Center for Independent Experts (CIE) Independent Peer Review Report

On

CCAMLR Toothfish Stock Assessments

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I. Executive Summary

The External Independent Peer Review for the 2021 CCAMLR Toothfish Stock Assessments was conducted on August 4, 15, 16 and 17, 2023 (US EST). The three Toothfish Stock Assessment Teams (TSAT) were responsible for preparing documents and delivering presentations to provide relevant information on the history of fisheries and management, monitoring and tagging-recapture programs, fishery-dependent and fishery-independent data and biological data for stock assessment, stock assessment models, reference points and stock status, and projection for the following four stocks: Patagonian toothfish (*D. eleginoides*) stocks in Subarea 48.3 (South George), Subarea 48.4 (South Sandwich Islands) and Division 58.5.2 (Heard Island and the McDonald Islands); and Antarctic toothfish (*D. mawsoni*) in Subarea 88.1 and 88.2 (Ross Sea). The TSATs prepared their presentations to address all Terms of Reference pre-defined for this review. Both the TSATs and fisheries managers provided valuable discussion and insights. The TSAT were open to suggestions and provided additional information upon request. The whole review process was open and constructive. The CCAMLR Secretariat made all documentation available to the Review Panel and provided logistical support.

The Review was conducted based on a set of predefined Terms of Reference, aimed at evaluating the implementation of research recommendations that were a result of the 2018 independent review, fisheries-dependent and fisheries-independent data quality and quantity, stock assessment model configuration and parameterization, stock assessment outputs, model projection, catch advice, alternative approaches, and uncertainty associated with the assessments. The Review also determined if each of the ToRs was adequately addressed, if the stock assessments were appropriate, represented the best available science, and were adequate for providing management advice. Additionally, the review also made recommendations to improve both the stock assessment modeling and process.

Using fisheries-independent, fisheries-dependent and tagging-recapture data, as well as compiled key life history information, the TSATs conducted an extensive analysis to evaluate various model configurations using the CASAL model for each stock assessment. A base CASAL model was developed for each stock, and various sensitivity runs were also conducted to evaluate uncertainties associated with the model assumptions, input data, and alternative model configurations. The base model was used to provide estimates of stock biomass, fishing mortality, recruitment, and biological reference points. Additionally, the base model was employed to make stock projections and to provide catch advice. As a CIE reviewer, I am charged to evaluate the CCAMLR Toothfish Stock Assessments with respect to the Terms of Reference I was provided.

Overall, I conclude that the TSATs have done a good job in developing and parameterizing the CASAL stock assessment models for the four stocks reviewed by the Panel. In the stock assessment documents, key input data and their statistical properties are defined with justifications. Various sensitivity runs were developed to evaluate the impacts of major sources of uncertainty on the estimation of key population statistics, including stock biomass, exploitation, and recruitment. I would like to commend the three TSATs for their work. I was impressed by the breadth of expertise in the review; the amount of effort invested in developing and improving historical fisheries data in addition to compiling all the input data for the assessment; the consideration of plausible scenarios; the open discourse on stock assessment uncertainty; the discussion of alternative approaches and suggestions; and the constructive dialogues among the TSATs, the Review Panel, and other participants during the review.

Based on the stock assessments presented and the materials provided, I believe that the TSATs have adequately addressed the ToRs. The stock assessment modeling framework used in the four assessments is cutting edge and takes advantage of the available data from many different sources, including fishery-dependent and fishery-independent data, life history parameters, and tagging-recapture data. The quality control process and data filtering procedure were developed and applied to all the data before being inputted into the assessment models. The alternative values for many key life history parameters were evaluated and considered in the sensitivity analysis. For all four toothfish stocks, the integration of all of the data in the assessment provides a parsimonious view of the stock status and represents the best available information on the population dynamics. The analyses suggest that the stock assessment results are rather robust with regard to the uncertainty in stock assessments for Subarea 48.3 (South George), Subarea 48.4 (South Sandwich Islands), Division 58.5.2 (Heard Island and the McDonald Islands), and the Antarctic toothfish in Subarea 88.1 and 88.2 (Ross Sea). I conclude that the assessments are scientifically sound, yield the best available information, and adequately address management needs.

I also reviewed the alternative assessment approach based on historical length composition and maturation data proposed for Subarea 48.3, and compared the approach with the CASAL-based assessment. Based upon this review, I conclude that the alternative approach is unable to adequately capture the population dynamics, does not represent the best available science, and is inadequate to provide catch advice for the management of the Subarea 48.3 toothfish stock.

However, the current assessment and review process still has room for improvement. The stock assessment documentations can be greatly improved to combine working papers (rather than cross-referencing them, which is harder to track). Protocols for developing the base model and sensitivity runs with their justifications should be explicitly documented to ensure the transparency of the assessment process. For each stock assessment, major biological and statistical assumptions in the assessment, explicit and implicit, should be listed in a summary table. Retrospective analysis (within the model) should be conducted for each assessment, and retrospective errors should be quantified (i.e., using Mohn's rho) for the estimation of SSB, fishing mortality, and recruitment. Possible adjustment of retrospective errors should be evaluated using the existing best practice guidelines (e.g., Legault 2009). The impacts of possible retrospective errors on the stock status determination and projection should be evaluated and considered in developing catch advice.

For stocks with possible mixing and sex-specific life history and fishery (e.g., Subareas 48.3 and 48.4), sex-specific and/or spatially explicit assessment models (e.g., the two box model) should be considered. The tagging-recapture data play an important role in assessing the toothfish stock dynamics because of very low fishing mortality rates in these fisheries (which provides less information for determining the stock size scale in the assessment), and current tagging-recapture programs should continue to be conducted, with a careful evaluation of the impact of possible changes in toothfish spatial distribution dynamics on tagging-recapture. The potential consequence of climate-induced change in the ecosystem on key life history parameters and habitat (and spatial distributions and carry capacity) should be carefully evaluated for the Patagonia toothfish in Subareas 48.3 and 48.4 and Division 58.5.2, and Antarctic toothfish in Subareas 88.1 and 88.2 (Ross Sea).

My detailed research recommendations to improve the future toothfish stock assessments can be found under ToR 7 and in the section of Conclusions and Recommendations.

II. Background

The two main species of toothfish, Patagonian toothfish (*D. eleginoides*) and Antarctic toothfish (*D. mawsoni*), are large nototheniids endemic to Antarctic and sub-Antarctic waters. Their distribution is circumpolar, although Antarctic toothfish are more prevalent in southern latitudes beyond the Antarctic Convergence. Within the Ross Sea region, Patagonian toothfish are typically only found in the north-west, while Antarctic toothfish dominate the rest of the region.

Patagonian toothfish and Antarctic toothfish support various licensed fisheries in the Southern Ocean. These fisheries mainly use bottom-set longlines at depths spanning from 1200 to 1800 m. These species may also be caught by trawl and pot in relatively shallow waters. There are currently 13 licensed fisheries currently targeting toothfish in CCAMLR Areas 48, 58 and 88, including seven exploratory fisheries. These fisheries are reviewed annually by CCAMLR's Working Group on Fish Stock Assessment and the Scientific Committee. This review covers Patagonian toothfish in Subarea 48.3 (South George), Subarea 48.4 (South Sandwich Islands), Division 58.5.2 (Heard Island and the McDonald Islands), and Antarctic toothfish in Subarea 88.1 and 88.2 (Ross Sea).

This review is a Center for Independent Experts (CIE) review for the CCAMLR Toothfish Stock Assessments. I was provided with all of the necessary assessment reports, logistics support, documentation, and background information. The Review Panel was composed of three scientists selected by the CIE. The Review Panel was chaired by Dr. Dirk Welsford, the Chair of the CCAMLR Scientific Committee, and assisted by Dr. Steve Parker, the Science Manager of CCAMLR.

Stock assessment documentation was prepared by three Toothfish Stock Assessment Teams (TSAT), responsible for assessing toothfish in the CCAMLR Subareas 48 (48.3, and 48.4), 58.5.2, and 88 (88.1 and 88.2). All three TSATs were open to suggestions, provided additional information upon request, and engaged in collegial discussion. The whole process was open and constructive.

As a CIE reviewer, I am charged to evaluate the CCAMLR Toothfish Stock Assessment for Subarea 48.3 (South George), Subarea 48.4 (South Sandwich Islands), Division 58.5.2 (Heard Island and the McDonald Islands), and Subarea 88.1 and 88.2 (Ross Sea) with respect to a set of pre-defined Terms of Reference. This report includes an executive summary (Section I), a background introduction (Section II), a description of my role in the review activities (Section III), my comments on each item listed in the Terms of Reference (ToRs, Section IV), a summary of my comments and recommendations (Section V), and references (Section VI). The final part of this report (Section VII) includes a collection of appendices, including the Performance Work Statement.

III. Description of the Individual Reviewer's Role in the Review Activities

My role as a CIE independent reviewer was to conduct an impartial and independent peer review of the CCAMLR Toothfish Stock Assessments. This review encompassed Patagonia toothfish in Subarea 48.3 (South George), Subarea 48.4 (South Sandwich Islands), and Division 58.5.2 (Heard Island and the McDonald Islands), as well as Antarctic toothfish in Subarea 88.1 and 88.2 (Ross Sea) with respect to the defined Terms of Reference.

Prior to the meeting, assessment documents were made available to me through a google folder (https://drive.google.com/drive/u/1/folders/1duIE9HH6tP1-xI245qLSjgEd79fYiWQY). At

the beginning of the review, the Panel reviewed and discussed the meeting agenda, reporting requirements, meeting logistics and overall process. Additional information and all presentation slides were provided during the review.

