Developments toward an MSE framework for Indian Ocean skipjack tuna using Stock Synthesis III

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Contents

Project Background and Objectives

Based on simulation evaluations of candidate harvest control rules by Adam and Bentley (2013), Bentley and Adam (2014a,b, 2015, 2016), reviewed and endorsed by the Working Party on Tropical Tunas (WPTT), Working Party on Methods (WPM), and the Scientific Committee (SC), the IOTC adopted Resolution 16/02 "On Harvest Control Rules for Skipjack in the IOTC Area of Competence." This described the harvest control rule (HCR) to be used for setting a recommended catch for skipjack (SKJ) and stated that its first implementation will be based upon the 2017 stock assessment agreed by the WPTT and then endorsed by SC. Implementation of the HCR to give a recommended catch limit for 2018–2020 is described in IOTC (2017a). The Resolution also requested a further review and possible modification of the HCR to be conducted no later than 2021.

In 2018, the IOTC WPM noted that the SKJ HCR is not a fully specified Management Procedure (MP), since the underlying data required and assessment methodology are not defined. Hence the WPM suggested that the review and potential revision required under Resolution 16/02 be conducted with the aim of determining a full MP for SKJ. This was noted by the SC in 2018 and provides the motivation and basis for the current work.

An MP includes the assessment or estimation method on which the HCR is based, as well as the data inputs and the HCR itself. Simulation evaluation requires an operating model (OM), to describe dynamics of the resource and how it responds to harvesting, plus a computational framework that will generate artificial observations, apply the MP to estimate a management recommendation, and then simulate the implementation of that recommendation in a closed loop forward projection. The current report describes initial developments of such a framework, specifically implementing Stock Synthesis III as the OM. Closed loop simulation evaluations of the current HCR are performed so as to demonstrate the framework's functionality.

1 Introduction

The current project report outlines development of an Indian Ocean skipjack tuna (SKJ) simulation evaluation framework for the testing of candidate Management Procedures (MPs) using Stock Synthesis III (SS3) as an operating model (Methot Jr. and Wetzel, 2013). Since the stock assessment is also conducted using SS3 (IOTC, 2017b), there are a number of benefits to this approach. Most importantly, the operating model (OM) or models can be conditioned with explicit reference to the grid of runs used for the assessment (currently 36 different structural alternatives) and easily expanded to include plausible alternatives, with plausibility measured using likelihood-based fits to the data. Given uncertainty in the SKJ assessment (with 144 models investigated in the most recent assessment, IOTC, 2017b) the ability to easily explore alternative structural options is necessary. Alongside the benefits of using a standardized and tested code base, it is also advantageous that this approach will allow the management strategy evaluation (MSE) framework to evolve with developments in SS3 and the dependent assessment.

Previously, the OM was coded independently of SS3 (`https://github.com/iotcwpm/SKJ`). 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 and Langley, 2012). Details of the model are given in Bentley and Adam (2015, 2016). However it was not clear to what extent the OM dynamic equations matched those of the stock assessment. Therefore it is unknown whether the input parameter values would have lead to derived (output) values matching the stock assessment dynamics.

It is not unusual practice for an OM to be coded independently of the stock assessment. For example, MSE has been conducted by the International Pacific Halibut Commission using an SS3 OM (Hicks, 2018), but is currently being re-coded as an independent framework to allow evaluation of a more diverse set of spatial scenarios (Hicks et al., 2020a). Similarly, an independent OM has been constructed for Indian Ocean albacore tuna that mirrors closely the dynamics of the assessment model but allows for a greater degree of flexibility when testing MPs (Mosqueira, 2016, Mosqueira and Scott, 2015). This allows the testing of candidate MPs against a range of scenarios typically poorly represented by stock assessment models, such as the non-stationarity of parameters and fine spatial scale (Sharma et al., 2020). However, it is important that dynamics of the OM are similar to that of the assessment model, not least because the assessment typically represents our best understanding of the resource. If the stock assessment and OM have different properties then our ability to select an appropriate harvest control rule (or MP) will be compromised. For example, it may be that the OM is more optimistic than the assessment (IOTC, 2018), which would bias 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. For the tuna RFMOs, a wide range of structurally different assessment models is usually implemented, and the OM should be able to, at the least, accurately represent the full spectrum of uncertainty contained therein (Sharma et al., 2020). If a more flexible OM is required, then extensive validation and testing is needed (e.g. Hicks et al., 2020b). If this is not feasible, then using the assessment model, or variations thereof, is a suitable and defensible approach (e.g. Breen et al., 2016).

