Annex 5

Report of the Working Group on Statistics, Assessment and Modelling 2023 (WG-SAM-2023)

(Kochi, India, 26 to 30 June 2023)

Contents

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Introduction

1.1 The 2023 meeting of the Working Group on Statistics, Assessments and Modelling (WG-SAM) was held at the Holiday Inn Hotel in Kochi, India, from 26 to 30 June 2023. The meeting was hosted by the Centre for Marine Living Resources and Ecology (CMLRE), an attached office of the Ministry of Earth Sciences, Government of India.

Opening of the meeting

1.2 The meeting Co-conveners, Dr C. Péron (France) and Dr T. Okuda (Japan) welcomed participants back to in-person meetings (Appendix A). The meeting was opened with a traditional ceremony and lighting of the lamp, to symbolise success in finding the correct pathway for the future and a Sanskrit song of good intentions. Dr GVM Gupta, CCAMLR Commissioner for India and Director of the CMLRE, welcomed all participants and noted that India was very happy to be hosting the meeting, which has been in planning for three years. He wished the participants success in their work and a comfortable stay in Kochi. Dr S. Saravanane, the Scientific Committee Representative for India to CCAMLR, also welcomed the group on behalf of the CMLRE, Ministry of Earth Sciences, Government of India.

Adoption of the agenda

1.3 With minor changes to the agenda topics within Agenda Item 6, the agenda was adopted (Appendix B) and a schedule was developed for the week.

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

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

1.6 The report was prepared by J. Devine and A. Dunn (New Zealand), T. Earl (UK), C. Jones (USA), S. Kawaguchi and C. Masere (Australia), F. Massiot-Granier (France), S. Parker (Secretariat), C. Péron (France), J. Quiroz Espinosa (Chile), L. Readdy (UK), S. Somhlaba (South Africa) and S. Thanassekos (Secretariat).

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

Review of the terms of reference and workplan

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

2.2 The Working Group reviewed the workplan set out in SC-CAMLR-41, Table 6, and agreed that some of the tasks could be progressed through discussions at this meeting. The Working Group further agreed to discuss additional modifications to the workplan under 'Future Work' (paragraph 10.1).

Development of methods to estimate biomass for krill

Gear selectivity

3.1 WG-SAM-2023/19, a continuation of the work described in WG-SAM-2022/27 (WG-SAM-2022, paragraphs 3.17 and 3.18), considered methodological aspects of trawl selectivity assessment for krill focusing on the gear selectivity function by Krag et al. (2014) which was used to estimate the selectivity parameter values for the krill stock assessment model (Grym). The authors maintain their position on the need for additional data to assess the gear selectivity for krill fishing and presented the results of the analysis of krill biometrics. The results of this study confirmed the presence of sexual dimorphism in the body proportions of krill and demonstrated the difference in biometrics between different sex and maturity stages, especially the measure of their body height that may affect the estimation of gear selectivity, one of the input parameters for the Grym. The authors stated that the results obtained are additional evidence that the data used to construct the selectivity function (Krag et al., 2014) does not adequately describe the krill fishing process. The authors of WG-SAM-2023/19 concluded that caution should be exercised when using biometrics for deriving gear selectivity functions, and stated that the gear selectivity function derived by Krag et al. (2014) is currently the best available information, but the function is not sufficient to be used to parameterise the Grym, and has not been peer reviewed by the Scientific Committee for its practical use. The authors noted that the topic related to methodological aspects of gear selectivity functions for krill should be considered by working groups as part of a revision of krill resource management.

3.2 The Working Group recalled the work by Krag and colleagues on gear selectivity and reiterated that it had been extensively reviewed by both WG-EMM (WG-EMM-2012, paragraph 2.34; WG-EMM-2016, paragraphs 2.15 to 2.17) and WG-SAM-2022, and that it has been agreed that the gear selectivity function described by Krag et al. (2014) was currently the best available information to parameterise the Grym (WG-SAM-2022, paragraph 3.18).

3.3 The Working Group further noted the difficulty in evaluating the gear selectivity described in WG-SAM-2023/19 without any statistical information, such as confidence bounds, and encouraged the authors to present their analysis in detail. The Working Group also noted that it is important for the authors to demonstrate how a selectivity function derived using different biometry between different sex may influence the output of the Grym.

Data collection needs and standards

Effective sampling to estimate length-frequency distribution

3.4 Dr Earl summarised an initial analysis on effective sampling size for krill length-frequency distributions that is currently being undertaken (Table 1, Task 1) in order to obtain any feedback from the Working Group on the intended analysis. In the analysis, krill observer data from Area 48 were aggregated by vessel and subarea, with gaps of less than 10 days between samples. This resulted in ~100 blocks of data, and by bootstrapping, Dr Earl estimated variability in the mean length depending on the effective sampling size as a first approach.

3.5 The Working Group suggested using metrics that could be more representative of the whole length distribution, such as inter-quartile range, root mean square error or an approach similar to that used for the tag-overlap statistic.

Development of integrated stock assessment for krill

4.1 WG-SAM-2023/25 presented preliminary results from a pilot model using Casal2 to conduct an assessment of Antarctic krill (*Euphausia superba*) in Subarea 48.1. Model inputs included fishery catches, acoustic survey data (either nautical area scattering coefficient (NASC)-derived biomass estimates or raw NASC data, which produced similar population estimates), length-frequency distributions from the fishery and from research surveys. The proposed use of Casal2 would result in the same integrated modelling framework being used for krill as for toothfish. The authors noted that the Scientific Committee could design future data-collection plans for the krill fishery that facilitate the application of integrated assessment models by combining frequent surveys that simply report NASC data with occasional surveys during which length-frequency data are collected using research nets.

4.2 The Working Group agreed that this pilot model was a useful exploration of the use of Casal2 for the assessment of krill, and encouraged the authors to continue progressing this approach for the potential future stock assessment of krill.

4.3 While the Working Group expressed interest in the approach, its ability to inform data collection plans, its practical use of NASC data instead of biomass estimates, and its usefulness in providing an additional approach to assessing krill stock status, it recalled that the development of an integrated stock assessment for krill was considered desirable within three to five years (Table 1, Task 2) and that the ongoing revision of the krill fishery management approach was, inter alia, relying on the use of the Grym (SC-CAMLR-41, paragraph 3.31). The Working Group discussed the presented implementation of Casal2 to assess krill stocks and suggested the authors consider the following future work:

(i) the impact of using an age-based or a length-based implementation could be assessed, noting that a preservation of the source data would be preferred (i.e. the conversion between length composition and age composition should be considered, with conversions from length to age to length avoided)

(ii) if an age-based model is to be used, that age classes known to be difficult to age might be included as a ‘plus’ group

(iii) the effect of different interannual recruitment variability assumptions should be tested

(iv) a Casal2 implementation using the same assumptions, data inputs, and parameters as those used in the Grym should be performed to help validate the model

(v) consideration of the krill stock hypothesis in Area 48 (i.e. linkages to adjacent subareas) could be given in further developments

(vi) the presentation of model configuration and outputs should be made consistent with other Casal2 implementations (paragraphs 6.33 to 6.35).

Develop methods to estimate biomass for finfish

5.1 The Working Group discussed work that Members were encouraged to conduct on conversion factors for Patagonian (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*) in the Convention Area. It recalled discussions on conversion factors during the dedicated workshop in 2022 (SC-CAMLR-41, Annex 9) and by WG-FSA-2022, paragraphs 8.15 to 8.20, and the importance of calculating accurate green weight by considering factors such as sample sizes and biological information (e.g. sex, gonad and liver weights) collected on appropriate spatial and temporal scales.

5.2 Dr Massiot-Granier brought to the attention of the Working Group that French vessels conduct sampling for conversion factors that are year-round, widely spatially distributed and frequent. These data could be used for conducting power analyses for estimating appropriate sample sizes for conversion factors in other areas of the CAMLR Convention Area.

5.3 The Working Group requested the Secretariat to work with French scientists to progress work on conversion factors that could clarify recommendations to other Members who need to improve data collection methods for their vessel operations. The Secretariat will further develop a paper for WG-FSA-2024 on an implementation strategy based on the recommendations made by Members.

5.4 WG-SAM-2023/18 presented a review of tag-overlap statistic calculation methodology given in footnote 3 of Conservation Measure (CM) 41-01, Annex 41-01/C. The paper highlighted a possible upward bias that might arise in calculating tag-overlap statistics if a randomly sampled length frequency by observers is not scaled by length frequencies of caught fish, which include retained and tagged fish. The sample from which length frequencies are derived must be representative of the entire catch.