I reviewed all relevant reports, background information papers and reports, and other relevant documents (e.g., the 2018 Independent Review Reports) that were sent to me (see the list in Appendix I). I also researched and organized references relevant to the topics covered in the reports and the Performance Work Statement (PWS) prior to the online review, and prepared for my questions and discussions.

The review was held from August 3, 15, 16 and 17, 2023 (US EST) via Zoom (see Appendix II for the schedule). The three Toothfish Stock Assessment Teams (TSATs) made the presentations to provide relevant information on the history of fisheries and management, monitoring programs and relevant research programs for the following four stocks: Patagonian toothfish stocks in Subarea 48.3 (South George), Subarea 48.4 (South Sandwich Islands), and Division 58.5.2 (Heard Island and the McDonald Islands), in addition to Antarctic toothfish in Subarea 88.1 and 88.2 (Ross Sea). The TSATs prepared their presentations to address all Terms of Reference pre-defined for this review. The TSAT and fisheries managers provided valuable discussion and insights. The four days of review were chaired by Dr. Dirk Welsford (Chair of the CCAMLR Scientific Committee) and attended by the TSAT scientists, CCAMLR staff, three CIE reviewers, and other stakeholders (see the List of Participant in Appendix III).

Presentations were given during the Review on stock assessment input data, information on model configuration and parameterization, management, stock assessment modeling outputs and results, reference points and stock status determination, and model projections (see the list of presentations in Appendix I). I was actively involved in the discussion during the review by (1) asking for clarification on data quality and quantity, statistical analyses, stock assessment models, model configuration, assumptions, projections, and uncertainties of various sources and interpretations; (2) commenting on the assessment and review processes; and (3) providing constructive comments and suggestions for alternative approaches and additional analyses. I had also been interacting with relevant scientists and other panel members regarding issues raised during the review process for further clarification and discussion during the review.

IV. Summary of Findings

My detailed comments on each TOR are provided under their respective subtitles (see below).

TOR 1. Reviewing the status and report on the implementation of the recommendations arising from the CCAMLR Independent Stock Assessment Review for Toothfish in 2018 (SC-CAMLR-XXXVII/02 Rev. 1, and SC-CAMLR-XXXVII, Annex 9, Table 3).

This TOR was adequately addressed. Each TSAT prepared a summary of their implementations based on the recommendations made by the CCAMLR Independent Stock Assessment Review for Toothfish in 2018. Most recommendations have been adequately addressed, and some recommendations for the long-term research are currently under way.

The 2018 CCAMLR Independent Review Panel made a long list of recommendations for improving model configurations, model fitting and diagnostics, research recommendations, and the quality and quantity of input data and life history and biological parameters. Some of these recommendations are stock specific and some are general, applicable to all stocks. Many

recommendations have been implemented, leading to improved understanding of uncertainty in various sources in the assessment and better quantification of stock assessment uncertainty.

However, I believe a "precautionary" approach or principle should not be used when advising research. The precautionary approach should be considered by managers when they consider addressing the "scientific uncertainty" in developing management regulations. Scientific research should develop the best available information to inform decision-making. There should not be "bad uncertainty" or "good uncertainty".

In general, all TSATs followed the recommendations for better documentation and better presentations. However, I believe there are too many working papers cited in the assessment, which makes it difficult to keep track of references. A more comprehensive report including all aspects of stock assessments should be compiled. I also believe better documentation is needed to explicitly describe the protocol used to develop the base model and sensitivity analyses with justifications. Currently the protocol for developing the base model and sensitivity scenarios is not clearly defined. It is not easy to evaluate if major sources of uncertainty were evaluated with current documentation. There is also a need to summarize the major implicit and explicit biological and statistical assumptions made in each assessment. Any effort put toward improving the documentation will make the stock assessment process more transparent and understandable.

For each specific stock included in this review, my comments for this TOR are below.

<u>Subarea 48.3 Patagonia toothfish</u>
I believe the TSAT has done an excellent job in summarizing the work that has been done to implement the recommendations made by the 2018 CCAMLR Independent Stock Assessment Review Panel. A few items are still under way, including the development of CASAL 2. More ageing work has been done, which greatly improved the age composition data. Historical data and tagging-recapture data were evaluated and reanalyzed to better reflect the changes in the fishing fleet. The stock assessment appears to be improved after the implementation of research recommendations.

<u>Subarea 48.4 Patagonia toothfish</u>
Some of the information used in the assessment of this stock was obtained from other stocks (mainly from Subarea 48.3). Studies are still needed to evaluate the suitability of borrowing information from other stocks. There appears to be an issue in the time steps used in the assessment of this stock. It is good to hear that research effort is currently under way to align the time steps used in the assessment with the seasonality of the fishery and life history processes for this stock. It is also good to see that research effort is under way with regards to considering the possible movement of toothfish between Subareas 48.3 and 48.4.

<u>Division 58.5.2 (HIMI) Patagonia toothfish</u>
The TSAT has implemented most of the suggested research recommendations. As a result, the input data and stock assessment have been greatly improved.

<u>ROSS SEA Antarctic toothfish</u>
Since 2018, following CCAMLR Independent Review Panel recommendations, improvements have been made in estimating tagging survival and detection rates, increasing sampling efforts for biological data (e.g., ageing data), estimating life history parameters, and revising estimates of tag loss parameters. As a result, the stock assessment has improved. The most recent assessment is also able to estimate potential impacts of the MPA under 3 alternative effort scenarios.

TOR 2. Reviewing if biological parameters used in the assessment models are estimated using best available science and appropriately used in the stock assessment models:

Overall, I am impressed by the TSATs effort to continue improving the estimation of biological parameters used in the assessment models. Their improvements included spatial and temporal coverage of sampling efforts for biological data (e.g., size composition, more otolith samples for ageing, and observers program), ageing more historical samples to improve growth estimation, and explore alternative approaches to estimate biological parameters such as growth, natural mortality, length-weight relationship, and size-dependent maturation. I conclude that this TOR has been adequately addressed, with biological parameters being estimated using the best available science and appropriately applied in stock assessment models.

a. Sex-specific maturation: While there is limited evidence of elapsing spawning, collecting spawning individuals to examine the elapsing spawning is difficult. For the logistic relationship between fish size and maturation, an implicit assumption is that physiological maturity is the same as functional maturity. There is no evidence that egg sizes (and thus quality) are related to spawner sizes. There is evidence of sex-specific differences in life history parameters.

b. Natural mortality: The TSATs explored various approaches for estimating natural mortality. For all four stocks, natural mortality is estimated externally and used as a fixed value in the assessment. There is no consideration of possible interactions between natural mortality and stock-recruitment steepness (often highly negatively correlated) when either natural mortality or steepness was set.

c. Length-weight relationship: the relationship was estimated for each stock, and there is limited research to suggest that this relationship is rather consistent over time. Given the changing ecosystem in the study area, it is likely that the toothfish condition may change, which may result in changes in the length-weight relationship. Thus, a close evaluation of possible temporal changes in the length-weight relationship is recommended.

d. Growth: The growth of all four stocks is described by the von Bertalanffy growth function. The model parameters were estimated externally and used as fixed input parameters. The lack of small/young fish may influence the estimation of growth parameters (e.g., to), but I do not expect this would alter stock assessment results. Possible temporal variation in growth is unclear, but would probably need to be monitored closely given the changing ecosystem. Evaluating possible spatial variations within a stock could also be valuable, given the toothfish do not tend to move and mix well in the stock. Such an understanding of spatial variations can help inform sampling effort to collect otoliths and length data so that the final length at age data have good spatial coverage and representation, and that the growth model is representative.

e. Stock-recruitment steepness: this important parameter is fixed in all four assessments because the TSATs believe there is no sufficient information in the data to estimate this parameter in the assessment. The TSATs did not examine the relationship between M and h, both of which were estimated independently outside the assessment model, which ignores the relationship between h and M. I recommend providing a steepness profile, while estimating *M* for females and males. The sensitivity analyses included in the current stock assessment only change *M* or *h* individually. However, *M* and *h* tend to be highly correlated. An examination of LL (log likelihood) values under a varying *M* and *h* (over a reasonable range) would help understand how these parameters interact and how they may influence the assessment of population dynamics.

Limited documentation was provided to evaluate the possible impacts of climate-induced changes in life history parameters and phenology. For all four toothfish stocks under this review, tagging-recapture data provide a unique opportunity to study phenology and how environmental variables may affect life history parameters, and how such impacts and changes are coherent across all four stocks.

A sex-specific stock assessment model is preferred in order to account for differences in life history and fisheries. However, a lack of historical sex-specific information makes the parameterizing the sex-specific model a challenge. This issue may be addressed by developing the CASAL 2 model and increasing the years of sex-specific information with time.

