INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

14TH MEETING

La Jolla, California (USA)
15-19 May 2023

DOCUMENT SAC-14 INF-F

MANAGEMENT STRATEGY EVALUATION (MSE) FOR TROPICAL TUNA FISHERIES IN THE EPO: PROGRESS REPORT

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CONTENTS

1. SUMMARY

The purpose of the Management Strategy Evaluation (MSE) process in fisheries is to compare the performance of alternative management strategies in meeting management objectives, using computer simulations and relevant fisheries performance metrics. MSE is recognized as best practice to evaluate alternative management strategies, and has been widely used both nationally and internationally, including all tuna RFMOs which are at different stages in their implementation. There is an ongoing MSE process for EPO tropical tunas, with an initial focus on bigeye tuna. The process includes a dialogue component and a technical component. The dialogue component has resulted in three IATTC sponsored workshops both to familiarize stakeholders on MSE and elicit input on management strategy elements (such as objectives, performance indicators) needed for their evaluation. The technical component has included writing and customizing code for conducting the MSE, conditioning of operating models, describing alternative biological and fishery dynamics and online tools to communicate the MSE process and results. The MSE process at IATTC has been funded by the European Union between 2021 and 2023, with funds ending at the end of 2023. Funding has not been secured yet for continuation of the MSE work for EPO bigeye tuna during 2024 and beyond, to allow the inclusion of skipjack and yellowfin in the MSE work.

2. BACKGROUND

The main purpose of fishery management is the sustainable exploitation of fishery resources, fostering both the long-term viability of fish stocks and of the fisheries and other activities that depend on them. Fishery management is a complex interplay of multiple stakeholders with potentially different interests, roles, and objectives. Among some of those stakeholders are fishermen, industry, managers, members of the public, and fishery scientists. The roles and involvement of different stakeholders in fisheries management varies depending on cultural, institutional, and historical factors. The role of fishery scientists has traditionally been to conduct analysis in support of the decision-making process, particularly by providing quantitative information about the status and trends of fish stocks both historically and projected under alternative management choices. The provision of scientific advice for fisheries management can take many forms, depending on the fishery, their historical context, the level of monitoring, available analyses, and management systems.

The traditional approach for providing management advice typically relies on a "best assessment" model that integrates available data (e.g., catches, size compositions), external estimates of important processes (e.g. growth), assumptions about non- or poorly estimable parameters (e.g. natural mortality) and structure (e.g. stock structure). This approach has often shown over-sensitivity of model results (independently of the true changes in the stock) to changes in new data, data types, data analyses and assessment methodology or modeler. Since results of the assessment are often fed into a harvest control rule (HCR) that specifies management actions in relation to estimated stock status relative to estimated reference points, problems with assessment models can translate into management issues when the estimation of reference points may also be biased, compounding the issues. Further issues are the lack of proper consideration of mid- to long-term tradeoffs (e.g. between exploitation and biological risk), tendency to focus on immediate or short term considerations of particular levels of management actions (e.g. the actual TAC or effort level) rather than on the decision process of setting them, tendency to a system of minimal management changes (particularly when assessment results are uncertain), and incomplete treatment of uncertainty (i.e. typically only assessment uncertainty is considered).

Management strategies (often referred to as management procedures) are the integrated combinations of agreed upon specific data inputs, specific analyses applied to that data and the HCR used to determine specific management actions (e.g., catch quotas, length of fishing seasons). Management strategy evaluation (MSE) is widely considered to be the most appropriate way to evaluate the trade-offs achieved by alternative management strategies, while integrating multiple sources of uncertainty, for achieving management goals. A fundamental difference between the traditional approach and MSE is that the former typically focuses on just assessment uncertainty, while the later integrates and appropriately deals with multiple sources of uncertainty such as implementation uncertainty, management/institutional uncertainty, sampling uncertainty, projection uncertainty. Another difference is the proper evaluation of risk through the feedback loop between a management strategy and the simulated system, differentiating MSE from risk assessments which tend to overestimate risk by failing to consider management responses to future data. MSE is the process of evaluation of management strategies using computer simulations, but it goes beyond being a scientific exercise since the process requires the involvement of stakeholders for refinement of current strategies and its elements (objectives, performance metrics, etc.) and the development of alternative strategies to evaluate. That is, while part of the MSE process is highly technical and done by scientists, another equally important part, such as defining objectives, performance metrics and candidate management strategies, requires input and participation of managers and other stakeholders. Those two parts should evolve in synergy for a successful MSE process. MSE has been widely used both nationally and internationally, including by all five regional fisheries management organizations for tuna (t-RFMOs: IATTC, IOTC, WCPFC, ICCAT, CCSBT) which are in different stages of development and implementation with CCSBT the furthest along with a successful MSE development, testing and implementation of a management procedure already in place and with IATTC at the earliest stage in the process.

