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

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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. Implementing reliable stock assessments to act as operating models is an essential part of the MSE process. The BET assessment has been evolving over time with several substantial improvements being made recently. The 2020 BET assessment still had substantial uncertainties, including a bimodal pattern in management quantities (one group of models with estimates of biomass above the level corresponding to maximum sustainable yield (B_{MSY}), another group below B_{MSY} with little probability in between) along with a suspect apparent regime shift in recruitment coincidental with the increase of floating object purse seine catches in the 1990s. Although the 2020 assessment models covered the range

of uncertainties, this led to operating models that may not result in the best strategy being selected had a better set of operating models been available. The 2024 assessment has resolved many of the structural issues of previous BET assessments, so using that assessment for the operating models in the update of the MSE should result in a better strategy being selected. These changes, along with staff's evolving view on potential changes to target reference points for tropical tunas in the EPO, prompted the staff to revise the workplan for the bigeye tuna MSE work by replacing the original set of operating models with a new set of operating models derived from the 2024 bigeye tuna benchmark assessment, as well as incorporating proposed alternative HCRs and reference points. The MSE process at IATTC has been funded by the European Union between 2021 and 2023. A newly established (2024) IATTC staff harvest strategies permanent position has secured continuation of the MSE work. The revised timeline includes bigeye MSE work during 2024 and 2025, with plans to expand the MSE work to the other tropical tunas (likely skipjack next and then yellowfin) now that funding has been secured for continuation of the MSE work for EPO tropical tunas.

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. A major 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, indices of relative abundance, 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 been shown to be often problematic due to over-sensitivity of model results to changes in new data (independently of the true changes in the stock), data types, data analyses and assessment methodology or modeler doing the analyses. 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 robustness of 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 as management procedures or harvest strategies) 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 successful MSE development, testing and implementation of a management procedure already in place for many years, other RFMOs with evaluated management procedures for tropical tunas (e.g. bigeye tuna in IOTC, skipjack tuna in WCPFC) and with IATTC at the earliest stage in the process with an ongoing bigeye tuna MSE.

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 and a benchmark assessment conducted in 2024). 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 predetermined and pre-agreed specific management actions. When lacking reliable assessments (such as with BET in 2018 or YFT in 2019 and 2024) 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 for tropical tunas in the EPO 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 (see SAC-15-08). 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, particularly for bigeye tuna. However, a proper MSE process requires a complete specification of 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 as recommended for Commission consideration by the SAC-14) 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 conducted with funding support from the European Union 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.

This document describes work conducted on 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 up until the end of 2023, working with IATTC staff. Starting in 2024, MSE work has continued with the establishment of a new harvest strategies permanent position in the 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. Initial technical work was started with a set of operating models based on results of the 2020 bigeye benchmark stock assessment, which had a concerning bimodal pattern in management quantities (one group of models with estimates of biomass above the level corresponding to maximum sustainable yield (B_{MSY}), another group below B_{MSY} with little probability in between) along with a suspect apparent regime shift in recruitment coincidental with the increase of floating object purse seine catches in the 1990s. Recently, substantial changes in modeling of bigeye tuna (SAC-15-02) related to data, biology, and model specifications following panel recommendations of the two recent stock assessments external reviews (RVMTT-01-RPT and RVDTT-01-RPT) removed the apparent regime shift in recruitment estimates and the bimodal pattern in management quantities. These changes, along with staff's evolving view on potential changes to target reference points for tropical tunas in the EPO (SAC-15-05), prompted the staff to revise the workplan for the bigeye tuna MSE work by replacing the original set of operating models with a new set of operating models derived from the 2024 bigeye tuna benchmark assessment, as well as incorporating proposed alternative HCRs and reference points. The revised timeline includes bigeye MSE work during 2024 and 2025, with plans to expand the MSE work for the other tropical tunas (likely skipjack next and then yellowfin) now that funding has 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 using results of 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 at the time, it was decided to start with BET on the technical work, adding the other species (YFT, SKJ) as their current assessment models are improved. 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 conclude the work on bigeye tuna, moving to the other tropical tuna species towards the end of the timeframe.

