

**SCIENTIFIC COMMITTEE FOR THE CONSERVATION
OF ANTARCTIC MARINE LIVING RESOURCES**

**REPORT OF THE FORTIETH MEETING
OF THE SCIENTIFIC COMMITTEE**

VIRTUAL MEETING
11 – 15 OCTOBER 2021

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Chair of the Scientific Committee
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Abstract

This document presents the adopted report of the Fortieth Meeting of the Scientific Committee for the Conservation of Antarctic Marine Living Resources held online from 11 to 15 October 2021.

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**Report of the Fortieth
Meeting of the Scientific Committee**
(Virtual meeting, 11 to 15 October 2021)

Opening of the meeting

1.1 The Scientific Committee for the Conservation of Antarctic Marine Living Resources (SC-CAMLR) met from 11 to 15 October 2021 online. The meeting was chaired by Dr D. Welsford (Australia).

1.2 Dr Welsford welcomed to the meeting representatives from Argentina, Australia, Belgium, Brazil, Chile, People's Republic of China (China), European Union (EU), France, Germany, India, Italy, Japan, Republic of Korea (Korea), The Kingdom of the Netherlands (The Netherlands), New Zealand, Norway, Poland, Russian Federation (Russia), South Africa, Spain, Sweden, Ukraine, United Kingdom of Great Britain and Northern Ireland (UK), United States of America (USA) and Uruguay.

1.3 Other Contracting Parties, Bulgaria, Canada, Cook Islands, Finland, Greece, Mauritius, Islamic Republic of Pakistan, Republic of Panama, Peru and Vanuatu were invited to attend the meeting as Observers. Canada and Cook Islands attended. Ecuador, Thailand and Turkey were also invited as Non-Contracting Parties (NCPs) and attended the meeting.

1.4 Dr Welsford also welcomed to the meeting Observers from intergovernmental organisations – the Agreement on the Conservation of Albatrosses and Petrels (ACAP), the Committee on Environmental Protection (CEP), the International Union for the Conservation of Nature and Natural Resources – the World Conservation Union (IUCN), the Scientific Committee on Antarctic Research (SCAR), the Scientific Committee on Oceanic Research (SCOR), the South Pacific Regional Fisheries Management Organisation (SPRFMO), and non-governmental organisations – the Association of Responsible Krill harvesting companies (ARK), the Antarctic and Southern Ocean Coalition (ASOC), the Coalition of Legal Toothfish Operators (COLTO) and Oceanites Inc.

1.5 The List of Participants is given in Annex 1. The List of Documents considered during the meeting is given in Annex 2.

1.6 The report of the Scientific Committee was prepared by the Secretariat and the Scientific Committee Chair. While all parts of this report provide important information for the Commission, paragraphs of the report summarising the Scientific Committee's advice to the Commission have been highlighted. Contributed statements are indicated in italics.

1.7 Due to time constraints, the report could not be adopted in full (paragraph 12.1). All non-adopted paragraphs are indicated by inclusion in square brackets.

Adoption of the agenda

1.8 The meeting's provisional agenda was discussed, and the Scientific Committee adopted the proposed agenda (Annex 3).

Chair's report

1.9 Dr Welsford noted the Scientific Committee's work in the 2020/21 intersessional period, successfully undertaken online. The following online meetings had taken place:

- (i) Working Group on Acoustic Survey and Analysis Methods (WG-ASAM), 31 May to 4 June 2021 (Annex 4). Convened by Dr S. Fielding (UK) and Dr X. Wang (China) and attended by 46 participants from 11 Members with 16 papers considered
- (ii) Working Group on Statistics, Assessments and Modelling (WG-SAM), 28 June to 2 July 2021 (Annex 5). Convened by Dr T. Okuda (Japan) and Dr C. Péron (France) and attended by 79 participants from 18 Members with 22 papers considered
- (iii) Working Group on Ecosystem Monitoring and Management (WG-EMM), 5 to 9 July 2021 (Annex 6). Convened by Dr C. Cárdenas (Chile) and attended by 118 participants from 22 Members with 41 papers considered
- (iv) Working Group on Fish Stock Assessment (WG-FSA), 13 to 20 September 2021 (Annex 7). Convened by Mr S. Somhlaba (South Africa) and attended by 97 participants from 19 Members with 63 papers considered.

1.10 Dr Welsford welcomed Dr Steve Parker (New Zealand) as the new Science Manager at the Secretariat, acknowledging Dr Parker's extensive history as a member of the New Zealand delegation and as a Convener of WG-SAM.

1.11 Dr Welsford noted the retirement of Dr Keith Reid, the previous Science Manager at the Secretariat, and acknowledged his significant and lengthy contributions to the work of CCAMLR at the Secretariat and previously as a member of the UK delegation.

1.12 Dr Welsford encouraged all participants to work together to provide scientifically based advice to the Commission and to avoid providing new points of view at the time of the adoption of the report. He stressed that the desire of the Scientific Committee was to reach agreement on important issues, and where agreement cannot be found, the report should reflect the points of difference and the alternative hypotheses that they reflect.

Advances in statistics, assessments, modelling, acoustics and survey methods

Acoustic survey and analysis methods

2.1 The Scientific Committee reviewed advice from WG-ASAM (WG-ASAM-2021, paragraph 5.1) noting that, as WG-ASAM was the first of a series of intersessional activities of the Scientific Committee, a number of the advice items listed had been considered by other working groups.

2.2 The Scientific Committee noted the work undertaken by WG-ASAM to summarise acoustic biomass estimates for Area 48 in an intersessional e-group (WG-ASAM-2021,

paragraphs 2.16 and 2.17) for use by WG-SAM to calculate biomass estimates for four strata in Subarea 48.1 (paragraph 3.8), and thanked Dr C. Reiss (USA) and Dr T. Dornan (UK) for leading the e-group discussion and participants for contributing to this work.

2.3 The Scientific Committee noted that the krill biomass data for Area 48 summarised by WG-ASAM were estimated using different analysis methods (for krill identification) and data collection methods (day and night data, biological samples from different types of gear). The Scientific Committee noted the importance of clearly identifying how the methodologies used may affect the results of acoustic survey estimates.

2.4 The Scientific Committee noted the discussion from WG-ASAM which advised that the krill biomass estimate of 4.325 million tonnes, with a coefficient of variation (CV) of 17.0%, represented the best available estimate for Division 58.4.1, and that the krill biomass estimate of 6.477 million tonnes, with a CV of 28.9%, represented the best available estimate for the eastern sector of Division 58.4.2 (WG-ASAM-2021, paragraph 2.30).

2.5 The Scientific Committee reflected that survey transects conducted in 2021 in Division 58.4.2 were not able to fully repeat the previous survey conducted in 2006 in its entirety along the shelf due to ice coverage, and that the estimated areal biomass density for Division 58.4.2 had decreased by over a factor of four (WG-ASAM-2021, paragraphs 2.25 and 2.26). The Scientific Committee noted that variability in krill biomass estimates was to be expected given the time between surveys, and the short life cycle of krill. The Scientific Committee also noted that the biomass estimates based on a survey conducted by Japan in 2019 for the adjacent Division 58.4.1 (paragraph 2.4) were comparable to the previous survey (BROKE-West, Nicol et al., 2010).

2.6 The Scientific Committee recommended that the biomass estimates for Divisions 58.4.1 and 58.4.2 be considered the best available estimates of krill biomass for these regions. The Scientific Committee also noted the need to undertake further analyses of the data in Division 58.4.2 if they are to be used as a basis for updated management advice for this division.

2.7 The Scientific Committee endorsed the request of WG-ASAM (WG-ASAM-2021, paragraph 2.32) to develop standardised procedures analogous to the review of finfish stock assessments, to ensure that all future acoustic survey results and analysis methods contributing areal krill density biomass estimates for the management of the fishery can be checked and verified by the Scientific Committee and its working groups.

2.8 The Scientific Committee noted SC-CAMLR-40/BG/25 proposing the development of standardised methods for collecting, processing and reporting the results from future acoustic surveys of Antarctic krill (*Euphausia superba*), particularly those that produce estimates of krill biomass. The Scientific Committee encouraged further work by WG-ASAM on the methods proposed by the authors in SC-CAMLR-40/BG/25.

2.9 The Scientific Committee recommended that the development of standardised methods for processing and reporting future acoustic survey results, and the review of these results, be considered by WG-ASAM and intersessionally in the WG-ASAM e-group. Results from this discussion will be presented to the Scientific Committee in 2022 (paragraph 3.16).

2.10 The Scientific Committee endorsed the recommendation by WG-ASAM to use the Secretariat as a central repository for acoustic data collected by fishing vessels along nominated transects.

Statistics, assessments and modelling

2.11 The Scientific Committee reviewed advice from WG-SAM (WG-SAM-2021, paragraph 12.1).

Krill resources

2.12 The Scientific Committee noted the work undertaken by WG-SAM to review model configuration, assumptions and parameterisation of the generalised R yield model (Grym), to be used for krill stock assessment simulations, and thanked colleagues, especially Mr D. Maschette (Australia), for leading the Grym model development (WG-SAM-2021, paragraphs 3.2 to 3.21).

2.13 The Scientific Committee further noted the intersessional work that was undertaken after WG-SAM through the ‘GYM/Grym assessment model development’ e-group using an ensemble approach with multiple parameter value combinations (paragraph 3.9; WG-FSA-2021/39).

2.14 The Scientific Committee noted that the krill fishery operates different gear types and fishing methods (see CCAMLR-40/27) and proposed to consider the selectivity of different types of krill fishing gear intersessionally and include this item under ‘Future work’. The Scientific Committee welcomed the offer from Russia to provide data on the methodology and results of such studies for krill.

Toothfish resources

2.15 The Scientific Committee welcomed the ongoing development of Casal2 software to overcome, inter alia, potential computational limitations due to large tagging datasets in the Ross Sea assessment (WG-SAM-2021, paragraph 3.28).

2.16 The Scientific Committee endorsed the recommendations from WG-SAM on the revision of the trend analysis for research blocks in data-limited fisheries (WG-SAM-2021, paragraph 3.32) and noted that a number of the recommendations had been applied to the trend analysis results presented in WG-FSA-2021/06.

2.17 The Scientific Committee noted the discussions on alternative harvest-rate-based decision rules that would be consistent with the objectives of the current CCAMLR decision rules (WG-SAM-2021, paragraphs 4.1 to 4.6) and recommended further evaluation of alternative decision rules, including exploring the effects of auto-correlation and bias in stock assessments, and delays and errors in the management implementation of catch limits (see also paragraph 3.63).

2.18 The Scientific Committee noted that WG-SAM had reviewed, and commented on, all research plans and research results submitted to the meeting. The process had followed the research proposal template agreed by SC-CAMLR-XXXVII, Annex 13.

2.19 The Scientific Committee noted the discussion in WG-SAM on gear types in exploratory fisheries and the proposal to conduct research in Divisions 58.4.1 and 58.4.2 (WG-SAM-2021, paragraphs 8.8 to 8.14 and 9.6 to 9.9).

Future work

2.20 The Scientific Committee reflected that under ‘Future work’, WG-SAM requested an update to the five-year workplan agreed in 2017, noting the need to include work related to krill (for example, Grym for the revised krill management strategy), and opportunities for online workshops and other mechanisms to progress issues given the limited time of Members to prepare and participate in working groups (WG-SAM-2021, paragraphs 10.1 to 10.4). Pending update of the workplan, the Scientific Committee agreed that the items listed in WG-SAM-2021, paragraph 10.7, be used to develop the agenda for WG-SAM-2022, noting the use of toothfish assessment models to develop and test stock structure hypotheses.

Management of marine resources

3.1 The Scientific Committee noted CCAMLR-40/BG/14, which reported on a research fishery for Patagonian toothfish (*Dissostichus eleginoides*) in Ecuador, outside the Convention Area.

3.2 The Scientific Committee noted CCAMLR-40/BG/01, which presented a brief overview of catches of target species from directed fishing on toothfish, icefish and krill in the Convention Area in the 2019/20 and 2020/21 seasons and from research fishing under Conservation Measure (CM) 24-05.

Krill resources

Status and trends

3.3 The Scientific Committee reviewed krill fishing activities for 2019/20 and 2020/21 (SC-CAMLR-40/BG/01). The Scientific Committee noted that:

- (i) in 2019/20 (1 December 2019 to 30 November 2020), 12 vessels fished in Subareas 48.1, 48.2 and 48.3, and the total catch of krill reported was 450 782 tonnes of which 157 081 tonnes, 178 382 tonnes and 115 318 tonnes were taken from Subareas 48.1, 48.2 and 48.3 respectively
- (ii) in 2020/21 (to 31 July 2021), 12 vessels fished in Subareas 48.1, 48.2 and 48.3, and the total catch of krill reported was 320 014 tonnes of which 161 772 tonnes, 158 242 tonnes and 0 tonnes were taken from Subareas 48.1, 48.2 and 48.3 respectively. Subarea 48.1 was closed on 4 June 2021.

3.4 The Scientific Committee noted that the catch in 2019/20 was the highest catch in Area 48 in history (the highest previously was 425 871 tonnes in 1985/86).

3.5 The Scientific Committee noted the WG-EMM discussions on krill management (WG-EMM-2021, paragraphs 2.1 to 2.19) and endorsed its recommendation regarding further considerations of krill green weight reporting and estimation (WG-EMM-2021, paragraph 2.22), given the importance of accurately quantifying total removals for the management of the fishery. The Scientific Committee noted that issues relating to the vessels mentioned in WG-EMM-2021, paragraph 2.22(ii), may have to be considered by the Standing Committee on Implementation and Compliance (SCIC).

Ecosystem effects of krill fishing

3.6 The Scientific Committee noted WG-FSA-2021/56, which presented an analysis indicating that, over time, there was an increasing spatial contraction and concentration of the krill fishery which was due to the highly patchy and dynamic nature of krill distribution, which had consequences on the scale of future management units (see also paragraph 3.12).

3.7 The Scientific Committee noted SC-CAMLR-40/BG/17, which detailed the breeding chronology of gentoo penguins (*Pygoscelis papua*) through data provided by time-lapse cameras funded via the CCAMLR Ecosystem Monitoring Program (CEMP).

Revised krill management strategy

3.8 The Scientific Committee noted WG-EMM discussions on krill acoustic surveys (WG-EMM-2021, paragraphs 2.23 to 2.29) and the efforts made towards the collation of acoustic data from several Members. It further noted the importance of considering spatial and temporal variability on the resulting overall uncertainty in biomass estimates, the periodicity observed in krill population dynamics in Subarea 48.1, as well as the need for additional winter data.

3.9 The Scientific Committee noted discussions on the parameterisation of the Grym (WG-EMM-2021, paragraphs 2.30 to 2.33) and the collaborative efforts made towards an agreed set of parameter values to estimate precautionary catch limits. It noted, in particular, the need for refinements regarding recruitment parameters, maturity-at-length and gear selectivity. The Scientific Committee also noted that consideration of the Grym's outputs needed to include discussions on a potential revision of the CCAMLR decision rules as they apply to krill.

3.10 The Scientific Committee noted the WG-EMM discussions on the risk assessment framework (WG-EMM-2021, paragraphs 2.34 to 2.60) and the continued effort required to inform input data layers, in particular for the distribution of krill in different seasons, especially winter, and the distribution and food demand of fish. It noted that the risk assessment for Subarea 48.1 constitutes the best science currently available to CCAMLR (WG-EMM-2021, paragraph 2.46) and that its future development will benefit from data collected in collaboration with the fishing industry, together with other conservation and management tools such as the proposed marine protected area (MPA) in Domain 1 (D1MPA; CCAMLR-39/08 Rev. 1).

3.11 The Scientific Committee noted the very large amount of work conducted towards the revision of the krill management strategy and congratulated all scientists involved, especially

given the constraints during the past year. It further noted that its elements were co-dependent and further collaboration across working groups will be essential (e.g. existing fish surveys in Subareas 48.1 and 48.2 could help WG-FSA revise the fish layer in the risk assessment) for future refinements.

3.12 The Scientific Committee noted WG-EMM discussions on the spatial concentration of the krill fishery (WG-EMM-2021, paragraph 2.47; see also paragraph 3.6), which is a major factor driving the need for spatial and temporal management of the krill fishery, however, the Scientific Committee also noted the new findings that may alleviate such concerns (see also WG-FSA-2021, paragraph 5.18).

3.13 The Scientific Committee endorsed WG-EMM recommendations on the review of CM 51-07 (WG-EMM-2021, paragraphs 2.61 to 2.68) and noted the importance of the collaborative development of management unit boundaries. The Scientific Committee noted the uneven availability of data across current management areas, with considerably more data being available in Subarea 48.1 than in Subareas 48.2 to 48.4.

3.14 The Scientific Committee recognised the importance of the periodicity observed in krill population dynamics in Subarea 48.1 for both the management of the fishery and the design of monitoring plans. It further noted that future monitoring plans should also try to document the connectivity between subareas and provide recruitment and biomass estimates in order to inform the management of the krill fishery in a coordinated manner.

3.15 The Scientific Committee endorsed the WG-FSA recommendation to develop a standardised approach to the calculation of stratum area (WG-FSA-2021, paragraph 5.6; see also paragraph 3.20) and noted that this will be progressed intersessionally with the support of the Secretariat.

3.16 The Scientific Committee endorsed WG-FSA recommendations on the submission of data by Members to the Secretariat (WG-FSA-2021, paragraphs 5.12 and 5.13) to develop a centralised database (survey design, acoustics, biology, size frequencies etc.) for use in the future krill fishery management approach. The Scientific Committee recalled the requirement under CM 24-01 (CM 24-01, paragraph 4(d)ii) for Members to submit data collected on research trawl surveys to CCAMLR using C4 forms where relevant. It further requested Members make their existing data available for this database. In the case of acoustic data, the Scientific Committee noted that templates from past synoptic surveys could be of interest, and that SC-CAMLR-40/BG/25 offered a useful roadmap towards the standardisation of collection procedures and analyses of acoustic data. It noted that the participation of the Data Services Advisory Group (DSAG) in the development of such a database would be beneficial. The Scientific Committee further noted that the rules for access and use of CCAMLR data may need reviewing to ensure protection of the interests of data originators while promoting the scientific work of CCAMLR (paragraph 11.8).

3.17 The Scientific Committee noted the WG-FSA discussions on the revision of CM 51-07 (WG-FSA-2021, paragraphs 5.25 to 5.27), in particular that the current management approach has been precautionary.

[3.18 The Scientific Committee noted CCAMLR-40/BG/10 and BG/11 ~~submitted by ASOC, who introduced CCAMLR-40/BG/10,~~ which [inter alia](#) stressed the need for CCAMLR to complete the agreed work plan and develop an improved conservation measure to replace

CM 51-07. If an improved measure could not be agreed this year, then ASOC recommended the rollover of CM 51-07, since, in the author's view, research revealed that krill habitat was under threat from climate change and that krill predators are already being negatively affected by climate change and concentrated fishing. ~~Additionally, three whales were caught as by-catch in the krill fishery this year, and, in the author's view, these whales may be an indication of the state of the ecosystem. Given these concerns, ASOC believes that the complete lapse of CM 51-07 must be avoided, as this would be a regression in management and allow an increase in fishery concentration.~~]

3.19 The Scientific Committee noted SC-CAMLR-40/BG/16, which outlined ARK activities in the 2020/21 season, including implementation of voluntary restricted zones (VRZs) in Subarea 48.1 and the annual acoustic surveys undertaken in all subareas fished. ARK indicated its support for the ongoing revision of the krill fishery management approach to ensure a sustainable krill fishery, however, if consensus on progress of a revised CM 51-07 could not be achieved this year, ARK supported the rollover of CM 51-07 until a future approach was ready for implementation.

3.20 The Scientific Committee considered SC-CAMLR-40/10, which presented boundaries of five candidate management units in Subarea 48.1 and SC-CAMLR-40/11 which provided acoustic biomass estimates of Antarctic krill within these management units, with area calculations based on the *Raster* R package, which resulted in an increase of about 14% in krill biomass estimates in the US AMLR strata (see also paragraph 3.15 and WG-FSA-2021, paragraphs 5.4 and 5.6). It noted that the size of management units needed to take into account the spatial scale at which the fishery operated, ecosystem processes, data availability and operational considerations (e.g. fishery closure mechanisms), recalling the recommendation by WG-FSA for a joint workshop of several working groups to design a statistically robust set of management units for each subarea (WG-FSA-2021, paragraph 5.21).

3.21 The Scientific Committee discussed the need for a review of CEMP indices and their potential use as indicators to quantify the impacts of the fishery. It further noted recent CEMP proposals aiming to investigate interactions between krill predators and krill (paragraph 7.25).

3.22 The Scientific Committee noted CCAMLR-40/27, which presented a proposal to establish limits on the use of continuous krill fishing systems in Area 48, where harvesting using such systems would be limited to 70% of the total allowable catch. It noted that a potential subdivision of catch limits by gear type was not currently a scientific issue, but that potential differences in ecosystem effects between traditional and continuous trawlers deserved further evaluation.

3.23 The Scientific Committee noted SC-CAMLR-40/BG/18, which presented proposals on the risk assessment framework to facilitate the spatial distribution of the catch limit, including: (i) the development of scientifically based indicators accompanied by criteria and diagnostics to assess the potential ecosystem impact of the fishery, taking into account the mixed effects of fishing, environmental variability (or climatic changes), and the competitive relationship between predator species; (ii) the set of indicators for the risk assessment framework, accompanied by transparent descriptions, criteria and diagnostics that should be approved by the Scientific Committee; (iii) investigating the possibility of using data from CEMP to provide information on the effects of fishing on dependent species.

3.24 The Scientific Committee noted that the revised krill management strategy had been discussed and iteratively developed through the four working groups during 2021, resulting in an inter-working group work plan on the revision of the krill management strategy that includes:

- (i) Data collection –
 - (a) krill fishery capacity analysis (WG-FSA-2021, paragraph 5.2)
 - (b) development of databases for acoustic data and biological data from surveys and from fishing vessels (paragraph 3.16)
 - (c) inclusion of acoustic survey data and metadata in an acoustic survey repository (WG-ASAM-2021, paragraph 4.7)
 - (d) development of standardised procedures for data collection and analysis (WG-ASAM-2021, paragraph 2.32)
 - (e) improvement of green weight estimation, both historical and current (WG-EMM-2021, paragraph 6.1vi)
 - (f) krill fishing vessel data workshop and revision of data reporting forms (WG-FSA-2021, paragraphs 2.11 and 6.16ii).
- (ii) Biomass estimation –
 - (a) statistical approaches to acoustic data emerging from new acoustic observation platforms (WG-SAM-2021, paragraph 10.6)
 - (b) e-group on krill length frequency data to inform acoustic biomass estimates (WG-ASAM-2021, paragraph 3.7)
 - (c) development of analytical approaches to the estimation of CVs when averaging multiple and time series surveys (see also paragraph 3.8)
 - (d) biomass estimates from Division 58.4.1 (WG-ASAM-2021, paragraph 2.23) and Division 58.4.2 (WG-ASAM-2021, paragraph 2.30).
- (iii) Grym and decision rules –
 - (a) Grym parameters for krill assessments in Areas 48 and 58 (WG-SAM-2021, paragraph 10.6)
 - (b) development of standard protocols for the reconstruction of krill length composition for proportional recruitment calculation (WG-EMM-2021, paragraph 6.1iii)
 - (c) agreement on parameter estimates and decision rules for krill (paragraph 3.9).
- (iv) Risk assessment –
 - (a) introduction of new data, such as additional acoustic survey data and data from summer and winter periods (WG-EMM-2021, paragraphs 6.1ii and 6.1iii)

- (b) further development of habitat models, including for fish (WG-EMM-2021, paragraph 6.1ii)
 - (c) incorporation of changes in trophic interactions (WG-EMM-2021, paragraph 6.1ii)
 - (d) consideration of MPAs as independent risk assessment scenarios (WG-EMM-2021, paragraph 6.1ii)
 - (e) improvement of collaboration with other groups outside CCAMLR (WG-EMM-2021, paragraph 6.1v).
- (v) Spatial scale and connectivity –
- (a) stratum area and management unit calculation (WG-FSA-2021, paragraphs 5.6 and 5.21)
 - (b) spatial- and temporal-scale effects on biomass uncertainty (paragraph 3.8)
 - (c) workshop on population hypotheses taking into account circumpolar and regional advection of krill (WG-EMM-2021, paragraph 6.1i)
 - (d) management unit definitions (WG-FSA-2021, paragraph 5.21 and this report, paragraph 3.13).
- (vi) Ecosystem impacts –
- (a) move-on rule (WG-FSA-2021, paragraph 6.4)
 - (b) by-catch estimation (WG-FSA-2021, paragraph 6.16)
 - (c) net monitoring cable (WG-FSA-2021, paragraph 6.12)
 - (d) additional information on whale mortality incidents (WG-FSA-2021, paragraph 6.6)
 - (e) assessment of ecosystem impacts of krill fishing, including the development of indicators to assess these impacts (WG-EMM-2021, paragraph 6.1vi).

3.25 The Scientific Committee considered SC-CAMLR-40/BG/28, which presented the outcomes of the e-group on the revision of CM 51-07. The paper suggested a temporary rollover of CM 51-07 until work on the revision of the krill management approach was progressed (see also SC-CAMLR-40/07), using China's proposal (see Annex 8) as a starting point to develop a candidate example.

3.26 Due to the abbreviated format of the meeting, the Scientific Committee noted WG-FSA-2021/16, 2021/17 and SC-CAMLR-40/07 but did not have time to consider them in plenary.

Advice to the Commission

3.27 Some Members noted that a revision of CM 51-01 will be required to fully implement the new krill management procedure in Subarea 48.1.

3.28 The Scientific Committee recommended a rollover of CM 51-07 for one year to provide time to consolidate the revision of the krill management approach in Subarea 48.1, with additional time needed to provide advice on other subareas.

Data reporting and general issues in CCAMLR fisheries

3.29 The Scientific Committee noted SC-CAMLR-40/BG/01, which provided an update of catches in 2019/20 and for 2020/21 up to 31 July 2021.

3.30 The Scientific Committee noted the discussions and recommendations by WG-FSA on the CCAMLR Scheme of Scientific Observation (SISO) observer reporting forms and instructions (WG-FSA-2021, paragraphs 2.1 to 2.3), and endorsed the revisions to observer logbooks (longline, krill and finfish trawl), the new observer pot form, and the *Scientific Observer's Manual – Finfish Fisheries* (2020), for implementation in the 2021/22 season.

3.31 The Scientific Committee endorsed the recommendation by WG-FSA (WG-FSA-2021, paragraph 2.10) to hold a focused krill fishery data collection workshop to assist in developing a new C1 vessel haul-by-haul form, and a draft krill commercial data collection manual.

3.32 The Scientific Committee noted recommendations by WG-EMM for the inclusion of a product type and associated conversion factor in any new C1 form, as well the request for a designated focus topic on krill conversion factors (WG-EMM-2021, paragraphs 2.22iii to 2.22iv). The Scientific Committee welcomed the offer by ARK to support a krill fishery workshop in 2022 to address these issues.

3.33 The Scientific Committee noted the postponed krill observer workshop (due to COVID-19 restrictions), which was to be held by China in 2020 (SC-CAMLR-38, paragraph 13.1i). The Scientific Committee noted the intent of China to hold this workshop once restrictions are eased, and reflected that this workshop would be suitable for discussion of biological data collection protocols to ensure that data collected are appropriate for the further developments of the CCAMLR krill risk assessment framework and Grym input parameters, as well as any other monitoring of the fishery that may be required from observers.

3.34 The Scientific Committee noted the discussions and recommendations on updates to commercial data reporting forms and a draft longline commercial data manual by WG-FSA (WG-FSA-2021, paragraphs 2.8 to 2.10). The Scientific Committee endorsed the revisions to the commercial data forms, including the implementation of a new longline fine-scale catch and effort data form (C2) for implementation in the 2022/23 season.

3.35 The Scientific Committee endorsed the recommendation and terms of reference drafted by WG-FSA (WG-FSA-2019, paragraphs 2.6 and 2.7) to designate a virtual workshop in the intersessional period on conversion factors in toothfish fisheries, with results of the workshop to be presented to WG-FSA-2022. The Scientific Committee thanked France and New Zealand for offering to co-convene this workshop (Table 1) with assistance from the Secretariat, and recommended that the Secretariat's Science Manager and Fisheries and Observer Reporting Coordinator attend this workshop and the krill fishery data workshop (paragraph 3.32) to ensure any cross-cutting data issues are addressed.

3.36 The Scientific Committee noted the intent of New Zealand to convene the postponed tagging workshop in 2022, provided COVID restrictions have eased (SC-CAMLR-38,

paragraph 13.1v) recalling the importance of the CCAMLR tagging program for toothfish stock assessments. The Scientific Committee welcomed the offer from COLTO to assist with this workshop and recommended the Secretariat's Science Manager be involved in the workshop.

3.37 The Scientific Committee noted the discussions and recommendations on the fishery closure forecasting procedures implemented by the Secretariat (WG-FSA-2021, paragraphs 2.12 to 2.14) and endorsed the proposed changes to the forecasting algorithm.

Fish resources

Status and trends

Champscephalus gunnari

C. gunnari in Subarea 48.3

3.38 The fishery for mackerel icefish (*Champscephalus gunnari*) in Subarea 48.3 operated in accordance with CM 42-01 and associated measures. In 2020/21, the catch limit for *C. gunnari* was 2 132 tonnes. Details of this fishery and the stock assessment of *C. gunnari* are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_483_ANI_2020.pdf).

3.39 The Scientific Committee noted that an assessment of *C. gunnari* in Subarea 48.3 based on the random stratified bottom trawl survey estimated the median demersal biomass at 18 013 tonnes with a lower one-sided 95% interval estimate of 10 627 tonnes. A catch limit of 1 457 tonnes for 2021/22 and 1 708 tonnes for 2022/23 would ensure at least 75% biomass escapement after a two-year projection period and therefore satisfy the CCAMLR decision rules.

Management advice

3.40 The Scientific Committee recommended that the catch limit for *C. gunnari* should be set at 1 457 tonnes for 2021/22 and 1 708 tonnes for 2022/23.

C. gunnari at Heard Island (Division 58.5.2)

3.41 The fishery for *C. gunnari* in Division 58.5.2 operated in accordance with CM 42-02 and associated measures. In 2020/21, the catch limit for *C. gunnari* was 406 tonnes. Fishing was conducted by one vessel and the total reported catch up to 31 July 2021 was 359 tonnes. Details of this fishery and the stock assessment of *C. gunnari* are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_HIMI_ANI_2020.pdf).

3.42 The Scientific Committee noted that an assessment for *C. gunnari* using the Grym had been conducted based on a random stratified trawl survey in Division 58.5.2 undertaken between late March and mid-April 2021. Projecting forward from the lower 5th percentile of fish of ages 1+ to 3+ gave yields of 1 528 tonnes for 2021/22 and 1 138 tonnes for 2022/23 that allow for 75% escapement and therefore satisfy the CCAMLR decision rules.

Management advice

3.43 The Scientific Committee recommended that the catch limit for *C. gunnari* should be set at 1 528 tonnes for 2021/22 and 1 138 tonnes for 2022/23.

Dissostichus spp.

IUU fishing

3.44 The Scientific Committee noted CCAMLR-40/06 which summarised information held by the Secretariat in relation to illegal, unreported and unregulated (IUU) fishing and vessel activity relevant to CCAMLR from October 2020 to August 2021. It noted the proposed updates, amendments, inclusions and removals to IUU Vessel Lists and vessel details.

Dissostichus eleginoides in Subarea 48.3

3.45 The fishery for *D. eleginoides* in Subarea 48.3 operated in accordance with CM 41-02 and associated measures. In 2020/21, the catch limit for *D. eleginoides* was 2 327 tonnes and the total reported catch up to 31 July 2021 was 1 344 tonnes.

3.46 The Scientific Committee noted that WG-FSA-2021/59 and 2021/60 presented an updated integrated CASAL assessment model for *D. eleginoides* in Subarea 48.3. The model estimated B_0 at 72 600 tonnes (95% confidence interval (CI): 68 200–78 500 tonnes) and spawning stock biomass (SSB) status in 2021 at 47% (95% CI: 43–53%). Based on the results of this assessment, removals of 2 153 tonnes are consistent with the CCAMLR decision rules. This results in a catch limit of 2 072 tonnes when following the procedure to account for a recent average estimated depredation rate of 3.9% (2011–2020) as agreed by the Scientific Committee (SC-CAMLR-38, paragraph 3.70).

3.47 The Scientific Committee considered SC-CAMLR-40/15, by Russia, which presented analyses based on available data from working group papers, Fishery Reports and publications and, in the author's opinion, indicated that since 2008/09, the *D. eleginoides* fishery in Subarea 48.3 has been based on recruitment of fish less than 100 cm in length, an excessive number of immature *D. eleginoides* and those maturing for the first time (recruits) in the process of intensive weight gain are currently being caught in Subarea 48.3, which indicates a change in the size structure of spawning *D. eleginoides* and is accompanied by decrease in the toothfish biomass. Russia noted that the *D. eleginoides* population in Subarea 48.3 requires protection and proposed to revise the precautionary approach for the use of the *D. eleginoides* stock in the CCAMLR area (Subarea 48.3) as the current approach does not provide for the sustainable use of this living resource and called for closure of the *D. eleginoides* fishery in Subarea 48.3.

3.48 Russia noted that taking into account the long lifespan of *D. eleginoides* (up to 50 years), its population should consist of a large number of size and age groups, which on the histogram usually decreases quite smoothly consistent with the species' long life cycle, but overall it is very high and provides the bulk of catches. This is exactly what is observed on the histogram

of the size composition of Antarctic toothfish (*D. mawsoni*) from catches in Subarea 88.1 (SC-CAMLR-40/15). At the same time, the *D. eleginoides* fishery in Subarea 48.3 has been based on recruitment of fish.

3.49 The Scientific Committee also considered SC-CAMLR-40/BG/08, by the UK, which summarised reviews of SC-CAMLR-40/15 and its previous versions conducted since 2018, by the Scientific Committee and its working groups and also provided additional analyses to address the claims in SC-CAMLR-40/15. SC-CAMLR-40/BG/08 noted that the Scientific Committee and its working groups considered that:

- (i) data used in SC-CAMLR-40/15 was taken from a range of sources and was not standardised or analysed with appropriate statistical rigour
- (ii) there has been no systematic decrease in length and weight at maturity in the exploited population (WG-SAM-2018, paragraph 3.13)
- (iii) a reduction in the catch of large fish and an increase in the proportion of smaller fish was to be expected in an exploited stock (WG-FSA-2019)
- (iv) the proportion of immature fish caught in the Subarea 48.3 fishery was consistent with the size caught in all other CCAMLR *D. eleginoides* and *D. mawsoni* fisheries (Figures 1 to 3; appended from SC-CAMLR-38, Annex 7, Figures 4 to 6).

3.50 The Scientific Committee also noted that comparisons with *D. mawsoni* raw length distributions were not appropriate as the species has different growth parameters and achieves significantly larger sizes.

3.51 Dr A. Petrov (Russia) noted that SC-CAMLR-40/BG/08 does not provide scientific data regarding issues of an irrational use of the *D. eleginoides* stock in Subarea 48.3. He also noted that an excessive number of immature toothfish was caught in the southern small-scale research units (SSRUs) L and J in the Ross Sea region, and this problem was solved by closing the fishery in these SSRUs and including these SSRUs in the Ross Sea region MPA (RSRMPA) (SC-CAMLR-XXXIII/BG/23 Rev. 1 and CCAMLR-XXXV/25 Rev. 1).

3.52 Dr G. Watters (USA) clarified that, as co-proponents of the RSRMPA, the USA and New Zealand did not propose the MPA in an effort to address 'irrational' use of toothfish stocks in Subareas 88.1 and 88.2.

3.53 The Scientific Committee noted the discussion in WG-FSA (WG-FSA-2021, paragraphs 3.24 to 3.35) concerning toothfish in Subarea 48.3.

3.54 Many Members noted that SC-CAMLR-40/15 repeated the content of documents submitted over the last three years, and that the authors had not taken into account the numerous previous reviews, and, as such, did not follow the normal scientific procedure of the Scientific Committee (SC-CAMLR-XXXVII, paragraphs 3.64 to 3.71; SC-CAMLR-38, Annex 4, paragraphs 3.12 to 3.19 and SC-CAMLR-38, Annex 7, paragraphs 3.52 to 3.57). They noted that issues brought to the Scientific Committee should be presented as scientific hypotheses, which can be analysed, tested, subjected to independent review and updated based on discussions in the Scientific Committee and its working groups.

3.55 The Scientific Committee noted that in implementing Article XV of the Convention, CCAMLR has established long-standing procedures to assess stock status, employ expert review in its working groups and the Scientific Committee, and provide advice to the Commission, including decision rules and modelling frameworks. It further recalled that the stock assessment models and decision rules for toothfish fisheries in Subareas 48.3 and 48.4, Division 58.5.2 and the Ross Sea region have been reviewed by international and independent experts and were found to be both precautionary and world leading (SC-CAMLR-XXXVII, paragraphs 2.7 and 3.54).

3.56 The Scientific Committee agreed that the established processes and procedures for stock assessment and review had been followed and that the CCAMLR decision rules had been applied correctly. However, the Scientific Committee could not reach consensus on whether the resulting catch limit was precautionary, and two alternative views were expressed.

- (i) Russia considered that the resulting catch advice did not constitute rational use in Subarea 48.3 as stated by SC-CAMLR-40/15, and that the fishery should be closed
- (ii) all other Members considered that the resulting catch advice in Subarea 48.3 was precautionary and followed CCAMLR's long-standing approach to managing its toothfish fisheries.

3.57 Some Members noted that the same CCAMLR assessment procedures and decision rules are applied to all assessed toothfish stocks and if considered inappropriate for Subarea 48.3, this calls into question the management approach for all assessed stocks. They noted that the toothfish stock in Subarea 48.3 was similar to other toothfish fisheries in the Convention Area as demonstrated by the Scientific Committee in 2019 (Figures 1, 2 and 3).

3.58 Dr S. Kasatkina (Russia) noted that, in her opinion, the CCAMLR assessment procedures and decision rules have not ensured the rational use of the toothfish stock in Subarea 48.3 but in her view were considered rational use in other assessed areas.

3.59 Given the lack of agreement that the CCAMLR decision rules are precautionary and should be applied equally to all stocks (refer to WG-FSA-2021, paragraphs 3.20, 3.21 and 3.32 to 3.34), the Scientific Committee was unable to provide consensus catch advice for all assessed toothfish stocks (Subareas 48.3 and 48.4, Division 58.5.2 and the Ross Sea region).

3.60 However, for all assessed toothfish stocks, the Scientific Committee noted advice based on the use of the best available science and the resulting catch levels that are consistent with both the CCAMLR decision rules and the established CCAMLR procedures.

Management advice

3.61 The Scientific Committee noted that a catch limit for *D. eleginoides* in Subarea 48.3, set at 2 072 tonnes for 2021/22 and 2022/23 based on the outcome of this assessment, would be consistent with the precautionary yield estimated using the CCAMLR decision rules, the process for setting catch limits used in previous years and the use of best available science.

3.62 The Scientific Committee noted that it had been unable to provide consensus advice on catch limits for assessed toothfish stocks in Subarea 48.3 (paragraph 3.59).

3.63 The Scientific Committee recommended a workshop to evaluate CCAMLR's precautionary approach and decision rules implemented across all toothfish stocks, and how toothfish populations in different parts of the Convention Area are expected to respond under CCAMLR's management framework to progress the issue of performance of CCAMLR's decision rules regarding toothfish management.

3.64 Some Members proposed an independent external peer review of SC-CAMLR-40/15 to identify any issues and review the methodologies used to reach the conclusions, consistent with the scientific peer-review process.

3.65 The Scientific Committee noted that, if a workshop on the performance of CCAMLR's precautionary approach and decision rules were to be undertaken, this would require that information addressing the previous recommendations from WG-FSA and the Scientific Committee be presented by the authors of SC-CAMLR-40/15.

3.66 The Scientific Committee noted that understanding the population structure and regional connectivity of *D. eleginoides* within and beyond the Convention Area is an urgent issue and further noted that the investigations made for *D. mawsoni* could provide a template for such work.

D. eleginoides in Subarea 48.4

3.67 The fishery for *D. eleginoides* in Subarea 48.4 operated in accordance with CM 41-03 and associated measures. In 2020/21, the catch limit for *D. eleginoides* was 27 tonnes. Details of this fishery and the stock assessment of *D. eleginoides* are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_484_TOT_2020.pdf).

