Annex 6

Report of the Working Group on Ecosystem Monitoring and Management
(Bologna, Italy, 4 to 15 July 2016)

Contents

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Opening of the meeting

1.1 The 2016 meeting of WG-EMM was held at the National Research Council (CNR), Bologna, Italy, from 4 to 15 July. The meeting was opened by the Convener, Dr S. Kawaguchi (Australia), who welcomed participants (Appendix A) including Dr J. Zuzunaga from Peru (Acceding State; see also SC CIRC 16/39). Dr Kawaguchi thanked CNR for hosting the meeting. The Working Group was warmly welcomed by Dr A.M. Fioretti (Institute of Geosciences and Earth Resources, CNR).

1.2 Dr Kawaguchi reviewed the current work of WG-EMM and recalled that in 2015 the Scientific Committee indicated that the development of feedback management (FBM) of the krill fishery and the evaluation of candidate decision rules could be advanced by holding a workshop in 2016, perhaps associated with WG-EMM (SC-CAMLR-XXXIV, paragraph 3.44). Dr Kawaguchi advised that it had not been possible to hold such a workshop during WG-EMM-16. The Working Group's work remained focused on the krill-centric ecosystem and issues related to the development of FBM.

Adoption of the agenda and organisation of the meeting

1.3 The Working Group discussed the provisional agenda and agreed to add an item on general issues for spatial management (Subitem 3.3). The agenda was adopted (Appendix B), and subgroups were formed to address detailed aspects of the agenda. A one-day symposium on the Ross Sea ecosystem was held during the meeting (Item 4).

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 5.

1.6 The report was prepared by M. Belchier (UK), T. Brey (Germany), R. Cavanagh (UK), A. Constable (Australia), R. Currey (New Zealand), C. Darby (UK), K. Demianenko (Ukraine), S. Fielding (UK), L. Ghigliotti (Italy), O.R. Godø (Norway), M. Goebel (USA), S. Grant (UK), E. Grilly (Secretariat), S. Hill (UK), J. Hinke and E. Klein (USA), P. Koubbi (France), B. Krafft (Norway), S. Olmastroni (Italy), P. Penhale (USA), D. Ramm (Secretariat), N. Ratcliffe (UK), K. Reid (Secretariat), C. Reiss (USA), L. Robinson (Secretariat), M. Santos (Argentina), M. Söffker and P. Trathan (UK), M. Vacchi (Italy) and G. Watters (USA).

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

Fishing activities

2.1 The Working Group reviewed the content of the draft Krill Fishery Report (WG-EMM-16/07) which provided a consolidated summary of information related to the krill fishery prepared in a similar format to the fishery reports completed for finfish fisheries (www.ccamlr.org/node/75667). Recommendations from WG-EMM-14 (SC-CAMLR-XXXIII, Annex 6, paragraphs 2.2 to 2.7) and WG-EMM-15 (SC-CAMLR-XXXIV, Annex 6, paragraphs 2.4 to 2.11) on the report were included along with information provided in previous reports (i.e. an introduction on the background of the fishery, an inventory of catch and Scheme of International Scientific Observation (SISO) data, including incidental mortality of marine mammals and seabirds as well as CCAMLR's approach to the management of the krill fishery), decadal catch maps at 1° latitude by 2° longitude grid cell resolution, and a comparison of by-catch occurrence in C1 and SISO data. Gridded monthly catch maps at 1° latitude by 2° longitude grid cell resolution for 2014/15 and 2015/16 (to 8 June 2016) were included as an appendix for use by working groups only, and will not be included in the published version of the fishery report (CCAMLR-XXXIV, paragraph 5.3).

2.2 The Working Group reviewed the fishing activity information for 2014/15 and 2015/16, provided in the Krill Fishery Report, and noted that:

(i) in 2014/15 (1 December 2014 to 30 November 2015), 12 vessels fished in Subareas 48.1, 48.2 and 48.3 and the total catch of krill reported was 225 466 tonnes of which 154 177 tonnes (68%) was taken from Subarea 48.1; Subarea 48.1 was closed on 28 May 2015

(ii) in 2015/16 (to 8 June 2016), 11 vessels fished in at least one of the three Subareas 48.1, 48.2 and 48.3; the total catch of krill reported in catch and effort reports was 189 609 tonnes of which 154 460 tonnes was taken from Subarea 48.1; Subarea 48.1 was closed on 28 May 2016

(iii) in both 2014/15 and 2015/16, fishing occurred in Subarea 48.1 in December and January, particularly in the southern part of Bransfield Strait (Gerlache Strait). The spatial distribution of the fishery during February and March was also similar in both seasons with a focus towards the central part of Bransfield Strait in April and May prior to the closure of Subarea 48.1.

2.3 The Working Group noted that historically fishing in Subarea 48.1 had been primarily in the summer, but for the past few seasons fishing in this area had been occurring throughout the austral summer and winter. The Working Group also noted that the fishery was regularly operating in areas in the southern part of Subarea 48.1 where no regular krill surveys are conducted.

2.4 The Working Group agreed that a spatial measure of fishing concentration, including a measure of the number of vessels operating in a given area, could be a useful way to describe the operation of the fishery that could potentially be included in future Krill Fishery Reports.

2.5 Dr Godø offered to investigate how such indices were used in other fisheries and report back to the Working Group next year.

2.6 The Working Group discussed the change in the distribution of fishing in Subarea 48.1 from Drake Passage to the Bransfield Strait over recent seasons and the potential for such a change to influence the size of krill selected by the fishery. The Working Group noted that these changes were likely due to a combination of factors that included management restrictions (i.e. fishery closures), abundance of krill, weather conditions and proximity to the market.

2.7 The Working Group noted that more information from the fishing industry on what drives its behaviour and decisions to fish in an area at a particular point in time would be useful in assisting with those studies that aim to determine whether there are predictable attributes that give rise to fishing in some areas.

2.8 The Working Group agreed that the data on krill catches by month and small-scale management unit (SSMU) (WG-EMM-16/07, Table A2.1) should be included in the *Statistical Bulletin*.

Krill fishery notifications

2.9 The Working Group reviewed the notifications for krill fisheries in 2016/17 which had been received by the submission deadline (1 June 2016) and summarised in the Krill Fishery Report, noting that additional information on vessel details and subsequent withdrawals of notifications are provided on the CCAMLR website (www.ccamlr.org/en/fishery-notifications/notified). Six Members had notified a total of 18 vessels for krill fisheries in Subareas 48.1 (17 vessels), 48.2 (16 vessels), 48.3 (15 vessels) and 48.4 (10 vessels), and Divisions 58.4.1 (3 vessels) and 58.4.2 (3 vessels), and there were no notifications submitted for exploratory fisheries for krill in 2016/17. The Secretariat advised during the meeting that Poland had withdrawn the notifications for its vessels *Alina* and *Saga*.

2.10 The Working Group also reviewed WG-EMM-16/72 Rev. 1 which summarised the information notified for krill fishing operations and gears in 2016/17. The data presented in that paper was extracted directly from the new online submission system for fishery notifications (SC-CAMLR-XXXIV, Annex 6, paragraphs 2.22 to 2.27).

2.11 The Working Group noted that the daily processing capacity for notified vessels ranged from 120 to 700 tonnes green weight per day (Table 1), and that two Norwegian- and one Chinese-flagged vessels had notified use of the continuous fishing system (Table 2).

2.12 The Working Group sought further information about the intentions of the three Chinese-flagged vessels notified in Divisions 58.4.1 and 58.4.2. Dr G. Zhu (China) advised that the decision to send the notified vessels to these divisions in 2016/17 would rest with the vessels' operator.

2.13 The Working Group agreed that the new online system for submitting fishery notifications had greatly facilitated its work in reviewing the krill fishery notifications and thanked the Secretariat for successfully introducing this system. The Secretariat thanked Members that had submitted online notifications for providing feedback and assistance in developing appropriate data checks and constraints used in the online system.

2.14 The Working Group agreed that the information provided in the notifications for krill fisheries in 2016/17 was consistent with the requirements of Conservation Measure (CM) 21-03.

Escape mortality

2.15 WG-EMM-16/04 reported on further developments in the estimation of krill mortality which escape from trawl nets. WG-EMM-13/34 (see also Krag et al., 2014) had demonstrated that most of the length classes of krill can escape through commonly used commercial trawl mesh sizes. Further, a method to estimate escape mortality for krill was developed and presented in WG-EMM-14/14 (see also Krafft and Krag, 2015). WG-EMM-16/04 reported that haul duration, hydrological conditions, maximum fishing depth and catch-size had no significant effect on mortality of krill escaping the trawl, nor was there any further mortality associated with the holding tank conditions. The mortality of krill escaping the trawl nets in the study was 4.4 ± 4.4%, which indicated that krill are fairly robust to the capture-and-escape process in trawls.

2.16 The Working Group noted that the results from WG-EMM-16/04, in combination with the modelling work on proportions of krill with different morphology classes escaping trawl meshes ranging from 5 to 40 mm and mesh opening angles ranging from 10° to 90° (WG-EMM-13/34 and Krag et al., 2014), enabled the calculation of escapement from the entire trawl body (including side panels and codend). The total escape mortality for the fishery may be estimated when parameters from the trawl nets used and size/demography of the krill in the geographical area, in addition to the landed catch, are known.

2.17 The Working Group agreed that quantifying escape mortality is an essential element of estimating the total removals by the fishery. The Working Group agreed that it would be useful for the Secretariat to compile results on escape mortality into a single document once the work is completed.

Reporting interval for the continuous fishing system

2.18 WG-EMM-16/05 evaluated the reporting of 'haul-by-haul' catch and effort data (C1 data) for the continuous fishing system and proposed a change in the current two-hour reporting period to produce more robust and appropriate catch statistics. The authors summarised issues related to the choice of the current two-hour reporting interval for the continuous fishing system which had led to apparent anomalies in the reported catches. According to the vessels' owners and captains, this variability in catches is a consequence of the two-hour reporting period not coinciding with the vessel's daily production routine. The authors suggested that a six-hour reporting period more closely matches the processing schedule and, as a result, would improve the accuracy of the reported catch.

2.19 The Working Group discussed the data required for scientific analysis of the spatial pattern of catch rates from continuous trawls and noted that the catch data are required to be reported for each net in a two-hour period. It had been previously assumed that the catch reported for a two-hour period had actually been caught during that period. However, information from the krill fishing vessels has revealed that this is not the case and the catch reported in a two-hour period is, in fact, the amount of krill passing from the holding tanks to the factory in that period.

2.20 The Working Group agreed that the objective of developing technology and methods that would ensure that the catch reported for a particular two-hour period is the catch that is actually caught during that period would be most effectively addressed by discussion with vessel owners and captains. The Working Group provided the following suggestions for the fishing companies to consider:

(i) using trawl-mounted sensors that could aid to quantify the amount of krill entering the trawl mouth per time unit

(ii) recording the amount of krill entering the holding tank

(iii) recording the time to fill a holding tank and final quantity of krill it contained after it has been emptied

(iv) addition of pump capacity to the vessel details included in the notification such that periods of saturation (i.e. the pump is operating at full capacity) can be identified

(v) clarification of the potential time lag between the fishing time reported for the catch and the time at which the catch was taken in order to evaluate how existing data from continuous fishing operations might be analysed.

2.21 The Working Group agreed that paragraphs 2.20(i) and (ii) above would provide close to real-time spatial distribution of krill catch and would also allow the actual catch in a two-hour period to be reported. Paragraph 2.20(iii) would most likely result in reporting every six hours, which is currently considered less optimal and would also imply a time lag in catch reporting similar to the time lags noted for the current two-hour reporting period and which need to be corrected for. The Working Group recommended that, during the development of a revised process for catch reporting, the two-hour reporting is continued in order to provide continuity and comparative analyses. Any new method developed should be trialled alongside the two-hour reporting procedure and the result presented to WG-EMM for evaluation.

2.22 The Working Group noted that any vessel that uses the continuous fishing system should consider the issues highlighted here in order to implement accurate catch reporting methods.

Use of net monitoring cables

2.23 WG-EMM-16/06 reviewed the current regulation of net monitoring cables in CCAMLR fisheries and proposed a revision which would enable krill fishing vessels to collect larger quantities and quality of monitoring and research data. The prohibition on the use of net monitoring cables was introduced in 1994 to minimise the risk of seabirds striking the cable and resultant incidental mortality of seabirds in trawl fisheries. As a result, vessels that use net sensors are required to transmit trawl net data using underwater wireless communication which has limited bandwidth and requires the use of a submerged receiver. The authors proposed a revision to CM 25-03 to allow the use of net monitoring cables which are deployed using purpose-built rigging which guide the cable into the water within 2 m from the vessel's stern and thereby minimise the risk of seabirds striking the cable.

2.24 The Working Group recognised the advantages of using data transfer cables connected to trawls for monitoring net performance and catches, as well as collecting research and environmental data of interest to WG-EMM's work.

2.25 The Working Group requested that Dr Godø liaise with the Secretariat to distribute this proposal by Scientific Committee Circular for consideration by relevant specialists on seabird by-catch mitigation in trawl fisheries in order that advice can be formulated for submission to WG-FSA-16. The Working Group noted that the formulation of that advice should also include a review of the tasks for scientific observers related to seabird by-catch mitigation.

CPUE and fishery performance

2.26 WG-EMM-16/10 reviewed catch and effort data from the krill fishery from 2000/01 to 2015/16 in Subareas 48.1 to 48.3 to determine whether catch-per-unit-effort (CPUE) might be used to produce a fishery-scale performance index. The vessels-specific mean CPUE (log catch (kg) per minute fishing) was estimated using all data for each vessel, and an annual index was calculated as the difference between this overall mean and the mean for each year in which the vessel fished. An overall fishery performance index (FPI) was derived from the sum of the vessel-specific indices for each season. The annual FPI for each of the three subareas showed no synchronous relationship with each other and showed a differing relationship with the total catch in the same subarea. Comparison of the annual FPI with the krill biomass (from research surveys) and the combined standardised indices (CSIs) from CCAMLR Ecosystem Monitoring Program (CEMP) data suggests (at least qualitatively) some concordance between the performance of the fishery and krill abundance.

2.27 The Working Group thanked the authors for this analysis and encouraged further work on addressing data quality issues (including catch reporting precision), alternative approaches (including generalised linear models (GLMs)) to estimate the FPI, the impact of sea-ice and the spatial and temporal scales at which the FPI is compared with other indicators of krill abundance.

2.28 The Working Group noted WG-EMM-16/40, which reported on an integrated analysis of the krill fishery in Subareas 48.1 to 48.3 from 2005/06 to 2014/15. The authors found a significant spatial–temporal trend in CPUE which was influenced by krill distribution patterns as well as the fishing technique used. In general, fishing using conventional trawls was characterised by higher CPUE and higher interannual variability in each SSMU compared with data from the continuous fishing system. The authors found significant variability of the CPUE indices between fishing vessels operating with conventional trawl in the same fishing grounds. One of the reasons for this CPUE variability was vessels using different designs of fishing gear and producing a range of krill products. The latter is clearly illustrated in the Bransfield Strait.

2.29 Dr S. Kasatkina (Russia) proposed to investigate the effect of the on-board krill processing on CPUE dynamics for understanding the dynamics and strategies in the krill fishery. She noted that the corresponding information should be included in the CCAMLR database.

2.30 The Working Group agreed that CPUE data are an important element of fisheries data and encouraged further investigation of the influence of fishery strategy on CPUE dynamics. The Working Group noted that the analysis of catch data and acoustic data collected during fishing operations could provide a means to develop standardised CPUEs from the krill fishery.

Fishing season

2.31 The Working Group discussed WG-EMM-16/16, which considered whether the CCAMLR season for the krill fishery should start at a time of year that is based on ecological events, rather than on a date that is convenient for management. The authors of WG-EMM-16/16 used data on the breeding period of predators and catch data to explore whether there are times of year that would reduce the potential for competition between land-based krill-eating predators and the fishery.

2.32 Dr Kasatkina noted that WG-EMM-16/16 only reported evidence of temporal overlap between the krill fishery and breeding predators. However, in considering the start date of the krill fishing season, Dr Kasatkina indicated that the Working Group should have evidence on spatial and functional overlap between fishery and predators and to take into account the sea-ice conditions being the important factor for fishing vessel allocations. Dr Kasatkina noted that moving the start of the fishing season would have an impact on fishery efficiency and safety of navigation for fishing vessels.

2.33 The Working Group advised that the start date of the fishery and the period when fishing might actually take place each year must be balanced with overall requirements for land-based predators during both the summer breeding period and other times of year, including the requirements for predators which overwinter in the areas in which the fishery operates. The Working Group agreed that such requirements may vary between subareas and this may require different management approaches.

2.34 The Working Group discussed the spatio–temporal overlap between krill-eating predators and the fishery, as well as the potential for fishing to disrupt the structure of krill swarms (i.e. functional overlap) and agreed to give this matter further consideration while developing FBM.

SG-ASAM report

2.35 The Working Group noted the report from the 2016 meeting of SG-ASAM (Annex 4). The Subgroup has been developing methods to use fishing-vessel-based acoustic data to provide qualitative and quantifiable information on the distribution and relative abundance of krill, and the 2016 meeting focused on: analysis to generate validated acoustic data suitable for further analyses; and analysis to produce specific products from those validated acoustic data. The Working Group thanked Dr Reiss for convening that meeting.

2.36 The Working Group's discussion of the SG-ASAM report (Annex 4) focused on the development of methods for the evaluation of uncertainty in acoustic estimates of krill biomass which include the development of metrics of acoustic data quality, and processes to estimate the proportion of bad and missing data and the signal-to-noise ratio.

2.37 The Working Group encouraged SG-ASAM to develop a single processing approach for use with acoustic data collected by all fishing vessels (paragraph 2.271) and to continue work on statistical techniques that adequately represent uncertainty in data processing decisions.

2.38 The Working Group noted that analyses using the three-frequency method for differentiating krill usually integrated data to a depth of 250 m because the acoustic data from frequencies above 120 kHz did not have sufficient signal-to-noise ratio below 250 m. The increasing use of 70 KHz for collecting acoustic data may allow integration to depths greater than 250 m in the future.

2.39 The Working Group supported SG-ASAM's advice to explore incentives to achieve the broad-scale participation in the collection of acoustic data in the krill fishery, for example, by allowing extra catch to be available to those vessels that voluntarily undertake surveys or repeated transects.

2.40 The Working Group noted that, as requested by SG-ASAM, the Secretariat has included information for fishing vessels on how to collect acoustic data along nominated transects in its routine communications with Members and vessels participating in the krill fishery.

Scientific observation

Observer coverage

2.41 Two papers resulted from the discussions at WG-EMM-15 and SC-CAMLR-XXXIV on observer coverage and the associated metrics. WG-EMM-16/63 highlighted that uncertainties in stock status for Antarctic krill do not allow for the development of a comprehensive FBM at present, and these uncertainties would best be addressed through better, more frequent observations in the fishery. In order to monitor rapid changes in the Antarctic ecosystem in the context of climatic change, the authors suggested 100% mandatory observer coverage.

2.42 WG-EMM-16/11 by the Secretariat followed the request of WG-EMM-15 (SC-CAMLR-XXXIV, Annex 6, paragraph 2.34) and SC-CAMLR-XXXIV (paragraph 7.5) to develop a metric to describe actual levels of observer coverage in the krill fishery. The metric evaluated in this paper was the number of days observed during a trip, consistent with the practice in the finfish fishery, where 100% coverage means having a SISO observer on board for the entire fishing activity of a given vessel. The authors first evaluated the level of observation (in days) for the past five years in the krill fishery, concluding that during that time period, 90% of fishing days were observed (WG-EMM-16/11, Table 1). Furthermore, within the krill fishing fleet, 92% of vessels had 100% observer coverage. Previous work had shown that observers on krill vessels exceed sampling requirements under SISO, and thus the authors concluded that data collection on krill vessels is methodical and systematic.

2.43 The Working Group noted that both papers have independently defined observer coverage the same way.

2.44 Some participants noted that, at present, there is no need to rewrite the level of observer coverage required in CM 51-06, because (i) current coverage of 50% as required under CM 51-06 is suitable for understanding spatial and temporal variation in krill lengths, and increase to the observer coverage should be based on scientific analysis; (ii) observer data is currently not used for krill fishery management; and (iii) quality of observer data with regard to finfish larvae is not equivalent between vessels, and suggested that effort should focus on increasing the quality of observer data, not the quantity of coverage. Furthermore, the implementation of observer coverage would be a matter for the Scientific Committee, not WG-EMM.

2.45 Other participants pointed out that it is the common responsibility of CCAMLR to conserve its living resources and, as such, there is a need to collect all data, as scientific information will allow better management and development of the krill fishery. Furthermore, although scientific observation data is not used to set catch limits, it is used for fishery management, for example through the development of seal by-catch mitigation which was an issue first identified using observer data.

2.46 The Working Group recalled that the discussion on the level of observer coverage has taken place several times in the past (WG-EMM-14/58, Annex 1; SC-CAMLR-XXXIV, Annex 6, paragraph 2.41; SC-CAMLR-XXXIV, paragraphs 7.4 to 7.22; CCAMLR-XXXIV, paragraphs 3.70 to 3.73 and 6.2 to 6.4) and reiterated its previous general acknowledgement that 100% observer coverage on krill vessels is scientifically desirable.

2.47 In order to reach the scientifically desirable state of 100% observer coverage (SC-CAMLR-XXXIV, paragraph 7.4), the Working Group noted the importance of understanding the circumstances preventing the remaining vessels from reaching this target.

2.48 The Working Group advised the Scientific Committee that an analysis of the observer coverage in the last five years (defined as the number of days when an observer was on a krill fishing vessel as a percentage of the days fished) showed that 90% of fishing days had been observed and 92% of vessels had achieved 100% observer coverage.

2.49 The Working Group considered the request by WG-SAM-16 (Annex 5, paragraphs 2.13 and 2.14) to consider metrics relevant to krill sizes and distribution as part of the observer requirements, as presented in WG-SAM-16/39.

2.50 WG-SAM-16/39 examined the efficiency of the sizes of krill length samples taken by observers by looking at effective sample sizes. All SISO observers on krill fishing vessels collect krill length data which is a basic component in stock assessments, but to date the actual sample size necessary to provide sufficient information has not been examined. This study simulated the effect of reducing the sample size for krill length measurements per haul on the estimate of effective sample size for overall lengths per SSMU/month, randomly subsampling without replacement. At the same time, the effect of spreading out sampling effort over a larger number of hauls at the same temporal–spatial scale was tested. The authors concluded that the sample sizes per haul could be reduced to 50 measurements without reducing the effective sample size, but increasing the number of hauls increased effective sample size, and therefore recommended to reduce sampling of length per haul to 50 but increase sampling effort on haul numbers.

2.51 The Working Group discussed the effects of reducing sample size but spreading sampling effort, noting this will efficiently increase the effective sample size without increasing the number of krill individuals to be processed. It suggested that an evaluation on effective sample sizes looking at the complete length-frequency distributions may be needed in addition to looking at the mean for each haul.

2.52 The Working Group further reflected if there are other questions that are asked of the data collected by observers, and concluded that it is not the samples or sample sizes that need to be primarily considered, but the sampling design. To achieve maximum use from the collected data, sampling could be stratified to include different locations, times and sample sizes.

2.53 The Working Group recommended to examine whether the current sampling design is appropriate to the overall questions raised, and to consider sample sizes after the sampling design is confirmed.

2.54 The Working Group recognised the large amount of data that is provided by observers on krill fishing vessels and thanked all observers for their good work at sea and the high level of coverage, supporting CCAMLR and krill fishery management.

2.55 The Working Group noted that there needs to be commitment to continue collecting data for contribution to FBM and krill management, and that national commitment and the ability of observers to collect krill data need to be considered when designing FBM procedures.

Krill biology, ecology and ecosystem interactions

Krill

2.56 WG-EMM-16/39 examined the interannual variability of krill transport in the Scotia Sea using data from available mesoscale surveys during three seasons (January–March 1984, October–December 1984, January–March 1988). The water circulation patterns were calculated using the geostrophic approximation from hydrographic data while data from the Russian trawl surveys were used to estimate krill abundance. Krill transport was considered as a passive transport with the water flow, and the total flux of krill was calculated assuming a constant supply of krill along sections between adjacent conductivity temperature depth probe (CTD) stations where flux was calculated. The authors analysed variability of water mass and krill biomass transported across different meridional transects in each survey. The authors noted that significant seasonal and interannual variability in water circulation can be clearly observed by SSMU.

2.57 Dr Kasatkina noted that krill coming to the Scotia Sea across the Antarctic Peninsula area can be transported in different ways along the Scotia Arc depending on the current speed and direction. She also noted that estimates of water mass and krill biomass transported across the Scotia Sea have high spatial–temporal variability along and between transects. Dr Kasatkina noted that these calculations of krill biomass transported out of the Bransfield Strait and the Drake Passage might constitute 3.19 million tonnes for the fishing season, and the total krill biomass transported into the Scotia Sea might constitute up to 10.6 million tonnes and 16.2 million tonnes for the fishing season. These estimates of krill flux exceed the trigger level and the precautionary catch limit in Area 48. Dr Kasatkina highlighted that the presence or absence of krill in a subarea/SSMU is in a greater degree a reflection of the dynamics of krill flux, and is not determined by the local stock state or the influence of the krill fishery. Developing the FBM for the krill fishery in Area 48 requires studying krill flux in different spatial–temporal scales.

2.58 The Working Group thanked Dr Kasatkina for her contribution and noted that this presentation built on previous studies (Sushin and Shulgovsky, 1999).

2.59 Dr Kasatkina noted that data from AtlantNIRO's mesoscale surveys during three seasons (January–March 1984, October–December 1984, January–March 1988) was used for the first time to estimate krill flux and compare its indices with those obtained by the authors of WG-EMM-16/39 from the CCAMLR 2000 Krill Synoptic Survey of Area 48.

2.60 The Working Group noted that the assumptions regarding the estimate of the total flux of krill using this approach were dependent on the assumption of time-invariant flow and constant source concentrations of krill as measured at one instant in time. The Working Group noted that an estimate of the variability of flux could be useful.

2.61 The Working Group noted that there were a number of different approaches to the calculation of currents that could be used to estimate the flux of krill (WG-EMM-16/45 and 16/15). Dr Reiss presented a general overview of these methods that included derivation of currents from surface drifters or hydrographic data to generate static surface flow fields and the development of fine-scale four-dimensional numerical circulation models that could better represent the temporal variability and total flux of krill. The Working Group noted that:

(i) the circulation models could be used to examine the sensitivity of the flux estimates by conducting simulations that could be used to determine where to place, and how often to sample, transects

(ii) simulations from numerical models could be used to examine the aggregation and concentration of krill under conditions of both passive and active vertical migration or directed movements for feeding and that these simulations could help to understand the local depletion or recovery of krill in different areas as well as connectivity between areas

(iii) the aggregation of krill in hotspots or in areas of low current flow could generate patterns of krill harvest in those areas that would be hyper stable, and that such attributes could complicate the use of CPUE as indices of abundance.

2.62 The Working Group recalled the previous work (SC-CAMLR-XIII, Annex 5) to understand the flux of krill through the ecosystem, given the importance of this variable to developing FBM and to allocation of catch amongst areas. The Working Group recommended that the Scientific Committee consider how to progress the development of methods to quantify flux, and to better understand the role of both behaviour of krill and oceanographic processes that can aggregate krill and transport krill to downstream areas. This may need the involvement of experts from WG-EMM, SG-ASAM and oceanographers.

2.63 WG-EMM-16/51 presented an analysis of the abundance of larval stages of krill species in the Weddell–Scotia Confluence during the 2011 austral summer. The authors compared abundance estimates with previously published work from the early 1980s and early 1990s and showed that larval abundance for Antarctic krill (*Euphausia superba*) was lower than over the last 25 to 35 years. The authors also show that since the earlier period, considerable freshening of waters may have occurred in this region, suggesting that environmental conditions have changed coincident with the lower krill larval abundance.

2.64 The Working Group noted the importance of these kinds of studies, given the changes occurring at the Antarctic Peninsula owing to climate change. The Working Group also noted that the apparent changes in larval krill were associated with changes in the oceanographic properties of the water column, but that, given the variability associated with krill population dynamics and production, detecting a systematic change using existing data was difficult.

2.65 WG-EMM-16/53 presented the results of a modelling analysis of the potential future effects of changing temperature based on a best-case and worst-case scenario of climate change on individual weight and population biomass of krill through changing gross growth potential (GGP). It examined these potential changes on predator populations using an ecosystem model (the FOOSA or KPFM models) to drive the predator populations and the GGP. The authors first assessed outcomes of climate change for individual krill weight, and then compared the effects of (i) climate change alone, (ii) fishing at the precautionary catch limit (with the spatial distribution of catch following the historical pattern) alone, and (iii) GGP and fishing together relative to a base simulation with no fishing and a constant GGP. The results of this analysis show that changing ocean temperatures are likely to decrease individual krill weights and decrease krill population biomass with concomitant effects on a krill-dependent species. In the model, average krill weight declined by 22%. The authors compared these direct effects of climate-driven changes in temperature on krill biomass and predator performance to models with the addition of fishing where both biomass and penguin abundance showing greater declines when both climate change and fishing occurs. The authors argue that these data provide some evidence that long-term climate change predictions must be considered as part of the strategy to manage krill.

2.66 The Working Group noted that there could be evolutionary or adaptive responses by krill to the changing environmental conditions that are unrecognised at present and that these changes may give rise to an absence of a response of krill to climate change. However, the model also assessed only one impact of climate change and one pathway for impact, whereas climate change will likely impact environmental conditions beyond temperature, and have more complex consequences for krill and krill-dependent predators than are represented in the paper.

2.67 The Working Group had a number of questions regarding the dynamics of the model under different conditions. The dynamics in long-term simulations might change if changes were stabilised half way through the simulation. Such an investigation could indicate whether there are substantial lags in the response of the populations to changing climate forcing, or if the system would be resilient to moderate impacts. In addition, the long time scale of the model currently, while necessary to include output from climate change models, is less informative for making management decisions.

2.68 The Working Group noted that management strategies based on this approach would need to be robust to these kinds of unforeseen responses and protect against the worst effects. The Working Group indicated that some further work to develop evaluation strategies for the potential effects could help mitigate against differences between model projections and suggested management decisions that might be developed using this model.

2.69 WG-EMM-16/P02 reported on progress to further develop a direct ageing technique for Antarctic krill based on counting of what is believed to be growth zones in cross sections of eyestalks. The authors were able to find up to six growth bands isolated from krill. The authors found a number of interesting size-, sex- and maturity-based relationships. In particular, the authors showed that females tended to have narrower growth zones from the third zone and onwards compared with males. The data showed that sub-adult male krill (MIIA1, MIIA2 and MIIA3) had 2.2 ± 0.8 (average ± SD) zones and adult male krill had 3.8 ± 0.8 zones. Female juvenile krill (FIIB) had 1.7 ± 0.5 zones and adult female krill (FIIIA-E) had 3.7 ± 1.0 zones. The authors noted that there were positive relationships between the number of zones and the maturity stage, and between the number of zones and body length.

2.70 The Working Group welcomed the progress being made towards the development of a direct ageing method for krill. The Working Group recalled WG-EMM-15/45 that also worked towards validating krill ages, and noted that validating the methodology was critical and encouraged the continued development of the technique, including calibration of the technique between laboratories. It agreed that further development of the approach to age krill will be useful to the development of age-based assessments and comparative studies of krill biology and ecology.

2.71 WG-EMM-16/P04 reported on an analysis that examined seasonal changes in the size of male and female krill in Scotia Sea (South Georgia and the Antarctic Peninsula). By using a combination of fishery-dependent and fishery-independent data on the length of krill, the authors demonstrated that female krill in the Scotia Sea shrink approximately 3 mm during winter when modal size classes were tracked over seasons and sex ratio changes were accounted for. The authors tested for other explanatory factors, like differential mortality, immigration and emigration and argued these could not explain the observed patterns. The authors fitted seasonally modulated von Bertalanffy growth functions for males and females and showed a pattern of overwintering shrinkage in all body-length classes of females, but only stagnation in growth in males. This shrinkage most likely reflects morphometric changes resulting from the contraction of the ovaries and is not necessarily an outcome of winter hardship. The authors argue that the sex-dependent changes that were observed should be incorporated into life-cycle and population dynamic models of this species, particularly those used in managing the fishery.

2.72 The Working Group noted that this paper highlights the utility of fishery data to fill in gaps in our understanding of krill biology.

2.73 WG-EMM-16/76 presented results of two acoustic surveys conducted by Peru during the austral summers of 2013 and 2014. The Working Group thanked Peru for presenting its data to the Working Group and Peru indicated a willingness to continue to collaborate with Members. The Working Group also noted that such collaborations can help to meet broader CCAMLR goals.

2.74 The Working Group received presentations by two early career scientists. Ms Fokje Schaafsma from the EU (mentor Jan van Franeker) had been selected for the CCAMLR Scientific Scholarship. Dr Aleksandr Sytov from Russia (mentor Svetlana Kasatkina) was a candidate for a scholarship in 2014 but was unable to participate in the scheme for technical reasons.

2.75 Ms Schaafsma provided an update on her research to examine patterns of krill and zooplankton distributions in the water column and under sea-ice during a number of cruises to the Antarctic (WG-EMM-16/P16). Using data collected by the surface and under-ice trawl (SUIT) she outlined how krill (larvae and adults) are distributed within the pack ice. Ms Schaafsma highlighted that, given the importance of sea-ice to the life history of krill and the potential impact of climate change on sea-ice dynamics, the study is very timely.

2.76 The Working Group thanked Ms Schaafsma for her work and encouraged her to present the findings to WG-EMM in the future. The Working Group expressed interest in details of the gear regarding the size of nets within the gear, deployment details and the kinds of animals (whales, penguins and fish) that were observed by the camera attached to the net system. Dr Vacchi was interested in whether platelet ice, an important habitat for silverfish, was observed with the camera in any of the sampled areas. Others expressed interest in details of the distribution of krill and zooplankton within and outside the ice, and in relation to hypotheses regarding concentrations of krill across the open water and pack-ice habitat.

2.77 Dr Sytov presented results from his research (WG-EMM-16/41) on analyses of historical catch and acoustic data from the Russian krill fishery between 1988 and 2002 in the Atlantic sector (Subareas 48.1, 48.2 and 48.3) of the Southern Ocean. In particular, Dr Sytov's research focussed on questions of the spatial distribution of krill in terms of swarms and patch structure. Additionally, the research focussed on some aspects of the changes in maturity stages and feeding rates over the fishing seasons. Investigation was focused on the following aspects: What are the characteristics of krill spatial distribution, apart from biomass density, that are important for the fishery? In what way does the variability of these characteristics during the fishing season affect the indices of fishing vessels?

2.78 Dr Sytov indicated that variability of the fishing indices of commercial vessels (catch per hour, catch per trawling, daily catch, trawl efficiency) during the fishing season is in a great degree a reflection of changing swarm spatial distributions (i.e. parameters swarm distribution in two-dimensional and three-dimensional space) and not determined by swarm size. Moreover, the catch per hour trawling is mostly sensitive to the changing krill spatial distribution. The daily catch is limited by the vessel's technological equipment capacity and it may be attained by application of different fishing effort. Dr Sytov noted that the impact of variability of krill biological state (length composition, maturity stages, feeding rate) on krill distribution in the fishing ground was not revealed. Dr Sytov noted the importance to investigate the characteristics of krill spatial distribution in fishing grounds by using acoustic observation on board commercial vessels.