5.5 The Working Group welcomed the review of the methodology and it further noted that observers might require non-random sampling of fish from time to time (e.g. sampling fish for otolith) and it emphasised the need to separate the lengths of non-randomly sampled fished from those randomly sampled for length frequencies in order to avoid introducing any bias. Historic non-random sampled length frequency could be hard to detect since there is no provision in the 'Biologicals' form to record them.

5.6 The Working Group recommended, consistent with advice (SC-CAMLR-41, paragraph 3.121) the Secretariat to:

(i) use the calculation which scales the length distribution of the retained fish based on the number of fish caught for the calculation of tag-overlap statistics (WG-SAM-2023/18)

(ii) utilise tag-overlap statistics calculated using this method for Fishery Reports and the CCAMLR Compliance Evaluation Procedure (CCEP)

(iii) consider developing a publicly available R package for working with CCAMLR data extracts, including the calculation of the tag-overlap statistic

(iv) consider the usefulness of modifying CM 41-01, Annex C, footnote 3, to further clarify the tag overlap statistic calculation method

(v) consider the addition of a column in 'Biologicals' in order to specify if fish have been randomly sampled or not.

Develop stock assessments to implement decision rules for finfish

6.1 WG-SAM-2023/12 provided a summary of progress against the 2018 Independent Stock Assessment Review for Toothfish (ISART) recommendations for the stock assessment of Antarctic toothfish in the Ross Sea region, including references to papers and discussions in CCAMLR reports.

6.2 The Working Group noted that most of the recommendations from the ISART have been addressed and resulted in a number of improvements to the Ross Sea toothfish assessment model. Work had been completed on all but a few of the recommendations.

6.3 The Working Group noted that WG-SAM-2023/12 provided a useful template document for other integrated assessments to track the progress made on CCAMLR integrated stock assessments since ISART.

6.4 The Working Group developed a summary for all of the integrated toothfish assessments involved in the upcoming review by the Center for Independent Experts (CIE) of the progress made against the ISART recommendations (Appendix D).

6.5 The Working Group recognised that addressing the ISART recommendation 18 on tagging mortality would be challenging and require field experiments.

6.6 The Secretariat provided an update on the status of the upcoming CCAMLR independent stock assessment review for toothfish. A panel of experts will be selected as reviewers by the CIE, and the review will take place in August as outlined in SC CIRC 23/52.

Develop new methods for stock assessments

6.7 WG-SAM-2023/14 presented a generalised additive mixed modelling (GAMM) framework to estimate the probability of a macrourid sampled in the Ross Sea region (RSR) is either *Macrourus caml* or Whitson's grenadier (*M. whitsoni*). This GAMM was used to

underpin recent vector autoregressive spatio–temporal (VAST) modelling analyses presented to WG-SAM-2022 and WG-FSA-2022. Preliminary results indicated that the selected GAMM had a good fit to the data, with 55.3% of the deviance explained and with model residuals randomly distributed in a narrow range around zero. Preliminary results also suggested that *M. caml* occurs in higher proportions than *M. whitsoni* in each management area of the RSR.

6.8 The Working Group recommended that the data inputs of the GAMM and VAST models be expanded to include more data from the fishery and investigations of model sensitivity to such expansion be conducted. To support the expansion of data inputs in the GAMM and VAST models, the Working Group also recommended future work to confirm the accuracy of species identification by scientific observers operating across the three gear types employed in the RSR (autoline, Spanish line and trotline), and in particular, confirmation that species codes are being used as intended (e.g. that the code WGR is being used specifically for *M. whitsoni*).

6.9 The Working Group agreed that training material should be developed to ensure that scientific observer biological records are identified to the species level, as opposed to the generic GRV code, and be developed by the Secretariat.

6.10 The Working Group recommended the results of the modelling be used to support the development of a revised framework for determining macrourid by-catch limits in the RSR by taking into account the species of macrourid present, their relative abundances, spatial distributions, productivities and catches by the RSR toothfish fishery.

6.11 The Working Group noted that the effect of excluding data with a difference of more than 300 m between start and end haul depths could be explored and be part of recommendations for this type of analysis in the future if it improves the model.

6.12 The Working Group noted that the effects of environmental covariates on species proportion in this study are likely to be relevant to the distributions of these species in populations in other areas. The Working Group noted that a similar study related to species identification based on otolith morphometrics that in part underpins the dataset for the GAMM model is under development in Division 58.5.2 based on these papers. This work may serve as a useful dataset to explore whether correlations between grenadier species' distribution and environmental variables differ between regions.

6.13 The Working Group noted that this approach has limited potential for use with historical data since *Macrourus* species were not identified by observers historically and would require other methods such as the use of otolith morphology to identify to species level, noting that otoliths were not routinely collected from macrourids at the time.

6.14 WG-SAM-2023/13 presented methods for updating biomass estimates and exploitation rates consistent with the CCAMLR decision rules for Antarctic starry skate (*Amblyraja georgiana*) in the Ross Sea. It included a risk assessment methodology, summarised the data available for this update, and proposed sensitivity simulations to input parameters to account for life-history uncertainties. Specifically, it provided a range of possibilities for biomass and exploitation rate estimates, but model uncertainties still exist, particularly around post-release mortality and age determination. An updated version of this risk assessment for the starry skate will be presented to WG-FSA-2023. Further updates would benefit from the data collected from: (i) the planned year of skate tagging commencing in the 2027/28 season, (ii) continued

recording of skate injury condition at recapture or release when tagging occurs, and (iii) research to improve post-release mortality estimates.

6.15 The Working Group noted that the analyses could be limited to a core area where skates are in high abundance. It also noted that the results of the risk analysis are likely to depend on age estimation (as they relate to growth and maturity). Age readings using spines are ongoing and results will be presented at WG-FSA-2023.

6.16 The Working Group highlighted that studies are ongoing on Kerguelen sandpaper skates (*Bathyraja irrasa*) involving pop-up satellite archival tags (PSATs) to explore post-tagging survival and blood sampling to assess stress levels. Results of this work may be helpful for the starry skate assessment and will also be shared with CCAMLR working groups when they are completed.

6.17 WG-SAM-2023/15 provided a comparison of methods to estimate von Bertalanffy growth parameters for *D. eleginoides* in Subarea 48.3. Growth models were compared between three sex categories (combined sex; females; males) and the same time periods used in previous studies. Comparison of the estimation methods suggested that the Bayesian growth model allowing for additional uncertainty for older ages had the best fit to the data and least bias when examining model residuals. It explored the sensitivity of this growth model to the inclusion of young fish (≤6 years) using trawl survey data. Results showed that including the youngest age classes of fish (ages 2 to 3) from survey data had a large influence on the model estimates, suggesting that the von Bertalanffy model could be inappropriate to capture growth at early ages.

6.18 The authors proposed to use the Bayesian growth model for future estimation of von Bertalanffy growth parameters to be used in assessments for *D. eleginoides* in Subarea 48.3, and to include survey data in the age dataset, with the exception of the age 2–3 fish, given their large influence on model estimates.

6.19 The Working Group noted that data from Subarea 48.4 were not included in this study due to differences in the specific growth of fish in that area. It also noted that young fish in Subarea 48.3 predominantly occur in one area around Shag Rocks, and therefore spatial patterns could not explain the different growth pattern observed in the age 2–3 fish.

6.20 The Working Group noted that priors could be revisited (e.g. the τ parameter of heteroscedasticity). Correlation between parameters could be explored by plotting full posterior distributions, recognising that it is not likely to have a strong impact on the estimation considering the quantity of data used.

6.21 WG-SAM-2023/09 explored different tag-loss models for *D. mawsoni* in the Ross Sea region, including: (i) assessing the effect of increasing the maximum time at liberty included in the analysis to those tags recaptured beyond six years at liberty, (ii) determining if ongoing tag loss was a function of time at liberty, (iii) determining the effect of initial tag loss on ongoing tag-loss rates, and (iv) allowing tag-loss rates to differ by size-class of tagged fish or season of tag release. Models with an initial tag loss and a constant ongoing annual tag loss were the most parsimonious based on likelihood ratio tests. Estimated rates of initial and ongoing tag loss from the 3 555 double-tagged fish since 2005 and subsequently recaptured suggested that about 5.7% (95% confidence interval (CI) 0.042–0.072) of individual tags were lost immediately, followed by an ongoing loss rate of 0.033 tags per year. The loss rates were similar to previous

estimates, with the initial tag-loss rate slightly higher than 3.5% and the ongoing tag-loss rate slightly lower than 0.039 y^{-1}. A key assumption of the tag-loss rate estimation is that probability of a lost tag on an individual fish was independent of the loss of the other tag and that the two tags had identical tag-loss rates.