Fisheries for tropical tunas in eastern Pacific Ocean (EPO) ranged around 500 to 800 thousand tons since the year 2000, representing almost 14% of the world's production of tuna and around 1.7 billion US$ ex-vessel value in 2012. Management advice for EPO tropical tunas in the IATTC has traditionally been based on a 'best assessment' approach. Two species, bigeye (BET) and yellowfin (YFT) tunas, are assessed via formal stock assessment models, while the status of skipjack (SKJ) tuna has until recently been surmised based on the status of BET (although an interim assessment has been conducted in 2022). The IATTC staff concluded that their BET (2018) and YFT (2019) stock assessments were not reliable to be used as the basis to provide management advice. Although Stock Status Indicators (trends in catch, CPUE, etc.) produced for the three species are often used in support of the assessments, they are not operationalized for example in an HCR to link them to specific management actions. When lacking reliable assessments there is no currently quantitative default process to provide management advice. The assessments were improved resulting in new benchmark assessments in 2020, but several uncertainties remain. To overcome issues with current assessments for BET and YFT, the staff recently proposed a weighted multi-model risk analysis that considers parameter and assessment model structure uncertainty (2020). Incorporating assessment uncertainty in the management advice is an improvement over the previous approach, allowing the evaluation of probability statements included in the current HCR. However, the IATTC staff recognizes ongoing unresolved issues in the understanding of the stocks that can have large management implications for the combined species tropical tuna fishery, which is managed based on the species needing the strictest management (BET in recent history, see Figure 1). The staff proposed two venues to address ongoing issues and to improve management advice: 1) improving stock assessments and 2) continuing ongoing MSE for tropical tunas (one of the main goals of the IATTC Strategic Science Plan). The IATTC has adopted elements of a harvest strategy such as interim HCR and reference points, however some elements may need to be refined (e.g. specificity of management objectives, probability of being above target reference points) and other elements added (e.g. type, duration and derivation of management actions) to constitute a complete strategy. On the technical component of MSE work, initial simulation testing work of a simplified HCR was conducted in 2016 and 2018 and substantial progress has been made on developing operating models, however a proper MSE process requires a complete specification or alternative strategies to evaluate, for which the input and participation of managers and other stakeholders is desired. Although there are no dedicated, formal communication channels on MSE (such as a Working Group) within the IATTC, SAC meetings and dedicated workshops provide opportunities for dialogue, communication, and training on MSE. Introductory MSE workshops on MSE were held in Panama (2015) and the United States (2018), aimed at managers, and a further five, aimed at the tuna industry, took place during 2019 in Colombia, Ecuador, Mexico, Panama, and USA. Three workshops have been held part of the 2018-2023 MSE workplan. The 1st IATTC sponsored MSE workshop (on objectives and performance metrics) was held in person in December 2019. The 2nd IATTC sponsored MSE workshop (on reference points and harvest control rules) was held virtually during 2021. The 3rd IATTC tropical tuna MSE workshop was held (also by videoconference) at the end of 2022. These workshops have been conducted with the support of the EU.

This document describes continuation of the two components of ongoing tropical tuna MSE work for years 2021 to 2024: 1) continuation of technical development, 2) organization and facilitation of stakeholder dialogue / communication workshops. Both components of the MSE work have been conducted by a contractor funded by external funds or a combination or external and IATTC funds, working with IATTC staff. Although SAC-10 supported the MSE Workplan and recommended continued funding support for this work, the current delay in IATTC meetings and funding uncertainties due to COVID-19 were a challenge for the continuation of funding of the MSE work beyond 2020. Funding was awarded by a contribution by the European Union to for the MSE of tropical tunas from 2021 to the end of 2023. At the 98th IATTC meeting (18-22 October 2021) it was decided that the staff, consulting with the SAC, shall then present for the Commission's consideration in 2024 a candidate harvest strategy for bigeye tuna, including candidate management actions to be taken under various stock conditions. Although the current timeline includes bigeye MSE work during 2024, with plans to expand the MSE work for the other tropical tunas (skipjack and yellowfin) current funding expires at the end of 2023 and funding has not been secured for continuation of the MSE work for EPO tropical tunas.

3. WORKPLAN

3.1. SCOPE

The current work plan combines the technical development of MSE for tropical tunas and a series of workshops for training and enhancing dialogue and communication among all interested parties regarding the MSE process. Tropical tuna fisheries in the EPO are multispecies (BET, YFT and SKJ), however management has been based on the species needing the strictest management evaluated using single species stock assessments of BET and YFT. Historically, the estimated status of BET has determined management for tropical tunas (see Table 1) and was therefore selected as the initial focus of MSE work. Although the ultimate goal is to evaluate harvest strategies in a multispecies context, experience from RFMOs and other organizations show that MSE processes are multi-year undertakings, even for single species. Given the limited and time-constrained funds available for MSE of EPO tropical tunas to date, it was decided to start with BET on the technical work, adding the other species as their current assessment models are improved (YFT, SKJ). The stakeholder engagement has focused on dialogue on the three species, and the technical work conducted for BET will streamline the MSE work on YFT and SKJ as their modelling improves. Therefore, ongoing MSE work will continue to focus on bigeye tuna, moving to the other species towards the end of the timeframe, pending securing of funding beyond 2023. Both components of the MSE work are conducted by a contractor working with IATTC staff. Computer work is being conducted at the IATTC headquarters, La Jolla, California, USA, and at the contractor's location of choice in a similar arrangement to what has worked effectively in previous years. Workshop locations and format (in person or via conference) have depended so far on interest and logistics of stakeholders, including IATTC staff, and external factors such as the COVID-19 pandemic.

