Original: English

Atlantic Bluefin Tuna MSE – Structure & Preliminary Results

Executive summary

This document describes core concepts of the Atlantic bluefin tuna management strategy evaluation (MSE). The intention is to provide sufficient knowledge to facilitate discussion among scientists, fishery managers and other stakeholders, commencing with the Ambassador meetings in October, the Panel 2 meeting on 12 November 2021 and continuing with further meetings during 2022. This document summarizes the MSE structure, some preliminary results, and highlights key areas for Panel 2 input.

Background

The SCRS's Bluefin Tuna Species Group has been developing a management strategy evaluation (MSE) framework for Atlantic bluefin tuna (BFT) since 2014 with support from the Atlantic-Wide Research Programme for Bluefin Tuna (GBYP). In 2015, the Commission called for adoption of a management procedure (MP) based on the MSE (Rec. 15-07), and preliminary work was first presented to the Commission in 2016. Since then, an MSE expert has been contracted to develop and coordinate the MSE. There have been multiple meetings in which the SCRS interacted with the Commission on MSE, and this included apprising the Commission of progress for the purpose of soliciting feedback. The Commission adopted conceptual management objectives for BFT in 2018 (Res. 18-03) to help guide MSE development. The MSE work is on track for ICCAT to adopt an MP in 2022, in accordance with the Commission's MSE workplan. Further discussion on the need for and rationale behind MSE is provided in **Appendix A**.

MSE Overview

Mixing of East and West stocks

The Atlantic bluefin tuna MSE framework assumes that there are two genetically distinct *stocks* (western and eastern) that migrate and mix throughout the North Atlantic. The 45°W management boundary is used to divide the East and West *management areas*, but unlike the current stock assessment, the MSE takes account of the reality that bluefin from the eastern stock migrate into the West management area, and *vice versa*. Only western fish are assumed to be found in the Gulf of Mexico, and only eastern fish are assumed to be found in the Mediterranean Sea, but stock mixing takes place in the other 5 spatial strata, with stock composition varying by calendar quarter and age class (i.e., 1-4, 5-8, and 9+ year olds). Stock movements are projected based on data from electronic tagging, as well as genetic and otolith analyses (GBYP-supported research). Importantly, conservation targets are (appropriately) by *stock*, not by *area*.

Indices of abundance

Data from 26 different indices, both fishery dependent and independent, are used to condition the MSE. The MSE's historical period is from 1965 through to 2019 (with an additional data-poor historical period of 1864-1965), and analysis of projections focuses on the next 30 years. The MSE computer code was independently reviewed in 2021, and no substantive problems were found.

Operating Models

Each operating model (OM) in the MSE represents a plausible scenario/a potential truth for the dynamics of the stocks and the fishery. The BFT MSE includes 48 main operating models (i.e., the "reference set or grid of OMs") based on four major sources of uncertainty:

1. Recruitment: the number of age 1 fish; reflects stock productivity over time (3 options)[1]
2. Spawning fraction/Natural mortality: the percent of individuals who reproduce/die of natural causes at a given age (2 options)
3. Scale: Rough abundances of fish in the West and East management areas (4 options)
4. Length composition weighting: a gauge of the confidence in the size data (2 options)

The 48 OMs allow for all combinations of these options (3x2x4x2=48). The relative plausibility of each assumption has been ranked by the SCRS according to a schema, referred to as "weighting," so that the results reflect more importance given to the more plausible OMs. The recruitment and scale options have been weighted based upon expert opinion, and the other two uncertainties are weighted equally. There are 44 additional "robustness" OMs to evaluate less likely but still possible scenarios, similar to more extreme "sensitivity runs" in a stock assessment.

Management objectives

Based in part on suggestions from the March 2019 Intersessional Meeting of Panel 2, the BFT MSE includes seven key performance statistics as an initial benchmark for evaluation of the Commission's selected management objectives (see **Appendix B**). Nine additional performance statistics are being evaluated to provide supplemental information, and full results are available elsewhere. Panel 2 input is requested to a) operationalize the management objectives (possibly in completing the probability blanks in Res. 18-03 and add timeframes) and b) provide input on the proposed performance statistics.

