Annex 6

Report of the Working Group on Ecosystem Monitoring and Management

(Virtual meeting, 5 to 9 July 2021)

Contents

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Introduction to the meeting

1.1 The 2021 meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM) was held online from 5 to 9 July. The Convener, Dr C. Cárdenas (Chile) welcomed the participants (Appendix A).

Adoption of the agenda and organisation of the meeting

1.2 The meeting's provisional agenda was discussed and the Working Group adopted the proposed agenda (Appendix B).

1.3 Documents submitted to the meeting are listed in Appendix C. The Working Group thanked the authors of papers and presentations for their valuable contributions to the work of the meeting.

1.4 This report was prepared by the Secretariat and the Convener. Sections of the report dealing with advice to the Scientific Committee and other working groups are highlighted and collated in 'Advice to the Scientific Committee'.

Krill management

2.1 WG-EMM-2021/07 presented an overview and early results from the multidisciplinary large-scale survey of the eastern sector of CCAMLR Division 58.4.2 to update the biomass estimate of krill and the understanding of the ecosystem within the region, conducted from February to March 2021.

2.2 The Working Group thanked the authors for their comprehensive report on the survey and noted that the survey design included two transects on the boundary of the study area. The Working Group acknowledged this design was chosen to allow direct comparison of the transect data between this survey and the BROKE-West transects conducted in 2006 (Nicol et al., 2010).

2.3 The Working Group further noted the comprehensive data collected on oceanography, krill, predators and benthic habitat, and that these data will be utilised to design a monitoring plan for the region.

2.4 WG-EMM-2021/08 presented the annual report of the Scientific Committee on Antarctic Research (SCAR) Krill Action Group (SKAG), which aims to be a conduit between CCAMLR and the wider krill science community and to foster networking between early career and senior scientists. The SKAG online workshop was held in partnership with WWF and took

place from 26 to 30 April 2021. Around 100 participants from 19 countries identified key research areas to contribute to management of the krill fishery and assessed the capability in existing, and developing sampling methods to address these areas.

2.5 The Working Group thanked SKAG for its work. It highlighted that SKAG is exploring opportunities to further support collaborations between scientists and industry for data collection to close knowledge gaps in the identified key research areas.

2.6 WG-EMM-2021/23 presented a summary of the workshop sponsored by the Integrating Climate and Ecosystem Dynamics in the Southern Ocean program (ICED), held in May 2021, which was attended by approximately 80 scientists across every career stage. The workshop concluded with agreement that a road map is needed to address data and knowledge gaps across disciplines to improve krill modelling and support decision-making for conservation and management.

2.7 The Working Group noted the success of the workshop which will contribute to CCAMLR's work. The Working Group reflected that CCAMLR would benefit from more communication with the wider scientific community about its key research issues and management needs.

2.8 The Working Group considered the findings of WG-EMM-2021/09, an analysis of the effects of spatial scale on hotspot analysis of Antarctic krill (*Euphausia superba*) distribution, and WG-EMM-2021/32, an analysis of variability in the spatial–temporal distribution of krill by calculating the Moran's I value of krill density distribution at differing spatial scales.

2.9 The Working Group noted that the analyses found that an increase in spatial scale resulted in a non-linear decrease in hotspot frequency, and as the spatial scale coarsened on the Antarctic Peninsula, krill density became homogenised. The Working Group further noted the recommendations in the paper that a spatial scale of less than one degree should be used to identify the local spatial pattern for hotspot analyses of krill density for the Southern Ocean, and that a spatial scale of 15 minutes should be used for analysing the distribution of krill density on the Antarctic Peninsula.

2.10 The Working Group thanked the authors for examining the appropriateness of scale in analyses of krill dynamics using KRILLBASE data and noted the importance of spatial scale when analysing krill distribution. The Working Group noted that differences can occur in abundance between day and night, and differences in krill maturity between coastal and offshore regions. The Working Group further noted that the spatial scales of future analyses based on this database could consider both the objectives of such analyses, and the scales of the original data collection. The Working Group encouraged the authors to continue such analyses.

2.11 WG-EMM-2021/21 presented a preliminary evaluation of the evidence supporting fishery-driven localised depletion effects on the performance and demographic trends of pygoscelid penguins in Subarea 48.1. The authors raised several areas of concern about the analysis presented in WG-EMM-2019/11 and 2019/10, including spatial and seasonal differences in penguin distribution, temporal and spatial mismatches of predictor and response variables, the omission of the impact of interspecific competition and the appropriate consideration of climate variability and its impacts on the Peninsula. In the paper, the authors noted that a simple reconditioning of the model of WG-EMM-2019/11 to more accurately reflect known penguin migratory patterns produced counterintuitive results and cautioned on

using its outputs. The authors also highlighted that they could reproduce neither the original dataset nor analyses presented in WG-EMM-2019/10, and were therefore unable to conduct any form of sensitivity analyses. In light of their findings, the authors noted that the disagreement with the findings of these papers remains, and should be brought to the attention of the Scientific Committee and Commission.

2.12 The Working Group welcomed this contribution and recalled that in previous discussions of WG-EMM-2019/10 and 2019/11 it had noted that the exact temporal and spatial scale of the impact of the fishery on penguin populations is unknown (WG-EMM-2019, paragraph 4.41).

2.13 The Working Group also noted that fishing activities may impact penguin populations even during the winter season when the penguins utilise the area less, because there may be lagged effects of fishing activities and the high variability of the krill distribution and biomass. Krill fishing may also impact fledgling penguins, particularly during autumn and early winter. The Working Group further noted that WG-EMM-2021/21 estimated a non-trivial chance (1 in 2.7) that fishing alone can reduce predator performance below their long-term average.

2.14 Dr J. Hinke (USA) welcomed the review of the findings in WG-EMM-2019/11 and reiterated the confidence held by the paper's authors that the analysis had plausibly demonstrated the risks of spatially concentrated fishing on the performance of pygoscelid penguins. Dr Hinke further noted that the analyses in WG-EMM-2021/21 also supported these findings. He introduced several lines of evidence to question the three central modifications to the original model used in WG-EMM-2019/11 regarding the spatial scaling, the removal of winter performance indices from chinstrap (*Pygoscelis antarcticus*) and Adélie (*Pygoscelis adeliae*) penguins and the assignment of catches from March to either summer or winter. Despite disagreement over the underlying model assumptions, Dr Hinke recommended that the results of WG-EMM-2021/21 and WG-EMM-2019/11 be compared to allow the Commission the opportunity to decide the level of risk it is willing to take regarding krill fishing impacts on dependent predators and to account for the future risks to predators, especially as climate changes, when local harvest rates exceed about 10%.

2.15 Dr A. Lowther (Norway) highlighted that the evidence of chinstrap penguins being present in the model domain was acknowledged in WG-EMM-2021/21, but given that the evidence suggested these local non-breeding penguins remained within 500 km of their colony during winter, this represented a spatial area 20% larger than the entirety of Subarea 48.1, thus reducing the effects of localised fishing. Furthermore, he noted that if two alternate migratory strategies were persistent within chinstrap penguin populations, the ability to appropriately match performance indices (such as those collected under the CCAMLR Ecosystem Monitoring Program (CEMP)) to either of the strategies, and thus to overwinter harvesting pressure, would not be possible.

2.16 The Working Group noted the difficulties in distinguishing the natural and fishery-induced effects on the performance of penguins and the importance in gaining insights in the functional relationships between penguins and the fishery in the future.

