Peninsula, from around Alexander Island and Marguerite Bay northeast to the tip of the peninsula and Joinville Island, including various islands and archipelagos such as the South Shetland Islands. These areas largely coincide with the Palmer LTER and US AMLR study areas, and their prioritisation is consistent with the stakeholders' aspiration to 'preserve the integrity of existing studies'. The highest conservation targets were inferred for two small canyons cutting across the continental shelf north of Livingston Island, and for the Gerlache Strait, which is an inshore nursery for larval krill.

3.5 Participants at the workshop also agreed that the size of an MPA should be determined by the spatial requirements needed to achieve its specific objectives; that several scientific issues are relevant to the duration of MPAs; and that existing international research and monitoring efforts in Domain 1 provide a useful baseline for assessing future changes.

3.6 The Working Group thanked Dr Watters for this informative report, which is useful in highlighting the areas that US stakeholders believe are important for protection. It noted that broad engagement with stakeholders in such discussions is very valuable and, in particular, that there had been a positive response from the International Association of Antarctic Tour Operators which was pleased to have been involved in this process.

3.7 Dr Watters noted that the current status of protection in some areas by ASPAs and Antarctic Specially Managed Areas (ASMAs) did not influence stakeholder priorities, and that such areas were too small to significantly influence the outcomes. There was a range of opinions in this stakeholder group on whether or not to prioritise the existing South Orkney Islands MPA, however, it was noted that it falls outside the main area of US interest.

3.8 WG-EMM-15/42 presented a report on the Second International Workshop for identifying MPAs in Planning Domain 1. This workshop was held in Buenos Aires, Argentina (25 to 29 May 2015), and was as co-convened by Drs E. Marschoff (Argentina) and J. Arata (Chile). It was attended by representatives from Argentina, Chile, European Union, Germany, Norway, UK, USA, NGOs and the fishing industry.

3.9 The Working Group thanked the workshop conveners and participants, and welcomed the progress made on MPA planning in Domain 1. It acknowledged the valuable opportunity provided by the international workshop in Buenos Aires for Members to review and contribute to the work being done by Argentina and Chile.

3.10 New and updated data available for this workshop was shared before the start of the meeting through a CCAMLR e-group. Preliminary activities included national workshops carried out by Argentina, Chile, UK and USA and aimed to (i) compile new data, (ii) discuss different conservation objectives, (iii) analyse penguin habitat modelling and (iv) identify high-priority areas for conservation within Domain 1.

3.11 Workshop discussions focused on reviewing and analysing new and updated data, and in further developing the conservation objectives. A large amount of new data had been provided for objectives that previously had incomplete information, including prey distributions (larval and adult krill, crystal krill (*Euphausia crystallorophias*), bigeye krill (*Thysanoessa macrura*) and salps), important areas for zooplankton life cycles (krill nurseries), non-breeding whale distributions, emperor (*Aptenodytes forsteri*) and macaroni penguin colonies, and new information on benthic communities. Updated data included new classifications for canyons, minimum and maximum sea-ice extent, predator colonies with relevant buffers and tracking data (breeding and non-breeding distributions) and important areas for fish life cycles.

3.12 In previous workshops, Marxan software was agreed to be the most appropriate tool to support decision-making in the design of a system of MPAs in Domain 1. The workshop recognised the value of exploring a range of different Marxan scenarios to better understand the influence of conservation objectives and cost layers. Parameters for three different protection scenarios (low, medium and high) were agreed during the workshop for use in Marxan analyses. Discussions also focused on definition of the cost layer, reviewing available data on human activities and investigating the parameters involved in its estimation.

3.13 The workshop noted the importance of considering the development of MPAs in Domain 1 in the context of the development of FBM of the krill fishery.

3.14 The workshop also noted the importance of considering the area at the boundary between Domain 1 and 3 (Weddell Sea planning domain), as the northern Antarctic Peninsula region is an area of particular ecological interest. It was suggested that WG-EMM-15 would provide a good opportunity for those involved in both the Domain 1 and Weddell Sea MPA planning processes to discuss common issues and approaches for this boundary region.

3.15 The Working Group thanked the workshop conveners and participants and welcomed the progress made on MPA planning in Domain 1.

3.16 Drs Arata and Santos indicated that a bilateral workshop between Chile and Argentina would be held in December 2015 and that the aim is to present a draft MPA proposal in 2016 or 2017.

3.17 Dr Santos noted that further updates would be made to penguin colony location and predator tracking data layers and that these will be made available to all Members through the Domain 1 Planning e-group. As agreed in the workshop, Dr Santos also noted that Marxan input files would be uploaded in this e-group to encourage other Members to conduct their own analysis.

3.18 The Working Group discussed how other spatial management processes (ASPAs, ASMAs, CEMP sites, vulnerable marine ecosystems (VMEs) and the existing South Orkney Islands MPA) integrate into the broader Domain 1 planning process. Dr Arata noted that Marxan analyses will be undertaken, both with and without VMEs and existing protected areas, to explore how such areas might influence the selection of additional areas for protection based on the conservation objectives. He noted that CEMP sites are not protected by CCAMLR and are not used as an input to the Marxan analysis, but that it may be useful to consider how spatial management of areas surrounding CEMP sites could contribute to FBM, in the context of Domain 1 conservation objectives relevant to scientific reference areas. He further noted that, while the existing South Orkney Islands MPA was not designed in the context of the wider Domain 1, it is useful to consider how it contributes to the Domain 1 conservation objectives.

3.19 Dr Jones suggested that the consideration of CEMP sites as part of the MPA planning process could also be included in future work towards refining stage 2 or moving to stage 2 of FBM, through potentially closing or limiting krill fishing near selected CEMP sites.

3.20 The Working Group also noted the importance of considering the broader circumpolar context of some of the data layers included in such regional analyses, for example the extent to which geomorphic features, such as seamounts occurring in Domain 1, are represented across the Convention Area.

3.21 WG-EMM-15/41 described a study of population structure changes in common benthic species of the proposed Stella Creek MPA in the vicinity of Akademik Vernadsky Station. It presented the results of scuba diving surveys during two seasons of observations (2012 and 2014). This was a non-destructive survey method using analysis of underwater photos. The study reported on changes in the population structure of three common species (limpet *Nacella concina*, sea urchin *Sterechinus neumayeri* and sea star *Odontaster validus*). The authors plan to continue this monitoring of the population dynamics of common species and their dependence on the hydrological characteristics in the Stella Creek MPA.

3.22 The Working Group welcomed the ongoing work in this area and noted that it would be useful to incorporate consideration of this proposal within the wider Domain 1 MPA planning process. It was also noted that there had been previous suggestions for this proposal to be considered as an ASPA rather than an MPA. Consideration of current threats and the urgency of protection will be important in determining the best way to achieve protection for this area.

3.23 The Working Group noted that future joint SC-CAMLR–CEP interactions may provide a useful opportunity to discuss how the respective protected area systems of these two bodies could be harmonised.

MPA Planning Domains 3 and 4 (Weddell Sea)

3.24 Prof. Brey and Dr K. Teschke (Germany) presented three scientific background documents in support of a CCAMLR MPA in the Weddell Sea: WG-EMM-15/38 Rev. 1 (Part A: General context of the establishment of MPAs and background information on the MPA planning area); WG-EMM-15/39 (Part B: Description of available spatial data); and WG-EMM-15/46 (Part C: Data analysis and MPA scenario development).

3.25 The Working Group acknowledged the extensive work done by the Weddell Sea MPA project group to date. A large amount of relevant data are compiled for the Weddell Sea planning domain, which provides a good foundation for the MPA planning process. The Working Group also noted the valuable opportunity for discussion of data layers and conservation objectives that was provided by the International Expert Workshop held in Berlin, Germany, in April 2015.

3.26 WG-EMM-15/38 Rev. 1 includes four chapters: (i) synopsis of establishment of MPAs in general, (ii) boundaries of planning domain, (iii) comprehensive description of Weddell Sea ecosystem, and (iv) future work. WG-EMM-15/39 includes information on environmental data and biological parameters, with descriptions of new datasets that have been added and updates to existing datasets.

3.27 As an update to the information provided in chapter 1 of WG-EMM-15/38 Rev. 1, Dr Trathan reminded the Working Group of recent progress made by the UN 'Ad Hoc Open-ended Informal Working Group to study issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction'.