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 the tools to conduct MSE 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 has consisted of two components that evolved 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. Both the OM and EM are implemented in the integrated stock assessment platform *Stock Synthesis*, using custom code similar in structure and functionality to that used for the recent North Pacific Albacore tuna MSE and the ongoing Pacific Bluefin tuna MSE.

- **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. As mentioned in the Background section, although initial work was started using the set of models developed for the 2020 bigeye tuna Risk Analysis as the basis of the grid of OMs (Figure 2), final MSE work will be conducted using the models developed for the 2024 benchmark assessment as the basis for the OM grid (Figure 3). Main structural uncertainties of the 2024 bigeye tuna model ensemble that will be carried into the MSE as alternative states of nature includes 36 model configurations with different assumptions on individual growth, selectivity for fisheries (some asymptotic or all dome-shape), steepness of the Beverton-Holt stock recruitment relationship (*h* values: 1.0, 0.9, 0.8), natural mortality (*M* values for adult male 0.1, 0.12, 0.125, 0.13) and three rates of annual increase in longline catchability (0%, 1%, 2%).

- **Sampling models** define how data (e.g., catches, size compositions, CPUE) are collected from the simulated "true" population (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 with recruitment deviates (ASPM-R), are being used in the current MSE framework. Alternative empirical HCRs based 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 in the future.
- **Management models** use the perceived stocks status and trends to derive management action (e.g., fishery closure days, catch limits). Implementation uncertainty will be incorporated in the relationship between intended and realized changes in fishing mortality (0%, 10%, 20% implementation error) to represent the different approaches to implement the HCR (e.g. closure days, Individual Vessel Thresholds, active FAD limits). This approach is used because the actual relationship is unknown for some of these measures and only the order of magnitude can be represented at this stage. Alternative periodicity in the implementation of management changes will 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 5), 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. Given potential changes in the interpretation of target reference points and their relationship to MSY (see Resolution C-23-06 and SAC-15-05), alternative target reference points and control points of the HCRs will be considered, including $B_{30\%}$ and $F_{30\%}$. The HCRs would be applied on a 1 or 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 the 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 user friendly 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 4).

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 future dynamics. The basic procedure of the modeling component of the

MSE includes the following steps, to be modified as needed (we illustrate it based on a three-year management cycle, but the same approach can be used for other cycles, i.e. one year):

1. 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 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. Project the OMs forward for alternative management cycle lengths (e.g., 1 year or 3 years) using the derived management action from an HCR of a candidate strategy using simulated data and random recruitment deviations (process error). This updates the stock trajectory for 3 years.
4. Change the data files of the updated OMs by a) adding 1 or 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.
5. 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.
6. Repeat (2) - (5) for as many times as desired.
7. Repeat (2) - (6) for as many times as desired with different random recruitments.
8. Repeat (1) - (7) 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.
9. 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 about MSE elements, such as management objectives, performance metrics, specification of HCRs.

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/

There have been requests by stakeholders for the establishment of a dedicated dialogue Working Group, which could enhance or replace the MSE workshops. Recommendations during SAC-14 stated that the Commission consider the Science-Management Dialogue (SMD) or informal workshops approach to continue the MSE process.

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 which resulted in the 2nd and 3rd workshops being conducted via video conference instead of in person as originally planned. We are planning on having at least one workshop during 2024 and more during 2025 to present MSE results and plan/receive feedback for expansion of the MSE work to the other tropical tuna species

2024: SAC-15 and Annual Meeting: Report on revised MSE plan

Workshop/s to show MSE updated results, gather feedback on harvest strategy elements (e.g. TRPs), plan additional evaluation work

Technical implementation of revised MSE with new OMs, evaluation

2025: Workshop/s to discuss MSE results, plan for other tropical tunas.

