Annex 6

Report of the Working Group on Ecosystem Monitoring and Management 2023 (WG-EMM-2023)
(Kochi, India, 3 to 14 July 2023)

Contents

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Introduction

1.1 The 2023 meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM) was held at the Holiday Inn Hotel in Kochi, India, from 3 to 14 July 2023. The meeting was hosted by the Centre for Marine Living Resources and Ecology (CMLRE), an attached office of the Ministry of Earth Sciences, Government of India.

Opening of the meeting

1.2 The meeting convener, Dr C. Cárdenas (Chile) welcomed participants (Appendix A) back to in-person meetings. The meeting was opened with a traditional ceremony and lighting of the lamp, to symbolise success in finding the correct pathway for the future and a Sanskrit song of good intentions. Commander PK Srivastava, Scientist G of the Ministry of Earth Sciences, began the inauguration to provide the context for the meeting. Dr GVM Gupta, CCAMLR Commissioner for India and Director of the CMLRE, and Dr V. Kumar, Advisor, Ministry of Earth Sciences, welcomed all participants and outlined the many ways in which India has contributed and intends to contribute to the science of CCAMLR in coming years. They wished the participants success in their work and a comfortable stay in Kochi despite the monsoons. Mr N. Saravanane, the Scientific Committee Representative for India to CCAMLR, provided a vote of thanks to the speakers and also welcomed the group on behalf of the CMLRE.

Adoption of the agenda

1.3 The agenda was adopted.

1.4 Documents submitted to the meeting are listed in Appendix B and the Working Group thanked all authors of papers for their valuable contributions to the work presented to the meeting.

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

1.6 The report was prepared by C. Adams (New Zealand), P. Brtnik (Germany), M. Collins (UK), J. Devine (New Zealand), L. Emmerson (Australia), G. Griffith (Norway), S. Hill (UK), J. Hinke (USA), O. Hogg (UK), S. Kawaguchi (Australia), T. Knutsen (Norway), B. Krafft (Norway), B. Meyer (Germany), H. Murase and T. Okuda (Japan), C. Oosthuizen (South Africa), E. Pardo (New Zealand), S. Parker (Secretariat), G. Robson (UK), M. Santos (Argentina), F. Schaafsma (Kingdom of the Netherlands), K. Teschke (Germany), S. Thanassekos (Secretariat) and C. Waluda (UK).

1.7 A glossary of acronyms and abbreviations used in CCAMLR reports is available online at https://www.ccamlr.org/node/78120.

Review Terms of Reference and workplan

2.1 The Working Group reviewed the terms of reference agreed by the Scientific Committee in 2022 and set out in SC CIRC 23/52.

2.2 The Working Group reviewed the workplan set out in Table 7 of SC-CAMLR-41 and agreed that the Working Group would discuss additional modifications to the workplan under 'Future Work' (See paragraphs 10.1 to 10.3).

Krill fishery

Fishing activities (updates and data)

3.1 WG-EMM-2023/13 presented a review of sea ice data in relation to fishing vessel activities in Subareas 48.1 and 48.2. The paper highlighted inter-annual and seasonal dynamics in sea ice conditions recorded between 1997 and 2022 and proposed that variability in ice conditions and associated vessel accessibility should be considered when developing management schemes for the krill (*Euphausia superba*) fishery, and in particular when developing approaches to the fishery management schemes by subdividing the allowable catch into summer and winter (Zhao and Ying, 2022; Watters and Hinke, 2022). The authors noted that fishing grounds may not be accessible to fishing for most of the winter season, specifically for up to four out of six winter months in the Bransfield Strait and up to six out of eight winter months around the South Orkney Islands. The authors noted that the proposal to subdivide the allowable catch into winter and summer is based on the assumption of the impact of fishing on the ecosystem, especially during the summer period, and suggests a drastic limitation of the available catch in the summer and an increase in the catch in the winter. The authors emphasized that such an approach to fishery management requires further discussion and justification.

3.2 The Working Group noted that it was helpful to discuss changes in fishing behaviour and the impact of sea ice dynamics on the accessibility to fishing grounds. It also noted, however, that sea ice is just one factor influencing fishing vessel activities and that consideration should also be given to the effect of Voluntary Restricted Zones (VRZs) (Hill et al., 2022), the experience of captains, logistical costs, strategic reasons (e.g., quality of krill oil) and the use of supply vessels.

3.3 The Working Group noted that sea ice does not prevent the krill fishery in Subarea 48.1 from regularly reaching the subarea trigger level and reiterated the importance of the precautionary approach considering the effect of reduced sea ice (especially along the Antarctic Peninsula) on the opening of previously inaccessible fishing grounds, and the importance of the summer season as a time when predators are more constrained to breeding colonies.

3.4 WG-EMM-2023/56 provided a summary of the activities on the krill fishing vessel *Antarctic Endeavour* in Subareas 48.1 and 48.2 between January and July 2022. The document provided a compilation of data on catch, effort, CPUE, krill length frequency distributions, by-catch, and bird and mammal interactions with the fishery. Additionally, the report detailed yield obtained in krill fishmeal production. Comparisons were drawn with the three preceding years of operations of this vessel within the same subareas. The authors encouraged similar periodic reporting from other CCAMLR vessels participating in the krill fishery.

3.5 The Working Group welcomed the data provided and agreed on the usefulness of this type of reporting as an account of krill fishing in Subareas 48.1 and 48.2. The Working Group noted that the fishing complied with the Voluntary Restricted Zones (VRZs) in Subarea 48.1 but expressed concern that fishing occurred close to the South Orkney Islands during the breeding season of land-based krill-dependent predators. The Working Group recognised the importance of this type of reporting as a means of recording how patterns of fishing change over time and encouraged other krill fishing Members to provide this kind of reporting in the future.

Scientific observation

3.6 WG-EMM-2023/28 reported on a training course of 19 Chilean Scientific Observers held during June 2023 as part of the CCAMLR International Scientific Observation (SISO) scheme. The report highlighted the topics covered during this training and the readiness of these trained observers to work both on Chilean vessels and on vessels of other CCAMLR Members.

3.7 The Working Group noted the importance of the work of SISO observers and highlighted the need for coordination between Members to ensure standardisation in methods, and training and exchange between scientists and observers to maximize data quality. The Working Group also noted that it would be useful for the Secretariat to receive feedback on the SISO training materials, specifically if anything was deemed to be missing or unclear. The Working Group further noted linkages with WG-IMAF and the possibility for coordination to feed into intersessional work focused on the development of protocols and seabird and mammal identification guides.

Fishing vessel surveys

3.8 WG-EMM-2023/01 presented the report of the 2023 annual Norwegian krill survey off the South Orkney Islands (Subarea 48.2). The survey was undertaken by the support vessel *Antarctic Provider*, which was equipped with four custom shipping containers housing laboratories, monitoring equipment and acoustic data processing capability to generate krill biomass estimates using the swarms method. The generated data included acoustic recordings, taxonomic sorting of trawl catches and marine mammal and seabird sighting data collected during daylight hours along the transects. A pilot study using drones was also undertaken, providing information on the distribution and body morphometrics of whales. A land party was deployed on Powell Island to tag penguins for satellite tracking of foraging movements and to study potential overlap with fishing activities. This study forms part of an integrated monitoring effort extending across the Scotia Sea (along with the UK and USA annual surveys in Subareas 48.3 and 48.1 respectively).

3.9 The Working Group welcomed the integrated approach used by Norway, which will generate important data for the spatial overlap analysis. In addition, the Working Group noted technological developments in net towing cables which can integrate towing and power supply allowing a single cable to be used for towing the research trawl.

3.10 WG-EMM-2023/P02 presented a summary of the distribution and biomass estimates of Antarctic krill off the South Orkney Islands during a ten-year annual time series (late January to early February, 2011 to 2020). Surveys were undertaken using a random stratified parallel transect design with combined acoustic and biological trawl samples. The paper demonstrated consistently high krill densities in the Scotia Sea region with krill concentrated along the shelf break and associated submarine canyons. Average krill biomass within the 60 000 km^2 survey area ranged from 1.4 to 7.8 million tonnes. According to the statistical method used, there were no clear trends in estimated krill biomass over the ten years. The paper noted that compared with the CCAMLR 9.3% reference exploitation rate (gamma), the management of the krill fishery in the South Orkneys region is precautionary. The results show that industry-based surveys are cost-efficient approaches to high-quality monitoring of krill.

3.11 The Working Group welcomed the data provided as a valuable ecosystem monitoring timeseries which will support future management in Subarea 48.2. The Working Group noted that the time series of biomass estimates could indicate changes in krill availability over the course of the past decade (Fig. 1) and requested that reports suggesting an absence of a trend should be accompanied by analyses of statistical power. The Working Group also noted that the simple ratio of catch to regional biomass may not be the best way to assess whether catch is precautionary and that matching the spatial scales of biomass estimates with the footprint of the fishery provided an alternative (e.g., Watters et al., 2020). The Working Group also noted that the recently updated estimate of gamma for neighbouring Subarea 48.1 (SC-CAMLR-41, paragraph 3.33) is 3.38%, which is lower than the 9.3% used as a precautionary reference point in WG-EMM-2023/P02.

Krill fishery management

4.1 WG-EMM-2023/05 presented a comparison of length frequency sampling between krill researchers and scientific observers on board a commercial krill fishing vessel over several seasons. Observers are required to sample 200 individuals every 3 or 5 days, depending on the month and other requirements according to CM 51-06, whereas researchers sampled every day at the same time and analysed krill from one or two subsamples. Observers tended to use a monocular microscope that had lower magnification, and there were differences in how the two groups defined maturity stages. There were significant differences in the length frequency distributions for most of the compared samples. The paper concluded that current CCAMLR observer protocols tended to under-sample small krill, the juvenile component of the catch, and the different staging protocols resulted in different life-stage compositions. The bias created by this will have an effect on estimating the spawning component of the catch and determining the amount of sub-adult stages that will develop into mature krill the following season.

4.2 The Working group noted that the paper clearly demonstrated the differences in measurements between krill researchers and scientific observers, but that the variability in size measurements depending on the season of sampling was to be expected. The Working Group agreed that there was a need to improve accuracy when measuring and determining the sex of krill, particularly for the juveniles. The Working Group further noted the need for an accurate length frequency distribution for the acoustic target strength and acoustic estimates of biomass.

4.3 The Working Group recommended that the CCAMLR observer protocols should be modified to include a random selection of individuals to measure, and that the change to the protocol should be linked to the data form for traceability. The Working Group also recommended that measurements should be taken daily at a similar time of day, the entire subsample should be measured instead of focusing on a specific number of krill, and observers should have appropriate equipment (e.g., a stereomicroscope). The Working Group recommended that regular krill staging training workshops for observers should be held.

4.4 The Working Group noted that the impact on observer workload needed to be considered when making recommendations on sampling frequency. The requirements of the data collection have changed from historic needs, and current requirements should also be considered if tasking the observers with additional measurements.

4.5 Using the appendix of WG-EMM-2023/05 as a starting point, the Working Group developed draft sampling protocols to be followed by SISO observers on board vessels using the continuous fishing system as well as on traditional trawlers. The protocol included details on subsampling from the catch, measuring krill and determining stage and sex. The protocol was developed with the understanding that feedback from WS-KFO-2023 was required on its practicality and on its inclusion within the SISO Scientific Observer's Manual - Krill Fisheries. The draft protocol is provided in Appendix D.

4.6 Paper WG-EMM-2023/44 presented updated Grym parameters for the assessment for Divisions 58.4.1 and 58.4.2-east, where most of the data used were from a survey conducted in 2022 by Australia. The output of a "ramped" model of maturity was compared with the logistic model, and the output of the "ramped" model was proposed to be used for the Grym parameterisation. Feedback was requested from the Working Group about additional updates or information that might have been missed.

4.7 The Working Group noted that the use of maturity ogive model was consistent with both what has historically been done for Area 48 and the work plan. The Working Group recalled that methods had been previously discussed at WG-FSA (WG-FSA-2021, paragraphs 5.10 to 5.11). The Working Group noted some of the parameters were updated using data collected from a survey in the area and were deemed the best available data for these Subareas. The Working Group discussed that differences in size and maturity are likely due to the habitat and environment of Divisions 58.4.1 and 58.4.2-east being different from Subarea 48.1.

4.8 The Working Group supported the work on the assessment for Divisions 58.4.1 and 58.4.2-east with the proposed parameterisation described in Table 1 of WG-EMM-2023/44 and noted that it should be considered by WG-FSA-2023.

4.9 WG-EMM-2023/03 presented a summary of the current and ongoing development of the revised approach to the management of the Antarctic krill fishery. In this collaboratively developed document, the authors described the status of the revised approach that was adopted by CCAMLR in 2019 and is currently in development, which integrates three components, namely regular updates of biomass estimates, a population projection model to estimate precautionary harvest rates, and a krill-predator spatial overlap analysis to adjust the spatial and seasonal allocation of catch limits. The document was developed to address the recommendation by WG-FSA-2022 (paragraph 9.14) to expand the krill management documentation available as part of the fishery reports. Noting that this document was intended to be a living document to be updated annually, to help Commissioners and the public understand the process, the authors recommended the Working Group recommend forwarding it for consideration at SC-CAMLR-42.

4.10 The Working Group welcomed this useful document and noted it provided transparency on the ongoing development of the krill fishery management approach. It noted that the document identified important future work under the section "Additional elements under consideration" and that this document, intended to be a living document, should be updated as needed. The Working Group noted that the document was derived from Scientific Committee report paragraphs (and supporting Working Group report paragraphs), and that other important elements had been progressed since the SC-CAMLR-41, such as the development of a Krill Stock Hypothesis by SKEG, further considerations of climate change impacts, and the relationship between fishery dynamics and krill developmental stages and sex. The Working Group noted that it would be useful to define an annual review process, through communication between the Secretariat and Members (including those not usually involved in fishery reports review), at the time of the annual fishery reports update.

4.11 The Working Group recommended the Scientific Committee adopt this document at its next meeting as additional documentation of the krill fishery management approach documents available on the CCAMLR website.

WG-ASAM advice and considerations of the krill fishery management strategy (biomass survey designs, methods to use fishing fleets as monitoring platforms, data collection)

4.12 Dr S. Parker (Secretariat), on behalf of the WG-ASAM co-conveners, summarised the discussions regarding the management of the krill fishery as provided in WG-ASAM-2023. He noted that WG-ASAM discussed the CCAMLR acoustic data repository, data collection by fishing vessels on nominated transects, the development of automatic analysis methods in collaboration with Norway and the Secretariat, updates of biomass estimates in Subarea 48.1 (WG-ASAM-2023, Table 1), and the development of a workflow to calculate biomass estimates for each management stratum (WG-ASAM-2023, Appendix E).

4.13 The Working Group welcomed the outcomes of the WG-ASAM meeting and looked forward to further technical developments which will contribute to the management of the krill fishery.

WG-SAM advice and considerations of the krill fishery management strategy (development of integrated stock assessment for krill)

4.14 Dr. Okuda (co-convenor of WG-SAM) summarised the discussions on gear selectivity, effective sample size for length frequency distributions, and a draft integrated stock assessment for krill using Casal2 (WG-SAM-2023). He noted that WG-SAM recognized that the gear selectivity function reported in Krag et al. (2014) constitutes the best available science and it is just one of the parameters used in the Grym, and suggested sensitivity analyses be conducted to understand the effect of different selectivity relationships.

4.15 The Working Group welcomed the outcomes of the WG-SAM meeting and looked forward to further developments which will contribute to the management of the krill fishery.

4.16 WG-EMM-2023/02 presented the modelling work for krill movement between and within key regions of the Southern Ocean including Area 48. Lagrangian drifters were used to simulate transport pathways during the early life stages of krill. The drifters simulated simplistic behaviour of the early life stages including the initial descent/ascent cycle, diel vertical migration (DVM), and advection with simulated sea ice velocity, instead of ocean velocity, under certain conditions. This study aimed to explore differences in the pathways to Marguerite Bay on the Western Antarctic Peninsula, a suspected larval winter nursery ground, in response to changes in the vertical movement rates in the initial descent/ascent cycle based on embryo size, the timing and depth of DVM, and when and if advection with sea ice occurred. The results showed how embryo size can significantly change potential source regions for krill along the Western Antarctic Peninsula as larger embryos allow for survival over shallower bathymetry.

4.17 The Working Group encouraged future work including laboratory and field experiments on egg sinking rates.

4.18 The Working Group noted the absence of sensitivity analysis in this work especially related to the sinking rate of embryos, but highlighted the contribution of this research to the krill stock hypothesis. It also noted that interannual changes in circulation patterns among years including a deep current, are important for the large-scale transport of krill, and recalled similar discussions of toothfish transport models (WG-FSA-12/48, WG-FSA-18/40, Behrens et. al., 2021, Mori et. al., 2021) which highlighted that interannual differences can subsequently influence recruitment patterns. It further noted that this kind of modelling work is important for the discussions on the D1MPA.

Develop methods to estimate biomass for krill

4.19 WG-EMM-2023/55 presented results from two deployments of the wind and solar powered Sailbuoy (www.sailbuoy.no) autonomous vehicle, equipped with a 200 kHz Simrad EK80 echosounder. The 2021 mission covered transects off the South Orkney Islands with limited success due to collisions with sea ice and limited navigational precision. The 2023 mission successfully focused on a krill feeding hotspot, and provided an otherwise unavailable backscatter time series covering a 10 by 40 km area. The authors found the Sailbuoy to be most suitable in "station keeping mode", acting as a self-deploying and recovering acoustic mooring that can provide echosounder data in near-real time, which could be complemented by krill length frequency data collected by vessels.

4.20 The Working Group welcomed this use of new technologies which provided a cost-effective method to collect acoustic data. It noted that similar efforts were underway in Subarea 48.3 (WG-EMM-2022/18) and suggested future deployments use a 120 kHz echosounder to better detect krill.

Data collection needs (SISO (recognising the Report of the Krill Fishery Observer Workshop), vessels)

4.21 WG-EMM-2023/23 presented an analysis of SISO observer sampling rates in the krill fishery for each vessel that fished for krill from 2018 to 2022, including krill biological sampling, fish by-catch sampling, and warp observations. Current sampling rate requirements were given to aid in the interpretation of results, noting that WS-KFO-2023 may provide useful perspectives on this interpretation. Results indicated that the majority of biological sampling rates were above the required minimum rates, by-catch sampling rates were generally high despite the absence of a required minimum rate, and warp observation rates did not always reach the required rate (1 sample per day).

4.22 The Working Group welcomed this analysis and supported its recommendations, including that future analyses could keep both sampling rate computation methods (per-day and per-haul) and also present sample sizes. It recommended the paper be forwarded to WG-IMAF-2023 for consideration of warp observation rates and their potential usefulness to the extrapolation of bird mortalities. The Working Group noted the higher biological observation rates for traditional trawlers than for vessels using the continuous fishing system, as well as the potential need for higher observation rates in particular geographical areas or when krill catches are large, and recommended forwarding the paper to WS-KFO-2023 for consideration of these issues.