2.79 Dr Kasatkina, as Dr Sytov's mentor, underlined that the investigation fulfilled by Dr Sytov (SC-CAMLR-XXXIII, paragraph 13.12) would be important for: developing FBM; providing approaches for acoustic data processing to analyse the krill fishing performance; and studying functional overlap between krill fishery and dependent predators.

2.80 The Working Group welcomed this research especially because the use of acoustic data to examine the structure of krill distributions during the early part of the time series could be compared to the structure of the spatial distribution of krill during operation of the current fishery. The Working Group noted how far offshore the fishery operated in the past (well into the pelagic SSMUs in each subarea). The Working Group indicated that previous analyses of both the Japanese and former Soviet fishery data showed that the fleet-based searching that the Soviet fleet used allowed that fishery to operate farther offshore compared to the individual ship effort that was used by the Japanese fishery, and that advances in technology could change the effort required to search these areas in the current fishery.

2.81 The Working Group noted that analysing historical acoustic fishing data was as important as analysing the current fishery data as the data could be used to compare a variety of biological characteristics of krill at a variety of spatio–temporal scales.

Ecosystem monitoring and observation

2.82 WG-EMM-16/29 presented phyto- and zoo-plankton density distribution in relation to the environment from continuous plankton recorder (CPR) data collected on repeated transects in the Scotia Sea over the period from 2005 to 2015. The analysis used satellite information on sea-surface height (SSH) to identify fronts and eddies, which were overlaid plankton distributions, demonstrating clear physical–biological relationships that can be used to inform predictions about potential impacts of global climate change on biological production.

2.83 WG-EMM-16/70 provided an update on the Southern Ocean Observing System (SOOS) which was established by SCAR and SCOR and has direct relevance for CCAMLR. It is motivated by data scarcity and the difficulties in collecting information due to high costs and difficult logistics, which call for cooperation and coordination. Its four objectives include to: (i) facilitate multidisciplinary data collection, (ii) optimise observation effort, (iii) establish long-term time series and (iv) provide services that make data accessible to users. The aim of assessing the state of the Southern Ocean is ambitious, as is the aim of circumpolar benchmarking in 2022. SOOS has a technology focus and invited CCAMLR to join, as CCAMLR infrastructure represents a resource for SOOS, for example due to the potential of using fishing vessels as platforms for data collection.

2.84 The Working Group agreed that there is a need for cooperation with SOOS and that this should be brought up when discussing collaboration between other organisations and CCAMLR (paragraphs 6.22 to 6.26).

2.85 WG-EMM-16/75 presented the results of abundance studies of *Salpa thompsoni* over a time series from 1975 to 2001 as a follow-up to the information presented in WG-EMM-15/P08. Scientific questions addressed in the study included: (i) which environmental factors determine presence or absence of salps? and (ii) which of these factors influence their abundance?

2.86 The presence–absence of salps was correlated with presence or absence of sea-ice; temperature and depth and the abundance was inversely related to sea-ice concentration and the highest concentration was found in water around 1°C. The authors suggested further study of the issue in relation to climate change.

2.87 The Working Group recalled that salps were discussed more broadly in CCAMLR in earlier years but have received less attention in recent years. Dr T. Ichii (Japan) recalled that salps impacted fishing 20 years ago as krill swarms occasionally contained large quantities of salps. This situation, as reported from the current fishery, is not the same and the Working Group suggested that the more inshore operation of the fleet might be an important explanatory factor.

2.88 The Working Group suggested that available data and information about salps could be used to establish models that enable CCAMLR to understand the potential impact of climate change on the relationship between krill and salps. Such data exist from routine surveys and Members were advised to analyse this information and make it available to WG-EMM and SOOS.

2.89 The Working Group noted that information on the acoustic identification and target strength of salps have been published (Wiebe et al., 2010) and this provides an opportunity for using acoustics to distinguish salps from krill as well as estimating their biomass.

2.90 The Working Group recommended that the SISO fish by-catch data reporting form be modified to collect data on salps by requesting observers to record whether salps were present or absent in the 25 kg sample collected for the analysis of fish by-catch.

2.91 WG-EMM-16/P03 reported the update of the annual Norwegian standard acoustic trawl survey (WG-EMM-15/54). The report documents survey methods and the krill abundance estimates for this year. Antarctic krill demography is reported as well as occurrence of other zooplankton from the trawl catches. Sighting data of cetaceans, pinnipeds and seabirds were collected along the survey transects. Additional experiments were also conducted on board to collect data for the verification of a method to determine the age of krill and to model trawl net mesh penetration behaviour of krill.

2.92 Dr Krafft informed the Working Group that pack-ice concentration was low this season and that the zooplankton distribution was different compared to previous years. Salps were found distributed more or less throughout the entire study area, which was in contrast to previous seasons when they were more abundant in the northern part. Also, there were more fish in the krill catch, a situation that was underlined by Dr Trathan who reported more fish in the diet of penguins in the South Orkney Islands.

2.93 WG-EMM-16/P11 reported on developing priority variables (ecosystem Essential Ocean Variables – eEOVs) for observing dynamics and change in Southern Ocean ecosystems. The paper organised a framework for prioritising eEOVs to be collected within the SOOS monitoring program. These variables address questions regarding ecosystem status, trends, attribution and scenarios for marine ecosystems. The authors underlined that efficiency in data collection is enhanced by first agreeing on eEOVs. The paper raised several issues of direct relevance to CCAMLR.

2.94 The Working Group agreed that interaction with SOOS, and particularly regarding the development of eEOVs, is needed. It was recommended that this issue be discussed by the Scientific Committee.

Ecosystem interactions

2.95 WG-EMM-16/14 reported on the second meeting of the workshop on the Retrospective Analysis of Antarctic Tracking Data (RAATD), sponsored by the Expert Group on Birds and Marine Mammals (SCAR-EGBAMM), held in Delmenhorst, Germany, in 2016. The first workshop, held in Brussels, Belgium, in 2015, established a database of Antarctic animal tracking data that now holds 3 447 tracks from 15 species (10 species of seabirds and five species of marine mammals). The data were provided by more than 37 data holders from 23 institutions in 11 countries. The workshop reviewed interim progress on:

(i) developing habitat utilisation models for each species

(ii) using those models to make global species-specific predictions of important habitat based on colony locations

(iii) identifying areas of ecological significance (AES).

2.96 The specific goals of the meeting were outlined for two areas: data management and data modelling. The goals included identifying and sourcing missing datasets and developing specific guidelines for quality control of datasets. For the data modelling group, the objectives included running state–space movement models for each species, extracting environmental datasets and developing statistical habitat use models for each species. The report also provided an extensive list of candidate environmental variables that will be used in developing predictive models of habitat use for each species.

2.97 Significant progress was made on all the stated objectives and post-sessional work was identified for providing habitat use models for all tracked species and identifying AES.

2.98 The Working Group recognised that, given the scale at which predators are distributed and the inability to monitor all colonies, habitat modelling is an important approach to identifying ecologically important habitat and identifying where potential overlap with fisheries occurs.

2.99 The Working Group noted that the work of SCAR on animal tracking and habitat use models will be important for developing predator consumption models and will potentially have implications for managing the krill fisheries at finer scales.

2.100 The Working Group further recognised the importance of the SCAR-EGBAMM RAATD for a variety of CCAMLR analyses, including work on the development of a variety of FBM approaches for the krill fishery and work on the spatial planning processes needed for identifying candidate CCAMLR marine protected areas (MPAs).

2.101 WG-EMM-16/20 reported on a first attempt at using a methodology established by BirdLife International over 35 years ago to identify important bird and biodiversity areas (IBAs) for penguins in Subareas 48.1 and 48.2. The authors used all available tracking data for four species of penguin and identified candidate IBAs based on BirdLife International's internationally established criteria: (i) the species is a globally threatened species, (ii) the site is known, or thought, to hold on a regular basis >1% of the global population of the species, and (iii) the site holds on a regular basis >20 000 waterbirds or >10 000 seabird pairs. The analysis identified candidate IBAs for Subareas 48.1 and 48.2 (Hope Bay; Powell Island; Gourlay Penisula, Signy Island; North Point, Signy Island; and Admiralty Bay, King George Island). The authors outlined future intersessional work for developing a more complete Antarctic IBA network.

2.102 The Working Group noted that the criteria used by BirdLife International may exclude some important smaller datasets. The Working Group encouraged the authors of WG-EMM-16/20 to work closely with other CCAMLR-led habitat modelling initiatives and to submit a paper to WG-SAM for evaluation of methods and provide an update on their progress for WG-EMM-17.

2.103 The Working Group noted that multiple approaches to the analysis of animal tracking data with the aim of identifying important predator habitat can be useful in a comparative approach to identifying habitat important to predators.

2.104 WG-EMM-16/15 described preliminary progress on high-resolution hydrodynamic modelling using a modelling framework developed by the Nucleus for European Modelling of the Ocean (NEMO) for Subareas 48.2 and 48.3 continental shelves and adjacent areas. Past ocean models have been instrumental in describing and studying large-scale transport of water and biota. However, much less is known about movement and transport over finer scales (<10 km) that are relevant to understanding distribution and movement of krill, fish, predators and fishing. The working scale for these models is ~3 km.

2.105 The results provided are simulations for one year, however, it is the intention of the authors to provide model results for a historical 20-year period. The South Georgia model has already undergone validation with favourable results using an extensive CTD dataset and satellite-derived sea-surface temperature (SST) data collected in 1995. The South Orkney Islands model is currently undergoing validation using in situ data collected from 1997 to 1998. Dr Trathan noted that sea-ice dynamics will be included in future developments of the models.

2.106 The Working Group agreed that such models will improve our fundamental understanding of hydrodynamic impacts over the scales that predator–prey relationships take place and will provide the basis for examining the local controls on prey availability and distribution of predators. Once completed, such models offer hindcast capabilities for numerous past studies of both prey and predators, including during the CCAMLR-2000 Survey and the recent international cruise at the South Orkney Islands in 2016 (WG-EMM-16/19). Such analyses will help inform future management and conservation measures within CCAMLR.

2.107 WG-EMM-16/19 reported on a recent multinational effort led by the UK and Norway and included participants from the US AMLR Program, University of Washington and the University of Coimbra. The survey was conducted in January and February 2016 around the South Orkney Islands in an area important to the krill fishery. It was coordinated with an annual five-day survey of an important fishing area northwest of the South Orkney Islands conducted by Norway. It included extensive net and CTD sampling. The acoustic survey was also supplemented with data collected from two newly designed stationary moorings and a third mooring deployed by the *Saga Sea*. At-sea predator distribution data was collected concurrently.

2.108 The Working Group noted the importance of this multinational effort as the data collected will be important in understanding krill and mesopelagic fish distributions in relation to oceanography and predators.

2.109 WG-EMM-16/P06 analysed several climate indices and krill densities at South Georgia to show significant correlations with annual calf production of southern right whales (*Eubalaena australis*) in southern Brazil over a 17 year period. The results are noteworthy because most CEMP indices are necessarily collected using land-based predators and this study provides evidence of a significant correlation between krill abundance at South Georgia and reproductive success for a recovering cetacean species.

2.110 The Working Group welcomed this paper and noted that southern right whales are known to be important krill consumers which are present near South Georgia in the summer. The Working Group recognised that, while the krill density data were from a local-scale survey, these data may well reflect changes in the variability in krill abundance over the feeding area of the population of southern right whales that calve in Brazil.

2.111 The Working Group encouraged further work on data from long-term monitoring of the reproductive success of baleen whales and variability in krill abundance in their summer feeding areas.

2.112 WG-EMM-16/P15 reported on the at-sea distribution and prey selection of Antarctic petrels (*Thalassoica antarctica*) and commercial fisheries. Past working groups and the Subgroup on Status and Trend Assessment for Predator Populations (WG-EMM-STAPP) have often identified the need for more information on flying seabirds. This paper provided new information on the degree of overlap in krill fisheries and Antarctic petrels during the breeding and non-breeding phases. The study occurred over three consecutive years beginning in 2011 using global positioning system (GPS) data loggers providing 133 tracks of 124 individuals during the breeding phase. An additional 51 loggers provided data during the non-breeding phase. The authors found that the degree of overlap with the fishery varied greatly within and between years and was higher during the non-breeding phase. They compared krill length frequencies in the diet of Antarctic petrels and found that they did not differ from the fishery. Their results indicate that competition, although limited, may exist between Antarctic petrels and krill fisheries and may increase with increased fishing.

2.113 WG-EMM-16/28 reported on the present status of the marine ecosystem at South Georgia using long-term datasets of predator performance indices coupled with data collected concurrently on krill density offshore. The paper found: (i) some predator performance indices at large scales broadly correlated across two sites separated by ~65 km; (ii) at smaller scales, however, some variables reflected local ecological conditions; (iii) previously documented predator–prey relationships were not apparent and this may reflect the fact that the analyses used a different subset of data covering different years during which fewer years of extreme low krill density were apparent; (iv) variability in krill was evident at different spatial and temporal scales and, at low densities, spatial variability and patchiness may become important as determinants of predator performance. The authors noted that mean krill density alone may not be adequate to explain variability in predator performance.

2.114 The Working Group noted that the recent work on developing mesoscale models (WG-EMM-16/15 and 16/45) to describe flux and prey movement at scales relevant to predator foraging may help provide better metrics for explaining variability in predator success.

2.115 Dr Kasatkina noted that the proposed analysis of spatial variability and patchiness of krill distribution would provide important information for understanding relationships between predators and krill, as well as competition between fishing and krill-dependent predators. She also noted that knowing the critical density thresholds of krill for foraging predators would also provide management information for understanding reproductive success for different predators in relation to annual estimates of variability in krill biomass.

2.116 WG-EMM-16/26 examined temporal changes in historical distribution and sighting density of baleen whales in Subareas 48.1 and 48.2 in response to the request of

WG-EMM-15 that an analysis of historical cetacean surveys could provide a context for at-sea observations of cetaceans (SC-CAMLR-XXXIV, Annex 6, Table 3). Whale sighting data were obtained during a series of Antarctic sighting cruises organised by the International Whaling Commission Scientific Committee (IWC SC) in three circumpolar surveys (CPI, II and III) that took place in Subareas 48.1 and 48.2 between 1982 and 2000. The density indices in both subareas reflect variation in sighting density for blue (*Balaenoptera musculus*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*) and Antarctic minke (*B. bonaerensis*) whales, with some evidence to suggest an increase in fin and humpback whale sightings, and a decrease in Antarctic minke whale sightings across one or both areas over time. The authors noted that due to differences in survey design from CPI, comparison of density across CPII and CPIII is more appropriate. The authors concluded that stock abundance estimates of baleen whales, and concentration of whales in fishing and other predator foraging areas, are of importance for managing krill under FBM.

2.117 The Working Group noted the differences in transect design between CPI and both CPII and CPIII. It recalled previous discussion of survey design for the concurrent krill and cetacean sightings survey (SC-CAMLR-XXXIV, Annex 6, paragraphs 2.239 to 2.241; Annex 5, paragraphs 2.7 to 2.10). The Working Group noted that inferring a trend in whale populations in Subareas 48.1 or 48.2 on the basis of three periods of data collected using inconsistent survey design, in a region that we know to be characterised by high interannual variability, may be problematic. Furthermore, it noted the importance of consistent survey timing to reduce the risk of conflating inter- and intra-annual variability. On this point, it was clarified that International Decade of Cetacean Research/Southern Ocean Whale Ecology Research (IDCR/SOWER) surveys in each year were carried out at similar times. The Working Group noted that the dedicated cetacean surveys reported in WG-EMM-15/26 had not been conducted since 2000. The Working Group encouraged further cetacean sighting surveys in Subareas 48.1 and 48.2 and encouraged analysis of other sources of cetacean sighting data that are available for these subareas.

2.118 The Working Group agreed the importance of considering krill consumption by baleen whales in the development of an effective FBM regime. It highlighted the increasing numbers of humpback and fin whales in Bransfield Strait as one area where consideration of cetaceans in FBM may be important. It noted that with a staged approach to FBM, effects on cetaceans could be incorporated in the future but that temporal lags due to cetacean life-history characteristics would need to be considered. It noted that cetaceans may be good candidates for monitoring the ecosystem as a whole.

2.119 The Working Group agreed that it is valuable to receive regular updates from IWC on the status of whale populations and noted the reciprocal interest from IWC with regard to CCAMLR data. It noted that the Joint CCAMLR–IWC Workshop next year could provide a basis for data sharing related to the krill-based ecosystem (paragraphs 6.3 to 6.7).

2.120 WG-EMM-16/64 reviewed information that could be indicative of changes in the east Antarctic ecosystem in the context of two hypotheses, the 'krill surplus' hypothesis in the middle of the past century and the recovery of baleen whales since the 1980s. The authors suggested that increased krill availability in the middle of the past century may have translated into better nutritional conditions for some krill predators like Antarctic minke whales, resulting in a decreasing trend in the age at sexual maturity of this species between approximately 1940 and 1970. A low age at sexual maturity could help explain an increase in the recruitment rate and total population size over a similar period. The authors noted that the evidence available since the 1980s showed a sharp increase in the abundance of some species in East Antarctica such as the humpback and fin whales. In contrast, the authors described a stable trend of age at sexual maturity and recruitment for Antarctic minke whales after the 1970s. They noted this was consistent with the total abundance of Antarctic minke whales estimated by sighting surveys, which has been broadly stable since the 1980s. The authors suggested the availability of krill for Antarctic minke whales could have decreased in recent years, possibly as a result of competition with recovering whale species. The authors noted the concurrent recovery of baleen whales and an increasing trend in Adélie penguin (*Pygoscelis adeliae*) numbers in East Antarctica. While this appears inconsistent with conditions of resource limitation, the authors supported one of the explanations provided by Southwell et al. (2015) that environmental factors such as decreasing sea-ice extent may explain this. The authors explained that the motivations to prepare this document were: (i) to start discussions on possible differences in the kind of ecosystem changes observed in the eastern and western Antarctic; (ii) highlight the importance of the long-term monitoring of sea-based krill predators like baleen whales.

2.121 The Working Group noted that aspects of the paper were still being considered by IWC SC and focused its comments on aspects related to interactions with the krill-based ecosystem. It noted the Joint CCAMLR–IWC Workshop would provide an opportunity to discuss areas of mutual interest. It noted the focus of the workshop was the Antarctic Peninsula, and that approaches developed there may be able to be applied in other areas like East Antarctica.

2.122 The Working Group noted the evidence of spatial overlap of humpback and Antarctic minke whale distribution at the sea-ice edge in East Antarctica and agreed that krill biomass data in this area would be valuable to examine the authors' hypotheses, or alternative hypotheses, for ecosystem interactions in East Antarctica. In considering alternative hypotheses, the Working Group noted the large increase in Adélie penguin numbers in the region and in the adjacent Ross Sea region over the past two decades that occurred despite variable and increasing sea-ice extent and recovering whale populations. It encouraged the exploration of alternative hypotheses to resource limitation in East Antarctica, including shifts in Antarctic minke whale distribution with respect to sea-ice and polynyas as noted in the paper, positive feedback loops associated with recovering whale populations (Lavery et al., 2014) that may explain simultaneous increases in whale and penguin numbers, and the impacts of climate change.

2.123 WG-EMM-16/P01 provided an example of the use of passive ocean acoustic waveguide remote sensing techniques to study the foraging behaviour of an assemblage of more than eight species of cetaceans preying on herring shoals in their spawning areas in the Gulf of Maine in the North Atlantic (Wang et al., 2016). The vocal cetacean species detected include blue, fin, humpback, sei (*B. borealis*), minke, sperm (*Physeter macrocephalus*), pilot (*Globicephala* spp.) and killer (*Orcinus orca*) whales along with other delphinids. All these species spatially converge on fish spawning areas containing massive densely populated herring shoals at night-time and diffuse herring distributions during daytime. Vocalisation rates for baleen whales are highly correlated with trends in fish shoaling density and with each other over the diel cycle but some species-related spatial preferences occurred. The results reveal the dynamics of combined multi-species foraging activities in the vicinity of an extensive prey field that forms a massive ecological hotspot.

2.124 The Working Group noted that the study revealed spatial and temporal complexity of predator–prey interactions, coupled with potential niche partitioning, at the mesoscale (30–100 km) consistent with findings from fine-scale studies of baleen whales in Antarctic waters (Santora et al., 2010; Friedlaender et al., 2014). It noted the potential application of passive ocean acoustic waveguide remote sensing techniques to study the foraging behaviour of baleen whales and the krill-based ecosystem. It noted that for krill, it would be necessary to increase the active acoustic frequency to 12 kHz, which would reduce the detection range, but that passive acoustic arrays could be deployed from vessels at up to 8 knots. It noted the need for bathymetric data and the potential environmental impact of using low-frequency active acoustics. However, it noted that this system used only the same energy levels as the whales themselves, and multiple sub-sources to minimise impacts.

2.125 The Working Group noted the value of passive acoustics for localising cetaceans in the Southern Ocean and recalled the SORP initiative 'the Southern Ocean Hydrophone Network' (van Opzeeland et al., 2013). It noted that such gear may be able to be deployed opportunistically from fishing vessels if the post-processing requirements can be addressed. It noted that candidate sites and systems for trials (e.g. baleen whales and krill in Bransfield Strait, or sperm whale depredation of toothfish fisheries) could be considered by the steering group for potential discussion at the Joint CCAMLR–IWC Workshop next year.

CEMP and WG-EMM STAPP

CEMP data

2.126 As of 1 June 2016, nine Members working at 15 sites in Areas 48, 58 and 88 contributed data for 12 CEMP parameters on six species of krill-dependent predators for the 2015/16 breeding season. Additional data have since been submitted by Ukraine and entered into the CEMP database.

2.127 At the request of WG-EMM, an analysis of data in the CEMP database was undertaken by the Secretariat to support use of CEMP data in FBM development. The analysis in WG-EMM-16/08 noted several potential issues with data submissions. A subgroup was convened to discuss these issues and the Working Group agreed that Members would continue discussions intersessionally on the e-group to resolve outstanding issues. Issues to be resolved are:

(i) Parameter A3: Efforts were ongoing to identify appropriate units of breeding unit aggregation for reporting A3 data. Thus far, the subgroup recommended that CEMP data providers submit updated maps of nest census areas that clearly define the spatial scale of their A3 data.

(ii) Parameter A6: There is uncertainty in the estimation method for reproductive success. That is, should aggregate totals of nest and chick census data for the entire colony be used or should an average of reproductive success across multiple sites within a colony be used to estimate colony success.

(iii) Parameter A7: It was noted that submission of ancillary data for estimating mean fledging weights was often incomplete, particularly the estimates of the percent of the population fledging over time. Additionally, different interpretations of the standard methods, driven in part by differences in colony sizes and the degree of synchrony in the colony, result in different data collection methods. While some Members report data collected every fifth day, others report daily data aggregated on five-day intervals.

(iv) Parameter A8: Diet data suggest methodological changes in the field may compromise the ability to estimate diet mass. There has been a general decline in the collection of diet data across the CEMP network. The subgroup recognised the loss of potentially valuable diet composition and diet mass data, but noted that isotopic and genetic analyses may be useful tools to recover diet composition data. Additionally, it was suggested that krill length-frequency distributions for predator diets may be valuable additions to CEMP, as similar data are increasingly used in assessment models and complement fishery observer and research survey data.

(v) Parameter A9: Inconsistencies in proper formatting of A9 data are evident and an example of proper formatting was provided. The Working Group recommended intersessional work to advance camera-specific methods for parameter A9.

(vi) Parameter C1: Foraging trip durations for fur seal cows are only reported for the first six trips to sea. The Working Group noted that this method was based on historical considerations of occupancy of field camps by researchers. Additional data may be available; however, no specific reason to amend this CEMP method was determined.

(vii) Parameter C2: Estimates of fur seal pup mass resulted in differences in the relative trends in growth rates for males and females between sites. The Working Group noted that such differences in pup growth rates may be related to latitudinal differences in energetics.

2.128 On the whole, it was noted that despite potentially small differences in the implementation of the CEMP standard methods between sites, consistency of the method used within a site is critical. Such consistency ensures that standardisation of the data, for example as standard normal deviates or as a CSI for a particular site, enables direct comparisons across sites.

2.129 As a follow-on to the description of the CEMP inventory, the Secretariat reported on the spatial scales over which CSIs from existing CEMP sites are correlated. Correlations between CSIs of summer CEMP parameters were generally positive across all sites considered in Subareas 48.1, 48.2 and 48.3. Sites in Subareas 48.1 and 48.3 showed concordant interannual variation and the patterns of interannual variability in sites in the Bransfield Strait (Subarea 48.1) showed an increased level of concordance in the period since 2008.

2.130 The Secretariat also presented a comparison of summer CSIs from the three longest-running monitoring programs in each of Subarea 48.1 (Admiralty Bay), 48.2 (Signy Island) and 48.3 (Bird Island) and the Working Group noted that a three-year running average of CSIs from these sites exhibited a strong concordance suggesting region-scale concordance in predator responses.

2.131 The Working Group agreed that, while there was evidence of concordant responses in CSIs from sites, there was also evidence of site-specific signals that underlined the importance of understanding local-scale effects for some parameters. Reconciling these local impacts within the broader regional concordance remains an important task for understanding the spatial scales reflected by CEMP monitoring data.

2.132 The Working Group noted that the importance of local effects on monitoring data was provided by an analysis of an acute mortality event of penguins in WG-EMM-16/59. In the austral summer of 2011/12, the abnormal presence of summer sea-ice may have limited feeding opportunities for gentoo penguins (*P. papua*) at the southern limit of their range. Abandonment of nests by adults resulted in high chick mortality rates, estimated at >84%. Dr G. Milinevskyi (Ukraine) noted that research dives (through holes in the ice) at the time near the colony recorded the presence of krill, suggesting that breeding failure was linked to blocked access to foraging grounds.

2.133 A mortality event of gentoo penguin chicks, potentially restricted to the southwestern Bransfield Strait and West Antarctic Peninsula in 2015/16, was reported to the Working Group. The initial observations were reported by the international association of Antarctica tour operators (IAATO) members and later confirmed by researchers at the Palmer long-term ecological research (LTER) study area. Autopsies of available chicks suggested starvation, rather than disease, as the mechanism of death.

2.134 The Working Group noted the importance of addressing health issues to determine not only mortality events but also the performance of seabirds and marine mammals. The Working Group recalled the existence of a SCAR Working Group on Health Monitoring of Birds and Marine Mammals included in the SCAR EGBAMM that could provide help and advice on these issues.

2.135 The Working Group recalled that the *CEMP Standard Methods*, Part 4, Section 6, contain a protocol for collection of samples for pathological analysis in the event that disease is suspected in mortality events.

2.136 The Working Group agreed that ancillary data that describe Members' research activities and document the general conditions encountered during monitoring activities would be a useful contribution to CEMP. Such metadata would improve interpretation of submitted data. The Working Group encouraged Members to provide such metadata when submitting CEMP data and requested that the Secretariat include a request for this information in its annual request for CEMP data.

2.137 In addition to the ongoing data submissions, the Working Group welcomed submission of new CEMP data from the Republic of Korea. Since 2006/07, Korea has maintained a monitoring program on gentoo and chinstrap penguin (*P. antarctica*) abundance and breeding success in Antarctic Specially Protected Area (ASPA) No. 171 on the Barton Peninsula of King George Island. Korea also indicated plans to monitor Adélie penguins at Cape Hallett in the Ross Sea beginning in 2016/17. Dr J.-H. Kim (Republic of Korea) thanked the Secretariat for its assistance in completing the CEMP data submission forms and he noted that this had made the process much easier.

2.138 The Working Group welcomed the commitment of Korea to initiate a long-term monitoring program in the Ross Sea, including data from Adélie penguins at Cape Hallett that would be submitted to CEMP. The Working Group noted that such data may be useful to support the MPA process being considered there.

2.139 The Working Group welcomed the proposed submission of CEMP data from Korea and noted that discussions underway with France, Spain and the USA may also lead to new CEMP data submissions from existing long-term monitoring programs.

2.140 The Working Group considered three papers that contain analyses based on CEMP data that support development of an FBM procedure based on an existing monitoring program in Subarea 48.1. WG-EMM-16/45 (vignette 6) reported that Antarctic fur seal (*Arctocephalus gazella*) foraging trip duration and within-individual variance in trip durations are correlated with krill size and biomass estimates on the west shelf of the South Shetland Islands. The analysis demonstrates sensitivity of the CEMP foraging trip duration parameter (C1) to variation in krill populations.

2.141 WG-EMM-16/45 (vignette 7) reported on a meta-analysis to quantify predator performance based on multiple CEMP indices and to relate that index of performance to krill biomass and local harvest rates. The analysis suggested that there is sufficient signal in existing CEMP indices to detect reduced predator performance when krill biomass is low or when local harvest rates are of similar magnitude as local biomass.

2.142 WG-EMM-16/47 (vignette 1) built on the meta-analysis to demonstrate a method for evaluating predator performance in a binary 'red light'/'green light' classification and how using such an evaluation could lead to adjustment in catch allocations in an FBM.

2.143 The Working Group agreed that, together, these analyses draw attention to the value of existing CEMP data for understanding predator performance and their utility for developing FBM strategies.

2.144 The Working Group noted that the analysis of WG-EMM-16/45 (vignette 7) presented plausible evidence for impacts of fishing on krill-dependent predator performance in Subarea 48.1. While interannual variability in krill and predator data had seemed too large to allow such an assessment previously, the analysis showed that assumptions about a lack of impact may not be supported. Given such plausible impacts, it was recommended that CM 51-07 be retained in its current form as a precautionary management strategy while alternative allocation options and proposed FBM strategies are evaluated further.

2.145 The Working Group noted that the length of time series and methods necessary to differentiate fishing and climate effects in monitoring data remain a critical issue. In particular, the Working Group recalled the importance of identifying the spatial scale over which monitoring data integrate. Understanding the spatial scale of such variability and its major drivers will be useful for providing robust advice to the Commission.

2.146 The Working Group agreed that identifying reference areas may help identify major drivers of variation in monitoring data. Ideally, multi-site and multi-scale concordance of monitoring data would facilitate the use of reference areas. The Working Group noted the temporal concordance of CSIs of CEMP data across Area 48 presented by the Secretariat in WG-EMM-16/09 and suggested that such concordance may allow identification of reference monitoring areas.

2.147 The Working Group considered three papers related to the development of a camera network in Subarea 48.1 for monitoring predators. WG-EMM-16/55 and 16/58 described implementation and progress of a CEMP Fund project to establish an extended camera network in Subarea 48.1. In total, 53 cameras have been deployed at sites on King George Island, Livingston Island, Deception Island and along the Antarctic Peninsula from Cierva Cove south toward the Argentine Islands. Species coverage includes the three Pygoscelid penguin species (Adélie, gentoo and chinstrap).

2.148 The Working Group noted the successful collaboration of multiple Members in establishing the network and invigorating data collection efforts to support CEMP and FBM efforts. While the original intent of the camera network was to provide data on reproductive success and breeding phenology, the Working Group noted that camera techniques provide an opportunity for monitoring numerous other parameters. In particular, time-lapse imagery could be used to examine nest survival, predation events, the impacts of storms, or foraging trip durations, among others. In addition, automated weather stations installed in parallel with cameras might provide additional data streams for interpreting data derived from photographs.

2.149 WG-EMM-16/46 (vignette 3) presented a method to estimate breeding parameters from photo-derived observations of adult attendance at focal nests. The method was validated for chinstrap penguins, following advice of WG-EMM (SC-CAMLR-XXXIV, Annex 5, paragraph 2.185). The results suggest equivalency of ground and photo-derived observations and demonstrate the potential for cameras to provide CEMP data. Consequently, breeding success and breeding chronology data derived from some deployments of time-lapse cameras have already been submitted to the CEMP database. The CEMP camera project expects data from all cameras to be available following the 2016/17 field season.

Predator consumption

2.150 WG-EMM-16/37 estimated macaroni penguin (*Eudyptes chrysolophus*) prey consumption in terms of krill and fish mass in Subarea 48.3. A bioenergetics model developed in WG-EMM-16/P10 for Adélie penguins was applied to monitored colonies on Bird Island and extrapolated across the estimated South Georgia population. The resulting estimates of krill consumption per capita were comparable to estimates from other published studies. The authors proposed that the modelling framework for predator consumption developed in WG-EMM-16/P10 could provide a common basis for understanding prey consumption by penguins across CEMP sites and species. The authors noted that the results represented preliminary estimates, and that these would continue to be revised.

2.151 WG-EMM-16/65 presented a bioenergetics-derived estimate of krill consumption by Adélie penguins in Divisions 58.4.1 and 58.4.2. The authors estimated contemporary population sizes from older survey data and forward-projecting estimated regional rates of change. Contemporary population estimates across the divisions were approximately 5.8 million and included estimates of pre-breeding and intermittent breeding penguins. The estimated breeding population of 2.9 million individuals consumed approximately 195 000 tonnes of krill in a breeding season. Acknowledging the difficulties in estimating consumption of non-breeders, the authors finished by highlighting this study as the first Adélie penguin krill consumption estimate at CCAMLR-relevant spatial scales.

2.152 The Working Group noted that the paper provided a good example of methods to estimate population sizes of non-breeding, as well as breeding, penguins and concomitant levels of krill consumption by these demographics.

2.153 WG-EMM-16/66 presented crabeater seal (*Lobodon carcinophagus*) krill consumption rates for 1999/2000 in Divisions 58.4.1 and 58.4.2. Population estimates are based on the Antarctic pack-ice seal (APIS) survey conducted over the 1999/2000 season, and the authors utilised the estimated per capita consumption rates provided by Forcada et al., 2009 and 2012. During the period of the study, crabeater seals were estimated to consume approximately 3.8 million tonnes of krill, approximately 20% of the estimated stock in the region.

2.154 The Working Group noted that surveys of krill during the winter in the Bransfield Strait yielded estimated stocks in the range of 4 to 5 million tonnes, and that, given that crabeater seals were the dominant seal species observed in the region during this time, estimating consumption rates at different spatial scales of this species will be of considerable importance.

2.155 WG-EMM-16/67 provided a synopsis of work currently underway aiming to estimate spatio–temporal foraging effort of flying seabirds in Divisions 58.4.1 and 58.4.2. The focus is on four species, southern fulmar (*Fulmarus glacialoides*), Antarctic petrel, Cape petrel (*Daption capense*) and snow petrel (*Pagodroma nivea*). The paper outlined plans to generate a database of population demographic data from historical and unpublished data sources, and to conduct a large-scale survey of snow petrels in the future. Further work is to be conducted on the bioenergetics model in WG-EMM-16/P10 to make it appropriate for application to flying seabirds. The authors outlined the methodology involved in telemetry tracking these four species during the 2014/15 seasons and in the winter. Preliminary results show that Cape petrels forage at distances of up to 970 km from their breeding sites.

2.156 The Working Group highlighted the general absence of data on flying seabirds in the considerations of the Working Group and noted that this paper represented a good start to bringing the data into this group.

2.157 WG-EMM-16/68 summarised WG-EMM-16/37, 16/65, 16/66 and 16/67. The authors highlighted that estimates of consumption of krill by whales, squid and fish are currently not addressed within the WG-EMM-STAPP framework. Furthermore, the authors highlighted that estimation of consumption is currently restricted to the breeding period for each taxa.

2.158 The Working Group welcomed the substantial progress made by WG-EMM-STAPP, given the magnitude of effort required for data collation and analysis. The Working Group further commented on the need to link these efforts with groups focusing on krill predator tracking data, such as SCAR RAATD and the penguin habitat modelling project, funded by the CEMP Fund, in order to more fully resolve areas of high predation pressure or foraging intensity.