3.68 The Scientific Committee noted that WG-FSA-2021/61 and 2021/62 presented an updated integrated CASAL assessment for *D. eleginoides* in Subarea 48.4. The assessment model followed the same procedure as described in WG-FSA-2019/29 and was updated with the observations for the 2018/19 and 2019/20 seasons. Stock projections indicated that the stock was at 65% of B_0 in 2021 and that a yield of 23 tonnes in 2021/22 and 2022/23 would be consistent with the application of the CCAMLR decision rule.

3.69 The Scientific Committee noted that a catch limit for *D. eleginoides* in Subarea 48.4, set at 23 tonnes for 2021/22 and 2022/23 based on the outcome of this assessment, would be consistent with the precautionary yield estimated using the CCAMLR decision rules, the process for setting catch limits used in previous years, and the use of best available science.

Dissostichus mawsoni in Subarea 48.4

3.70 The fishery for *D. mawsoni* in Subarea 48.4 operated in accordance with CM 41-03 and associated measures. In 2020/21, the catch limit for *D. mawsoni* was 45 tonnes. Details of this fishery and the stock assessment of *D. mawsoni* are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_484_TOT_2020.pdf).

3.71 The Scientific Committee noted that WG-FSA-2021/63 Rev. 1 presented a Chapman biomass estimate for *D. mawsoni* in Subarea 48.4 from mark-recapture data. Based on the recommendation of WG-FSA-2019, the biomass was calculated using a geometric mean of the last five years of Chapman estimates as a robust and precautionary approach (WG-FSA-2019, paragraphs 3.75 to 3.77). In 2021, the tagging data resulted in a geometric mean biomass of 1 311 tonnes. Applying a harvest rate of $\gamma = 0.038$ resulted in a yield of 50 tonnes.

3.72 The Scientific Committee noted that a catch limit for *D. mawsoni* in Subarea 48.4, set at 50 tonnes for 2021/22 based on the outcome of this assessment, would be consistent with the precautionary yield, the process for setting catch limits used in previous years, and the use of best available science.

D. eleginoides in Division 58.5.1

3.73 The fishery for *D. eleginoides* in Division 58.5.1 is conducted in the French exclusive economic zone (EEZ) of the Kerguelen Islands. Details of the fishery and the stock assessment are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_KI_TOP_2020.pdf).

3.74 The Scientific Committee welcomed the substantial development of the stock assessment of *D. eleginoides* in Division 58.5.1. It noted WG-FSA-2021, paragraphs 3.46 to 3.49, describing improvements to the integrated CASAL assessment, and that the catch limit of 5 200 tonnes for 2021/22 that accounts for depredation was consistent with the CCAMLR decision rules.

3.75 The Scientific Committee welcomed the stock annex for the Kerguelen Islands EEZ *D. eleginoides* fishery in Division 58.5.1 and endorsed the recommendation to update the Fishery Report (WG-FSA-2021, paragraph 3.49).

Management advice

3.76 No new information was available on the state of fish stocks in Division 58.5.1 outside areas of national jurisdiction. The Scientific Committee, therefore, recommended that the prohibition of directed fishing for *D. eleginoides*, described in CM 32-02, remain in force in 2021/22.

D. eleginoides in Division 58.5.2

3.77 The fishery for *D. eleginoides* in Division 58.5.2 operated in accordance with CM 41-08 and associated measures. Details of the fishery and the stock assessment are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_HIMI_TOP_2020.pdf).

3.78 The Scientific Committee noted that a catch limit of 3 010 tonnes for 2021/22 and 2022/23 would be consistent with the precautionary yield estimated using the CCAMLR decision rules.

3.79 The Scientific Committee noted WG-FSA-2021, paragraphs 3.53 to 3.56, describing the updated stock assessment for Division 58.5.2, and that a catch limit for *D. eleginoides* in

Division 58.5.2, set at 3 010 tonnes for 2021/22 and 2022/23 based on the outcome of this assessment, would be consistent with the precautionary yield estimated using the CCAMLR decision rules, the process for setting catch limits used in previous years, and the use of best available science.

3.80 Dr P. Ziegler (Australia) noted his disappointment and the absence of a scientific reason that catch advice could not be provided for the toothfish fishery in Division 58.5.2, despite agreement on the outcome of the stock assessment, which is considered to be consistent with the precautionary yield estimated using the CCAMLR decision rules, the process for setting catch limits used in previous years, and the use of best available science.

Management advice

3.81 No new information was available on the state of fish stocks in Division 58.5.2 outside areas of national jurisdiction. Therefore, the Scientific Committee recommended that the prohibition of directed fishing for *D. eleginoides*, described in CM 32-02, remain in force in 2021/22.

D. eleginoides in Subarea 58.6

3.82 The fishery for *D. eleginoides* at Crozet Islands is conducted within the French EEZ and includes parts of Subarea 58.6 and Area 51 outside the Convention Area. Details of this fishery and the stock assessment are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_CI_TOP_2020.pdf).

3.83 The Scientific Committee noted WG-FSA-2021, paragraphs 3.61 to 3.62, describing the updated stock assessment for Subarea 58.6, and noted that the catch limit of 800 tonnes for 2021/22 that accounts for depredation and catches on Del Cano Rise in the Southern Indian Ocean Fisheries Agreement (SIOFA) Convention Area was consistent with the CCAMLR decision rules for this fishery.

Management advice

3.84 No new information was available on the state of fish stocks in Subarea 58.6 outside areas of national jurisdiction. Therefore, the Scientific Committee recommended that the prohibition of directed fishing for *D. eleginoides*, described in CM 32-02, remain in force in 2021/22.

New and exploratory fisheries

D. mawsoni in the Ross Sea region

3.85 The exploratory fishery for *Dissostichus* spp. in Subarea 88.1 and SSRUs 882A–B operated in accordance with CM 41-09 and associated measures. In 2020/21, the catch limit for *Dissostichus* spp. was 3 140 tonnes, including 65 tonnes set aside for the Ross Sea shelf survey.

Fishing was conducted by 19 longline vessels and the total reported catch was 3 146 tonnes. Details of this fishery and the stock assessment are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_881_TOA_2020.pdf).

3.86 The Scientific Committee noted WG-FSA-2021, paragraphs 3.67 to 3.69, describing the updated stock assessment and that implementation of the RSRMPA had led to some concentration of fishing effort on the continental slope south of 70°S, with the number of *D. mawsoni* recaptured in 2020/21 being higher than the average annual number over the past decade. The Scientific Committee also noted that a catch limit of 3 495 tonnes for 2021/22 and 2022/23 would be consistent with CCAMLR's decision rules and the procedure outlined in CM 91-05, with a catch split of 19% for the area north of 70°S, 66% for south of 70°S, and 15% in the special research zone (SRZ).

3.87 The Scientific Committee welcomed the updated stock annex for the Ross Sea region stock assessment (WG-FSA-2021/28) and endorsed the recommendation to update the Fishery Report (WG-FSA-2021, paragraph 3.69).

3.88 The Scientific Committee noted that a catch limit for the Ross Sea region (Subarea 88.1 and SSRUs 882A–B), set at 3 495 tonnes for 2021/22 and 2022/23 based on the outcome of this assessment (and, following the procedure outlined in CM 91-05, with a catch split of 19% for the area north of 70°S, 66% for south of 70°S, and 15% in the SRZ), would be consistent with the precautionary yield estimated using the CCAMLR decision rules, the process for setting catch limits used in previous years, and the use of best available science.

Ross Sea shelf survey

3.89 The Scientific Committee noted the discussions by WG-FSA on the results from the 2020/21 Ross Sea shelf survey, and the proposed catch limits for the 2021/22 survey (WG-FSA-2021, paragraphs 4.32 to 4.37).

3.90 The Scientific Committee recalled that the survey is effort-limited with core strata sampled every year and other strata sampled in alternate years (i.e. McMurdo Sound and Terra Nova Bay; WG-FSA-2017, paragraph 3.83). The McMurdo stratum will be sampled in the 2021/22 season.

3.91 The Scientific Committee recommended a catch limit of 65 tonnes for the shelf survey in the 2021/22 season to ensure that the survey could be completed in order to achieve its objectives.

3.92 The Scientific Committee noted that there were three methods proposed for the catch allocation for the shelf survey (Table 2) and that this would be reviewed by the Commission (CCAMLR-39, paragraph 5.39). It noted that the Commission had used method 1 for 2017/18–2018/19 and method 2 for 2019/20–2020/21.

Subarea 88.2

3.93 The Scientific Committee noted the WG-FSA discussions (WG-FSA-2021, paragraphs 4.38 to 4.41) on the data-limited exploratory fishery in Subarea 88.2, which includes SSRUs 882C–H in the Amundsen Sea region.

3.94 The Scientific Committee endorsed the recommendations from WG-FSA (WG-FSA-2021, paragraph 4.40) that a workshop be convened to compare age-determination methods among research programs to develop procedures and criteria for pooling age data; request the Secretariat to implement an age database to encourage, organise and archive age data; and recommended the creation of a Subarea 88.2 e-group to establish the terms of reference of that workshop.

Management advice

3.95 The Scientific Committee recommended that catch limits for research blocks in Subarea 88.2, given in Table 3, should apply for the 2021/22 season.

Trend analysis

3.96 The Scientific Committee noted the WG-FSA discussion (WG-FSA-2021, paragraphs 4.1 to 4.4) on the recommended catch limits for the 2021/22 season as determined using the trend analysis decision rules.

Area 48

Subarea 48.1

3.97 The Scientific Committee noted the WG-FSA discussion (WG-FSA-2021, paragraphs 4.5 to 4.7) on research results on *Dissostichus* spp., conducted in Subarea 48.1 by Ukraine from 2018/19 to 2020/21 as well as the Working Group's recommendations for future work.

Subarea 48.6

3.98 The Scientific Committee noted the WG-FSA discussion (WG-FSA-2021, paragraphs 4.8 to 4.15) on research results and the proposal by Japan, South Africa and Spain to continue the longline research survey for *D. mawsoni* in Subarea 48.6.

3.99 The Scientific Committee recommended that this exploratory fishery should proceed, and the catch limits, given in Table 3, should apply in Subarea 48.6.

Area 58

Divisions 58.4.1 and 58.4.2

3.100 The Scientific Committee noted the WG-FSA discussion (WG-FSA-2021, paragraphs 4.17 to 4.28) on research results and the plan to continue research in the exploratory fishery for *D. mawsoni* in Divisions 58.4.1 and 58.4.2. It noted the continued lack of agreement in the case of Division 58.4.1, in particular regarding the use of different longline types.

3.101 The Scientific Committee noted the WG-FSA discussion (WG-FSA-2021, paragraphs 4.23 to 4.24) about a proposal for a derogation to CM 21-02, paragraph 6(iii), to remove the requirement for a research plan for this division, to enable the collection of tag-based data required to make progress towards management objectives. However, the Scientific Committee could not reach consensus on this proposal and requested the Commission consider this matter.

3.102 Russia proposed to open a new fishery in Division 58.4.1 under CM 21-01.

3.103 The Scientific Committee noted that CM 41-11 identifies the toothfish fishery in Division 58.4.1 as an exploratory fishery and that the classification of all toothfish fisheries is an issue for the Commission. It noted that no catch and effort data was outstanding from fishing and research activities in that division. Many Members therefore considered it would be inconsistent with CM 21-01, paragraph 1(iii), to designate this fishery as a new fishery as proposed by Russia.

3.104 The Scientific Committee recommended that the exploratory fishery should proceed in Division 58.4.2 following the design presented in WG-SAM-2021/03 with a catch limit of 72 tonnes in research block 5842_1 (Table 3) and a new effort-limited research block 5842_2 with a catch limit of 55 tonnes (Table 4).

Division 58.4.4b

3.105 The Scientific Committee noted the WG-FSA discussion (WG-FSA-2021, paragraphs 4.29 to 4.31) on research results of the multi-Member longline survey of *D. eleginoides* in Division 58.4.4b, conducted between the 2016/17 and 2020/21 fishing seasons by Japan and France. It noted that these results were a testament to the commitment for valuable desk-based analyses to be progressed after the end of fishing operations.

Scientific research exemption

D. mawsoni in Subarea 88.3

3.106 The Scientific Committee noted the WG-FSA discussion (WG-FSA-2021, paragraphs 4.42 to 4.45) on a proposed new research plan in Subarea 88.3 on *D. mawsoni* from 2021/22 to 2023/24, to be undertaken by Korea and Ukraine. The main objectives of this research were to determine the abundance and distribution of *D. mawsoni* in Subarea 88.3, improve the understanding of stock and population structures of toothfish in Area 88, the collection of data on the spatial and depth distributions of by-catch species, and the trial of scientific electronic monitoring technologies.

3.107 The Scientific Committee recommended that this research should proceed, and the catch limits given in Tables 3 and 4 should apply in Subarea 88.3. It further noted the updated sampling rate requirement for by-catch species of 30 specimens per species per line, or the entire catch for a line if this is less than 30 specimens.

Non-target catch and ecosystem impacts of fishing operations

Fish and invertebrate by-catch

3.108 The Scientific Committee endorsed the recommendation of WG-FSA (WG-FSA-2021, paragraph 6.16i) and noted the willingness of Chile and Ukraine to engage with the Secretariat to examine how data collection and reporting methods may affect krill by-catch data.

3.109 The Scientific Committee endorsed the recommendation of WG-FSA (WG-FSA-2021, paragraph 6.16ii) for a krill fishing vessel data workshop to assist in developing standardised instructions for the collection of by-catch data by vessels. It discussed the possibility of establishing guidelines on collecting stomach content data from fish caught as by-catch in the krill fishery, as this may prove informative to the risk assessment framework.

3.110 The Scientific Committee noted that data and samples related to by-catch were collected from the CCAMLR fisheries and that those were currently underused. The Scientific Committee recommended Members use those data and samples to improve the understanding of ecosystem dynamics in the Convention Area.

3.111 The Scientific Committee noted the need for accurately quantifying finfish by-catch (paragraph 3.31), as well as considering move-on rules, similar to those existing in conservation measures for toothfish, following events of high finfish by-catch.

3.112 The Scientific Committee endorsed the recommendations by WG-FSA (WG-FSA-2021, paragraph 6.19) to:

- (i) develop a data collection plan for the Ross Sea to support both a revised medium-term fishery-based research plan as well as the broader objectives of the RSRMPA research and monitoring plan (RMP)
- (ii) undertake a review of the observer biological reporting form to ensure it is clear in the form whether a sampled individual was tagged and whether non-otolith tissues were sampled
- (iii) request the Secretariat to include a summary of the available data on by-catch species and biological data holdings in the Fishery Reports.

Incidental mortality of seabirds and marine mammals associated with fisheries

3.113 The Scientific Committee noted the discussions of WG-FSA on incidental mortality of seabirds and marine mammals (WG-FSA-2021, paragraphs 6.1 to 6.13), including the recommendation on the investigation of mitigation measures and potential move-on rules in the krill fishery (WG-FSA-2021, paragraph 6.4).

3.114 The Scientific Committee considered SC-CAMLR-40/BG/27, which presented further information, provided by a Norwegian-flagged vessel and the UK SISO observers, on the incidental mortality of three humpback whales (all potentially juvenile based on estimated body length), as requested by WG-FSA (WG-FSA-2021, paragraph 6.6). The paper indicated that the three fishing operations were conducted as normal, that the whales were only discovered

when the nets were hauled and that there was no significant by-catch of finfish associated with these three hauls. The paper concluded that it was not possible to determine whether the humpback whales were dead prior to becoming entangled, or if they died as a consequence of becoming entangled in the trawl in any of the three incidents. The authors noted that they were taking these regrettable incidents very seriously and that they highlighted the need for reinforcement of marine mammal exclusion measures.

3.115 The Scientific Committee noted that the three recorded humpback whale by-catch events occurred within the area of the proposed D1MPA (CCAMLR-39/08 Rev. 1). It considered whether these incidents reflected an increasing overlap between the krill fishery and krill predators. Some Members expressed concern about the krill fishery moving further into the Gerlache Strait where an increasing number of whales are reported, and noted that this highlighted the importance of the D1MPA proposal as a measure to prevent and mitigate the potential ecosystem impacts of the fishery.

3.116 The Scientific Committee thanked the authors for the detailed report, the SISO observers for providing additional information, and noted the usefulness of observer reports for clarifying the circumstances surrounding these incidents.

3.117 The Scientific Committee noted that SISO observer cruise reports provide valuable scientific information in addition to data reported in both observer and vessel data forms, and requested the Commission consider whether SISO observer cruise reports could be made available to Scientific Committee Representatives upon request, without the necessity to seek permission from designating and receiving Members.

3.118 The Scientific Committee reflected on the likelihood of catching dead whales on three separate occasions, considering that dead whales are more likely to float to the surface or sink to the bottom than to remain at midwater depths where trawling occurs. Some Members questioned: (i) the utility of net monitoring systems (that require the use of net monitoring cables) as they did not appear to detect these events, and (ii) whether the marine mammal exclusion devices were sufficient to prevent whale mortalities.

3.119 The Scientific Committee noted that 60 seals were reported as by-catch in the last two seasons in the krill fishery, including 16 mortalities. The Scientific Committee further noted that these unusual events highlighted the need for an assessment of the ecosystem impacts of krill fishing operations using continuous and traditional trawling systems (including a comparison to other CCAMLR trawl fisheries), in addition to the consideration of design and functioning of marine mammal exclusion devices in CCAMLR trawl fisheries (see also paragraph 3.135).

3.120 The Scientific Committee recalled the extensive and successful work undertaken historically by the Working Group on Incidental Mortality Associated with Fishing (WG-IMAF) in reducing incidental mortalities of seabirds associated with CCAMLR longline fisheries. It noted that external expertise on mitigation measures to reduce marine mammal by-catch existed in the International Whaling Commission (IWC) Scientific Subcommittee on Non-deliberate Human-Induced Mortality of Cetaceans, and on seabird mitigation devices in trawl fisheries through ACAP.

3.121 The Scientific Committee therefore agreed to reconvene WG-IMAF with a focus on addressing issues associated with krill fishing identified above and any other issues from other CCAMLR fisheries (paragraph 3.135 and Annex 9).

3.122 ASOC supported reconvening WG-IMAF, as well as the suggestion to get more historic information on whale by-catch from the Secretariat. ASOC was concerned by these by-catch incidents, noting that, in its view, they highlighted the increasing overlap of the fishery with whale and other predator feeding areas and that this indicated a need for MPAs. Further research on the impact of climate change on krill predator interactions could also be considered. ASOC appreciated the steps taken to improve the marine mammal exclusion devices and suggested that this could be looked at for all vessels operating in the fishery.

3.123 The Scientific Committee noted the discussions of WG-FSA (WG-FSA-2021, paragraph 6.7 to 6.13) and deliberated further on the derogation of the use of net monitoring cables used by continuous trawling krill fishing vessels.

3.124 The Scientific Committee noted SC-CAMLR-40/BG/23, which provided an update to incidental mortalities of seabirds and marine mammals associated with fishing activities in the Convention Area, including details of extrapolated warp strike numbers of seabirds from krill fishing vessels, as requested by WG-FSA (WG-FSA-2021, paragraph 6.5). Total extrapolated warp strike estimates for continuous trawlers were 147 strikes in 2020 and 1 019 strikes in 2021. For traditional trawlers, estimates were 3 318 strikes in 2020 and 157 strikes in 2021.

3.125 The Scientific Committee noted the high variability in the extrapolated warp strikes among vessels and reflected that this variability was likely due to the extrapolation of rare events obtained from low observation coverage of the total trawl duration (between 1% and 4%) and the different levels of risk during the multiple observation periods. It also noted the high number of warp strikes reported by the traditional trawling vessel *Sejong* in 2020 and requested WG-IMAF provide guidance to ensure a consistent and reliable way of recording and observing warp strikes. The Scientific Committee requested Members consider, with the assistance of the Secretariat, further analyses on warp strikes in the krill fishery and methods for estimating the likely total number of interactions, taking into consideration the potential diurnal, seasonal and trawling operation related patterns characterising incidents.

3.126 The Scientific Committee reflected that while SC-CAMLR-40/BG/23 reported the lowest-ever estimated seabird mortality numbers recorded in CCAMLR longline fisheries in 2020, there is a concern regarding the mortalities associated with warp strikes in the krill fishery. It noted that warp strikes may result in delayed mortalities in albatross species, and that these species are particularly vulnerable to injuries from contact with trawl warps.

3.127 COLTO welcomed the lowest ever extrapolated seabird mortality count from longliners in 2020 and thanked all toothfish vessels and their crew for their continued diligence in this area. COLTO also asked for consideration on whether an extrapolated seabird mortality count in relation to longline fishing is still warranted given the high observation rates and compliance implications for misreporting.

3.128 The Scientific Committee considered SC-CAMLR-40/BG/26, which provided the preliminary results from the second year of the trial for evaluating bird interactions with monitoring cables on krill trawlers using continuous trawling methods as requested by WG-FSA (WG-FSA-2021, paragraph 6.13). The trial was conducted from April to June 2021 and the methods were presented in WG-FSA-2021/14. The paper noted that, while the results of the first trial, and the preliminary results from the second trial, demonstrate that there is a low risk to birds from contact with the net monitoring cables with the current mitigation designs in use, the design could be improved by enclosing the cable area exposed in air from beam to

surface, on stern trawlers using continuous pumping and a third wire. The paper proposed extending the derogation for the use of net-monitoring cables in CM 25-03 for another year.

3.129 The Scientific Committee welcomed the results presented and thanked Norway for producing these in such short time. It noted that these results were preliminary and that more comprehensive results should be presented for consideration by WG-IMAF.

3.130 The Scientific Committee noted with concern: (i) the level of strikes recorded in the trial (SC-CAMLR-40/BG/26) that occurred on both the warp and the net monitoring cable, and (ii) that these occurred while mitigation measures were in use, indicating that their design was not providing sufficient mitigation. The Scientific Committee recommended that the design of mitigation measures should be improved in future trials, and agreed that the streamer system should surround the area containing the warp and net monitoring cables.

3.131 The Scientific Committee considered trade-offs in the use of a monitoring cable. Some Members questioned their effectiveness considering that the monitoring devices failed to detect the presence of three juvenile humpback whales (paragraph 3.118). Other Members recalled that if monitoring cables were not used, this could potentially increase the number of high-risk setting and hauling events required to replace the batteries of wireless sensors used instead. The Scientific Committee noted the potential improvement of mitigation measures to reduce the probability of any future whale entanglements suggested in SC-CAMLR-40/BG/27.

3.132 ASOC noted that this issue is one of several related to by-catch, and therefore supported the suggestion to reconvene WG-IMAF. With regard to the trial, ASOC stated that it did not appear the objective of the trial had been met, and that the level of observations was very low. ASOC therefore recommended that the derogation and the trial only continue with changes, including dedicated observers and mitigation measures to protect the warp and the net monitoring cables from seabirds. These issues should be further discussed at WG-IMAF. ASOC added that some vessels are using electronic monitoring and that this could be useful in collecting information to devise bird by-catch mitigation strategies.

3.133 ACAP, which had been involved in the development of improved protocols for Norway's second trial, acknowledged the improved level of observation coverage achieved. ACAP supported the view expressed by some Scientific Committee Members that there should be a further one-year derogation of CM 25-03 (perhaps with some additional requirements) to enable testing of further improvements to seabird by-catch mitigation options. ACAP would be pleased to contribute to any further work and noted that the results of the further trials and mitigation solutions would be helpful to ACAP's ongoing development of tailored advice for krill trawl fisheries. ACAP agreed with Scientific Committee Members that the wider reporting on warp interactions in SC-CAMLR-40/BG/23, indicating a relatively high level of warp strikes, highlighted some areas of concern. ACAP would be very interested in participating in any intersessional process to look into these issues, within WG-IMAF.

3.134 The Scientific Committee noted SC-CAMLR-40/BG/20, presented by ACAP, which provided a summary of the conservation status, population trends and priorities for albatrosses and petrels in the CCAMLR area. The paper highlighted some relevant outcomes from recent ACAP Working Group and Advisory Committee meetings, such as new data collection guidelines for observer programs, which include recommended standard protocols for observation of warp strikes in trawl fisheries and seabird abundance counts.

3.135 The Scientific Committee endorsed the re-formation of WG-IMAF co-convened by Mr N. Walker (New Zealand) and Dr M. Favero (Argentina) with terms of references shown in Annex 9, and the following priorities for its next meeting:

- (i) consideration of New Zealand's risk assessment for seabirds in the waters surrounding Antarctica, including consideration of CCAMLR bird strike data
- (ii) consideration of mitigation measure designs to reduce bird strikes on trawl warps and net monitoring cables
- (iii) consideration of bird strike trials and provision of guidance on warp/cable strike counts by observers
- (iv) consideration of a standard method for the extrapolation from incidental mortalities and warp/cable strikes observations to estimate total interactions and mortality numbers, accounting for differences between fishing methods, hauling/setting versus trawling period, time of day and season
- (v) consideration of the design of marine mammal exclusion devices
- (vi) consideration of collection of data and samples from marine mammals, including carcasses if possible, in a standard format
- (vii) consideration of move-on rules or avoidance techniques in the krill fishery in relation to IMAF
- (viii) coordination with ACAP, IWC, ARK and COLTO.

3.136 The Scientific Committee encouraged Members to send appropriate experts to WG-IMAF, including observers and industry representatives as had occurred in the past.

Other research notifications

3.137 The Scientific Committee noted the upcoming cruise to the Weddell Sea on the RV *Polarstern* in February–March 2022, which will include sampling of *D. mawsoni* by German and US scientists for genetic analysis and tracking by pop-up satellite tags. The research aims to address some of the gaps in the life-history hypothesis of *D. mawsoni* and provide additional data for the proposed MPA in that area.

3.138 The Scientific Committee noted Australia's intent to conduct the annual random stratified trawl survey in Division 58.5.2 in 2022.

Marine debris

3.139 The Scientific Committee noted the discussions by WG-FSA (WG-FSA-2021, paragraphs 6.25 and 6.26) on marine debris and the generation of plastic pollution in the ocean

from lost lines, as well as the potential unobserved and unaccounted mortality they may cause via ghost fishing. It encouraged Members to prevent, mitigate and recover lost lines which posed a potential threat to marine mammals and required continuous attention.

3.140 COLTO thanked the Secretariat for its work in compiling data around lost fishing gear. COLTO is committed to the fight against this major challenge to our oceans. COLTO is strongly supporting the initiative of a number of Members in the recovery of lost gear from both current and previous seasons. COLTO asked the Scientific Committee to consider the best way to report to CCAMLR the recovery of gear that was lost in previous seasons, so that records can be kept accurate and up to date.

Advice to the Commission

3.141 The Scientific Committee requested the Commission consider making SISO observer cruise reports available to Scientific Committee Representatives, without the requirement to seek permission from designating and receiving Members (paragraph 3.116).

3.142 Noting the cessation of the focused skate tagging program, the Scientific Committee recommended the removal of: (i) the first sentence of CM 41-01, Annex 41-01/C, paragraph 2(vi), and (ii) the paragraph starting with ‘During the 2020/21 season all live skates up to 15 per line...’ in CM 41-09, paragraph 6 (‘by-catch’).

3.143 The Scientific Committee recommended extending the derogation for use of net-monitoring cables in CM 25-03 for one more year, with the following conditions: (i) observation rates must reach equivalent levels to those achieved in 2021 (20%), (ii) mitigation is improved prior to the trial commencing (paragraph 3.130) to enable the evaluation of further improvements to seabird by-catch mitigation options and consideration by WG-IMAF.

Spatial management of impacts on the Antarctic ecosystem

4.1 The Scientific Committee noted SC-CAMLR-40/BG/09, which detailed the methods used to identify candidate important marine mammal areas (IMMAs) and the selection process to nominate IMMAs through an international collaboration including scientists from SCAR, IUCN and the French Biodiversity Agency. The IMMAs were determined using a set of criteria supported by data on critical aspects of marine mammal (seals and cetaceans) biology, ecology and population structure and are designed to inform policy makers about general management and conservation processes.

4.2 Mr L. Yang (China) recalled that WG-FSA-2019 noted that any fishery is expected to have an impact on the fished population. The CCAMLR precautionary approach defines what impact is acceptable and that changes need to be reversible over a time frame of two to three decades as defined in Article II of the Convention. In the same way, he suggested that CCAMLR also needs to define what impact from fishery is acceptable to the marine mammals as dependent or associated species, particularly in terms of its population, to better inform the management decision-making.

4.3 The Scientific Committee welcomed the submission by the Southern Ocean Observing System (SOOS) of SC-CAMLR-40/BG/02, which presented an overview of SOOS's regional working groups and observing system design capabilities, demonstrating how SOOS can support the design and implementation of ecosystem and climate change monitoring, to complement CCAMLR and SCAR monitoring systems.

Marine protected areas (MPAs)

General issues

4.4 The Scientific Committee noted SC-CAMLR-40/18, which presented the critical elements for the development of RMPs for CCAMLR MPAs updated from SC-CAMLR-38/20, with the aim to ensure the transparency of all RMPs and to provide a guiding framework for all Members participating in RMPs and future reviews on a scientific basis. The paper identified critical elements including, inter alia, that: (i) baseline data be collated from the very beginning of elaboration of MPAs and presented, (ii) broadly stated objectives be translated into specific, measurable, achievable, relevant or realistic and time-bound (SMART) management objectives, (iii) indicators and their parameters be identified, (iv) states of system or decision triggers be defined, (v) management actions in relation to decision triggers be developed, (vi) data collected be standardised, and (vii) the principle of cost-effectiveness should be always kept in mind. It recommended that the Scientific Committee recognise the importance of these critical elements in the development of RMPs for CCAMLR MPAs, and use them as a foundation to facilitate further cooperation on this important matter.

[4.5 The Scientific Committee further recalled that CCAMLR endorsed the creation of a representative system of MPAs to ensure conservation of marine biodiversity. [This includes measurements of](#) ~~, including~~ species diversity and ecosystem functioning diversity.]

[4.6 [Some Members](#) ~~It~~ noted that representativeness was one of the key elements providing guidance to a holistic approach in developing MPAs. ~~It~~ [They](#) recognised that indicator species are useful, but that they in many instances only represent a fraction of ecosystems.]

4.7 Some Members proposed to provide a unified approach for development of RMPs for CCAMLR MPAs as an annex to CM 91-04, and noted that this unified approach could be developed by taking into account historical papers by China (SC-CAMLR-38/BG/15) and Russia (SC-CAMLR-38/11 Rev. 1). Some Members considered that the development of unified requirements for an RMP should precede the establishment of new MPAs.

4.8 Some Members recalled that there was no requirement under CM 91-04 to develop an RMP until after an MPA was designated.

4.9 The Scientific Committee noted, but due to the limited meeting time available did not comment on, SC-CAMLR-40/BG/11, submitted by ASOC.

D1MPA

4.10 Mrs M. Abas (Argentina) brought the attention of the Scientific Committee to CCAMLR-40/BG/20, which was not tabled to the Scientific Committee, and detailed an update of the latest considerations for the D1MPA proposal during the 2020/21 intersessional period.

[4.11 The Scientific Committee welcomed the initial steps towards a comprehensive and collaborative RMP for the D1MPA proposal, including planning for an international workshop during 2022/23. It noted the extensive number of national Antarctic programs, private initiatives and multilateral consortia that carry out scientific research related to the RMP priority elements (CCAMLR-40/BG/20, Annex A) and encouraged interested stakeholders to actively participate in the upcoming workshop and related activities.]

[4.12 The Scientific Committee noted the work developed along a number of years in the framework of CM 91-04 applying methods established and adopted by consensus. With regard to the proposed MPA in Domain 1, the Commission supported the work of the proponents through its scholarship program and a proposal was presented in 2018 (CCAMLR-XXXVII/31). Since the presentation, the proponents worked through e-groups, virtual and in-person meetings and significant improvements have been achieved both in the design of limits and functions of the different zones. When the D1MPA was considered by itself in the risk evaluation process, it resulted in an improvement in the spreading of catches. This result was obtained with different datasets demonstrating that the methodology used is robust and useful. Thus, the significant efforts made by the Scientific Committee over a number of years provided a technically mature tool for the Commission to determine how to use it in applying the precautionary approach in Domain 1.]

[4.13 Many Members noted the importance of participative and inclusive work regarding the discussion on MPAs from the basis of scientific concerns, highlighting that this was the spirit in the development of the current proposal on D1MPA, which is fully mature and ready for the Commission to use this tool in the application of a precautionary approach in the administration of its resources.]

[4.14 Many Members noted the importance of climate change and its relationships with discussions on MPAs, especially in areas such as Domain 1, where significant environmental changes are occurring. Further noted was the importance of establishing general protection zones (GPZ) which would allow the protection of other objectives and to provide the opportunities to species to adapt to the impact of climate change on diverse species in the absence of human-related pressures.]

Weddell Sea

4.15 SC-CAMLR-40/13 presented an invitation from Norway to CCAMLR Members and Observers to participate in a workshop, proposed for the first half of 2022, with the aim of exploring spatial planning solutions for the Weddell Sea MPA (WSMPA) phase 2, and to jointly identify a range of candidate spatial planning solutions. SC-CAMLR-40/12 provided details of the scientific data that have been compiled to support the workshop, and SC-CAMLR-40/BG/19 detailed the developing scientific data compilation and analysis used to achieve the best available science for the conservation objectives of the WSMPA phase 2.

4.16 The Scientific Committee welcomed the progress on the WSMMPA by Norway and participating Members, noting the extensive scientific knowledge that has been collected and synthesised for the region, and the new data, models and decision-supporting frameworks that have been introduced since the last update of information supporting the WSMMPA proposal (CCAMLR-38/BG/14). The Scientific Committee strongly encouraged all interested Members to attend the proposed workshop in 2022, and noted that it presented an excellent opportunity to progress this proposal and discuss matters such as those raised in SC-CAMLR-40/16. The Scientific Committee also encouraged the authors of SC-CAMLR-40/BG/19 to provide potential biological explanations on the differences in parameters selected by the habitat suitability models for similar species, drawing the model outcomes of Antarctic krill and ice krill (*Euphausia crystallorophias*) as an example.

4.17 The Scientific Committee noted SC-CAMLR-40/16 presented by China with observation and comments on the scientific basis and draft RMP of the WSMMPA proposal. China reported that many of the elements raised in this paper had been presented in SC-CAMLR-38/BG/15, but are still relevant and outstanding for the WSMMPA proposal phase 1, and should also be taken into account in the design process of the phase 2 proposal. China requested further scientific evidence to justify the extraordinarily large size of the proposed WSMMPA phase 1, which includes a high percentage of inaccessible data-poor area covered by year-round heavy sea-ice, while the supporting background documents submitted in 2016 indicate relatively low threats from the well-managed fishery and other low-level human activities.

[4.18 SC-CAMLR-40/16 further suggested to simplify the dual set of WSMMPA objectives, and provide more scientific data to justify the rationale of each objective, including: 1) the linkage between each of the objectives to the specific key species; 2) the status and trends of such key species with the support of identified baseline data; 3) the threat on the potential Antarctic marine living resources that justify the proposed objectives; 4) the effectiveness of the current conservation measures, and the necessity of the proposed management measures and its cost-effectiveness or alternatives; 5) the SMART criteria to assess whether and the extent to which the objectives will be achieved consistent with Article II of the Convention, and the indicator that can be monitored and evaluated to make such assessment; 6) the feasibility to distinguish the climate change impact and the impact of harvesting activities in the vast proposed reference area, and the resources and effort needed to support such research; and the scientific uncertainties and further scientific effort needed to address these issues. The paper also encourages the proponents to further improve the RMP to ensure the extent of achievement of the proposed objectives can be evaluated, including baseline data corresponding with the proposed indicators.]

4.19 Many Members noted that many of the concerns raised had been addressed in updated papers provided by the proponents of the WSMMPA to WG-EMM-2021 (WG-EMM-2021/18) and in SC-CAMLR-40/12, 40/13 and 40/BG/19.

4.20 Many Members congratulated the proponents on progress in developing the WSMMPA proposal, considering that it utilised the best available science, and that it would make a substantial contribution to the development of a representative system of MPAs in the Convention Area. They considered that it was now the role of the Commission to decide how to implement the proposal.

4.21 Some Members considered that more work was required for the proposal, noting that further scientific evidence was needed to justify the size of the WSMPA, given the limited impacts from human-related activities in the region, and large areas where limited data were available on indicator species and ecosystem processes.

4.22 Dr Kasatkina noted that clarity on hypotheses regarding the distribution and life cycle of *D. mawsoni* would be required for the WSMPA proposal, recalling the recommendations of the 2018 Workshop for the Development of a *Dissostichus mawsoni* Population Hypothesis for Area 48 (WS-DmPH). Dr Kasatkina also highlighted that the WSMPA will include potential fishing grounds for krill and a number of fish species. Therefore, further study would be required to ensure that the WSMPA design includes potential fishing and protected areas managed by different conservation measures.

4.23 Some Members noted that while individual species may be important indicators, MPAs were designated to conserve ecosystem processes so a lack of comprehensive information on *D. mawsoni* would not preclude designation of the WSMPA.

Ross Sea region

4.24 The Scientific Committee noted SC-CAMLR-40/17, which presented a possible example for updating the baseline data for emperor penguins (*Aptenodytes forsteri*) and Adélie penguins (*P. adeliae*) in the Ross Sea region, with the aim to establish comprehensive knowledge on the penguins in this region. The paper further explored the trends and possible reasons for penguin population fluctuations in the region to provide guidance for future research, and found that the breeding population of emperor penguins in the Ross Sea region had increased since 2000 despite the annual fluctuations among various colonies, and the breeding population of Adélie penguins in the Ross Sea region was on a steady rise in major colonies. The paper recommended that Members collect and analyse literature and data on different species in a coordinated way under CCAMLR throughout the region, with the view to establish a comprehensive baseline database, including the key components of the ecosystem, and that Members cooperate and coordinate among their national programs to improve the relevance and accuracy in the surveys, and to update and improve Table 1 and Table 2 of SC-CAMLR-40/17 with the aim to establish a reliable baseline database.

[4.25 The Scientific Committee suggested the authors of SC-CAMLR-40/17 provide the list of the papers they have used for this systematic literature analysis, how these papers were queried from bibliographic databases and to detail the methodologies on how data were processed for generating the figures shown in the paper.]

4.26 The Scientific Committee noted the suggestion by the authors of SC-CAMLR-40/17 for more coordinated work between Members. It recalled that that extensive coordinated research, including by those implementing CEMP for penguins, currently exists, and welcomed participation by experts from China.

4.27 Many Members noted that combining and reviewing scientific studies on particular topics is difficult without considering methodologies of individual studies, the data used in those studies, and the associated confidence intervals of results. Noting the above, many Members recommended that Members move towards statistical meta-analysis of studies and

datasets which may have been presented for a different purpose than a literature review, rather than just considering published results. Many Members reiterated the benefit of Members initially submitting papers in the first instance to the appropriate working groups for consideration by experts in a less time-pressured environment.

4.28 The Scientific Committee encouraged an update of the paper to be presented to WG-EMM-2022 to allow consideration by relevant experts.

4.29 The Scientific Committee noted the submission of, but due to the limited meeting time available did not comment on, SC-CAMLR-40/BG/22, presented by ASOC. The paper provided a detailed explanation of the governance of the RSRMPA, including the active and ongoing management, research and monitoring. The paper further described how and why the majority of the MPA qualifies under the new MPA Guide as a highly protected MPA, and concluded that the RSRMPA is currently, and for the foreseeable future, highly protected from potentially destructive human activities, and is thus exemplary of a large-scale highly protected MPA.

Climate change

5.1 The Scientific Committee considered CCAMLR-40/19 Rev. 1, which proposed to designate a newly exposed marine area adjacent to the Pine Island Glacier (Amundsen Sea, Subarea 88.3) as a stage 2 Special Area for Scientific Study (SASS) in accordance with CM 24-04. Following the expiration of the original designation as a stage 1 SASS on 31 May 2021, the area was redesignated as a stage 1 SASS following notification by the UK in June 2021 (COMM CIRC 21/76). The paper noted that by June 2021 the glacier had undergone a 22% reduction in area compared to the baseline extent recorded in September 2017. The paper provided information, in addition to CCAMLR-38/20, on the extent and characteristics of the proposed SASS.

