Report of the Working Group on Ecosystem Monitoring and Management

(Cambridge, UK, 9 to 13 July 2018)

Contents

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Introduction and opening of the meeting

1.1 The meeting of the Working Group on Ecosystem Monitoring and Management was held at the British Antarctic Survey (BAS), Cambridge, UK, from 9 to 13 July 2018. Dr Beatrix Schlarb-Ridley (BAS Director of Innovations and Impact) welcomed participants to the Aurora Innovation Centre at BAS. She described the particular importance of the collaborative research that characterised the output work of WG-EMM and hoped that this week's meeting would include more of the same

1.2 Dr M. Belchier (Chair of the Scientific Committee) informed the workshop that Dr M. Korczak-Abshire (Poland), the Convener of WG-EMM, was not able to attend the Working Group. He conveyed Dr Korczak-Abshire's disappointment at not being able to attend and also her best wishes for a successful meeting. As there had been insufficient time to appoint an alternative Convener, Dr Belchier undertook to take on the role of Convener for this meeting.

1.3 Dr Belchier also welcomed all participants (Appendix A) to Cambridge and hoped that they would have an enjoyable time at the Working Group meeting and also an opportunity to enjoy the unprecedented hot and sunny weather.

1.4 The Agenda was adopted unchanged (Appendix B).

1.5 Dr Belchier noted the large number of papers (listed in Appendix C) that had been presented to the meeting and requested the indulgence of those presenting papers to be brief and focus on the key issues for consideration by the Working Group. He also emphasised the importance of providing clear advice and recommendations to the Scientific Committee.

1.6 In this report, paragraphs that provide advice to the Scientific Committee and its other working groups have been indicated in grey. A summary of these paragraphs is provided in Item 9.

1.7 The report was prepared by T. Brey (Germany), R. Cavanagh, C. Darby and S. Fielding (UK), D. Freeman (New Zealand), S. Hill (UK), J. Hinke and C. Jones (USA), S. Kawaguchi and N. Kelly (Australia), B. Krafft and A. Lowther (Norway), B. Meyer (Germany), E. Murphy (UK), K. Reid (Secretariat), G. Robson (UK), M.M. Santos (Argentina), E. Seyboth (Brazil), I. Staniland (UK) and G. Watters (USA).

Ecosystem impact of the krill fishery

Risk assessment framework for Divisions 58.4.1 and 58.4.2

2.1 The Working Group noted WG-EMM-18/37, which described an application of a risk assessment to krill fishing in East Antarctica, particularly in Divisions 58.4.1 and 58.4.2 to evaluate whether the current management procedure has a high likelihood of achieving

CCAMLR's objectives in this region. Application of the risk assessment method was largely as it was described by WG-FSA-16/47 Rev. 1, a method endorsed by SC-CAMLR (SC-CAMLR-XXXV, paragraph 3.62). In this implementation of the risk assessment framework, predation needs of baleen whales, crabeater seals (*Lobodon carcinophagus*) and Adélie penguins (*Pygoscelis adeliae*) were explored, in parallel with the currently agreed krill biomass estimates across Divisions 58.4.1 and 58.4.2. This risk assessment found the regional risk of the current conservation measures in Divisions 58.4.1 and 58.4.2 to be higher than the baseline regional risk. That would suggest that, in the event that krill fishing within a CCAMLR season begins to approach the catch/trigger limits, krill predators across Division 58.4.1 could be potentially exposed to disproportionate effects of fishing (noting that the regional risk of historical krill fishing from 1974 to 1995 did not approach the baseline regional risk). Given this result is largely driven by the krill biomass/density estimates across Divisions 58.4.1 and 58.4.2, it would be useful to have updated surveys (Table 1), in addition to data from the fishery, to ensure the potential risk can be managed as it expands.

2.2 The Working Group welcomed the further work on the risk assessment for the krill fishery in Divisions 58.4.1 and 58.4.2. In terms of future data streams for risk assessments for krill fishing, it suggested that there was potential in emerging remote sensing methods for estimating abundances of pack-ice seals, particularly in East Antarctica. It also noted existing smaller-scale surveys in East Antarctica (such as the Collaborative East Antarctic Marine Census for the Census of Antarctic Marine Life (CEAMARC) collaboration in 2007/08; Amakasu et al., 2011) are promising sources of data to inform on the more recent distributions and abundances of krill, but stressed the importance of updating these parameters for CCAMLR management units, which is planned for Divisions 58.4.1 (WG-EMM-18/17) and 58.4.2 (proposal in development). In terms of refining the risk assessment approach, it noted that more accurate and precise estimates of krill consumption rates by various krill predators could help the risk assessment framework move from providing relative risk to being able to provide estimates of absolute risk. The Working Group suggested modifying the risk assessment framework to account for the potential for stochastic broad-scale events, such as calving of ice shelves. It also noted the potential of a Bayesian approach to improve the krill fishery risk assessment framework, which has already been applied to a spatially explicit fisheries risk assessment (Ministry for Primary Industries, 2017).

Risk assessment framework for Area 48

2.3 The Working Group noted the discussion on the risk assessment approach for Area 48 described in WS-SM-18/04 which took place during the Workshop on Spatial Management (WS-SM-18).

Fishing activities

2.4 The Secretariat presented the Working Group with an update to the krill fishing information for 2016/17 and 2017/18, and noted that:

(i) in 2016/17 (1 December 2016 to 30 November 2017), for Subareas 48.1, 48.2 and 48.3, the total catch of krill reported was 236 939 tonnes

(ii) in 2017/18 (to June 2018), Subareas 48.1 and 48.2 were fished; the total catch of krill reported was 250 159 tonnes of which 151 564 tonnes were taken from Subarea 48.1 (closed on 25 June at 98% of the catch limit) and 98 595 tonnes taken from Subarea 48.2

(iii) in both 2016/17 and 2017/18, main fishing activity took place in Subarea 48.2 and then shifted to Subarea 48.1 from March–April, with most effort concentrated within Bransfield Strait in May and June

(iv) in both 2016/17 and 2017/18, fishing activity took place in Subarea 58.4, with a total catch of 513 tonnes (9 tonnes and 504 tonnes from Divisions 58.4.1 and 58.4.2 respectively) in February 2017, and 246 tonnes from Division 58.4.2 in January 2018.

2.5 The Working Group congratulated the Secretariat on the effective implementation of the fishery forecasting process for the krill fishery that had resulted in the fishery closure in Subarea 48.1 on 25 June within 2% of the catch limit.

2.6 The Working Group noted that projection of catch to determine the timing of fishery closures is based on the reported catch under Conservation Measure (CM) 23-06, which is reported monthly until a set percentage of the catch limit is reached, then it moves to five-day reporting. The Working Group noted that with monthly reporting, catches at the start of one month might not be reported until the end of the following month. The Working Group noted that real-time submission of vessel monitoring system (VMS) data will allow the Secretariat to confirm the presence of a vessel in the fishery and this would improve the ability of CCAMLR to ensure data required to forecast the closure of the fishery is available in a timely manner.

Fishery notification

2.7 The Working Group noted that 12 vessels from five Members had notified their intention to fish for krill in 2019, with two vessels notified to fish in Area 58.

Fishery index

2.8 The Working Group noted that an index of krill fishery performance in all three subareas was strongly negative in 2015 while CCAMLR Ecosystem Monitoring Program (CEMP) combined standardised indices (CSIs) in 2015 were generally positive, but were negative in all three subareas in 2016 (WG-EMM-18/44). It was suggested that this lag may mean that the performance of the fishery in the post-breeding season (winter) could be a better indicator of predator performance/krill availability in subsequent breeding seasons.

Scientific observation

Finfish by-catch observation

2.9 WG-EMM-18/30 outlined a study carried out to examine the accuracy of juvenile fish taxonomy as reported by observers in the Antarctic krill (*Euphausia superba*) fishery using

DNA barcoding to provide independent identification from those identified by observers over two krill fishing seasons. The observer taxonomic identification was reasonably accurate. The diversity of fish identified by observers (five families; eight species) was considerably lower than with DNA barcoding (seven families; 20 species). How important this additional level of information is for CCAMLR management needs to be considered. The authors of the paper recommended some additional observer training and improved manuals for fish taxonomic identification are warranted given the effort invested in the high-quality observer program.

2.10 The Working Group highlighted the accuracy of finfish larvae identification by scientific observers. It also emphasised the importance of correctly identifying species that are recovering from historical overfishing, such as mackerel icefish (*Champsocephalus gunnari*) and marbled rockcod (*Notothenia rossii*).

2.11 The Working Group noted that the potential cost and effort involved in the DNA barcoding method may not allow it to be applied as a routine tool to monitor fish by-catch samples for taxonomic identification, but would be more suitable to periodically confirm identifications and/or highlight where any errors in identification occur.

2.12 The Working Group suggested that photographs of finfish larvae identified to species level based on DNA analysis could be used as an identification guide for observers, highlighting the sources of incorrect identification and requested that those photographs be sent to the Secretariat for inclusion in CCAMLR Scheme of International Scientific Observation (SISO) materials.

Revised krill trawl logbook for the 2019 season

2.13 The Working Group noted WG-EMM-18/39 that summarised the changes to the e-logbook for proposed introduction in the 2019 season. The data collection requirements for krill observers were discussed at the Workshop on the Scheme of International Scientific Observation (WS-SISO-17) (SC-CAMLR-XXXVI/08) for amendments to the krill e-logbook used by observers.

2.14 The Working Group endorsed the proposed changes, including the removal of the subsampling requirement from each 25 kg sample of krill for fish by-catch sampling and the inclusion of invertebrate by-catch reporting in addition to finfish. The Working Group noted that the proposed new format had been developed via the SISO e-group.

Ice krill by-catch

2.15 WG-EMM-18/05 analysed publicly available aggregated decadal-scale krill catch data to evaluate the likelihood that ice krill (*Euphausia crystallorophias*) will have been included in the reported Antarctic krill catch. The Antarctic krill fishery operates in geographic areas that overlap with the known range of ice krill, potentially occupying similar depths in the water column. The authors of the paper concluded that as both species are morphologically similar, the possibility of ice krill being caught as by-catch, and the failure to detect it, cannot be dismissed and that the likelihood of ice krill by-catch is effectively 100%.

2.16 The Working Group noted that some krill fishery operations occur in areas where datasets from scientific net hauls indicate the likelihood of co-existence of these two species. The Working Group further noted that the absence of ice krill reports does not necessarily indicate an absence of ice krill by-catch, and underlined the importance of providing scientific observers with the appropriate materials needed to identify ice krill in their routine observations.

2.17 The Working Group noted that there are various methods to detect ice krill and other by-catch, such as the use of lipid or DNA markers. However, it was also noted that these methods may not be practical to apply to a large number of samples in a routine manner. The Working Group noted that a combination of different approaches, including DNA barcoding and traditional analyses such as morphology, as presented in WG-EMM-18/03, might be useful in order to address this issue.

2.18 The Working Group noted that the absence of ice krill in by-catch could be because the fishery is targeting Antarctic krill, and avoiding catch of ice krill due to its smaller size.

2.19 Dr S. Kasatkina (Russia) recalled that Russian research surveys provided in previous years in Area 48 did not reveal the presence of ice krill in catches using research gear.

2.20 The Working Group requested that Members compile relevant survey and catch data in order to provide advice in the future on by-catch in terms of finfish and invertebrates in the krill fishery.

Krill biology, ecology and population dynamics

2.21 WG-EMM-18/06 provided an update on work to improve the current understanding of the regional and local-scale processes that determine the distribution of Antarctic krill in Area 48. The modelling is focused on the South Orkney Islands at regional scales relevant to the krill fishery and predators. Results suggested that resolving the interaction of krill with sea-ice is critical for determining the pathways and timescales of transport into and out of the region.

2.22 The Working Group noted that the analysis in WG-EMM-18/06 indicated that krill from the parts of Subarea 48.1 used by the fishery had a very low probability of being advected to the part of Subarea 48.2 used by the fishery when only the ocean flows were considered. The Working Group agreed that improving understanding of krill interactions with both the ocean currents and sea-ice drift is important.

2.23 The Working Group welcomed the development of this work and encouraged further modelling studies to examine controls on distribution and abundance of krill at multiple scales. It was noted that such high-resolution modelling would be extremely valuable to provide information on krill movement and distribution at scales relevant to inform the development of small-scale management measures.

2.24 WG-EMM-18/21 described an analysis of krill flux across the Scotia Sea using geostrophic circulation, spatial distribution of krill density, water flow intensity and krill biomass based on the analysis of data from the CCAMLR 2000 Krill Synoptic Survey of Area 48. The results indicated that the krill flux through the Antarctic Peninsula area and the South Orkney Islands area may be higher than the annual catch of krill and the catch limits in place for Area 48. The authors of WG-EMM-18/21 concluded that the results show that development of krill resource management schemes requires a study of the variability of its distribution under the influence of geostrophic flux at various space–time scales and that such information is necessary to understand the competitive relationship between predators and fisheries for krill resources.

2.25 The Working Group noted transport of krill in ocean currents is an important process in generating the observed large-scale distribution of krill, however, the pathways and timescales of movement and retention affecting krill distribution at scales relevant to the fishery and predators are particularly important.

2.26 It was noted that the data used in WG-EMM-18/21 were based on a single snapshot observation and that more data across time (seasonal and interannual) and in specific areas are needed to improve understanding of stock dynamics. Recognising that field studies of these processes are logistically and technically challenging, the Working Group welcomed the modelling studies that are implemented at fine-scale (<5 km) resolution and include sea-ice movement that can be used to provide insights into the krill distribution relevant to management.

2.27 Dr Kasatkina recalled that data from Soviet/Russian meso- and small-scale surveys and local area surveys (6 × 8 n miles) as well as data from the CCAMLR-2000 Survey suggest that the variability of krill biomass in the studied fishing grounds is more a reflection of krill flux in the region rather than the effect of fishing on krill resources.