Candidate Management Procedures

There are currently 9 candidate management procedures (CMPs)[2] under development by 6 different international teams of scientists (Appendix C). All currently assume a 2-year management cycle and calculate a separate total allowable catch (TAC) for the West and East management areas. Some include limits on maximum or minimum TAC, or on the percent change in TAC from one management cycle to the next. Panel 2 input is solicited with regard to these specifications.

Preliminary results

We present preliminary results from anonymous CMPs selected to show key performance tradeoffs for competing management objectives. All CMPs will be refined and improved over the coming year.

Key terminology

The key terminology used in this document is compiled in **Appendix D**.

[1] The first two recruitment scenarios in the OMs mimic the still unresolved debate between the low and high recruitment scenarios for the west Atlantic bluefin assessment. For the first of these two scenarios, the western stock switches from a high to a low productivity regime in the mid-1970s, while the eastern stock switches in the opposite direction in the mid-1980s. For the second recruitment scenario, there is no regime shift for either stock (this corresponds to the high recruitment scenario for the west Atlantic bluefin assessment). The third recruitment scenario in the OMs is identical to the first historically, but sees a reversal of the earlier regime shifts in the near future. The three options are weighted 40/40/20%.

[2] While 9 CMPs are under development, not all will be deemed effective enough to be eligible candidates for MP adoption. Only 2 or 3 CMPs will be presented to the Commission for final consideration.

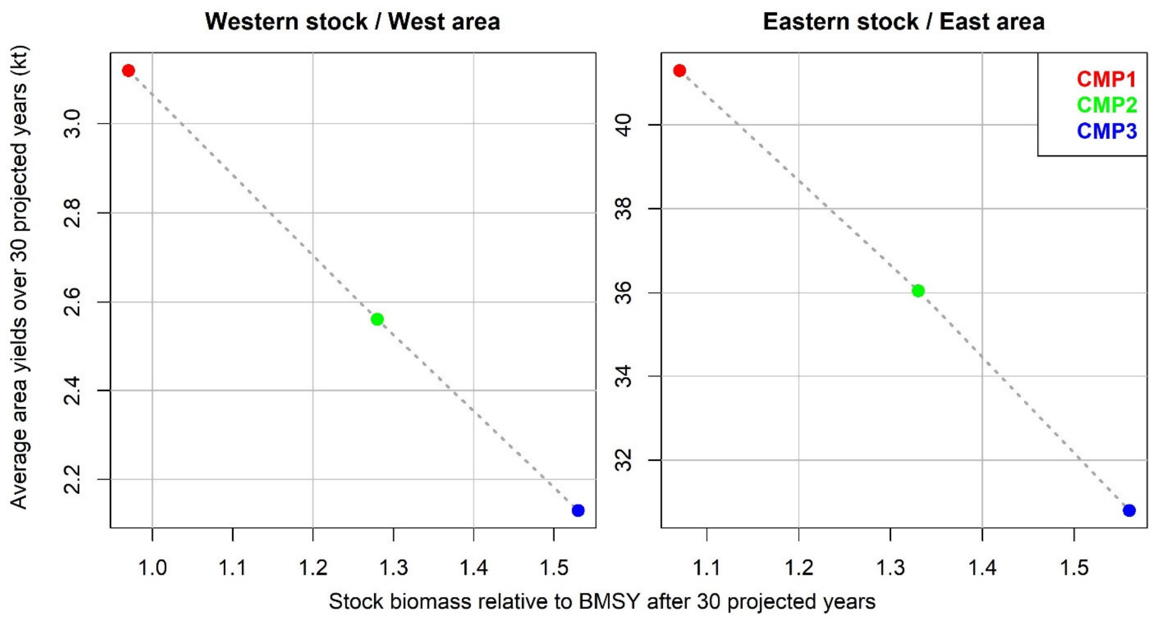

Figure 1. An example of the primary trade-off between yields (what is taken by fishing over 30 years, expressed as an annual average) and stock biomass (what remains in the resource after those 30 years) for three CMPs (CMP1 – red, CMP2 – green, CMP3 – blue). The left panel features western *stock* biomass (relative to dynamic B_{MSY}) on the horizontal axis and West *area* catch (in 1000s of tons) on the vertical axis. The right panel features eastern *stock* biomass (relative to dynamic B_{MSY}) on the horizontal axis and East *area* catch (in 1000s of tons) on the vertical axis. CMP1 has the highest catches but also the lowest eventual biomass relative to dynamic B_{MSY}. CMP3 has the lowest catches but also the highest eventual biomass relative to dynamic B_{MSY}. CMP2 has intermediate performance for both catch and biomass.