6.22 The Working Group recommended using all years at liberty when estimating tag-loss parameters for all stocks, that these tag-loss rate estimates be updated periodically and that the updated estimates (WG-SAM-2023/09) be used in future stock assessments of the Ross Sea region. It further recommended alternate model formulations be investigated to evaluate the effect of the correlation between initial and ongoing tag-loss rates and simulation studies be carried out to investigate the potential effect of non-independence of tag loss with time.

6.23 The Working Group noted that tag placement could be a factor contributing to tag-loss rates, and taking pictures of the tag placement at recapture would help assess this effect. It also noted that T-bar tags in larger fish may not be anchored as they are designed to be, as noted at the 2023 COLTO–CCAMLR Tagging Workshop (WS-TAG-2023) (paragraphs 11.1 to 11.5).

6.24 The Working Group noted that practices might differ by vessel which may affect tag-loss rates and recommended further analyses exploring this.

6.25 The Working Group noted that the approximated double-tag-loss rate that could be calculated from the results of this paper is likely to be negligibly different from the value of 0.0084 currently in use in trend analysis (WG-SAM-2011/18). This value was previously used in the Ross Sea region stock assessment, and the double-tag-loss rate function is now available in Casal2.

6.26 WG-SAM-2023/11 presented methods to calculate the numbers at age of tagged fish and of recaptured fish which could be provided to the assessment model of the Ross Sea region *D. mawsoni* instead of numbers at length as has been done in the past. Results showed that the numbers at age of tagged fish calculated using this age-based approach were close to the numbers at age of tagged fish calculated within the assessment model when using the existing length-based approach, and that the numbers at age of recaptured fish calculated using the age-based approach were consistent with the otolith-derived age data for those same recaptured fish where otolith readings were available.

6.27 The Working Group recommend that the use of the age-based approach for tagged fish and for recaptured fish be explored in future toothfish stock assessments for the Ross Sea region and evaluated as an alternative to the use of the length-based approach.

6.28 The Working Group noted that results of this new method could be compared with the age frequencies estimated from otolith reading of recaptured fish.

6.29 The Working Group noted that the methodology might be difficult to apply to year-round fisheries since it relies on adding the time at liberty to an overall age. This issue does not influence the Ross Sea fishery data, which sample fish during a short summer period.

Draft integrated stock assessments in Casal2

6.30 The Working Group thanked Mr. N. Walker (New Zealand) and Mr Dunn for organising four Casal2 workshops held online during the intersessional period and noted the usefulness of these workshops which assisted Members to develop Casal2 assessment models for WG-FSA-2023.

6.31 The Working Group requested that the Secretariat create a private GitHub repository for the Casal2 training materials and example R code to aid Members to develop their stock assessment models.

6.32 The Working Group noted the need for development of a standard set of diagnostic tools and formats for presentation of model diagnostics in Casal2. It recalled its advice from WG-SAM-2015, paragraphs 2.33 to 2.43, that described a standard set of outputs and diagnostics for CASAL models and agreed that these should be applied and updated for Casal2. It was noted that Casal2 had advantages over CASAL in that summary plots and diagnostics are more easily generated, which allows the development of more informative summaries.

6.33 The Working Group recommended that integrated stock assessments, irrespective of the assessment, using CASAL and Casal2 include (where relevant) the following:

(i) table of annual cycle with time steps used in the assessment model (Table 2)

(ii) table of tagging release and recaptures by year

(iii) table of process error weighting

(iv) plot of the observations by year and their relative weights (e.g. WG-SAM-2023/10, Figure 1)

(v) table of the maximum of the posterior density (MPD) likelihood components

(vi) plots of fits to age and length-frequency and abundance data and mean age

(vii) likelihood profiles

(viii) Markov chain Monte Carlo (MCMC) model convergence diagnostics

(ix) model-derived estimates with MCMC credible intervals for example for selectivity functions, spawning, stock status, year-class strength (YCS), stock biomass projections and risk profiles.

6.34 The Working Group encouraged the development and use of other plots and diagnostics, including:

(i) graphical representation of the MPD likelihood components

(ii) time-at-liberty likelihood profile

(iii) r-hat statistics for MCMC convergence

(iv) projections with constant F that gives a long-term expected stock biomass of 50% B_0 with a 90% probability of being above 20% B_0

(v) Kobe plot with the 20% and 50% reference points and a target F reference point (from (iv) above)

(vi) stacked bar charts of the catch

(vii) retrospective analyses.

6.35 The Working Group recommended that Members develop and share code related to paragraphs 6.33 and 6.34 via a CCAMLR GitHub repository.

6.36 WG-SAM-2023/08 showed that using parameter transformations improved model optimisation and MCMC performance and was useful for parameters when there was evidence of poor convergence. The paper also noted that the use of more up-to-date algorithms in Casal2 or the use of catch in numbers rather than catch in biomass had a negligible impact on model estimates. Comparison of the catch in numbers with the catch in biomass models suggested that the assumptions used for the conversion factors, length-weight and age-length relationships were appropriate and did not create a bias. The Working Group thanked the authors for the work, agreed that it was valuable in providing some guidance to new assessments for setting up models.

6.37 The Working Group recommended that Members developing integrated assessments consider parameter transformations where improvements in diagnostics of MCMC convergence are required. Specifically, the use of the simplex method for parameterising recruitment deviates or YCSs and the inverse transformation for the right-hand limbs of selectivity relationships be considered as useful defaults. A $\log(B_0)$ transformation may also be considered when assessments are fitted to time series of surveys or catch-per-unit-effort (CPUE) indices.

6.38 WG-SAM-2023/10 investigated the double-tag-loss rate function and the effect of including tag-recapture observations with greater time at liberty in the Ross Sea region *D. mawsoni* assessment using Casal2.

6.39 The Working Group noted that the double-tag-loss rate function (WG-SAM-2023/10) was preferred over the single-tag-loss rate function for double-tagged fish. The Working Group recommended the use of the double-tag-loss rate function for double-tagged fish in future assessments using Casal2.

6.40 The Working Group noted tag releases for 2001–2004 in the Ross Sea region were in the years prior to CCAMLR standardising the tagging protocols and different tag types had been used. The Working Group noted that the amount of information from these years was no longer a significant component of the tagging data and recommended that tag-release data for 2001–2004 for the Ross Sea region should be omitted from future assessments.

6.41 WG-SAM-2023/10 showed that model diagnostics indicated a trend in the likelihood profiles with increasing time at liberty, and four hypotheses were identified that might explain the patterns. Analyses presented suggested that tag dispersion was the most plausible explanation, but models that included an effect for tag dispersal did not fully explain the pattern in the first three years of time at liberty.

6.42 The Working Group agreed that the framing and investigation of the hypotheses was a useful approach to investigating issues within stock assessments. The Working Group suggested that additional ecological hypotheses, such as higher than expected natural mortality, ontogenetic changes in residence time, or age-based changes in movement patterns, could be explored as well as incorporating hypotheses concerning fishing behaviours or localised changes to fishing grounds, which may explain the residual pattern in tag-recapture data.

6.43 The Working Group encouraged further investigation of the patterns in likelihood profiles identified in WG-SAM-2023/10, and that this be presented to future meetings of the Working Group.

6.44 WG-SAM-2023/20 presented the translation of the 2021 integrated stock assessment of *D. eleginoides* around Heard Island and McDonald Islands from CASAL to Casal2. Differences in model outputs and diagnostics were negligible.

6.45 The Working Group agreed that the Casal2 assessment model has been validated against the CASAL assessment model and that the Casal2 model can be progressed to WG-FSA-2023.

6.46 In light of progress by Members on using Casal2, the Working Group discussed how stock assessments for which both CASAL and Casal2 might be ready to use would be presented at WG-FSA-2023. The Working Group recalled paragraph 3.31 of WG-SAM-2022 and recommended that equivalent CASAL and Casal2 models would only need to be presented for the base case.

Trend analysis rule development

6.47 WG-SAM-2023/16 presented a provisional trend analysis for research blocks in data-limited toothfish fisheries and requested feedback from the Working Group. The document included summaries of fish releases and recaptures within and between research blocks, annual biomass estimates and updated trends, the decision tree of the trend analysis, preliminary catch limits and retrospective analyses. The 2023 update to the general bathymetric chart of the Oceans (GEBCO) dataset was used to re-estimate fishable areas and associated CPUE-by-seabed area biomass estimates and preliminary catch limits.

6.48 The Working Group noted the value of the trend analysis and thanked the Secretariat for the report.

Management strategy evaluations for target species

7.1 WG-SAM-2023/17 presented a proposed agent-based modelling framework to support management strategy evaluations (MSEs) for the CCAMLR trend analysis and potential alternative data-limited approaches for managing toothfish fisheries under research plans. The paper described the use of agent-based models (ABMs) to simulate toothfish populations, coded in R, which could be used by Members to develop collaboratively. The paper introduced some of the core concepts of the ABM approach, and simple implementations of key processes (growth, natural mortality, recruitment, fishery removals and tagging) were described.