2.28 WG-EMM-18/07 provided a summary of research published last year, to obtain a mechanistic understanding of the interaction between krill larvae and sea-ice (WG-EMM-18/P04 and 18/P05). Earlier studies led to the development of a traditional concept that early onset of sea-ice formation and prolonged sea-ice coverage result in higher krill recruitment the following summer. An important assumption in this hypothesis is that krill larvae are able to access food within the sea-ice. A study in late winter of 2013 on board the icebreaker *Polarstern* demonstrated that the pack-ice zone represents a nutrient-poor habitat for larvae development, whereas ice-free areas provide enhanced food conditions during winter. Chlorophyll-a concentration, as well as particulate organic matter underneath the ice within the pack-ice zone, can only sustain consistently low growth rates of larvae krill during winter. This contradicts the traditional hypothesis outlined above. These new insights have challenged a long-standing hypothesis and initiated a paradigm shift concerning the relationship between krill population dynamics and sea-ice. Based on these findings on larval krill and sea-ice, future studies conducted during autumn, late winter and early spring should focus on the northeastern Weddell Sea to get a better understanding of krill connectivity between the northeastern Weddell and the Scotia Sea to better predict krill population dynamics in the future.

2.29 The Working Group noted the importance of this paradigm shift in understanding of the processes influencing krill recruitment, which is recognised as the key driver of interannual variability in biomass, as well as the identification of areas and times of the year that are important for future studies.

2.30 WG-EMM-18/P18 presented stomach content analysis, as well as a stable isotope and fatty acid analysis, providing information on the diet of krill larvae and age class 0 (AC0) juveniles in late winter. The study highlighted the high diversity of autotrophs and heterotrophs in the diet of the larvae and AC0 juveniles in winter, which reflects the food availability in the regions where the individuals were caught, and suggest that AC0 krill mainly feed on ice-associated food sources. Variability in the diet, revealed by fatty acid profiles and stable isotope values, suggested that less availability of sea-ice resources over a long term may negatively affect larval condition in ice-covered waters.

2.31 The Working Group noted that the complementary investigations on the same expedition (WG-EMM-18/07 and 18/P04) indicated that the ice-associated food sources may not support high growth rates during winter, but are probably important for larval krill that are residing in pack-ice regions.

2.32 WG-EMM-18/34 provided information on the interannual variability in indices of krill density, recruitment and diurnal vertical distribution at South Georgia during winter based on Japanese krill fishery data during the period 1990–2012. The paper highlighted that the eastern region of South Georgia tends to be a highly stable fishing ground during winter. The krill recruitment index at South Georgia showed a congruent pattern with that in the Antarctic Peninsula in the 1990s, whereas this congruence was not apparent during 2000–2006. In addition, the data show that median winter trawling depth (a proxy for krill vertical migration) for each daytime and night-time was significantly positively correlated with average krill body length in winter. The authors suggested that this could be the optimal behaviour of krill to balance food intake against predation risk by Antarctic fur seals (*Arctocephalus gazella*), the most abundant krill-eating predator in the region.

2.33 The Working Group welcomed this analysis that highlighted the large amount of information available from the fishery that could provide insight into krill ecology and population dynamics. The Working Group also noted that the study used to define fur seal diving depths was based on data from lactating female seals, whereas during the winter months the population at South Georgia will be made up of a greater mix of the two sexes and different age classes.

2.34 WG-EMM-18/42 provided information on the spatial distribution and swarm characteristics of Antarctic krill which were studied using the swarm-based method established in SG-ASAM. Acoustic data were collected by the FV *Fu Rong Hai* using Simrad EK60 echosounders (38/70/120 kHz) in December 2013, March 2015, January 2016 and February 2018 around the South Shetland Islands. The mean krill densities in December 2013 and February 2018 were markedly higher than in the other two years, whereas many more swarms (1 055) were detected in February 2018 than in the other three years. The majority of swarms were found in the upper 100 m layer with the exception of March 2015 when more krill swarms were located in deeper water layers.

2.35 The Working Group agreed that the swarm-based method provides a useful approach to estimate krill biomass and to provide biologically relevant data on swarm characteristics.

2.36 The Working Group discussed the relative roles of local processes of retention and larger-scale processes of advection and flux in relation to krill distribution and abundance. It noted that fine-scale processes such as ocean current interaction around bathymetric features and krill behaviour are likely to be important in determining the distribution of krill at scales relevant to the fishery.

2.37 The Working Group noted that more research is required to improve the basic understanding of the physical and biological processes that determine the spatial structure of these ecosystems and that in addition to undertaking repeat mesoscale surveys, use of new autonomous technologies (e.g. moorings or gliders being developed in US AMLR and BAS programs) is likely to be important for improving understanding of seasonal changes in distribution and abundance.

Krill life-history parameters

2.38 WG-EMM-18/P16 provided information on a method for estimating krill age by detecting the growth bands of eyestalk sections of krill fixed in 70% ethanol and 5% formalin. This study presented important information for age determination, particularly for specimens preserved in formalin, and will benefit the stock assessment of this species in the future. Further studies are required to validate the correlation between growth bands and age. Additionally, more samples from different seasons and regions are also needed to fully understand the growth dynamics of this species.

2.39 The Working Group highlighted the importance of this study and strongly encouraged performing further studies to validate the correlation of age and annual bands in eye stalks with known age samples from krill grown in aquaria.

CPUE and spatial dynamics

2.40 WG-EMM-18/41 provided information on temporal and spatial dynamics of the krill population and the krill fishery in Subarea 48.1 by using catch per unit effort (CPUE) data collected from the Chinese FV *Fu Rong Hai* from the 2012/13 to the 2016/17 fishing seasons. Acoustic data collected throughout the fishing season showed the krill population development and that in most years krill abundance in the fishing area was higher in autumn than in the summer season.

2.41 WG-EMM-18/P11 provided an update of WG-EMM-16/52 on krill fishing hotspots and daily CPUE patterns for the krill fishery. The fleet took 48–57% of the seasonal catch in fishing hotspots that persisted for 2–6 months with high catch densities. Within these fishing hotspots there was a dome-shaped pattern of CPUE over time such that when CPUE decreased, the fleet moved to contiguous zones; such displacements occurred every 4–17 days and previously exploited zones were revisited.

2.42 The Working Group noted the importance of the data in WG-EMM-18/41 and 18/P11 in providing information on the seasonal distribution behaviour of krill and encouraged Members to contribute to such analyses. The Working Group noted that the results corroborate the outcomes of the AMLR winter surveys that indicated that krill biomass increases inshore in winter.

2.43 The Working Group also noted that the behaviour of the krill fishing fleet shows a consistent pattern of distribution in Subarea 48.1 with fishing initially in the Drake Passage and then focusing in Bransfield Strait and it was useful to understand the drivers of this behaviour of the fleet. The Working Group noted that VMS data from the krill fishery could be used to examine fleet dynamics to better understand the relationship between krill distribution and behaviour and the activities of the krill fishery.

Continuous trawl catch recording

2.44 WG-EMM-18/22 provided a review of the recording of two-hourly catch weight from the Norwegian continuous trawling vessels, as requested by the Scientific Committee in 2016 and 2017 (SC-CAMLR-XXXVI, paragraphs 3.6, 3.7 and 7.6vii). The questions raised by the Scientific Committee had been addressed in accordance with a plan proposed to the Scientific Committee in 2017 and included analysis of historic data from the vessels and onboard investigations during the 2017/18 season.

2.45 The Working Group noted that:

(i) the time lag between krill entering the trawl until it was taken on board was negligible (nine minutes) compared to the tow duration and the sampling time periods

(ii) the reported catch per two-hour interval is the total catch over a longer period that is scaled by an onboard estimate taken from the rate at which the holding tank fills. However, differences between vessel and officer procedures generate variation between the data series of samples

(iii) reporting differences and delays cause uncertainty in any reported catch value but not major bias

(iv) the geographical distribution of reported catch at different spatial scales showed only minor deviances between what was previously reported to CCAMLR and the catch reallocated in relation to the delay in reporting.

2.46 The Working Group noted that the uncertainty associated with the historical reported catch data is higher than has been previously assumed, and that whereas bias appears small, precision is lower than expected using the previously applied estimation approaches.

2.47 The Working Group noted that while the total catch and catches reported as part of monthly or five-day catch and effort reporting would not be impacted, the C1 data should be used with caution when conducting fine-scale (i.e. haul-by-haul) analyses.

2.48 While methods for determining less variable estimates of continuous trawling two-hour catch rates are developed, users of data should be informed of the uncertainty regarding the uncertainty associated with individual records. The records appear robust, at the finest spatial scale analysed (0.25° longitude by 0.125° latitude), however, temporal aggregation at or greater than, for example, 24-hour intervals will be required to provide unbiased estimates of catch.

2.49 The Working Group agreed that appropriate metadata should accompany any data extracts, and contain an advisory wording that the data from continuous fishing vessels should not be used at a haul-by-haul (two-hourly catch reporting period) for routine analysis given uncertainties in the methods implemented to allocate catches to two-hourly catch reporting by continuous vessels.

2.50 The Working Group noted that in the context of:

(i) CM 23-06 (closure of the fishery), the reporting procedures do not impact on CCAMLR management of the vessel catch and the overall krill fishery

(ii) CM 21-03 (two-hourly catch reporting by continuous vessels) the method used to estimate the catches (holding tank krill depth) is considered appropriate but requires standardisation, in terms of an agreed protocol that is consistent across vessels and in its application on the vessel.

2.51 The Working Group noted that the sampling of fish by-catch by observers takes place before the catch enters the holding tank as described in WS-SISO-17/11 and agreed that the methodology was appropriate. Based on the findings in WG-SAM-18/22 that the geographic distribution of reported catches showed minor deviances, the georeferencing of length-frequency distribution would not be impacted. However, linking of these samples to the overall vessel catch during a specific two-hourly catch reporting period may not be possible for existing data and requires an agreed standard approach for future data collection. This will ensure that finer-scale raising of by-catch sample data to total catch can be applied in future data collection. This may require amendment of instructions to observers and crew, as well as the relevant recording form.

2.52 Dr O.A. Bergstad (Norway) reported that consistency has been achieved between vessels and skippers in the procedures for estimation of 2-hourly catches. It would seem difficult to improve the precision further with the current processing and operational procedures.

2.53 The Working Group agreed that analysis of the continuous trawl data, particularly CPUE standardisation and analysis and the investigation of krill swarm dynamics, should proceed with caution and provide clarity on the temporal scale of aggregation of the two-hourly catch reporting periods. The Working Group therefore recommended that the Scientific Committee provide advice on appropriate advice to accompany data extracts.

2.54 The Working Group noted Norway's intention to pursue other options, in particular the acoustic recording and quantification of catches in the trawl mouth. There are actions to implement and develop such methods, and Norway would report on progress in due course.

Data layers from the krill fishery

2019 large-scale survey in Area 48

3.1 The Working Group considered papers concerning the proposed 2019 large-scale survey (WG-EMM-18/08, 18/12 and 18/23). The Working Group was reminded of the primary scientific objectives that were proposed by Norway in late 2017:

(i) to derive an estimate of abundance for Antarctic krill in the survey area, i.e. the subarea recognised as the primary distributional range of krill within Area 48

(ii) to compare and contrast density distribution patterns of krill between the surveys in 2000 and 2019

(iii) to compare distributions of krill and other biota in relation to oceanographic conditions, with particular focus on potential effects of climate variation and change

(iv) to enhance spatially and temporally relevant knowledge on interactions between krill and apex predators and the potential impacts of krill fishing.

3.2 WG-EMM-18/08 expanded paragraph 3.1(iv) and presented a project aimed at developing knowledge on the marine environment essential for the implementation of a feedback management (FBM) system. Data supporting FBM as an integral part of the broader management strategies of the krill fisheries within Domain 1 are critical if the fishery is to be managed by an empirical understanding of krill density, distribution, availability and predator needs. A future developed FBM system, as presented in SC-CAMLR-XXXVI/BG/20, requires acoustic data to be collected, processed and reported continuously during the fishing season as a measure of the available prey field. This information can be integrated with finer-scale knowledge of krill predator feeding strategies and updated through specific scientific studies at regular (multiyear) intervals. The FBM process studies will take place during the austral summer 2018/19 in association with the large-scale survey planned for Area 48.

3.3 WG-EMM-18/12 and 18/23 were presented to the Working Group in response to feedback on SG-ASAM-18/07 presented during SG-ASAM-18 in Punta Arenas, Chile. SG-ASAM-18/07 described plans for the execution of the multinational large-scale krill survey in Area 48 during 2019. The 2019 large-scale survey is coordinated by Norway working with international partners and CCAMLR scientific working groups to endorse methodology that has used the CCAMLR-2000 Survey as the basis for the survey design and sampling protocols. SG-ASAM-18/07 was endorsed by SG-ASAM, but that Subgroup recommended additional description of the implementation of technical issues to the survey be presented to WG-EMM.

3.4 WG-EMM-18/12 described acoustic procedures, the acoustic reporting procedures, analysis procedures and contingency plans, also with appendices containing acoustic sampling protocols and lists for the dedicated transect allocations of individual vessels. The survey summarises the collaborative efforts of Norway, the Association of Responsible Krill harvesting companies (ARK: companies from Norway, the Republic of Korea, China and Chile), the UK, Ukraine, Korea and China, all of whom have confirmed a commitment of survey ship time. With these commitments it is feasible to implement all transects and stations occupied during the CCAMLR-2000 Survey. A survey coordination group is established and has progressed substantially during the planning time; it was announced that it is still open for additional members.

3.5 WG-EMM-18/23 presented a protocol for sampling of biological data and hydrographic data for the survey. The aim is to facilitate a joint understanding of the field and laboratory work for participants that carry out the survey to standardise equipment and methods. The net sampling and laboratory protocols are based on the protocols developed for the CCAMLR-2000 Survey. Notably, the sampling locations will be the same stations as those undertaken during the CCAMLR-2000 Survey.

