

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-convenor 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-convenor 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.

References

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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 *Dissostichus* 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 (*Dissostichus mawsoni*) 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, *Dissostichus mawsoni* 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 (*Dissostichus mawsoni*) 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 *Euphausia superba* populations
D. Maschette, S. Wotherspoon, S. Kawaguchi and P. Ziegler
- WG-FSA-2021/40 Use of parameters within *Euphausia superba* 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 (*Dissostichus eleginoides*) 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
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