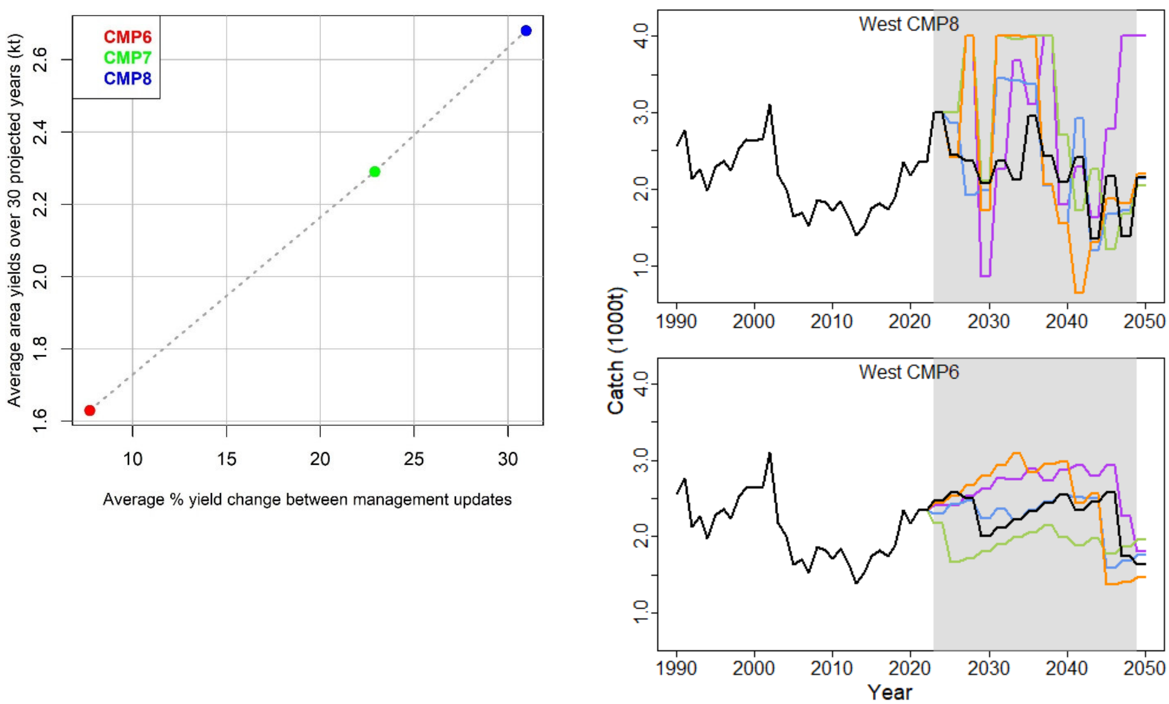

Figure 2. Performance trade-off between West area yields and yield variability. The left panel shows the tradeoff on average over the 30-year projection period across three CMPs (CMP6 – red, CMP7 – green, CMP8 – blue) with comparable biomass performance. Higher catches of CMP8 (upper right blue point) result in higher variability (>30%) whereas CMP6 (lower right red point) has lower but more stable catches (<10% average annual change in TAC). The right panel shows the time series of annual catches for CMP6 (bottom right) and CMP8 (top right) for the 30-year projection period (shaded), as well as the historical period. The four colored lines depict projections from four different possible future realities (arising mainly from differences in future recruitments) generated from one operating model to display the potential variability, with the average shown in black. The tighter cluster of runs in CMP6 illustrates the greater stability in catches compared to CMP8 with its higher average yield, demonstrating the trade-off between yield and yield variability.

