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MODELLING APPROACHES: SUPPORT TO ICCAT TROPICAL TUNAS MULTI-STOCK MSE PROCESS IN 2024

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SUMMARY

This Final report documents the work carried out in the second semester of 2024 for the Atlantic tropical tunas MSE under the short-term contract for modelling approaches: support to ICCAT tropical tunas multi-stock MSE process. During this project, we have (i) provided and discussed a workplan for finalizing the MSE, (ii) proposed and discussed a series of options for operational management objectives for tropical tunas, (iii) conditioned the yellowfin Operating Models from the new assessment carried out in 2024, (iv) developed options to incorporate climate change impacts as robustness tests, (v) explored alternative candidate multistock harvest control rules (and MPs) and (vi) sought external guidance with regards to the approach, the methodology and the finalization of this MSE. All data, results and scripts developed for this project are available for ICCAT Secretariat together with SCRS documents. This document summarizes the activities, deliverables and milestones carried out for this project.

RESUME

Ce rapport final documente le travail réalisé au cours du second semestre 2024 sur la MSE pour les thonidés tropicaux de l'Atlantique dans le cadre du contrat à court terme pour les approches de modélisation : soutien au processus de MSE multi-stocks pour les thonidés tropicaux de l'ICCAT. Au cours de ce projet, nous avons (i) fourni et discuté un plan de travail pour finaliser la MSE, (ii) proposé et discuté une série d'options pour les objectifs de gestion opérationnels pour les thonidés tropicaux, (iii) conditionné les modèles opérationnels pour l'albacore à partir de la nouvelle évaluation réalisée en 2024, (iv) développé des options pour incorporer les impacts du changement climatique en tant que tests de robustesse, (v) exploré de possibles règles de contrôle de l'exploitation multi-stocks alternatives (et des MP) et (vi) demandé une orientation externe concernant l'approche, la méthodologie et la finalisation de cette MSE. Toutes les données, les résultats et les scripts développés dans le cadre de ce projet sont disponibles pour le Secrétariat de l'ICCAT, ainsi que les documents du SCRS. Ce document résume les activités, les résultats et les étapes de ce projet.

RESUMEN

Este informe final documenta el trabajo realizado en el segundo semestre de 2024 sobre la MSE para los túnidos tropicales del Atlántico bajo el contrato de corta duración para los enfoques de modelación: respaldo al proceso de MSE multistock de túnidos tropicales de ICCAT. Durante este proyecto, hemos (i) proporcionado y discutido un plan de trabajo para finalizar la MSE, (ii) propuesto y discutido una serie de opciones para los objetivos de ordenación operativos para los túnidos tropicales, (iii) condicionado los modelos operativos de rabil a partir de la nueva evaluación realizada en 2024, (iv) desarrollado opciones para incorporar los impactos del cambio climático como pruebas de robustez, (v) explorado normas de control de la captura candidatas alternativas multistock (y MP) y (vi) buscado orientación externa con respecto al enfoque, la metodología y la finalización de esta MSE. Todos los datos, resultados y scripts desarrollados para este proyecto están a disposición de la Secretaría de ICCAT junto con los documentos del SCRS. Este documento resume las actividades, resultados e hitos del proyecto.

KEYWORDS

Tropical tunas, bigeye, yellowfin, skipjack, management strategy evaluation

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1. Introduction, background and objectives of the project

Science underpins the management decisions made by ICCAT. The Standing Committee on Research and Statistics (SCRS) is responsible for developing and recommending to the Commission all policy and procedures for the collection, compilation, analysis, and dissemination of fishery statistics. The SCRS also coordinates various national research activities, develops plans for special international cooperative research programmes, carries out stock assessments, and advises the Commission on the need for specific conservation and management measures.

At its 2014 meeting, the SCRS adopted the 2015-2020 Science Strategic Plan for the functioning and orientation of the SCRS, which was adopted at the 19th Special Meeting of the Commission (Genova, November 2014). The Plan comprises among other aspects, Goals, Objectives, the Strategies to achieve each goal as well as measurable targets. The range of the Plan is extensive and ambitious aimed at providing a response to the changing demands on the SCRS and increased amount of work required from the Committee. The work plan is flexible and is open to revision according to requests by the Commission. Accordingly, the SCRS develops annual work plans for each of its Sub-Committees and Species Groups to provide the Commission with the necessary advice aimed at the conservation and management of the different stocks.

An important element of the programme is to develop a robust advice framework consistent with the Precautionary Approach. This requires the development of new stock assessment methods that consider the main sources of uncertainty and use the new data sets and knowledge provided by the SCRS Species Groups. New data sets include, for example, historical catch and effort data, aerial surveys of spawning aggregations and tagging of juveniles. To evaluate novel approaches the SCRS is developing a Management Strategy Evaluation (MSE) framework for several species as recommended by the KOBE process. This includes one or more simulations or Operating Models (OMs). This will allow current and alternative assessment and advice frameworks to be evaluated with respect to their ability to meet multiple management objectives with acceptable levels of risk.

Work on the multi-stock MSE for tropical tunas started in 2018, with some initial development of the framework to use in the OM development. This work continued in subsequent years with the exploration of uncertainties (Merino *et al*., 2021a and b), and the development and running of computer code that informed the hypotheses to be considered in the operating model grid (Moron *et al*., 2023).

In order for the ICCAT/SCRS to carry out the detailed multi-year work programme that is required in order to meet the Commission objectives, there is a need to continue development of the multi-stock MSE, including the hire of MSE Technical Expert(s) to work directly with the Tropical Tunas Species Group and its Coordinator, Rapporteurs, the SCRS Chair (and Vice-Chair, if one is appointed), and in consultation with the Secretariat.

For this endeavour, we prepared a workplan to continue the development of the multi-stock tropical tunas MSE, including communication materials to improve engagement with the SCRS and Commission and to increase the understanding of the complexities inherent to the management of fisheries that target more than one species simultaneously. Our proposal was based on the SCRS roadmap for the completion of MSEs for different stocks and, importantly, on our skills and expertise in multi-stock MSEs, stock assessment modelling and experience in tropical tuna working groups in the Atlantic and other areas.

This report includes details of how we developed the proposed workplan including SCRS documents and discussions within the tropical tunas working group, how we have developed components of the MSE simulation framework and the external guidance with regards to the approach, the methodology and the finalization of this MSE that we expect will help finalize this process in 2025 or 2026.

2. Methodology and workplan

The development of the multi-stock MSE for tropical tunas requires a series of steps:

1. Continue the design and implementation of the MSE framework under the guidance of the Tropical Tunas Species Group and its Coordinator, Rapporteurs, the SCRS Chair (and Vice-Chair, if one is appointed) and the ICCAT Population Dynamics Expert (or any other specialist designated by the ICCAT Secretariat);
2. Continue work with the SS3 modelers, grid developers and Tropical Tunas Species Group to modify the OM grid through changes to the reference set and to the robustness set as deemed appropriate by the SCRS and/or Panel 1. This could include considering new information from catch data, stock indicators, environmental data, and scientific research;

3. Continue to work with the Tropical Tunas Species Group to develop and tune Candidate multi-species Management Procedures (CMPs);
4. Test the robustness of projections and CMPs to data lags and gaps;
5. Continue development of diagnostics to evaluate CMPs against performance metrics;
6. Compare OMs and management objectives and provide diagnostics to evaluate suitability of individual OMs for inclusion in the final grid;
7. Consider and discuss the impact of uncertainty not considered in the OM grid in projections and CMP performance/selection;
8. Create a Shiny app (e.g. SLICK app) with new data visualizations as required;
9. Develop visualizations to support evaluations of tradeoffs among performance metrics;
10. Attend and provide updates at Tropical Tunas Technical Sub-group on MSE meetings (both formal and informal), and Intersessional Meetings of the Tropical Tunas Species Group.
11. Support development of analyses and visualizations for the tropical tuna multi-stock MSE Ambassador Sessions and Panel 1 dialogue meetings.

We developed the following specific tasks to address some of the steps described above in 2024:

Task 1. To develop new OMs (e.g. for yellowfin after the new assessment to be carried out in 2024) in collaboration with the SS3 modelers within the tropical tuna species group and in consultation with the SCRS and Panel 1. This could include additional OMs to account for climate-driven impacts on tropical tunas.

Task 2. To design multi-stock Harvest Control Rules (HCRs) suitable for tropical tuna fisheries based on other experiences of fisheries that target more than one stock simultaneously. Specifically, we will use examples from demersal fisheries in ICES to search for compatible rules that help achieving management objectives that account for the technical interactions between gears and more than one stock. We will use diagnostics and performance metrics developed for other Atlantic tuna MSEs and by ICES and discuss if additional metrics are necessary for this MSE.

Task 3. Investigate options for management objectives for tropical tunas. Starting from a previous document (Merino *et al.,* 2023, SCRS/2023/020) and recent discussions in Panel 1 and Commission, we will evaluate management options to maintain the three tropical tuna stocks at sustainable levels and increase the productivity of fisheries by reducing the mortality on juveniles of bigeye and yellowfin.

Task 4. Illustrate the need for a multi-stock approach for tropical tuna fisheries. We used the most recent advice provided in the Kobe II Strategy Matrices developed for the three tropical tuna stocks to show the consequences of not accounting for the technical interactions between the three stocks that are captured simultaneously in specific fisheries (e.g. purse seine and longline). We showed the Shinny visualization tool for use by the SCRS, MSE Ambassador sessions, Panel 1 and the Commission in the future.

Updates of these tasks were provided during the yellowfin stock assessment meeting (8-12 July 2024), Tropical Tuna species group meeting (16-20 September 2024), SCRS meeting (26-31 September 2024) and any other formal or informal meeting of the MSE technical subgroup.

These four specific tasks were completed in 2024 and we reported on some of them to the tropical tuna working group and the SCRS during the second semester of 2024 as illustrated in the following Gantt chart.

		Months					
Task Nr.	**Task name**	**July**	**August**	**September**	**October**	**November**	**December**
Task 1	Develop new Oms						
Task 2	Design multi-stock HCRs						
Task 3	Management objectives						
Task 4	Illustration						
Deliverables Nr.	**Deliverable name**						
Dvble 1	SCRS doc- description of work and plan.						
Dvble 2	Draft Final report						
Dvble 3	Final report						
Meetings Nr.	**Meeting name**						
Meeting 1	Yellowfin SA						
Meeting 2	Species WG/SCRS						

3. Results achieved during this project

Deliverables

For the development of the tropical tuna MSE we are developing well-documented object-oriented sources code for all the components of the MSE, including the Operating Models consistent with the recommendations of the Tropical Tuna Species Group and the Technical sub-Group on MSE. During the methodological developments we are doing the following:

1. Update diagnostic reports for OMs – for OM selection/weighting should there be any further updates to the SS3.30 reference set and robustness set as needed. Identify key OMs spanning the range of uncertainty axes and produce pair-wise OM comparison reports.

2. Report performance of CMPs for reference and robustness OMs and report on CMP selection process.

3. Report on additional robustness analyses as guided by the group (e.g. data lags and gaps).

4. Participate in the development and provide candidates of multi-species management procedures (HCRs).

5. Create Shiny app (e.g. SLICK) to communicate new OMs, performance metrics and CMPs.

6. Update and provide trial specification document.

7. Support development, testing, and tuning of CMPs.

8. Provide support (analyses, visualizations) for Tropical Tuna MSE Ambassador sessions and Panel 1 meetings (as per the ICCAT calendar).

9. Attend and provide updates at Tropical Tuna Species Group meeting in September 2024.

10. Participate in the drafting of SCRS reports and other document submissions.

11. Misc. Webinars, contingencies, individual calls/support with MSE package.

12. A report with an external view on the current direction of the MSE process and suggestions for more effective feedback from the tropical tuna WG, Panel 1 and the Commission will be provided.

