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Specifications of the IOTC Bigeye Tuna Management Procedure

IOTC Working Party on Methods

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Executive summary

The Indian Ocean Tuna Commission (IOTC) adopted a Management Procedure (MP) in 2022 to recommend the total allowable catch (TAC) for bigeye tuna in the Indian Ocean (Resolution 22/03). The bigeye MP is the first fully-specified MP to be adopted in the IOTC. This paper provides a full technical and non-technical specification of the MP, including the specifications of the data required and a description of the estimation model, the process for calculating the TAC from applying the harvest control rule, the annual evaluation of exceptional circumstances, and the implementation schedule for running the MP and setting TAC. The role of the stock assessment is distinct from the MP and will be offset in the workplan of the Commission.

1 Introduction

The IOTC, at its 15th Session in 2011, endorsed the development of a management strategy evaluation (MSE) process for the development of MPs. In addition, Kobe III, a joint meeting of all tuna RFMOs in 2011, recognised that an MSE process needs to be widely implemented in tuna RFMOs to support a precautionary approach for tuna fisheries management. In 2016, the IOTC established the Technical Committee on Management Procedures (TCMP) specifically to "*enhance the decision-making response of the Commission in relation to management procedures*".

The MSE process and development of an MP for bigeye tuna commenced 2014. A set of population dynamics models (operating models) that encapsulate the range of plausible stock and fishery dynamics have been developed. The operating models (OMs) were used for simulation testing of a wide variety of candidate MPs. A set of robustness tests were developed to assess how candidate MPs would respond to more extreme or unusual but plausible scenarios. From this MSE process a single MP was selected and adopted by the Commission in 2022 (Resolution 22/03).

The BET MP will be used from 2022 to set the TAC for bigeye tuna in the Indian Ocean Tuna Commission Area of Competence. Previously, there was no TAC for bigeye tuna, and scientific advice was provided to the Commission based on projections (Kobe II Strategy matrix) from periodic stock assessments. These projections are limited because they do not include uncertainty propagated through the MSE operating models or the management-assessment feedback loop that captures the fishery response to management changes. Furthermore, scientific advice provided is not definitive and provides the opportunity for negotiations and changes to be made at the Commission level. The adoption of an MP for bigeye tuna (Resolution 22/03) resolves these issues by having a single pre-agreed rule for setting the TAC that is robust to a range of uncertainties and is not subject to negotiation or changes.

The bigeye tuna MP is the first fully-specified MP to be adopted in the IOTC. Technical details of the bigeye tuna MP, together with specifications of the data input to the MP, the exceptional circumstances process that the Commission has adopted, and the implementation schedule, are provided in the following sections of this document.

2 Distinction between stock assessment and MP

Assessment of stock status

The updated role of the bigeye tuna stock assessment in providing scientific advice to the IOTC consists of an important but distinct process to the MP. Now that bigeye tuna MP has been adopted, the stock assessment is no longer used to provide TAC advice. The stock assessment now provides information on bigeye tuna stock status, which can also be used to evaluate the performance of the MP.

The IOTC Scientific Committee (SC) completes a "full stock assessment" every three years, offset from the year for running the MP. The stock assessment provides information on the current stock size relative to the management objective (i.e. 60% probability of being in the green zone of Kobe plot) and fishing mortality relative to commonly used reference points. Following the implementation of the MP, the stock assessment is not used to:

- Run the MP
- Provide management advice
- Recommend the TAC

Running the MP for TAC advice

The MP is used to calculate the TAC which is recommended by the SC to the Commission for decision. The bigeye tuna MP uses a standardised CPUE series and total reported catch as input data, a defined estimation model, and harvest control rule to recommend the TAC. The MP is fully specified (as originally tested in the MSE process) and is used as specified following selection by the Commission. The estimated values in the MP are internally consistent and are not intended to align with those from the stock assessment (Kolody & Jumppanen 2016), and therefore should not be directly compared.