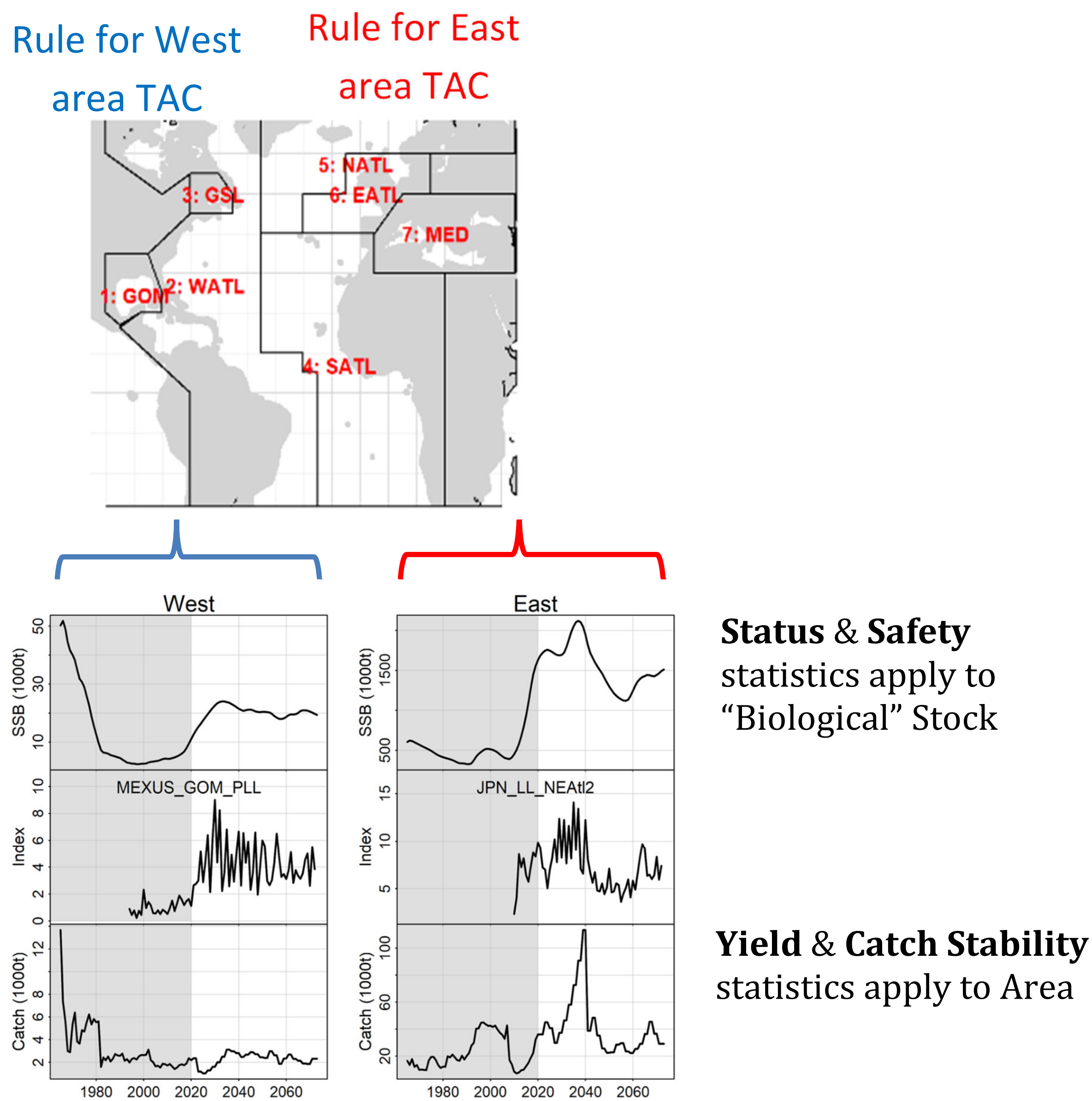

Figure 3. Illustration of how a management procedure would operate. Any CMP would consist of two catch rules, one for each area. The top panel shows the 7 geographic strata used in the MSE. Strata 1-3 are part of the western management area, and strata 4-7 are part of the eastern management area. The time series plots in the bottom panel show the historical period starting in 1965 and projections through 2073 for the West (left) and East (right). The top time series shows spawning stock biomass (SSB), the middle shows the values for one index used in the catch rule (Mexico-US Gulf of Mexico longline index for the West and Japanese longline index for the East, in this example), and the bottom shows the total allowable catch. Values are for one potential outcome from one example CMP, and based on one operating model. In essence, any increase or decrease in the SSB leads to an increase or decrease, respectively, in the abundance index, which in turn modifies the TAC to similarly increase or decrease, based on the CMP. This is why the three time-series have roughly similar, but slightly offset, trends. Note that performance statistics related to status and safety are reported by biological stock, whereas statistics related to yield magnitude and stability apply to management area.

These preliminary results illustrate how CMPs impact abundance and catch over time, as well as some of the key performance tradeoffs. As catch increases, biomass relative to dynamic B_{MSY} decreases and variability in catch increases, and *vice versa*. The goal is to use the MSE results to balance these tradeoffs, for example, by maximizing catch while also meeting minimum biomass and stability objectives.

Next steps

Several meetings are envisioned for the exchange of information among the SCRS, Panel 2/Commission, and stakeholders between now (September 2021) and the 2022 Commission meeting. The Bluefin Species Group has also appointed ambassadors to help improve understanding of the MSE and answer questions. These experts include English, French and Spanish speakers.

There is one Panel 2 meeting, as well as the annual Commission meetings, in the last quarter of 2021. Initial feedback will be requested from managers at that time on:

- Acceptable ranges in tradeoffs
  - Catch vs. biomass
  - Other trade-offs, including catch stability vs. average catch
- Refinement of operational management objectives and associated performance statistics
- CMP structure, such as TAC setting interval (proposed options: 2 years or an alternative[3]), limitations on max/min TAC and catch stability.
- Reference points, including a potential limit reference point for stock size (B_{LIM})

Other resources