The implementation of code is done using Github for SCRS participants and other scientists. Drafts of deliverables and any prototypes were provided by the Species Group during the September 2024 meeting.

As specific deliverables of the project we have submitted:

1) A short SCRS document/presentation for the September Tropical Tuna Species Group meeting, with a description of the work carried out and the workplan for the activities to be developed until the end of 2024. The Tropical Tunas Species Group, the SCRS Chair, in consultation with the ICCAT Secretariat, will review the deliverable and communicate any necessary revisions (if applicable) and/or inform of approval of this deliverable. We will submit the revised final documents (if changes are requested) within 10 days after the conclusion of the above-mentioned Species Group meeting.

This SCRS document was SCRS/P/2024/103 with details on the current state of this MSE and the plans for the second semester of 2024.

2) The draft final report has been submitted to the Secretariat by on 13th December 2024, including the following:

   a) Full description of the work carried out;

   b) Detailed description of the methodology and protocols related to the design and implementation of the MSE framework;

   c) Update and provide the trial specification document;

   d) List of meetings attended, including Tropical Tunas Technical Sub-group on MSE, Tropical Tunas MSE Ambassador sessions and Panel 1 meetings (the latter as per the ICCAT calendar);

   e) Bibliographic references;

   f) An Executive Summary.

3) The final report will be prepared taking into account any comments provided by ICCAT, the relevant SCRS officers and the Secretariat, and the full administrative report including copies of all the administrative documents, will be submitted by 31 December 2024, at the latest.

With regards to the contents of this final report, we have prepared a first trial specification document (see Appendix I) with a compilation of the tasks and deliverables presented throughout the different phases of this MSE. This includes the full description of the work, the methodology, approach, design and current implementation of the MSE work. The newly developed document also contains the external reviews provided for guidance of this MSE. In addition, we specify below the working documents prepared during the duration of this contract and the list of meetings attended.

To sum up, five working documents have been produced during this project:

- SCRS/2024/P/103 Workplan for tropical tunas MSE in 2024 by, Merino, G., A. Urtizberea, G. M. Correa, A. Laborda, J. Santiago.

- SCRS/2024/P/108 Development of operational management objectives for tropical tunas, by Merino, G., A. Urtizberea, G. M. Correa, A. Laborda, J. Santiago.

- SCRS/2024/118 Incorporating climate change effects in the MSE for Atlantic tropical tunas, by Giancarlo M. Correa, Agurtzane Urtizberea, Gorka Merino, Maite Erauskin-Extramiana, and Haritz Arrizabalaga.

- SCRS/P/2024/081 Harvest control rule options for multistock tropical tuna MSE: Demersal fisheries Bay of Biscay case study by, Agurtzane Urtizberea, Dorleta Garcia, Giancarlo M. Correa, Ane Laborda, Haritz Arrizabalaga and Gorka Merino.

- SCRS/P/2025/xxx Mixed fisheries HCR options for multi Stock tropical fisheries in the Atlantic Ocean by, Agurtzane Urtizberea, Dorleta Garcia, Giancarlo M. Correa, Ane Laborda, Haritz Arrizabalaga and Gorka Merino. This document will be submitted to the next Bigeye data preparatory meeting in 2025.

The meetings attended include:

- ICCAT Yellowfin Tuna Stock Assessment Meeting (hybrid/ Madrid, Spain, 8-12 July 2024).
- ICCAT Species Groups meeting (hybrid/ Madrid, Spain, 16-20 September 2024).
- 2024 Meeting of the Standing Committee on Research and Statistics (SCRS), (hybrid/ Madrid, Spain, 23-27 September 2024).

Acknowledgments

This work was carried out under the provision of the ICCAT. The contents of this document do not necessarily reflect the point of view of ICCAT, which has no responsibility over them, and in no ways anticipate the Commission's future policy in this area.

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Annex A

Draft trial specification document

Consolidated report for the Management Strategy Evaluation of Atlantic tropical tunas
Thursday, 12 December 2024

SUMMARY

The Atlantic tropical tuna Management Strategy Evaluation (MSE) process started in 2018 with the aim to support the development of a robust scientific advice and management framework consistent with the Precautionary Approach. Basically, the technical developments of this MSE aim to evaluate candidate management procedures (MP) for the common management of the tropical tuna stocks under the purview of ICCAT, in particular, the Eastern stock of skipjack and the Atlantic stocks of bigeye and yellowfin. At the end of 2024, most of the components of the MSE framework have been adopted including: The identification of uncertainties, a reference set of Operating Models, an Observation Error Model, a set of plausible conceptual and operational management objectives and, a preliminary set of candidate multi-stock MPs. This document presents a review of the different steps taken for this MSE since it started in 2018. We include a summary of how each one of the components of the MSE simulation framework have been developed with specific references to the SCRS documents from which additional information will be provided. We have compiled the most important information of the working documents that describe the tropical tunas MSE in a consolidated report in a way that contains all the information needed to understand the current development of this MSE. This document is intended to be a reference document that can be updated in the future, if necessary, as the tropical tunas albacore MSE evolves.

Introduction

The Standing Committee on Research and Statistics (SCRS) is responsible for developing and recommending to the Commission all policy and procedures for the collection, compilation, analysis, and dissemination of fishery statistics. The SCRS also coordinates various national research activities, develops plans for special international cooperative research programs, carries out stock assessments, and advises the Commission on the need for specific conservation and management measures.

An important element of SCRS's strategic plan is to develop a robust advice framework consistent with the Precautionary Approach. This requires the development of new stock assessment methods that consider the main sources of uncertainty and use the new data sets and knowledge provided by the SCRS Species Groups. New data sets include, for example, historical catch and effort data, aerial surveys of spawning aggregations and tagging of juveniles. To evaluate novel approaches the SCRS is developing a Management Strategy Evaluation (MSE) framework for several species as recommended by the KOBE process. This will allow current and alternative assessment and advice frameworks to be evaluated with respect to their ability to meet multiple management objectives with acceptable levels of risk.

The MSE for the Atlantic tropical tuna stocks work started in 2018 through an ICCAT contract for a first phase of the project awarded to a consortium of researchers (Merino et al., 2020). The objective of the first phase was to initiate the design of the MSE framework and to support a robust advice framework for the Atlantic tropical tuna stocks. For this, the main tasks were to develop a workplan for the MSE simulation framework, to initiate its implementation and to engage with ICCAT experts in meetings and a specific workshop. In this first phase, a series of SCRS papers and presentations were completed and a three-day workshop was carried out to discuss progress and potential developments. Overall, a suitable methodology was agreed and potential paths of development were outlined. Also, FLBEIA (Garcia et al., 2012; Garcia et al., 2017) was identified as the software to develop the MSE for Atlantic tropical tunas.

Phase 2, which was planned for 2019 and 2020, was not carried out, following the indication from the Commission at the end of 2018 to revise the schedules for the different ICCAT species MSE process, lowering the priority of Tropical Tunas MSE. In 2021, a dedicated tropical tunas MSE Technical Group meeting was established with the initial objectives of reviewing the most important uncertainties inherent to tropical tuna fish and fishery dynamics as well as reinvigorating the development of this MSE.

In 2022, 2023 and 2024, the technical development of the MSE simulation framework continued and several working documents were discussed under the tropical tuna working group and SCRS meetings. By the end of 2024, most of the components of the MSE framework have been adopted including: The identification of uncertainties, a reference set of Operating Models, an Observation Error Model, a set of plausible conceptual and operational management objectives and, a preliminary set of candidate multi-stock MPs. In this document we review the different steps taken and include a summary of each one of the SCRS documents of this development.

1. General approach and components of the MSE

MSE is used to evaluate the impacts of uncertainties inherent to fisheries (Punt et al., 2014). Conducting an MSE requires following a series of basic steps that were followed for albacore. Here we advance the general steps followed in the tropical tunas multistock MSE.

Step 1. Identification of management objectives and performance statistics

The conceptual objective of ICCAT is to maintain populations at levels that can permit the maximum sustainable yield (or above). However, this may need to be more elaborated for multistock management framework. In the document SCRS/2023/020 we reviewed and discussed a series of alternative multispecies management objectives based on ICES mixed fisheries and recent publications. From the alternatives, the SCRS agreed that maintaining all the stocks in the green quadrant of the Kobe plot was probably the one that would better reflect the mandate of ICCAT.

In 2024, a new document (SCRS/2024/P/108) were used to develop operational management objectives (OMO) from the discussions that followed the presentation of SCRS/2023/020 and recent stock assessments. In this document, the main factors that ICCAT would need to take into account for the adoption of OMOs for tropical tunas were discussed in order to build a common understanding of the productivity of tropical tuna stocks and what may be a desired status for the tropical tuna fisheries system. In this document, the technical interactions between fleets that capture two or three tropical tunas simultaneously were described and also, the specific impact of each one of the fleets on the mortality of juveniles of bigeye and yellowfin, as well as the overall productivity were discussed. Also, this document highlighted the need to adopt interim limit reference points for tropical tunas likewise other Atlantic tuna stocks. This document and the discussions that were held during the SCRS meeting in 2024 contributed to the adoption of interim OMOs for Atlantic tropical tunas by the ICCAT Commission in 2024 (PA1-508B). Today, the OMOs include a 50% or greater probability of maintaining the stocks in the green quadrant of the Kobe plot and preliminary probabilities of breaching the interim limit reference point of $0.4xSB_{MSY}$.

The initial performance statistics selected for this MSE are directly taken from the indicators used for other MSEs in ICCAT:

Stock Status

- Minimum spawner biomass relative to $B_{MSY.}$
- Mean spawner biomass relative to B_{MSY}.
- Mean fishing mortality relative to F_{MSY}.
- Probability of being in the Kobe green quadrant.
- Probability of being in the Kobe red quadrant.

Safety

- Probability that spawner biomass is above BLIM (0.4xBMSY).
- Probability of $B_{LIM}<B<B_{THRESH}$.

Yield

- Mean catch – short term (Mean over 1-3 years)
- Mean catch – medium term (Mean over 5-10 ye
- Mean catch – long term (Mean over 15-30 years)

Stability

- Mean absolute proportional change in catch
- Variance in catch
- Probability of shutdown
- Probability of TAC change over a certain level (10%)
- Maximum amount of TAC change between management periods

Step 2. Selection of hypotheses of system dynamics

Management Strategy Evaluation (MSE) requires characterizing the main sources of uncertainty inherent to fisheries. The unknowns that challenge the interpretation of fish stock assessments include gaps on biological processes and fishery dynamics. The first are often dealt with hypotheses on input biological parameters to stock assessment models; and the second with hypotheses over the available datasets. In this MSE we characterize uncertainty using alternative model runs of the stock assessment models developed using Stock Synthesis (Methot Jr and Wetzel, 2013). These uncertainties were reviewed in document SCRS/2021/055. The document corresponds to the second phase of the tropical tuna MSE and attempts to define the axes of uncertainty to be considered in the Operating Models of the tropical tuna MSE. This work follows document SCRS/2021/016 where the main sources of uncertainty characterized for tropical tunas in ICCAT and other RFMOs were reviewed. In this document we expanded the description of potential axes of uncertainty by reviewing the uncertainty of other tuna stocks and by summarizing the points of discussion and agreements reached in ICCAT's Tropical Tuna MSE meeting (29-31st March 2021). The main sources of uncertainty characterized in tropical tuna stock assessments are:

- Steepness (as in all tropical tuna stock assessments and MSEs)
- SigmaR (considered in Atlantic bigeye stock assessment)
- Natural mortality (as in Atlantic and East Pacific bigeye stock assessments and Indian Ocean bigeye and yellowfin MSEs).
- Growth (as in West and Central Pacific bigeye, East Pacific bigeye and yellowfin and Indian Ocean bigeye and yellowfin MSEs).
- Selection of the largest fish of the population (shape of selectivity for longline fleets) (considered in the East Pacific assessments of bigeye and yellowfin and Indian Ocean bigeye and yellowfin MSEs).
- Maturity (not seen in any uncertainty grids of tropical tunas' assessments or MSE).
- Additional options for data (CV of CPUEs at different values and other options of weighting considered in the assessments).