Table 1: Glossary of terms used for description and evaluation of the HCR.

Notation	Description
C_y	Total catch in year y summed across fleets and seasons
$C_{40\%}$	Estimated equilibrium yield at $SSB_{40\%}$
C_{2036}	Annual catch from projection to equilibrium under $F_{40\%}$
C_{TARGET}	Median of C_{2036} across runs
SSB_0	Unexploited equilibrium spawning stock biomass
SSB_y	Spawning stock biomass in year y
$SSB_{40\%}$	Target spawning stock biomass; equivalent 40% of SSB_0
$SSB_{10\%}$	Limit spawning stock biomass; equivalent 10% of SSB_0
SSB_{2036}	Spawning stock biomass from projection to equilibrium under $F_{40\%}$
SSB_{TARGET}	Median of SSB_{2036} across runs
B_0	Summary biomass (age 1+) at unfished equilibrium
B_y	Summary biomass in year y
B_{2036}	Summary biomass from projection to equilibrium under $F_{40\%}$
E_y	Current exploitation rate as a proportion of the exploitable biomass
$E_{40\%}$	Exploitation rate that will yield $SSB_{40\%}$ at equilibrium
F_y	Current exploitation rate as a proportion of B_y
$F_{40\%}$	Exploitation rate that will yield $SSB_{40\%}$ at equilibrium
F_{2036}	Exploitation rate from projection to equilibrium under $F_{40\%}$
F_{TARGET}	Median of F_{2036} across runs
I_y	Fishing intensity in year y (see Equation 1a)

This report details the outcome of development work that allows the use of SS3 as an OM, making considerable use of **r4ss**, an R-package already available for the interrogation of SS3 models (Taylor et al., 2020). The current harvest control rule and its implementation is first described, followed by some preliminary evaluations, with and without feedback control and with appropriate diagnostics. This first required updating of the stock assessment to SS3.30, and the derivation of appropriate reference points for the control rule. Terminology used in this report is listed in Table 1. Where appropriate, SS3 input settings are given using the format <ss_file>::<variable> = <value> (with options listed in Methot, 2020). All code was developed in R (R Core Team, 2020).

2 The control rule

Using the terminology of Bentley and Adam (2016), the control rule outputs an intensity (I_y) as a function of the spawning stock biomass (SSB_y), using a step-linear relationship (Figure 1):

$$I_y = \begin{cases} 1 & \text{for } SSB_y \geq SSB_{40\%} \\ \frac{SSB_y - SSB_{10\%}}{SSB_{40\%} - SSB_{10\%}} & \text{for } SSB_{10\%} < SSB_y < SSB_{40\%} \\ 0 & \text{for } SSB_y \leq SSB_{40\%} \end{cases} \tag{1a}$$

Multiplication of the intensity by a target exploitation rate gives the realised exploitation rate:

