# State of the IOTC Bigeye Operating Models for Management Procedure evaluation Sep 2019

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## Introduction

This document provides a brief description of the most recent state of the bigeye tuna Operating Models (OMs) used for Management Procedure (MP) evaluation, including the reference set *OMrefB19.6,* and various robustness tests. The documentation for the latest version of the MSE software, technical documentation, and series of project reports is publicly available from github <https://github.com/pjumppanen/niMSE-IO-BET-YFT/>. The iterative and sometimes circuitous decision process undertaken by the IOTC technical working groups and analysts to reach the current state of the OM are not described here. These may be found in various IOTC working papers, information papers and meeting reports, along with various model results and diagnostics that were used to guide the OM development process.

*OMrefB19.6* was proposed by the MSE task force in March 2019, and provided the basis for the MP evaluations presented to the TCMP in May 2019. A couple of minor specification errors were subsequently identified and corrected (with negligible implications for the MP evaluation results). The definition and role of the robustness tests is continuously evolving and not described here.

## Conditioning Software

This version of the OM is an ensemble of models conditioned using the *Stock Synthesis* assessment software version SS3.24z.exe (e.g. Methot and Wetzel 2013).

## Projection Software

The projection software is available from <https://github.com/pjumppanen/niMSE-IO-BET-YFT/>. The population dynamics equations conform to fairly standard assumptions, and are fully documented in the technical reference (also on github).

## Reference Set OM

The various models in the OM ensemble are derived from the reference case stock assessment defined from the 2016 assessment (Langley 2016), except that the temperate seasonal CPUE series were aggregated into a single series (each weighted by their respective series means). Key structural assumptions include:

* 4 regions (Figure 1) with age-dependent movement
* Quarterly dynamics (implemented with calendar quarters as SS model-years)
* 15 fisheries (Table 1)
* Beverton-Holt recruitment dynamics
* Parameter estimation objective function includes
  + Standardized longline CPUE. Region 1A and 1B share one series and R2 has one series. In the assessment, R3 was split into 4 seasonal series with independent catchability – in the OM these series were aggregated into one series with each season independently re-normalized.
  + Size composition data
  + Tags (excluded in some OM scenarios)
  + Recruitment penalties on deviations from stock recruit relationship and mean spatial distribution
  + Diffuse priors on all estimated parameters
* Estimated parameters:
  + Fishery selectivity (stationary, various functional forms, parameters shared among some fleets)
  + Longline catchability - regional scaling factors are used to scale relative density to relative abundance among regions, such that 1A, 1B, 2 share catchability and catchabilities are estimated independently for the 4 seasonal fisheries in region 3
  + Virgin recruitment
  + Recruitment deviations from the Beverton-Holt stock-recruit relationship, recruitment spatial partitioning among tropical regions (1 and 2). There are no spatial deviations over time.
  + Juvenile and adult movement rates
  + Initial fishing mortality

## OM Reference Set Grid

* Model structural and parameter uncertainty is introduced to the OM through the alternative assumptions listed in Table 2.
* Only the point estimates for parameters and states from each model specification (maximum posterior density) are retained for the OM.
* A fractional-factorial experimental design was used to evaluate a subset of 144 models, which would allow the estimation of all main effects in the context of a GLM (the full factorial grid with all interactions would require 576 models).
* In recognition that the IOTC bigeye assessment model parameter estimates can be sensitive to initial starting conditions, minimization was repeated from randomly jittered starting conditions until either (i) successful minimization was achieved 3 times (maximum gradient of the objective function with respect to the estimated parameters <0.01) or (ii) 10 attempts at minimization were completed.

## OM Reference Set *OMrefB19.6*

* Within an individual model configuration, the version with the lowest objective function value (from the jittered minimizations) were retained (initially). The best fit models were subsequently rejected from the reference grid if:
  + Minimization unsuccessful (max. grad. >0.01)
  + SS3 Catch Penalty >1E-5 (i.e. model struggles to remove the observed catch, which is assumed to be related to the pessimistic retrospective patterns)
* All retained models were subject to a qualitative comparison of simple diagnostics to identify outlier behaviour or polymodal stock status inferences (no obvious problems were noted). The four most extreme models (highest and lowest depletion and productivity) were visually examined in more detail, without obvious evidence for blatant model failure.
* The OM reference set grid is fully balanced with respect to each factor, while the retained grid has 94 of the original models, with the factor level distribution shown in Table 4. Rejected models were notably associated with option M06 (and to a lesser extent iH and q1).
* Each SS model is assigned a plausibility weighting. To date, models have only been assigned a weighting of 0 or 1, such that all retained models are uniformly weighted. *OMrefB19.6* consists of 500 models randomly sampled (with replacement) from the grid of retained models.
* Key projection assumptions are summarized in Table 4.

## References

Langley, A. 2016. Stock assessment of bigeye tuna in the Indian Ocean for 2016 — model development and evaluation. IOTC-2016-WPTT18-20.

Methot, R.D., Wetzel, C.R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research 142 (2013)* 86–99.

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Figure 1. Spatial structure for the bigeye tuna OM (figure from Langley 2016).