7.2 The Working Group welcomed the work by the Secretariat and recalled that the development of an ABM was one of approaches recommended by WG-FSA-2022 (WG-FSA-2022/53; WG-FSA-2022, paragraphs 4.66 and 4.67). The Working Group agreed that further development of the ABM framework would constitute a reasonable starting point towards building one of the operating models of the planned MSE for the trend analysis rules.

7.3 The Working Group recommended that further work would be useful, and that it should include:

(i) a paper to a future meeting of WG-FSA that describes ABMs for those unfamiliar with the general method

(ii) undertake parameter perturbation analyses to validate the ABM model code

(iii) further development of the ABM and comparison of a set of simple ABM implementations with a cohort simulation model (e.g. using Casal2) using equivalent parameters

(iv) develop an initial draft MSE for the current trend analysis rules using the ABM and cohort simulation models as operating models

(v) introduce additional complexity into the ABM that would extend its assumptions beyond those that could be simulated in a cohort model (for example, site fidelity of fish in ontogenetic and spawning migrations) to evaluate the effect of these assumptions on the MSE

(vi) develop candidate parameter values (including parameter correlations and functional forms) for use in the operating models. These could draw on analyses from *D. eleginoides* and *D. mawsoni* stocks that are data rich and include analyses to inform these candidate parameter values, such as growth parameters, mortality, selectivities, migration rates, spatially explicit residence time, or other parameters that are required for the operating models

(vii) develop scenarios for the operating models with different assumptions of stock structure hypotheses for *D. eleginoides* and *D. mawsoni* toothfish, including:

  (a) an assumption of a closed population within each research block

  (b) assumptions of broader stock hypotheses, including the stock hypotheses of *D. eleginoides* in Divisions 58.4.1 and 58.4.2 (WG-SAM-2022/09) and for *D. mawsoni* for Area 48 (WG-SAM-2018/33 Rev. 1) and Subarea 88.2 (WG-SAM-2014/26)

(viii) the development of methods for the evaluation and presentation of the MSE for the trend analysis rules by the Scientific Committee.

7.4 The Working Group recommended the Secretariat set up an e-group combined with a private CCAMLR GitHub repository to share code and allow Members to collaborate on code development.

7.5 The Working Group requested that any developments be presented to WG-SAM.

Review of new research proposals

New proposals under Conservation Measure 21-02

8.1 WG-SAM-2023/07 presented a fisheries operation plan by a Uruguayan vessel for the exploratory toothfish fishery in Subarea 48.6. The Working Group noted that the paper did not follow the requirements for research notifications under CM 21-02, and was written in Spanish, so an evaluation of a research plan was not possible.

New proposals under Conservation Measure 24-01

8.2 WG-SAM-2023/05 set out a proposal by Chile to undertake research for *Dissostichus* spp. under CM 24-01 in Subarea 48.2 during the 2023/24–2025/26 seasons. There are four specific objectives: (i) explore the connectivity based on the modelling of spatial distribution, relative abundance, and length and age structure, (ii) review the fisheries potential impacts on dependent and related species, (iii) improve the hauling and tagging process to help with standardisation procedure, and (iv) improve the knowledge of near-bottom and seabed marine ecosystems using scientific electronic monitoring.

8.3 The Working Group recalled previous research activities on *Dissostichus* spp. undertaken by Ukraine (WG-FSA-2019/51), and the UK (WG-FSA-2021/22) on connectivity, catch rates, and *Dissostichus* species composition in this region of Subarea 48.2, as the research area in WG-SAM-2023/05 overlaps with areas from these previous studies. It was further noted that previous discussions at WG-SAM and WG-FSA would assist in improving the planning of this research proposal.

8.4 In relation to survey design, the Working Group noted that the proposal identified five areas where the research will be focused. Within each of these areas, 10 sets were proposed to be deployed across three depth strata. The Working Group recommended that there should be a minimum number of sets by depth stratum needed, potentially three or four sets in each stratum and area (9–12 by area). Subsequent surveys could then adjust deployments within strata based on catch from previous surveys.

8.5 In terms of the spatial distribution of *Dissostichus* spp. in this region and how it might impact the survey design, the Working Group noted that the distribution of the two species was mapped in WG-FSA-21/22. The Working Group noted that small numbers of *D. eleginoides* had only been encountered in the northern portion of each of the areas defined in WG-SAM-2023/05. The Working Group recommended that the location of the sets be redesigned not only by depth strata but also by target species distribution.

8.6 The Working Group recommended that this research be effort limited, and that sets by area should be multiples of 3 (9 to 12 sets in each area), with set length (or number of hooks per set) defined. Although this research is designed to be effort limited, the Working Group recommended the calculation of a precautionary catch limit using CPUE obtained from previous research activities, and a CPUE-by-seabed area calculation.

8.7 The Working Group noted that where there was no prior information on toothfish abundance or distribution, the location of research areas where sets should be placed be based on toothfish habitats based on bathymetry. Where a pre-defined station was found to be

unsuitable for setting gear, the station should be repositioned in a nearby area and the rules for the radius of movement or use of alternate station should be clearly defined in the proposal.

8.8 The Working Group noted that macrourids were likely to be the main by-catch taxa in this region. The Working Group recommended that there should be some additional analyses undertaken on by-catch rates from previous research activities by Ukraine and the UK.

8.9 Dr Quiroz Espinosa notified the Working Group that WG-SAM-2023/05 would be revised to incorporate the recommendations of WG-SAM-2023 and presented at WG-FSA-2023.

8.10 WG-SAM-2023/06 Rev. 1 presented a research proposal under CM 24-01 by Ukraine to continue the acoustic trawl survey of mackerel icefish (*Champsocephalus gunnari*) in Subarea 48.2 for 2023/24 and 2024/25. The Working Group noted the results of similar research activities undertaken in the 2022/23 season (WG-SAM-2023/22) and that the principal objective of this research is to determine the distribution and abundance of *C. gunnari* around the western South Orkney Islands shelf using information from acoustic and targeted trawls.

8.11 The Working Group noted that other objectives of this proposal included better understanding of the stock structure of *C. gunnari* in Subarea 48.2 and comparing it to the adjacent Subarea 48.1 stock, the estimation of catchability of fishing gear, data collection on the spatial and depth distributions of by-catch species, comparison of the main biological parameters of *C. gunnari* with historical data, plankton and oceanographic research, and supporting objectives of the South Orkney Islands southern shelf marine protected area (MPA).

8.12 The Working Group recalled the deliberations of WG-ASAM-2023 on the preliminary results of the research undertaken by Ukraine in 2022/23 (WG-ASAM-2023, paragraphs 7.1 to 7.4), particularly that acoustic data were gathered with an ES80 echosounder using a single frequency 120 kHz transducer.

8.13 The Working Group noted that the species distribution in catches was varied and that it may not be possible to distinguish between the acoustic signals of pelagic krill and icefish without multi-frequency methods. It further noted that the transducer had not been calibrated on the vessel for four years.

8.14 Dr S. Kasatkina (Russia) highlighted that the target strength data from the *Atlantida* for icefish and myctophids may be useful for identifying targets within the acoustic data for the research undertaken by Ukraine. However, the quantitative assessment of icefish requires the use of a multi-frequency method for collecting and processing acoustic data. The practical implementation for an acoustic survey of icefish requires equipping the vessel with an additional hull-mounted transducer with a frequency of 38 kHz, calibrating the ship's echosounder at each operating frequency, and engaging a specialist with experience in analysing data from a multi-frequency acoustic survey. Dr Kasatkina emphasised that such an approach would make it possible to achieve the principal objective of characterising the distribution and abundance of *C. gunnari* around the western South Orkney Islands shelf.

8.15 The Working Group recalled that although calibration is preferable, some analysis with data from vessels that had not been recently calibrated was carried out with data collected by commercial vessels in the krill fishery.

8.16 Dr I. Slypko (Ukraine) informed the Working Group that the vessel plans to additionally install a 38 kHz transducer (provided by Australia) and to calibrate the echosounders prior to the next survey.

8.17 The Working Group noted that the new proposal includes two new transects north of Coronation Island based on acoustic scattering layers that likely represent dense aggregations of Antarctic krill and finfish, as well as the removal of one transect in the southern part of the survey area.