Step 3. Constructing OMs

Operating Models are representations of the "true" dynamics of the system and may include a set of the most plausible hypotheses or unlikely but not impossible situations (ISSF, 2013). In MSE frameworks the OMs represent the system that has to be managed through MPs, i.e. the "true" system that is observed, analyzed and managed through data collection systems, stock assessment and harvest control rules.

The outputs of the Stock Synthesis scenarios of the most recent stock assessments of tropical tunas were used to condition a reference set of OMs. The OMs were conditioned using libraries from the FLR-project (www.flr-project.org) and features of the FLBEIA software. The conditioned OMs are objects composed by a multiple fisheries and include parameters (selectivity, growth, natural mortality, stock-recruitment and maturity), time series of catch and biomass (in total and by age) and harvest time series, among other information. Currently, the OMs conditioned with FLBEIA describe the trends estimated by Stock Synthesis (Figure 1).

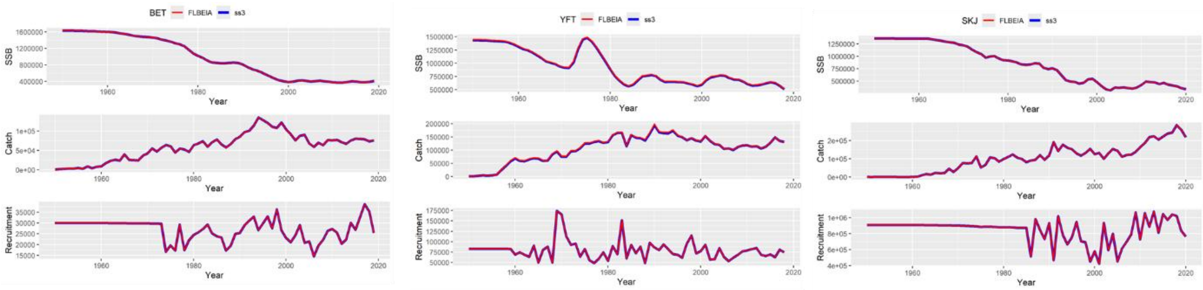

Figure 1. Operating Models in FLBEIA and output of Stock Synthesis assessments.

The main features of the reference set of OMs were presented in SCRS/2023/141 based on the most recent stock assessments of bigeye (2021), Eastern skipjack (2022) and yellowfin (2019). A new conditioning of the yellowfin OMs will be developed in 2025 using the output of the stock assessment in 2024.

Additionally, in document SCRS/2024/118, there is a proposal to include climate change impacts as robustness tests or robustness OMs.

Step 4. Defining MPs

Management Procedures represent how the true dynamics underlying fisheries exploitation are represented through stock assessment and driven by fisheries management. A population-model-based framework within which the data obtained from the fishery are analyzed and the current status, productivity and RPs of the fishery are estimated through a stock assessment model (Rademayer et al., 2007). The outputs of this are plugged into a decision framework or HCR that, in combination with RPs, provides recommendation for a management action. The observation error model (OEM) generates simulated abundance indices that are used in an estimator (to be developed in 2025) to estimate stock status and MSY-based RPs. These will be used in combination with HCRs to determine TAC every three years.

By the end of 2024, the OEM has been described and discussed based on document SCRS/2023/P/093 with examples from the three stocks' assessments. SCRS/2023/P/093 explores alternative ways to incorporate autocorrelation of the residuals obtained from observed CPUE data and model fits and investigates the relationship between spawning stock biomass (SSB) and vulnerable biomass and CPUE. The simulated CPUE is calculated by applying an error structure to the selected biomass indicator.

With regards to the estimator of the MP, this will include model based and empirical estimators. These will be used in combination with multistcok HCRs to define the management system for tropical tunas. In SCRS/2024/P/081 a preliminary set of options for multistock HCRs was discussed (Figure 2). However, this component of the MSE will be further developed in 2025.

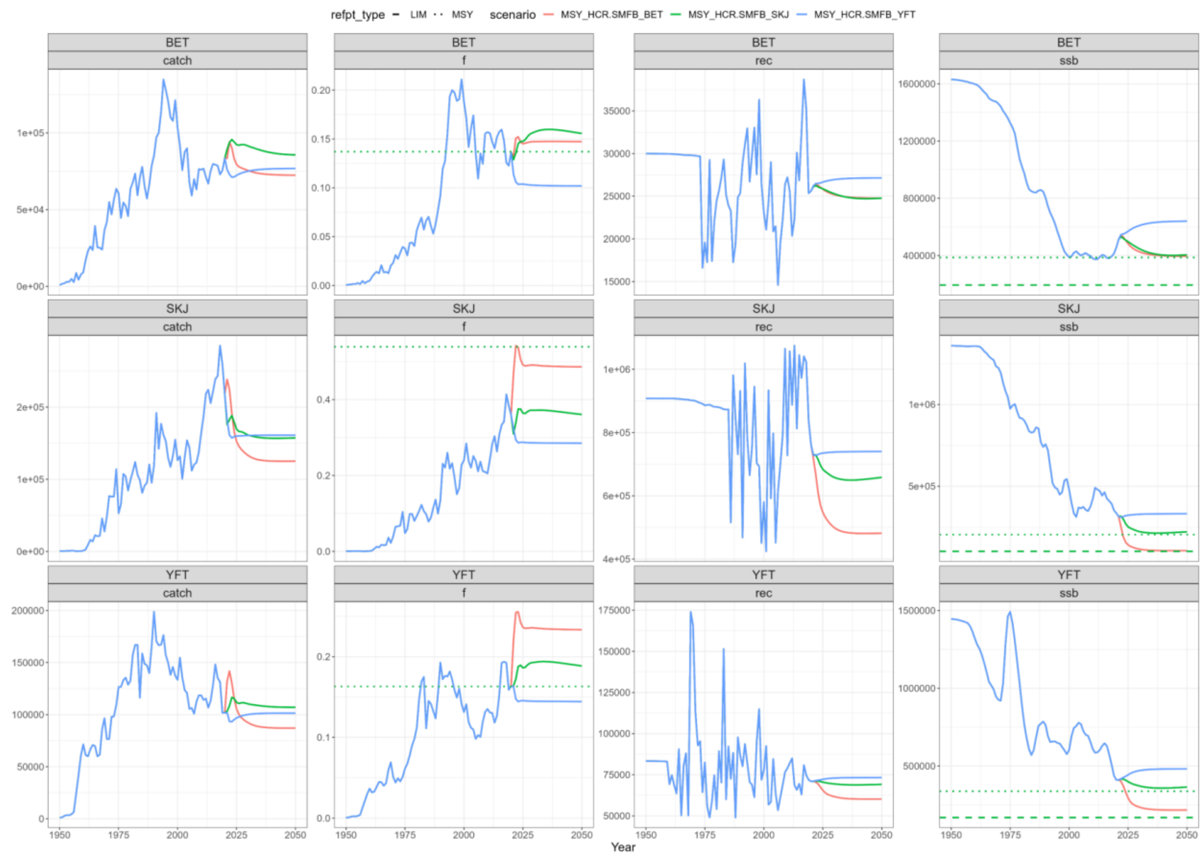

Figure 2. Illustrative example of multistock MPs as shown in SCRS/2024/P/081.

Step 5. Simulation with feedback

The Operating Models and the Management Procedures have been linked through specifically tailored R functions under the FLBEIA simulation framework. The OMs produce series of biomass, catch, fishing mortality, recruitment and other fishery trends, which are measured every three years to generate series of catch and abundance indices through an Observation Error Model. These are then used to fit the MP estimator and the HCRs. The outputs of this feedback will include estimates of relative biomass and fishing mortality, of RPs (B_{MSY}, F_{MSY}, MSY) and model parameters. This process will be simulated every three years for the duration of simulation. The interest will be on the outcome of the OMs and therefore, biomass, catch and harvest series of the OMs will be used to produce performance statistics for interpretation by managers and scientists.

The simulations with feedback will be developed in 2025.

Step 6. Summary and interpretation of performance statistics

The evaluation of HCRs is completed with the summary and interpretation of the performance of the OMs. Indicators relative to stock status, safety, yield and stability will be used. A summary of the performance of the candidate MPs and HCRs will also provided. In general, their performance is summarized using median values across OMs but we other figures that illustrate the variability of performance across OMs will be included.

2. Numerical Framework

The MSE developed for Atlantic tropical tunas is built from FLBEIA (Garcia et al., 2012; Garcia et al., 2017). This software can be used to evaluate multi-stock candidate MPs and the impact of alternative data sources on stock assessments. FLBEIA can adapt to relatively simple MP (model based or empirical) but also to more complex models. For example, it can evaluate the potential benefit of moving from SS3 to a simpler SS3 set up, a surplus production etc. The implementation can be fleet, gear, time, or other variables dependent.

The MSE framework as designed by FLBEIA is shown in Figure 3.

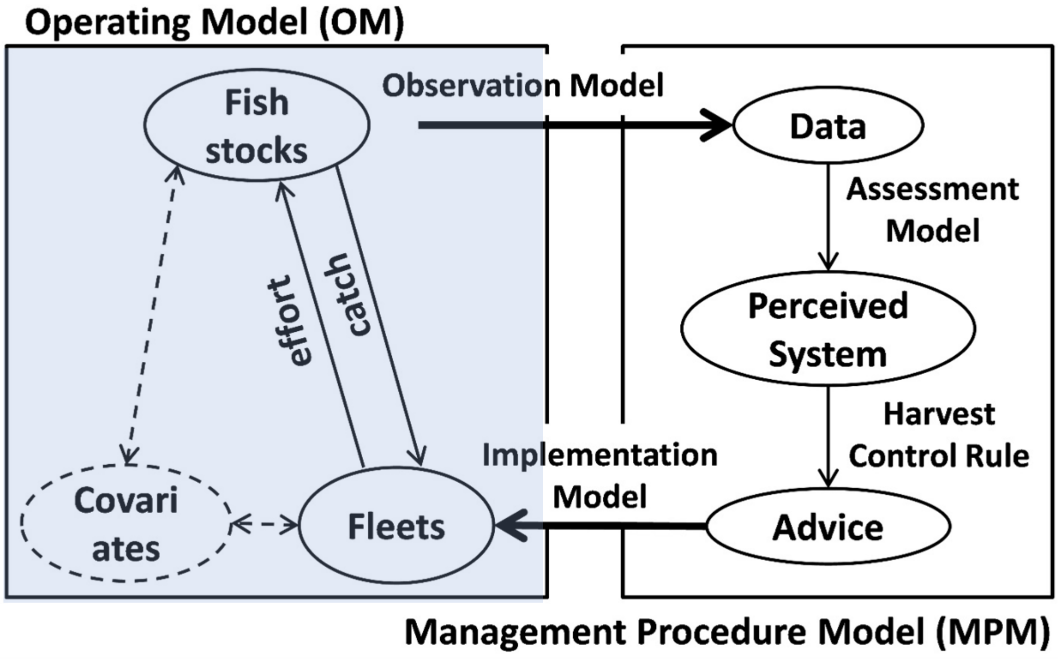

Figure 3. Conceptual description of Atlantic tropical tunas' MSE. The OMs represent the "true dynamics" of the fishery system and the MP represent the "perceive dynamics".

3. Exceptional Circumstances

A protocol of exceptional circumstances will need to be developed for this MSE.

4. External guidance for the finalization of the MSE process

In 2024, noting the need of guidance for the final stages of this project, a team of experts in MSE and stock assessments in general was identified to help design the completion of this MSE. The tasks of these experts would include reviewing the general approach, the objectives, the need of the multi-stock perspective for management, the advantages and disadvantages of the methodology and providing recommendations to finalize the MSE framework.