3.28 Prof. Brey explained that information on pelagic fish will be included in the next version of the analysis and that the Russian toothfish data will be included when available. An additional scientific background chapter on demersal fish is currently being prepared.

3.29 The Working Group recalled that the toothfish data from the Weddell Sea were quarantined (CCAMLR-XXXIII, paragraph 3.12).

3.30 Prof. Brey noted that some data layers remain to be updated, including the sponge communities layer. He indicated that once data layers have been finalised, they would be published to a data repository such as Pangaea (www.pangaea.de), which would assign a unique digital object identifier (DOI) number to each dataset that can also be used when the data are uploaded to the relevant CCAMLR database. Version numbers will be included to allow tracking of the history of each dataset.

3.31 In discussing the scientific background information available for the Weddell Sea planning domain, the Working Group suggested that individual chapters from WG-EMM-15/38 Rev. 1 could be separated and attached to the respective data layers. Further discussions on general issues surrounding the archiving of data for MPA planning are summarised in paragraphs 3.67 to 3.69.

3.32 Dr Godø asked for clarification of the reasons for including such a large part of Planning Domain 4. Prof. Brey responded that limiting the planning area to Domain 3 would have cut through a major biogeographic region and that it was more meaningful to include the whole of the shelf and the Weddell Gyre (SC-CAMLR-XXXII, paragraphs 5.22 and 5.23).

3.33 WG-EMM-15/46 includes further analyses of the available data and a description of the development of MPA scenarios using Marxan analysis as part of a systematic conservation planning approach. The Working Group discussed a number of issues regarding these analyses and the data used therein.

3.34 Dr Trathan noted that there is little spatial overlap between the distribution patterns of krill and *Pleuragramma* with emperor penguins. Prof. Brey responded that the data have been accumulated from separate investigations, and may in addition be too patchy and sparse to show spatial correlation across such a large area. Dr V. Siegel (EU) indicated that spatial overlap between krill and emperor penguins would not be expected in the Weddell Sea. Dr Trathan agreed that the onshelf/offshelf distribution of krill could lead to such outcomes as could temporal mismatches in data collection. He therefore suggested that levels of uncertainty could be included in the analyses.

3.35 Dr L.A. Pastene Perez (Japan) indicated that the boundaries of any MPA within the Weddell Sea planning area will cover only part of the migratory range of humpback and Antarctic minke whales, and noted that there was little information on how these species might be monitored within the Weddell Sea.

3.36 Dr Trathan noted that data from cetacean observations in the eastern part of the Weddell Sea MPA planning region (Domain 4) have recently been submitted to the IWC (Findlay et al., 2014) and may be relevant for inclusion in future analyses.

3.37 Dr J. van Franeker (EU) proposed that information on flying seabird distribution be included in the MPA planning analysis, in particular for Antarctic petrels (*Thalassoica antarctica*) as the largest colony of this species in the Antarctic is located in the region. Although data on such species are currently poor, he suggested that distributions could be approximated using habitat models based on the available environmental data.

3.38 Prof. Brey noted that most flying seabirds target open water and the marginal ice zone, and that these habitats are presumably already covered by other data layers, but a seabird habitat model will be developed to investigate this.

3.39 Dr Kasatkina stated that data on the state of toothfish as an important component of the ecosystem were currently not available. Such data can be obtained through research fishing, which Russia considers should be undertaken in the Weddell Sea and results included in the MPA planning analysis.

3.40 The Working Group recognised the problems of toothfish data availability for this area, given that the Scientific Committee has determined that some data are quarantined and that these data cannot, therefore, be recommended for use until they have been deemed suitable. However, it suggested that generic toothfish data from elsewhere could be used as an alternative. Dr Trathan noted that a similar approach has been taken for emperor penguins, where data from elsewhere were used to generate a habitat model in the absence of tracking data for the Weddell Sea.

3.41 With regard to the conservation objectives for benthic habitats, the Working Group suggested that VME notifications for features such as sponge associations could be considered in parallel with the MPA planning process. Notification of VMEs under CM 22-06 may provide additional support for the designation of these areas as MPAs.

3.42 The Working Group discussed Table 2.3 in WG-EMM-15/46, which shows the results of the Marxan analyses and the extent to which the defined targets for each conservation objective had been achieved. It was noted that the results indicate that many of the objectives were easily achieved, with the spatial coverage for some objectives being greater than that specified by the nominal targets. This arose because of the spatial overlap of many objectives.

3.43 Prof. Brey explained that target values are set according to the importance of each feature; these may be low for features covering large areas such as krill distribution, or high for very important or unique features such as sponge communities. The targets defined in WG-EMM-15/46, Table 2.3, resulted from extensive discussions and reflect agreement at the workshop on what was considered to be reasonable.

3.44 The Working Group suggested that WG-EMM-15/46, Table 2.3, could be rearranged so that the conservation objectives which are the primary drivers of the Marxan results are listed separately to those that are achieved as a consequence. Demonstrating which objectives are driving the analysis will be important for understanding the effects of intercorrelation between objectives.

3.45 The Working Group also suggested that it would be useful to include a description of the properties of each data layer included in the analysis, together with the reasons for including it (or the reasons for excluding other data). Some data may not be relevant, and it would be helpful to set out a clear justification for which datasets are most important for each objective. The Working Group noted that much of this information is already available in WG-EMM-15/39.

3.46 The Working Group noted that information on data quality could also be added to data descriptions, including, for example, data accuracy, gaps and levels of uncertainty for different data layers. Marxan outputs could then be evaluated in relation to data quality. While the next steps will need to consider data uncertainties, the presentation of MPA scenarios is not dependent on the same level of detail being provided for all data relevant to the different conservation objectives.

3.47 Prof. Brey acknowledged the issue of data quality, but noted that it may be difficult to provide a common measure of quality for every dataset. In the current approach, expert knowledge was used to evaluate the Marxan results, and emphasis was placed on finding stable solutions to provide confidence in the outputs. In future analyses it may be useful to undertake further sensitivity testing by excluding one data layer at a time, which would also help to identify the data layers to which the result is most sensitive.

3.48 Dr Ichii drew the attention of the Working Group to the importance of including a cost layer in analyses. The Working Group discussed the types of information that this could incorporate.

3.49 The Working Group noted that analyses which do not include a cost layer can be used to identify priority areas, and that a separate process including a cost layer would then identify areas for protection. The cost layer modifies the outcomes and may reduce the spatial coverage for some objectives, but usually only for areas with low or medium targets.

3.50 The Working Group noted that the current analyses are focused on identifying priority areas and developing guidance on conservation objectives.

3.51 The Working Group discussed the possibility of using existing research fishing blocks as part of a cost layer, for example assigning a higher cost to more intensively fished areas, and a lower cost to areas in which there is no current fishing. Some suggestions were made on what could be included in a cost layer, including possibly: areas of toothfish habitat, inversely weighted with an index of sea-ice concentration (e.g. WG-FSA-14/54) and potentially with a minimum size for fishable areas; and potential krill fishing areas.

3.52 The Working Group further noted that although the research or exploratory fishing zones identified in Figure 2.4 of WG-EMM-15/46 have been considered by the Scientific Committee, they have not been formally established as spatial management zones. It would be useful to harmonise the terminology used to describe such areas.

3.53 Mr H. Moronuki (Japan) raised a general concern about the approach to designating objectives for a Weddell Sea MPA. He suggested that although MPAs are an important tool, there already exist other management tools such as fishery management measures or VMEs under the Convention, most of which are working well for the conservation and management of living resources in the Convention Area. He noted that, while the proposed MPA covers most of the area shallower than 550 m, there should be clear conservation objectives to justify such a large area. Mr Moronuki also noted that the MPA checklist proposed by Japan may be useful in this process.

3.54 The Working Group agreed that the three scientific background documents presented in support of a Weddell Sea MPA provide a good indication of priority areas of conservation importance, noting that it has not been presented as a complete MPA proposal at this stage. The Working Group recommended that further analyses be undertaken, taking into account recommendations on issues including missing data layers (e.g. paragraphs 3.39 and 3.40), data quality and uncertainty (paragraphs 3.46 and 3.47), the use of a cost layer (paragraphs 3.48 to 3.51) and the overlap with Domain 1 (paragraphs 3.55 to 3.59). The Working Group looked forward to future discussions on how best to achieve the conservation objectives for this MPA planning domain.