Review of ongoing research plan results and proposals

Research results and proposals from Area 48

9.1 WG-SAM-2023/22 presented initial results from a combined acoustic and trawl survey by the Ukrainian fishing vessel *More Sodruzhestva* targeting *C. gunnari* in Subarea 48.2. The results indicated that the survey was completed in accordance with the program, although only a small amount of *C. gunnari* (46.5 kg) was caught, raising the possibility that there may not be sufficient icefish to identify in the acoustic data. Video recordings showed that fish species could be identified in the majority of cases, and showed behaviour of the fish within the swept area of the trawl, which may be useful to better understand the interaction between fish and the trawl gear. Oceanographic results suggested a cold eddy within the survey area providing an area of high productivity. Further results will be presented to WG-FSA-2023.

9.2 Some participants noted that the observations of the composition of icefish species were similar to that previously observed around the South Orkney Islands.

9.3 The Working Group noted that with the single-frequency transducer used in this research it may not be possible to distinguish krill and icefish distributions in the water column (paragraph 8.13). It also noted the comments of WG-ASAM-2023, paragraphs 7.1 to 7.4, concerning the acoustic data collection and processing, and the use of a multi-frequency method of data collection and processing.

9.4 The Working Group noted that the efficiency of the trawl was likely to be much less than 100%, when defined as the proportion of fish within the fishing zone that are retained in the net. As a result, any estimate of biomass from such a trawl survey is likely to be highly precautionary and provides useful scientific information if the efficiency is similar between surveys and within stations in the survey.

9.5 The Working Group noted that combined trawl and acoustic surveys have already been used to provide information on fish biomass in the Convention Area, for example the surveys provided by Russian scientists using the *Atlantida* and UK scientists using the *Dorada* respectively (WG-FSA-2002, paragraphs 5.95 to 5.101).

9.6 WG-SAM-2023/24 presented an updated analysis of the dynamic sea-ice concentration (SIC), sea-ice temperature and winds in research blocks 4 and 5 of Subarea 48.6. Results indicated a decreasing trend in annual sea-surface temperature spikes through time later shifting to an increase in 2022, suggesting the cooling phase of a 5–6-year periodical cycle may have concluded. Although SIC is estimated to be decreasing from 2022, the repeated accessibility

averaged from 2016 to 2023 is lower than was previously estimated based on SICs from 2002 to 2017.

9.7 The Working Group noted the useful information on the distribution of the sea ice, and the probability of repeated access, and requested that any future analysis be extended to include:

(i) previous occasions when fishing has occurred in the research blocks relative to the estimated SIC

(ii) indicate the likely impact of the ice cover on future survey design.

9.8 WG-SAM-2023/01 Rev. 1 provided an update to the efforts involved in the research plan pertaining to Subarea 48.6 in 2021/22–2023/24 under CM 21-02, paragraph 6(iii). This is the third year of an ongoing three-year plan. The authors noted that South Africa will be unable to participate in fishing activities in 2023/24 due to vessel availability, but would still be contributing to other milestones as planned. As a result of the reduction in the number of vessels from three to two, catch allocations were revised to ensure that the same amount of research would be achieved.

9.9 WG-SAM-2023/21 presented a tentative outline for supplementing the existing research plan in Subarea 48.6 by including Korea in the research. The potential research topics proposed were:

(i) releasing additional tags for better understanding toothfish abundance and distribution

(ii) the use of PSATs to better estimate the mortality rates associated with tagging

(iii) a dietary analysis to provide information on trophic relationships

(iv) identifying the abundance and distribution of by-catch species such as icefish and grenadier species.

9.10 The Working Group noted that the existing research in Subarea 48.6 would be completed in 2023/24, and that the results of this research may be useful when planning further research in the area. Korea was encouraged to work with the proponents of the existing research plan to explore possibilities for future collaborative research, and present a research plan to future meetings of WG-SAM.

9.11 Dr Masere noted that work using PSATs is currently being undertaken in Division 58.5.2. The Working Group welcomed Dr Masere's offer to share results as they become available.

Research results and proposals from Area 58

9.12 WG-SAM-2023/03 presented a multi-Member research plan by Australia, France, Japan, the Republic of Korea and Spain to conduct exploratory fishing for *Dissostichus* spp. under CM 21-02, paragraph 6(iii), for 2022/23 to 2025/26 in East Antarctica (Divisions 58.4.1 and 58.4.2). The plan is an update of WG-SAM-2022/04 with some modifications to the spatial

design of fishing haul locations in Division 58.4.1 and a change of vessel. Additionally, the design has reverted to an effort-limited approach in all research blocks in Division 58.4.1 owing to a lack of available data from the last five fishing seasons.

9.13 The Working Group thanked the authors for the comprehensive research plan, and recalled discussions during the meeting of the Scientific Committee in 2022, WG-FSA-2022 and WG-SAM-2022 on the plan.

9.14 Dr Kasatkina stated that her position remains the same as last year with regard to the research plan under CM 21-02, paragraph 6(iii) (SC-CAMLR-41, paragraphs 3.129 and 3.130).

9.15 Dr Kasatkina noted that the research plan for the *Dissostichus* spp. exploratory fishery for 2022/23 to 2025/26 in East Antarctica (Divisions 58.4.1 and 58.4.2) is provided under CM 21-02, paragraph 6(iii), and should fully comply with the requirements of CM 24-01 (Annex 24-01/A, Format 2), including standardisation of fishing gears. There are no provisions in the Rules of Procedure of the Scientific Committee and the Commission for partial implementation of CCAMLR conservation measures. She noted that the International Council for the Exploration of the Sea (ICES) working groups widely used standardisation of fishing gears and methods to implement multi-vessel survey and programs within the ICES area.

9.16 Dr Kasatkina noted that the 'new' fishery may be notified in East Antarctic (Divisions 58.4.1 and 58.4.2) according to CM 21-01, paragraph 1.

9.17 The Working Group noted that fishing has occurred in this area previously and the definition of what is considered a new fishery is the decision for the Commission.

9.18 The Working Group recalled that CM 24-01 Format 2, item 3.a, bullet 3 'Calibration/standardisation of sampling gear' could be misinterpreted (WG-FSA-2022, paragraph 3.134), however, the planned survey design allows for calibration across vessels and gears and therefore would fulfill this criterion. This type of survey design is similar to that carried out by ICES members where multiple vessels and gears are used and inter-calibration made possible by including some spatial overlap of vessel fishing locations within an area. The data from these multi-vessel research surveys are then combined using methods such as those developed by Thorson and Ward (2014), Berg et al. (2014) and Berg (2020) to provide a single index for inclusion into a stock assessment for management advice.

9.19 Most participants considered that there was no scientific rationale against this research proposal as nothing was presented and recalled from WG-FSA-2022, paragraph 5.35, that Dr Kasatkina agreed to present a paper to the Scientific Committee in 2023 to facilitate further discussions on scientific aspects of the regulatory framework.

Research results and proposals from Area 88

9.20 WG-SAM-2023/02 comprised a notification to continue research for *Dissostichus* spp. for the second year of a three-year research plan under CM 24-01, paragraph 3, and was not required to be reviewed by WG-SAM (CCAMLR-38, paragraph 5.64).

9.21 WG-SAM-2023/23 presented a progress report on research conducted in 2023 under CM 24-01 on *D. mawsoni* in Subarea 88.3 by the Republic of Korea and Ukraine. The report

noted CPUE variability between vessels and research blocks for both target and by-catch species (*D. mawsoni* and mainly *Macrourus* spp.).

9.22 The Working Group thanked the authors for this paper and noted the use of the generic family level code for *Macrourus* spp., with results showing that species identified at this family level mainly consisted of *M. caml* and that it was important to identify specimens to species when collecting biological data. It also noted the very informative species spatial distribution maps which may allow determination of the factors influencing the differences in their distributions. The Working Group advised that to facilitate further work on species-specific life histories and spatial distributions, that species-specific codes be used.

9.23 The Working Group welcomed the collection of *Macrourus* otoliths. Australia mentioned its work on developing an ageing reference set of grenadier otoliths which may provide a useful guide for this work.

9.24 The Working Group also noted that research block 883_5 was not fished owing to logistical reasons and encouraged the proponents to ensure that this block be surveyed next year.

9.25 The Working Group noted that the research plan in Subarea 88.3 intends to coordinate with the Domain 1 MPA proposal. Integrated spatial management in the Antarctic Peninsula area, including toothfish fisheries, will be progressed through the harmonisation symposium discussions currently occurring in an e-group and within the Scientific Committee.

9.26 WG-SAM-2023/04 presented a notification to continue research for *Dissostichus* spp. for the third year of a three-year research plan under CM 24-01, paragraph 3 in Subarea 88.3 by Korea and Ukraine, and was not required to be reviewed by WG-SAM (CCAMLR-38, paragraph 5.64).