SAC-16 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 a 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 for BET (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 potential establishment of a dedicated MSE Working Group could help formalize the process and alleviate some of the challenges on representation and turnover of representatives, along with streamlining the feedback and dialogue process. 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 ending of the COVID pandemic, extension of the workplan and securing of a permanent staff position to continue the work on harvest strategies at the IATTC.

Implementing reliable stock assessments to act as operating models is an essential part of the MSE process. The BET assessment has been evolving over time with several substantial improvements being made recently. The 2020 BET assessment still had substantial uncertainties and although the assessment models covered the range of uncertainties, this led to operating models that may not result in the best strategy being selected had a better set of operating models been available. The 2024 assessment has resolved many of the structural issues of previous BET assessments, so using that assessment for the operating models in the update of the MSE should result in a better strategy being selected.

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, 2002-2023, 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
2021-23	C-21-04	No assessment	No assessment	72+ add. measures [12	72+ BET IVT

[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 (2024-2028).

	2024	2025	2026	2027	2028
SAC	Assess stock status	Second run of MSE			
AM	Initial run of MSE	Select/Adopt BET MP Set Measures (2026-2028)			Set Measures (2029-2031)
Staff work	Update MSE, new OMs	Start MSE for SKJ or YFT Check Excep. Circumst.	Collate data for MP Run MP Check Excep. Circumst.	Collate data for MP Run MP Check Excep. Circumst. Assess stock status	Check Excep. Circumst.

Table 3. Objectives, quantities and performance indicators summarized during the 3rd IATTC MSE workshop.

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	$SB \geqq$ dynamic SB_{MSY} and $F<F_{MSY}$ • *60% probability* • *75% probability*	% 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)	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)

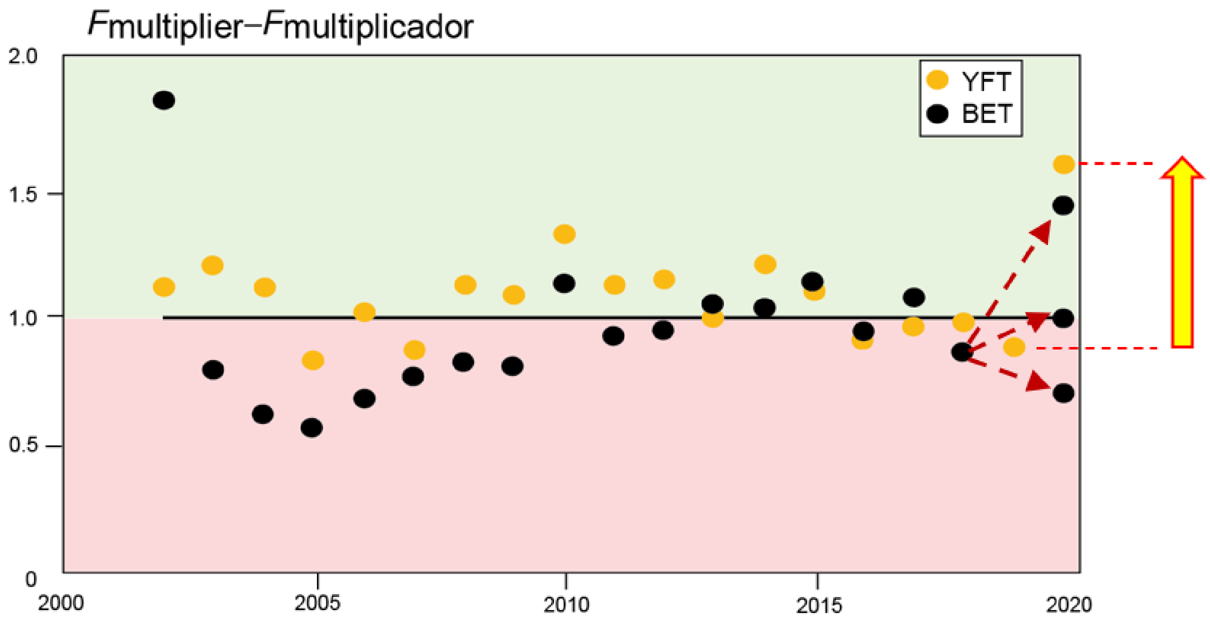

FIGURE 1. Timeseries $F_{multiplier}$ ($F_{MSY}/F_{current}$) estimated by yellowfin (YFT) and bigeye (BET) tuna, as estimated by their respective stock assessment from 2002 to 2020. The area in red (below 1) indicates that recent fishing mortality has exceeded that estimated to produce MSY. The 2022 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.