2.159 WG-EMM-16/P10 outlined the derivation of the bioenergetics model for Adélie penguins that is referred to in WG-EMM-16/37, 16/65, 16/67 and 16/68. The paper is primarily methodological, and the model is parameterised by data from long-term monitoring of Adélie penguin colonies at Béchervaise Island in East Antarctica. The modelling results identify clear peaks in periods of krill consumption throughout the penguin breeding cycle, particularly during incubation and the pre-moult periods.

Predator trends and dynamics

2.160 WG-EMM-16/P07 described the population trends and breeding performance of Adélie and gentoo penguins on Petermann Island; a site that is the focus of frequent tourist visits. The Working Group recognised that the study presents an analytical and experimental framework for disentangling drivers of breeding success that could be replicated across sites to examine drivers of change at regional scales. The finding that breeding success was reduced by precipitation was also discussed, with the Working Group noting that climatic change is likely to exacerbate variation in breeding success.

2.161 WG-EMM-16/P08 described an online tool for accessing penguin count data known as Mapping Application for Penguin Populations and Projected Dynamics (MAPPPD). This comprises a database populated with penguin count data, presence–absence data for 16 species of Antarctic seabird, and a model that predicts habitat distribution across the region based on previous occurrence and habitat variables. For Adélie penguins, missing values are imputed using a hierarchical Bayesian model which can also be used to generate forecasted counts, with uncertainty. There are plans to develop these models for other penguin species.

2.162 The Working Group noted that this useful tool was the result of considerable effort by the authors and the wider penguin research community. The Working Group noted that the online application is intuitive and looked forward to continued development and improvement. Finally, the Working Group noted that raw data can be extracted from the database to allow scientists to fit population models specific to their own requirements.

2.163 The Working Group also noted that it would be useful to establish mechanisms to access the results of those analyses and any datasets that would be helpful to CCAMLR (paragraph 6.14). This would best be achieved through links with the Secretariat data management facilities. The Working Group recommended that such links to datasets be made using metadata records, which would include commentaries from working groups on those datasets so that Members understand how they may best be used for CCAMLR work, including any reviews and validation analyses.

2.164 If the model is to be used for management advice, then the Working Group recommended that the model and analyses presented in WG-EMM-16/P08 be reviewed by WG-SAM.

2.165 WG-EMM-16/P09 described the population trends and diets of Antarctic shags (*Phalacrocorax bransfieldensis*) at two sites in the South Shetland Islands from 1988 to 2010 and at two sites along the Danco Coast during the 1997/98 austral summer. The authors concluded that declines in marbled rockcod (*Notothenia rossii*) and humped rockcod (*Gobionotothen gibberifrons*) due to fisheries are responsible for the declines in shag numbers at the South Shetland Islands colonies.

2.166 The Working Group welcomed this analysis of piscivorous species, noting that WG-EMM has historically considered primarily krill-dependent predators.

2.167 WG-EMM-16/P13 described the effects of snow storms on the stage-dependent nest survival and productivity of Antarctic petrels in Dronning Maud Land. The Working Group recognised that this is a valuable study of storm effects on a little-studied species. The Working Group noted that analyses of CEMP data may benefit from inclusion of weather effects (paragraph 2.136) as explanatory variables, since these may obscure effects of variation in food availability. Dr A. Lowther (Norway) noted that the monitoring project has now ended and there are no plans at present to continue the study.

2.168 WG-EMM-16/P14 assessed the effects of large-scale climate variables on the demography of Antarctic petrels in Dronning Maud Land from 1992 to 2012. The Working Group noted that this is an interesting paper that provides valuable and robust information on the demography of a krill-eating petrel species in relation to climatic processes.

Krill integrated assessment model

2.169 WG-SAM-16/36 Rev. 1 described recent developments towards an integrated stock assessment for krill in Subarea 48.1. The model was fitted to time series of survey biomass indices and length-composition data from research surveys as well as to catches and length compositions from the krill fishery. A simulated population with parameters estimated from these data was projected 20 years into the future under various candidate levels of catch.

2.170 WG-SAM-16 (Annex 5, paragraphs 2.1 to 2.6) noted that, in its present implementation, too many parameters are being estimated. The parameter estimates are confounded and are likely to be unstable, particularly as new data are added. It was recommended that retrospective analyses and fits to simulated data be conducted to explore the properties of the estimated parameters. Plotting the marginal likelihoods of parameters that are likely to be confounded would also help identify which parameters are estimable from the available data and clarify model performance. The Working Group further noted that model stability might be enhanced by treating fishery catches as known, rather than estimated, quantities.

2.171 The model had been reviewed by two independent referees whose findings largely paralleled those previously made by the three working groups and which were summarised in WG-SAM-16/37. WG-SAM therefore noted that additional work is required to systematically document how all past recommendations made by WG-SAM, WG-FSA, WG-EMM and the independent review have been considered and either used to revise the model or suitably rebutted. The model should not presently be used to provide management advice on setting krill catch limits.

Acoustic surveys

2.172 WG-EMM-16/23 presented the use of the random forest statistical method to classify mackerel icefish (*Champsocephalus gunnari*) and Antarctic krill echoes from 38 and 120 kHz acoustic data collected during fish and krill surveys. It identified that for commonly used frequencies, the acoustic signal from krill and from co-occurring fish without swim bladders may be similar. The random forest analysis classified krill, icefish and mixed aggregations with an estimated accuracy of 95%. In addition to the difference between the dual frequency acoustic data ($S_{v120\text{-}38kHz}$), min S_v, mean aggregation depth, mean distance from seabed and geographic position were important classifiers.

2.173 The Working Group noted that CCAMLR is currently using a three-frequency (38/120/200 kHz) method to identify krill as outlined in SG-ASAM-16 (Annex 4). The Working Group noted that for vessels having only two frequencies (38/120 kHz), using the supplementary information such as described in WG-EMM-16/23 may enable them to better identify krill from other scatterers. The Working Group further noted such approaches may provide estimates of relative biomass, but the method still needed further validation before it can be used in absolute abundance estimation.

2.174 The Working Group agreed that it was important to identify an approach for better identifying and estimating krill from acoustic data, highlighting that technological development in both hardware platforms and software analysis methods means that there are now several tools available for better identification of Antarctic krill.

2.175 The Working Group recommended this paper be forwarded to SG-ASAM, and that SG-ASAM discuss different ways of improving the identification of Antarctic krill in acoustic data in light of the current and future technology available on krill fishing vessels.

2.176 The Working Group noted that the current method for estimating stocks of mackerel icefish at South Georgia uses a groundfish survey (Annex 5, paragraph 4.66). It also noted that methods for identifying icefish within acoustic data are important for addressing the currently unsampled component of juvenile icefish that reside in the pelagic realm, as well as for investigating the known but unobserved predator–prey interactions between icefish and krill (SC-CAMLR-XX, Annex 5, Appendix D).

2.177 Dr Kasatkina noted that the possibility for classification of krill and icefish echoes could facilitate the acoustic estimation of the pelagic component of icefish biomass unavailable to fishing with a bottom trawl survey. Combining acoustic and trawl survey data should improve estimates of the standing stock for *C. gunnari*. She recalled that the Russian trawl acoustic survey in 2002 revealed that a bottom trawl survey significantly underestimates *C. gunnari* biomass (WG-FSA-02/44; WG-FSA-SAM-04/10).

2.178 WG-EMM-16/36 presented an overview of the Southern Ocean Network of Acoustics (SONA) 'Acoustic processing and methods' workshop that was attended by six international (Australia, France, New Zealand, Norway, UK and USA) partners. SONA identified a number of national programs that aim to appropriately steward and facilitate access to bioacoustic datasets, using standardised internationally recognised metadata standards. The SONA workshop aimed to assess how comparable these datasets and their processing were, and identified that these types of regional datasets are likely to provide a framework for global coverage. A comparison of Australian, New Zealand and UK data showed that, where processing was undertaken using the same program and similar templates, resultant acoustic data were comparable (in both intensity and variability), but there were still subtle differences based on user decisions.

2.179 The Working Group identified that SONA had provided a good vehicle for coordinated analysis, pertinent to using acoustic data from multiple fishing vessels, and taken the first steps towards where acoustic data and processing protocols should develop to. It thanked Dr Fielding and the SONA participants for starting the process and sharing this with CCAMLR.

2.180 The Working Group noted that reinforcing the benefit of the work of the group and identifying opportunities to further collect data were important, particularly in identifying rapid processing and improved design of observations with a view to improving types of data for feedback. The Working Group was made aware of a new emerging EU Horizon 2020 project 'Mesopelagic Southern Ocean Prey and Predators' (MESOPP, www.MESOPP.eu), a collaboration between Australia, France, Norway and the UK, which aims to fuse acoustic data with models. MESOPP will encourage wider participation, and SONA will be an important data provider to this project.

2.181 The Working Group recognised that SONA was an active outward-facing network that was open to discussion with new collaborators.

2.182 WG-EMM-16/38 summarised the acoustic data collection and processing methods used to calculate the 2010 B_0 estimate, and identified where changes were made compared with previous estimates. In particular, Table 1 in the paper detailed the original method implemented in 2000, and the changes made in order to make the 2010 estimate. It highlighted that the main changes made were in the areas of the target strength model used to convert acoustic backscatter to krill biomass and target identification.

2.183 The Working Group noted that the method used to estimate krill biomass using the CCAMLR method had been the subject of confusion last year (SC-CAMLR-XXXIV, Annex 6) and commended the efforts of Dr Fielding and her co-authors in collating documentation to resolve this issue. The Working Group identified that this paper should enable all Members to analyse acoustic data for krill density estimates in a consistent manner in order to get comparable numbers across current and future surveys.

2.184 The Working Group requested CCAMLR Members to review the document to confirm that it adequately describes the method used in 2010, and identify or clarify any ambiguities. The Working Group recommended this document be reviewed by SG-ASAM at its next meeting, and its corrected form be included in the meeting report and made available on the CCAMLR website.

2.185 The Working Group noted that WG-EMM-16/38 provided important information to improve acoustic surveys for estimating krill density and biomass, and this document will be useful when deriving krill density estimates from acoustic observations made on board commercial vessels.

2.186 The Working Group noted that there would continue to be developments to the methods used to estimate krill density in acoustic data and recommended that, in order to allow for these, a living document of the most up-to-date method should be hosted by the Secretariat following agreement at SG-ASAM.

2.187 WG-EMM-16/60 presented an estimate of krill biomass from the South Shetland Islands in April 2016 conducted by the Korean fishing vessel *Kwangja-Ho*. Two-frequency (38 and 120 kHz) acoustic data were collected along transects using an EK60 echosounder and net samples were collected using a midwater trawl (15 mm codend mesh size of inner net). Antarctic krill were identified using a two-frequency identification ($S_{v120-38kHz}$) estimated from a distribution of dB differences and converted to krill biomass using an empirically derived log-linear relationship.

2.188 The Working Group noted that the inclusion of flow diagrams of the method used to estimate krill (WG-EMM-16/60, Figure 2) was advantageous in highlighting the methodology used to estimate krill and potential areas for processing variability. It encouraged other Members to include such diagrams in presenting their analyses.

2.189 The Working Group noted that these were preliminary results and identified that the method used to estimate krill in WG-EMM-16/60 and the CCAMLR 2010 method were different, and how they varied should be examined. Dr J. Lee (Republic of Korea) identified Korea's intention to submit survey results using the CCAMLR 2010 protocol for discussion at the next SG-ASAM meeting.

2.190 WG-EMM welcomed the submission of krill survey information derived from an industry vessel in support of management, and highlighted that it was a significant event to be discussing fishery-collected acoustic data from several fishing nations at WG-EMM.

2.191 WG-EMM recommended that the geographic distribution of net samples within a survey area, what type of net samples (targeted or oblique) and how many net samples are required to provide a relevant krill length-frequency distribution to parameterise the krill density estimates from acoustic surveys, should be discussed at the next SG-ASAM meeting.

2.192 The Working Group noted the concordance in krill length-frequency distribution described from the midwater trawls in WG-EMM-16/60 and predator diet data that AMLR had collected during 2015/16, and highlighted the benefit of receiving additional data from the South Shetland Islands region during an alternative season to the US AMLR survey.

2.193 WG-EMM-16/61 presented the use of seabed data to calibrate an ES70 fisheries echosounder and addressed a request by SG-ASAM to investigate alternative methods to calibrate fishery echosounders. The *Kwangja-Ho* was used to collect both ES70 and calibrated EK60 acoustic data along two transects. Data from the seabed at water depths shallower than 300 m were used to apply a correction to the ES70 data. After correction, the ES70 identified more targets as krill using the dual-frequency identification method.

2.194 The Working Group agreed that comparison of EK60 and ES70 data from a single vessel over a common transect presented in WG-EMM-16/61 is an exemplar method to estimate the errors associated with utilising seabed acoustic returns for system calibration. It recommended SG-ASAM discuss this paper at its next meeting.

2.195 WG-EMM-16/P12 described a geostatistical approach to estimate the distribution, density and relative abundance of krill using acoustic data collected during commercial fishing operations. The approach was selected to account for the lack of sampling design and likely correlation in time and space, and generated estimates of the probability of presence, conditional density and relative abundance estimates on a monthly, weekly and daily basis. Monthly and weekly estimates were robust, but lower and more variable estimates were obtained from daily datasets. The authors were not able to evaluate potential bias due to preferential sampling of high-density krill aggregations and limited area coverage, and identified that this method would be enhanced by implementing a minimum quota of mandatory design-based coverage of fishing grounds and the ability to combine acoustic data from all vessels operating in a single area.

2.196 WG-EMM-16/74 identified that whilst pre-determined survey design supports stock abundance information, a geostatistical analysis of fishing acoustic data might inform about patterns in the ecosystem of importance to FBM. WG-EMM-16/74 proposed combining these approaches and presented a feeding opportunity index (FOI) that includes the relative abundance of krill, concentration of krill (patchiness) and flux of krill that could be expressed in a multiple linear regression. This FOI is assumed to be positively linked to the relative abundance of krill, flux of krill and concentration of krill.

2.197 The Working Group noted that the geostatistical method (WG-EMM-16/P12) could enable an estimate of relative krill abundance to be calculated for areas that are fished but not surveyed and, combined with a pre-determined survey for absolute krill biomass, these estimates of relative krill abundance could be placed in a wider context pertinent to FBM. It noted the following with respect to further development of the method:

(i) this technique may also enable temporal or spatial changes in patchiness characteristics and relative krill abundance to be detected as the fishery progressed. The Working Group commended the approach of endeavouring to simplify the complexity of fishing operations into informed metrics

(ii) in some cases, the fishing vessel appeared to be fishing on low abundances and identified that caution was required in interpreting krill density values at the boundaries of the geospatial analysis. Dr Godø reminded the group that vessels target krill swarms and this behaviour would influence the relative krill abundance derived from the data

(iii) this approach, when combined with CPUE, may add value to the interpretation of the data and also identify that an adaptive survey design, for example over regions of gradients in krill density, would further constrain the relative index

(iv) sensitivity analyses may be useful to help determine the optimal strategy for the commercial vessel to map swarm characteristics using this method.

2.198 WG-SAM-16/38 presented information on survey design and results of the dedicated cetacean sighting vessel-based krill (CSVK) survey by Japan in East Antarctica (115°−130°E) conducted during the 2015/16 austral summer season. Acoustic data were collected along a zig-zag stratified survey, designed for obtaining systematic sighting data for whale abundance. A small vertically hauled net (1 m mouth diameter) was used to collect qualitative information on species occurring in the echograms. The authors aim to estimate relative krill abundance from the annual CSVK surveys (carried out for 12 years) and undertake additional surveys with a design compatible with CCAMLR survey protocols to obtain an index of absolute krill abundance at a lower frequency.

2.199 The Working Group noted that WG-SAM-16/38 had been discussed at WG-SAM (Annex 5, paragraphs 2.7 to 2.10) and that the design of the survey in relation to estimating abundance of whales is a matter for the IWC SC. In relation to krill, it also noted that the zig-zag survey design was not the recommended random stratified design utilised to estimate absolute krill density, but acknowledged that the CSVK survey's primary aim was obtaining abundance estimates of cetaceans under the IWC standard zig-zag track line with the secondary objective of obtaining relative krill abundance.

2.200 The Working Group agreed that the statistical properties of krill acoustic data collected using a survey designed for another purpose (e.g. the IWC standard zig-zag track line) should be examined prior to their use so that their suitability for application to other studies can be assessed. The Working Group also noted that autocorrelation would be an important issue to resolve during analysis of krill acoustic data using a zig-zag survey design.

Feedback management

Stage 1

Background material considered by the Working Group

2.201 The Working Group recalled its obligation to review and advise on CM 51-07, which is due to lapse at the end of the 2015/16 fishing season. Members submitted several papers on topics of relevance to the review of CM 51-07. These are summarised here, in an order that is intended to facilitate review of CM 51-07:

(i) paragraphs 2.202 to 2.214 summarise the Working Group's work to assess whether exploitation rates of krill are precautionary at the subarea scale

(ii) paragraphs 2.215 to 2.221 summarise discussions on recent spatial concentration of krill fishing effort

(iii) paragraphs 2.222 to 2.227 summarise work to describe the physical and ecological conditions in areas where krill fishing effort has concentrated

(iv) paragraphs 2.228 to 2.244 summarise consideration of methods that can be used to evaluate the risks associated with changing the spatial distribution of krill fishing effort and catches in the future.

Subarea-scale exploitation rates

2.202 Dr Hill presented results from WG-EMM-16/21, which provides estimates of potential, annual, subarea-scale krill exploitation rates (estimated as catch/biomass ratios). The calculations use conservative estimates of subarea biomass calculated as annual biomass estimates from local area acoustic surveys, scaled by the relevant estimate of subarea biomass from the CCAMLR-2000 Survey. Exploitation rates of 9.3% and 12.4% are used as the basis for the precautionary evaluation. The former rate was estimated from application of the GYM and decision rules for krill using the total biomass estimate from the CCAMLR-2000 Survey (SC-CAMLR-XXIX, Annex 6). The latter exploitation rate would be expected if the precautionary catch limit for krill (5.61 million tonnes) is divided by 75% of the total biomass estimate from the CCAMLR-2000 Survey (60.3 million tonnes). Catching the entire trigger level in a single subarea was estimated to cause subarea exploitation rates to exceed the range of precautionary reference levels 47% of the time. The subarea catch limits defined in CM 51-07 reduce this probability to 0.09. Improved comparisons of krill biomass at the local survey and subarea scales would further improve the accuracy of exploitation rate estimates.

2.203 The Working Group agreed to review and repeat the calculations described in WG-EMM-16/21 during the meeting for the purposes of reviewing CM 51-07. It noted that the calculations in WG-EMM-16/21 can provide an initial risk analysis that indicates how often, and to what degree, the subarea catch limits in CM 51-07 might cause reference exploitation rates such as 9.3% and 12.4% to be exceeded due to natural variations in krill biomass recorded by the local area acoustic surveys. The calculations can also be easily extended to consider alternative proposals for subarea catch limits, such as might be proposed in a revision to CM 51-07.

2.204 Results from repeating the calculations in WG-EMM-16/21 are illustrated in Figures 1 and 2. These results indicate that if the fishery continues to achieve the catch limits established in CM 51-07 and the trigger limit in CM 51-01 continues to be fixed, the precautionary exploitation rate of 9.3% agreed by CCAMLR might be exceeded in one out of every five years within Subarea 48.1 (Figure 1). The precautionary exploitation rate of 9.3% might be exceeded less frequently in Subareas 48.2 and 48.3. Figure 2 shows how the exploitation rate in Subarea 48.1 may exceed the precautionary rate of 9.3%.

2.205 The results illustrated in Figures 1 and 2 also indicate that both the frequency of exceeding the precautionary exploitation rate and the average catch that exceeds 9.3% of the estimated biomass will increase if the proportional allocation of the trigger limit to Subarea 48.1 is increased in any proposed future revisions to CM 51-07.

2.206 Dr Kasatkina noted that exploitation rates estimated for krill in Subareas 48.1, 48.2, and 48.3 were estimated inappropriately. Catch and acoustically based estimates of krill biomass were obtained over different temporal scales. In each subarea, the surveys are carried out only during a brief period and not throughout the fishing season, but krill biomass in the survey area would be significantly changed by flux over the fishing season.

2.207 Dr Kasatkina underlined that considering the question ‘whether current management of the Antarctic krill fishery in the Atlantic sector is precautionary’ requires an understanding of krill consumption by overall predators and status of overlapping between predators and fishery. She recalled, as an example, in the South Georgia area it is evident that the mean krill consumption by predators, is an estimated 900 000 tonnes per month (11.2 million tonnes per year) (Boyd, 2002). This consumption is extremely large in comparison with the maximum monthly krill catch.

2.208 Although participants agreed that it is important to understand overall krill consumption by predators, it was noted that the reference exploitation rates of 9.3% and 12.4% considered in WG-EMM-16/21 and used to recalculate the results presented in Figures 1 and 2 already take account of predator demand.

2.209 The authors of WG-EMM-16/21 also emphasised that the assumptions made to estimate potential, annual, subarea-scale krill exploitation rates were precautionary. The analysis used available data as far as possible and can be refined as new information becomes available.

2.210 Dr Milinevskyi summarised WG-EMM-16/56, which is a proposal to revise CM 51-07. Specifically, Ukraine proposed that the percentage of the trigger limit allocated to Subarea 48.1 should be increased from 25% to 45% and accompanied with a prohibition of krill fishing within 3 n miles of the coast from 1 November to 1 March every fishing season.

The former revision is intended to allow for further development of the krill fishery, and the latter is intended to protect land-based predators during the breeding season. Dr Milinevskyi indicated that increasing the percentage allocation to Subarea 48.1, while prohibiting krill fishing in a coastal buffer zone, should be viewed as a trade-off.

2.211 The Working Group noted that no scientific evidence had been provided to support the proposal in WG-EMM-16/56, including whether an increase in the catch in Subarea 48.1 would impact on predators, and resolving trade-offs such as that suggested in the paper is the remit of the Commission.

2.212 Many participants noted that increasing the percentage of the trigger limit allocated to Subarea 48.1 would increase the risk that a precautionary exploitation rate would be exceeded in Subarea 48.1 (Figure 2).

2.213 Other participants noted that increasing the percentage of the trigger limit distribution for Subarea 48.1 can be implemented because, in recent years, the total krill catch has not exceeded 50% of the trigger limit. These participants also noted that the krill stock has not been impacted by historical fishing, and that there are no clear negative impacts to krill predators or other components of the Antarctic marine ecosystem.

2.214 The Working Group did not attempt to evaluate the potential consequences of prohibiting krill fishing within 3 n miles of the coast, but some participants noted that such a buffer zone might negatively impact on the performance of the fishery. The Working Group referred the proposal to the Commission, noting it has already been submitted for consideration by the Scientific Committee.

Concentration of fishing effort

2.215 Dr Trathan summarised WG-EMM-16/17, which explored krill catches and fishing effort for the period 1999/2000 to 2014/15. The paper documented how, since 2013, both the levels of catch as well as the associated numbers of hauls have increased in Subarea 48.1 during the penguin breeding season. WG-EMM-16/17 also explored the detailed fishing patterns in Subarea 48.1 during 2014/15, showing that concentrated fishing took place in two areas, one in the Bransfield Strait and one in Hughes Bay on the Danco coast. The latter concentration took place over 153 days from 27 December until 28 May. Four vessels operated over this period, collectively taking over 42 000 tonnes of krill from an area less than 30 km in diameter; this equates to approximately 27% of the catch limit established in CM 51-07. The fishing concentration comprised three periods of harvesting; catch rates showed evidence of decline at the end of the first two periods, but were increasing at the end of the third period, when Subarea 48.1 was closed because the subarea trigger allocation had been reached.

2.216 The Working Group noted that although the total catch in Hughes Bay during 2014/15 comprised 27% of the catch limit for Subarea 48.1, it is uncertain whether any ecological impact to krill-dependent predators ensued, as data collected at the nearest CEMP site, 13 km away in Cierva Cove, have yet to be analysed in full.

2.217 The Working Group considered WG-EMM-16/52, which presented a novel analysis to identify fishing grounds using a statistical analysis of fishing hotspots, combined with a temporal analysis, to assess persistence of these hotspots. Results indicated that the fishery is consistently concentrating in hotspots across years, particularly during those years when the catch limit is reached. These events occur mainly in the centre of the Bransfield Strait and the northern section of the Gerlache Strait, and have a duration of 3 to 5 months. In years when catch limits were reached, the identified hotspots were generally small (approximate radius 25 km), and have a high catch density (>10 tonnes km^{-2}). The analysis showed that the krill fishing fleet repeatedly visits such fishing grounds year after year, where they obtain high catches, suggesting that catch density within hotspots can index krill biomass in a given area.

2.218 The Working Group agreed that results from WG-EMM-16/17 and 16/52 demonstrate that krill fishing activity is not randomly distributed with respect to the spatial distribution of krill itself. The spatial distribution of recent fishing activity is also different from patterns found in the past, with an increased emphasis on fishing in the Bransfield and Gerlache Straits, but there is no evidence that the distribution of krill itself has changed. It was suggested that fishing activities have become more concentrated partly because of improved technologies that allow for more efficient searching and better communication among vessels. Modern fishing vessels can now locate krill more quickly and from farther away and are also more likely to recognise that other vessels are successfully fishing.

2.219 There continues to be substantial uncertainty about why krill fishing vessels choose to operate where they do when other locations have previously supported viable fishing. It is not clear why, for example, the fishery no longer focuses operations around Elephant Island, which was a historically important fishing ground where comparable catch rates were achieved and significant biomass of krill still occurs. The Working Group noted that an improved understanding about fishing patterns might be inferred from analyses of haul-by-haul and vessel monitoring system (VMS) data and urged Members to undertake such work if possible.

2.220 Concentrated fishing in predictable locations or hotspots motivates consideration of the potential for local depletion. The Working Group noted that there were few data available that addressed the question of local depletion in fishing hotspots. It was recognised that the level of krill flux through such hotspots would determine whether, and to what degree, local depletion in fishing hotspots might occur.

2.221 The Working Group also noted that WG-EMM-16/74 and 16/P12 suggested that acoustics data collected by fishing vessels could be used to estimate temporal changes in available biomass within hotspots. Such estimates might be used as a tool to avoid local depletion.

Physical and ecological conditions in areas where krill fishing effort has concentrated

2.222 Dr Watters drew from results provided in WG-EMM-16/45 to present four issues of specific relevance to discussions on CM 51-07. Several short papers, or vignettes, are compiled within WG-EMM-16/45, and, in discussions relevant to CM 51-07, Dr Watters primarily referred to vignettes 2, 5, 7 and 8 (other vignettes in WG-EMM-16/45 provide results that are relevant to the development of a stage 2 FBM strategy in Subarea 48.1):

(i) The authors of WG-EMM-16/45, vignette 2, examined the influence of oceanic and shelf circulation on the distribution of krill biomass and fishery catch and effort in Subarea 48.1 to better understand how retention and concentration mechanisms aggregate krill in fishable quantities above the background concentration. A circulation model and particle tracking were used to show that areas with high catches also tend to be areas of retention and are generally separated from the prevailing circulation. In addition, indices of krill abundance observed in the Palmer LTER study area (which is generally considered to be upstream from the fishing grounds in Subarea 48.1) were correlated with those in the US AMLR study area (which overlaps the fishing grounds in Subarea 48.1), suggesting that local depletion within retentive areas where fishing is concentrated may not be alleviated by flux on short time scales.

(ii) The authors of WG-EMM-16/45, vignette 5, examined the overlap of krill catches and predator foraging distributions using data from a large, long-term telemetry dataset on multiple species of seabirds and marine mammals during the austral summer and winter. Direct overlap, on small spatio–temporal scales, of krill-dependent predators and the krill fishery was observed to be common throughout the Antarctic Peninsula region. Overlap was prominent in local areas where krill were retained and fishing was concentrated. The authors argued that such overlap highlights the potential for competitive interactions between predators and the krill fishery and underscores the goal of the Commission to prevent localised concentration of fishing effort.

(iii) The authors of WG-EMM-16/45, vignette 7, quantified functional relationships between penguin performance and both local krill biomass and local harvest rates of krill. These functional relationships empirically demonstrate reduced penguin performance in the Antarctic Peninsula region when local krill biomass is low or when local krill catches are high relative to local biomass. The results further demonstrate that krill fishing in Subarea 48.1 may have already had negative impacts on penguin performance.

(iv) The authors of WG-EMM-16/45, vignette 8, outlined three alternatives for allocating the catch limit for krill in Subarea 48.1 among four groups of SSMUs (gSSMUs, see also paragraph 2.255). In general, alternatives that allocate a greater proportion of the catch limit to coastal SSMUs are considered to increase risks to krill-dependent predators, while those that allocate a greater proportion to the pelagic SSMUs will likely increase risks to the krill fishery.

2.223 The Working Group discussed the analyses and results summarised in WG-EMM-16/45. In response to questions, it was clarified that:

(i) local biomasses and local exploitation rates of krill were both relatively high in two out of the four periods and locations in which reduced penguin performance was observed (during summer 2009/10 in the Bransfield Strait SSMUs and during winter 2013/14 in the same SSMUs), suggesting that the estimated relationship between local harvest rate and penguin performance was not simply tracking changes in local biomass

(ii) the estimated relationship between penguin performance and local exploitation rate was not necessarily causal, noting that both causal effects and correlations were plausible

(iii) winter and summer indices of penguin performance were both used to estimate relationships with local biomass and local harvest rates under the assumption that all indices are exchangeable and by ensuring that season-specific performance indices of penguins were matched with season-specific krill indices

(iv) summer indices of predator performance were exactly coincident in time with summer estimates of krill biomass, and winter indices of predator performance lagged winter estimates of krill biomass by about 2 to 3 months

(v) each time series of penguin performance parameters was standardised to have zero mean and unit variance, thus the analysis only considered interannual variations in penguin performance

(vi) results from the analysis of penguin performance were insensitive to whether the winter data were excluded from the analysis

(vii) overlap between foraging locations of Adélie penguins and locations where fishing has occurred has been observed

(viii) assessing overlap on the basis of the joint presence (absence) of predators and fishing activities in a spatio–temporal unit was considered sufficient for the purpose of identifying locations where the risks of fishery effects on foraging krill-dependent predators may occur

(ix) krill behaviour would be expected to increase levels of aggregation in locations where ocean currents and bathymetry already lead to retention.

2.224 The Working Group reviewed the results in the light of the clarifications provided. Some participants suggested that the results of this analysis indicated plausible impacts of localised krill fishing on penguin performance. Other participants considered that the analyses did not support this conclusion. It was suggested that interactive effects be explored to disentangle the relative contributions of, and potential interactions between, fishing activity and krill abundance on measured penguin performance.

2.225 The Working Group noted, however, that continuing the current spatial allocation of the trigger level to Subarea 48.1 (25% in CM 51-07) would offer an opportunity for continued evaluation of the potential impacts to krill-dependent predators of catching nearly 155 000 tonnes per year in the subarea. The Working Group requested that the Scientific Committee highlight this issue to the Commission.

2.226 Dr Kasatkina noted that it is necessary to clarify a temporal scale for considering penguin performance as a function of variation in local krill biomass. Dr Kasatkina emphasised there is no scientifically based evidence that observed negative changes in penguin performance was stipulated by fishing activity, and such changes should also be considered in the context of penguins themselves being prey for some marine mammals. The top–down impacts of predation on penguins will further complicate the potential relationships between penguin state variability and krill fishing.

2.227 Dr Darby noted that the statistical approach used in WG-EMM-16/P07 might provide an alternative way to estimate the possible relationships between local krill biomass or local exploitation rates and penguin performance.

Methods to evaluate the risks associated with changing the spatial distribution of krill fishing

2.228 Dr Demianenko summarised WG-EMM-16/57, which proposed a new indicator, the availability index (AI). The AI integrates the existing information on the availability of a specific marine living resource (e.g. krill) to a fishery. The AI takes account of the difference in days that fishery operations are permitted via conservation measures and prevailing weather conditions as well as the difference in fishing area that is feasible given prevailing sea-ice conditions and what is permitted via conservation measures. A weighted sum of AIs for several small areas, where the weights are proportional to the distribution of the resource among those small areas, can be used to compute AI for a larger area. The authors of the paper noted that AI could be used to examine new management decisions that impact fishing activities.

2.229 The Working Group noted that it was difficult to review the AI because no examples of its application to any assessment and draft management decision were presented in WG-EMM-16/57. The Working Group recommended that, in the future, the authors demonstrate the applicability of the AI and develop it further.

2.230 Dr Constable summarised an approach, outlined in WG-EMM-16/69, which computes relative spatial risks associated with proposals to subdivide the trigger limit, or any other catch limit, among subareas, SSMUs, or other spatial units. The risk assessment integrates data that characterise spatial patterns in the krill stock, predator foraging and fishing operations. Multiple types of spatial data can be used, and each dataset (called 'factors' in the context of the risk analysis) is summarised into a spatially specific index (called a 'quantity' in the risk analysis) whose values range from zero to one (a flexible scaling function is provided in WG-EMM-16/69). For data describing spatial patterns in krill and predators, indices that equal zero indicate spatial units of critical importance, and indices that equal one indicate spatial units where the risks of krill fishing would be of no concern. For data describing spatial patterns in the krill fishery, indices that equal zero indicate spatial units that are of no value to the fishery, and indices that equal one indicate those that are of maximum value to the fishery. All indices are used to calculate the relative risks to krill, predators and the fishery within each spatial unit. To spread the risks across spatial units, all indices specific to each spatial unit are multiplied together and by the density of krill in the spatial unit. These spatially specific 'overall' indices are then divided by the sum of all the overall indices (computed across the spatial units considered in the assessment) to give a proportion of the catch limit, including the trigger limit, to be taken in each spatial unit. WG-EMM-16/69 presented example calculations for the SSMUs in Area 48 using several datasets that have previously been vetted through the Working Group. The results of that work provide support for the existing distribution of the trigger limit in CM 51-07, but the authors of WG-EMM-16/69 acknowledged that Members may wish to revise the calculations using alternative datasets and methods of summarising the data to range from zero to one.

2.231 Dr Demianenko noted that the risk-assessment framework presented in WG-EMM-16/69 is applicable together with other important criteria for making decisions on fishery management in the Convention Area. He mentioned that the risk assessment provides valuable information that can be used to focus research in zones of maximum risk to the Antarctic ecosystem and living marine resources and to prevent negative impacts from concentrated fishing.

2.232 Dr Kasatkina noted that the data describing spatial patterns for krill, predators and the fishery weight used in WG-EMM-16/69 reflect information at different spatial and temporal scales. Therefore, it is necessary to clarify how this fact would impact on the risk-assessment method to distribute the catch for FBM and what approaches would be used to provide adequate management information.

2.233 The Working Group thanked the authors of WG-EMM-16/69 and agreed that results from the risk-assessment approach summarised in the paper can be used to provide advice on CM 51-07 in the current year and on future proposals that envision spatial subdivisions of catch limits (e.g. the stage 2 FBM strategy proposed for Subarea 48.1). In all cases, the inputs and results would need to be satisfactory to the Scientific Committee, including datasets (factors) to be integrated into such risk assessments, the indices to be computed from such data and the parameters used to scale each index so that it ranges between zero and one.

2.234 The Working Group noted that several issues could ultimately be addressed in future applications of the risk assessment, including development and scaling of spatially specific indices that:

(i) appropriately characterise historic, recent and future fishing patterns, including the desirability and suitability of different fishing grounds (as might, for example, be inferred from prevailing weather patterns, sea-ice coverage, oceanographic conditions and bathymetry), given observed changes in the spatial distribution of the fishery and the known habitats of krill

(ii) address flux

(iii) explicitly account for krill consumption by fishes and flying seabirds

(iv) characterise spatial and temporal patterns in fish by-catch within the krill fishery

(v) describe temporal variability in krill biomass or predator performance

(vi) take account of the number of monitoring sites that might detect impacts should they arise

(vii) take account of seasonal (summer and winter) patterns in the spatial distributions of krill, predators and the fishery

(viii) take account of climate change.