Approaches to MPA planning in the boundary region between Domains 1 and 3

3.55 The Working Group noted that the area east of the northern tip of the Antarctic Peninsula has been identified to be of high conservation value both in Domain 1 and Domain 3. In both domains the conservation value of this area arises from a number of similar or identical objectives. This indicates that the border between Domains 1 and 3 artificially cuts through an area that may constitute a potentially important area for management.

3.56 The Working Group considered ways to account for this finding, i.e. how to adjust or modify the MPA evaluation process in both domains in order to demonstrate that it is a potentially important area for management. It was suggested that three alternative approaches might be considered:

(i) use expert knowledge to decide on the significance of the common border area in the MPA planning process at each domain

(ii) incorporate a buffer zone for both domains at their intersection (e.g. 2° latitude) to perform separate expanded spatial analyses (Marxan), including the relevant data layers identified in Table 5, to identify whether there are potential areas of overlap considered important for conservation in both domains

(iii) review, share and incorporate relevant data that describe those objects/features which extend across the boundary area (Table 5) into each separate analysis.

3.57 The Working Group recognised that either approach (ii) or (iii) could provide an objective and independent cross-validation of the identification of priority areas. The Working Group identified a preliminary list of data layers describing objects/features that cross the domain boundary and that may be relevant for this validation process, which are presented in Table 5. These data layers will be shared among both planning processes, using the CCAMLR rules of data access.

3.58 The Working Group recommended that those working on the MPA planning processes for Domain 1 and Domain 3 should include independent analyses for this boundary region and report their findings to the next meeting of WG-EMM.

3.59 The Working Group noted that similar issues may arise for other planning domains, particularly if the boundary region includes a high concentration of features likely to be identified as important for achieving conservation objectives. Future MPA planning analyses could consider including a buffer across the boundary area, if required.

Archiving of background information and data layers used in MPA planning processes

3.60 The Working Group discussed the importance of making background information and data layers relevant to MPA planning available to all Members through the CCAMLR website. It was agreed that there are three broad types of information that might be useful in this regard, noting the distinction between MPA Reports, MPA planning reference documents and working materials. These could be made available in a hierarchical structure where access to some pages would be restricted to Members only:

(i) information on the status of MPAs and general background (public)

(ii) background information and MPA planning documents submitted to CCAMLR meetings (password-protected)

(iii) working information for MPA planning in progress (password-protected, e.g. e-groups).

3.61 In 2014, the Scientific Committee agreed that MPA planning reference documents could be placed on the CCAMLR website under a separate ‘Conservation’ tab, with an area for Member-only access. This area could also be used by Members to post documents related to, or commenting on, the MPA planning and proposals in a certain planning domain or region (SC-CAMLR-XXXIII, paragraph 5.48).

3.62 Dr Constable presented a potential structure for how information under such a Conservation tab might be organised, with separate pages for each MPA planning area, as well as general documents. He noted that there is currently no central place on the website for information on a range of conservation issues, such as incidental mortality, and that these could also be included under this tab.

3.63 The Working Group agreed that finding this information from the CCAMLR home page needed to be straightforward and intuitive. The need for headings to be easily discoverable by search engines was also emphasised. Some Members thought that a different term might be more appropriate as a heading for this website tab, as ‘Conservation’ includes all of the business of the Commission.

3.64 The Working Group agreed that it is up to individual Members to decide which document(s) they wish to have displayed as MPA planning reference documents in relation to a specific MPA planning region. This might be a single document expressing the current status of a proposal or analysis, or it may include a more extensive collation of papers that have previously been submitted to CCAMLR meetings and working groups.

3.65 The Working Group recognised the difference between MPA planning reference documents and MPA Reports, which would be provided once an MPA has been established. MPA planning reference documents would not need to be submitted in a standardised format, as there may be a wide variety of different approaches and information for different MPA planning regions. However, MPA Reports should have a standardised format, as previously agreed by the Scientific Committee (SC-CAMLR-XXXI, paragraph 5.33).

3.66 In addition to the MPA planning reference documents, the Working Group recognised the importance of areas on the CCAMLR website where Members can share information and discuss work in progress as part of MPA planning processes. The current system of e-groups is useful for this and could be maintained as part of the hierarchy suggested above.

3.67 While there is a facility for datasets to be shared via e-groups as part of work in progress, there is also a need to archive final versions of the datasets used in MPA planning processes. Some data relevant to MPA planning in Domains 7 and 8 are currently available through the data pages of the CCAMLR website, but it would be useful for links to such information to be accessible from the relevant MPA planning region web page.

3.68 The Working Group made the following general recommendations on issues to be considered for archiving data related to MPA planning:

(i) data layers used in MPA analyses should be made available for review and use by all Members as far as possible

(ii) multiple updates to different data layers during the MPA planning process will make it critical to have accurate and standardised metadata and control over use of the most recent version

(iii) metadata records for all data layers should provide information on where the data reside, how to access them and how to initiate discussions with data owners

(iv) such metadata records could also be included in papers describing analyses in which these data are used

(v) issues of data ownership and access may make it necessary to restrict access to some datasets

(vi) CCAMLR data access rules may need to be revisited to ensure that they provide sufficient protection for unpublished data

(vii) several data portal initiatives (e.g. SOOS, SCAR Biogeographic Atlas, Pangaea) are now assembling datasets. Some Members may choose to make their datasets available elsewhere (see e.g. paragraph 3.30), but it is important that all portals point to the same metadata.

3.69 The Working Group noted that similar types of datasets are being produced and analysed in different forms, and that facilitating shared access to such datasets for different aspects of CCAMLR's work could save significant time and effort. For example, data on penguin colonies relates not only to MPAs but also to management of the krill fishery.

3.70 The Working Group requested that the Scientific Committee consider how it wished to implement its recommendation from last year to help the Secretariat to implement this facility. Some MPA-related web pages are currently under development by the Secretariat, and these can be made available to Members to facilitate discussion.

Vulnerable marine ecosystems

3.71 No papers were submitted under this agenda item. However, the Working Group noted the discussions under Agenda Item 3.1 on ecologically important sponge associations identified in the Weddell Sea MPA planning domain (paragraph 3.41) and the potential notification of these areas as VMEs under CM 22-06.

3.72 Dr Jones informed the Working Group that US scientists had recently identified two areas containing large sponges and gorgonians close to the Rosenthal Islands off the west coast of Anvers Island. No formal notification of a VME encounter has yet been made, but the appropriate documentation will be put together for next year.

Advice to the Scientific Committee and its working groups

4.1 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.

4.2 The Working Group advised the Scientific Committee and other working groups on the following topics:

(i) Krill fishing activities –

(a) Finfish by-catch (paragraphs 2.6 and 2.8)
(b) Fishing gear library (paragraph 2.26)
(c) Notifications for 2015/16 (paragraphs 2.22 to 2.24)
(d) Reporting changes in the spatial distribution of catch (CM 23-06) (paragraph 2.9).

(ii) Scientific observations –

(a) Fish species reference guide (paragraph 2.29)

(b) General measure for scientific observation (CM 51-06) (paragraphs 2.34, 2.37, 2.39 and 2.42)

(c) Establishing a SISO working group (paragraph 2.43).

(iii) Krill biology and ecology –

(a) Acoustic protocols (paragraph 2.59)
(b) Disease in krill (paragraph 2.66)
(c) Krill catch impacts on biomass (paragraphs 2.72 and 2.74)
(d) Interim distribution of the trigger level in the fishery (CM 51-07) (paragraph 2.83).

(iv) Role of fish in the ecosystem –

(a) Depredation (paragraph 2.88).

(v) FBM –

(a) General (paragraphs 2.127, 2.175, 2,177 and 2.178)

(b) Implementation of FBM (paragraph 2.158) and specifically stage 2 (paragraphs 2.130, 2.131, 2.132 and 2.159)

(c) Krill surveys and CEMP in stage 2 (paragraphs 2.165 to 2.167)

(d) Fishing vessels contributing to FBM (paragraph 2.141)

(e) Interim distribution of the trigger limit (CM 51-07) (paragraphs 2.135 to 2.138).

(vi) CEMP and WG-EMM-STAPP (paragraphs 2.185 and 2.189).