2.17 The Working Group recommended that the authors of WG-EMM-2021/21, 2019/10 and 2019/11 continue to resolve the modelling and data issues, since analyses such as these, alongside the risk assessments (paragraphs 2.34 to 2.60) could provide a basis for advice to the Scientific Committee and Commission in future meetings.

2.18 WG-EMM-2021/33 outlined the development of the initial steps for the science-based management of krill in Subarea 48.1 and suggested to use: (i) the CCAMLR 2000 Krill Synoptic Survey of Area 48 or the 2019 International Area 48 Krill Survey as an option of initial spatial scale and biomass to start with, and (ii) the 2-year-olds to represent recruits, and (iii) the US AMLR survey strata as a basis to allocate the precautionary catch limit to spread the relative risk.

2.19 The Working Group noted the continued importance of scale in analyses and acknowledged that further discussions were required on the appropriate age class for recruitment, the scale of natural mortality and the development of a risk assessment, and agreed to continue this work in the relevant e-groups.

Krill fishery green-weight estimation

2.20 WG-EMM-2021/16 presented a review of krill green-weight estimation using parameters submitted by vessels in C1 data, from methods specified in Conservation Measure (CM) 21-03, Annex 21-03/B. The paper noted that there was generally a good relationship between reported parameters and estimated green weights with some notable exceptions, and that a wide range of conversion factor values were reported by vessels for estimation and processing method combinations.

2.21 The Working Group expressed some concern at the inconsistencies of historic data particularly for the vessels *Betanzos* and *Juvel* in the 2014 and 2015 seasons. The Working Group requested that Norway, with the help of the Secretariat, work on a method for correcting the *Juvel* historic data, possibly by comparing to conversion factors from subsequent years.

2.22 The Working Group supported the proposals in WG-EMM-2021/16 and recommended:

(i) the continued engagement by the Secretariat with Members to resolve existing historical issues in C1 data

(ii) that when issuing data extracts, data submitted by the vessels *Bentazos* and *Juvel* in the 2014 and 2015 seasons, the Secretariat should note that the estimated krill green weight cannot be independently verified using parameters supplied using the direct estimation fields for the FLOWMETER_1 method

(iii) the inclusion of a product weight field that relates to the product type and associated conversion factor in the new C1 form, as this would enable the comparison of product weights with krill green-weight estimation parameters

(iv) that the Scientific Committee designate krill conversion factors as a focus topic during the coming intersessional period, including a request that the Secretariat conduct a survey with Members on how krill conversion factors are calculated on vessels and report back to the next meeting of WG-EMM with relevant recommendations as necessary, as this may benefit the work of WG-EMM by increasing the understanding of krill biomass removals by the fishery.

WG-ASAM advice and consideration of WG-ASAM e-group acoustic survey summary table

2.23 WG-EMM-2021/05 Rev. 1 presented results from the Krill biomass estimates from acoustic surveys intersessional e-group. Krill biomass estimates from acoustic surveys in Subarea 48.1 were compiled and summarised with the aim of developing a method to provide estimates of krill biomass for use in the implementation of the revised krill management strategy.

2.24 The Working Group welcomed the large amount of work that had been conducted in a short time since the conclusion of WG-ASAM-2021. The Working Group noted the removal of data from surveys where there were incomplete records for density, CV or where there was reduced areal coverage. The Working Group also noted the need to combine data from slightly different data analysis methods and the need to only use data from summer surveys due to lack of sufficient data from other seasons. It further noted that for Subarea 48.1 the e-group had restricted its spatial scale to that of the US AMLR strata (Elephant Island (E), West (W), Joinville Island (J) and the Bransfield Strait (S)) and had not extrapolated its estimates to the whole of Subarea 48.1.

2.25 The Working Group noted that krill biomass data estimated using different analysis methods (krill identification) and data collection methods (day and night data, biological samples from different types of gear) were combined. It further noted that data from the historic time series and the 2019 Area 48 Survey produced similar estimates of krill biomass and density, supporting the approach outlined in the report. The Working Group also noted that the merit of the 2019 Area 48 Survey was that it covered a similarly large spatial scale in Subarea 48.1 as did the CCAMLR-2000 Survey. The Working Group noted the importance of additional analysis to clearly identify how the methodology of an acoustic survey affects its result. This will be important for maintaining long time series and subsequent acoustic surveys. The Working Group further identified the importance of long time series of surveys in addition to large multi-Member collaborations for detecting interannual variability and periodicity.

2.26 At the time of report adoption, Dr S. Kasatkina (Russia) noted that such analysis should be brought to the attention of WG-ASAM and the result be reported to the next meeting of WG-EMM.

2.27 The Working Group further noted the importance of the periodicity observed in the time series as the estimated average could change depending on the period of time from which data are averaged. It also noted that biomass periodicity should be accounted for in the duration for which future catch limits will be set.

2.28 The Working Group noted that for model-based estimates using models such as generalised additive mixed models (GAMMs) the along-track krill biomass density (g m^{-2}) per n mile values would be required. The Working Group recommended that WG-ASAM consider how to compile the higher-resolution krill biomass density estimates from all available surveys in their intersessional e-group.

2.29 The Working Group welcomed further work that will be undertaken by the Krill biomass estimates from acoustic surveys e-group, with results to be presented to WG-FSA-2021, and drew attention to the successful development of both scientific understanding and advice in CCAMLR e-groups.

WG-SAM advice: Parameterisation for GYM at scale of subareas
and advice on the application of the GYM to subareas

2.30 The Co-convener of WG-SAM-2021, Dr T. Okuda (Japan), reported on the discussions held regarding the parameterisation of the generalised R yield model (Grym). He noted that discussions were ongoing and would progress through the GYM/Grym assessment model development e-group that will investigate multiple parameter value combinations (WG-SAM-2021, paragraph 3.22). The e-group, coordinated by Mr D. Maschette (Australia), had defined terms of reference (WG-SAM-2021, paragraph 3.23) and will present its results to WG-FSA-2021. Dr Okuda noted that contributions of relevant data and suggestions for sensibility tests should be forwarded to the e-group by 30 July 2021.

2.31 The Working Group welcomed the collaborative approach outlined above and encouraged all interested participants to join this effort. The Working Group noted that using the current set of tentative parameter values presented in WG-SAM-2021/12 resulted in a Grym simulation that did not meet CCAMLR decision rule requirements even in a no-fishing scenario, highlighting the need for scenario and sensibility testing that will be addressed by the e-group (paragraph 2.30). Noting that the knowledge of krill population dynamics had improved since the existing decision rules were devised, it discussed the possibility of revising the decision rules in the future, but agreed that the establishment of realistic Grym parameter values was a priority.

2.32 Mr Maschette highlighted that there currently is disagreement in the e-group on parameter estimates for proportional recruitment and size at maturity. In order to move forward with the Grym simulations, these parameters would use the approved parameters from the WG-EMM-2010 assessment runs for the initial simulations (Table 1). Subsequent simulation runs would then include the alternate parameter estimates proposed by the GYM/Grym assessment model development e-group.

2.33 The Working Group agreed that this was a sensible way to progress this work towards WG-FSA-2021 and encouraged all Members to actively engage in the GYM/Grym assessment model development e-group. The e-group should also consider alternate length-weight relationships and selectivity of commercial gears.