Future work

10.1 The Working Group reviewed the current workplan (SC-CAMLR-41, Table 6) and adjusted the timing and collaborators associated with the current tasks (Table 1). It also added several new tasks generated from discussions during the meeting such as the impact of including non-randomly selected fish in the observer biological data forms (paragraph 5.6v), and analysis of factors that may influence tag release mortality (paragraph 11.3).

10.2 The Working Group discussed the potential for hybrid working group meetings in the future and noted that the Secretariat will be preparing a discussion paper on this subject for the Scientific Committee.

10.3 The Working Group noted that there was an increasing need within CCAMLR Members to improve and expand quantitative analytical capacity, especially in relation to developing stock assessments in CASAL and Casal2. The Working Group noted that although some mechanisms exist to support capacity development, such as the CCAMLR Scientific Scholarship Scheme, they do not cover mentor time or travel and that additional mechanisms could be developed. The Working Group encouraged Members to develop proposals for mechanism to address this important need for discussion by the Scientific Committee and the Standing Committee on Administration and Finance (SCAF).

Other business

11.1 The Working Group noted that two workshops had been held in 2023 that were relevant to its work: A workshop on the CCAMLR tagging program (WS-TAG-2023) and a workshop on age determination methods (WS-ADM-2023). Brief summaries were provided on relevant aspects of the workshops.

11.2 Dr Jones (Co-convener of WS-TAG-2023) summarised the outcomes of the joint COLTO–CCAMLR Workshop which aimed to develop best practices for tagging toothfish and skates, as well as mechanisms to maximise survival rates of released fish. The Workshop developed a tagging protocol, posters to help communicate the tagging protocol to those responsible for tagging, and the components of a tagging training manual. The report of the Workshop will be submitted to WG-FSA-2023 for review.

11.3 The Working Group noted that the Secretariat had compiled information about how vessels are configured for tagging, including aspects such as the height above sea level that fish are released, the distance fish are transported on deck and types of lifting aides used. The Working Group considered that this type of information could be useful to better understand tagging mortality and how it may vary among vessels. The Working Group agreed to include this analysis as a task in its workplan (Table 1).

11.4 The Working Group noted that information on vessel configuration relevant for tagging was not currently available for all toothfish vessels and recommended that the Scientific Committee consider requesting this important information be included in fishery notifications.

11.5 The Working Group noted that PSATs were also briefly discussed during the workshop. The Working Group agreed that it would be useful to have a focus topic/workshop on the use of PSATs and the analysis of PSATs data. The Working Group noted that Australia has recently collected video and other relevant information during a PSAT tagging experiment in Division 58.5.2.

11.6 Dr Devine (Co-convener of WS-ADM-2023) summarised the outcomes of the age determination methods workshop. Recommendations to WG-SAM included (see also paragraph 10.1):

(i) determine potential bias to stock assessments resulting from poor otolith readability scores

(ii) develop target levels of precision for age determination among readers or compared to reference sets (e.g. mean weighted coefficient of variation (CV)) to monitor and maintain consistency in age interpretation

(iii) determine the minimum level of double reading necessary to ensure consistency in age readings

(iv) determine minimum sample size of otoliths to read for the determination of age composition for stock assessments

(v) support the development of an otolith image reference collection, which would require an in-person age determination workshop to train and develop consistent age interpretation procedures.

11.7 The Working Group agreed with the workshop recommendation to hold an in-person workshop in early 2024 to progress this work, and that the workshop could potentially be hosted at the University of Colorado (Dr C. Brooks). Dr Devine agreed to develop terms of reference for discussion at WG-FSA-2023.

11.8 The Working Group noted that the database structure needed to store and utilise reference set data was a more immediate priority than that needed to store age data from multiple laboratories given that reference set comparisons were required to develop collaborative ageing programs, and that currently no stock assessments were using cross-laboratory age data.

Advice to the Scientific Committee

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

(i) vessel tagging configuration to be included in fishery notifications (paragraph 11.4)

(ii) tag-overlap statistic (paragraph 5.6).

Adoption of the report and close of the meeting

13.1 The report of the meeting was adopted.

13.2 At the close of the meeting, Dr Okuda and Dr Péron thanked the participants for their collaboration and coordination in completing the meeting. They thanked the rapporteurs and the Secretariat for their work and support in developing the report. They especially thanked the hosts and support team for their coordination with hotel shuttles, a site tour of the CMLRE facility, and the wonderful food and social gathering.

13.3 On behalf of the meeting participants, Dr Jones and Dr Somhlaba thanked the Co-conveners for their clear leadership, well organised and efficient planning and conducting of the meeting, and for the significant preparation and hard work.

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Table 1: Intersessional work plan for WG-SAM. Timeframe periods are: short = 1–2 years, medium = 3–5 years and long = 5+ years. Items tasked to WG-SAM from the Scientific Committee Strategic Plan (SC-CAMLR-41, Table 6). Numbers following level of urgency indicates the stated value in the box which replaced 'X', i.e. the year. CEMP – CCAMLR Ecosystem Monitoring Program, MSE – management strategy evaluation, SISO – Scheme of International Scientific Observation.

Theme	Priority research topic	Timeframe			Contributors	Secretariat participation
		Global	2024	2025		
1. Target species	(a) Develop methods to estimate biomass for krill (iii) Data collection – SISO and vessels and CEMP Task 1: Effective sampling to estimate length-frequency distribution	short	X		Dr Robson, Dr Kawaguchi	
	(b) Develop stock assessments to implement decision rules for krill Task 2: Development of integrated stock assessment for krill	medium	X	X	Mr Mardones, Dr Watters	
	(c) Develop methods to estimate biomass for finfish (i) Survey design Task 3: Gear standardisation – tagging program	short	X	X	Dr Péron, Dr Masere, Dr Kasatkina	Yes
	(ii) Data collection – SISO and vessels Task 4: Metrics of vessel tagging performance	short	X	X	Dr Péron, Dr Masere, Mr Dunn, Dr Hoyle	Yes
	Task 5: Recording selection of non-random biological data	medium	X	X	Mr Gasco, Dr Massiot-Granier	Yes
	Conversion factors Task 6: Develop protocol for conversion factors	short	X		Mr Gasco, Dr Massiot-Granier, Mr Walker	Yes
	(iii) Improve biomass estimation methods Task 7: Optimise tag-based study (spatial overlap)	medium	X	X	Dr Masere, Dr Péron, Dr Devine	
	Task 8: Vessel configuration factors affecting tagging mortality	medium	X	X	Dr Devine	Yes
	(iv) Data for stock assessment (1) Age Reading					

(continued)

Table 1 (continued)

Theme	Priority research topic	Timeframe			Contributors	Secretariat participation
		Global	2024	2025		
	Task 9: Determine bias of poor otolith readability	short	X		Dr Devine, Dr Quiroz, Mr Sarralde	
	Task 10: Develop target precision levels for ageing	short	X		Dr Devine, Dr Quiroz, Mr Sarralde	
	Task 11: Determine minimum double reading level for ageing	short	X		Dr Devine, Dr Quiroz, Mr Sarralde	
	Task 12: Determine minimum otolith sample size for age composition	short	X		Dr Devine, Dr Quiroz, Mr Sarralde	
	Task 13: Build an otolith image reference collection – In-person ageing workshop	short	X		Dr Devine, Dr Quiroz, Mr Sarralde	Yes
	(d) Develop stock assessments to implement decision rules for finfish					
	(i) Research to develop new assessments					
	(1) Research plan evaluations:					
	Task 14: Research plan assessment	short			WG-SAM	
	48.2 Icefish		X	X		
	48.6 Antarctic toothfish		X			
	58.4.1–58.4.2 Antarctic toothfish		X	X		
	88.1 shelf survey Antarctic toothfish		X	X		
	88.3 Antarctic toothfish		X			
	(e) Management strategy evaluations for target species (Second Performance Review, Recommendation 8)					
	(i) Evaluation of the CCAMLR decision rules and potential alternative harvest control rules for assessed fisheries:					
	Task 15: Develop and agree on an operating model	medium	X	X	Dr Ziegler, Mr Dunn, Dr Massiot-Granier, Dr Earl, Mr Somhlaba	Yes
	Task 16: MSE	medium	X	X		Yes

(continued)

Table 1 (continued)

Theme		Priority research topic	Timeframe			Contributors	Secretariat participation
			Global	2024	2025		
		(ii) Development and testing of data-limited fishery decision rules					
		Task 17: Develop and agree on an operating model	medium	X	X	Dr Ziegler, Mr Dunn, Dr Massiot-Granier, Dr Earl, Mr Somhlaba	Yes
		Task 18: MSE (WG-FSA-2022/53, WG-FSA-2022, paragraph 4.67)	medium	X	X		Yes
		(iii) Finfish management strategies that are robust to climate change					
2. Ecosystem impacts	(a)	Ecosystem monitoring (Second Performance Review, Recommendation 5) Structured ecosystem monitoring programs (CEMP, fishery) Task 19: effective sample size for fish by-catch monitoring in the krill fishery	medium	X	X	Dr Jones	
3. Adminis-trative topics	(e)	Communication of progress, internal and external: Task 20: Diagnostic graphs on stock status	short	X	X	Stock assessors	

Table 2: Template for a table of annual cycle for determining time steps in Casal2 models. AF – age frequency; LF – length frequency; CPUE – catch per unit effort.