Biomass estimation methods (Grym parameters for krill stock model)

4.23 WG-EMM-2023/11 (also presented as WG-SAM-2023/19 and a continuation of the work described in WG-SAM-2022/27; see WG-SAM-2022, paragraphs 3.17 to 3.18), considered methodological aspects of trawl selectivity assessment for krill, focusing on the gear selectivity function published by Krag et al. (2014) which was used to estimate the selectivity parameter values for the Grym. The authors maintained their position that the data used to construct the selectivity function (Krag et al., 2014) does not adequately describe the krill fishing process and that additional data was needed to assess the gear selectivity for krill fishing. The results of the analysis of krill biometrics were presented and confirmed the presence of sexual dimorphism in the body proportions of krill and, according to the authors, demonstrated the statistically significant difference in biometrics between different sexes and maturity stages of krill that may especially affect the estimation of gear selectivity function, and affect the krill demographic structure in catches. The authors stated that while the gear selectivity function derived by Krag et al. (2014) is currently the best available information, it is not sufficient to be used to parameterise the Grym and has not been peer reviewed by the Scientific Committee for its practical use. The authors noted that the topic related to methodological aspects of gear selectivity function for krill should be considered by Working Groups as part of the revision of the krill fishery management.

4.24 The Working Group noted that this paper had been considered by WG-SAM (WG-SAM-2023, paragraphs 3.2 and 3.3, see also paragraph 4.14) and agreed that the Krag et al. (2014) selectivity function constituted best available science. Noting the subsequent contribution by Herrmann et al. (2018), the Working Group encouraged the authors to conduct sensitivity analyses using different gear selectivity parametrizations in the Grym to assess the effects on its outputs.

4.25 WG-EMM-2023/35 presented an evaluation of the Grym's sensitivity to seasonal trends in mortality using within-year patterns in natural and fishing mortality to simulate changes in predator pressure and contemporary trends of the fishing fleet. Results indicated that the inclusion of intra-annual variations in these mortality rates increased precautionary yield, that fishing mortality had a greater effect than natural mortality, and that current harvest levels in Subarea 48.1 were more precautionary than in Subarea 48.2 (the latter being fished in the peak summer months). The authors advised taking contemporary spatio-temporal fishing trends into account in future stock assessments, as well as considering models that include additional ecosystem components.

4.26 The Working Group welcomed this analysis and noted that such sensitivity analyses were beneficial to understanding model behaviour (see also paragraph 4.24). It noted that additional scenarios could be tested to account for low predator pressure outside of summer, instead of setting natural mortality to zero.

4.27 The Working Group agreed that good modelling practices could include:

(i) Sensitivity analyses to assess the robustness of models, their assumptions, and any resulting advice,

(ii) Medium-term projections (e.g., 20-35 years) to describe plausible futures rather than short-term, specific predictions,

(iii) "Bookending" simulations, where parameter values are set close to, or at their extremes to test model boundaries and develop precautionary advice.

Account for spatial structure of krill

4.28 WG-EMM-2023/06 presented the report of the workshop of the SCAR Krill Expert Group (SKEG), held online from 20 to 24 March 2023, focused on the development of a Krill Stock Hypothesis (KSH) in Area 48 (see also Meyer et al., 2023). Noting that the number of participants (83 participants from 13 countries, including early career researchers) provided a sufficient sample size for polling questions to support the development of a KSH, the authors indicated that the workshop developed a preliminary KSH (and identified key data requirements to support its further refinement, including more data on krill length distributions, information on egg and larvae distribution, recruitment locations, and year-class strength. Several recommendations were made to WG-EMM including reviewing and recommending the Krill Stock Hypothesis (KSH) as a useful management tool (e.g., to help refine spatial management units), identifying critical aspects of the KSH that needed testing, and identifying data collection needs and protocols.

4.29 The Working Group welcomed this report and thanked SKEG for its effective response to the Scientific Committee's request to develop a working stock hypothesis for krill in Area 48 (SC-CAMLR-41, paragraph 3.28). It noted that the ambitious action plan would require funding coordination and international collaboration to take advantage of the range of sampling platforms (trawlers, research vessels and autonomous platforms) proposed. The Working Group established a workplan, including timelines and identified priorities, taking into consideration the elements presented in WG-EMM-2023/50 (paragraph 4.31).

4.30 WG-EMM-2023/50 presented a proposed scientific strategy to improve the understanding of krill population connectivity in Area 48 and adjacent waters. The strategy included (i) the collection of multiple sources of data (krill samples, acoustic data, and environmental data), (ii) krill genetic characteristics to evaluate gene flow and migration rates among areas, and (iii), the development of oceanographic models to better understand observed spatial and temporal distributions and simulate transports across areas. The authors indicated that the goal was to better understand the causative mechanisms influencing krill distribution patterns, which will provide information to support the spatial overlap analysis and help design biological sampling protocols.

4.31 The Working Group welcomed this paper, noted the novel use of genetic analyses (e.g., Shao et al., 2023) to assess transport and retention, and encouraged CCAMLR scientists to share krill samples from across the Convention Area to conduct such analyses. While noting that the paper provided, inter alia, an effective framework to improve the understanding of spatial population structure and krill flux, the Working Group considered that its recommendations could be considered along with those of WG-EMM-2023/06 (paragraph 4.29) to draft a combined workplan.

4.32 Recalling the discussion in WG-SAM-2022 (paragraph 3.13), the Working Group noted that progressing field and laboratory work to better understand krill stock dynamics in Area 48 and adjacent waters, and the resulting patterns that are observed in survey and fishery data, was a priority in the context of the revision of the krill fishery management approach. Noting the fruitful and effective collaboration between SKEG and CCAMLR scientists (paragraph 4.29), the Working Group developed an ambitious workplan aimed at addressing the wide range of underlying issues. Combining the extensive international expertise and multiple sampling platforms, specific tasks will be addressed using a variety of scientific approaches. With the understanding that the proposed workplan was to be further refined and that both scientific funding and fishing industry incentives needed to be brought forward, the Working Group agreed to the Krill Stock Hypothesis Information Collection Plan (Table 1).

4.33 The Working Group recalled that the revision of the krill fishery management approach for Subarea 48.1 is being progressed by following the krill work plan agreed by the Scientific Committee in 2019 (SC-CAMLR-38, paragraphs 3.29 to 3.34), and that the Scientific Committee agreed that scientific information is available to allow progress of the work (SC-CAMLR-41, paragraphs 3.43 to 3.51). The Working Group noted that the revisions of krill catch limits can be progressed by taking account of the uncertainties in a staged manner while the KSH is being updated in the longer term.

Develop stock assessments to implement decision rules for krill in Subarea 48.1

4.34 WG-EMM-2023/48 presented an application of the open-source Management Strategy Evaluation (MSE) tool, OpenMSE (https://cran.r-project.org/package=openMSE) which is currently used to test and measure performance of various management strategies on selected fisheries (teleosts) and inform management bodies. The authors approximated the Grym under the OpenMSE framework by running eight scenarios with identical input parameters to compare outputs. Using appropriate parameterizations and modifications, OpenMSE was able to approximate the Subarea 48.1 krill implementation of the Grym. OpenMSE provides substantial flexibility, can be built on a dynamic approach to access large datasets, is transparent and open source. The OpenMSE tool will provide a valuable resource to model and test potential management procedures in the future.

4.35 The Working Group welcomed this work and recognized the importance and need for exploring a dynamic management tool where management implementation, data generation, and updating can be done continuously. It recognised OpenMSE as a potentially useful tool and the Working Group encouraged the authors to further explore its development. Possibilities for complementing input variables for the calculation of total fishing mortality were suggested, for example including additional work on mortality associated with escapement from fishing gear (Krafft et al., 2016; Herrmann et al., 2018; Krag et al., 2021). The Working Group referred the authors to the SKEG as a possible source for improved or additional data inputs. The Working Group noted that similar work was being carried out by Chilean colleagues, and that there were opportunities for collaboration. The Working Group also noted the work may benefit from being reviewed by WG-SAM.

4.36 WG-SAM-2023/25 presented a pilot model using Casal2 to perform a 20-year forward projection to assess the effect of fishery catches on the Antarctic krill population in Subarea 48.1. Data supplied to the model included a time-series of fishery catches, acoustic biomass surveys, and length frequency distributions. Biomass estimates derived from fishing and research vessel acoustic surveys were combined. The model reported that at the end of the 20-year projection with 620 000 metric tons caught per year, spawning biomass was about 64% of the estimated unexploited biomass. The results demonstrated that Casal2 provided a method to convert NASC estimates to biomass estimates without collecting length-frequency data during every acoustic survey and subsequently applying a target-strength model. Based on this assessment the authors proposed that the Scientific Committee design a data-collection plan for the krill fishery that facilitates the application of integrated assessment models by combining frequent acoustic surveys that simply report NASC with occasional surveys during which length frequency data are collected using research nets.

4.37 The Working Group welcomed this work and encouraged the authors to continue further development to complement or evaluate the outputs of the Grym. The Working Group noted the comments by WG-SAM-2023 (paragraphs 4.1 to 4.3), that Casal2 development within CCAMLR had been previously supported by Mr A. Dunn (New Zealand) and that similar support could be possible.

4.38 WG-EMM-2023/39 demonstrated the Length-Based Spawning Potential Ratio (LBSPR) method to estimate the reproductive potential of Antarctic krill. The study used size composition data of Antarctic krill collected over the last 20 years by SISO observers during fishing activities in Subarea 48.1. Knowledge about the species' reproductive potential is crucial to informing spatial and temporal catch limits to reduce the risk of overfishing recruits. The study demonstrated that it was possible to identify differences in reproductive potential and therefore in reproductive resilience over different temporal and spatial scales. The authors concluded that this approach could contribute to the development of a more informed and sustainable krill fishery management plan.

4.39 The Working Group welcomed this numerical approach and encouraged the authors to continue this important work. The Working Group also noted that this is another illustration that

CCAMLR scholarship recipients can bring a fresh view into scientific discussions, facilitate progress in a short time, and develop tools that are constructive for fishery management discussions.

4.40 WG-EMM-2023/12 presented results of the two survey legs performed by the Russian research vessel *Atlantida* during February and March 2020 in the Bransfield Strait (Subarea 48.1). Each leg had a 6-day duration, with a one-month intermediate interval, covering the same locations with five acoustic transects and 16 CTDs and Isaacs-Kidd trawl stations. Systematic registration of marine mammal and seabird sightings were made during daylight hours. Spatial and temporal variability of geostrophic circulation of water masses, distribution of density and length of krill, direction and intensity of krill transport were analyzed in relation to predator distribution and their calculated consumption of krill. Data on seabird and mammal dependence on krill as individual krill requirement (g/day) were used as described in Warwick-Evans et al. (2021). During the periods of observations almost no krill fishing vessels were operating in the study area. The paper suggested that a significant difference in krill biomass (792 569 t) was found between the two survey legs and that the krill length distribution shifted from predominantly large krill to predominantly small recruiting krill over the 1-month period. The krill biomass changes were not comparably higher than catches ranging from the annual krill catch in Subarea 48.1 (155 000 t trigger level) and the maximum annual krill catch achieved in the krill fishery in Area 48 (450 782 t in 2020/21 fishing season) as well as the potential predator consumption estimated for the study area. The authors concluded that these changes cannot be due to natural biological processes such as growth, spawning, predation, or fishery, but rather that they are a consequence of krill transport, redistribution and replenishment processes caused by ocean currents. They suggested further considerations of the significance of krill for penguin and pinniped colonies in shallow coastal waters that may be ecologically more important. The authors emphasized that the results of the multidisciplinary two-leg survey carried out by RV *Atlantida* (2020) in the Bransfield Strait are the best available data on krill flux characteristics in relation to spatial and temporal variability in krill biomass distribution, and the distribution and consumption of dependent predators. The authors noted that the survey design was presented to the Working Group and data collection and processing were carried out in full compliance with CCAMLR recommendations, with particular attention to the implementation of an acoustic survey based on the three-frequency krill identification method, as well as following the known recommendations for standardizing at-sea monitoring surveys and observation for marine birds and mammals (Kasatkina et al., 2021; Shnar et al., 2021; Trufanova et al., 2021).

4.41 The Working Group welcomed this contribution of a unique and large dataset. It noted that the combination of predator sighting data and simultaneous logging of hydro-acoustic data was a useful combination that provided valuable possibilities to study krill-predator relationships.

4.42 The Working Group did not concur with all conclusions of the paper as local depletion can occur due to the combined effects of predation and harvesting, which likely impact other ecosystem components. The Working Group emphasized the ongoing need to develop a better understanding of predator consumption rates, including for fish and seabirds, which are highly uncertain. The Working Group noted that although the survey design was reported to follow CCAMLR recommendations, it had not yet been reviewed by CCAMLR Working Groups and that the reported sightings of cetaceans were regarded to be low for the area and season.

The Working Group also noted that other methods were available to measure the effect of flux (e.g., Cutter et al., 2022), and that the methods used in this work by comparing biomass estimates from two periods, may not be optimal.

Symposium on holistic approach to management in Subarea 48.1

4.43 The Working Group recalled that following COMM CIRC 23/13–SC CIRC 23/14, the 'Harmonised approach to krill management' e-group was established to progress the development of the format, scheduling and terms of reference (ToR) for a joint science, policy and industry symposium meeting during 2023 (CCAMLR-41, paragraphs 4.17 and 4.18).

4.44 The Working Group discussed the draft ToR from the e-group and considered that:

(i) The areas in question involve overlap with the CCAMLR MPA Planning Domain 1 (D1MPA), which also includes Subareas 48.2 and 88.3, and suggested the Scientific Committee clarify the spatial scope of the discussion.

(ii) The ToR should not discuss revisions of Conservation Measures, which were matters for the Commission, and therefore the Working Group suggested modifying the ToR to reflect this.

(iii) Following the example set by the meeting in Concarneau (2019), an informal format for a workshop would make best use of the time available and help to foster discussions. The output from the workshop could be a Chair's report to the Scientific Committee.

(iv) Arranging one large meeting as suggested by CCAMLR-41, paragraph 4.18 was problematic because it would require a large number of people to participate while the scientific options for scenarios had yet to be developed.

4.45 Based on these considerations, the Working Group considered that ToR 1 and 2 (Appendix E) could be addressed through sequential discussions of the Scientific Committee and the Commission under 'Spatial Management' agenda items. The Working Group suggested that following those discussions, the Commission could consider a follow-up science-focussed workshop prior to the WG-EMM-2024 meeting to address ToR 3 and 4 (Appendix E).

4.46 The Working Group noted that funds for running the 2024 workshop may be necessary and could be sought through contributions from NGOs and the fishing industry.

4.47 The Working Group noted that the ToR were still in draft and in development in the e-group. The Working Group posted its proposals to the e-group as a contribution to the discussion (Appendix E).

Ecosystem monitoring and observation

5.1 WG-EMM-2023/33 reported results of oceanographic research conducted on Ukrainian fishing vessels in the season 2022/23. Results indicated that the temperature of the bottom layer ranged from -0.20° C to +1.47° C, and that there was a tendency for decreasing temperature from the Ross Sea region to the north of the Amundsen Sea.

5.2 The Working Group welcomed the collection of additional data on fishing vessels during fishing operations and noted the importance of strategic data collection. The Working Group advised completing CTD calibrations prior to data collection each year, and the CCAMLR Secretariat offered assistance for liaising with SOOS for submitting the data into international databases.

5.3 WG-EMM-2023/53 summarised research on euphausiid larvae and salps conducted by Argentina on board the Peruvian polar vessel Carrasco during summers in 2019 and 2020 off the West Antarctic Peninsula (Mar de la Flota / Bransfield Strait) and Elephant Island surroundings. Results were compared with the PS112 cruise of 2018 dataset from the same area to determine interannual differences in salp densities. During 2019, *E. superba* and *Thysanoessa macrura* abundances were high, and all euphausiid larvae had very low densities in 2020. Salp densities showed the opposite pattern and were very high in 2018. The changes in abundance of krill and salps were correlated with environmental conditions (*in situ* chlorophyll-a, temperature and salinity, water masses properties), suggesting these were possible drivers of the observed changes.

5.4 The Working Group welcomed this study which compared the densities of krill and salps. The latter are currently understudied. The Working Group noted that salps may have an impact on krill eggs and larvae through predation in the water column but that this may depend on the phytoplankton community present and that further studies would be needed to understand these processes and assess their change.

5.5 WG-EMM-2023/40 presented a case study using bio-loggers and machine learning analysis to determine the functional response of marine predators to changes in their prey field. The study used animal-borne video cameras and accelerometer dive loggers to obtain concurrent visual, acceleration and dive data from foraging chinstrap penguins. The paper indicated a strong correlation between individual prey capture events and events derived from signals in the accelerometer and dive data alone and proposed the outcomes from this approach be considered for CEMP monitoring to link prey capture rates of chinstrap penguins to environmental variability or fishing pressure.

5.6 The Working Group acknowledged the strong statistical relationships between prey capture events and signals from the bio-loggers, and noted that ongoing monitoring would be valuable given inter-bird variability. The Working Group indicated that extending the analysis to assess krill size from the footage would be useful, but noted the difficulties in doing so as well as the existence of other experiments exploring this process.

5.7 WG-EMM-2023/P06 evaluated the temporal trends, range of decreases, and predicted population changes within three generations for multiple colonies of chinstrap penguins across the Antarctic Peninsula and South Orkneys. A total of 133 colonies were analysed using the Mapping Application for Penguin Populations and Projected Dynamics (MAPPPD) data for the period 1960 to 2020, and reported that 62% of the 133 colonies experienced decreases between the first and the last counts, and that 46% of colonies had decreased by over 75%. Potential factors behind chinstrap declines could include changes in krill productivity, competition with other krill predators (e.g., cetaceans) and with the krill fishery (especially in years of low abundance). The authors proposed that the current trends in chinstrap penguin populations would persist in the short- to mid-term, and that this may result in the species being considered as a vulnerable species according to the IUCN A2 criteria.

5.8 The Working Group noted that some populations were decreasing in close proximity to those that were increasing, which was thought to be either due to different foraging locations or potentially to the data analysis approach.

5.9 WG-EMM-2023/41 highlighted the need to assess model diagnostics or model fit to allow robust inferences about changes in chinstrap penguin abundance to be made. More generally, the paper highlighted that (1) future analysis of the MAPPPD data should take into account the uncertainty in these estimates; (2) limited data are available to determine the demographic drivers of chinstrap penguin population change; and (3) adopting reproducible research practices enables validation of research results.

5.10 The Working Group noted limitations in time series and estimates of uncertainty associated with the MAPPPD data and the need to account for these when inferring population change or projected trajectories, and agreed on the importance of analysis code availability for assessing reproducibility of results. It noted that the decline of chinstrap penguins is of concern and that while analytical approaches differed between the two papers, both WG-EMM-2023/P06 and WG-EMM-2023/41 supported the finding of decreasing population trends.

5.11 WG-EMM-2023/P04 presented results of a survey of sperm whales using acoustic mooring data in the Ross Sea region. The study demonstrated that sperm whales are present in the Ross Sea region almost year-round, and found a significant preference for day-time foraging rather than during the night or nautical twilight from the southern mooring, but no clear diel differences from the northern mooring. High sea ice concentrations were generally associated with fewer detections, and less distance to open water (<50 km) was associated with more detections. The authors stated that this research provides baseline information on sperm whale occurrence and establishes a method to track long-term change to help evaluate the conservation values of the Ross Sea region Marine Protected Area (RSRMPA).