2.235 It was acknowledged that not all of the issues outlined in the preceding paragraph can be addressed in the near term; some will need to be addressed over a period of several years. It was also noted that the risk-assessment approach is flexible, and, as new analyses for specific areas become available over time, they can be integrated into the approach.

2.236 The Working Group agreed to progress a set of scenario-based risk assessments across subareas within Area 48, including finer-scaled risk assessments across SSMUs within Subarea 48.1, to investigate potential subdivisions of the trigger limit and manage the risks of krill fishing. Given the time available before the next meeting of the Scientific Committee, it might be necessary to limit the focus of these initial risk assessments to Subarea 48.1; this could be determined by correspondence via the e-group described below. It agreed that the initial risk assessments would be updated, using new data as they become available and are vetted through the Working Group, but that the initial simple set of assessments be conducted as soon as possible, using data already available to CCAMLR.

2.237 An e-group (Conservation Measure 51-07 WG-EMM review) was established to progress the initial risk assessments, with the aim of providing further advice on CM 51-07 to the 2016 meeting of the Scientific Committee. The outcomes of the e-group discussions could provide guidance to Members conducting the initial set of risk assessments, including the priority elements for consideration; recommendations from WG-EMM to the e-group are provided in Appendix D.

2.238 The Working Group also requested that WG-FSA:

(i) review the outcomes of the initial risk assessments according to the requirements set out in paragraph 2.239

(ii) schedule this review to occur late in its meeting so that Members could more efficiently schedule travel to Hobart

(iii) forward the outcomes of the initial risk assessments, accompanied with comments from the review indicated in the preceding point, to the Scientific Committee. The Scientific Committee would then advise the Commission on CM 51-07.

2.239 The Working Group agreed that results from risk assessments intended to advise on the spatial distribution of catch limits should be presented as maps of each index (or scaled quantity) used in the risk assessment; the krill densities or biomass estimates used to calculate the proportional subdivision of the catch limits; and the proportional subdivision of the catch limit to be taken from each spatial unit. The estimates of risk indices and catch-limit proportions should also be provided in a table. These results should be accompanied with clear descriptions of, and justifications for, the factors, quantities and scaling parameters used in the risk assessment.

2.240 Given the importance of reviewing CM 51-07, the Working Group agreed that clear terminology and a concise presentation of results from the initial risk assessments will be critical to improve understanding of the approach and provide advice. The Secretariat was asked to work with Members conducting initial risk assessments to clarify communication of the approach and results.

2.241 The Working Group also agreed that, in the future, risk analyses such as those envisioned for the review of CM 51-07 should be conducted on a regular basis, and the assumptions underlying such risk assessments should be continually reviewed. Future risk analyses would provide the Scientific Committee and Commission with updated perspectives on risk as assumptions change, existing datasets improve, new datasets are vetted and changes in the ecosystem occur. The Working Group recommended that risk assessments should be added to the standing work program of WG-EMM.

2.242 Dr Demianenko noted that, to establish the spatial distribution of catch limits, the risk assessments should be considered together with information on the status of the krill stock and an assessment of the potential impacts of the fishery.

2.243 Dr Kasatkina noted that the current exploitation rates for the krill fishery in Subareas 48.1 to 48.3 were considered by the Working Group in relation to the regional trigger levels. Dr Kasatkina recalled that the trigger level for the krill fishery in Area 48 (620 000 tonnes) corresponds to the value of the maximum historical catch achieved during the 1980s and reflects neither the status of the krill stock and predators in the past nor the current status of the krill stock and predators. She noted that the estimate of unexploited biomass (B_0) and the precautionary catch limit for krill in Area 48 were revised several times using data collected during the CCAMLR-2000 Survey. Dr Kasatkina underlined that the trigger level has remained the same magnitude regardless of updates to the precautionary catch limit for krill in Area 48 from 4 million tonnes (2007) to 5.61 million tonnes (since 2011). Dr Kasatkina noted that there is no scientific-based argument for the trigger level, and it is necessary to clarify reference points for management of the krill fishery in Area 48.

2.244 Dr Darby agreed with Dr Kasatkina in that there was a lag in updating the reference exploitation rates. However, as the Commission had agreed the trigger levels and also that they could be adjusted once an FBM approach had been agreed, there was already a process in place to update catch limits in the future.

Move-on rules for krill fishing vessels

2.245 Drs Godø and Currey suggested that appropriately structured move-on rules could provide an alternative or complement to strategies that aim to manage the risks of concentrated fishing by distributing catch limits in space. They noted that the Commission is already familiar with the concept and application of move-on rules and suggested the types of parameters that would need to be considered to develop such rules.

2.246 The Working Group agreed that move-on rules may be useful for spatially distributing fishing activities to mitigate the risks of concentrated fishing, noting that WG-EMM-16/17 also highlighted how such rules could be used to reduce the risks of concentrated fishing. The Working Group was uncertain whether a single move-on rule could be equitably applied to all vessels operating in the fishery given the range of vessel-specific capacities and fishing strategies in the fleet. It was recommended that Members discuss such issues with representatives from the fishing industry and use the Conservation Measure 51-07 WG-EMM review e-group to discuss and develop ideas. As for the initial risk assessments that are planned to facilitate review of CM 51-07, a paper could be tabled for consideration by WG-FSA.

Advice to the Scientific Committee

2.247 The Working Group agreed that:

(i) the trigger level in CM 51-01 applies to a spatial scale that is larger than the subarea scale

(ii) the trigger level was not established in reference to an assessment of krill biomass or predator consumption

(iii) there are no studies that provide results supporting an increased trigger level

(iv) the entire trigger level (620 000 tonnes) has never been caught in a single fishing season

(v) the staged approach to develop FBM provides the mechanism through which the trigger limit could be revised or eliminated altogether

(vi) the spatial subdivision of the trigger level in CM 51-07 establishes stage 1 catch limits that apply at the subarea scale.

2.248 The Working Group noted that the preambular text of CM 51-07 recognises, inter alia, the needs to:

(i) 'distribute the krill catch in Statistical Area 48 in such a way that predator populations, particularly land-based predators, would not be inadvertently and disproportionately affected by fishing activity', as well as

(ii) 'provide for flexibility in the location of fishing'

and advised that any revisions to the conservation measure should aim to do the same.

2.249 The Working Group recalled its previous discussions on the trigger limit and CM 51-07 and agreed its previous advice still applies (SC-CAMLR-XXXIV, Annex 6, paragraphs 2.136 to 2.138).

2.250 The Working Group encouraged Members to participate in the e-group to progress the risk assessment approach in time for review by WG-FSA and the Scientific Committee in 2016 (Appendix D). It agreed that in the event the risk assessment discussed in paragraphs 2.228 to 2.244 is unable to provide adequate information before the next meeting of the Scientific Committee, the following advice should apply:

(i) at scales greater than, or equal to, the subarea scale, there is no evidence that the trigger limit and catch limits currently established by CM 51-07 have adversely impacted the krill stock

(ii) the subarea catch limits currently established in CM 51-07 achieve the objectives in Article II of the Convention at the subarea scale (SC-CAMLR-XXXIV, Annex 6, paragraph 2.136).

2.251 Many participants agreed that:

(i) at the subarea scale, the risks to achieving the objectives in Article II of the Convention could be managed by maintaining the subarea catch limits currently established in CM 51-07 because:

   (a) conservative extrapolations of biomass estimates from recurring research surveys to subarea scales indicate that precautionary harvest rates might already be exceeded in as many as one out of every five years within Subarea 48.1 and less frequently in Subareas 48.2 and 48.3

(b) precautionary harvest rates in any subarea will be exceeded more frequently than at present if the proportional allocation of the trigger level to that subarea is increased

(ii) at scales smaller than the subarea scale, the risks to achieving the objectives in Article II could also be managed by maintaining the catch limits currently established in CM 51-07 noting that increased concentration above current levels may not be suitable at scales of SSMUs or finer scales, particularly in Subarea 48.1, because

(a) fishing activity has become concentrated into some areas that are smaller than SSMUs and which regularly retain or concentrate krill

(b) penguin performance may be impacted by locally high harvest rates on birds that are known to forage in such areas

(c) the catch limits currently established in CM 51-07 have successfully closed the fishery before such impacts have become obvious and consequential.

2.252 The Working Group also advised the Scientific Committee that a future revision of CM 51-07 should consider how catch limits could be spatially and temporally apportioned within subareas to avoid negative impacts on predator populations at smaller spatial scales, particularly in Subarea 48.1. The risk assessment approach will be developed within an e-group and prepared for review by WG-FSA-16. The Working Group also noted that buffer zones which prohibit fishing within fixed distances of the coast during specific times of the year could be considered as alternative or additional management options.

Stage 1–2 Subarea 48.1

2.253 WG-EMM-16/46, 16/47 and 16/48 described a stage-2 strategy for in-season FBM for the krill fishery in Subarea 48.1, with additional background information also contained in WG-EMM-16/45.

2.254 The papers presented the ecological background for the strategy, the decision rule for adjusting local catch limits and a series of retrospective analyses showing how the approach would work. The strategy is based on a broad foundation of work to answer questions raised by WG-EMM in 2015 (SC-CAMLR-XXXIV, Annex 6, Table 2, and other advice contained in the body of the WG-EMM report).

2.255 The decision rule in the papers is designed to adjust catches in four gSSMUs (1 = APBSW + APBSE; 2 = APDPW + APDPE + APEI; 3 = APPA; and 4 = APW + APE); it has four components:

(i) if penguin recruitment is expected to be sufficient for population maintenance, and CEMP monitoring indicates acceptable predator performance during the current breeding season, and krill biomass has increased during the present summer, the local catch limit would be increased

(ii) if penguin recruitment is expected to be sufficient for population maintenance but CEMP monitoring indicates a poor breeding season, or krill biomass has not increased during the summer, the local catch limit would not be adjusted

(iii) if penguin recruitment is expected to be so poor that the population will decline even if adult survival through the forthcoming winter is very high, the local catch limit would be decreased

(iv) if penguin recruitment is expected to be so poor that the population will decline even if almost all adults survive through the forthcoming winter, the local catch limit would be set to zero.

2.256 In the papers, the implementation of the FBM strategy includes defining a base catch limit for each gSSMU, collecting data on predators and krill, delaying the start of the fishing season until this data collection effort is underway, submitting the data to the Secretariat, increasing the frequency of catch and effort reporting by the fishery, having the Secretariat compute various state variables from the submitted data and applying the decision rule with the state variables relevant to each gSSMU, providing advance notice to fishing vessels about the outcomes of applying the decision rule, and adjusting the catch limit in each gSSMU.

2.257 The Working Group noted that the FBM strategy proposed in the papers also utilises results from fishing vessel acoustic surveys, it permits some fishing to occur prior to the 'adjustment date' so that fishing vessels have sufficient time to conduct repeat acoustic surveys. A timeline for this implementation process is proposed, detailing when particular actions would need to take place. Adjusted catch limits would only apply for a single fishing season and the implementation process would restart every year (Figure 3).

2.258 The papers assessed the impacts of missing data and used historical data to conduct retrospective analyses of the FBM strategy for two gSSMUs. These analyses demonstrated that local catch limits would have been decreased about half the time, and would not have been adjusted or might have been increased the other half of the time.

2.259 The retrospective analyses in the papers suggested that delaying the start of the fishing season but permitting some fishing to occur prior to the adjustment date can be a reasonable compromise between minimising risks to krill-dependent predators and minimising economic risks and opportunity costs for the fishery.

2.260 The authors of the FBM strategy for Subarea 48.1 suggested that it is fully consistent with the agreed definition of a stage-2 strategy, and they advocated that it should be trialled in the field.

2.261 The Working Group thanked the authors of WG-EMM-16/45, 16/46, 16/47 and 16/48 for their comprehensive body of work contributing to the development of FBM stage 2 in Subarea 48.1.

2.262 During subsequent Working Group discussions related to the proposed strategy for Subarea 48.1, the authors clarified a number of points:

(i) Lower base catch limits could have been proposed, with only upward catch increments. However, the choice of higher base catch limits with both upward and downward catch increments was selected as this was considered to be a better compromise between minimising risks to krill-dependent predators and minimising impacts on the fishery; it was also considered that the higher base limits would be more appealing to the fishery. This could incentivise them to participate in collecting the necessary data for the proposed FBM approach.

(ii) Having four gSSMUs, two of which would have a substantial base catch limit, provides more flexibility for the fishery.

(iii) The strategy proposes use of uncalibrated acoustic systems on fishing vessels as this would provide a minimum level of useable information; however, calibrated acoustic systems would help provide a more robust FBM strategy.

(iv) The strategy also utilises predator monitoring data, with some of the parameters based on CEMP or CEMP-like indices.

(v) The parameters used in the proposed FBM strategy can be reliably collected in most years; the remote camera network, recently funded by the CEMP Fund, and the ongoing collection of CEMP data provide a reliable series of input data. Logistic constraints may impact CEMP data collection in some years, but the remote camera network should provide a reliable and continuous data stream. The proposed use of CEMP data should be relatively robust to missing observations; however, the proposal includes defaults for how the decision rule would be applied when different types of data, including CEMP data, were missing.

(vi) Many factors contribute to the ecological status of both krill and penguins, however, the proposed FBM approach uses the age of penguin chicks at crèching, as this provides an early indication about the strength of the current penguin chick cohorts. This proposed leading indicator is based on many years of CEMP monitoring and all three *Pygoscelis* penguin species are used in the approach.

(vii) There are currently no analyses of leading ecological indicators for Antarctic fur seals.

Stage 1–2 Subarea 48.2

2.263 WG-EMM-16/18 reviewed the state of ecological knowledge for Subarea 48.2 and suggested that the development of any new management approach based on ecological indicators is limited by the current level of relevant ecological information. The authors proposed that there is an urgent need to improve the ecological knowledge base, but identified that this will take time. They concluded that, if the krill fishery in Subarea 48.2 is to expand beyond its current level, a new experimental approach must be developed that will help provide the ecological and management information needed by CCAMLR. WG-EMM-16/18 outlined one possible framework that has the potential to provide the types of information required. The proposed framework identifies some of the main data requirements, including oceanographic modelling, predator monitoring and fisheries acoustics. The authors proposed that the experimental framework should be evaluated periodically in order to explore initial results and to determine if the framework should be continued.

2.264 WG-EMM-16/18 noted that the proposed experimental framework might not be feasible, either because of: a lack of engagement by sufficient Members; the cost of implementing the necessary framework; or that the framework will take too long to provide appropriate management information. However, other management approaches may still be feasible for distributing effort, including (i) coastal buffers closed to fishing, (ii) closed areas during critical ecological time periods, or (iii) harvesting limits and move-on rules. However, such approaches would also require evidence that they would still achieve the objectives and an appropriate evaluation of the risks, including the risk of displacing problems elsewhere. The paper noted that the preferred option, therefore, remains an objective experimental framework that enhances science and provides evidence-based management for the future.

2.265 The Working Group recalled its discussion last year (SC-CAMLR-XXXIV, Annex 6, paragraphs 2.111 to 2.120 and 2.130 to 2.132) on this proposed FBM approach for Subarea 48.2. It noted that:

(i) acoustics surveys would be fundamental to the proposed experimental framework. It also noted that obtaining a time series of CEMP data would take some time

(ii) the distribution and abundance of predators, particularly in the western area, will be useful, as this is the current hotspot for the fishery

(iii) limitations of field data may not necessarily be an impediment to evaluate this approach. Simulations using ocean and food-web models could be used to do this evaluation within a management strategy evaluation (MSE) framework

(iv) utilisation of the region by predators from other areas will be useful to consider

(v) the establishment of the baseline data will need to be contributed to by many Members.

2.266 Dr Kasatkina noted that the framework would also require investigation of the prey–predator relationship for understanding how seals and other mammals might affect the foraging success and population state of penguins determined by authors as reference consumers of krill for developing FBM in Subarea 48.2.

2.267 The Working Group requested the Scientific Committee to consider how resources could be committed to the experimental framework in Subarea 48.2 and to develop baseline data in the subarea.

Stage 1–2 General recommendations

2.268 The Working Group noted that the proposed FBM approaches for both Subarea 48.1 and Subarea 48.2 require acoustic information from krill fishing vessels, in particular, results from acoustic surveys and estimates of relative or absolute krill stock biomass (paragraph 2.40).

2.269 The Working Group agreed that processing and analysing acoustic data so that they provide useful information was vital. It recognised that delivering these analyses required the assistance and advice of SG-ASAM. It noted that SG-ASAM has been considering the need to derive indices of krill stock biomass from fishing vessel acoustic data for some time, and agreed that this remains a very high priority.

2.270 WG-EMM agreed that to further the staged approach to FBM, it requires help and advice from SG-ASAM on:

(i) defining the spatial and temporal aspects of fishing vessel acoustic transects needed for FBM, including the location, number and frequency of transects within Subareas 48.1 and 48.2

(ii) determining the system performance and processing of acoustic data from vessels (both commercial and research) to ensure that FBM is working with the highest-quality data available.

2.271 The Working Group recognised that implementing FBM may require calibrated data to be delivered by fishing vessels at the same interval as catch reporting to CCAMLR. These data will be used for calculating acoustic estimates of biomass during the season. In order to achieve this delivery, automated on-board processing will need to be developed, including implementation of algorithms to remove noise and to package the data at appropriate spatial and/or temporal scales. Given the analytical challenges associated with these types of data, Members were encouraged to develop automated algorithms that specifically account for the advice from SG-ASAM.

2.272 The Working Group noted that a number of krill fishing vessels now have the capability of collecting appropriate acoustic data, but that some vessels are not able to provide such information. It recognised that vessels which conduct acoustic surveys could be disadvantaged over other vessels that did not conduct such surveys, as they lost potential fishing time (paragraph 2.39).

2.273 WG-EMM advised the Scientific Committee that the collection of appropriate acoustic information from fishing vessels was critical for both proposed FBM approaches and highlighted that there was a need for SG-ASAM to meet and continue its work program for delivering the necessary acoustic procedures, data and information required. It requested that the Scientific Committee set the necessary priorities for SG-ASAM so that it could complete this work, including developing procedures for processing data, undertaking comparisons between different fishing vessels, and determining appropriate statistical analyses. It also requested that the Scientific Committee bring to the attention of the Commission the importance of acoustic data from the fishing fleet, collected and processed in accordance with SG-ASAM advice, for underpinning FBM.

2.274 WG-EMM agreed that it would be necessary to liaise with the krill fishing industry following advice from SG-ASAM about how fishing-vessel derived acoustic data might contribute to the future development and implementation of FBM. It recognised that feedback from the industry about proposed data collection methods would be vital and that only when concrete proposals for each FBM strategy are available would some operators be able to provide comments.

2.275 The Working Group emphasised that for FBM to be successful, liaison through individual Members would help ensure that all operators were informed about the critical involvement of industry and about the necessary requirements for data collection. WG-EMM recognised that the Association of Responsible Krill harvesting companies (ARK) was a useful coordinating forum for some krill fishery operators, but that not all operators were part of ARK.

2.276 The Working Group recalled that the krill fishing industry has, since the FBM symposium in 2011 (SC-CAMLR-XXX, Annex 4, paragraphs 2.149 to 2.192), made considerable progress in providing acoustic information that is appropriate for krill stock assessment. It thanked all those involved in this process and encouraged others to become involved.

2.277 Dr Constable informed the Working Group that Australian scientists will continue participating in the work on FBM, including progressing work from 2015. He also indicated their desire to work with Members interested in participating in the development of CEMP and FBM for krill in Divisions 58.4.1 and 58.4.2.

2.278 The Working Group reiterated its thanks to the proponents of both FBM strategies and noted that the proposed strategies need to be owned by CCAMLR in order to progress further. It recommended that:

(i) A formal MSE assessment would help highlight potential weaknesses and strengths in the proposed strategies and would help in providing a comprehensive risk assessment. In particular, it could help evaluate whether either strategy presented a risk of instability for the fishing fleet or a risk that the conservation objectives in Article II would not be achieved. A full MSE assessment would take time, however, a partial evaluation, if clearly specified, could be feasible to provide advice in the near term.

(ii) A series of performance measures which could be used for reviewing each FBM approach and determining whether that approach was working in the field, or not, were necessary (SC-CAMLR-XXXIV, Annex 6, paragraphs 2.130 to 2.132).

(iii) Agreed timelines for advancing the work, including timelines for SG-ASAM to complete its work, are necessary. If timelines are not agreed, or are not met, further development of the krill fishery will not be feasible given the existing conservation measures and the existing advice from the Commission.

(iv) A special focus topic would be necessary during WG-EMM-17 so that the Working Group has adequate time to discuss the continued development, implementation and future review of existing FBM approaches. Special attention to ongoing and future work on FBM (e.g. Appendix E) would be particularly important.

2.279 The Working Group noted that implementing an FBM strategy will require commitment from Members to acquire, analyse and deliver data for use in the decision-making procedures. It agreed that implementation issues could be progressed in parallel with the development of FBM strategies. This is because a number of implementation requirements will be the same across different options, including:

(i) the use of fishing vessels to obtain and provide data on krill distribution, abundance and size

(ii) the provision of CEMP data at specific times of the season and at sufficient places to be useful for a management strategy

(iii) procedures for analysing the data in sufficient time for the outputs to be used in decision-making.

2.280 The Working Group requested the Scientific Committee consider how these requirements for implementation of FBM strategies could be progressed. Future development of FBM will require coordination between WG-EMM, SG-ASAM and the fishing industry. The Scientific Committee is requested to provide advice on how best to achieve this.

2.281 In order to help progress future work related to the proposed FBM approach for Subarea 48.1, representatives from the US AMLR program developed a table describing how they had addressed the extensive advice from WG-EMM-15 (Appendix E, Table 1) and a list describing how CCAMLR could address advice provided by WG-EMM-15 and WG-EMM-16 (Appendix E, Table 2), recognising that future development of the proposed FBM approach needed to involve the wider CCAMLR Membership.

2.282 WG-EMM recognised the very considerable amount of effort involved in preparing the tables in Appendix E and acknowledged that it would be extremely valuable for helping direct how the FBM approach for Subarea 48.1 should continue to develop in the future.

2.283 The Working Group thanked Dr Darby following his kind offer that Cefas, which has considerable experience in MSE, could lend analytical support to the evaluation of both FBM proposals.

2.284 The Working Group advised the Scientific Committee that in order to progress work on FBM, it will be essential for the Working Group to dedicate time to this issue, and that a focus topic to discuss the following would be advantageous during WG-EMM-17:

(i) Spatial distribution of catches for base case –

  (a) catch levels
  (b) feedback that base case is appropriate.

(ii) Implementation –

  (a) data processing and analysis
  (b) krill surveys (what will these look like and who by – e.g. fishing vessels)
  (c) CEMP coverage.

(iii) What needs to be done to satisfy the Commission that the risk of the strategy is appropriate for krill, predators and the fishery –

  (a) performance measures (trailing indicators, in-principle measures)
  (b) MSE:
    - robustness of approach to krill flux and competition amongst predators.

2.285 The Working Group emphasised that dedicating time to the proposed focus topic would mean that other topics would receive less attention in 2017. It, therefore, requested that the Scientific Committee provide guidance regarding prioritisation of FBM during WG-EMM-17.

Spatial management

Marine protected areas (MPAs)

MPA Planning Domains 3 and 4 – Weddell Sea

3.1 Prof. Brey and Dr K. Teschke (Germany) presented three updated scientific background documents for a CCAMLR MPA in the Weddell Sea: WG-EMM-16/01 (Part A: General context of the establishment of MPAs and background information on the MPA planning area); WG-EMM-16/02 (Part B: Description of available spatial data); and WG-EMM-16/03 (Part C: Data analysis and MPA scenario development). The authors summarised modifications and additions to the 2015 versions of these documents (WG-EMM-15/38 Rev. 1, 15/39 and 15/46).

3.2 The Working Group thanked all those involved in the Weddell Sea MPA planning process for their efforts in undertaking this very significant amount of work. It identified the following issues for discussion:

(i) coordination and strategy to accommodate both the Weddell Sea MPA proposal and fishery research in the planning area

(ii) spatial distribution and bathymetric range used to define the bounds of toothfish habitat and the toothfish fishing cost layer

(iii) target levels of protection for toothfish habitat (currently set at 75%)

(iv) target levels of protection for demersal fish habitat (currently set at 75%)

(v) fisheries research zones (objective 12).

3.3 In terms of a strategy to accommodate both the MPA proposal and existing research fishing in the planning area, the Working Group discussed the recommendations of WG-SAM relating to the review of research proposals in Subarea 48.6 (Annex 5, paragraph 3.40) that highlighted the need to develop the stock hypothesis for Antarctic toothfish (*Dissostichus mawsoni*) in Subarea 48.6. The specific recommendations discussed included the need for ice analysis along the southwestern shelf to better define alternatives to existing research blocks covered by ice, deployment of satellite tags to study fish movement, sub-adult surveys to monitor recruitment on the shelf, and winter surveys to detect spawning locations on northern seamounts.

3.4 The Working Group noted that satellite tagging and ice analysis in this area would be consistent with the planned objectives of the proposed MPA and with developing a stock hypothesis for *D. mawsoni*. It encouraged those Members engaged in research in Domains 3 and 4 to develop a coordinated satellite tagging program. It further noted that refining toothfish habitat and cost layers may help with considering how best to structure research fishing in the planning area and highlighted the importance of developing a consistent set of advice to the Scientific Committee from WG-SAM, WG-EMM and WG-FSA.

3.5 In a discussion on the approach to generating the toothfish potential habitat layer, Dr Teschke explained that a depth range of 400–3 100 m was used as a proxy according to habitat suitability model predictions for *D. mawsoni* compiled by the Secretariat (WG-FSA-15/64; WG-EMM-16/03, Figure 1-16). This depth range (400–3 100 m) includes suitable habitat for toothfish as predicted by the circum-Antarctic model published in WG-FSA-15/64. Furthermore, the current data layer also includes smaller-scale areas where there are no model predictions but where habitat suitability for toothfish can be inferred. The contiguous unweighted data layer was used as the potential habitat of adult toothfish for the subsequent Marxan scenario.

3.6 The Working Group recommended examining if weighting the toothfish habitat and cost layers by depth using CPUE from Subarea 48.6 or the Ross Sea is possible to refine the habitat availability predictions. It also recommended that toothfish habitat and the toothfish fishing cost layer should be bounded separately, with the fishing cost layer specified as a bathymetric range from 550 to 2 000 m according to fishing practise.

3.7 The Working Group noted that the target level of protection for toothfish habitat of 75% was chosen following stakeholder consultation, including at the second international expert workshop that recommended a range of 20 to 100%.

3.8 The Working Group noted that toothfish are a key species in the ecosystem and should have an appropriate protection value. It also noted that it is a target species and there is a distinction in the level of protection between these two aspects. It was acknowledged that in the protection levels given to toothfish within the Weddell Sea MPA proposal this difference should be reflected. In recognising these objectives, the Working Group recommended the exploration of a range of protection levels from 20% to 80% in 20% increments to assess the sensitivity of the Marxan analyses to the level of protection. It agreed that consideration of smaller increments, as appropriate, would be helpful to identify important thresholds.

3.9 The Working Group noted that there are limited data available for other demersal fish in the planning area, with some species recovering from overexploitation in adjacent areas. The demersal fish habitat layer (WG-EMM-16/03, Figure 1-17) was generated using data mostly collected from shelf waters less than 1 000 m deep but with some sampling to 3 000 m (data layer described in WG-EMM-16/02). In light of the level of uncertainty regarding the ecology and status of these species, the Working Group recommended precaution in setting the target level for demersal fish habitat protection. Exploration of a range of protection levels from 65% to 85% in 10% increments was recommended to assess the sensitivity of the Marxan analyses to the level of protection. The Working Group further recommended selected two-factor sensitivity analyses of the protection-level scenarios for toothfish and other demersal fish habitat as appropriate to explore a range of protection-level scenarios.

3.10 The Working Group noted that the MPA planning documents referred to fisheries research zone(s) that are under development as part of the MPA proposal. It recommended that information specifically on the design and objectives of the fisheries research zone(s) be presented for consideration by WG-FSA and the Scientific Committee. Of particular interest for WG-FSA would be whether fisheries research zone(s) would be established according to specific research questions, i.e. either as spatially fixed zones or on a case-by-case basis.

3.11 It further recommended that, prior to WG-FSA, the MPA proponents, Members with existing research fishing proposals within the planning domain, and other interested Members consider coordination of existing fishery research proposals and the proposed MPA objectives in this area. This could be undertaken via the Weddell Sea e-group.

3.12 Dr Freeman asked if there was any information on the extent to which Weddell Sea environmental conditions and ecology are likely to be affected by predicted climate change, and whether this had been considered in the MPA planning process. Prof. Brey explained that current models predict significant oceanographic changes to be evident in the Weddell Sea in >50 years (warm deep water moving up the Filchner shelf). Meanwhile, it remains difficult to separate long-term trends from decadal oscillations and stochastic noise.

3.13 Dr Kasatkina noted the improvements in the proposals for the MPA planning in the Weddell Sea. However, information on dominant fish species of potential commercial importance remains underrepresented. Especially data on the state of toothfish as an important component of the ecosystem are currently not available. Research surveys are needed to determine stock status and commercial potential of these fish species. She underlined that results of these investigations should be included in the scientific background document in support of the MPA planning in the Weddell Sea.

3.14 Dr Kasatkina indicated that a significant part of the Weddell Sea MPA planning area is permanently ice-covered and this fact will significantly complicate annual navigational access to the areas identified for possible protection. She noted that MPA boundaries should comply with sea-ice conditions suitable for vessel navigation, as this is an important factor for the proper implementation of assigned research tasks in designated areas.

MPA Domain 1

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

3.15 WG-EMM-16/73 introduced the Domain 1 MPA planning progress related to data sharing and future enhanced work. On 9 July 2016, an informal workshop was held with the participation of 12 Member countries. It aimed to share the technical progress on Marxan analysis made during the intersessional period, to introduce complementary analyses that could be integrated into the process, and to engage Members in different stages of analysis and preparation of support information. The Domain 1 MPA database and related information used for these analyses, including spatial layers for conservation objectives, costs and input files for running Marxan, were made available for all Members' consideration within the Domain 1 planning e-group.

3.16 WG-EMM-16/73 also introduced the idea of a CCAMLR MPA monitoring program (MPAMP) developed by scientists from Argentina, Chile, UK and USA in light of the need to secure an appropriate and centralised monitoring system for MPAs. The proposed MPAMP would be based on the concept of CEMP, for example using standard data collection methods, and selection of variables and/or species, agreed by the Scientific Committee and centralised at the Secretariat. This monitoring program could provide a useful structure to centralise the information about MPA monitoring.

3.17 The Working Group welcomed the document and the development of the informal workshop, highlighting the progress made by scientists from Argentina and Chile. It encouraged all contributors to continue this work. The Working Group noted the value of sharing data to enhance Members' participation and the potential of the CCAMLR MPAMP.

3.18 The authors highlighted the importance of the cost layer for the Marxan analysis and requested technical advice from experts on the most appropriate time periods for krill fishing activity to be considered within the Domain 1 MPA process, to account for yearly krill fishing dynamics.

3.19 The Working Group agreed the use of a 3-year period for the most recent krill fishing activity (current krill fishing pattern), extending it to 10-year periods prior to current fishing pattern (historical krill fishing patterns).

3.20 Dr Kasatkina noted that the MPA Planning Domain 1 project covered a huge area in the western Antarctic Peninsula and southern Scotia Sea. The MPA Planning Domain 1 area includes potential fishing grounds and current fishing grounds for the krill fishery and that it is contrary to CM 91-04. Moreover, the MPA Planning Domain 1 project includes the existing South Orkney Islands southern shelf MPA (SOISS MPA). Dr Kasatkina noted that the experience of the SOISS MPA showed failure of proper implementation of the monitoring program and assigned research tasks in frame of the vast designated area. She proposed that the MPA Planning Domain 1 project should be subdivided into several smaller areas for the further planning process.

3.21 Dr Santos noted that planning domains were defined and agreed by the Scientific Committee in 2011 (SC-CAMLR-XXX, paragraph 5.20). She also stated that there are no MPA boundaries defined for Domain 1.

3.22 WG-EMM-16/35 described a Marxan study undertaken to identify important benthic areas within MPA Planning Domain 1, using the conservation objectives previously agreed during Domain 1 planning workshops, and data layers that have been shared with all Members as part of this process. This separate benthic analysis provides a means to differentiate whether benthic or pelagic objectives drive the selection of areas in future combined analyses. In considering potential management options in future planning, this separate analysis may also help to determine how benthic and pelagic activities could be managed differently in some areas.

3.23 The Working Group welcomed this work, noting that there was considerable overlap between the core areas identified in this study and the areas that had been identified as important for meeting conservation objectives in other studies for Domain 1. It noted the value of shared datasets in facilitating this type of additional supporting analysis as part of the MPA planning process.

South Orkney Islands

3.24 WG-EMM-16/13 Rev. 1 is a preliminary report on the benthic research voyage carried out on board the RRS *James Clark Ross* around the South Orkney Plateau in February–March 2016. The expedition was led by the British Antarctic Survey in collaboration with the SCAR State of the Antarctic Ecosystem (AntEco) research program. It included 22 participants from nine different countries, including eight CCAMLR Members.

3.25 The aim of the survey was to understand the distribution and composition of the benthic communities associated with different geomorphic features both within and outside the SOISS MPA. It also aimed to record the locations and distributions of all species identified as vulnerable marine ecosystem (VME) indicator taxa (paragraph 3.45iii).

3.26 The survey used a range of trawled sampling gear, as well as video and camera systems, to investigate species diversity, assemblage composition, abundance and habitat zonation along the shelf break of the South Orkney Islands. The results will help to ascertain whether there are characteristic indicator species prevalent in each proxy geomorphic habitat, and assist with future habitat mapping. New species were found in most groups of animals examined on the cruise, including corals, anemones, echinoderms and polychaete worms, with many other probable new species awaiting further identification. The authors noted that more detailed results from the wide range of analyses resulting from this cruise will be submitted to the Working Group and the Scientific Committee as they become available.

3.27 This research addresses some of the requirements of the SOISS MPA research and monitoring plan. The results will help to inform and support the management of the MPA, and provide new information to evaluate the extent to which its conservation objectives are being achieved. This will form an important basis for the development of scientific advice to inform the next review of the SOISS MPA, which is due in 2019.

3.28 The Working Group welcomed the preliminary results from this survey, and noted the important connection with the SCAR AntEco program.

MPA Planning Domains 5 (Crozet – del Cano) and 6 (Kerguelen Plateau)

3.29 Prof. Koubbi presented WG-EMM-16/43 and 16/54 on the 'Ecoregionalisation of the Kerguelen and Crozet Islands oceanic zone' and 16/42 on the 'Atlas of top predators from French Southern Territories in the southern Indian Ocean'. These papers add new information on Planning Domains 5 and 6 following the objectives proposed in SC-CAMLR-XXIX/13. These papers update scientific elements that were submitted to the CCAMLR Workshop on Marine Protected Areas in 2011 (WS-MPA11/09, 11/P03, 11/08, 11/P04, 11/10 and 11/P02) and to the CCAMLR Technical Workshop on Planning in Domain 5 in 2012 (WG-EMM-12/33 Rev. 1).