3.6 The Working Group welcomed the Norwegian-led initiative as proposed and noted the major commitments already made by several Members and the industry facilitating a synoptic sampling of all major fishing areas as well as the remainder of relevant areas of Area 48.

3.7 The Working Group also noted that the progress plan for developing the survey as a CCAMLR activity was presented with the first draft plan. WG-EMM welcomed the formation of a survey coordination group, which met at WG-EMM, building on previous work undertaken by correspondence since SG-ASAM. The Working Group agreed that many of the SG-ASAM recommendations had been addressed, and that that work is continuing. It emphasised the need to schedule further meetings and the pre-survey meeting early in order to ensure relevant participation.

3.8 The Working Group noted that while the 2019 large-scale survey protocols were based on the CCAMLR-2000 Survey acoustic, net and oceanography protocols, some differences were identified:

(i) net types used differed between vessels, and also differed from the single RMT8+1 used in 2000

(ii) the acoustic sampling will occur through day and night, compared with only daytime sampling undertaken in 2000

(iii) stratified net sampling stations would be undertaken at variable times of day/night (compared with fixed midnight and midday timings in 2000).

3.9 Dr Krafft identified that all the nets mentioned in WG-EMM-18/23 were approved by CCAMLR to sample Antarctic krill, that their selection properties can be calculated and that results can be used to look at inter-net selection variability of sampling of Antarctic krill. In addition, it was noted that more than 70% of the biological sampling stations would use the same trawl type.

3.10 The Working Group further noted that the spatial extent of the survey and time allocated by contributing vessels meant acoustic surveying would have to occur throughout the 24 hour period, different from the CCAMLR-2000 Survey. It also highlighted that in Subarea 48.1, alternative sampling platforms such as moorings and gliders would provide detailed information on the diurnal pattern of krill distribution that could be used to interpret diel variability and would be advantageous to a daytime-only view of krill distribution.

3.11 It was also noted that due to limited available resources (ship time), it will not be possible to carry out the same biological sampling strategy as in 2000 with regard to station timing. In 2019, station work will be performed at the same geographic locations as in 2000, but not at midnight and midday.

3.12 The Working Group discussed whether the intended coordinated meeting of SG-ASAM, WG-EMM and WG-SAM planned for 2019 to discuss survey design could be an opportunity to consider a strategy for the frequency of large-scale surveys, or whether science should focus on regional variability. The Working Group recognised that the results from the 2019 large-scale survey would be compared with the estimate from 2000 and it needed to be confident that methodological differences were understood. The Working Group was reminded of the annual national krill surveys (e.g. in Subareas 48.1, 48.2 and 48.3), that could be used to interpret differences between the two point measurements.

3.13 The Working Group agreed that the 2019 large-scale survey will provide a framework for studies into FBM. It recommended that the mesoscale transect components of the CCAMLR-2000 Survey were aligned with the long-term national surveys, particularly in the Bransfield Strait where fishing activities have shifted geographic location since 2000.

3.14 It was highlighted that the 2019 large-scale survey would provide a wealth of new observations from Area 48 and that appropriate data stewardship and sharing strategies should be established. During WG-EMM-18 the survey coordination group identified that a data management plan would be developed, led by Dr G. Macaulay (Norway) (acoustic) and Dr Krafft (biology) and supported by Drs Fielding and Hill. This would include common cruise reports and outline station reporting requirements.

3.15 The Working Group considered plans for post-processing and analyses. It agreed that acoustic data processing should, where possible, be undertaken during the survey (on board the vessel) using the swarms-based approach to determine krill density. It reminded the group that the appropriate software template and R markdown script describing the methods were available from https://github.com/ccamlr/CCAMLREchoviewR and Members should use the supporting documentation within the SG-ASAM reports (SC-CAMLR-XXXVI, Annex 4 and Annex 4). It was agreed to support SG-ASAM's suggestion for a survey analysis workshop in 2019.

3.16 The Working Group recommended that the 2019 large-scale survey dataset be used to further examine the performance of swarms-based methods over different temporal and spatial scales by also calculating krill density distribution using the two-frequency identification method.

3.17 Dr Kasatkina emphasised that the CCAMLR-2000 Survey was strongly standardised in terms of acoustic data collection and analysis using the multi-frequency acoustic method to identify krill, accompanied by biological sampling with standard research trawl and data collection during the daytime. The timeline for each transect was determined in advance of the survey and was monitored. The 2019 large-scale survey will be carried out by vessels that collect acoustic data during day and night with krill identification undertaken on a single frequency using the swarms-based approach. She highlighted that the multi-frequency identification method should be applied to the data. In addition, biological sampling will be undertaken using both commercial and research trawls. She noted that results of the 2000 and 2019 surveys of krill distribution patterns and biomass estimates will be estimated using different techniques that may not be comparable.

3.18 Dr Kasatkina outlined the necessity to clarify differences in the 2019 survey. In particular, how to establish the baseline acoustic data by summarising data from each vessel and whether these data are accompanied by different sources of uncertainty and how to assess this uncertainty in density estimates. She stressed that clarity regarding these issues raised would facilitate both clarity regarding the practical utility of expected outcomes from the 2019 survey as well as the development of survey design and methodology.

3.19 The Working Group summarised the expected outcomes of the 2019 large-scale survey as:

(i) provide an overall reference, in terms of abundance and distribution, to krill assessments in the fishing areas and provide an indication of biomass within the survey area

(ii) analyse large-scale distribution in relation to environmental conditions to inform analyses of impacts of climate change

(iii) evaluate and develop survey strategies incorporating the future utilisation of fishing vessels

(iv) undertake a synoptic assessment of biomass, distribution and population characteristics in those areas currently fished

(v) provide information pertinent to the development of risk assessment, FBM and the spatial management considerations in Domain 1

(vi) provide ocean-scale opportunity for sampling of krill biology and other taxa.

2019 krill Survey in Division 58.4.1

3.20 WG-EMM-18/17 described the revised proposal for a dedicated krill survey for Division 58.4.1 during 2018/19 carried out by the *Kaiyo-maru*. The survey will follow the BROKE transects, use multifrequency narrowband acoustics, and a number of different net types. The survey will include both national and international participants.

3.21 The Working Group identified that the BROKE transects were being repeated and queried whether knowledge gained and other survey efforts in the area undertaken since 1996 could be used to inform different survey designs, particularly within neritic regions. The Working Group noted, however, that the Japanese vessel is not ice-strengthened and survey efforts will be limited to the ice edge or the 200 m isobath.

3.22 The Working Group noted that SG-ASAM had also considered papers outlining the *Kaiyo-maru* survey in Division 58.4.1 and endorsed the method outlined to determine krill density and distribution (SC-CAMLR-XXXVI, Annex 4, paragraphs 5.1 to 5.3 and Annex 4, paragraphs 5.16 and 5.17). It had focused its discussion and recommendations around the novel wideband acoustic methodology to be employed during the survey.

Krill survey in Subarea 48.2

3.23 WG-EMM-18/P03 presented the activities and preliminary results from the annual (since 2011) krill and ecosystem monitoring survey conducted during February 2018 at the South Orkney Islands. This year the FV *Juvel* was provided by the fishing company Aker Biomarine AS and acoustic information was recorded using three frequencies (38, 70 and 120 kHz), trawl hauls were made every 25 n miles along the transect lines. Catches were weighed and sorted by taxonomy. A conductivity temperature depth probe (CTD) with a fluorescence sensor was attached to the trawl to obtain profiles of hydrography. Systematic sightings for seabirds and marine mammals were carried out along the transects during daylight hours. Data from echosounder and acoustic doppler current profiler moorings deployed in 2017 were recovered and the moorings were redeployed programmed for logging until recovery in 2019.

3.24 Dr Krafft noted that the vessel was unable to trawl during the survey within the South Orkney Islands southern shelf marine protected area (MPA). The Working Group recalled that CM 91-03 identifies that fishing activity is prohibited with exception of research activities in the South Orkney Islands southern shelf MPA. The Working Group recommended that Norway consider how this annual survey could contribute to the RMP of the South Orkney Islands southern shelf MPA and submit a proposal outlining this for approval.

Acoustic data methods and analysis

3.25 WG-EMM-18/15 presented a new drone technology available through a Sailbuoy concept, which offers new opportunities for an industry–science partnership in collecting environment and krill distribution data independent of vessel availability. This concept has demonstrated robustness and reliability under other rough conditions and will be tailored to support data for FBM and for a more environmentally efficient fishery in the Antarctic. The system can be equipped with echosounders and environmental sensors to feed science and industry with data in near-real time. The system does also have the possibility to collect data from moorings through underwater communication using an acoustic modem. The first test is planned for 2019 and the goal of the paper is to establish interaction with potential users to ensure that the tailored system includes most of their requirements.

3.26 WG-EMM-18/11 provided an update on the Antarctic Wildlife Research Fund (AWR) project 'Rapid unsupervised automated krill density estimation from fishing vessels' (Rapid-Krill), which aims to summarise acoustic data to krill density information in near-real time on board research and fishing vessels. The project has been building the CCAMLR acoustic protocols in the open-source software Python, building on a wider community effort to develop open-source acoustic processing tools. It showed the output of a two-frequency (120-38 kHz) identification technique undertaken in Python. The alternative swarms-based approach for krill identification in acoustic data has yet to be implemented.

3.27 The Working Group noted that the swarms-based approach, agreed by SG-ASAM, can operate using single-frequency data (120 kHz) and is used to identify krill in swarms, whilst a multifrequency identification method is required to estimate krill not contained within swarms and recommended that the Rapid-Krill project should facilitate either method.

Marine mammal surveys

3.28 WG-EMM-18/33 introduced two concepts for observing pelagic predators from fishing vessels, including specific questions that can be addressed with different data collection and sampling methods:

- (i) using SISO observers to collect data to establish potential interactions and competition of the krill fishery and krill-dependent predators during fishing operations, as identified by WG-FSA-16 (SC-CAMLR-XXXV, Annex 7, paragraph 6.14) and WG-EMM-17 (SC-CAMLR-XXXVI, Annex 6, paragraphs 2.11, 2.25 and 2.26)

- (ii) the use of trained marine mammal observers to collect data on abundance and distribution of marine mammals during surveys and transects using krill fishing vessels.

3.29 The Working Group noted that whilst the CEMP land-breeding higher predator monitoring was well developed, there is no similar program for pelagic krill predator observations within CCAMLR. The Working Group commended the outline of pelagic predator observations possible from krill fishing vessels in WG-EMM-18/33 and highlighted the potential use of krill fishing vessels as a platform for these observations.

3.30 With respect to using SISO to collect data for understanding potential interactions and competition of the krill fishery and krill-dependent predators during fishing operations, the Working Group acknowledged that there is little information on pelagic predators in comparison to land-based krill predators. As cetaceans are major krill predators, an understanding of how they overlap with the krill fishery is of relevance to the work of WG-EMM and should be considered further.

3.31 The Working Group encouraged Members to undertake experiments or designs of a feasibility study (see also WS-SISO-17/05) noting the concerns about whether the krill fishery observers had the time, alongside their existing responsibilities, to undertake additional marine mammal observations during fishing operations as described in WG-EMM-18/33.

3.32 Regarding wider ecosystem monitoring through surveys and transects by krill fishing vessels, WG-EMM highlighted that marine mammal observations require appropriate training to ensure quality of recorded observations, and this required consideration as well. The Working Group noted that WG-EMM-18/33 included specific methods for marine mammal observations and identified that greater interaction with the International Whaling Commission (IWC) would enable wider exploration of the suitability of krill fishing vessels for cetacean surveys.

3.33 Dr Kasatkina noted that observations from krill commercial vessels do not provide information on marine mammal or other pelagic predators in relation to their biology, feeding and krill consumption. Therefore, it is possible to study only the spatial overlap between the foraging zones and the fishing grounds. To assess the degree of this overlap, information is needed regarding the number and biology of the observed predators relative to the abundance and population structure of their colonies. Some errors in the counting of predators from the vessel cannot be excluded, in particular, bearing in mind the possibility of re-registration of the same predator from neighbouring vessels.

Ecosystem monitoring and observation

CEMP data

4.1 WG-EMM-18/44 summarised the data submitted to CEMP for the 2017/18 season. Eleven Members working at 18 sites in Areas 48, 58 and 88 contributed data for 13 CEMP parameters on six species of krill-dependent predators.

4.2 The Working Group welcomed Cape Hallett as a CEMP site operated by the Republic of Korea and the planned contributions of monitoring at Cape Hallett to contribute to the research and monitoring plan (RMP) of the Ross Sea region MPA (RSRMPA).

4.3 The Working Group noted that the CSI analysis of the CEMP data had been updated to compare patterns of interannual variability of predator performance in Area 48. The CSI analysis indicated an increase in synchrony of the site-specific CSIs within subareas in recent years. Such concordant responses of CEMP indices suggested that predator performance is tracking similar processes on a regional scale. There was no indication of an overall trend in predator performance, but substantial interannual variation that warrants continued research.

4.4 The Working Group considered two papers that suggested updates to several CEMP e-forms. WG-EMM-18/46 provided a rationale for updates to the e-forms for CEMP parameters A3 (breeding population size) to request only data on occupied nests and for A8 (penguin diet) to facilitate submission of krill length-frequency data obtained from predator diets. WG-EMM-18/27 reviewed the type of data available from nest camera images and described their relationship to the CEMP parameters A3, A6 (breeding success) and A9 (breeding phenology) and potential application to A2 (incubation shifts) and A5 (trip durations). The paper proposed minor revisions to the CEMP data forms A3, A6a, A6b and A6c and A9 to accommodate camera-derived data streams.

4.5 The Working Group recalled prior analyses (Lynch et al., 2009; Southwell et al., 2010) that explored how nest camera data can be used to correct off-peak census data.