Month	Catch (%)		Biological processes							Observations				Assigned time step
	Actual	Assumed	Ageing	Recruitment	Maturation	Growth (%)	Natural mortality	Spawning	Tag release	Tag recapture	Surveys	AFs/LFs	CPUE	
Year start														
Nov														
Dec														
Jan														
Feb														
Mar														
Apr														
May														
Jun														
Jul														
Aug														
Sep														
Oct														
Year end														
Total	100	100												

Appendix A

List of Participants

Working Group on Statistics, Assessments and Modelling
(Kochi, India, 26 to 30 June 2023)

Co-conveners	Dr Clara Péron Muséum national d'Histoire naturelle
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CCAMLR Secretariat	Dr Steve Parker Science Manager
	Dr Stephane Thanassekos Fisheries and Ecosystems Analyst

Appendix B

Agenda

Working Group on Statistics, Assessments and Modelling
(Kochi, India, 26 to 30 June 2023)

1. Introduction

    1.1 Opening of the meeting
    1.2 Adoption of the Agenda

2. Review of the terms of reference and workplan

3. Development of methods to estimate biomass for krill

    3.1 Data collection needs and standards
        3.1.1 Effective sampling to estimate length frequency distribution

4. Develop stock assessments to implement decision rules for krill

    4.1 Development of integrated stock assessment for krill

5. Develop methods to estimate biomass for finfish

    5.1 Research plan design
        5.1.1 Gear standardisation effects on toothfish tagging program
        5.1.2 Development of toolbox for research plan design

    5.2 Data collection needs
        5.2.1 Develop protocol for toothfish conversion factor sampling
        5.2.2 Tag recapture reconciliation issues

6. Develop stock assessments to implement decision rules for finfish

    6.1 Develop new methods for stock assessments
    6.2 Draft integrated stock assessments in Casal2
    6.3 Trend analysis rule development
    6.4 Diagnostic summaries of stock status

7. Management strategy evaluations for target species

    7.1 Evaluation of the CCAMLR decision rules and potential alternative harvest control rules for assessed fisheries
        7.1.1 Development of an operating model
        7.1.2 Management strategy evaluation (MSE)
            7.1.2.1 Develop operating model for data-limited toothfish fisheries

8. Review of new research proposals

    8.1 New proposals under CM 21-02
    8.2 New proposals under CM 24-01

9. Review of ongoing research plan results and proposals

    9.1 Research results and proposals from Area 48
    9.2 Research results and proposals from Area 58
    9.3 Research results and proposals from Area 88

10. Ecosystem monitoring

    10.1 Structured ecosystem monitoring programs
    10.2 Effective sample size for fish bycatch monitoring in the krill fishery

11. Future work

12. Other business

13. Advice to the Scientific Committee

14. Adoption of report and close of meeting.

Appendix C

List of Documents

Working Group on Statistics, Assessments and Modelling
(Kochi, India, 26 to 30 June 2023)

WG-SAM-2023/01 Rev. 1	Continuation of the Research on Antarctic toothfish (*Dissostichus mawsoni*) in Statistical Subarea 48.6 in 2023/24 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-SAM-2023/02	Notification for the Ross Sea shelf survey in 2024: second year of an approved three-year research plan. Research plan under CM 24-01, paragraph 3 – Continuing Research Delegation of New Zealand
WG-SAM-2023/03	Continuing research in the *Dissostichus mawsoni* exploratory fishery in East Antarctica (Divisions 58.4.1 and 58.4.2) from 2022/23 to 2025/26; Research plan under CM21-02, paragraph 6(iii) Delegations of Australia, France, Japan, Republic of Korea and Spain
WG-SAM-2023/04	Continuing research plan for *Dissostichus* spp. under CM 24-01, paragraph 3, in Subarea 88.3 by Korea and Ukraine from 202122 to 202324 (Notification ID 120784) Delegations of Korea and Ukraine
WG-SAM-2023/05	New Fishery Research Proposal Plan for *Dissostichus* spp. under CM 24-01, paragraph 3, Subarea 48.2 during season 2023/24 – 2025/26 Delegation of Chile
WG-SAM-2023/06 Rev. 1	New fishery research proposal under CM 24-01, paragraph 3, to continue the acoustic-trawl survey *Champsocephalus gunnari* in Statistical Subarea 48.2 for 2024 and 2025 Delegation of Ukraine
WG-SAM-2023/07	Notificación de intención de participar en la pesquería exploratoria de *Dissostichus* spp. en la subárea 48.6 de la CCRVMA durante la temporada 2023/24
WG-SAM-2023/08	Parameter transformations and alternative algorithms in Casal2 models A. Dunn and A. Grüss

WG-SAM-2023/09	An update of tag loss rates for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea J.A. Devine
WG-SAM-2023/10	Evaluation of the impacts of using a double tag loss rate function and changing the time at liberty in the assessment of Ross Sea region Antarctic toothfish (*Dissostichus mawsoni*) A. Dunn and A. Grüss
WG-SAM-2023/11	Development of methods to use age-based tag-release and tag-recapture data in the assessment model of Ross Sea region Antarctic toothfish (*Dissostichus mawsoni*) A. Grüss, S. Mormede, A. Dunn and J.A. Devine
WG-SAM-2023/12	Summary of progress on the recommendations of the Independent Stock Assessment Review for Toothfish (2018) for the Ross Sea A. Dunn and J.A. Devine
WG-SAM-2023/13	Risk assessment for the Antarctic starry skate (*Amblyraja georgiana*) in the Ross Sea B. Finucci, J.A. Devine, S.J. Holmes and M.H. Pinkerton
WG-SAM-2023/14	A generalised additive mixed modelling framework to determine the probability that a sampled macrourid is either *Macrourus caml* or *M. whitsoni* in the Ross Sea region: Methods and preliminary results B.R. Moore, A. Grüss and M.H. Pinkerton
WG-SAM-2023/15	Comparison of growth estimation methods for Patagonian toothfish in South Georgia (Subarea 48.3) J.E. Marsh, T. Earl, P. Hollyman and C. Darby
WG-SAM-2023/16	2023 provisional trend analysis: preliminary estimates of toothfish biomass in research blocks Secretariat
WG-SAM-2023/17	A proposed agent-based modelling framework to support management strategy evaluations S. Thanassekos
WG-SAM-2023/18	Tag-overlap statistic calculation method Secretariat
WG-SAM-2023/19	On the issue of gear selectivity in relation to krill in the current CCAMLR topics S. Sergeev and S. Kasatkina

WG-SAM-2023/20	Comparison of outputs from integrated stock assessments using CASAL and Casal2 for the 2021 Patagonian toothfish (*Dissostichus eleginoides*) fishery at Heard Island and McDonald Islands (HIMI) C. Masere and P. Ziegler
WG-SAM-2023/21	Tentative research topics to contribute to the research on *Dissostichus mawsoni* in Subarea 48.6 from 2024/25 to 2026/27; Research plan under CM21-02, paragraph 6(iii) Delegation of the Republic of Korea
WG-SAM-2023/22	Progress report of the acoustic trawl survey *Champsocephalus gunnari* in Statistical Subarea 48.2 in 2023 Delegation of Ukraine
WG-SAM-2023/23	Progress report on the joint research for *Dissostichus* spp. in Subarea 88.3 by the Republic of Korea and Ukraine in 2023 Delegations of the Republic of Korea and Ukraine
WG-SAM-2023/24	2023 updated analysis of the sea-ice concentration in research blocks 4(RB4) and 5(RB5) of Subarea 48.6 with sea-surface temperature and winds and statistical analysis of repeated accessibility T. Namba, R. Sarralde, K Teschke, H. Pehlke, T. Brey, S. Hain, T. Okuda, S. Somhlaba and J. Pompert
WG-SAM-2023/25	Casal2 assessment for Antarctic krill in Subarea 48.1: a pilot model D. Kinzey and G.M. Watters
Other documents	
WG-SAM-2022/27	Methodical aspects of measuring the selectivity of gears in krill fishery S. Sergeev and S. Kasatkina

Appendix D

Update on Table 3 of SC-CAMLR-38, Annex 7, showing progress since the 2018 Independent Stock Assessment Review for Toothfish

Table 1: Progress since the 2018 Independent Stock Assessment Review for Toothfish.