3.2. OBJECTIVES

The general objective is to develop, evaluate and implement sustainable management strategies for tropical tunas in the EPO, continuing the ongoing MSE process at IATTC. Specific objectives are to provide technical support for the IATTC staff and to improve stakeholders understanding and communication of the MSE process, elicit objectives, performance metrics, alternative control rules, and specification of risk. The development of MSE workshop materials and online resources, along with conducting of workshops with managers, industry and other stakeholders will allow communication of MSE results and feedback.

3.3. IMPLEMENTATION

The work consists of two components that evolve in synergy 1) technical development and execution of MSE simulation framework to evaluate alternative harvest strategies, 2) enhance stakeholder dialogue, and two-way communication of required inputs for the MSE and via development of online resources and workshops (see timeline of implementation in Table 2). Both components are described below:

3.3.1. TECHNICAL COMPONENT

The technical work of MSE involves writing, testing, and implementing computer code and models of tropical tunas (continuing ongoing work with BET) under exploitation following simulated alternative harvest strategies, summarizing results, and communicating them effectively. MSE is being structured as a modular system consisting of three major components (Conditioning, Projection and Evaluation) around several model types including operating models (OM), sampling models, estimation models (EM), management models and summary models.

- **OMs** describing the assumed true population (under different scenarios of growth, natural mortality, steepness, productivity regimes) and fishery dynamics (selectivity, catchability) are being implemented in the modeling platform *Stock Synthesis*. Both parameter and structural uncertainty are considered when developing OMs, which will be weighted using a combination of Bayesian methods (MCMC, for model parameters) and grids across models with different structure. We will use the set of models developed for the 2020 bigeye tuna Risk Analysis as the basis of the grid of OMs (Figure 2).
- **Sampling models** simulate how data (e.g., catches, size compositions, CPUE) are collected from the simulated "true" population and how they relate to simulated data (including observation uncertainty, the effect of measurement error and bias). The bootstrap functionality of *Stock Synthesis* is used to generate the observed data.
- **EMs** use the simulated data to derive perceived stock status and trends, either using simplified assessment models or empirical stock status indicators (e.g., longline CPUE trends), allowing for evaluating their value as actual elements of empirical (data-based) HCRs. One of the reasons for using simplified assessment models is that it often is computationally prohibitive to try to replicate assessment models of the complexity used during real benchmark assessments given that as part of the MSE the EMs would have to be conducted potentially thousands of times depending on the evaluation design. Adding to the complexities to try to simulate complex real-life assessments, benchmark assessments for BET and YFT in the EPO are currently conducted using several different reference models which are subsequently weighted to compute overall management quantities used for management recommendations. Alternative simplified EMs, such as Age Structured Production Models (ASPM), are being evaluated. Alternative empirical HCRs based at the onset on BET longline CPUE are being currently explored. Stock Status Indicators (such as those based on sizes of the fish in the catch, CPUEs of other fleets) regularly computed and reported by the IATTC staff as well as others currently in development (Buoy Index) could also be incorporated and evaluated as components of empirical HCRs.
- **Management models** use the perceived stocks status and trends to derive management action (e.g., fishery closure days, catch limits) either via alternative model-based (simplified assessment models) or empirical HCRs (based on linking changes in a stock status indicators, such as longline CPUE, to a particular management action for example closure days). Implementation uncertainty will be incorporated, for example in the relationship between intended and realized changes in effort and fishing mortality by adjusted closure days. Alternative periodicity in the implementation of management changes could be explored, from annual to triennial, to reflect recommendations made during recent SAC meetings. The current plan is to evaluate three alternative HCRs for the bigeye tuna MSE (Figure 4), one reflects the current HCR used for EPO tropical tunas at IATTC, the second one is a more moderate HCR by gradually decreasing exploitation rate between the target and the limit, and the third HCR is more conservative by having a higher biomass limit, lower target exploitation rate and gradual changes between the target and the limit. The HCRs would be applied on a 3-year cycle with effort controls (days of closure) for surface fleets and catch limits for longline fleets. The data inputs for the HCRs will be 1) Empirical HCR: standardized Japanese longline index of abundance; 2) Model-based HCR: simplified model (e.g. ASPM) fit to standardized Japanese longline index of abundance and total catches.
- **Summary models** will use performance metrics (e.g., variability in the catch, probability of falling below target or limit reference points) to evaluate the relative performance of alternative harvest strategies in

achieving management objectives and inform the quantitative trade-offs among competing goals. To provide a friendlier interface to access and explore results, a graphical interface is being developed, similar to the one already in use during recent MSE workshops (see Figure 3).

OMs are conditioned (a process to ensure consistency with historical data) similarly to the process involved while fitting an assessment model but allowing for further processes (e.g., time varying parameters) depending on the scenario considered. OM parameters are then fixed to represent the underlying “true” population dynamics. Projections are done with stochastic recruitment and provisions to incorporate other stationary or directional (e.g., changes in productivity or exploitation regimes) future dynamics. The basic procedure of the modeling component of the MSE includes the following steps, to be modified as needed:

1. **Condition OMs:** Fit a set of assessment models to historical data under alternative population and fishery scenarios. This provides the parameters of the OMs that will be fixed for the analyses.
2. **Compile historic data:** Compile the historical data and structure of the OMs to be used in either simplified assessment models (i.e., grouping of fisheries, reduced model complexity) or stock status and trends indicators (e.g. longline CPUE, simulated standardized purse-seine index).
3. **Evaluate HCR:** Evaluate the HCR using the current data including running the assessment model if applicable. The management action determined at this step will be used in the projections of the next step.
4. **Project OMs:** Project the OMs forward for alternative management cycle lengths (e.g., 3 years) using the derived management action from an HCR of a candidate strategy using simulated data and random recruitment deviation (process error). This updates the stock trajectory for 3 years.
5. **Update OMs files:** Change the data files of the updated OMs by a) adding 3 years to the model end year; b) put the catch calculated from the projected years from (3) in as catch (incorporating additional variability such as implementation error) of the updated 3 years; c) put the random recruitments used in the projected period into the updated 3 years; and d) add dummy data (CPUE, length composition, and last five years' average of sample size for the length composition) to the data file for the 3 new years.
6. **Create data:** Bootstrap to generate “perceived” catch observations, CPUE, and length composition for the whole time period (historical and forecast period). Update the fishery data by replacing the catch and dummy data with bootstrapped data only for the updated 3 years.
7. Repeat (2) - (6) for as many times as desired.
8. Repeat (7) for as many times as desired with different random recruitments.
9. Repeat (8) for each scenario and candidate strategy. The random recruitment deviations and simulated data for the historic period will be the same across scenarios to eliminate the impact of random recruitments when making comparisons between different scenarios and candidate strategies.
10. Results will be summarized across candidate strategies for different performance metrics to illustrate tradeoffs between different goals and the performance of candidate harvest strategies in achieving management objectives will be compared relative to each other.

The success and relevance of the technical work relies on inputs on elements and integration of candidate harvest strategies, such as management objectives, performance metrics, specification of HCRs. At the same time, results of the implementation of those inputs and preliminary results should be communicated effectively and regularly to stakeholders. These aspects are described in the next section.

3.3.2. STAKEHOLDER DIALOGUE COMPONENT

Strategies are based on choosing tactics (temporal or spatial closures, catch or effort limits) to achieve management objectives. If management objectives are not explicit and clear, alternative strategies cannot be realistically evaluated. Since there are no dedicated communication channels on MSE within the IATTC, SAC meetings (if time allows) and recent workshops (such as the 2019 Industry workshops and the 1st IATTC sponsored MSE workshop) have provided opportunity for dialogue, communication, and training on MSE, along with initial discussions on potential candidate management objectives. This component of the project consists of providing training and enhancing dialogue / communication among scientists, managers, and other stakeholders regarding the MSE process for tropical tunas through the facilitation of a series of workshops between 2021 and 2023. The work involves development/tailoring of MSE Workshop materials and online resources to EPO tropical tuna fisheries including presentations and hands-on working sessions. As part of this project, three IATTC sponsored workshops have been conducted with managers, industry, and other stakeholders to improve understanding of the MSE process, elicit objectives, performance metrics, alternative control rules, and risk, as well as to show initial results and gather feedback. A summarized table (Table 3) of Management Objectives, Performance Indicators and other elements discussed during previous IATTC MSE workshops was presented and modified during the 3rd IATTC MSE workshop, which will provide the basis for the next step of the technical work. Training, communication materials and online interactive tools in English and Spanish will be continued to be developed to enhance understanding of the MSE process and results. See, for example, the online MSE demonstration tool used in recent workshops:

https://valeromaspez.shinyapps.io/TunaMSE_EPO_ENG/

https://valeromaspez.shinyapps.io/TunaMSE_OPO_SPN/

3.4. NEXT STEPS

The proposed timeline of technical work and workshops is as follows (see also Table 2), subject to modifications, for example, as with Resolution 17-02 with regards to 1st IATTC MSE WS, or for other unanticipated events such as the recent COVID-19 pandemic with resulted in the 2nd and 3rd workshops being conducted via conference instead of in person as originally planned:

2023:

Workshops to show MSE updated results, gather feedback, plan additional evaluation work

SAC-14 and Annual Meeting: Report on revised MSE plan

Technical implementation of revised MSE, evaluation

2024:

Workshop to discuss MSE results, plan for other tropical tunas.

SAC-15 and Annual Meeting: Report / presentation of MSE results and plan for other tropical tunas.

4. EXPECTED RESULTS

The results will show the performance of the IATTC interim reference points and HCR, along with alternatives, for tropical tunas under different sources of uncertainty, facilitating adoption of an evaluated HCR for tropical tunas as per Resolution C-16-02. The initial focus will continue to be on BET, which has been the species driving management measures for tropical tunas in the EPO (Table 1, Figure 1), moving to other tropical tunas towards the end of the BET process. The results will be used to inform IATTC staff, Commissioners and their scientific advisers, Industry and other stakeholders, so that the current strategy can be refined, improved or modified based on results of the MSE. Reporting of the MSE development progress and results will be done at regular SAC meetings, MSE workshops and other meetings, both as presentations, reports and communication materials and tools. This project will contribute to at least three of the seven overarching themes in the IATTC Strategic Science Plan: *Sustainable Fisheries* (Evaluating the robustness of alternative harvest strategies with a proper treatment of uncertainty and risk using MSE, widely recognized as best practice for promoting sustainable management strategies), *Knowledge Transfer and Capacity Building* (Multiple opportunities for stakeholder input, dialogue and training) and *Scientific Excellence* (Promoting training and advancement of scientific staff in the MSE process and promoting the advancement of scientific research on MSE).