TOR 3. Reviewing the extent to which the choice and analyses of observations are estimated using the best available science and appropriately used in the stock assessment models, including the representativeness of observations in space and time:

Overall, I conclude that the fishery-dependent, fishery-independent, and tagging data have been developed, analyzed and compiled using the best available science and have been appropriately used in the stock assessment models. In particular, I would like to commend the TSATs for their continued efforts to improve historical data quality and quantity (e.g., total catch, fleet-specific catch, discards, IUU catch, and size and age composition data).

a. Catch observations: Because of relatively small fishing fleets and strict monitoring programs, the catch data are likely to be of high quality. Some historical IUU estimates were made based on an implicit assumption of the IUU vessels having the same catch rate as the legal vessels. This implicit assumption was not tested, and a violation may introduce uncertainty in estimating the total catch in the early years.

b. Survey data: All survey programs follow a random stratified survey design, which serves to yield representative survey abundance indices for tracking the inter-annual variability of stock sizes. However, there might be changes in stock distributions over time, which might introduce biases in the design-based abundance indices. I suggest that the model-based abundance indices be developed and compared with the design-based abundance indices to evaluate the quality of design-based abundance indices commonly used for fishery-independent surveys. Some surveys may also only cover a fraction of the stock areas, often focusing on shallow areas that serve as habitats for juvenile and young toothfish. Such indices may not capture the adult and old toothfish population dynamics in the stock.

c. Catch per unit effort (CPUE) abundance indices: Although some references are cited for the CPUE standardization, a detailed CPUE standardization protocol may be needed to describe how the data were filtered, how environmental variables and spatial/temporal variables were selected, and how the model was finalized. The model estimated variance for CPUEs were likely to under-estimate variability associated with CPUEs, which should be considered in fitting the stock assessment model.

d. Tag release and recapture observations: A unique set of input data for the toothfish stock assessment includes tagging-recapture data. In general, the tagging-recapture experiment was well-designed and well-implemented, although I believe it necessary to evaluate possible temporal changes in the spatial dynamics of fishing fleets, which may affect the recapture efforts (and thus data interpretation in the assessment). Tagging data are critical information to define absolute stock size and life history parameters (e.g., growth) for the toothfish stock assessments, because the low exploitation rates in the fisheries make the catch data inadequate in defining the absolute scales of

stock sizes. The CASAL input parameters related to the tagging-recapture data include initial tagging mortality, initial tag loss, instantaneous loss, detection rate, and growth retardation. Similar values were used for the rest of the stocks, but some of these parameters (e.g., initial tagging mortality) may vary over space and time. If they cannot be estimated precisely, their range can be estimated to inform the development of sensitivity analyses. Given the importance of tagging-recapture data in the assessment, I would encourage the continued effort to conduct tagging-recapture experiments. It is essential to better understand how changing fleet dynamics and toothfish spatial distributions in a dynamic ecosystem affect tagging-recapture experiments and tagging parameters (e.g., initial tagging mortality).

e. Age and length compositions: The sampling protocol and data analysis for age and length composition were well-described. Effective sizes used in model fitting and weighting schemes appear reasonable and follow best practice.

f. Selectivity: Various selectivity functions were used for the surveys and fisheries for each stock. The choices of selectivity were well-justified and evaluated with the goodness-of-fits for the age- and length-composition data. However, limited studies were done to explore potential temporal changes in selectivity. I suggest that, for each stock, a timeline of changes in management regulations is listed to examine possible changes in fishing fleets (e.g., changed fishing grounds or practice), which might lead to changes in fisheries selectivity. I also believe more sensitivity analyses need to be developed to further explore and evaluate alternative selectivity functions in fitting the age- and length-composition data.

<u>Subarea 48.3 Patagonia toothfish</u>
The TSAT included the data up to 2021. Survey uncertainty estimation was updated. More historical otolith readings were included in the estimation of age composition data. Data quality assurance processing was well-developed and used for the data quality control. Depredation factors from 2003 were recalculated as part of the CPUE standardization, which provide the best available estimates for the possible marine mammal consumption of toothfish.

The CPUE standardization excludes the period between 1998-2003 due to an absence of cetacean presence. This was considered as a separate block with the identical selectivity but varying catchability q. This implicitly assumes that mammals had comparable size selectivity as the fishery. Notably, catch age compositions prior to 2009 differ before and after 2009. This divergence could be the result of changes in selectivity and/or changes in age sampling (only applicable after 2009). Further investigation may be necessary to identify possible causes.

Tagging-release data were corrected for length-dependent instantaneous tagging mortality (initial release mortality). Only recaptured fish larger than 60 cm and smaller than 120 cm in the four seasons following release were used in the assessment. This decision was a result of small sample sizes for fishes beyond this size range. The potential effects of this size range restriction on the assessment may need to be evaluated.

Biennial shallow trawl surveys are mainly conducted in shallow water, targeting juvenile toothfish abundance. The abundance index appears highly variable over time. However, ecosystem changes may result in changes in toothfish distribution and movement over time (especially for young fish), which may introduce potential bias to the survey abundance index. I recommend that spatiotemporal models (e.g., VAST) or a model-based abundance index be explored.

<u>Subarea 48.4 Patagonia toothfish</u>

New data in 2019 and 2020 (i.e., catch, length composition, tag release, and tag recaptured and otolith aging data) were added since the last stock assessment. The 2021 data were not available for this assessment.

Catch length and age composition data were estimated based on data collected by observers on an annual basis since 2011, which involved random sampling of otoliths from the catch. This approach appears to improve the catch age composition data. I would like to encourage the TSAT to continue this practice for data prior to 2011 in order to further improve the historical catch age composition.

This stock does not have survey and CPUE data. A stock-specific survey or standardized CPUE may need to be developed to better quantify the temporal variability in stock size in the assessment of this toothfish stock.

Among the tagging data from 2005 to 2019 examined in this assessment, a total of 136 *D. eleginoides* were released in 48.4 and recaptured in 48.3. These data are currently excluded from the assessment. Although such a practice makes sense, it raises concerns about the potential migration between these two subareas and its impact on stock assessment results for both subareas when these instances were ignored in both assessments. A spatially explicit model that integrates Subareas 48.3 and 48.4 (e.g., 2-box model) may be a good choice.

<u>Division 58.5.2 (HIMI) Patagonia toothfish</u>
For this stock, random stratified trawl survey and commercial fishery (longline, trawl, and traps) data from 1997-2020 were available for this assessment. Depredation was considered low in this time period, and not included in catch estimates, but will be estimated and included in catch assessments in future.

IUU catch was considered large in the 1990s and 2000s and was estimated based on the sighting of IUU vessels, their fishing capacities, and licensed catch and effort data. This estimation assumes the IUU and licensed vessels have similar catch rates, which may not necessarily be true.

The structure and intensity of the surveys have varied over the years, but have become more stable since 2003 for this stock. The derived survey q, estimated by comparing survey abundance estimates against tag-recapture stock estimates, may carry biases. However, such a value may be useful to inform prior settings. The possible inconsistencies in the early survey years may be overcome by developing model-based abundance indices, which in theory should be able to remove changes in q over time.

The fishing fleets were categorized into two trawls, one trap, and one shallow longline and deep longline. This categorization was based on detailed analyses of the fishing grounds and catch composition, and represents the best available information.

Only longline-caught toothfish were tagged and used in the assessment, primarily because longline offers a wide spatial coverage. The tagging effort has increased since 2008, leading to improved tagging data quality. However, spatial extent of longline fishing effort increased between 2003-2018 before becoming restricted to a small area in 2019 and 2020, which might negatively impact tagging data quality and make maintaining the consistency of the tagging program more difficult. More studies are needed to better understand longline fleet dynamics, which may improve our understanding of their impacts on tagging data quality. I recommend conducting habitat suitability modeling and species distribution modeling to evaluate possible temporal changes in suitable habitat and toothfish distributions, and to evaluate how their changes may be linked to fleet

dynamics. Interviewing fishing vessel captains for their motivations for changing fishing grounds may also be valuable.

ROSS SEA Antarctic toothfish

Various standardized CPUEs and Ross Sea Survey abundance indices were available for the assessment. I suggest that pairwise plots and correlation analysis be carried out to evaluate their coherency. For any pair of inconsistent CPUEs and/or abundance indices, there is a need to identify the potential factors causing the inconsistency before incorporating them into the stock assessment.

Growth was assumed to occur at the end of year for this stock, which sets it apart from the other stocks under review. Biological justification and discussion of potential implications should be discussed for this assumption.

The survey is a longline survey. Incorporating relevant studies of the effects of hook saturation, hook number/density, and positioning on catch rates can improve the design of the longline survey. The longline survey focuses on a relatively small shallow region, which may be a good indicator for recruitment but may not be a good indicator for the stock.

TOR 4. Determining whether the statistical modelling (including model assumptions, model structure, priors and penalties, data selection and weighting) and the resulting inferences on stock status and dynamics and catch limits are implemented using best-practice methods.

Overall, I conclude that the statistical modeling and the resulting inferences on stock status, dynamics, and catch limit are implemented following the CCAMLR guideline using the best practice methods. The stock assessment modeling structure is well-described for each stock and the work clearly follows the CCAMLR guideline in determining stock status and dynamics and catch limits.

However, I believe there is still room for improvement. There is a need to describe the main model assumptions (both biological and statistical) and discuss how each assumption may introduce uncertainties and potential consequences if violated. The choices of priors and penalties need to be explicitly stated, summarized, and justified. The description of data filtering and weighting is provided, but the weighting is more related to variances (e.g., effective sample sizes for compositional data and CVs for abundance index data) connected to input data, not the relative differences among the data sets (e.g., some programs only cover part of the stock, but give the same weights as those covering the whole stock areas).

No retrospective analysis or the quantification of retrospective patterns (e.g., Mohn's rho, Legault 2009) were conducted. Retrospective patterns can introduce biased errors to the recent stock size, recruitment and fishing mortality estimates, which are most relevant to stock status determination, stock projection and catch advice development. It is critical to include the retrospective analysis as a required component in a stock assessment (Legault 2009). It is important to develop a relevant protocol for correcting retrospective errors in accordance with the commonly accepted best practice guideline (Legault 2009) before using recent estimates of stock size, recruitment, and fishing mortality for stock status determination, stock projection and catch advice development.

Subarea 48.3 Patagonia toothfish

For this stock assessment, both M and growth are assumed to be proportional to the duration of each time period, which implicitly assumes that there is no seasonality in growth and natural mortality. This assumption may not be true, and can potentially introduce uncertainty in the assessment. Tagging data can be used to evaluate the assumption for growth. A data limited assessment was

also conducted using tag recapture rates, which is helpful, although further consideration would be required if large differences were found between this data limited method and the CASAL assessment. I am also wondering if tag dispersion would be constant over the years. Conducting a sensitivity run could be beneficial to evaluate possible effects of these assumptions on assessment outcomes.