$$E_y = I_y \times E_{40\%} \tag{1b}$$

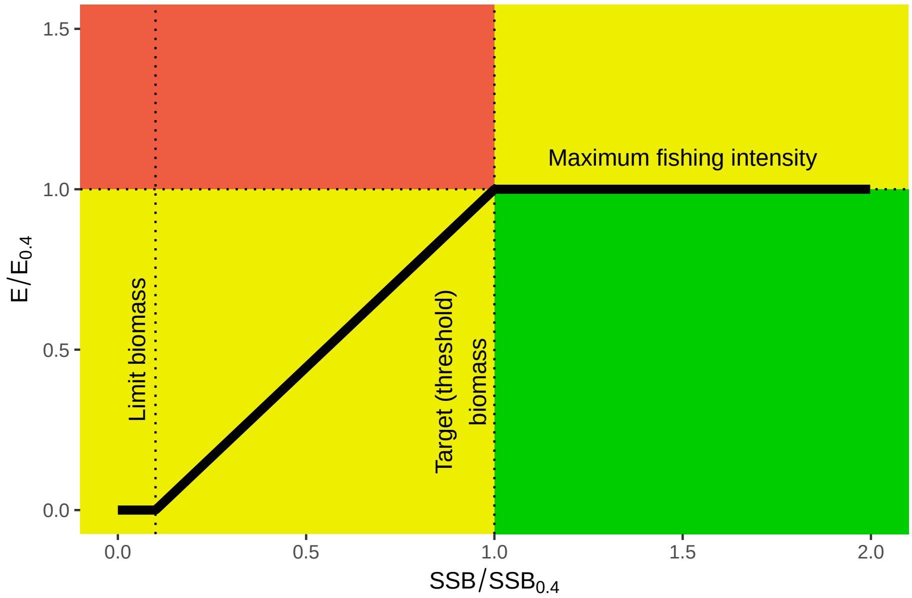


Figure 1: Control rule schematic, with a target exploitation rate of $E_{40\%}$ and target and limit biomass reference points of $SSB_{40\%}$ and $SSB_{10\%}$ respectively.

The exploitation rate is defined as the catch over the vulnerable (selected) component of the biomass (Section 2.1.3, Bentley and Adam, 2016). However in the control rule itself, as specified in Resolution 16/02, the exploitation rate is implicitly re-defined as a proportion of the spawning stock biomass. Thus the recommended catch is set using the following relationship:

$$C_{y+1} = I_y \times E_{40\%} \times SSB_y \tag{1c}$$

The following additional meta-rules were also endorsed:

- The recommended catch limit should not exceed 900,000 tonnes;
- The change in recommended catch from the previous year should not exceed 30% unless $SSB_y \leq SSB_{10\%}$, in which case C_{y+1} will always be zero.

Input values for the control rule ($SSB_{40\%}$, $SSB_{10\%}$, and $E_{40\%}$) are obtained as medians across estimated values from the grid of SS3 assessment runs in the year in which the control rule is applied. In 2017, there were 36 alternative assessment model runs in the final grid (IOTC, 2017b,c), yielding the median values listed in Table 2. These were used to calculate a recommended catch of 470.0 thousand tonnes for the three years 2018 to 2020. This was higher than the catch in 2016 (446.7 thousand tonnes) and the average catch from 2012 to 2016 (407.5 thousand tonnes), but less than the median estimated yield at $SSB_{40\%}$ (510.1 thousand tonnes). Following implementation of the control rule, the catch in 2017 was approximately 524.2 thousand tonnes. However, in 2018 catches were approximately 607 thousand tonnes: 29% above the recommended catch limit. This potential for over catch of the recommendation will be important for future developments of the testing framework.

Quantity	Median	80% CI
Yield at $SSB_{40\%}$	510.1	(455.9 – 618.8)
$E_{2016}/E_{40\%}$	0.9259	(0.70–1.13)
$C_{2016}/C_{40\%}$	0.88	(0.72–0.98)
SSB_0	2,015.2	(1,651.2–2,296.1)
Total Biomass	910.4	(873.6–1195)
$SSB_{2016}/SSB_{40\%}$	1.00	(0.88–1.17)
SSB_{2016}/SSB_0	0.40	(0.35–0.47)
SSB_{2016}	796.66	(582.65–1059.4)
$E_{40\%}$	0.59	(0.53–0.65)

Table 2: Assessment derived quantities used by the control to set a catch limit for 2018 – 2020. Catch and biomass values are given in units of 1000 tonnes.