5.2 The Scientific Committee agreed that additional research is needed to understand how ecosystems change in newly exposed marine areas. It recalled that, under the provisions of CM 24-04, research can be undertaken within a stage 1 or stage 2 SASS; further that the two-stage process defined by CM 24-04 was to facilitate the development of research, recognising the time required to mobilise at-sea research. However, Members had different views on how to proceed with respect to the designation of a stage 2 SASS under CM 24-04:

- (i) some Members encouraged research to be conducted with results describing the ecological characteristics of the area brought back to the Scientific Committee for review prior to progression to a stage 2 SASS
- (ii) many Members considered that the requirements under CM 24-04 had been met and that a stage 2 SASS designation was necessary to provide an appropriate period to plan expeditions, conduct analyses and provide results
- (iii) some Members noted that the SASS should remain in stage 1 until it expires and scientific research within the SASS may be undertaken in stage 1 as well as stage 2 under CM 24-04.

5.3 The Scientific Committee considered SC-CAMLR-40/08, which proposed updated terms of reference for the ‘Climate change impacts and CCAMLR’ e-group to allow it to conduct work which will enable the Scientific Committee to assess the risks presented by climate change, and to ensure the Commission takes timely responses to address such risks.

5.4 The Scientific Committee thanked the members of the e-group and noted that the e-group on climate change was an important mechanism to facilitate progress on identifying issues and implications arising from climate change research and developing scientific advice related to conservation and management. The Scientific Committee noted the proposed revision of the terms of reference for the e-group. Many Members expressed their willingness to participate in discussions using this mechanism as well as in the Scientific Committee and its working groups.

5.5 Dr X. Zhao (China) considered the proposed terms of reference for the e-group as not necessary now by recalling the increasing efforts of the Scientific Committee and its various working groups in taking into consideration the climate change effect in its scientific work, and requested the Scientific Committee to encourage Members and scientists to continue the efforts in studying climate change effects in concrete scientific endeavours, including but not limited to, through data collection and analysis.

5.6 The Scientific Committee considered SC-CAMLR-40/09 Rev. 1 which provided an update on the vulnerability of the emperor penguin populations to ongoing and projected climate change. It highlighted the draft version of the revised Specially Protected Species Action Plan for the emperor penguin developed by the CEP and invited CCAMLR to provide advice on practical measures.

5.7 The Scientific Committee welcomed the analysis and encouraged CCAMLR Members to contribute to further development of the action plan through Dr K. Hughes (as convener of the group developing the action plan), the contacts listed in the paper, or the intersessional contact group site at CEP.

5.8 The Scientific Committee noted SC-CAMLR-40/BG/04 which summarised the activities of Oceanites since CCAMLR-39 to ensure the penguin data and population information are available through MAPPPD, an Antarctic continent-wide penguin database. It recalled that MAPPPD data is freely available through the website www.penguinmap.com.

5.9 Oceanites made the following statement:

‘At this point, I want to elaborate climate change aspects of Oceanites’ report (SC-CAMLR-40/BG/04), which will be presented in full under Agenda Item 6.2.

Oceanites and so many colleagues participating in this Scientific Committee meeting are focused on distinguishing the interactive effects of climate change vis-à-vis human activities as well as other factors that might definitively explain penguin population changes which are being detected.

All of us understand that the precautionary principle embodied in the CAMLR Convention requires that conservation measures need to be based on the best available scientific data and information, whether dealing with impacts caused by climate change, human activities, or still unknown synergies.

To ensure the best penguin data and information are available in this regard, Oceanites continues to update MAPPPD, the Antarctic continent-wide penguin database that we maintain. This ensures that everyone in CCAMLR and the Antarctic Treaty System can freely and readily access the most current data on Antarctica's penguins and penguin population changes.

Of particular note, Oceanites continues to closely track the significant trends in the vastly warmed Antarctic Peninsula, where Adélie and chinstrap penguins have declined and gentoo penguins have increased.

Regarding the ongoing science examining climate change and other causative factors, Oceanites' most recent State of Antarctic Penguins report, based on the MAPPPD database, notes a suite of factors that, it is hoped, when analysed, will add to the trove of scientific data and analyses already available, and explain more precisely the population changes being detected. These factors include:

- *a potentially shifting or shrinking krill stock*
- *the location of krill fishing vis-à-vis the foraging range of breeding penguins; the foraging range of juvenile penguins post-breeding season; the foraging range of overwintering gentoo penguins; and the winter foraging ranges of Adélie and chinstrap penguins*
- *competition for krill with whales and seals*
- *rising temperatures and retreating sea ice due to global warming.'*

5.10 The Scientific Committee noted SC-CAMLR-40/BG/10 in which ASOC noted that there is a considerable mismatch between the urgency of addressing climate change and the pace of climate action in the Southern Ocean, and identified priorities for CCAMLR to address in response to the threat posed by climate change to its objective.

5.11 The Scientific Committee noted SC-CAMLR-40/BG/12 which draws attention to critical findings from the recent Special and Assessment Reports of the Intergovernmental Panel on Climate Change. These reports provide the clearest current summaries of global climate change that has taken place, impacts that are being realised, and changes that are forecast. The paper also describes research undertaken by SCAR, including through its three new scientific research programs to address uncertainties and understand the implications of climate change for ecosystems, species and their management. SCAR will next year provide an update of its Antarctic Climate Change and the Environment Report to the Antarctic Treaty Consultative Meeting (ATCM) and to CCAMLR.

5.12 The Scientific Committee noted SC-CAMLR-40/BG/13 which draws attention to the effects ocean acidification is predicted to have on habitats, organisms and ecosystems in the coming decades, especially in a warming environment. The paper noted that further targeted research is important to understand the impact of ocean acidification on marine living resources in the Southern Ocean.

Cooperation with other organisations

6.1 The Scientific Committee considered CCAMLR-40/12, which describes cooperation under the formal arrangements and memorandums of understanding (MoUs) that CCAMLR has signed with other regional organisations.

6.2 The Scientific Committee noted the increasing level and importance of cooperation with other regional organisations. It further noted that the Arrangement with SPRFMO comes to an end in March 2022, and that the MoU with ACAP comes to an end in November 2021. The Scientific Committee endorsed the re-signing of the Arrangement with SPRFMO and the MoU with ACAP to extend both for an additional three years.

6.3 The Scientific Committee endorsed the Secretariat routinely sharing summarised seabird mortality data with the ACAP Secretariat in advance of the CCAMLR Scientific Committee meetings in the format used in submissions to WG-FSA (for example WG-FSA-2021/04 Rev. 1). It noted that these summary data would be shared exclusively for the purpose of assisting ACAP in developing advice for CCAMLR. Otherwise, data sharing would follow the Rules for Access and Use of CCAMLR Data.

6.4 The Scientific Committee noted the joint SIOFA–CCAMLR Workshop on the exchange of scientific toothfish data which will be held online on 29 November and 1 December 2021 (Table 1 and SC CIRC 21/130).

Cooperation within the Antarctic Treaty System

Committee for Environmental Protection

6.5 The Scientific Committee noted SC-CAMLR-40/BG/21 which presented the annual report of the CEP to the Scientific Committee of CCAMLR. The report summarised the discussions at CEP XXIII, hosted by France from 14 to 18 June 2021, on the five issues (climate change, biodiversity and non-native species, species requiring special protection, spatial management and area protection, and ecosystem and environmental monitoring) agreed to be of common interest with SC-CAMLR.

Scientific Committee on Antarctic Research

6.6 The Scientific Committee noted SC-CAMLR-40/BG/15 in which SCAR presented recent and future activities of relevance to CCAMLR from its Annual Report 2020/21.

6.7 The Scientific Committee noted SC-CAMLR-40/BG/14 which presented the Antarctic Environments Portal (<https://environments.aq>) which SCAR has assumed oversight and management over since January 2020. The paper provided examples of how information summaries published in the portal link directly to issues of priority interest to CCAMLR. The paper encouraged CCAMLR Members to support further development of the portal and the publication of information summaries, recognising their value in contributing to CCAMLR's work and to identify any additional information summaries that would be useful to CCAMLR's interests.

Reports of observers from other international organisations

6.8 The Scientific Committee noted CCAMLR-40/BG/16 which presented the report from the CCAMLR Observer (Australia) to the 24th and 25th Annual Meetings and the 4th Special Session of the Indian Ocean Tuna Commission (IOTC).

6.9 The Scientific Committee noted SC-CAMLR-40/BG/02, which provided an overview of the regional working groups and observing system design capabilities of SOOS and demonstrated how they can support the design and implementation of ecosystem and climate change monitoring to complement CCAMLR and SCAR monitoring systems.

6.10 The Scientific Committee noted SC-CAMLR-40/BG/03 which presented SOOSmap (<https://soosmap.aq>) and DueSouth (<https://soos.aq/activities/duesouth>): two SOOS data activities that are relevant to the CCAMLR community. The Scientific Committee welcomed the offer to work with SOOS to identify data products that would aid in CCAMLR's work.

6.11 The Scientific Committee noted SC-CAMLR-40/BG/04 in which Oceanites made the following statement:

'Oceanites is pleased to report ongoing success in its efforts to advance science-based conservation in the Antarctic and to champion increased awareness of climate change, its potential impacts, and climate change adaptation through the lens of Antarctic penguins. Though complicated by the pandemic, Oceanites' Antarctic Site Inventory collected new data for a 27th consecutive field season, over which time frame the project has amassed more than 2 100 census visits at more than 258 sites. Antarctic Site Inventory data plus data from other sources then flow into the Antarctic continent-wide MAPPPD database that Oceanites maintains, which now contains 4 510 records from 748 sites, and 121 data sources of on-the-ground colony counts and satellite photo analyses. In the past year, the number of records in MAPPPD has increased by 20% and the number of data sources by 2%. Oceanites greatly appreciates the growing use of our open-sourced, publicly available data repository by the entire Antarctic community — and again, we encourage those who have not yet contributed to, or utilised MAPPPD, to do so. Importantly, Oceanites is completing a full-scale revision and update to MAPPPD that will enable much more extensive and expeditious searching of the MAPPPD database; in particular, this involves the creation of a package that can be accessed in the R programming language that will allow users access to the latest version of the MAPPPD database, with some straightforward tools allowing the filtering and exploring of data in an interactive map, or with some standard functions. MAPPPD's goals are to: assist and ensure that conservation management decisions in CCAMLR and the Antarctic Treaty System are based upon the best and most currently available scientific data and information; and provide a database that is easy to access and use, and freely open to scientists, governments, managers, Antarctic stakeholders (fishing, tourism, environmental), and the general public. In terms of MAPPPD-related projects, Oceanites continues to work with: ARK to assist in the evaluation of voluntary restricted zones (VRZs) that have been established to avoid krill fishing near penguin breeding colonies; and IAATO to re-analyse whether tourism potentially impacts Antarctic Peninsula penguin populations. The MAPPPD database serves as the predicate for Oceanites' State of Antarctic Penguins reports, the most recent of which notes that the five Antarctic penguin species totalled 5.77 million breeding pairs and highlights further chinstrap and Adélie penguin declines. As we

noted earlier under Agenda Item 5, our latest State of Antarctic Penguins report describes a suite of factors being examined, which, it is hoped, will add to the trove of scientific data and analyses already available, and explain more precisely the population changes being detected. These factors include:

- (i) a potentially shifting or shrinking krill stock*
- (ii) the location of krill fishing vis-à-vis the foraging range of breeding penguins; the foraging range of juvenile penguins post-breeding season; the foraging range of overwintering gentoo penguins; and the winter foraging ranges of Adélie and chinstrap penguins*
- (iii) competition for krill with whales and seals; and rising temperatures and retreating sea-ice due to global warming.*

Lastly, on behalf of everyone at Oceanites, we extend our sincere thanks to the Scientific Committee and its working groups for their ongoing support, cooperation and assistance, all of which helps to keep Oceanites' work going.'

6.12 The Scientific Committee noted SC-CAMLR-40/BG/16 which reported on the activities by ARK in the 2020/21 krill fishing season. The paper highlighted ARK's participation in forums organised by the SCAR Krill Action Group (SKAG) and Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) and its willingness to further strengthen the science–industry forum. The paper further noted the late arrival of part of the krill fishing fleet into the fishing areas due to the global pandemic.

6.13 The Scientific Committee welcomed these papers (paragraphs 6.5 to 6.12). Although the papers tabled under Agenda Items 6.1 and 6.2 were briefly presented, the Scientific Committee was unable to comment on any of these submissions as there was not sufficient time to discuss them in plenary. The Scientific Committee invited interested Members to contact the authors directly.

6.14 Mr R. Arangio (COLTO) announced the winners of the annual CCAMLR toothfish tag-return lottery for the 2020/21 season. First place went to the UK-flagged vessel *Argos Georgia*, second place went to the Ukrainian-flagged vessel *Simeiz*, and third place went to the Spanish-flagged vessel *Tronio*.

6.15 The Scientific Committee thanked COLTO for supporting this initiative and congratulated the winners.

Priorities for work of the Scientific Committee and its working groups

General issues

7.1 The Scientific Committee considered CCAMLR-40/08 which proposed gender-neutral changes to the English and Spanish language versions of the Rules of Procedure for the Commission and Scientific Committee.

7.2 The Scientific Committee endorsed the proposed changes to the Rules of Procedure noting the importance of the issue. The Scientific Committee noted the desire by France to include gender-neutral language in the French version of the Rules of Procedure in the future.

7.3 The Scientific Committee considered CCAMLR-40/09 which outlined different options for publication and printing of the CCAMLR meeting reports and proposed to discontinue the involvement of an external publisher to publish CCAMLR meeting reports.

7.4 The Scientific Committee recommended discontinuing printing of bound copies of CCAMLR meeting reports, with printed reports available to Members upon request at cost price.

7.5 The Scientific Committee considered CCAMLR-40/10 which outlined the rules of access that apply to CCAMLR meeting documents and suggested changes to streamline the process of document request and release and increase transparency.

7.6 The Scientific Committee welcomed this contribution and noted that the need for readers to be aware of the context of the papers within meeting reports should be indicated at their release. It also noted the need to consider rules for making 30-year-old meeting documents publicly available.

7.7 The Scientific Committee reflected on how to improve access by Observers to working group documents to allow better engagement at Scientific Committee meetings considering that currently Scientific Committee meeting documents marked as ‘release upon request’ only become available after the completion of the Scientific Committee meeting. The Scientific Committee further noted the need for a procedure to ensure releases of working group documents are not in breach of the Rules for Access and Use of CCAMLR data, and concluded that the rules of access that apply to CCAMLR meeting documents need further consideration.

7.8 ASOC expressed its support for the recommendations presented in CCAMLR-40/10 and noted that other organisations such as SPRFMO make the Scientific Committee papers public. It further noted that it is in CCAMLR’s interest to have papers available for academic review.

7.9 The Scientific Committee requested the Secretariat to establish an e-group to further discuss the rules of access that apply to CCAMLR meeting documents and requested that the Secretariat consult with Members and revisit the issue at SC-CAMLR-41.

7.10 The Scientific Committee considered CCAMLR-40/11 which discussed options to enable Observers to CCAMLR meetings to circulate material to Members.

7.11 The Scientific Committee recommended a two-year trial period for enabling Observers to circulate material to Members. The Scientific Committee requested the Secretariat set up a new type of circular to allow easy prioritisation of consideration of the disseminated information.

7.12 The Scientific Committee noted SC-CAMLR-40/14 which reported on a workshop held in Kaliningrad, Russia, in August 2021 to train Russian scientific observers to work in CCAMLR fisheries.

Priorities for the work of the Scientific Committee

7.13 The Scientific Committee considered SC-CAMLR-40/01, presented by the Scientific Committee Chair, which proposed to hold an online symposium to develop the next five-year strategic plan for SC-CAMLR, recalling the development and implementation of the previous strategic plan (SC-CAMLR-XXXV/12, SC-CAMLR-XXXV, paragraphs 13.1 to 13.7).

7.14 The Scientific Committee agreed that the development of the next five-year strategic plan for SC-CAMLR was of a high priority, and endorsed the recommendations in the proposal to hold the symposium online, in all CCAMLR official languages, with the support of the Secretariat and the Interprefy platform. The timing of the symposium and the list of priority topics will be developed in an e-group led by the Scientific Committee Chair.

7.15 The Scientific Committee noted the proposed dates for meetings of its working groups:

- (i) WG-ASAM (Yokohama, Japan, 30 May to 3 June 2022) (Co-conveners: Drs Fielding and Wang)
- (ii) WG-SAM (Kochi, India, 27 June to 1 July 2022) (Co-conveners: Drs Péron and Okuda)
- (iii) WG-EMM (Kochi, India, 4 to 15 July 2022) (Convener: Dr Cárdenas)
- (iv) WG-IMAF (Co-conveners: Mr Walker and Dr Favero, location and timing to be determined)
- (v) WG-FSA (Hobart, Australia, 3 to 14 October 2022) (Convener: Mr Somhlaba).

7.16 The Scientific Committee noted the large number of workshops proposed for the intersessional period (Table 1). Where dates and conveners had not been agreed for a workshop, the Scientific Committee considered that it would not include them in its program of intersessional work yet, pending full discussion at the second Scientific Committee symposium.

7.17 The Scientific Committee also noted three previously recommended e-groups to be established in addition to e-groups designated at this meeting to progress its high priority work items:

- (i) progress discussions on krill length frequency data (WG-ASAM-2021, paragraph 3.7)
- (ii) collaborate with ARK to progress phytoplankton data collection (WG-EMM-2021, paragraph 4.8)
- (iii) development of an approach to improve structured fishing in SSRU 882H (WG-FSA-2021, paragraph 4.40).

Ross Sea region MPA

[\[7.18 The Scientific Committee noted that CM 91-05 requires Members to “report on their activities conducted according to, or related to, the MPA Research and Monitoring Plan,](#)

including any preliminary results.” These reports are due during the forthcoming intersessional period, and the Scientific Committee is obligated to review the reports including preliminary results as a matter of priority.]

[7.19 Mr Yang made the following statement:

‘The RMP of the RSRMPA has not been updated taking to the advice of scientific committee made since the year 2018, and been adopted by the commission in accordance with the Conservation Measure 91-04 and CM 91-05. In the current draft RMP there are still outstanding issues that may substantially affect the evaluation of the RSRMPA, such as the inconsistency among the objectives of the MPA, its subareas, the research topics and monitoring. Some and other members have proposed series of recommendations to improvement of the RMP for the RSRMPA, including solve the above issue and the standardisation of methods, protocols and/or formats for data collection and analysis, not just activities, in order to ensure the success of the evaluation. Mr Yang again called for the scientific committee to take into those recommendations seriously to facilitate the future evaluation. ’

7.20 Mr Yang also suggested to take some opportunity to discuss the format of the CCAMLR MPA Information Repository (CMIR), which has been delayed by the pandemic.

[7.21 The Scientific Committee encouraged Members to submit activity reports, including any preliminary research and monitoring results, to the Secretariat through CMIR. The Scientific Committee agreed that standardisation of methods, protocols and/or for data collection and analysis to guide Members’ research and monitoring activity and the evaluation by the Scientific Committee. reports would make it easier to track the progress of research related to the RSRMPA and facilitate future gap analyses. The Scientific Committee requested that the Members the Secretariat to develop such standardized standardisation methods reports by querying the CCAMLR MPA Information Repository, and Dr Watters offered to work with the Secretariat to identify useful content for these reports.]

Science-related funds

7.22 The Scientific Committee considered CCAMLR-40/02, which outlined the terms of reference and Deed of Funding template for the General Science Capacity Fund (GSCF). The Scientific Committee endorsed the terms of reference and the template presented in the paper.

7.23 The Scientific Committee noted SC-CAMLR-40/BG/05 Rev. 1, which detailed several special science funds managed by the Secretariat on behalf of the Commission. The Scientific Committee noted that access to these funds was potentially challenging for Members, and requested the Scientific Committee Bureau consider ways to simplify this.

CEMP Fund

7.24 The Scientific Committee noted that the CEMP camera network has been a successful method of expanding both the temporal and spatial scope of CEMP and the capacity of several Members to initiate and continue to engage in CEMP (WG-EMM-2019, paragraphs 5.18

and 5.19). The Scientific Committee noted that in 2021, 2022 and 2023 expenditure of A\$20 000 for each year has been approved for the purchase of outdoor cameras and batteries. An additional sum of A\$30 000 has been included in each of these three years for any additional expenditure that may be approved by the Scientific Committee.

7.25 The Scientific Committee noted that two proposals (from Lowther et al. and from LaBrousse et al., see SC-CAMLR-40/BG/29) seeking support from the CEMP Special Fund submitted by the proposed deadline (SC CIRC 21/133) were reviewed according to the assessment criteria. An additional proposal was referred to the CEMP Special Fund Management Panel from the GCBF Panel.

7.26 The Scientific Committee endorsed the recommendations from the CEMP Special Fund Management Panel that a sum of A\$70 000 be allocated to a proposal for determining overwinter migration strategies and identification of regional foraging hotspots within Subarea 48.1 of chinstrap penguins (*P. antarcticus*).

7.27 The Scientific Committee noted that the LaBrousse proposal was scientifically important and if phase 1 was successful then it could contribute to a re-evaluation of including crabeater seals (*Lobodon carcinophagus*) as a CEMP indicator species and recommended that the authors provide an updated proposal to the fund next year with results from phase 1 presented to WG-EMM-2022.

7.28 The Scientific Committee endorsed the recommendations from the CEMP Special Fund Management Panel, that a sum of A\$50 000 be allocated to non-salary components of a proposal from Uruguay directed to incorporating Ardley Island (near King George Island) as a CEMP site (and initiating a long-term monitoring scheme of the site), and initiating a long-term monitoring scheme of marine debris on King George Island, and plastics in sea waters in the western Antarctic Peninsula and South Scotia Arc region.

7.29 The Scientific Committee recommended that the CEMP Special Fund Management Panel formalises a review process as in SC-CAMLR-XXXI, Annex 8, paragraph 9, to set grant review dates for ongoing CEMP Special Fund grants with reporting requirements for transparency and oversight of fund expenditures.

7.30 The Scientific Committee recommended that the Secretariat or the Scientific Committee Bureau review the management panel and operational arrangements to develop consistent and efficient structures and processes among all three science-related funds and bring recommendations to SC-CAMLR-41.

7.31 The Scientific Committee endorsed the nomination of Dr J. Hinke (USA) as the junior member of the CEMP Special Fund Management Panel for the 2021/22 period.

CCAMLR Scientific Scholarship Scheme

7.32 Dr G. Zhu (China, Senior Vice-Chair of the Scientific Committee) announced that the CCAMLR scholarship fund received only one application for 2022/23, however, the application was of high quality, on a topic of relevance to CCAMLR science on krill ecology and management, as well as to CCAMLR's management of the impacts of climate change. The scholarship laureate for 2021 is Ms Zephyr Sylvester from the USA, working on her PhD at the

University of Colorado, Boulder. Her research aims to demonstrate how climate change mechanisms could affect phytoplankton and zooplankton productivity in the Southern Ocean to potentially drive changes in community composition and trophic transfer of energy up the food chain. She will be mentored by Dr A. Van de Putte (Belgium) and will present her work at future WG-EMM meetings.

7.33 The Scientific Committee congratulated Ms Sylvester on her scholarship and noted the productivity of the CCAMLR scholarship scheme, with many past recipients going to leadership positions both within CCAMLR and Member delegations.

7.34 The Scientific Committee noted the scholarships awarded in 2018 and 2019 were extended for one year due to the COVID-19 pandemic. The Scientific Committee further noted that a significant portion of scholarship funding is contingent on attending an in-person CCAMLR meeting as well as meeting with mentors, and the ability to do this has been curtailed for the last two years.

7.35 The Scientific Committee requested that scholarships awarded in 2018, 2019 and 2020 be extended, where still relevant, for a further year to allow recipients to meet with mentors and attend in-person CCAMLR meetings. It requested that the Standing Committee on Administration and Finance (SCAF) consider the implications of the scholarship extension (paragraph 9.2).

Secretariat supported activities

8.1 The Scientific Committee considered SC-CAMLR-40/02 Rev. 1, which summarised Secretariat activities over the past two years and made recommendations for Secretariat tasks for 2022 to:

- (i) work with the Editorial Board on a review of the Scientific Committee's publication policy
- (ii) proceed with the special issue of *CCAMLR Science* focusing on management of the krill fishery.

8.2 The Scientific Committee endorsed the review of the publication policy, especially regarding how *CCAMLR Science* may best be used to increase the visibility and transparency of science conducted by CCAMLR. The Scientific Committee noted that options explored could include revitalising the earlier *Selected Scientific Papers*, and requiring scientists using CCAMLR data extracts to publish in *CCAMLR Science*, and recommended that an e-group be used to aid in the review process and to bring recommendations to SC-CAMLR-41.

8.3 The Scientific Committee recommended that the Secretariat progress the publication of the special issue of *CCAMLR Science* focussing on the development of the management approach for the krill fishery (SC-CAMLR-38, paragraph 13.8), using papers already submitted (SC-CAMLR-40/02 Rev. 1) as well as papers submitted to more recent working groups.

8.4 The Scientific Committee noted the following tasks that had been requested to be undertaken by the Secretariat for the 2021/22 intersessional period, as requested by

WG-ASAM-2021, WG-SAM-2021, WG-EMM-2021 and WG-FSA-2021, in addition to the routine support provided to Members:

- (i) Data collection and form development –
 - (a) develop an archive of data collection forms and manuals (WG-FSA-2021, paragraph 2.9)
 - (b) implement revised C2 forms (WG-FSA-2021, paragraph 2.9)
 - (c) develop new C1 and C5 forms and support a krill fishing data workshop (WG-FSA-2021, paragraph 2.11)
 - (d) work with Norway to correct inconsistencies in historic krill catch data (WG-EMM-2021, paragraph 2.21)
 - (e) work to further improve historic krill catch data, including conversion factors and green weight estimation (WG-EMM-2021, paragraph 2.22)
 - (f) implement revised observer logbooks and *Scientific Observer Manuals* and continue to improve linking of biological samples and tagging data to the biological form (WG-FSA-2021, paragraphs 2.3 and 6.19)
 - (g) undertake analysis of VME data collection practice on board vessels, and provide info on spatial and temporal trends on VME triggers to WG-FSA-2020 (WG-FSA-2019, paragraph 6.30).
- (ii) Develop and improve data storage –
 - (a) develop an acoustic data repository (WG-ASAM-2021, paragraph 4.7)
 - (b) work with Ukraine on correcting C2 data using observer data, including how to archive and track the revisions (WG-SAM-2021, paragraphs 11.5 and 11.6)
 - (c) develop a database for biological and survey data from the krill fishery (WG-FSA-2021, paragraph 5.12).
- (iii) Implement a toothfish age database, and support a workshop to develop criteria for pooling age data among laboratories (WG-FSA-2021, paragraph 4.40).
- (iv) Fishery reports and other reports –
 - (a) update Fishery Reports with stock annexes (WG-FSA-2021, paragraph 3.49 and 3.69)
 - (b) develop a summary of available by-catch data for inclusion in Fishery Reports (WG-FSA-2021, paragraph 6.19)
 - (c) compile and publish special issue of *CCAMLR Science* (SC-CAMLR-38, paragraph 13.9)

- (d) collaborate with the USA and New Zealand to develop standard reporting template for CMIR activities.
- (v) Routine reporting –
 - (a) modify the trend analysis summary report based on recommendations in WG-SAM-2021, paragraph 3.32 and WG-FSA-2021, paragraph 4.2
 - (b) continue to improve analyses and report annually on gear loss (WG-FSA-2021, paragraph 4.40)
 - (c) assist Members in the production of standardised reports regarding their research activities associated with the RSRMPA (WG-EMM-2021, paragraph 3.24)
 - (d) compile and summarise data on catch limit overruns (WG-FSA-2021, paragraph 2.13)
 - (e) revise and continue the catch forecasting procedure in the Ross Sea (WG-FSA-2021, paragraph 2.14) and improve catch forecasting in the krill fishery (WG-FSA-2021, paragraph 5.2)
 - (f) further engagement with the wider scientific community on CCAMLR's key research and management needs (WG-EMM-2021, paragraph 2.7)
 - (g) work with Chile and Ukraine to improve quality of krill by-catch data and continue to revise and update summaries of fish by-catch in the krill fishery (WG-FSA-2021, paragraphs 6.15 and 6.16).

Advice to SCIC and SCAF

9.1 The Scientific Committee drew the attention of SCIC to its discussions on krill catch reporting (paragraph 3.5).

9.2 The Scientific Committee considered that although scholarship recipients had been able to attend the virtual meetings of the working groups in 2021, there was still a need to extend all existing scholarships for another year due to travel restrictions during the pandemic, to allow opportunities for scholarship recipients to attend physical CCAMLR meetings and to attend meetings with mentors (paragraph 7.35). The Scientific Committee noted that by extending the term of the scholarships by one year, there would be eight scholarship recipients in 2022 and this would have budget implications. The Scientific Committee requested the Secretariat to provide an estimate of the budget implications of the extension to SCAF.

9.3 The Scientific Committee considered issues that would require the attention of SCAF and noted that a proposed workshop to review CCAMLR's decision rules in 2022 would require external experts and therefore require funding by CCAMLR. Because the terms of reference for the review are yet to be developed, the Scientific Committee anticipated a cost of approximately US\$30 000.

Election of Chair and Vice-Chair

10.1 The Scientific Committee noted that the Chair of the Scientific Committee, Dr Welsford, had completed chairing two meetings, had done an excellent job and was unanimously elected for another two years of service, which he accepted with gratitude.

10.2 The Scientific Committee noted that the Senior Vice-Chair, Dr Zhu, had polled Scientific Committee Members and received nominations for the role of Junior Vice-Chair. He announced that Dr F. Schaafsma (Netherlands) was nominated to the role of Junior Vice-Chair for the 2021/22 period. The current Junior Vice-Chair, Dr A. Makhado (South Africa), will assume the Senior Vice-Chair role, and Dr Zhu will retire from the Senior Vice-Chair position and resume his busy schedule at his university.

10.3 The Scientific Committee thanked Dr Zhu for his hard work as Senior Vice-Chair, noting the added efforts applied during the pandemic in undertaking his role.

10.4 Dr Schaafsma thanked the Scientific Committee for the nomination and its support. She noted that she had been a previous recipient of the CCAMLR scholarship program, underscoring the importance of that program, and looked forward to working with the Scientific Committee.

Other business

11.1 The Scientific Committee noted SC-CAMLR-40/BG/06, which presented an update on activities of the Southern Ocean Task Force (www.sodecade.org/about). The Task Force is developing a Southern Ocean Action Plan as a framework for activities and contributions in the context of the UN Decade of Ocean Science for Sustainable Development and will develop procedures for those interested to join the process and provide input.

11.2 The Scientific Committee noted SC-CAMLR-40/BG/07, which presented an update on the content of the SCAR Antarctic Biodiversity Portal (www.biodiversity.aq), which seeks to increase our knowledge and understanding of Antarctic and Southern Ocean biodiversity.

11.3 Dr A. Fedchuk (Ukraine), on behalf of the Ukrainian Antarctic Research Program, informed the Scientific Committee that the RV *James Clark Ross*, which had been operated by the British Antarctic Survey for 30 years, was sold to Ukraine in August 2021 to facilitate the next phase of Ukrainian marine research in the Southern Ocean. He noted that from the 2022/23 season onwards, this ice-capable ship will be available year-round as a well-equipped mobile platform for biological, oceanographic and geophysical research and invited Members to cooperate to develop research program proposals of common interest.

11.4 The Scientific Committee welcomed the continuing role of the *James Clark Ross* in Antarctic research and expressed its appreciation for the invitation for collaboration.

11.5 The Scientific Committee expressed its appreciation for the closed captions provided by the stenographers during the online meetings using the Interprefy platform, particularly during the working group meetings when no interpretation is available.

11.6 The Scientific Committee requested the Commission consider the availability of closed captions during future in-person meetings.

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

Rules for Access and Use of CCAMLR Data

11.8 The Scientific Committee noted the increasing amount of data, including raw and unpublished data, which the originating Members are requested to submit to the Secretariat to facilitate access by the working groups (paragraph 3.16), that can be requested for release under the current Rules for Access and Use of CCAMLR Data. It further noted that some of these data may still be under analysis by the originating Members and that their ability to publish their research might be compromised by prior publication by the data requester.

11.9 The Scientific Committee requested that DSAG review the Rules for Access and Use of CCAMLR Data for consideration by the planned Scientific Committee symposium (paragraph 7.14).

Adoption of report of the 40th Meeting

12.1 The Chair noted at the close of the meeting that due to time constraints, the report could not be adopted in full. The Chair advised that all non-adopted paragraphs would be indicated by inclusion in square brackets, with track changes included to detail where changes had taken place at the time of the finish of the meeting.

Close of the meeting

13.1 Dr Welsford thanked all participants for their hard work and patience and encouraged all Members to work cooperatively to facilitate the ongoing priorities of the Scientific Committee. He thanked the conveners of the working groups, the retired Science Manager Dr Keith Reid, and the Executive Secretary for their support. He expressed his disappointment that there was text of the Scientific Committee report that remained unadopted, however, he suggested that this simply reflected the unprecedented circumstances and the technical issues faced by the Scientific Committee and its Members this year.

13.2 Dr Welsford undertook to present the advice of the Scientific Committee to the Commission and in doing so to make clear the very limited elements of the report where agreement of the Scientific Committee had not been reached.

13.3 Dr Agnew, on behalf of the Scientific Committee, thanked Dr Welsford for his patience and responsiveness to the challenging circumstances of this year's meeting which had made extensive progress. He congratulated Dr Welsford on his reappointment as the Scientific Committee Chair and looked forward to his continuing leadership of the Scientific Committee in the future.

References

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Table 1: Proposed workshops by the Scientific Committee and its working groups.

Title	Convener(s)	Location	Date	Secretariat support
Krill age interlaboratory comparison (SC-CAMLR-38, paragraph 3.15)	Dr Kawaguchi	Online	Part A complete. Part B November 2021	No
Priorities for observers in the krill fishery and coordination (WG-EMM-2019, paragraph 3.38)	Drs Zhu and Kawaguchi	Shanghai, China	August/September 2022	Yes
Focussed krill fishery data collection C1 workshop (forms, conversion factors, by-catch move on rules)		Online		Yes
ASAM–SAM cross working group analyses of acoustic data (WG-SAM-2021, paragraph 10.3)		Online	Future work	Yes
Grym training workshop (WG-SAM-2021, paragraph 10.3)	Mr Maschette	Online	8 and 9 December 2021	Yes
Conversion factors in toothfish fisheries including summarising trends in conversion factor calculation (WG-FSA-2021, paragraphs 2.6 and 2.7)	Mr Gasco and Mr Walker (or Alternate)	Online	March 2022	Yes
Revise the Ross Sea data collection plan for fishing vessels WG-FSA-2021, paragraph 8.1 to 8.3)	New Zealand and Italy	Online	Late July 2022	Yes
Scientific Committee strategic plan symposium (paragraphs 7.13 and 7.14)	Dr Welsford	Online	February 2022	Yes
Toothfish tagging workshop (paragraph 3.36)	Mr Arangio (COLTO), Dr Devine (NZ)	Nelson, NZ	July/August 2022	Yes
Joint SIOFA–CCAMLR Workshop on the exchange of scientific toothfish data (paragraph 6.4)	Mr Dunn (SIOFA) Dr Welsford (CCAMLR)	Online	29 November and 1 December 2021	No
Weddell Sea phase 2 workshop (paragraph 4.15)	Norway	Europe	1st half 2022	No
Climate Change Impact Symposium (paragraph 5.3)	Dr Trathan, Dr Cavanagh, or UK alternate			No
CCAMLR Decision Rules workshop (paragraph 2.17, 3.63)		Online		No
Workshop to compare age determination methods for toothfish (paragraph 3.94)			2022	

Table 2: Catch allocation options in the Ross Sea region.

	Area	Percent	No survey	Method 1	Method 2	Method 3
				(2017/18–2018/19)	(2019/20–2020/21)	(SC-CAMLR-39/BG/03)
	North of 70°S	19	664	652	664	650
	South of 70°S	66	2 307	2 263	2307	2256
	Special Research Zone	15	524	515	459	524
	Shelf Survey	-	-	65	65	65
	Total		3 495	3 495	3 495	3 495
N70	Skates (5%)		33	32	33	32
	Macrourids		106	104	106	103
	Other (5%)		33	32	33	32
S70	Skates (5%)		115	113	115	112
	Macrourids (388 t)		316	316	316	316
	Other (5%)		115	113	115	112
SRZ	Skates (5%)		26	25	22	26
	Macrourids (388 t)		72	72	72	72
	Other (5%)		26	25	22	26
Total	Skates (5%)					
	Macrourids		494	492	494	491
	Other (5%)					

Table 3: Proposed catch limit (tonnes) for consideration by the Commission for 2021/22. AUS – Australia; CHL – Chile; CHI – China; ESP – Spain; FRA – France; GBR – United Kingdom; JPN – Japan; KOR – Republic of Korea; NOR – Norway; NZL – New Zealand; UKR – Ukraine; URY – Uruguay; ZAF – South Africa.

Subarea/ division	Fishing area	Target species	Catch limit			<i>Macrourus</i> spp.	Skates and rays	Other species	Conservation measure	Notified Members
			2019/20	2020/21	2021/22					
48.3	483	<i>C. gunnari</i>	3225	2132	1457			See CM 33-01	42-01, 33-01	Not applicable
48.6	486_2	<i>D. mawsoni</i>	140	112	134	21	6	21	41-04, 33-03	JPN, ESP, ZAF
	486_3	<i>D. mawsoni</i>	38	30	36	5	1	5	41-04, 33-03	JPN, ESP, ZAF
	486_4	<i>D. mawsoni</i>	163	196	196	31	9	31	41-04, 33-03	JPN, ESP, ZAF
	486_5	<i>D. mawsoni</i>	329	263	210	33	10	33	41-04, 33-03	JPN, ESP, ZAF
	Total	<i>D. mawsoni</i>	670	601	576				41-04, 33-03	JPN, ESP, ZAF
58.4.2	5842_1	<i>D. mawsoni</i>	60	60	72	11	3	11	41-05, 33-03	AUS, FRA
58.5.2	5852	<i>C. gunnari</i>	527	1276	1528			See CM 33-02	42-02, 33-02	Not applicable
88.2	882_1	<i>D. mawsoni</i>	192	192	230	36	11	36	41-10, 33-03	AUS, GBR, JPN, KOR, NZL, UKR, URY
	882_2	<i>D. mawsoni</i>	232	186	223	35	11	35	41-10, 33-03	AUS, GBR, JPN, KOR, NZL, UKR, URY
	882_3	<i>D. mawsoni</i>	182	170	204	32	10	32	41-10, 33-03	AUS, GBR, JPN, KOR, NZL, UKR, URY
	882_4	<i>D. mawsoni</i>	128	128	154	24	7	24	41-10, 33-03	AUS, GBR, JPN, KOR, NZL, UKR, URY
	882H	<i>D. mawsoni</i>	160	128	102	16	5	16	41-10, 33-03	AUS, GBR, JPN, KOR, NZL, UKR, URY
	Total	<i>D. mawsoni</i>	894	804	913	143	44	143	41-10, 33-03	AUS, GBR, JPN, KOR, NZL, UKR, URY
88.3	883_1	<i>D. mawsoni</i>	16	-	16	2	0	2	24-05	KOR, UKR
	883_2	<i>D. mawsoni</i>	20	-	20	3	1	3	24-05	KOR, UKR
	883_3	<i>D. mawsoni</i>	60	-	60	9	3	9	24-05	KOR, UKR
	883_4	<i>D. mawsoni</i>	60	-	60	9	3	9	24-05	KOR, UKR
	883_5	<i>D. mawsoni</i>	8	-	8	1	0	1	24-05	KOR, UKR
	Total	<i>D. mawsoni</i>	164	-	164	24	7	24	24-05	KOR, UKR

(continued)

Table 3 (continued)

Subarea/ division	Fishing area	Target species	Catch limit			<i>Macrourus</i> spp.	Skates and rays	Other species	Conservation measure	Notified Members
			2019/20	2020/21	2021/22					
48.1, to 48.4	48.1	<i>E. superba</i>	155000	155000	155000			51-01, 51-07	CHL, CHI, KOR, NOR, UKR	
	48.2	<i>E. superba</i>	279000	279000	279000			51-01, 51-07	CHL, CHI, KOR, NOR, UKR	
	48.3	<i>E. superba</i>	279000	279000	279000			51-01, 51-07	CHL, CHI, KOR, NOR, UKR	
	48.4	<i>E. superba</i>	93000	93000	93000			51-01, 51-07	CHL, NOR	

Table 4: Proposed catch limit (tonnes) for consideration by the Commission for 2021/22, for effort-limited research in Subarea 88.3 (WG-FSA-2021/34) and Division 58.4.2 (WG-SAM-2021/03).