The running of the MP is independent of the bigeye tuna stock assessment. The MP is not used to:

- Estimate the spawning stock biomass or depletion
- Estimate stock status relative to reference points

3 Non-Technical Summary of the Bigeye Tuna Management Procedure

The IOTC bigeye tuna MP is a model-based MP, which uses only catch and CPUE as input data (see details below). The MP fits a simple biomass dynamics model to determine an estimate of stock

depletion, which is then used in a hockey stick-shaped harvest control rule (HCR) to calculate the TAC for the next 3-year cycle[1] (see details below).

The MSE process allowed for the MP to be 'tuned' to reach the Commission's performance objective, given the large reference set of operating models that incorporated alternative potential states of the stock and dynamics. The MP has been 'tuned' to achieve a 60% probability that bigeye tuna is in the green zone of the Kobe plot (i.e. spawning stock biomass > B_{MSY} and fishing mortality < F_{MSY}) by 2034-2038, and a high probability that the bigeye spawning stock biomass is greater than the interim limit reference point specified in Resolution 15/10 (i.e. $0.4B_{MSY}$). The MP has a limit on the maximum change to the TAC of 15% of the previous TAC. The MP calculates a TAC for the entire IOTC Area of Competence.

4 Specification of the estimation model and HCR used in the MP

The bigeye tuna MP has two data inputs: total catch biomass and spatially aggregated longline CPUE from 1979 to the most recent year of catch data (see below for details). It then fits a Pella-Tomlinson biomass dynamic model (estimation model) to the CPUE data given the catch biomass. As noted above, this model is far simpler, with fewer data sources, than a full stock assessment and the estimates from the MP and the stock assessment will be different and should not be compared.

The Pella-Tomlinson biomass dynamic model consists of:

$$B_{y+1} = B_y + \left(\frac{p+1}{p}\right) r B_y \left(1 - \left(\frac{B_y}{K}\right)^p\right) - C_y$$

where B_y is aggregate biomass in year y, C_y is the total catch in mass in year y, r and K are the estimated population growth rate and carrying capacity, and p is the equilibrium yield "shape" parameter. CPUE and biomass are modelled as random effects and other parameters as fixed effects. The model is fit using Template Model Builder (TMB) and uses maximum likelihood estimation to minimise the objective function:

$$\sum_y (\hat{I}_y - I_y)$$

[1] The Commission agreed to set a 2-year TAC (2024 and 2025) when running the MP for the first time in 2022 to ensure the next time the MP is run, it does not coincide with the year in which the stock assessment is conducted.

Where I_y is the aggregate annual CPUE index in year y, and

$$\hat{I}_y = \frac{\sum_y I_y}{\sum_y B_y} B_y$$

MSY is then calculated as:

$$MSY = \frac{rK}{(p+1)^{p^{-1}}}$$

The key variables used in the harvest control rule (HCR) are the ratio of fishing mortality to the value which produces MSY (F_{MSY} ratio) calculated as -log(1-MSY/K) and relative biomass or depletion in most recent year y, calculated as B_y/K.

The HCR is a simple hockey stick type rule: for biomass depletion above 0.4 the HCR multiplier (HCR_{mult}) is 1, it decreases linearly to (almost) zero for biomass depletion below 0.4, and is fixed at a very low 0.0001 for biomass depletion below 0.1. The overall fishing mortality used to estimate the TAC is calculated as follows: F_{MSY} ratio x HCR_{mult} x tuning parameter (F_{mult}). This fishing mortality is used in conjunction with the estimated biomass B_y to calculate the new TAC. A symmetric maximum change of 15% is then applied to calculate the actual recommended TAC. F_{mult} is the fixed parameter (3.718) derived from tuning the MP (during the MSE process) to achieve the Commission's objection of achieving a 60% probability of being in the green zone of the Kobe plot by 2034-2038. The main suite of equations that define the HCR are as follows:

$$HCR_{mult} = 1 \; if \; \frac{B_y}{K} \geq 0.4$$

$$HCR_{mult} = \frac{\frac{B_y}{K} - 0.1}{0.3} \; if \; 0.1 < \frac{B_y}{K} < 0.4$$

$$HCR_{mult} = 0.0001 \; if \; \frac{B_y}{K} \leq 0.1$$

$$TAC_{new} = B_y(1 - exp(-F_{mult} \times HCR_{mult} \times F_{MSY} \; ratio))$$

All the code required to run the Pella Tomlinson estimation model and the MP are located on a public GitHub repository (Jumppanen & Kolody 2022).