WG-EMM advice on the details of the risk analysis for
Subarea 48.1, data layers, catch scenarios, updates

2.34 WG-EMM-2021/27 presented an application of the risk assessment framework, developed in WG-FSA-16/47 Rev. 1, to Subarea 48.1, with the aim of identifying the most appropriate management units by which to spatially and temporally distribute the catch limit for the commercial krill fishery. The Working Group considered the framework and the following contributions that detailed the data layers that were used when developing the risk assessment:

(i) WG-EMM-2021/26 – models of the seasonal (summer and winter) spatial distribution and density of krill across the northern Antarctic Peninsula region

(ii) WG-EMM-2021/28 – the use of seabird and whale distribution models to estimate spatial consumption of krill

(iii) WG-EMM-2021/29 – reports on the ongoing development of the data layers necessary to implement the risk assessment in Subareas 48.2 and 48.3

(iv) WG-EMM-2021/P06 – models of the distribution and density of procellariiform seabirds within the Northern Antarctic Peninsula region (Warwick-Evans et al., 2021).

2.35 The Working Group congratulated the authors on their considerable effort collating the data, modelling habitat use layers, and developing the risk assessment framework. It noted that the best available data had been used to develop the assessment at the time the work was conceived in 2018 (Workshop on Spatial Management).

2.36 The Working Group noted that the winter krill biomass distribution layer generated by the model (WG-EMM-2021/26) indicated much lower estimates of krill density for the Joinville Island stratum, and for the Bransfield Strait stratum, when compared to earlier studies (Reiss et al., 2017). The authors clarified that the winter krill biomass distribution model was generated using only four years of acoustic data and that interannual variability in krill abundance could have led the model to underestimate the krill biomass in these areas if the data were collected at a time when the krill biomass was at a cyclic low, relative to a longer-term average. The authors further noted that the years of these surveys, 2012–2016, were coincident with a period of relatively low biomass reported in WG-EMM-2021/05 Rev. 1. The Working Group recognised the need to check the winter krill distribution model in the Risk assessment framework e-group (paragraph 2.46).

2.37 The Working Group considered differences in the distribution of juvenile krill between winter and summer and reflected on whether protection of juvenile krill is required at this stage in the development of a management framework.

2.38 The Working Group considered the fish layer in the risk assessment which was included from WG-FSA-16/47 Rev. 1 based on data from Hill et al., 2007, the data for which were only available at small-scale management unit (SSMU) scale. The Working Group further recognised that given that fish account for significant krill consumption, new layers based on survey data will be needed in the future.

2.39 The Working Group noted that acoustic data have been collected in recent years by fishing vessels along transects nominated by WG-ASAM, including during the winter season. The Working Group requested that WG-ASAM prioritise further work related to the collection of acoustic data by fishing vessels during winter, as well as highlighting the importance of summer surveys that estimate krill biomass during the key predator breeding season.

2.40 The Working Group noted that other relevant acoustic data have been collected around the South Shetland Islands from 2013 to 2019 (WG-ASAM-2021/13), by the 2019 Area 48 Survey (SG-ASAM-2019/08 Rev. 1) and the 2020 RV *Atlantida* survey (WG-ASAM-2021/04 Rev. 1) with some as part of ongoing time series of krill surveys. The Working Group noted that these additional datasets could be included in the krill biomass distribution layers or used as validation datasets.

2.41 The Working Group further noted that the krill habitat model presented in WG-EMM-2021/26 included known spatial and temporal limitations as a result of the lack of available data, particularly during the winter season.

2.42 The Working Group noted that liaison with the fishing industry could improve opportunities to enhance the collection of certain data types.

2.43 The Working Group noted how risk spreads over different spatial scales and how the current spatial distribution of krill catches is the riskiest scenario of all. It also noted that the risk scenario based on the Domain 1 marine protected area (D1MPA) proposal, tabled at CCAMLR-39, implies a spatial allocation of krill catches offering a lower risk to predators while accounting for the desirability of the krill fishery at a spatial scale adequate for research and management purposes.

2.44 The Working Group encouraged Members to provide relevant data for the future development of the risk assessment, noting that other datasets are available, such as the D1MPA data and Myctobase (SC-CAMLR-39/BG/42). The Working Group noted that the D1MPA database is now uploaded to the CCAMLR MPA Information Repository (CMIR) platform and available for all Members to use, including during the development of the risk assessment for Subarea 48.2.

2.45 Dr Kasatkina welcomed the considerable efforts of the authors in developing the risk assessment framework for Subarea 48.1 and collecting available data layers (WG-EMM-2021/26–28, P06). Dr Kasatkina further noted that developing scenarios to spatially distribute the catch limit for the krill commercial fishery using the most appropriate management units assumed that the risk to predator populations affected by the krill fishery should be minimised. However, the available data layers only revealed the spatial overlap between the fishing grounds and foraging zones. Dr Kasatkina pointed out that she was not aware of the scientific evidence of the fishing impact on krill and krill-dependent predators through their trophic chains and competitive relationships that had been discussed in Scientific Committee meetings. Dr Kasatkina further noted that the risk analysis for Subarea 48.1 as well as for Subareas 48.2 and 48.3 requires development of scientifically based criteria to assess the possible ecosystem impact of krill fishing, taking into account the mixed effects of fishing, environmental variability (or climatic changes) and the competitive relationship between predator species. Dr Kasatkina recommended that for developing scenarios to spatially distribute the catch limit for the krill fishery in Subarea 48.1 it is advisable to clarify how possible it is under the current level of fishing, to reveal the impact of catch on krill and krill-dependent species.

2.46 The Working Group agreed that the risk assessment for Subarea 48.1 constitutes the best science currently available to CCAMLR. It agreed that the development of the risk assessment framework should be further progressed in an intersessional e-group to be led by Dr V. Warwick-Evans (UK), with results to be presented to WG-FSA-2021. In the limited time available until WG-FSA-2021, the e-group should address and consider the following:

(i) the progression of sensitivity and sensibility tests enabling assessment of the performance of the framework. Such tests may include the exclusion of selected data layers such as pelagic species, juvenile krill and central-place foragers to observe the simulation results and identify the key data layers and data gaps

(ii) the volume of work involved in these tests could be reduced by limiting the scenarios considered to the most promising ones across similar scenarios, and limiting the number and/or size of spatial scales to those in which fishery management measures could be reasonably implemented

(iii) evaluating the risk for a range of spatial and seasonal catch proportions, for example for the horizontal split scenario, across summer and winter and north and south, in addition to using the fishery desirability based on the fishery operations between 2013 and 2018 (WG-EMM-2021/27)

(iv) checking of the winter krill distribution model, and to the extent possible in the time available, also consider additional data for the summer krill model.

2.47 The Working Group recalled discussions on the possible impacts of spatial and temporal concentration of the krill fishery (WG-EMM-2019, paragraphs 2.6 to 2.8) and agreed that the results presented in WG-EMM-2021/27 supported the requirement for spatial and temporal management.

2.48 WG-EMM-2021/10 presented length distributions and biological indicators (weight, sex, maturity phases and nutrition indicators) of krill obtained during the Russian survey on board the *Atlantida* in January–March 2020.

2.49 The Working Group welcomed the analysis, indicating that this large amount of valuable data would be beneficial to the work undertaken in the GYM/Grym assessment model development e-group (paragraph 2.33), and encouraged the proponents to submit data to this e-group. The Working Group further noted that aggregating the data at a finer scale than presented (e.g. splitting the Bransfield Strait into north/south zones) could help document the different size compositions in the region. It recognised that single surveys provide a valuable snapshot of the krill population state whilst time series of surveys reveal a more complete picture of population dynamics.