3.30 WG-EMM-16/43 and 16/54 listed the general conservation objectives to evaluate boundaries of ecoregions based on abiotic (geography, geomorphology and oceanography) and biotic features, including pelagic species, benthic species (including the demersal ichthyofauna), seabirds and marine mammals. There are discrepancies in the amount of data between sectors; Crozet can be considered as an area with less ecological information than Kerguelen, except for oceanography and top predators. The abiotic regionalisation of both areas was based mainly on the analysis of meso- and sub-mesoscale oceanographic features (such as fronts, retention zones, iron enrichment) which favour biological productivity linked to island mass effects.

3.31 Spatial patterns of biodiversity were determined based on spatial distributions of species and assemblages, or on species' potential habitats estimated regionally for top predators (WG-EMM-16/42) or globally for the Southern Ocean as for mesopelagic fish (De Broyer et al., 2014). Both islands support a high biodiversity of seabirds with a high range of dispersion in the sub-Antarctic and the Polar Frontal zone (WG-EMM-16/42). However, individuals from only a few colonies are tracked, and the conclusions of the reports are also based on observations from scientific and fishing vessels.

3.32 The papers also included descriptions of spatial patterns linked to functional diversity, including location of foraging habitats of seabirds and marine mammals, essential fish habitats (only for Kerguelen) and spatial distribution of VME indicator taxa. The maps of the six ecoregions for Crozet and 18 for Kerguelen were presented, noting that the reports summarise the essential ecological characteristics supporting the delineation of these ecoregions.

3.33 Prof. Koubbi explained that the aim of this project is to extend the Crozet and Kerguelen marine reserves beyond the existing 12 n miles around some of the islands of both archipelagos. The priority areas identified show that the process should consider also areas outside the Crozet and Kerguelen exclusive economic zone (EEZ).

3.34 The Working Group recognised the integrated ecosystem approach presented in these papers and the relevance of the ecoregionalisation of the Crozet and Kerguelen oceanic zones. It welcomed the scientific progress made on these areas of Planning Domains 5 and 6. As these areas are in the most northerly part of the Convention Area, together with Prince Edward Islands, they provide a unique opportunity to study biogeographic patterns in the Subantarctic and Polar Frontal zones and to consider the potential consequences of climate change, in particular for the pelagic realm (including mesopelagic fish), seabirds and marine mammals.

3.35 The Working Group agreed that these three papers should be considered as a scientific basis to initiate future work. These areas could also be discussed more broadly in a representative system of Indian Ocean sub-Antarctic MPAs. To achieve this goal, the Working Group recommended that an e-group be established to investigate the proposal to conduct a spatial planning process in the CCAMLR area in the south of the Crozet EEZ in Planning Domain 5 and to the east of Kerguelen in Planning Domain 6, based on oceanographic features and top predator tracking. These areas have been recognised as being important, for example, for king penguin (*Aptenodytes patagonicus*) foraging in the Polar Frontal Zone south of Crozet and for elephant seals (*Mirounga leonina*) in relation to gyres to the east of Kerguelen. An e-group would facilitate community work on those areas and enable sharing of assembled data through the CCAMLR website.

3.36 The Working Group also considered the recommendation to extend discussions between CCAMLR and regional fishery management organisations (RFMOs) on the del Cano Rise and other oceanic sectors north of the Convention Area, to facilitate a regional approach. It was agreed that such interactions would be beneficial.

3.37 The Working Group highlighted the importance of these sub-Antarctic areas regarding climate change impacts, as predicted change shows a southward shift of the Polar Front and a reduction of the Subantarctic zone surface. The designation of future MPAs will need to consider potential shifts southwards of these areas. For example, it is important to take into account the different impacts of climate change, in particular, for king penguins in Crozet.

Ross Sea krill research zone

3.38 WG-EMM-16/49 provided a review of previous research undertaken on krill and krill-dependent predators in the proposed krill research zone (KRZ), part of the proposed Ross Sea region marine protected area (RSRMPA). A central aim of the proposed KRZ is to enhance research opportunities within the RSRMPA, and WG-EMM-16/49 aimed to demonstrate this potential by reviewing previous scientific work relevant to krill and krill-dependent predators in the proposed KRZ. First, it was noted that sea-ice dynamics are an important structuring force acting on krill and their predators in the proposed KRZ. Most of the research found regarded baleen whales, and indicated that whale abundance is increasing in a larger area that overlaps with the proposed KRZ. Relatively little research was found on seabirds and seals, but WG-EMM-16/49 noted breeding colonies in and around the proposed KRZ. These were reported along with buffer zones at 60 n miles in accordance with CM 51-04 (fishing for krill in the proposed KRZ would be in accordance with CM 51-04, CCAMLR-XXXIV/29 Rev. 1, paragraph 9). The authors noted that these buffer areas do not overlap with historical krill fishing in the proposed KRZ. Overall, the authors concluded that the potential importance of this area to krill and krill predators presents an important opportunity for research.

3.39 The Working Group asked for clarification on how WG-EMM-16/49 related to, and aided in, furthering the ability of the RSRMPA to meet its objectives. The authors responded that the revised proposal for the RSRMPA submitted to the Commission in 2015 had identified a specific objective relating to the KRZ (CCAMLR-XXXIV/29 Rev. 1, paragraph 3xi). In terms of furthering this objective in the future, this review aims to motivate Member countries to utilise the proposed KRZ for further research. Specifically, the proposed KRZ may be particularly important for comparing conditions with nearby Balleny Islands, which are within the proposed RSRMPA General Protection Zone (i). Being able to conduct research on spatial areas with contrasting management objectives, such as in the Balleny Islands and the proposed KRZ, is of strong scientific importance and interest.

3.40 The Working Group noted that the draft research and monitoring plan (SC-CAMLR-IM-I/BG/03 Rev. 1) would be finalised, once the RSRMPA is adopted by the Commission, to reflect the final agreement. Priority elements for scientific research and monitoring, including those specifically relating to the KRZ, are included in the draft conservation measure for the MPA proposal, and the final monitoring plan should include input from all Members. To accomplish this, a focus session at WG-EMM or a workshop could be convened in the year following the agreement of the MPA by the Commission to revise the draft research and monitoring plan to reflect all Member contributions in this area.

3.41 Dr Zhu asked the authors to clarify the potential for krill fishing in the future. Dr Watters replied that, per the draft conservation measure, krill fishing as it is proposed in the KRZ is envisioned to adhere to CM 51-04 and the requirements therein (CCAMLR-XXXIV/29 Rev. 1, paragraph 9), which include the aforementioned buffer zones and a series of fishing vessel data collection plans. If the RSRMPA is adopted, Members who want to fish for krill in the proposed KRZ would then determine how they would carry out those research aspects, which would be encouraged to align with the research and monitoring plan developed with the adoption of the RSRMPA.

3.42 Dr Godø reiterated the Norwegian continuous support to the Ross Sea MPA and its development on a scientific basis. He asked what the process of a scientific review of the proposed KRZ would be, as it has already been accepted at the Commission and whether WG-EMM and/or the Scientific Committee will review the KRZ at a future stage or whether any evaluation will remain within the Commission.

3.43 The proponents responded that there is precedence for decisions at the Commission to drive the work of WG-EMM. The specific boundary modifications regarding the KRZ were put in place to address concerns raised by a Member, an option implied in the original proposal. While the proponents acknowledged that a boundary change may raise process questions, they also recalled that the remainder of the proposed RSRMPA had already been considered and endorsed by the Scientific Committee (SC-CAMLR-IM-I, paragraphs 2.31 to 2.33).

3.44 Dr Kasatkina emphasised that scientifically based arguments for creating this KRZ were not provided when the KRZ was discussed at the close of the CCAMLR meeting in 2015, and its establishment is not adopted by all CCAMLR Members. Dr Kasatkina, therefore, asserted that discussion of future research in the proposed KRZ is premature, and noted that an investigation on krill in the Ross Sea might be undertaken in the frame of CM 24-01.

Vulnerable marine ecosystems

3.45 There were no papers submitted under this agenda item; however, the Working Group noted work relevant to VMEs in other papers, particularly in the context of MPA planning and MPA research and monitoring, including:

(i) WG-EMM-16/43 (paragraphs 3.29 to 3.37) used niche modelling predictions and VME indicator group presence/absence data in the Kerguelen Island shelf and surrounding seamounts as the basis of a benthic ecoregionalisation of the area. The distribution of soft corals, hard corals and sponge assemblages allowed the differentiation of different coherent zones with representative ecosystems for each, along with related conservation issues.

(ii) WG-EMM-16/54 (paragraphs 3.29 to 3.37) summarised the available historical data of known VME indicator taxa in the Crozet area.

(iii) WG-EMM-16/13 Rev. 1 (paragraphs 3.24 to 3.28) presented a preliminary report of a UK-led benthic research cruise around the South Orkney Plateau in 2016. One of the aims of this cruise was to record the locations and distributions of all species identified as VME indicator taxa. Initial results showed a correlation between abundance of animals from VME indicator groups and the overall diversity of seafloor life, both inside and outside the SOISS MPA. The importance of VME indicator groups such as corals, sponges and pencil urchins as habitats for other species was noted and previously unknown associations and interactions were revealed. More detailed results from this work will be submitted to WG-EMM as they become available. Further analyses will also consider how VME risk areas can be identified using the results of research sampling and photography/video, rather than data from fishing vessels.

(iv) WG-EMM-16/35 (paragraphs 3.22 and 3.23) considered the locations of existing VMEs as a basis for identification of important benthic areas for conservation in MPA Planning Domain 1.

3.46 The Working Group noted that information relevant to VMEs was also discussed in papers other than those in paragraph 3.45, which focused on VMEs as part of work in support of spatial management proposals. The Secretariat reminded Members that there is a formal VME notification process (CM 22-06, Annex 22-06/B 'Guidelines for the preparation and submission of notifications of encounters with Vulnerable Marine Ecosystems (VMEs)') and encouraged Members to report VMEs as appropriate.

3.47 The Working Group recognised that it would be very useful to have the existing VME registry (www.ccamlr.org/node/85695) more apparent for annual meetings of the Scientific Committee and its working groups so that the information could be used to support discussions of these bodies. It recommended that links to the VME registry and other pertinent information on VMEs be made in annotated agendas of the Scientific Committee and the working groups to provide ready access to this information.

Other issues for spatial management

3.48 WG-EMM-16/27 referred to the draft conservation measure that was proposed by the EU in 2015 with the aim of promoting and facilitating scientific research in newly exposed marine areas following ice-shelf retreat or collapse around the Antarctic Peninsula (CCAMLR-XXXIV/21). The proposed conservation measure would provide for the establishment of special areas for scientific study in such areas, with a designated 10-year study period during which time there would be a moratorium on all fishing activities, except for scientific research fishing activities undertaken in accordance with CM 24-01. There was broad support by the Scientific Committee in 2015 for the scientific basis of the proposal. WG-EMM-16/27 addressed a number of points for clarification that were raised by the Scientific Committee and the Commission.

3.49 In addressing these points, the authors noted that:

(i) Ice-shelf retreat can be defined as the landward movement of the ice front over a period of at least 10 years, whereas collapse may occur over a shorter time period. However, recognising the difficulties of defining the terms 'collapse' or 'retreat' in a way that is applicable for all cases, and given the unique set of physical circumstances that are likely to lead to any individual collapse or retreat event, areas for potential designation as special areas for scientific study should be proposed and considered on a case-by-case basis.

(ii) The SCAR Antarctic Digital Database (ADD) remains the best available source of information on ice-shelf and glacier margins. The most recent version (ADD v.7.0, 2016) includes new data showing changes to the ice coastline, as well as a new 'coastal change' layer showing historic ice extent across the Antarctic Peninsula region, which will be regularly updated.

(iii) The main change in the proposed conservation measure is in the operation of the 10-year moratorium. The new plan includes a two-stage process. An initial two-year period (stage 1) would begin immediately following notification of an ice-shelf collapse/retreat. During stage 1, the fishing moratorium would begin, along with a review of the available data by WG-EMM and the Scientific Committee to determine whether the area warrants designation as a special area for scientific study. Stage 2 would begin before the end of the two-year period, if agreed by the Commission, based on advice from the Scientific Committee. Once agreed, special areas for scientific study would be established for a period of 10 years.

3.50 There was general support for the proposed updates to the draft conservation measure; however, the Working Group asked for further clarification on three issues. In response to these questions, the authors clarified that:

(i) The rationale for the two-year stage 1 period is to allow for review and consideration of scientific data for the proposed special area for scientific study (noting also that this period may in fact be shorter than two years, depending on the timing of notification and consideration by the Commission). The 10-year stage 2 period is seen as an appropriate time period in which to plan and initiate scientific research activities once a special area has been designated.

(ii) To ensure appropriate initiation of a stage 1 special area, it will be important to ensure that adequate scientifically robust data are submitted during the notification process.

(iii) A retrospective analysis of past ice-shelf collapses/retreats, will help increase understanding about whether such events would have warranted a special area for scientific study designation in the recent past, and the extent to which the proposed conservation measure would have been applied. Such an analysis will be undertaken following agreement of the proposed conservation measure.

3.51 The authors thanked the Working Group for the questions, noting that consideration of these issues will be incorporated into the development of a revised draft conservation measure for submission to the Commission.

3.52 The Secretariat introduced a new section of the CCAMLR website dedicated to managing reference material entitled 'Spatial Management Resources for CCAMLR Members' (www.ccamlr.org/node/90100) that was developed in response to the recommendation of the Scientific Committee (SC-CAMLR-XXXIV, paragraphs 16.2 and 16.3). The Secretariat demonstrated how this web resource can be used by Members to easily share information, enhancing their participation in MPA planning processes. The Working Group welcomed this webpage and encouraged Members to make relevant datasets available where possible.

Ross Sea symposium

4.1 A one-day Symposium on the Ross Sea Ecosystem was held on 13 July 2016 with the general aim to give the opportunity for scientists who do not routinely attend meetings of CCAMLR to get to know where the CCAMLR interests are and also for the CCAMLR scientists to know the work being undertaken on the Ross Sea ecosystem. The symposium also aimed to promote the sharing of common interests to tackle some of the questions that CCAMLR would like to address into the future. The symposium was co-convened by Drs Ghigliotti, Olmastroni and Kawaguchi, and was attended by over 80 scientists including 30 local participants.

4.2 The Co-conveners thanked Drs E. Brugnoli (CNR-DTA) and A. Meloni (President of the CSNA), and the local organisers Drs Fioretti and Vacchi for making it possible to hold the symposium. Dr Belchier (SC-CAMLR Chair) welcomed participants and presented CCAMLR's aims and structure. Dr G. Budillon (University of Naples 'Parthenope', member of the Italian National Scientific Committee for Antarctica, CSNA) on behalf of CSNA welcomed participants and presented the Italian National Antarctic Program.

4.3 The symposium included a number of contributions spanning from oceanography to microbiology, from fish to penguins and killer whales, and the presentations were organised in the following three thematic sessions:

(i) ecosystem structure and functioning (four abstracts)
(ii) krill and fish, fisheries and their impact on the ecosystem (four abstracts)
(iii) ecosystem monitoring and conservation (11 abstracts).

4.4 The series of presentations were followed by general discussion. Key points of the discussion were:

(i) The CCAMLR community was impressed by the amount of quality science undertaken across the regional ecosystem.

(ii) The Ross Sea area is an impressively data-rich area with a wealth of long-term data being collected. Compilation of all available time series may potentially reveal concordant changes that may indicate broader-scale effects which are not evident from each individual time series analysis.

(iii) The need for stronger interaction between CCAMLR and SCAR was suggested but communications at the scientists and national delegation level, which already exists, will naturally strengthen this relation.

(iv) Importance of national capacity building was stressed, and the CCAMLR scholarship scheme for young researchers and students was suggested to be an excellent vehicle to promote involvement of the Italian scientific community in CCAMLR.

(v) Creation of an e-group for the Ross Sea ecosystem, facilitated by the Italian CCAMLR Delegates Drs Vacchi and Fioretti, to continue the momentum gained from this symposium.

(vi) The symposium functioned as an excellent dialogue for CCAMLR to connect to the host community, and it may be beneficial to organise similar events in future meetings.

(vii) An information paper on the summary of the symposium should be published, facilitated by the Co-conveners.

4.5 The symposium program and the abstracts of presentations are appended to this report (Appendix F).

4.6 The Working Group congratulated the Co-conveners for such a successful symposium, making it possible to connect the Working Group to the local scientists.

4.7 The Working Group noted that the symposium format with a large number of presentations made it difficult to discuss details of each presentation, and that CCAMLR may benefit from having a mechanism to extract key information that is relevant to CCAMLR objectives and effectively utilise this to provide advice.

4.8 The Working Group further noted that such a symposium is an excellent means for outreach but at the same time there is a trade-off since it takes a certain amount of time out of the Working Group meeting, and this should be one of the topics to be brought up and discussed at the Scientific Committee Symposium later this year.

Advice to the Scientific Committee and its working groups

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

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

(i) Krill fishing activities –

(a) publication of krill catches by month and SSMU (paragraph 2.8)
(b) notifications for 2016/17 (paragraph 2.14)
(c) escape mortality (paragraph 2.17)
(d) start date of the fishery (paragraph 2.33)
(e) collection of acoustic data and net samples (paragraphs 2.39, 2.191, 2.194 and 2.273).

(ii) Scientific observations –

(a) observer coverage (paragraph 2.48)
(b) sampling design (paragraph 2.53)
(c) collection of data on salps (paragraph 2.90).

(iii) Krill biology, ecology and ecosystem interactions –

(a) flux of krill through the ecosystem (paragraph 2.62)
(b) ecosystem-essential ocean variables (paragraph 2.94)
(c) status of whale populations (paragraphs 2.118 and 2.119).

(iv) CEMP and WG-EMM-STAPP –

(a) impact of krill fishing in Subarea 48.1 (paragraph 2.144)
(b) reference monitoring areas (paragraph 2.146).

(v) FBM –

(a) spatial allocation of the trigger level to Subarea 48.1 (paragraph 2.225)
(b) risk assessments (paragraph 2.241)

(c) trigger level and catch limits in CM 51-07 (paragraphs 2.247 to 2.252)
(d) transition from stage 1 to stage 2 (paragraph 2.284)
(e) prioritisation and coordination of further work (paragraphs 2.280 and 2.285).

(vi) Spatial management –

(a) VME registry (paragraph 3.47).

(vii) Ross Sea Symposium –

(a) outreach (paragraph 4.8).

(viii) Future work –

(a) climate change (paragraph 6.12)
(b) data management group (paragraph 6.21).

(ix) Other business –

(a) meeting papers (paragraphs 7.2 and 7.3).

Future work

6.1 The Working Group noted that future work relating specifically to FBM is discussed in paragraphs 2.278(iv), 2.280 and 2.285 and Appendix E.

Third International Krill Symposium

6.2 WG-EMM-16/34 announced the Third International Krill Symposium (http://synergy.st-andrews.ac.uk/3iks), which follows previous symposia held in 1982 and 1999. The symposium will be held in St Andrews, Scotland, in June 2017 and will consider a range of krill species including Antarctic krill. Scientists with experience in the work of WG-EMM are particularly encouraged to participate. The Co-conveners hope that the symposium will increase interaction between WG-EMM and the wider community of Euphausid researchers.

Joint CCAMLR–IWC Workshop

6.3 WG-EMM-16/12 presented an update on the drafts of the terms of reference and agenda for two joint CCAMLR–IWC workshops planned for 2017 and 2018 (SC-CAMLR-XXXIV, paragraphs 10.26 and 10.27), following consideration at IWC SC at its meeting in June 2016. These workshops will consider multispecies models of the Antarctic marine ecosystem at a scale appropriate for informing strategic management advice and set directions for future collaborative work between CCAMLR and the IWC.

6.4 The Working Group noted the following:

(i) The IWC SC had made minor modifications to the agenda of the first workshop:

(a) Item 2.3 was modified to 'Purpose, status of, and suggestions regarding, relevant multispecies models'

(b) Item 2.4 was inserted: 'Abundance and trends of species relevant for developing and fitting multispecies models'.

(ii) It was confirmed that the first workshop would be held as a pre-meeting to IWC SC 2017 (6 to 8 May 2017 in Slovenia). One and a half days have been allocated for the workshop by the IWC SC during the pre-meeting period, but it will be possible to continue discussions during the IWC SC as the IWC SC allows. This is a change in the strategy since this was last discussed at CCAMLR.

(iii) The geographic focus for the workshop will be the Antarctic Peninsula, but it was noted that connectivity between the neighbouring areas may also be of interest since the foraging ranges of predators may change between summer and winter and this could be different between species.

(iv) Whales, krill, penguins and seals were identified as key taxa for including in multi-species models, but it was noted that others such as flying seabirds were potentially important.

(v) The expectation is for descriptions of models and datasets on key taxa to be tabled at the first workhsop to provide an overview of what is available.

(vi) The IWC approved a budget to invite four experts, but two of their nominations (Dr Watters and Dr A. Friedlaender (USA)) are subcommittee members for the IWC SC, freeing up the budget for two more experts. Current nominations include Drs E. Plagányi (South Africa) and D. Kinzey (USA).

(vii) The current steering group consists of Drs Kawaguchi (Co-convener), T. Kitakado (Japan) (Co-convener), Watters, Currey, Trathan, Hill, Ichii and K. Kovacs (Norway) (SC-CAMLR-XXXIII, paragraph 10.26). The subgroup agreed that the Secretariat should also be represented on the steering group.

(viii) The steering group's main tasks are to: list potential participants and presenters by January 2017; publicise the workshop to WG-EMM; consider ways of allowing remote participation in the workshop.

6.5 The Working Group agreed that:

(i) a metadata catalogue would be useful for consideration at the first workshop describing datasets and models, noting that it may be difficult to complete this by the first workshop and that such a catalogue could be progressed up to the second workshop

(ii) costings will be required for attendance of experts in order to seek support from SC-CAMLR. CCAMLR to develop a matching budget to IWC SC to invite experts

(iii) an e-group will be established to progress the development of the metadata catalogue and to consider what needs to be discussed at the first workshop

(iv) the Steering Committee consider having an introductory session to help the workshop participants to identify common goals but to recognise that the motivation and level of understanding between the two groups may be different.

6.6 Given that the workshop is proposed to take place over 1.5 days, with the understanding that there will be time during the margins of the IWC SC to continue the workshop discussions as required, the Working Group suggested that it would be useful to ask in advance for dedicated time and space to ensure this happens.

6.7 An e-group has been established to make progress on the items listed in the draft agenda (WG-EMM-16/12) for the first workshop, including reviewing the status/availability (and preparing short descriptions) of the data and models (updated from the 2008 workshop) available/being developed. The Working Group agreed that this would allow the clarification of what remains to be discussed in the first workshop, including an indication of whether 1.5 days is appropriate, that would allow the Scientific Committee to review the planning and proposed attendance at the first workshop.

Joint CEP–SC-CAMLR Workshop

6.8 WG-EMM-16/30 reported on the Joint CEP–SC-CAMLR Workshop on Climate Change and Monitoring held in Punta Arenas, Chile, in May 2016, and co-convened by Drs Grant and Penhale. This workshop produced 16 recommendations. The Co-conveners highlighted to WG-EMM Recommendation 2 – 'to encourage the articulation of clear questions to be addressed to scientific programs in order to obtain the best scientific advice relevant to the goals of the CEP and SC-CAMLR'. The report includes a process for identifying and conveying shared climate change research and monitoring needs which includes identification by WG-EMM of components of CEP's Climate Change Response Work Program (CCRWP) relevant to SC-CAMLR.

6.9 The Working Group noted the recommendations arising from the Joint Workshop (WG-EMM-16/30) and agreed that this workshop had been a productive and valuable opportunity to share information and consider issues of common interest.

ICED

6.10 WG-EMM-16/22 provided an overview of the work of the Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) program. ICED is a regional program of the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) program and is closely linked with SCAR. The paper highlighted scientific progress in aspects where the interests of ICED and CCAMLR overlap. It noted that ICED can help coordinate the development of activities of joint priorities. A range of multidisciplinary research is underway and considerable progress has been made in understanding the structure and functioning of ecosystems, modelling species and food webs, and with qualitative assessments of change. ICED's current major focus is to more comprehensively assess (and where possible quantify) key impacts of change on Southern Ocean ecosystems.

6.11 WG-EMM-16/71, which was also presented to the Joint CEP–SC-CAMLR Workshop on Climate Change and Monitoring, summarised knowledge of the impacts of climate change and acidification on Southern Ocean ecosystems, and the attention that SC-CAMLR has given to these impacts. It also summarised planned activities of ICED and SOOS and identified these as opportunities for SC-CAMLR and CEP to cooperate with SCAR to progress work on climate change and acidification. These activities include an ICED conference on marine ecosystem assessment for the Southern Ocean to be held in Hobart, Australia, in April 2018.

6.12 The Working Group recommended the SC-CAMLR Symposium consider whether, and how, discussions on climate change (such as those presented in WG-EMM-16/22, 16/30 and 16/71) may be considered in future working group meetings, in order to provide appropriate advice to the Scientific Committee.

Developing links with SCAR and other programs

6.13 The Working Group noted Table 2 of WG-EMM-16/30, which sets out a process for CEP and SC-CAMLR to identify and convey shared climate change research and monitoring needs to SCAR, ICED and SOOS. It noted that the related discussions and recommendations from the Joint Workshop focus on climate change issues, but agreed that the dialogue with SCAR, ICED and SOOS should be broader in scope and can draw on their expertise in a number of relevant areas, including:

(i) ICED can help with investigating the consequences of change, the development of scenarios and investigations into the implications of these changes for ecosystems and fisheries (see WG-EMM-16/22)

(ii) SOOS provides an overarching framework for observing and monitoring (see WG-EMM-16/71)

(iii) SCAR has a number of groups carrying out relevant work (e.g. AnT-ERA – Antarctic Thresholds – Ecosystem Resilience and Adaptation and AntEco).

6.14 The Working Group recognised the potential benefits of collaborations with the wider science community in terms of exchanging valuable ecological information on key taxa and regions to develop useful baselines and to understand the effects of change (e.g. consequences for predators, e.g. WG-EMM-16/P07 and 16/P08, krill, mesopelagic fish, benthic and deep-water ecosystems, invasive species, etc.).

6.15 The Working Group noted that ICED desires to have closer collaboration with CCAMLR, and to identify and address key scientific issues of interest to both groups towards improving the provision and uptake of valuable information for ecosystem-based management. This is consistent with the recommendations of the recent Joint CEP–SC-CAMLR Workshop on Climate Change and Monitoring, including those that encourage the strengthening of links between ICED and SC-CAMLR. The Working Group suggested that an initial small set of priority activities of joint interest be identified and used as a focus for strengthening links. These could include consideration of key species, regional ecosystems, scenarios and projections of change, and exploring the potential for ICED science to contribute specifically to informing key areas in CCAMLR decision-making (see e.g. paragraph 6.25).

6.16 The Working Group noted that the Secretary of the SCAR Standing Committee on the Antarctic Treaty System (SCATS) is keen to develop linkages with CCAMLR and that further discussion is planned at the SCAR Open Science Conference in August 2016. It was noted that a set of key questions from WG-EMM that could be addressed by ICED, SOOS and SCAR would be a useful contribution to these discussions (paragraphs 6.22 and 6.23 and Table 3). The Working Group also noted that a number of potential focus regions and focus topics have been raised during this meeting (e.g. Crozet and Kerguelen Islands and MPA Planning Domain 1) in this regard.

6.17 The Working Group agreed that an e-group be established to facilitate ongoing dialogue between Working Group participants and as a means of updating the group on relevant communication and progress between CEP and SC-CAMLR.

Data and information exchange

6.18 The Working Group agreed to investigate ways of facilitating information exchange with external groups. It was noted that the provision of regular summaries in this regard is a useful recommendation from the Joint CEP–SC-CAMLR Workshop (WG-EMM-16/30).

6.19 The Working Group noted that the Secretariat is preparing metadata for CEMP data which will be displayed on the CCAMLR GIS and is useful for facilitating engagement with science programs. In addition, the Secretariat has registered the CCAMLR Data Centre with the Global Change Master Directory (GCMD) (http://gcmd.nasa.gov) and is working towards making CCAMLR datasets discoverable through metadata records submitted to GCMD.

6.20 The Working Group recognised the value of working from standard datasets, especially in its work on FBM and planned work with the IWC. The Working Group agreed that such a mechanism may be implemented through the use of standard data extracts and accompanying documentation which describe each data extract and outline data quality assurance issues and updates. The matter was also discussed during WG-SAM-16 (Annex 5, paragraphs 2.17 to 2.20).

6.21 The Working Group endorsed the recommendation of WG-SAM that a data management group would be useful to provide a conduit between data users and the Secretariat.

Development of priority questions relating to climate change

6.22 The Working Group considered which components of CEP's Climate Change Response Work Program (CCRWP) (WG-EMM-16/30, Appendix 5) are of specific interest to

CCAMLR. Table 3 sets out relevant questions, actions, tasks and activities from other groups. It was recommended that this table be communicated to the Chair of the CEP. It would also be useful to make this table available to facilitate informal discussion at the SCAR Open Science Conference in August 2016.

6.23 The Working Group noted that issues 6 (marine species at risk due to climate change) and 7 (marine habitats at risk due to climate change) identified in Table 3 are of most relevance to its work. It further noted that similar priorities and questions could be identified for other issues relating to climate change that are of relevance to CCAMLR only (i.e. not included in the CCRWP). In discussing the development of such priorities, the Working Group noted that it would be important to consider the following points:

(i) What relevant work is currently underway?

(ii) What do we need to know (e.g. status and trends of species now and in the future)?

(iii) Types of advice that may be provided to the Commission, e.g. interpreting Article II under climate change; adapting management strategies to climate change; and the consequences of climate change to biodiversity.

6.24 In discussing specific questions relating to these points, the Working Group recognised that developing a better understanding of the potential effects of climate change on krill and krill fishing would include elements of:

(i) status and trends of the krill fishery

(ii) FBM

(iii) CEMP methods to evaluate the impacts of fishing, monitoring to provide ecosystem baselines and detect the impacts of environmental change

(iv) biology, ecology and dynamics of krill and its related ecosystem through scientific research and research using fishing vessels.

6.25 In relation to addressing these issues, and noting the request from the Joint CEP–SC-CAMLR Workshop for the clear articulation of research questions, the Working Group identified the following key questions (noting that further questions may be developed in due course):

(i) What are plausible scenarios for changes in the krill population in the Scotia Sea over the next 2 to 3 decades?

(ii) How might changes in the extent of seasonal sea-ice affect the accessibility of krill fishing areas?

(iii) What is the magnitude of change in krill and the krill-based food web that could be agreed to have occurred using current data sources?

6.26 The Working Group agreed that further information from SCAR and programs such as ICED, SOOS and others, would assist in addressing these questions. In particular, it identified existing ICED work and the proposed 2017 ICED workshop on developing scenarios for the effects of change on ecosystems (see WG-EMM-16/22) as relevant to addressing questions (i) and (ii). Scientists from WG-EMM are encouraged to contribute to planning this workshop.

6.27 The Working Group noted that an intersessional correspondence group (ICG) has been established by the Commission to consider approaches for enhancing consideration of climate change impacts in the work of CCAMLR.

6.28 The Working Group also agreed that, given climate-change impacts have already been observed, and such impacts are expected to continue, any revision of the management, including the staged approach under development by WG-EMM, must be suitably precautionary (paragraph 2.212 and Figure 3).

Scientific Committee Symposium and prioritisation of future work

6.29 The Working Group discussed preparation for, and key advice required for, the Scientific Committee Symposium, including priority focus topics, and noted that links to external groups in these areas (as discussed above) would be valuable. The Working Group agreed that it would be useful to distil this information and present it clearly for the Symposium.

6.30 The Working Group agreed that the following list of questions provide a useful guide:

(i) What is the key advice we need to provide to the Scientific Committee and the Commission?

(ii) What are the risks of not providing this advice?

(a) terms of reference of WG-EMM

- is the current working group structure appropriate to efficiently undertake the work?

(iii) What should be focus topics and their priorities?

(iv) How can external groups assist our work?

(v) How does the CCRWP relate to our work?

6.31 The Working Group considered the above questions in relation to specific areas of work such as FBM and noted that this type of analysis on all WG-EMM main topics would be useful.

6.32 The Working Group reviewed priorities and a work plan developed by the Convener for SC-CAMLR-XXXIV and agreed this will assist with the discussion of priorities at the forthcoming symposium. It was noted that with focus years on priorities we may only be able to cover those of high priority/risk. This list of priorities was also attached to the draft agenda of the Scientific Symposium that was distributed as SC CIRC 16/36.

Other business

Consideration of papers under Other business

7.1 The Working Group noted that there were a number of papers (WG-EMM-16/24, 16/25, 16/31, 16/32, 16/33, 16/50 and 16/P05) that had been allocated to this agenda item because there was not a more specific agenda item under which they would be considered. The Working Group did not consider these papers in detail and acknowledged that, given the large number of papers submitted to the meeting, it was unrealistic to consider all of the papers in an equivalent level of detail.

7.2 The Working Group recognised that there are scientific issues relevant to the work of CCAMLR for which it is unclear where discussion should take place, e.g. the ecosystem effects of finfish fishing, and agreed that the general question of how best to provide a forum for discussion of these issues should be considered by the Scientific Committee.

7.3 The Working Group also recommended that as part of the document submission approval process, Scientific Committee Representatives (or others with delegated authority) ensure that papers are tabled to the appropriate agenda item taking into account any pre-meeting guidance provided by the Convener. In situations where a suitable agenda item does not exist, then a discussion with the Convener may help to clarify the appropriateness of the submission of a particular paper.

Global Environment Facility proposal

7.4 The Secretariat provided a brief update on the CCAMLR Global Environment Facility (GEF) proposal for strengthening capacity for international cooperation in the ecosystem-based management of the Antarctic large marine ecosystem (SC-CAMLR-XXXIV, paragraphs 10.30 and 10.31). Letters of endorsement have been received from Chile, India, Namibia, South Africa and Ukraine and the project proposal has been submitted for the second formal review at the meeting of the GEF Council from 24 to 27 October 2016. The Secretariat hoped that the timing of the GEF Council meeting would mean that an update would available by the end of CCAMLR-XXXV.

CCAMLR Science

7.5 The Science Manager, as Editor of *CCAMLR Science*, recalled the discussion in WG-EMM and the Scientific Committee in 2015 on the review of the future role of the journal (SC-CAMLR-XXXIV, paragraphs 14.1 to 14.6). He indicated that there were only four papers from WG-EMM this year that were submitted for consideration for the journal.

CCAMLR Scientific Scholarship Scheme

7.6 The Working Group noted the presentations given by Ms Schaafsma and Dr Sytov (paragraphs 2.74 to 2.81) and recognised the importance and the success of the scholarship scheme in building capacity in the working groups and encouraged engagement in the scheme, either as mentors or applicants. The Working Group also asked for clarification from the Scientific Committee on the eligibility of scientists from Acceding States to apply to the scholarship fund.

7.7 The Working Group requested that the papers that were submitted to the Working Groups by recipients of scholarships be linked from the scholarship webpage in order to better highlight the contribution of the scheme to the work of CCAMLR.

CEMP Special Fund

7.8 The Working Group noted that there were no applications to the CEMP Special Fund this year. The Working Group also suggested that the administration of the CEMP Fund may need to be clarified in order to increase the visibility of the fund, the application process and subsequent procedures for disbursement of funds. The Working Group suggested that the Scientific Committee consider the composition of the management group, including the potential addition of the Convener of WG-EMM and the Science Manager.

7.9 Dr Watters provided an update on the project, funded by the CEMP Fund, on tracking the overwinter habitat use of krill-dependent predators from Subarea 48.1, including on the involvement of the Secretariat in managing the purchasing of satellite tags and the utilisation of existing Secretariat data management systems for VMS data to record the location data for the tracked penguins.

