Project description for Skipjack Management Procedure Evaluation

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Background and Motivation

Since 2013, the Maldives has been working with the IOTC to undertake a Management Procedure Evaluation (MPE) for the Indian Ocean Skipjack (SKJ) fishery, to partially fulfil conditions of the Marine Stewardship Council (MSC) for certification for the domestic pole and line fishery (Adam et al., 2013). Bentley & Adam (2014a, 2014b, 2015) developed an operating model, evaluation methods, performance statistics and alternative Harvest Control Rule (HCR) structures to be tested through simulation. These were reviewed and endorsed by the Working Party on Tropical Tunas (WPTT), Working Party on Methods (WPM), and the Scientific Committee (SC). Based upon the simulation trials subsequently implemented by Bentley & Adam (2016), the Commission adopted Resolution 16/02 "On Harvest Control Rules for Skipjack in the IOTC Area of Competence." This specified the HCR and stated that its first implementation would be based upon the 2017 SKJ stock assessment agreed by the WPTT and then endorsed by SC. The Resolution also requested a further review and possible modification of the HCR to be conducted after it had been applied, and no later than 2021. This request forms the basis for the current work.

The stock assessment

The 2017 stock assessment for SKJ tuna (IOTC-WPTT19, 2017a) built on work by Kolody (2011) and Sharma et al. (2012, 2014) and was implemented in SS3.24z. It was considered the best representation of the stock dynamics, in preference to a cohort-aggregated biomass dynamic model that had been developed in parallel (Li et al., 2017). The WPTT agreed that a final grid of model runs from the SS3 stock assessment would be used for the development of management advice for the Scientific Committee's consideration (IOTC-WPTT19, 2017b). This included application of the HCR to the outputs of the assessment grid.

Representing the assessment as a collection of alternative runs, each with slightly different assumptions but assumed to have equal validity, elevates our consideration of structural model uncertainty, which is usually much greater than the statistical uncertainty conditional on any individual model (Kolody et al. 2011). Model runs are not orthogonal. Instead a reference model is used as a starting point, with each alternative taken to be a deviation from it. Derived outputs from the assessment are taken to be median values across those estimated by the different alternatives. The stock assessment process detailed in IOTC–2017–WPTT19 (2017a) therefore consists of the definition of alternative model structures (initially 144 alternatives) and exploratory runs. These were then refined in a preliminary manner, with further refinement taking place through the WPTT (recorded in IOTC-2017-WPTT19, 2017b). A final selection of 37 models was then used as input to the harvest control rule (IOCT-2017_SC20, 2017).

The reference case model had the following characteristics:

- Dimensions: Single area, sex-aggregated, age-structured (0-8 years) and iterated on an annual cycle containing four seasons from 1950 through to 2016 (assumed to be at unexploited equilibrium in 1950).
- 4 fishing fleets: ML - Maldivian pole and line; PSLS - EU/Seychelles FAD/log associated purse seine fleet; PSFS - EU/Seychelles free-school purse seine fleet; Other fleets (comprising a heterogenous mix of fisheries with limited data on abundance or catch composition)
- Selectivity: Cubic spline for each fleet.
- Recruitment: Beverton-Holt recruitment function. Total annual recruitment calculated as a function of the total spawning stock biomass at the beginning of the year, with age-0 recruits then allocated to each season. Recruitment deviations are allowed for 1983-2015.

Available data inputs were:

- Catch: biomass time series for all fleets by year, assumed to be known without error.
- Relative abundance time series (CPUE): Annual for ML and PSLS fleets
- Length frequency distributions: by quarter for all fleets;
- Tagging release and recapture data: releases from the RTTP and small-scale releases; recaptures from the PSLS and PSFS, and the PL fleets. Good data on reporting rates for PS fleets. Fish length recorded at time of release/recapture and converted into age using the age-length growth curve.

Parameters:

- Estimated for all models: Catchability per CPUE time series, Virgin recruitment, Selectivity by fleet, Recruitment deviations by year, Seasonal pattern of recruitment.
- Estimated for some model alternatives: Spatial distribution of recruitment, Natural Mortality, Tag recovery reporting rate for the PL fleet.
- Fixed: Stock Recruitment relationship, Maturity ogive, Growth (length and weight at age).