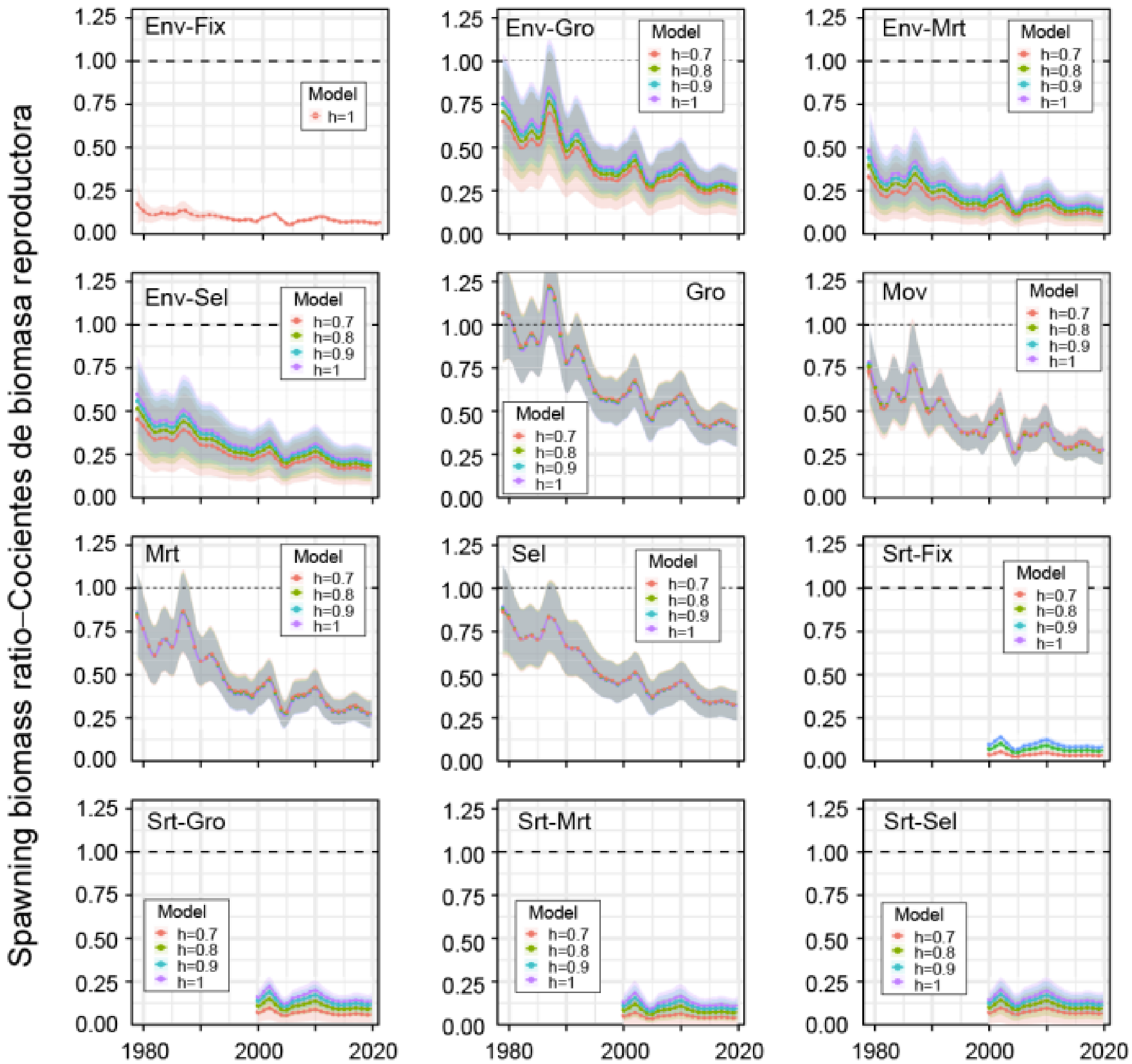

FIGURE 2. Comparison of estimated spawning biomass ratio of bigeye tuna in the eastern Pacific Ocean from each reference model used in the 2020 benchmark assessment (Xu et al., 2020) under different assumptions on the steepness of the Beverton-Holt stock-recruit relationship (*h*). The shaded areas represent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