2.50 The Working Group further welcomed the use of a statistical weighting method to reconstruct the krill length composition (as documented in WG-ASAM-2021/03). The Working Group recalled the need for standardised methodologies in the computation and weighting of length frequency distributions (e.g. WG-ASAM-2021, paragraphs 3.7 and 3.8).

2.51 WG-EMM-2021/12, 2021/17 and 2021/22 together presented the results of a survey conducted on board the *Atlantida* in 2020 reporting on the interaction between krill and the environment in Subareas 48.1 and 48.2.

2.52 The Working Group welcomed these results and highlighted the large amount of work conducted during this survey, noting that the survey was repeated after an interval of one month. The Working Group recognised that the evaluation of any fishery impact would require data to be collected over a longer time scale and encouraged the repetition of this survey in future years.

2.53 WG-EMM-2021/11 presented results of a krill flux study in Subarea 48.1 based on survey data collected during the *Atlantida* survey in 2020.

2.54 The Working Group welcomed this analysis and acknowledged the importance of flux to the understanding of krill distribution. It noted that in addition to geostrophic flow, Ekman transport and diel vertical migrations are of importance to krill transport. The Working Group noted that the paper discussed the contribution made by the Bellingshausen and Weddell Seas to the population in Subarea 48.1, and noted that until such contributions were adequately quantified, future management would need to make the precautionary assumption that the Subarea 48.1 krill biomass was independent of this input, to recognise this uncertainty. The

Working Group recalled the conclusion of WG-ASAM (WG-ASAM-2021, paragraph 4.3) that the endorsed krill management strategy could progress with a staged approach in which krill flux would be put aside at first. It also noted the importance of mesoscale eddies along the peninsula as well as the dynamic nature of the southern part of the Bransfield Strait (as illustrated by the more variable fluxes reported in these areas), compared to the more regular, linear eastward flow in the north of the Bransfield Strait. The Working Group agreed that its future work should include an international collaborative effort to elucidate these questions.

2.55 WG-EMM-2021/20 presented intra-season variations in distribution and abundance of humpback whales (*Megaptera novaeangliae*) in the western Antarctic Peninsula, using cruise vessels as opportunistic observation platforms.

2.56 The Working Group welcomed the study and noted that the absence of humpback whales in the months June and July may reflect the absence of data collection effort, rather than absence of whales themselves.

2.57 The Working Group noted that collaboration with the International Whaling Commission (IWC) regarding the design of the whale surveys, observation methods and approaches to analyses would generally improve confidence in the results from cetacean distance sampling studies being used to support CCAMLR management decisions. Such a collaboration, which would cover a range of topics, is currently being developed under a draft memorandum of understanding (MOU). Specifically, timely guidance from experts within the IWC on cetacean survey methods and analyses would be a clear and definable outcome from the MOU. The Working Group noted that CCAMLR and IWC have some common objectives and recalled the successful Joint CCAMLR–IWC Workshop in 2008 and previous discussions on future collaborations (SC-CAMLR-38, paragraph 3.43).

2.58 WG-EMM-2021/19 Rev. 1 presented an estimation of spatial overlap, including removals from the commercial krill fishery, humpback whales and pygoscelid penguins at three breeding sites in the Bransfield Strait, Subarea 48.1, using data from penguins instrumented during the 2018/19 fishing season.

2.59 The Working Group welcomed this work and noted that the study reported low spatial overlap between penguin foraging and the krill fishery during the breeding season. The Working Group noted that the analysis conducted in this study used only tracking data collected during the 2018/19 summer and emphasised the importance of data collection during the winter season.

2.60 The Working Group considered whether interference competition by humpback whales could disturb penguin foraging and might contribute to the observed decline of chinstrap penguins in Subarea 48.1 (Naveen et al., 2012; Sander et al., 2007), as krill biomass shows no declining trend according to US AMLR surveys (WG-EMM-2021/05 Rev. 1). The Working Group noted that collaboration with the IWC may help with addressing this research question.

Advice to the Scientific Committee on the review of CM 51-07

2.61 The Working Group recalled that during 9 of the past 11 years, the trigger level in Subarea 48.1 has been reached by the fishery, and that the subarea had been closed to directed fishing for krill before the end of the fishing season.

2.62 Although catches taken by the fishery currently represent less than 1% of the estimated total krill biomass in Area 48, the Working Group noted that the increased temporal and spatial concentration of the fishery, particularly within Subarea 48.1, may contribute to localised ecological effects.

2.63 The Working Group agreed that CM 51-07 has ensured precautionary management of the krill fishery, noted that the proportion of the trigger level distributed to Subarea 48.1 may have resulted in an appropriate threshold to balance between fishery desirability and reducing the risk for local krill-dependent predators, and that a spatial distribution of the catch limit at a finer scale than Area 48 is required to ensure this continues.

2.64 The Working Group agreed that enhanced spatial and temporal management, both between and within subareas, is an important part of a revised krill management approach. The Working Group considered that in Subarea 48.1, catch limits could be allocated to strata corresponding to the four US AMLR strata, with the remaining area in Subarea 48.1 divided into one or two additional strata and that such a scenario could be tested with the risk assessment.

2.65 The Working Group reflected that it had made significant progress this year in developing and parameterising the risk assessment modelling approach, following the progress made by WG-ASAM and WG-SAM on the other elements of the revised krill management approach.

2.66 The Working Group agreed that advice in respect of an appropriate subdivision of the precautionary catch limit within Subarea 48.1 can be generated this year, and further refined within one or two years. The Working Group noted that whilst considerable data has been collected for Subarea 48.1, far less data is available for Subareas 48.2, 48.3 and 48.4 and many areas lack winter information, therefore, development of management advice for these other subareas will take longer.

2.67 The Working Group recognised that areas with less data and less frequent survey information, and consequently greater uncertainty, should be approached with greater precaution with regard to management advice on catch limits, comparable to the CCAMLR research protocols used for development of toothfish assessments.

2.68 The Working Group noted the interannual variation and apparent periodicity evident in krill biomass estimates in Subarea 48.1 (WG-EMM-2021/05 Rev. 1) and that detection of such periodicity requires long time series of data. It noted that the length of time for which catch management limits are set, should account for such levels of periodicity.

Spatial management

Data analysis supporting spatial management approaches in CCAMLR

3.1 WG-EMM-2021/03 presented an analysis of the foraging behaviour of non-breeding Adélie penguins in the western Antarctic Peninsula during the breeding season, research supported by the Antarctic Wildlife Research Fund (AWR).

3.2 The Working Group welcomed the analysis, as it improved understanding about the behaviour of non-breeding penguins, a poorly documented portion (>15%) of the adult Adélie penguin population. The Working Group noted the observed migrations into the Weddell Sea and the authors' hypothesis about the movement (migration to sea-ice covered areas for moulting). It suggested further research into the feeding habits of such individuals as this could inform the management of the krill fishery, although it noted that collecting such data would be challenging given that non-breeding penguins may be less likely to return to a known location to enable dietary sampling. The Working Group further noted the need for observations of more colonies, over longer time scales and including juveniles, in order to increase the representativeness of such analyses.

3.3 WG-EMM-2021/13 presented an analysis of the functional responses of penguins and their use in developing better monitoring indices for adaptive management of the krill fishery.