5 Specification of Catch Data for the MP

The catch dataset to be used in the MP is the nominal catches reported to the IOTC Secretariat by Contracting Parties and Cooperating Non-Contracting Parties (CPCs) as per the IOTC Conservation and Management Measures (CMMs) and following the standards and formats defined in the IOTC

Reporting guidelines. These data are reviewed, consolidated and reported annually by the IOTC Secretariat (https://iotc.org/data/datasets).

The dataset to be used in the MP includes annual catches, in weight, aggregated across fleets, gears, and IOTC areas from 1979 to the most recent year of data available.

6 Specification of Standardised CPUE for the MP

The CPUE standardisation process for bigeye tuna are described in detail in a series of reports to the IOTC working parties (see Hoyle et al. 2015, 2016, 2018, 2019, Kitakado et al. 2021, 2022), and for brevity are not repeated in detail here. Instead, the salient aspects of the CPUE standardisation process relevant to the application of the bigeye tuna MP are described below.

Data to be used in CPUE standardisation

The CPUE dataset to be used in the MP is the aggregated longline catch and effort data provided by Japan, Korea, and Taiwan,China for the years 1979 to present. These data are collated under a data sharing protocol among the three countries and consist of aggregated data at the 1° cell level by month and by vessel. CPUE is defined as catch in number divided by the number of hooks set. Other data fields available for the CPUE analysis include vessel identifier, number of hooks, hooks between floats, cluster (based on species composition data) and catch in numbers. For the CPUE standardisation, data were stratified by the 4-region structure used in the 2019 bigeye tuna stock assessment (Figure 1).

CPUE standardisation

Generalised linear models (GLMs) are used to standardise the CPUE data for input to the bigeye tuna MP. Due to some zero catches in the data from the temperate region, two different approaches are used to model the CPUE data, depending on the region. For the tropical regions (R1N, R1S and R2), a lognormal constant analysis is used. For the temperate region, a delta lognormal analysis is used.

For the lognormal constant analysis, which assumes a lognormal distribution, the response variable was log($CPUE$ + c), and a Normal distribution was assumed. The constant c was 10% of the overall mean CPUE across all sets. The form of the GLM was:

$$log(CPUE + c) = yr + qtr + yr * qtr + vessid + cell5 + cell5 * qtr + cluster + \epsilon$$

where,

yr	is the Year
qtr	is the Quarter
vessid	is the Vessel identifier
cell5	is the 5x5° grid cell
cluster	is the hooks between floats