Subarea/ division	Research block	Target species	Catch limit			<i>Macrourus</i> spp.	Skates and rays	Other species	Conservation measure	Notified Members
			2019/20	2020/21	2021/22					
58.4.2	5842_2	<i>D. mawsoni</i>			55	8	2	8	41-05, 33-03	AUS, FRA
88.3	883_6	<i>D. mawsoni</i>	30		30	4.8	1.5	4.8	24-05	KOR, UKR
	883_7	<i>D. mawsoni</i>	30		30	4.8	1.5	4.8	24-05	KOR, UKR
	883_8	<i>D. mawsoni</i>	10		10	1.6	0.5	1.6	24-05	KOR, UKR
	883_9	<i>D. mawsoni</i>	10		10	1.6	0.5	1.6	24-05	KOR, UKR
	883_10	<i>D. mawsoni</i>	10		10	1.6	0.5	1.6	24-05	KOR, UKR
	Total	<i>D. mawsoni</i>	90		90	14.4	4.5	14.4	24-05	

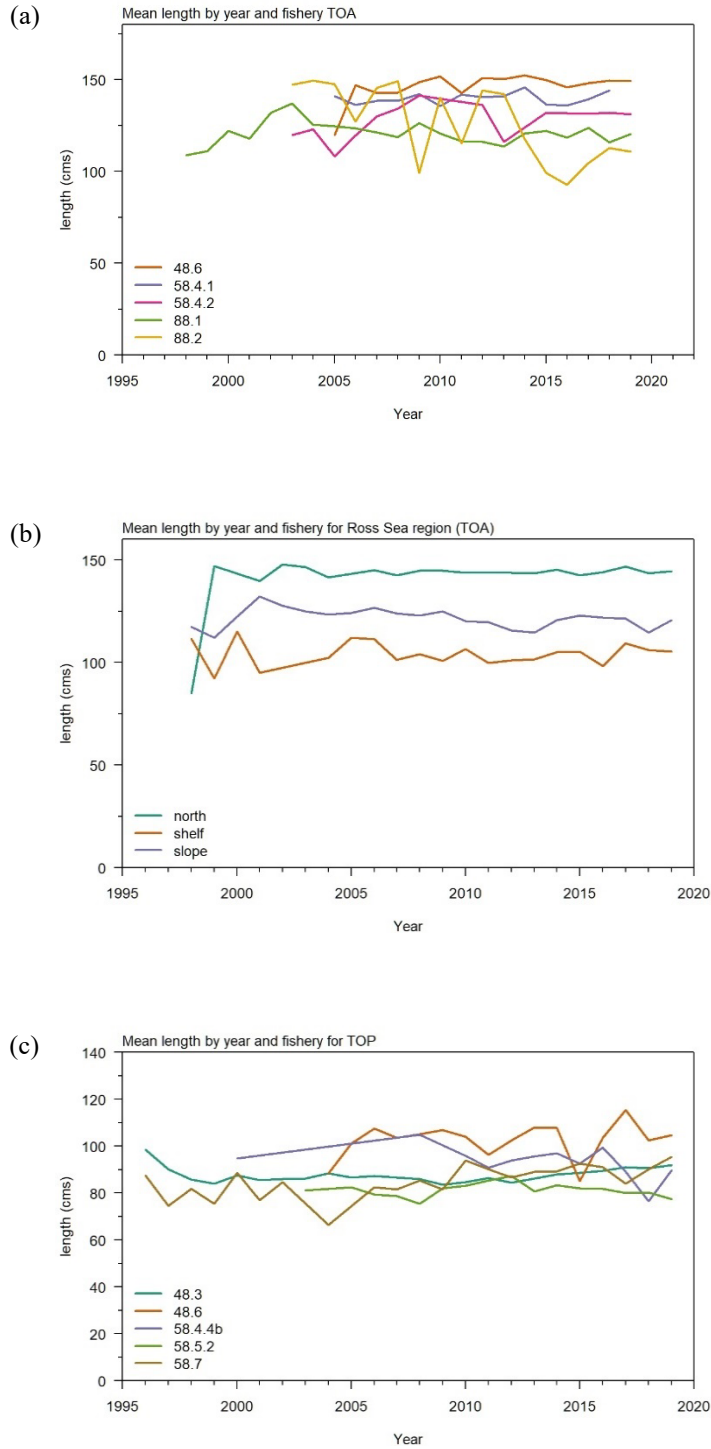


Figure 1: Mean length by year in catches of Antarctic toothfish (*Dissostichus mawsoni*) fisheries in: (a) across the Convention Area, (b) in the Ross Sea, and (c) Patagonian toothfish (*D. eleginoides*) fisheries across the Convention Area.

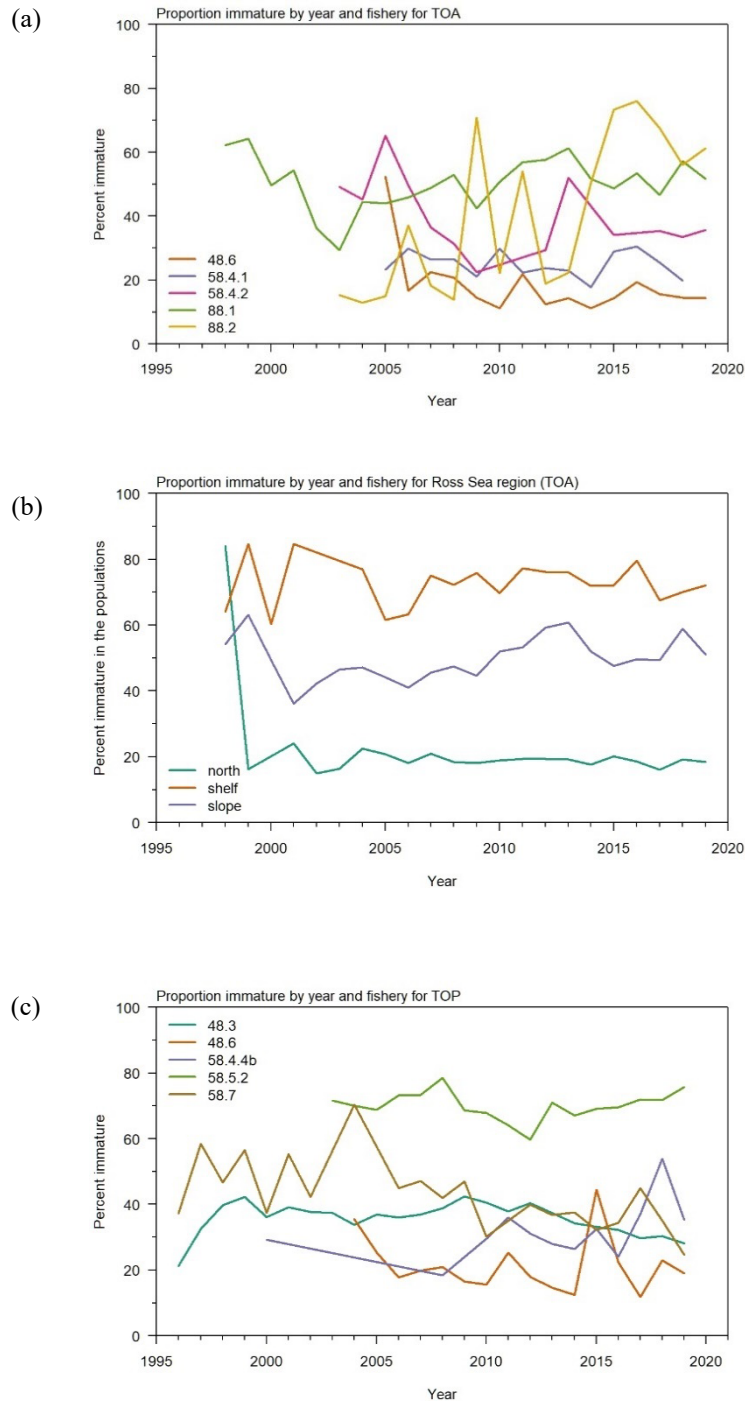


Figure 2: Percent immature fish by year in catches of Antarctic toothfish (*Dissostichus mawsoni*) fisheries: (a) across the Convention Area, (b) in the Ross Sea, and (c) Patagonian toothfish (*D. eleginoides*) fisheries across the Convention Area.

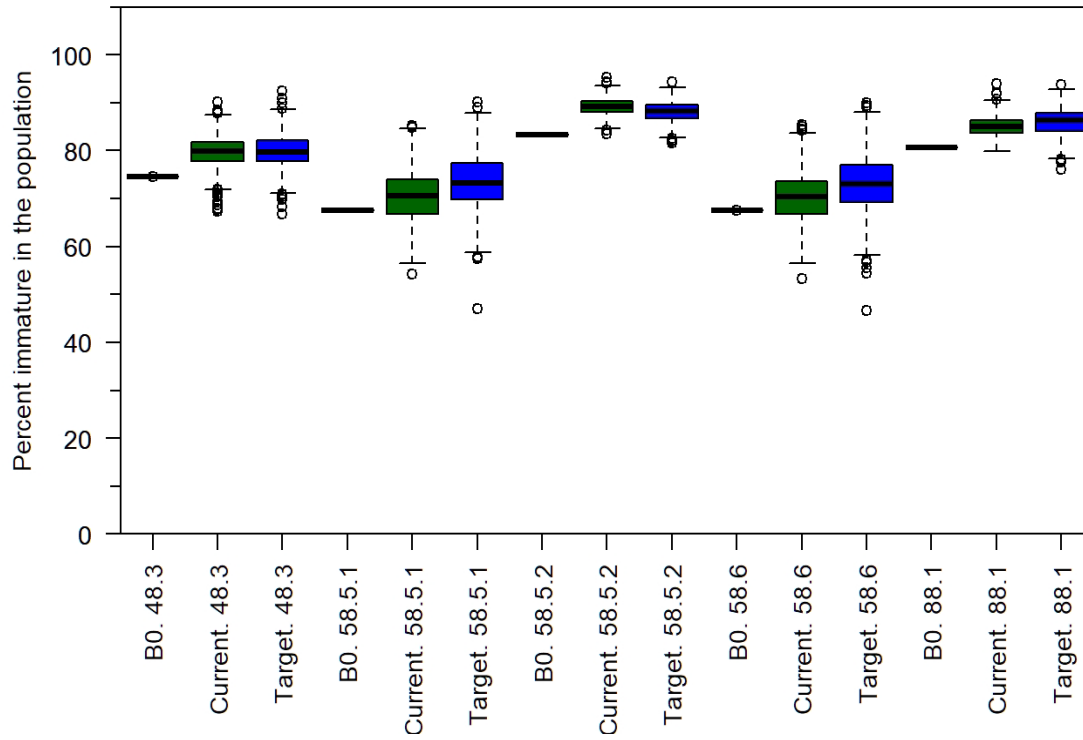


Figure 3: Percent immature fish when the stock is at B_0 , in the current year 2019, and at target level at the end of the 35-year projection period, as estimated by the CASAL stock assessment models for the Patagonian toothfish (*Dissostichus eleginoides*) fisheries in Subareas 48.3 and 58.6 and Divisions 58.5.1 and 58.5.2, and for the Antarctic toothfish (*D. mawsoni*) fishery in Subarea 88.1 and small-scale research units (SSRUs) 882A–B.

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SC-CAMLR-40/03	Report of the Working Group on Ecosystem Monitoring and Management (Virtual meeting, 5 to 9 July 2021)
SC-CAMLR-40/04	Report of the Working Group on Fish Stock Assessment (Virtual Meeting, 13 to 20 September 2021)
SC-CAMLR-40/05	Report of the Working Group on Statistics, Assessments and Modelling (Virtual meeting, 28 June to 2 July 2021)
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- SC-CAMLR-40/BG/25 Proposal for quality control of krill acoustic biomass survey processing
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- SC-CAMLR-40/BG/26 Preliminary results from trial #2; examining bird interactions with monitoring cable on krill trawlers using continuous trawling methods, during the 2020/21 fishing season
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**Agenda for the Fortieth Meeting
of the Scientific Committee**

**Agenda for the Fortieth Meeting of the
Scientific Committee for the Conservation
of Antarctic Marine Living Resources**

1. Opening of the meeting
 - 1.1 Adoption of the agenda
2. Advances in statistics, assessments, modelling, acoustics and survey methods
 - 2.1 Acoustic survey and analysis methods
 - 2.1.1 Advice to the Commission
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 - 3.1 Krill resources
 - 3.1.1 Status and trends
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 - 3.1.4 Advice to the Commission
 - 3.2 Fish resources
 - 3.2.1 Status and trends
 - 3.2.2 Assessment of fish resources
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 - 3.2.4 Advice to the Commission
 - 3.3 Scientific Research under Conservation Measure 24-01
 - 3.4 Non-target catch and ecosystem impacts of fishing operations
 - 3.4.1 Fish and invertebrate by-catch
 - 3.4.2 Incidental mortality of seabirds and marine mammals associated with fisheries
 - 3.4.3 Bottom fishing and vulnerable marine ecosystems
 - 3.4.4 Marine debris
 - 3.4.5 Advice to the Commission
4. Spatial management of impacts on the Antarctic ecosystem
 - 4.1 Marine protected areas (MPAs)
 - 4.2 Advice to the Commission
5. Climate change
 - 5.1 Advice to the Commission
6. Cooperation with other organisations

- 6.1 Cooperation within the Antarctic Treaty System
 - 6.1.1 Committee for Environmental Protection
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- 6.2 Reports of observers from other international organisations
- 6.3 Reports of representatives at meetings of other international organisations
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7. Scientific Committee activities
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 - 7.2 General Science Capacity Fund
 - 7.3 Next meeting
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9. Advice to SCIC and SCAF
10. Election of Chair and Vice-Chair
11. Other business
12. Adoption of report of the Fortieth Meeting
13. Close of meeting.

**Report of the Working Group
on Acoustic Survey and Analysis Methods**
(Virtual meeting, 31 May to 4 June 2021)

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**Report of the Working Group on
Acoustic Survey and Analysis Methods**
(Virtual meeting, 31 May to 4 June 2021)

Introduction to the meeting

1.1 The 2021 meeting of the Working Group on Acoustic Survey and Analysis Methods (WG-ASAM) was held online from 31 May to 4 June. The Co-conveners, Dr S. Fielding (UK) and Dr X. Wang (China) welcomed the participants (Appendix A).

1.2 The meeting's provisional agenda was discussed and the Working Group adopted the proposed agenda with minor additions (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 Co-conveners. Sections of the report dealing with advice to the Scientific Committee and other working groups are highlighted and collated in Agenda Item 5.

Krill biomass survey estimates

Area 48

2.1 WG-ASAM-2021/09 presented the differing spatial scales between existing acoustic survey programs and the fishery's operation in relation to Subarea 48.1 to facilitate the discussions of the Working Group.

2.2 The Working Group noted that scientific large-scale and mesoscale survey transects do not necessarily cover the area where the krill fishery operates today, therefore a future review optimising the temporal and spatial scales of surveys should be considered, including a cost-benefit analysis. The design and intent of future surveys are important considerations, as are fishery locations and the placement of transects, as well as the data collection method (commercial versus research vessel) and the way that the data are processed.

2.3 The Working Group noted the potential utility of re-evaluating the priority and location of transects nominated for collection of acoustic data by fishing vessels by SG-ASAM-2015 (SC-CAMLR-XXXIV, Annex 4, Appendix D, Table 1) to reflect new knowledge gained in recent years.

2.4 WG-ASAM-2021/04 Rev. 1 considered the results from a daytime acoustic survey in Subareas 48.1 and 48.2 by the Russian research vessel *Atlantida*, conducted between 2 January and 22 February 2020. The authors noted that the survey was completed in full compliance with CCAMLR methodology and recommendations (WG-EMM-16/38; WG-EMM-11/20;

SG-ASAM-16/01). The total survey area covered was 474 017 km², and total krill biomass for the study area was estimated as 39.287 million tonnes (CV = 9.29%). The mean krill density in the study area was 82.88 g m⁻².

2.5 The Working Group recalled that over the last five years two krill identification methods have been used by WG-ASAM, the swarms-based and the three-frequency (38, 120 and 200 kHz) dB-difference, with biomass estimation for both implemented on 120 kHz frequency data. The Working Group noted that the analysis presented in WG-ASAM-2021/04 Rev. 1 used the latter method and that a comparison of the results of an analysis using the swarms-based method would be valuable to build on the work of SG-ASAM-18/04 Rev. 1.

2.6 The Working Group noted that for February 2020 in the Bransfield Strait, the *Atlantida* results were similar to those presented for February 2019 in WG-ASAM-2021/13. However, results in other areas differed from the results of the 2019 International Area 48 Krill Survey. It was noted that an overlay of the daytime transects on the density contour plots could help explain some of these differences and that it would be valuable to relate this survey to previous studies. Differences in krill biomass estimates may be attributed to the specific spatial and temporal distribution of krill in the different strata as well as attributed to the differences in method used by the two surveys.

2.7 WG-ASAM-2021/13 considered biomass estimates from krill surveys conducted by the Chinese fishing vessel *Fu Rong Hai* around the South Shetland Islands from 2013 to 2019.

2.8 The Working Group reiterated the value of including the nautical area scattering coefficient (NASC) values in survey results in addition to krill density estimates, as was done in WG-ASAM-2021/13, since these were often informative of the underlying variability of NASC.

2.9 WG-ASAM-2021/14 considered krill biomass estimates from the 2019 international krill survey, including post-hoc stratification of krill density estimates for Subareas 48.1 to 48.4, on- and off-shelf areas, and estimates for currently fished areas.

2.10 The Working Group noted that large multi-Member surveys were conducted infrequently in comparison to smaller surveys conducted by individual research and fishing vessels.

2.11 The Working Group noted that subarea-based estimates of krill biomass are a plausible unit of management, but that the fishery operates at a much smaller scale. When scaling the mesoscale survey data up to the subarea level, the variances need to be considered appropriately.

2.12 The Working Group agreed to update the table of metadata on acoustic surveys with the results reported in WG-ASAM-2021/04 Rev. 1 and 2021/13.

2.13 The Working Group recalled the request from the Commission for the regular update of biomass estimates at the subarea scale as well as potentially at multiple scales (CCAMLR-38, paragraph 5.17). The Working Group noted that the subarea estimates provided in WG-ASAM-2021/14 demonstrated an example of how density estimates made using ASAM-reviewed methods (e.g. krill identification and target strength (TS) to biomass) could be extrapolated to the subarea scale.

2.14 The Working Group further noted that the methodology in WG-ASAM-2021/14 did not allow for the calculation of CVs in the results. It noted that CVs were a requirement for inclusion of biomass estimates for management.

2.15 The Working Group also noted that various approaches could be used to average density estimates from multiple surveys, including means weighted by the areas to which density estimates applied, by the inverse of the variances of such estimates, or by the recentness of such estimates. Subarea-scale density estimates could be developed from stratified estimators and model-based estimators (e.g. generalised additive models). Variance estimates for subarea-scale biomasses could also be estimated analytically using model-based estimators or via bootstrapping.

2.16 The Working Group agreed to summarise the acoustic survey biomass estimates from the updated table of metadata collated during WG-ASAM-2021 (also see paragraph 2.12) in an intersessional e-group, and undertook to provide advice on biomass and krill density estimates to WG-EMM-2021 at the subarea and any other appropriate spatial scales, with preliminary results on estimates of uncertainty provided to WG-SAM-2021 to assist with generalised R yield model (Grym) projections. A draft template developed by the Working Group for the summary of estimates is shown in Table 1.

2.17 The Working Group noted that the intersessional group should consider the following issues when compiling the summary table:

- (i) the extrapolation of krill biomass density estimates made from surveys with various spatial scales to subarea scales, keeping in mind the need for a precautionary approach and the potential differences between on-shelf and off-shelf krill density
- (ii) the metadata table contains biomass density estimates obtained using different methodologies (e.g. TS, krill identification methods and net sampling) and conducted in different seasons
- (iii) the necessity to clearly identify how estimates from different surveys are allocated to a stratum
- (iv) how estimates from each stratum may be combined to provide larger-scale estimates.

2.18 WG-ASAM-2021/P01 considered glider-based estimates of krill biomass around the northern Antarctic Peninsula, and comparisons with current and previous ship-based surveys conducted in the region.

2.19 The Working Group welcomed the results presented and noted the potential utility of gliders for surveying areas, both for biomass and for predator–prey related studies. The Working Group noted that establishing accepted protocols for krill biomass estimates from gliders should be agreed in the future.

2.20 The Working Group welcomed future developments planned for glider studies, including cameras for estimating krill length frequencies and real-time transmission of acoustic data, and encouraged the authors of the study to continue with their research program.

Area 58

2.21 WG-ASAM-2021/06 considered a revised biomass estimate for Division 58.4.1 from a survey conducted by the Japanese vessel *Kaiyo-maru* in the 2019 season. The total survey area was 909 000 km², the revised biomass estimate was 4.325 million tonnes (CV = 17.0 %) based on the swarms-based method, and overall survey mean areal krill biomass density was 4.758 g m⁻².

2.22 The Working Group welcomed the results from the Japanese survey and noted the undertaking to compare the biomass estimation with the 'traditional' dB-difference method, as well as the comparison of difference of biomass between daytime and night-time.

2.23 The Working Group advised the Scientific Committee that the krill biomass estimate of 4.325 million tonnes, with a CV of 17.0%, represented the best available estimate for Division 58.4.1.

2.24 WG-ASAM-2021/12 considered a biomass estimate for the eastern sector of Division 58.4.2. The total survey area was 775 732 km², the revised biomass estimate was 6.477 million tonnes (CV = 28.9%) based on the swarms-based method and using the daytime mean areal biomass density of 8.3g m⁻².

2.25 At the time of report adoption, Dr S. Kasatkina (Russia) noted that WG-ASAM-2021/12 showed estimates of krill biomass and density that are significantly lower than those from the previous survey (WG-EMM-12/31). The new estimates are accompanied by a very high CV (6.477 g m⁻² with CV = 28.9% and 20.5 g m⁻² with CV = 16%). A decrease in the density of krill by more than four times is revealed. It is not clear if this decrease in krill biomass is related to the krill stock or to the different TS model. Dr Kasatkina did not believe that the krill biomass estimate of 6.477 million tonnes, with a CV of 28.9%, represents the best available estimate for the eastern sector of Division 58.4.2.

2.26 At the time of report adoption, Dr S. Kawaguchi (Australia) noted that the comparison made by Dr Kasatkina was not of the same survey area. When comparing similar survey areas from WG-EMM-12/31 (Table 4, eastern region), the mean biomass density estimate was 18.7 g m⁻² with a CV of 28% in 2006 compared to an estimate of 8.3 g m⁻² with a CV of 28.9% in 2021. When CVs are considered, both surveys have an overlapping 95% confidence interval, with the 2006 survey ranging from 10.9 to 32 g m⁻² and the 2021 survey from 4.76 to 14.45 g m⁻². The reduction in estimate may be a result of the 2021 survey not being able to sample sea-ice regions and shelf-break area as was done in 2006, it may also be a result of analysis methods (e.g. TS model) or krill dynamics in the region changing in the 15 years between surveys, or some combination of the above. Regardless of the cause, estimates provided within WG-ASAM-2021/12 follow the agreed CCAMLR protocols for data processing and provide the best available science for this region.

2.27 The Working Group welcomed the intention of Australia to design regular repeated smaller-scale surveys in Division 58.4.2 based on the 2021 survey as outlined in online discussions in 2020.

2.28 The Working Group noted the experimental work conducted during the survey to determine the acoustic properties of several species of zooplankton, and appreciated that the methodology developed could be potentially widely applied across vessels.

2.29 The Working Group noted that this is the first time that the krill biomass density results from the Division 58.4.2 survey, conducted in February and March 2021, had been presented to WG-ASAM, therefore, there had been limited consideration of the survey design and analysis methods.

2.30 The Working Group advised the Scientific Committee that the krill biomass estimate of 6.477 million tonnes, with a CV of 28.9%, represented the best available estimate for the eastern sector of Division 58.4.2.

2.31 The Working Group commented that consideration needed to be given on how results from the Division 58.4.1 and Division 58.4.2 acoustic surveys are potentially used given differences between the latest survey results and historic surveys conducted in the same regions.

Future work for krill biomass survey estimates

2.32 The Working Group requested that the Scientific Committee consider developing a standardised procedure analogous to the review of finfish stock assessments, to ensure that all future acoustic survey results and analysis methods contributing areal krill density biomass estimates to the management of the fishery can be checked and verified by the Scientific Committee and its working groups.

Survey design for future routine biomass estimates

Krill length frequency impacts

3.1 WG-ASAM-2021/02 considered biases in acoustic biomass density estimates related to using length frequency distributions from different sources.

3.2 The Working Group noted the implications on the uncertainty of biomass estimates resulting from the different sampling methods (commercial vessels, research vessels and predators) and their behaviours (e.g. commercial vessels target aggregations, predators select larger krill than small scientific nets, land-based predators have limited foraging areas) that influence the length composition of krill in samples.

3.3 WG-ASAM-2021/03 examined krill length compositions from catches obtained by the Russian research vessel *Atlantida* and commercial midwater trawls from several fishing vessels operating in the same fishing ground. Results indicated differences in sampled length compositions between research and commercial trawls as well as between commercial trawls. In particular, the under-representation of recruits (<36 mm) in commercial samples was highlighted and attributed to differences in gear construction and fishing method.

3.4 The Working Group noted the importance of this research and discussed the potential implications of the spatial mismatch between the research vessel and the commercial vessels used in this comparison.

3.5 WG-ASAM-2021/10 considered the effects of sampled length frequency distributions on the derivation of biomass estimates of Antarctic krill from acoustic data.

3.6 The Working Group noted the importance of the krill sampling methodology, including the impact of spatial variability and the choice of nets, as well as the way length frequency distributions were computed (e.g. unweighted, weighted by catch or normalised by volume filtered).

3.7 Recognising the importance of length frequency data on the estimation of TS and krill weight for acoustic estimates, the Working Group agreed to continue these important discussions within a dedicated e-group led by Dr M. Cox (Australia) and Dr Wang during the intersessional period and report to the next WG-ASAM meeting, which will:

- (i) review the available sources of krill length frequency distribution that can be used to estimate the conversion factor (C) used to convert acoustic scattering coefficient data (NASC) to krill biomass density (Equation 1):

$$C = \frac{\sum f_i \times w(l_i)}{\sum f_i \times \sigma_{sp}(l_i)} \quad \text{(Equation 1)}$$

where f_i is the frequency of occurrence of the i^{th} class of krill length l_i , $w(l_i)$ [g] the mass of a krill of length l_i , and $\sigma_{sp}(l_i)$ [m²] the spherical scattering cross-section of a krill of length l_i . C therefore has units of g m⁻², noting that the m⁻² term refers to acoustic scatter

- (ii) review the methods used to reconstruct length frequency distributions
- (iii) identify the impact of different sources of length frequency data to generate the conversion factor and the uncertainty
- (iv) examine the sensitivity of biomass estimates to the use of multiple length frequency data, derived from a range of sources and sampling methodologies
- (v) establish recommendations for future best practices.

3.8 The Working Group noted that krill length frequency distributions are used in other components of the krill management strategy (e.g. to estimate proportional recruitment for the Grym) and there may be wider discussions related to krill length frequency distributions of interest to other working groups.

Noise removal

3.9 WG-ASAM-2021/07 presented an analysis indicating echogram noise removal can erroneously remove significant amounts of krill backscatter. Resolving this produced a 16% increase in the biomass estimate from the large-scale 2019 Area Survey.

3.10 The Working Group discussed the importance of the findings presented and how best to incorporate them in future noise removal protocols, including careful consideration of individual survey noise thresholds on a case-by-case basis and semi-automated approaches to detect high-intensity spikes. The Working Group noted that in light of these results, the current default -40dB upper threshold used in the EchoView template was biased towards lower

biomass estimates and constituted a precautionary approach. The Working Group agreed that future work for the group should include the development of further guidance for adjusting thresholds.

Acoustic observations of krill to inform spatial and temporal dynamics of krill

Spatial and temporal variability

4.1 WG-ASAM-2021/05 Rev. 1 presented an analysis of acoustic data collected on the *Atlantida* in 2020 in Subareas 48.1 and 48.2, examining spatial and temporal variability of krill distribution from repeated transects. The paper noted that the observed variability of krill distribution is potentially a consequence of the influence of the krill flux by the current. Analysis of the structure and dynamics of water masses in Subareas 48.1 and 48.2 and krill distribution at different spatial scales will be presented to WG-EMM-2021.

4.2 The Working Group congratulated the authors for the great amount of work leading to this paper and noted the similarity of observations within the one month surveyed, in particular, regarding the spatial distribution of krill, where the consistency of some aggregations was noticeable. The Working Group further noted that the factors (e.g. growth and flux) impacting the change in length frequency distributions over the relatively short period of time were complicated and encouraged Members to collaborate to further investigate these processes.

4.3 The Working Group recalled that WG-EMM had discussed flux in the past (e.g. WG-EMM-2019, paragraph 2.58; SC-CAMLR-39/BG/16) and recognised its importance to krill dynamics. The Working Group also recalled that due to the complexity of mathematically incorporating oceanic fluxes into management strategies, the endorsed krill management strategy (CCAMLR-38, paragraph 5.17) may progress with a staged approach in which flux would be put aside at first. As scientific understanding increases, the management strategy could incorporate krill flux in a future stage.

4.4 The Working Group agreed on the importance of continuing to work to understand flux and discussed potential future international collaboration to investigate flux dynamics and the incorporation of these results in management strategies.

4.5 Dr Kasatkina noted that krill flux should be included in the development of management options and did not agree with the development of the first stage in which flux would be put aside. Integration of krill flux into management schemes will require a comprehensive analysis of the available information and the development of appropriate mathematical models.

Fishing vessels data

4.6 WG-ASAM-2021/01 summarised the repository of acoustic data collected by fishing vessels held by the CCAMLR Secretariat.

4.7 The Working Group welcomed this contribution and indicated that additional metadata should be included in the repository, in line with Table 1 of WG-ASAM-2021/15. The Working Group supported the suggestion to use the Secretariat as a central repository for acoustic data

collected by fishing vessels along nominated transects (WG-ASAM-2021/01). It noted that this would benefit collaboration and that Members could contribute their data through their Scientific Committee Representative. The Working Group noted the need for data validation prior to submission.

4.8 WG-ASAM-2021/11 presented an analysis of monthly variation of Antarctic krill biomass in a main fishing ground in the Bransfield Strait based on three years of fishing vessel acoustic data collected during routine fishing operations. The results showed that krill stock in the fishery hotspot is rather dynamic, with very high biomass towards the end of the fishery, implying flux must have played an important role that needed to be addressed in the future.

4.9 The Working Group welcomed the contribution and noted the potentials of such analysis in the study of krill flux.

4.10 The Working Group noted that in addition to flux, krill behaviour or predation from penguins and whales might also contribute to the dynamics of krill stocks.

4.11 WG-ASAM-2021/15 presented an analysis of acoustic transects undertaken by fishing vessels at South Georgia in winter.

4.12 The Working Group welcomed the successful collaboration between scientists and the fishing industry and encouraged the continuation and expansion of these valuable partnerships. The Working Group noted the need to establish clear sampling guidelines to enhance the standardisation of the resulting data, when scientists are not on board the vessel. It noted this should include krill size composition data, a subject that would fit within the scope of the length frequency data e-group (paragraph 3.7).

Autonomous vehicles data

4.13 WG-ASAM-2021/08 presented an analysis on the use of unmanned surface vehicles to monitor krill density during fishing and obtain regular updates of pre-exploitation biomass.

4.14 The Working Group welcomed the new emerging technologies which will prove helpful in understanding krill dynamics, including during wintertime, and also noted the contribution from WG-ASAM-2021/P01 on this topic.

Advice to the Scientific Committee and future work

5.1 The Working Group identified the following items relevant to providing advice to the Scientific Committee and its future work:

- (i) the formation of an e-group to summarise acoustic survey results, with the intent to provide advice to WG-SAM-2021 and WG-EMM-2021 (paragraphs 2.16 and 2.17)
- (ii) krill biomass estimate in Division 58.4.1 (paragraph 2.23)

- (iii) krill biomass estimate in the eastern sector of Division 58.4.2 (paragraph 2.30)
- (iv) the development of a standardised procedure to enable the checking and verification of acoustic survey results by CCAMLR (paragraph 2.32)
- (v) the formation of an e-group to establish recommendations for the use of krill length frequency data on the estimation of target strength, and krill weight for acoustic estimates (paragraph 3.7)
- (vi) the addition of survey data and the inclusion of metadata by Members in the repository of acoustic surveys held by the Secretariat (paragraph 4.7).

Adoption of the report and close of the meeting

6.1 The report of the meeting was adopted.

6.2 At the close of the meeting Dr Fielding and Dr Wang thanked all the participants for their hard work and collaboration that had contributed greatly to the successful outcomes from WG-ASAM this year, and to the Secretariat for their support.

6.3 On behalf of the Working Group, Dr X. Zhao (China) thanked Dr Fielding and Dr Wang for their guidance during the meeting and noted that WG-ASAM-2021 had the highest-ever number of participants for this Working Group, which had greatly contributed to successful meeting outcomes.

Table 1: Draft template for summary of acoustic survey estimates. AMLR – Antarctic marine living resources; Grym – generalised R yield model.

	Most recent three years	Most recent five years	Since adoption of CM 51-07 (2009)	All data in metadata table
Season (December, January, February)	n, xbar, var(x), med(x)			
AMLR Stratum				
West				
South				
Joinville				
Elephant Island				
Season (March, April, May)				
AMLR Stratum				
West				
South				
Joinville				
Elephant Island				
Summed biomass to AMLR study area (125 000 km ²)				
Season (December, January, February)				
Season (March, April, May)				
Subarea (Area 48.1) scaled mean biomass and variability for total allocation for Grym				
CV for biomass estimates				
Season (December, January, February)				
Season (March, April, May)				

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Working Group on Acoustic Survey and Analysis Methods
(Virtual Meeting, 31 May to 4 June 2021)

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Agenda

Working Group on Acoustic Survey and Analysis Methods (Virtual meeting, 31 May to 4 June 2021)

1. Opening of the meeting
2. Krill biomass survey estimates
 - 2.1 Area 48
 - 2.1.1 Subarea biomass estimates from 2019 and any other relevant survey data
 - 2.1.2 Local-scale biomass estimates within subareas relevant to the area of operation of the krill fishery
 - 2.2 Area 58
 - 2.2.1 Area 58 subarea estimates of krill biomass
3. Survey design for future routine biomass estimates
4. Acoustic observations of krill to inform spatial and temporal dynamics of krill
5. Advice to the Scientific Committee
6. Adoption of the report and close of the meeting.

List of Documents

Working Group on Acoustic Survey and Analysis Methods
(Virtual Meeting, 31 May to 4 June 2021)

WG-ASAM-2021/01	Repository of acoustic data collected by fishing vessels CCAMLR Secretariat
WG-ASAM-2021/02	Biases in acoustic biomass density estimates used for calculating catch limits C.S. Reiss, J. Hinke, A.M. Cossio, G.R. Cutter and G.M. Watters
WG-ASAM-2021/03	Comparison analysis of krill length compositions from catches obtained by research and commercial midwater trawls S. Sergeev and S. Kasatkina
WG-ASAM-2021/04 Rev. 1	Results of acoustic survey in Subarea 48.1 and 48.2 carried out by Russian RV «Atlántida» in 2020 S. Kasatkina, A. Abramov, M. Sokolov, A. Sytov and D. Kozlov
WG-ASAM-2021/05 Rev. 1	Analysis of acoustic data to examine spatial and temporal variability of krill distribution from repeated transects S. Kasatkina, A. Abramov, M. Sokolov and A. Malyshko
WG-ASAM-2021/06	A revised biomass estimation of Antarctic krill based on the up-to-date swarm based method for CCAMLR Division 58.4.1 in 2018/19 using data obtained by Japanese survey vessel, <i>Kaiyo-maru</i> K. Abe, R. Matsukura, N. Yamamoto, K. Amakasu and H. Murase
WG-ASAM-2021/07	Echogram noise removal can remove significant amounts of krill backscatter G. Macaulay, G. Skaret and B. Krafft
WG-ASAM-2021/08	Using unmanned surface vehicles to monitor krill density during fishing and obtain regular updates of pre-exploitation biomass S. Menze, A. Lowther and B.A. Krafft
WG-ASAM-2021/09	The various spatial scales available for consideration and the distribution of the krill fishery in Subarea 48.1 Y. Ying, X. Zhao, G. Fan and X. Wang

- WG-ASAM-2021/10 Potential effect of the chosen length-frequency distribution on acoustic biomass estimates of Antarctic krill
X. Wang, X. Zhao and Q. Xu
- WG-ASAM-2021/11 Monthly variation of Antarctic krill biomass in a main fishing ground in the Bransfield strait based on fishing vessel acoustic data collected during routine fishing operations
Y. Zhao, X. Wang, X. Zhao, Y. Ying and J. Zhang
- WG-ASAM-2021/12 Biomass of Antarctic krill (*Euphausia superba*) in the eastern sector of the CCAMLR Division 58.4.2
M.J. Cox, G. Macaulay, N. Kelly, R. King, D. Maschette, J. Melvin, A. Smith, S. Wotherspoon and S. Kawaguchi
- WG-ASAM-2021/13 Biomass estimates of Antarctic krill around the South Shetland Islands based on surveys conducted by a Chinese fishing vessel from 2013 to 2019
X. Wang, X. Yu, X. Zhao, J. Zhang, G. Fan, Y. Ying and J. Zhu
- WG-ASAM-2021/14 Developing plausible estimates of subarea and fished area biomasses
B.A. Krafft, G. Macaulay, S. Fielding and P.N. Trathan
- WG-ASAM-2021/15 Acoustic transects undertaken by fishing vessels at South Georgia
S. Fielding, J. Arata and P.N. Trathan
- Other Documents
- WG-ASAM-2021/P01 Glider-Based Estimates of Meso-Zooplankton Biomass Density: A Fisheries Case Study on Antarctic Krill (*Euphausia superba*) Around the Northern Antarctic Peninsula
C.S. Reiss, A.M. Cossio, J. Walsh, G.R. Cutter and G.M. Watters
Frontiers in Marine Science, 8 (2021): 1–18,
doi: 10.3389/fmars.2021.604043

**Report of the Working Group
on Statistics, Assessment and Modelling**
(Virtual meeting, 28 June to 2 July 2021)

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**Report of the Working Group on
Statistics, Assessment and Modelling**
(Virtual meeting, 28 June to 2 July 2021)

Introduction to the meeting

1.1 The 2021 meeting of the Working Group on Statistics, Assessment and Modelling (WG-SAM) was held online from 28 June to 2 July 2021. The Co-conveners, Dr C. Péron (France) and Dr T. Okuda (Japan), welcomed the participants (Appendix A).

Adoption of the agenda and organisation of the meeting

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

2.2 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.

2.3 This report was prepared by the Secretariat and the Co-conveners. Sections of the report dealing with advice to the Scientific Committee and other working groups are highlighted and collated in 'Recommendations to the Scientific Committee'.

Development and progress of stock assessments

Stock assessments for krill

3.1 The Working Group recalled that Conservation Measure (CM) 51-07 will expire in November 2021 and will need to be replaced by an integrated krill management strategy. To establish this strategy, WG-ASAM-2021 has made progress on establishing baseline krill biomass estimates and a report has been submitted for review to WG-EMM-2021. WG-SAM-2021 has been requested to review the generalised R yield model (Grym) configuration, its assumptions and parameterisation. WG-EMM-2021 will develop the risk assessment, examining spatial allocation scenarios for the catch limits. WG-FSA-2021 will combine the outcomes for the Scientific Committee, which will provide advice to the Commission. In this context, the Working Group noted that it was important to differentiate between work needed for advice this year regarding the revision of CM 51-07 and work which could be incorporated later.

3.2 WG-SAM-2021/09 introduced an improvement to the proportional recruitment model developed by de la Mare (1994a, 1994b) to simulate stochastic recruitment based on proportional recruitment estimates derived from survey data. This development provides a more flexible representation of a number of recruitment distribution models within the Grym and more representative recruitment simulations under high recruitment variability using a parametric bootstrap method.