Antarctic Wildlife Research Fund

7.10 Dr Trathan informed WG-EMM that the Antarctic Wildlife Research Fund (AWR; www.antarcticfund.org) had received a large number of high-quality scientific research proposals in response to its second call for proposals. The AWR Scientific Advisory Group would make recommendations about these proposals in the near future so that results could be announced towards the end of the year. He also advised that following the first call for proposals, the AWR had funded research on:

- (i) foraging range and habitat preference of non-breeding penguins
- (ii) foraging behaviour of humpback whales
- (iii) ageing methodology for Antarctic krill.

The AWR envisaged that the funded research would contribute to CCAMLR's management of the krill fishery.

Next meeting of WG-EMM

7.11 Dr Santos informed the Working Group that she will be delighted to host the 2017 meeting of WG-EMM in Argentina.

Adoption of the report and close of the meeting

8.1 In closing the meeting, Dr Kawaguchi thanked all participants and the Secretariat for their contributions to the meeting and the work of WG-EMM, and the Italian Antarctic research community for the successful one-day symposium on the Ross Sea ecosystem. He also thanked the subgroup coordinators and rapporteurs, and especially Drs Constable, Demianenko, Trathan and Watters, for facilitating the discussions on FBM. Dr Kawaguchi thanked Drs Ghigliotti and Olmastroni for co-convening the symposium and Dr Watters who also co-convened some of the Working Group sessions on krill and FBM. Dr Kawaguchi also thanked Drs Fioretti and Vacchi and colleagues at CNR for organising and supporting the meeting and symposium, and for the excellent facilities and generous hospitality. This meeting marked the end of Dr Kawaguchi's term as Convener.

8.2 Dr Watters, on behalf of the Working Group, congratulated Dr Kawaguchi for his leadership and vision during his five-year term as Convener during which time the Working Group had made substantial progress in advancing its work on FBM and spatial management. The Working Group looked forward to welcoming Dr Kawaguchi back as a participant at future meetings.

8.3 Dr Kawaguchi was presented with a small gift in appreciation of his term as Convener.

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Table 1: Summary of vessels and fishing operations notified to fish for krill in 2016/17. GW – green weight; CV – codend volume; FM – flow meter; FS – flow scale; HTV – holding tank volume; MC – meal conversion; PT – plate tray.

Member	Vessel	Method for direct estimation of GW of krill caught by product type					Processing capacity (tonnes GW/day)	Subarea/Division					
		Whole frozen	Boiled	Meal	Oil	Other product		48.1	48.2	48.3	48.4	58.4.1	58.4.2
Chile	*Betanzos*			FM			120	X	X	X			
	Saint Pierre			FS			250	X	X	X			
China	*Fu Rong Hai*	HTV	HTV	HTV			350	X	X	X	X		
	Kai Fu Hao	PT		MC			200					X	X
	Long Da	PT		MC			160	X	X	X	X		
	Long Fa	PT		MC			500	X	X	X	X		
	Long Teng	PT		MC			180	X	X	X	X	X	X
	Ming Kai	HTV		HTV			200	X	X	X	X	X	X
	Ming Xing	HTV		HTV			200	X	X	X	X		
Korea,	*Insung Ho*	HTV					160	X	X				
Republic of	*Kwang Ja Ho*	HTV	HTV	HTV		HTV (paste)	240	X					
	Sejong	HTV	HTV	HTV		HTV (peeled)	240	X	X	X			
Norway	*Antarctic Sea*			FS	FS		700	X	X	X	X		
	Juvel				FM	FM (hydrolysate, lipid complex)	250	X	X	X			
	Saga Sea			FS	FS		700	X	X	X	X		
Poland	*Alina*	HTV		MC			320	X	X	X	X		
	Saga	HTV		MC			250	X	X	X	X		
Ukraine	*More Sodruzhestva*			CV		CV (blanched and frozen meat)	250	X	X	X			
Count	18							17	16	15	10	3	3
Minimum							120						
Maximum							700						

Table 2: Summary of trawl gear proposed by vessels notified to fish for krill in 2016/17. A – panel across mouth; B – panel in net and escape window; OTM – midwater otter trawl; TMB – midwater beam trawl; C – continuous; T – traditional.

Member	Vessel	Trawl gear	Trawl technique	Net mouth		Total net length (m)	Codend mouth		Codend		Marine mammal exclusion device
				height (m)	width (m)		height (m)	width (m)	length (m)	mesh size (mm)	
Chile	*Betanzos*	OTM	T	15	22	99	3.2	3.0	28	16	A
		OTM	T	19	26	107	3.2	3.0	28	16	A
	Saint Pierre	OTM	T	15	22	99	3.2	3.0	28	16	A
		OTM	T	19	26	107	3.2	3.0	28	16	A
China	*Fu Rong Hai*	OTM	T	30	30	129	3.8	7.6	31	15	B
	Kai Fu Hao	OTM	T	30	29	268	3.4	3.4	50	20	B
	Long Da	OTM	T	15	20	135	1.2	2.2	30	15	B
		OTM	T	25	30	159	1.8	1.8	30	15	B
	Long Fa	TMB	C	20	16	152	1.5	1.5	29	16	A
	Long Teng	OTM	T	20	40	132	1.8	1.8	24	16	A
		OTM	T	20	40	175	1.8	1.8	30	15	B
		OTM	T	30	40	348	1.8	1.8	30	15	B
	Ming Kai	OTM	T	25	26	280	1.8	1.8	40	15	B
		OTM	T	26	28	185	2.0	2.0	37	15	B
	Ming Xing	OTM	T	25	26	280	1.8	1.8	40	15	B
		OTM	T	26	28	185	2.0	2.0	37	15	B
Korea,	*Insung Ho*	OTM	T	20	57	105	2.1	2.5	23	15	B
Republic of	*Kwang Ja Ho*	OTM	T	40	72	168	1.5	3.0	32	15	B
	Sejong	OTM	T	26	30	109	8.8	8.8	24	15	B
Norway	*Antarctic Sea*	TMB	C	20	20	135	3.8	3.8	28	11	A
		TMB	C	20	20	135	3.8	3.8	28	20	A
	Juvel	OTM	T	20	23	375	2.9	2.9	25	11	A
	Saga Sea	TMB	C	20	20	135	3.8	3.8	28	11	A
		TMB	C	20	20	135	3.8	3.8	28	20	A
Poland	*Alina*	OTM	T	45	45	128	2.4	2.4	36	11	B
	Saga	OTM	T	45	45	128	2.4	2.4	36	11	B
Ukraine	*More Sodruzhestva*	OTM	T	25	40	121	7.6	7.6	48	12	A
Minimum				15	16	99	1.2	1.5	23	11	
Maximum				45	72	375	8.8	8.8	50	20	

Table 3: Issues and priority questions relating to climate change. This table sets out the issues identified in the CEP's Climate Change Response Work Programme (CCRWP) that are of joint interest to CCAMLR and the CEP. The table follows the same format as the CCRWP (with corresponding numbers for ease of reference). Items in red are new items that were added during this meeting. Actions in **bold** are of particular priority to WG-EMM.

Climate-related issue	Gaps/needs/key questions	Action/task	Relevant CEP/SCAR/other activities	CCAMLR interest/involvement
1) Enhanced potential for non-native species (NNS) introduction and establishment	• Assessment of whether existing regimes for preventing NNS introductions and transfer are sufficient. Analyse management tools applied in other areas. • Assessment of risks of introducing non-native marine species. • Ongoing surveillance program to identify status of NNS in light of climate change.	b. Review of IMO biofouling guidelines to check adequacy for Southern Ocean and vessels moving from region to region. c. Undertake a risk assessment: identification of native species at risk of relocation, and pathways for intra-continental transfer, including developing regional maps/descriptions of habitats at risk of invasion. d. Undertake a risk assessment: identification of marine habitats at risk of invasion and pathways for introduction. f. Implement marine and terrestrial monitoring in accordance with established surveillance framework (pt. a) once developed.	CEP Parties to identify existing research projects relevant to surveillance and bring information to CEP 2017.	Request further information from CEP, SCAR and other programs as available.

(continued)

Table 3 (continued)

Climate-related issue	Gaps/needs/key questions	Action/task	Relevant CEP/SCAR/other activities	CCAMLR interest/involvement
3) Change to marine near-shore abiotic and biotic environment	• Understanding and ability to predict near-shore marine changes and impacts of the change. • Broader understanding of what monitoring data will be required to assess climate driven changes to the marine environment.	**a. Encourage research by national programs and SCAR and seek state of knowledge updates from SCAR on climate impacts on marine biota.** **b. Support and undertake collaborative long-term monitoring of change (e.g. SOOS and ANTOS) and seek regular state of knowledge reports from such programs.** d. Continue to work with CEP to identify the process for defining reference areas for future research. e. Maintain regular dialogue (or sharing of information) with the CEP on climate change and the Southern Ocean, in particular on actions being taken.	SCAR to assimilate current research initiatives relevant to marine environmental change. Update reports to be provided, incl. through the Environments Portal. CEP to assimilate overview of how existing research programs (such as SOOS and ANTOS) can contribute to CEP's management interests. CEP Chair to write to Steering Committees of relevant international research programs (e.g. ICED) to request regular update reports.	Request further information from CEP, SCAR and other programs as available. Maintain dialogue with CEP, including future joint workshops.

(continued)

Table 3 (continued)

Climate-related issue	Gaps/needs/key questions	Action/task	Relevant CEP/SCAR/other activities	CCAMLR interest/involvement
4) Ecosystem change due to ocean acidification (OA)	• Understanding the impacts of OA on marine biota and ecosystems.	**a. As required, encourage further research and assessment on impact of OA informed by the SCAR report.** **b. Consider forthcoming SCAR report on OA and act accordingly.** c. Review and revise where necessary existing relevant management tools to consider if they afford the best practical adaptation measure to species or geographic areas at risk from ocean acidification.	SCAR report on OA released August 2016.	Request further information from SCAR and other programs as available.

(continued)

Table 3 (continued)

Climate-related issue	Gaps/needs/key questions	Action/task	Relevant CEP/SCAR/other activities	CCAMLR interest/involvement
6) Marine species at risk due to climate change	• Understand population status, trends, vulnerability and distribution of key Antarctic species. • Improved understanding of effect of climate on species at risk, including critical thresholds that would give irreversible impacts. • Framework for monitoring to ensure the effects on *key* species are identified. • Understand relationship between species and climate change impacts in important locations/areas. • Understand systematic changes to community structure, including for example mesopelagic community structure.	**a. Encourage research by national programs and SCAR, e.g. through programs such as AntEco and AnT-ERA.** b. Consider if and how the IUCN red list criteria can be applied on a regional basis for the Antarctic in the context of climate change[1]. d. Review and revise where necessary existing management tools, to consider if they afford the best practical adaptation measure to species at risk of climate change. e. Where necessary develop management actions to maintain or improve the conservation status of species threatened by climate change, e.g. through SPS action plans.	Facilitate a program of work with SCAR, SC-CAMLR, ACAP and IUCN to provide regular update reports on the status of Antarctic species. 2018 ICED conference on Marine Ecosystem Assessment for the Southern Ocean. 2017 Krill Symposium in St Andrews.	Request further information from SCAR and other programs as available, including on the development of work on the application of IUCN red list criteria.

[1] Note that the IUCN criteria cover many aspects besides climate change, and does not necessarily identify the effects solely due to climate change. The benefit of using IUCN criteria in our response to climate change will be assessed prior to its use.

(continued)

Table 3 (continued)

Climate-related issue	Gaps/needs/key questions	Action/Task	Relevant CEP/SCAR/other activities	CCAMLR interest/involvement
7) Marine habitats at risk due to climate change	• Understand habitat status, trends, vulnerability and distribution. • Improved understanding of the effects of climate change on habitat, e.g. sea-ice extent and duration. • Improved understanding of potential expansion of human presence in Antarctica as a result of changes resulting from climate change through e.g. changes in sea-ice distribution; collapse of ice shelves.	**a. Encourage research by national programs, SCAR and other programs.** b. Review and revise where necessary existing management tools to consider if they afford the best practical adaptation measure to habitats at risk of climate change.	CEP to encourage national programs and SCAR to support and facilitate new and ongoing research activities. Update reports to be provided, incl. through the Environments Portal. 2017 proposed ICED Workshop on projections of change.	Request further information from SCAR and other programs as available, recognising existing relevant objectives and ongoing work by ICED (see WG-EMM-16/22).

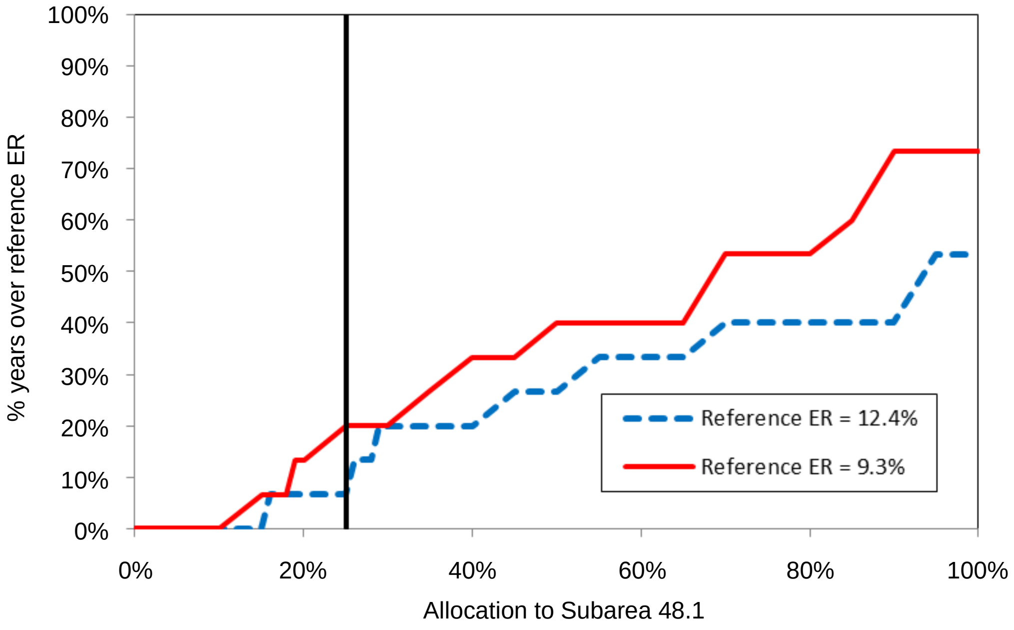

Figure 1: Potential risk of exceeding a precautionary, reference exploitation rate (ER) in Subarea 48.1 given observed variability in krill biomass (using acoustic data from the US AMLR Program) and catch limits set to fixed percentages of the trigger limit. The vertical line at 25% on the x-axis indicates the percentage of the trigger limit currently allocated to Subarea 48.1 in CM 51-07. Two reference exploitation rates are considered: 9.3% is equal to the precautionary catch limit for krill (as established in CM 51-01) divided by the estimate of krill biomass from the CCAMLR-2000 Survey; 12.4% is equal to the precautionary catch limit divided by 0.75 times the CCAMLR-2000 Survey estimate.

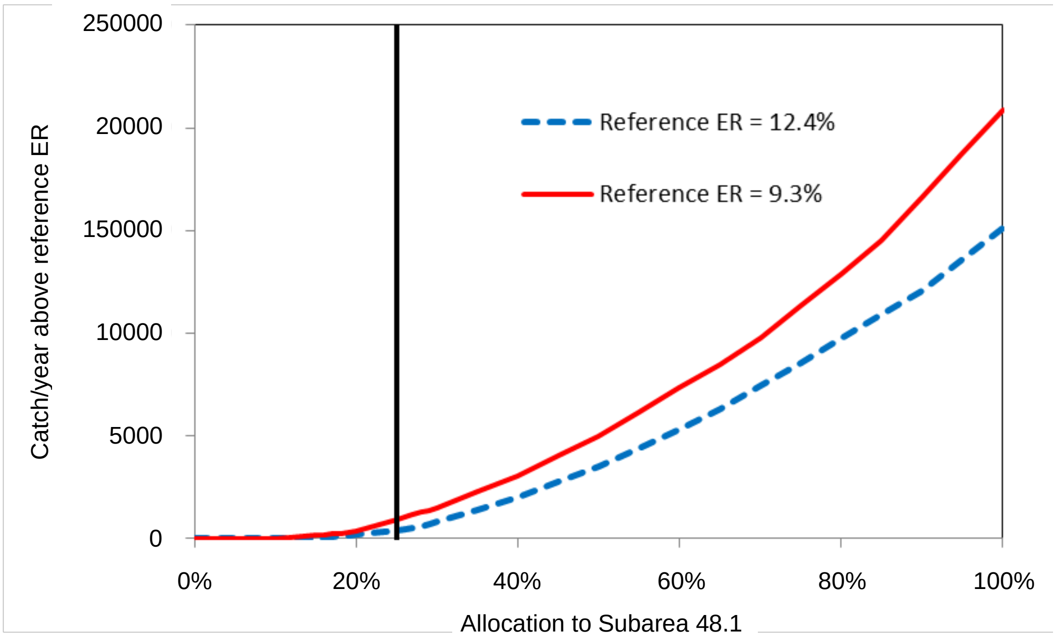

Figure 2: Potential average ‘excess’ catch during years when the exploitation rate (ER) in Subarea 48.1 might have been greater than the reference exploitation rates of 9.3% and 12.4%. The excess catch is the average amount by which the subarea catch limit would have exceeded the catch implied by one of the reference exploitation rates (e.g. 155 000 tonnes in the case of 9.3%). The vertical line at 25% on the x-axis indicates the percentage of the trigger limit currently allocated to Subarea 48.1 in CM 51-07.

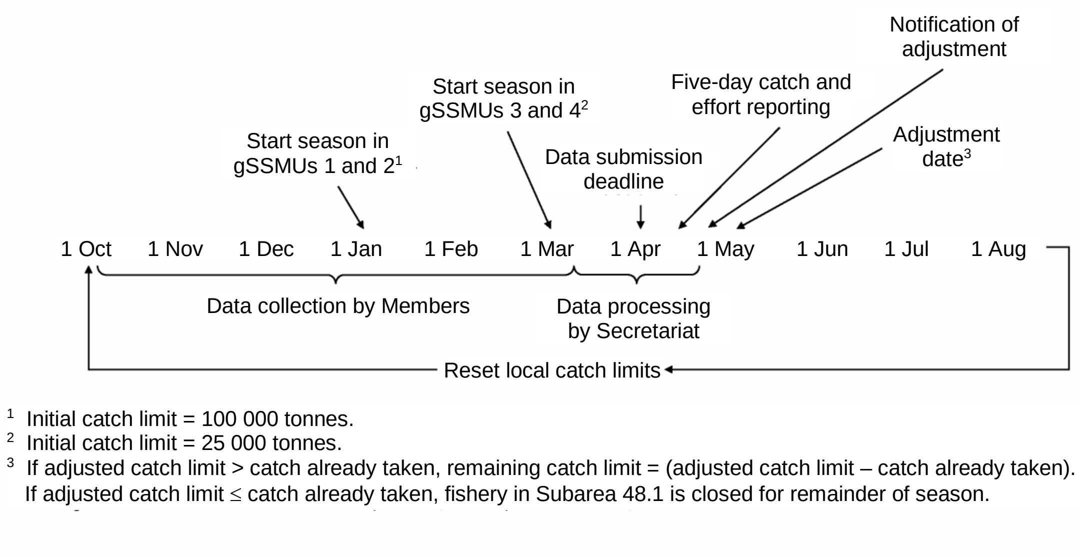

Figure 3: A timeline for implementation of a proposed feedback management strategy in Subarea 48.1, detailing when particular actions would need to take place each year.

Appendix A

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(Bologna, Italy, 4 to 15 July 2016)

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Appendix B

Agenda

Working Group on Ecosystem Monitoring and Management
(Bologna, Italy, 4 to 15 July 2016)

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 Fishing activities (updates and data)
    2.2 Scientific observation
    2.3 Krill biology, ecology and ecosystem interactions
        2.3.1 Krill
        2.3.2 Ecosystem monitoring and observation
        2.3.3 Ecosystem interactions: predators
        2.3.4 Ecosystem observation and interactions: cetaceans

    2.4 CEMP and WG-EMM STAPP
        2.4.1 CEMP data
        2.4.2 Predator consumption
        2.4.3 Predator trends and dynamics

    2.5 Integrated assessment model
    2.6 Fishing vessel surveys
    2.7 Feedback management strategy
        2.7.1 Stage 1
        2.7.2 Stage 1–2 Subarea 48.1
        2.7.3 Stage 1–2 Subarea 48.2

3. Spatial management

    3.1 Marine protected areas (MPAs)
        3.1.1 Weddell Sea
        3.1.2 Domain 1
        3.1.3 South Orkney Islands
        3.1.4 Crozet Island (French EEZ)
        3.1.5 Ross Sea krill research zone

    3.2 General issues for spatial management
    3.3 Vulnerable marine ecosystems (VMEs)

4. Forum 'Ross Sea Ecosystem'

5. Advice to the Scientific Committee and its working groups

6. Future work
   6.1 CCAMLR–IWC
   6.2 ICED
   6.3 Joint CEP–SC-CAMLR Workshop
   6.4 Krill Workshop
   6.5 SC-CAMLR climate change work

7. Other business

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

Appendix C

List of Documents

Working Group on Ecosystem Monitoring and Management
(Bologna, Italy, 4 to 15 July 2016)

WG-EMM-16/01	Scientific background document in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica) – Version 2016 – Part A: General context of the establishment of MPAs and background information on the Weddell Sea MPA planning area K. Teschke, D. Beaver, M.N. Bester, A. Bombosch, H. Bornemann, A. Brandt, P. Brtnik, C. de Broyer, E. Burkhardt, B. Danis, G. Dieckmann, L. Douglass, H. Flores, D. Gerdes, H.J. Griffiths, J. Gutt, S. Hain, J. Hauck, H. Hellmer, H. Herata, M. Hoppema, E. Isla, K. Jerosch, S. Kaiser, P. Koubbi, K.-H. Kock, R. Krause, G. Kuhn, P. Lemke, A. Liebschner, K. Linse, H. Miller, K. Mintenbeck, U. Nixdorf, H. Pehlke, A. Post, M. Schröder, K.V. Shust, S. Schwegmann, V. Siegel, V. Strass, K. Thomisch, R. Timmermann, P.N. Trathan, A. van de Putte, J. van Franeker, I.C. van Opzeeland, H. von Nordheim and T. Brey
WG-EMM-16/02	Scientific background document in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica) – Version 2016 – 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-16/03	Scientific background document in support of the development of a CCAMLR MPA in the Weddell Sea (Antarctica) – Version 2016 – Part C: Data analysis and MPA scenario development K. Teschke, H. Pehlke, M. Deininger and T. Brey on behalf of the German Weddell Sea MPA project team
WG-EMM-16/04	Quantifying the escape mortality of trawl caught Antarctic krill (*Euphausia superba*) B.A. Krafft, L.A. Krag, A. Engås, S. Nordrum, I. Bruheim and B. Herrmann
WG-EMM-16/05	Reporting procedures for the continuous fishing method O.R. Godø and T. Knutsen
WG-EMM-16/06	Use of net cable in monitoring trawl and marine organisms during operations O.R. Godø

WG-EMM-16/07	Draft: Krill Fishery Report 2016 Secretariat
WG-EMM-16/08	CEMP data inventory and summary analysis Secretariat
WG-EMM-16/09	A spatial analysis of CEMP data in Area 48 to support work on feedback management in the krill fishery Secretariat
WG-EMM-16/10	An initial examination of using CPUE as a fishery performance index for the krill fishery Secretariat
WG-EMM-16/11	Observer coverage in CCAMLR krill fisheries from 2011 to 2015 Secretariat
WG-EMM-16/12	Plans for the Joint SC-CAMLR and SC-IWC Workshop 2017–2018 S. Kawaguchi and T. Kitakado (Co-conveners of the Joint SC-CAMLR and SC-IWC Workshop)
WG-EMM-16/13 Rev. 1	Preliminary report on SO-AntEco (South Orkneys – State of the Antarctic Ecosystem) benthic survey (JR15005) around the South Orkney Plateau (February–March 2016) H. Griffiths, S. Grant, K. Linse, P. Trathan and the SO-AntEco scientific team
WG-EMM-16/14	Report on the Second SCAR Retrospective Analysis of Antarctic Tracking Data Workshop Delegation of the United Kingdom
WG-EMM-16/15	High-resolution ocean modelling of the South Georgia and South Orkney Islands regions E. Young, E. Murphy and P. Trathan
WG-EMM-16/16	Start date of the CCAMLR fishing season for Antarctic krill P. Trathan and S. Hill
WG-EMM-16/17	Spatial aggregation of harvesting in Subarea 48.1, in particular during the summer and close to the coast P. Trathan and S. Hill
WG-EMM-16/18	Possible options for the future management of the Antarctic krill fishery in Subarea 48.2 P. Trathan, O.R. Godø and S. Hill

WG-EMM-16/19	Preliminary report on the South Orkneys Ecosystem Studies (SOES) field work undertaken by RRS *James Clark Ross* (JR15004) and associated field camps in January–February 2016 J. Watkins, O.R. Godø, S. Fielding, C. Reiss, P. Trathan and E. Murphy
WG-EMM-16/20	A first assessment of marine Important Bird and Biodiversity Areas for penguins in Subarea 48.1 (Antarctic Peninsula, and South Shetland Islands) and Subarea 48.2 (South Orkney Islands) K. Lorenz, C. Harris, B. Lascelles, M. Dias and P. Trathan
WG-EMM-16/21	Is current management of the Antarctic krill fishery in the Atlantic sector of the Southern Ocean precautionary? S. Hill, A. Atkinson, C. Darby, S. Fielding, B. Krafft, O.R. Godø, G. Skaret, P. Trathan and J. Watkins
WG-EMM-16/22	Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme: developing links between ICED and CCAMLR E. Murphy, R. Cavanagh, N. Johnston, E. Hofmann and A. Constable
WG-EMM-16/23	Classification of Southern Ocean krill and icefish echoes using Random Forests N. Fallon, S. Fielding and P. Fernandes
WG-EMM-16/24	By-catch of morid cods (Gadiformes: Moridae) in the CCAMLR area and adjacent areas during commercial fishing and research surveys Delegation of the Russian Federation
WG-EMM-16/25	Lipid metabolism features of Antarctic toothfish *Dissostichus mawsoni* (Nototheniidae) I.I. Gordeev, D.V. Mikryakov, N.I. Silkina and A.S. Sokolova
WG-EMM-16/26	Temporal changes in sighting density indices of baleen whales in CCAMLR Subareas 48.1 and 48.2 based on three circumpolar sighting surveys L.A. Pastene and T. Hakamada
WG-EMM-16/27	Establishing time-limited Special Areas for Scientific Study in newly exposed marine areas following ice shelf retreat or collapse in Subarea 48.1, Subarea 48.5 and Subarea 88.3 – Clarifications and options to further develop the 2015 proposal S. Grant and P. Trathan

WG-EMM-16/28	Using predators and their prey to characterise the status of the marine ecosystem at South Georgia P. Trathan, S. Fielding, S. Hill, M. Belchier and J. Forcada
WG-EMM-16/29	Monitoring variability and change in the plankton communities of the Scotia Sea through Continuous Plankton Recorder surveys G.A. Tarling, M.Z. Wootton, D.G. Johns, T.D. Jonas, E.J. Murphy and P. Ward
WG-EMM-16/30	Co-conveners' report of the Joint CEP–SC-CAMLR Workshop on Climate Change and Monitoring – Introduction for WG-EMM-16 S. Grant and P. Penhale (Co-conveners of the Joint CEP–SC-CAMLR Workshop)
WG-EMM-16/31	Diet composition of Antarctic toothfish caught in Divisions 58.4.1 and 58.4.2 in 2014/15 inferred from fatty acid stable isotope analyses Delegation of the Republic of Korea
WG-EMM-16/32	Microbial study of toothfish tissue in Divisions 58.4.1 in 2014/15 Delegation of the Republic of Korea
WG-EMM-16/33	Metabarcoding analysis of zooplankton collected from Division 58.4.1 in 2014/15 using NGS platform Delegation of the Republic of Korea
WG-EMM-16/34	Third International Symposium on Krill Secretariat
WG-EMM-16/35	Identification of important benthic areas for conservation – using shared data from the Domain 1 MPA planning process M. Bristow, S. Grant, M. Santos and A. Capurro
WG-EMM-16/36	Southern Ocean Network of Acoustics (SONA): Report on Acoustic Processing and Methods Workshop, Vigo, 24 and 25 April 2016 S. Fielding, J. Thomas, C. Anderson, A. Conchon, A. Cossio, A. Dunford, P. Escobar-Flores, J. Horne, T. Jarvis, R. Kloser and T. Ryan
WG-EMM-16/37	A bioenergetics model assessment of the prey consumption of macaroni penguins in Subarea 48.3 P.N. Trathan, L. Emmerson, C. Southwell and C. Waluda
WG-EMM-16/38	A condensed history and document of the method used by CCAMLR to estimate krill biomass (B_0) in 2010 S. Fielding, A. Cossio, M. Cox, C. Reiss, G. Skaret, D. Demer, J. Watkins and X. Zhao

WG-EMM-16/39	Some aspects of spatial–temporal variability of hydrodynamic water circulation and krill distribution in the Scotia Sea S.M. Kasatkina and V.N. Shnar
WG-EMM-16/40	Integrated analysis of the krill fishery in Area 48 (2006–2015) S. Kasatkina, P. Gasyukov and L. Boronina
WG-EMM-16/41	Analysis of the krill spatial distribution characteristics as the important factor in fishery management in Area 48 (report of the CCAMLR scholarship recipient) S.M. Kasatkina and A. Sytov
WG-EMM-16/42	Atlas of top predators from French Southern Territories in the southern Indian Ocean K. Delord, C. Barbraud, C.-A. Bost, Y. Cherel, C. Guinet and H. Weimerskirch
WG-EMM-16/43	Ecoregionalisation of the Kerguelen and Crozet Islands oceanic zone. Part I: Introduction and Kerguelen oceanic zone P. Koubbi, C. Guinet, N. Alloncle, N. Ameziane, C.S. Azam, A. Baudena, C.A. Bost, R. Causse, C. Chazeau, G. Coste, C. Cotté, F. D'Ovidio, K. Delord, G. Duhamel, A. Forget, N. Gasco, M. Hautecœur, P. Lehodey, C. Lo Monaco, C. Marteau, A. Martin, C. Mignard, P. Pruvost, T. Saucède, R. Sinegre, T. Thellier, A.G. Verdier and H. Weimerskirch
WG-EMM-16/44	Background papers considered relevant to the WG-EMM discussions on feedback management Delegation of the United Kingdom
WG-EMM-16/45	Background information to support development of a feedback management strategy for the krill fishery in Subarea 48.1 Antarctic Ecosystem Research Division, Southwest Fisheries Science Center and NOAA Fisheries
WG-EMM-16/46	Downward adjustments to local catch limits for the krill fishery in Subarea 48.1 Antarctic Ecosystem Research Division, Southwest Fisheries Science Center and NOAA Fisheries
WG-EMM-16/47	Upward adjustments to local catch limits for the krill fishery in Subarea 48.1 Antarctic Ecosystem Research Division, Southwest Fisheries Science Center and NOAA Fisheries
WG-EMM-16/48	A feedback management strategy for the krill fishery in Subarea 48.1 G.M. Watters, J.T. Hinke and C.S. Reiss

WG-EMM-16/49	A brief review of information relevant to the establishment of a Krill Research Zone within the proposed Ross Sea Region Marine Protected Area E.S. Klein and G.M. Watters
WG-EMM-16/50	Population status of Ross Sea killer whales (*Orcinus orca*, Type C) in McMurdo Sound, Antarctica, based on photo-identification studies R. Pitman, H. Fearnbach and J.W. Durban
WG-EMM-16/51	Density and geographical distribution of krill larvae on the Weddell–Scotia Confluence region during summer 2011 E. Rombolá, C. Franzosi, G. Tossonotto, V. Alder and E. Marschoff
WG-EMM-16/52	Spatio–temporal dynamics of Antarctic krill fishery: identification of fishing hotspots F. Santa Cruz, B. Ernst and J.A. Arata
WG-EMM-16/53	Preliminary modelling of potential climate-change impacts on krill and a krill-dependent predator in CCAMLR Subareas 48.1 to 48.3 E.S. Klein, S.L. Hill, G.M. Watters and J.T. Hinke
WG-EMM-16/54	Ecoregionalisation of the Kerguelen and Crozet Islands oceanic zone. Part II: The Crozet oceanic zone P. Koubbi, C. Mignard, R. Causse, O. Da Silva, A. Baudena, C. Bost, C. Cotté, F. D'Ovidio, A. Della Penna, K. Delord, S. Fabri-Ruiz, M. Ferrieux, C. Guinet, C. Lo Monaco, T. Saucède and H. Weimerskirch
WG-EMM-16/55	CEMP camera installations by Ukraine at the Galindez, Petermann and Yalour Islands penguin colonies as a part of CEMP Fund project ‘Establishing a CEMP camera network in Subarea 48.1’ Delegation of Ukraine
WG-EMM-16/56	On interim distribution of the trigger level in the fishery for *Euphausia superba* in Statistical Subareas 48.1, 48.2, 48.3 and 48.4 G. Milinevskyi and K. Demianenko
WG-EMM-16/57	The proposal of Availability Index to summarise the availability of harvested resources K. Demianenko and G. Milinevskyi

WG-EMM-16/58	Progress report of the CEMP camera network in Subarea 48.1 J. Hinke, G. Watters, M. Santos, M. Korczak-Abshire, G. Milinevsky, A. Barbos, C. Southwell and L. Emmerson
WG-EMM-16/59	The effect of abiotic factors on the reproduction of seabirds on the Argentine Islands I.V. Dykyy
WG-EMM-16/60	Biomass of Antarctic krill around South Shetland using 2-dB difference method in April 2016 Delegation of the Republic of Korea
WG-EMM-16/61	A study on calibration for commercial echosounder using the bottom backscattering strength from a fishing vessel near the South Shetland Islands in Antarctic Delegation of the Republic of Korea
WG-EMM-16/62	Report on the monitoring program of chinstrap and gentoo penguins at Narębski Point (ASPA No. 171), King George Island, since 2006 Delegation of the Republic of Korea
WG-EMM-16/63	Proposed amendments to Conservation Measure 51-06 (2014) General measure for scientific observation in fisheries for *Euphausia superba* K. Demianenko, L. Pshenichnov and G. Milinevskyi
WG-EMM-16/64	Cetaceans as indicators of historical and current changes in the East Antarctica ecosystem Y. Fujise and L.A. Pastene
WG-EMM-16/65	Krill consumption by Adélie penguins in CCAMLR Divisions 58.4.1 and 58.4.2 C. Southwell and L. Emmerson
WG-EMM-16/66	Krill consumption by crabeater seals in CCAMLR Divisions 58.4.1 and 58.4.2 C. Southwell, J. Forcada, L. Emmerson, A. Constable, S. Kawaguchi and P. Trathan
WG-EMM-16/67	Current work towards estimating krill consumption by flying seabirds in CCAMLR Divisions 58.4.1 and 58.4.2 L. Emmerson and C. Southwell
WG-EMM-16/68	Progress by WG-EMM-STAPP in estimating krill consumption by air-breathing predators within CCAMLR areas C. Southwell and P. Trathan