The survey index and CPUE had CVs estimated outside the model. A small fixed process error was considered in initial runs, but estimated in subsequent runs with iterative weighting (Francis 2011) methods. This approach follows the best practice to account for the under-estimated CVs often associated with model-based abundance indices. The estimated process error for the survey was much higher than the initial constraint (1.663 vs 0.0015), which demonstrates that this iterated fitting protocol accounts for the extra process errors not considered in the CPUE standardization and model, or design-based survey abundance indices.

Subarea 48.4 Patagonia toothfish

The CASAL model for this stock is a combined-sex, single-area model with an annual cycle that comprises 4 periods (same Subarea 48.3). Model spans the period from 1990 to 2021. Given that the fishery in this subarea is more likely to occur during the recruitment time step than the spawning period, using the same current time steps as 48.3 may not be the best choice. The observed movement between subareas 38.3 and 38.4 highlights the necessity of developing a spatially explicit model linking 48.3 and 48.4.

The 2021 stock assessment model had memory allocation issues. It might be advisable to estimate the growth function outside the stock assessment model. The 2018 and 2019 size-at-age data contributed the most to the overall likelihood. This may suggest the necessity to explore alternative selectivities, given the changes in the spatial dynamics of fishing fleets.

Division 58.5.2 (HIMI) Patagonia toothfish

The modeling procedure includes an initial bridging analysis, which uses the assessment model designed to provide management advice to progress stepwise toward a new proposed assessment model. The new model incorporates updated data, input biological parameters, and model configuration. An iterative weighting scheme is carefully designed, adhering to best practice guideline. A retrospective analysis was conducted, yielding plots for stock size and YCS estimates. However, no quantification was provided. I also did not see much discussion on the effects of retrospective errors on stock status determination and stock projection.

ROSS SEA Antarctic toothfish

Sensitivity runs were developed to evaluate the RSSS data, YCS (year class strength) estimation, M, growth, selectivity shape and changing selectivity time. A retrospective analysis was undertaken, which revealed a more conservative estimate of SSB. However, no quantification (e.g., Mohn's rho) was performed, and only limited discussion regarding the results and implications was provided. The retrospective analysis is incomplete and insufficient for understanding the effects of possible retrospective errors on both stock assessment and stock projection.

TOR 5. Reviewing if there are trends in parameters through time or other spatial and temporal effects on the biological parameters, other parameters such as selectivity, and observations that should be taken into account in each stock assessment.

Although some studies were conducted to evaluate possible temporal and spatial variations in life history and fisheries processes, this TOR was only partially addressed. Ecosystem factors have

received minimal consideration in evaluating possible changes in stock productivity over time. There is limited synthesis of toothfish recruitment dynamics and life history parameters across all stock areas. I suggest having pairwise plots of recruitment dynamics from different stock areas to evaluate the potential similarities in recruitment dynamics among stock areas. This can provide some information on recruitment dynamics over the entire area of the population.

I suggest the development of a habitat suitability model (bioclimatic model) and species distributional model for each stock in order to evaluate the spatiotemporal dynamics of suitable habitats and toothfish distribution, identify any significant changes in habitats to inform the analysis for temporal trends in life history, and evaluate the impact of possible changes in stock distributions on monitoring and fisheries.

Subarea 48.3 Patagonia toothfish

No large systematic temporal trends were found in growth, maturity, length-weight, estimated length at age, and tag loss rate. Changes in depredation rates increased over time, which was considered and updated in the assessment. CPUE standardization was consistent over time (among models), which shows that CPUE standardization modeling is robust.

I recommend that possible changes in fleet dynamics be evaluated due to changing management regulations (e.g., reductions in bird bycatch leading to shortened seasons, extra requirements, and more restrictions in fishing areas), might affect the population availability to fisheries (and thus selectivity).

Subarea 48.4 Patagonia toothfish

Most of the information, model structure, and configuration for this stock was the same as subarea 48.3. However, fishing time for this stock differed from that of subarea 48.3, and the current time steps for this stock did not line up well with the model configuration. It is necessary to tailor the time step to this fishery better. The ongoing research effort to develop CASAL 2 model can address this issue.

A preliminary retrospective analysis was conducted for this review, which did not reveal any clear retrospective patterns. However, no quantification or discussion was provided for the retrospective analysis.

Division 58.5.2 (HIMI) Patagonia toothfish

The fishery started as a trawl fishery but moved to longline fishery. The spatial range of the longline fishing effort increased between 2003-2018 before becoming restricted to a small area in 2019 and 2020, which might have influenced fishing fleet dynamics and tagging-recapture data. An evaluation of these changes is warranted.

Possible changes in survey selectivity over time may also be evaluated because juveniles might be more sensitive to changes in their environment.

ROSS SEA Antarctic toothfish

Some evidence of temporal trends in average size at age (decadal) was observed, but there was little evidence of trended temporal variations in growth, maturation, and length-weight. Systematic patterns were observed in age composition residuals. Blocking years in selectivity did not address the issue, indicating the potential presence of other processes (e.g., growth) that might change over time and affect the patterned age composition residuals.

TOR 6. Reviewing whether population projection methods, recruitment series used, and implementation of decision rules are conducted using the best available science.

Overall, I conclude that the TSATs have used the best available science to conduct the population projection, identify recruitment series for the projection, and implement the CCALMR decision rules.

For all four stock assessments, MCMC estimates were used to quantify uncertainty in the projection, which is a standard practice. The projection method, recruitment series used and implementation of decision rules are similar for all the four stocks under review.

No retrospective errors were considered, which may introduce biases in the most recent years of estimates for recruitment, stock biomass, and exploitation rate. This could result in additional uncertainty or bias at the very beginning of the projection and determination of stock status.

Because of low exploitation rates, there is a lack of contrast in population dynamics. It is likely that the projected population dynamics were not experienced in the past, which may make the projection questionable (i.e., the model projection is beyond the dynamics a stock has experienced and the projection model is built upon). However, this may only be evaluated using a computer simulation approach such as a management strategy evaluation (MSE). The performance of decision rules and alternative management strategies can also be evaluated using a properly developed MSE.

TOR 7. Identify and consider any additional stock specific analyses or investigations that are critical for this assessment and warrant peer review, and develop additional TOR(s) to address as needed.

No additional TORs were developed during the review. Many additional research and analysis recommendations have been suggested in TORs 1-6. However, I would like to highlight the following recommendations for additional research and analyses to further improve the assessment of the four toothfish stocks under review.

- The current version of the model will no longer receive updates, as all the model development efforts will be focused toward the development of a new model version (CASAL 2). Some simulation studies should be conducted to compare the performance of both versions and to bridge the transition between the current model and the new model.

- Patagonia and Antarctic toothfish stocks are widely distributed, but the stock structure, connectivity, movement, and possible variability in key life history parameters among the current stock areas remain unclear. There is a need to evaluate the coherence of the dynamics of different stocks and identify possible differences among stocks in key stock parameters (e.g., recruitment dynamics, growth, maturation and weight-length) across their whole distribution ranges. Possible differences may be linked to environmental variability among the stock areas.

- The assessments lack explicit ecosystem considerations. Possible changes in distributions and phenology over time in response to changing environments and their possible impacts on the dynamics of toothfish stocks need to be evaluated and considered in future stock assessments.

- A retrospective analysis should be conducted as an essential part of a stock assessment. The impacts of retrospective errors on stock status determination, projections, and uncertainty

should be carefully evaluated. A protocol should be developed to adjust possible retrospective errors in the stock status determination and catch advice development. A good practice guideline can be found in Legault (2009).

- Sex-specific CASAL model should be developed, if possible.

- Habitat suitability modeling and species distribution modeling should be performed to evaluate possible temporal changes in suitable habitat and toothfish distributions and evaluate how their changes may be linked to fleet dynamics. It may also be valuable to interview the fishing vessel captains for their reasons for changing fishing grounds. Temporal changes in the distributions derived from the distributional modeling can also be compared with the spatial distribution of surveys and fisheries to identify possible changes in their spatial coverages.

- Stock-recruitment steepness is fixed in all four assessments because the TSATs believe there is no sufficient information in the data to estimate this parameter in the assessment. This, together with the fixed natural mortality, has essentially fixed the stock productivity (essential MSY). This is perhaps the most serious issue I have with all four assessments included in this review. The TSATs did not examine the relationship between M and h. Both were estimated independently outside the assessment model, which ignores the relationship between h and M. I recommend providing a steepness profile, while estimating *M* for females and males. The sensitivity analyses included in the current stock assessment only change *M* or *h* individually. However, *M* and *h* tend to be highly negatively correlated. An examination of LL (log likelihood) values under a varying *M* and *h* (over a reasonable range) would help us understand how M and h interact and may influence the population dynamics assessment. This recommendation will also inform the development of sensitivity runs in evaluating the potential uncertainty associated with M and h.

- The tagging-recapture data play an important role in assessing the toothfish stock dynamics because of relative fishing mortality rates in these fisheries. Current tagging-recapture programs should continue to be conducted, and the impact of possible changes in the dynamics of toothfish spatial distributions on the tagging-recapture should be carefully evaluated.

V. Conclusions and Recommendations

Overall, I conclude that the TSATs have done an excellent job in developing and parameterizing the CASAL stock assessment models for the four stocks reviewed by the Panel. In the stock assessment documents, key input data and their statistical properties are defined with justifications. Various sensitivity runs were developed to evaluate the effects of major sources of uncertainty on the estimation of key population statistics including stock biomass, exploitation, and recruitment. I would like to commend the three TSATs for their excellent work. I was impressed by the breadth of expertise in the review; the dedicated effort invested in compiling the assessment data; the consideration of plausible scenarios; the transparent discourse on stock assessment uncertainty; the discussion of alternative approaches and suggestions; and the constructive dialogues observed among the TSATs, the Review Panel and other participants during the review.