3.3 The Working Group welcomed this improvement to the Grym and noted that time series of US AMLR krill survey data show that estimated recruitment is highly variable, and that years with very large recruitment do not appear to occur consecutively. Recruitment parameters for Grym simulations should aim to reflect the potential recruitment variability while minimising biases introduced by data collection methods.

3.4 The Working Group reviewed an example of diagnostic plots showing interactions between simulations using different biological parameters in the Grym and noted that such plots will be very useful when calibrating plausible model scenarios.

3.5 WG-SAM-2021/10 described an extension of the Grym to permit the inclusion of multiple fleets within a season, allowing it to model more complex fishery behaviour and evolving fisheries practices.

3.6 The Working Group noted that at present this extension could be used in a range of fisheries assessments, and thanked the authors for these important developments which allow more flexibility in Grym assessments.

3.7 WG-SAM-2021/22 outlined some general considerations that needed to be taken into account when choosing an appropriate spatial scale to run Grym simulations, including that the chosen spatial scale may need to be large enough to cover the various components of the krill stock adequately. The pros and cons of using the biomass estimates resulting from the 2019 International Area 48 Krill Survey and the multiple mesoscale surveys were also discussed.

3.8 The Working Group welcomed this contribution and noted that there would be value in exploring results at both the mesoscale and large scales. It further noted that the spatial scale may be important for ensuring that recruitment is adequately represented, and that recruitment estimates derived from spatially restricted surveys may not necessarily be representative of recruitment at larger scales.

3.9 The Working Group agreed that the Grym could be run at different scales. In the absence of spatially explicit stock assessment models, focus needs to be on scales considered as appropriate given our current knowledge of the stock and available data and parameters.

3.10 WG-SAM-2021/07 presented estimates of krill proportional recruitment in Subareas 48.1–48.3, calculated using the Scheme of International Scientific Observation (SISO) observer data, as requested by WG-EMM-2019.

3.11 The Working Group noted that 40 mm was selected as an upper boundary for the recruitment ratio, which may include krill individuals aged between 1 and 2 years old, and the age-1 group may not be represented adequately.

3.12 The Working Group also noted that analyses of length frequency distribution can be influenced by variability in the gear types and mesh sizes used in the commercial krill fishery, and by an avoidance effect which occurs in scientific nets when the mouth openings are too small.

3.13 WG-SAM-2021/19 presented proportional recruitment and length-weight indices obtained during research trawls in Subareas 48.1 and 48.2 from the RV *Atlantida*. The paper noted that the length-weight relationship obtained by stratum differed from the length-weight equation used by the CCAMLR 2000 Krill Synoptic Survey of Area 48 (CCAMLR-2000

Survey) ($w = 2.236 \times 10^{-6} \times l^{3.314}$ (w = mass (mg), l = length (mm)) (WG-EMM-16/38), and that the use of the CCAMLR-2000 Survey relationship would underestimate the krill areal biomass density by 10 to 26% depending on the stratum, when compared to the length-weight relationships developed on this survey.

3.14 The Working Group noted the large number of krill measured as part of the survey, that data from these measurements could be used for parameter inputs into the Grym, and that the differing length frequency values for each stratum highlight the importance of working with appropriate spatial scale and having an appropriate length cut-off for the proportional recruitment parameter.

3.15 The Working Group requested that Members provide the raw length and weight data from surveys to the Grym e-group (paragraph 3.22) for combined analyses of the length-weight relationship and length frequencies from all sampled areas within Subarea 48.1.

3.16 WG-SAM-2021/20 Rev. 1 presented a summary of proportional recruitment and multiyear biomass variability for krill in Subarea 48.1, from historic research surveys and fishery data. The paper noted that the US AMLR research survey data showed highly structured length distributions for krill that varied with time on a five-to-six-year cycle but were similar across the four survey strata. These cohorts were not observed in the fishery data, and the variability on an interannual basis was much greater in the US AMLR survey data than in the fishery data.

3.17 The Working Group noted the high variability in the proportional recruitment parameters calculated from the US AMLR survey data, and that the selectivity of the fishery data may be due to pooling data from different vessels, as typical krill trawls use small mesh sizes (15–16 mm) which may produce comparable results with research survey trawls. The Working Group highlighted the importance of consistent time series of survey information in order to determine changes in population dynamics.

3.18 WG-SAM-2021/12 presented a summary table of preliminary Grym parameter values which resulted from discussions of the Grym e-group (paragraph 3.15).

3.19 The Working Group noted that the krill stock simulations using the Grym are a relatively simple representation of the krill population that, for example, assuming spatial homogeneity and that all parameters and data are reflective of processes of the krill population within the area represented by the simulation.

3.20 The Working Group further recalled that de la Mare (1994b), used the age-2 group, instead of the age-1 group collated in the summary table, to represent the recruits.

3.21 The Working Group noted the importance of an appropriate parameterisation of the Grym, and that there was no clear agreement yet on the most appropriate values to use for Grym parameters.

3.22 The Working Group agreed that a constructive way forward would be to investigate multiple parameter value combinations within an ensemble modelling approach, using the Grym. The Working Group noted that, as a result, a set of sustainable yield estimates could be presented to WG-FSA-2021. The Working Group agreed that this work would be carried out collaboratively via an e-group coordinated by Mr D. Maschette (Australia) (the Grym parameters ensemble e-group).

3.23 The Working Group noted that the Grym parameters ensemble e-group should focus on Subarea 48.1 and consider the following issues:

- (i) continue the development of diagnostic plots that can be used in the evaluation and comparison of simulation scenarios
- (ii) use of a length interval, rather than only an upper length boundary, to represent recruits
- (iii) explore dependencies and correlations between parameters (e.g. recruitment and natural mortality)
- (iv) develop a number of different scenarios which are ensembles of parameter values that are internally consistent. Scenarios (parameter value combinations) may take advantage of efforts that have already been made (e.g. WG-SAM-2021/07, 2021/12, 2021/19, 2021/20 Rev. 1)
- (v) scenarios could include a range of ecologically meaningful spatial scales (e.g. WG-SAM-2021/22), given the scales at which parameters have been estimated
- (vi) run the Grym for these different scenarios
- (vii) the realism of simulation outputs should be investigated and used to eliminate parameter combinations that do not provide sensible results (e.g. validation should include inspection of the internally estimated mortality rate to ensure it was not unrealistically low or high, and comparison between the variability in simulated biomass and long-term acoustic biomass estimate to ensure that it was consistent with results reported in WG-EMM-2021/05 Rev. 1).

3.24 The Working Group agreed that in order to undertake this work, contributions of length frequency and other data important for generating parameter values, and suggestions for sensibility tests, should be forwarded to the e-group by 30 July 2021. The e-group should undertake the work of developing and running plausible Grym scenarios in order to present a report in time to be submitted to WG-FSA-2021 at the end of August.

Stock assessments for toothfish fisheries

3.25 WG-SAM-2021/13 presented a proposed update to the method for the stock assessment of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region. The analysis presented some alternative methods for the treatment of tag data and sensitivities that could be investigated for the next assessment. Diagnostic plots for a partial update of the 2021 assessment model (WG-SAM-2021/14) and a stock annex (WG-SAM-2021/15) accompanied this paper.

3.26 The Working Group noted the computational limitations of the current CASAL version as applied to the Ross Sea region assessment. As new data and new partitions are added to this assessment model, CASAL may be unable to compute a stock assessment for this stock with complete data in time for WG-FSA-2021.

3.27 The Working Group noted that although the exclusion of three years of tagging data (2001–2003) has the advantage of reducing computational difficulties, with virtually no impact on estimation results in the CASAL model assessment while improving overall model fit, the decision to exclude specific data requires careful consideration. The Working Group noted that the CCAMLR tagging protocol had not yet been established during these years.

3.28 The Working Group welcomed the intention of New Zealand to present Casal2 to Members at WG-FSA-2021 which may overcome these computational limitations in future assessments. The Working Group discussed the potential introduction of Casal2 for integrated stock assessments and recalled its previous discussions on software changes such that if Casal2 was to be introduced into CCAMLR, initial assessments using Casal2 would need to be presented using both CASAL and Casal2 methods for comparison.

3.29 The Working Group considered the inclusion of data from outside the CCAMLR area in the assessment model and noted that catches in the South Pacific Regional Fisheries Management Organisation (SPRFMO) areas are treated as removals from the Ross Sea in the assessment but are not included in the projection phase because it is not known if these catches will continue.

3.30 The Working Group recommended that the 2021 stock assessment of toothfish in the Ross Sea region be an update of the 2019 assessment, and requested that the paper to WG-FSA-2021 present additional information justifying any removal of tag cohorts and further exploring the impact of their removal on the assessment. It was also recognised that, if CASAL was unable to compute a stock assessment with tagging data for 2001–2020, the exclusion of the 2001–2003 tagging data may be warranted.

Trend analysis for data-limited toothfish fisheries

3.31 WG-SAM-2021/06 presented a provisional trend analysis for research blocks in data-limited fisheries and requested feedback from WG-SAM regarding four points, as listed in the paper.

3.32 The Working Group considered the requested feedback and recommended that:

- (i) A provisional trend analysis would only be required for presentation at WG-SAM if the underlying data (e.g. GEBCO bathymetry data) had changed or if the structure of the analysis itself was revised (e.g. adding or changing a step in the decision tree).
- (ii) The vulnerable biomass estimates from the reference areas (in Division 58.5.2 and the Ross Sea region) would only be used once the stock assessments for these areas had been agreed by the Commission.
- (iii) In order to establish catch limits in research blocks where fishing has not taken place in recent fishing seasons, the Working Group agreed that if data were not available from the most recent fishing season, the previous catch limit should be carried forward. Such an approach should be limited to five years, after which time the catch limit would need to be re-evaluated outside the current trend analysis framework.

- (iv) Fishable area estimates should be updated every time a new version of the GEBCO bathymetry data is released, and an analysis similar to the one presented in the appendix of the paper should be undertaken to compare the impact. The new GEBCO data should be used in its native resolution, e.g. 450 m resolution for the 2020 GEBCO dataset instead of 500 m as in previous versions (see WG-SAM-15/01).
- (v) When values for input variables change (e.g. seabed area, historical CPUE data or tagging data), the differences should be applied retrospectively to maintain comparability of values for the trend analysis.

Management strategy evaluations: consideration of alternative toothfish harvest control rules, including F-based rules for stocks with integrated assessments

4.1 WG-SAM-2021/08 presented simple simulations to outline alternative decision rules that would be consistent with the current CCAMLR decision rule and its objective. The rules in the paper were based on a harvest rate, H , which was stochastically estimated from stock productivity and fishery selectivity to result in the long-term 50% spawning stock biomass (SSB) depletion with a probability of 50%.

4.2 The Working Group recalled the discussions on the CCAMLR decision rules at WG-FSA in 2019 (WG FSA-2019, paragraphs 3.14 to 3.41) and at the Scientific Committee (SC-CAMLR-38, paragraphs 3.61 to 3.64), where it was noted that refinement of the current decision rule could include the addition of harvest control rules under specific circumstances, such as when productivity changes are detected or when the level of historical illegal, unreported and unregulated (IUU) catches is unknown.

4.3 The Working Group further recalled its recommendation to include in any future CCAMLR stock assessment a comparison of catch limits based on the CCAMLR decision rule alongside catch limits based on the harvest rate associated with achieving 50% B_0 (WG-SAM-2019, paragraphs 3.9 to 3.11).

4.4 The Working Group agreed that the approach taken by the paper (WG-SAM-2021/08) to conduct harvest control rule simulations as a proxy for management strategy evaluations for stock assessments was appropriate to evaluate decision rules.

4.5 The Working Group recommended exploration of different shapes for the harvest control rule in addition to those already explored in the paper (constant and ‘hockey-stick’ harvest rate where harvest rate decreased when the stock status was below the target) and presentation of comparisons of the risk to the stock and expected yield from the alternative rules.

4.6 The Working Group recommended further evaluation of alternative decision rules to explore the effects of, inter alia:

- (i) auto-correlation and bias in stock assessments, with values comparable to those seen in historical CCAMLR stock assessments
- (ii) delays and error in management implementation of catch limits.

Cross-cutting issues in toothfish fisheries affecting data or stock assessment model quality

5.1 No papers were submitted to this agenda item and the Working Group did not discuss it.

Development of a toolbox for designing research plans

6.1 No papers were submitted to this agenda item and the Working Group did not discuss it.

Data service advisory group

7.1 No papers were submitted to this agenda item and the Working Group did not discuss it.

Review of new research proposals

8.1 WG-SAM-2021/01 presented a proposal for a new research plan to continue research on *D. mawsoni* in Subarea 88.3 by the Republic of Korea and Ukraine.

8.2 The Working Group welcomed the proposal and recalled that WG-FSA had discussed in 2019 accessibility issues caused by sea-ice in this area and recommended that a revised proposal to WG-FSA should address this issue using updated data (WG-FSA-2019, paragraph 4.179). The Working Group noted that the survey design had taken into account past comments. It also noted that milestones on age determination should be incorporated in the proposal, that the proposed longitudinal extension of research block 1 would need to be justified within the context of its potential impact on tag recaptures, and that minimum sampling requirements should be set for by-catch species.

8.3 WG-SAM-2021/04 Rev. 2 presented a proposal for a new research plan to continue research on *D. mawsoni* in Subarea 48.6 by Japan, South Africa and Spain.

8.4 The Working Group welcomed the proposal and indicated that it would benefit from linking its objectives to those of the Workshop for the Development of a *D. mawsoni* Population Hypothesis for Area 48 (WS-DmPH). The Working Group noted the importance of understanding stock connectivity between research blocks in the area (seamounts versus continental shelf) and requested further details about how the stock structure will be represented in the planned CASAL assessment for the region. It also noted that the otolith sampling rate (10 otoliths per 5 cm length bin) was lower than in other areas and that minimum sampling requirements should be set for by-catch species and designed to meet the research objectives. The Working Group noted that the *Shinsei-maru No. 8* fished in the Ross Sea region in the 2020/21 season, hence improving the ability to link relative tagging performance to vessels in this research plan. It recalled that a structured fishing design was necessary to optimise tagging performance evaluation.

8.5 The Working Group endorsed the design of this research proposal and recommended that it proceed.

8.6 WG-SAM-2021/05 presented a proposal to conduct a new research survey targeting mackerel icefish (*Champsocephalus gunnari*) in Subarea 48.2 by Ukraine.

8.7 The Working Group welcomed this proposal and noted that given its significant acoustics component, it would need to also be reviewed by WG-ASAM. In particular regarding its areal coverage, choice of acoustic frequencies, day–night sampling, the size of trawl used for target identification and the methodology used to discriminate icefish from krill. The Working Group questioned the need for the high catch limit proposed, given the low expected standing stock in the area from the 2018 Chilean trawl survey (WG-SAM-18/25), and suggested that a by-catch limit might be required for krill instead of it being a proportion of the catch limit. The Working Group noted that given the proposed catch limit being greater than 50 tonnes of finfish, a revised proposal needed to follow the standardised guidelines and format adopted by the Scientific Committee given in CM 24-01, Annex 24-01/A, format 2.

8.8 WG-SAM-2021/18 presented a proposal for a new research plan to continue research on *D. mawsoni* in Divisions 58.4.1 and 58.4.2 by Russia.

8.9 The Working Group considered only the methodological aspects of this proposal since this research was not notified by the required deadline of 1 June. The Working Group discussed the issue of gear standardisation in multi-Member surveys and recalled past discussions on the subject, over several years and in different working group meetings (e.g. SC-CAMLR-39, paragraph 4.10; SC-CAMLR-38, paragraphs 3.105 to 3.108; SC-CAMLR-XXXVII, paragraphs 3.139 to 3.141). The Working Group further noted that standardisation is performed both through survey design (e.g. side-by-side sampling with different gears) and statistical analyses of the data.

8.10 Dr S. Kasatkina (Russia) reiterated her position in relation to methodical issues for the multi-Member research in the *Dissostichus* spp. exploratory fishery in Divisions 58.4.1 and 58.4.2 that she had raised in the past regarding the need for standardisation of fishing gear and survey design (SC-CAMLR-XXXVII, paragraph 3.137). Dr Kasatkina highlighted that any Member for participation in the particular exploratory fishery in Divisions 58.4.1 and 58.4.2 should prepare and submit to the Secretariat a Research Plan in accordance with CM 24-01 for review by WG-SAM, WG-FSA, the Scientific Committee and Commission and then reporting for evaluation and review of this Research Plan (CM 21-02, paragraph 6iii). The catch limit for the exploratory fishery in Divisions 58.4.1 and 58.4.2 is set only for implementation of this Research Plan and subdivided between vessels declared in this Research Plan. However, for the exploratory fishery in Subarea 88.2, being an example of other CCAMLR exploratory fisheries, the catch limit is set according to a stock assessment for the *D. mawsoni* population and any vessel can participate in the Olympic fishery here in accordance with CM 21-02. Dr Kasatkina noted that the *D. mawsoni* multi-Member research in East Antarctic should not be considered an exploratory fishery and continuing of such research requires standardisation of sampling fishing gear and survey design in accordance with common practice.

8.11 The Working Group noted that various longline gear types are permitted in exploratory fisheries in the Convention Area, and that integrated assessments have been, and are currently being, developed based on data collected using mixed gear types. The Working Group was unable to determine Dr Kasatkina's rationale as to why the exploratory fishery in Division 58.4.1 should proceed with only a standardised gear type requirement. The Working Group requested that the Scientific Committee discuss this.

8.12 The Working Group noted that catch allocation between participating Members of a research plan, as opposed to an Olympic fishing arrangement, allowed Members to conduct their research with sufficient catch available.

8.13 The Working Group recalled that the data-limited exploratory fishery in Subarea 88.2 had only sufficient tag-recapture data to perform a Chapman estimate of biomass in one research block in 2019 while it used to be assessed with an integrated stock assessment. As a consequence, SC-CAMLR-38 recommended to include small-scale research units (SSRUs) 882C–H as a data-limited exploratory fishery in CM 21-02, paragraph 6(iii) (SC-CAMLR-38, paragraphs 3.139 and 3.140).

8.14 The Working Group noted that the classification of all toothfish fisheries is an issue for the Commission.

Review of ongoing research results and proposals

Research results and proposals from Area 48

9.1 WG-SAM-2021/17 presented a report on the toothfish survey in Subarea 48.1 conducted by the Ukrainian vessel *Calipso* in 2021.

9.2 The Working Group welcomed this report and, while noting that this survey had to be interrupted again due to high macrourid by-catch levels, it had generated a large amount of data on toothfish, by-catch species and ecosystem information in a poorly surveyed area. The Working Group further noted that these results could inform the toothfish population hypothesis in Area 48.

9.3 Noting that the by-catch levels would render the establishment of a directed toothfish fishery in the area difficult, the Working Group recommended highlighting which research milestones could not be achieved due to by-catch issues (WG-SAM-2021/17), in order to inform any potential future research in this area.

9.4 WG-SAM-2021/21 presented an updated analysis of the sea-ice concentration in research blocks 4 and 5 of Subarea 48.6.

9.5 The Working Group welcomed this analysis and noted its pertinence to the research proposal in Subarea 48.6 (WG-SAM-2021/04 Rev. 1) given the effect of sea-ice on the accessibility of research blocks. The Working Group recalled the previous work on sea-ice accessibility done in Subarea 48.1 (WG-FSA-18/01) and suggested a similar analysis may be valuable for these areas.

Research results and proposals from Area 58

9.6 WG-SAM-2021/03 presented a multi-Member research proposal for continuing research in the *D. mawsoni* exploratory fishery in East Antarctica (Divisions 58.4.1 and 58.4.2). The proponents proposed to continue the research in the existing research blocks in Divisions 58.4.1 and 58.4.2 with a revised sampling design for hauls within each research

block. If directed fishing was again not allowed in Division 58.4.1 in 2021/22, the proponents proposed to continue the research plan in the one existing, and one new, research block in Division 58.4.2. The location of this new research block was determined by a suitability assessment and fishing in this block would be effort-limited.

9.7 The Working Group welcomed the change in survey design presented by the proponents following previous advice and recalled past discussions regarding the use of different gear types by the vessels involved, noting that no current conservation measure required the use of single gear types in exploratory fisheries (WG-FSA-2019, paragraphs 4.89 to 4.114). It also recalled that the catch allocation in research blocks was designed to facilitate vessel coordination and completion of research objectives. The Working Group further noted the strong interest of the proponents of this proposal to resume their research on toothfish stock assessment, stock structure hypothesis (e.g. using archival tags) and ecology (e.g. stomach contents).

9.8 The Working Group noted that the new research block, proposed for the case that directed fishing was not allowed in Division 58.4.1 in 2021/22, was located in SSRU 5842C. This SSRU has a current catch limit of 0 tonnes in CM 41-05.

9.9 The Working Group endorsed the survey design as presented, acknowledging the quality of the proposal, and collaborative research between several Members.

Research results and proposals from Area 88

9.10 WG-SAM-2021/02 presented a notification for the Ross Sea shelf survey in 2022.

9.11 The Working Group noted that this was the last year of this five-year research plan aiming at monitoring juvenile toothfish in the Ross Sea region. The Working Group noted the great importance of the time series generated by this survey for the stock assessment in this area given the information it provided on biomass and year-class strength. The Working Group recalled that the management areas to which the survey catch will be allocated will be decided by the Commission (CCAMLR-39, paragraph 5.39).

9.12 The Working Group recalled that data on the abundance of juvenile toothfish obtained by the Ross Sea shelf survey are reflected in the subsequent fish length frequency in fishing catch data, and integrated within the Ross Sea stock assessment to track recruitment into the adult population.

9.13 The Working Group highlighted that in previous years increasing catch rates had led to the survey not being completed and suggested WG-FSA-2021 consider if a higher catch limit should be set for this survey to avoid undermining its objectives.

Future work

10.1 The Working Group recalled that the five-year work plan agreed by the Scientific Committee in 2017 (SC-CAMLR-XXXVI/BG/40) needed to be updated. Noting previous discussions of future work (WG-SAM-2019, paragraph 7.2; SC-CAMLR-38, paragraph 13.4) it discussed potential future strategic areas of WG-SAM work that could be considered by the

Scientific Committee. Considering the topics of the 2017 work plan, the Working Group noted, in particular, the need to add krill issues to the WG-SAM work plan given the need to revise the krill management approach.

10.2 The Working Group noted that the list of future work topics for WG-SAM is large and growing through time and requested the Scientific Committee consider priority work topics and mechanisms to progress those issues given the limited time available during WG-SAM meetings and limited capacity for Members to prepare work for the meetings.

10.3 The Working Group discussed the possibility of holding online workshops and symposia during the intersessional period, including an update to the five-year work plan, and cross-working group workshops (e.g. WG-ASAM–WG-SAM to discuss statistical approaches to acoustic and other data), Casal2 and Grym training workshops. The Working Group noted that the Science Capacity Building Fund could be used for the organisation of such workshops.

10.4 The Working Group agreed that over the last two years, the burden sharing over the timing of the virtual meetings had been unequal across time zones and that an equitable solution needed to be devised in the future for formal and informal virtual meetings.

10.5 The Working Group noted the future Data Services Advisory Group (DSAG) webinar (see SC CIRC 21/112) and requested it be recorded for those who would be not available during the dark hours. It also noted the relevance of a tagging workshop involving the fishing industry (COLTO–CCAMLR Workshop, WG-EMM-2019, paragraph 4.8) as well as a krill observer workshop (SC-CAMLR-38, paragraph 3.38), which both have been delayed due to COVID-19.

10.6 The Working Group recommended that the Scientific Committee consider the following tasks for cooperation between WG-SAM and other working groups:

- (i) consideration of the statistical approaches to acoustic data emerging from new acoustic observation platforms (WG-ASAM)
- (ii) establishment of Grym parameters for krill stock assessments in Areas 48 and 58 (WG-EMM).

10.7 The Working Group requested that the Scientific Committee consider the following topics as potential future tasks for WG-SAM:

- (i) future evaluation of Casal2 and CASAL
- (ii) update and evaluation of the trend analysis framework
- (iii) evaluation of the CCAMLR decision rules and potential alternative harvest control rules
- (vi) progress on toothfish population hypothesis in Area 48.

Other business

11.1 WG-SAM-2021/11 presented an examination of fishery data collected by Russian scientific observers on longline vessels operating Spanish and trotline systems in CCAMLR

and adjacent Atlantic waters during the 2002–2017 fishing seasons. Considerations of the fishing impact zone of the gears were discussed, including the effect of bottom currents, bathymetry and water stratification on the area influenced by bait odour plumes.

11.2 The Working Group thanked the authors for their paper and noted that the catchability of gear types is dependent on many variables. The Working Group encouraged the continuation of the research and encouraged the authors to design field experiments or controlled experiments (e.g. aquaculture tanks) to test their hypotheses.

11.3 The Working Group noted that the term ‘fishing impact zone’ could be confused with the term ‘fishery footprint’ used to assess vulnerable marine ecosystem (VME) impact, and suggested to use the term ‘area fished’ instead. It also recalled that WG-FSA-18/62 and WG-EMM-2019/50 used baited remote underwater video cameras to document toothfish behaviour in proximity to bait.

11.4 WG-SAM-2021/16 presented a proposal to include corrected data from the Ukrainian fishing vessels *Simeiz*, *Koreiz* and *Calipso* in the CCAMLR database, as data from these vessels from 2014 to 2018 are currently quarantined by the Scientific Committee (SC-CAMLR-38, paragraph 3.56). The authors noted that both the corrected and original data should be available to Members, as well as information on the method used to correct the data.

11.5 The Working Group welcomed the work undertaken by Ukraine and the Secretariat to evaluate the causes of the data discrepancies from these vessels. The Working Group encouraged the continuation of this work, including a proposed alternative approach based on using observer data to identify and indicate actual catch weights and subsequently correct the C2 data.

11.6 The Working Group noted that the inclusion of corrected data in the CCAMLR database would potentially result in the overwriting of the original data, that it did not consider this best practice, and that DSAG may be a suitable forum for consideration of this topic.

Advice to the Scientific Committee

12.1 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) trend analysis (paragraph 3.32)
- (ii) gear types in exploratory fisheries (paragraph 8.11)
- (iii) research proposal for continuing research in Divisions 58.4.1 and 58.4.2 (paragraph 9.9).

Adoption of the report and close of meeting

13.1 The report of the meeting was adopted.

13.2 At the close of the meeting Dr Péron and Dr Okuda thanked all the participants for their hard work and collaboration that had contributed greatly to the successful outcomes from WG-SAM this year, and to the Secretariat, Interprefy staff and the stenographers for their support. The Co-conveners 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 and a considerable future workplan developed for WG-SAM.

13.3 On behalf of the Working Group Dr C. Darby (UK) and Mr N. Walker (New Zealand) thanked Dr Péron and Dr Okuda for their guidance during the 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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Agenda

Working Group on Statistics, Assessments and Modelling
(Virtual meeting, 28 June to 2 July 2021)

1. Introduction
2. Opening of the meeting
 - 2.1 Adoption of the agenda and organisation of the meeting
3. Development and progress of stock assessments
 - 3.1 Stock assessments for krill
 - 3.2 Stock assessment for established toothfish fisheries
 - 3.3 Stock assessment for data-limited toothfish fisheries
 - 3.3.1 Trend analysis for data-limited toothfish fisheries
4. Management strategy evaluations: consideration of alternative toothfish harvest control rules, including F-based rules for stocks with integrated assessments
5. Cross-cutting issues in toothfish fisheries affecting data or stock assessment model quality
 - 5.1 Uncertainties in tagging programs (tag matching, vessel calibration method, etc.)
 - 5.2 Conversion factors
6. Development of a toolbox for designing research plans
 - 6.1 Demo of the CCAMLR R GIS package
 - 6.2 Tools to design sampling strategy for research surveys (under CM 24-01)
7. Data service advisory group
8. Review of new research proposals
9. Review of ongoing research results and proposals
 - 9.1 Research results and proposals from Area 48
 - 9.2 Research results and proposals from Area 58
 - 9.3 Research results and proposals from Area 88
10. Future work
11. Other business
12. Advice to the Scientific Committee
13. Adoption of report and close of meeting.

List of Documents

Working Group on Statistics, Assessments and Modelling
(Virtual Meeting, 28 June to 2 July 2021)

WG-SAM-2021/01	New research plan for <i>Dissostichus</i> spp. under CM 24-01, paragraph 3 in Subarea 88.3 by Korea and Ukraine from 2021/22 to 2023/24 Delegations of the Republic of Korea and Ukraine
WG-SAM-2021/02	Notification for the Ross Sea shelf survey in 2022 Delegation of New Zealand
WG-SAM-2021/03	Continuing research in the <i>Dissostichus mawsoni</i> exploratory fishery in East Antarctica (Divisions 58.4.1 and 58.4.2) from 2018/19 to 2021/22; Research plan under CM21-02, paragraph 6(iii) Delegations of Australia, France, Japan, Republic of Korea and Spain
WG-SAM-2021/04 Rev. 2	Proposal for continuing research on Antarctic toothfish (<i>Dissostichus mawsoni</i>) in Statistical Subarea 48.6 in 2021/22 from a multiyear plan (2021–2024): Research Plan under CM 21-02, paragraph 6(iii) Delegations of Japan, South Africa and Spain
WG-SAM-2021/05	Proposal to conduct a local survey of <i>Champscephalus gunnari</i> in Statistical Subarea 48.2 Delegation of Ukraine
WG-SAM-2021/06	Provisional Trend Analysis – Preliminary 2021 research blocks biomass estimates Secretariat
WG-SAM-2021/07	Antarctic krill proportional recruitment indices (2010–2020) in Subareas 48.1–48.3 from the observer data Secretariat
WG-SAM-2021/08	Preliminary exploration of H-based decision rules for managing toothfish fisheries R. Hillary, P. Ziegler and J. Day

WG-SAM-2021/09	Recruitment modelling for <i>Euphausia superba</i> stock assessments considering the recurrence of years with low recruitment C. Pavez, S. Wotherspoon, D. Maschette, K. Reid and K. Swadling
WG-SAM-2021/10	Multi-fleet stock assessment modelling with the Grym J. Liu, S. Wotherspoon and D. Maschette
WG-SAM-2021/11	Analysis of the factors influencing the fishing impact zone for the longline toothfish fishery O. Krasnoborodko, S. Kasatkina and A. Remeslo
WG-SAM-2021/12	Grym parameter values for Subareas 48.1, 48.2 and 48.3 S. Thanassekos, K. Reid, S. Kawaguchi, S. Wotherspoon, D. Maschette, P. Ziegler, D. Welsford, G. Watters, D. Kinzey, C. Reiss, C. Darby, P. Trathan, S. Hill, T. Earl, S. Kasatkina and Y.-P. Ying
WG-SAM-2021/13	Updated stock assessment model for the Antarctic toothfish (<i>Dissostichus mawsoni</i>) population of the Ross Sea region for 2021 A. Grüss, A. Dunn and S. Parker
WG-SAM-2021/14	Diagnostic plots for the 2021 assessment model for the Antarctic toothfish (<i>Dissostichus mawsoni</i>) population of the Ross Sea region A. Grüss, A. Dunn and S. Parker
WG-SAM-2021/15	Stock Annex for the 2021 assessment of the Antarctic toothfish (<i>Dissostichus mawsoni</i>) population of the Ross Sea region A. Grüss, A. Dunn and S. Parker
WG-SAM-2021/16	Options to include the Ukrainian quarantined data to the CCAMLR database I. Slypko and K. Demianenko
WG-SAM-2021/17	Report on the toothfish survey in the Subarea 48.1 by the Ukrainian vessel <i>Calipso</i> in 2021 Delegation of Ukraine
WG-SAM-2021/18	Research Plan under CM 21-02, paragraph 6 (iii). Proposal for new multi-Member research on <i>Dissostichus</i> spp. in Divisions 58.4.1 and 58.4.2 from 2021/22 to 2023/24 Delegation of the Russian Federation

- WG-SAM-2021/19 Proportional recruitment and weight-length relationship for krill in Subarea 48.1 and 48.2 from RV *Atlantida* survey, 2020
S. Kasatkina and S. Sergeev
- WG-SAM-2021/20 Rev. 1 Summary of proportional recruitment and multiyear biomass variability for krill in Subarea 48 from research surveys
D. Kinzey
- WG-SAM-2021/21 2021 updated analysis of the sea ice concentration (SIC) in research blocks 4 (RB4), and 5 (RB5) of Subarea 48.6 with sea surface temperature (SST) and winds
T. Namba, R. Sarralde, T. Ichii, T. Okuda, S. Somhlaba and J. Pompert
- WG-SAM-2021/22 Moving from biomass estimates towards precautionary catch limit: spatial scale revisited
Y. Ying, X. Wang, X. Zhao, Y. Zhao, G. Fan and J. Zhu

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

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

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 *Bentazos* 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	<i>Proportional</i>	
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)
$B_0 \log SD$	0.361	WG-SAM-2021/21 Rev. 1
Target escapement	75%	Constable and de la Mare (1996)

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(Virtual meeting, 5 to 9 July 2021)

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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.

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 <i>Pygoscelis adeliae</i> 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 |

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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 *Atlántida* 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. Shnar, 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
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- 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
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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

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- WG-EMM-2021/P05 Risk assessment of SARS-CoV-2 in Antarctic wildlife
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- WG-EMM-2021/P07 Utilising IPCC assessments to support the ecosystem approach to fisheries management within a warming Southern Ocean
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Report of the Working Group on Fish Stock Assessment
(Virtual Meeting, 13 to 20 September 2021)

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**Report of the Working Group
on Fish Stock Assessment**
(Virtual meeting, 13 to 20 September 2021)

Opening of the meeting

1.1 The 2021 meeting of the Working Group on Fish Stock Assessment (WG-FSA) was held online from 13 to 20 September 2021. The Convener, Mr S. Somhlaba (South Africa) welcomed the participants (Appendix A). He encouraged the discussions of the working group to be based on testable scientific hypotheses to ensure that, where participants held alternative views or perspectives, these could be debated using sound scientific principles.

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 Agenda Item 8.

Review of the 2020/21 fishery

2.1 WG-FSA-2021/02 presented a summary of the implementation of the CCAMLR Scheme of International Scientific Observation (SISO) during 2019/20 and 2020/21. The Secretariat presented proposed updates to observer forms due to the standardisation of species codes undertaken as part of the taxon data project (WG-FSA-2019/14), a new pot observer logbook developed in conjunction with Australia and France, and the development of a metadata repository for historic observer sampling information.

2.2 The Working Group thanked SISO observers and the Secretariat for the logbook developments and noted that all observers present on vessels may be included in the deployment tables presented in the paper, noting that for some Members' privacy requirements may prevent this.

2.3 The Working Group endorsed the revised observer logbooks and the update to the *Scientific Observer's Manual – Finfish Fisheries* to cover the new observer pot form, and recommended the Scientific Committee endorse the logbooks for use in the 2021/22 season.

2.4 WG-FSA-2021/03 presented results from a survey conducted on vessels participating in exploratory fisheries, conducted by the Secretariat in 2020, summarising how conversion factors were determined and used in longline vessel catch data. The survey results noted that

the headed, gutted and tailed processing method was used by all vessels, and the provision of conversion factors by Members, and the methods of calculation of conversion factors by vessel crews and observers, varied between vessels and Members.

2.5 The Working Group welcomed this contribution and noted that the survey results indicated that data on the C2 form are sometimes completed by the scientific observer. It underscored that recording data in the C2 form is the responsibility of the vessel.

2.6 The Working Group recommended that the Scientific Committee designate a virtual workshop in 2021/22 on conversion factors and requested the Scientific Committee appoint conveners to facilitate the workshop and to prepare a workshop report. The Working Group recommended that the workshop have the following terms of reference:

- (i) To review and develop standardised guidelines for on-board sampling procedures and the calculation, and use of, conversion factors in all CCAMLR toothfish fisheries.

2.7 The Working Group additionally recommended that the Scientific Committee:

- (i) Task the workshop with reviewing a summary of on-board sampling procedures, and an analysis of the calculation and implementation of conversion factors in deriving catch weights between and within vessels, Members and fisheries to be undertaken by the Secretariat as an update to WG-FSA-15/02, including consideration of the effect of conversion factor variability on total catch removals.
- (ii) Designate that the workshop be hosted virtually, facilitated by the Secretariat during March/April 2022, with the meeting of a duration of two days. Results from the workshop will be presented as a convener report to WG-FSA-2022.

2.8 WG-FSA-2021/10 presented updates to commercial data forms due to the standardisation of species codes undertaken as part of the Secretariat's taxon data project (WG-FSA-2019/14), a draft longline commercial data manual for consideration by Members, and a proposed new fine-scale catch and effort longline data form (C2) for implementation in the 2022/23 season.

2.9 The Working Group welcomed the developments undertaken on the commercial forms and longline fishery data manual and requested that the Secretariat develop an archive of the current and historic data collection forms, relevant manuals and instructions on its website that can be accessed by Members.

2.10 The Working Group endorsed the proposed changes to the commercial vessel data forms and the accompanying commercial data manual, and the proposed new C2 form. The Working Group recommended that the Scientific Committee endorse the commercial form updates and longline fishery data manual for use in the 2021/22 season, and the new C2 form be implemented in the 2022/23 season.

2.11 The Working Group further recommended that the Scientific Committee consider:

- (i) a focused krill fishing vessel data workshop to develop a new C1 haul-by-haul form, ensuring data collected are appropriate for the CCAMLR krill risk assessment framework (WG-FSA-2021/17)

(ii) the development of new forms for C1 finfish and the C5 pot haul-by-haul forms.

2.12 WG-FSA-2021/07 presented a summary of the operation of the fishery closure forecasting algorithm used by the Secretariat in the Ross Sea fisheries. The implementation of the current closure forecasting procedures was considered to be consistent with the objective of avoiding catch limit overruns, and some improvements to the algorithm were detailed.

2.13 The Working Group welcomed this contribution and agreed that the current closure forecasting approach is appropriate and precautionary. The Working Group recommended establishing a compendium detailing the circumstances of catch limit overruns, as this would be helpful in improving closure forecasting procedures.

2.14 The Working Group endorsed the recommendations in the paper, maintaining the existing elements of the current forecasting algorithm, with the inclusion of the following procedures:

(i) in the Ross Sea region north of 70°S, the move from stage 1 to stage 2 forecasting should take place on day 3

(ii) forecasting in stage 2 should use a vessel's average daily catch from the latest catch reporting period rather than using an average from all data from the beginning of the season. The addition of the potential catch from hooks already in the water should not be included

(iii) when a vessel(s) arrives in an area where fishing is already occurring, the Secretariat should use the average catch rate from vessels already present in the area, rather than a historic catch rate for the arriving vessel(s) for the first two days.

2.15 The Working Group noted WG-FSA-2021/09, which presented the first iteration of an annual report on the Secretariat database of linked tags, following the request by WG-SAM-2019, paragraph 4.4(i).

2.16 The Working Group noted SC-CAMLR-40/BG/01, which presented an overview of catches of target species from directed fishing on toothfish, icefish and krill in the Convention Area in the 2019/20 and 2020/21 seasons and from research fishing under Conservation Measure (CM) 24-05.

Fish stock assessments and management advice

3.1 The Working Group noted that due to the shortened and virtual nature of its 2021 meeting, a discussion group (i.e. an e-group limited to Working Group participants) to facilitate cross-verifications of stock assessments had been created prior to the meeting (SC CIRC 21/137). The Working Group welcomed this effective collaboration and noted that all assessments leading to catch advice had been successfully verified and that suggestions from reviewers to assessors had been made for future assessments. A document summarising the outcomes of the discussion group was made available on the meeting server for review by the Working Group; all reviews were reported to WG-FSA in plenary.

Champscephalus gunnari

C. gunnari in Subarea 48.3

3.2 The fishery for mackerel icefish (*Champscephalus gunnari*) in Subarea 48.3 operated in accordance with CM 42-01 and associated measures. In 2020/21, the catch limit for *C. gunnari* was 2 132 tonnes. Details of this fishery and the stock assessment of *C. gunnari* are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_483_ANI_2020.pdf).

3.3 The Working Group noted that in recent years, low amounts of fishing effort were being deployed in Subarea 48.3 and that this had resulted in very low catches by the fishery.

3.4 As part of its regular monitoring program, the UK undertook a bottom trawl survey of Subarea 48.3 in May 2021 (WG-FSA-2021/12). The biomass of *C. gunnari* was estimated at 18 013 tonnes with a lower one-sided 95% interval estimate of 10 627 tonnes, one of the lowest biomasses estimates in the survey series. The 2021 survey mainly comprised fish of length 10–20 cm.