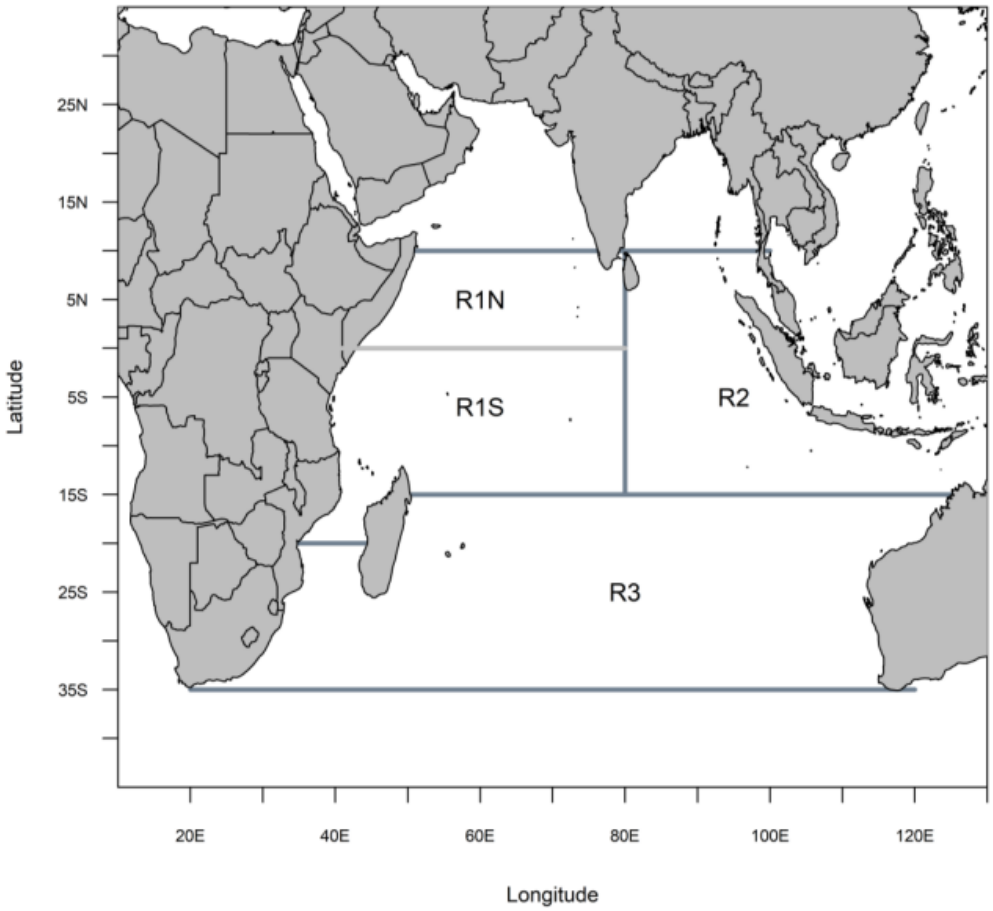

Figure 1. Spatial stratification of the Indian Ocean into the 4 regions used for the Bigeye tuna CPUE standardisation (source: Fu 2019).

For the delta lognormal analyses (for region 3), the first component used a binominal distribution to model the probability (*w*) of zero (i.e. non-positive) CPUE, while the second component used a probability distribution *f*(*y*), with *y* being log(catch per hooks set), to model non-zero (i.e. positive) CPUE. The CPUE index estimated for each year-quarter was the product of the year effects from the two model components, (1 – *w*). *E*(*y*|*y* ≠ 0).

$$\Pr(Y = y) = \begin{cases} w, & y = 0 \\ (1 - w) f(y) & otherwise \end{cases}$$

$$g(w) = (CPUE = 0) \sim covariates + \epsilon \qquad \text{where } g \text{ is the logistic function.}$$

$$f(y) = (CPUE = 0) \sim covariates + \epsilon \qquad \text{for non-zero sets}$$

where the covariates were the same as those used in the lognormal constant analyses, with the addition of a covariate for the logarithm of the number hooks in the delta model (zero CPUE model).

A standardised year-quarter CPUE series was then predicted for each of the 4 regions using least square means and fixing all variables (other than year-quarter) at either the median for continuous variables, or the mode for categorical variables. For regions R1N, R1S and R2, the results were normalised and represented as relative CPUE with mean of 1. For the temperate region R3, where there are strong seasonal trends in CPUE, 4 seasonal CPUE series were first independently normalised, before aggregating to a single year-quarter CPUE series.

CPUE Series used as input to the Management Procedure

A single aggregate CPUE index is used as the input data to the bigeye tuna MP. The aggregate CPUE series is a weighted combination of the 4 region-specific, year-quarter CPUE series described above. The weighting takes account of the different areas of each region. The weighting factors for each region are fixed and are derived using the analysis by Hoyle & Langley (2020) for the period 1979 – 1994 (R1N=0.626, R1S=0.799, R2=1, R3=0.859). The area weighted CPUE series is then renormalised to a value of 1 to provide a single aggregate CPUE index for input into the MP.