4.6 The Working Group recommended that the proposed changes to the CEMP e-forms be implemented to increase data provision to CEMP and to progress the use of camera data in the collection of multiple CEMP parameters.

Nest cameras

4.7 The Working Group considered WG-EMM-18/26 and 18/P01 that presented results from validation studies to compare ground and nest camera observations of breeding chronology and success of *Pygoscelid* penguins. The observations demonstrated a correspondence of major phenological events observed directly or with nest cameras to within 1–2 days. The Working Group noted the utility of repeating validation studies as a means to test the robustness of new methods. The Working Group also noted the clear progress made in the development and uptake of camera-based monitoring of seabirds by many Members.

4.8 The Working Group noted that the R code published in the appendix of WG-EMM-18/P01 is accessible to Members as an R Shiny application (available at: https://jefferson.shinyapps.io/photor2). The application is designed to assist with summarisation of nest-camera data to populate CEMP e-forms for parameters A6b (breeding success) and A9 (breeding chronology).

4.9 The Working Group agreed that such applications are useful tools to provide consistent analysis techniques with utility that could extend beyond camera-based analyses. For example, applications could be built for estimation of foraging trip duration (CEMP parameter A5). Such methods may help ease the provision of CEMP data to the Secretariat. The Working Group welcomed future coordination with the Secretariat to develop capacity to utilise such methods.

Diet studies

4.10 The Working Group discussed WG-EMM-18/29 and 18/45 that introduced new methods to collect penguin diet data. The Working Group recalled that penguin diet is a CEMP parameter. Given the current reduction in lavage sampling, it is important to identify and assess alternative, less invasive methods as potential supplementary approaches for studying penguin diet.

4.11 WG-EMM-18/29 provided results to compare stomach lavage techniques and faecal DNA analysis using Adélie penguin samples collected from Signy Island during two seasons. Both methods produced a similar pattern of penguin diet, with a shift from almost exclusively krill in 2014/15 to a mixture of fish and krill in 2015/16.

4.12 The Working Group welcomed this new approach to estimate diet composition but noted several trade-offs with such approaches. While stomach flushing is invasive, it allows, inter alia, prey size, frequency of occurrence and meal mass information to be collected. Alternatively, faecal prey DNA is non-invasive, simple to collect, and provides a more comprehensive sampling of diet composition. The Working Group recalled that the percent occurrence of prey items estimated by both methods were not directly comparable and that further work is needed in this sense.

4.13 The Working Group noted that to consider faecal DNA diet analysis as a CEMP monitoring tool, future requirements need to be considered, such as validation of the technique, sample standardisation and costs of implementation for national programs. The Working Group noted a CEMP review in the near future could be helpful for including these considerations.

4.14 WG-EMM-18/45 reported the results of a pilot study conducted at Esperanza Station during the 2017/18 breeding season. Data on diet composition and krill length were obtained from collecting samples of 'krill spill', which come from regurgitation during chick feeding. The krill length frequency of the krill spill sample (N = 145) was compared to data collected utilising the A8 (chick diet) standard methods (N = 632 krill for 'A8 guard stage' and N = 1 568 krill for 'A8 crèche stage'). The authors identified trade-offs with taking this specific opportunistic approach to data collection, namely that the samples will be much smaller, that samples can be heavily digested and that setting a minimum standard required for analyses may not be possible. The authors concluded that while the length frequencies were similar, more opportunistic data must be collected alongside routine A8 monitoring.

4.15 The Working Group noted that this is a useful approach and encouraged those Members already collecting this data to undertake similar analyses. The combination of two non-invasive methodologies, faecal analysis and krill spill, may help reducing some of the limitations of the DNA faecal analysis method.

4.16 The Working Group noted that krill length distribution between samples from regurgitation and krill spill appears to be different, but preliminary bootstrapping analysis suggests that the overlapping distribution shows that they belong to the same population.

4.17 The Working Group recalled the use of predators as samplers of krill and the use of such data to parameterise target strength calibrations in acoustic analysis (see Reid and Brierley, 2001) to estimate krill biomass noting that such data would be helpful for the analysis of acoustic data collected from autonomous acoustic platforms.

4.18 The Working Group noted that additional species can provide information for management purposes that have not yet been considered as CEMP species, as for example the long-term diet data series from icefish from South Georgia.

Population census

4.19 The Working Group noted WG-EMM-18/25 that provided a thorough description of the topographical characteristics, geographic locations and estimated abundances of *Pygoscelid* penguins at breeding colonies near the Ukrainian Antarctic station Vernadsky during the 2017/18 austral summer. Within the study region, gentoo penguins were the most abundant (13 320 breeding pairs in 14 colonies), followed by Adélie penguins (5 300 nesting pairs in

8 colonies) and chinstrap penguins (16 nesting pairs in 1 colony). The authors report on a gentoo colony with 17 nests on the northwest coast of Green Island (65°19'S 64°09'W) possibly representing the southern-most colony established by this species.

4.20 Routine CEMP monitoring near Vernadsky Station is currently conducted primarily on Galindez and Petermann Island, but the Working Group noted that monitoring of other colonies would be welcome given the importance of the region for the expanding gentoo population. Ice conditions in the region have prevented the development of monitoring, however, the Working Group noted that deployment of nest cameras may be a useful approach to expand routine monitoring in this study area.

4.21 The Working Group discussed WG-EMM-18/38 that reported on the use of unmanned aerial hexacopters to census large penguin colonies and monitor habitat conditions at Cape Hallett in the Ross Sea. The Working Group welcomed the updated census of Adélie penguins breeding at Cape Hallett, noting that continued monitoring will be useful for the RMP of the RSRMPA.

4.22 The Working Group also noted the general utility of drones for monitoring and research and that their use is likely to increase. The Working Group recalled that guidelines for the use of drones in Antarctica have been developed by the Committee for Environmental Protection (CEP) (Resolution 4 (2018)) and supported by active research to quantify the effects of drones on wildlife.

4.23 The Working Group noted that traditional aerial methods (e.g. helicopter surveys) will remain viable alternatives in many cases. In particular, to ensure continuity in data streams, comparisons of data from traditional aerial census methods with drone-based census methods would be desirable in areas where methods transition from one to the other.

4.24 The Working Group noted that the imagery collected during the survey of Cape Hallett were very useful for identifying human-generated debris (e.g. plastic, wood, and metal). Aerial drone surveys that use photography or hyperspectral/multispectral imaging to locate and identify such debris have potential to enhance information on marine debris and terrestrial management efforts.

Reports by CEMP Special Fund projects

4.25 The Working Group received reports from two CEMP Special Fund projects that were funded in 2015/16.

4.26 WG-EMM-18/24 provided an update on an overwinter penguin tracking project. The data-collection phase is complete and analysis of the data in underway.

4.27 Based on the preliminary analyses in WG-EMM-18/24, the Working Group noted that the environmental characteristics of the habitats occupied by gentoo penguins, traditionally considered a more temperate species relative to the more polar chinstrap and Adélie penguins, was unexpected. The Working Group recalled that gentoo penguin populations in Subarea 48.1 are increasing and expanding their range southward (paragraph 4.19), in contrast to the other *Pygoscelid* penguin populations in the region. The Working Group encouraged further research on their habitat characteristics during winter and potential interactions with other penguin species in the region.

4.28 The Working Group noted that sample sizes used in this tracking study were similar to other tracking programs in the region. The Working Group agreed that the collected data would therefore be representative for achieving the goals outlined in the project (see WG-EMM-17/07).

4.29 WG-EMM-18/28 provided an update on the software developed for assessing nest camera images through the CEMP Special Fund project 'Developing an image processing software tool for analysis of camera network monitoring data'. The nest camera image software was developed for the purpose of assessing time series of images from fixed cameras established overlooking a cluster of nests for surface-nesting seabirds.

4.30 The Working Group noted the significant progress towards finalising the nest camera image software so that it is available for the broader camera network community. The Working Group agreed that it would be useful for the broader nest camera user group to trial the software on test data to provide feedback tailored for finalising the software in time for the meeting of the Scientific Committee where a presentation of the software can be provided.

CEMP review

4.31 The Working Group noted management strategies for Antarctic marine living resources are diversifying to include spatial management, risk assessments and FBM. For such strategies, the necessary data to meet the objectives of the Commission may extend beyond the current CEMP framework.

4.32 The Working Group recalled the objectives of CEMP to:

(i) detect and record significant changes in critical components of the marine ecosystem within the Convention Area, to serve as a basis for the conservation of Antarctic marine living resources

(ii) distinguish between changes due to harvesting of commercial species and changes due to environmental variability, both physical and biological.

4.33 While the CEMP effort is currently focusing on krill-dependent predators, there remains a broader set of ecosystem monitoring data that are required by CCAMLR for, inter alia, krill fishery management and MPA RMPs.

4.34 The Working Group recommended that the Scientific Committee consider a review of the ecosystem monitoring requirement of CCAMLR, given the current priorities of the Scientific Committee, in which the current CEMP would be one important component.

4.35 This review should consider a change in emphasis from only having a set of standard-method-based approaches, to an approach that incorporates more data to address the objectives set out above. This change should be accompanied with appropriate metadata to allow the evaluation of its utility in a particular monitoring application.

4.36 To facilitate a review of the ecosystem monitoring requirement of CCAMLR, draft terms of reference are to:

(i) review objectives for ecosystem monitoring within CCAMLR with reference to Article II

(ii) review the current scope of CEMP with reference to the objectives identified in term of reference (i) and the priorities of the Scientific Committee by:

(a) reviewing current CEMP data holdings to ensure that relevant data are collected to achieve the objectives established under term of reference (i)

(b) identifying other methodologies of relevance to CCAMLR ecosystem monitoring

(c) identifying how the integrity of time series should be maintained when methods change

(d) reviewing how monitoring data can be used in the priority work of the Scientific Committee

(e) compiling a list of relevant data sources and the methods to access them within and beyond CCAMLR

(iii) advise on priorities for expanding CEMP to achieve the objectives identified in term for reference (i) and the priority work of the Scientific Committee.

4.37 The Working Group discussed if a review of the current CEMP would be appropriate, given the current priorities of the Scientific Committee. In this respect, the Working Group noted concerns about how to best constrain the scope and duration of a review so that advice to the Scientific Committee could be focussed and timely.

4.38 The Working Group suggested that the scope of the review could be made manageable by adopting a two-part process to first review the current CEMP framework and then consider the broader ecosystem monitoring requirements of CCAMLR.

4.39 The Working Group noted that a review of CEMP is linked to other priority work of the Scientific Committee, particularly the development of FBM and MPA RMPs. The Working Group encouraged the voluntary work of Members to reflect on and improve upon the current CEMP framework.

Ecological interactions: predators

4.40 WG-EMM-18/03 presented foraging data from Antarctic shags (*Phalacrocorax bransfieldensis*) breeding at Harmony Point, Nelson Island, during the 1995 and 1996 summer seasons. Prior to egg laying, individuals conducted one foraging trip per day. In contrast, when rearing chicks, breeding adults increased the number of foraging trips and the time spent foraging relative to the number and age of chicks in individual nests. The authors suggested that Antarctic shags invest time in activities that buffer variability in energetic demands of nestlings, and further highlighted the possibility of using foraging parameters in ecosystem monitoring programs.

4.41 The Working Group noted that non-krill eating species are also monitored as part of CEMP, and that these data have been, and are continuing to be, collected and will be made available to the Secretariat in due course.

4.42 WG-EMM-18/04 used dietary data from nine bird and two seal species collected each austral summer between 1996 and 2000 at the South Orkney Islands to characterise interspecific trophic relationships among top predators in the area. Prey re-occurrence in diets was intermediate and consisted mainly of krill, fish or penguins. Most frequent reoccurrences reported were notothenids as well as the myctophid *Electrona antarctica*. Predators foraging in the water column had yearly variable diets that were most likely related to fluctuations in krill availability, with switches to notothenids in periods of low krill abundance. The authors discussed the recovery of *Gobionotothen gibberifrons* stocks around the South Orkney Islands and highlighted the potential for interspecific trophic competition between predators under scenarios of decreasing krill availability.

4.43 The Working Group welcomed the multispecies approach. It was noted that the *G. gibberifrons* abundance estimates from the recent Chilean survey around the South Orkney Islands represented the second-highest biomass estimate of all fish species observed, and that these biomass estimates in particular contrasted sharply with those in the South Shetlands Islands where *G. gibberifrons* populations appear to continue to decline.

4.44 WG-EMM-18/10 utilised data on migrating adult male Antarctic fur seal abundance coupled with published energetics models to estimate the removal of approximately 86 500 tonnes of krill in the South Orkney Islands area. The authors suggested this is likely an underestimate and provided several caveats including population size increases of Antarctic fur seals over the preceding 30 years and consumption estimates above those predicted by energetic models due to animals recovering body condition.

4.45 Dr Lowther indicated that recent tracking work of adult male Antarctic fur seals from the South Orkney Islands suggested that their post-breeding foraging behaviour in the Bransfield Strait where it overlapped with the foraging distribution of breeding chinstrap penguins (*Pygoscelis antarcticus*) at the same time.

4.46 The Working Group noted that diet data from WG-EMM-18/04 from the same population used to estimate abundance during (part of) the years might be useful in refining consumption estimates in the current paper.

4.47 The Working Group discussed the similarity in movement strategies between adult male Antarctic fur seals and the fishery, but noted that the majority of individuals instrumented with satellite tags at the South Orkney Islands did not remain in the area for long and transited into the Bransfield Strait within several days of arriving.

4.48 The Working Group further noted that, given the consumption estimates provided in the paper, it would be useful to collate data on the historical trends in adult male Antarctic fur seal arrivals into the Bransfield Strait to better understand their potential competition with breeding krill-dependent predators in the area.

4.49 WG-EMM-18/40 showed the preliminary analysis of tracking studies of gentoo and chinstrap penguins at Devil's Point, Byers Peninsula, and Vapour Col, Deception Island, between December 2016 and January 2017. At-sea location data collected from breeding adult birds were used to generate basic foraging behaviour parameters including trip length, maximum distance and trip duration.