Based on the stock assessments presented and the materials provided, I believe that the TSATs have adequately addressed the ToRs. The stock assessment modeling framework used in the four assessments is cutting edge and takes advantage of available data, including fishery-dependent

and fishery-independent data, life history parameters, and tagging-recapture data. The quality control process and data filtering procedure were developed and applied to all data before being inputted into assessment models. Alternative values for many key life history parameters were evaluated and considered in the sensitivity analysis. The integration of all data in the assessment provides a parsimonious view of the stock status and represents the best available information on the population dynamics of toothfish. All analyses suggest the stock assessment results are rather robust with regard to the uncertainty in stock assessments for Subarea 48.3 (South George), Subarea 48.4 (South Sandwich Islands), Division 58.5.2 (Heard Island and the McDonald Islands), and Antarctic toothfish in Subarea 88.1 and 88.2 (Ross Sea). I conclude that the assessments are scientifically sound, yield the best available information, and adequately address management needs. I also reviewed the alternative assessment approach based on historical length composition and maturation data proposed for Subarea 48.3 and compared the approach with the CASAL-based assessment. Based on this assessment, I conclude that the alternative approach is unable to adequately capture the population dynamics, does not represent the best available science, and is inadequate in providing catch advice for the management of the Subarea 48.3 toothfish stock.

However, the current assessment and review process has room for improvement. The documentation can be improved to combine more working papers (rather than cross-referencing them, which is hard to track). Protocols for developing the base model, sensitivity runs, and their justifications should be explicitly documented to ensure the transparency of the assessment process. For each stock assessment, major biological and statistical assumptions in the assessment, explicit and implicit, should be listed in a summary table. A retrospective analysis (within the model) should be conducted for each assessment, and retrospective errors should be quantified (i.e., using Mohn's rho) for the estimation of SSB, fishing mortality, and recruitment. A possible adjustment of retrospective errors should be evaluated using the existing best practice guidelines (e.g., Legault 2009). The effects of possible retrospective errors on stock status determination and projection should be evaluated and considered in developing catch advice. For stocks with possible mixing and sex-specific life history and fishery (e.g., Subareas 48.3 and 48.4), sex-specific and/or spatially explicit assessment models (e.g., two box model) should be considered. The tagging-recapture data play an important role in assessing the toothfish stock dynamics because of relative fishing mortality rates in these fisheries. Current tagging-recapture programs should continue to be conducted, with the impact of possible changes in the dynamics of toothfish spatial distributions on the tagging-recapture carefully evaluated. The potential impact of climate-induced ecosystem change on key life history parameters and habitat (in addition to spatial distributions and carrying capacity) should be carefully evaluated for the Patagonia toothfish in Subarea 48.3 and 48.4, Division 58.5.2, and the Antarctic toothfish in Subarea 88.1 and 88.2 (Ross Sea). My detailed research recommendations for improving future toothfish stock assessments can be found under ToR 7 and in the Conclusions and Recommendations section.

VI. References

Legault, C.M., Chair. 2009. Report of the Retrospective Working Group, January 14-16, 2008, Woods Hole, Massachusetts. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 09-01; 30 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/nefsc/publications/

VII. Appendices

VII-1. Bibliography of materials provided for review

Documents for independent review of toothfish stock assessments, 2023

1 Division 58.5.2

1.1 Stock assessment

Ziegler P. (2021) Draft integrated stock assessment for the Heard Island and McDonald Islands Patagonian toothfish (*Dissostichus eleginoides*) fishery in Division 58.5.2. Document WG-FSA-2021/21, CCAMLR, Hobart, Australia

1.2 Main supporting documents

Agnew D., Moir Clark J., McCarthy P.A., Breedt G., Du Plessis S., van Heerdon J. and Moreno G. (2006) A study of Patagonian toothfish (*Dissostichus eleginoides*) post-tagging survivorship in Subarea 48.3. CCAMLR Science 13:279-289.

Agnew D.J., Kirkwood G.P., Payne A., Pearce J., and Clarke J. (2005) Parameters for the assessment of toothfish in Subarea 48.3. Document WG-FSA-05/18, CCAMLR, Hobart, Australia.

Burch P., Ziegler P.E., de la Mare W. and D.C. Welsford (2014) Investigating the uncertainty of age determinations for Patagonian toothfish (*Dissostichus eleginoides*) and the implications for stock assessments. Document WG-FSA-14/46. CCAMLR, Hobart, Australia.

Burch P., Ziegler P.E., Welsford D.C. and C. Péron (2017) Estimation and correction of bias caused by fish immigration and emigration in a tag-based stock assessment. Document WG-SAM-17/11, CCAMLR, Hobart, Australia.

Candy S.G. (2004) Modelling catch and effort data using generalised linear models, the Tweedie distribution, random vessel effects and random stratum-by-year effects. CCAMLR Science **11**:59-80.

Candy S.G. (2011) Estimation of natural mortality using catch-at-age and aged mark-recapture data: a multi-cohort simulation study comparing estimation for a model based on the Baranov equations versus a new mortality equation. CCAMLR Science **18**:1-27.

Candy S.G., Welsford D.C., Lamb T., Verdouw J.J. and J.J. Hutchins (2011) Estimation of natural mortality for the Patagonian toothfish at Heard and McDonald Islands using catch-at-age and aged mark-recapture data from the main trawl ground. CCAMLR Science, **18**:28-46.

Candy S.G., Constable A.J., Lamb T. and R. Williams (2007) A von Bertalanffy growth model for toothfish at Heard Island fitted to length-at-age data and compared to observed growth from mark-recapture studies. CCAMLR Science **14**:43-66.

Candy S.G., Ziegler P.E. and D.C. Welsford (2013) A distribution free model of length frequency distribution to inform fishery stratification for integrated assessments. Document WG-SAM-13/18 CCAMLR Hobart, Australia.

Dunn A., Horn P.L. and S.M. Hanchet (2006) Revised estimates of the biological parameters for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea. Document WG-SAM-06/08, CCAMLR Hobart, Australia.

Francis R.I.C.C. (2011a) Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences, **68**:1124-1138.

Francis, R.I.C.C. (2011b). Corrigendum: Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences **68**: 2228.

Kock K.-H. and A. Kellermann (1991) Review: Reproduction in Antarctic notothenioid fish. Antarctic Science **3**:125-150.

Yates P., Welsford D., Ziegler P., McIvor J., Farmer B., and E. Woodcock (2017) Spatio-temporal dynamics in maturation and spawning of Patagonian toothfish (*Dissostichus eleginoides*) on the subantarctic Kerguelen Plateau. Document WG-FSA-17/P04, CCAMLR Hobart, Australia.

Ziegler P.E (2017) Estimation of tag loss rates for tagged fish in the Patagonian toothfish (*Dissostichus eleginoides*) fisheries at the Heard Island and McDonald Islands and the Kerguelen Island. Document WG-FSA-17/21. CCAMLR Hobart, Australia.

2 Subarea 48.3

2.1 Stock assessment

Readdy L. and Earl T. (2022) Stock assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3: assessment diagnostics. Document WG-SAM-2022/22, CCAMLR, Hobart, AUS.

Earl T. and Readdy L. (2022). Assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3. Document WG-FSA-2022/57 Rev 1, CCAMLR, Hobart, AUS.

Earl T. and Readdy L. (2022) Assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3: Assessment diagnostics. Document WG-FSA-2022/58, CCAMLR, Hobart, AUS.

2.2 Main supporting documents

Marsh J., Earl T., and Darby C. (2022). Fishery characterisation for Patagonian toothfish around South Georgia (Subarea 48.3). Document WG-FSA-2022/56 Rev 1

Marsh J., Earl T., Hollyman P., and Darby C. (2022). Maturity and growth estimates of Patagonian toothfish in Subarea 48.3 between 2009 to 2021. Document WG-FSA-2022/59, CCAMLR, Hobart, AUS.

Earl T., MacLeod E., Söffker M., Gasco N., Massiot-Granier F., Tixier P., and Darby C. (2022) Whale depredation in the South Georgia Patagonian toothfish (*Dissostichus eleginoides*) fishery in the South Atlantic: a comparison of estimation methods WG-FSA-2022/P05, CCAMLR, Hobart, AUS.

Dunn A., Grüss A., Devine J.A.; Miller C., Ziegler P., Maschette D., Earl T., Darby C. and Massiot-Granier F. (2022). Integrated toothfish stock assessments using Casal2. Document WG-SAM-2022/14, CCAMLR, Hobart, AUS.

Marsh J., Earl T., and Darby C. (2022) Estimates of tag loss rates for Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3 tagged between 2004 to 2020. Document WG-SAM-2022/17, CCAMLR, Hobart, Australia.

Readdy L., Earl T., and Darby C. (2022) Stock assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.4: assessment diagnostics. Document WG-SAM-2022/19, CCAMLR, Hobart, Australia.

Readdy L. and Earl T. (2022) Stock assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3– proposed model updates. Document WG-SAM-2022/20, CCAMLR, Hobart, Australia.

Marsh, J., Earl T., Hollyman P., and Darby C. (2022) A comparison of estimates of Patagonian toothfish (*Dissostichus eleginoides*) maturity and growth in Subarea 48.3 using different otolith selection procedures. Document WG-SAM-2022/24, CCAMLR, Hobart, Australia.

Delegation of the Russian (2021) Revision of the precautionary approach to ensuring the rational use of a living resource (*Dissostichus eleginoides*) in CCAMLR Subarea 48.3 Federation. Document SC-CAMLR-40/15, CCAMLR, Hobart, Australia.