Two different reviews were completed in 2024: The first, by the modelling team of Oceanic Fisheries Programme within the Fisheries, Aquaculture and Marine Ecosystems (FAME) at the Pacific Community (SPC): Dr Graham Pilling, Dr Robert Scott and Dr Finlay Scott (Annex I). The second was prepared by Drs Ana Parma, Principal Scientist at the National Council for Scientific and Technological Research (CONICET) in Argentina (Annex II).

These reviews are done to ensure that this important MSE development is carried out in a transparent and effective manner, and to facilitate the communication of our results to the tropical tuna WG, SCRS, Panel 1 and the Commission.

The developments expected in 2025 will be carried out following the recommendations of these two independent reviews.

5. SCRS Documents

The development and advances of the tropical tunas MSE has been periodically presented to ICCAT working groups by means of SCRS documents. The following list includes all the documents produced in this process:

- SCRS/2018/112 A simple operating model for a basis of a discussion about the development of a management strategy evaluation for tropical tuna fisheries. Urtizberea A., Merino G., García, D., Korta M., Santiago J., Murua H., Walter J., Die D., and D. Gaertner.
- SCRS/2018/146 The steps to consider during the conditioning of the OMS of a multispecific model of tropical tuna fisheries in a Management Strategy Evaluation frame work Urtizberea A., Merino G., García D., Korta M., Harford W., Die D., Walter J., Gaertner D., Santiago J., and Murua H.
- SCRS/2018/147 Management procedure options for a Management Strategy Evaluation in tropical tuna fisheries Urtizberea A., Merino G., García D., Harford W., Die D., Walter J., Gaertner D., Santiago J., and Murua H.
- SCRS/P/2018/052 Initial development of a stock synthesis model for Eastern skipjack tuna to support tropical tuna management strategy evaluation Harford W.J., Die D., Urtizberea A., Murua H., Walter J.F., and Merino G. (One SCRS paper will also be submitted with this task).
- SCRS/P/2018/053 The initial steps of a shiny web application developed to facilitate communication and share the results of the management strategy evaluation model for tropical tuna fisheries Urtizberea A., Merino G., García D., Korta M., Harford W., Die D., Walter J., Gaertner D., Santiago J., and Murua H.
- SCRS/2021/016 Characterization of structural uncertainty in tropical tuna stocks' dynamics. Merino, G., Die, D., Urtizberea, A. and A. Laborda.
- SCRS/2021/055 Progress on characterization of structural uncertainty in tropical tuna stocks dynamics with summary of discussions held during the tropical tuna MSE meeting (29-31st March 2021). Merino, G., Die, D., Urtizberea, A. and A. Laborda.
- SCRS/2023/141 Development of Operating Models for tropical tunas Management Strategy Evaluation (MSE), by Correa, G.M, Urtizberea, A., Laborda, A., Merino, G. and J. Santiago.
- SCRS/P/2023/093 Observation Error Model (OEM) for the tropical tuna multispecies MSE, by Urtizberea, A., Correa, G.M., Laborda, A. and G. Merino.
- SCRS/2023/020 Options for multispecies management objectives for tropical tunas, by Gorka Merino, A. Urtizberea, A. Laborda, J. Santiago, M. Grande and H. Arrizabalaga.
- SCRS/2024/P/103 Workplan for tropical tunas MSE in 2024… by, Merino, G., A. Urtizberea, G. M. Correa, A. Laborda, J. Santiago.
- SCRS/2024/P/108 Development of operational management objectives for tropical tunas, by Merino, G., A. Urtizberea, G. M. Correa, A. Laborda, J. Santiago.

- SCRS/2024/P/076 State of development of tropical tuna Management Strategy Evaluation, by G. Merino, A. Urtizberea, G. Correa and A. Laborda.
- SCRS/2024/118 Incorporating climate change effects in the MSE for Atlantic tropical tunas, by Giancarlo M. Correa, Agurtzane Urtizberea, Gorka Merino, Maite Erauskin-Extramiana, and Haritz Arrizabalaga.
- SCRS/P/2024/081 Harvest control rule options for multistock tropical tuna MSE: Demersal fisheries Bay of Biscay case study by, Agurtzane Urtizberea, Dorleta Garcia, Giancarlo M. Correa, Ane Laborda, Haritz Arrizabalaga and Gorka Merino.

Acknowledgments

This work was carried out under the provision of the ICCAT. The contents of this document do not necessarily reflect the point of view of ICCAT, which has no responsibility over them, and in no ways anticipate the Commission's future policy in this area.

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Annex B

Review of Atlantic tropical tunas' MSE by Ana Parma

Review of Approach Applied to Develop a Multi-Stock Management Strategy Evaluation Framework for Atlantic Tropical Tunas

Ana Parma, 23 December 2024

Introduction

The Fundación AZTI (AZTI) has been contracted by the International Commission for the Conservation of Atlantic Tunas (ICCAT) to develop a Management Strategy Evaluation (MSE) framework for the three tropical tuna species in the Atlantic Ocean: bigeye, yellowfin and eastern stock of skipjack. As part of that process, which was initiated in 2018, AZTI has requested external expert advice on technical aspects of the modeling and analyses conducted on the project, as well as the approach proposed to design a multi-stock management procedure (MP). The MP should be aimed at meeting ICCAT's management objectives of high long-term yields whilst maintaining stocks within sustainable limits with high probability, consistent with the Precautionary Approach. This report presents an initial review of the approach described in a series of documents made available by AZTI.

Review Process

On 22 November 2024, AZTI organized a brief online meeting with Drs. Gorka Merino and Agurtzane Urtizberea, where they presented a summary of the MSE project and made available a Sharepoint containing several documents and presentations from past ICCAT meetings, and a GitHub repository containing the codes used for conditioning the operating models (OMs), running the simulations and evaluating the outputs (a Shiny app). Given the short time available for this initial review, and my lack of previous exposure to the Atlantic tropical tunas assessments and MSE project, it was agreed that the main focus of this report would be on the general MSE approach and some specific technical aspects, while leaving out aspects related to the FLBEIA and Shiny softwares.

The documents contained in the Sharepoint cover a period starting in 2017 when the first steps for conditioning the OMs were outlined (SCRS/2017/198). Considerable progress has been made since then in the development of the OMs and MSE as reflected in the reports that folllowed. Several of the documents present alternatives offered for discussion at upcoming ICCAT meetings. While these documents were useful to follow the evolution of concepts and ideas, it was difficult at times to identify decisions that had already been made from proposals and aspects that are still under consideration by the species working group. A document that summarizes the current status and outlines the main components and issues that are under development would be very helpful for future external reviews.

MSE approach

The approach followed for designing an MP for Atlantic tropical tunas (ATTs) corresponds to best practices for MSE (e.g., Punt et al. 2014), whereby the actual assessment model or empirical rule proposed to be used for calculating future recommended TACs is implemented in the simulations. This is a preferred approach compared to using a "shortcut MSE" to try to mimic the type of errors that could be made when applying a (usually more complex) assessment model to drive the MP during its actual implementation. The problem with the use of proxies is that the assumptions made about the estimation errors around the true state variables may fail to reproduce the true error distribution associated with the actual assessments. In addition, implementing in the simulations the actual fully-specified rule that will be used in practice allows evaluation of some specific robustness tests related for example to the impact of possible biases in the input data or indices of abundance, or of misspecification of model components such as somatic growth.

Management Objectives

Presentation SCRS/P/2024/108 listed candidate conceptual objectives for ATTs that were proposed considering the estimated status of the three stocks, which indicates that there is no need for urgent rebuilding plans. Rather, MPs should seek to maintain the stocks at desirable levels consistent with MSY:

– Maintain the stocks in the green quadrant of the Kobe plot (e.g., probability of being in the green part of the Kobe plot: PGK ≥ 50%).

– Maximize catch constrained by the conservation objectives. Trade-off bigeye vs yellowfin/skipjack (PS)

– Increase productivity of bigeye and yellowfin (by increasing average size) vs maintain/increase productivity of skipjack (PS).

In November 2024, ICCAT adopted interim OMOs for tropical tunas for the purpose of developing, testing, and refining candidate MPs for the three stocks, while recognizing that the Commission will need to review the initial management objectives and consider trade-offs with respect to the yield and stability of three tropical tuna stocks. The adopted OMOs on the four standard dimensions are similar to suggestions made in document SCRS/P/2024/108, namely:

– Sustainability: each of the stocks should have a PGK ≥50% during a projection period of xx years to be determined by SCRS.

– Safety: each of the stocks should have a probability ≤ 15% of falling below the Limit Reference Point set at 0.40 BMSY at any point during the projection period.

– Catch: Overall catch levels should be maximized to the extent possible with respect to each stock over the short (1-3 years), medium (4-10 yrs) and long (11-20 yrs) term.

– Stability: limit changes in TAC between management periods to plus/minus 25%.

Having minimum sustainability and safety standards already adopted by ICCAT will facilitate reducing the number of acceptable CMPs during testing, which will speed up the MSE. However, it is important to note that the calculated values of risk probabilities depend on how much uncertainty is built into the reference set of models, a process that inherently involves some degree of arbitrariness. As such, the meaning of probability values cannot be interpreted in absolute terms; rather estimated risks are useful in relative terms for comparing the performance of alternative CMPs (i.e., CMP1 is riskier than CMP2 if $P_{CMP1}(B< Blim) > P_{CMP2}(B< Blim)$). Moreover, it is impossible to predict in advance, before the reference set is finalized, how challenging it will be to meet the safety standards selected by managers and what their impact on catches will be. As noted in SCRS/P/2024/108, satisfying safety minimum standards for one of the species (presumably BFT) will constrain catches on the other two. Given these considerations, it is positive that these OMOs are considered “initial” and that it was recognize that they will need to be reviewed.

Once a reference set of OMs is adopted and some initial CMPs have been tested, it will be possible to evaluate trade-offs between yield and stock risks, and provide the type of information that managers need to review the OMOs. Considering the difficulties in resolving trade-offs between OMOs set individually for the three species, in my view it is best to proceed with the MSE so that the relative weighting of the OMOs are selected AFTER ICCAT managers consider actual possible outcomes informed by the simulations. While the existence of trade-offs among OMOs is central to any MSE, the multi-stock nature of the MSE for tropical tunas adds an extra layer of complexity, as was evident in the East-West trade-offs evaluated for Atlantic bluefin tuna. A main trade-off that has been identified for ATTs is between maintaining high productivity of YFT/SKJ from the purse-seine FAD fleet versus mortality imposed by this fleet on juveniles of BET and YFT.

The Commission requested the SCRS to “evaluate the differential impacts of fishing operations (e.g., purse seine, longline, and baitboat) on the whole range of the stock, including on juvenile mortality and yield at MSY, …”. Some of the open questions posed in document SCRS/P/2024/108 appear to involve possible changes in allocations between fleets. However, mixing changes in allocation with the development and fine-tuning of CMPs would make the task even more complex. My recommendation would be to start with a few plausible scenarios for gear allocation, using the current/recent allocation as a base case, and proceed to fine tune the CMPs conditioned on each of the allocation schemes explored. Departures from the current allocation scheme should be limited to a few scenarios that may be considered realistic (a priori, or ideally after discussion with ICCAT managers) and be aimed at illustrating possible impacts on performance. Conditioning on allocation will be especially important if different allocation schemes lead to different fine-tunings of the CMPs, a situation that is highly likely considering the differences in selectivities between the fleets.

Operating Model Structure

The base Operating Model is a simplified version of the last Stock-Synthesis (SS3) models applied for the stock assessments of the three species: yellowfin tuna (YFT) in 2019, bigeye tuna (BET) in 2021, and skipjack (SKT) in 2022. Simplifications involve the use of a single season instead of four seasons and a reduction of the number of fleets to a total of 12 fleets. Comparisons of the full SS3 predictions with those of the simplified OM appear adequate.