Atlantic Bluefin Tuna MSE splash page, including interactive Shiny App (English only)
Harveststrategies.org MSE outreach materials (multiple languages)

[3] While a 3-year management cycle was discussed in Panel 2, the current MSE uses a 2-year management cycle because it allowed CMPs to be more reactive, thus improving CMP performance.

Appendix A

Motivation for and advantages of MSE

The move towards Management Strategy Evaluation (MSE) as the basis for managing fisheries had its origins in the "Precautionary Principle" enunciated at UNCED in Rio de Janeiro in 1992. The 1995 FAO Technical Consultation on the Precautionary Approach (PA) to Capture Fisheries, held in Lysekil, effectively endorsed the MSE approach (as developed shortly before then in Australia and in the Scientific Committee of the IWC) as the way for fisheries management to take the PA into account. Decision rules for setting catch limits needed to be adopted, where these had been shown through using simulation testing to be very likely to avoid undesirable outcomes.

A meeting of all the tuna RFMOs (i.e., Kobe III) in 2011 decided on a general move towards this approach for setting catch limits. This was reconfirmed by ICCAT for eight priority stocks, including the two stocks of Atlantic bluefin tuna, in 2015 (Rec. 15-07), both to follow the Kobe III agreement and as a way to implement ICCAT's principles of decision making practically (Rec. 11-13).

A further motivation for moving away from the conventional "best assessment" approach to setting catch limits was to be able to introduce greater stability into fisheries management decisions in the interests of the industry. The often poor precision of fisheries assessments, clearly evidenced by the differences between the 2020 and 2021 WBFT assessments, and changes made over time to attempt to improve the associated methodology, frequently leads to catch limit recommendations that can be highly variable from year to year. MSE allows this to be avoided by providing a basis that allows limits to be set on the extent of this variability without placing the resource at undue risk. MSE can also be used to evaluate - and account for - the main sources of uncertainty in both biological and fishery dynamics, as well as natural variability. Critically, in the case of Atlantic bluefin tuna, the MSE accounts for mixing between two distinct stocks, an influential complexity that the current stock assessment has been unable to address. Furthermore, time spent by scientists attempting to explain changes in models from one year to the next and in perennial negotiations over minor changes to catch limit recommendations (which will have only very limited impact on the resource) can be put to better use.