3.5 The Working Group noted that both the late timing of the survey and the presence of a large iceberg (A68) in the area might have contributed to the distribution patterns and biomass observed. It suggested future reports on this survey include longer timeseries of length frequency distributions, as these would be informative of the dynamics of cohorts in the area.

3.6 WG-FSA-2021/15 presented an assessment for *C. gunnari* in Subarea 48.3 fitting a length-based assessment in R with the FLCore package following the results of the trawl survey described in WG-FSA-2021/12. Projecting forward from the lower 5th percentile of biomass resulted in yields of 1 457 tonnes for 2021/22 and 1 708 tonnes for the 2022/23 season. These yields allow for 75% escapement of the unfished projection and satisfy the CCAMLR decision rules.

Management advice

3.7 The Working Group recommended that the catch limit for *C. gunnari* in Subarea 48.3 should be set at 1 457 tonnes for 2021/22 and 1 708 tonnes for 2022/23.

C. gunnari in Division 58.5.2

3.8 The fishery for *C. gunnari* in Division 58.5.2 operated in accordance with CM 42-02 and associated measures. In 2020/21, the catch limit for *C. gunnari* was 406 tonnes. Details of this fishery and the stock assessment of *C. gunnari* are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_HIMI_ANI_2020.pdf).

3.9 The results of a random stratified trawl survey in Division 58.5.2 undertaken during late March to mid-April 2021 were summarised in WG-FSA-2021/19. The survey recorded the highest estimate of total biomass of *C. gunnari* on record at 18 933 tonnes, mainly comprised fish of age 3+.

3.10 WG-FSA-2021/20 presented an assessment of *C. gunnari* in Division 58.5.2 using the generalised yield model in R (Grym) following the results of the trawl survey described in WG-FSA-2021/19. Projecting forward from the lower 5th percentile of fish of ages 1+ to 3+ gave yields of 1 528 tonnes for 2021/22 and 1 138 tonnes for 2022/23 that allow for 75% escapement and therefore satisfy the CCAMLR decision rules.

Management advice

3.11 The Working Group recommended that the catch limit for *C. gunnari* in Division 58.5.2 should be set at 1 528 tonnes for 2021/22 and 1 138 tonnes for 2022/23.

Dissostichus spp.

General issues

3.12 In 2019, the Working Group requested that Members running integrated stock assessments calculate the equilibrium harvest rate consistent with CCAMLR decision rules from the assessment projections (WG-FSA-2019, paragraph 3.14). These values are presented in Table 1.

3.13 In assessment years, the Secretariat verifies that stock assessments submitted to WG-FSA using CASAL (Table 2) are reproducible, using a three-step verification process:

- (i) CASAL version: all assessments are required to use the same version of CASAL. For WG-FSA-2021, all assessments used CASAL v2.30-2012-03-21 rev.4648
- (ii) parameter files verification: the files population.csl, estimation.csl and output.csl used in each assessment reported in meeting papers are used as inputs to a CASAL run performed by the Secretariat. If no errors are reported during the process, the files are considered as verified
- (iii) maximum posterior density (MPD) estimate verification: the virgin spawning stock biomass (B_0) estimate produced by a given model run is compared to that reported in the accompanying meeting paper.

3.14 CASAL versions and parameter files were successfully verified for the CASAL assessments submitted to WG-FSA in 2021. Verifications of the MPDs produced the same B_0 estimates as reported in the papers (Table 2).

3.15 WG-FSA-2021/31 reported development progress on the Casal2 stock assessment software package. The package is approaching a development point where it can be considered for use by CCAMLR for tag-based toothfish assessments. A Casal2 workshop will be held later in 2021 for scientists who wish to engage in the development and testing of Casal2, and the authors invited Members to participate in this workshop and in an e-group to develop test cases for presentation at WG-SAM in 2022.

3.16 The Working Group noted that the impact of climate change on stock productivity and B_0 estimates needs to be taken into account in relation to toothfish stock assessments. This has been considered by WG-FSA (WG-FSA-2019, paragraphs 3.15 to 3.21) and the Scientific Committee in 2019 (SC-CAMLR-38, paragraphs 3.61 to 3.65) but needs to be developed further.

3.17 The Working Group noted that all stock assessments relying on tag-based stock assessments are likely to be influenced by the spatial distribution of tagged fish, low mixing rates, and the subsequent spatial variability or contraction of fishing effort. The Working Group recommended that this issue be discussed in a special focus topic at WG-SAM-2022.

3.18 The Working Group recalled that the CCAMLR Independent Stock Assessment Review for Toothfish made a number of recommendations to improve the integrated assessments (SC-CAMLR-XXXVII/02 Rev. 1 and SC-CAMLR-XXXVII, Annex 5). The Working Group recommended that WG-SAM-2022 review the progress made in addressing the recommendations of the expert group (SC-CAMLR-XXXVII, Annex 5; WG-FSA-2019, Table 3).

3.19 At the end of the plenary discussion on agenda item 3, and following the agreed CCAMLR Scientific Committee procedures, the Chair confirmed with the meeting that consensus advice had been agreed for the catch limit recommendations for toothfish in all areas. No attendee at the meeting objected to the Chair's summary during plenary.

3.20 At the time of report adoption, Dr S. Kasatkina (Russia) noted that there was no consensus on catch advice for Subarea 48.3.

3.21 Dr C. Darby (UK) stated that Dr Kasatkina's position on the application of CCAMLR's precautionary assessment methods and decision rule is inconsistent with the best available science. Her position requires the presentation of scientific analysis to working groups to address the points they have raised rather than continually repeating the same statements which have been refuted by all members of consecutive meetings of CCAMLR working groups. It is unfortunate that she had not allowed the Working Group to provide consensus advice again, similar to 2019. Dr Darby noted that the issues raised by Dr Kasatkina apply to all toothfish fisheries and as such we have no consensus on catch advice.

3.22 The Working Group noted that the CCAMLR assessment procedures and decision rules are applied to all assessed toothfish stocks. Given the lack of agreement during report adoption of WG-FSA-2021 that the CCAMLR decision rule is precautionary (refer to paragraphs 3.20, 3.21 and 3.32 to 3.34), the Working Group noted it had been unable to provide consensus catch advice for all assessed toothfish stocks and associated research proposals. However, for all assessed toothfish stocks, the Working Group provided advice based on the use of the best available science in the assessments on what catch levels are consistent with the CCAMLR decision rules.

3.23 As in 2019, the Working Group requested that the Scientific Committee consider precautionary catch limits for all the assessed stocks and research proposals associated with them so that advice to the Commission can be provided on the basis of the best available science. The Working Group also requested that the Scientific Committee consider how WG-FSA can provide advice on precautionary catch limits in the future.

D. eleginoides in Subarea 48.3

3.24 The fishery for Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3 operated in accordance with CM 41-02 and associated measures. In 2020/21, the catch limit for *D. eleginoides* was 2 327 tonnes. Details of this fishery and the stock assessment of *D. eleginoides* are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_483_TOP_2020.pdf).

3.25 WG-FSA-2021/59 and 2021/60 presented an updated integrated CASAL assessment model for *D. eleginoides* in Subarea 48.3. The model estimated B_0 at 72 600 tonnes (95% confidence interval (CI): 68 200–78 500 tonnes) and spawning stock biomass (SSB) status in 2021 at 47% (95% CI: 43–53%). Based on the results of this assessment, removals of 2 153 tonnes are consistent with the CCAMLR decision rules. This results in a catch limit of 2 072 tonnes when following the procedure to account for a recent average estimated depredation rate of 3.9% (2011–2020) as agreed by SC-CAMLR-38 (paragraph 3.70).

3.26 The Working Group noted that the estimate for B_0 was lower than in the last two assessments, which was mainly driven by higher-than-expected tag recaptures from release cohorts since 2015 associated with spatial contraction of fishing effort. It noted that the effects of low fish movement rates, spatial variability and contraction in fishing effort pose challenges to all tag-based stock assessments.

3.27 In future assessments, the Working Group recommended that assessors:

- (i) include all model specifications in the assessment reports, including values of all input parameters, specifications of prior distributions and bounds, and final effective sample size (ESS) and tag dispersion
- (ii) explore the influence of the catch-at-length data from the fishery between 1988 and 1997 in sensitivity runs
- (iii) explore potential drivers for consistently high MPD estimates of the most recent year-class strength (YCS), and whether there is sufficient information available to estimate the YCS value for that cohort.

3.28 WG-FSA-2021/41 presented an examination of the variability in *D. eleginoides* biological parameters in catches from the beginning of the longline fishery (1985–1990) in Subarea 48.3. In the authors' opinion, a decrease in the length and weight of mature females and males was shown, as well as a reduced number of large spawning fish, which indicates a change in the length structure of the spawning part of *D. eleginoides* population in Subarea 48.3. Since 2008/09, the fishery has been based on recruitment of fish less than 100 cm in length. In the authors' opinion, this fishery may have a negative impact on the abundance of spawning populations in the future. In the authors' opinion, the risk of the population having impaired reproductive capability is increased. In the author's opinion, the paper noted that the *D. eleginoides* population in Subarea 48.3, which has been fished for more than 40 years, requires protection because the precautionary approach to the use of this resource in the CCAMLR area does not ensure rational use.

3.29 The Working Group recalled that similar analyses had been submitted in the past and that the raised issues had been extensively addressed by WG-FSA in 2019 (WG-FSA-2019,

paragraphs 3.22 to 3.68), including the potential for bias when interpreting raw data from a fishery. The Working Group noted that immature individuals are caught in many CCAMLR fisheries, and that maturity was accounted for in CCAMLR's management approach (SC-CAMLR-38, paragraphs 3.61 to 3.65).

3.30 Some Members noted that if fisheries were to be closed because of the removal of immature individuals, most CCAMLR fisheries would have to close, including the krill fishery.

3.31 The Working Group noted SC-CAMLR-40/BG/08, which addressed all concerns raised by WG-FSA-2021/41. It further recalled the recommendations from the CCAMLR Independent Stock Assessment Review for Toothfish and the Scientific Committee in 2018 (SC-CAMLR-XXXVII, paragraphs 3.52 to 3.56) that CCAMLR's stock assessment approach was appropriate for the management of its toothfish stocks and that CCAMLR applies assumptions in the stock assessments in a precautionary manner and consistent with Article II.

3.32 At the time of report adoption, Dr Darby recalled that:

'A series of papers submitted to WG-FSA in 2018, 2019 and now in 2021 have repeatedly raised the same issues regarding CCAMLR's management protocols for toothfish stocks. The papers lack any statistical analysis for the arguments presented and demonstrate fundamental scientific misunderstandings regarding the CCAMLR management approach (Scientific Committee, WG-FSA and WG-SAM discussions on the key misinterpretations are summarised in SC-CAMLR-40/BG/08).

All the points the authors have raised have been addressed by the Scientific Committee, WG-SAM and WG-FSA in their meetings. If the authors have remaining scientific concerns with the CCAMLR management approach, they are welcome to raise them intersessionally in the WG-FSA e-groups, or through debate during the plenary sessions of appropriate CCAMLR meetings. The Convener of WG-FSA, as noted by many Members, made similar requests during the plenary sessions of this meeting.

Dr Darby reiterated, as he had during the plenary sessions of the meeting, that WG-FSA-2021/41 included:

- A table of historic maturity studies from Subarea 48.3 that are not standardised and contain errors in the values taken from the quoted papers.*
- A lack of analysis of any maturity data from the most recent 16 years of CCAMLR Members' data from the fishery.*
- An incorrect inference that there is a decreasing trend in maturity based on the data shown.*
- The claim that the Subarea 48.3 fishery selection pattern is unique and selects predominantly immature toothfish; WG-FSA-2019 demonstrated that this is clearly not the case.*

Dr Darby highlighted the information presented in the working group reports that has been used by WG-FSA to determine the dynamics of the Subarea 48.3 stock:

- A full statistical analysis of 100 000 maturity records from 1995 to 2018 showing no decrease in maturity in time for males or females – reviewed and agreed by WG-SAM (2019)*

- *A full integrated CASAL statistical assessment reviewed by world-leading experts using 800 000 data points, >750 000 fish measured, >50 000 tags released, >7 000 fish aged*
- *>9 000 tags recaptured – including, in the most recent years of fishing, from the initial releases 16 years ago, demonstrating low exploitation rates.*

Dr Darby further noted that WG-FSA applies the CCAMLR agreed scientific methods and decision rules to provide advice for its toothfish stocks, and that these are applied consistently across all stocks. The application of the CCAMLR assessment methods has been reviewed by WG-FSA members and external experts for the Scientific Committee (SC-CAMLR-XXXVII, Annex 5), including to the stock in Subarea 48.3. All reviews have raised no issues of substance that would indicate over-exploitation. In contrast to the claims in WG-FSA-2021/41 about CCAMLR’s assessment and management approach, the external peer review noted that the methods applied for all the toothfish stocks are world leading and highly precautionary and are consistent with CCAMLR’s Article II.’

Management advice

3.33 Dr Kasatkina (Russian Federation) proposed to:

- (i) close the fishery in Subarea 48.3 from 2022
- (ii) revise the precautionary approach to the use of the *D. eleginoides* stock in the CCAMLR area (Subarea 48.3) because the current approach does not ensure the rational use of this living resource, as evidenced by the above scientific and fishery-based facts.

3.34 All other participants noted that a catch limit for *D. eleginoides* in Subarea 48.3, set at 2 072 tonnes for 2021/22 and 2022/23 based on the outcome of this assessment, would be consistent with the precautionary yield estimated using the CCAMLR decision rules, the process for setting catch limits used in previous years and the use of best available science.

3.35 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22).

D. eleginoides in Subarea 48.4

3.36 The fishery for *D. eleginoides* in Subarea 48.4 operated in accordance with CM 41-03 and associated measures. In 2020/21, the catch limit for *D. eleginoides* was 27 tonnes. Details of this fishery and the stock assessment of *D. eleginoides* are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_484_TOT_2020.pdf).

3.37 WG-FSA-2021/61 and 2021/62 presented an updated integrated CASAL assessment model for *D. eleginoides* in Subarea 48.4. The assessment model followed the same procedure as described in WG-FSA-2019/29 and was updated with the observations for the 2019 and 2020

seasons. Stock projections indicated that the stock was at 65% of B_0 in 2021 and that a yield of 23 tonnes in 2022 and 2023 would be consistent with the application of the CCAMLR decision rule.

3.38 The Working Group welcomed the inclusion of catch tonnage, scanned length distribution, tag-release data, tag-recapture data and otolith aging data from a sample of the catch for the 2018/19 and 2019/20 seasons. It noted that the 2021 assessment model encountered memory allocation issues from the large amount of length and tagging data and that it was resolved by using finite differences for the MPD run. The Working Group welcomed the proposition to present future work to WG-SAM to modify the parameterisation to address this issue.

Management advice

3.39 The Working Group noted that a catch limit for *D. eleginoides* in Subarea 48.4, set at 23 tonnes for 2021/22 and 2022/23 based on the outcome of this assessment, would be consistent with the precautionary yield estimated using the CCAMLR decision rules, the process for setting catch limits used in previous years, and the use of best available science.

3.40 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22).

D. mawsoni in Subarea 48.4

3.41 The fishery for Antarctic toothfish (*D. mawsoni*) in Subarea 48.4 operated in accordance with CM 41-03 and associated measures. In 2020/21, the catch limit for *D. mawsoni* was 45 tonnes. Details of this fishery and the stock assessment of *D. mawsoni* are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_484_TOT_2020.pdf).

3.42 WG-FSA-2021/63 Rev. 1 presented a Chapman biomass estimate for *D. mawsoni* in Subarea 48.4 from mark-recapture data. Based on the recommendation of WG-FSA-2019, the biomass was calculated using a geometric mean of the last five years of Chapman estimates as a robust and precautionary approach (WG-FSA-2019, paragraphs 3.75 to 3.77). In 2021, the tagging data resulted in a geometric mean biomass of 1 311 tonnes. Applying a harvest rate of $\gamma = 0.038$ resulted in a yield of 50 tonnes.

Management advice

3.43 The Working Group noted that a catch limit for *D. mawsoni* in Subarea 48.4, set at 50 tonnes for 2021/22 based on the outcome of this assessment, would be consistent with the precautionary yield, the process for setting catch limits used in previous years, and the use of best available science.

3.44 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22).

D. eleginoides in Division 58.5.1

3.45 The fishery for *D. eleginoides* in Division 58.5.1 is conducted in the French exclusive economic zone (EEZ) of the Kerguelen Islands. Details of the fishery and the stock assessment are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_KI_TOP_2020.pdf).

3.46 WG-FSA-2021/46 and 2021/57 presented an updated integrated CASAL assessment model for the Kerguelen Islands *D. eleginoides* fishery in Division 58.5.1 up to the end of 2019/20. Two assessment models were developed: a model where YCS was assumed to be 1 in all years (M1); and a model where YCS was estimated over the period 2000–2016 (M2). The base-case assessment model (M2) estimated B_0 at 233 130 tonnes (95% CI: 207 030–265 460 tonnes). Estimated SSB status in 2020 was 69% (95% CI: 65–73%).

3.47 The Working Group welcomed the inclusion of new age frequency data and the estimation of YCS in the base model (M2). It noted that estimated YCS were highly uncertain and had a large impact on the long-term biomass trend, and welcomed the authors' plan to age an additional 12 000 fish from the Kerguelen and Crozet Islands over the next three years to improve the age data in the model. The Working Group also strongly supported the organisation of a scientific survey to sample fish in shallower waters to provide crucial information on changes in juvenile abundance, improve YCS estimation, and inform changes in productivity.

3.48 The Working Group noted that the diagnostics (WG-FSA-2021/57) suggested some evidence of non-convergence for a few parameters in the Markov Chain Monte Carlo (MCMCs) for model M2 and recommended that future work be undertaken to improve those diagnostics. It suggested the authors produce an audit trail in future assessment papers, to better understand the impacts of new data and inputs on model predictions, particularly the age data from newly read otoliths.

3.49 The Working Group welcomed the presentation of a Stock Annex for the Kerguelen Islands EEZ *D. eleginoides* fishery in Division 58.5.1 (WG-FSA-2021/47) and recommended that this be published as a part of the CCAMLR Fishery Report for this area.

3.50 The Working Group agreed that the catch limit set by France of 5 200 tonnes for 2021/22 that accounts for depredation was consistent with the CCAMLR decision rules for the model runs presented.

Management advice

3.51 No new information was available on the state of fish stocks in Division 58.5.1 outside areas of national jurisdiction. The Working Group, therefore, recommended that the prohibition of directed fishing for *D. eleginoides*, described in CM 32-02, remain in force in 2021/22.

D. eleginoides in Division 58.5.2

3.52 The fishery for *D. eleginoides* in Division 58.5.2 operated in accordance with CM 41-08 and associated measures. Details of the fishery and the stock assessment are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_HIMI_TOP_2020.pdf).

3.53 WG-FSA-2021/21 presented an updated integrated CASAL assessment model for the *D. eleginoides* fishery in Heard Island and McDonald Islands (HIMI) in Division 58.5.2 up to the end of 2020/21. The base-case assessment estimated B_0 at 69 210 tonnes (95% CI: 64 811–74 758 tonnes). Estimated SSB status in 2021 was 45% (95% CI: 44–47%). Based on the results of this assessment, a catch limit of 3 010 tonnes for 2021/22 and 2022/23 would be consistent with CCAMLR’s decision rules.

3.54 The Working Group noted that model fits to tagging data varied substantially for recent release cohorts and agreed that this may be as a result of two factors: (i) an increase in tag-release numbers since 2015 resulting in larger absolute fluctuations in numbers, and (ii) stronger variation in the spatial location of fishing effort and the recent contraction of fishing footprint. It noted that analyses to investigate the spatial effects of tagging in the integrated assessment model would be beneficial.

3.55 The Working Group noted that the 2021 survey biomass estimate (WG-FSA-2021/19) was consistent with above-average recent recruitment, but that these data were not included in the assessment model as full season data for 2020/21 were not yet available. It noted that stronger recent recruitment could result in a less pessimistic stock trajectory.

3.56 The Working Group noted that the predicted stock trajectory, from the data used by the model, would be expected to remain below the target level until the final year of the projection period. It recommended that an update on stock parameters, including recruitment indices from the trawl survey, and age frequency data and tag-recapture data from the fishery, be presented to WG-FSA-2022 to evaluate whether recent recruitment and stock status remained consistent with those estimated in the 2021 assessment (e.g. as in SC-CAMLR-39/BG/36).

Management advice

3.57 The Working Group noted that a catch limit for *D. eleginoides* in Division 58.5.2, set at 3 010 tonnes for 2021/22 and 2022/23 based on the outcome of this assessment, would be consistent with the precautionary yield estimated using the CCAMLR decision rules, the process for setting catch limits used in previous years, and the use of best available science.

3.58 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22).

3.59 No new information was available on the state of fish stocks in Division 58.5.2 outside areas of national jurisdiction. The Working Group, therefore, recommended that the prohibition of directed fishing for *D. eleginoides*, described in CM 32-02, remain in force in 2021/22.

D. eleginoides in Subarea 58.6

3.60 The fishery for *D. eleginoides* at Crozet Islands is conducted within the French EEZ and includes parts of Subarea 58.6 and Area 51 outside the Convention Area. Details of this fishery and the stock assessment are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_CI_TOP_2020.pdf).

3.61 WG-FSA-2021/45 presented an updated integrated CASAL assessment model for the Crozet Islands *D. eleginoides* fishery in Subarea 58.6 up to the end of 2019/20. The assessment model assumed YCS was one in all years. The base-case assessment model estimated B_0 at 55 740 tonnes (95% CI: 49 220–60 500 tonnes). Estimated SSB status in 2020 was 65% (95% CI: 61–69%).

3.62 The Working Group noted YCSs were assumed to be one, as there were no age frequency data available. It welcomed the authors' plan to age an additional 12 000 fish from the Kerguelen and Crozet Islands over the next three years to improve the age data in the model. The Working Group agreed that the minor non-convergence in the trawl selectivity was not of concern in interpreting the model outputs.

3.63 The Working Group agreed that a catch limit of 800 tonnes (which would be total removals of 1 162 tonnes including depredation and catches on Del Cano Rise in the Southern Indian Ocean Fisheries Agreement (SIOFA) Convention Area) for *D. eleginoides* in Subarea 58.6 for 2021/22 would be consistent with CCAMLR's decision rules for the precautionary yield for this fishery.

Management advice

3.64 No new information was available on the state of fish stocks in Subarea 58.6 outside areas of national jurisdiction. The Working Group, therefore, recommended that the prohibition of directed fishing for *D. eleginoides*, described in CM 32-02, remain in force in 2021/22.

D. mawsoni in the Ross Sea region

3.65 The exploratory fishery for *D. mawsoni* in Subarea 88.1 operated in accordance with CM 41-09 and associated measures. In 2020/21, the catch limit for *D. mawsoni* was 3 140 tonnes. Details of this fishery and the stock assessment are contained in the Fishery Report (https://fishdocs.ccamlr.org/FishRep_881_TOA_2020.pdf).

3.66 WG-FSA-2021/24 presented a summary of fishing operations in the Ross Sea region together with biological characteristics of the catch of *D. mawsoni* up to, and including, the 2020/21 fishing season. The authors noted that the implementation of the Ross Sea region marine protected area (RSRMPA) from 1 December 2017 had concentrated subsequent fishing on the continental slope south of 70°S, with recent fishing effort in the North extending east into small-scale research units (SSRUs) 882A–B and to the west. Analyses showed several modes of strong recruitment progressing through time on the slope (south of 70°S), while the size and age distributions in the north had not changed. There was a small change in the sex ratio of *D. mawsoni*, with a gradual pattern of more males caught in all areas until 2015. The number of *D. mawsoni* recaptured in 2020/21 was higher than the average annual number over the past decade, likely a consequence of the concentration of fishing effort on the Ross Sea slope with the implementation of the RSRMPA.

3.67 WG-FSA-2021/26 and 2021/27 presented an updated integrated CASAL assessment model for *D. mawsoni* in the Ross Sea region. The assessment showed that the current estimated

stock status was 62.7% B_0 (95% Cis: 59.9–65.6% B_0), and that a catch limit of 3 495 tonnes would be consistent with CCAMLR's decision rules for the precautionary yield for the *D. mawsoni* fishery.

3.68 The Working Group noted that the sensitivity runs requested by WG-SAM-2021 had been undertaken, and showed that excluding the initial three years of data made negligible differences to the model fits or estimates. It noted the patterns in the age frequency residuals of age classes >35 and less than ~ 5 , and noted that previous analyses (WG-FSA-2019) had suggested that these did not impact the model outcomes. However, the Working Group suggested that future work include analyses to investigate model improvements to address these patterns. In addition, it recommended that investigation into approaches to reduce the cohort patterns in age frequency residuals also be conducted, including consideration of temporal fishery splits and the range of YCS estimated in the model.

3.69 The Working Group noted the updated Stock Annex for the Ross Sea region *D. mawsoni* fishery (WG-FSA-2021/28) and recommended that the CCAMLR Fishery Report for this area be updated with this Stock Annex.

3.70 The Working Group noted that the constant F calculations for the Ross Sea region were consistent with the yields using CCAMLR's decision rules (Table 1).

Management advice

3.71 The Working Group noted that a catch limit for the Ross Sea region (Subarea 88.1 and SSRUs 882A–B), set at 3 495 tonnes for 2021/22 and 2022/23 based on the outcome of this assessment (and, following the procedure outlined in CM 91-05, with a catch split of 19% for the area north of 70°S, 66% for south of 70°S, and 15% in the Special Research Zone), would be consistent with the precautionary yield estimated using the CCAMLR decision rules, the process for setting catch limits used in previous years, and the use of best available science.

3.72 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22).

Fish research notifications and exploratory fisheries

Trend analysis and proposed catch limits

4.1 WG-FSA-2021/06 presented toothfish biomass estimates in research blocks in data-limited exploratory fisheries and in research conducted under CM 24-01, and the recommended catch limits for the 2021/22 season as determined using the trend analysis decision rules (Table 3).

4.2 The Working Group thanked the Secretariat and confirmed that the rule developed by WG-SAM-2021 (if no fishing occurred in the last season, the previous catch limit was carried forward) was applicable for five years, starting from the first season in which fishing did not occur. The Working Group recognised the development of this analysis by the Secretariat over

the last few years, and its importance to the work of the Scientific Committee and the Commission. It requested that in future iterations of the trend analysis:

- (i) the figure of biomass estimates and trends (WG-FSA-2021/06, Figure 1) be separated into management area figures
- (ii) the colours in the decision tree (WG-FSA-2021/06, Figure 2) be removed
- (iii) that Table 2 in WG-FSA-2021/06 be replaced by two tables, one describing the method used in that year (Chapman or catch per unit effort (CPUE)), and one describing whether the catch had increased, decreased or remained stable (with actual catch limits)
- (iv) different approaches to scaling of the y-axes in the figure of biomass estimates and trends (WG-FSA-2021/06, Figure 1) be investigated, as in some cases, relatively stable trends appeared exaggeratedly variable
- (v) it retain the calculation and presentation of trends and potential catch limits for all research blocks.

4.3 The Working Group noted that the trends of biomass estimates declined consistently for five years within some research blocks, and highlighted the importance of exploring stock connectivity between research blocks.

4.4 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22), however, it had provided advice based on the use of best available science in the trend analysis rules on what catch level would be consistent with the CCAMLR decision rules. It further noted that the catch limits included in Table 3 were developed using the same procedure as used last year, which has in the past been considered to follow a consistent approach, and to provide precautionary catch limits.

Management area research reviews and management advice

Dissostichus spp. in Area 48

Subarea 48.1

4.5 WG-FSA-2021/44 presented a summary of research on *Dissostichus* spp., conducted in Subarea 48.1 by Ukraine from 2018/19 to 2020/21. The report noted that all surveys were interrupted before the completion of research objectives. The first season of research was affected by sea-ice limiting access to the fishing area, whilst the second and the third seasons of research were not completed due to the by-catch limit of *Macrourus* spp. limiting the number of research hauls. Scientific data on pelagic and benthic ecosystems, including high-quality underwater footage, video monitoring of hauling lines and also photo and video footage of tagged toothfish releases were collected.

4.6 The Working Group welcomed the research and the large amount of data that had been collected. The Working Group noted the comments of WG-SAM (WG-SAM-2021, paragraphs 9.1 to 9.3) and that analysis of these data, including the ageing of otoliths, is ongoing

and requested that the proponents prepare a paper to a future WG-FSA meeting to highlight how the research increased the general understanding of the ecosystem in Subarea 48.1. The Working Group requested more detail on how parameters such as length weight relationships were calculated and the inclusion of parameter values in this paper. The Working Group further noted the proponents' interest to conduct future collaborative research in this area.

4.7 The Working Group noted that the survey captured a few toothfish with an 'axe handle' morphology, a notably thinner trunk which might merit further study. The Working Group further noted that three new vulnerable marine ecosystem (VME) risk areas have been notified in Subarea 48.1 as a result from this survey, on 25 February 2021.

Subarea 48.6

4.8 WG-FSA-2021/50 presented a report of research on *D. mawsoni* conducted in Subarea 48.6 between 2012/13 and 2020/21 by Japan, South Africa and Spain noting the achievement of the milestones detailed in the research objectives.

4.9 WG-FSA-2021/49 presented a preliminary integrated stock assessment for *D. mawsoni* in Subarea 48.6, using the data collected from research blocks 486_2 to 486_5. The model showed some improvements, especially in the age/tagging-related assumptions, however, some unexpected results on CPUE fits and MPD profiles were also present which require further investigation.

4.10 WG-FSA-2021/48 reported on the progress of the development of statistical modelling to estimate abundance trends of by-catch species (grenadiers) caught by longline fisheries in Subarea 48.6 using a spatial delta-generalised linear mixed model (GLMM) implemented in the R package vector autoregressive spatio-temporal (VAST) analysis.

4.11 WG-FSA-2021/38 presented a proposal for continuing research in Subarea 48.6 on *D. mawsoni* by Japan, South Africa and Spain. The revised proposal took into account comments from WG-SAM (WG-SAM-2021, paragraph 8.4) on the importance of understanding stock connectivity between research blocks in the area (seamounts versus continental shelf), on further details about how the stock structure will be represented in the planned CASAL assessment for the region, on increasing the otolith sampling rate from 10 to 20 otoliths per 5 cm length bin, and on detailing minimum sampling requirements for by-catch species.

4.12 The Working Group welcomed the work presented and the revised research proposal. The Working Group noted that while the research proposal meets many of the research objectives, spatially limited fishing effort and associated deployment of tagged fish may prove to be insufficient to collect the amount of tagging data necessary to underpin a successful stock assessment. The Working Group recommended developing further options to ensure the necessary tagging data were obtained possibly by further coordination on catch-sharing plans or focussing on some higher-priority research blocks.

4.13 The Working Group welcomed the increased by-catch sampling requirement for *Macrourus* spp. to 30 specimens per line and noted that the lower sampling rate requirement

for other by-catch species of 10 specimens per line may be insufficient to conduct the planned VAST analysis. The Working Group further noted the large number of toothfish otoliths that had been collected, and requested an update of the ageing data.

4.14 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22), however, it had provided advice based on the use of best available science in the trend analysis rules on what catch level would be consistent with the CCAMLR decision rules. The Working Group agreed on catch limits to be calculated for Subarea 48.6 using the trend analysis rules (WG-FSA-2017, paragraph 4.33) as shown in Table 3.

4.15 The Working Group endorsed the design of this research proposal.

4.16 The Working Group recommended that all research plans submitted under CMs 24-01 or 21-02 paragraph 6(iii) include a power analysis or simulation study outlining how the sampling rates of by-catch species are both representative of the expected catch, and adequate to meet the objectives of the research plan.

Dissostichus spp. in Area 58

Divisions 58.4.1 and 58.4.2

4.17 WG-FSA-2021/18 presented a report on exploratory fishing in Divisions 58.4.1 and 58.4.2 from the 2011/12 to the 2020/21 fishing seasons, including a summary of the fishing activity in Division 58.4.2 in 2020/21.

4.18 WG-SAM-2021/03 detailed the continuing research plan by Australia, France, Japan, the Republic of Korea and Spain. The research plan has been updated with 2021/22 operating details, a change to the sampling design within existing research blocks, and a proposed new research block in Division 58.4.2 if directed fishing was not allowed in Division 58.4.1 in 2021/22.

4.19 The Working Group recalled that this and preceding proposals had been thoroughly reviewed by WG-SAM and WG-FSA and had achieved all research milestones as noted by the Scientific Committee in 2019 (SC-CAMLR-38, paragraph 3.111). The Working Group further noted that WG-SAM-2021 had reviewed the updated research proposal and endorsed the design as presented, acknowledging the quality of the proposal, and the collaborative research between several Members (WG-SAM-2021, paragraph 9.9).

4.20 The Working Group recalled that only Division 58.4.2 was open for fishing in 2020/21. The Working Group reiterated its concern that the loss of several seasons of data from Division 58.4.1 has resulted in a break in the time series of data collected in the division. The Working Group highlighted that the lack of recent data from Division 58.4.1 had caused problems for the further development of the preliminary stock assessment (SC-CAMLR-39/BG/38) in Divisions 58.4.1 and 58.4.2, and the ability of the Scientific Committee to provide advice to the Commission for this area.

4.21 WG-FSA-2021/42 presented a proposal by Russia for a multi-Member research program on *D. mawsoni* in the East Antarctic (Divisions 58.4.1 and 58.4.2) from 2021/22 to 2023/24. The paper noted that the methodical aspects of the multi-Member research program on

D. mawsoni in the East Antarctic implemented during the 2011/12–2017/18 seasons, as outlined in WG-FSA-2021/18, did not provide scientific-based data for understanding abundance, population structure and productivity indices, distribution of toothfish and dependent species according to the objectives and goals of this research in Divisions 58.4.1 and 58.4.2. The authors noted that the use of different gear types and non-standardised sampling design was the critical factor for the efficiency of that research program. The authors highlighted that the continuation of that scientific program using a stratified-randomised design for the haul positions, still using different gear types as shown in WG-SAM-2021/03, did not address the problems noted again in WG-FSA-2021/42. The authors proposed a multi-Member research program on *D. mawsoni* in Divisions 58.4.1 and 58.4.2 from 2021/22 to 2023/24 based on standardisation of sampling longline gear and survey design. The objectives and goals of this research would correspond to those in WG-SAM-2021/03, to be conducted only by vessels equipped with a standard autoline system. The authors noted that the haul positions had been created based on stratified-randomised design in depth layers for each research block and proposed to optimise longline surveys using ‘Neumann’ location in the second year.

4.22 The Working Group noted that WG-SAM-2021 had only reviewed methodological aspects of this proposal since this research was not notified by the required deadline of 1 June. The Working Group further noted that the issue of gear standardisation in multi-Member surveys had been extensively discussed and recalled past discussions on the subject, over several years and in different working group meetings, including that there is no requirement for the exclusive use of one gear type in an exploratory fishery (e.g. SC-CAMLR-39, paragraph 4.10; SC-CAMLR-38, paragraphs 3.105 to 3.108; SC-CAMLR-XXXVII, paragraphs 3.139 to 3.141).

4.23 Recognising that fishing has not occurred in Division 58.4.1 over the last four years, and to enable progress towards management objectives by collecting required tag-based data from this division, the Working Group considered a proposal developed during the meeting, to apply a derogation to CM 21-02, paragraph 6(iii), for this division. The proposed change would remove the requirement for a research plan in the exploratory fishery for this division making the requirements analogous to those in Subarea 88.2. This derogation was proposed to apply for two years (fishing seasons 2021/22 and 2022/23), with reporting after the first season to WG-FSA and review at WG-FSA and Scientific Committee at the end of the derogation. The conditions of the derogation were that:

- (i) fishing must occur only within the existing research blocks
- (ii) the agreed catch limits apply within these research blocks (Table 3), for those vessels that have notified for that fishery, in an Olympic-style fishery
- (iii) toothfish are to be tagged at a rate of 5 fish per tonne.

4.24 Most participants of the Working Group supported this approach as a possible way forward for Division 58.4.1, but they also noted that the research plans undertaken in this, and other exploratory fisheries had been very successful in generating valuable data towards the development of stock assessments.

4.25 Dr Kasatkina stated that in her opinion exploratory fisheries required a stock assessment to determine a catch limit, and that a stock assessment for toothfish was not provided in Division 58.4.1. The catch limit in Division 58.4.1 was only established for the implementation of a research program. She further noted that according to CM 21-01, an exploratory fishery

could not be established in Division 58.4.1 and that it should be considered as a new fishery. Dr Kasatkina highlighted that the use of the catch limit established for the research program in Division 58.4.1 as a catch limit for exploratory fishery does not ensure the rational use of the *D. mawsoni* resource in this CCAMLR area.

4.26 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22), however, it had provided advice based on the use of best available science in the trend analysis rules on what catch level would be consistent with the CCAMLR decision rules. The Working Group agreed on catch limits to be calculated for Divisions 58.4.1 and 58.4.2 using the trend analysis rules (WG-FSA-2017, paragraph 4.33) as shown in Table 3.

4.27 The Working Group noted that CM 41-11 identifies the toothfish fishery in Division 58.4.1 as an exploratory fishery and that the classification of all toothfish fisheries is an issue for the Commission.

4.28 The Working Group endorsed the research proposal in WG-SAM-2021/03 for Division 58.4.2 but was unable to reach consensus on the research proposal for Division 58.4.1. The Working Group requested that the Scientific Committee consider the proposal outlined in paragraph 4.23, and the discussion in paragraphs from 4.24 to 4.27.

Division 58.4.4b

4.29 WG-FSA-2021/51 presented the final report of the multi-Member longline survey of *D. eleginoides* in Division 58.4.4b, conducted between the 2016/17 and 2020/21 fishing seasons by Japan and France. For the 2020/21 fishing season, both Japanese and French vessels did not undertake any research fishing due to operational restrictions caused by COVID-19. Although progress and achievements of each objective were reported, the paper noted that there are ongoing studies that will be presented at future Working Group meetings.

4.30 WG-FSA-2021/52 presented an updated CASAL assessment for *D. eleginoides* in Division 58.4.4b for the 2020/21 fishing season. Estimated maximum constant yields (MCYs) for *D. eleginoides* were higher than the current catch limit of 18 tonnes in research block 1 in Division 58.4.4b. Harvest rates to achieve the CCAMLR management target (50% B_0), F_{CAY} , were estimated to be close to 7%, which is higher than the current precautionary harvest rate for exploratory fisheries where there is no estimate of B_0 .

4.31 The Working Group welcomed the report on the research undertaken in Division 58.4.4b, and noted the results presented for the updated CASAL model. The Working Group encouraged the results from ongoing studies to be presented at a future meeting of WG-FSA.

D. mawsoni in Area 88

Shelf survey

4.32 WG-FSA-2021/23 presented the results from the 2021 Ross Sea shelf survey. The estimated relative biomass index of toothfish showed an increase and was the second highest

in the survey time series and toothfish age estimates from the surveys were included in the 2021 Ross Sea stock assessment as an index. The paper proposed a catch limit for the 2022 survey of 51 tonnes.

4.33 The Working Group welcomed the paper, recalling the importance of this time series of surveys for the Ross Sea region stock assessment in delivering improved estimates of recruitment, as highlighted by the Independent Stock Assessment Review for Toothfish (WG-FSA-2018, paragraph 4.148). The Working Group further noted that the research provided information on the connectivity of the Area 88 *D. mawsoni* population, as well as data that contributed to the objectives of the RSRMPA.

4.34 The Working Group noted that to achieve the research aims, a higher catch limit had been suggested by WG-SAM (WG-SAM-2021, paragraph 9.13). The Working Group recalled that the survey is effort limited with core strata sampled every year and other strata sampled in alternate years (i.e. McMurdo Sound and Terra Nova Bay; WG-FSA-2017, paragraph 3.83). The McMurdo stratum will be sampled in the 2021/22 season.

4.35 The Working Group reflected that as this is an effort-limited survey, and although the maximum estimated catch is approximately 60 tonnes, leaving the current catch limit of 65 tonnes in the conservation measure would ensure that the survey could be completed in order to achieve its objectives.