Document SCRS/2018/112 states that effort data are not available by metier and therefore effort share per metier is approximated from the catch share. However, catchability is said to be estimated from the relationship between catch and effort. I am confused about which effort data are available.

Representation of Uncertainty

Uncertainty is represented by an ensemble or grid of models usually called the "reference set". In addition, scenarios that are more speculative ("what if" type scenarios) and/or extreme, and for which there is little or no empirical basis for assigning plausibility, will be treated as robustness tests. This distinction is standard practice in MSE and has proved very useful for the selection of final CMPs. Relative robustness may allow better discrimination of CMPs that otherwise perform similarly in the reference set, especially after being tuned to achieve certain management targets.

The selection of uncertainty axes to define the reference set was based on alternative models and parameter values examined for the stock assessments of the three stocks. These included steepness, natural mortality, the variability around the stock-recruitment function (sigmaR), growth, maturity and the shape of longline selectivity, as well as different data weightings.

A series of diagnostics was applied to evaluate (i) model convergence, (ii) goodness of fit and patterns in residuals, (iii) model consistency by evaluating the influence of the different data sources on the likelihood and the existence of retrospective patterns and (iv) prediction skill (SCRS/2023/P/141). It is normal practice when dealing with a large ensemble of models to apply diagnostics only to a base case as it would be computationally intensive and time consuming to evaluate all models in the reference set (Merino et al. 2022). Here diagnostics were applied to all 27 models in the reference set for BET (ICCAT 2021), four models for YFT (ICCAT 2019) and 18 for SKT (ICCAT 2022).

A plot that was found useful to evaluate goodness of fit across the entire reference set of models used for Southern Bluefin tuna is shown in Figure 1 (extracted from CCSBT-ESC/2008/Rep 01). The plot served to examine possible tension between different likelihood components and helped to choose parameter values for the grid.

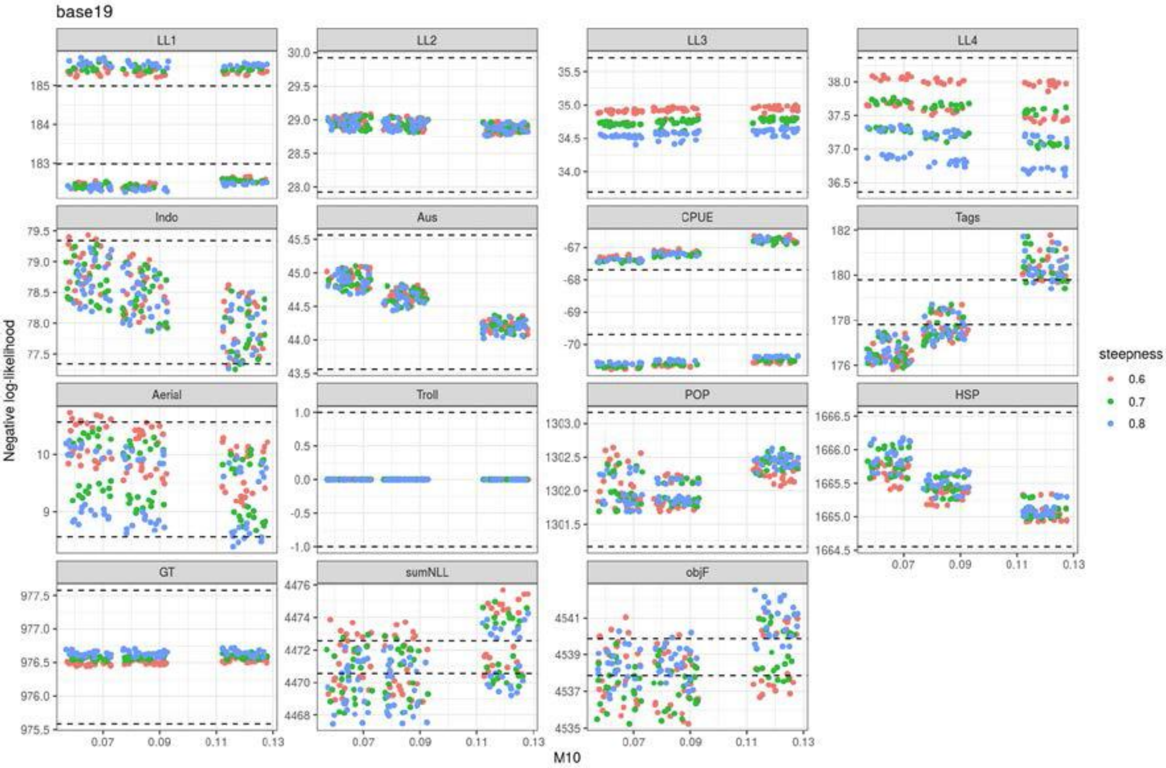

Figure 1. Example of likelihood profile plot used for Southern Bluefin's Tuna reference set of operating models. Negative log-likelihood (NLL) components for different data type; the sum of the negative log-likelihood components (sumNLL), and the total objective function (objF) are plotted by M at age 10 (M10) on the x-axis and colored by three steepness values. The M10 values are randomly jittered (within a category) so that values do not all sit on top of each other. The dashed horizontal lines represent ± 2 units of NLL.

The different sources of uncertainties considered in other tuna MSEs were reviewed in documents SCRS/2021/016 and SCRS/2021/055 for possible application to the Atlantic tropical tuna stocks. This review was very informative and suggested some useful avenues for expanding the uncertainties considered, in particular regarding CPUE indices and trends in catchabilities.

Two aspects that have been considered in other cases but were not included in the initial list for the ATTs stocks were discussed. The first was uncertainty about fecundity assumptions, noting that a range of values for a power relationship between fish weight and fecundity was included as a grid axis in the Southern bluefin tuna (SBT) MSE. The possible use of alternative fecundity parametrizations for ATTs was considered, which could have some effects on the stock recruitment relationship. I suspect, however, that expanding the grid to include uncertainty in the fecundity parameters may not be warranted in this case given the lack of a strong relationship between recruitment and spawning biomass. I note that in the case of SBT, the inclusion of a fecundity parameter in the grid was motivated by the incorporation of close-kin-mark-recapture data both in the conditioning of the OM and as input to the adopted MP. The second aspect considered for other tuna stocks was uncertainty in movement rates (mixing) between areas, included for example in Atlantic bluefin. The current OM for ATTs is not spatially explicit but uses the common "areas-as-fleets" assumptions to account for spatial variations in catch at age/size. While including spatial structure and movements would allow developers to explore robustness of CMP with respect to some relevant scenarios about possible failures of observation model assumptions, the increase in complexity is huge especially when information about mixing is limited or lacking. I **recommend** that the inclusion of explicit spatial structure in the OM be postponed and reconsidered in the future, after this first round of MSE is concluded.
Observation Errors

Presentation SCRS/P/2023/093 describes the observation error model proposed for simulating abundance indices in projections. The approach follows the assumptions applied to Atlantic bluefin and other tuna and non-tuna MSEs where CPUE and other indices have a log-normal distribution with variance and autocorrelation parameters estimated from the conditioning residuals. It is **recommended** to estimate these parameters for each of the models that comprise the reference set, as parameter estimates may be sensitive to model specifications. If there is a lag between the last year of data used for conditioning the models and the first year of projections it is **recommended** to use the actual indices observed after the final conditioning year. This would involve calculating the residuals between the observed indices and the simulated exploitable biomass and use them as predictors in the autocorrelated model. Likewise, it is **recommended** that actual catches be used in place of MP-calculated catches for past years not covered in the conditioning. The use of actual data (catches and indices) ensures that the first time the CMP is applied to simulate a TAC, it uses the same data as would be available in reality when a selected MP is implemented.

Other potential sources of observation errors could stem from alternative assumptions used in standardizing CPUE, leading to different CPUE time series. If these have been identified, different OMs could be fitted to the alternative indices and the respective residuals used to estimate the variance and autocorrelation parameters. Note however that in this case, a single historical CPUE series (i.e., the one that will be used in practice) should be used as input to the CMPs in simulations.

The presentation demonstrates a linear relationship between CPUE and spawning biomass (SSB) but raises the question of whether it might be more appropriate to use the vulnerable biomass, instead of the SSB, to simulate future data. The standard **recommendation** is to use the same vulnerable biomass (i.e., applying the same estimated selectivity) as was fitted in the conditioning.

Effects of climate change

Document SCRS/2024/118 explores the evidence of climate change impacts on tunas and proposes methods to incorporate the associated uncertainty into the multi-stock MSE for ATTs. The suggested approach aligns with methodologies used in other tuna MSEs, which involve empirically modeling changes in productivity (R_0), both as trends and regime shifts, and in somatic growth (Linf and K) and use them in robustness tests. For robustness tests involving future regime shifts, it is **recommended** that their timing be randomized to prevent differences in CMP performance arising from specific fixed schedules. This will ensure that the test results reflect the ability of the CMPs to "detect" and respond to regime shifts in the operating model (OM) rather than being influenced by predetermined timings.

The authors state that they "will not test climate-adaptive reference points", which I interpret here as HCR with parameter values that vary as a function of some environmental indicator. It is important, especially in this context, to clarify the terminology and differentiate between "biological reference points", which are used to interpret biological indicators, and HCR parameters or "operational control points" (sensu Cox et al. 2013). While operational control points (e.g., $B_{trigger}$) are often set equal to certain biological reference point (e.g., B_{LIM} or B_{MSY}), they are conceptually and functionally distinct. In the context of nonstationary dynamics, even if HCR are time-invariant, the use of dynamic biological reference points (like dynamic R_0 or B_0) is **recommended** for correct interpretation of performance statistics (e.g. SSB/SSB_0). This is particularly appropriate when OM scenarios incorporate historical and/or future changes in productivity and somatic growth. While I agree that, at least initially, candidate HCRs may need to be time-invariant, it is essential for performance statistics to reflect the changes in reference points assumed across the different OMs.

Management Procedures

SCRS/P/2024/081 discusses some initial CMPs that have been used to motivate the use of multi-stock MSE for ATT given the technical interactions between the stocks caught simultaneously by the main fishing fleets. I begin by summarizing my understanding of the methods, based primarily on the limited documentation provided in the presentation, complemented by details from Ulrich et al. (2011, 2017) and García et al. (2020). Following this, I offer some initial reflections for consideration and future discussion.

Different approaches were presented and implemented in SCRS/P/2024/081. The first is based on the so-called Fcube method (Ulrich et al. 2011), developed for ICES mixed fisheries, which includes the following steps:

1. Apply a standard harvest control rule (HCR) independently to each stock to set a stock's target fishing mortality (F) as a function of an estimate of stock biomass.

2. Using a prespecified catch allocation between the fleets, calculate the target catch by species and fleet corresponding to the target F from 1.

3. Estimate the effort that would be required by each fleet to catch each species' allocation.

4. Simulate the actual catches by species and fleets using alternative effort options: the minimum, maximum and average of the stock-specific efforts for each fleet, the effort levels that matched the target F for each of the stocks (i.e. three alternatives, one for each stock) and the status quo efforts (most similar to previous).

This approach contrasts how much the realized catches and fishing mortalities may be expected to depart from the respective single-species targets under alternative effort levels. It is a valuable exercise for managers to understand the range of quantitative trade-offs associated with assigning different relative weights to species and OMOs. For instance, it can help evaluate how much catch is forgone by adopting the most conservative (i.e., min effort) strategy.

The second approach, described in Garcia et al. (2020), seeks to achieve "pretty good yield" by maintaining Fs within a pre-specified range that ensures long-term yields of at least 95% of MSY (when fishing at a fixed F). Similar to the first approach, this strategy retains the recent effort share between fleets (and between FAD and free-school sets) but applies a common multiplier to fleet-specific efforts to meet the stated objectives as closely as possible. Initial multipliers are based on the ratios between the single-species F targets and the previous Fs by species, from which a minimum, maximum, or average multiplier across species can be selected. Further second-stage effort adjustments are introduced if the pre-specified F ranges are exceeded for one or more of the species. Garcia et al. (2020) applied the HCR to the real values simulated in the OM, except for a two-year time lag between the populations used to generate the TAC advice and the year when the TAC was implemented. In the initial application to ATTs parameters of the hockey-stick HCR and the F ranges were calculated as a function of F_{MSY} and B_{MSY}, assumed known at the OM values.