(vii) Fishing vessel surveys (paragraph 2.231).

(viii) Multination coordination (paragraphs 2.248 and 2.249).

(ix) Spatial management –

(a) MPA planning data (paragraph 3.68).

(x) Future work –

(a) Climate change (paragraph 5.15)
(b) SC-CAMLR communication (paragraph 5.17).

(xi) Other business –

(a) Working group paper submissions (paragraphs 6.20 and 6.21).

Future work

Streamlining the work of the Scientific Committee
and its working groups

5.1 WG-EMM-15/59 proposed some options for reorganising the work and structure of the Scientific Committee. These options include having three meeting periods timetabled through the year: a two-week period for workshops, a three-week period for the Scientific Committee and its working groups (and maybe workshops) in mid-year, and a short meeting of the Scientific Committee just prior to the annual Commission meeting. The paper also suggested a coordinating group be established in the Scientific Committee, comprising the Chair and Vice-Chairs of the Scientific Committee and the conveners of standing working groups (supported by the Secretariat) to coordinate the business of the meeting and to stimulate and guide intersessional activities. The motivation for these suggestions is that the current workload of the Scientific Committee and its working groups is too high; some topics are discussed every year, despite not necessarily needing to be addressed at that frequency, and there is a need for increased flexibility.

5.2 The Working Group welcomed the idea of a coordinating body to advise the Scientific Committee and noted that this is a model that is used successfully in other organisations. The Working Group also noted potential costs to the host Member country in a given year of hosting both working group and Scientific Committee meetings. There may be some difficulty for small delegations to cover all issues of interest under this model, although the Working Group also discussed some of the advantages of such a model for small delegations. Previous trials of concurrent working group meetings (WG-EMM and WG-SAM) have had mixed results, although there was insufficient opportunity at those times to coordinate the scheduling of the meetings to accommodate the requirements of Members.

5.3 The Working Group agreed that the way that science flows from the Scientific Committee to the Commission is a key strength of CCAMLR, and that any changes to meeting structures that might risk decoupling the interaction between the Scientific Committee and the Commission would need to be carefully considered. It also noted that changing the timing of WG-FSA and Scientific Committee meetings would have implications for the timing of stock assessments and may affect the data available to inform these.

5.4 The Working Group recommended the following options in terms of progressing ideas for streamlining the work of the Scientific Committee and its working groups:

(i) that an e-group be developed for continuing these discussions in advance of this year's Scientific Committee meeting

(ii) that the working group conveners and the Scientific Committee Chair might prepare a paper for this year's meeting of the Scientific Committee consolidating the discussion from the e-group and providing options for the future

(iii) the paper in (ii) could include draft terms of reference for a coordinating body.

Joint workshops

5.5 Drs Grant and P. Penhale (USA) introduced WG-EMM-15/18 on the proposed Joint SC-CAMLR–CEP Workshop (2016) on climate change and monitoring that was agreed at the CEP and SC-CAMLR meetings in 2014. A Steering Committee – chaired by Drs Grant and Penhale – for this joint workshop has been established, together with terms of reference. A tentative suggestion for the timing and location is in Chile, prior to the CEP meeting in early June 2016. There is an intention to facilitate virtual participation at the workshop through appropriate technology.

5.6 The Working Group considered the scope of the terms of reference in the context of the duration of the workshop (two days). It noted that, while the scope of the 2016 workshop is narrower than the previous joint workshop in 2009, two days will be a short period of time in which to fully address the questions outlined in WG-EMM-15/18. One option to help in making the discussion more tractable might be to focus on a particular region, for example the Antarctic Peninsula region.

5.7 Dr Penhale noted that narrowing the spatial focus of discussions at the workshop may not satisfy the interests of both groups fully, but that certain regions could certainly be used as examples. The Steering Committee would take responsibility for keeping the agenda sufficiently well-focused to match the time frame.

5.8 The Working Group recommended changing the wording of the second draft term of reference from 'Review existing monitoring programs…' to 'Consider existing monitoring programs…'. It noted that there are clear links between this term of reference and work in programs such as SOOS, SCAR and ICED, and that it would be useful to enable observers to attend the joint meeting. Invitations should be extended to those groups that are not represented. However, given the length of time of the workshop, the Working Group did not consider that the cost of invited experts may be warranted.

5.9 The Working Group requested that circulars be used between now and the Scientific Committee's 2015 meeting to advise on further preparatory work for the Joint SC-CAMLR–CEP Workshop.

5.10 Dr T. Kitakado (Japan) provided an update regarding a planned joint SC-CAMLR and IWC SC workshop on ecosystem modelling, in particular focusing on knowledge gaps that have been identified since the last workshop in 2008. He indicated that there is a preference to hold two workshops; the first to review data availability, and the second as a comprehensive discussion of approaches in relation to modelling and monitoring. He raised the question of whether to hold the first workshop in 2016 or to delay it to 2017 to avoid clashes with other meetings and to allow additional time for preparation.

5.11 The Working Group agreed that an extra year would be helpful in providing sufficient time to consider data and information that is outside normal CCAMLR and IWC communities (e.g. through SCAR) and that may also be important for modelling. It suggested that the steering group should consider developing draft terms of reference for the workshop, in particular relating to reviewing outcomes from the first joint workshop and assessing progress and directions. The Working Group agreed on the proposed thematic separation of data collection and modelling and suggested that the workshop steering group consider reflecting this in the draft terms of reference. A paper on the draft terms of reference could then be tabled to the coming meetings of SC-CAMLR and IWC SC for both to consider.

Workshop reports

5.12 WG-EMM-15/61 reported on 2015 activities of SOOS relevant to the work of CCAMLR, in particular the formation of regional and capability working groups, notably working groups on ecosystems, estimated abundance of pack-ice seals from satellites and acoustics. The development of the SOOS Data Management System and Portal will also be important to CCAMLR.

5.13 The Working Group agreed that SOOS provides a useful opportunity to interact with many other organisations, in particular for addressing climate change and FBM questions and as a vehicle for getting data from fishing vessels into the science community. It also acknowledged a need for SC-CAMLR and its working groups to develop better procedures for reviewing and leveraging outside expertise.

5.14 The Secretariat indicated that it is currently looking at the development of a data portal to facilitate sharing of data with the broader scientific community (subject to restrictions, etc.). It also noted that both the CCAMLR and SOOS Secretariats are located in Hobart and are intending to continue dialogue in relation to data systems.

Climate change

5.15 The Working Group noted that impacts of climate change were highlighted under several items in the agenda. It was agreed that it is vital to bring climate change considerations into its work now to ensure that scientific studies are designed and time series are built on which long-term analyses can be run and serve the scientific basis for implementation in CCAMLR management approaches, including FBM. The issues that need attention include:

(i) building long time series that enable disentangling climate change impact from natural variability

(ii) designing scientific studies that can predict or uncover changes in ecosystem function at an early stage (e.g. the salp–krill interaction, paragraphs 2.77 and 2.78).

Understanding CCAMLR's approach to management

5.16 Dr Constable provided a summary on work to update documentation around CCAMLR's approach to management (SC-CAMLR-XXXIII, paragraph 3.3). One mechanism to do this might be to use facilities through the CCAMLR website to update and compile 'chapters' on various topics.

5.17 The Working Group recommended that the Scientific Committee should consider developing a communication strategy, as a strategic priority, for informing Commissioners, stakeholders and new participants in its work of the approaches it uses and the history of discussions. This could include updating reference material such as *CCAMLR's Approach to Management*.

FBM

5.18 The Working Group agreed that FBM of the krill fishery was a priority for the coming years and recommended the Scientific Committee review its recommendations for future work in paragraphs 2.159 to 2.178.

Three-year work plan

5.19 The Working Group agreed that the Convener consult with Members and other conveners (paragraph 5.2) in preparing a three-year plan for consideration by the Scientific Committee at its coming meeting, noting the priority for developing FBM for krill.

Other business

The CCAMLR Scientific Scholarship Scheme

6.1 The Convener of WG-EMM invited the current recipient of the CCAMLR scholarship who was attending the meeting this year, Dr A. Panasiuk-Chodnicka (Poland), to give a presentation to the Working Group on the research that she is undertaking in association with the scholarship scheme.