It is expected that results of the project will be used by the Commission or its members in the development, evaluation, and adoption of robust harvest strategies for the tropical tuna fisheries. The tools developed during the project will be useful in future MSE work not only for tropical tunas but for other related species. Although the scope of the MSE plan is initially on BET (as outlined in the MSE work plan in the IATTC 2019-2023 Strategic Science Plan), this project will help expand the process to the other species (YFT, SKJ) towards the end of the proposed plan pending securing of funding which ends at the end of 2023 (See Table 2). The transition towards MSE for the other tropical species (YFT and SKJ) will benefit from ongoing progress in their respective stock assessment modeling, required to develop OMs for both species.

5. CHALLENGES

Some of the challenges faced so far include impacts from the COVID-19 pandemic, such as the inability to have in-person workshops, changes in workplan timeline and limitations due to virtual meetings. Other challenges include under-representation or absence of some CPCs during workshops along with a relatively high turnover of representatives between workshops. The multiple additional and extraordinary Commission meetings during 2020 and 2021 related to the establishment of consensus for the establishment of new conservation measures put the focus of staff, Commissioners, Industry, and other stakeholders on the immediate needs for setting the next management cycle and limited the time available for strategic work, as is needed for MSE work. Some of these challenges are expected to be ameliorated by the improvement of the COVID pandemic, extension of the workplan to 2024, and the recent adoption of tropical tuna conservation measures for the 2022 to 2024 management cycle. However, tropical tuna MSE work for 2024 and beyond is pending securing of additional funds (see next session).

6. FUNDING

The MSE process for tropical tunas has been carried out by an external contractor funded by IATTC, external sources, or a combination of both. At present, funding is available through the end of 2023 via a contribution by the European Union. Continuation of the MSE process after 2023 is pending securing additional funds.

TABLE 1. Days of closure and additional measures for the EPO purse-seine (PS) fishery recommended by the IATTC staff and closures implemented by the IATTC, 2002-2022, along with Resolutions and *F* multipliers (F_{MSY}/F). YFT: yellowfin; BET: bigeye. Updated from SAC-07-07g.

Year	Resolution	*F* multiplier		Closure (days)	
		YFT	BET	Recommended	Implemented
2002	C-02-04	1.12	1.85	31	31
2003	C-03-12	1.2	0.79	61 + add. measures[1]	42
2004	C-04-09	1.12	0.62	61[2] + add. measures[3]	42
2005	C-04-09	0.83	0.57	61 + add. measures[3]	42
2006	C-04-09	1.02	0.68	61 + add. measures[4]	42
2007	C-06-02	0.88	0.77	74	42
2008	None	1.13	0.82	84	49
2009	C-09-01	1.09	0.81	84	59
2010	C-10-01	1.33	1.13	62	62
2011	C-11-01	1.13	0.93	62	62
2012	C-12-01	1.15	0.95	62-74[5]	62
2013	C-13-01	1.01	1.05	62	62
2014	C-13-01	1.21	1.04	62	62
2015	C-13-01	1.11	1.14	62	62
2016	C-17-01	1.02 (0.92) [6]	1.05 (0.94) [6]	87	62 + OBJ DEL catch limits [7], amended to 72 days OBJ, UNA and 62 DEL
2017	C-17-02	1.03 (0.97) [8]	1.15 (1.08)[8]	72	72
2018	C-17-02	0.99	0.87[9]	72+ add. measures [12]	72
2019	C-17-02	0.89[10]	No assessment	72+ add. measures [12]	72
2020	C-20-06	1.61	0.7 / 1 / 1.44[11]	72+ add. measures [12]	72
2021	C-21-04	No assessment	No assessment	72+ add. measures [12	72+ BET IVL
2022	C-21-04	No assessment	No assessment	72+ add. measures [12	72+ BET IVL

[1] Additional 61 days between 90°W and 150°W from 5°N to 10°S
[2] 2-month closure, which is 61 days for most combinations
[3] One of three options: (1) 6-month PS closure W of 95°W between 8°N and 10°S; (2) 6-month closure of PS fishery on floating objects W of 95°W; (3) Limit BET annual catch by each PS vessel with an observer to 500 t
[4] Additional 95 days for PS fishery for bigeye on floating objects
[5] 74 days after adjusting for capacity
[6] Number between () corrected by increases in PS capacity, 11.2% larger than previous 3-year average
[7] Amended by resolution C-17-02
[8] Number between () corrected by increases in PS capacity, 6.7% larger than previous 3-year average
[9] [10] Assessments determined not reliable for providing advice
[11] Computed from pessimistic / overall / optimistic models from BET risk analysis
[12] Limits on the number of OBJ and/or unassociated sets and vessel limits

TABLE 2. Timeline for current Management Strategy Evaluation (MSE) workplan (2021-2024).