5.12 The Working Group noted that there were fewer sperm whales observed from fishing vessels in the Ross Sea region than in Subarea 48.3. The Working Group noted historical data on sperm whale presence over deep waters east of the Ross Sea slope region and suggested that this area may be a useful target area to monitor. The Working Group noted that the high mobility of sperm whales may influence their usefulness in assessing the Ross Sea region MPA. It further noted that long-term acoustic moorings can be a powerful observation tool and recommended continued development of their use.

5.13 WG-EMM-2023/54 (originally presented to the Ecosystem Modelling group of the Scientific Committee of the International Whaling Commission in April 2023) provided an overview of the role of baleen whale science in the revised krill fishery management approach (through the spatial overlap analysis), and highlighted the need for robust estimates of whale abundance, seasonal spatial distribution, krill consumption rates, residency times in feeding grounds, and an understanding of krill swarm preferences. It highlighted the importance of developing methods to minimise/eliminate risk of whale incidental mortality in the krill fishery, and how data needs are complementary to longer-term efforts to model ecosystem function, including the role of climate change, to inform feedback management. The authors proposed further work towards a framework to include cetacean ecology in CCAMLR management framework, and a strategy for supporting future survey efforts.

5.14 The Working Group recognised the importance of increased collaboration between CCAMLR and IWC to include whales in the krill fishery management approach and recalled that Dr N. Kelly (Australia) had been tasked to liaise between these two groups to develop areas of common interest. The Working Group also noted that prey availability, including krill swarm size and the size distribution of krill, are important to prey-predator interactions in addition to krill biomass.

5.15 WG-EMM-2023/P07 compared chinstrap penguin foraging performance and breeding success over two years with contrasting environmental conditions and krill availability at Harmony Point, Nelson Island and South Shetland Islands. Associated with krill availability being lower and deeper in the water column in winter when sea ice cover and summer productivity (chlorophyll-a) were lower, penguins increased their foraging effort (longer distance and duration of trips) and had lower breeding success. The paper proposed continued efforts for coordinating penguin tracking and acoustic monitoring in other colonies to determine whether the results presented explained the local and global decline of chinstrap penguins, and recommended including such studies within the CEMP protocols.

5.16 The Working Group noted that shifts in penguin foraging behaviour can occur rapidly and will vary in relation to phenology. The Working Group suggested that concurrent diet data may allow hypothesis testing in relation to alternate energy pathways. The Working Group noted that the foraging performance parameter "number of wiggles" (i.e., rapid movements detected by the accelerometer), can indicate foraging success and that the reported unexpected relationship with krill abundance may be related to krill size, and that this could be important ancillary data to collect in the future.

5.17 WG-EMM-2023/P08, 2023/P09 and 2023/P10 together presented a synopsis of recent results from Australia's seabird monitoring program in East Antarctica for Cape petrels breeding in Elizabeth Land, and Adélie penguins breeding in Wilkes Land and the Western Mac Robertson Land. Adjustment factors were developed to allow correction for population surveys conducted at sub-optimal times. Cape petrel population size across the Vestfold Islands in 2019 were similar to levels in the early 1970s. WG-EMM-2023/P09 and WG-EMM-2023/P10 showed diverging population trajectories for the two large regional Adélie penguin populations, with a significant increase across Wilkes Land over several decades, and a rapid decrease over the decade from 2010 in Mac Robertson Land. The decline was likely due to a combination of poor breeding conditions in years with extensive fast ice, with a declining fledgling survival that was linked to smaller cohorts.

5.18 The Working Group welcomed the submission of publications that had been through peer-review, and noted the importance of long-term monitoring for detecting and understanding seabird population change, and for understanding whether CEMP sites reflect population dynamics at a broader scale. The Working Group noted the merit in monitoring response parameters in addition to population size, including breeding success and mark-resight programs to estimate survival.

CEMP monitoring (1-day focus topic)

5.19 WG-EMM-2023/42 provided an overview of the CCAMLR Ecosystem Monitoring Program (CEMP) and identified topics that the Working Group may wish to consider as part of the process to revise CEMP to enhance ecosystem monitoring and to support krill fishery management approaches in Subareas 48.1 to 48.4.

5.20 The Working Group welcomed the paper and noted that ToR would need to be developed intersessionally, including specific tasks, to support any future workshops to expand or enhance CEMP.

5.21 WG-EMM-2023/24 presented a summary of CEMP data submissions received by the Secretariat for the 2022/23 monitoring season, and provided an overview of existing CEMP time series data. The paper highlighted consistent spatial relationships between CEMP sites and the recent distribution of the krill fishery and noted that few CEMP sites were located relatively close to fishing areas, while fishing occurred distant to many CEMP sites. The paper noted that CEMP could be enhanced to directly support both fishery management, ecosystem status and MPA objectives and that the long-term goals of CEMP remain focused on monitoring krill-dependent predators and other ecosystem components.

5.22 The Working Group welcomed the paper and thanked the Secretariat for developing some innovative presentations of the location of CEMP sites relative to krill fishing activities. The Working Group noted that this information was very useful for identifying gaps in coverage and knowledge. The Working Group further noted that disaggregating the data by species, season, timing, and according to krill fishery catch might be useful to explore the effects of krill fishing pressure on krill-dependent predators and that these data could also be presented at different spatial scales.

5.23 The Working Group noted that the collaborative development of tools used to help understand status and trends of harvested, dependent, and related species, such as the trend analysis for toothfish (WG-SAM-2023/16), is an iterative process which could be improved and progressively expanded over time.

5.24 The Working Group noted that the Secretariat is developing a data exploration tool to better convey the metadata associated with CCAMLR data holdings and that this could include CEMP data in the medium term. This tool was presented to WG-ASAM-2023 (paragraph 3.14) and will continue to be developed for use by Members.

5.25 The Working Group noted that a key element for the CEMP review was to consider how CEMP data would be used to ensure meeting the objective of the Convention. The Working Group noted that, beyond the collection and submission of CEMP data, a strategy for the analysis of CEMP data and delivery of scientific advice must be clearly defined. The Working Group noted that developing such a strategy should include consideration of data access, how to progress the analyses, and nuances regarding the interpretation of the data.

5.26 The Working Group also discussed the need to rethink the scope of the CEMP monitoring program. It noted that CEMP is currently focused on summertime monitoring of krill-dependent predators, but that it should include enhanced predator monitoring during summer and winter periods, designate additional monitoring sites and species, identify new or alternate CEMP parameters, and incorporate the monitoring necessary to understand the impacts of climate change and fisheries on the ecosystem, including CCAMLR MPA monitoring.

5.27 The Working Group recalled that other established monitoring programs can provide data to help understand status and trends in the ecosystem. For example, the SISO and agreed protocols for conducting acoustic surveys from fishing vessels may contribute to an expanded CEMP. The Working Group also noted that there are several monitoring programs external to CCAMLR that may contribute to an expanded CEMP, including Penguin Watch, Oceanites, SOOS, and the seabird tracking database hosted by Birdlife International, but that these data would need to be analysed to inform the Scientific Committee.

5.28 The Working Group further noted that Members may hold additional data on other ecosystem components that are valuable for understanding variation in CEMP data (e.g., data on phytoplankton, local meteorological data). The Working Group noted that compiling the metadata of such data could raise awareness among Members and aid in collaborative analysis and interpretation of CEMP data.

5.29 The Working Group recalled that current CEMP sites provide important long-term context for understanding ecosystem status and trends and that these sites were likely to remain key sources of land-based predator monitoring in the future. The Working Group further noted that some CEMP indices that are monitored during the summer period indicate conditions experienced by animals during the winter, thus expanding the spatial and temporal footprint of data collected at CEMP sites. The Working Group noted, however, that temporal and spatial mismatches in fishing and monitoring exist and that reconciling such mismatches remains a key topic for research. The Working Group noted that such mismatches may help identify where and when future monitoring would be needed. In particular, the Working Group agreed the need to expand beyond land-based monitoring to include at-sea monitoring, particularly within areas where the fishery operates.

5.30 The Working Group noted that, while an expansion of the CEMP was desirable, the CEMP review may benefit from initial efforts to identify specific objectives for the use of CEMP data with respect to management of the krill fishery. Identifying such objectives first would facilitate future consideration of the specific details of an expansion, such as designating additional CEMP species, monitoring methods, or identifying environmental variables for assessing impacts on the ecosystem arising from climate change or fishery-ecosystem interactions.

5.31 The Working Group agreed that the current CEMP database contains a large, but underutilized, dataset. The Working Group agreed that progress towards identifying relevant and useful outputs for informing management decisions would require considerable analyses of existing CEMP data. The Working Group noted that this rich data set provides a basis for developing diagnostic tools and candidate summary outputs, both quantitative and qualitative, with the potential to inform ecosystem health checks, MPA monitoring, the spatial overlap analysis, and to identify trends related to the impacts of climate change.

5.32 The Working Group agreed that a priority task is to initiate collaborative analyses to better understand the status and trends in existing CEMP data, to identify gaps that may inform future data requirements, and explore alternatives to the Combined Standardized Index (CSI) for representing aggregate indices of status and trends in the ecosystem.

5.33 The Secretariat introduced a recent Status of the Ecosystem report used by the Alaska Fisheries Science Center (USA) to summarize the status of the ecosystem and its bearing on fisheries management in the Bering Sea (https://apps-afsc.fisheries.noaa.gov/REFM/docs/2022/EBS-ESR-Brief.pdf). The Working Group noted that this report provided a useful demonstration for how summaries from different types of monitoring data, including physical and biological data, could be structured to communicate a status report, or health check, to Commissioners and stakeholders.

5.34 The Working Group thanked the Secretariat for introducing the example status report. The Working Group noted that the frequency with which catch limits and their spatial distributions are updated may help inform the development of such reports for use in CCAMLR.

5.35 The Working Group recalled that advice arising from the CEMP could take the form of strategic (i.e., long-term) advice or tactical (i.e., short-term) advice. The Working Group noted that using regular summaries of CEMP data to produce ecosystem status reports represented longer-term strategic health checks that could contribute to assessments of whether current management practices remained precautionary.

5.36 WG-EMM-2023/26 presented an overview of CCAMLR-related ecosystem monitoring and scientific activities undertaken by the British Antarctic Survey (BAS) during the 2022/23 season. Data summaries for physical environmental conditions, monitoring from four CEMP sites on seabirds, pinnipeds, and marine debris, and at-sea surveys for krill and groundfish were highlighted.

5.37 The Working Group welcomed the paper, noting it was the second consecutive year that such a summary had been provided by BAS. The Working Group encouraged other Members to provide similar summaries from their CEMP monitoring data and especially in collaboration with other Members.

5.38 The Working Group noted that in years of low krill abundance, alternative prey resources may sustain predators in Subarea 48.3. The Working Group noted that consideration should be given to such alternative food webs in a revised CEMP.

5.39 WG-EMM-2023/29 presented results from a monitoring programme for three penguin populations in Ardley Island, southwest of King George Island from 2019-2023. The paper highlighted the recent decline of Adélie penguin populations in contrast to a stable gentoo population, as well as tracking data to identify the core summer foraging areas of Adélie penguins and the broader spatial footprint of Adélie penguins during the winter. The authors noted that long-term monitoring of both predator and prey is important to understand drivers of year-round population change.

5.40 The Working Group welcomed this paper and the establishment in 2022 of a CEMP monitoring program by Uruguay at Ardley Island. The Working Group noted the importance of year-round data collection for understanding drivers of population and ecosystem change and encouraged the authors to continue to progress this important work.

5.41 WG-EMM-2023/43 described progress towards using remotely operated time-lapse cameras as a tool for cost-effective, large-scale monitoring of flying seabirds. Cameras can help describe breeding phenology, breeding success, and adult attendance curves that can be used to estimate local abundance and its inter-annual changes. The authors suggested that the use of cameras in conjunction with ground-based monitoring could significantly enhance the CEMP if applied to flying seabirds.

5.42 The Working Group welcomed the paper and noted that the use of cameras to monitor several CEMP parameters for penguin species had been successfully implemented by several Members. The Working Group noted that camera selection, placement, and monitoring objectives were key considerations for implementing camera-based monitoring of flying seabirds, whose behaviours, sensitivity to researchers, and spatial distributions differ from penguins.

5.43 The Working Group noted the benefit of methods that provide information on breeding population size, in addition to the more detailed information derived from fixed cameras that focus on subsets of the population. For example, The Working Group noted that small Unoccupied Aerial Systems (UAS, or drones) or ground-based counts could complement camera-based work where practical.

5.44 The Working Group encouraged further field-based validation of the monitoring approach for flying seabirds as outlined in WG-EMM 2023/43 and progress towards developing standard methods and data submission forms.

5.45 The Working Group noted that automated image analysis may expedite delivery of data to the CEMP and to the Scientific Committee. Developing a catalogue with images and annotations to help develop, train, and test automated image analysis techniques may provide for useful collaborations among Members involved in camera-based monitoring.

5.46 WG-EMM-2023/45 reported on land-based monitoring of Antarctic breeding seabirds by the Australian Antarctic Program and the principles used to redesign the program to address multiple monitoring objectives. This report described the rationale for a hierarchical approach to monitoring seabirds that combines annual, local-scale monitoring with periodic (4 to 7 years), broad scale monitoring to deliver large scale seabird monitoring data to achieve CCAMLR's objective. The program was designed to deliver regular health checks and further develop datasets needed for a spatial overlap analysis to distribute the krill catch limit in east Antarctica.

5.47 The Working Group welcomed the paper and noted its relevance to developing a health check concept for the CEMP. The Working Group noted that a health check, or ecosystem status report, like that envisioned in WG-EMM-2023/45, could become a fourth leg of the krill management strategy.

Planning for the CEMP review

5.48 The Working Group recalled that the CEMP was established in 1985 (SC-CAMLR-IV, paragraph 7.2) 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.

5.49 The Working Group recalled that the CEMP was originally designed to collect data on multiple parameters using standardized methods, including environmental conditions, data on harvested species, and data on dependent predators (Agnew, 1997).

5.50 The Working Group recalled the CEMP review that was conducted in 2003, which was convened to assess the strengths and weaknesses of the existing program and the limitations these might impose for meeting the original objectives, and potential additions and improvements to the existing program (SC-CAMLR-XXIII, Appendix D).

5.51 The Working Group noted that, despite the initial plans for the CEMP and several recommendations from the 2003 review, a full implementation of an ecosystem monitoring program remains largely incomplete. Given the need to support growing interest in the krill fishery and other ecosystem monitoring requirements within CCAMLR, the Working Group reaffirmed that another review to update and expand the CEMP was timely and necessary.

5.52 The Working Group noted the original aims of the CEMP (paragraph 5.48). Recalling the outcomes of the 2003 Review, the Working Group agreed that an additional aim was needed.

5.53 The Working Group recommended that the Scientific Committee consider adding a third aim to formalize an objective that CEMP data be analysed, and the results be clearly communicated to inform management decisions regarding catch limits and their spatial distribution. The Working Group noted that target audiences for the results of analyses from CEMP data were broader than the CCAMLR community.

5.54 The Working Group recalled the substantial progress made on the krill work plan and the agreement reached on the new fishery management approach based on management strata within Subarea 48.1. However, despite this progress no consensus was reached for its implementation (SC-CAMLR-41, paragraph 3.67). To progress the development of its implementation, the Scientific Committee in 2022 highlighted the critical role that CEMP is required to play to support new management. The Scientific Committee recommended that future monitoring include: (i) krill biomass recruitment and demography, (ii) fish by-catch, (iii) status of dependent predator species including cetaceans, and (iv) the development and assessment of potential impact of the increased fishery on the ecosystem in general (SC-CAMLR-41, paragraph 3.49), and that an increase in catch limits requires a commensurate increase in data collection and monitoring on krill and other components of the Antarctic ecosystem that may be impacted (SC-CAMLR-41, paragraph 3.54).

5.55 With respect to the scope of the CEMP, the Working Group agreed that a CEMP review should consider how to expand beyond the current land-based predator monitoring focus of the CEMP. The Working Group noted that expanding the scope of the CEMP should parallel the objectives and needs of the corresponding management framework for which the data are collected.

5.56 The Working Group noted the importance of considering baleen whale distributions and abundance, as well as other at-sea observations in areas where the fishery operates. The Working Group also noted that identifying a broader range of indicator taxa from across trophic levels or foraging guilds may be useful. For example, changes in primary production and mesopelagic fish populations were identified as important knowledge gaps in the understanding of ecosystem status.

5.57 The Working Group noted that an expanded CEMP requires not only data to detect a change in the status of an indicator variable, but also data to understand why that change has occurred. The Working Group noted that such supporting information could be derived from expanded monitoring by Members or, where appropriate, liaison with other programs that collect and share the necessary data on relevant environmental (e.g., meteorological data, remotely sensed data, or model output) and biological (primary production) conditions.

5.58 The Working Group noted that progressing a review of CEMP would likely require intersessional work and dedicated workshops that would allow expertise from beyond the community of WG-EMM to participate. The Working Group noted that a general structure for progressing the work might be based on a categorical approach derived from the original aims of CEMP to consider 'environmental data', 'harvested species', and 'dependent and related species'.

5.59 The Working Group discussed the requirements from Commission to consider future monitoring requirements of krill biomass and other ecosystem components (including fish by-catch and krill dependent predator species to detect potential impacts of the increased fishery on the ecosystem) to support the revised krill management approach (CCAMLR-41, paragraph 4.17).

5.60 The Working Group identified a need for clarity about how the remit of WG-EMM and the CEMP contribute to the broader endeavour of ecosystem monitoring. The current and proposed uses of ecosystem monitoring data within CCAMLR include ecosystem health checks, spatial overlap analysis and MPA monitoring. CEMP currently delivers data on land-based predators, monitored at specified sites using standard methods. Members who submit CEMP data generally monitor multiple variables at CEMP sites and some of these variables are not submitted to the CCAMLR Secretariat. This existing additional monitoring can include tracking data and environmental variables which may be useful for interpreting predator data. CCAMLR oversees various monitoring programmes, some of which are currently included in CEMP and some of which (e.g., SISO) are not. There are several other organisations, many of which are not directly connected to CCAMLR, which collectively monitor a wide range of variables in the Southern Ocean. The scope of WG-EMM can encompass the monitoring of any ecosystem variable to achieve CCAMLR objectives (WG-EMM ToRs).

5.61 WG-EMM also has specific tasks related to ecosystem monitoring, including the current priority of supporting the revised krill fishery management approach for subarea 48.1. In this case the focus is on harvested, dependent and by-catch species. An enhanced CEMP designed to address this issue might include standardized monitoring of the target species (krill), its land-based and pelagic predators, and potentially relevant environmental variables at appropriate scales.

5.62 The Working Group identified three broad objectives for ongoing discussion of CEMP:

(i) Supporting the implementation of the revised krill fishery management approach for Subarea 48.1,

(ii) Enhancing circumpolar ecosystem monitoring in the context of climate change and fishing,

(iii) Supporting MPA design and monitoring.