Delegation of the Russian Federation (2022) On the revision of the precautionary approach to ensure the rational use of the living resource (*Dissostichus eleginoides*) in Subarea 48.3. Document WG-FSA-2021/41, CCAMLR, Hobart, Australia.

Delegation of the United Kingdom (2021) Comments on WG-FSA 2021/41 and SC-CAMLR-40/15. On the revision of the precautionary approach to ensure the rational use of the living resource (*Dissostichus eleginoides*) in Subarea 48.3. Document SC-CAMLR-40/BG/08, CCAMLR, Hobart, Australia.

Collins M.A., Coleman J., Gregory S., Hollyman P.R., James R., Marsh M., Reid J., and Socodo P. (2021) Report of the UK Groundfish Survey at South Georgia (CCAMLR Subarea 48.3) in May 2021. Document WG-FSA-2021/12, CCAMLR, Hobart, Australia.

Dunn A. and Rasmussen S. (2021) Development of Casal2. Document WG-FSA-2021/31, CCAMLR, Hobart, Australia.

Delegation of the United Kingdom (2019) The CCAMLR Decision Rule, strengths and weaknesses. Document SC-CAMLR-38/15, CCAMLR, Hobart, Australia.

2.3 Supplemental documents

Earl T. and Readdy L. (2021) Assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3. Document WG-FSA-2021/59, CCAMLR, Hobart, Australia.

Earl T. and Readdy L. (2021) Assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3: assessment diagnostics Document WG-FSA-2021/60, CCAMLR, Hobart, Australia.

Earl T. and L. Readdy (2021) Assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3. Document WG-FSA-2021/61, CCAMLR, Hobart, Australia.

Earl T. (2019) Assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3. Document WG-FSA-2019/28, CCAMLR, Hobart, Australia.

MacLeod E., Bradley K., Earl T., Söffker M., and Darby C. (2019) An exploration of the biological data used in the CCAMLR Subarea 48.3 Patagonian toothfish stock assessments Document WG-SAM-2019/32, CCAMLR, Hobart, Australia.

Delegation of the Russian Federation (2019) Revision of the precautionary approach to ensuring the rational use of the living resource (*Dissostichus eleginoides*) in Subarea 48.3 (full version) Document WG-FSA-2019/40, CCAMLR, Hobart, Australia.

CCAMLR (2018) Summary Report of the CCAMLR Independent Stock Assessment Review for Toothfish (Norwich, United Kingdom, 18 to 22 June 2018). Document SC-CAMLR-XXXVII/02 Rev. 1, CCAMLR, Hobart, Australia.

Kukharev N.N. and Petrov A.F. (2018) Long-term changes in the length composition of Patagonian toothfish (*Dissostichus eleginoides*) in longline catches in waters around South Georgia. Document SC-CAMLR-XXXVII/14 Rev. 2, CCAMLR, Hobart, Australia.

Kukharev N.N. and Petrov A.F. (2018) On multi-year variability of the Patagonian toothfish (*Dissostichus eleginoides*) size composition in longline catches in the South Georgia maritime zone (full version). Document SC-CAMLR-XXXVII/BG/25, CCAMLR, Hobart, Australia.

Delegation of the Russian Federation (2019) Revision of the precautionary approach to ensuring the rational use of a living resource (*Dissostichus eleginoides*) in Subarea 48.3. Document CCAMLR-38/31 Rev 2, CCAMLR, Hobart, Australia.

Mormede S. (2018) Introducing Casal2 for toothfish stock assessments. Document WG-SAM-18/14, CCAMLR, Hobart, Australia.

Doonan I., Large K., Dunn A., Rasmussen S., Marsh C., and Mormede S. (2018) Casal2: New Zealand's integrated population modelling tool. Document WG-SAM-18/P01, CCAMLR, Hobart, Australia.

Earl T. and Fischer S. (2017) Assessment of Patagonian toothfish (*D. eleginoides*) in Subarea 48.3. Document WG-FSA-17/53, CCAMLR, Hobart, Australia.

Earl T., Soeffker M., and Darby C. (2015) Assessment of the Patagonian Toothfish (*D. eleginoides*) in Subarea 48.3. Document WG-FSA-15/59, CCAMLR, Hobart, Australia.

Earl T. (2017) Sensitivities in the assessment of the Patagonian toothfish (*D. eleginoides*) in Subareas 48.3 and 48.4 to truncation of tagging data. Document WG-SAM-17/35, CCAMLR, Hobart, Australia.

Soeffker M., Belchier M., and Laptikhovsky V. (2015) A potential link between the *D. eleginoides* stocks of Statistical Subareas 48.3 and 48.4. Document WG-SAM-15/30, CCAMLR, Hobart, Australia.

Darby C., Laptikhovsky V., and Soeffker M. (2015) Fishery selection for Patagonian toothfish in CCAMLR Subarea 48.3, asymptotic or dome shaped? Document WG-SAM-15/29, CCAMLR, Hobart, Australia.

Soeffker M., Darby C., and Scott R.D. (2014) Nine years of tag-recapture in CCAMLR Statistical Subarea 48.3 – Part I: General data characterisation and analysis. Document WG-SAM-14/35, CCAMLR, Hobart, Australia.

Soeffker M., Darby C., and Scott R.D. (2014) Nine years of tag-recapture in CCAMLR Statistical Subarea 48.3 – Part II: Spatial movement and analysis. Document WG-FSA-14/49, CCAMLR, Hobart, Australia.

Soeffker M. and Scott R. (2013) A brief characterisation of Patagonian toothfish tag survival and tag detection in CCAMLR Statistical Area 48.3. Document WG-FSA-13/29, CCAMLR, Hobart, Australia.

Scott R. (2013) Preliminary assessment of Patagonian toothfish in Subarea 48.3 Document WG-FSA-13/30, CCAMLR, Hobart, Australia.

Peatman T., Martin S.M., Pearce J. and Mitchell R.E. (2012) Movement of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.3. Document WG-SAM-12/19, CCAMLR, Hobart, Australia.

Peatman, T., Mitchell R.E., Parkes G. and Agnew D.J. (2011) Preliminary assessment of toothfish in Subarea 48.3. Document WG-FSA-11/33 Rev. 1, CCAMLR, Hobart, Australia.

Collins M.A., Brickle P., Brown J., and Belchier M. The Patagonian toothfish: biology, ecology and fishery. Document WG-FSA-10/P05, CCAMLR, Hobart, Australia.

Agnew D.J. and Belchier M. (2009) Adding catch at age and survey data to the 48.3 toothfish CASAL assessment. Document WG-SAM-09/13, CCAMLR, Hobart, Australia.

Agnew D.J., Hillary R., and Pearce J. (2007) Preliminary assessment of the South Georgia toothfish stock, 2007. Document WG-FSA-07/29, CCAMLR, Hobart, Australia.

Agnew D.J., Hillary R., Belchier M., Clark J., and Pearce J. (2006) Assessment of toothfish in Subarea 48.3, 2006 Document WG-FSA-06/53, CCAMLR, Hobart, Australia.

Hillary R.M. and Agnew D.J. (2006) Estimates of natural and fishing mortality from toothfish mark–recapture and catch-at-age data at South Georgia. Document WG-FSA-06/54, CCAMLR, Hobart, Australia.

Agnew D.J., Kirkwood G.P., Payne A., Pearce J., and Clarke J. (2005) Parameters for the assessment of toothfish in Subarea 48.3. Document WG-FSA-05/18, CCAMLR, Hobart, Australia.

3 Subarea 48.4

3.1 Stock assessment

Earl T. and Readdy L. (2021) Assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.4. Document WG-FSA-2021/61, CCAMLR, Hobart, Australia.

Earl T. and Readdy L. (2021) Assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.4: assessment diagnostics. Document WG-FSA-2021/62, CCAMLR, Hobart, Australia.

Readdy, L., Earl T., and Darby C. (2022) Stock assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.4 – addressing the convergence issues encountered in the 2021 assessment. Document WG-SAM-2022/21, CCAMLR, Hobart, Australia.

3.2 Main supporting documents

Darby C. and Earl T. (2022) A comparison of fishing mortality estimates derived using data-rich and data-limited approaches Document WG-SAM-2022/23, CCAMLR, Hobart, Australia.

Söffker M., Hogg O., Hollyman P., Belchier M., Riley A., Readdy L., MacLeod E., Robson G., Olsson K., Pontalier H., and Darby C. (2021) Results from a three-year survey, 2017–2019, into the connectivity of toothfish species in Subareas 48.2 and 48.4. Document WG-FSA-2021/22, CCAMLR, Hobart, Australia.

3.3 Supplemental documents

Earl T. and MacLeod E. (2019) Assessment of Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.4. Document WG-FSA-2019/29, CCAMLR, Hobart, Australia.

Earl T. (2017) Assessment of Patagonian toothfish (*D. eleginoides*) in Subarea 48.4. Document WG-FSA-17/52, CCAMLR, Hobart, Australia.

Soeffker M., Laptikhovsky V., Earl T., and Darby C. (2015) An integrated stock assessment of Patagonian toothfish (*Dissostichus eleginoides*) in CCAMLR Subarea 48.4. Document WG-FSA-15/28, CCAMLR, Hobart, Australia.

Laptikhovsky V., Scott R., Söffker M., and Darby C. (2014) A preliminary CASAL population assessment of Patagonian toothfish in CCAMLR Subarea 48.4 based on data for the 2009–2014 fishing seasons. Document WG-FSA-14/29 Rev.1, CCAMLR, Hobart, Australia.

Scott R. and Laptikohvsky V. (2013) Preliminary assessment of Patagonian toothfish in Subarea 48.4. Document WG-FSA-13/31, CCAMLR, Hobart, Australia.