GREEN: COMPLETED; BLUE: FUNDED; RED: UNFUNDED

SSP ref.	Target/Project	2021		2022		2023		2024	
		1	2	1	2	1	2	1	2
	1. SUSTAINABLE FISHERIES								
	Goal I: Test harvest strategies using Management Strategy Evaluation (MSE)								
I.1.	Conduct a comprehensive MSE for bigeye tuna and plan MSEs for the other tropical tuna species								
I.1.a	1. Stakeholder and technical MSE workshops								
	a. Technical meetings to agree on overall/revised MSE Plan by IATTC staff and collaborators								
	b. Stakeholder workshops on training and communication on MSE development and results								
	2. Technical development of MSE, HCR, MP, outputs								
	a. Run preliminary MSE based on initial input from managers and stakeholders								
	b. Run final MSE based on revised input from managers and stakeholders								
	c. Present evaluated HCR/MP to Commission, plan work for other tropical tunas								

Table 3. Objectives, quantities and performance indicators summarized during the 3rd IATTC MSE workshop. Yelow indicates elements not completely defined yet.

OBJECTIVE	Quantity	Performance Indicators
Safety *Maintain stock above limit reference points*	*Equilibrium virgin spawning biomass SB_0* • *< 10% probability SB below 7.7% of SB_0* • *< 5% probability SB below 7.7% of SB_0* < 10% P SB < SBmsy Flim (< 5% *P* F > Fmsy)	Ratio of SB_{yr} over SB_0 Probability calculated over projected 30 years (All years, any year by replicates)
Status Maintain stock in green quadrant of Kobe plot	SB≧ dynamic SB_{MSY} and $F<F_{MSY}$ • *50% probability (too low?)* • *60% probability* • *75% probability* • *80% probability (too high?)*	% of simulated runs falling in Kobe's green quadrant Probability calculated over projected 30 years
Stability Maintain low variability of catch and effort limits, gradual changes in management measures. Caps at 10% (effort), 15% (catch), Min. change (X%)	Standard deviation of annual catch, effort Average interannual proportional change (catch, effort)	% change in catch and/or effort between years Calculated over projected 3, 15 and 30 years
Yield/Abundance Maintain catches/effort/CPUE above historical ranges	Average catch/effort/CPUE by fishery (PS and LL) • *1994-2019 (since FAD expansion)* • *2017-2019 (latest status quo)*	Ratio of projected 3, 15 and 30-year average catch/effort/CPUE by fishery over historical period
Status quo Maintain the stock at levels near the (2017-2019) status quo	Spawning biomass, Index (LL CPUE)	Ratio of projected 3, 15 and 30-year average SB, Index (LL CPUE) over status quo period (2017-2019)

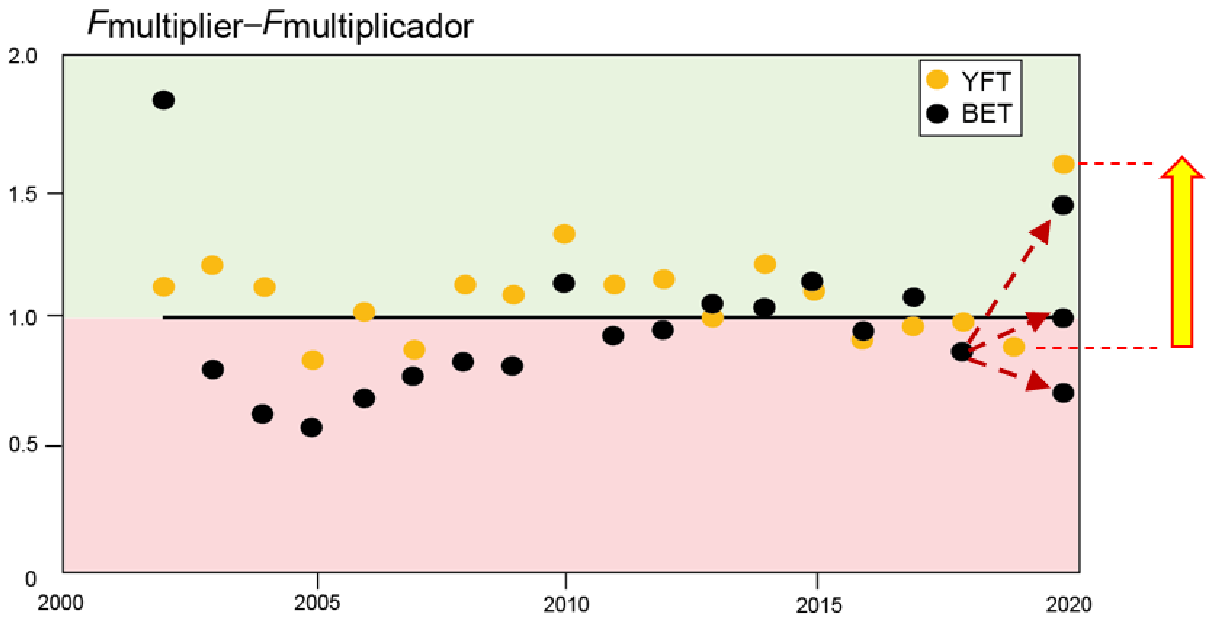

FIGURE 1. Timeseries $F_{multiplier}$ ($F_{MSY}/F_{current}$) estimated by yellowfin (YFT) and bigeye (BET) tuna, as estimated by their respective stock assessment from 2002 to 2020. The area in red (below 1) indicates that recent fishing mortality has exceeded that estimated to produce MSY. The 2022 assessments for YFT and BET were based on a weighted multi-model approach, resulting on a bimodal result for BET management quantities, the Figure shows the two modes and the overall result.