5.63 Supporting the revised krill fishery management approach was identified as the immediate priority.

5.64 The Working Group recommended that:

(i) Implementation of a revised krill fishery management approach in Subarea 48.1 should be accompanied by enhanced ecosystem monitoring at appropriate scales in those management strata that are fished,

(ii) such monitoring could include data collected on vessels and at breeding sites, using remote observations and automated monitoring systems for biological and physical variables,

(iii) partnership with other programmes that collect predator data in these areas might be an appropriate way of expanding CCAMLR's access to monitoring data,

(iv) sustainable funding mechanisms (potentially including incentives for submitting monitoring data) should be identified, as enhanced data collection and analysis require additional effort and resources,

(v) consideration should be given to the acquisition of environmental data at appropriate spatial and temporal scales to identify potential drivers of monitored parameters,

(vi) analysis should be conducted on existing CEMP data to advise the Scientific Committee on status and trends of the ecosystem and to progress implementation of the krill fishery management strategy (paragraphs 5.20, 5.21 and 5.53).

5.65 The Working Group proposed four temporary teams to progress these recommendations through intersessional work and a dedicated session at WG-EMM-2024:

(i) Analysis of existing monitoring data (Dr Hill with support from the Secretariat),

(ii) monitoring of current and potential sentinel species (Drs Emmerson, Waluda, Collins),

(iii) krill fishery and at sea monitoring (SKEG),

(iv) environmental/non-biological parameters of relevance to wider ecosystem monitoring (Dr Knutsen).

5.66 The Working Group encouraged participants who wish to join these teams to identify themselves in the existing CEMP e-group. The Working Group agreed that participation in these teams could be extended to external experts at the discretion of the team leaders.

Other monitoring data (marine debris)

5.67 WG-EMM-2023/14 reported a summary of the CCAMLR marine debris monitoring program (MDMP) that was established in 1986 to monitor marine debris in the Convention Area. The MDMP reported data collected by CCAMLR Members from beach surveys, seabird colony surveys, observations of marine mammal entanglements, hydrocarbon soiling events, opportunistic sightings, gear lost by fishing vessels, and marine debris (including fishing gear from other sources) observed at-sea and recorded by the SISO observers. Most of the debris reported was plastic or fishing gear. While spatial patterns in gear loss generally reflect spatial patterns in fishing effort, some areas show higher rates of loss, likely due to a combination of sea ice dynamics, currents, and seafloor characteristics.

5.68 The Working Group welcomed the report and recommended that the Scientific Committee consider endorsing:

(i) the proposed changes to the opportunistic e-form,

(ii) the development of the proposed e-form table (Annex 1 in WG-EMM-2023/14) to include in the C2 form to enable the quantitative monthly reporting of fishing gear lost onboard the vessel beyond the current reporting of the frequency of lost fishing gear (i.e., occasionally, weekly, and daily),

(iii) the development of the proposed e-form table (Annex 2 in WG-EMM-2023/14) for reporting debris found at-sea in the observer logbook.

5.69 The Working Group welcomed Dr. C. Waluda (United Kingdom) to lead the Intersessional Correspondence e-group with Secretariat assistance to progress the marine debris workplan.

5.70 The Working Group noted that further work to standardize reporting of marine debris by effort would be needed to provide time trends in marine debris and allow any extrapolation to other times or areas. The Working Group noted that beach surveys are time consuming, and that it is difficult to determine if all the debris in an area was collected during the survey. The Working Group recommended future work to examine this issue.

5.71 The Working Group noted that the proposed additions to the observer e-logbook form for reporting debris found at-sea will facilitate quantitative summaries of the different types and components of found debris.

5.72 The Working Group noted that “Sago Extreme” fish de-hooking and collection devices were deployed by a toothfish longline vessel in Subarea 58.7. The Working Group noted that 15 of the devices were reported as lost. The Working Group expressed concern about the marine debris aspects of the loss of the devices and noted that details about their operation had been discussed, but not extensively by WG-FSA-2021 (paragraphs 7.6 and 7.7).

5.73 The Working Group noted that when trotline gear is lost, part of that loss could include “cachaloteras” (cetacean exclusion devices). The Working Group requested that the loss of these devices should be summarised in a future marine debris report.

5.74 The Working Group noted that the Chilean Antarctic Institute and the British Antarctic Survey conducted collaborative research on Coppermine Peninsula at Robert Island. Marine debris collected during the survey was transported to Punta Arenas and data will be submitted to the Secretariat. The Working Group noted that Argentina and Australia also conducted marine debris surveys at some CEMP sites and plan to submit data to the Secretariat.

5.75 WG-EMM-2023/26 reported on marine debris surveys undertaken by the UK in 2022/23. Below average levels of beach debris were recorded at Bird Island, Signy Island and Goudier Island, with plastic being the most abundant material at all sites. Debris levels found in seabird colonies at Bird Island was close to the long-term mean. At King Edward Point, four Antarctic fur seals were observed entangled in debris, and two entangled fur seals and five foul-hooked/entangled albatrosses were observed at Bird Island.

5.76 The Working Group welcomed the results of the surveys and highlighted the value of this long-term data monitoring program. The Working Group discussed the possible reasons for lower-than-average debris compared to previous years, and noted that marine debris can persist for long periods, and that the number of fishing vessels has decreased at the same time as vessel practices to avoid loss of fishing gear have improved. The Working Group also noted that the loss of fishing gear can be increased by interactions with sea ice and that changes in sea ice patterns could affect the amount of lost gear.

5.77 The Working Group noted that large plastic items at the surface become small plastic items in the water column and persist through time and could have ecological effects. The Working Group noted that understanding marine debris patterns could be improved through the use of particle tracking models in the Convention Area.

Krill-based ecosystem interactions

Krill biology, ecology and population dynamics

6.1 WG-EMM-2023/22 presented preliminary results of a study on the distribution and abundance of krill, and krill predators in Subarea 48.3 during winter. Although krill fishing takes place from May to September in concentrated areas in Subarea 48.3, there was a lack of information on krill and their predators during this time. During the survey, krill data were collected using nets (RMT1) and acoustics, and bird and cetacean observations were performed. Krill size was highly variable between hauls, which influenced interpretation of acoustic data. Findings indicated that the vertical distribution of krill changes throughout the season, with higher krill estimates occurring in night-time acoustic transects, particularly in July. Krill is suspected to reside near the sea floor (below 250 m) during the day, which is not detected by acoustics. Several species of whales were present in high abundances and these were observed feeding actively. Little overlap was observed between the krill fishery and gentoo penguin foraging areas. Details on acoustic results were presented to WG-ASAM (WG-ASAM-2023/06). The survey will be repeated in 2023.

6.2 The Working Group discussed the observed decrease in krill biomass which is suspected to be a result of variable current flows and not of the krill fishery. The Working Group suggested that length frequency distributions from krill fishing vessels might provide information on krill demography for a comparison with net data collected during the survey. The Working Group proposed that more data on temperature and currents would be useful to investigate the effects of krill transport in the area, and suggested that analyses of the inter-annual variability in krill biomass as well as temporal and spatial variability in the condition of the krill collected would be valuable. The Working Group, furthermore, considered that feeding estimates by cetaceans used in ecosystem studies might need to be reconsidered, given that winter feeding is usually not taken into account.

6.3 The presence of late stage furcilia larvae was noted by the Working Group. The suggestion was made that these larvae might originate from areas as far as the Weddell Sea or the Antarctic Peninsula. The Working Group noted observations of large numbers of furcilia in winter during the 'Discovery period' (Marr 1962) as well as from the early phase of the Japanese krill fishery, but whether this is an annual event or episodic remains to be revealed through future monitoring. It also noted that these small-sized krill might be preferred by some predators. The Working Group discussed the distribution of fur seals which were rarely seen during the May survey, raising the question where the fur seals are during this time as high numbers occurred in July, particularly in the eastern core box (WG-EMM-2023/22).

6.4 The Working Group highlighted to the Scientific Committee the increasing amount of information being generated through winter krill monitoring by the UK in Subarea 48.3 and the long-term krill biomass survey by Norway in Subarea 48.2 since 2011 (WG-EMM-2023/01), representing significant progress in the development of data to underpin the spatial overlap analysis in subareas 48.2 and 48.3. The Working Group also re-affirmed the effectiveness of the krill work plan for facilitating data accumulation vital for progressing the development of the revised krill fishery management approach in Area 48.

6.5 In order to correlate krill biomass with environmental variables and concomitantly understand drivers of krill distribution, habitat models were developed and evaluated in paper WG-EMM-2023/34 using data from two synoptic surveys conducted in the Scotia Sea during 2000 and 2019. A previously published model (Silk et al., 2016), developed using 2000 survey data, fitted poorly to the 2019 data. Performance was somewhat improved when model parameters were re-estimated using the 2019 data, but a completely new model with a new suite of explanatory variables was necessary to achieve reasonable performance. Bathymetry and phytoplankton abundance were consistent predictors of krill distribution in the Scotia Sea, but there was a lack of consistency in other predictors. The apparent relevance of distance to sea-ice edge, salinity, temperature, geostrophic velocity and sea level anomaly depended on the specific data set and modelling approach used. Models generally failed to predict high density spots. The study concluded that models from one survey performed poorly at predicting distribution in another survey, and that krill distribution does not have consistent relationships with most environmental variables (apart from bathymetry) due to its dynamic nature.

6.6 The Working Group welcomed the paper and noted the importance of the analysis. The Working Group discussed the predictable presence of krill in areas used by fishing vessels, but noted that fisheries do not always necessarily operate in the area with the highest biomass and mainly use bathymetry and previous experience as predictors of krill presence. The Working Group further discussed behavioural components of krill that may be of influence, such as DVM, swarm aggregation and retention, and potentially, differences in these components in various life stages. The suggestion was made that the use of other modelling methods might increase comparability between years. Further investigations could include finer time scale variables and a further look into, for example, food availability and eddies. Knowledge on the factors that drive aggregation and swarming behaviour of krill, and on temporal and spatial variation of phytoplankton would be desirable to improve models.

Krill predator biology, ecology and population dynamics

6.7 WG-EMM-2023/30 evaluated the potential conservation threats to South Shetland Island Antarctic fur seals (*Arctocephalus gazella*) amidst precipitous population collapse in the last 15 years. The paper outlines an array of environmental and ecological threats to the successful recovery of South Shetland Island Antarctic fur seals, including natural processes, as well as the spatial and temporal overlap between the pups of the South Shetland Island Antarctic fur seal sub-population and the krill fishery.

6.8 The Working Group highlighted the importance of including updated juvenile fur seal tracking data during winter in future spatial analysis work to better represent their distribution. Such analyses include the spatial overlap analysis, and the D1MPA proposal (which currently incorporates data on breeding and post reproductive dispersion period of adults, SC-CAMLR-38/BG/03).

6.9 The Working Group highlighted the potential utility of collecting DNA samples from Antarctic fur seals by-caught in the krill fishery to help identify population structure.

6.10 The Working Group encouraged the authors to submit the paper to WG-IMAF-2023 and to the ATCM Climate Change Working Group, and highlighted the role of the CCAMLR Scientific Committee in identifying the potential causes for the observed Antarctic fur seal decline and in addressing them.

6.11 WG-EMM-2023/49 summarised the results of four dedicated sighting surveys during the Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A program) in four austral summer seasons (2019/20 – 2022/23). The main research objectives of JASS-A are i) the study of the abundance and abundance trends of large whale species, and ii) the study of the distribution, movement and stock structure of large whale species. The dominant whale species sighted were Antarctic minke, humpback, fin, and blue whales in all surveys. Antarctic minke whales were mainly distributed in the southern part of the research areas, and were observed in higher densities in coastal ice-free waters (145° W – 120° W). Whale abundance data will be used to estimate krill consumption by whales, analysed in conjunction with the data collected by the previous Japanese whale research programs and IWC IDCR/SOWER (International Whaling Commission International Decade of Cetacean Research/Southern Ocean Whale and Ecosystem Research, 1978/79 – 2009/10) surveys in the same region.

6.12 The Working Group noted the large number of Antarctic minke whales in schools relative to the other whale species observed during the survey.

6.13 The Working Group highlighted the utility of collecting acoustic data as part of future large-scale surveys and thanked the authors for this ongoing work and their offer of future collaboration.

Spatial management

7.1 WG-EMM-2023/47 provided scientific evidence to support a draft Conservation Measure for a “Weddell Sea marine protected area Phase 2” (i.e., in the section of Planning Domain 3 to the East of the prime meridian). The evidence was based on data which are available via an online atlas and converted to a binary spatial representation of taxa or features on a grid of 100 km^2 hexagonal units, using distribution modelling. A wide range of taxa and features was considered including areas of historic productivity indicated by whaling records, and generalised representations of predator habitat including "Important Bird Areas" and "Areas of Ecological Significance". Other features included pelagic bioregions and the boundary between biogeochemical cells. An additional analysis identified areas with the lowest rate of projected warming from an ensemble of climate models as a metric of climate resilience. The evidence does not include a fishing layer as there has been little fishing in the area. However, consideration was given to the effects of ice cover on accessibility to potential fishing grounds.

7.2 WG-EMM-2023/36 summarised the objectives of and scientific progress towards the proposed "Weddell Sea Marine Protected Area – Phase 2" and provided a draft Conservation Measure for the implementation of this MPA. The proposal, as defined by the draft Conservation Measure, does not include any specific restrictions on fishing and related activities. Rather, it provides a framework for policy makers to apply appropriate restrictions. The proposal was developed as the result of consultation with interested CCAMLR Members and Observers through a series of three workshops, and by bilateral and multilateral meetings. This consultation was facilitated by the data atlas and distribution modelling described in WG-EMM-2023/47, and an interactive software tool to aid spatial planning. The proposal lists nine MPA objectives, eight of which include protection targets. The overall aim was to identify the minimum spatial footprint of a set of protected areas that cover 50% and 10% of relevant hexagons for "important" and "representative" objectives respectively. A key priority was to protect large-scale processes which support primary productivity. The process led to the selection of five areas for protection, including three "General Protection Zones" (GPZs), a coastal "Special Connectivity Zone" (SCZ) and a "Climate Research Zone" (CRZ) (Figure 2 in WG-EMM-23/36). The SCZ is important for longitudinal population connectivity and the CRZ represents an area of expected temperature stability. The authors assert that the proposal conforms to the requirements of the General framework for the establishment of CCAMLR Marine Protected Areas (CM 91-04) and is formulated based on the best scientific evidence available.

7.3 The authors of WG-EMM-2023/36 clarified that their objective in presenting the draft Conservation Measure was to facilitate discussion of the supporting scientific evidence. They also clarified that the key threat that the proposed MPA is intended to address is climate change. The authors noted that the data layers will be made available including identification of original sources, consistent with FAIR principals. The interactive software tool (which is a front end for the R package prioritizr) will also be made available. An updated draft RMP proposal with SMART objectives, consistent with CCAMLR-SM-III/12, will be developed for SC-CAMLR-42.

7.4 The Working Group thanked the authors for an extensive analysis and commended them on their collaborative approach and commitment to sharing data and tools.

7.5 The Working Group recognized that WG-EMM-2023/36 was useful to facilitate discussions given that it contains the translation of the data layers into a MPA proposal. The Working Group discussed the scientific background for the MPA proposal and agreed that the actual draft Conservation Measure contained in WG-EMM-2023/36 is not a matter for discussion by the Working Group.

7.6 The Working Group agreed that distribution modelling is appropriate for this area where data are relatively scarce. It noted that additional data are available, especially for benthic communities, as the analyses have been delayed and would be completed in the future. The Working Group noted that while some potentially important taxa might have been omitted from the analysis, the protection targets for all the included groups were attained.

7.7 The Working Group noted that the analysis used generalised protection targets and that an alternative approach would be to define specific targets for individual taxa, particularly predators. For many of the taxa and processes, the level of protection achieved by the proposed MPA exceeded the target levels for individual taxa and features. The Working Group supported the potential to protect longitudinal connectivity using the SCZ and noted that the proposal does not include equivalent protection for latitudinal connectivity.

7.8 The Working Group noted that a standardised set of zone types and definitions for use in all proposed and current MPAs would be useful.

7.9 The Working Group recognised that understanding of environmental variability may change as new data and models become available and that there may be a future need for dynamic boundaries to allow adjustments. It suggested that the RMP should be designed to support such dynamic adjustments.

7.10 The Working Group noted that there are existing toothfish research blocks in some of the proposed GPZs and that further development of these fisheries may lead to repositioning of these research blocks. It also noted that continued research fishing might help with monitoring the effectiveness of an MPA.

7.11 Dr. Kasatkina (Russia) reiterated her position on the MPA process (articulated in CCAMLR-SM-III/07,08,09,10). Dr. Kasatkina noted that the proposals to designate MPA on Weddell Sea did not provide any evidence of threats from the fishery and climate change to marine living resources and biodiversity of the Weddell Sea region which require the protection and the urgency of providing this protection. Dr. Kasatkina also noted that potential threats from a fishery regulated by effective Conservation Measures on the basis of the precautionary and ecosystem approaches are very low, and protection against climate change cannot be achieved by an MPA. She stressed the need for clarity on the criteria for assessing the achievement of the MPA objectives.

7.12 Dr Kasatkina noted that MPA proposals (WG-EMM-2023/47 and WG-EMM-2023/36) did not justify the boundaries and specific objectives of the MPA and that the baseline data are mainly represented by fragmentary and historical data. Dr. Kasatkina highlighted the need for clarity on the quality and sufficiency of baseline data to meet the MPA objectives and developing measurable indicators for monitoring and criteria for achieving the MPA objectives.

7.13 Dr. Kasatkina suggested accompanying Tables 2 – 6 of WG-EMM-2023/36 by characteristics and trends for representative species and clarifying the protection targets taking into account evidence of potential threats. She also recalled the importance of the hypothesis on the life history and stock status of toothfish (*Dissostichus mawsoni*) in Area 48 for managing its resources (WS-DmPH, 2018) and noted that there are no references to such a hypothesis in WG-EMM-2023/47 and WG-EMM-2023/36, due to a lack of baseline data.

7.14 Additionally, Dr. Kasatkina recalled the Russian position that the MPA Research and Monitoring Plan accompanied by characteristics and trends estimated at start of the MPA for indicators of monitoring and criteria for achieving specific objectives should be an integral part of MPA proposals.

7.15 At the time of adoption, Dr G. Griffith (Norway) suggested the following response to paragraphs 7.11 to 7.14:

> 'It is realized that there are some possible misunderstandings of the scientific justification for the areas proposed to be within the WSMPA Phase 2, and how the SMART Criteria can be applied to the proposal. The WG subgroup discussions on "Developing SMART criteria, with baselines and decision rules, to evaluate CCAMLR MPAs" (CCAMLR-SM-III/12) was thorough and detailed. WG-EMM-2023/47 and CCAMLR-SM-III/12 have the potential to handle dynamic changes in environmental variability as well as fisheries concerns by incorporating the SMART criteria. These can be discussed bi- or multilaterally between Norway and interested CCAMLR members before Scientific Committee 2023.'

7.16 At the time of adoption, the Working Group recalled paragraph 2 of CM 91-04, which does not require evidence of a negative effect of fishing, or the establishment of a stock hypothesis, in order to establish an MPA.