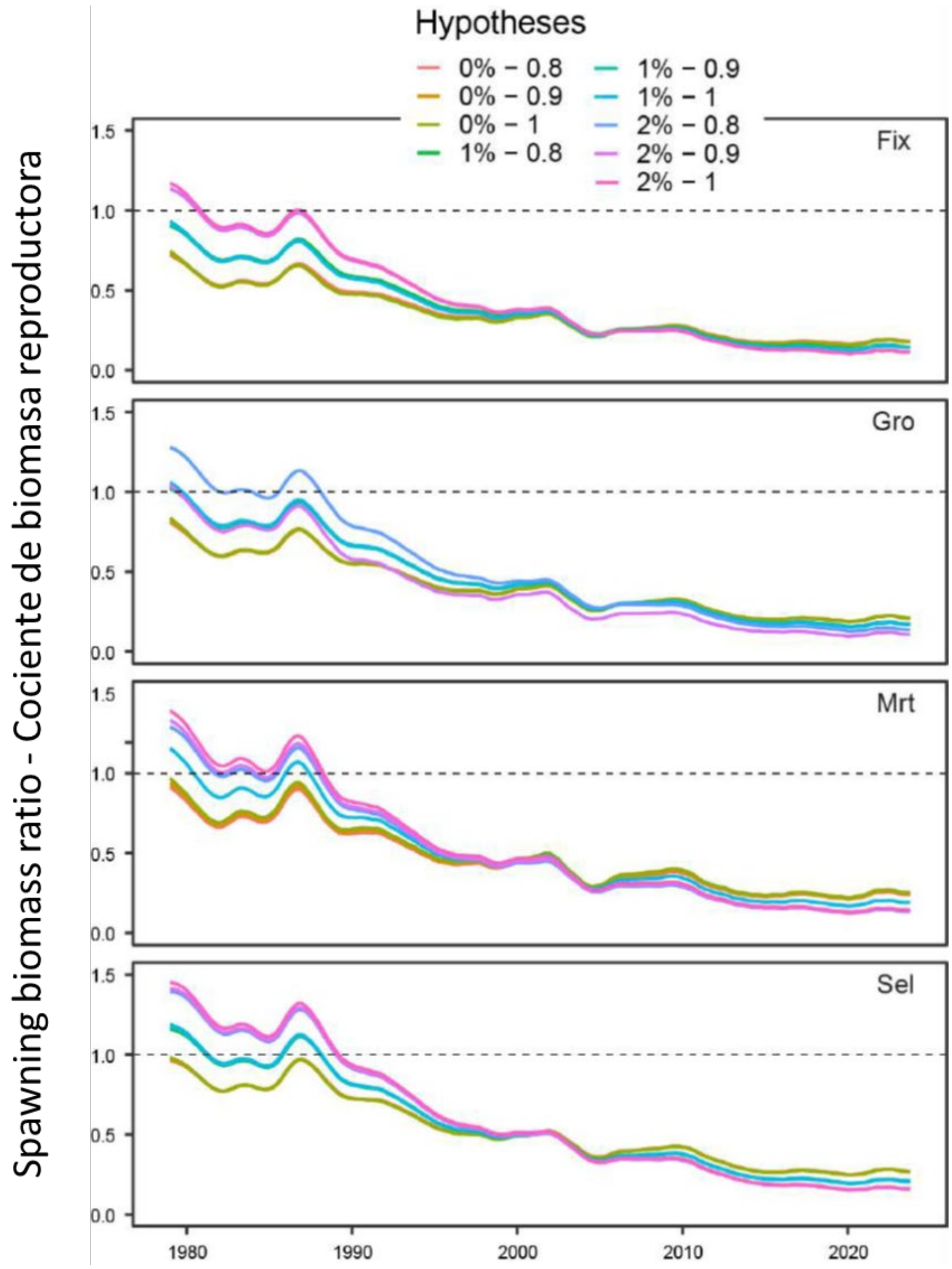

FIGURE 3. Comparison of estimated spawning biomass ratio of bigeye tuna in the eastern Pacific Ocean from each reference model used in the 2024 benchmark assessment (modified from Xu et al., 2024) under different assumptions on the rate of change in survey catchability and steepness of the Beverton-Holt stock-recruit relationship (line colors) for each of the models under different configurations of growth, natural mortality, and fishery selectivity (panels).