6.2 Dr Panasiuk-Chodnicka provided an overview of the ecological monitoring program in Admiralty Bay, King George Island, South Shetland Islands, conducted by Poland. This multidisciplinary monitoring includes the collection of geophysical, chemical and biological data in marine and terrestrial environments. Dr Panasiuk-Chodnicka also described how in the conduct of such a program there was a strong requirement for individual scientists to work in a range of roles.

6.3 Dr Panasiuk-Chodnicka also presented an analysis of distribution, ecology and population structure of salps (*S. thompsoni*) in the Antarctic Peninsula/Drake Passage region. Her data indicated the preference of salps for water of +1.5°C. She highlighted the contrasting response of krill and salps to a warming oceanic ecosystem and, in particular, the contracting energy pathways presented to species such as penguins in a salp-dominated ecosystem compared to a krill-dominated system.

6.4 Dr Panasiuk-Chodnicka thanked CCAMLR for the support provided by the scholarship and her mentor Dr M. Korczak-Abshire (Poland) for her support and advice throughout the period of her scholarship. Drs Panasiuk-Chodnicka and Korczak-Abshire both noted their thanks to Dr Siegel for his invaluable help and advice in relation to the work on salps and on wider issues concerning the Southern Ocean ecosystem.

6.5 The Working Group congratulated Dr Panasiuk-Chodnicka on the multidisciplinary nature of her work, including the international collaboration on the role of salps. The Working Group agreed that, while its focus was very often on krill, it was essential to consider alternative pathways for energy flow in Antarctic ecosystems.

6.6 The Working Group agreed that the CCAMLR Scientific Scholarship Scheme was working well, achieving its original objectives and is an integral part of CCAMLR. It encouraged all Members to support the scheme by supporting applications as well as through financial support to ensure the long-term success of the scheme.

6.7 The Working Group noted that the other recipient of a current CCAMLR scholarship, Mr A. Sytov (Russia), was invited to attend WG-EMM but was unable to do so for technical reasons.

CEMP Special Fund

6.8 The Convener of the CEMP Special Fund Management Group (hereinafter referred to as the ‘management group’), Dr Ichii, updated the Working Group on the membership of the group and the consideration of CEMP Fund proposals received this year. The management group (Drs Ichii (Chair), Arata (Senior Vice-Chair), Melbourne-Thomas (Junior Vice-Chair), Godø (Adviser)) evaluated the four proposals during WG-EMM-15:

1. tracking the overwinter habitat use of krill-dependent predators from Subarea 48.1 (Dr Watters)

2. penguin habitat preference and extrapolation to data-deficient colonies to model how krill-dependent predators overlap with krill fishing in Area 48 (Dr Trathan)

3. developing an image-processing software tool for analysis of camera network monitoring data (Dr Southwell)

4. a comparison of penguin diet sampling techniques; the CEMP standard method (stomach lavage) versus DNA sampling of prey remains in penguin guano (Dr C. Waluda (UK)).

6.9 The management group found that all proposals had relevance to the overall objectives of the CEMP Special Fund (SC-CAMLR-XXXII/BG/11; SC-CAMLR-XXXI, Annex 8) as well as enhancing capability and methods in CEMP. Three proposals (1, 2 and 3) were clearer on their contributions to immediate priorities in CCAMLR, particularly as they relate to the development of FBM approaches. The fourth proposal would contribute methodology that might enhance the efficiency of CEMP sampling in the future. The management group identified a set of questions for each proposal. Responses to these questions from the proponents will contribute to a final decision by the next meeting of the Scientific Committee.

6.10 The management group also noted that proposals 1 and 2 exceeded the 500 word limit for project objective and background text. Such overriding of word limits should be avoided as it might alter competition. The guidelines for applications will be updated so that it is clear that figure captions are included in word limits. Proposal 2 contained recruitment of additional experts to the Working Group through the post-doctoral position. While this is not relevant to CEMP objectives, recruitment of young capable experts is important for CEMP activities and hence this should be considered as a positive point in the evaluation.

6.11 Dr Watters, who led the first successful proposal to the CEMP Special Fund in 2014 (SC-CAMLR-XXXIII, paragraphs 3.47 to 3.50), provided an update on progress on that project.

6.12 The Working Group agreed that the lead scientist on CEMP Fund funded projects should be requested to report to WG-EMM annually with a brief update (to describe whether the project is going according to plan, etc.) and to report at project completion presenting the scientific results.

6.13 The Working Group thanked the Republic of Korea for the large donation that it had made to the CEMP Special Fund (COMM CIRC 15/38) and encouraged all Members to consider making contributions to the fund.

The Antarctic Wildlife Research Fund

6.14 Dr Trathan informed the Working Group that the Antarctic Wildlife Research Fund (AWRF) (www.antarcticfund.org) was launched in February 2015 and is a new partnership between industry, academia and non-government organisations. The fund aims to facilitate and promote research on the Antarctic marine ecosystem, including determining potential impacts from the Antarctic krill fishery. The first call for proposals closed on 16 June 2015 and resulted in 10 proposals, including from a number of scientists with existing links to CCAMLR. Results about which proposals will be funded will be announced by the AWRF in due course, as will a second call for proposals.

CCAMLR Science

6.15 The Science Manager, as Editor of *CCAMLR Science*, described the discussion in WG-SAM related to the reduction in the number of papers submitted to, and published in, *CCAMLR Science* in recent years (Annex 5, paragraphs 5.3 to 5.5) and sought the views of the Working Group on whether there was a future for the journal.

6.16 In considering the role of *CCAMLR Science*, the Working Group noted that:

(i) it would be important to consider the reasons why *CCAMLR Science* was originally established and review how best to meet those original objectives

(ii) there needs to be an avenue to publish and publicise science done in support of CCAMLR and to provide recognition for those scientists that make large contribution to that science that contributes to the success of CCAMLR

(iii) there is a role for *CCAMLR Science* in publishing papers, which would be difficult to publish in other peer-reviewed journals, providing a status of more than simply submitting a working group paper

(iv) there could be an important role for CCAMLR promoting the science collaborations between CCAMLR and other organisations, such as SOOS.

6.17 The Science Manager thanked the Working Group for its comments and advice and undertook to prepare a paper to the Scientific Committee on the future options for *CCAMLR Science*.

WG-EMM Convener

6.18 Dr Kawaguchi informed the Working Group that he intended for next year to be his last as Convener and encouraged potential conveners to consider co-convening the Working Group with him next year as this process worked well in the transition to a new convener in 2012.

6.19 The Chair of the Scientific Committee encouraged interested scientists to consider co-convening the Working Group next year.

Author affiliation of working group papers

6.20 The Working Group noted that multi-author papers submitted to the Working Group included the author affiliation (Member) and requested that the Scientific Committee review the need to display the affiliation after the names of authors on the cover page of working group papers.

6.21 The Working Group also noted that it would be useful to have an indication on the cover page of working group papers of the Scientific Committee Representative who was responsible for submitting the paper.

GEF proposal

6.22 The Working Group welcomed the update on the proposal for Global Environment Facility (GEF) funding to support capacity building in the GEF-eligible CCAMLR Members (WG-EMM-15/15 Rev. 1), noting that the Secretariat had agreed to be the lead body in developing this proposal. Scientists from GEF-eligible Members attending the Working Group undertook to engage in discussions with their respective GEF Focal Point and to work with the Secretariat to further develop this proposal.

CCAMLR website

6.23 The Working Group requested that the Secretariat should improve the search facility on the CCAMLR website, as it is not considered to be effective in its current form.

Adoption of the report and close of the meeting

7.1 On Saturday 11 July 2015 the Working Group visited the Institute of Biochemistry and Biophysics Polish Academy of Sciences and the Department of Antarctic Biology. WG-EMM was welcomed to the Institute by Profs. P. Zielenkiewicz (Director) and P. Jonczyk (Deputy Director, Scientific Affairs). Aspects of the Institute's research were discussed during several short presentations. WG-EMM also visited the Department of Antarctic Biology where Dr K. Chwedorzewska (Head of Department) welcomed the group and hosted a reception. Dr Kawaguchi thanked the institute for hosting the visit and reception, and Dr Korczak-Abshire for coordinating the visit.

7.2 During the second week of the meeting, Vice-Minister K. Plocke and Dr T. Nawrocki (Director, Fisheries Department) of the Ministry of Agriculture and Rural Development also visited the meeting and extended their welcome to WG-EMM. Dr Kawaguchi thanked the ministry for hosting the meeting.