4.50 The Working Group noted the novel data from the area and supported further work that was being planned, including increased coordination and collaboration with the forthcoming multination survey effort in 2019. The Working Group agreed that such work would be useful to test recently developed penguin foraging habitat models (WG-EMM-17/34), and the authors confirmed that future studies will also include dietary information to further characterise diurnal variability in foraging trip durations and corresponding diets identified in other regions. The Working Group further agreed that this data can be useful for the supporting information for the MPA in Planning Domain 1 (D1MPA) proposal.

4.51 WG-EMM-18/P09 outlined the at-sea movement behaviour of four instrumented leopard seals (*Hydrurga leptonyx*). Tracking data, ranging from 142 to 446 days, showed seasonal migratory behaviour between the pack-ice and South Georgia and an increased propensity for undertaking longer haul-outs during the summer. The authors highlighted that peak haul-outs were around midday between October and April, which may have implications for visual surveying efforts. Furthermore, the authors suggested that, given the movement of individuals between, and subsequent behaviours within, areas important to breeding populations of birds and other seals, further consideration of leopard seal ecology is vital in the context of Southern Ocean sustainable management.

4.52 WG-EMM-18/P12 presented tracking data from pre-moult Adélie and chinstrap penguins breeding on the South Orkney Islands. The authors showed that Adélie penguins foraged throughout their foraging trip, more frequently in close proximity to sea-ice, on which they subsequently moulted. In contrast, chinstrap penguins remained over shallower shelf waters to forage and returned to land to moult. Models derived from the data had low predictive power, and the authors highlighted that additional empirical data is required to improve predictability and further understanding of the impacts of climate change and fishing.

4.53 The Working Group noted that similar areas in the Weddell Sea are used by juvenile and pre-moult Adélie penguins tracked from the South Shetland Islands, and agreed that areas to the south of the current South Orkney Islands southern shelf MPA may also be important. The importance of this area to leopard seals reported in WG-EMM-18/P09 was noted. The Working Group discussed the utility of satellite-based detection of Adélie penguins whilst moulting on the sea-ice, and agreed that this may have the potential to more readily characterise moulting areas.

4.54 WG-EMM-18/P13 reported on a project examining Adélie and gentoo penguin breeding chronology and success at islands across the Wilhelm Archipelago via data collected by remote cameras since 2016, established as part of the CEMP camera network. These data are reviewed in the context of a dataset collected on gentoo penguins at Petermann Island between 2003 and 2017.

4.55 The Working Group thanked the authors for the continued development of a time series of breeding success data, and commented on general trends in breeding success decline with decreasing latitude. The Working Group also agreed that such studies contributed greatly to characterising potential climate change impacts across latitudinal clines.

4.56 WG-EMM-18/P14 presented tracking data on chinstrap penguins from southern Powell Island in the South Orkney Islands during the austral summers of 2014 and 2016. The authors noted that the second season coincided with one of the largest El Niño events ever recorded. High-resolution global positioning system (GPS) data were used to characterise significantly longer foraging trips and more pelagic foraging behaviour in the latter season, contrasting strongly with more coastal shelf water foraging detected in 2014. Using in-situ collected weather data, the authors identified a signal of strong coastal downwelling that was temporally concurrent with the extension of foraging trips by individual penguins and suggested that this event likely displaced krill away from coastal areas into the open ocean which penguins subsequently followed. Remotely sensed climatology failed to resolve the same downwelling signal, and the authors cautioned using insufficiently resolved environmental covariates to explain predator foraging behaviour.

4.57 Some participants of the Working Group noted that there was a strong teleconnection between the south tropical Pacific Ocean and the west Antarctic Peninsula in the context of El Niño events, and it was noted that local-scale results presented in WG-EMM-18/P14 were detected at Area 48 scale in the CEMP CSIs (WG-EMM-18/44). The Working Group highlighted the need to take advantage of multiple datasets to better characterise the response of predators to such changes.

Other monitoring data

4.58 WG-EMM-18/02 described research conducted during New Zealand's 2018 voyage to the Ross Sea region, and gave notice of a second cruise in 2019. The 2018 cruise had seven objectives, and all were achieved. Four berths were allocated to international collaborators on the 2019 cruise. Colleagues are also invited to collaborate on post-cruise data analyses and interpretation. The draft objectives for the 2019 cruise are to:

(i) recover oceanographic and acoustic moorings deployed in 2018

(ii) undertake oceanographic and atmospheric observations of the Southern Ocean

(iii) study the structure and function of marine microbial planktonic communities in the Southern Ocean

(iv) survey benthic and demersal habitats and fauna of the southern Ross Sea shelf and slope

(v) carry out a demersal trawl survey of the Ross Sea slope to provide information relevant to estimating abundances and distributions of grenadiers and icefish

(vi) study the distribution and abundance of mesopelagic fishes and zooplankton in the Ross Sea region of the Southern Ocean.

4.59 The Working Group welcomed New Zealand's invitation for scientific collaboration during and after the 2019 cruise. Further details on cruise dates etc. are provided in Table 1.

Toothfish

4.60 SC-CAMLR-XXXVII/01 summarised outcomes from the Workshop for the Development of a *Dissostichus mawsoni* Population Hypothesis for Area 48 (WS-DmPH-18), which included development of three population hypotheses for Antarctic toothfish

(*Dissostichus mawsoni*) in Area 48 and recommendations for data collections and analyses that might resolve which hypothesis is most likely (also see Annex 7 for further discussion on outcomes from the WS-DmPH).

4.61 The Working Group noted that data collected during research and monitoring activities customarily considered within its agenda may be informative about stock hypotheses for *D. mawsoni* in Area 48. For example, toothfish eggs and larvae might be caught during the conduct of krill research (e.g. in under-ice trawls), and juvenile and adult toothfish might occur in the diets of seabirds and pinnipeds (e.g. macaroni penguins (*Eudyptes chrysolophus*) and Weddell seals (*Leptonychotes weddellii*)). Members were encouraged to report such observations to the Development of a *D. mawsoni* Population Hypothesis for Area 48 e-group for further consideration.

4.62 Mr D. Di Blasi (Italy) summarised plans for research on *D. mawsoni* in the Ross Sea region; Mr Di Blasi is a recipient of the CCAMLR scholarship. Mr Di Blasi and colleagues intend to further develop a non-extractive technique for studying *D. mawsoni* using baited underwater video cameras deployed through the sea-ice. The work will include application of a quantitative approach to estimating the local abundance of *D. mawsoni* from videos collected by a small array of such cameras. The proposed research demonstrates that non-extractive techniques can be used to study toothfish within the general protection zone (GPZ) of the RSRMPA. The research is being developed in the context of the RSRMPA RMP and will be further presented to WG-FSA.

4.63 Mr Di Blasi's research was welcomed, and the Working Group provided several suggestions for further developing his work. These suggestions mostly related to analysis and interpretation of the data that will be collected by the cameras and include accounting for tides, territorial 'guarding' of baits by large toothfish, and fish that may swim in and out of the field of view.

Cetaceans

4.64 WG-EMM-18/16 presented new results on the abundance and trends of Type B killer whales around the western Antarctic Peninsula. The authors used satellite telemetry to study movements and photo identification to estimate the abundances of Types B1 and B2 killer whales. Type B1 whales primarily forage on pinnipeds, and their range extends further south along the Peninsula than Type B2 whales, which are thought to forage on fish and penguins. Both ecotypes are coastally distributed, and individuals occasionally migrate to and from warmer subtropical waters. During the period from 2008/09 to 2013/14 the abundance of Type B1 killer whales was estimated to be stable with an average of about 50 whales (95% credible interval, 39–53). Type B2 whales were likely increasing in abundance during this period, with estimates ranging from 181 to 299 individuals coming from a larger population of about 502 (95% credible interval, 434–662).

4.65 The Working Group acknowledged the importance of the results in WG-EMM-18/16, which will be valuable for understanding trophic dynamics in the western Antarctic Peninsula. When considered in combination with results from WG-EMM-17/49 (which reported on the distribution and abundance of Type A killer whales that eat Antarctic minke whales (*Balaenoptera bonaerensis*) and southern elephant seals (*Mirounga leonina*) in the same region), it appears that the overall abundance of this suite of apex predators has recently increased along the Peninsula.

4.66 WG-EMM-18/18 reported on genetic analyses that aim to investigate the breeding-group provenance and individual identity of southern right whales distributed throughout the Indian Ocean sector during summer. This study was based on 157 biopsy samples collected during IWC and Japanese sighting surveys. The study assesses site-fidelity and sex-specific ranges of whales on the feeding grounds. The main findings were that southern right whales in the Indian Ocean sector have a genetic correlation with individuals from the southwest Australian calving ground. Both sexes returned to the same feeding area every year, but the longitudinal range used by females was smaller than that used by males. The authors are interested in investigating the diet of southern right whales in the Indian Ocean sector using stable isotope analysis in the near future.

4.67 WG-EMM-18/18 also provided a preliminary estimate of the abundance of southern right whales in the Indian Ocean sector using a genetic mark–recapture analysis and compared this to estimates from previously published sightings data. For the period from 1993/94 to 2007/08 the two methods indicate similar increasing trends, and the most recent abundance estimate from both approaches is similar, about 1 500 animals. The Working Group noted that the trends in abundance indicated in WG-EMM-18/18 are similar to those estimated on the calving grounds off southwest Australia.

4.68 WG-EMM-18/43 presented preliminary results on the distribution of fin whales around the northern Antarctic Peninsula. Results from line-transect surveys undertaken by the Brazilian Antarctic Program from 2013 to 2018 indicate that the species is mainly sighted near Elephant Island and in Bransfield Strait. The authors highlighted that data since 1998 are available and might be considered in further analyses. The paper was presented by Ms Seyboth, a recipient of the CCAMLR scholarship scheme for the 2018/19 term, who thanked Dr Watters (her mentor) and his team for their support and contributions to the analysis. She also acknowledged CCAMLR for the scholarship, which is allowing her to pursue this research and is also allowing her and other early career researchers to have enriching experiences while contributing to CCAMLR's needs.

4.69 Ms Seyboth also introduced WG-EMM-18/P15, which was recently submitted to the peer-reviewed literature. The main aim of the study was to analyse the correlation between the reproductive success of those humpback whales (*Megaptera novaeangliae*) from breeding stock G that use the southwest coast of Ecuador and krill biomass in feeding grounds around the northern Antarctic Peninsula using data from 2004 to 2010. A positive and significant cross-correlation with a one-year lag was found between an index of calf production and krill biomass, which may indicate that the food supply may affect either gestation or lactation of humpback whales reproducing off the coast of Ecuador.

4.70 The Working Group welcomed the paper. It was recommended that the authors weight the correlation by the inverse of the coefficients of variation in the krill density data. It was also noted that authors might consider whether data collected near Ecuador are representative of the breeding stock G as a whole. The same consideration should be given to the feeding area, as the authors focused on krill biomass data from Bransfield Strait and some individuals from breeding stock G may migrate to other feeding areas or even not migrate at all.

Climate change and associated research and monitoring

5.1 WG-EMM-18/14 summarised the objectives of the Australian-led initiative to produce a Marine Ecosystem Assessment for the Southern Ocean (MEASO), and provided a timetable to produce a first MEASO by June 2019. Initial discussions were held at a conference in Hobart, Australia, in April 2018. The organisers thanked participants, noting substantial input from members of CCAMLR working groups. They encouraged participation in the development of the first MEASO (by contacting measo2018@acecrc.org.au) and noted that while the geographical scope will be circumpolar, further aspects of its scope are under development.

5.2 The Working Group noted that MEASO aims to generate a useful assessment of ecosystem status given the resources available within the proposed timescale. MEASO might be a conduit by which the expertise of the wider scientific community can feed into the work of CCAMLR, especially by providing information on ecosystem status and trends.

5.3 WG-EMM-18/P02 described simulation modelling, using Foosa (Watters et al., 2013), to investigate how potential climate change impacts on krill growth (Hill et al., 2013) might affect populations of krill-dependent predators in Subareas 48.1 to 48.3, and whether stopping krill fishing can offset climate change impacts on predators. The projections suggested that the magnitudes of climate change impacts on predators are likely to vary between small-scale management units (SSMUs) and predator taxa, with penguins being the most strongly effected group, especially under severe warming (representative concentration pathway (RCP) 8.5). Although impacts on krill are likely to be most severe in Subarea 48.3, projected impacts on penguins also occurred in Subareas 48.1 and 48.2. Climate change impacts under RCP8.5 are likely to be more severe than the impacts of fishing alone. Nonetheless, cessation of fishing slightly reduced the projected overall impact on penguins. The authors concluded that targeted spatial controls on fishing might be necessary to protect vulnerable predation populations.

5.4 The Working Group recalled that penguins, as represented in the current Foosa parameters, have depensatory dynamics which tend to amplify perturbations (Watters et al., 2013; Hill and Matthews, 2013) and noted that care is needed in interpreting such projections. There may be other potential mechanisms by which climate change might influence krill availability to predators, such as by modifying aggregation characteristics. Nonetheless, a strength of the approach in WG-EMM-18/P02 is that it quantified the impact of a single clearly defined process, allowing the community to assess whether that process is likely to be an important influence that merits more investigation.

5.5 Dr Kasatkina noted that there has been a significant decline in macaroni penguin abundance from 3 million pairs in the 1980s to 1 million pairs in 2003 (Trathan et al., 2012). There was a substantial change in krill catch at South Georgia over this time period with catches greater than 100 000 tonnes in the early years and about 40 000 tonnes more recently. She pointed out that at the same time a number of marine mammal populations have recovered, or are beginning to recover. Therefore, competitive relationships between krill-dependent predators may be important mechanisms that influence penguin populations. Dr Kasatkina suggested that modelling considerations should include competitive relations, particularly as krill consumption by penguins and other krill predators is far greater than the annual krill catch in Subarea 48.3.