	Review Panel (RP) comments 2018	Progress to date
Documentation		
1.	It is recommended that a standardised format be developed by CCAMLR for the presentation of details of assessments to facilitate understanding of the assumptions, data preparation and inputs, parameter estimation and results across the assessments performed by CCAMLR, and that a public summary document with these details be developed and updated at a fixed period (e.g. five years).	WG-FSA-2019/08, WG-SAM-2019/35, WG-SAM-2021/14, WG-FSA-2021/24, WG-FSA-2021/26, WG-SAM-2022/14, WG-SAM-2023/08, WG-SAM-2023/10, WG-SAM-2023 Casal2 Development Team 2023 Fishery summary 2022, Species description 2022, Fishery report 2022, Stock assessment 2022 and Stock annex 2022, CCAMLR Secretariat, 2023 https://fisheryreports.ccamlr.org/
Stock hypotheses		
2.	A number of assessments described the proposed stock hypotheses and described ideas for future work. The RP suggests that appropriate experts be consulted, and a review be planned if these assessments or CCAMLR require evaluation of the hypotheses.	WG-FSA-2019/32, WG-FSA-2019/36, WG-FSA-2019/59, WG-FSA-2019/61, WG-FSA-2019/P01, WG-FSA-2021/21 Parker et al., 2019, 2021 Behrens et al., 2021 Maschette et al., 2023
Surveys		
3.	Where possible, such surveys should be continued and optimised to ensure recruitment variability can be detected.	WG-SAM-2019/03, WG-FSA-2019/03, WG-FSA-2019/20, WG-FSA-2019/08, WG-FSA-2021/12, WG-FSA-2021/19, WG-SAM-2022/01 Rev. 1, WG-FSA-2022/07, WG-FSA-2022/09, WG-SAM-2023/20, WG-SAM-2022/13, WG-FSA-2023/xx (RSSS results)
4.	Subareas 88.1/88.2 – Consideration should be given to restricting the data from the survey to be more representative of recruitment.	WG-FSA-2019/08
5.	Subareas 88.1/88.2 – Consideration should be given to designing the [Ross Sea shelf] survey to take this into consideration or increasing the catch limit, so that the unused catch limit can be released after the survey, or by releasing excess fish, etc.	WG-SAM-2022/01 Rev. 1 SC-CAMLR-41, paragraph 3.138
6.	Division 58.5.2 – a more appropriate approach to fitting the survey might be to fit the index-at-age data using a multivariate likelihood function and the empirical variance-covariance matrix.	

(continued)

Table 1 (continued)

	Review Panel (RP) comments 2018	Progress to date
Ageing		
7.	In some cases, just a single experienced reader has been used. The RP suggests that, where possible, increasing the number of readers to a minimum of two experienced readers, within laboratories, would be beneficial.	WG-FSA-2019/32, WG-FSA-2019/28, WG-FSA-2019/29, WG-FSA-2023/xx (RSSS results) CCAMLR Ageing Workshop
8.	It would be interesting to investigate how smoothing the age–length key (ALK) matrix (by applying a kernel or using some sort of spline function) would affect the stock assessment.	WG-SAM-2022/49
Growth		
9.	The RP suggests that all SAs implement methods to account for these potential biases in fitting Von Bertalanffy relationship growth curves.	WG-FSA-2019/11, WG-FSA-2019/32, WG-SAM-2022/21, WG-SAM-2022/24, WG-FSA-2022/59, WG-SAM-2023/15
10.	Additionally, investigation of the impact of errors in ageing on the VB by the SA scientists have shown that the fit is robust to this error. The RP suggests that this be investigated occasionally to ensure that no biases occur.	WG-FSA-2019/11
11.	Because changing the VB can affect the calculated virgin biomass, and thus the depletion estimates, the RP suggests that the SA scientists explore whether the fitted VB in these cases is sufficiently precautionary.	WG-FSA-2019/32, WG-FSA-2019/11, WG-FSA-2019/08, WG-SAM-2019/32, WG-SAM-2023/08
12.	The RP also suggests that the SA scientists investigate the use of other growth curves that may exhibit better properties in regard to the data. A more flexible curve might produce a more realistic fit.	WG-FSA-2019/11, WG-SAM-2019/32, WG-FSA-2019/08
13.	The RP recommends that sensitivity analyses be used to assess the impact of the different choices of the growth model on stock assessment results and on biological reference points.	WG-FSA-2019/11, WG-FSA-2019/08, WG-SAM-2019/32
14.	Potential changes in growth rates and fishery selectivity will influence tag-recapture rates, particularly due to the dome-shaped selectivity of these fisheries. The RP also recommends that more flexible growth curves be investigated.	WG-FSA-2019/08, WG-FSA-2021/26
15.	The RP recommends that the use of ALKs be investigated to estimate the age composition of tagged fish released as an input to the assessment models for all the toothfish stocks, instead of the current approach.	WG-SAM-2023/11 Casal2 Development Team 2023

(continued)

Table 1 (continued)

	Review Panel (RP) comments 2018	Progress to date
Data weighting		
16.	The RP recommends that data weighting methods for tagging data should be further investigated. For example, consideration should be given to using data weighting methods based on the average time at liberty.	WG-FSA-2019/08
Tag loss		
17.	The RP suggests that it is timely to update this analysis for Subareas 48.3 and 48.4 and Subarea 88.1 and small-scale research units (SSRUs) 882A–B stocks based on more recent information that may include fish with a longer time at liberty. Changes in tag-loss rates should be investigated. Information on the uncertainty involved in the estimation should be provided.	WG-SAM-2022/17, WG-SAM-2023/09, WG-SAM-2023/10
Initial tagging mortality		
18.	The RP encourages future research on the estimation of initial tagging mortality rates, and factors that may cause this to vary.	WG-FSA-2023/xx (Tagging Workshop)
Tag detection		
19.	The RP encourages future research on the estimation of tag detection rates, and factors that may cause this to vary.	WG-FSA-2023/xx (Tagging Workshop)
20.	The RP recommends that implementation of good tagging protocols (release and recapture) be encouraged for all vessels involved in these fisheries.	WG-FSA-2019/15, SC-CAMLR-38/01, WG-FSA-2023/xx (Tagging Workshop)
Time at liberty truncation		
21.	Tagging data was limited to recapture years-at-liberty less than four for Division 58.5.2 (although data exist for up to six years at liberty)* and Subarea 48.3 and Subarea 48.4 assessments, but six years at liberty for Subarea 88.1 and SSRUs 882A–B assessments. The RP recommends further investigation of this issue.	WG-FSA-2019/32, WG-SAM-2023/10
Selectivity		
22.	The spatial distribution of the fleets has changed over time, particularly in the early years of the fisheries and in Subarea 88.1 and SSRUs 882A–B and temporal changes in selectivity should be considered.	WG-FSA-2019/08, WG-SAM-2023/11

(continued)

Table 1 (continued)

	Review Panel (RP) comments 2018	Progress to date
Natural mortality		
23.	The RP recommends that consideration should be given to estimating age-specific natural mortality rates using a functional form with few parameters and sex-specific natural mortality rates. Simulation analysis should be conducted to determine in what circumstances natural mortality rates can be reliably estimated.	WG-FSA-2019/32, WG-SAM-2019/04, WG-FSA-2019/08
Recruitment standard deviation		
24.	The RP recommends that consideration should be given to adjusting the penalty for years in which there is incomplete information about year-class strength.	WG-SAM-2023/08
Sex structure		
25.	The RP suggests that a more thorough evaluation is needed on the necessity of sex. If it is concluded that a sex-structured model is appropriate, all the data collection programs need to be modified to collect the appropriate sex information.	WG-FSA-2021/26
Diagnostics		
26.	A standard set of diagnostic plots across the assessments covering important and sensitive parameters is encouraged to be included in each stock assessment.	WG-FSA-2019/32, WG-FSA-2019/10, WG-FSA-2019/28, WG-FSA-2019/29 WG-FSA-2019/08, WG-FSA-2021/21, WG-SAM-2022/14, WG-SAM-2023/08 Casal2 Development Team 2023

*Erratum: Tagging data used for Division 58.5.2 stock assessment was limited to recapture years-at-liberty less than six and not four.

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Maschette, D., S. Wotherspoon, A. Polanowski, B. Deagle, D. Welsford and P. Ziegler. 2023. Circumpolar sampling reveals high genetic connectivity of Antarctic toothfish across their spatial distribution. *Rev. Fish. Biol. Fisheries*, 33: 295–310, doi: https://doi.org/10.1007/s11160-023-09756-9.

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