3 Updating the stock assessment to SS3.30

The 2017 stock assessment (IOTC, 2017b) was performed using SS3.24z. It initially considered 144 alternative model runs, but this was refined following discussions by the WPTT to 36 (IOTC, 2017c). The current work was developed around the 2017 assessment. But since it needs to be forward compatible, and since the assessment is scheduled to be updated, we updated the 2017 assessment files from SS3.24z to SS3.30 (version 3.30.15.09; 2020-07-06). An initial step in constructing the evaluation framework was to therefore check that projections performed using SS3.24z and SS3.30 are comparable.

A complete set of SS3.24z input and output files from the 2017 assessment grid was provided by the Secretariat. These were converted to SS3.30 and projected forward for 10 years with a catch multiplier of 0.6, 0.8, 1.0, 1.2 and 1.4. Results are shown in Figure A1. The dynamics are broadly comparable, although not for the largest of the catch multipliers, for which SS3.30 produced spuriously high fishing mortality values. The reasons for this are unclear. Nevertheless the SS3.30 model files were considered sufficient for the current developmental work, and will be refined in future iterations.

3.1 Reference point estimates

Each assessment model was used to estimate a set of reference points needed for parameterisation and evaluation of the control rule. The models were configured to project the stock forward for 20 years according to an internally estimated target exploitation rate $F_{40\%}$, defined as a rate that will yield $SSB_{40\%}$ at equilibrium (`forecast::Btarget = 0.4`). The exploitation rate itself if measured as a proportion of the summary biomass that is caught (`starter::F_report_units = 1`). The summary biomass is defined as the sum of the biomass of age one and over (`starter::min_age_summary_bio = 1`).

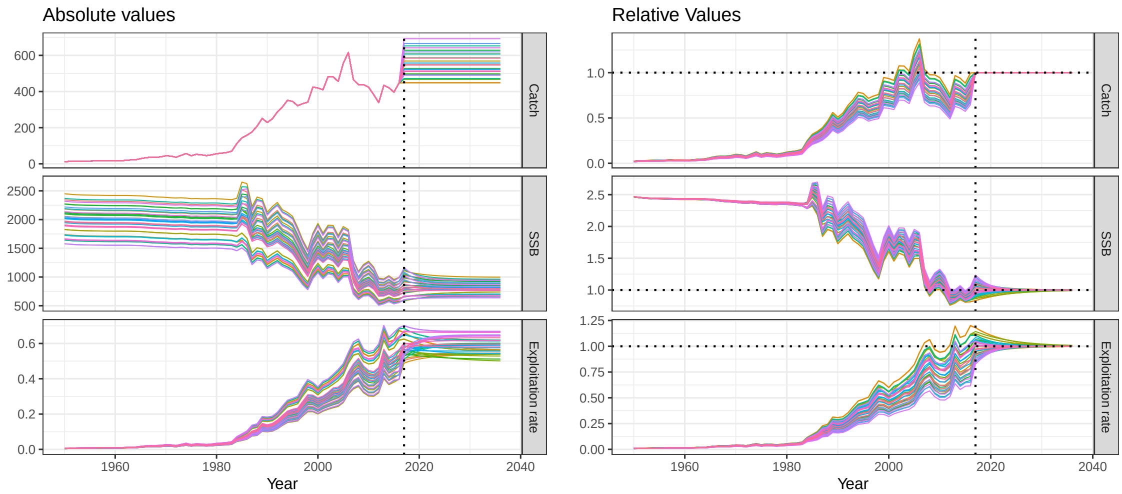
Results are listed as median values in Table 3, with the full list given in Table 3. We note that terminal values following the 20 year projection period are different from the equilibrium target values. Because we will need to evaluate control rule performance against the expectations listed in Table A1, we use the terminal values as input reference points, rather than the equilibrium estimates. This was to ensure internal consistency of the evaluations. Future revisions to the SS3 code may resolve this discrepancy.