5.6 The Working Group noted that Foosa incorporates competitive interactions between predator groups and that such simulations are useful to the work of CCAMLR. The Foosa approach can be adapted to consider different spatial units and scales, and different groups of predators, for example by providing more resolution of penguin groups (WG-EMM-08/51). Other complementary approaches such as Ecosim can also be used.

5.7 WG-EMM-18/P17 provided a review of the energetic density of zooplankton and nekton species in the Southern Ocean based on a new publicly available database compiling the results of previous studies. Energy densities are mainly based on whole animals, including the exoskeleton. The authors noted that information on the seasonal and regional variability in energy densities is limited for most species but that such information is necessary for the improvement of bio-energetic and food-web models. The authors encouraged further contributions to the database.

5.8 The Working Group thanked the authors for this valuable resource and noted that forthcoming surveys may be useful for collecting samples to address some of the data gaps. The authors were encouraged to provide advice on the collection, storage and analysis of relevant samples.

5.9 WG-EMM-18/P19 provided a summary of knowledge about climate change impacts on Southern Ocean marine fisheries, as part of the Food and Agriculture Organization of the United Nations (FAO) global report on impacts of climate change on fisheries and aquaculture. The Southern Ocean is characterised by complex interactions between climate change and natural variability. While climate change may impact the productivity of fished stocks in the long term, there may be shorter-term effects on fishing effort distribution as a result of changes to sea-ice. Although there are no concerns about local livelihoods, the underexploited Antarctic krill fishery could be important for future global food security. The existence of CCAMLR and its approach, including ecosystem-based management and the development of a system of MPAs, provides a measure of institutional resilience to climate change.

5.10 WG-SAM-18/22 described an approach to monitoring and managing the effects of environmental change on toothfish assessments, which focuses on recording key parameters relevant to stock assessment and identifying trends in these parameters. While such trends may be related to the effects of environmental variability and change, demonstration of such relationships is not required for this understanding to be useful. The approach also identified some changes that may occur that may not be used in stock assessments, consideration may need to be given to how these may be monitored and effectively accounted for in management advice.

5.11 The Working Group noted that clear recommendations relating to this paper had been provided by WG-SAM in relation to toothfish (Annex 6, paragraph 3.4). In relation to krill, the Working Group noted that long-term change may alter the value of parameters and reference points including the krill B_0 and the 75% escapement reference point. There may be a need to consider alternative reference points that take account of changing productivity of the target stock. Reference points which update as parameter estimates change are being considered for toothfish and are already used in the International Council for the Exploration of the Sea (ICES).

5.12 WS-SM-18/05 discussed the use of reference areas to assess the impacts of the krill fishery. In addition, it also considered the physical properties of the environment and highlighted that glacial retreat is more limited towards the tip of the Antarctic Peninsula (Cook et al., 2005), which is also an area of Adélie penguin concentration. This area is strongly influenced by the outflow from the Weddell Sea. Ocean dynamics at the tip of the Peninsula are a major influence on ecological dynamics in the Bransfield Strait, where krill catches have become increasingly concentrated. Understanding large-scale processes is therefore important for understanding both krill and predator processes in the Bransfield Strait.

ICED Workshop

5.13 WG-EMM-18/09 provided a preliminary report of the Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED)–CCAMLR Projections Workshop. The Workshop brought together ecologists, physical and ecological modellers, and fisheries scientists to consider the development of projections of the impacts of climate change on krill in Area 48, and to provide advice to enable CCAMLR to plan for, and adapt to, the consequences.

5.14 The Working Group agreed that the Workshop and associated work (including jointly developing questions of interest to CCAMLR that ICED was in a position to address) had been a valuable process.

5.15 The Working Group recognised that global analyses of climate change often include a range of alternative outcomes for the Southern Ocean. The Working Group discussed the specific suggestion from the Workshop that the position of the Polar Front is highly constrained and is not expected to change in the coming century, even under the highest emissions scenario. The importance of this point to CCAMLR was emphasised.

5.16 The Working Group noted that the report emphasised that the global models can provide general scenarios but do not resolve many key regional processes and require careful interpretation for particular regions such as Area 48. It was agreed that regional investigations, comparisons and development of high-resolution models would be valuable.

5.17 The Working Group acknowledged that the RCP2.5 and 8.5 pathways are projected to diverge, and that models suggest that clear signals of divergence (e.g. of sea-ice and sea-surface temperature) are unlikely to emerge from the overall variability of the models until around 2050. It was noted that this timescale is crucial for CCAMLR (2–3 decades). Attention was drawn to the proposed future SCAR Scientific Research Programme 'Near-term Variability and Prediction of the Antarctic Climate System'(AntClimnow). This proposed new program (currently awaiting endorsement from SCAR) will focus on near-term changes (from years to multiple decades). It was also noted that the next round of the Intergovernmental Panel on Climate Change (IPCC) assessment report (AR6) will produce the next generation of climate models (CMIP6), and as such it was emphasised that this work is ongoing and iterative.

5.18 The Working Group noted that the set of summary papers provided to the Workshop are a useful source of background information, particularly for Area 48. It agreed that it would be valuable to make these more widely accessible, and suggested that the Antarctic Environments Portal could be one possible mechanism for achieving this.

5.19 Information regarding variability and climate change in the Antarctic Peninsula region is highly relevant for planning, and for contributing to the D1MPA RMP. The broader scope for ICED and CCAMLR to work together on spatial management issues was also recognised (WS-SM-18/17).

5.20 The Working Group noted the next steps and looked forward to the outcomes of an iterative process developing models and collaborations. These include:

(i) an updated ICED–CCAMLR Projections Workshop report will be submitted to SC-CAMLR-XXXVII

(ii) the results will provide clear input to IPCC (for AR6, CMIP)

(iii) field and observational studies are required to improve knowledge of key processes

(iv) systematic improvement of krill and ecosystem models will be undertaken

(v) high-resolution regional models are needed for understanding processes and regional response.

5.21 The Working Group agreed that the engagement between ICED and CCAMLR on this activity has been successful and provides a good example of engaging broader expertise in CCAMLR's work (Annex 7, paragraphs 6.12 to 6.14). The potential for future joint activities was noted, and ICED encouraged suggestions and input from the Working Group.

SOOS

5.22 WG-EMM-18/P10 presented the vision for the Southern Ocean Observing System (SOOS). The Working Group noted Figure 2 in WG-EMM-18/P10 in particular with regard to the range of instruments that SOOS is intending to deploy to create an integrated network of Southern Ocean observations. The Working Group also recognised the potential for this information to inform CCAMLR work, including marine spatial management.

5.23 WG-EMM-18/P08 highlighted the SOOS West Antarctic Peninsula regional work (part of SOOS's circumpolar initiative).

5.24 WG-EMM-18/P06 proposed that CCAMLR build even stronger links with SOOS with regard to a hierarchical approach to monitoring.

5.25 The Working Group acknowledged the range of ongoing work by SOOS. It was agreed that integrating these efforts with CCAMLR's work would be valuable, including for RMPs for spatial management.

5.26 The Working Group recalled current interactions with SOOS, including the recent SOOS Synergies Workshop (SC-CAMLR-XXXVI, paragraph 10.17).

5.27 The Working Group discussed the potential for a two-way process regarding data collection, for example, equipment on fishing vessels as a potential source of data. Consideration should be given to how such data might be integrated and used, and how to facilitate this process. Indices of krill fishery performance and CEMP metrics might be of use to SOOS. CEMP data were discussed in the SOOS Synergies Workshop, particularly with regard to access to comprehensive metadata. Coordinated publication of CEMP data in the peer-reviewed literature would also be useful to inform SOOS.

Integration of VME data into broader spatial planning data analyses

Ecoregionalisation

6.1 WG-EMM-18/19 described a modelling approach that was used to build a benthic ecoregionalisation within the French exclusive economic zone (EEZ) of Division 58.5.1 using CCAMLR's vulnerable marine ecosystem (VME) indicator taxa. The Working Group noted that this was an extract from the article 'Benthic ecoregionalisation and conservation issues in the French Exclusive Economic Zone of Kerguelen' that has been submitted for publication to *Proceedings of the Second Symposium on Kerguelen Plateau Marine Ecosystems and Fisheries*.

6.2 The Working Group noted that there appeared to be commonalities between this approach and that described in WS-SM-18/P02, although the latter was used to characterise ecoregions of demersal finfish. Mr A. Martin (France) noted that initial comparisons between the modelling approaches yielded convergent patterns, although the statistical methodologies underpinning them were different.

6.3 The Working Group noted that increasing the number of taxa used to build ecoregionalisation using this method can result in less precise and low-resolution results, and that there were benefits in using reduced datasets with this approach. The Working Group agreed that it would be useful to compare this approach to that of MARXAN, and further explore the effect of restricting relevant data groups and how this may impact results.

6.4 WG-EMM-18/20 described an application of the data acquisition protocol for benthos by-catch in the French fisheries in Division 58.5.1 previously presented at WG-EMM-17 (SC-CAMLR-XXXVI, Annex 6, paragraphs 5.15 and 5.16). The methodology was used during the POKER 4 survey to sample specimens and significantly improve the characterisation of benthic invertebrate by-catch. This, coupled with the first use of cameras mounted on the bottom trawl in this division, allowed for more complete descriptions of invertebrate communities on the seabed, as well as substrates on the northern part of the Kerguelen Plateau.

6.5 The Working Group agreed that this was a valuable approach for direct comparison of benthic communities, seafloor substrate composition, and the by-catch of invertebrates in bottom trawls. Mr Martin indicated that further work in relation to invertebrate by-catch identification from the POKER 4 survey catches and video imagery was ongoing.

Proposals for additions to the CCAMLR VME registry

6.6 WG-EMM-18/35 characterised benthic invertebrate communities and VME taxa from a series of manned submersible dives along the northern Antarctic Peninsula and South Shetland Islands in Subarea 48.1. Five sites are proposed for inclusion in the CCAMLR VME registry in accordance with CM 22-06: three based on significant VME indicator taxa abundances, one based on high density and diversity of cold-water coral taxa, and one based on rare and unique populations. Also proposed are amendments to CCAMLR's *VME Taxa Classification Guide*.

6.7 The Working Group reviewed conservation measures in force relevant to the notification process for adding VMEs to the CCAMLR VME registry from fishery-independent research activities under CM 22-06, and agreed that the information set out in WG-EMM-18/35 was properly structured in accordance with CM 22-06, Annex 22-06/B. The Working Group noted that the authors made raw footage of all dive sites available for consideration by WG-EMM.

6.8 After reviewing the characteristics of VME indicator taxa at the five sites proposed for VME registration, the Working Group recommended that four of the five sites be added to the CCAMLR VME registry as 1 n mile radius circles centred on the following midpoint locations:

Latitude	Longitude	Location
63.3861°S	56.9146°W	Hope Bay, northern Antarctic Peninsula
63.3085°S	56.5364°W	Kinnes Cove, northern Antarctic Peninsula
63.9276°S	60.6225°W	Off Trinity Island
64.3004°S	62.0014°W	Off Lecointe Island

6.9 The Working Group reviewed the fifth VME proposed in WG-EMM-18/35 that was notified on the basis of rarity and uniqueness, located in Half Moon Bay near Livingston Island. The Working Group noted that the taxa described, a tube anemone (Ceriantharia (Hexacorallia)), was not currently part of the VME indicator taxa that had been adopted by the Scientific Committee based on the recommendations at the 2009 Workshop on Vulnerable Marine Ecosystems (WS-VME-09). Although the Working Group agreed that it demonstrated attributes consistent with rarity and uniqueness (one of the seven criteria that underpin VME indicator taxa), it agreed that a fuller consideration of this taxa should be undertaken, that it be assessed against all criteria (SC-CAMLR-XXVIII, Annex 10, paragraph 3.5), formally considered for addition as a VME indicator taxa, and that this notification be submitted again for consideration. The Working Group noted that the suggestion of adding Staurozoa (stalked jellyfishes) in WG-EMM-18/35 should undergo the same process as outlined for the addition of Ceriantharia.

6.10 WG-EMM-18/36 identified high densities of pennatulaceans (Phylum Cnidaria: Order Pennatulacea) encountered at three sites on the northeastern shelf of the South Orkney Islands (Subarea 48.2) from a recent Chilean bottom trawl survey (WG-SAM-18/25), submitted in accordance with CM 22-06, Annex 22-06/B.

6.11 The Working Group noted that the three sites are in close proximity to two other currently registered VMEs, one of which was based on high densities of pennatulaceans, and that this VME indicator taxa was likely the tallest of all groups, with specimens encountered >5 m in height.

6.12 After reviewing the information of the three sites proposed for VME registration, the Working Group recommended that they be added to the CCAMLR VME registry as 1 n mile radius circles centred on the following midpoint locations:

Latitude	Longitude	Location
60.4767°S	45.0950°W	Northeastern South Orkney Islands shelf
60.5425°S	44.8150°W	
60.6108°S	44.2625°W	

6.13 The Working Group considered the benefits of creating a larger precautionary buffer region around the three proposed new VMEs (similar to that of the VMEs in CM 22-09, and the scallop beds near Terra Nova Bay), given their close proximity to other currently registered VMEs in the region. The Working Group recommended that further consideration be given to the depth distribution of pennatulaceans, as this could inform an appropriately sized precautionary VME buffer region.

6.14 The height of these pennatulaceans, and the potential for krill trawls to disturb these communities was considered by the Working Group, as it was noted that there were instances where midwater krill trawling inadvertently catches benthic organisms although the krill fishing vessels try to avoid any contact of fishing gear with the seabed. The Working Group suggested exploring existing data, which could inform potential future advice on precautionary actions.

6.15 The Working Group acknowledged that although GPZs of MPAs would prevent disturbance of VMEs from commercial activities, there remains great value in having the locations of VMEs registered, as potential future research and monitoring activities would be aware of VMEs within MPAs. Further, the Working Group noted that registered VMEs do not expire.