Responsible fisheries management requires an appropriate choice between maximising the catches to be achieved in the longer term, while at the same time avoiding serious risk of the stock unintentionally resulting in the stock being reduced to a dangerously low level. MSE provides the basis to quantify the trade-offs involved and make them clearly understood by decision makers. It also allows for more holistic consideration of socioeconomic objectives. Importantly, MSE provides a structured feedback approach to incorporating new index information, with the progress of time.

Appendix B

Management objectives (from Res. 18-03), 2019 guidance from Panel 2 on how to operationalize the management objectives and the proposed corresponding performance statistics.

Management Objectives (Res. 18-03)	**Guidance from PA2 (2019)**	**Corresponding Performance Statistics**
The stock should have a greater than [__]% probability of occurring in the green quadrant of the Kobe matrix	"There should be a 60% or greater probability of being in the green zone of the Kobe plot. The SCRS will present results of the simulation in plots with a trajectory so that managers can evaluate the status of the stock (F relative to F_{MSY} and B relative to B_{MSY}) at intermediate points between zero and 30 years, and at the end of the 30-year period."	**AvgBr** – Average Br [i.e., biomass ratio, or spawning stock biomass (SSB) relative to dynamic SSB_{MSY}[1]] over projection years 11-30 **Br30** – Br after 30 years **OFT** – Overfished Trend, SSB trend if Br30<1.
There should be a less than [__]% probability of the stock falling below B_{LIM} (to be defined)	"There should be no more than a 15% chance of the stock falling below B_{LIM} at any point during the 30 year evaluation period. A definition of B_{LIM} should be recommended by SCRS."	**LD** – Lowest depletion (i.e., SSB relative to dynamic SSB_0[2]) over 30-year projection period
Maximize overall catch levels	"Evaluate outcomes related to maximizing mean catch levels with respect to each management area over the short, medium, and long-term."	**AvC10** – Median catches (t) over first 10 years **AvC30** – Median catches (t) over 30 years
Any increase or decrease in TAC between management periods should be less than [__]%	"Evaluate outcomes of 20%, 30%, and 40% as well as no limitation on the change in TAC between management periods."	**AAVC** – Average annual variation in catches (%) between management cycles

[1]Dynamic SSB_{MSY} is a set fraction of dynamic SSB_0 (see below).
[2]Dynamic SSB_0 is the spawning stock biomass that would occur in the absence of fishing, historically and in the future. The value can change over time since it is based on current recruitment levels, which typically fluctuate.

Appendix C

Table of candidate management procedures

CMP	Indices used		Formulae for calculating TACs	References
	EAST	WEST		
FZ	FR AER SUV2 JPN LL NEAtl2 W-MED LAR SUV	US RR 66-144, CAN SWNS RR US-MEX GOM PLL	TACs are a product of stock-specific F0.1 estimates and an estimate of US-MEX GOM PLL for the West and W-MED LAR SUV for the East.	SCRS/2020/144 SCRS/2021/122
AI	All	All	Artificial intelligence MP that uses an artificial neural network to estimate regional biomass and then fishes at a fixed harvest rate.	SCRS/2021/028
BR	FR AER SUV2 W-MED LAR SUV MOR POR TRAP JPN LL NEAtl2	GOM LAR SUV US RR 66-144 US-MEX GOM PLL JPN LL West2 CAN SWNS RR	TACs set using a relative harvest rate for a reference year (2018) applied to the 2-year moving average of a combined master abundance index.	SCRS/2021/121 SCRS/2021/152
EA	FR AER SUV2 W-MED LAR SUV MOR POR TRAP JPN LL NEAtl2	GOM LAR SUV JPN LL West2 US RR 66-144 US-MEX GOM PLL	Adjust TAC based on ratio of current and target abundance index.	SCRS/2021/032 SCRS/2021/P/046
LW	W-MED LAR SUV	GOM LAR SUV	TAC is adjusted based on comparing current relative harvest rate to the reference period (2019) relative harvest rate.	SCRS/2020/127
NC	MOR POR TRAP	US-MEX GOM PLL	TAC is updated using an average of an index in the recent years compared to and average in previous years. The scale of TAC increase/decrease is controlled based on the trend in catches and indices	SCRS/2021/122
PW	JPN LL NEAtl2	US-MEX GOM PLL	TAC is adjusted based on comparing current relative harvest rate to the reference period (2019) relative harvest rate.	SCRS/2021/155
TC	MOR POR TRAP JPN LL NEAtl2 W-MED LAR SUV GBYP AER SUV BAR	US RR 66-144	A constant rate of eastern migration into the west is assumed and regional indices are calibrated to estimated regional biomass. The TAC is calculated as a fixed harvest rate of the estimated regional biomass.	SCRS/2020/150 SCRS/2020/165
TN	JPN LL NEAtl2	US RR 66-144 JPN LL West2	Both area TACs calculated based on their respective JPN_LL moving averages, unless drastic drop of recruitment is detected by US_RR index.	SCRS/2020/151 SCRS/2021/041