The validity of these reference point estimates is illustrated in Figure 2. Figure 2a shows a projection for each model assuming F_{2036} (Table A1) as a constant input exploitation rate. In each case the distribution of fishing mortalities across fleets and seasons was taken to be equivalent to the estimated distribution associated with the F_{2036} terminal value. Each model converges to its expectation. Similarly, Figure 2b shows projection assuming an input catch calculated as F_{2036} multiplied by the current summary biomass B_{2017}. Again each model converges to the terminal expectations listed in Table A1. Fishing mortality and biomass target reference points for each model were therefore set as F_{2036} and SSB_{2036} (and C_{2036}). These are approximately, but not exactly, equal to $F_{40\%}$ and $SSB_{40\%}$ respectively.

Table 3: Reference point estimates across the grid of 36 assessment model runs.

Matric	Median	80% CI
$F_{40\%}$	0.602	(0.546 - 0.664)
F_{2016}	0.584	(0.534 - 0.649)
F_{2036}	0.596	(0.540 - 0.656)
SSB_0	1993.78	(1651.16 - 2296.225)
$SSB_{40\%}$	797.512	(660.463 - 918.49)
SSB_{2016}	799.553	(601.177 - 1071.3)
SSB_{2036}	807.656	(669.388 - 931.304)
B_0	2132.597	(1760.51 - 2448.744)
B_{2016}	917.086	(694.133 - 1206.354)
B_{2036}	932.066	(766.424 - 1064.484)
$C_{40\%}$	522.191	(466.774 - 634.226)
C_{2016}	518.644	(426.196 - 704.564)
C_{2036}	523.147	(468.294 - 635.112)

(a) Application of a constant target rate of exploitation (F_{2036}) to each model run.



(b) Application of a constant target catch ($F_{2036} \times B_{2017}$) to each model run.

Figure 2: Validation of reference point estimates for each model run, demonstrating convergence of model runs to terminal reference point estimates C_{2036}, SSB_{2036} and F_{2036} as listed in Table A1.

4 Evaluation of Resolution 16/02

We first evaluate the current HCR as specified in Resolution 16/02 using SS3.30 as the OM. Given that the control rule requires as input the median values across assessment model runs, we summarise from Table 3:

$$\begin{aligned} F_{\text{TARGET}} &= 0.596 \\ SSB_{\text{TARGET}} &= 807.656 \\ C_{\text{TARGET}} &= 523.147 \end{aligned}$$

with F_{TARGET} given as a proportion of the summary biomass and biomass values given in units of thousand tonnes.

The following projections were performed in order to explore limiting properties of the control rule as it was implemented in 2017:

- Constant catch of 470,029 tonnes (as specified in IOTC, 2017a);
- Constant exploitation rate of $F_{\text{TARGET}} = 0.596$ (Table 3) applied across all model runs;
- Constant catch of 546,411 tonnes ($F_{\text{TARGET}} \times B_{2017}$, Table 3) applied across all model runs.

For each model run, performance was evaluated against the reference points listed in Table A1 (not the median values).

It can be seen that a target catch of 470,029 tonnes is sustainable according to the scenarios evaluated here (Figure 3a). However we can also conclude that applying a median value obtained from a range of assessment model runs may not be a robust approach. From Figures 3b and 3c it appears that this logic would likely lead to overexploitation according to some of the assessment scenarios considered.