3.4 The Working Group welcomed this analysis using modern technologies, such as accelerometers, which brings new insights into functional responses, and enables their evaluation for potential use within the management of the krill fishery. It noted that future research plans included the additional use of cameras to enable the calibration of these responses in light of the prey field, as well as the future assessment of the potential effect of the fishery on these responses. The Working Group noted that the use of new technologies underscored the need for a review of the CEMP standard monitoring methods, recalling this had been highlighted in the past (e.g. WG-EMM-2018, paragraphs 4.34 to 4.39).

3.5 WG-EMM-2021/34 presented cetacean observations collected on board a krill fishing vessel near the South Orkney Islands during the austral summer of 2020/21.

3.6 The Working Group welcomed these observations and noted that such data collection from fishing vessels will be an important part of the future krill management strategy. It noted that linking these observations to the congruent CCAMLR Scheme of International Scientific Observation (SISO) data (e.g. krill size composition) would be valuable.

3.7 WG-EMM-2021/18 presented a summary report of progress on spatial layers to support the development of the Weddell Sea MPA Phase 2.

3.8 The Working Group welcomed this report and noted the large amount of work that led to this summary. In particular, the Working Group noted the development of a particle tracking framework and its relevance to the management of the krill fishery, given the importance of krill transport between areas. The Working Group welcomed the proponents' consideration of areas beyond that of the proposed MPA and the relevance of their approach to the establishment of a representative network of MPAs around the continent. The Working Group noted the potential improvement of the species distribution models that could be brought by considering other environmental variables that may better reflect the habitat niche of the species in question. The Working Group noted that consideration be given to including Gunnerus Ridge in further spatial analysis.

3.9 Dr X. Zhao (China) noted that some conservation objectives outlined in the summary report were aiming to protect fishery target species that have been managed and conserved by the Commission through existing conservation measures.

3.10 WG-EMM-2021/30 presented evidence supporting the current designation of a newly exposed marine area adjacent to Pine Island Glacier (Subarea 88.3) as a Stage 1 Special Area for Scientific Study under CM 24-04.

3.11 The Working Group welcomed this timely designation given the rapid changes observed in the area and suggested that a summary of relevant research plans for the planned *Polarstern* cruise in 2022/23 could be informative for the Scientific Committee; however, it recognised that such information was not required by CM 24-04.

Research and monitoring plans

3.12 WG-EMM-2021/04 presented a workshop report on the US research and monitoring in support of the Ross Sea region MPA (RSRMPA).

3.13 The Working Group noted the large list of projects and research papers presented and suggested the authors make a bibliographical database and possibly a map indicating the researched areas available via the CMIR website.

3.14 The Working Group recalled the relevance of the recently held Southern Ocean – UN Decade of Ocean Science for Sustainable Development workshop held in San Diego, USA (16 February 2021) to international collaboration on research in the vast area covered by the Ross Sea region. It noted the authors' intent to expand the geographical scope of monitoring via international collaborations and the use of new technologies (e.g. remote sensing, animal-borne technologies).

3.15 WG-EMM-2021/P04, 2021/14 and 2021/15 together presented a synopsis of New Zealand's 2020/21 contributions to the research and monitoring plan (RMP) in the Ross Sea region in support of the RSRMPA. The papers covered topics such as benthic biodiversity, demersal fish stock structure, trends in primary productivity and a report from the 2021 survey of the Victoria Land coast. WG-EMM-2021/14 showed that relevant New Zealand research has spanned almost all objectives of the RSRMPA. The detail of this research will be uploaded to the CMIR and the authors noted that international collaboration in synthesising the research would be valuable.

3.16 The Working Group welcomed the multi-Member nature of the research presented and its relevance to the MPA objectives. It noted continuing collaborations such as a moored acoustic monitoring system to study silverfish in Terra Nova Bay, a planned multidisciplinary research voyage to continue study of latitudinal trends in plankton productivity, research efforts on Antarctic toothfish (*Dissostichus mawsoni*) early life history, and analyses of biodiversity data from inside and outside the MPA stemming from the International Polar Year in 2008, to improve understanding on sea-ice effects on productivity in a range of ecoregions and on trophic web structure. The Working Group recommended that the CMIR is made accessible to researchers to enable knowledge sharing and collaboration.

3.17 WG-EMM-2021/01 presented an analysis of the diet of Adélie and emperor penguins (*Aptenodytes forsteri*) considering the regional differences in the Ross Sea region.

3.18 The Working Group welcomed this analysis and noted that in other locations, documented variability in emperor penguin diets through seasons and breeding stages was indicative of opportunistic behaviour. It encouraged the continuation and expansion of this work to increase its representativeness and develop time series.

3.19 WG-EMM-2021/02 presented a molecular diet analysis of Adélie penguins in the Ross Sea using fecal DNAs.

3.20 The Working Group noted the relevance of this research which could be replicated in other areas to inform the management of the krill fishery and suggested that efforts be put towards linking the estimated proportions of prey consumed to actual consumed mass, recognising this would be beneficial. The Working Group noted the need for large sample sizes in such research, standardisation of methodologies across Members to enable cross-comparisons, as well as the changes in feeding habits observed through space and time. It also noted that stomach content analyses would enrich these results and help explain the reported presence of benthic fish DNA.

3.21 WG-EMM-2021/P01 presented an analysis of acoustic detection of krill scattering layers in the Terra Nova Bay polynya.

3.22 The Working Group welcomed this research, encouraged its continuation, and suggested it be submitted to WG-ASAM given its reliance on acoustic methodologies. It noted the reported acoustic signals at depths below 250 m, as was reported in the same region in 2004/05 (Taki et al., 2008) and hypothesised this could be indicative of the importance of the benthic habitat to krill in this area.

3.23 The Working Group thanked the Republic of Korea for its contributions to the research supporting evaluation of RSRMPA objectives. It congratulated Korean scientists on the five-year extension to Korean research efforts in the region.

3.24 The Working Group recalled that Members should submit a report on their activities related to the RSRMPA RMP early next year under CM 91-05, paragraph 15. The Working Group requested the Secretariat to assist Members with the production of standardised reports and graphics for this purpose, utilising the CMIR database.

3.25 The Working Group encouraged the authors to continue identifying knowledge gaps and future work, relating those gaps to the zones and geographical areas within the RSRMPA and to relevant performance indicators.

3.26 The Working Group also noted that work related to the Ross Sea region and other MPAs represented a body of research that could benefit from collective publication in a special journal issue to expand CCAMLR's outreach and highlight the science conducted within the MPA. It also noted that relevant special issues are currently in progress (e.g. a special issue of *Diversity* (ISSN 1424-2818) with a deadline for manuscript submissions of 31 December 2021 on 'Biodiversity of the Ross Sea Region Marine Protected Area (Antarctica)').

3.27 WG-EMM-2021/06 presented preliminary results on the density and distribution of euphausiid larvae in the Bransfield Strait including Gerlache Strait and South Shetland Islands surroundings during the summers of 2017–2020.

3.28 The Working Group welcomed this contribution and noted its importance to the understanding of krill population dynamics and encouraged Argentinian colleagues to continue their work in the future.

3.29 WG-EMM-2021/24 presented a report on CEMP on Ardley Island.

3.30 The Working Group welcomed this monitoring effort on an island that represents one of the main hotspots of human activity around Antarctica. It encouraged continuation of these efforts and suggested the use of automated data collection systems (e.g. trap cameras) to enhance the stream of information from this site.