4.36 The Working Group recommended a catch limit of 65 tonnes for the Ross Sea shelf survey in the 2021/22 season.

4.37 Mr N. Walker (New Zealand) presented the options for catch allocation in the Ross Sea (Table 4).

D. mawsoni in Subarea 88.2

4.38 WG-FSA-2021/25 provided a summary of the toothfish fishery and tagging program in the Amundsen Sea region from the 2002/03 to the 2020/21 seasons. It highlighted that the management issues for SSRU 882H include a lack of spatial representation within the seamount complex, decreasing catch limits, catches exceeding the catch limits and limited tag recaptures. WG-FSA-2021/29 described a range of options to improve the current fishery dynamics in SSRU 882H which range in complexity of design, coordination and monitoring required, and likelihood of success.

4.39 The Working Group recalled the discussion at WG-FSA-2017 relating to age determination of toothfish in this region (WG-FSA-2017, Table 1), and encouraged Members to continue to make age data available. The Working Group welcomed the offer from Ukraine to provide age data from toothfish otoliths collected on its vessels.

4.40 The Working Group endorsed the proposals outlined in WG-FSA-2021/25 and WG-FSA-2021/29 and:

- (i) recommended that a workshop be convened to compare age determination methods among research programs in the region, and to develop procedures and criteria for pooling age data

- (ii) requested the Secretariat to implement an age database to encourage, organise and archive age data
- (iii) recommended the creation of a Subarea 88.2 e-group for Members to collaborate and develop an approach to improve structured fishing in SSRU 882H.

4.41 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22), however, it had provided advice based on the use of best available science in the trend analysis rules on what catch level would be consistent with the CCAMLR decision rules. The Working Group agreed on catch limits to be calculated for Subarea 88.2 using the trend analysis rules (WG-FSA-2017, paragraph 4.33) as shown in Table 3.

D. mawsoni in Subarea 88.3

4.42 WG-FSA-2021/34 presented a proposed new research plan in Subarea 88.3 on *D. mawsoni* from 2021/22 to 2023/24, to be undertaken by the Republic of Korea and Ukraine. Objectives include improving the understanding of stock and population structures of toothfish in Area 88, the collection of data on the spatial and depth distributions of by-catch species, and the trial of scientific electronic monitoring technologies.

4.43 The Working Group welcomed the research proposal and noted the value of the data which will be collected during this research for developing the Research and Monitoring Plan for the proposed MPA in Domain 1 (Antarctic Peninsula). The Working Group further noted that research block 883_2, although close, does not encroach into the Pine Island Glacier Special Areas for Scientific Study.

4.44 The Working Group noted that whilst extensive data have been collected for this area, the research proposal focuses on data collection and includes few milestones related to by-catch analysis. It questioned whether additional data collection is necessary to characterise the toothfish stock structure in this area and noted that the sampling rate requirement for by-catch species of 10 specimens per species per line may be insufficient to conduct by-catch analysis in a closed area. The proponents agreed to increase the sampling rate for by-catch species. The Working Group further noted that objective 4 relating to by-catch has only data collection planned with little detail of analysis. The Working Group requested more detail on planned analysis be provided to WG-SAM-2022.

4.45 The Working Group endorsed the design of this research proposal with an updated sampling rate requirement for by-catch species of 30 specimens per species per line, or the entire catch if this is less than 30 specimens.

4.46 The Working Group noted it had been unable to provide consensus advice on catch limits (see paragraph 3.22), however, it had provided advice based on the use of best available science in the trend analysis rules on what catch level would be consistent with the CCAMLR decision rules. The Working Group agreed on catch limits to be calculated for Subarea 88.3 using the trend analysis rules (WG-FSA-2017, paragraph 4.33) as shown in Table 3.

Table for evaluating research proposals

4.47 The Working Group noted that all research plans submitted to WG-SAM-2021 and WG-FSA-2021 had provided a self-assessment table of the research plan as recommended at WG-FSA in 2019 (WG-FSA-2019, paragraph 4.28). However, due to the compressed agenda and limited time of the meeting, the Working Group did not review the self-assessment tables presented.

Krill fishery management

5.1 WG-FSA-2021/08 presented an estimation of vessel capacity in CCAMLR krill fisheries and simulated a range of management closure scenarios based on smaller catch limits, and a range of fleet compositions, to better understand whether the current reporting requirements for the krill fishery require future revision. The analysis demonstrated that whilst fishery capacity had exceeded the capability to take the current catch limits in Subareas 48.1–48.3, the risk of overrunning the limits given current daily catch rates was minimal unless catch limits were reduced to 30 000 tonnes and the fleet size increased.

5.2 The Working Group thanked the Secretariat for this analysis as it was a useful approach to monitoring the evolution of this fishery. It requested an analysis of the risk of overrunning based on a daily reporting frequency (in comparison to the current five-day reporting requirement in CM 23-01) to evaluate whether reporting requirements required revision. The Working Group agreed that including the magnitude of the estimated catch overrun in addition to the risk of overrunning would be useful in future iterations of this analysis, as well as investigating other metrics of capacity (e.g. realised maximum capacity for each vessel).

Krill biomass estimates

5.3 The Co-convener of the Working Group on Acoustic Survey and Analysis Methods (WG-ASAM), Dr X. Wang (China), presented an overview of relevant advice pertaining to the management of the krill fishery (WG-ASAM-2021). He noted that WG-ASAM compiled a summary and metadata from long-term time series of acoustic biomass surveys in Area 48, and identified that biomass estimates for the different subareas could be obtained from this resource. In a subsequent e-group, these data were summarised for Subarea 48.1, and krill biomass estimates for the four US AMLR strata were presented to WG-EMM (WG-EMM-2021/05 Rev. 1). The Co-convener noted that the e-group reported a quasi-decadal variability in krill density estimates for Subarea 48.1 (see also WG-EMM-2021, paragraphs 2.27 and 2.68) and that both the survey scale and the period over which data were averaged were important. He further reported that WG-ASAM noted that the source of krill length frequency data used to determine acoustic parameters (from research surveys, the fishery, or predator diet sampling) had an impact on the acoustic estimates of biomass and had recommended the formation of an e-group to establish recommendations for the use of krill length frequency data for acoustic estimates.

5.4 SC-CAMLR-40/11 presented acoustic biomass estimates of Antarctic krill (*Euphausia superba*) in Subarea 48.1 to facilitate the development of the new management approach for the krill fishery. Krill biomass was estimated for six strata (four AMLR strata, one extra stratum,

and one outer stratum) using the data from the 2019 Area 48 Krill Survey, the CCAMLR-2000 Krill Synoptic Survey of Area 48 and the *Atlantida* 2020 survey. The paper also presented new calculations of areas (with an increase of 14.2%) for the four AMLR strata using the shapefile and the Raster package (Hijmans, 2021) in R (R Core Team, 2021) applied in the risk assessment model (WG-FSA-2021/16).

5.5 The Working Group welcomed this contribution and noted that the definition of the extra stratum was given in SC-CAMLR-40/10 (paragraph 5.16). It also noted that the estimated biomass for the extra stratum was derived from transects (north of Brabant Island) that did not cover the entire fished area (in the Gerlache Strait) and the need for future refinement.

5.6 The Working Group recommended that the Scientific Committee develop an agreed approach to the calculation of stratum area to be used consistently in the future, and recalled the default projection in the CCAMLRGIS R package (i.e. South Pole Lambert azimuthal equal-area, EPSG:6932), as agreed in 2017 (WG-FSA-2017, paragraph 4.13), should be used for maps and area calculations.

5.7 The Working Group noted the need for regular acoustic surveys, recognising practical limitations in conducting such surveys in the Southern Ocean, and for consistency between survey design (both net and acoustic surveys) and strata boundary definitions (see also paragraph 5.21).

Grym assessment model

5.8 The Co-conveners of the Working Group on Statistics, Assessment and Modelling (WG-SAM), Dr C. Péron (France) and Dr T. Okuda (Japan), presented an overview of relevant advice pertaining to the management of the krill fishery (WG-SAM-2021). They noted that WG-SAM discussed the Grym (generalised yield model recoded in R, SC-CAMLR-39/BG/19) configuration, its assumptions and parameterisation. An extension of the Grym to permit the inclusion of multiple fleets was discussed as well as issues relating to the estimation of krill proportional recruitment. They noted that the GYM/Grym assessment model development e-group, led by Mr D. Maschette (Australia) had been tasked to develop diagnostic plots, run multiple scenarios, including ensembles of parameter values, and to verify the realism of simulation outputs.

5.9 WG-FSA-2021/40 presented a document describing the use and function of all Grym parameters in the krill assessment and, where possible, provided examples as to how these parameters had been, or could be, calculated. This document was motivated by the lack of clarity on the origin of some of these parameter values (when used in the GYM) and the need to ensure that these values were derived in ways that did not violate the assumptions of the model.

5.10 WG-FSA-2021/39 presented the results of Grym krill assessment model ensembles for Subarea 48.1, using parameter values that were either contributed to the Grym e-group, or calculated based upon data submitted to that e-group. The code is available on the CCAMLR GitHub page (https://github.com/ccamlr/Grym_Base_Case/tree/Simulations). The authors recommended the use of the weight-at-length parameters based on data of the RV *Atlantida* 2020 survey specific to Subarea 48.1, and maturity-at-length relationships estimated from the

US AMLR data. The paper provided a range of options for values pertaining to proportional recruitment, resulting in a set of four provisional scenario outcomes selected for their realistic estimated mortality.

5.11 The Working Group thanked Mr Maschette for the quality and amount of work conducted in such a short time. It noted that scenarios resulting in a gamma (γ) of zero suggested that the simulated krill stock fails the depletion probability decision rule even without a fishery or that the model and/or the decision rules needed refinement. The Working Group recalled the extensive work carried out in the early 1990s, including the choice of age 2+ krill in estimating the proportional recruitment (de la Mare, 1994; WG-Krill-1994). The Working Group also recalled WG-EMM's future work plan regarding cross-working-group collaborations on Grym parameter values (WG-EMM-2021, paragraph 6.1iv) to progress this work further in the near future. It noted the issue of representativeness of parameter values given the spatial dynamics of krill, and the potential presence of biases in proportional recruitment estimates brought by sampling gears, in particular for those that have much smaller openings and/or much larger mesh size compared to, for example, an RMT8 (e.g. de la Mare, 1994). It requested that WG-FSA-2021/40 be part of the Grym documentation.

5.12 The Working Group requested the Scientific Committee to consider that Members submit their biological and catch data accompanied by a description of the data collection and processing procedures to the Secretariat, in order to develop a quality controlled, centralised database of krill survey and biological data, and that the data from any parameter estimates used to provide management advice for krill be included in that database.

5.13 The Working Group further recommended that more surveys at the subarea scale would be beneficial to Grym simulations. The Working Group further encouraged WG-ASAM to develop an acoustic survey manual including data templates for submission to the centralised database.

Risk assessment

5.14 The Convener of the Working Group on Ecosystem Monitoring and Management (WG-EMM), Dr C. Cárdenas (Chile), presented an overview of relevant advice pertaining to the management of the krill fishery (WG-EMM-2021). He noted that WG-EMM agreed that the risk assessment for Subarea 48.1 constituted the best science currently available to CCAMLR (WG-EMM-2021, paragraph 2.46) and that work on the risk assessment had been progressed in an e-group led by Dr V. Warwick-Evans (UK).

5.15 WG-FSA-2021/17 presented a summary of the intersessional work and discussion by the CCAMLR Risk assessment framework e-group. The paper described developments on the adjustment of the krill winter layer (the approach used to increase biomass discussed by the e-group resulted in reduced risk and a larger proportion of the catch assigned to winter than summer), sensitivity analyses and a workplan for future work. The authors stressed the importance of the need for winter survey data for use in the risk assessment. The e-group also tested various scenarios adjusting the US AMLR strata boundaries, including addition of an extra stratum to the west of the US AMLR survey grid (see also paragraph 5.20).

5.16 WG-FSA-2021/16 presented an update on the implementation of the risk assessment framework presented at WG-EMM-2021 (WG-EMM-2021/27) with the aim of identifying the most appropriate management units by which to distribute the krill catch limit spatially and temporally. The authors noted that since the risk assessment assumes that fishing is homogeneously distributed within management units, these units should not be too large, as risk needs to be evaluated at the scale at which the fishery operates. They further noted the need for more data to ensure that risk was assessed more accurately.

5.17 The Working Group thanked Dr Warwick-Evans for the quality and amount of work conducted in such a short time. It noted the need for collaboration on the definition of management unit boundaries (see also WG-FSA-2021/56 and SC-CAMLR-40/10), the need to update the habitat model with those new data that are already available as well as the need for increased data collection efforts to improve the risk assessment. In particular, the Working Group noted the importance of winter acoustic surveys, currently lacking in existing datasets, to depict a more complete picture of biomass at the annual scale.

5.18 WG-FSA-2021/56 presented an analysis of the reason for the gradual contractions and concentration of the krill fishery in relation to the characteristics of krill distribution based on acoustic data, fishery statistics and sea-ice data. The analysis indicated that the distribution of krill is highly patchy and dynamic both interannually and intra-annually, and that the concentration of the fishery in an area was due to high krill abundance in that area. The authors indicated that future management units needed to be large enough to accommodate the highly patchy and dynamic nature of krill distribution to avoid potential inadvertent risks to the local krill stock and dependant predators.

5.19 The Working Group thanked the authors for their contributions and agreed the need for better understanding of krill hotspots and their links to oceanographic processes and bathymetric features, potentially through the use of moored acoustic instruments.

5.20 SC-CAMLR-40/10 presented five coastal candidate management units to facilitate the development of the new management approach to the krill fishery in Subarea 48.1. The boundaries of the five candidate management units were derived from the four US AMLR strata, with an extra stratum adjacent to the US AMLR strata covering the Gerlache Strait area. A sixth outer stratum was also included that covered the rest of Subarea 48.1.

5.21 The Working Group noted that potential issues may arise in the future regarding an 'outer' management area in cases where data are unavailable; if the fishery were to move into such an area, it would lead to the ad-hoc addition of management areas which may be ecologically irrelevant. The Working Group recommended that, since management areas are often those that are surveyed, the Scientific Committee design a statistically robust set of management areas for each subarea that would be suitable for fishery management, net and acoustic surveys and catch allocation. This could be done through a joint workshop of several working groups on spatial management areas concerning krill.

5.22 The Working Group agreed on the importance of krill biomass interannual variability for the management of the krill fishery and the periodicity of its revisions in the future (see also WG-EMM-2021, paragraph 2.27).

Advice to the Scientific Committee on CM 51-07

5.23 Dr Darby reported on the progress of the CM 51-07 revision e-group. He noted the enormous progress made by Members, through effective scientific collaboration on the three elements of the revision of the krill management strategy (acoustic biomass estimates, Grym yield estimates and risk assessment) and thanked all those involved. He noted that although some reservations had been raised on individual parameterisation or data elements, no major issues had been identified that would suggest that this approach could not generate a revised krill management strategy.

5.24 The Working Group thanked Dr Darby for coordinating the e-group work that brought all this work together and agreed that major progress was being made thanks to the concerted efforts from all Members. The Working Group also agreed that concerted and collaborative effort would continue to be required to address the data requirements of each of the three elements of the revised krill management strategy.

5.25 The Working Group recalled WG-EMM-2021, paragraph 2.63, and agreed that CM 51-07 was precautionary. It noted the substantial scientific progress made towards a revised krill fishery management approach. Most attendees agreed that a temporary rollover of CM 51-07 was the preferred way forward while the science was developed further. Others considered that sufficient information was already available to give interim advice.

5.26 The Working Group was not able to provide conclusive advice to the Scientific Committee on the revision of CM 51-07 by the end of its formal session. It agreed that discussions would continue on the CM 51-07 revision e-group and that a summary would be submitted to the Scientific Committee as a background paper in 2021.

5.27 The Working Group noted that a program of future work would be required to expedite progress in the short, medium and long term, including on data collection and analysis, and requested the e-group to develop such a plan.

Non-target catch and ecosystem impacts

Incidental mortality of seabirds and marine mammals

6.1 WG-FSA-2021/04 Rev. 1 presented a summary of incidental interactions between fishing vessels, seabirds and marine mammals during fishing activities undertaken during the 2020 and 2021 seasons from data collected by SISO observers and vessels. The extrapolated total of 44 seabirds caught in 2020 is the lowest on record for CCAMLR longline fisheries, whilst no extrapolated mortality figure was provided for 2021 due to outstanding observer data related to the timing of the meeting. In the krill fishery, three humpback whales were recorded as incidental mortalities in krill fisheries in 2021, the first mortality records for this species. Seal (60 Antarctic fur seals (*Arctocephalus gazella*) were caught by six vessels, leading to 16 mortalities in 2020) and seabird mortalities (in 2021) in the krill fishery were noted as higher than in previous seasons and a total of 139 warp strikes by seabirds were reported for 2020 and 2021.

6.2 The Working Group welcomed the lowest-ever estimated seabird mortality numbers recorded in CCAMLR longline fisheries in 2020 and acknowledged the role of SISO observers in providing the incidental mortality data used in the paper.

6.3 The Working Group expressed concern at the increased levels of marine mammal mortality in the krill fishery, noting the comments received by the Secretariat that large numbers of icefish had been captured in several hauls in the krill fishery this season, and that they may have provided an additional attractant to marine mammals.

6.4 The Working Group noted that move-on rules exist in toothfish fisheries when large quantities of by-catch taxa are landed, and recommended that the Scientific Committee consider a similar mechanism for krill fisheries. Additionally, the Working Group recommended the Scientific Committee also consider move-on rules for when whales are at risk around krill fishing vessels. The Working Group encouraged Members to investigate marine mammal mitigation measures in other trawl fisheries to ensure CCAMLR's mitigation measures were best practice.

6.5 The Working Group requested that the Secretariat issue an update to WG-FSA-2021/04 Rev. 1 and present it at SC-CAMLR-40. The updated paper should detail mortalities and warp strike numbers by individual krill fishing vessel and gear type, and present an extrapolation of warp strike numbers from observation effort, to provide a more comprehensive assessment of total incidental mortality impacts of the krill fishery.

6.6 The Working Group requested that, where possible, further information on the whale mortality incidents from the vessel Flag State and the SISO designating Member (Norway and the UK respectively) be presented to SC-CAMLR-40. Where possible, information on morphological measurements, samples, additional photographs (which could aid potential identification and the condition of the individual specimens) and by-catch records from the hauls where the whales were recovered should be included in the report to further evaluate potential causes.

6.7 At the time of report adoption, Dr B. Krafft (Norway) informed the Working Group that it may not have been by-catch but those were carcasses of dead whales. More information will be provided for the meeting of the Scientific Committee.

6.8 The Working Group requested the Scientific Committee to consider a mechanism whereby additional information can be collected on marine mammal by-catch by observers in a standard format.

6.9 WG-FSA-2021/13 presented initial results from a two-year program conducted in 2019/20 to evaluate bird strikes on net monitoring cables used by continuous trawling vessels in the krill fishery. Seabird mitigation measures used on all three vessels were determined by ACAP best-practice guidelines. A combination of deck observations and video monitoring were used to observe warps and monitoring cables and a total of 1 193 hours of observations were made, representing 4.5% coverage of the total fishing time. From the first year of observations, the paper concluded that for both types of trawlers (side and stern), the risk to seabirds of interacting with the monitoring cable was minimal. At the conclusion of the presentation, Dr Krafft noted that an extension to the derogation in CM 25-03 would be requested from the Scientific Committee and the Commission to allow the use of net monitoring cables, provided that a seabird risk mitigation plan was developed.

6.10 WG-FSA-2021/14 presented the methods employed in the 2020/21 fishing season for evaluating bird interactions with monitoring cables on krill trawlers using continuous trawling methods. The final method design was developed through previous discussions at SC-CAMLR-39 and a dedicated e-group facilitated by the Secretariat.

6.11 The Working Group noted that the paper indicated that only 15% of the footage recorded in 2020/21 was planned to be viewed and noted that this may be insufficient to get an accurate count of cable interactions and that automating software may help with the analysis of the video footage. Additionally, the Working Group noted that most interactions occurred during summer on the stern trawling vessel, and more work should be conducted on these vessels, including conventional trawlers, to investigate potential interactions. The Working Group also noted that warp strike risk, if seasonally variable, may be a useful layer in future versions of the krill risk assessment once these investigations have been completed.

6.12 The Working Group noted that as the preliminary report of the second year of the trial was still to be presented to WG-FSA, conclusions on the efficacy of the mitigation measures used in the trial could not be determined, nor could the risks of the net monitoring cable to seabirds be accurately quantified. The Working Group further noted that it was unclear in the report if the requirements of the derogation in CM 25-03 had been met in the trial, and any recommendation on extending this derogation was not in the remit of this Working Group. The Working Group requested the Scientific Committee to consider this issue further at SC-CAMLR-40.

6.13 Dr Krafft noted that Norway will provide an update on results from the current trial at SC-CAMLR-40.

Fish by-catch

6.14 WG-FSA-2021/05 presented an update to fish by-catch in the krill fishery, and results from responses provided to the Secretariat consultation on krill by-catch data collection practices. In general, the frequency of occurrence of by-catch was higher in observer data than C1 data, and higher in C1 hauls for which observer data existed compared to hauls where there was no matching observer data. With the exception of one Member, C1 data collection and reporting was undertaken by vessels crews, although it was unclear how the information had been recorded in C1 and observer data for two Members.

6.15 The Working Group welcomed the update to the analysis and noted that accurate by-catch data reporting would be required for any potential move-on-rules in the krill fishery (paragraph 6.4). The Working Group reflected that the differences in the frequency of fish occurrence reported by observers and vessels may be due to the requirements for observers to also pay attention to larval fish. The Working Group requested that future updates of this analysis should include individual vessel plots to determine if there were specific vessel by-catch reporting issues.

6.16 The Working Group recommended that:

- (i) the Secretariat work with Chile and Ukraine to examine how their data collection and reporting methods may affect krill by-catch data currently held in the CCAMLR database. The Working Group noted with appreciation the willingness of Chile to engage with the Secretariat
- (ii) the Scientific Committee consider convening a krill fishing vessel data workshop (noting the agreement in 2019 to hold a krill fishery observer workshop;

SC-CAMLR-38, paragraph 13.1(i) that has been postponed due to the COVID-19 pandemic) to assist in developing standardised instructions for the collection of by-catch data by vessels.

6.17 WG-FSA-2021/32 presented a preliminary examination of catches and data holdings for by-catch species in the Ross Sea toothfish fishery. By-catch species composition varied between management areas, however, catch of most species groups were generally highest in SSRUs 881H and I in the south of 70°S management area where most of the fishing effort occurs. As found in other areas of the Convention Area, macrourids were the most commonly observed by-catch group, and macrourids, skates, icefish, eel cods and morid cods comprised almost 99.5% of the total by-catch by weight.

6.18 The Working Group welcomed the report into the data holdings from the Ross Sea and noted the large amount of work that had been undertaken in the region by scientists and SISO observers to collect and catalogue the data. The Working Group noted that the number and estimated weight of skates released alive should be presented in such analyses since a proportion of these individuals may not survive after release causing additional mortality to the retained catch. The Working Group also reflected that a comparative analysis between these data holdings and information collected from the shelf survey may provide valuable information on the effectiveness of the RSRMPA.

6.19 The Working Group recommended that:

- (i) a data collection plan be developed for the Ross Sea to support both a revised medium-term fishery-based research plan for the fishery as well as the broader objectives of the RSRMPA Research and Monitoring Plan
- (ii) a review of the observer biological reporting form be undertaken to ensure it is clear in the form whether a sampled individual was tagged and whether non-otolith tissues were sampled
- (iii) the Secretariat include a summary of the available data of by-catch species and biological data holdings in the Fishery Reports.

6.20 WG-FSA-2021/33 presented an update on the focused two-year skate tagging program conducted in the Ross Sea to monitor trends in the population size and to validate the thorn ageing method for Antarctic starry skate (*Amblyraja georgiana*). A total of 8 506 skates were tagged and released over the past two seasons in the Ross Sea region, with a further 484 individual skates voluntarily tagged in the Amundsen Sea region. More than 2 000 skates were injected with a marker for age validation. A total of 44 skates tagged during the program have been recaptured to date. Results from the age validation experiments, as well as those of biological and movement analysis, will be provided to future WG-FSA meetings.

6.21 The Working Group noted the results presented and welcomed future updates from the research.

6.22 The Working Group noted that the cessation of the focused skate tagging program would require minor changes to CMs 41-01 and 41-09, and recommended the removal of the first sentence of CM 41-01, Annex 41-01/C, paragraph 2(vi). The Working Group also recommended that the paragraph starting with ‘During the 2020/21 season all live skates up to 15 per line...’ in CM 41-09, paragraph 6 (‘by-catch’) be deleted.

6.23 WG-FSA-2021/43 presented a discussion on the impact of *Macrourus* spp. by-catch limits on research conducted under CM 24-01 by Ukraine in Subarea 48.1. The report noted that surveys were not completed in 2020 and 2021 due to the by-catch limit of *Macrourus* spp. limiting the number of research hauls (paragraph 4.5), and suggested that in the future, by-catch limits should be assessed for each individual research plan to ensure that research activities can be completed.

6.24 The Working Group thanked the proponents for their interesting presentation and noted that CM 24-05 outlines a procedure to modify the by-catch limits of research surveys.

Marine debris

6.25 WG-FSA-2021/11 presented gear loss reported from longline vessels operating in the Convention Area from the 2019/20 and 2020/21 fishing seasons. Vessels reported 1 363 km of line lost in the Convention Area, of which 22% were complete lines. Differences in reported hook loss rate by gear type were noted, with rates of loss ranging from 2.5% to 4.6% for each gear type for the past two seasons. There was a significant difference in the frequency of complete line loss between gear types, with a higher rate of complete line loss for trotline than for Spanish or autoline. Fields for improving quantification of gear loss rates are noted in the proposed new C2 form (WG-FSA-2021/10).

6.26 The Working Group thanked the Secretariat for the presentation and noted that the 1 363 km of line lost represents a considerable amount of plastic pollution in the ocean, as well as potential unobserved and unaccounted mortality effects to fish species caught on those lines. The Working Group welcomed the Secretariat to continue to report annually on gear loss in fisheries to WG-FSA and requested the presentation of spatial distribution of gear loss in updated analyses by the Secretariat.

Other business

7.1 WG-FSA-2021/22 presented results from a three-year longline fishing research survey (2017–2019), conducted to improve understanding of *Dissostichus* spp. population connectivity, biological characteristics and spatial structure across Subareas 48.2 and 48.4. The results provide evidence linking *D. mawsoni* in these subareas with the Antarctic continental shelf and indicate a potential *D. mawsoni* spawning region in Subarea 48.2. The movements of recaptured tagged fish indicate potential connections with the Lazarev Sea (Subarea 48.6) as well as the southern South Sandwich Islands. The results contribute to the information available for further refinement of the *D. mawsoni* stock hypothesis.

7.2 WG-FSA-2021/53 compared the results of three different methods (conventional measurement analysis, elliptical Fourier analysis and landmark method) to analyse the ontogenetic variation in otolith shape of *D. mawsoni* collected from the Ross Sea, the Amundsen Sea, the Weddell Sea and the Lazarev Sea. The paper concluded that the elliptical Fourier method provided better results.

7.3 WG-FSA-2021/54 presented the results of a study which used six indices to compare the otolith shape of *D. eleginoides* collected from the Crozet and Kerguelen Islands. The study

found that although there are small differences in the outer contours of the otoliths, their shape is similar. The paper concluded that these results indicate stock connectivity between the Crozet Islands and the Kerguelen Islands, consistent with the results of tagging and genetic studies. The authors noted that the approach used by WG-FSA-2021/53 and 2021/54 can serve as an alternative for exploring stock structure. They highlighted the importance of collecting and photographing otolith samples using the standardised protocol and encouraged Members to strengthen inter-laboratory collaborations to analyse the data related to those samples.

7.4 WG-FSA-2021/35 presented the results of a molecular diet analysis of using the stomachs of 436 specimens of *D. mawsoni* collected in 2017/18, 2018/19 and 2020/21 in Subarea 88.1 and WG-FSA-2021/36 presented the results from a morphological analysis of the stomach contents of 548 specimens of *D. mawsoni* collected from Subarea 88.1 during the 2020/21 fishing season. The results of both studies were consistent with previous studies and showed that *D. mawsoni* mainly preys on fish species (among which *Macrourus* spp. and *Cryodraco antarcticus* were the most abundant in the areas sampled) and to a lesser extent on molluscs, crustaceans and cnidarians. The papers concluded that *D. mawsoni* should be classified as an opportunistic carnivore which selects its prey largely based on availability and spatial abundance. As such, the stomach contents of toothfish can be used to assess whether ecological changes occur which impact local toothfish populations.

7.5 WG-FSA-2021/01 presented the results of observations of 4.5 hours of video footage of benthic fauna which was obtained by underwater cameras attached to longlines set in research block 481_2 during the toothfish survey by the Ukrainian vessel *Calipso* in 2021. The paper concluded that while relatively few organisms were observed, this type of data can help to improve the understanding of benthic ecosystems and help estimate the biomass of some animals.

7.6 WG-FSA-2021/58 described the implementation and performance of the SAGO extreme fishing system, which is an innovative technology which has been developed to prevent marine mammal depredation on longlines, on the Uruguayan fishing vessel *Ocean Azul*. The paper also introduced an intrinsic mitigation measure to prevent incidental seabird mortality.

7.7 The Working Group welcomed these papers. Although the papers tabled under Agenda Item 7 were briefly presented, the Working Group was unable to comment on any of these submissions as there was not sufficient time to discuss them in plenary. The Working Group invited interested Members to contact the authors directly.

Advice to the Scientific Committee and future work

8.1 WG-FSA-2021/30 proposed a workshop for Members to update the fishery-based research and data collection plan for the Ross Sea region toothfish fishery. The Secretariat would also coordinate on any changes needed to observer and catch reporting forms to ensure data collected by vessels and observers were suitable for the revised research plan (paragraph 6.19).

8.2 The Working Group welcomed this proposal and noted that Italy and New Zealand offered to co-convene the workshop with Secretariat support.

8.3 The Working Group recommended that the Scientific Committee endorse a workshop to revise the fishery-based research and monitoring plan for the Ross Sea and encouraged Members to participate. The proposed terms of reference are given in WG-FSA-2021/30.

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

- (i) Review of the 2020/21 fishery –
 - (a) observer logbooks (paragraph 2.3)
 - (b) conversion factors workshop (paragraphs 2.6 and 2.7)
 - (c) C2 forms (paragraph 2.10)
 - (d) krill fishing vessel data workshop and forms development (paragraph 2.11)
 - (e) closure forecasting (paragraph 2.14).
- (ii) Catch limits for *C. gunnari* in Subarea 48.3 and Division 58.5.2 (paragraphs 3.7 and 3.11).
- (iii) Advice on catch limits for toothfish fisheries in the future (paragraph 3.23, noting paragraph 3.22).
- (iv) *D. eleginoides* in Division 58.5.1 –
 - (a) prohibition of directed fishing as described in CM 32-02, remain in force in 2021/22 (paragraph 3.51).
- (v) *D. eleginoides* in Division 58.5.2 –
 - (a) prohibition of directed fishing as described in CM 32-02, remain in force in 2021/22 (paragraph 3.59).
- (vi) *D. eleginoides* in Subarea 58.6 –
 - (a) prohibition of directed fishing as described in CM 32-02, remain in force in 2021/22 (paragraph 3.64).
- (vii) Fish research notifications and exploratory fisheries –
 - (a) research on *D. mawsoni* in Subarea 48.6 (paragraph 4.15)
 - (b) research on *D. mawsoni* in Division 58.4.2 (paragraph 4.28)
 - (c) catch limit for the Ross Sea shelf survey (paragraph 4.36)
 - (d) research on *D. mawsoni* in Subarea 88.2 (paragraph 4.40)
 - (e) research on *D. mawsoni* in Subarea 88.3 (paragraph 4.45)

- (f) Ross Sea biological data collection and skate tagging (paragraphs 6.19 and 6.22).

(viii) Krill fishery management –

- (a) advice on CM 51-07 (paragraph 5.26)
- (b) stratum area and management unit calculation (paragraphs 5.6 and 5.21)
- (c) data collection, collation, and analyses for revised krill fishery management approach (paragraph 5.12)
- (d) move-on rule (paragraph 6.4)
- (e) by-catch (paragraph 6.16).

8.5 The Working Group noted its discussions of the following items of future work:

- (i) Secretariat archive of forms (paragraph 2.9)
- (ii) Secretariat overruns analysis (paragraph 2.13)
- (iii) Casal2 development (paragraph 3.15)
- (iv) review of progress in addressing recommendations made by the Independent Stock Assessment Review for Toothfish (paragraph 3.18)
- (v) Secretariat trend analysis updates (paragraph 4.2)
- (vi) Secretariat krill fishery capacity analysis (paragraph 5.2)
- (vii) data collection, collation, and analyses for revised krill fishery management approach (paragraphs 5.7, 5.11, 5.17, 5.24 and 5.27)
- (viii) krill management areas definitions (paragraph 5.21)
- (ix) advice on CM 51-07 (paragraph 5.26)
- (x) request for additional information on whale mortality incidents (paragraph 6.6)
- (xi) Secretariat update to WG-FSA-2021/04 Rev. 1 (paragraph 6.5), WG-FSA-2021/05 (paragraph 6.15), fishery reports (paragraphs 3.49, 3.69 and 6.19iii) and WG-FSA-2021/11 (paragraph 6.26)
- (xii) net monitoring cable (paragraph 6.12).

Adoption of the report

9.1 The report of the meeting was adopted.

9.2 On behalf of the Working Group, Dr D. Welsford (Chair of the Scientific Committee) and other participants thanked Mr Somhlaba for his guidance and leadership during this shortened and at times challenging meeting, the Secretariat for their assistance in compiling the report, and the technical support provided by the Interprefy team. Dr Welsford noted that there appeared to be increasing concern over the way that science is used to develop advice in working group meetings. He urged participants to reflect on what science is, and how decisions are made in CCAMLR using best available science, in preparation for the upcoming Scientific Committee meeting.

9.3 In closing the meeting, Mr Somhlaba noted that at times the discussions, and the use of science to provide advice during the meeting, had been challenging. He thanked all participants for their hard work and collaboration that had contributed to the successful outcomes from WG-FSA this year, and to the Secretariat, the stenographers and Interprefy staff for their support.

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Table 1: Constant harvest rates calculated to be consistent with the CCAMLR decision rules.

Species	Area	Equilibrium harvest rate	Reference
<i>D. eleginoides</i>	48.3	0.039	WG-FSA-2021/59
<i>D. eleginoides</i>	48.4	0.063	WG-FSA-2021/61
<i>D. eleginoides</i>	58.5.1	0.08	WG-FSA-2021/46
<i>D. eleginoides</i>	58.5.2	0.058	WG-FSA-2021/21
<i>D. eleginoides</i>	58.6	0.07	WG-FSA-2021/45
<i>D. mawsoni</i>	Ross Sea region	0.044	WG-FSA-2021/26

Table 2: Maximum posterior density (MPD) B_0 estimates (tonnes) reported to WG-FSA and comparison with Secretariat estimates.

Assessment/model run	Reported B_0	Secretariat B_0	Difference (%)	Paper number
<i>D. eleginoides</i>				
Subarea 48.3	74 047	74 047	0	WG-FSA-2021/59
Subarea 48.4	955	955	0	WG-FSA-2021/61
Division 58.5.1				
M1	218 730	218 730	0	WG-FSA-2021/46
M2	233 110	233 110	0	WG-FSA-2021/46
Division 58.5.2				
M2	69 894	69 894	0	WG-FSA-2021/21
Subarea 58.6				
M3	54 723	54 723	0	WG-FSA-2021/45
<i>D. mawsoni</i>				
Ross Sea region	78 892	78 892	0	WG-FSA-2021/26

Table 3: Research block biomasses (B, tonnes) and catch limits (CL, tonnes) estimated using the trend analysis. PCL: previous catch limit; ISU: increasing, stable or unclear; D: declining; Y: Yes; N: No; -: No fishing occurred in the last Season. Recommended catch limits are subject to approval by the Commission.

Subarea or Division	Research block	Species	PCL	Trend decision	Adequate recaptures	CPUE Trend Decline	B	B × 0.04	PCL × 0.8	PCL × 1.2	Recommended CL for 2021/22
48.6	486_2	<i>D. mawsoni</i>	112	ISU	Y	N	5 617	225	90	134	134
	486_3	<i>D. mawsoni</i>	30	ISU	N	N	957	38	24	36	36
	486_4	<i>D. mawsoni</i>	163	ISU	Y	Y	10 816	433	130	196	196
	486_5	<i>D. mawsoni</i>	263	D	Y	Y	15 036	601	210	316	210
58.4.1	5841_1	<i>D. mawsoni</i>	138	-	-	-	-	-	-	-	138
	5841_2	<i>D. mawsoni</i>	139	-	-	-	-	-	-	-	139
	5841_3	<i>D. mawsoni</i>	119	-	-	-	-	-	-	-	119
	5841_4	<i>D. mawsoni</i>	23	-	-	-	-	-	-	-	23
	5841_5	<i>D. mawsoni</i>	60	-	-	-	-	-	-	-	60
	5841_6	<i>D. mawsoni</i>	104	-	-	-	-	-	-	-	104
58.4.2	5842_1	<i>D. mawsoni</i>	60	ISU	Y	N	3 416	137	48	72	72
88.2	882_1	<i>D. mawsoni</i>	192	ISU	Y	N	6 588	264	154	230	230
	882_2	<i>D. mawsoni</i>	186	ISU	Y	Y	17 892	716	149	223	223
	882_3	<i>D. mawsoni</i>	170	ISU	N	N	5 308	212	136	204	204
	882_4	<i>D. mawsoni</i>	128	ISU	Y	Y	8 274	331	102	154	154
	882H	<i>D. mawsoni</i>	128	D	Y	Y	4 500	180	102	154	102
88.3	883_1	<i>D. mawsoni</i>	16*	-	-	-	-	-	-	-	16
	883_2	<i>D. mawsoni</i>	20*	-	-	-	-	-	-	-	20
	883_3	<i>D. mawsoni</i>	60*	-	-	-	-	-	-	-	60
	883_4	<i>D. mawsoni</i>	60*	-	-	-	-	-	-	-	60
	883_5	<i>D. mawsoni</i>	8*	-	-	-	-	-	-	-	8

* Catch limits for the 2019/20 season. All other catch limits were for the 2020/21 season.

Table 4: Catch allocation options in the Ross Sea Region.

Area		Percent	No survey	Method 1 (2017/18–2018/19)	Method 2 (2019/20–2020/21)	Method 3 (SC-CAMLR-39/BG/03)
	North of 70°S	19	664	652	664	650
	South of 70°S	66	2 307	2 263	2307	2256
	Special Research Zone	15	524	515	459	524
	Shelf Survey	-	-	65	65	65
	Total		3 495	3 495	3 495	3 495
N70	Skates (5%)		33	32	33	32
	Macrourids		106	104	106	103
	Other (5%)		33	32	33	32
S70	Skates (5%)		115	113	115	112
	Macrourids (388 t)		316	316	316	316
	Other (5%)		115	113	115	112
SRZ	Skates (5%)		26	25	22	26
	Macrourids (388 t)		72	72	72	72
	Other (5%)		26	25	22	26
Total	Skates (5%)					
	Macrourids		494	492	494	491
	Other (5%)					

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(Virtual Meeting, 13 to 20 September 2021)

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Agenda

Working Group on Fish Stock Assessment
(Virtual Meeting, 13 to 20 September 2021)

1. Opening of the meeting
2. Review of the 2020/21 fishery
3. Fish stock assessments and management advice
4. Fish research notifications and exploratory fisheries
5. Krill fishery management
6. Non-target catch and ecosystem impacts
7. Other business
8. Advice to the Scientific Committee and future work
9. Adoption of the report.