WG-EMM-16/69	A method for spreading the risk of localised effects of catches of Antarctic krill up to the trigger level, during the development of stage 2 of feedback management A.J. Constable, S. Kawaguchi and M. Sumner
WG-EMM-16/70	An introduction to the Southern Ocean Observing System (Paper XP18 to CEP–SC-CAMLR Workshop 2016) A.J. Constable, L. Newmman, O. Schofield, A. Wahlin and S. Swart
WG-EMM-16/71	SC-CAMLR work on Climate Change (Paper XP19 to CEP–SC-CAMLR Workshop 2016) A. Constable
WG-EMM-16/72 Rev. 1	Summary of notifications for krill fisheries in 2016/17 Secretariat
WG-EMM-16/73	Domain 1 MPA designation process: data sharing and future enhanced work M. Santos, A. Capurro and C.A. Cárdenas
WG-EMM-16/74	Using data recorded during commercial krill fishing in feedback management O.R. Godø, G. Skaret and E. Niklitschek
WG-EMM-16/75	Multiyear changes in distribution and abundance of *Salpa thompsoni* in the Western Antarctic Peninsula region A. Panasiuk, A. Słomska, J. Wawrzynek, M. Konik and A. Weydmann
WG-EMM-16/76	Acoustic monitoring and evaluation of krill in the Antarctic ecosystem Bransfield Strait and around Elephant Island during ANTAR XXI and XXII, aboard RV *Humboldt*, Peru R. Cornejo, M. Flores and J. Zuzunaga

Other Documents

WG-EMM-16/P01	Vast assembly of vocal marine mammals from diverse species on fish spawning ground D. Wang, H. Garcia, W. Huang, D.D. Tran, A.D. Jain, D.H. Yi, Z. Gong, J.M. Jech, O.R. Godø, N.C. Makris and P. Ratilal *Nature*, 531 (2016), doi: 10.1038/nature16960

WG-EMM-16/P02	Detection of growth zones in the eyestalk of the Antarctic krill *Euphausia superba* (Dana, 1852) (Euphausiacea) B.A. Krafft, M. Kvalsund, G. Søvik, E. Farestveit and A.-L. Agnalt *J. Crust. Biol*., 36 (3) (2016): 267–273, doi: 10.1163/1937240X-00002428
WG-EMM-16/P03	South Orkney Island 2016 Antarctic krill and ecosystem monitoring B.A. Krafft, G. Skaret, L.A. Krag, T. Rustand and R. Pedersen Institute of Marine Research Report, 20 (2016): www.imr.no/filarkiv/2016/05/antarctic_krill_survey_at_south_orkney_islands_2016.pdf/nb-no
WG-EMM-16/P04	Growth and shrinkage in Antarctic krill *Euphausia superba* is sex-dependent G. Tarling, S. Hill, H. Peat, S. Fielding, C. Reiss and A. Atkinson *Mar. Ecol. Prog. Ser*., 547 (2016): 61–78
WG-EMM-16/P05	Parasites of the Antarctic toothfish (*Dissostichus mawsoni* Norman, 1937) (Perciformes, Nototheniidae) in the Pacific sector of the Antarctic I.I. Gordeev and S.G. Sokolov *Polar Res*., 35 (2016): 29364, http://dx.doi.org/10.3402/polar.v35.29364
WG-EMM-16/P06	Southern right whale (*Eubalaena australis*) reproductive success is influenced by krill (*Euphausia superba*) density and climate E. Seyboth, K.R. Groch, L. Dalla Rosa, K. Reid, P.A.C. Flores and E.R. Secchi *Sci. Rep*., 6 (2016): 28205, doi: 10.1038/srep28205
WG-EMM-16/P07	Population trends and reproductive success at a frequently visited penguin colony on the western Antarctic Peninsula H.J. Lynch, W.F. Fagan and R. Naveen *Polar Biol*., 33 (2010): 493–503, doi: 10.1007/s00300-009-0726-y
WG-EMM-16/P08	Mapping Application for Penguin Populations and Projected Dynamics (MAPPPD): Data and tools for dynamic management and decision support G.R.W. Humphries, C. Che-Castaldo, R. Naveen, M. Schwaller, P. McDowall, M. Schrimpf and H.J. Lynch *Polar Rec*. (in review)

WG-EMM-16/P09	Linking population trends of Antarctic shag (*Phalacrocorax bransfieldensis*) and fish at Nelson Island, South Shetland Islands (Antarctica) R. Casaux and E. Barrera-Oro *Polar Biol*., (2015), doi: 10.1007/s00300-015-1850-5
WG-EMM-16/P10	A bioenergetics model for estimating prey consumption by an Adélie penguin population in east Antarctica D. Southwell, L. Emmerson, J. Forcada and C. Southwell *Mar. Ecol. Prog. Ser*., 526 (2015): 183–197, doi: 10.103354/meps11182
WG-EMM-16/P11	Developing priority variables ("ecosystem Essential Ocean Variables" – eEOVs) for observing dynamics and change in Southern Ocean ecosystems A.J. Constable, D.P. Costa, O. Schofield, L. Newman, E.R. Urban Jr., E.A. Fulton, J. Melbourne-Thomas, T. Ballerini, P.W. Boyd, A. Brandt, W. de la Mare, M. Edwards, M. Eléaume, L. Emmerson, K. Fennel, S. Fielding, H. Griffiths, J. Gutt, M.A. Hindell, E.E. Hofmann, S. Jennings, H.S. La, A. McCurdy, B.G. Mitchell, T. Moltmann, M. Muelbert, E. Murphy, T. Press, B. Raymond, K. Reid, C. Reiss, J. Rice, I. Salter, D.C. Smith, S. Song, C. Southwell, K.M. Swadling, A. Van de Putte and Z. Willis *J. Mar. Sys*., 161 (2016): 26–41
WG-EMM-16/P12	Distribution, density and relative abundance of Antarctic krill estimated by maximum likelihood geostatistics on acoustic data collected during commercial fishing operations E.J. Niklitschek and G. Skaret *Fish. Res*., 178 (2016): 114–121, http://dx.doi.org/10.1016/j.fishres.2015.09.017 0165-7836
WG-EMM-16/P13	Demographic effects of extreme weather events: snow storms, breeding success, and population growth rate in a long-lived Antarctic seabird S. Descamps, A. Tarroux, Ø. Varpe, N.G. Yoccoz, T. Tveraa and S.-H. Lorentsen *Ecology and Evolution*, (2014), doi: 10.1002/ece3.1357
WG-EMM-16/P14	Large-scale oceanographic fluctuations drive Antarctic petrel survival and reproduction S. Descamps, A. Tarroux, S.-H. Lorentsen, O.P. Love, Ø. Varpe and N.G. Yoccoz *Ecography*, 39 (2016): 496–505, doi: 10.1111/ecog.01659

WG-EMM-16/P15	At-sea distribution and prey selection of Antarctic petrels and commercial fisheries S. Descamps, A. Tarroux, Y. Cherel, K. Delord, O.R. Godø, A. Kato, B.A. Krafft, S.-H. Lorentsen, Y. Ropert-Coudert, G. Skaret and Ø. Varpe *PLoS ONE* (2016) (in press)
WG-EMM-16/P16	Size and stage composition of age class 0 Antarctic krill (*Euphausia superba*) in the ice-water interface layer during winter/early spring F. Schaafsma, C. David, E. Pakhomov, B. Hunt, B. Lange, H. Flores, J.A. van Franeker *Polar Biol*., (2016), doi: 10.1007/s00300-015-1877-7
WG-SAM-16/36 Rev. 1	The integrated krill assessment model for Subarea 48.1 with future catches meeting alternative decision rules D. Kinzey, G.M. Watters and C.S. Reiss
WG-SAM-16/37	Independent peer review of an integrated stock assessment model for Antarctic krill (*Euphausia superba*) conducted by the Center for Independent Experts J. Rusin, D. Kinzey and G. Watters
WG-SAM-16/38	Preliminary results of a dedicated cetacean sighting vessel-based krill survey in East Antarctica (115°–130°E) during the 2015/16 austral summer season K. Matsuoka, A. Wada, T. Isoda, T. Mogoe and L.A. Pastene
WG-SAM-16/39	Using effective sample sizes to evaluate the efficiency of length samples collected by at-sea observers in the krill fishery in Subarea 48.1 N. Kelly, S. Kawaguchi, P. Ziegler and D. Welsford

Recommendations to the Conservation Measure 51-07 WG-EMM review e-group in respect of initial risk assessments to review Conservation Measure 51-07

1. The Working Group recommended that the Conservation Measure 51-07 WG-EMM review e-group provide guidance to Members conducting initial risk assessments to review CM 51-07, on all issues identified in this appendix. The e-group should also provide guidance on issues identified in paragraph 2.234.

2. The Working Group also recommended that Members conducting initial risk assessments for consideration at the 2016 meeting of WG-FSA prioritise two points:

(i) the assembly of data layers contributing to the factors describing spatial patterns for krill, predators and the fishery based on available data as follows:

(a) use the 'factors', 'quantities', datasets and scaling parameters identified in WG-EMM-16/69 as a starting point for their work

(b) evaluate scenarios with fishing patterns indexed from data collected or reported during the most recent three years (this would be considered the current fishing pattern), data collected or reported during 10-year periods prior to the current fishing pattern (these would be considered historical fishing patterns), and projections of how the fishing pattern may change over the coming five years

(c) consider historical fishing patterns that are indexed by the maximum value of fishing effort or catch achieved within each spatial unit over the time period examined in the risk assessment

(d) consider the spatial density of fishing operations, as indicated by separate analyses of haul-by-haul data, to define both the historical and current fishing patterns

(e) consider using the relative importance of each spatial unit to the reproductive performance of krill throughout Area 48 as a 'factor' in the risk assessment

(f) consider indexing the values of spatial units as sources or sinks for krill using information from particle-tracking studies

(g) consider the use of krill habitat variables such as those described by Silk et al. (2016) and a 'factor' that indexes primary production (e.g. using satellite data)

(h) consider using predator occupancy data (e.g. data derived from at-sea observations or predator-tracking studies) if estimates of predator demand are found to be unsuitable

(ii) the development of means of communication and use of language that is clear and understandable at the commission level.

Reference

Silk, J.R.D., S.E. Thorpe, S. Fielding, E.J. Murphy, P.N. Trathan, J.L. Watkins and S.L. Hill. 2016. Environmental correlates of Antarctic krill distribution in the Scotia Sea and southern Drake Passage. *ICES J. Mar. Sci.*, doi:10.1093/icesjms/fsw097.

Appendix E

Details of how the US AMLR Program has addressed the advice from WG-EMM-15 in relation to the feedback management (FBM) approach for Subarea 48.1

(G. Watters, C. Reiss, J. Hinke, M. Goebel, E. Klein, A. Dahood and D. Krause)

1. In order to help progress future work related to the proposed feedback management (FBM) approach for Subarea 48.1, representatives from the US AMLR program developed the following tables describing how they had addressed the extensive advice from WG-EMM-15 (Table 1) and a list describing how CCAMLR could address advice provided by WG-EMM-15 and WG-EMM-16 (Table 2) (see paragraph 2.281).

Table 1: Progress in addressing advice from WG-EMM-15, this table includes references to papers submitted to WG-EMM-16 or elsewhere; some references include a 'V' to indicate individual 'vignettes' within those papers.

Advice from WG-EMM-15	Issue	Progress and notes	Papers submitted to WG-EMM-16 or elsewhere
Table 2 – Estimation of base catch limit	The integrated model and its diagnostics to be reviewed by WG-SAM.	Diagnostics reviewed by WG-FSA-15 and model reviewed by WG-SAM-16. Model is not currently considered suitable to provide advice. The stage 2 proposal in WG-EMM-16/48 does not require catch limits to be estimated from an integrated model. Rather, the proposal in WG-EMM-16/48 can be adapted to use catch limits estimated from an integrated model when those estimates become available.	WG-SAM-16/36 Rev. 1, WG-SAM-16/37
	Revise decision rules for krill.	Alternative approaches to estimate the reference biomass used in decision rules for krill have been presented to WG-EMM-15 and WG-SAM-16. Discussion on this issue has been limited and neither working group has agreed to revise the reference biomass. The stage 2 proposal in WG-EMM-16/48 does not require catch limits to be estimated from an integrated model. Rather, the proposal in WG-EMM-16/48 can be adapted to use catch limits estimated from an integrated model when those estimates become available.	WG-SAM-16/36 Rev.1, WG-SAM-16/37

(continued)

Table 1 (continued)

Advice from WG-EMM-15	Issue	Progress and notes	Papers submitted to WG-EMM-16 or elsewhere
	Identify data required from the krill fishery (e.g. standardised acoustic transects and net hauls).	SG-ASAM provided guidance on standard transects for Subarea 48.1 in 2015 (SC-CAMLR-XXXIV, Annex 4, Figure 1). WG-EMM-16/48 identified additional candidate transects near Anvers Island, Joinville Island and in the Gerlache Strait for gSSMU 4. Transects for the Antarctic Peninsula Pelagic Area SSMU are also proposed in WG-EMM-16/48. The stage 2 proposal in WG-EMM-16/48 does not require that echosounders on fishing vessels be calibrated if those vessels repeat surveys in a standardised fashion.	WG-EMM 16/47 V2, WG-EMM-16/48
	Integration of additional data available for assessment (e.g. krill length-frequency data from CEMP).	Contingent on progress on the development of the integrated model.	
Table 2 – Decision rule to adjust catches up from the base	Design acoustic surveys to be undertaken by fishing vessels.	WG-EMM-16/47 V2 demonstrated how repeat surveys on standardised transects could provide biomass indices necessary to determine local biomass trends of krill.	WG-EMM-16/47 V2
	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).	WG-EMM-16/47 V1 provided an analysis of CEMP datasets derived from penguin and fur seal studies in Subarea 48.1. Identification of red or green light conditions is informed by a threshold value of standardised predator performance that is determined from a meta-analysis of CEMP parameters provided in WG-EMM-16/45 V7.	WG-EMM-16/45 V7, WG-EMM-16/47 V1
	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).	WG-EMM-16/47 V2 provided an analysis of the use of simple ratios of biomass that are estimated from surveys, on standardised transects that are repeated during the course of the fishery.	WG-EMM-16/47 V2
	Evaluation of decision rule.	WG-EMM-16/47 V3 provided an evaluation of a decision rule to adjust catches up. Retrospective analyses of historical data in Subarea 48.1 suggest that ‘adjust up’ conditions would have occurred roughly 33% of the time.	WG-EMM-16/47 V3

(continued)

Table 1 (continued)

Advice from WG-EMM-15	Issue	Progress and notes	Papers submitted to WG-EMM-16 or elsewhere
Table 2 – Decision rule to adjust catches down from the base	Identify appropriate groups of SSMUs from penguin tracking data.	WG-EMM-16/45 V1 provided justification for four candidate SSMU groupings.	WG-EMM-16/45 V1
	Determine default 'allocation factors' for groups of SSMUs.	Several candidate allocation fractions have been identified. WG-EMM-16/45 V8 provided three candidate options. WG-EMM-16/48 also identified a 'default' static allocation but suggested that an assessment-based allocation for the four groups of SSMUs would ultimately be preferable.	WG-EMM-16/45 V8, WG-EMM-16/48
	Parameterise species-specific decision rules for adjusting catch on the basis of fledging mass and age at crèche.	A decision rule for adjusting catches down has been proposed in WG-EMM-16/46 V6. The rule is based on age-at crèche and is not species specific. Rather, the rule proposed to use the minimum standardised mean age at crèche across all species considered to adjust catches. The analysis that used to support age at crèche as the primary indicator is provided in WG-EMM-16/46 V2.	WG-EMM-16/46 V2, WG-EMM-16/46 V6
	Evaluation of decision rule.	WG-EMM-16/46 V4 provided an evaluation of a decision rule to adjust catches down. Retrospective analyses of historical data in Subarea 48.1 suggest that 'adjust down' conditions would have occurred roughly 30−40% of the time.	WG-EMM-16/46 V4
Paragraphs 2.140(i–iii), 2.160(i), 2.161(v)(f)	Consider krill flux, including the implications of krill behaviour, and evaluate krill biomass relationships between SSMUs.	Circulation within Subarea 48.1 was considered using drifter data and particle transport simulations from a ROMS. The krill fishery appears to target krill that occur in retentive areas, and foraging predators overlap with the krill fishery therein. Comparison of Palmer LTER and US AMLR time-series data on krill indicate coherent variation in krill abundance throughout Subarea 48.1, suggesting that sources of krill within the subarea will not always provide abundant krill to replace those that die in the retentive areas. Krill generally tend to migrate towards the coast in winter.	WG-EMM-16/45 V2, WG-EMM-16/47 V2

(continued)

Table 1 (continued)

Advice from WG-EMM-15	Issue	Progress and notes	Papers submitted to WG-EMM-16 or elsewhere
Paragraphs 2.147, 2.160(i), 2.161(iii)	Evaluate CPUE in relation to krill density, including whether SSMU-scale krill surveys indicate the proportion of krill vulnerable to the fishery. Assess whether CPUE is useful for quantifying variability and trends in SSMU-scale krill biomass.	Nominal CPUEs of the krill fishery have been compared to local biomass estimates from surveys conducted by the US AMLR Program. Clear relationships between nominal CPUE and research survey biomass estimates were not identified. Given the completely uncoordinated 'sampling designs' by the fishery and the US AMLR Program, it seems that substantially more complicated methods (e.g. an integrated assessment model) are needed to link fishery data to data from research cruises. Available data do indicate, however, that research vessels generally catch krill over a wider range of sizes than are caught by the fishery, with smaller krill more likely to be caught during research surveys.	WG-EMM-16/45 V3
Paragraph 2.152(i)	Develop indicator of fishery performance using sea-ice imagery.	Analyses of sea-ice imagery and fishing activities in Subarea 48.1 indicate that fishing activities are reduced when sea-ice coverage reaches about 30% and may be stopped altogether when coverage reaches about 50%. Retrospective analyses of the decision rules proposed in WG-EMM-16/48 indicate that sea-ice coverage will mediate the amount of krill that is ultimately taken by the fishery when a stage 2 strategy is implemented in Subarea 48.1. Note also that, inter alia, sea-ice coverage was considered as a component of a fishery-specific 'availability index' proposed in WG-EMM-16/57, and the Working Group considered this index in the context of discussions on CM 51-07.	WG-EMM-16/45 V4, WG-EMM-16/48
Paragraphs 2.137(iv), 2.160(iii), 2.161(v)(a)	Examine predator–fishery overlap at different temporal and spatial scales.	Predator-tracking and fishery data indicate overlap at a range of temporal and spatial scales. In general, overlap increases with increasing temporal and spatial scale. Tracking data from two CEMP sites in the South Shetland Islands indicate particularly high overlap in the Bransfield Strait and on the continental shelf north of Livingston Island. In general, overlap occurs in areas where krill are retained, which are areas where fishery 'hot spots' have been identified (WG-EMM-16/52).	WG-EMM-16/45 V5

(continued)

Table 1 (continued)

Advice from WG-EMM-15	Issue	Progress and notes	Papers submitted to WG-EMM-16 or elsewhere
Paragraphs 2.107, 2.135(iv), 2.143(ii–iv), 2.160(iv), 2.161(v–vi), 2.214	Explore and characterise functional relationships between krill and krill predators, including the effects of current fishing activities on krill-dependent predators.	A functional relationship between the magnitude of local krill biomass and penguin performance is indicated, with performance expected to be low when local krill biomass is in the order of 104 tonnes; high performance is expected when local krill biomass is in the order of 106 tonnes. A weaker functional relationship between local krill biomass and performance of Antarctic fur seals is indicated. An analysis of penguin performance in relation to local exploitation rates of krill indicates plausible impacts of locally concentrated krill fishing, with lower performance when the difference in orders of magnitude between local biomass and reported catch is less than, or equal to, one.	WG-EMM-16/45 V6, V7
Paragraph 2.137(viii)	Consider using krill consumption by predators within different SSMUs as a basis for distributing catch limits.	Previous work considered by WG-EMM (e.g. Hill et al., 2007) provided estimates of krill consumption in each SSMU. There have been no updates of these estimates, and they have been used to indicate an alternative basis for distributing catches among groups of SSMUs. It is acknowledged that previous modelling work (e.g. Plagányi and Butterworth, 2012; Watters et al., 2013) indicated that using estimates of krill consumption as the basis for distributing catch limits would lessen risks to krill-dependent predators but increase risks to fishery performance.	WG-EMM-16/45 V8

(continued)

Table 1 (continued)

Advice from WG-EMM-15	Issue	Progress and notes	Papers submitted to WG-EMM-16 or elsewhere
Paragraphs 2.143(i), 2.148(iii), 2.160(v)	Examine predator performance during 'critical years' and improve understanding of how CEMP indices might be related to changes in abundance over the long term.	A model of Adélie penguin population dynamics has been fitted to available band-resight data; this model was then used to simulate population growth rates under different scenarios with initial perturbations that negatively affect survival followed by longer-term conditions in which survival is purposefully tuned to promote population growth. Results indicate that weak recruitment during the initial perturbations can have long-term impacts on population growth rates. Thus, it is possible to use the results to identify the recruitment rates needed for population maintenance. Any CEMP index that can reliably predict recruitment in advance can thus be used in a management strategy that aims to maintain resilience of penguin populations. Complementary, but separate, results from an analysis of data collected during long-term banding and breeding phenology studies demonstrate that age at crèche can usefully predict cohort strength of penguins, with cohorts composed of birds crèching at relatively young ages likely to be relatively weak. The stage 2 strategy proposed in WG-EMM-16/48 thus includes a decision rule parameterised to adjust local catch limits when observations of mean age at crèche lead to expectations of weak penguin cohorts.	WG-EMM-16/46 V1, V2, V4
Paragraphs 2.151(iii), 2.156, 2.170, 2.185, 2.211	Development of standard camera-based methods to collect CEMP-related indices of predator performance as effective alternatives or complements to existing standard methods, including image analysis and comparison to existing standard methods.	Methods to analyse nest-level photographic observations of breeding success and chronology have been developed, and initial work to compare photo-based estimates of breeding success and chronology to estimates based on CEMP Standard Methods A6 and A9 has been conducted. Results indicate that photo-based estimates of breeding success and chronology are comparable to those made with the standard methods. With support from the CEMP Fund, six Members have established a CEMP camera network in Subarea 48.1. The network has nodes that are distributed throughout the subarea and can observe several hundred penguin nests, with Adélie, chinstrap and gentoo penguins all being observed.	WG-EMM-16/46 V3

(continued)

Table 1 (continued)

Advice from WG-EMM-15	Issue	Progress and notes	Papers submitted to WG-EMM-16 or elsewhere
Paragraphs 2.109, 2.110, 2.164(i)	Parameterise one or more decision rules for a stage 2 strategy, including 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 these rules should be quantified in terms of risks, mean effects and variability in the effects, including the consequences for catches. The consequences of applying the decision rules can be evaluated using retrospective analyses in the short term and management strategy evaluations (MSEs) in the long term.	Retrospective analyses of three decision rules have been completed: a marginal rule to decrease local catch limits, a marginal rule to increase local catch limits, and a combined rule that can be used to both decrease and increase local catch limits. The marginal retrospective analyses indicate that the rules for downward and upward adjustment would, if implemented separately, lead to adjustments about 30–40% of the time. Results from the retrospective analysis of the combined decision rule indicate that downward adjustments to catch limits would have been made about half the time and upward adjustments would have been made up to 10% of the time. The expected value of applying the combined decision rule (including proposed, initial catch limits of 100 000 tonnes each in the Bransfield Strait and the combined coastal SSMUs north of the South Shetland Islands) has been estimated as 163 000 tonnes, and the variance in adjusted catches is less than, or equal to, the variance in actual catches.	WG-EMM-16/46 V4, WG-EMM-16/47 V3, WG-EMM-16/48
Paragraphs 2.109, 2.135(iii), 2.148(i–ii), 2.170, 2.214	Evaluation of CEMP data to detect temporal and spatial variations in predator performance, including as they relate to krill availability and how CEMP data can be aggregated across sites, species, etc.	The stage 2 strategy proposed in WG-EMM-16/48 utilises CEMP data from multiple sites and species to possibly increase local catch limits. The CEMP data were standardised and then an average value of all CEMP indices of performance during the breeding season and relevant to a group of SSMUs (where the location of the CEMP site determines its relevance to a group of SSMUs) is used as an overall index of performance. A separate analysis of covariation among CEMP indices collected in Subarea 48.1, summarised as CSIs, suggested an increased level of concordance in the period since 2008 (WG-EMM-16/09).	WG-EMM-16/47 V1
Paragraphs 2.109, 2.150, 2.164(iii), 2.168, 2.169, 2.225, 2.230	Consider the use of fishing vessels to collect data for use in stage 2, including undertaking krill surveys to assess within-season dynamics of krill and providing data to SG-ASAM to aid survey design and analysis.	Fishing vessel acoustic data were not submitted to SG-ASAM-16. As an alternative, acoustic data from the US AMLR Program were analysed, and results from this analysis suggest that fishing vessels could potentially track within-season changes in krill biomass by conducting repeat surveys of two transect lines.	WG-EMM-16/47 V2

Table 2: Description of how CCAMLR can address future work on implementing FBM in Subarea 48.1. Each issue (row) is organised into one of three future work categories: (i) 'Spatial distribution of catch for base case' describes analytical approaches to establish a base catch level, and then spatially distribute and evaluate future catch levels within Subarea 48.1; (ii) 'Implementation' describes data processing, analysis and survey details that will be required to implement FBM; (iii) 'Performance measures' describes approaches to evaluate the real and potential performance of the proposed FBM approach with respect to krill, predators and the fishery.

Advice from WG-EMM – year and paragraph numbers	Issue	Notes
Spatial distribution of catch for base case		
2015 (Table 2)	Estimation of base catch limit using integrated assessment model, including alternative estimates of the reference biomass to be used in decision rules for krill and fitting to additional data (e.g. krill length-frequency data from predator diet studies).	Further development of the integrated assessment model can be addressed in parallel with implementation of stage 2.
2015 (2.121ii)	Further development of approaches to apportion catch limits between management areas.	Work to advise on spatial apportionment of catch limits based on assessment of relative risks and using methods derived from those presented in WG-EMM-16/69 will be ongoing and can be conducted in parallel with implementation of stage 2.
2015 (2.144)	Identification of potential, precautionary no-take buffer zones around predator colonies.	Evaluation of buffer zones can be conducted in parallel with implementation of stage 2, noting that initial analyses of krill catch as a function of distance from land have already been conducted (WG-EMM-16/17), that the SSMUs were partly based on summer foraging ranges of krill-dependent predators, and that more recent tracking data can be used to consider the time that predators spend at different distances from their colonies.
Implementation		
2016 and 2015 (Table 2)	Specify data required from the krill fishery (e.g. number, frequency and location of standardised acoustic transects and net hauls).	SG-ASAM is requested to provide additional clarification on survey requirements for fishing vessel transects and the numbers of net hauls required for characterising krill length-frequency distributions that are necessary for biomass estimation, etc.
2015 (2.176i)	Continuing facilitation of meetings with fishing industry stakeholders to encourage participation of fishing vessels in collecting acoustic data.	Meetings with industry stakeholders are likely to occur over the long term and continue beyond implementation of stage 2 to stages 3 and 4 of FBM.

(continued)

Table 2 (continued)

Advice from WG-EMM – year and paragraph numbers	Issue	Notes
2015 (2.149)	Development and implementation of future surveys that cover spatial scales similar to that of the CCAMLR-2000 Survey.	It is unclear whether new surveys of this scale will be conducted in the near future; costs are substantial.
Performance measures		
2015 (2.140iii)	Assessment of krill behaviour and implications of such behaviour for krill flux.	A work program to study krill behaviour and flux should be designed by WG-EMM, will be ongoing, and can be conducted in parallel with implementation of stage 2.
2015 (2.160iv), 2.161vd)	Examination of the response of predators to variability in krill density.	The data that were used to describe the functional relationship between penguin performance and local krill biomass in WG-EMM-16/45 could also be used to examine the functional relationship between penguin performance and krill density. This work can be conducted in parallel with implementation of stage 2.
2015 (2.160vi)	Using models to explore competition between krill-dependent predators.	The ecosystem model developed by Watters et al. (2013) includes functionality to explore different degrees of competition between krill-dependent predators. This work can be conducted in parallel with implementation of stage 2.
2016 and 2015 (2.110)	Evaluation of decision rules with simulation models (management strategy evaluation (MSE)), empirical analyses of time-series observations (retrospective analyses), and/or other methods.	Full MSE of the strategy proposed in WG-EMM-16/48 could be pursued in parallel with the implementation of stage 2.
2015 (2.161vb)	Evaluating whether penguins are attracted to fishing vessels.	See next row.
2015 (2.161ve)	Considering using at-sea observations of predators (presumably from observers) as a way to establish predator–fishery overlap.	At-sea observations of predators would likely be necessary to evaluate whether penguins are attracted to fishing vessels. Acoustic data collected by research vessels indicate extremely fine-scale overlap of predators and fishing vessels can be observed (see e.g. WG-EMM-16/19). This work can be conducted in parallel with implementation of stage 2.

References

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Watters, G.M., S.L. Hill, J.T. Hinke, J. Matthews and K. Reid. 2013. Decision-making for ecosystem-based management: evaluating options for a krill fishery with an ecosystem dynamics model. *Ecol. Appl*., 23 (4): 710–725.

Appendix F

Symposium on the Ross Sea Ecosystem
(Bologna, Italy, 13 July 2016)

(Available in English only)

Symposium on the Ross Sea Ecosystem

(Bologna, Italy, 13 July 2016)

Program

Introduction (Co-conveners) (9:00–9:10)

Ecosystem structure and functioning

1. Castagno et al. Temporal variability of the circumpolar deep water inflow onto the Ross Sea continental shelf (9:10–9:20)

2. Rivaro et al. Ocean acidification state in the Ross Sea surface waters: physical and biological forcing (9:20–9:30)

3. Celussi et al. Ocean ventilation effect on microbial metabolism in the Ross Sea (9:30–9:40)

4. di Prisco and Verde. The Ross Sea and its rich life: research on molecular adaptive evolution of Antarctic organisms and the Italian contribution (9:40–9:50)

Krill and fish, fisheries and their impact on the ecosystem

5. Leonori et al. Dynamics of middle trophic level of the Ross Sea pelagic ecosystem (9:50–10:00)

6. Ghigliotti et al. The coastal fish fauna of Terra Nova Bay, Western Ross Sea: from the first baseline information to the ongoing research on two key species, the Antarctic silverfish and the Antarctic toothfish (10:00–10:10)

7. Caccavo et al. Population structure of *Pleuragramma antarctica* in the Ross Sea (10:10–10:20)

Coffee break (10:30–11:00)

8. Currey et al. Ecological effects of the fishery for Antarctic toothfish in the Ross Sea region (11:00–11:20)

Discussion (11.30–12.30)

Lunch break (12.30–14.00)

Ecosystem monitoring and conservation

9. La Ferla et al. Microbial community inhabitants in the Ross Sea (14:00–14:10)

10. Calizza et al. Biodiversity organisation in a species-rich Antarctic ecosystem: insights from food web ecology for ecosystem monitoring, management and conservation (14:10−14:20)

11. Schiaparelli and Cummings. The Antarctic Near-shore and Terrestrial Observation System (ANTOS) network in the Ross Sea (14:20–14:25)

12. Olmastroni. Seabirds as sentinels of ecosystem change (14:25–14:35)

13. Lauriano and Panigada. Habitat use of the Ross Sea killer whale in Terra Nova Bay by means of satellite telemetry: a support to the conservation measures in ASPA 173 (14:35−14:45)

14. Zappes et al. Genetic studies of the Weddell seal in the Ross Sea: a closer look on the colonies in Mario Zucchelli Station area (14:45–14:50)

15. Corsolini and Cincinelli. Persistent organic pollutants (POPs) in abiotic and biotic compartments of the Ross Sea ecosystems: from the past to the future (14:50–15:00)

16. Benedetti et al. Ecotoxicology and use of bioindicators for monitoring the Ross Sea (15:00–15:10)

17. Bergami et al. PLastics in ANtarctic EnvironmenT – the PLANET International scientific project aimed to assess both the presence and impact of micro and nanoplastics to Antarctic marine biota (15:10–15:20)

18. Caccia et al. Modular portable robotic systems for the non-invasive observation of Ross Sea coastal ecosystem (15:20–15:30)

Coffee break (15.30–16.00)

19. Vacchi et al. The Antarctic silverfish, a keystone species in a changing ecosystem (M. Vacchi, E. Pisano, L. Ghigliotti (Eds)). Springer Book Series ‘*Advances in Polar Ecology*’ (Short Note)

Discussion (16:05–17:30)

Temporal variability of the circumpolar deep water inflow onto the Ross Sea continental shelf

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The intrusion of Circumpolar Deep Water (CDW) is the primary source of heat, salt and nutrients onto Antarctica's continental shelves and plays a major role in the shelf physical and biological processes. Different studies have analysed the processes responsible for the transport of CDW across the Ross Sea shelf break, but until now, there are no continuous observations that investigate the timing of the intrusions.

Also, few works have focused on the effect of the tides that control these intrusions. In the Ross Sea, the CDW intrudes onto the shelf in several locations, but mostly along the troughs. We use CTD observations and a moored time series placed on the outer shelf in the middle of the Drygalski Trough in order to characterise the spatial and temporal variability of CDW inflow onto the shelf. Our data span from 2004 to the beginning of 2014. In the Drygalski Trough, the CDW enters as a 150 m thick layer between 250 and 400 m, and moves upward towards the south. At the mooring location, about 50 km from the shelf break, two main CDW cores can be observed: one on the east side of the trough spreading along the west slope of Mawson Bank from about 200 m to the bottom and the other one in the central-west side from 200 m to about 350 m depth. A signature of this lighter and relatively warm water is detected by the instruments on the mooring at bottom of the Drygalski Trough. High frequency periodic CDW intrusion at the bottom of the trough is related to the diurnal and spring/neap tidal cycles. At lower frequency, a seasonal variability of the CDW intrusion is noticed. A strong inflow of CDW is observed every year at the end of December, while the CDW inflow is at its seasonal minimum during the beginning of the austral fall. In addition an interannual variability is also evident. A change of the CDW intrusion before and after 2010 is observed.

Ocean acidification state in the Ross Sea surface waters: physical and biological forcing

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The Ross Sea is vulnerable to Ocean Acidification (OA) due to its relatively low total alkalinity and because of increased CO_2 solubility in cold water. OA induced decreases in the saturation state (Ω) for calcite and aragonite have potentially serious consequences for Antarctic food webs. Throughout the ocean, mesoscale processes (on spatial scales of 10−100 km and temporal ranges from hours to days) have first-order impacts on phytoplankton physiochemical controls and are critical in determining growth patterns and distribution. The circulation of the surface waters in the Ross Sea is affected by the presence of small-scale structures such as eddies, fronts and filaments, which can penetrate deep below the surface layer and hence influence the intensity of the bloom by supplying nutrients and trace elements, such as iron. Little is known about the effects of mesoscale structures on the carbonate system, but predicting future surface OA state and estimating future CO_2 fluxes on a regional scale require understanding of the mesoscale processes controlling the carbonate system.