Other business

SCAR Krill Action Group

7.1 WG-EMM-18/01 Rev. 1 provided an overview of the proposal to create a Scientific Committee on Antarctic Research (SCAR) Krill Action Group (SKAG) (SC-CAMLR-XXXVI, paragraphs 10.9 to 10.11). Prof. Meyer provided an update to the Working Group that SCAR had agreed to create this action group.

7.2 The Working Group welcomed this update and the creation of this action group that would provide a very useful conduit between the broader krill research community and CCAMLR and recognised that it also meant that krill would be considered by scientists in SCAR.

7.3 The Working Group noted that the SKAG would have its first meeting in the week following WG-EMM and encouraged the submission of a report of this meeting to the Scientific Committee.

Dronning Maud Land research

7.4 WG-EMM-18/13 provided an overview of planned research activities to be conducted by Norway in Dronning Maud Land, including research directed on Antarctic toothfish, krill and predators. Dr Lowther informed the Working Group that as part of this cruise, Norway also proposed to conduct research in the north of Subarea 48.6 near Bouvet Island and near the Antarctic Polar Front.

7.5 The Working Group welcomed this proposal, noting that relatively limited research had been conducted in this region, and looked forward to receiving the results from this in the future.

Indian research proposal

7.6 Dr S. Bal Raj (India) informed the Working Group that India was preparing to undertake research in the Indian Ocean sector on krill-based ecosystem processes in 2019 and that when plans were finalised there would be opportunities for collaboration. She invited interested scientists to contact her for further details.

7.7 The Working Group welcomed this news from India and looked forward to receiving further news about the Indian research program.

Proposal for an MPA in Argentine Islands

7.8 The work presented in WG-EMM-18/32 provided a comprehensive overview of research that Ukraine has developed in the Wilhelm Archipelago area, Antarctic Peninsula, including underwater and acoustic surveys, chemical analyses of bottom sediments and soils of nearshore areas. Importantly, Ukraine has been undertaking research on Adélie and gentoo penguins at the same area since 2003, including the establishment of remote cameras in 2016, as part of the CEMP camera network (WG-EMM-18/P13 and 18/26). In relation to this, the Working Group agreed that such studies contributed greatly to characterising potential climate change impacts across latitudinal clines.

7.9 The Working Group recalled the advice of Scientific Committee (SC-CAMLR-XXXVI, paragraphs 5.36 and 5.37) that it may be useful to coordinate spatial planning efforts around in the Wilhelm Archipelago area around the Argentine Islands with those efforts supporting development of the D1MPA. The Working Group encouraged the authors of WG-EMM-18/32 to work with the D1MPA Expert Group as this site could form one of the potential reference areas for assessing the effects of climate change on benthic communities and penguin populations and distribution, noting that the D1MPA proposal is a wider process.

Acoustic backscatter

7.10 WG-EMM-18/P06 and 18/P07 described the collection and modelling analysis of acoustic backscatter on latitudinal transects from New Zealand to the Ross Sea. The data were collected from a variety of vessels, including longline fishing vessels, and the results showed a decrease in deep mesopelagics with increasing latitude.

7.11 The Working Group welcomed these papers as together they demonstrated that quality scientific acoustic data could be collected from fishing vessels and how these data can be used to provide biologically useful information.

Interaction with the IWC

7.12 The Working Group recalled previous proposals for a Joint SC-CAMLR–IWC Workshop on multi-species models (SC-CAMLR-XXXV, paragraphs 10.16 to 10.18 and SC-CAMLR-XXXVI, paragraph 13.7). Dr Kawaguchi informed the Working Group that the steering group had been through a number of iterations and he recalled that the Scientific Committee had indicated that the proposal for a workshop should be considered in the context of demands and priorities of the Scientific Committee. The Working Group agreed that, based on the advice of the Scientific Committee, the priority for this workshop had been de-emphasised.

7.13 The Working Group noted the increase in discussion of cetacean research in its meeting this year, including through the CCAMLR scholarship scheme, and agreed that where there were areas of mutual interest with the IWC, including, for example, guidelines for cetacean surveys, that it was important to maintain a mechanism for interaction and engagement (see paragraph 3.32).

CEMP Special Fund

7.14 The Working Group noted the excellent progress made on research supported by the CEMP Special Fund (paragraphs 4.25 to 4.30).

7.15 Drs C. Cárdenas (Chile) and Santos (Co-Chairs of the CEMP Special Fund Management Committee) reported to the Working Group that the management group had undergone a large change of personnel and had been working on a revision to the terms of reference to clarify the application criteria, eligibility and reporting requirements associated with the CEMP Fund. They informed the Working Group that the revised terms of reference would be circulated to all Members.

7.16 The Working Group noted the success of the camera network supported by the CEMP Fund and suggested that the Scientific Committee consider a mechanism for ongoing funding to support camera refurbishment and battery replacement to maintain the network.

Future work

Future research cruises

8.1 The Working Group noted the large number of research cruises planned for 2018/19 that have objectives relating to krill and the pelagic ecosystem, across a wide geographic range within the Convention Area and collated these in Table 1.

Priorities and approaches for the Working Group

8.2 Dr Belchier noted the breadth of material that had been submitted for consideration by the Working Group but that in many cases it was not clear how the discussion contributed to the core work of CCAMLR or the priorities of the Scientific Committee. He further noted that one of the key roles of WG-EMM remains to provide advice to the Scientific Committee to manage the krill fishery and that is was important to ensure that this remained a core element of its role.

8.3 The Working Group recalled the discussion at WG-SAM on the priorities for its work (Annex 6, paragraphs 7.1 to 7.7) and noted in many of the generic issues faced by the two working groups were very similar. In particular, the Working Group agreed in general that:

(i) there was a lack of time to discuss issues in detail due to the large amount of material submitted to the Working Group

(ii) the current structure of the working groups may be limiting flexibility in the prioritisation of issues for which the Scientific Committee has requested advice

(iii) the use of workshops to consider specific items may be a more efficient mechanism to facilitate the attendance of subject matter experts

(iv) the relative status of workshops and working groups in providing advice to the Scientific Committee should be clarified, including the process and format for reporting and the implications for attendance by Members at multiple meetings.

8.4 The Working Group agreed that it was important to be inclusive but that time allocated to the consideration of items should be directed to issues relevant to CCAMLR's objectives and priorities and recognised that some issues that may be scientifically interesting in the context of Southern Ocean ecosystems might not be a priority for the Working Group.

8.5 The Working Group reviewed the establishing terms of reference www.ccamlr.org/node/74341 in which the Scientific Committee had requested the group to:

(i) assess status of krill

(ii) assess status and trends of dependent and related populations, including identification of information required to evaluate predator/prey/fisheries interactions and their relationships to environmental features

(iii) assess environmental features and trends which may influence abundance and distribution of harvested, dependent, related and/or depleted populations

(iv) identify, recommend and coordinate research necessary to obtain information on predator/prey/fisheries interactions, particularly those involving harvested, dependent, related and/or depleted populations

(v) liaise with WG-FSA on stock assessment related matters

(vi) develop further, coordinate the implementation of, and ensure continuity in CEMP

(vii) taking into account assessments and research carried out under terms of reference (i) to (v) above, develop management advice on status of Antarctic marine ecosystems and for management of krill fisheries in full accordance with Convention Article II.

8.6 The Working Group noted that, as indicated on the webpage that includes the terms of reference, addressing these terms of reference is the core work of WG-EMM which now includes providing advice on aspects of spatial protection, including MPAs and VMEs.

8.7 The Working Group agreed that overall the terms of reference remained appropriate and that, should the Scientific Committee undertake to review the terms of reference of its working groups, the following be taken into consideration:

(i) in term of reference (i) definition of krill stocks and regular advice on their status is vital for ensuring that CCAMLR can meet its objectives, especially in the context of climate change. The trigger level approach taken by CCAMLR means that the status of krill stocks at the large scale does not have to be assessed annually. The development of a krill assessment model that makes use of available data from small-scale surveys and length-frequency data from the fishery and from predator diet studies would also need to include a spatially explicit krill stock hypothesis

(ii) in term of reference (iv) coordination of research between Members has resulted in positive examples such as the CEMP camera network, but this term of reference could also refer to coordination with other bodies for which an engagement strategy should be developed

(iii) term of reference (v) refers only to WG-FSA and should be updated to include WG-SAM and SG-ASAM

(iv) in term of reference (vi) replace ‘ensure’ with ‘promote’ noting that the proposal for a review of CEMP would directly address this term of reference

(v) in the context of term of reference (vii) work on spatial management is not in the original terms of reference and only appears as commentary on the work that the group now undertakes, however, this topic has formed the majority of the advice to the Scientific Committee from WG-EMM in recent years.

8.8 The Convener of WS-SM-18 reported on discussions at WS-SM-18 on mechanisms to progress future work on spatial management, (Annex 7, paragraphs 6.6 to 6.8). The Working Group discussed possible mechanisms to enable spatial management issues to be considered, including the possible creation of a new working group or further spatial management workshop(s) and recommended that the Scientific Committee consider how such work should be progressed in the context of its other priorities.

Priorities for the next meeting

8.9 The Working Group discussed the priority issues for consideration in 2019 and requested that the Scientific Committee consider these when agreeing the priorities for its subsidiary meeting:

(i) The Working Group noted that in the five-year plan for the work of the Scientific Committee (SC-CAMLR-XXXVI/BG/40) the priority for WG-EMM in 2019 included (under the theme of Ecosystem-based management of Southern Ocean krill resources) using geospatial data and analysis to examine krill flux and spatial structure.

CM 51-07

(ii) The Working Group recalled that in CM 51-07 there was a requirement for the Scientific Committee to provide advice to the Commission on progress towards the development of the risk assessment framework, FBM and the spatial allocation of catch no later than the annual meeting in 2019 and that this conservation measure would need to be replaced or updated no later than the end of the 2020/21 fishing season.

(iii) Given this schedule, the Working Group agreed that the issue of risk assessment framework, FBM and the spatial allocation of catch should form a key part of the agenda of the Working Group in 2019.

Krill surveys

(iv) The Working Group noted that the five-year plan for the work of the Scientific Committee (SC-CAMLR-XXXVI/BG/40) also included a proposal for a joint workshop of SG-ASAM, WG-EMM and WG-SAM to develop acoustic survey methods and design to facilitate FBM.

(v) The Working Group noted that while the results of the large-scale survey in Area 48 being conducted in 2019 would contribute towards this work, the time between the end of the survey and the meeting of WG-EMM meant that it was unlikely that the full set of results from the survey would be available for consideration in 2019.

CEMP review

(vi) The Working Group noted the proposal for a review of CEMP (paragraphs 4.31 to 4.39).

Other workshops

8.10 Dr P. Trathan (UK) recalled the proposal to hold an intersessional workshop to advance technical discussions related to FBM (SC-CAMLR-XXXVI, paragraph 13.8) noting a planning meeting had been scheduled to develop the terms of reference.

Advice to Scientific Committee

9.1 The paragraphs containing the advice of the Working Group to the Scientific Committee are summarised below; these advice paragraphs should be considered along with the body of the report leading to the advice:

(i) changes to logbooks for krill fishery observers (paragraph 2.14)

(ii) advice on appropriate temporal scale of aggregation of the two-hourly catch reporting periods continuous trawl data (paragraph 2.53)

(iii) changes to the CEMP e-forms (paragraph 4.6)

(iv) recommendation for a review of the ecosystem monitoring requirement of CCAMLR (paragraphs 4.34 to 4.39)

(v) proposals for addition of eight sites be added to the CCAMLR VME registry (paragraphs 6.8 and 6.12)

(vi) consideration of the terms of reference of the Working Group (paragraph 8.7)

(vii) possible mechanisms to enable spatial management issues to be considered (paragraph 8.8)

(viii) priority issues for consideration by the Working Group in 2019 (paragraph 8.9).

Close of meeting

10.1 Dr Belchier thanked all participants for their perseverance and engagement in the meeting that had made his position as temporary Convener very enjoyable. He particularly thanked the Secretariat, both at the meeting and in Hobart, and the local BAS hosts, in particular Dr Grant and Ms Pilvi Muschitiello, who had ensured the smooth running of the meeting.

10.2 On behalf of the Working Group, Dr Watters thanked Dr Belchier for stepping into the Convener role at such short notice and doing such an excellent job. Dr Jones also thanked Dr Belchier and thanked BAS for hosting the meetings.

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Table 1: Planned research cruises (noting that details may change) in the Convention Area during the 2018/19 season, with objectives relevant to the work of WG-EMM.