7.17 The working group provided the following recommendations to the authors to improve the analysis and clarity of presentation prior to submission to the Scientific Committee:

(i) include data on the post-breeding season distribution of Adélie penguins,

(ii) update the assessment of emperor penguin distribution using relevant data from tracking studies near Mawson Station,

(iii) enhance the protection target for the declining Antarctic petrel population and provide specific advice to the Scientific Committee on the protection of declining populations,

(iv) clearly explain how the inclusion or exclusion of the Fisheries Research Blocks affects the calculation of protection targets using the interactive software tool,

(v) explain how the protection targets were derived,

(vi) alter the wording of objective (iv) of WG-EMM-2023/36 to include pelagic mammals,

(vii) provide an explanation of the process which identified the CRZ,

(viii) include binary rasters and the thresholds used to derive the proposed MPA, and digital object identifiers (DOIs) for input data alongside the input data in the atlas,

(ix) document the history of research fishing in the planning area.

7.18 The Working Group also recommended that the additional existing data should be included in the benthic layers, but agreed that this was unlikely to influence the outcome.

Data analysis supporting spatial management approaches in CCAMLR

7.19 WG-EMM-2023/10 reported on using the Spatial Population Model (SPM) to assess the potential impacts of the Ross Sea region MPA for Antarctic toothfish. This analysis showed that under a range of fishing scenarios, both the medium- and long-term impacts of the MPA are to increase yield and increase stock size compared to projections without it.

7.20 The Working Group welcomed progress in the use of spatially resolved population models and noted that this methodology could be applied in other areas / MPAs. The Working Group encouraged further development of the SPM to consider sex-specific differences in Antarctic toothfish. The Working Group suggested the SPM was a useful tool to determine if the population structure and distribution of toothfish has changed in the two areas of importance to mammalian predators in the western General Protection Zones (McMurdo Sound and Terra Nova Bay).

7.21 WG-EMM-2023/46 described the usefulness of phylodiversity as a measure of biodiversity at the Southern Ocean scale to include historical depth in future assessments of climate change impact on biodiversity. The work showed that existing and proposed MPAs will protect a significant proportion of when implemented fully, but also that a significant proportion of phylogenetic diversity would fall outside MPA boundaries.

7.22 The Working Group thanked the authors for their work on the phylogeography of four key Southern Ocean taxonomic groups. The Working Group noted that caution was needed in interpreting open-access biogeographic data, as the taxonomic resolution of these data may not be resolved equally across the study region, creating the possibility of data artifacts in the diversity outputs. The Working Group agreed with the authors that conserving phylodiversity in the Southern Ocean was important.

7.23 WG-EMM-2023/04 described the structure of the 0-group (aged <1 year) fish community of the Scotia Sea using data from a basin-scale survey conducted in early 2019. The study sampled the top 200 m of the water column and caught 347 0-group fish from 19 genera, with one third of all specimens belonging to the genus *Notolepis*. The study recommended that dedicated monitoring is required to understand the seasonal differences in larval community assemblages and the implications of 0-group fish by-catch in the krill fishery.

7.24 The Working Group thanked the authors and welcomed this important contribution to research directed on fish larvae.

7.25 WG-EMM-2023/P01 explored the potential for precise and direct estimation of catch weight (green weight) for Antarctic krill using acoustic sensors installed in the mouth of a trawl net. A linear relationship was found between acoustically estimated catch weight and observed catch weight. Acoustically estimated catch weight significantly predicted actual catch weight, which demonstrated that acoustically based methods for catch weight monitoring have the potential to be used to report total catch weight in a trawl, potentially in real-time, and that similar methods could also be employed in similar types of trawl fisheries. This study also observed the increased acoustic densities of krill toward the centre of the trawl opening suggesting that krill were herded during fishing.

7.26 The Working Group thanked the authors for this important progress in their study exploring a new way of estimating green weight of catch in the krill fishery by using acoustics.

The Working Group noted that acoustic catch weight seemed to be underestimated when actual catch was high and encouraged the authors to explore the likely reasons for this through further study. The Working Group also noted the importance of understanding the accuracy of this method to estimate krill catch when it is scaled up to commercial nets with a larger mesh size. Further study to investigate whether the herding effect can be observed in nets with larger mesh size and mouths, taking into account krill escaping through nets from trawl mouth to codend, would provide important information on the selectivity of the nets. The Working Group further noted the potential application of this method for detecting by-catch of marine mammals and recommended that the authors submit the document to WG-IMAF-2023.

7.27 WG-EMM-2023/31 presented an overview of baseline spatial data prior to the ecoregionalisation of the eastern Sub-Antarctic Region, which focussed on the region between 20° W to 160° E and 30° S to 60° S. This work resulted from The Expert Workshop on Pelagic Spatial Planning for the eastern Sub-Antarctic Region in Cape Town, South Africa in 2019. WG-EMM-2023/17 described hydrologic regionalisation from Crozet to Kerguelen and subtropical southern Indian Ocean and WG-EMM-2023/18 described regionalisation of the physical and biogeochemical environment in the southern Indian Ocean.

7.28 The Working Group thanked the authors for a set of valuable papers. The Working Group encouraged additional analytical steps which could help resolve finer-scale environmental features and quantify uncertainty associated with the analysis, based on similar approaches previously applied in sub-Antarctic benthic ecoregionalisation studies.

7.29 WG-EMM-2023/51 described large scale pelagic acoustic ecoregionalisation in the eastern Sub-Antarctic and WG-EMM-2023/57 used temporal and spatial patterns from multi-frequency acoustic data to describe pelagic structuring in the eastern Sub-Antarctic Region.

7.30 WG-EMM-2023/58 mapped the distribution of trophically important sub-Antarctic zooplankton using data from 30 years of Continuous Plankton Recorder (CPR) surveys. WG-EMM-2023/21 and WG-EMM-2023/38 described zooplankton communities at Crozet and Kerguelen, and Prince Edward Island respectively. WG-EMM-2023/16 described preliminary steps for an atlas of macro-zooplankton in the Sub-Antarctic Indian Ocean and in the South Indian Ocean utilizing historical and new survey data combined with open-access biogeographic data.

7.31 The Working Group commended the authors on their use of a diverse range of data sources, particularly long-term data from CPR analysis and encouraged the use of network metrics and metabarcoding to complement the results presented.

7.32 WG-EMM-2023/20 presented some new results on mesopelagic fish populations from surveys from Crozet to Kerguelen and in the subtropical Indian Ocean. The study integrated both subtropical and Southern Ocean species to investigate the species richness and geographical distribution of species and assess their alignment with established biogeographic provinces. The study also highlighted the crucial role of mesopelagic fauna in the trophic food web.

7.33 The Working Group thanked the authors for their work on mesopelagic fish and encouraged them to contribute their data to MYCTOBASE. The Working Group discussed the importance of linking work on myctophids and zooplankton, and the importance of mesopelagic fish for climate feedback, carbon flux and the carbon pump. It encouraged further collaboration between Members working on these topics.

7.34 WG-EMM-2023/32 and WG-EMM-2023/37 described the distribution and abundance of seabirds and marine mammals in the Sub-Antarctic and subtropical Indian Ocean from a suite of land-based long-term monitoring studies along with animal-borne biotelemetry/biologging and at-sea observations. These studies aimed to support spatial conservation and management planning, and to identify broader challenges for understanding marine predator distributions in this region.

7.35 The Working Group thanked the authors for this significant body of work which substantially improves understanding of the structure of the eastern Sub-Antarctic region and Indian Ocean and encouraged further collaborations. The Working Group noted that adding Subareas/Divisions to the maps included in the papers would help consider fishing activities in relation to ecoregionalisation and encouraged members to contribute to the Joint Exploration of the Twilight Zone Ocean Network (https://jetzon.org/).

Research and monitoring plans for MPAs

7.36 WG-EMM-2023/07 reported on research conducted by New Zealand in the Ross Sea region relevant to the specific objectives of the RSRMPA. Research highlights included new information on top predator species, the application of alternative method to identify phytoplankton classes from pigments and assessment of the Coupled Model Intercomparison Project (CMIP)5 and CMIP6 Earth System Models for the Ross Sea region.

7.37 The Working Group welcomed the contributions and cooperation of countries operating scientific stations and research vessels in the Ross Sea region and conducting research and monitoring studies in support of the RSRMPA.

7.38 The Working Group noted the implementation of research and monitoring projects in support of the RSRMPA for the period 2022 to 2026 by Republic of Korea.

7.39 The Working Group further noted the importance of research on salps to estimate their contribution to the biological carbon pump and to assess changes in primary production.

7.40 WG-EMM-2023/15 Rev. 1 reported the findings of a multidisciplinary survey of meso-zooplankton conducted on the Korean icebreaker RV *Araon* in the RSRMPA in December 2020. The results showed three meso-zooplankton communities for the Terra Nova Bay polynya, the Ross Sea polynya, and the marginal polynya region, which differ in species composition and abundance. Salinity was identified as the driving environmental factor for different community structure in the three geographical regions.

7.41 The Working Group welcomed this paper and congratulated the authors on this impressive work. The Working Group noted the results on the dynamics of the polynya systems and how oceanic current characteristics shape the meso-zooplankton community.

7.42 The Working Group also welcomed the planned acoustic survey in the Krill Research Zone (KRZ) of the RSRMPA to take place in 2023/24. The Working Group noted that additional data collections, such as observational data on seabirds and whales, samples of substrate in the area identified as a skate nursery (paragraph 7.64), benthic species assemblage and meso-zooplankton samples, could be useful in providing a better overview of ecosystem functioning in the area.

7.43 The Working Group noted studies from Japan and Australia that have recently taken place in East Antarctica (Cox et al., 2022; WG-EMM-2019/42). With the planned KRZ survey combined, this will constitute a set of contemporary krill biomass data spanning the area between 55° E to 160° E.

7.44 The Working Group recommended seeking advice from WG-ASAM after the research cruise regarding the standardisation of acoustic methods and data analysis. The Working Group noted that the EU Copernicus project (https://www.copernicus.eu/en) might provide additional spatio-temporal data sets that could be incorporated into future analyses.

7.45 WG-EMM-2023/P03 presented the report of a Ross Sea research planning meeting held in October 2022 (hybrid meeting) which focused on refining existing questions and to formulate an innovative and sustainable research program aimed at better understanding, conserving, and managing the RSRMPA through the coordination of collaborative, inclusive, and interdisciplinary science (http://www.rosssearesearch.org/).

7.46 The Working Group welcomed this paper and congratulated the authors on the website as an outcome of the workshop; which gives an excellent overview of the workshop itself and the background of the RSRMPA and ongoing activities in this context. The Working Group recognised this website as an exemplary tool to create transparency and openness to engage interested people in the RSRMPA research network.

7.47 WG-EMM-2023/P05 presented CRITTERBASE, a publicly accessible data warehouse that currently hosts quality-controlled and taxonomically standardised data for almost 19,000 samples and more than 3,500 benthic taxa in Arctic, North Sea, and Antarctic regions. CRITTERBASE already supports marine conservation efforts in the Weddell Sea as the data management system for the WSMPA P1 baseline data and is also envisaged to manage data collected as part of a future WSMPA P1 RMP.

7.48 The Working Group welcomed this paper and congratulated the authors on this important contribution. The Working Group noted the large amount of quality-controlled data already in the data warehouse including data to support CCAMLR activities.

7.49 The Working Group noted the ability of CRITTERBASE to store other types of data including video and tracking data and to integrate with other data repositories.

7.50 CCAMLR-SM-III/12 presented the principles and concepts used to develop candidate SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) criteria, with baselines and decision rules, for the RSRMPA. Six candidate examples were presented based on the SMART criteria.

7.51 CCAMLR-SM-III/BG/01 presented forty-six candidate SMART criteria for assessing the effectiveness of the RSRMPA.

7.52 The Working Group welcomed these papers and noted the significant contribution to the development of the SMART criteria approach under the RSRMPA RMP.

7.53 The Working Group supported the SMART criteria approach to assist in characterising the baselines, determining the research and monitoring required and assessing the effectiveness of MPAs, noting that this approach addresses the concerns expressed in e.g., SC-CAMLR-XXXVII/19 and SC-CAMLR-40/18.

7.54 The Working Group noted that the SMART criteria approach may be useful as a general framework for other MPA RMPs. The Working Group further noted that the SMART criteria approach needs to be tailored to the particular MPA and its objectives and may need to be flexibly adapted in its design. The Working Group further noted that developing a flexible framework for identifying SMART indicators that are based on the general and specific objectives of an MPA would be helpful for the application of SMART criteria.

7.55 The Working Group recognised the complexity and comprehensiveness of this approach and noted that the SMART criteria should be streamlined in terms of the number of indicators arising from the specific objectives of the RSRMPA.

7.56 The Working Group agreed that it is appropriate to develop at least one SMART indicator for each of the specific objectives of an MPA. For example, the paragraph 3 of CM 91-05 contains 11 specific objectives suggesting that at least 11 SMART indicators would be appropriate.

7.57 The Working Group noted that the specific objectives of the MPA are often supported by multiple baseline data layers that were used to develop the MPA and that some data layers may support multiple specific objectives. To provide a simplified set of SMART indicators from a potentially large number of baseline data layers, the Working Group agreed that a prioritization of potential SMART indicators would be helpful to implement RMPs and MPA objectives.

7.58 The Working Group noted that a prioritization of potential SMART indicators could be achieved by considering at least three conditions:

(i) The quality, richness, and levels of uncertainty in the baseline data should be considered, noting that the ability to detect changes in the status of a SMART indicator is linked to the uncertainty in the baseline data.

(ii) A prioritization of SMART indicators should consider the current and planned research activities in the MPA region to identify which indicators were likely to be assessed within reasonable time frames.

(iii) The Working Group recalled that an MPA is a spatial management tool. SMART indicators that assess spatially explicit baseline data may provide a more direct link between the indicator and their corresponding decision rules to modify the MPA to ensure the MPA is meeting its specific objectives. The Working Group noted, however, that non-spatial data (e.g., population size) remained important for consideration and should not be automatically discounted in a prioritization process.

7.59 The Working Group noted that the process of balancing trade-offs within this prioritization may not be straightforward and encouraged further work to develop examples illustrating the process.

7.60 The Working Group also identified several questions and suggestions for future work to develop SMART indicators:

(i) Develop a clear and comprehensive definition of SMART indicators.

(ii) How can SMART indicators be used in rapidly changing ecosystems?

(iii) What is the appropriate timeframe for assessing SMART indicators?

(iv) How do SMART indicators apply to different management zones (e.g., climate reference zones, special research zones)?

(v) How do we balance individual SMART indicators versus the collection of SMART indicators when assessing performance of the MPA?

VME data and spatial planning approaches

7.61 WG-EMM-2023/52 presented the first records of *Chionodraco hamatus* nests in Terra Nova Bay during a survey using Baited Remote Underwater Video systems (BRUVs) to investigate the distribution of Antarctic toothfish in support of research and monitoring objectives in the RSRMPA. Fish nests were observed at depths of 356 m, 475 m, and 543 m within the GPZ of the RSRMPA. These findings document the existence of a *Chionodraco hamatus* nesting area in Silverfish Bay. The results highlighted the ecological value of the nearshore coastal areas and a future focus area for research and monitoring in the RSRMPA.

7.62 The Working Group congratulated the authors for the discovery of the icefish nests and highlighted that the study was led by a current CCAMLR scholarship recipient (Dr E. Carlig (Italy)).

7.63 The Working Group noted that the discovery was opportunistic and that it is likely that more nests are still to be discovered in the area and that it can be assumed that the unoccupied but un-silted nests can be considered as active nests. The Working Group noted the importance of further research in the area, and that information from other studies or observer data could assist in identifying possible areas for further surveys.

7.64 WG-EMM-2023/08 presented detailed information on the first records of a deepwater skate *Bathyraja* sp. (*cf. eatonii*) egg case nursery in the Ross Sea within the GPZ of the RSRMPA. Observations were recorded using a deepwater video imaging system as part of a wider programme established for monitoring the RSRMPA. The results meet the criteria for an egg case nursery (Martins et al., 2018). Egg case density, where egg cases were most abundant, was estimated at 0.26 per m^2. The results highlighted the ecological importance of the area and the continued need for non-destructive survey methods to categorize essential skate habitat.

7.65 The Working Group congratulated the authors on the discovery of the egg case nursery of high ecological value. The Working Group recommended sampling of egg cases from these areas to aid species identification. The Working Group noted that observer data such as on toothfish diet and surveying areas where gravid skates have been found could help identify further areas of interest, and that further research is needed to identify possible proxies to serve as indicators of such nursery areas. The Working Group further noted that this discovery highlights the importance of the RSRMPA in this area.

7.66 WG-EMM-2023/25 presented an overview of the outcomes and recommendations of WG-EMM-2022, WG-FSA-2022, SC-CAMLR-41, and CCAMLR-41 regarding a potential protection mechanism for the fish nest area for notothenioid icefish (*Neopagetopsis ionah*), which had been discovered in the southern Weddell Sea (Purser et al. 2022). The authors proposed potential definitions of fish nest and fish nest area, relevant indicators, rationale for a protective buffer zone around fish nest areas, and a potential review process for opening and closing fish nest areas to bottom fishing activities.

7.67 The Working Group welcomed the document and highlighted again, the importance of protecting this fish nest areas in a timely manner.

7.68 The Working Group noted that relying on the presence of eggs in the nest as a criterion for a nest would be too restrictive, given that nests may be observed during the preparation stage.

7.69 The Working Group noted that critical habitats are defined as necessary to the long-term maintenance of a population (Heithaus, 2007), which includes spawning, breeding, feeding, or growth to maturity (Martins et al., 2018).

7.70 The Working Group considered that a fish nest is a visibly altered site/structure used for laying eggs and/or sheltering young, and:

(i) appears as a circular depression in the substrate delineated by gravel and/or sediment, or is contained in a secondary biological structure,

(ii) may be attended by one or more fish.

7.71 Fish nests may be characterized as either:

(i) *active*: benthic areas observed to have defined fish nest structure that may or may not include fish eggs or be attended by fish, and structures are clean of debris and re-sedimentation, or

(ii) *potential:* sites showing defined fish nest structure, but with no signs of active construction or maintenance activities.

7.72 The Working Group agreed that a 10-n mile protective buffer zone is appropriate, but recommended that, in order to be precautionary, reduction or removal of the protective buffer zone should require evidence of abandonment of the fish nest area.

7.73 The Working Group considered broader protection of 'Essential Fish Habitats' throughout the Convention Area, including a sub-category for fish nest areas, and having the provision to add additional sub-categories in the future such as skate nurseries is needed (CCAMLR-41, paragraphs 4.89 and 4.90). The Working Group suggested that the Scientific Committee consider recommending a mechanism such as a Conservation Measure to the Commission.

Climate change and associated research and monitoring

8.1 WG-EMM-2023/09 provided a summary of the New Zealand research voyage to the Ross Sea region in January to February 2023 on RV *Tangaroa* (voyage code TAN2302). The focus was to provide information on the RSRMPA to allow scientific evaluation of its ecological status, spatial adequacy, and effectiveness, covered through 15 specific objectives. The over-arching purpose of this multi-disciplinary research voyage was to increase knowledge about key environmental and biological processes in the Ross Sea region of the Southern Ocean. The research was carried out by New Zealand and Italian scientists on the 38-day voyage.

8.2 The Working Group welcomed the presentation and commended the work done by New Zealand and Italy. It was noted that New Zealand is currently planning two further research voyages on RV *Tangaroa* to the Ross Sea region scheduled for 2025 and 2027, and that applications for the 2025 voyage must be submitted soon. International scientists interested in participating or collaborating on these future voyages are encouraged to contact the authors of this paper for more information. The *Tangaroa* voyages have been collecting long term data that may be of use for the review of the CEMP.