To this purpose, water samples were collected in January 2014 in the framework of Ross Sea Mesoscale experiment (RoME) Project to evaluate the physical and biological forcing on the carbonate system at distance between stations of 5–10 km. Remote sensing supported the determination of the sampling strategy and helped positioning each sampling station. Total alkalinity, pH, dissolved oxygen, phytoplankton pigments and composition were investigated in combination with measurements of temperature, salinity and current speed. Total inorganic carbon, sea water CO_2 partial pressure and **Ω** for calcite and aragonite were calculated from the measured total alkalinity and pH. In addition, continuous measurements of atmospheric CO_2 concentration were completed. Different mesoscale physical features, such as fronts and eddies were observed in the investigated areas, which influenced the distribution of chemical parameters and of phytoplankton community in terms of biomass concentration (Chl-a) and species composition. The carbonate system properties in surface waters exhibited mesoscale variability with a horizontal length scale of about 10 km. Our results document substantial spatial heterogeneity and complexity in surface water carbonate system properties and the magnitude of the CO_2 flux at a horizontal length scale of about 10 km, emphasising the importance of mesoscale events to regional biogeochemistry. We believe that the resolution of these short length scale distributions provides insight into the biogeochemical dynamics which drive surface and subsurface variability in the Ross Sea.

Ocean ventilation effect on microbial metabolism in the Ross Sea

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A deep knowledge on the ocean C cycle functioning is fundamental to predict the consequences of increased CO2 in the atmosphere. Current researches indicate that the amount of CO2 fixed in deep marine systems via chemosynthetic processes is comparable to the one taken up by photosynthetic organisms in the lit portion of the water column. Despite the pressing need, we still lack of information on the deep sea biodiversity and metabolism of the Southern Ocean and in particular of the Ross Sea (Pacific sector of Antarctica). The Ross Sea represent a key study area because (1) it is a system where dense water masses with different features are formed, potentially involved in different quantity and quality of organic matter export to the deep sea and (2) these water masses, eventually forming the Antarctic Bottom Water (AABW), act as an engine for global ocean circulation, ventilating 60% of the whole ocean mass.

During two oceanographic cruises in Southern Ocean (austral summers 2014 and 2016) we have performed 64 incubation experiments in order to understand the C fluxes in the dark portion of the Ross Sea (200–2000 m). We evaluated dissolved inorganic C uptake (via chemosynthesis) and production (via respiration) together with dissolved organic C utilisation (via heterotrophic production) and release (via excretion or viral lysis). The study focussed on the newly formed, organic carbon-rich High Salinity Shelf Water (HSSW), on the oxygen-depleted Circumpolar Deep Water (CDW), and on the Antarctic Bottom Water.

Results indicate that in the three water masses (in the same depth range) marine microbes behave at different rates. The fastest bulk chemosynthetic C fixation, heterotrophic production and respiration were measured in the oxygen- and organic C-rich HSSW. Significantly lower values were found in CDW, whereas AABW maintained the metabolic signature typical of both parental water masses showing intermediate values. Excretion/lysis data were negligible or not measurable (below the detection limit of the method). Prokaryotic abundance mirrored the trend observed in metabolic activities. The per-cell normalisation of C uptake and production did not reveal significant differences among the water masses indicating that metabolism do not spatially vary at the single organism-level.

Overall, these data indicate that the signature of newly-formed water masses significantly affect the metabolism of microbes living in Antarctic Bottom Water possibly having profound implications for the global bathypelagic biogeochemistry.

The Ross Sea and its rich life: research on molecular adaptive evolution of Antarctic organisms and the Italian contribution

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The involvement of Italy in Antarctic research dates back to 1985, when Mario Zucchelli Station (MZS), the former TNB Station, was established in Terra Nova Bay. This presentation is an overview of the research in marine biology performed in the last 30 years by the authors' team in the Ross Sea.

Fundamental questions (with special attention to the molecular bases) have been addressed, related to cold adaptations evolved by a wide array of marine organisms (*fish, birds, urchins, whales*, *seals* and *bacteria*) along with progressive cooling in this area, also analysed when relevant in comparison with other important areas, i.e. the Peninsula, the Weddell Sea, the sub-Antarctic and the Arctic. In recent years, the urge to extend these studies to the north has become stronger; and comparison with the Arctic is developing within the IPY program Team-Fish.

The basic approach integrated ecophysiology with molecular aspects, in the framework of biodiversity, adaptation and evolution. This comprehensive research has special meaning in view of the control that Antarctica exerts on the world climate and ocean circulation. Polar organisms are exposed to strong environmental constraints, and we need to understand how they have adapted to cope with these challenges, and to what extent current climate changes will impact on adaptations.

The important role of the poles in Global Change has awakened great interest in the evolutionary biology of the organisms that live there. The Antarctic is a natural laboratory and the Ross Sea is one of its most important sectors. In contrast to the Arctic and the Peninsula, the Ross Sea is not hit by warming, but this might only be temporary. Marine biology has easy access to complex ecosystems and richness of organisms, from mammals to microbes.

The Ross Sea is rich of science/logistics facilities. McMurdo Station and Scott Base became active in the 50's; in recent years, the Ross Sea is being selected by other nations to install their stations. Thanks to investigations facilitated by this infrastructure network, as an example, the suborder Notothenioidei is one of the best known fish groups in the world for many aspects, in particular the molecular bases of adaptations to extreme conditions. There is compelling evidence for widespread changes in polar ecosystems due to climate change. The study of cold-adapted organisms will allow to look at the impact and consequences of anthropogenic challenges on species distribution.

The challenging agenda for the next decade will be to incorporate thinking along the physiological/biochemical viewpoint into evolutionary biology. Such approach can provide answers to the question of how polar marine organisms will respond, and whether they will be able to develop resilience, to ongoing Global Warming, already in full action in the Peninsula and in the Arctic, and foreseen to occur soon in the Ross Sea. The importance of comparing the resilience of organisms thriving in the as yet unimpacted Ross Sea with those of the warming Peninsula (and with the Arctic) will steadily increase, also because of possible predictions regarding lower latitudes.

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Dynamics of middle trophic level of the Ross Sea pelagic ecosystem

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Since 1989/90, the Acoustic Group of Institute of Marine Sciences of Research Council of Italy (CNR-ISMAR) carried out eight acoustic surveys in the Ross Sea to obtain important data on the two krill species, Ice krill (*Euphausia crystallorophias*) and Antarctic krill (*Euphausia superba*), constituting the 'Middle Trophic Level (MTL)' of this area. Their biomass, the geographical distribution and the demography were estimated and the relations with the environment (CTD and XBT samplings) were studied in the years. The last large scale survey was in 2004, then two small scale surveys were done in 2014 and 2016. The investigated area is included in the statistical division 88.1 and concerns the western part of the Ross Sea (from Lat. 77° to Lat. 68° S and from Victoria Land to Long. 180° E) for a total of around 80000 n miles ^{2}. In 2009 a study concerning Antarctic Silverfish (*Pleuragramma antarctica*) was started in order to better explain the exceptional abundance of the species belonging to the 'Top-Trophic Level (TTL)' which characterises the Ross Sea (marine mammals and birds). Its distribution area overlaps partly with that of *Euphausia crystallorophias* in the coastal area of western Ross Sea (mainly juveniles) and partly with that of *Euphausia superba* (adults and juveniles) in the north-central area of the Ross Sea, far offshore. During the oceanographic cruises the study area was monitored acoustically with a multifrequency modality (38, 120 and 200 kHz) by means of a SIMRAD EK60 scientific echosounder on board R/V Italica. Periodical pelagic trawls were performed targeting the key species with improved efficiency in capture due to the connection between the echosounder and the integrated trawl monitoring system SIMRAD ITI, giving information on net position in the water column.

The aim of the project is to continue past analyses on this matter performing a scientific survey possibly covering at least the area within the cores of the two krill populations, quite well known from past surveys, and the silverfish.

Another interesting possibility would rely on the installation of a moored echosounder in the study area of the survey, the Simrad WBAT (Wideband Autonomous Transceiver) with a 70 kHz transducer in order to analyse the seasonal krill variations in abundance and localisation in the water column, in function of ice cover variations.

The main objectives of this research are: to improve the knowledge on biologic and acoustic aspects concerning the two main species of Ross Sea krill; to improve the knowledge on acoustics parameters that allow the discrimination of Antarctic silverfish and to allocate specific echotraces to this species; to assess the biomass and spatial distribution of the three species of MTL in the area; to use the three MTL species as model-organisms; to study the interactions between the physical and biological environment (spatial distribution of the three species); to study the temporal variations of thermohaline characteristics and krill abundance in the area; to refine the knowledge on krill and silverfish Target Strength with the use of Simrad EK80 scientific echosounder working in broadband modality to obtain a better discrimination of the species and more precise estimations of their biomass.

The coastal fish fauna of Terra Nova Bay, Western Ross Sea: from the first baseline information to the ongoing research on two key species, the Antarctic silverfish and the Antarctic toothfish

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Ecological studies on the coastal fish community at Terra Nova Bay (TNB) date back to the 3rd Italian Antarctic Expedition (1987-1988), following the settlement of the Italian Mario Zucchelli Station (74°41'S, 164°07'E) in the Western Ross Sea. At that time Italy had just received the status of Consultative Member of the Antarctic Treaty. Being a largely unexplored area, the aim of those first pioneering studies was to draw a general picture of the local assemblage. Over years, owing to repeated summer surveys, such a goal has been largely achieved, as we now have quite detailed information on the fish fauna at TNB up to 500 m depth that includes not only species diversity, distribution and relative abundance, but also trophic ecology and reproductive features for the most of the species. The combination of traditional catch-based methods and in situ observations through Remotely Operated Vehicles (ROVs) allowed to document several aspects of the fish ecology and behaviour, including parental care in icefish species.

Here we will provide an overview on the ongoing researches on two key-stone fish species of the Ross Sea ecosystem, whose information on biology and ecology is claimed for proper management of the future Ross Sea Region MPA: the Antarctic silverfish (*Pleuragramma antarctica*) and the Antarctic toothfish (*Dissostichus mawsoni*).

Researches on the Antarctic silverfish in the area increased following the discovery of the first, and only known to date, nursery area for the species northern to TNB, in an area thereafter named Silverfish Bay. Thousands of eggs develop and hatch there, within the platelet ice under the sea-ice cover. Such a unique feature has been recognised in its outstanding scientific relevance, and has contributed to the establishment of the Antarctic Specially Protected Area (ASPA) n.173 Cape Washington and Silverfish Bay. Under the umbrella of PNRA, the nursery area has been continuously monitored from 2005 to 2013, and monitoring still is a priority of ongoing research at ISMAR, CNR, Genoa. The backbone of such researches are conventional methods and remotely operated video surveys; acoustics, in collaboration with New Zealand scientists of NIWA, and winter sampling at Jang Bogo Station, in collaboration with Korean colleagues of KOPRI, are expanding the geographic and seasonal investigation timeframe.

The Antarctic toothfish hasn't historically been targeted by researchers at TNB, however it has occasionally been caught by trammel nets (Antarctic expedition 1990-1991), and specifically targeted by small vertical longline fishing through holes in the sea-ice (Antarctic expedition 2002-2003). Improvement of the biological and ecological knowledge on this top predator in the Ross Sea ecosystem is within the goals of the ongoing collaborative research with New Zealand that include land-based activities at McMurdo Sound and TNB and participation in CCAMLR-sponsored off-shore surveys in the Ross Sea Region.

Population structure of *Pleuragramma antarctica* in the Ross Sea

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Research into the early life stages of *Pleuragramma antarctica* is essential to understanding how oceanographic variation will impact spatial distributions over time. *P. antarctica* collected near the Antarctic Peninsula and the Ross and Weddell Seas between 1989 and 1997 were the first to show evidence of weak population structure at the circum-Antarctic scale using mitochondrial DNA sequences (Zane et al., 2006).

This weak structuring of *P. antarctica* could either be explained by high levels of connectivity, or is indicative of inadequate sampling and markers. Thus, studies employing microsatellite markers with the potential to reveal finer genetic differences using more sampling sites on a smaller geographic scale were undertaken. A first investigation in the Antarctic Peninsula revealed significant structuring despite strong circumpolar currents moving through these areas (Agostini et al., 2015).

A microsatellite based population structure analysis was recently planned on larvae collected in the austral summer of 2013 from Terra Nova Bay and the Bay of Whales in the Ross Sea, morphologically identified as *P. antarctica*. Poor preservation precluded microsatellite amplification in these larvae, but successful amplification of the 16S rDNA and the *D-Loop* region of mitochondrial DNA was achieved. Sequence alignment with known GenBank sequences for *P. antarctica* and several related notothenioids confirmed the species identity of larvae as *P. antarctica*. This work supported evidence of a newly discovered nursery ground for *P. antarctica* in the vicinity of the Bay of Whales (Brooks & Goetz, 2014) and showcased the use of mitochondrial DNA to test morphological identification when examining spatial distributions of marine organisms that depart from expectation (Caccavo et al., 2015). An ongoing effort to understand the circumpolar connectivity of *P. antarctica* using microsatellite markers in individuals both from the initial mitochondrial DNA study, as well as newly collected samples from the Weddell Sea, shows a marked differentiation between *P. antarctica* from Terra Nova Bay and from areas of the Antarctic Peninsula and Weddell Sea. Microsatellites revealed stronger differentiation between the Terra Nova Bay groups collected in 1996 and 1997 but as in the initial analysis with mitochondrial DNA, failed to achieve significance. Successful population analyses in other areas of the Southern Ocean support the utility of such an endeavor in the Ross Sea. Greater sampling efforts are imperative to forge an understanding of population structure in the Ross Sea, where few such studies exist and for which new specimens are vital to addressing these questions. Furthermore, nursery grounds in the Ross Sea that might support *P. antarctica* populations at a circumpolar scale are at risk from the changing extents of seasonal polynyas in this crucial Southern Ocean habitat.

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Ecological effects of the fishery for Antarctic toothfish in the Ross Sea region

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In this presentation, the potential ecological effects of the fishery for toothfish in the Ross Sea region are discussed under five broad headings.

1. Effect of the fishery on by-catch species: The main by-catch species are macrourids (*Macrourus whitsoni* and *M. caml*), icefish (mainly *Chionobathyscus dewitti*), skates (mainly *Amblyraja georgiana*), eel cods (*Muraenolepis* spp.) and deep-sea cods (*Antimora rostrata*).

2. Effects of the fishery on the prey of toothfish: Except for skates, the main by-catch species are also the main prey items for toothfish, and "predation release" effects are discussed.

3. Effects of the fishery on the predators of toothfish: The main predators of toothfish in the Ross Sea region include Weddell seals, type-C ("fish-eating") killer whales and sperm whales. Effects of the fishery on these predators will be related to: (a) the ecological dependence of the predator on toothfish; (b) the potential for the fishery to reduce the availability of toothfish as prey to these predators.

4. Effects on habitat: The effect of the fishery on structure-forming benthic invertebrates ("vulnerable marine ecosystems") is discussed in terms of the (a) footprint of the fishing gear (how much of the sea-bed is affected by long-lines); (b) impact of the fishing gear on a particular habitat; (c) spatial overlap between a particular habitat and fishing effort.

5. Cascading ecosystem effects: The potential for the fishery to affect the wider ecosystem through indirect or second-order effects is discussed. In particular, could the recent doubling of the number of Adélie penguins breeding in the south-west Ross Sea be related to fishing?

The state of knowledge on each of these potential ecological effects is presented, and measures to avoid, mitigate or manage the risks are described. Finally, research that is underway or planned on the potential ecological effects of the Ross Sea toothfish fishery is presented.

Microbial community inhabitants in the Ross Sea

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The microbial assemblage plays a key role in the costal and pelagic food web of the Ross Sea; it controls many processes, including primary production, turnover of biogenic elements, degradation of organic matter and mineralisation of xenobiotics and pollutants. Prokaryotic abundance and activity shift significantly over the annual cycle as sea ice melts and phytoplankton blooms develop. Marine microbes in the Ross Sea exhibit a diversity which also depends on the timing, location and sampling method; research devoted to this group is increasing, using also genetic and molecular approaches in surface and deep waters.

Our contribution will focus on the presentation of microbial data (standing stock and activity, as well as diversity and biotechnological potentialities of bacterial isolates) collected in the Ross Sea (coastal and pelagic) from 1988 to 2016, in the framework of the Italian National Programme for Antarctic Research (PNRA). Particular emphasis will be given to the inter-annual and decadal variability of microbial community in coastal and pelagic zones of the Ross Sea.

Biodiversity organisation in a species-rich Antarctic ecosystem: insights from food web ecology for ecosystem monitoring, management and conservation

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The Ross Sea is considered the most pristine marine ecosystem on Earth. The absence of direct anthropogenic pressure, in association with substantially stable environmental conditions over a geological scale, resulted in high levels of biological diversity, mainly represented by benthic invertebrate consumers. In turn, marked seasonality in light and sea-ice coverage control biological productivity in the region. This forced benthos to adapt to pulsed resource inputs and to prolonged periods of resource shortage, in association with low temperature and physical disturbance. Disentangling these mechanisms will improve our understanding of biodiversity organisation and adaptation in the Ross Sea ecosystem and our ability to conserve and manage biodiversity under a global change scenario. Indeed, diversity and temporal fluctuation of resource inputs are key ecosystem properties promoting species coexistence, and modification of sea-ice dynamics associated to climate change are expected to alter the relative contribution of different resource guilds to benthic consumers. While adaptive physiological mechanisms to extreme physical conditions in polar biota have been relatively more investigated, trophic-functional mechanisms underlying adaptation, resource partitioning and species coexistence are poorly understood. This hinders a mechanistic understanding on if and how variations in sea-ice coverage and resource supply will rebound into changes in species composition, food web dynamics, and biodiversity loss within the Ross Sea ecosystem.

Our research in the Ross Sea focused on the description of food web organisation and adaptation to changes in sea-ice coverage and resource inputs at Terra Nova Bay, which represented an exceptional natural laboratory to study the effect of sea-ice dynamics on the ecological community. By mean of stable isotope analyses of numerous taxa, we described both vertical (i.e. feeding) and horizontal (i.e. competition) ecological links subtending to species coexistence and nutrient flux across trophic levels. The description of spatial and temporal variations in food web structure can be key to unravel mechanisms linking climate change and its ecological consequences both at the population and community level, providing early signals of subtle ecological changes which could lead to species exclusion that could not be inferred based on physicochemical data alone. As a part of our results, we observed a highly diverse and “packaged” biological community. The food web seemed to be highly adapted to the seasonal availability of different resource inputs, including detritus, benthic, sympagic and pelagic primary production. Indeed, species were able to vary their diet following changes in resource inputs associated to sea-ice dynamics. Inputs of sympagic algae to benthic consumers (both in shallow and deep waters) were key to relax interspecific niche overlap and species packaging during the summer months. Abundant species were found to differentiate their trophic niche on alternative resource axes, which reduced competition for food, plausibly improving the fitness of competitors. In turn, the feeding choices of species had a profound effect on the configuration and coupling of energy pathways within the food web. This had implications for nutrient and contaminant transfer within the ecosystem, and provided a direct link between the functional response of populations and effects of climate change at the ecosystem level.

Thus, biodiversity organisation at Terra Nova Bay seemed to be highly adapted to the dynamic stability of the Antarctic environment on one hand, and to the seasonal sea-ice dynamics and release of sympagic production on the other hand. Ecological theory suggests that such dynamic stability in environmental conditions and resource input could be a key factor allowing for the observed elevated "packaging" of species along the trophic niche axis, and hence the high biodiversity level characterizing our study area. We argue that rapid environmental modifications associated to climate change and to potential anthropic activities impacting the Ross Sea food web could represent an unprecedented ecological change which could have profound implications for food web stability and biodiversity persistence, with a high risk of species extinction and relevant changes in nutrient transfer across trophic levels as a consequence.

The Antarctic Near-shore and Terrestrial Observation System (ANTOS) network in the Ross Sea

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The Antarctic Near-Shore and Terrestrial Observation System (ANTOS) is a SCAR Action Group, established in August 2014. Its major aim is to foster and facilitate collection and sharing of long-term automated climate and associated environmental observations across Antarctica and national programs. In August 2015, a workshop was held to develop an implementation plan for ANTOS and focused on the key characteristics of locations, parameters to measure, frequencies, scales and gradients of measurement, and technical requirements needed to establishing a network of marine and terrestrial observation systems, which are now available to the scientific community. In the present contribution we will outline the state-of-the-art for the Ross Sea coastal sites and illustrate the ongoing monitoring activities performed in the Ross Sea under the Italian, New Zealand and Korean Antarctic research programs and in accordance to ANTOS implementation plan.

Seabirds as sentinels of ecosystem change

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The Ross Sea, despite its relatively small size, contains one of the largest concentrations of marine birds in the World (e.g., 38% and 26% of the World breeding populations of Emperor and Adélie penguins, respectively). The high biodiversity at both species and communities level make the area between Terra Nova Bay and Wood Bay, along the mid Victoria Land coast, a site of important ecological and scientific value. Terra Nova Bay and Wood Bay have been included as Important Bird Areas in Antarctica by BirdLife International. The penguin colonies are located in well-defined sites between 17 and 75 km from each other. Other species, such as skua and petrel, breed in ice/snow-free areas scattered along the same coastline. Seabird and marine mammal concentrations and distribution highlight the importance of this stretch of Victoria Land's coast to these species during the Antarctic summer. Numerous studies conducted by Italian researchers and others since the mid-1980s have contributed greatly to the knowledge about the present ecological communities in this area. Italian biologists (University of Siena, within the PNRA) have been studying seabirds and collecting standardised data using CCAMLR protocols, as well as employing other methods, since 1994. This research has described effects relating to annual changes in the population and the ecosystem, at both local and regional levels. Long term individual survival rate estimation together with reproductive parameters (i.e. breeding success) has revealed the dynamics of growth or decline of the populations and highlighted environmental factors that may influence these trends. Seabirds, and especially penguins, provide "warning signals" of ecosystem change, which is why the long-term research studying their life cycles and population dynamics are particularly important. Climate is known to affect seabirds on both long and a short-term bases. It appears to be responsible for summer prey availability and distribution and to affect directly or indirectly survival in wintering areas. Nonetheless increasing human activities such as research station operations and building, tourism and the development of fisheries may be responsible for disturbances both locally and on a regional scale in the Antarctic and Ross Sea ecosystems. Summer foraging habitats, and likely wintering foraging areas, of penguins may overlap with the potential fishing grounds. Interannual population size appear to be intimately connected to local environmental variables (i.e. food accessibility and availability, local weather), which can have a direct effect on one or more demographic parameters (e.g. chick survival) or behaviour (i.e. adult feeding strategies). Therefore, as the food web is altered the value of penguin population trends as indicator of climate change can be in turn negatively affected. It is of particular importance to promote the conservation of these indicator species in the Antarctic ecosystem and to recommend mitigation measures in areas affected by the growing human impact, as required by the Protocol on the Environmental Protection to the Antarctic Treaty. Colonies having long-term time series of data are of special value and need to be protected from direct human impacts.

Habitat use of the Ross Sea killer whale in Terra Nova Bay by means of satellite telemetry: a support to the conservation measures in ASPA 173

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The Ross Sea Killer whale (*Orcinus orca*) is known to be a fish eating species. In northern Terra Nova Bay presence and occurrence of this ecotype has been described in 2004, nevertheless information on habitat use and the relationship with preys are still not available for this area. From mid-January to mid-February 2015, ten killer whales were equipped with location-only satellite (SPOT) and additional vertical behaviour (SPLASH) transmitters, to investigate horizontal and vertical movements. Mean transmission period was 28.6 days (range=19-44; SD=8.79). The whales predominantly engaged in feeding activities along the pack ice edge, between the Campbell Ice Tongue and Cape Washington (Closs Bay). After 9 days spent in this area, the whales began heading north with consistent route along the Ross Sea towards Culman Island, Cape Hallet and Cape Adare. Gradually, they left the Antarctic waters and travelled constantly undertaking a long-distance migration (4,700 nm) towards subtropical waters close to New Zealand.

Vertical behaviour data indicate more deep diving activities in the tagging area than in the northward route; the diving activities reported are in the foraging range for the Silverfish (*Pleurogramma antarcticum*), which is known to occur from mid-water to up 500 m. Terra Nova Bay is a nursery ground for the Silverfish, a keystone species for the lower and higher trophic level, including the Antarctic Toothfish (*Dissostichus mawsoni*). The occurrence and the behaviour of Ross Sea killer whales in the Silverfish Bay Antarctic Special Protected Area (ASPA n°173) and in surroundings is indicating a key role of the area for the killer whales life stage. This deserves an update of the existing management measures in the area also considering the development of the research activities and the related infrastructures such as the gravel runway proposed.

Genetic studies of the Weddell seal in the Ross Sea: a closer look on the colonies in Mario Zucchelli Station area

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Weddell seals (*Leptonychotes weddellii*) have the most southern distribution among all mammals, with breeding colonies that spread along the whole Antarctic coast. Several genetic, behavioural and population studies on this species can be found in literature, but almost all of them have been concentrated on the colony of McMurdo Sound. The present work is the first analysis of the genetic diversity of two colonies, Terranova Bay and Wood Bay, both located in the Ross Sea area. Their genetic structure was analysed and results compared with those already available from McMurdo.

Dloop and CytB (with different mutation rates) were used to estimate the effective number (Ne) of the whole Ross Sea population, test the possible recent expansion of the colonies and observe the variation and distribution of the haplotypes. 15 microsatellite markers were used to obtain the Ne for the colonies and tested for a possible genetic structure.

Both mtDNA fragments showed a Ne of around 50,000 females for the whole Ross Sea population. Expansion test using mismatch distribution was positive, and the beginning was around 58,000 years, a little later than McMurdo (81,000 years), but always during the last glacial cycle. Haplotype analysis showed a high diversity (Hd > 0.90), and the quantity of exclusive haplotypes varied from 43% to 81%, huge values, if we consider that all these colonies are very close to each other. So Antarctic seals tend to present a high intraspecific haplotype variation, with large populations that persist for long periods of time, perhaps due to the lack of human hunting and terrestrial predation. Microsatellites analysis showed very low differentiation between the colonies, confirming that they are indeed part of the same population. This was also confirmed by the number of most likely clusters (K=1). The Ne value for both colonies was estimated in around1,340 individuals.

Our results show that Weddell seals undergone through a demographic expansion since the last glacial cycle and that today they present a local remarkable genetic variation, with large populations that persist for long periods of time in the same area. These patterns are likely a consequence of their high site fidelity, lack of human hunting and terrestrial predation. Nevertheless, as a top predator mammal, the role of this species in the Ross Sea is crucial, and its demographic dynamics should be monitored to follow the future changes of such an important ecosystem.

Persistent organic pollutants (POPs) in abiotic and biotic compartments of the Ross Sea ecosystems: from the past to the future

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Atmospheric long range transport (LRT) is the major responsible for advection of Persistent Organic Pollutants (POPs) as gases and aerosols to the polar regions. Cold condensation and subsequent bioaccumulation has led to their occurrence in polar animals, with consequent effects, ranging from interference with sexual characteristics to dramatic population losses. In the last decades, various studies have shown the presence and bioaccumulation of POPs in Antarctic abiotic and biotic compartments, with concentrations in top predators sometimes higher than those found in industrialised part of the world. Among the pollutant of greatest concern, there are organochlorine pesticides (i.e. DDTs, DDE, HCB, HCHs, CHLs), polychlorinatedbiphenyls (PCBs), polychlorinated dibenzo-dioxins and –furans (PCDDs/Fs) halogenated flame retardants (HFRs, e.g. polybrominated diphenyl ethers, PBDEs), and others. The Stockholm Convention (www.chm.pops.int) considers reducing/banning, future production, and use of these chemicals as a top priority. POPs reach Antarctica by LRT or are released from scientific stations. For instance, because fire risk is very high in Antarctica due to the very dry air, there was a large use of HFRs in buildings and furniture of stations for those built when there were no restrictions on flame retardants use; the construction of new stations and landing routes in the Ross Sea (in progress or recently completed) can be a further HFR source. Due to global warming, melting glaciers could represent a secondary, likely important, source of POPs in the seawaters. In fact, glaciers represent a cold trap for atmospherically-derived POPs and provide records of the deposition of POPs over time. With melting, their remobilisation from these reservoirs allow POPs to enter in the Antarctic food webs and thus biomagnify from the low trophic levels (e.g. larvae, krill) to the higher ones. For instance, the PCB peak concentrations found in *Trematomus bernacchii* in 2001 and 2005 as well as the highest concentrations also reported in 2005 for p,p'-DDE and PBDEs may be affected by the iceberg B-15, that calved from the Ross Ice Shelf in March 2000: contaminants may be released during iceberg melting. The climate change and other human impacts, i.e. increasing human presence due to new scientific stations and related transport of people and equipment, a likely increasing of fishing activities and touristic cruise can affect the Ross Sea ecosystems. Fishing and air and maritime traffic contribute to the contaminant release (POPs, polycyclic aromatic hydrocarbons, PAHs) and the synergy among contaminant release, human presence, climate change, fishing exploitation may affect the Ross Sea ecosystem structure, functioning and health. Moreover, krill seem to bioaccumulate higher POP amount than predicted on the base of their trophic position, thus being at risk as well as all the krill-dependent species.

The challenge of the scientific community for the future should be a coordinated monitoring based on specific and shared criteria of sampling and reporting of data. This is a very important key-point especially in the light of the possible delay of contaminant transport and deposition in the Antarctic region, of the increasing air and maritime traffic. All these human impacts, together with an increase of the fishing exploitation, may affect the health of ecosystem, its homeostasis and the population equilibrium.

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Ecotoxicology and use of bioindicators for monitoring the Ross Sea

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The use of bioindicators and ecotoxicological responses is of particular importance in the Ross Sea Region for the possibility to early detect the impact of anthropogenic activities or future scenarios of climate change. Among the organisms monitored around the Italian Station at Terra Nova Bay, the scallop *Adamussium colbecki* revealed an elevated sensitivity of cellular biomarkers toward different pollutants and environmental stressors like temperature and acidification.

The natural enrichment of cadmium at Terra Nova Bay and the elevated basal concentrations in biota influence the responsiveness of organisms toward this element and other organic pollutants. Notothenioid fish have a limited capability to metabolise PAHs with important consequences in case of oil spill events. Male specimens of *T. bernacchii* from TNB also exhibit vitellogenin gene expression, and the marked seasonality of this estrogenic response seems to be associated to trophic transfer of cadmium or some natural estrogen in the diet during the austral summer. Oxidative responses have a fundamental role for larval development of *Pleuragramma antarctica* within platelet ice, but they also modulate the sensitivity of this key pelagic fish to prooxidant chemicals. These examples highlight that polar ecotoxicology should carefully evaluate specific adaptation mechanisms in endemic sentinel organisms when assessing the impact of anthropogenic activities or variations of environmental factors in these areas.

PLastics in ANtarctic EnvironmenT- the PLANET International scientific project aimed to assess both the presence and impact of micro and nanoplastics to Antarctic marine biota

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The presence of trillions of pieces of plastic debris throughout the world oceans has been internationally recognised as one of the most important worldwide threats for marine ecosystems alongside with loss of biodiversity, ocean acidification and climate change. Although Antarctica has been historically seen as a remote region physically isolated by the Antarctic Polar Front, macroplastics (> 1 cm) have been reported in the Southern Ocean since the 1980s and, more recently, south of the Antarctic Convergence (South Georgia Islands). This might be due in part to increasing local human impacts, such as fishing, tourism and activities from scientific stations, but they may also be potentially transported from transboundary sources. Currently, there is a lack of information concerning the presence of micro- (< 5 mm) and nanoplastics (< 1 µm) in the Antarctic marine environment resulting from weathering and fragmentation processes of this macrodebris. The PLANET project (PLastics in ANtarctic EnvironmenT) launched in 2015 by the Italian National Antarctic Research Programme is an international network among research groups having continued experience in Antarctica, led by Italian researchers jointly with Brazilian (University of Sao Paulo, PROANTAR) and Australian (University of Tasmania), partners all sharing common interests and objectives concerning plastic pollution in the Antarctic marine environment. The aim of PLANET is to evaluate the presence of micro and nanoplastics in the Antarctic marine environment and study the potential impact on marine biota in terms of bioaccumulation, toxicity and trophic transfer. Within the PLANET project, specific regions located south of the Antarctic Convergence are considered, including South Georgia and the South Shetland Islands and also the Ross Sea, all representative of Antarctic marine environments subject to a range of human impacts. Initial studies have included accurate sampling of water and biota in order to determine the amount of micro- and nanoplastics, as well as examining their effects in organisms at different trophic levels (e.g. phytoplankton, krill, scallops, fish and seabirds). The role of bacteria is also under investigation. Our preliminary results confirm the widespread presence of plastic debris of different sizes (both macro- and micro-) and polymeric nature in the Antarctic terrestrial and aquatic environment as well as in organisms from various trophic levels collected from around the Ross Sea region. The recent increasing involvement of more Italian researchers and international Polar Institutions (Instituto Antarctico Chileno and the British Antarctic Survey), will help facilitate our understanding of the wide spread nature of micro and nanoplastics contamination in the Antarctic marine environment. The creation of a network of researchers in this emerging field is necessary in order to develop the first ecological risk assessment to be used for policy decisions focused on the conservation of the Antarctica.

Modular portable robotic systems for the non-invasive observation of Ross Sea coastal ecosystem

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In the last years, the Institute of Intelligent Systems for Automation of the Italian National Research Council developed, starting from the projects POLE e RAISE, portable robotic technology for the observation of underwater environment in polar regions, including under-ice.

Activity focused on the scientific objective of sampling larvae and eggs of Antarctic Silverfish in the platelet ice as well as observing the process of formation of the platelet ice itself during the winter.

To this aim a couple of technologies were applied in Terra Nova Bay and surrounding areas:

1) adaptation of a commercial mini-ROV with a custom sampler for under-ice operations with light logistics, transportable by helicopter

2) development and installation of a persistent under-ice monitoring system equipped with cameras and multi-parametric gauge

and a portable highly automated ROV, P2-ROV, for monitoring and sampling of biological samples inside the platelet ice was developed.

Current research aims at extending the concept of portable under-ice ROV to develop a family of modular portable underwater, semi-submersible and surface robotic vehicles able to support the study of the water masses from air-ice interface to the seabed.

Discussion with marine scientists is fundamental for the development of suitable tools for non-invasive monitoring and sampling of the Ross Sea ecosystem.

The Antarctic silverfish, a keystone species in a changing ecosystem (M. Vacchi, E. Pisano, L. Ghigliotti (Eds). Springer Book Series 'Advances in Polar Ecology'

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As the prevalent plankton-feeder of the intermediate trophic level, and main prey of top predators, the Antarctic silverfish plays a pivotal role in the trophic structure of the High-Antarctic coastal system, and in its patterns of energy flow. Important evolutionary changes in body density and buoyancy places this small fish at one extreme of the notothenioid evolutionary/ecological axis from benthic to secondary pelagic life style. Indeed, the Antarctic silverfish is the only known notothenioid living all stages of its life throughout the water column, from eggs to adults.

Its abundance and ecological relevance, together with peculiar evolutionary adaptations, fully justifies the interest for this species of a wide community of Antarctic scientists. The discovery of the first (and only known to date) nursery area for the Antarctic silverfish, in Northern Terra Nova Bay, Ross Sea, has further propelled researches aimed at clarifying the relationship of early life stages with the ice canopy, a crucial issue in the light of the ongoing environmental changes.

Thirteen chapters roping in high level competences of over 30 scientists from 10 countries, the book aims at providing the scientific community with an updated overview of the Antarctic silverfish biological and ecological information, including perspectives for future monitoring, conservation and management.

The volume, included in the Springer Book Series "Advances in Polar Ecology" (editor-in chief D. Piepenburg), is organised in three thematic sections: 1) Evolutionary history and adaptation; 2) Ecology and life cycle; 3) Protection initiatives.

Given the high scientific quality of contributors and referees, the book is expected to be a comprehensive review on the species, but also an advancement in our knowledge on the coastal Antarctic ecosystems, including those of the Ross Sea.

Publication is scheduled for early 2017.