4.1 Feedback control

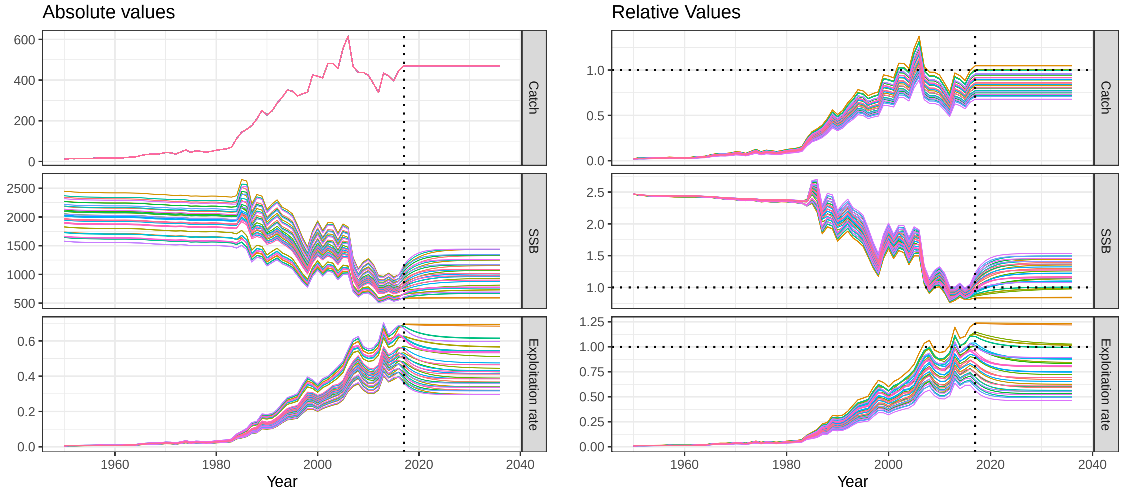
By including feedback control the risk of over-exploitation can be mitigated, even if the target rate is set too high. This was illustrated by application of the control rule in Equation 1, but with the exploitation rate E_y replaced by a rate (F_y) that is applied explicitly to the summary biomass B_y (Table 1). Therefore:

$$I_y = f(SSB_y/SSB_{\text{TARGET}}) \tag{2a}$$

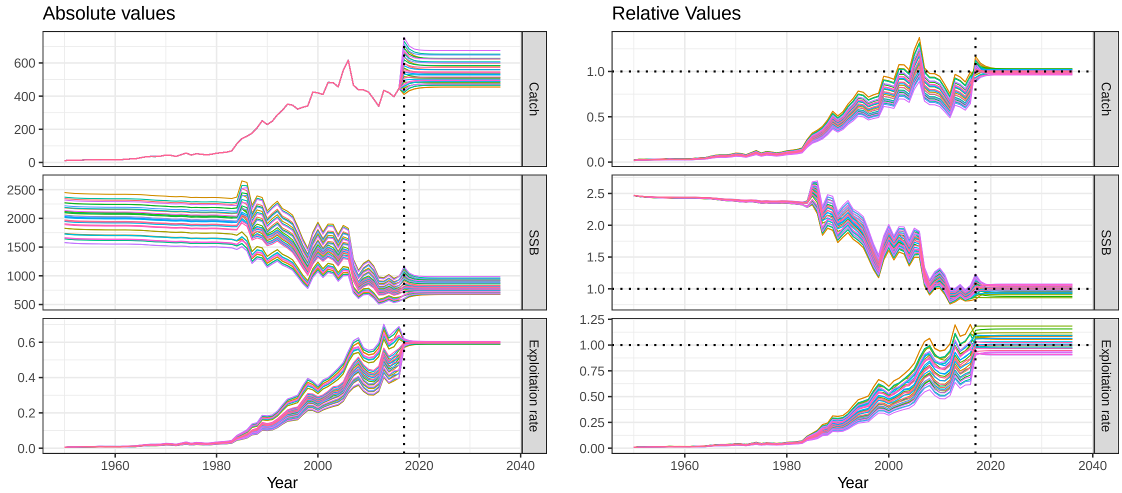
$$F_y = I_y \times F_{\text{TARGET}} \tag{2b}$$