8.3 The Working Group discussed the upcoming SC-CAMLR Climate Change workshop (WS-CC-2023) in September 2023. The Scientific Committee agreed to hold this workshop to improve the integration of scientific information on climate change and ecosystem interactions throughout CCAMLR's work program (SC-CAMLR-41, paragraphs 7.4 to 7.13 and Appendix 1). The Working Group noted that the format of the workshop is hybrid, with options to attend one of two regional hubs in the UK and New Zealand, either in-person or online, followed by daily plenary sessions (see schedule https://meetings.ccamlr.org/ws-cc-2023).

8.4 The Workshop co-conveners (Dr R. Cavanagh (UK) and Mr E. Pardo (New Zealand)) encouraged registration to the workshop, the inclusion of relevant experts within delegations, the identification of keynote speakers, and submission of papers related to the agenda items. They welcomed engagement during the planning process and noted that Scientific Committee observers had been invited to participate.

Other business

9.1 In accordance with requirements under CM 24-01 paragraph 4 (c), WG-EMM-2023/26 provided a brief summary of the groundfish survey in Subarea 48.3 which took place in February 2023. The Working Group noted that a full report will be provided to WG-FSA-2023.

Future work

10.1 The Working Group discussed its future workplan (Table 2) and updated it to reflect current participation and discussions, including contributors, timeline and urgency assignments, including elevating the urgency associated with developing MSEs for both krill and finfish.

10.2 The Working Group noted that some of the krill management work topics fall outside of the goal to implement the CCAMLR decision rules and therefore the structure of the workplan could be revised in the future to account for this. In addition, the Working Group noted that the brief descriptors for the work items may lead to some lack of clarity and that cross references to more descriptive paragraphs would be helpful.

10.3 The Working Group added several work items including:

(i) a new priority research topic to reflect agreed work on the Krill Stock Hypothesis Information Collection Plan to inform about krill life history and population dynamics (paragraph 4.32),

(ii) teams be developed to provide advice on monitoring methods and designs for an enhanced CEMP programme (paragraph 5.65),

(iii) the harmonisation and/or integration of different spatial management initiatives within Subarea 48.1, including the ARK voluntary restricted zones and the D1MPA proposal (SC-CAMLR-41, paragraph 3.65),

(iv) develop methods and metrics for integrated ecosystem reporting (WG-EMM-2022, paragraph 2.18),

(v) develop mechanisms to integrate ecosystem and climate change monitoring into the workstreams of the Scientific Committee and its advice (WS-CC-2023).

Advice to the Scientific Committee and its working groups

11.1 The Working Group's advice to the Scientific Committee is summarised below; these advice paragraphs should be considered along with the body of the report leading to the advice:

(i) SISO protocols (paragraphs 4.3 and 4.4)

(ii) Krill fishery management approach document (paragraph 4.11),

(iii) Good modelling practices (paragraph 4.27),

(iv) Marine debris reporting (paragraph 5.74),

(v) CEMP (paragraphs 5.53, 5.64, 5.65),

(vi) Krill work plan progress (paragraph 6.4),

(vii) Essential fish habitats (paragraph 7.73).

Adoption of the report and close of the meeting

12.1 The report of the meeting was adopted, requiring 5 h and 23 min of discussion.

12.2 The Working group expressed its sadness at the news of the untimely death of our Spanish colleague, Dr Andres Barbosa, who died last January. The Working group noted its appreciation of Dr Barbosa's valuable contribution to the work of CCAMLR and in particular to penguin ecology as well as his role at SCAR.

12.3 Dr Parker, on behalf of the WG-EMM-2023 participants, thanked Dr Cárdenas for his calm and insightful leadership of the meeting resulting in an efficient and fast adoption process.

12.4 Dr Cárdenas thanked the meeting participants for their willingness to work together in a collaborative spirit and support for his role, noting how the return to in-person meetings was both pleasurable and productive. He also thanked the CMLRE team for their hard work, coordination, and introduction to Indian culture, and thanked the Secretariat for their support of the meeting.

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Table 1: Krill Stock Hypothesis Information Collection Plan.
N.B. additional contributors will be identified in the future and the current ones are listed in no particular order.

Priority activities	**Data**	**Samples /Approach**	**Platform**	**Sampling by whom**	**Measurement and/or analysis by whom**	**Purpose**	**Urgency**		**Time frame**	**Contributors**
							For short-term management	To improve process understanding		
Multiple source data collection	Length, maturity, and weight	Krill biological measurement using SISO krill sampling protocol	Fishery	Scientific Observers, CCAMLR Scientists, SKEG community scientists	Scientific Observers, CCAMLR Scientists, SKEG community scientists	Understand spatial seasonal distribution of krill population and pinpoint hot spots	Medium	High	Continuous	Mr J Zhu, Dr Fan, Dr Kim
		Krill biological measurement using random subsampling method consistent with SISO protocol	Research vessels, other vessels	CCAMLR Scientists, SKEG community scientists	CCAMLR Scientists, SKEG community scientists					Dr Krafft, Dr Kutsen, Mr J Zhu, Dr Fam, Dr La
	Length and maturity data from predator diet	Krill from predator stomach contents	Penguins, fur seals	CEMP Parameter A8	CCAMLR Scientists	Understand krill length consumed by predators within the foraging area	Medium	Medium	Continuous	Dr Waluda, Dr Hill, Dr Collins
	Krill larvae	CPR sampling	Tourist vessels	CCAMLR Scientists, SKEG community scientists	CCAMLR Scientists, SKEG community scientists	Understand spatio-temporal distribution of krill larvae	Medium	Medium	Continuous	Dr Schaafsma, Dr Mu
	Genetics	Development of molecular markers for analysing subarea level population	Research vessels, Fishing vessels, other vessels	SKEG community scientists, in collaboration with industry for fishing vessels	CCAMLR Scientists, SKEG community scientists	Understand Connectivity and retention	Medium	High	3-5 Years	Dr Shao Dr Meyer Dr Kawaguchi
		Molecular analysis of microbiome assembly that are geographically structured	Research vessels, Fishing vessels, other vessels	SKEG community scientists, in collaboration with industry for fishing vessels	CCAMLR Scientists, SKEG community scientists			Medium		Dr Kawaguchi Dr Cleary

(continued)

Table 1 (continued)

Priority activities	Data	Samples /Approach	Platform	Sampling by whom	Measurement and/or analysis by whom	Purpose	Urgency		Time frame	Contributors
							For short-term management	To improve process understanding		
	eDNA	Seawater	Research vessels Fishing vessels			Understand habitat use and distribution	Medium	High	3-5 years	Lu Liu Dr Kawaguchi Dr Liszka
	Behaviour	Acoustic data	Research vessels Fishing vessels	Scientists, SKEG community scientists	Scientists, SKEG community scientists	Seasonal horizontal and vertical krill behaviour	Medium	High	5-8 years	Dr Meyer, Dr Krafft, Dr Kasatkina, Dr Wang, Dr La Dr Kawaguchi Dr Smith, Dr Knutsen
	Environment	Sea ice, Chlorophyll (food availability), sea surface temperature	Satellite	CCAMLR Scientists, SKEG community scientists	CCAMLR Scientists, SKEG community scientists	Seasonal food availability	Medium	High	5 years	Dr Meyer, Dr Y. Zhao, Dr Kasatkina
		CTD	Vessels, gliders, animal borne sensors	CCAMLR Scientists, SKEG community scientists	CCAMLR Scientists, SKEG community scientists	Understand habitat environment	Medium	Medium	5 years	
	Currents	Moorings and ship hull mounted ADCP	Moorings, research vessels, Fishing vessels	CCAMLR Scientists, SKEG community scientists	CCAMLR Scientists, SKEG community scientists	Krill behaviour, spatial distribution	High	High	3 years	Dr Krafft Dr Smith

(continued)

Table 1 (continued)

Priority activities	Data	Samples /Approach	Platform	Sampling by whom	Measurement and/or analysis by whom	Purpose	Urgency		Time frame	Contributors
							For short-term management	To improve process understanding		
Modelling & Measurements	Development of oceanographic numerical models	Existing observation data, krill acoustic density, satellite remote sensing, reanalysis database, ocean circulation model, Lagrange particle tracking model, and krill habitat suitability assessment.	Existing data	SKEG community scientists	SKEG community scientists	To better understand population structure and connectivity and retentions between subareas and regions.	High	High	5-10 years	Dr Mori Dr Thorpe
	Krill habitats	Krill habitat suitability assessment								Dr Y Zhao
	Population dynamics	Spatial life cycle model for krill stock, Mechanistic relationship between sea ice and recruitment and other stages, quantification of climate change impacts on population dynamics across life history stages, regional population connectivity (advection and life cycle modelling)		SKEG community scientists, CCAMLR scientists	SKEG community scientists, CCAMLR scientists	Hypothesis testing	High	High	5-10 years	Dr Meyer, Dr Ying, Dr Kawaguchi Dr Hill

(continued)

Table 1 (continued)

Priority activities	**Data**	**Samples /Approach**	**Platform**	**Sampling by whom**	**Measurement and/or analysis by whom**	**Purpose**	**Urgency**		**Time frame**	**Contributors**
							For short-term management	To improve process understanding		
Experimental approach	Experimental results	Measure life history parameters such as egg sinking rates and developmental rates, under controlled environments	Aquarium and field experiments	SKEG community scientists	SKEG community scientists	To better parameterise models to simulate transport pathways during early life stages to help pinpoint spawning hotspots.	Medium	High	5-10 years	Dr Kawaguchi
Field Study	Krill behaviour, Flux	Analysing the drivers of the seasonal horizontal migration of krill (oceanic vs shelf regions)	Research / Fishing vessels, Antarctic stations	SKEG community scientists	SKEG community scientists	To get a mechanistic understanding of krill flux	Medium	High	5-8 years	Dr Meyer Dr Kawaguchi Dr Smith, Dr Kasatkina
Mine existing information (Knowledge, data, and samples)	Existing data, samples and knowledge	Literature review and analysis of historical data		SKEG community scientists	SKEG community scientists	To ensure KSH is consistent with published knowledge and is available in scientific literature	High		1 year	Dr Okuda, Dr Hill, Dr Kawaguchi
	Existing samples that can be extracted for genetic analysis	Different laboratories use agreed methodologies to deliver comparative sequences		SKEG community scientists	SKEG community scientists		Medium	High	3-5 years	

Table 2: Intersessional work plan for WG-EMM updated by WG-EMM-2023. Timeframe periods are short = 1–2 years, medium = 3–5 years and long = 5+ years. Items tasked to WG-EMM from the Scientific Committee Strategic Plan (Annex 4 in SC-CAMLR-41). CEMP – CCAMLR Ecosystem Monitoring Program, SISO – Scheme of International Scientific Observation.

Theme	Priority research topic	Priority research topic task	Timeframe	Contributors	Secretariat participation
1. Target species	(a) Develop methods to estimate biomass for krill	(iii) Data collection – SISO, vessels, and CEMP Urgency: High (2) Develop diagnostic approaches for data quality Urgency: High	Short	Dr Zhu Dr Kawaguchi Dr Collins	Yes
		(iv) Acoustic data storage and processing Urgency: High (3) Develop the use of krill length frequency data in the estimation of target strength, and krill weight for biomass estimates Urgency: High	Medium	Dr Cox, Dr Wang	Yes
		(v) Biomass estimation methods Urgency: High (1) Establish Grym parameters for krill stock assessments in Areas 48 and 58 Urgency: High	Short	Dr Ying Mr Johannessen Dr Kawaguchi Dr Murase Dr Lowther	
		(vi) Account for spatial structure of krill Urgency: Medium	Short		
	(b) Develop stock assessments to implement decision rules for krill	(i) Krill management approach (synthesis of krill recruitment, spatial scale, biomass estimates, predator risk) Urgency: High (1) Subarea 48.1 (2022) Urgency: High (2) Subareas 48.2, etc… (2023/24) Urgency: Medium	Short/medium	Dr Kawaguchi Dr Watters	
		(ii) Develop diagnostic tools Urgency: Medium	Medium		

(continued)

Table 2 (continued)

Theme	Priority research topic	Priority research topic task	Timeframe	Contributors	Secretariat participation
		(iii) Develop ecosystem indicators to inform risk assessment framework Urgency: Low		Dr Warwick-Evans	
		(iv) Methods to account for uncertainty in stock status Urgency: Low (2) Spatial structure within subareas Urgency: High (3) Interannual variability Urgency: Low			
		(v) Develop krill management approach as a multiannual cycle Urgency: High		Dr Hill Dr Watters	
		(vii) Krill management strategies that are robust to climate change Urgency: Medium	Long	Dr Hill	
	(e) Management strategy evaluations for target species (Second Performance Review, Recommendation 8)	(iii) Finfish management strategies that are robust to climate change Urgency: Medium	Medium/Long	Dr. Devine	
		(iv) MSE for krill	Medium	Mr. Mardones Dr. Lowther Mr. Johannessen	
	(f) Krill Stock Hypothesis Information Collection Plan	See Table 1	See Table 1	See Table 1	

(continued)

Table 2 (continued)

Theme	Priority research topic	Priority research topic task	Timeframe	Contributors	Secretariat participation
2. Ecosystem impacts	(a) Ecosystem monitoring (Second Performance Review, Recommendation 5)	(i) Structured ecosystem monitoring programs (CEMP, fishery)	Short/medium	Dr Collins	
		(1) CEMP		Dr Hinke	Yes
				Dr Lowther	
				Dr Hill	
				Dr Waluda	
				Dr Santos	
				Dr Emmerson	
				Dr Makhado	
		(2) Fishery via SISO			
		Urgency: Medium			
		(ii) Ecosystem modelling Urgency: Low	Long	Dr Schaafsma Dr Pinkerton	
		(iii) Invasive species Urgency: Low	Long		
		(iv) Marine debris monitoring	Long	Dr Waluda	Yes
		Urgency: Low		Dr Schaafsma	
				Dr Makhado	
				Dr Emmerson	
				Dr Santos	

(continued)

Table 2 (continued)

Theme	Priority research topic	Priority research topic task	Timeframe	Contributors	Secretariat participation
	(b) Spatial management	(i) Science advice on proposals for a Representative System of MPAs Urgency: High (1) Current proposals Urgency: High (2) Future proposals Urgency: Low	Short/Medium Short	Prof. Koubbi Dr Teschke	
		(ii) the harmonisation and/or integration of different spatial management initiatives within Subarea 48.1, including the ARK voluntary restricted zones and the D1MPA proposal (SC-CAMLR-41, paragraph 3.65) Urgency: High		Dr Santos Mr Santa Cruz	
		(ii) Research and monitoring plans Urgency: High	Medium/Long	Dr Devine et al	
	(c) By-catch risk assessment for krill and finfish fisheries	(i) Monitoring status and trends Urgency: High	Medium		
		(ii) By-catch species catch limits Urgency: High		Dr Devine	
	(d) Habitat protection from fishing impacts	(i) Habitat classification, bioregionalisation and monitoring Urgency: Low			
		(ii) VME identification and management Urgency: Medium		Dr Eléaume Dr Teschke Dr Devine et al.	

(continued)

Table 2 (continued)

Theme	Priority research topic	Priority research topic task	Timeframe	Contributors	Secretariat participation
		(iii) Protection of biodiversity and ecosystems (Second Performance Review, Recommendation 7) Urgency: High (1) Ecosystem impacts from krill and finfish fishing, including analyses whether research and sampling design is able to detect such impacts Urgency: High (2) Physical disturbance of longline fishing on benthic ecosystems Urgency: Low (3) Suitability of reference areas for comparison between fished and unfished areas Urgency: Medium		Dr Hill Dr Hill	
	(e) Monitoring and adaptation to effects of climate change	(i) Develop methods to detect change in ecosystems given variability and uncertainty (Second Performance Review, Recommendation 6) Urgency: Medium	Medium	Dr Schaafsma Dr Dahlgren Dr Hill, Dr Collins, Dr Emmerson, Dr Waluda, Dr Knutsen	Yes
		(ii) Develop integrated ecosystem reporting (WG-EMM-2022, paragraph 2.18)	Medium	Mr Pardo Dr Cavanagh Dr Parker	Yes
		(iii) Develop mechanisms for integration in SC work		Mr Pardo Dr Cavanagh	

(continued)

Table 2 (continued)

Theme	Priority research topic	Priority research topic task	Timeframe	Contributors	Secretariat participation
	Administrative topics	(a) Advise on database facilities required through DSAG Urgency: High			Yes
		(b) Advise on quality control and assurance processes for data provided to and supplied by the Secretariat Urgency: High			Yes
		(c) Refine the scheme of international scientific observation (SISO) across all fisheries Urgency: Medium			Yes
		(d) Further develop data management systems Urgency: Medium (1) Quality assurance Urgency: High (2) DOI Urgency: Medium (3) Data access Urgency: Low			Yes
		(e) Communication of progress, internal and external Urgency: Medium			Yes
		(f) Working group terms of reference Urgency: Low			
		(g) Scientific Committee Symposium in 2027 Urgency: High			

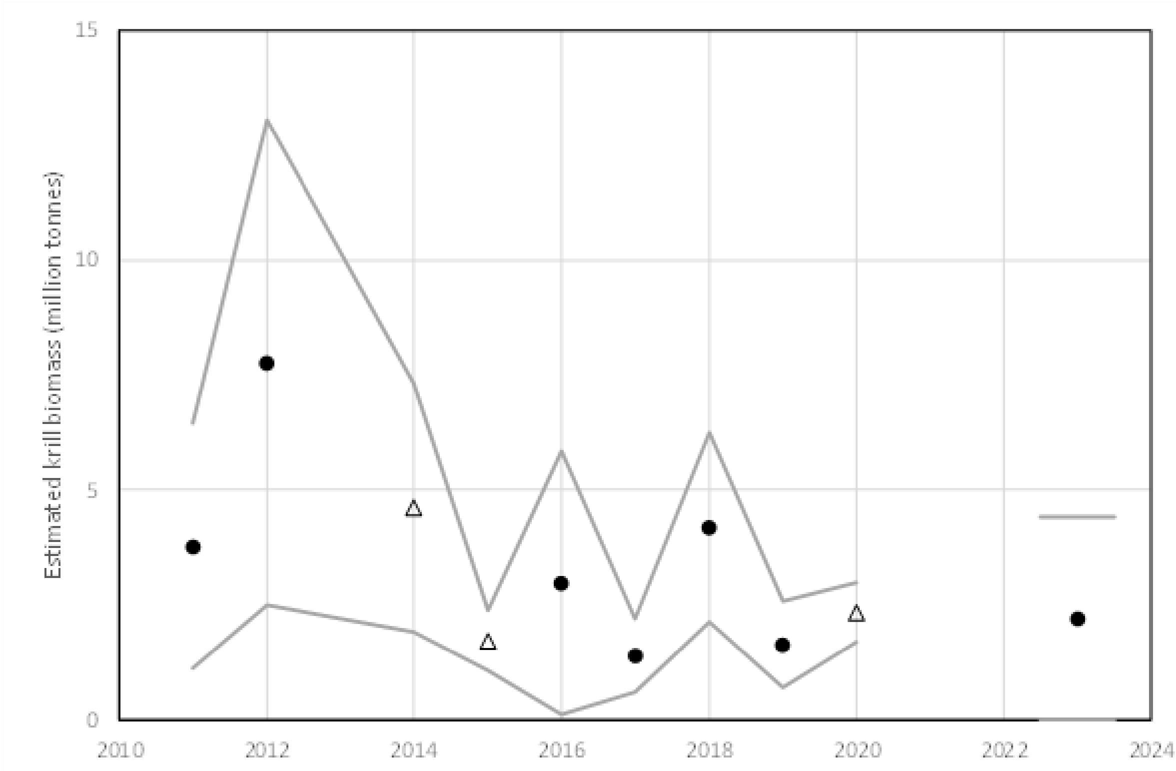

Figure 1. South Orkney Islands krill biomass estimates for 2011–2023. The grey lines mark the 95% confidence interval (±1.96 × standard deviation) around the mean based on the Jolly and Hampton estimator using the transects as the primary sampling unit. Years with swarm detection and integration done at 38 kHz are marked with triangles. The other estimates are based on 120 kHz data. The 2013 estimate is not included due to poor survey coverage. Redrawn from WG-EMM-2023/P01 with additional data from WG-EMM-2023/01.