Climate change

4.1 WG-EMM-2021/P07 presented an analysis utilising the United Nations' Intergovernmental Panel on Climate Change (IPCC) assessments to support the ecosystem approach to fisheries management within a warming Southern Ocean. The paper highlighted the risks to species and ecosystems within the Convention Area and the consequential management challenges that may arise from climate change effects. The paper provides recommendations to CCAMLR with respect to addressing climate change impacts and the need for precautionary management, emphasising the need to reduce and manage the risks that climate change presents.

4.2 The Working Group thanked the authors for their presentation of the study and noted that much of the work being progressed by the Scientific Committee and its working groups is already considering potential climate change signals in data and analyses. It acknowledged the importance of this work, noting that improved mechanisms to better coordinate, target and integrate research on the effects of climate change into CCAMLR's work would be valuable. The Working Group further noted that whilst responding to observed climate change effects was a short-term management strategy, in order to ensure that management is responsive to future change, medium- and longer-term management actions in advance of projected climate change impacts on harvested species and the ecosystem will need to be considered by the Scientific Committee.

4.3 WG-EMM-2021/31 presented an analysis indicating that sympatric species respond differently to environmental changes. Both Adélie and chinstrap penguins breed earlier in warmer years, both at the individual colony and species levels, and have shown a population decline over the approximately 10 years of the study. Gentoo penguins (*Pygoscelis papua*) have stable or increasing populations and commence breeding during a much larger window, indicating less sensitivity to temperature.

4.4 The Working Group noted that temperature may affect the phenology of higher predators. This study was an example of a medium-term time series generated using remote camera equipment, and the Working Group encouraged its continuation to provide a long-term monitoring time series.

4.5 WG-EMM-2021/P02 presented analyses of recent trends in phytoplankton biomass, primary production and irradiance within the mixed layer (as a proxy for primary production in the deep chlorophyll maximum) in the Southern Ocean, and summarised projections of primary

productivity patterns spatially, noting that differences between carbon-based and chlorophyll-based projections may be due to changes in the species composition of phytoplankton through time.

4.6 The Working Group noted the importance of monitoring phytoplankton biomass, phytoplankton community structure and primary production at a circumpolar scale, its use in providing comparisons with regional studies, and the availability of spatial primary production data through the University of Oregon available for use by researchers.

4.7 The Working Group further noted the potential for fishing vessels to collect localised phytoplankton data with a focus on phytoplankton community composition, to ground-truth productivity models, and that some Members had initiated research programs to do this.

4.8 The Working Group recommended the creation of an e-group to define standard protocols for the collection of phytoplankton data from fishing vessels for this purpose and considered that a collaboration with the Association of Responsible Krill harvesting companies (ARK) at a planned workshop next year may progress a more systematic approach to phytoplankton data collection.

4.9 WG-EMM-2021/P03 presented a methodology and an analysis to estimate variability and long-term change in sea-ice primary productivity using a satellite-based light penetration index.

4.10 The Working Group welcomed the publication of the sea-ice productivity index and noted that these data were available to the wider CCAMLR scientific community.

Other business

5.1 WG-EMM-2021/25 presented an update on the activities of the SCAR Antarctic Biodiversity Portal (https://www.biodiversity.aq) relevant to CCAMLR.

5.2 WG-EMM-2021/P05 presented a risk assessment of SARS-CoV-2 in Antarctic wildlife.

5.3 WG-EMM-2021/35 presented a parasitological study of fish specimens collected by a krill fishing vessel in Subarea 48.1.

5.4 The Working Group welcomed the contributions to this agenda item and invited interested Members to contact the authors directly as there was not sufficient time to discuss these papers in plenary (see paragraph 5.5).

5.5 The Working Group noted that the duration of the meeting was reduced to one week at the request of one Member, while all other Members supported the usual two-week meeting duration. The Working Group noted that the meeting agenda was shortened and that in response to the reduced time available, Members had limited the number of papers submitted and both the frequency and the length of their interventions and presentations. The Working Group recognised that while many agenda items would have benefitted from longer discussions, progress has been made in good spirit and in good cooperation.

5.6 The Working Group noted that the online meetings of WG-ASAM, WG-SAM and WG-EMM had similar starting times and recommended that planning for online meetings should consider more diversified starting times to ensure that the burden of meeting outside normal office hours is shared equitably.

Advice to the Scientific Committee and future work

Future work

6.1 The Working Group requested that the Scientific Committee consider the following potential future tasks for WG-EMM related to krill fishery management:

(i) convene a krill workshop on population hypotheses taking into account circumpolar and regional advection of krill

(ii) continue the development of the risk assessment for Subarea 48.1 and for other subareas, including:

  (a) the introduction of new data, such as additional acoustic survey data and data from summer and winter periods, as they become available

  (b) the further development of habitat models, including for fish

  (c) the incorporation of changes in trophic interactions

  (d) the consideration of MPAs as independent risk assessment scenarios

(iii) encourage Members to increase data collected in winter, spring and autumn for Area 48, as these data can be used in future risk assessment development and to inform Grym parameters

(iv) undertake cross-working-group collaborations on Grym parameter values and on the establishment of a standard protocol for the reconstruction of krill length composition for proportional recruitment calculation

(v) enhance collaboration with other groups (SKAG, Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED), IWC, Southern Ocean Observing System (SOOS)), for instance through invitation to the CCAMLR workshop (paragraph 6.1i)

(vi) develop methods to assess ecosystem impacts of krill fishing

(vii) further work on green-weight estimation through collaboration between Norway and the Secretariat.

6.2 The Working Group requested that the Scientific Committee comment on these issues and how they relate to other priorities for the Working Group.

6.3 The Working Group noted that the Scientific Committee would review Members' reports on activities related to the RSRMPA RMP next year under CM 91-05, paragraph 15, and suggested that the Scientific Committee consider this as a task for WG-EMM in 2022.

6.4 The Working Group recalled the five-year work plan for the Scientific Committee (SC-CAMLR-XXXVI/BG/40) and suggested this be reviewed by the Scientific Committee to incorporate outstanding relevant tasks.

Advice to the Scientific Committee

6.5 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) green-weight focus topic (paragraph 2.22)
(ii) risk assessment in Subarea 48.1 (paragraph 2.46)
(iii) spatial and temporal concentration of the kill fishery (paragraph 2.47)
(iv) advice on the review of CM 51-07 (paragraphs 2.61 to 2.68)
(v) starting times of virtual meetings (paragraph 5.6)
(iv) RMP reporting (paragraph 6.3).

Adoption of the report

7.1 The report of the meeting was adopted.

7.2 At the close of the meeting, Dr Cárdenas thanked all the participants for their hard work and collaboration that had contributed greatly to the successful outcomes from WG-EMM this year, and to the Secretariat, the stenographers and Interprefy staff for their support. Dr Cárdenas further noted that although the length of the meeting had been shorter than an in-person event, a large body of work had been accomplished through the e-groups and a considerable future workplan developed for WG-EMM.

7.3 On behalf of the Working Group, Dr C. Darby (UK) thanked Dr Cárdenas for his guidance during this foreshortened meeting, the Secretariat for their work compiling the report, and the technical support provided by the Interprefy team. The Working Group acknowledged the successful use of the Interprefy platform for hosting the meeting, and the provision of official advice to the Scientific Committee.

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Table 1: Grym parameters and their values based on e-group discussions for initial krill simulation. Where agreement on parameters has not been reached (e.g. proportional recruitment), values used in initial simulation will be the WG-EMM-2010 model run parameters, with alternate values tested in additional model runs. Note that natural mortality is calculated within the model as a function of proportional recruitment and is included in this table to provide an expected range for comparing to those calculated for different proportional recruitment values.