East indices: FR AER SUV2 – French aerial survey in the Mediterranean; JPN LL NEAtl2 – Japanese longline index in the Northeast Atlantic; W-MED LAR SUV – Larval survey in the western Mediterranean; MOR POR Trap – Moroccan-Portuguese trap index; GBYP AER SUV BAR – GBYP aerial survey in the Balearics.
West indices: US RR 66-144 – U.S. recreational rod & reel index for fish 66-144 cm; CAN SWNS RR – Canadian South West Nova Scotia handline index; US-MEX GOM PLL – U.S. & Mexico combined longline index for the Gulf of Mexico; GOM LAR SUV – U.S. larval survey in the Gulf of Mexico; JPN LL West2 - Japanese longline index for the West Atlantic.

Appendix D

Key terminology used in this document

Limit reference point (LRP): A benchmark for an indicator that defines an undesirable biological state of the stock such as the B_{lim} or the biomass limit which is undesirable to be below. To keep the stock safe, the probability of violating an LRP should be very low.

Management objectives: Formally adopted social, economic, biological, ecosystem, and political (or other) goals for a stock and fishery. They include high-level or conceptual objectives often expressed in legislation, conventions or similar documents. They must also include operational objectives that are specific and measurable, with associated timelines. When management objectives are referenced in the context of management procedures, the latter, more specific definition applies, but sometimes conceptual objectives are adopted first (e.g., Rec. 18-03 for ABFT).

Management procedure (MP): Some combination of monitoring, assessment, harvest control rule and management action designed to meet the stated objectives of a fishery, and which has been simulation tested for performance and adequate robustness to uncertainties. Also known as a harvest strategy.

Management strategy evaluation (MSE): A simulation-based, analytical framework used to evaluate the performance of multiple management procedures relative to the pre-specified management objectives.

Operating model (OM): A model representing a plausible scenario for stock and fishery dynamics that is used to simulation test the management performance of CMPs. Multiple models will usually be considered to reflect the uncertainties about the dynamics of the resource and fishery, thereby testing the robustness of management procedures.

Performance statistic: A quantitative expression of a management objective used to evaluate how well an objective is being achieved by determining the proximity of the current value of the statistic to the objective. Also known as a performance metric or performance indicator.

Reference Grid: The operating models that represent the most important uncertainties in stock and fishing dynamics, which are used as the principal basis for evaluating CMP performance. The reference operating models are specified according to factors (e.g., natural mortality rate) that have multiple levels (possible scenarios for each factor, e.g., high / low natural mortality rate). Reference operating models are organized in a usually fully crossed orthogonal ‘grid’ of all factors and levels.

Robustness Set: Other potentially important uncertainties in stock and fishing dynamics may be included in a Robustness Set of operating models that provide additional tests of CMP performance robustness. They can be used to further discriminate between CMPs. Compared to the Reference Grid operating models, the Robustness Set models will be typically less plausible and/or influential on performance.