Appendix A

List of Participants

Working Group on Ecosystem Monitoring and Management
(Kochi, India, 3 to 14 July 2023)

Chair	Dr César Cárdenas Instituto Antártico Chileno (INACH)
Argentina	Dr Emilce Florencia Rombolá Instituto Antártico Argentino
	Dr María Mercedes Santos Instituto Antártico Argentino
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	Dr So Kawaguchi Australian Antarctic Division, Department of Climate Change, Energy, the Environment and Water
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	Dr Katharina Teschke Alfred Wegener Institute for Polar and Marine Research
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Dr Eunjung Kim
National Institute of Fisheries Science

	Dr Hyoung Sul La Korea Ocean Polar Research Institute (KOPRI)
	Mr Jeongseok Park National Institute of Fisheries Science
	Mr Sang Gyu Shin National Institute of Fisheries Science (NIFS)
Netherlands, Kingdom of the	Dr Fokje Schaafsma Wageningen Marine Research
New Zealand	Dr Clare Adams Ministry for Primary Industries
	Dr Jennifer Devine National Institute of Water and Atmospheric Research Ltd. (NIWA)
	Mr Enrique Pardo Department of Conservation
Norway	Mr Elling Deehr Johannessen Norwegian Polar Institute
	Dr Gary Griffith Norwegian Polar Institute
	Dr Tor Knutsen Institute of Marine Research
	Dr Bjørn Krafft Institute of Marine Research
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	Dr Azwianewi Makhado Department of Forestry, Fisheries and the Environment
	Dr Chris Oosthuizen University of Cape Town
	Mr Sobahle Somhlaba Department of Agriculture, Forestry and Fisheries

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	Dr Simeon Hill British Antarctic Survey
	Dr Oliver Hogg Centre for Environment, Fisheries and Aquaculture Science (Cefas)
	Ms Georgia Robson Centre for Environment, Fisheries and Aquaculture Science (Cefas)
	Dr Claire Waluda British Antarctic Survey
United States of America	Dr Jefferson Hinke National Marine Fisheries Service, Southwest Fisheries Science Center
Secretariat	Dr Steve Parker Science manager
	Dr Stéphane Thanassekos Fisheries and ecosystems analyst

Appendix B

Agenda for the Working Group on Ecosystem Monitoring and Management

(Kochi, India, 3 to 14 July 2023)

1. Introduction

   1.1 Opening of the meeting
   1.2 Adoption of the agenda and organisation of the meeting

2. Review Terms of Reference and workplan

3. Krill Fishery

   3.1 Fishing activities (updates and data)
   3.2 Scientific observation
   3.3 CPUE and spatial dynamics
   3.4 Fishing vessel surveys

4. Krill Fishery Management

   4.1 WG-ASAM advice and considerations of the krill fishery management strategy
   4.2 WG-SAM advice and considerations of the krill fishery management strategy
   4.3 Develop methods to estimate biomass for krill
      4.3.1 Data collection needs (SISO (recognising Observer Workshop), vessels)
      4.3.2. Biomass estimation methods (Grym parameters for krill stock model)
      4.3.3. Account for spatial structure of krill

   4.4 Develop stock assessments to implement decision rules for krill for subarea 48.1
      4.4.1 Synthesis of krill recruitment
      4.4.2 Spatial scale
      4.4.3. Biomass estimates
      4.4.4. Krill spatial overlap analysis

   4.5 Symposium on holistic approach to management in Subarea 48.1

5. Ecosystem monitoring and observation
   5.1 CEMP monitoring (1-day focus topic)
   5.2 Other monitoring data (marine debris)
   5.3 Review of CCAMLR research and monitoring design and implementation

6. Krill-based ecosystem interactions
    6.1 Krill biology, ecology and population dynamics
    6.2 Krill life-history parameters and population models
    6.3 Krill predator biology, ecology and population dynamics

7. Spatial management
    7.1 Data analysis supporting spatial management approaches in CCAMLR
    7.2 Integration of existing measures in spatial management approaches
    7.3 Research and monitoring plans for MPAs
    7.4 VME data and spatial planning approaches

8. Climate change and associated research and monitoring

9. Other business

10. Future work

11. Advice to the Scientific Committee and its working groups

12. Adoption of the report and close of the meeting

Appendix C

List of Documents

Working Group on Ecosystem Monitoring and Management
(Kochi, India, 3 to 14 July 2023)

WG-EMM-2023/01	Report on the annual Norwegian krill survey off the South Orkney Islands, 2023 B.A. Krafft, R. Pedersen, G. Zhang, S. Menze, A. Rasmussen, H. Skaar, J. Dale, M. Biuw, C. Oosthuizen and A. Lowther
WG-EMM-2023/02	The impact of how the early life cycle is physically represented on the modelled transport and retention of Antarctic krill Z.T. Sylvester, M.S. Dinniman, K.S. Bernard, S.E. Thorpe, V. Pham, A.C. Williams and C.M. Brooks
WG-EMM-2023/03	CCAMLR's revised krill fishery management approach in Subareas 48.1 to 48.4 as progressed from 2019 to 2022 X. Zhao, M. Collins, G.M. Watters, P. Ziegler and the Secretariat
WG-EMM-2023/04	Spatial structuring in 0-group fish diversity in the Scotia Sea region of the Southern Ocean T. Dornan, T. Knutsen, B.A. Krafft, M. Kvalsund, A. Mateos-Rivera, G.A. Tarling, R. Wienerroither and S.L. Hill
WG-EMM-2023/05	Current krill sampling protocols followed by fishery observers undersample small krill and underestimate the proportion of juvenile krill caught D. Bahlburg, L. Hüppe and B. Meyer
WG-EMM-2023/06	Development of a krill stock hypothesis (KSH) for CCAMLR Area 48 – Report of the online workshop of the SCAR Krill Expert Group (SKEG), 20 to 24 March 2023 B. Meyer on behalf of the SKEG board and workshop participants
WG-EMM-2023/07	New Zealand research and monitoring in support of the Ross Sea region marine protected area: 2022–2023 update M. Pinkerton, C.I.M. Adams, E. Behrens, J. Devine, R. Eisert, B. Finucci, A. Grüss, S. Halfter, I. Hawes, B. Moore, J. Mountjoy, E. Pardo, E. Robinson, N. Robinson, C. Stevens and D. Thompson

WG-EMM-2023/08	First observation of a skate egg case nursery in the Ross Sea B. Finucci, C. Chin, H.L. O'Neill, W.T. White and M.H. Pinkerton
WG-EMM-2023/09	Research vessel Tangaroa 2023 Ross Sea Antarctic voyage, 15 January to 23 February 2023 J. Mountjoy and M. Pinkerton
WG-EMM-2023/10	Using the spatial population model (SPM) to assess the potential impacts of the Ross Sea region marine protected area for Antarctic toothfish (*Dissostichus mawsoni*) A. Grüss, M.H. Pinkerton, S. Mormede and J.A. Devine
WG-EMM-2023/11	On the issue of gear selectivity in relation to krill in the current CCAMLR topics S. Sergeev and S. Kasatkina
WG-EMM-2023/12	Comments on the management approach to krill fishery S. Kasatkina
WG-EMM-2023/13	Intra- and interannual variability in seasonal sea ice and krill fishery in Subareas 48.1 and 48.2 V. Shnar and S. Kasatkina
WG-EMM-2023/14	CCAMLR marine debris monitoring program, 2023 Secretariat
WG-EMM-2023/15 Rev. 1	Spatial distribution of the mesozooplankton community in the coastal polynyas of the Ross Sea region marine protected area (RSRMPA) during early summer S.-H. Kim, W. Son, J.-H. Kim and H.S. La
WG-EMM-2023/16	Preliminary steps for an atlas of macrozooplankton in the subantarctic Indian and in the South Indian Ocean P. Koubbi, M. Thellier, V. Djian, C. Merland and B. Leroy
WG-EMM-2023/17	Hydrologic regionalisation from Crozet to Kerguelen and subtropical southern Indian Ocean V. Djian, C. Cotté and P. Koubbi
WG-EMM-2023/18	Regionalisation of the physical and biogeochemical environment in the Southern Indian Ocean C. Merland, C. Azarian, F. d'Ovidio and C. Cotte
WG-EMM-2023/19	Withdrawn

WG-EMM-2023/20	Atlas of mesopelagic fish in the sub-Antarctic Indian and in the South Indian Ocean P. Koubbi, V. Djian, M. Vacchi, C. L. Rintz, B. Leroy, A. Walters, B. Serandour, E. Tavernier and REPCCOAI scientists
WG-EMM-2023/21	Macrozooplankton from Crozet to Kerguelen and subtropical southern Indian Ocean V. Djian, C. Merland, M. Thellier, B. Leroy, C. Cotte, P. Koubbi and REPCCOAI scientists
WG-EMM-2023/22	Determining the distribution of Antarctic krill and krill-dependent predators at South Georgia (Subarea 48.3) during winter C. Liszka, S. Calderan, T. Dornan, S. Fielding, M. Goggins, J. Jackson, R. Leaper, P.A. Olson, N. Ratcliffe, K. Owen, R. Irvine and M.A. Collins
WG-EMM-2023/23	Observer sampling rates in the krill fishery Secretariat
WG-EMM-2023/24	Summary of CCAMLR ecosystem monitoring program (CEMP) data holdings through the 2022/23 monitoring season Secretariat
WG-EMM-2023/25	Fish nest area in the southern Weddell Sea: Discussions and recommendations of CCAMLR-41 and a proposal for further action K. Teschke, R. Konijnenberg, P. Brtnik, L. Ghigliotti and M. Eléaume
WG-EMM-2023/26	British Antarctic Survey: Ecosystem Monitoring in Area 48 (2022/23) C. Waluda, S.E. Thorpe, T. Dornan, P. Hollyman, R. Saunders, A. Bennison, M. Dunn, J. Forcada, R.A. Phillips, N. Ratcliffe, G. Tarling and M.A. Collins
WG-EMM-2023/28	Report of the second training course of Chilean scientific observers on the CCAMLR F. Santa Cruz, L. Rebolledo, L. Krüger and C. Cárdenas
WG-EMM-2023/29	Tracking ecosystem changes in Western Antarctic Peninsula to inform CCAMLR decision-making: insights from the ongoing ecosystem monitoring programme in Ardley Island's CEMP site. A. Soutullo, A.L. Machado-Gaye and N. Zaldúa

WG-EMM-2023/30	Crash and learn? An evaluation of potential conservation threats to South Shetland Island Antarctic fur seals amidst precipitous population collapse D.J. Krause, R. Brownell, C.A. Bonin, S.M. Woodman, D. Shaftel and G.M. Watters
WG-EMM-2023/31	Baseline spatial data prior to the ecoregionalisation of the eastern sub-Antarctic region A.B. Makhado, J. Huggett, F. Dakwa, N. Mdluli, F. Shabangu, P. Koubbie, C. Cotté, F. d'Ovidio, V. Djian, E. Goberville, L. Izard, A. Kristiansen, B. Leroy, C. Merland, C. Ly Rintz, M. Thellier, D. Thibault, K. Delord, C. Bost, E. Tavernier, C. Azarian, K. Swadling, J. Melvin, J. Kitchener, L. Brokensha, M.-A. Lea and A. Walters
WG-EMM-2023/32	Towards higher predator ecoregionalisation of the pelagic zone in the sub-Antarctic and subtropical Indian Ocean R. Reisinger, A.B. Makhado, K. Delord, C. Bost and M.-A. Lea
WG-EMM-2023/33	Next results of oceanographic research carried out on Ukrainian longline vessels in the CCAMLR area at the season 2022/23 V. Paramonov, L. Pshenichnov, R. Solod, A. Bazhan and P. Zabroda
WG-EMM-2023/34	Using two international synoptic surveys to test the predictive performance of krill habitat models in the Scotia Sea J. Freer, C. Liszka, S. Fielding, G. Tarling, S. Thorpe, S. Hill, B. Krafft and G. Macaulay
WG-EMM-2023/35	Evaluating sensitivity of the stock assessment tool for the Antarctic krill fishery to seasonal trends in natural and fishing mortality E.D. Johannessen, B.A. Krafft, C. Donovan, R. Wiff, B. Caneco and A. Lowther
WG-EMM-2023/36	Draft conservation measure for a Weddell Sea marine protected area – Phase 2 Delegation of Norway
WG-EMM-2023/37	Seabirds assemblages, abundance and distribution in the African sector of the southern Indian Ocean A.B. Makhado, R. Reisinger, M. Masotla, S.M. Seakamela, F. Shabangu and F. Dakwa
WG-EMM-2023/38	Zooplankton communities near the Prince Edward Islands – recent progress from image analysis J.A. Huggett, N. Mdluli and D. Thibault

WG-EMM-2023/39	Searching spatial–temporal changes in intrinsic productivity of Antarctic krill (*Euphausia superba*) in a fishery management context M. Mardones, G. Watters and C. Cárdenas
WG-EMM-2023/40	Identifying prey capture events in chinstrap penguins using accelerometer data and deep learning S. Schoombie, L. Jeantet, M. Chimienti, G. Sutton, P. Pistorius, E. Dufourq, A. Lowther and C. Oosthuizen
WG-EMM-2023/41	Unreliable inferences about chinstrap penguin population trends: a statistical critique and reanalysis C. Oosthuizen, M. Christian, A. Makhado and M. Ngwenya
WG-EMM-2023/42	The CCAMLR Ecosystem Monitoring Program – discussion points for a one-day special focus topic C.M. Waluda, S.L. Hill and M.A. Collins
WG-EMM-2023/43	Monitoring Antarctic breeding flying seabirds with nest cameras – a consideration for extending CEMP L. Emmerson, A. Lashko, M. Salton and C. Southwell
WG-EMM-2023/44	Grym assessment parameters for Divisions 58.4.1 and 58.4.2 *Euphausia superba* populations D. Maschette, S. Wotherspoon, H. Murase and S. Kawaguchi
WG-EMM-2023/45	Land-based monitoring of Antarctic breeding seabirds for krill fisheries management across East Antarctica by the Australian Antarctic Program L. Emmerson, C. Southwell, S. Kawaguchi, N. Kelly and P. Ziegler
WG-EMM-2023/46	Assessing phylodiversity spatial patterns of Southern Ocean fauna for biodiversity conservation A. Kondratyeva and M. Eléaume
WG-EMM-2023/47	Scientific evidence in support of the draft conservation measure for a Weddell Sea marine protected area Phase 2 Delegation of Norway
WG-EMM-2023/48	Applying the management strategy evaluation tool *openMSE* to the Antarctic krill fishery case E.D. Johannessen, B. Caneco, C. Donovan, R Wiff and A. Lowther

WG-EMM-2023/49	Summary of the dedicated sighting survey under the Japanese Abundance and Stock structure Surveys in the Antarctic (JASS-A) in four austral summer seasons (2019/20 to 2022/23) T. Isoda, T. Katsumata, Y. Kim, H. Murase and K. Matsuoka
WG-EMM-2023/50	Improve the understanding of population connectivity of Antarctic krill in CCAMLR Area 48 through multidisciplinary research Y. Zhao, Y. Ying, X. Wang, K. Liu, X. Mu and X. Zhao
WG-EMM-2023/51	Large-scale pelagic acoustic ecoregionalisation in the eastern part of the sub-Antarctic region F.E. Dakwa, F. Shabangu, L. Izard and A.B. Makhado
WG-EMM-2023/52	First records of *Chionodraco hamatus* nesting at Silverfish Bay (Terra Nova Bay, Ross Sea) E. Carlig, D. Di Blasi, S. Canese, M. Vacchi, S. Grant and L. Ghigliotti
WG-EMM-2023/53	Comparison of the density and distribution of krill larvae during the summer seasons of 2019 and 2020 in contrast with salps densities in the Mar de la Flota/Bransfield Strait and Elephant Island surroundings E. Rombolá, M. Sierra, F. Capitanio, C. Franzosi, W. Carhuapoma Bernabé, B. Meyer, C. Reiss and E. Marschoff
WG-EMM-2023/54	Opportunities for IWC-CCAMLR collaboration to contribute to CCAMLR's revised Krill Fishery Management approach N. Kelly, S. Parker, D. Maschette and C. Miller
WG-EMM-2023/55	Scientific use of the Sailbuoy unmanned surface vehicle to monitor Antarctic krill S. Menze, G. Skaret and B.A. Krafft
WG-EMM-2023/56	Chilean operation in the Antarctic krill fishery, years 2021 to 2022 P.M. Arana and R. Rolleri
WG-EMM-2023/57	Disentangling spatial and temporal patterns from multifrequency active acoustic data reveals pelagic structuring in the eastern sub-Antarctic region L. Izard, V. Djian, A. Kristiansen, E. Goberville and C. Cotté
WG-EMM-2023/58	Using CPR surveys to map distributions of trophically important subantarctic prey species K. Swadling, J. Huggett, L. Brokensha, E. Goberville, J. Melvin, J. Kitchener and P. Koubbi

Other Documents

WG-EMM-2023/P01	Antarctic krill (*Euphausia superba*) catch weight estimated with a trawl-mounted echosounder during fishing B.A. Krafft, L.A. Krag, R. Pedersen, E. Ona and G. Macaulay *Fish. Manag. Ecol.*, 30 (3) (2023): 323–331, doi: 10.1111/fme.12625
WG-EMM-2023/P02	Distribution and biomass estimation of Antarctic krill (*Euphausia superba*) off the South Orkney Islands during 2011–2020 G. Skaret, G.J. Macaulay, R. Pedersen, X. Wang, T.A. Klevjer, L.A. Krag and B.A. Krafft *ICES J. Mar. Sci.*, 0 (2023): 1–15, doi: 10.1093/icesjms/fsad076
WG-EMM-2023/P03	Ross Sea Research Planning Meeting Oct 3 to 5 2022, University of Colorado Boulder S. Stammerjohn, C. Brooks, G. Ballard, A. DuVivier and M. LaRue Published 2022, http://www.rossseаresearch.org/
WG-EMM-2023/P04	Sperm whales forage year-round in the Ross Sea region G. Giorli and M.H. Pinkerton *Front. Remote Sens.*, 4 (2023), doi: 10.3389/frsen.2023.940627
WG-EMM-2023/P05	CRITTERBASE, a science-driven data warehouse for marine biota K. Teschke, C. Kraan, P. Kloss, H. Andresen, J. Beermann, D. Fiorentino, M. Gusky, M.L.S. Hansen, R. Konijnenberg, R. Koppe, H. Pehlke, D. Piepenburg, T. Sabbagh, A. Wrede, T. Brey and J. Dannheim *Scientific Data*, 9:483, doi: https://doi.org/10.1038/s41597-022-01590-1
WG-EMM-2023/P06	Decreasing trends of chinstrap penguin breeding colonies in a region of major and ongoing rapid environmental changes suggest population level vulnerability L. Krüger *Diversity*, 15 (3) (2023): 327; doi: 10.3390/d15030327

WG-EMM-2023/P07	Contrasting environmental conditions precluded lower availability of Antarctic krill affecting breeding chinstrap penguins in the Antarctic Peninsula N. Salmerón, S. Belle, F. Santa Cruz, N. Alegria, J. Grohmann Finger, D. Corá, M.V. Petry, C. Hernández, C.A. Cárdenas and L. Krüger *Scientific Reports*, 13 (2023): 5265, doi: 10.1038/s41598-023-32352-7
WG-EMM-2023/P08	Phenology-based adjustments improve population estimates of Antarctic breeding seabirds: the case of Cape petrels in East Antarctica K. Kliska, C. Southwell, M. Salton, R. Williams and L. Emmerson *Royal Society Open Science*, 9 (2022): 211659, doi: 10.1098/rsos.211659
WG-EMM-2023/P09	Emerging evidence of resource limitation in an Antarctic seabird metapopulation after six decades of sustained population growth C. Southwell, S. Wotherspoon and L Emmerson *Oecologia*, 196 (2021): 693–705, doi: 10.1007/s00442-021-04958-z
WG-EMM-2023/P10	Environment-triggered demographic changes cascade and compound to propel a dramatic decline of an Antarctic seabird metapopulation L. Emmerson and C. Southwell *Glob. Chang. Biol.*, 28 (2022): 7234–7249, doi: 10.1111/gcb.16437

Appendix D

Protocol for length frequency measurements, sex and stage determination of Krill (*Euphausia superba*) on board fishing vessels using the continuous trawl pumping system.