In both approaches, the initial step involves calculating target Fs for each species independently of their technical interactions. These calculations could take many forms during future MSEs, applying either empirical or fully-specified model-based HCRs. Experience with other stocks provides a wide range of examples of tested MPs that could be applied to ATT stocks. The key challenge, however, will lie in addressing the incompatibilities or imbalances (e.g., Ulrich et al. 2017) between species-specific targets in the subsequent steps, as illustrated by the applications of the multi-stock HCR to ATTs. It remains unclear how variations in the initial single-species HCRs might affect trade-offs and the degree of incompatibility between single-species targets. This is an important angle to explore in future simulations.

The practical value of the approaches proposed in SCRS/P/2024/081 will depend on whether managers are willing to use a consistent approach that involves some implicit weighting across stocks and OMOs, as implied in the proposed methods, or if priority assigned to the different stocks and OMOs may vary depending on status of the individual stocks. For example, if one of the species is nearing its limit reference point, managers may prioritize adjusting fishing efforts to improve stock status of that species at the expense of overall yields. Conversely, if all stocks are within the safe zone, maximizing yields or economic returns may take priority, and effort adjustments could align with the optimal levels for the more productive or economically valuable species. The mixed-stock strategies proposed by Garcia et al. (2020) and applied initially to ATT (SCRS/P/2024/081) place a strong emphasis on maintaining all species Fs within predefined fixed bounds, following ICES's "pretty good yield" concepts. This may place constraints that are unnecessary for safeguarding the resources. Of the two dimensions of the Kobe plot that contribute to the PGK, I would give more weight to stock safety, noting that exceeding the upper F bound may not be a concern if a stock is in the green zone. I **recommend** that consideration be given to modifying mixed-stock strategies to take account of stock status when evaluating second-stage effort adjustments. For a practical multi-stock MP, it will be important to try to understand and capture how managers may respond to different situations, for example by differentially trading OMOs across species depending on their status. Progress through these complex issues will require an iterative MSE process as has been recommended elsewhere (Miller et al. 2019, SCRS/2024/103).

SCRS documents and presentations

ICCAT/2019. Informe de la reunión ICCAT de 2019 de evaluación del stock de rabil (Grand-Bassam, Cote d'Ivoire, 8-16 July 2019).

ICCAT/2021. Informe de la reunión ICCAT de 2021 de evaluación del stock de patudo (on line, 19-29 July 2021).

ICCAT/2022. Informe de la reunión ICCAT de 2022 de evaluación del stock de listado (on line, 23-27 May 2022).

SCRS/2017/198. Urtizberea, A., Merino, G., & Murua, H. First steps for the conditioning of a multispecies MSE model for tropical tuna fisheries.

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SCRS/2021/016. Merino, G., Die, D., Urtizberea, A., & Laborda, A. Characterization of structural uncertainty in tropical tuna stocks' dynamics.

SCRS/2021/055. Merino, G., Die, D., Urtizberea, A., & Laborda, A. Progress on characterization of structural uncertainty in tropical tuna stocks' dynamics with summary of discussions held during the tropical tuna MSE meeting (29-31 March 2021). Collect. Vol. Sci. Pap. ICCAT, 78(2): 227-230 (2021).

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SCRS/2024/103. Carrouthers, T. A preliminary roadmap for MSE development. Collect. Vol. Sci. Pap. ICCAT, 81(6).

SCRS/2024/118. Correa, G.M., Urtizberea, A., Merino, G., Erauskin-Extramiana, M., & Arrizabalaga, H. Incorporating climate change effects in the management strategy evaluation for Atlantic tropical tunas.

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Annex C

Review of Atlantic tropical tunas' MSE by Graham Pilling, Robert Scott and Finlay Scott

Initial review of AZTI's proposed multispecies approach for ICCAT tropical tuna harvest strategy development
Graham Pilling, Rob Scott and Finlay Scott
December 2024

Introduction

AZTI (Centro de Investigación Marina y Alimentaria) are undertaking a contract for the International Commission for the Conservation of Atlantic Tunas (ICCAT) to support ICCAT's tropical tuna multi-stock management strategy evaluation (MSE) process. As part of this process, AZTI sought external independent advice on the planned approach from the authors of this report. To facilitate this, a short online briefing meeting was held on the 15th November with Gorka Merino and Agurtzane Urtizberea, and access to online repositories of documentation and computer code enabled to facilitate the review.

We note that a large amount of material was made available through the Sharepoint directory and GitHub repository, reflecting the extensive work that has already been undertaken by AZTI. This material was too voluminous to thoroughly review in the time available prior to the reporting deadline. This report therefore provides some observations based upon the discussion with AZTI and the materials supplied, and reflects thoughts based upon our understanding of the current state of the modelling and ICCAT's discussions. They represent initial observations and highlight areas that may be considered as the work progresses. Any future reviews would benefit from a summary document highlighting where key documents on different subjects could be found. Some queries raised below may already have been addressed or may not be feasible within the ICCAT's management framework.

Key recommendations

This section summarises some of the key recommendations made throughout this document and are grouped by report sub-heading. Other suggestions are also contained within the main text. These recommendations are for consideration of both AZTI in terms of the technical work, and ICCAT members in terms of some of the wider issues that need to be considered.

Management objectives

- Get early definition of the desired timescale for bigeye recovery. This is important to define scenarios, focus the outputs being presented to managers and to highlight trade-offs.
- Consider testing tighter and asymmetric constraints on how much the MP output can change between management periods, particularly for stocks with less volatility over time.
- Develop and agree with managers and other stakeholders the suite of performance indicators that will be used to measure how likely a candidate MP is to achieve the agreed objectives.

Operating models

- Clarify interactions between the West skipjack and the yellowfin, bigeye and East skipjack stock MPs. E.g. assumptions about future fishing activities of gears potentially not managed through the multispecies MP, such as bait boats targeting skipjack in the eastern Atlantic.
- Present the spread of model estimates resulting from the model grids both for the historical and projection periods.
- If using the Monte Carlo approach for the OMs, we recommend further interrogation of the convergence success of the models.
- Refine and agree the OM framework early on, since OM additions can change the relative performance of candidate MPs and erode manager's confidence in the analyses.
- Consider future recruitment as an axis of uncertainty for the east Atlantic skipjack OM with 'recent' and 'long-term' assumptions for future recruitment levels.
- Further examine the prediction skill of the OMs, which is low for all three stocks.
- Consider performing some kind of 'Turing test' comparing simulated and 'real' CPUE to evaluate the performance of the observation error model.
- Consider OM scenarios where stock-specific abundance varies from a direct relationship with the combined 'FAD buoy' CPUE abundance index. Additionally, evaluate the situation where true abundance of the three stocks varies considerably as this could be masked with the combined stock index.

Estimation method

- Clarify whether MPB would be used as the EM once the MP is adopted, or if it is proposed within the evaluations as a simplified proxy for the actual use of an SS3 stock assessment to facilitate testing.

Practical issues

- Clarify length and timing of the management period of each stock, noting that running all three MPs at the same time implies additional scientific workload.

- Consider using less 'abstract' outputs such as actual catch (TAC) or effort (TAE) which may be more effective for a wider range of stakeholders than using F.

- Expand on the proposed activities within the roadmap to provide a timeline for decision making that underpins technical work.

- Limit the number of candidate MPs for which results are provided (e.g. to 10 or less), noting that this is outside the control of AZTI and driven by manager's requests.

Need for a multispecies approach

Very few fisheries catch a single fish species in isolation of others; a fishing gear generally catches multiple species although the degree of impact on those stocks will vary. Tuna fisheries are no exception. These interactions mean that management measures aimed at one stock can have an impact on others. Additionally, it may not be appropriate to consider the management of individual stocks in isolation.

The proportion of the recent catch of the main Atlantic tuna stocks taken by gear type can be seen in

Table 1. These data are taken from the ICCAT standard SCRS catalogue on catch statistics by species, stock and fishery (available here: https://www.iccat.int/en/accesingdb.html). These catch data are approximately the same as that reported in the stock assessment reports and the SS3 model outputs used to condition the operating models, but in a more convenient format. The interactions described in

Table 1, and illustrated by Figure 4, suggest that careful consideration will need to be given as to how a multispecies management procedure (MP) will work in practice, noting that it may be challenging to achieve desired management objectives for individual stocks simultaneously. Instead, trade-offs between objectives will need to be identified and communicated to managers and stakeholders.

Table 1. Proportion of average catches (2018-2020) by weight of each stock taken by gear type (data source: the ICCAT standard SCRS catalogue). Note that yellowfin has separate entries for the eastern and western components (as reported in the SCRS data), as well as a combined stock (consistent with the assessment and operating models). The western component of skipjack is included in the table but is not included in the ICCAT multispecies MSE. Bigeye data are for the Atlantic plus the Mediterranean. Shaded cells highlight the fishery with the greatest catch proportion of a particular stock/component.

Stock	***Stock***	***Purse seine***	***Bait boat***	***Longline***	***Handline***	***Other***
Skipjack	ATE	0.88	0.10	0.00	0.01	0.01
Skipjack	ATW	0.11	0.72	0.01	0.14	0.01
Bigeye	A+M	0.36	0.11	0.45	0.07	0.01
Yellowfin	ATEW	0.70	0.05	0.12	0.11	0.02
Yellowfin	ATE	0.86	0.06	0.05	0.03	0.01
Yellowfin	ATW	0.12	0.03	0.37	0.40	0.08

The spatial extent of the stocks considered by the multispecies MSE is not the same, with bigeye and yellowfin covering a wider area than eastern skipjack. The western component of skipjack is not included in the multispecies MSE. Catches of the western skipjack stock are far smaller than the eastern stock (Figure 4) and are predominantly taken by bait boats, which have a limited impact on the other stocks (

Table 1). This suggests that separate management of the western skipjack stock will have only a limited relative catch of the yellowfin and bigeye stocks. However, it may be necessary to make assumptions about the future fishing activities of bait boats in the eastern Atlantic if they are not to be managed through the multispecies MP considered here.

There are differences between the catch proportions by gear of yellowfin in the East and West Atlantic, with most of the western component being taken by longline and handline, whereas the eastern component is mainly taken by purse seine. Translating the output of a multispecies MP (potentially F based) into catch- or effort-limits for different fishery segments may therefore need to consider the spatial structure of the stock and the fisheries.