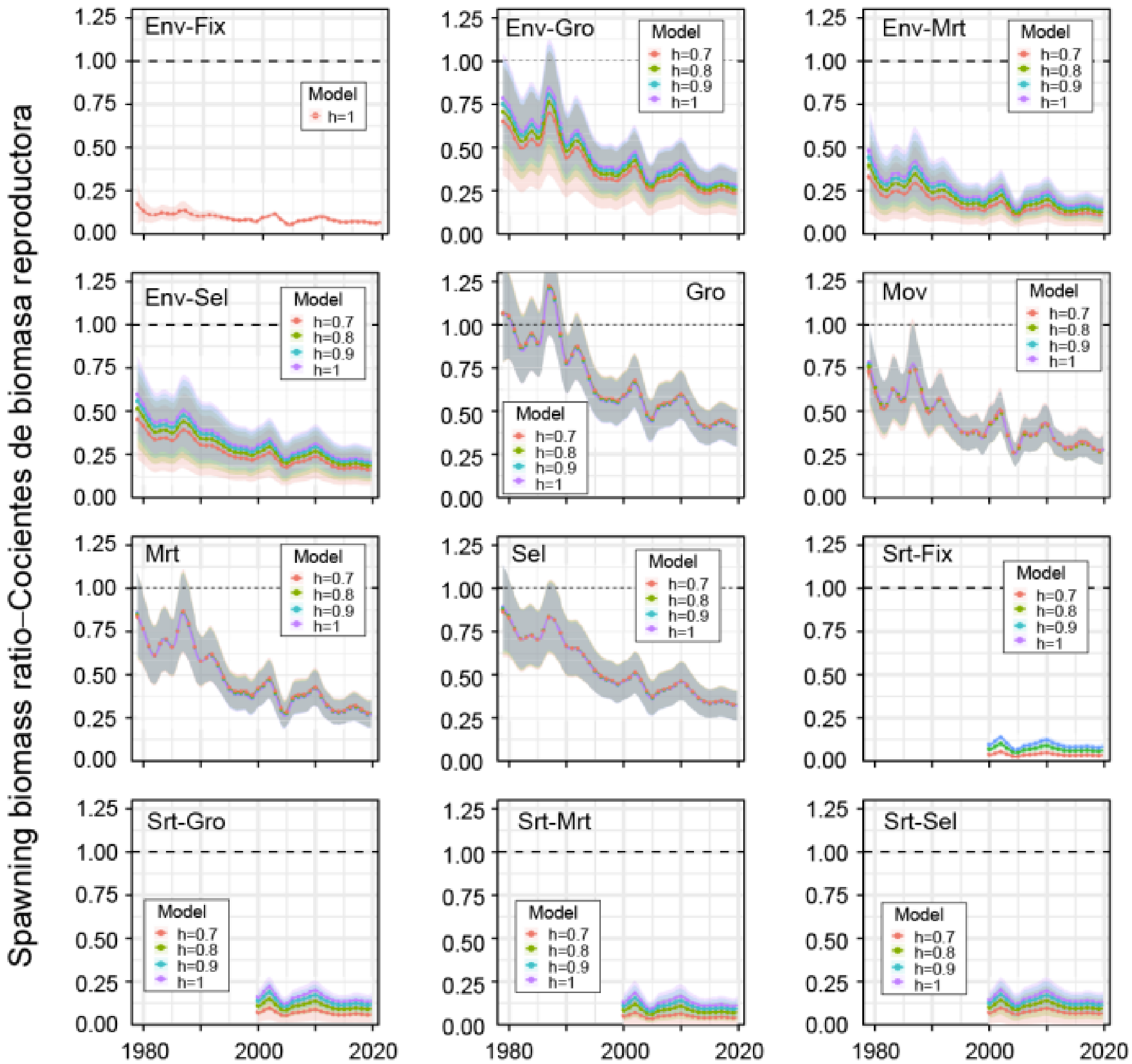

FIGURE 2. Comparison of estimated spawning biomass ratio of bigeye tuna in the eastern Pacific Ocean from each reference model used in the 2020 benchmark assessment (Xu et al., 2020) under different assumptions on the steepness of the Beverton-Holt stock-recruit relationship (*h*). The shaded areas represent the 95% confidence interval.