7.3 In closing the meeting, Dr Kawaguchi thanked all participants and the Secretariat for their contributions to the meeting and the work of WG-EMM. He also thanked the subgroup coordinators and rapporteurs, and especially Drs Constable, Trathan and Watters for bringing forward the discussions on FBM. Dr Kawaguchi also thanked Dr Kaniewska-Krolak, Mr L. Dybiec (former Chair of the Commission) and colleagues at the Ministry of Agriculture and Rural Development for the excellent facilities, support and kind hospitality during the meeting.

7.4 Dr Kaniewska-Krolak congratulated the Working Group on a successful meeting and looked forward to welcoming participants back to Warsaw at some time in the future.

7.5 Dr Darby, on behalf of the Working Group, congratulated Dr Kawaguchi for his leadership and guidance during this eventful meeting. The discussions during the past two weeks had marked a turning point for FBM and the work of WG-EMM.

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Table 1: Summary of krill fishery notifications for 2015/16 considered by WG-EMM (see paragraph 2.18).

(a) Expected level of catch of krill, type of product and method for the direct estimation of green weight caught.

Vessel	Flag	Expected level of catch of krill (tonnes)					Type of product	Method for green weight estimation (refer to CM 21-03, Annex B)
		Overall	Subarea 48.1	Subarea 48.2	Subarea 48.3	Subarea 48.4		
Betanzos	Chile	25 000	17 500	2 500	5 000	-	Meal	Flowmeter
Cabo de Hornos	Chile	12 000	10 000	2 000	-	-	Whole + meal	Flowmeter + Flowscale
Long Teng	China	30 000	15 000	5 000	10 000	-	Whole + meal	Codend volume
Long Fa	China	10 000	5 000	-	5 000	-	Whole + meal	Codend volume
Long Da	China	30 000	15 000	5 000	10 000	-	Whole + meal	Codend volume
Fu Rong Hai	China	50 000	28 000	12 000	10 000	-	Whole + meal + boiled	Holding tank volume
Kai Li	China	18 000	10 000	3 000	5 000	-	Whole + meal	Plate tray + meal conversion
Kai Yu	China	5 000	5 000	-	-	-	Whole + meal	Plate tray + meal conversion
Ming Kai	China	26 000	12 000	6 000	8 000	-	Whole + meal	Plate tray + meal conversion
Viktoriya	China	26 000	12 000	6 000	8 000	-	Whole + meal	Holding tank volume
Sejong	Korea, Republic of	60 000	20 000	20 000	20 000	-	Whole + meal + boiled + peeled	Holding tank volume
Kwang Ja Ho	Korea, Republic of	15 000	15 000	-	-	-	Whole + meal + boiled + paste	Holding tank volume
Insung Ho	Korea, Republic of	12 000	12 000	-	-	-	Whole	Holding tank volume
Juvel	Norway	35 000	18 000	17 000	-	-	Oil + hydrosylate + liquid complex	Flowscale
Saga Sea	Norway	75 000	20 000	20 000	20 000	15 000	Meal + oil	Flowscale
Antarctic Sea	Norway	75 000	20 000	20 000	20 000	15 000	Meal	Flowscale
Saga	Poland	25 000	12 500	12 500	-	-	Whole + meal	Holding tank volume + meal conversion
More Sodruzhestva	Ukraine	45 000	25 000	10 000	10 000	-	Whole + meal + meat	Codend volume
Total notified level of catch		574 000	272 000	141 000	131 000	30 000		
Total number of vessels		18	18	14	12	2		

(b) Net information, mammal exclusion device and acoustic equipment. A – panel across mouth; B – panel in net and escape window.

Vessel	Flag	Type of fishing	Mouth opening (m)		Codend mesh size (mm) inner panel	Exclusion device		Echosounder		Sonar	
			Vertical	Horizontal		Type	Panel mesh size (mm)	Make	Frequencies (kHz)	Make	Frequencies (kHz)
Betanzos	Chile	Conventional	15	26	16	A	125	Simrad EK70	38	Furuno FCV	21–27
Cabo de Hornos	Chile	Conventional	15	26	16	A	125	Simrad EK70	38	Furuno FCV	21–27
Long Teng	China	Conventional	30	40	15	B	200	Simrad EK60, Furuno FCV	38, 70, 120, 15, 200	Furuno FSV	50, 60
Long Fa	China	Conventional	30	40	15	B	200	Furuno FCV	15, 200	Furuno FSV	50, 60
Long Da	China	Conventional	25	30	15	B	200	Furuno FCV	50, 60	Simrad SX	26
Fu Rong Hai	China	Conventional	30	30	15	B	300	Simrad EK60	38, 70, 120	JRC JFS	28, 32, 45
Kai Li	China	Conventional	30	29	20	B	250	Simrad EK60, Furuno FCV	38, 68, 70, 120, 200	Furuno FSV	50, 60
Kai Yu	China	Conventional	30	29	20	B	250	Simrad ES60	38, 120	Furuno FSV	50, 60
Ming Kai	China	Conventional	26	28	15	B	250	Simrad ES60	38	Simrad SX	26
Viktoriya	China	Conventional	26	28	15	B	250	Furuno FCV	38, 50, 200	Furuno FSV	24
Sejong	Korea, Republic of	Conventional	25	30	15	A	240	Simrad ES70	38, 200	Simrad SX	26
Kwang Ja Ho	Korea, Republic of	Conventional	50	72	15	A	300	Simrad ES70	38, 120	Furuno FSV	38, 120
Insung Ho	Korea, Republic of	Conventional	25	60	15	A	300	Simrad	tba	Furuno FSV	24
Juvel	Norway	Conventional	20	23	11	A	200	Simrad ES60	38, 70, 120	Simrad SH	26, 116
Saga Sea	Norway	Continuous	20	20	16	A	200	Simrad ES60	38, 120	Simrad SH	114
Antarctic Sea	Norway	Continuous	20	20	11	A	200	Simrad ES70, Furuno FCV	50, 70, 120, 200	Furuno FEV	30, 80
Saga	Poland	Conventional	45	45	11	B	200	Furuno FCV	38, 50, 200	Furuno FCV	80
More Sodruzhestva	Ukraine	Conventional	25	40	20	A	200	Simrad ES70	200	Wesmar HD	110

Table 2: Topics that need to be addressed to advance feedback management in Subarea 48.1 so that an approach can be implemented. Additional information is available in WG-EMM-15/04 and 15/33 and from the authors of these papers.

Element of feedback approach	Topic to be addressed
Estimation of base catch limit	The integrated model and its diagnostics to be reviewed by WG-SAM. Revise decision rules for krill. Identify data required from the krill fishery (e.g. standardised acoustic transects and net hauls). Integration of additional data available for assessment (e.g. krill length-frequency data from CEMP).
Decision rule to adjust catches up from the base	Design acoustic surveys to be undertaken by fishing vessels. Define CEMP indicators to be used as 'traffic lights' in decision rule, including threshold values that determine whether an indicator is 'green' (upward adjustment possible) or 'red' (upward adjustment not possible). Determine the level of adjustment that would be applied (e.g. the increase in catch would be proportional to increased density observed during fishing vessel surveys). Evaluation of decision rule.
Decision rules to adjust catches down from the base	Identify appropriate groups of SSMUs from penguin tracking data. Determine default 'allocation factors' for groups of SSMUs. Parameterise species-specific decision rules for adjusting catch on the basis of fledging mass and age at crèche. Evaluation of decision rule.

Table 3: Topics that need to be addressed to advance feedback management in Subarea 48.2 so that an approach can be implemented.

Phase	Topic to be addressed
Phase 1	Interactions with the fishing industry. Design of acoustic surveys to be undertaken by fishing vessels. Development of the oceanographic model (WG-EMM-14/08) to confirm the location of the contrasting fished areas. Analysis of available data with CEMP-like objectives. Analysis of historical cetacean surveys in IWC Area II to provide context for at-sea observations of cetaceans. Appropriate time period for developing baseline monitoring information (five years).
Phase 2	Evaluation of fishery acoustics to provide krill stock information. Evaluation of the utility of remote camera sites. Evaluation of the need for two areas with contrasting fishing levels. Evaluation of monitoring to identify an effect of fishing given the concentration of the fishery. Evaluation of the use of a constant harvest level, rather than a constant harvest rate to elucidate functional responses between krill and predator performance.