Background:

Length measurements and sex and stage determinations of krill will provide data that gives insight into its demographic structure (proportion of juvenile and adult krill, sex ratio). By determining the sex and length of a random subsample of ~200 krill individuals, a representative picture of the targeted krill swarm`s demography can be drawn. Simultaneous collection of simple metadata on position, date, time of day, fishing depth and bathymetry, provides valuable insights into understanding krill distribution, behaviour, and life history across seasons and may contribute to managing the krill fishery.

Material:

- 3x Plastic buckets (~5 L volume), can be white or transparent (see example in figure 1)
- 2x Graduated measuring jugs (500 ml volume, see Figure 1)
- 1x Ladle 
- 1x Laminated millimetre paper (spanning at least 0 to 70 mm)
- Paper tissue
- 1x Stereomicroscope (requirements following CCAMLR recommendation)
- Set of forceps

Protocol:

Collecting Meta-Data:

On the continuous pumping trawlers, the krill take approximately 10 minutes (e.g. on the FV Antarctic Endurance) to travel from the mouth of the net through the pumping system to the dewatering location (ask the captain or one of the officers to get the exact time span of the continuous pumping trawler you are on, as this depends on the length of the hose). Metadata, including position, sampling date and time (UTC), should be noted on the bridge before taking a sample at the appropriate time when the krill reach the dewatering location.

On the traditional trawler, metadata including haul number, sampling date and time (UTC), must be collected before the sample is taken from the catch.

Sampling

Prior to the krill sampling procedure, have all the devices you need in place (see material above) and check the steps in Figure 1:

Three buckets, with two of them filled with cool surface seawater; two Graduated measuring jugs, a ladle.

When possible, krill should always be sampled from the same dewatering location (e.g. port side), where krill are pumped onto a wide grate, retained while the remaining seawater is pumped overboard and the krill continue into holding tanks.

- Three shovels of krill should be taken from three different spots on the grate, placed into a bucket that is not filled with seawater, and mixed gently without damaging the krill (see step 1 in Figure 1).
- From this bucket, one graduated measuring jug has to be filled to the ~200 ml mark with the ladle and the other one to the ~50 – 100 ml mark (see step 2 in Figure 1).
- The krill in each jug should be transferred to each separate buckets filled with cool surface seawater to prevent degradation of the krill (see step 3 in Figure 1).
- In the laboratory, place the bucket with the 200 ml krill, when possible, on ice and store the bucket with the backup subsample in a fridge (see step 4 in Figure 1).

The bucket with fewer krill numbers will be used as a backup sample in case the first bucket does not contain at least 200 krill. Have the laminated millimetre paper, forceps and paper tissue beside the stereomicroscope in place before starting the length-frequency measurements and sexing the krill.

On the Traditional trawler, the procedure of taking krill subsamples from the catch to be discussed on the KFO-workshop (WS-KFO-2023).

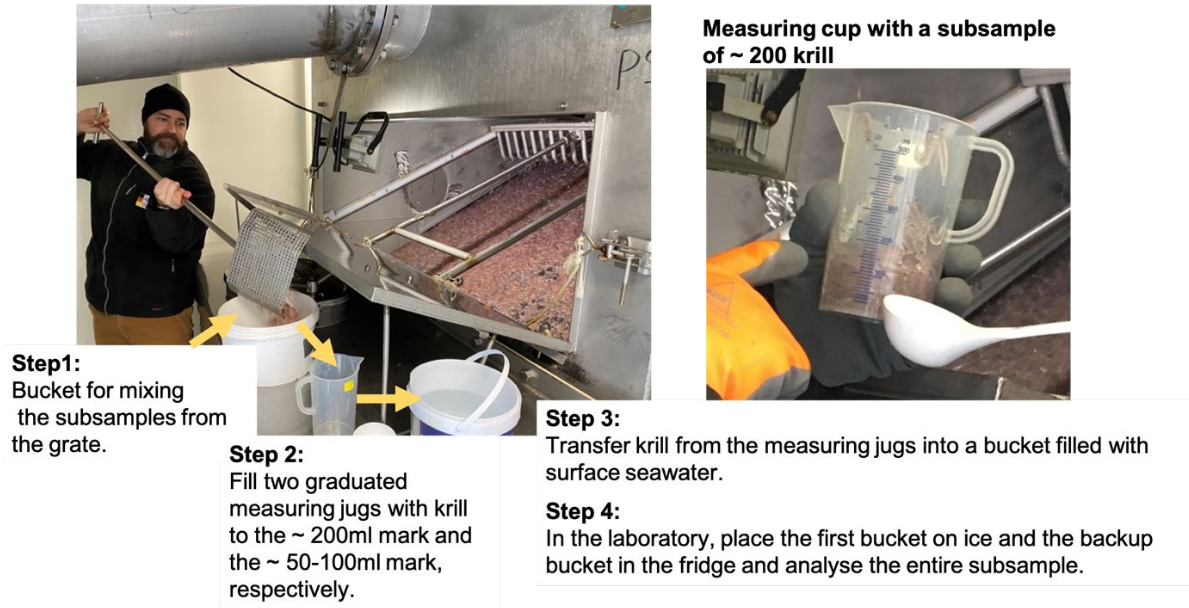

Figure 1: Procedure of krill sampling from the grate in the de-watering location.

Length-frequency measurements and sexing krill

To ensure a representative measurement of the length-frequency and sex distribution of the sampled krill, it is essential that always **all** krill individuals in a bucket are processed (length and sex determination), irrespective of the number of individuals in the bucket. Therefore, start with the bucket with the 200 ml krill and process **all** krill as described below. If all krill in this bucket are processed, and the number of krill is below 200, process **all** krill from the back-up bucket.

For each krill individual, determine and note the length and sex. To determine the length, take one individual with a forceps from the bucket and tap them a few times on the paper tissue to remove the water. Place the krill on the laminated millimetre paper (make sure the animal is stretched out horizontally), and measure the length from the anterior margin of the eye to the tip of the telson, excluding the setae (see Figure 2), to the nearest millimetre below.

To determine the sex, krill must be checked for the presence of the male and female copulatory organs, petasma and thelycum, respectively, under the stereomicroscope (see Figure 3 for positions). For this, place the individual on its back to look at it ventrally and check between the last pair of exopods for the thelycum (female copulatory organ; see Figure 4B for developmental stages of the thelycum). In addition, check the inner side of the first pleopod for the presence of a petasma (male copulatory organ; see Figure 4A and 4C for developmental stages of the petasma). Individuals with a petasma are classified as male and those with thelycum as female. If no petasma or thelycum can be found, krill are categorized as juvenile when smaller than 31mm and when larger than 31 mm as unknown

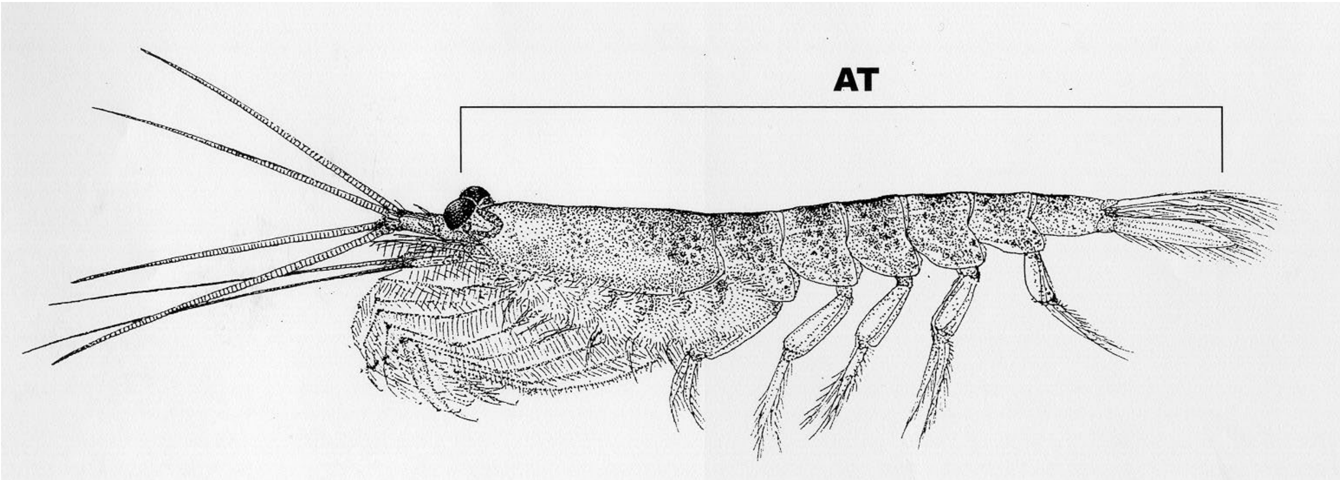

Figure 2: Method of length measurement of krill from the anterior margin of the eye to the tip of the telson, excluding the setae.

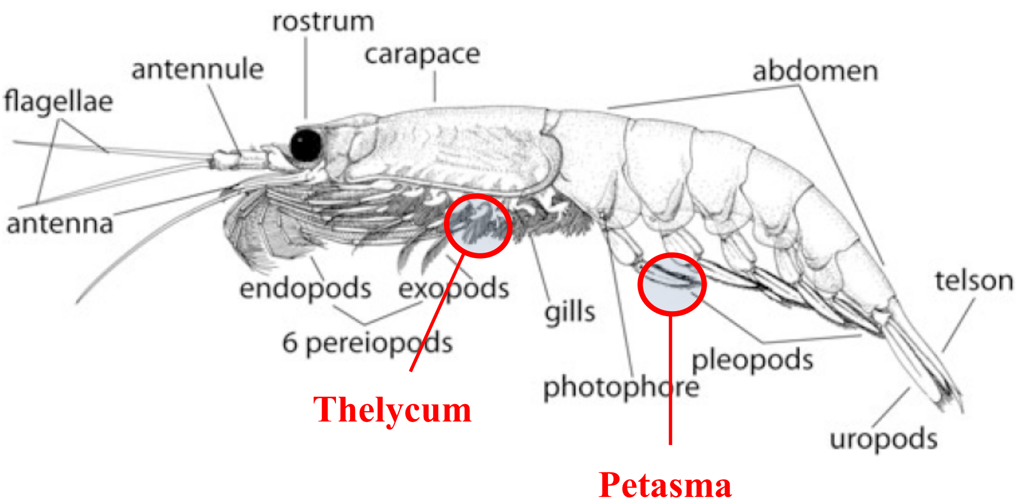

Figure 3: External morphology of *Euphausia superba*, depicting the position of male (petasma) and female (thelycum) copulatory organs (adapted after Siegel et al. (2016)).

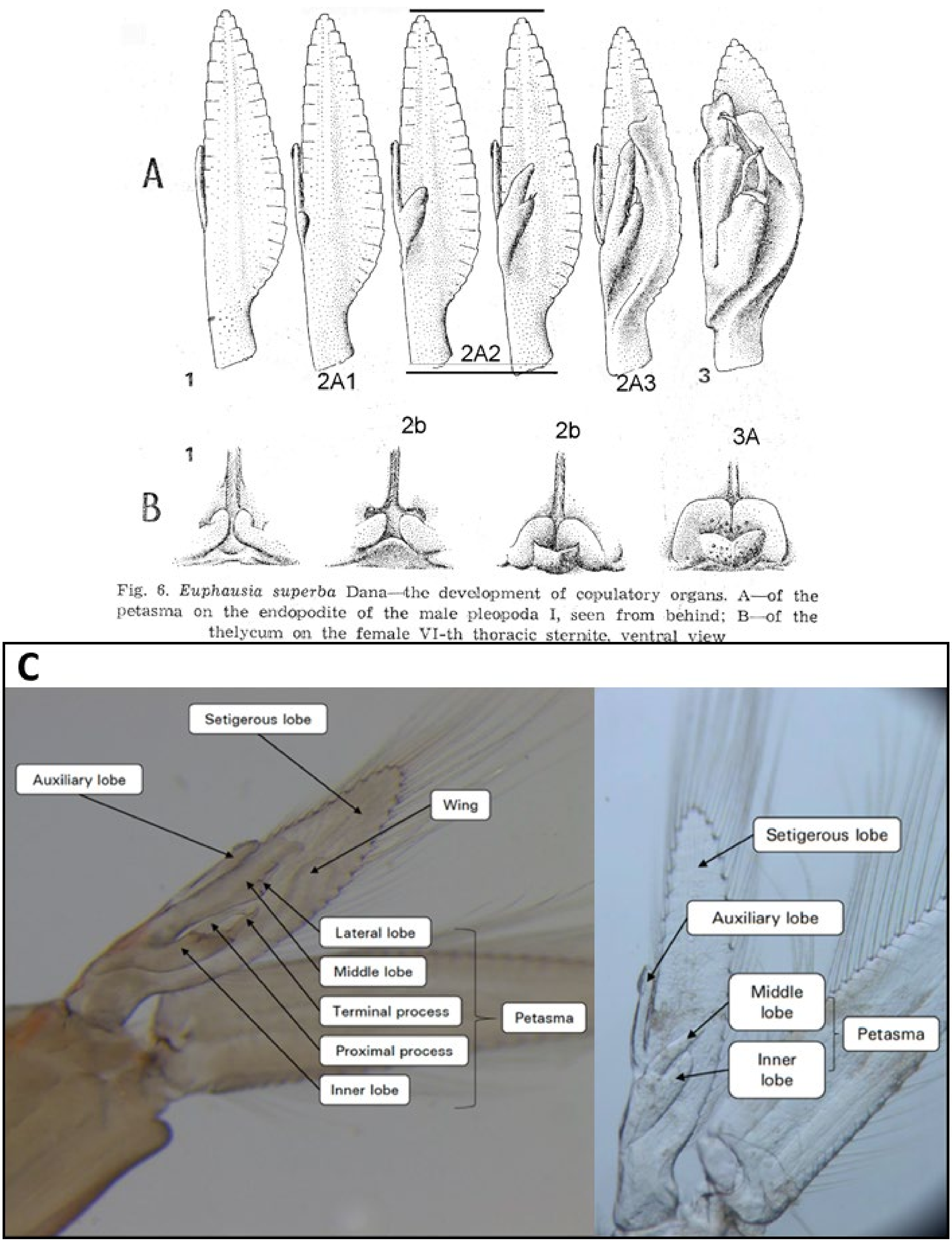

Figure 4: Developmental stages of the copulatory organs of *E. superba* after Makarov and Denys (1981). A) male petasma. B) female thelycum. C). Photos of first pleopods inner side, with petasma under the microscope (photo credit So Kawaguchi).

Appendix E

Title: Workshop on harmonisation of conservation measures in the Antarctic Peninsula Region

Objectives: Provide recommendations to CCAMLR for steps to harmonise the implementation of the revised krill fishery management approach and the establishment of the Domain 1 MPA in the Antarctic Peninsula Region, and recommendations for practical and cost-effective collection and analysis of data.

Terms of Reference:

Part I: Continue discussion of CAMLR-41-BG/43 and terms of reference from e-group. This can occur within normal discussions under spatial management agenda items in both the Scientific Committee and Commission (See WG-EMM-2023 paragraph 4.45).

1) Provide a forum to bring together SC-CAMLR and CCAMLR delegates, representatives from the krill fishing industry, and other CCAMLR observers with relevant expertise in ecosystem and fisheries research and monitoring, climate change, conservation and resource management, and operations in the krill fishery to progress conservation in the Antarctic Peninsula region.

2) Promote understanding within CCAMLR (WGs, SC, Commission and observers) of the current spatial management initiatives in the region, including:

a. the needs for developing a revised krill fishery management approach, including the state of knowledge of krill population in Area 48,

b. proposed management units for distributing catch limits in the krill fishery in Subarea 48.1, and the D1MPA, including the ARK VRZs,

c. that the Commission may need to revise several Conservation Measures related to the krill fishery in the region.

Part II: Science workshop to develop scenarios

3) Provide recommendations to CCAMLR for steps to harmonise the implementation of the revised krill fishery management approach and the establishment of the D1MPA in the Antarctic Peninsula Region.

4) Provide recommendations for practical and cost-effective collection and analysis of data and status indicators to support periodic CCAMLR decisions in the region including:

a. priority elements of an RMP pertaining to the krill-based ecosystem for the Domain 1 MPA,

b. the development of a data collection plan for the krill fishery, including data collected within the CCAMLR Ecosystem Monitoring Program (CEMP), standardised at-sea krill predator observations, as well as data to allow regular updates to krill biomass estimates, stock assessments, spatial-overlap analyses, and monitoring of reference areas as well as data standardisation.

c. Identifying contributions by national programs, the fishing industry, e.g., autonomous platforms and remote-sensing.

Host: TBD
Convener(s): TBD
Venue: TBD, possibly alongside WG-SAM-2024
Date: Prior to EMM-2024
Duration: 5 days
Invited experts: Yes
Observers or external organisations: CCAMLR observers
Funding required by CCAMLR: TBD
Secretariat Support required: Yes
Ability to submit papers: Yes
Output: Chair's report
Reported to: Scientific Committee