Subarea(s)	MPA planning domain(s)	Expedition/project	Vessel	Geographic focus	Members involved[1]	Summary/objectives (reference)	Gear type(s)	Dates
48.1	1	OPERANTARXXXVII/ Projects Interbiota, Baleias and Nautilus	*Alte. Maximiano* (Brazilian Navy)	Northern Antarctic Peninsula (Bransfield and Gerlache Straits, northwestern Weddell Sea – if the ice margin does not block our way to this last one)	Brazil	• Hydrography (CTD castings and seawater sampling: physical, chemical and biogeochemistry measurements) • Continuous CO_2 surface sampling and carbonate system parameters measurements • Phytoplankton sampling • Zooplankton sampling • Microplastic sampling • Line-transect cetacean survey • Whale biopsies • Fin whale tagging	• CTD Rosette • CPR (Continuous Plankton Recorder) • Manta net • Bongo net • Cross-bowls • Satellite transmitters	Jan 2019 (exact dates to be confirmed)
48.3	2	Western Core Box	*RRS Discovery*	South Georgia	UK	Annual marine ecosystem assessment (krill density, ocean acidification, plastic marine debris, carbon cycling)	• CTD, MOCNESS, MAMMOTH, RMT8+1, BONGO, possibly RMT25, EK60 (18, 38, 70, 120, 200, 333 kHz)	02/Jan/2019 – ~20/Jan/2019
48.4	2	South Sandwich Island krill survey	*RRS Discovery*	South Sandwich Islands	UK	Marine ecosystem assessment (krill density, plastic marine debris)	• CTD, MOCNESS, MAMMOTH, RMT8+1, BONGO, possibly RMT25, EK60 (18, 38, 70, 120, 200, 333 kHz)	21/Jan/2019 – 10/Feb/2019

(continued)

Table 1 (continued)

Subarea(s)	MPA planning domain(s)	Expedition/project	Vessel	Geographic focus	Members involved[1]	Summary/objectives (reference)	Gear type(s)	Dates
48.1, 48.2, 48.3, 48.4	1 and 2	Multinational large-scale krill synoptic survey in CCAMLR Area 48 and assay of ecosystem processes for the development of feedback management (FBM) of the krill fishery	• RV *Kronprins Haakon* (Norway) • FV *Cabo de Hornos* (Chile) • FV *Kwangjaho* (Korea) • FV *Fu Rong Hai* and FV *Long Teng* (China) • FV *More Sodruzhestva* (Ukraine)	Area 48	Norway Chile Korea China Ukraine UK South Africa USA Germany	1. Provide an indication of krill biomass at the larger scale 2. Consider the relationship between preferred fishery areas and the larger scale. 3. Ecosystem assessment of the marine environment essential for the development of the risk assessment, feed-back management (FBM) and spatial planning	• Trawl • Plankton nets • Moorings • CTD • ADCP • Acoustic sensors	Nov 2018–Mar 2019
48.6	3 and 4	ECOgaps survey cruise to inform spatial planning in CCAMLR	RV *Kronprins Haakon*	Astrid Ridge Fimbulisen (and the shelf area between) Maud Rise	Norway	Conduct a multidisciplinary survey across the trophic spectrum including benthic and pelagic biogeochemistry, oceanography and higher trophic ecology (WG-EMM-18/13)	• Acoustics, pelagic and benthic sampling, ROV, research fishing longlines	26/Feb/19 – 14/Apr/19
48.5 48.6	3 and 4	PS117	*Polarstern*	Weddell Sea	Germany	Hybrid Antarctic Float Observing System (HAFOS)	• ?	15/Dec/18 – 07/Feb/19
48.5	3	PS118	*Polarstern*	Weddell Sea	Germany	Larsen ice-shelf region bathymetry, ecology	• Hydrosweep, ROV, misc	09/Feb/19 – 10/Apr/19

(continued)

Table 1 (continued)

Subarea(s)	MPA planning domain(s)	Expedition/project	Vessel	Geographic focus	Members involved[1]	Summary/objectives (reference)	Gear type(s)	Dates
58.4.1	7	Dedicated krill survey for CCAMLR Division 58.4.1 during 2018/19 season by the Japanese survey vessel, *Kaiyo-maru*	RV *Kaiyo-maru*	Full longitudinal range of 58.4.1 (80°E–150°E) to the south of 63°S	Japan China EU USA	1) Estimation of krill biomass to update B_0 in Division 58.4.1 based on the CCAMLR standard method 2) Oceanographic observations in Division 58.4.1 to detect long-term changes if any 3) Multidisciplinary approach to elucidate current state of the ecosystem in the Division (SG-ASAM-18/02, SG-ASAM-18/05 and WG-EMM-18/17)	• Quantitative echosounder (EK80 with 38, 70, 120 and 200 kHz) • SADCP (Ocean Surveyor with 38 kHz) • LADCP (Ocean Surveyor with 300 kHz) • RMT1+8 for meso- and microzooplankton • SUIT for meso- and microzooplankton • Small ringed net for mesozooplankton • CTD (Seabird with various sensors) • Water sampling for biological, chemical and physical oceanographic studies • XCTD	12/Dec – 11/Jan (Leg 1) 26/Jan – 25/Feb (Leg 2)

(continued)

Table 1 (continued)

Subarea(s)	MPA planning domain(s)	Expedition/project	Vessel	Geographic focus	Members involved[1]	Summary/objectives (reference)	Gear type(s)	Dates
							• Free drifting float/buoys (Argo floats, DeepNinja, DeepApex and SOCCOM floats, and CO_2 buoy) • Multi-Excitation Fluorometer • Opportunistic sighting survey (marine mammals, seabirds and surface swarm of krill) • Video recording of behaviour of biological organisms using drifting camera, drop camera and drone	

(continued)

Table 1 (continued)

Subarea(s)	MPA planning domain(s)	Expedition/project	Vessel	Geographic focus	Members involved[1]	Summary/objectives (reference)	Gear type(s)	Dates
58.5.1 58.4.4b 58.5.1 58.5.2 58.6	5 and 6	OBSAUSTRAL with 4 scientific programs REPCCOAI (Réponses de l'Écosystème Pélagique aux Changements Climatiques dans l'Océan Austral – Indien) THEMISTO (Towards Hydroacoustics and Ecology of mid-trophic levels in Indian and Southern Ocean) OISO (Océan Indien Service d'Observation) OHASISBIO (Observatoire hydroacoustique de la sismicité et de la biodiversité)	*Marion Dufresne*	From the subtropical to the Antarctic waters (56°S) and from Crozet to Kerguelen and St Paul and New Amsterdam	France	• Oceanography and biogeochemistry including pCO2 • Continuous acoustics measurements (plankton and micronekton) • Biogeography of plankton (mesozooplankton, macroplankton) and micronekton (mesopelagic fish) • Ecophysiology of different euphausiids species (stress towards temperatures) • Acoustics moorings for seismicity and biodiversity (cetaceans)	• CTD, NISKIN bottles, continuous surface measurements, acoustics, WP2, IKMT, CPR, acoustic moorings (seismicity and whales)	5/Jan/19 to 15/Feb/19

(continued)

Table 1 (continued)

Subarea(s)	MPA planning domain(s)	Expedition/project	Vessel	Geographic focus	Members involved[1]	Summary/objectives (reference)	Gear type(s)	Dates
58.6	5	Prince Edward Islands summer survey 2019	SA *Agulhas 2*	Prince Edward Islands	South Africa (others to be confirmed)	1) Survey of top predators (seals and seabirds) at the island 2) Survey of the terrestrial biodiversity of the island 3) Undertake oceanographic and atmospheric observations 4) Study the structure and function of marine planktonic communities	• PTTs and helicopters • CTDs • Full-depth CTD casts and vertical Multinet (type Midi)	Oct/Nov 2019
88.1 58.4.1	7 and 8	The availability of Antarctic krill to large predators and their role in biogeochemical recycling in the Southern Ocean.	RV *Investigator*	South of 60°S, northward of the ice edge, and between 140°E and 175°W	Australia, UK, USA, Germany, South Africa, Argentina, New Zealand, China	• Explore relationship between Antarctic blue whales and krill swarms • Use passive acoustics to track and locate Antarctic blue whales • Study the distribution and density, and 3D structure of krill swarms • Study iron-fertilisation by whales and relationships to krill • Parameterise distance functions for passive acoustic monitoring of Antarctic blue whales	• Difar sonobuoys to detect and track Antarctic blue whales • Acoustic Recording Package + Simrad wide-band autonomous transceiver mooring • Visual observations for cetaceans (including 7 × 50 and 25 × 150 binoculars) • Cetacean photo-ID and PAXARMS biopsy	19/Jan – 5/Mar 2019

(continued)

Table 1 (continued)

Subarea(s)	MPA planning domain(s)	Expedition/project	Vessel	Geographic focus	Members involved[1]	Summary/objectives (reference)	Gear type(s)	Dates
							• Video-tracking of whales • UAS for whale photo-ID, body condition and behaviour • EK60 (calibrated), ME70 and SE90 echosounders • RMT 1+8 trawls for target trawls and live animal collection • CTDs and trace metal rosette ops to examine Fe availability, microbial production and biogenic climate gases	
88.1	8	Tangaroa Marine Environment and Ecosystem Project 2019	RV *Tangaroa*	Scott C Seamount Iselin Bank Ross Sea slope (within MPA SRZ and eastern GPZ(i)) Cape Adare	New Zealand 4 berths made available to scientists from other nations.	1) Recover oceanographic and acoustic moorings deployed in 2018 2) Undertake oceanographic and atmospheric observations	• Oceanographic moorings • Active acoustic moorings • Passive acoustic moorings • Multibeam echosounder • Underwater imagery	4/Jan – 17/Feb 2019

(continued)

Table 1 (continued)

Subarea(s)	MPA planning domain(s)	Expedition/project	Vessel	Geographic focus	Members involved[1]	Summary/objectives (reference)	Gear type(s)	Dates
						3) Study the structure and function of marine microbial planktonic communities 4) Survey benthic and demersal habitats and fauna of the southern Ross Sea shelf and slope 5) Carry out a demersal trawl survey of the Ross Sea slope to provide information relevant to estimating abundances and distributions of grenadiers and icefish. 6) Study the distribution and abundance of mesopelagic fishes and zooplankton in the Ross Sea region. WG-EMM-18/02	• Benthic and demersal trawl • MOCNESS for mesozooplankton • Midwater trawl for macro-zooplankton and mesopelagic fish • Water sampling, oceanographic and atmospheric measurements	

(continued)

Table 1 (continued)

Subarea(s)	MPA planning domain(s)	Expedition/project	Vessel	Geographic focus	Members involved[1]	Summary/objectives (reference)	Gear type(s)	Dates
88.1	8	Ecosystem structure and function of marine protected area in Antarctica (2017–2022)	RV *Araon*	Victoria Land Coast, Ross Sea (within MPA GPZ(i))	Korea	SC-CAMLR-XXXVI/BG/17 1. Biodiversity and species inventory 2. Spatial distribution of krill and mesozooplankton community 3. Food web structure and trophic level 4. Oceanographical observation	• Bongo net, Hamburg Plankton Net	5–30/Jan 2019

[1] Participation of scientists from Members may not necessarily indicate Member endorsement of cruise.

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(Cambridge, United Kingdom, 9 to 13 July 2018)

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Appendix B

Agenda

Working Group on Ecosystem Monitoring and Management
(Cambridge, United Kingdom, 9 to 13 July 2018)

1. Introduction

    1.1 Opening of the meeting
    1.2 Adoption of the agenda and appointment of rapporteurs, establishment of ad hoc subgroups if necessary

2. Ecosystem impact of the krill fishery

    2.1 Fishing activities

    2.2 Scientific observation

    2.3 Krill biology, ecology and population dynamics
        2.3.1 Krill life-history parameters
        2.3.2 CPUE and spatial dynamics

3. Data layers from the krill fishery

    3.1 Fishing vessel surveys

4. Ecosystem monitoring and observation

    4.1 CEMP data
        4.1.1 Ecological interactions: predators

    4.2 Other monitoring data

5. Climate change and associated research and monitoring

    5.1 ICED Workshop
    5.2 SOOS

6. Integration of VME data into broader spatial planning data analyses

7. Other business

    7.1 CEMP Special Fund

8. Future work

9. Advice to the Scientific Committee and its working groups

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

Appendix C

List of Documents

Working Group on Ecosystem Monitoring and Management
(Cambridge, United Kingdom9 to 13 July 2018)

WG-EMM-18/01 Rev. 1	Proposal for a New SCAR KRILL Action Group B. Meyer, A. Brierley, S. Kawaguchi, C. Reiss and S. Nicol
WG-EMM-18/02	New Zealand research voyages to the Ross Sea region in 2018 and 2019 D. Bowden, R. O'Driscoll and M.H. Pinkerton
WG-EMM-18/03	Foraging patterns in the Antarctic Shag *Phalacrocorax bransfieldensis* at Harmony Point, Antarctica R. Casaux and M.L. Bertolin
WG-EMM-18/04	Diet overlap among top predators at the South Orkney Islands, Antarctica M.L. Bertolin and R. Casaux
WG-EMM-18/05	On the very high likelihood of bycatch of ice krill (*Euphausia crystallorophias*) in the present-day fishery for Antarctic krill (*E. superba*) A.S. Brierley and R. Proud
WG-EMM-18/06	Modelling Movement of Antarctic Krill (MMAK): the importance of retention, dispersal and behaviour for krill distribution – a project update S.E. Thorpe, E.F. Young, E.J. Murphy, O.R. Godø and A.H.H. Renner
WG-EMM-18/07	Improving mechanistic understanding between larval krill, krill recruitment, and sea ice B. Meyer and S. Kawaguchi
WG-EMM-18/08	Development of methods relevant to feedback management (FBM) for the krill fishery B.A. Krafft, A. Lowther, G. Macaulay, M. Chierici, M. Biuw, A. Renner, T.A. Klevjer, R. Øyerhamn, C.A. Cárdenas, J. Arata, A. Makhado, C. Reiss and O.A. Bergstad
WG-EMM-18/09	Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme: Preliminary report of the ICED–CCAMLR Projections Workshop, 5 to 7 April 2018 E.J. Murphy, N.M. Johnston, S.P. Corney and K. Reid

WG-EMM-18/10	Consumption estimates for male Antarctic fur seals at the South Orkney Islands during the post mating migration I. Staniland and S. Hill
WG-EMM-18/11	Update: Rapid unsupervised automated krill density estimation from fishing vessels (RAPID-KRILL) S. Fielding, A. Ariza, R. Blackwell, G. Skaret and X. Wang
WG-EMM-18/12	Acoustic manual for the krill synoptic survey in 2019 G. Macaulay, G. Skaret, T. Knutsen, O.A. Bergstad and B.A. Krafft
WG-EMM-18/13	Filling knowledge gaps east in Dronning Maud Land to inform MPA planning by CCAMLR (ECOgaps): Norwegian cruise to DML 2019 H. Steen, A. Lowther and O.A. Bergstad
WG-EMM-18/14	Marine Ecosystem Assessment for the Southern Ocean – Brief Report, June 2018 A. Constable
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