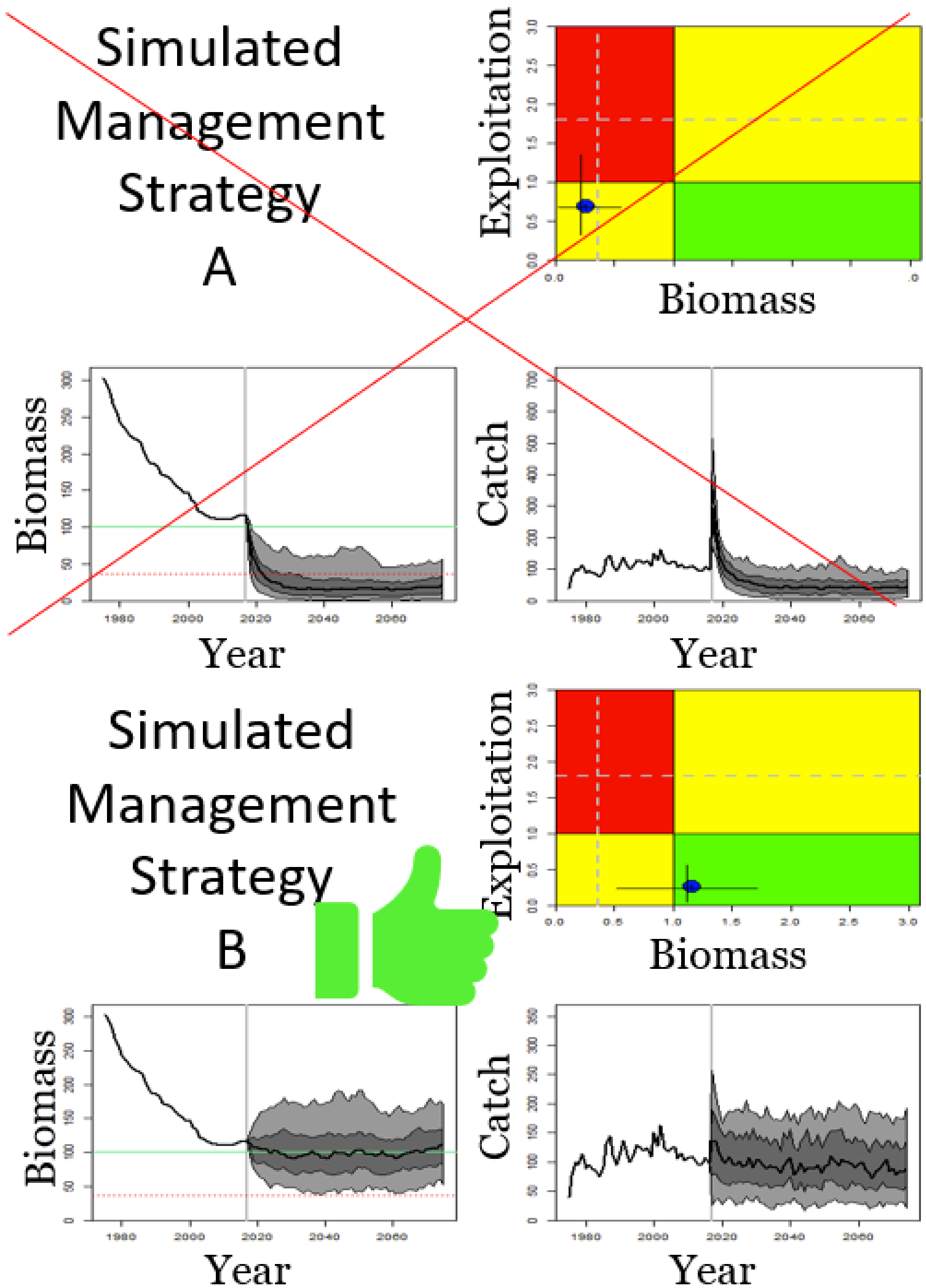

FIGURE 4. Screenshots of the interactive online application to illustrate MSE components for BET in the EPO, available at: https://valeromaspez.shinyapps.io/TunaMSE_EPO_ENG/

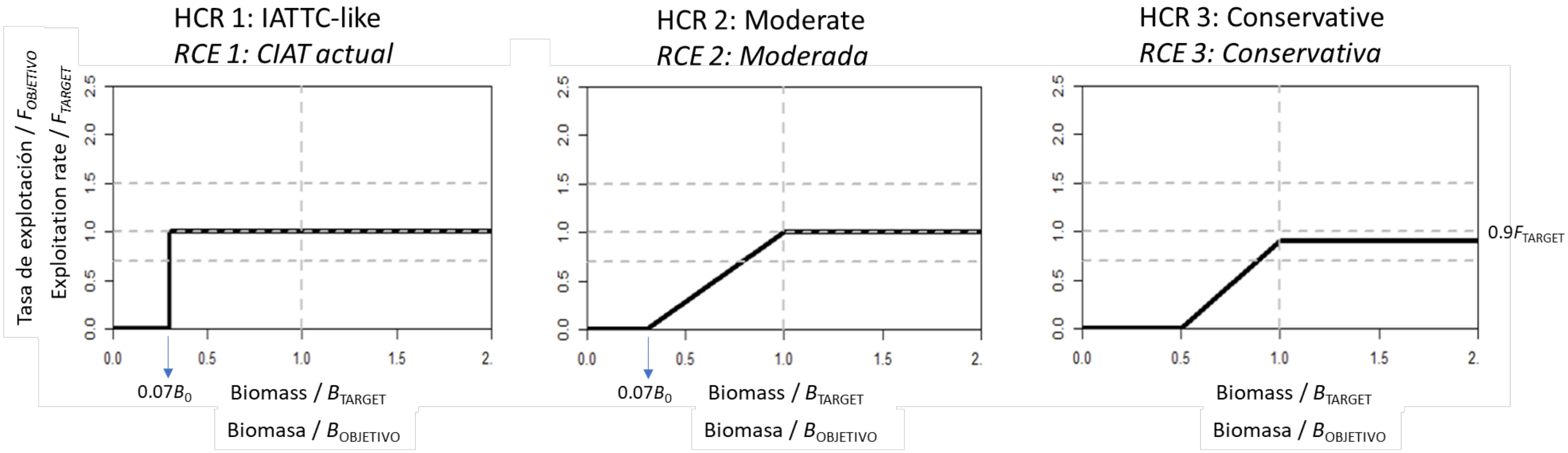

FIGURE 5. Alternative Harvest Control Rules (HCR) discussed during the 3rd IATTC Workshop on tropical tuna MSE as candidates for evaluation during the bigeye tuna MSE. B_{TARGET} and F_{TARGET} are either MSY-based quantities or $B_{30\%}$ and $F_{30\%}$.