Parameter	Subarea 48.1	Reference
First age class	1	WG-SAM-2021/12
Last age class	7	Constable and de la Mare (1996)
t_0	0	Constable and de la Mare (1996)
L_∞	60 mm	Constable and de la Mare (1996)
k	0.48	WG-SAM-2021/12
Start growth period (dd/mm)	21/10	WG-SAM-2021/12
End growth period (dd/mm)	12/02	WG-SAM-2021/12
Weight-length parameter – A (g)	2.236×10^{-6}	SC-CAMLR (2000)
Weight-length parameter – B	3.314	SC-CAMLR (2000)
Min length, 50% mature	32 mm	SC-CAMLR (2010)
Max length, 50% mature	37 mm	SC-CAMLR (2010)
Range over which maturity occurs	6 mm	WG-SAM-2021/12
Start of spawning season (dd/mm)	15/12	Kawaguchi (2016)
End of spawning season (dd/mm)	15/02	Kawaguchi (2016)
Monitoring interval (dd/mm)	01/01 to 15/01	WG-SAM-2021/12
Recruitment function	*Proportional*	
Mean proportional recruitment	0.557	SC-CAMLR (2010)
SD of proportional recruitment	0.126	SC-CAMLR (2010)
Natural Mortality range	0.5–1.1	Pakhomov (1995)
Min length, 50% selected	30 mm	WG-SAM-2021/12
Max length, 50% selected	35 mm	WG-SAM-2021/12
Range over which selection occurs	11 mm	WG-SAM-2021/12
Fishing season (dd/mm)	01/12 to 30/11	WG-SAM-2021/12
Reference date (dd/mm)	01/10	WG-SAM-2021/12
Reasonable upper bound for annual F	1.5	Constable and de la Mare (1996)
B_0logSD	0.361	WG-SAM-2021/21 Rev. 1
Target escapement	75%	Constable and de la Mare (1996)

Appendix A

List of Registered Participants

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(Virtual meeting, 5 to 9 July 2021)

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Appendix B

Agenda

Working Group on Ecosystem Monitoring and Management
(Virtual meeting, 5 to 9 July 2021)

1. Opening of the meeting

2. Krill management

    2.1 Krill fishery status
    2.2 WG-ASAM advice and consideration of WG-ASAM e-group acoustic survey summary table
    2.3 WG-SAM advice: Parameterisation for GYM at scale of subareas and advice on the application of the GYM to subareas
    2.4 WG-EMM advice on the details of the risk analysis for Subarea 48.1, data layers, catch scenarios, updates
    2.5 Advice to the Scientific Committee on the review of CM 51-07

3. Spatial management

    3.1 Data analysis supporting spatial management approaches in CCAMLR
    3.2 Research and monitoring plans
    3.3 VME data

4. Climate change

5. Other business

6. Advice to the Scientific Committee and future work

7. Adoption of the report.

Appendix C

List of Documents

Working Group on Ecosystem Monitoring and Management
(Virtual Meeting, 5 to 9 July 2021)

WG-EMM-2021/01	Diet of Adélie penguin and emperor penguin given the regional differences in the Ross Sea region, Antarctica S.-Y. Hong, J.-K. Gal, B. Lee, W. Son, J.-W. Jung, H.S. La, K.-H. Shin, J.-H. Kim and S.-Y. Ha
WG-EMM-2021/02	Molecular diet analysis of *Pygoscelis adeliae* in the Ross Sea using fecal DNAs N. Tabassum, J.-H. Lee, J.-H. Kim, H. Park and H.-W. Kim
WG-EMM-2021/03	The foraging behaviour of nonbreeding Adélie penguins in the western Antarctic Peninsula during the breeding season W.C. Oosthuizen, P.A. Pistorius, M. Korczak-Abshire, J.T. Hinke, M. Santos and A.D. Lowther
WG-EMM-2021/04	Workshop report and synthesis: United States research and monitoring in support of the Ross Sea region Marine Protected Area D. Ainley and C. Brooks
WG-EMM-2021/05 Rev. 1	Results from the WG-ASAM intersessional e-group on Krill biomass estimates from acoustic surveys WG-ASAM e-group on Krill biomass estimates from acoustic surveys
WG-EMM-2021/06	Preliminary results of the density and distribution of krill larvae in the Mar de la Flota (Bransfield Strait) including Gerlache Strait and South Shetland surroundings during summer 2017–2020 E. Rombolá, M. Sierra, B. Meyer and E. Marschoff
WG-EMM-2021/07	An overview of the ecosystem survey to quantify krill abundance for krill monitoring and management in Eastern Sector of CCAMLR Division 58.4.2: Trends in Euphausiids off Mawson, Predators, and Oceanography “TEMPO” N. Kelly, S. Bestley, A. Burns, L. Clarke, K. Collins, M. Cox, D. Hamer, R. King, J. Kitchener, G. Macaulay, D. Maschette, J. Melvin, B. Miller, A. Smith, L. Suter, K. Westwood, S. Wotherspoon and S. Kawaguchi

WG-EMM-2021/08	Annual report of the SCAR Krill Action Group (SKAG) 2021 B. Meyer, J. Arata, A. Atkinson, C. Cárdenas, R. Cavanagh, M. Collins, J. Conroy, C. Darby, T. Dornan, R. Driscoll, S. Fielding, S. Grant, S. Hill, J. Hinke, S. Kawaguchi, S. Kasatkina, D. Kinzey, T. Knutsen, B. Krafft, L. Krüger, A. Lowther, E. Murphy, F. Perry, C. Reiss, E. Rombolá, F. Santa Cruz, M. Santos, F. Schaafsma, A. Sytov, P. Trathan, A. Van de Putte and G. Watters
WG-EMM-2021/09	Effect of spatial scale on hotspot analysis of Antarctic krill (*Euphausia superba*) distribution G.P. Zhu and H. Liu
WG-EMM-2021/10	Krill biology and size composition in Subarea 48.1 and 48.2 based on the RV *Atlantida* survey in 2020 A. Sytov and D. Kozlov
WG-EMM-2021/11	Results of krill flux study in Subarea 48.1 based on RV *Atlántida* survey in 2020 V. Shnar, S. Kasatkina, A. Abramov and D. Shurin
WG-EMM-2021/12	Krill distribution and environment in Subareas 48.1 and 48.2 from results of the RV *Atlántida* cruise in 2020 S. Kasatkina, V. Shrar, A. Abramov, M. Sokolov, D. Shurin, A. Sytov and D. Kozlov
WG-EMM-2021/13	Functional responses of penguins: building towards better monitoring indices for adaptive management of the Antarctic krill fishery C. Oosthuizen, P. Pistorius, A. Makhado and A. Lowther
WG-EMM-2021/14	New Zealand research and monitoring in the Ross Sea region in support of the Ross Sea region Marine Protected Area: 2021 update M.H. Pinkerton
WG-EMM-2021/15	Ross Sea Life in a Changing Climate (ReLiCC) 2021 Voyage, 4 January – 17 February 2021 R. O'Driscoll, A. Pallentin, A. Gutierrez Rodriguez, K. Safi, C. Law, C. Chin, P. Escobar-Flores, Y. Ladroit, P. Marriott, M. Gall, S. George, S. Seabrook, M. Druce, V. Cummings and M. Pinkerton
WG-EMM-2021/16	A review of krill green-weight estimation using parameters submitted by vessels in C1 data, from methods specified in CM 21-03, Annex B CCAMLR Secretariat