4 Subarea 88.1 and SSRUs 88.2AB

4.1 Stock assessment

Grüss, A.; Dunn, A.; Parker, S.J. (2021) Assessment model for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region to 2020/21. WG-FSA-2021/26. CCAMLR, Hobart, Australia, 21 p.

Grüss, A.; Dunn, A.; Parker, S.J. (2021) Diagnostic plots for the 2021 assessment model for the Antarctic toothfish (*Dissostichus mawsoni*) population of the Ross Sea region. *Document WG-*SAM-2021/14. CCAMLR, Hobart, Australia, 42 p.

CCAMLR Secretariat. (2023) Stock Assessment Report 2022: *Dissostichus mawsoni* in Subarea 88.1. 23 p.

CCAMLR Secretariat. (2023) Stock Annex 2022: *Dissostichus mawsoni* in Subarea 88.1. 17 p.

4.2 Main supporting documents

McKenzie, A.; Devine, J.A.; Grüss, A. (2022) Characterisation of the toothfish fishery in the Ross Sea region through 2021–22. Document WG-FSA-22/49. CCAMLR, 38 p.

CCAMLR Secretariat. (2023) Fishery Summary 2022: *Dissostichus mawsoni* in Subarea 88.1. 3 p.

CCAMLR Secretariat. (2023) Species Description 2022: *Dissostichus mawsoni*. 5 p.

CCAMLR Secretariat. (2023) Fishery Report 2022: *Dissostichus mawsoni* in Subarea 88.1. 23 p.

Dunn, A. (2019) Assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region to 2018/19. WG-FSA-2019/08. CCAMLR, Hobart, Australia, 30 p.

Devine, J. (2022) A review of the Ross Sea shelf survey. Document WG-SAM-2022/13. CCAMLR, Hobart, Australia, 30 p.

Devine, J. (2023) An update of tag loss rates for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea. Document WG-SAM-2023/09. CCAMLR, Kochi, India, 10 p.

Dunn, A.; Grüss, A. (2023) Parameter transformations and alternative algorithms in Casal2 models. Document WG-SAM-2023/08. CCAMLR, Kochi, India, 21 p.

Dunn, A.; Grüss, A. (2023) 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*). Document WG-SAM-2023/10. CCAMLR, Kochi, India, 23 p.

Dunn, A.; Parker, S.J. (2019) Revised biological parameters for Antarctic toothfish in the Ross Sea region (881 & 882AB). Document WG-FSA-2019/11. CCAMLR, Hobart, Australia, 14 p.

Grüss, A.; Mormede, S.; Dunn, A.; Devine, J.A. (2023) 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*). Document WG-SAM-2023/11, CCAMLR, Kochi, India, 11 p.

4.3 Supplemental documents

Arangio, R.; De Pooter, D.; Fenaughty, J.; Forster, I.; Jones, C.; Ngcongo, S.V.; Parker, S.; Plum, B.; Williamson, M.; Ziegler, P. (2023) Report of the COLTO–CCAMLR Tagging Workshop. CCAMLR, Hobart, Australia, 27 p.

Behrens, E; Pinkerton, M H; Parker, S; Rickard, G; Collins, C (2021) The impact of sea-ice drift and ocean circulation on dispersal of toothfish eggs and juveniles in the Ross Sea and Amundsen Sea. Earth and Space Science Open Archive 126, e2021JC017329. https://doi.org/10.1029/2021JC017329

Bull, B.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H.; Bian, R.; Fu, D. (2012) CASAL (C++ algorithmic stock assessment laboratory) User Manual v2.30-2012/03/21. NIWA Technical Report 135. National Institute of Water and Atmospheric Research, Wellington, 280 p

Casal2 Development Team (2023) Casal2 user manual for age-based models, v23.06. NIWA Technical Report 139. NIWA. (Using source code from https://github.com/alistairdunn1/CASAL2), Wellington, New Zealand, 270 p.

Delegation of New Zealand. (2022) Proposal to continue the time series of research surveys to monitor abundance of Antarctic toothfish (*Dissostichus mawsoni*) in the southern Ross Sea, 2022/23-2024/25: Research Plan under CM 24-01. Document WG-FSA-2022/41 rev.1, CCAMLR, Hobart, Australia, 39 p.

Delegation of New Zealand. (2023) 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. Document WG-SAM-2023/02, CCAMLR, Kochi, India, 11 p.

Dunn, A.; Grüss, A.; Devine, J.A.; Miller, C.; Ziegler, P.; Maschette, D.; Earl, T.; Darby, C.; Massiot-Granier, F. (2022) Integrated toothfish stock assessments using Casal2. Document WG-SAM-2022/14, CCAMLR, Hobart, Australia, 20 p.

Francis, R.I.C.C. (2011) Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68, 1124–1138.

Francis, R.I.C.C. (2017) Revisiting data weighting in fisheries stock assessment models. Fisheries Research. https://doi.org/10.1016/j.fishres.2016.06.006

Grüss, A.; Devine, J.; Parker, S.J. (2021a) Characterisation of the toothfish fishery in the Ross Sea region through 2020/21. Document WG-FSA-2021/24. CCAMLR, Hobart, Australia, 38 p

Grüss, A.; Dunn, A.; Parker, S.J. (2021) Updated stock assessment model for the Antarctic toothfish (*Dissostichus mawsoni*) population of the Ross Sea region for 2021. Document WG-SAM-2021/13. CCAMLR, Hobart, Australia, 18 p.

Grüss, A.; Pinkerton, M.; Mormede, S.; Devine, J.A. (2023) Evaluating the impacts of the Ross Sea region marine protected area for Antarctic toothfish (*Dissostichus mawsoni*) with a spatially-explicit population model. Document WG-EMM-2023/10, CCAMLR, Kochi, India, 31 p.

Moore, B.; Mormede, S.; Parker, S.; Dunn, A. (2019) A preliminary model-based approach for estimating natural mortality of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea Region. Document WG-SAM-19/04, CCAMLR, Hobart, Australia., 10 p.

Maschette, D.; Wotherspoon, S.; Polanowski, A.; Deagle, B.; Welsford, D.; Ziegler, P. (2019) Stock connectivity of Antarctic toothfish. Document WG-FSA-2019/P01, CCAMLR, Hobart, Australia, 41 p.

Parker, S.J.; Hanchet, S.M.; Horn, P.J. (2014) Stock structure of Antarctic toothfish in Statistical Area 88 and implications for assessment and management. Document WG-SAM-14/26 CCAMLR, Hobart, Australia, 17 p.

Parker, S.J.; Stevens, D.W.; Ghigliotti, L.; La Mesa, M.; Di Blasi, D.; Vacchi, M. (2019) Winter spawning of Antarctic toothfish *Dissostichus mawsoni* in the Ross Sea region. Antarctic Science 1–11.

Parker, S J; Sundby, S; Stevens, D; DiBlasi, D; Schiaparelli, S; Ghigliotti, L (2021) Buoyancy of post-fertilised *Dissostichus mawsoni* eggs and implications for early life history. Fisheries Oceanography 30(6): 697–706.

Wei, L.; Zhu, G.P.; Okuda, T.; Parker, S.; Slypko, I.; Somhlaba, S. (2019) Otolith morphological analysis cannot distinguish Antarctic toothfish (*Dissostichus mawsoni*) stocks in the Southern Ocean. Document WG-FSA-2019/59. CCAMLR, Hobart, Australia, 13 p.

Zhu, G. (2019) Progress report on collaborative research for otolith chemistry of Antarctic toothfish *Dissostichus mawsoni* in the Southern Ocean. Document WG-FSA-2019/61. CCAMLR, Hobart, Australia, 7 p.

Ziegler, P.E.; Burch, P.; Constable, A.; Darby, C.; Dunn, A.; Jones, C.; Kinzey, D.; Mormede, S.; Welsford, D. (2015) Towards developing diagnostics tools for fishery stock assessments. Document WG-SAM-15/26. CCAMLR, Hobart, Australia, 20 p.

Ziegler, P. An integrated stock assessment for the Heard Island and McDonald Islands Patagonian toothfish (*Dissostichus eleginoides*) fishery in Division 58.5.2. Introduction. Based on WG-FSA-2021/21.

Presentations given during the review

British Antarctic Survey. South Georgia (Subarea 48.3) – Patagonian toothfish stock hypothesis.

Devine, J. and A. Dunn. Ross Sea Region Antarctic Toothfish. ToR (i): Reviewing the status and report on the implementation of the recommendations arising from the CCAMLR Independent Stock Assessment Review for Toothfish in 2018.

Devine, J. and A. Dunn. Ross Sea Region Antarctic Toothfish. ToR (ii): Reviewing if biological parameters used in the assessment models are estimated using best available science and appropriately used in the stock assessment models.

Devine, J. and A. Dunn. 2023. Ross Sea Region Antarctic Toothfish. ToR (vii): Identify and consider any additional stock specific analyses or investigations that are critical for this assessment and warrant peer review, and develop additional ToR(s) to address as needed.

Devine, J., A. Dunn and A. Grüss. 2023. Overview of the Ross Sea Region Antarctic toothfish stock assessment.

Dunn, A. and J. Devine. 2023. Introduction to stock assessment using CASAL.

Dunn, A. and J. Devine. 2023. Ross Sea Region Antarctic Toothfish. ToR (iii): Reviewing the extent to which the choice and analyses of observations are estimated using the best available science and appropriately used in the stock assessment models, including the representativeness of observations in space and time.

Dunn, A. and J. Devine. Ross Sea Region Antarctic Toothfish. ToR (iv): Determining whether the statistical modelling (including model assumptions, model structure, priors and penalties, data selection and weighting) and the resulting inferences on stock status and dynamics and catch limits are implemented using best-practice methods.