Table 4: Topics that need to be addressed to advance feedback management at SSMU scales using the ecosystem assessment approach to subdivide area-scale catch into SSMUs and/or to have short-term adjustments within SSMUs, so that these can be implemented.

Element of feedback approach	Topic to be addressed
Approach to subdivide area-scale catch limit into SSMUs (WG-EMM-15/36)	Assemble data suitable for an empirical ecosystem assessment (e.g. WG-EMM-15/36, Table 1a,), including krill biomass and CEMP time series from SSMUs. Consider parameters for predator reproductive performance and how predators relate to krill density. Consider parameters for empirical krill model. Assemble time series of krill density and recruitment strength, predator reproductive performance, catch and its length composition. Estimate availability of krill to predators and fishery. Submit model for review of its structure and diagnostics. Evaluate the properties of the decision rule.
Approach for short-term adjustment at SSMU scales (WG-EMM-15/55 Rev. 1)	Establish critical values of krill density for SSMUs, considering predator requirements. Projection model, including how to incorporate estimates of krill density and recruitment, to be reviewed. Estimates of krill density and recruitment. Consider utilisation of CEMP and structured fishing to test the practical application of the decision rule. Evaluate properties of the decision rule in relation to meeting long-term requirements of predators.

Table 5: Preliminary list of data layers describing objects/features that cross the border between Domain 1 and Domain 3.

Data layers	References
Adélie penguins breeding distribution	Antarctic Site Inventory BAS Inventory IAA-Programa de Monitoreo H. Lynch (unpublished data)
Adélie penguins non-breeding distribution	US AMLR Program BAS Inventory IAA-Programa de Monitoreo
Killer whales Type B1 and B2 distribution	Robert Pitman, Southwest Fisheries Science Center, NOAA Fisheries
Emperor penguin Snow Hill colony	Libertelli and Coria, 2014 Ratcliffe and Trathan, 2011 Fretwell et al., 2012
Coastal polynyas (pelagic regionalisation)	Kern, 2012 Kaleschke et al., 2001 Spreen et al., 2008 Arndt et al., 2013 Timmermann et al., 2009
Krill distribution (adult)	US AMLR Program Atkinson et al., 2004, 2008, 2009 Siegel, 1982, 2012 Siegel et al., 2013
Krill nursery Weddell Sea gyre	US, Argentinean and German research cruises
Satellite-derived surface summer chlorophyll-a (high productivity)	Feldman et al., 2010 Moore and Abbott, 2000
Ice-edge position in summer (proxy for ice seals)	US National Snow and Ice Data Center
Fish nursery	Marschoff et al., 2012 Kock et al., 2012 Kock and Jones, 2005 Barrera-Oro et al., 2000 and others

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(Warsaw, Poland, 6 to 17 July 2015)

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Appendix B

Agenda

Working Group on Ecosystem Monitoring and Management
(Warsaw, Poland, 6 to 17 July 2015)

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
        2.1.4 Role of fish in the ecosystem

    2.2 Issues for the future

        2.2.1 Feedback management strategy
        2.2.2 CEMP and WG-EMM-STAPP
        2.2.3 Integrated assessment model
        2.2.4 Fishing vessel surveys
        2.2.5 Multinational coordination

3. Spatial management

    3.1 Marine protected areas (MPAs)
    3.2 Vulnerable marine ecosystems (VMEs)

4. Advice to the Scientific Committee and its working groups

5. Future work

6. Other business

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

List of Documents

Working Group on Ecosystem Monitoring and Management
(Warsaw, Poland, 6 to 17 July 2015)

WG-EMM-15/01	Net diagrams for Norwegian vessels notified for krill fishery in 2015/16 – Notification ID 86750, 86751, 86780 and 86781 Delegation of Norway
WG-EMM-15/02	Net diagrams for Chinese vessels notified for krill fishery in 2015/16 Notification ID 86733, 86772 and 86773 Delegation of the People's Republic of China
WG-EMM-15/03	Net diagrams for Chilean vessels notified for krill fishery in 2015/16 Notification ID 86795, 86796 and 86797 Delegation of Chile
WG-EMM-15/04	Within season feedback management system – a pro forma for discussion at WG-EMM 2015 C.S. Reiss, G.M. Watters, J. Hinke and D. Kinzey (USA)
WG-EMM-15/05	Winter habitat selection by Antarctic krill will increase krill–predator–fishery interactions during ice free years C.S. Reiss, A. Cossio, C.D. Jones, A. Murray, G. Mitchell, J. Santora, K. Dietrich, E. Weiss, C. Gimpel, J. Walsh and G.M. Watters (USA)
WG-EMM-15/06	Species identification illustrated guide of the Southern Ocean – CCAMLR Convention Area 48, 58, and 88 Delegation of the Republic of Korea
WG-EMM-15/07 Rev. 1	CEMP Indices: 2015 update on data submissions and analyses CCAMLR Secretariat
WG-EMM-15/08	Net diagrams and MED of CM 21-03 for Korean krill fishing vessels Delegation of the Republic of Korea
WG-EMM-15/09	Scotia Sea Pygoscelid Penguin Tracking and Habitat Analysis Workshop P.N. Trathan (United Kingdom), J.T. Hinke (USA) and B. Lascelles (BirdLife International)

WG-EMM-15/10	Possible options for the future management of the Antarctic krill fishery in Subarea 48.2 P.N. Trathan (United Kingdom), O.R. Godø (Norway) and S.L. Hill (United Kingdom)
WG-EMM-15/11	A critical issue for feedback management – how do we determine the level of functional overlap between krill fishing operations and penguin foraging activity? P.N. Trathan, J.R.D. Silk, S.L. Hill (United Kingdom) and H.J. Lynch (USA)
WG-EMM-15/12	Introduction of the recent Korean research activity and future plan on penguin breeding and behavior Delegation of the Republic of Korea
WG-EMM-15/13	Acoustic and catch data collected by the fleet – relevance for feedback management O.R. Godø, T. Klevjer and G. Skaret (Norway)
WG-EMM-15/14	Antarctic krill; assessment of mesh size selectivity and escape mortality from trawls B.A. Krafft (Norway), L.A. Krag (Denmark), B. Herrmann, A. Engås, I. Bruheim and S. Nordrum (Norway)
WG-EMM-15/15 Rev. 1	Progress report 1: Proposal for GEF (Global Environment Facility) funding to support capacity building in the GEF-eligible CCAMLR Members CCAMLR Secretariat
WG-EMM-15/16	Variability in krill length distribution in 48.1 derived from data collected by scientific observers P. Ziegler, S. Kawaguchi D. Welsford and A. Constable (Australia)
WG-EMM-15/17 Rev. 1	A biomass estimate of Antarctic krill (*Euphausia superba*) at the Balleny Islands M.J. Cox (Australia), Y. Ladroit, P. Escobar-Flores and R.L. O’Driscoll (New Zealand)
WG-EMM-15/18	Joint CEP/SC-CAMLR workshop (2016) on climate change and monitoring S. Grant (UK) and P. Penhale (USA)
WG-EMM-15/19	Estimation of the green weight of krill caught CCAMLR Secretariat
WG-EMM-15/20	Vacant