Table 1. Fishery definitions in the BET 2016 assessment (ordered as in the model control files, not the stock assessment report).

|  |  |
| --- | --- |
| Fishery | Definition |
| FL2 | Fresh Tuna Longline Region 2 |
| LL1 | Longline R1S |
| LL2 | Longline R2 |
| LL3 | Longline R3 |
| PSFS1 | Purse Seine Free-school R1S |
| PSFS2 | Purse Seine Free-school R2 |
| OT1 | Other R1 (include gillnet, trolling and other minor artisanal gears) |
| OT2 | Other R2 (include gillnet, trolling and other minor artisanal gears) |
| PSLS1 | Purse Seine Log set R1S |
| PSLS2 | Purse Seine Log set R2 |
| BB1 | Bait Boat R1S |
| LINE2 | Includes small scale fisheries using handlines, small longlines and the gillnet/longline combination fishery of Sri Lanka. |
| LL4 | Longline R1N |
| PSFS4 | Purse Seine Free-school R1N |
| PSLS4 | Purse Seine Log set R1N |

Table . Assumptions in OMrefB19.6 Stock Synthesis conditioning. Bold indicates the reference case assumption from the Langley (2016) assessment.

|  |  |
| --- | --- |
| Abbreviation | Definition |
| h70  h80  h90 | Stock-recruit function (*h* = steepness)  Beverton-Holt, *h* = 0.7  **Beverton-Holt, *h* = 0.8**  Beverton-Holt, *h* = 0.9 |
| M10  M08  M06 | Natural mortality multiplier relative to reference case M vector  **1.0**  0.8  0.6 |
| t0001  t10 | Tag recapture data weighting (tag composition and negative binomial)  λ = 0.001  **λ = 1.0** |
| q0  q1 | Assumed longline CPUE catchability trend (compounded)  **0% per annum**  1% per annum |
| iH  iC | Tropical longline CPUE standardization method  **Hooks Between Floats**  Cluster analysis |
| iR1  iR2 | longline CPUE Regional-scaling factors  **reference case**  alternate |
| SL  SD | Longline fishery selectivity  **Stationary, logistic, shared among areas**  Stationary, double-normal (potentially dome-shaped), shared among areas |
| ESS10  CLRW | Size composition input Effective Sample Sizes (ESS)  **ESS = 10, all fisheries**  ESS = One iteration of re-weighting from reference case model, capped at 100. |

Table . Frequencies of reference set grid assumptions retained after convergence and plausibility criteria are applied. If all models were retained, each assumption would be equally represented (i.e. either 0.33 or 0.5, depending on the number of assumption levels). Assumption abbreviations are defined in Table 2.

|  |  |  |
| --- | --- | --- |
| Model Assumption  (proportion represented in OMrefB19.6) | | |
| h70  0.30 | h80  0.37 | h90  0.33 |
| M06  0.20 | M08  0.37 | M10  0.43 |
| t0001  0.41 | t10  0.59 |  |
| iC  0.62 | iH  0.38 |  |
| iR1  0.47 | iR2  0.53 |  |
| q0  0.63 | q1  0.37 |  |
| CLRW  0.41 | ESS10  0.59 |  |
| SD  0.49 | SL  0.51 |  |

Table 4. OM Projection assumptions in the bigeye reference set and robustness sets. Reference set values not listed are identical to the model-specific conditioning assumptions/estimates. Robustness case values are identical to the reference set except as noted.

|  |  |  |
| --- | --- | --- |
| OM | Projection assumption | Value |
| OMrefB19.6 | Reference set OM |  |
|  | Initial population error CV  (a = age in quarters) | 0.6exp(-0.1a) |
|  | Recruitment deviation penalty  Recruitment deviation lag(1) auto-correlation  quarterly (annual equivalents) | *σR* = 0.6 (0.42)\*  *ρR* = 0.5 (0.21)\* |
|  | CPUE observation error  CPUE observation error lag(1) auto-correlation  (annual) | *σR* = 0.2  *ρR* = 0.5 |
|  | Multinomial Catch-at-length sample size  (all fisheries) | 100 |
|  | Selectivity stationary for all fisheries |  |
|  | Quota Implementation error | CV = 0 |
|  | First MP quota year | 2021 |
|  | Assumed catches 2016, 2017-2020 | 87, 91 Kt |
|  | MP data lag  (i.e. data from 2018 informs 2021 quota) | 2 years\*\* |
|  | Quota allocation (average observed over) | 2014-2015 |
|  | Number of stochastic realizations | 500 |
| OMrobB19.6.iCV3 | elevated CPUE error in projections (conditioning as OMrefB19.6) | *σR* = 0.3  *ρR* = 0.5 |
| OMrobB19.6.10overRep | 10% overcatch for all fleets (catch is accurately reported) (conditioning as OMrefB19.6) |  |
| OMrobB19.6.10overIUU | 10% unreported overcatch for all fleets (conditioning as OMrefB19.6) |  |
| OMrobB19.6.qTrend3 | CPUE catchability trend of 3% per year in projections (conditioning as OMrefB19.6) |  |

\* Due to a change in parameterization between quarterly and annual units, results presented to TCMP 2019 erroneously overstated the intended recruitment projection CV with (annualized) *σR* = 0.6, *ρR* = 0.5.

\*\*Results presented to TCMP 2019 erroneously had a 3 year data lag.