WG-EMM-2021/17	Observations of birds and mammals in Subareas 48.1 and 48.2 provided by the Russian RV *Atlantida* during January–March 2020: species composition and abundance I. Trufanova, S. Kasatkina and M. Sokolov
WG-EMM-2021/18	Summary report of progress on spatial layers to support the development of the Weddell Sea MPA Phase 2 G.P. Griffith, B. Merkel, T. Hattermann, J. Aarflot, H. Kauko, A. Skoglund, C. vonQuillfeldt, A. Høgestøl, B. Njåstad and B.A. Krafft with contributions from the participants at the International Scientific Workshop (digital) 10–12 May 2021
WG-EMM-2021/19 Rev. 1	The commercial fishery and pygoscelid penguins at three breeding sites in the Bransfield Strait, Subarea 48.1 A. Lowther, H. Ahonen, C. Cárdenas, W. Jouanneau, B. Krafft, L. Krüger, A. Makkhado, A. Narvestad and C. Oosthuizen
WG-EMM-2021/20	Intra-season variations in distribution and abundance of humpback whales in the West Antarctic Peninsula using cruise vessels as opportunistic platforms E. Johannessen, M. Biuw, U. Lindstrøm, V. Ollus, L. Lopez, K. Gkikopoulou, C. Oosthuizen and A. Lowther
WG-EMM-2021/21	A preliminary evaluation of the evidence supporting fishery-driven localised depletion effects on the performance and demographic trends of pygoscelid penguins in Subarea 48.1 A. Lowther, M. Biuw, U. Lindstrøm and B. Krafft
WG-EMM-2021/22	Phytoplankton and zooplankton in Subareas 48.1 and 48.2 in January–March 2020 S.V. Aleksandrov, N.P. Dyushkov, S.N. Arkhipovsky and A.S. Semenova
WG-EMM-2021/23	Using models to improve our understanding of Antarctic krill and their ecological role: Report of the Integrating Climate and Ecosystem Dynamics of the Southern Ocean (ICED) workshop, 2021 Z. Sylvester, D. Veytia, A. Bahl, D. Bahlburg, E. Murphy, N. Johnston, S. Corney, C. Brooks, B. Meyer, E. Hofmann and S. Thorpe
WG-EMM-2021/24	CCAMLR Ecosystem Monitoring Program on Ardley Island A.L. Machado, M. Santos, L. Emmerson and A. Soutullo
WG-EMM-2021/25	Update on the activities SCAR Antarctic Biodiversity Portal A.P. Van de Putte, M. Sweetlove and Y.M. Gan

WG-EMM-2021/26	Estimating the average distribution of Antarctic krill at the northern Antarctic Peninsula V. Warwick-Evans, S. Fielding, C.S. Reiss, G.M. Watters and P.N. Trathan
WG-EMM-2021/27	Using the Risk Assessment Framework to spread the catch limit in Subarea 48.1 V. Warwick-Evans, L. Dalla Rosa, J.T. Hinke, N. Kelly, C. Reiss, E.R. Secchi, E. Seyboth, G.M. Watters, D. Welsford and P.N. Trathan
WG-EMM-2021/28	Using seabird and whale distribution models to estimate spatial consumption of Antarctic krill to inform fishery management V. Warwick-Evans, N. Kelly, L. Dalla Rosa, A. Friedlaender, J.T. Hinke, J.H. Kim, N. Kokubun, J.A. Santora, E.R. Secchi, E. Seyboth and P.N. Trathan
WG-EMM-2021/29	Towards a risk assessment for Subareas 48.2 and 48.3 V. Warwick-Evans, F. Perry, S. Fielding and P.N. Trathan
WG-EMM-2021/30	Designation of a newly exposed marine area adjacent to Pine Island Glacier (Subarea 88.3) as a Stage 1 Special Area for Scientific Study S.M. Grant, P.N. Trathan and L. Ireland
WG-EMM-2021/31	Sympatric species respond differently to environmental change I.J. Martinez, A. Kacelnik, F. Jones, M. Dunn and T. Hart
WG-EMM-2021/32	Characteristic spatial scale of distribution for Antarctic krill (*Euphausia superba*) density in the Antarctic Peninsula G.P. Zhu and H. Liu
WG-EMM-2021/33	A simple first step towards a science-based krill management for Subarea 48.1 X. Zhao, X. Wang, G. Fan and Y. Ying
WG-EMM-2021/34	Cetacean observations onboard krill fishing vessel near the Southern Orkney islands during Australian summer 2020/21 K. Vishnyakova and J. Ivanchikova
WG-EMM-2021/35	Parasitological monitoring of the fish species in the CCAMLR Area 48 T. Kuzmina, K. Vishnyakova and J. Ivanchikova

Other Documents

WG-EMM-2021/P01	Acoustic detection of krill scattering layer in the Terra Nova Bay Polynya, Antarctica M. Kang, R. Fajaryanti, W. Son, J.-H. Kim and H.S. La *Front. Mar. Sci.*, 7:584550 (2020): doi: 10.3389/fmars.2020.584550
WG-EMM-2021/P02	Evidence for the impact of climate change on primary producers in the Southern Ocean M. Pinkerton, P. Boyd, S. Deppeler, A. Hayward, J. Höfer and S. Moreau *Ocean. Front. Ecol. Evol*., 9:592027 (2021): doi: 10.3389/fevo.2021.592027
WG-EMM-2021/P03	Estimating variability and long-term change in sea ice primary productivity using a satellite-based light penetration index M. Pinkerton and A. Hayward *J. Mar. Sys*., 221:103576 (2021): doi: https://doi.org/10.1016/j.jmarsys.2021.103576
WG-EMM-2021/P04	Ross Sea benthic ecosystems: macro- and mega-faunal community patterns from a multi-environment survey V.J. Cummings, D.A. Bowden, M.H. Pinkerton, N.J. Halliday and J.E. Hewitt *Front. Mar. Sci*., 8:629787 (2021) : doi: 10.3389/fmars.2021.629787
WG-EMM-2021/P05	Risk assessment of SARS-CoV-2 in Antarctic wildlife A. Barbosa, A. Varsani, V. Morandini, W. Grimaldi, R.E.T. Vanstreels, J.I. Diaz, T. Boulinier, M. Dewar, D. González-Acuña, R. Gray, C.R. McMahon, G. Miller, M. Power, A. Gamble and M. Wille *Science of the Total Environment*, 755:143352 (2021): doi: https://doi.org/10.1016/j.scitotenv.2020.143352
WG-EMM-2021/P06	Multi-scale assessment of distribution and density of procellariiform seabirds within the Northern Antarctic Peninsula marine ecosystem V. Warwick-Evans, J.A. Santora, J.J. Waggitt amd P.N. Trathan *ICES J. Mar. Sci*. (2021): doi:10.1093/icesjms/fsab020
WG-EMM-2021/P07	Utilising IPCC assessments to support the ecosystem approach to fisheries management within a warming Southern Ocean R.D. Cavanagh, P.N. Trathan, S.L. Hill, J. Melbourne-Thomas, M.P. Meredith, P. Hollyman, B.A. Krafft, M.M.C. Muelbert, E.J. Murphy, M. Sommerkorn, J. Turner and S.M. Grant *Marine Policy*, 131 (2021): doi: https://doi.org/10.1016/j.marpol.2021.104589