Alternative model structures are summarised in Tables 4, 5 and 6 of IOTC-WPTT19 (2017a). Modifications to these, including the addition of further options, are given on pages 39-40 of IOTC–WPTT19 (2017b). The final collection of model runs included:

- 1 Growth scenario (fast growth)
- 1 CPUE option: Maldivian standardized CPUE and EU-PS-FAD standardized CPUE with a 1% annual catchability increase since 1995 (PS only).
- 2 mixing periods (3 and 4 quarters)
- 2 tagging programs options (i) RTSS (RTTP plus small-scale tagging), (ii) RTTP only
- 2 Natural Mortality options (Constant M and estimated M)
- 3 Steepness options (h=0.7, 0.8, 0.9)
- 2 options for release tag mortality (15% and 25%).

Not all combinations were represented, yielding a total of 37 model runs in the final assessment grid.

Overview of the current MPE framework

The Operating Model (OM) was coded independently of SS3 and based on an earlier stock assessment. As such it has some structural differences to the current assessment, including the spatial structure and definition of fleets. The model partitions the population by region, age, and size; and the fishery by region and gear (purse seine, pole-and-line, gill net, others). Conditioning was achieved by using as input the median parameter values from the then current grid of stock assessments. Probability distributions were defined for each parameter and a process of simulation and selection of feasible stock trajectories was used for further refinement of the model (Bentley & Langley, 2012). Details of the model are given in Bentley & Adam (2015, 2016).

Performance metrics for the simulation are given in Table 8 of Bentley & Adam (2016). They included catch, abundance, fishing mortality, and biomass-based summary statistics. For catch and abundance, summaries were used to measure the total absolute level as well as inter-annual variability and the distribution between fleets.

The current harvest control rule

Three contrasting classes of harvest control rule were explored by Bentley & Adam (2014b, 2016):

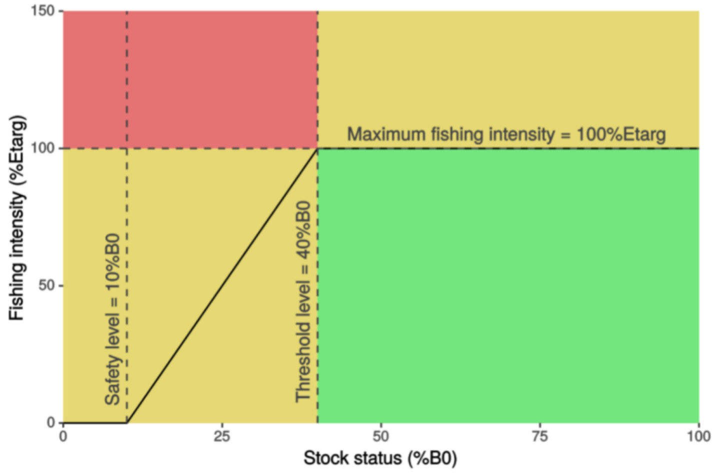
- BRule: a generic step-linear harvest control rule, common to other tuna fisheries, providing a target fishing mortality based on an estimate of stock status, usually the spawning stock biomass relative to a B_{MSY} reference point or proxy;
- FRange: a control rule which adjusts effort when fishing mortality is outside a target range;
- IRate: a control rule that recommends a total allowable catch using a CPUE-based biomass index.

As reported by Bentley & Adam (2016): in February 2016, the "Indian Ocean Coastal Meeting on Harvest Control Rules" engaged stakeholders in the process of narrowing down the options for a management procedure for Indian Ocean SKJ tuna. After considering alternatives, the workshop concluded that a functional form similar to the BRule provided the most appropriate basis for management. This was largely because the workshop felt that the assessment process incorporated as much of the available data as possible, including the data from tagging programmes, and was therefore the most appropriate basis for management.

On the basis of this recommendation, the Mald2016 control rule was developed and became the basis of Resolution 16/02 (IOCT-2017_SC20, 2017). Using the terminology of Bentley & Adam (2016), the control rule outputs a fishing intensity (*I*) as a function of the spawning biomass, using a step-linear relationship. The fishing intensity is a scalar multiple of the target exploitation rate (*Etarg*). The target exploitation rate is the rate that will lead to an equilibrium spawning biomass of 40% *B0*. Using the current estimate of the spawning biomass (*Bcurr*) the catch is calculated as:

Recommended catch limit = *I* x *Etarg* x *Bcurr*

When *Bcurr* >= 40% *B0*, the fishing intensity is set at a maximum value (*Imax* = 100%). For when *Bcurr* < 40% *B0*, the fishing intensity declines linearly towards zero. When *Bcurr* <= 10% *B0* then the recommended fishing intensity is zero. The HCR can therefore be summarised in the following functional form:



Application of the control rule in 2017

The control rule requires three model estimated values as input: the current spawning stock biomass, spawning stock biomass at unexploited equilibrium, and an equilibrium exploitation rate associated with long term sustainability of the stock at 40% of the unexploited spawning stock biomass. Median values output from the 2017 grid of 37 assessment models were used by the HCR to calculate a catch limit for 2018-2020. The spawning biomass was estimated in 2017 to be at or above the threshold spawning biomass (40% B0), which yielded a total annual catch limit of 470,029 tonnes for the period 2018-2020 (IOTC-WPTT19, 2017b). The average catch between 2012-16 was 407,456 tonnes. The catch in 2017 was approximately 524,282 tonnes. However, in 2018 catches were 607,000 tones: 29% above the catch limit.

Proposal for new work

Given the development work undertaken to date, the following problems have become apparent:

- The code platform (C++) is not accessible to third parties outside of the development process who may wish to run simulations. Recent attempts to compile the executable have proved unsuccessful.
- It is not clear to what extent the OM dynamic equations match those of the stock assessment (performed using SS3) and therefore it is unknown whether the input parameter values will lead to derived (output) values matching the stock assessment dynamics. If the stock assessment and OM have different properties, because the underlying equations are different, and assuming the stock assessment to be our best understanding of the resource, then our ability to select an appropriate HCR (or MP) will be compromised. For example, it may be that the OM is more optimistic than the assessment (IOTC 2018), which would have biased the evaluation towards a more aggressive control rule. More generally, differences between the OM and the assessment imply that we may not be representing the dynamics nor bounding the uncertainty appropriately. This problem is compounded when considering multiple runs with different structural assumptions.
- Conditioning using the feasible stock trajectories approach is non-standard and it is therefore difficult to assess "realism" of the OM and structural OM alternatives (in terms of how closely they match the data) compared to the stock assessment.
- Previous evaluations did not include an estimation step when assessing performance of the control rule (IOTC 2018): it was assumed that the HCR inputs are provided by an assessment, but the method of estimating these inputs was not defined or tested during the evaluation process. For SKJ, the stock assessment in any given year could require novel assumptions that fall outside the range of those explored by the OM or OMs used in developing the MP. In such cases, a novel means of generating

the MP inputs may (or may not) invalidate the MP itself.

In response to these concerns, we propose the following work:

1) **Develop an OM with population dynamics that match those of the SS3 stock assessment model**. To this end we propose using SS3 directly for simulations. There are a number of benefits to this approach. First, OM models could be conditioned with explicit reference to the grid of runs used for the assessment (currently 37 different structural alternatives) and easily expanded to include plausible alternatives, with plausibility measured using likelihood-based fits to the data. Given the uncertainty in the SKJ assessment the ability to easily explore alternative structural options is an advantage. Second, the MSE framework would evolve with developments in SS3 and the dependent assessments. Third, considerable code resources already exist to facilitate this approach and make it accessible (e.g. https://github.com/r4ss). Forth, this is an idea currently supported by the developers of SS3 (Nathan Vaughan, NOAA, personal communication). And finally, pre-existent coding frameworks already exist and could be modified for MP evaluation (e.g. Haltuch et al. 2019).

2) **Include an estimation step within the MP implementation** (IOTC 2018). Initially, this will take the form of a surplus production model fitting to the available PL and PSLS CPUE time series. This will require auxiliary developmental work to assess performance of the production model given current data. Depending on the outcome of this work, for example the estimation may not be sufficiently robust, it may be necessary to explore alternative ways of estimating the biomass, such as an age-structured production model.

3) **Improve accessibility**. We propose to place the MSE framework within a suitable R-package for accessible use.

Project objectives for 2020

1) Adapt the conceptual framework developed by Haltuch et al. (2019) for application to a set of existent stock assessment scenarios, currently coded in Stock Synthesis 3.24z;
2) Update the framework to do a more extensive MPE testing, specifically allowing for an estimation step when simulating implementation of the MP;
3) Develop and test a surplus production model for application to SKJ, as a means of providing control rule input, specifically the exploitable biomass relative to unexploited equilibrium;
4) Inclusion of a surplus production model within the simulation framework using functionality that allows for an estimation step;
5) Updating the framework to make use of Stock Synthesis 3.31, conditional on the assessment also being updated;

Project objectives for 2021

6) Perform the MPE, using new assessment results and with guidance from the WPTT and WPM.
7) Publication of code for dissemination to and testing by members of the Technical Committee on Management Procedures (TCMP) and Working Party on Methods (WPM)

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