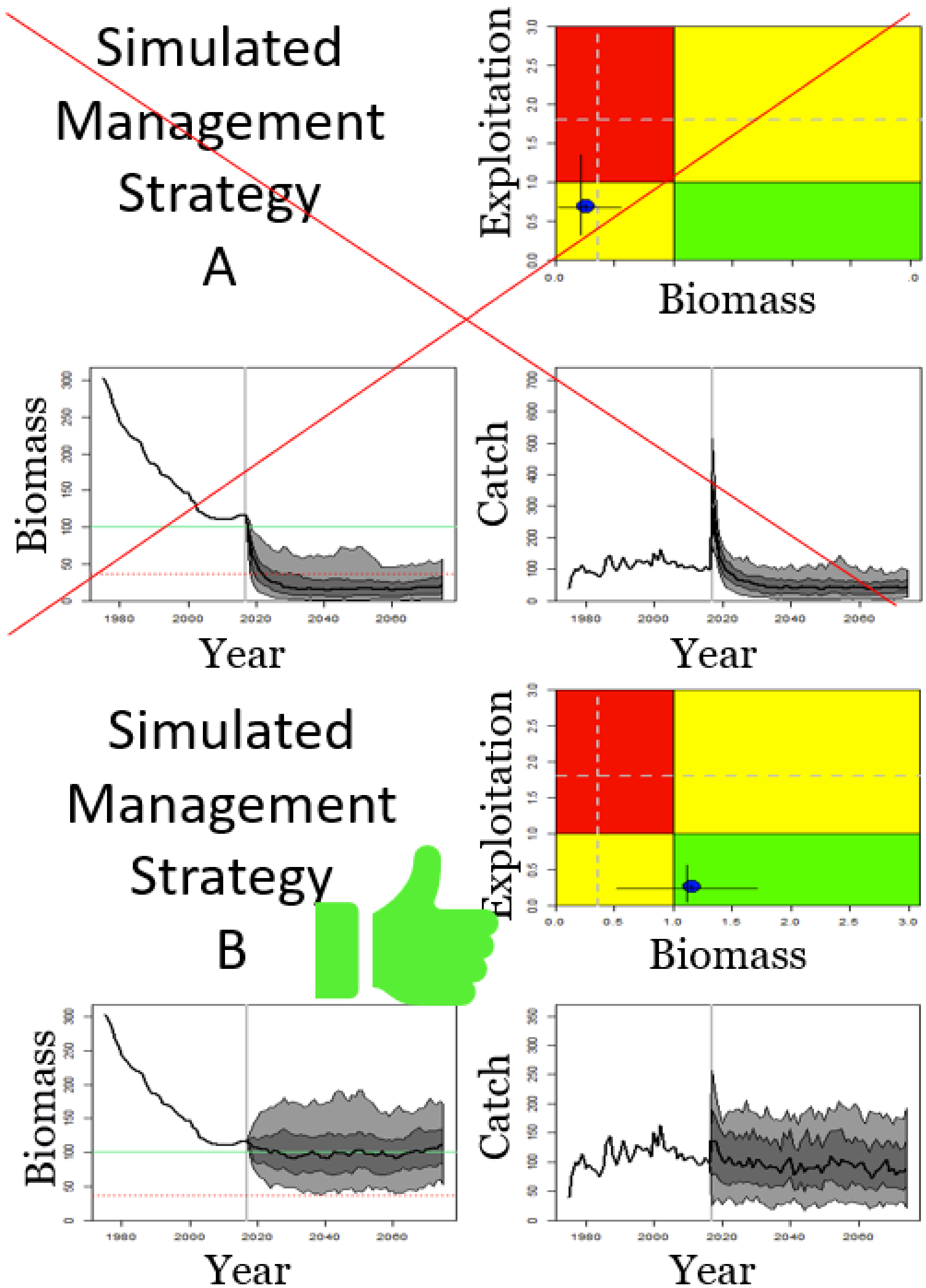

FIGURE 3. Screenshots of the interactive online application to illustrate MSE components for BET in the EPO, available at: https://valeromaspez.shinyapps.io/TunaMSE_EPO_ENG/

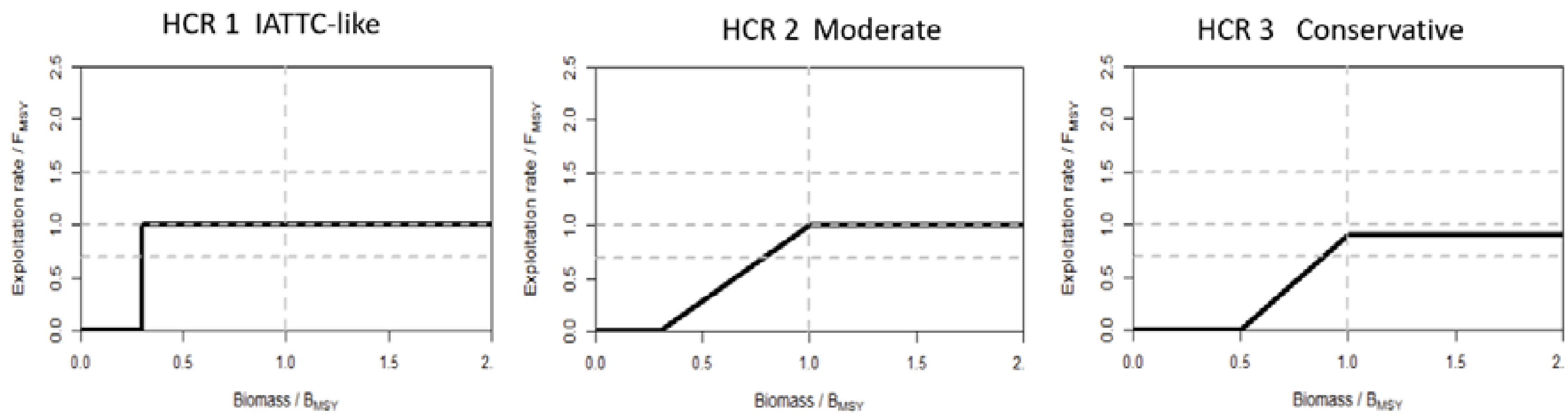

FIGURE 4. Alternative Harvest Control Rules (HCR) discussed during the 3rd IATTC Workshop on tropical tuna MSE as candidates for evaluation during the bigeye tuna MSE.