Dunn, A. and J. Devine. 2023. Ross Sea Region Antarctic Toothfish. ToR (v): Reviewing if there are trends in parameters through time or other spatial and temporal effects on the biological parameters, other parameters such as selectivity, and observations that should be taken into account in each stock assessment.

Earl, T. and L. Readdy. Assessment of Patagonian Toothfish in Subarea 48.3. ToRs 1 and 2.

Earl, T. and L. Readdy. Assessment of Patagonian Toothfish in Subarea 48.3. ToRs 3 and 4.

Earl, T. and L. Readdy. Assessment of Patagonian Toothfish in Subarea 48.3. ToRs 5, 6 and 7.

Readdy, L. and T. Earl. Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.4: ToRs i and ii.

Readdy, L. and T. Earl. Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.4: ToRs iii and iv.

Readdy, L. and T. Earl. Patagonian toothfish (*Dissostichus eleginoides*) in Subarea 48.4: ToRs v and vi.

Welsford, D. 2023. Governance of CCAMLR's toothfish fisheries.

Appendix VII-2. Performance Work Statement

Performance Work Statement (PWS)
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review
Independent Review of Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Toothfish Stock Assessments

Background The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions. Scientific peer review is defined as the organized review process where one (1) or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination. Specifically, science products that the agency can reasonably determine that will have, when disseminated*, "a clear and substantial impact on important public policies or private sector decisions*." Additionally, peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards1.

Scope The CCAMLR toothfish stocks are assessed every two (2) years on a routine basis. Four (4) Bayesian age-structured integrated stock assessments for toothfish using an advanced software package (**C++ Algorithmic Stock Assessment Laboratory** (CASAL)) were reviewed by three (3) independent stock assessment scientists in 2018 (SC-CAMLR-XXXVII/02 Rev. 1, Division 58.5.2, Subarea 88.1 and SSRUs 882A–B, Subareas 48.3 and 48.4). Since then, each assessment has been further developed to address the recommendations detailed by the review (SC-CAMLR- XXXVII, Appendix 9, Table 3). As it has been five (5) years since the review, a new assessment of the performance of these stock assessments is appropriate.

1 https://www.whitehouse.gov/wp-content/uploads/legacy_drupal_files/omb/memoranda/2005/m05-03.pdf

In addition, concerns have been raised by one (1) CCAMLR Member since 2018 about the performance of the stock assessment in Subarea 48.3 and the resulting precautionary management of the fishery. Currently, this disagreement has resulted in a lack of consensus to agree on an appropriate conservation measure for Subarea 48.3 in 2021 and in 2022. In an effort to resolve this issue, the Scientific Committee recommended an independent review of relevant data, the stock assessment, and application of CCAMLR decision rules, in the context of the assessment and management of all CCAMLR toothfish stocks (SC-CAMLR-41, paragraph 3.108). This task order will support a portion of this recommended independent review. It should be noted that the independent reviewer reports for this task order will be used by the U.S. Delegation to CCAMLR to inform the U.S. position on whether toothfish fisheries are managed in a manner consistent with U.S. objectives for these fisheries. Since decision making within CCAMLR is by consensus of all Members to the Commission, the U.S. position will affect how these fisheries are managed in the future.

Tasks

CCAMLR will convene a formal, virtual, multiple-day panel review meeting involving three (3) independent CIE stock assessment experts to conduct a peer review of the four (4) CCAMLR toothfish stock assessments in August 2023. The purpose of this meeting will be to provide an external peer review of the approach that CCAMLR uses to develop management advice for toothfish stocks as well as a technical review of four (4) toothfish stock assessments (SC- CAMLR-41, paragraph 3.108, CCAMLR-41, paragraph 4.39). Note that this task order is not responsible for any of the logistics, attendance, or facilitation of the multiple-day panel meeting.

Task 1: **Synthesize, quality control, and review all information and final materials from the panel review meeting**

●The three (3) CIE reviewers will evaluate the information provided at the August 2023 CCMALR review meeting for use as the basis for developing three (3) independent CIE peer review reports.

(i)Dissostichus eleginoides in Heard Island and McDonald Islands in Division 58.5.2
(ii)Dissostichus mawsoni in the Ross Sea in Subarea 88.1 and SSRUs 882A–B
(iii)Dissostichus eleginoides in South Georgia in Subarea 48.3
(iv)Dissostichus eleginoides in the South Sandwich Islands in Subarea 48.4.

Task 2: Produce draft independent CIE reviewer reports

●The contractor shall have the three (3) independent reviewers develop and create draft peer review reports addressing the PWS Terms of Reference (TORs) for the four (4)toothfish stock assessments.

Task 3: The contractor shall review and finalize all three (3) individual peer review reports.

●The contractor shall evaluate the reports to ensure that these work products address all the Terms of Reference and whether they are of a quality and robustness that qualifies these products as having met the CIE standard of independence and effectiveness. This task also includes all post-review contracting, invoicing, and related matters.

Final Task Order Deliverables - Independent CIE Peer Review Reports

Each CIE reviewer shall complete an independent peer review report in accordance with this PWS. Each CIE reviewer shall complete the independent peer review addressing each TOR as described in **Annex 1**. Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Annex 2**.

Period of Performance
The period of performance shall be from the time of award through **October 2023**. Each reviewer's duties shall not exceed **7** days to complete all required tasks.

Place of Performance
The place of performance shall be at the contractor's facilities and/or home site.
Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Timing	Deliverable/activity
Immediately following panel meeting	Reviewers evaluation information and materials received from the panel meeting and commence work on draft independent peer review reports
August 2023	Virtual panel review meeting
Approximately two (2) weeks following the panel meeting	Contractor receives draft independent peer review reports
Within two (2) weeks of receiving draft reports	Contractor submits final reports to the Government

* Tasks under this task order may not begin until the panel review meeting has concluded. Any modifications in the timing of the milestones shall be approved by the Contracting Officer Representative (COR) and the CIE contractor.

Travel
No travel is necessary.

Applicable Performance Standards The acceptance of the task order deliverables shall be based on three (3) performance standards: (1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each TOR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

NMFS Project Contact
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Annex 1. Terms of Reference

The aim for the CIE review is to provide advice to the Scientific Committee on the adequacy of the data collection, modelling approaches and methods used in CCAMLR's integrated toothfish stock assessments and if they are appropriate for all toothfish stocks relative to international best practices. Specifically, the terms of reference for the CIE review are to determine if the integrated toothfish stock assessments within the CCAMLR area, in particular for South Georgia in Subarea 48.3, the South Sandwich Islands in Subarea 48.4, Heard Island and McDonald Islands in Division 58.5.2, and the Ross Sea in Subarea 88.1 and SSRUs 882A–B, use the best available science, are consistent with Article II of the Convention, and likely to achieve CCAMLR's objective by:

(i)Reviewing the status and report on the implementation of the recommendations arising from the CCAMLR Independent Stock Assessment Review for Toothfish in 2018 (SC- CAMLR-XXXVII/02 Rev. 1, and SC-CAMLR-XXXVII, Annex 9, Table 3).

(ii)Reviewing if biological parameters used in the assessment models are estimated using are sufficient and appropriately used in the stock assessment models:

a.Sex-specific maturation
b.Natural mortality
c.Length-weight relationship
d.Growth
e.Stock-recruitment steepness.

(iii)Reviewing the extent to which the choice and analyses of observations are estimated using the best available science and appropriately used in the stock assessment models, including the representativeness of observations in space and time:

a.Catch observations
b.Survey data
c.Catch per unit effort (CPUE) abundance indices
d.Tag release and recapture observations
e.Age and length compositions
f.Selectivity.

(iv) Determining whether the statistical modeling (including model assumptions, model structure, priors and penalties, data selection and weighting) and the resulting inferences on stock status and dynamics and catch limits are implemented using best- practice methods.

(v) Reviewing if there are trends in parameters through time or other spatial and temporal effects on the biological parameters, other parameters such as selectivity, and observations that should be taken into account in each stock assessment.

(vi) Reviewing whether population projection methods, recruitment series used, and implementation of decision rules are conducted using the best available science.

(vii) Identify and consider any additional stock specific analyses or investigations that are critical for this assessment and warrant peer review, and develop additional TOR(s) to address as needed.

Annex 2. Individual Independent Peer Reviewer Report Requirements

1. The independent Peer Reviewer report shall be prefaced with an Executive Summary providing a concise summary of whether they accept or reject the work that they reviewed, with an explanation of their decision (strengths, weaknesses of the analyses, etc.).

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs. The independent report shall be an independent peer review, and shall not simply repeat the contents of the Peer Reviewer Summary Report.

a. Reviewers shall describe in their own words the review activities completed during the panel review meeting, including a concise summary of whether they accept or reject the work that they reviewed, and explain their decisions (strengths, weaknesses of the analyses, etc.), conclusions, and recommendations.

b. Reviewers shall discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.

c. Reviewers shall elaborate on any points raised in the Peer Reviewer Summary Report that they believe might require further clarification.

d. The report should include recommendations on how to improve future assessments.

3. The report shall include the following appendices:

Appendix 1: Bibliography of materials provided for review Appendix 2: A copy of this Performance Work Statement
Appendix 3: Panel membership or other pertinent information from the panel review meeting.

Appendix IIV-3. List of participants

2023 Independent peer review of toothfish stock assessments

CIE Reviewers

Cieri, Matthew
Chen, Yong
Sparholt, Henrik

Participants

Belchier, Mark
Collins, Martin
Devine, Jennifer
Dunn, Alistair
Earl, Timothy
Fields, Lauren
Ghebrezgabhier, Danait
John, Mitchell
Maschette, Dale
Masere, Cara
Parker, Steve
Readdy, Lisa
Stoute, Selina
Walker, Nathan
Wallis, Claire
Welsford, Dirk
Ziegler, Philippe