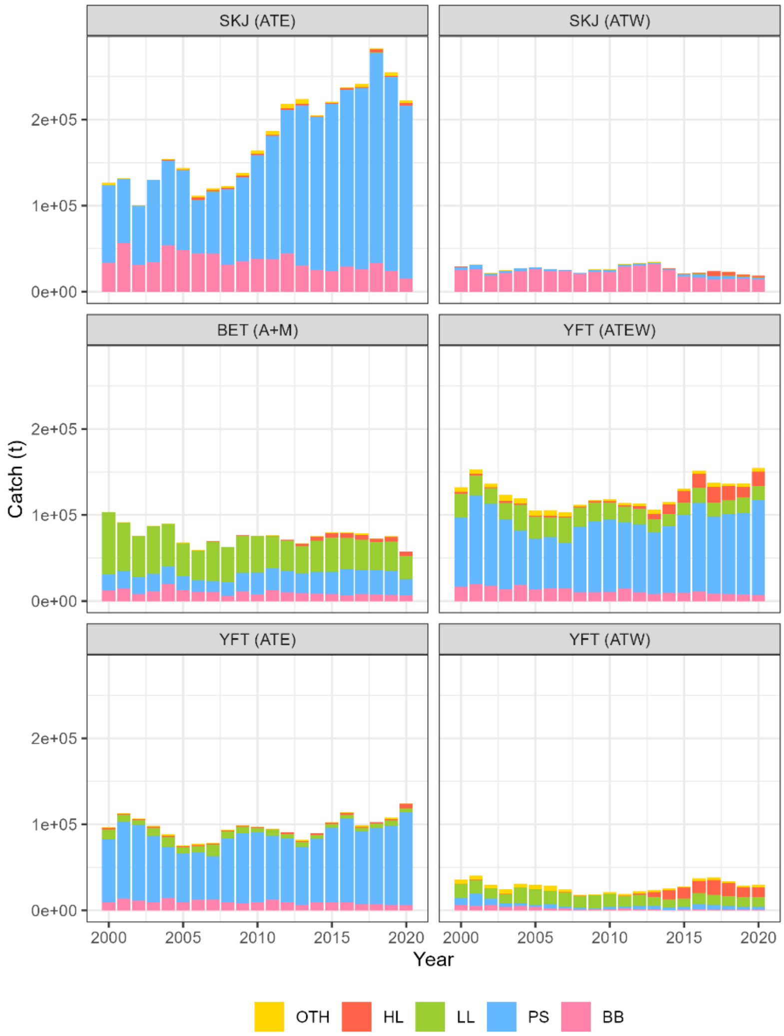

Figure 4. Catches of the main Atlantic tuna stocks by gear type. The multi-species MSE considers only the eastern component of the skipjack stock (SKJ ATE), and the yellowfin stock is a combination of the eastern and western components (YFT ATEW).

Based on the most recent stock assessment results, of the stocks being considered within the mixed fishery framework, bigeye is assessed to be in an overfished state and close to being subject to overfishing on average (Figure 5), while skipjack (East Atlantic) and yellowfin are assessed to be sustainably exploited. An aim of the framework will therefore likely be to rebuild bigeye to the desired stock status before balancing the stock status of all three stocks across the stated objectives (see 'management objectives' section below).

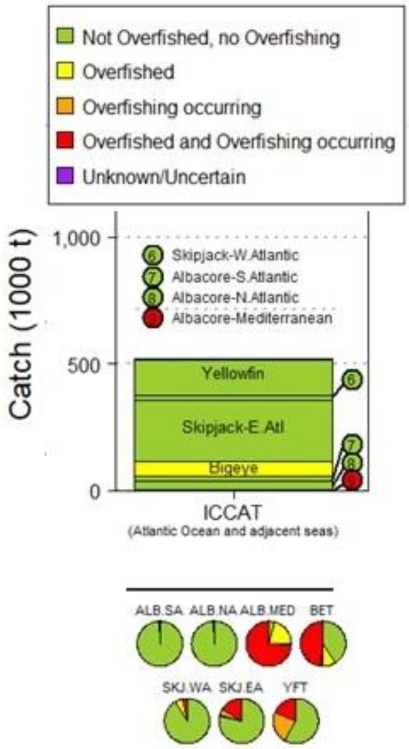

Figure 5. Summary of status of all ICCAT stocks (adapted and updated from Hare et al. 2023). The pie charts at the bottom of the figure present a summary of the fraction of models for each assessment that estimated stock status in each of the four Kobe quadrants.

Management objectives

Management objectives guide the development of MPs, since they identify the conditions desirable in the stock and fishery and allow performance indicators to be designed so that the success of candidate MPs can be evaluated.

The definition of management objectives is an issue for managers, and the 2024 ICCAT draft resolution PA1_508B/2024 that we understand was adopted at the recent ICCAT meeting identifies the following interim objectives for the purpose of developing, testing and refining candidate MPs:

- ***Stock Status***: Bigeye tuna, yellowfin tuna, and the eastern stock of skipjack tuna should each have a 50% or greater probability of occurring in the green quadrant of the Kobe phase plot (no overfishing occurring and not overfished) during the XX-year projection period (as determined by the SCRS);

- ***Safety***: Bigeye tuna, yellowfin tuna, and the eastern stock of skipjack tuna should each have a 15% or less probability of falling below the limit reference point (LRP) at any point during the XX-year projection period;

- ***Yield***: Overall catch levels should be maximized to the extent possible with respect to each stock of bigeye tuna, yellowfin tuna, and the eastern skipjack tuna [over short, medium and long-term time periods];

- ***Stability***: Any change in total allowable catch (TAC) between consecutive management periods for each stock of bigeye tuna, yellowfin tuna, and eastern skipjack tuna should be no more than a 25% increase or a 25% decrease.

The stock status objective will define significant trade-offs in terms of potential catch reductions to recover bigeye within the time specified by the SCRS. Early definition of that timescale will be important to define the potential scenarios, minimise the range of outputs being presented to managers and to provide key results that highlight the trade-offs involved.

The target yield is approximately MSY for each stock and the iLRP is set at 40% of SB_{MSY} where the risk of breaching the iLRP should not exceed 15% at any time. Depending on the mix of fishing practices in the fishery, estimates of MSY and corresponding SB_{MSY} may vary as the balance of fisheries changes under a mixed fishery and multispecies management system. Changes in the estimate of MSY may result from changes in, for example, the influence of different selection patterns between different gear types. This can lead to shifting targets through time as the mix of fisheries evolves under the MP. In this respect it would be informative to understand the gear specific impacts on estimates of MSY and the anticipated balance of fisheries under the multispecies MP.

A related issue that was highlighted to us by the AZTI team is the challenge of simultaneously achieving the target of a 50% probability of being in the green quadrant of the Kobe plot for multiple stocks that are caught in a mixed fishery. A balance of fisheries that approximately achieves MSY for one stock may not achieve MSY for others and some trade-off between stocks, or prioritisation of specific stocks may need to be made. The AZTI team noted an initial prioritisation of bigeye as the stock of primary interest, and that it might act as a limiting 'choke species' within this mixed fishery framework. Referring to

Table 1, this may involve controlling both purse seine and longline fisheries to achieve that goal, noting that these gears will likely have quite different selectivities, and that the same stock outcome may be achieved through quite different balances of fishing by these two gears. We acknowledge that an evaluation of such trade-offs will be conducted as part of this work and note previous studies to investigate multispecies MSY and the concept of PGY (pretty good yield) that has been developed to address such issues, a concept which has been highlighted to ICCAT.

The proposed 25% constraint on change between management periods is quite large, and applied proportionally could mean significant absolute changes in fishing and impact on fishing fleets. We assume this constraint would also be applied across all stocks. It may be worth considering also testing tighter constraints, particularly for stocks with less volatility over time. Asymmetric constraints could also be explored as an additional precautionary measure, where for example a smaller increase in fishing and a comparatively larger decrease might be allowed.

Operating Models

Operating models are designed to capture uncertainties within the stock and fishery system and allow the testing of MPs to identify whether they are robust to those uncertainties. A wide range of uncertainties should be captured, spanning beyond those that affect the perception of historical stock status that are generally captured within stock assessment model frameworks, to those that influence future stock and fishery dynamics.

Uncertainties to capture

Key uncertainties are generally captured within the 'reference set' of operating models. The results of evaluations across the reference set form the basis of performance indicators and are used to identify either a preferred MP, or reduced subset of preferred MPs. Other perhaps more extreme candidate scenarios or states of nature lie within the 'robustness set' of models. These can act as stress tests to evaluate the MP's performance in more extreme circumstances and to further narrow down the array of candidate MPs. We understand that the OM scenarios for the ICCAT evaluations will be divided into reference and robustness sets. Some initial discussion of the OM scenarios to be considered took place during the first meeting with the AZTI scientists, although a more thorough discussion of what scenarios will be considered and how they will be categorised will be required to better understand the proposed approach.

The proposed sources of uncertainty to be considered in the operating models focus on a limited number of model characteristics, which include the steepness of the stock and recruitment relationship (SRR); the variability of recruitment about the fitted SRR; the design and construction of the CPUE index; natural mortality and growth (e.g. Urtizberea et al. 2018). These axes of uncertainty presumably represent the most consequential factors affecting estimates of stock status and stock dynamics, though this is currently unclear from the information available. It would be useful to see the spread of model estimates resulting from the model grids both for the historical and projection periods to better understand the levels of uncertainty considered for the evaluations.

The range of uncertainties being considered differ for each of the stocks (bigeye, yellowfin, skipjack), and hence there is the potential for uncertainty to be 'overweighted' with one type of uncertainty that is not as thoroughly represented within the other stock OMs. A form of 'parity' between stock OMs may be considered. In the case of yellowfin, only two factors appear to be considered in early modelling, resulting in a grid of just 4 models (Urtizberea et al. 2023). Restricting the OM grid to such a small number of scenarios can potentially lead to problems where either, i) the range of uncertainty is too small such that the MP is not tested against a representative set of scenarios that fully characterise the potential dynamics of the stock and the fishery, or ii) the modelling assumptions are quite disparate with non-overlapping scenarios, leading to bi-modal or multi-modal distributions of the resulting performance indicators that can limit their utility when selecting preferred MPs. We note that for the yellowfin stock assessment, parameter values for steepness and natural mortality were randomly drawn from assumed distributions resulting in 4,000 models being used to characterise uncertainty, but it is unclear if the same approach will be used for the yellowfin OMs, for which only 2 steepness options and 2 CPUE indices appeared to be specified. If it is indeed the plan to use the Monte Carlo approach for the OMs we would recommend further interrogation of the convergence success of the models as the assessment report indicates a high failure rate for models with high steepness and high levels of natural mortality.

As noted above, uncertainties in future dynamics also need to be captured, as well as those identified as consequential in the estimation of historical dynamics and stock status through the assessment process. Within the WCPFC, these have included factors such as effort creep, hyperstability in CPUE (purse seine and potentially longline), and climate change. The last of these is already under discussion within IATTC. Correa et al. (2024) provides potential approaches that can incorporate climate impacts on stock recruitment and somatic growth.

Based on available information, this seems an appropriate approach. Whether those scenarios are within the reference set or robustness set of OMs, and the timing and degree of climate impacts, will need to be considered. In turn, further consideration of the uncertainties that affect future stock dynamics will be needed once the general framework is in place.

It is advisable to get as complete an OM reference set framework as possible early on, since the situation where additions to the OM reference set change the relative performance of candidate MPs would erode manager's comfort in the analyses being presented.

Conditioning of operating models

We highlight it is good to ensure that the OMs are not too closely conditioned on the stock assessment.

The approach taken by AZTI in the development of OMs is that they are conditioned upon the existing assessment models for the three tuna stocks, which are developed in Stock Synthesis 3 (SS3). We note that the SS3 assessment model for eastern Atlantic skipjack has been highlighted as 'preliminary' and not yet suitable as the basis for management advice (Urtizberea et al., 2022). The authors highlighted trends in estimated recruitment as a particular feature that required further investigation. This does not mean it is unsuitable as the basis for an OM. However, if this model is proposed for the east Atlantic skipjack OM, the implications of recent estimated recruitment trends on short-term MP performance and the assumptions for future recruitments should be considered. If necessary, this may form an axis of OM uncertainty with 'recent' and 'long-term' assumptions for future recruitment levels.

The relevant output files are converted into the format required by FLBEIA, a bio-economic impact assessment model based on the MSE approach (Urtizberea et al. 2018). That software has been used in several multi-stock and multi-fleet case studies, as detailed in that paper.

The FLBEIA model, when seeded with the SS3 output values (recruitment, fishing mortality, etc.), appears to effectively track the historical trajectory of the stock and the fisheries, and corresponds well with the estimates of the stock assessment (as would be expected). In this respect it represents the underlying dynamics of the stock and the fishery from the conditioned SS3 models. Our experience with SS3 and with FLBEIA is limited and we are not entirely clear what the benefits and costs of using FLBEIA are, over a framework that uses SS3 and the SS3sim R package. However, the proposed approach clearly simplifies the process of OM development and implementation of the MSE framework, which we consider particularly useful when developing the three stocks' OMs at the same time. It also allows for the incorporation of economic data and the development of economic performance indicators. However, a key consideration will be how uncertainty in the OMs and, in particular, the error distributions from the fitted SS3 models will be transferred to the FLBEIA framework.