WG-EMM-15/21	Notes of hydrobiologist "*Akademik Fedorov*" (the 60th RAE Expedition) East Antarctica (December 2014 – February 2015) A.M. Sytov (Russia)
WG-EMM-15/22	Preliminary report on krill survey off the coast of East Antarctica (Enderby Land to Prydz Bay) February–March 2015 S. Kawaguchi, A. Constable, L. Emmerson, C. Southwell, R. King, K. Westwood and K. Swadling (Australia)
WG-EMM-15/23	Chiller killers – first steps towards identifying krill pathogens K. Bateman, R. Hicks, G. Tarling, M. Söffker and G. Stentiford (United Kingdom)
WG-EMM-15/24	Why does it necessary to consider krill flux for developing the feedback management strategy for krill fishery in the Area 48? S. Kasatkina and V. Shnar (Russia)
WG-EMM-15/25	Using vessel acoustics to detect diving patterns of krill foraging predators automatically: Development of a novel method for quantifying impact of krill fishing on seals and penguins T.A. Klevjer, O.R. Godø and B. Krafft (Norway)
WG-EMM-15/26	Special features of the current krill fishery dynamics in the Southern Atlantic (Subareas 48.1, 48.2 and 48.3) during 2008–2014 S. Kasatkina and P. Gasyukov (Russia)
WG-EMM-15/27	Key considerations for planning a large-scale krill survey S. Hill, J. Watkins (United Kingdom), O.R. Godø (Norway), S. Kawaguchi (Australia), D. Kinzey, C. Reiss (USA), V. Siegel (Germany), P. Trathan (United Kingdom) and G. Watters (USA)
WG-EMM-15/28	Updating the Antarctic krill biomass estimates for CCAMLR Subareas 48.1 to 48.4 using available data S. Hill, A. Atkinson, C. Darby, S. Fielding (United Kingsom), B. Krafft, O.R. Godø, G. Skaret (Norway), P. Trathan, J. Watkins (United Kingdom)
WG-EMM-15/29	Net diagrams for Russian vessel notified for krill fishery in 2015/16 Delegation of the Russian Federation
WG-EMM-15/30	Krill Fishery Report CCAMLR Secretariat
WG-EMM-15/31	Citizen science for large-scale data extraction from a citizen science network T. Hart, C. Black (United Kingdom), L. Emmerson (Australia), J. Hinke (USA) and C. Southwell (Australia)

WG-EMM-15/32	Important Bird Areas (IBAs) in Antarctica P.A. Penhale (USA)
WG-EMM-15/33	Feedback management pro forma based on WG-EMM-12/44 G. Watters and J. Hinke (USA)
WG-EMM-15/34	Report of a domestic workshop to identify U.S. stakeholders' objectives and protection priorities for one or more marine protected areas in Planning Domain 1 G. Watters (USA)
WG-EMM-15/35	Development of the fishing gear library CCAMLR Secretariat
WG-EMM-15/36	An ecosystem-based management procedure for krill fisheries: a method for determining spatially-structured catch limits to manage risk of significant localised fisheries impacts on predators A. Constable and S. Candy (Australia)
WG-EMM-15/37	Seasonal variation in the diet of *Arctocephalus gazella* at 25 de Mayo/King George Island, South Shetland Islands, Antarctica A. Harrington, G.A. Daneri, A.R. Carlini, D.S. Reygert and A. Corbalán (Argentina)
WG-EMM-15/38 Rev. 1	Scientific background document in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica) – Version 2015 – Part A: General context of the establishment of MPAs and background information on the Weddell Sea MPA planning area- K. Teschke (Germany) on behalf of the Weddell Sea MPA (WSMPA) project team
WG-EMM-15/39	Scientific background document in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica) – Version 2015 – Part B: Description of available spatial data K. Teschke, H. Pehlke and T. Brey on behalf of the German Weddell Sea MPA (WSMPA) project team, with contributions from the participants at the International Expert Workshop on the WSMPA project (7–9 April 2014, Bremerhaven)
WG-EMM-15/40	On amendments to Conservation Measure 51-07 (2014) dealing with interim distribution of the trigger level in the fishery for *Euphausia superba* in Statistical Subareas 48.1, 48.2, 48.3 and 48.4 Delegation of Ukraine

WG-EMM-15/41	Changes of population structure in common benthic species of the proposed Stella Creek MPA in the vicinity of the Akademik Vernadsky Station, Galindez Island, Antarctica Delegation of Ukraine
WG-EMM-15/42	Report of the Second International Workshop for identifying Marine Protected Areas (MPAs) in Domain 1 of CCAMLR (Palacio San Martín, Buenos Aires, Argentina, 25 to 29 May 2015) Second WS-MPA Domain 1
WG-EMM-15/43	Information on Japan's plan for krill surveys in East Antarctic Delegation of Japan
WG-EMM-15/44	The importance of standardising and validating new methods for CEMP to maintain the robustness of long-term time series C. Southwell and L. Emmerson (Australia)
WG-EMM-15/45	Direct ageing of Antarctic krill (*Euphausia superba*) – potential utility of eyestalk sections for age determination C. Reiss (USA), R. Kilada (Canada) and S. Kawaguchi (Australia)
WG-EMM-15/46	Scientific background document in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica) – Version 2015 – Part C: Data analysis and MPA scenario development K. Teschke, H. Pehlke, M. Deininger, L. Douglass and T. Brey on behalf of the German Weddell Sea MPA project team
WG-EMM-15/47	Admiralty Bay (South Shetland Islands) – long-term marine monitoring program A. Panasiuk-Chodnicka, M. Korczak-Abshire, M.I. Żmijewska, K. Chwedorzewska, E. Szymczak, D. Burska, D. Pryputniewicz-Flis and K. Łukawska-Matuszewska (Poland)
WG-EMM-15/48	Unmanned Aerial Vehicles based monitoring of indicator species populations on King George Island (Subarea 48.1) M. Korczak-Abshire, A. Zmarz, R. Storvold, M. Rodzewicz, K. Chwedorzewska, A. Kidawa and A. Znój (Poland)
WG-EMM-15/49	Net diagrams for Ukrainian vessel notified for krill fishery in 2015/16 – Notification ID 86703, 86755 and 86757 Delegation of Ukraine
WG-EMM-15/50	UAV for monitoring environmental changes on King George Island (South Shetland Islands) Antarctica: preliminary study on wildlife disturbance A. Kidawa, M. Korczak-Abshire, A. Zmarz, R. Storvold, M. Rodzewicz, K. Chwedorzewska, S.-R. Karlsen and A. Znój (Poland)

WG-EMM-15/51 Rev. 1	Estimating future krill catches that meet the CCAMLR and alternative decision rules for FAO Subarea 48.1 using an integrated assessment model D. Kinzey, G.M. Watters and C.S. Reiss (USA)
WG-EMM-15/52	Activity, seasonal site fidelity, and movements of Type-C killer whales between the Ross Sea, Antarctica and New Zealand R. Eisert (New Zealand), G. Lauriano, S. Panigada (Italy), E.N. Ovsyanikova, I.N. Visser, P.H. Ensor, R.J.C. Currey, B.R. Sharp and M.H. Pinkerton (New Zealand)
WG-EMM-15/53	Predation release of Antarctic silverfish (*Pleuragramma antarctica*) in the Ross Sea M.H. Pinkerton, P. Lyver, D. Stevens, J. Forman, R. Eisert and S. Mormede (New Zealand)
WG-EMM-15/54	Evaluation of Antarctic krill biomass and distribution off the South Orkney Islands 2011–2015 G. Skaret, B.A. Krafft, L. Calise (Norway), J. Watkins (UK), R. Pedersen and O.R. Godø (Norway)
WG-EMM-15/55 Rev. 1	A candidate process for managing the krill fishery at a local scale for krill predators, particularly in the early phases of the development of the krill fishery A. Constable, S. Kawaguchi, C. Southwell, L. Emmerson, W. de la Mare, P. Ziegler, D. Welsford and J. Melbourne-Thomas (Australia)
WG-EMM-15/56	New Zealand-Australia Antarctic Ecosystems Voyage R.L. O'Driscoll (New Zealand)
WG-EMM-15/57 Rev. 1	Analysis of the scientific observer program on the krill fishery J.A. Arata and F. Santa-Cruz (Chile)
WG-EMM-15/58	Comparative analysis of flow meter and codend volume method for estimating green weight in '*Betanzos*' Delegation of Chile
WG-EMM-15/59	Streamlining the work of the Scientific Committee for the Conservation of Antarctic Marine Living Resources (SC-CAMLR) G. Watters (USA), A. Constable and D. Welsford (Australia)
WG-EMM-15/60	Notification of intent to participate in a fishery for *Euphausia superba* Delegation of Poland

WG-EMM-15/61	Report on 2015 Activities of the Southern Ocean Observing System relevant to the work of CCAMLR A. Constable (Australia), O.R. Godø (Norway) and L. Newman (SOOS)

Other Documents

WG-EMM-15/P01	Marine ecosystem acoustics (MEA): quantifying processes in the sea at the spatio-temporal scales on which they occur O.R. Godø, N.O. Handegard, H.I. Browman, G.J. Macaulay, S. Kaartvedt, J. Giske, E. Ona, G. Huse and E. Johnsen *ICES J. Mar. Sci*., 71 (8) (2014): 2357–2369
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