7 Exceptional circumstances guidelines for the MP

When implementing a Management Procedure (MP), a set of checks are essential to ensure that unexpected events do not result in MP advice that is risky for the stock and/or fisheries. These checks are part of the guidelines that provide a structure for providing and reviewing management advice when there are concerns about implementing an MP. The guidelines provide a scientific process for developing appropriate management responses to exceptional circumstances and, hence, provide transparency and confidence in TAC decision making by the Commission (Appendix 6a in IOTC 2021).

Exceptional circumstances are defined in the IOTC as "… circumstances (primarily related to future monitoring data falling outside the range covered by Management Strategy Evaluation (MSE) simulation testing) where overriding of the output from a Management Procedure should be considered…". Exceptional circumstance can include:

- New knowledge about the stock, population dynamics or biology
- Changes in fisheries or fishing operations
- Changes to input data to the MP, or missing data, or
- Inconsistent implementation of the MP advice (e.g. total catch is greater than the TAC).

Responses to exceptional circumstances can include review of additional information or new research, review of the performance of the MP (via reconditioned Operating Models), or management advice to precautionarily revise the TAC. These guidelines provide broad principles to govern the research or management actions to take in the event of exceptional circumstances.

The process has three stages: 1) determine whether any exceptional circumstances exist, 2) determine the severity and impact of the exceptional circumstances on achieving the objectives of

the MP, and 3) if necessary, identify the research or management actions that should be taken by the IOTC.

Stage 1: The IOTC SC will annually review the following items for evidence of exceptional circumstances:

- Information on the stock, fishing operations, population dynamics parameters, or biology that is outside the range (90% probability interval from MSE projections – or % to be decided by the SC) included in the MSE of the adopted MP.
- Input data to the MP that are missing, have changed, or are outside the range (90% – or % to be decided by the SC) simulated in the MSE.
- Implementation of the MP that is inconsistent with the MP advice (e.g. total catch is greater or consistently lower than the TAC recommended by the MP).

Stage 2: If there is evidence of exceptional circumstances the SC will review the potential impact and severity on implementation and performance of the MP.

Stage 3: Depending on the impact of the exceptional circumstance, the SC will provide advice on the action required, such as a collection of ancillary data to be reviewed, review of the MP and, if necessary, provide updated management advice (e.g. TAC advice). As a guide, the SC could consider the following:

If there is a very high potential impact the SC will consider TAC changes. TAC change can be determined by an x% change to the TAC, where the x% is based on an urgently updated assessment and projections, and is consistent with meeting the objectives of the MP.

8 MP implementation schedule

The Commission adopted an implementation schedule as part of the MP (Table 1). The MP will be run in 2022 to recommend the TAC, which is considered by the Commission in 2023 and applied for 2024-2025. This aim of setting the TAC for only 2 years, in the first instance, is to create an offset in the future workplan between running the MP for TAC advice and running the stock assessment for stock status advice. The MP will next be run in 2024 to recommend the TAC for 2026-2028, and then every 3 years. A stock assessment will occur in 2022 and then every 3 years (e.g., next in 2025). The review of exceptional circumstances is an annual process. The Commission has agreed to a review of MP performance in 2030, which is when the performance of the implemented MP relative to the objectives of the Commission should be measured via the stock assessment.

Table 1. Schedule for MP implementation, adapted from Annex II of Resolution 22/03

IOTC COMMITTEE	2022	2023	2024	2025	2026	2027	2028	2029
Commission (May/June)	**Select and adopt BET MP**	Annual Review of SC advice →						
		Set TAC (2024-2025)		**Set TAC** (2026-2028)			**Set TAC** (2029-2031)	
WPTT and WPM (Oct)	Collate catch data and CPUE series used in MP		Collate data used in MP			Collate data used in MP		
	Consider exceptional circumstances (EC), advise SC		Consider EC			Consider EC		
SC (Dec)	**Run MP**		**Run MP**			**Run MP**		
	Assess stock status			Assess stock status			Assess stock status	
	Annual Review of Exceptional Circumstances →							
	Provide TAC advice to the Commission		Provide TAC advice			Provide TAC advice		

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