The diagnostics relating to the conditioning of the OMs are thorough and include measures of goodness of fit, convergence, model consistency and prediction skill (Correa et al. 2023). However, it is noted that the OMs of all three stocks are considered to have poor prediction skill, as measured through hindcasting. We suggest that the prediction skill is examined further, given how important it is to the evaluation of candidate MPs. Additionally, this issue can be revisited through the monitoring strategy.

All the proposed OMs (and stock assessments) have a single region structure, given the lack of tagging data to inform movement within the model. AZTI noted that fisheries within the single region model have different catchabilities to act as a proxy for spatial dynamics. However, there is potential to build a spatially structured OM to evaluate whether candidate MPs are robust to that uncertainty – or what level of movement will lead to their failure. This is not a trivial exercise, would involve many assumptions, and may be best placed in future work for the robustness set of OMs.

Simulating data from the OMs

A key role of the OMs is to provide simulated data to the estimation method. These simulated data (e.g. CPUE) should have the same characteristics as the real data that will be available when a MP is put into operation, including the presence of observation error. AZTI plan to analyse the relationship between SSB or vulnerable biomass and the fitted CPUE to derive a 'reference biomass', to which autocorrelated error can be applied (Urtizberea et al. 2023). This approach seems reasonable, and the current results suggest that vulnerable biomass is a good guide to a range of CPUE indices. It may be worthwhile performing a kind of 'Turing test', whereby simulated and 'real' CPUE indices are compared to see if they are indistinguishable from each other.

A seasonal purse seine 'FAD buoy' CPUE abundance index has been developed for the ICCAT stock assessments. As we understand it, this series is proposed as a potential input into the estimation method. We note that the proposed fleet structure (Figure 6) has a primary 'purse seine' fleet, which we presume is predominantly FAD set related and hence will be the fleet from which this index can be generated. Indices for the three stocks were described as comparable given the challenges in developing stock-specific estimates from buoy data. AZTI may wish to consider OM scenarios where stock-specific abundance varies from a direct relationship with the index. In turn, the situation where the true abundance of the three stocks varies considerably – either due to reduced abundance or low recruitment events for a specific stock – should be evaluated, as this could be masked with the combined stock index this series provides.

The approach to simulating data from the OMs and the outputs may be an area for future review, as this will be an important component of the MSE.

Estimation Method

For the estimation method within the MP, AZTI proposes to use a species-specific biomass dynamics model (JABBA or MPB) that has been used within ICCAT for specific assessments or as alternative simplified assessments for key stocks. The performance of these models will need to be evaluated, given that their reactivity to changes in stock status may be slower than desired given the 'weight' of historical data within the estimation process. Experience at SPC of using biomass dynamic models (JABBA, SPiCT) within MSE simulations was that terminal stock status (of key importance for an EM as it is used by the HCR to set fishing opportunities) was often poorly estimated and as noted, slow to respond to changes in population abundance. In addition, we found both models could have relatively lengthy run-times, although this may be situation specific. We also experienced difficulties retrieving diagnostic outputs from JABBA when it was run in a simulation framework.

An alternative approach noted by AZTI was the use of an empirical EM based upon CPUE. SPC spent some time evaluating CPUE input series for an empirical EMs for South Pacific albacore and found it challenging to find a single or set of time series that tracked 'true' stock abundance well. While this approach may work better for other stocks, the time required to do so for three stocks may prove extensive.

Work is yet to start in earnest on the development of candidate MPs and specifically on the selection of an estimation method to use within the MP. The potential use of MPB was briefly discussed during the meeting with the AZTI scientists but it is unclear if MPB will be used to run the MP once adopted (i.e. the outputs of MPB will be used to 'drive' the HCR), or if it is used only as a simplified proxy for an SS3 stock assessment to facilitate testing and, when the MP is implemented, SS3 will be used to determine stock status feeding into the HCR. This is a fundamental issue concerning the design and testing of the candidate MPs. Some clarity on this issue will be required, recognising that this may be subject to ongoing work and may not be fully resolved at present. A particular concern regarding the use of MPB in either situation is the finding reported in the 2024 report of the yellowfin stock assessment meeting (ICCAT, 2024) that, due to a lack of fit to the data, the MPB model was discarded and not considered appropriate for the development of management advice for yellowfin.

Practical implementation of the MP

The approach initially proposed by AZTI is that all three stock MPs to be run each management cycle. How managers will then choose which output they wish to implement remains to be identified. Scenarios can be modelled within the MSE – consistently going with the most conservative or the most aggressive, etc. However there remains the risk that managers in reality do not follow a set approach, selecting different 'scenarios' in different management periods. This would result in an MP that has not been fully tested.

The output of the MP is proposed to be a fishing mortality (F) which is then translated into a catch/effort by gear group through allocation. We highlight that fleet structures are not comparable between the assessments/OMs for each stock, based upon Correa et al. (2023; Figure 6). This may present challenges for the allocation of output F across gears. We understand that this approach is not yet decided; AZTI commented that an initial approach may assume allocation based upon recent patterns of fishing by gear, and in preliminary analyses where fleets do not catch a 'controlling' stock, the F target was set to the minimum effort (e.g. Urtizberea et al. 2024).

BET		YFT		SKJ	
OM fleets	**SS3**	**OM fleets**	**SS3**	**OM fleets**	**SS3**
PS	PS	PS	PS_ESFR2	PS	PS
PSBB_GH	PSBB_GH	PSBB_GH	PSBB_GH	PSBB_GH	PSBB_GH
		Area2_BB	BB_area2_Sdak		
Dakar_BB	SouthDakar_BB	Dakar_BB	Dakar_BB	Dakar_BB	Dakar_BB
	NorthDakar_BB				SouthDakar_BB
North_BB	NorthAzores_BB	North_BB	NorthAzores_BB	North_BB	North_BB
JP_LL	NorthJapan_LL	JP_LL	NorthJapan_LL	Other_LL	LL
	TroJapan_LL		TroJapan_LL		
	SouthJapan_LL		SouthJapan_LL		
Other_LL	NorthOther_LL	Other_LL	NorthOther_LL		
	TroOther_LL		TroOther_LL		
	SouthOther_LL		SouthOther_LL		
CTP_LL	NorthCTP_LL				
	TroCTP_LL				
	SouthCTP_LL				
HL_Bra	HL_Bra	HL_Bra	HL_Bra		
RR_US	RR_West	RR_US	RR_US		
West_PS	West_PS	West_PS	West_PS		
Others	Others	Others	Others		

New Fleet Structure			
PS	BET	YFT	SKJ
PSBB_GH	BET	YFT	SKJ
Area2_BB	-	YFT	-
Dakar_BB	BET	YFT	SKJ
North_BB	BET	YFT	SKJ
JP_LL	BET	YFT	-
Other_LL	BET	YFT	SKJ
CTP_LL	BET	-	-
HL_Bra	BET	YFT	-
RR_US	BET	YFT	-
West_PS	BET	YFT	-
Others	BET	YFT	-

Figure 6. Fleet structures in the most recent assessments (left) and proposed fleet structures (right) from Correa et al., 2023.

Within the WCPFC mixed fishery approach, allocation of the MP output is a separate implementation decision, allowing MP evaluations to progress. Within the proposed ICCAT framework, the allocation process is a key component to evaluate the performance of the MP. We note that the approach proposed by Garcia et al. (2020) has been suggested for evaluation. Allocation is generally a management discussion and given its complexity, may lead to lengthy discussions with implications for the work timetable.

In terms of clarity for managers, the use of fishing mortality as the output of the MP requires considerable interpretation. For messaging, we have found that less 'abstract' outputs such as actual catch (TAC) or effort (TAE) have proven more effective for a wider range of stakeholders.

The management period – the period over which fishing activity is fixed by the output of the MP(s) before the MP is run again based upon new information – does not appear to have been defined yet by ICCAT. This may need to be evaluated since the life histories of the three stocks are quite different, and for skipjack a shorter management period may be more reactive to this shorter-lived stock. However, that will need to be balanced against the practical issues around running the three MPs together. Running all three MPs in practice implies additional workload for the scientists developing the data inputs and running the EM. The implications of this should be considered.

The management period also has implications for the monitoring strategy, where the output of the analytical assessment (e.g. in SS3) acts to monitor stock status relative to the expected behaviour from the MSE. Ideally, running of the MP and the analytical assessment should not be in the same year. However, if all three MPs are being run in one year under the proposed approach, there will be years when running of the MP and the analytical assessment of one of the three stocks overlap. This is not ideal but may be inevitable. However, it should be considered within the monitoring strategy.

Other considerations

The revised roadmap for the tropical tuna MSE process is found in Appendix 5 of the latest yellowfin stock assessment (ICCAT 2024). It presents at a high level the activities for the 'tropical tunas' and 'western skipjack' processes. We note that the technical work is developing at pace, however the decision making that must inform that work may not have been finalised, meaning strong assumptions may be required to allow the technical work to continue. This runs the risk that additional work is incurred if those assumptions are not realised, and the technical framework must be subsequently unpicked and reconstructed to deal with that change. We suggest that there is the potential to expand on the proposed activities within the roadmap to provide a timeline for decision making that underpins technical work. The WCPFC harvest strategy workplan (e.g. WCPFC 2023) expands on the work and decision making by that Commission and its subsidiary bodies and a similar approach may highlight the key areas and decision points to ICCAT members. We also found it useful to develop a working paper defining the key decisions to be made and responsibilities of the different Commission bodies within the harvest strategy process. The paper to WCPFC is here: *Key decisions for managers and scientists under the harvest strategy approach for WCPO tuna stocks and fisheries*.

Current assessments for the stocks under consideration have an end year in the period 2018-2020. We note that will be updated as new assessments are performed, although this will likely imply reconditioning of the OMs as a result. We highlight that regular reconditioning of the OMs is not desirable but may be necessary in some specific instances.

In the meantime, there is a need to bridge the modelled stock between the end of the stock assessment period and the year in which the first running of the MP occurs. Catch and effort levels can be fixed at 'actual' levels up until the last year of full data, although recruitment levels must be simulated, and catch levels in the period up to the first running of the MP then assumed. The assumptions made will need to be carefully considered. We have found in some cases that the assumed fishing level over that period can trigger limits in changes of output catch or effort from the MP where there are constraints applied on the first running of the MP. While the objectives detailed by IATTC allow a quite large 25% change in MP output from management period to management period, which may eliminate the issue, the transition assumptions should be considered as the short term performance of an MP is of key interest to managers.

It is important to balance providing as much information as possible for manager consideration with avoiding information overload and hence decision paralysis. While this is outside the control of AZTI and driven by manager's requests, limiting the number of candidate MPs for which results are provided (e.g. to 10 or less) is desirable.

A key step in the WCPFC tuna harvest strategy process was developing and agreeing with managers and other stakeholders the suite of performance indicators used to measure how likely a candidate MP is to achieve the agreed objectives. We found that this made communication of the MSE results easier and ensured that appropriate information was available to allow decisions on preferred candidate MPs to be made. From our communication with AZTI, it does not seem that performance indicators for the ICCAT harvest strategy have been agreed or discussed in detail yet. Agreeing candidate performance indicators and how to display them would be helpful at an early stage.

We support the use of the shiny app (e.g. SLICK) to allow managers to interrogate the results of MP evaluations. We have used a similar approach in the WCPFC and have learnt it's important to walk managers through how to use the application carefully. Providing different ways of displaying the results (box plots, bar plots, tables, etc) is important to cater for individuals who process information in different ways.

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