List of Documents

Working Group on Fish Stock Assessment
(Virtual Meeting, 13 to 20 September 2021)

WG-FSA-2021/01	Informational report on the results of underwater video observation of benthic fauna during the toothfish survey in Subarea 48.1 by the Ukrainian vessel <i>Calipso</i> in 2021 P. Zabroda, L. Pshenichnov and D. Marichev
WG-FSA-2021/02	Implementation of the CCAMLR Scheme of International Scientific Observation during 2019/20 and 2020/21, and proposed observer form updates Secretariat
WG-FSA-2021/03	Results from the Conversion Factor Survey conducted by the Secretariat in 2020, from Members' vessels participating in CCAMLR toothfish fisheries CCAMLR Secretariat
WG-FSA-2021/04 Rev. 1	Summary of incidental mortality associated with fishing activities collected in scientific observer and vessel data during the 2020 and 2021 seasons Secretariat
WG-FSA-2021/05	An update to fish by-catch in the krill fishery, and results from responses provided to the Secretariat consultation on krill by-catch data collection practices Secretariat
WG-FSA-2021/06	Trend analysis – 2021 research blocks biomass estimates CCAMLR Secretariat
WG-FSA-2021/07	Toothfish catch forecasting process and implementation review Secretariat
WG-FSA-2021/08	Estimation of capacity in CCAMLR krill fisheries Secretariat
WG-FSA-2021/09	Tag linking – 2021 Report CCAMLR Secretariat
WG-FSA-2021/10	Commercial form updates, and a proposed new fine scale haul by haul longline form and commercial data manual Secretariat

WG-FSA-2021/11	Gear loss reported by longline fishing vessels for the 2020 and 2021 fishing seasons Secretariat
WG-FSA-2021/12	Report of the UK Groundfish Survey at South Georgia (CCAMLR Subarea 48.3) in May 2021 M.A. Collins, J. Coleman, S. Gregory, P.R. Hollyman, R. James, M. Marsh, J. Reid and P. Socodo
WG-FSA-2021/13	Results from net monitoring cable bird-strike trials; basis for amending CM 25-03 to allow the use of net monitoring cables for vessels using the continuous pumping fishing method? B.A. Krafft, A. Lowther, S. Young, J. Moir Clark, J. Chapman, P. Nugent, S. Jennings, X. Zhao, G. Fan and J. Zhu
WG-FSA-2021/14	Method description of Trial #2; examining bird interactions with monitoring cables on krill trawlers using continuous trawling methods, during the 2020/21 fishing season B.A. Krafft, A. Lowther, S. Young, J. Moir Clark, J. Chapman, P. Nugent, S. Jennings, X. Zhao and N. Walker
WG-FSA-2021/15	Preliminary assessment of mackerel icefish (<i>Champsocephalus gunnari</i>) in Subarea 48.3 based on the 2021 Groundfish Survey T. Earl
WG-FSA-2021/16	Using the Risk Assessment Framework to spread the catch limit in Subarea 48.1 V. Warwick-Evans and P.N. Trathan
WG-FSA-2021/17	Summary of the intersessional work and discussion by the CCAMLR Risk assessment framework e-group V. Warwick-Evans, on behalf of the Risk assessment framework e-group
WG-FSA-2021/18	Report on exploratory fishing in Divisions 58.4.1 and 58.4.2 between the 2011/12 and 2020/21 fishing seasons G. Phillips and P. Ziegler
WG-FSA-2021/19	Estimates of abundance of <i>Dissostichus eleginoides</i> and <i>Champsocephalus gunnari</i> from the random stratified trawl survey in the waters surrounding Heard Island in Division 58.5.2 for 2021 C. Miller, P. Ziegler and T. Lamb
WG-FSA-2021/20	A preliminary assessment for mackerel icefish (<i>Champsocephalus gunnari</i>) in Division 58.5.2, based on results from the 2021 random stratified trawl survey D. Maschette, S. Wotherspoon and P. Ziegler

WG-FSA-2021/21	Draft integrated stock assessment for the Heard Island and McDonald Islands Patagonian toothfish (<i>Dissostichus eleginoides</i>) fishery in Division 58.5.2 P. Ziegler
WG-FSA-2021/22	Results from a three-year survey, 2017–2019, into the connectivity of toothfish species in Subareas 48.2 and 48.4 M. Söffker, O. Hogg, P. Hollyman, M. Belchier, A. Riley, L. Readdy, E. MacLeod, G. Robson, K. Olsson, H. Pontalier and C. Darby
WG-FSA-2021/23	2021 Ross Sea shelf survey results J. Devine, S. Parker and M. Prasad
WG-FSA-2021/24	Characterisation of the toothfish fishery in the Ross Sea region through 2020/21 A. Grüss, J. Devine and S. Parker
WG-FSA-2021/25	Summary of the toothfish fishery and tagging program in the Amundsen Sea region (small-scale research units 882C–H) to 2020/21 A. Grüss, J. Devine and S. Parker
WG-FSA-2021/26	Assessment model for Antarctic toothfish (<i>Dissostichus mawsoni</i>) in the Ross Sea region to 2020/21 A. Grüss, A. Dunn and S. Parker
WG-FSA-2021/27	Diagnostic plots for the 2021 assessment for Ross Sea region Antarctic toothfish (<i>Dissostichus mawsoni</i>) A. Grüss, A. Dunn and S. Parker
WG-FSA-2021/28	Stock Annex for the 2021 assessment of Ross Sea region Antarctic toothfish (<i>Dissostichus mawsoni</i>) A. Grüss, A. Dunn and S. Parker
WG-FSA-2021/29	Towards improved biomass estimation and stock assessment in the Amundsen Sea region (SSRUs 882C–H) S. Parker, M. Baird and N. Walker
WG-FSA-2021/30	Workshop proposal to update the fishery-based research and data collection plan for the Ross Sea region toothfish fishery Delegation of New Zealand
WG-FSA-2021/31	Development of Casal2 A. Dunn and S. Rasmussen

WG-FSA-2021/32	Catches and data available on by-catch species from the toothfish fishery in the Ross Sea region (Subarea 88.1 and SSRUs 88.2A–B) through 2020–2021 B. Moore and S. Parker
WG-FSA-2021/33	Update of 2-year tagging program for skates in the Ross Sea region B. Moore, B. Finucci and S. Parker
WG-FSA-2021/34	New research plan for <i>Dissostichus</i> spp. under CM 24-01, paragraph 3 in Subarea 88.3 by Korea and Ukraine from 2021/22 to 2023/24 Delegations of the Republic of Korea and Ukraine
WG-FSA-2021/35	Molecular diet analysis of Antarctic toothfish (<i>Dissostichus mawsoni</i>) collected from Subarea 88.1 S.R. Lee, S.-G. Choi, S. Chung, D. N. Kim and H.-W. Kim
WG-FSA-2021/36	Diet composition and feeding strategy of Antarctic toothfish, <i>Dissostichus mawsoni</i> in Subarea 88.1 for the exploratory longline fishery in 2021 G.W. Baeck, S.-G. Choi, S. Chung and D.N. Kim
WG-FSA-2021/37	The variability of egg and larval transport of Antarctic toothfish under the extreme SAM event in the East Antarctic region (Division 58.4.1 and 58.4.2) M. Mori, K. Mizobata, K. Kusahara, T. Ichii and T. Okuda
WG-FSA-2021/38	Revised proposal for continuing research on Antarctic toothfish (<i>Dissostichus mawsoni</i>) in Statistical Subarea 48.6 in 2021/22 from a multiyear plan (2021/22–2023/24): Research Plan under CM 21-02, paragraph 6(iii) Delegations of Japan, South Africa and Spain
WG-FSA-2021/39	Grym assessment for Subarea 48.1 <i>Euphausia superba</i> populations D. Maschette, S. Wotherspoon, S. Kawaguchi and P. Ziegler
WG-FSA-2021/40	Use of parameters within <i>Euphausia superba</i> Grym simulations D. Maschette and S. Wotherspoon
WG-FSA-2021/41	On the revision of the precautionary approach to ensure the rational use of the living resource (<i>Dissostichus eleginoides</i>) in Subarea 48.3 Delegation of the Russian Federation

WG-FSA-2021/42	Proposal for new multi-Member research on <i>Dissostichus</i> spp. in Divisions 58.4.1 and 58.4.2 from 2021/22 to 2023/24 Delegation of the Russian Federation
WG-FSA-2021/43	Impact of grenadier by-catch limits on surveys of toothfish in CCAMLR's area of responsibility under CM 24-01 (based on research surveys by Ukrainian vessels) Delegation of Ukraine
WG-FSA-2021/44	Summary report on the three years research for <i>Dissostichus</i> spp. in Subarea 48.1 by Ukrainian vessel <i>Calipso</i> in 2019–2021 Delegation of Ukraine
WG-FSA-2021/45	An integrated stock assessment for the Crozet Islands Patagonian toothfish (<i>Dissostichus eleginoides</i>) fishery in Subarea 58.6 F. Massiot-Granier and C. Péron
WG-FSA-2021/46	Updated stock assessment model for the Kerguelen Island EEZ Patagonian toothfish (<i>Dissostichus eleginoides</i>) fishery in Division 58.5.1 for 2021 F. Massiot-Granier, S. Landru and C. Peron
WG-FSA-2021/47	Stock Annex for the 2021 assessment of the Patagonian toothfish (<i>Dissostichus eleginoides</i>) population of Kerguelen F. Massiot-Granier and C. Péron
WG-FSA-2021/48	Progress on the spatial modelling of by-catch patterns for research fishing operations in Subarea 48.6 using VAST K. Sawada and T. Okuda
WG-FSA-2021/49	Preliminary results on the progress of the integrated stock assessment by CASAL for Antarctic toothfish <i>Dissostichus mawsoni</i> in Subarea 48.6 Y. Osawa, K. Sawada and T. Okuda
WG-FSA-2021/50	Final report of research fishing operations at Subarea 48.6 between the 2012/13 and 2020/21 fishing seasons Delegations of Japan, Spain and South Africa
WG-FSA-2021/51	Final report of research fishing operations at Division 58.4.4b between the 2016/17 and 2020/21 fishing seasons Delegations of Japan and France
WG-FSA-2021/52	Updating CASAL model for <i>D. eleginoides</i> at Division 58.4.4b for 2020/21 fishing season T. Okuda and F. Massiot-Granier

WG-FSA-2021/53	A comparison of methods used for assessing the ontogenetic variation in otolith shape for <i>Dissostichus mawsoni</i> G.P. Zhu, L. Wei, D. Yang, T. Okuda, I. Slypko, S. Somhlaba and S. Parker
WG-FSA-2021/54	Comparing otolith shape of Patagonian toothfish (<i>Dissostichus eleginoides</i>) between the Kerguelen Islands and the Crozet Islands, East Antarctic G.P. Zhu, D. Yang and L. Wei
WG-FSA-2021/55	Withdrawn
WG-FSA-2021/56	The potential impact of krill fishery concentration needs to be assessed against the highly patchy and dynamic nature of krill distribution X. Zhao, X. Wang, Y. Ying, G. Fan, Q. Xu, D. Gao and Y. Zhao
WG-FSA-2021/57	Diagnostic plots for the 2021 assessment model for the Kerguelen Island EEZ Patagonian toothfish (<i>Dissostichus eleginoides</i>) fishery in Division 58.5.1 F. Massiot-Granier and C. Péron
WG-FSA-2021/58	Description of the SAGO Extreme fishing system on the Patagonian toothfish (<i>Dissostichus eleginoides</i>) fishery in the southwestern Atlantic Ocean during austral summer 2021 A. Loureiro, P. Troncoso and O. Pin
WG-FSA-2021/59	Assessment of Patagonian toothfish (<i>Dissostichus eleginoides</i>) in Subarea 48.3 T. Earl and L. Readdy
WG-FSA-2021/60	Assessment of Patagonian toothfish (<i>Dissostichus eleginoides</i>) in Subarea 48.3: assessment diagnostics T. Earl and L. Readdy
WG-FSA-2021/61	Assessment of Patagonian toothfish (<i>Dissostichus eleginoides</i>) in Subarea 48.4 T. Earl and L. Readdy
WG-FSA-2021/62	Assessment of Patagonian toothfish (<i>Dissostichus eleginoides</i>) in Subarea 48.4: assessment diagnostics T. Earl and L. Readdy
WG-FSA-2021/63 Rev. 1	Preliminary tag-recapture based population assessment of Antarctic toothfish (<i>Dissostichus mawsoni</i>) in Subarea 48.4 – 2021 fishing season T. Earl, A. Riley and L. Readdy

Candidate Management Scenario Proposal for Subarea 48.1

Candidate Management Scenario Proposal for Subarea 48.1

The three components and workflow of the revised krill management approach developed by WG-EMM-2019, as illustrated in WG-EMM-2021/33, as shown in Figure 1.

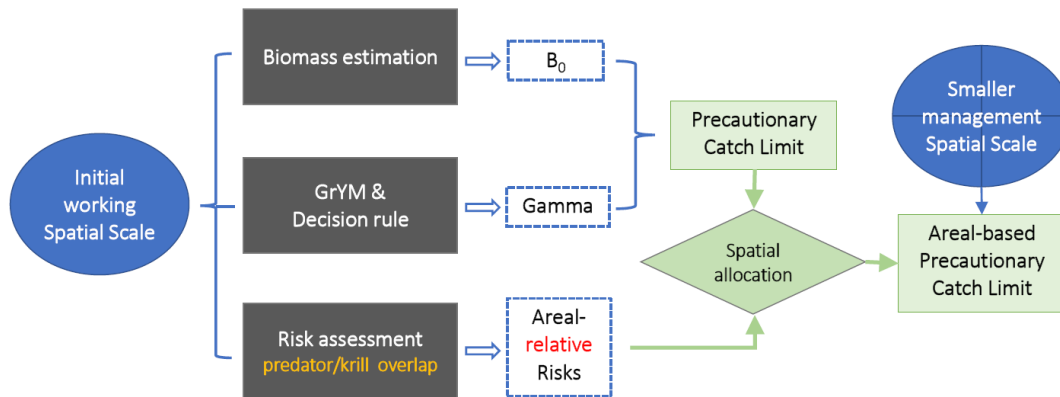


Figure 1: The workflow of the new krill management approach (after WG-EMM-2021/33).

The candidate management units are as proposed in SC-CAMLR-40/10 (Figure 2):

- (i) the four US AMLR strata with adjusted boundaries, namely the Elephant Island (EI), South Shetland Islands West (SSIW), Bransfield Strait (BS) and Joinville Island (JOIN) waters
- (ii) the extra stratum covering the Gerlache Strait area
- (iii) the outer stratum.

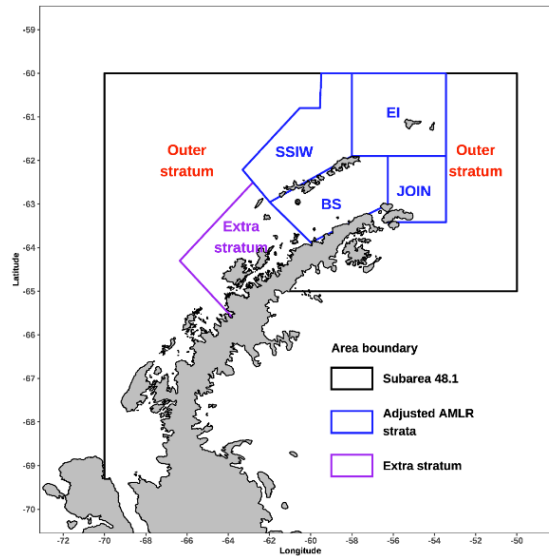


Figure 2: Boundary map showing the candidate management units in Subarea 48.1 (after SC-CAMLR-40/10).

The candidate management scenario includes the following for the three components from Figure 1

1. Biomass estimates

- (i) Four US AMLR strata with adjusted boundaries: B_0 _AMLR Strata, WESJ Combined estimates in Table 2.6 in WG-EMM-2021/05 Rev. 1 (with biomass adjusted using the revised area as suggested in SC-CAMLR-40/11)
- (ii) extra stratum: B_0 _Extra Stratum, Table 3 in SC-CAMLR-40/11
- (iii) outer stratum: B_0 _Outer Stratum, Option 2 (the conservative one) in Table 4 in SC-CAMLR-40/11.

2. Gamma from Grym model results

For the gamma as provided in WG-FSA-2021/39, three options are proposed for consideration:

- Option 1: Initial values, scenario 6 in Table 5 in WG-FSA-2021/39
- Option 2: *Atlantida* survey, scenario 24 in Table 5 in WG-FSA-2021/39
- Option 3: Initial values + *Atlantida* survey

3. Precautionary catch limits (PCL) for each candidate management unit

For the spatial allocation of catch limits as provided in WG-FSA-2021/16, two options are proposed for consideration:

Option 1: scenario '**AMLR strata adjusted**' on page 70 of WG-FSA-2021/16

For option 1, only the four US AMLR strata are considered in the risk assessment model:

- (i) for US AMLR strata with adjusted boundaries: B_0 only using the acoustic biomass estimate in this area, $B_{0_AMLR\ Strata} \times \text{gamma}$, the following options are proposed for consideration:
 - (a) baseline or with desirability
 - (b) with or without summer/winter consideration
 - (c) with or without juvenile
- (ii) extra stratum: $B_{0_Extra\ Stratum} \times \text{gamma}$
- (iii) outer stratum: $B_{0_Outer\ Stratum} \times \text{gamma}$ (with discount?).

Option 2: scenario '**AMLR strata new5**' on page 73 of WG-FSA-2021/16

For option 2, the four US AMLR strata and the extra stratum are both considered in the risk assessment model, and the B_0 for the US AMLR strata and the extra stratum will be the sum.

- (i) for US AMLR strata with adjusted boundaries: $B_{0_ (AMLR\ Strata+Extra\ Stratum)} \times \alpha_{AMLR\ Strata} \times \text{gamma}$, the following options are proposed for consideration:
 - (a) baseline or with desirability
 - (b) with or without summer/winter consideration
 - (c) with or without juvenile
- (ii) extra stratum: $B_{0_ (AMLR\ Strata+Extra\ Stratum)} \times \alpha_{Extra\ Stratum} \times \text{gamma}$
- (iii) outer stratum: $B_{0_Outer\ Stratum} \times \text{gamma}$ (with discount?).

**Working Group on Incidental Mortality Associated with Fishing (WG-IMAF)
Terms of Reference**

Working Group on Incidental Mortality Associated with Fishing (WG-IMAF) Terms of Reference¹

1. The purpose of the Working Group on Incidental Mortality Associated with Fishing (WG-IMAF) is to contribute to the conservation of Convention Area seabirds and marine mammals through the provision of advice to the CCAMLR Scientific Committee and its working groups. To achieve this, WG-IMAF will address the following terms of reference:

- (i) review and analyse data on the level and significance of direct impacts of interactions and incidental mortality associated with fishing
- (ii) review the efficacy of mitigation measures and avoidance techniques currently in use in the Convention Area, and consider improvements to them, taking into account experience both inside and outside the Convention Area
- (iii) review and analyse data on the level and significance of direct impacts of marine debris in the Convention Area
- (iv) collaborate and coordinate with the Agreement on the Conservation of Albatrosses and Petrels (ACAP) on achieving and maintaining a favourable conservation status for Convention Area seabirds
- (v) collaborate and coordinate with the International Whaling Commission (IWC) on Convention Area cetaceans
- (vi) provide the Scientific Committee with advice for:
 - (a) improvements and/or additions to the reporting and data collection requirements currently in use in the Convention Area
 - (b) improvements and/or additions to the measures in use to avoid or mitigate incidental mortality and interactions associated with fisheries within the Convention Area
 - (c) cooperation with other organisations with relevant expertise
 - (d) approaches to improve the conservation status of Convention Area seabirds and marine mammals directly impacted by fishing outside the Convention Area, including cooperation with adjacent regional fisheries management organisations (RFMOs).

¹ 2021.

**Glossary of Acronyms and Abbreviations
used in SC-CAMLR reports**

Glossary of Acronyms and Abbreviations used in SC-CAMLR reports

AAD	Australian Government Antarctic Division
ACAP	Agreement on the Conservation of Albatrosses and Petrels
ACAP BSWG	ACAP Breeding Sites Working Group (BSWG)
ACC	Antarctic Circumpolar Current
ACW	Antarctic Circumpolar Wave
ADCP	Acoustic Doppler Current Profiler (mounted on the hull)
ADL	Aerobic Dive Limit
AEM	Ageing Error Matrix
AFMA	Australian Fisheries Management Authority
AFZ	Australian Fishing Zone
AIS	Automatic Identification System
AKES	Antarctic Krill and Ecosystem Studies
ALK	Age-length Key
AMD	Antarctic Master Directory
AMES	Antarctic Marine Ecosystem Studies
AMLR	Antarctic Marine Living Resources
AMSR-E	Advanced Microwave Scanning Radiometer – Earth Observing System
ANDEEP	Antarctic Benthic Deep-sea Biodiversity
APBSW	Bransfield Strait West (SSMU)
APDPE	Drake Passage East (SSMU)
APDPW	Drake Passage West (SSMU)
APE	Antarctic Peninsula East (SSMU)
APEC	Asia-Pacific Economic Cooperation
APECS	Association of Polar Early Career Scientists

APEI	Elephant Island (SSMU)
APEME Steering Committee	Steering Committee on Antarctic Plausible Ecosystem Modelling Efforts
APIS	Antarctic Pack-Ice Seals Program (SCAR-GSS)
APW	Antarctic Peninsula West (SSMU)
ARK	Association of Responsible Krill harvesting companies
ASE	Assessment Strategy Evaluation
ASI	Antarctic Site Inventory
ASIP	Antarctic Site Inventory Project
ASMA	Antarctic Specially Managed Area
ASOC	Antarctic and Southern Ocean Coalition
ASPA	Antarctic Specially Protected Area
ASPM	Age-Structured Production Model
ATCM	Antarctic Treaty Consultative Meeting
ATCP	Antarctic Treaty Consultative Party
ATME	Antarctic Treaty Meeting of Experts on the Impacts of Climate Change for Management and Governance of the Antarctic region
ATS	Antarctic Treaty System
ATSCM	Antarctic Treaty Special Consultative Meeting
AVHRR	Advanced Very High Resolution Radiometry
BAS	British Antarctic Survey
BED	Bird Excluder Device
BICS	Benthic Impact Camera System
BIOMASS	Biological Investigations of Marine Antarctic Systems and Stocks (SCAR/SCOR)
BROKE	Baseline Research on Oceanography, Krill and the Environment
BRT	Boosted Regression Trees

CAC	Comprehensive Assessment of Compliance
cADL	calculated Aerobic Dive Limit
CAF	Central Ageing Facility
CAML	Census of Antarctic Marine Life
CAMLR Convention	Convention on the Conservation of Antarctic Marine Living Resources
CAML SSC	CAML Scientific Steering Committee
CAR	Comprehensiveness, Adequacy, Representativeness
CASAL	C++ Algorithmic Stock Assessment Laboratory
CBD	Convention on Biodiversity
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CCAMLR-2000 Survey	CCAMLR 2000 Krill Synoptic Survey of Area 48
CCAMLR-IPY- 2008 Survey	CCAMLR-IPY 2008 Krill Synoptic Survey in the South Atlantic Region
CCAS	Convention on the Conservation of Antarctic Seals
CCEP	CCAMLR Compliance Evaluation Procedure
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CCSBT-ERS WG	CCSBT Ecologically Related Species Working Group
CDS	Catch Documentation Scheme for <i>Dissostichus</i> spp.
CDW	Circumpolar Deep Water
CEMP	CCAMLR Ecosystem Monitoring Program
CEP	Committee for Environmental Protection
CF	Conversion Factor
CircAntCML	Circum-Antarctic Census of Antarctic Marine Life
CITES	Convention on International Trade in Endangered Species
CM	Conservation Measure

CMIR	CCAMLR MPA Information Repository
CMIX	CCAMLR's Mixture Analysis Program
CMP	Conservation Management Plan
CMS	Convention on the Conservation of Migratory Species of Wild Animals
COFI	Committee on Fisheries (FAO)
COLTO	Coalition of Legal Toothfish Operators
CoML	Census of Marine Life
COMM CIRC	Commission Circular (CCAMLR)
COMNAP	Council of Managers of National Antarctic Programs (SCAR)
CON	CCAMLR Otolith Network
COTPAS	CCAMLR Observer Training Program Accreditation Scheme
CPD	Critical Period–Distance
CPPS	Permanent Commission on the South Pacific
CPR	Continuous Plankton Recorder
CPUE	Catch-per-unit-effort
CQFE	Center for Quantitative Fisheries Ecology (USA)
CS-EASIZ	Coastal Shelf Sector of the Ecology of the Antarctic Sea-Ice Zone (SCAR)
CSI	Combined Standardised Index
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
CT	Computed Tomography
CTD	Conductivity Temperature Depth Probe
CV	Coefficient of Variation
C-VMS	Centralised Vessel Monitoring System
CVS	Concurrent Version System
CWP	Coordinating Working Party on Fishery Statistics (FAO)

DCD	<i>Dissostichus</i> Catch Document
DMSP	Defense Meteorological Satellite Program
DPM	Dynamic Production Model
DPOI	Drake Passage Oscillation Index
DSAG	Data Services Advisory Group
DQA	Data quality assurance
DVM	Diel vertical migration
DWBA	Distorted wave Born approximation model
EAF	Ecosystem Approaches to Fishing
EASIZ	Ecology of the Antarctic Sea-Ice Zone
E-CDS	Electronic Web-based Catch Documentation Scheme for <i>Dissostichus</i> spp.
ECOPATH	Software for construction and analysis of mass-balance models and feeding interactions or nutrient flow in ecosystems (see www.ecopath.org)
ECOSIM	Software for construction and analysis of mass-balance models and feeding interactions or nutrient flow in ecosystems (see www.ecopath.org)
EEZ	Exclusive Economic Zone
EG-BAMM	Expert Group on Birds and Marine Mammals (SCAR)
EIV	Ecologically Important Value
ENFA	Environmental Niche Factor Analysis
ENSO	El Niño Southern Oscillation
EOF/PC	Empirical Orthogonal Function/Principal Component
EoI	Expression of Intent (for activities in the IPY)
EPOC	Ecosystem, productivity, ocean, climate modelling framework
EPOS	European <i>Polarstern</i> Study
EPROM	Erasable Programmable Read-Only Memory

eSB	Electronic version of CCAMLR's <i>Statistical Bulletin</i>
ESS	Effective Sample Size(s)
FAO	Food and Agriculture Organization of the United Nations
FBM	Feedback Management
FEMA	Workshop on Fisheries and Ecosystem Models in the Antarctic
FEMA2	Second Workshop on Fisheries and Ecosystem Models in the Antarctic
FFA	Forum Fisheries Agency
FFO	Foraging–Fishery Overlap
FIBEX	First International BIOMASS Experiment
FIGIS	Fisheries Global Information System (FAO)
FIRMS	Fishery Resources Monitoring System (FAO)
FMP	Fishery Management Plan
FOOSA	Krill–Predator–Fishery Model (previously KPFM2)
FPI	Fishing-to-Predation Index
FRAM	Fine Resolution Antarctic Model
FV	Fishing Vessel
GAM	Generalised Additive Model
GATT	General Agreement on Tariffs and Trade
GBIF	Global Biodiversity Information Facility
GBM	Generalised Boosted Model
GCMD	Global Change Master Directory
GDM	Generalised Dissimilarity Modelling
GEBCO	General Bathymetric Chart of the Oceans
GEOSS	Global Earth Observing System of Systems
GIS	Geographic Information System
GIWA	Global International Waters Assessment (SCAR)

GLM	Generalised Linear Model
GLMM	Generalised Linear Mixed Model
GLOBEC	Global Ocean Ecosystems Dynamics Research
GLOCHANT	Global Change in the Antarctic (SCAR)
GMT	Greenwich Mean Time
GOOS	Global Ocean Observing System (SCOR)
GOSEAC	Group of Specialists on Environmental Affairs and Conservation (SCAR)
GOSOE	Group of Specialists on Southern Ocean Ecology (SCAR/SCOR)
GPS	Global Positioning System
GSCF	General Science Capacity Fund
GUI	Graphical User Interface
GRT	Gross Registered Tonnage
GTS	Greene et al., (1990) linear TS versus length relationship
GYM	Generalised Yield Model
HAC	A global standard being developed for the storage of hydroacoustic data
HCR	Harvest Control Rule
HIMI	Heard Island and McDonald Islands
IA	Impact Assessment
IAATO	International Association of Antarctica Tour Operators
IASOS	Institute for Antarctic and Southern Ocean Studies (Australia)
IASOS/CRC	IASOS Cooperative Research Centre for the Antarctic and Southern Ocean Environment
IATTC	Inter-American Tropical Tuna Commission
ICAIR	International Centre for Antarctic Information and Research
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICED	Integrating Climate and Ecosystem Dynamics in the Southern Ocean

ICES	International Council for the Exploration of the Sea
ICESCAPE	Integrating Count Effort by Seasonally Correcting Animal Population Estimates
ICES WGFAS	ICES Working Group on Fisheries Acoustics Science and Technology
ICFA	International Coalition of Fisheries Associations
ICG-SF	Intersessional Correspondence Group on Sustainable Financing
ICSEAF	International Commission for the Southeast Atlantic Fisheries
ICSU	International Council for Science
IDCR	International Decade of Cetacean Research
IFF	International Fishers' Forum
IGBP	International Geosphere-Biosphere Programme
IGR	Instantaneous Growth Rate
IHO	International Hydrographic Organisation
IKMT	Isaacs-Kidd Midwater Trawl
IMAF	Incidental Mortality Associated with Fishing
IMALF	Incidental Mortality Arising from Longline Fishing
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research (IGBP)
IMO	International Maritime Organization
IMP	Inter-moult Period
IOC	Intergovernmental Oceanographic Commission
IOCSOC	IOC Regional Committee for the Southern Ocean
IOFC	Indian Ocean Fisheries Commission
IOTC	Indian Ocean Tuna Commission
IPHC	International Pacific Halibut Commission
IPOA	International Plan of Action
IPOA-Seabirds	FAO International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries

IPY	International Polar Year
IRCS	International Radio Call Sign
ISO	International Organization for Standardization
ISR	Integrated Study Region
ITLOS	International Tribunal for the Law of the Sea
IUCN	International Union for the Conservation of Nature and Natural Resources – the World Conservation Union
IUU	Illegal, Unreported and Unregulated
IW	Integrated Weight
IWC	International Whaling Commission
IWC-IDCR	IWC International Decade of Cetacean Research
IWC SC	Scientific Committee of the IWC
IWL	Integrated Weighted Line
IYGPT	International Young Gadoids Pelagic Trawl
JAG	Joint Assessment Group
JARPA	Japanese Whale Research Program under special permit in the Antarctic
JGOFS	Joint Global Ocean Flux Studies (SCOR/IGBP)
KPFM	Krill–Predatory–Fishery Model (used in 2005)
KPFM2	Krill–Predatory–Fishery Model (used in 2006) – renamed FOOSA
KYM	Krill Yield Model
LADCP	Lowered Acoustic Doppler Current Profiler (lowered through the water column)
LAKRIS	Lazarev Sea Krill Study
LBRS	Length-bin Random Sampling
LMM	Linear Mixed Model
LMR	Living Marine Resources Module (GOOS)
LSSS	Large-Scale Server System

LTER	Long-term Ecological Research (USA)
<i>M</i>	Natural Mortality
MARPOL Convention	International Convention for the Prevention of Pollution from Ships
MARS	Multivariate Adaptive Regression Splines
MAXENT	Maximum Entropy modelling
MBAL	Minimum Biologically Acceptable Limits
MCMC	Markov Chain Monte Carlo
MCS	Monitoring Control and Surveillance
MDS	Mitigation Development Strategy
MEA	Multilateral Environmental Agreement
MEOW	Marine Ecoregions of the World
MFTS	Multiple-Frequency Method for in situ TS Measurements
MIA	Marginal Increment Analysis
MIZ	Marginal Ice Zone
MLD	Mixed-layer Depth
MODIS	Moderate Resolution Imaging Spectroradiometer
MoU	Memorandum of Understanding
MP	Management Procedure
MPA	Marine Protected Area
MPD	Maximum of the Posterior Density
MRAG	Marine Resources Assessment Group (UK)
MRM	Minimum Realistic Model
MSE	Management Strategy Evaluation
MSY	Maximum Sustainable Yield
MV	Merchant Vessel
MVBS	Mean Volume Backscattering Strength

MVP	Minimum Viable Populations
MVUE	Minimum Variance Unbiased Estimate
NAFO	Northwest Atlantic Fisheries Organization
NASA	National Aeronautical and Space Administration (USA)
NASC	Nautical Area Scattering Coefficient
NCAR	National Center for Atmospheric Research (USA)
NEAFC	North East Atlantic Fisheries Commission
NCP	Non-Contracting Party
NGO	Non-Governmental Organisation
NI	Nearest Integer
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
nMDS	non-Metric Multidimensional Scaling
NMFS	National Marine Fisheries Service (USA)
NMML	National Marine Mammal Laboratory (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
NPOA	National Plan of Action
NPOA-Seabirds	FAO National Plans of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries
NRT	Net Registered Tonnage
NSF	National Science Foundation (USA)
NSIDC	National Snow and Ice Data Center (USA)
OBIS	Ocean Biogeographic Information System
OCCAM Project	Ocean Circulation Climate Advanced Modelling Project
OCTS	Ocean Colour and Temperature Scanner
OECD	Organisation for Economic Cooperation and Development
OM	Operating Model
PaCSWG	Population and Conservation Status Working Group (ACAP)

PAR	Photosynthetically Active Radiation
PBR	Permitted Biological Removal
PCA	Principal Component Analysis
PCR	Per Capita Recruitment
pdf	Portable Document Format
PF	Polar Front
PFZ	Polar Frontal Zone
PIT	Passive Integrated Transponder
PRP	CCAMLR Performance Review Panel
PS	Paired Streamer Line
PSAT	Pop-up satellite archival tag
PTT	Platform Terminal Transmitter
RES	Relative Environmental Suitability
RFB	Regional Fishery Body
RFMO	Regional Fishery Management Organisation
RMT	Research Midwater Trawl
ROV	Remotely-Operated Vehicle
RPO	Realised Potential Overlap
RTMP	Real-Time Monitoring Program
RV	Research Vessel
RVA	Register of Vulnerable Areas
SACCB	Southern Antarctic Circumpolar Current Boundary
SACCF	Southern Antarctic Circumpolar Current Front
SAER	State of the Antarctic Environment Report
SAF	Sub-Antarctic Front
SBDY	Southern Boundary of the ACC

SBWG	Seabird Bycatch Working Group (ACAP)
SCAF	Standing Committee on Administration and Finance (CCAMLR)
SCAR	Scientific Committee on Antarctic Research
SCAR-ASPECT	Antarctic Sea-Ice Processes, Ecosystems and Climate (SCAR Program)
SCAR-BBS	SCAR Bird Biology Subcommittee
SCAR-CPRAG	Action Group on Continuous Plankton Recorder Research
SCAR-EASIZ	Ecology of the Antarctic Sea-Ice Zone (SCAR Program)
SCAR-EBA	Evolution and Biodiversity in Antarctica (SCAR Program)
SCAR-EGBAMM	Expert Group on Birds And Marine Mammals
SCAR-GEB	SCAR Group of Experts on Birds
SCAR-GOSEAC	SCAR Group of Specialists on Environmental Affairs and Conservation
SCAR-GSS	SCAR Group of Specialists on Seals
SCAR-MarBIN	SCAR Marine Biodiversity Information Network
SCAR/SCOR-GOSSOE	SCAR/SCOR Group of Specialists on Southern Ocean Ecology
SCAR WG-Biology	SCAR Working Group on Biology
SC-CAMLR	Scientific Committee for the Conservation of Antarctic Marine Living Resources
SC CIRC	Scientific Committee Circular (CCAMLR)
SC-CMS	Scientific Committee for CMS
SCIC	Standing Committee on Implementation and Compliance (CCAMLR)
SCOI	Standing Committee on Observation and Inspection (CCAMLR)
SCOR	Scientific Committee on Oceanic Research
SCP	Systematic Conservation planning
SD	Standard Deviation
SDWBA	Stochastic Distorted-wave Born Approximation

SEAFO	South East Atlantic Fisheries Organisation
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SG-ASAM	Subgroup on Acoustic Survey and Analysis Methods
SGE	South Georgia East
SGSR	South Georgia–Shag Rocks
SGW	South Georgia West (SSMU)
SIBEX	Second International BIOMASS Experiment
SIC	Scientist-in-Charge
SIOFA	Southern Indian Ocean Fisheries Agreement
SIR Algorithm	Sampling/Importance Resampling Algorithm
SISO	Scheme of International Scientific Observation (CCAMLR)
SKAG	SCAR Krill Action Group
SMOM	Spatial Multispecies Operating Model
SNP	Single Nucleotide Polymorphism
SO-CPR	Southern Ocean CPR
SO GLOBEC	Southern Ocean GLOBEC
SOI	Southern Oscillation Index
SO JGOFS	Southern Ocean JGOFS
SOMBASE	Southern Ocean Molluscan Database
SONE	South Orkney North East (SSMU)
SOOS	Southern Ocean Observing System
SOPA	South Orkney Pelagic Area (SSMU)
SOS Workshop	Southern Ocean Sentinel Workshop
SOW	South Orkney West (SSMU)
SOWER	Southern Ocean Whale Ecology Research Cruises
SPA	Specially Protected Area

SPC	Secretariat of the Pacific Community
SPGANT	Ocean Colour Chlorophyll- <i>a</i> algorithm for the Southern Ocean
SPM	Spatial Population Model
SPRFMO	South Pacific Regional Fisheries Management Organisation
SRZ	Special research zone
SSB	Spawning Stock Biomass
SSG-LS	The Standing Scientific Group on Life Sciences (SCAR)
SSM/I	Special Sensor Microwave Imager
SSMU	Small-scale Management Unit
SSMU Workshop	Workshop on Small-scale Management Units, such as Predator Units
SSRU	Small-scale Research Unit
SSSI	Site of Special Scientific Interest
SST	Sea-Surface Temperature
STC	Subtropical Convergence
SWIOFC	Southwest Indian Ocean Fisheries Commission
TASO	ad hoc Technical Group for At-Sea Operations (CCAMLR)
TDR	Time Depth Recorder
TEWG	Transitional Environmental Working Group
TIRIS	Texas Instruments Radio Identification System
TISVPA	Triple Instantaneous Separable VPA (previously TSVPA)
ToR	Term of Reference
TrawlCI	Estimation of Abundance from Trawl Surveys
TS	Target Strength
TVG	Time Varied Gain
UBC	University of British Columbia (Canada)
UCDW	Upper Circumpolar Deep Water

UN	United Nations
UNCED	UN Conference on Environment and Development
UNCLOS	UN Convention on the Law of the Sea
UNEP	UN Environment Programme
UNEP-WCMC	UNEP World Conservation Monitoring Centre
UNFSA	the United Nations Fish Stock Agreement is the 1995 United Nations Agreement for the Implementation of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks
UNGA	United Nations General Assembly
UPGMA	Unweighted Pair Group Method with Arithmetic Mean
US AMLR	United States Antarctic Marine Living Resources Program
US LTER	United States Long-term Ecological Research
UV	Ultra-Violet
UW	Unweighted
UWL	Unweighted Longline
VME	Vulnerable Marine Ecosystem
VMS	Vessel Monitoring System
VOGON	Value Outside the Generally Observed Norm
VPA	Virtual Population Analysis
WAMI	Workshop on Assessment Methods for Icefish (CCAMLR)
WC	Weddell Circulation
WCO	World Customs Organization
WFC	World Fisheries Congress
WCPFC	Western and Central Pacific Fisheries Commission
WG-ASAM	Working Group on Acoustic Survey and Analysis Methods
WG-CEMP	Working Group for the CCAMLR Ecosystem Monitoring Program (CCAMLR)

WG-EMM	Working Group on Ecosystem Monitoring and Management (CCAMLR)
WG-EMM-STAPP	Subgroup on Status and Trend Assessment of Predator Populations
WG-FSA	Working Group on Fish Stock Assessment (CCAMLR)
WG-FSA-SAM	Subgroup on Assessment Methods
WG-FSA-SFA	Subgroup on Fisheries Acoustics
WG-IMAF	Working Group on Incidental Mortality Associated with Fishing (CCAMLR)
WG-IMALF	ad hoc Working Group on Incidental Mortality Arising from Longline Fishing (CCAMLR)
WG-Krill	Working Group on Krill (CCAMLR)
WG-SAM	Working Group on Statistics, Assessments and Modelling
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WSC	Weddell–Scotia Confluence
WS-Flux	Workshop on Evaluating Krill Flux Factors (CCAMLR)
WS-MAD	Workshop on Methods for the Assessment of <i>D. eleginoides</i> (CCAMLR)
WSSD	World Summit on Sustainable Development
WS-VME	Workshop on Vulnerable Marine Ecosystems
WTO	World Trade Organization
WWD	West Wind Drift
WWF	World Wide Fund for Nature
WWW	World Wide Web
XBT	Expendable Bathythermograph
XML	Extensible Mark-up Language
Y2K	Year 2000
YCS	Year-class Strength(s)