$$C_{y+1} = I_y \times F_{\text{TARGET}} \times B_y \tag{2c}$$

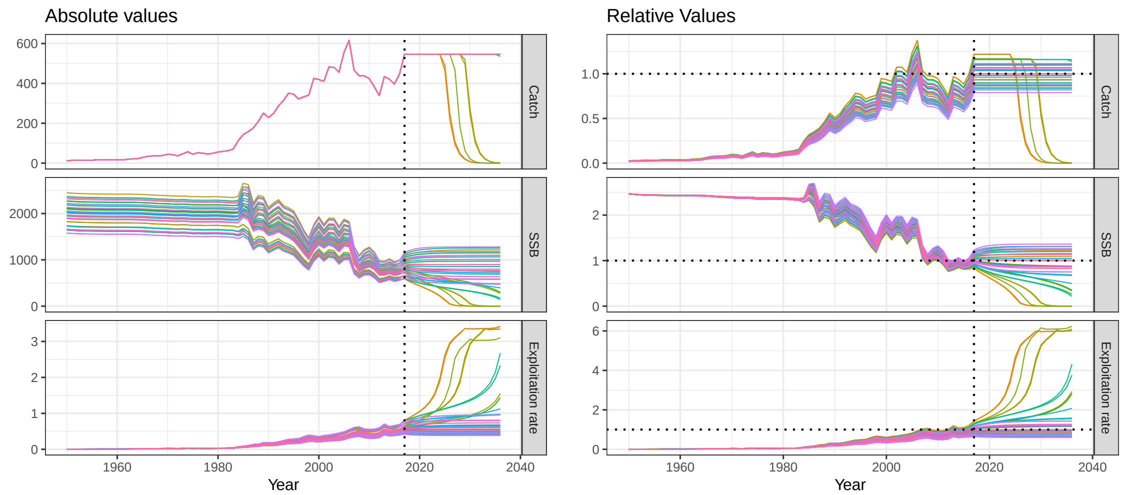
The SS3 OM was iterated forward in time, and at each annual time step an appropriate exploitation rate F_y was calculated assuming perfect information on the spawning stock biomass in the current year y (Equations 2a and 2b). The recommended F_y was then either applied directly to the OM in the next year (i.e. $F_{y+1} = F_y$), or converted into a catch using the summary biomass (Equation 2c). In each case the fishing pressure (either as an exploitation rate or catch) was distributed across fleets and seasons using values estimated by the OM for the year of application ($y + 1$).



(a) Application of a constant catch of 470,029 tonnes to all model runs



(b) Application of a constant exploitation rate of $F_{TARGET} = 0.596$ to all model runs



(c) Application of a constant catch of 546,411 tonnes to all model runs

Figure 3: Projections of each model run assuming either a constant catch or constant exploitation rate. Performance of each model is evaluated against the C_{2036}, SSB_{2036} and F_{2036} reference points listed in Table A1.

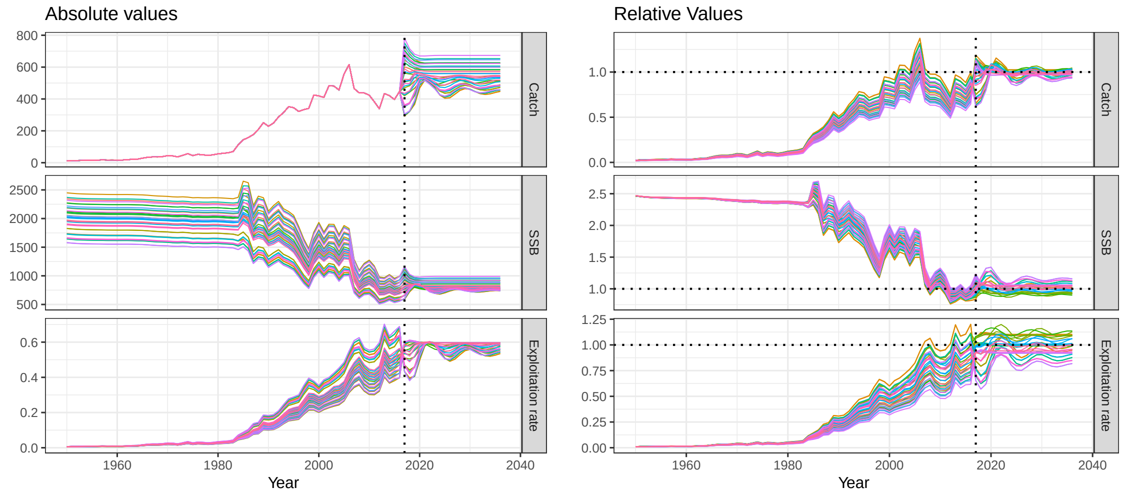
Results are illustrated in Figures 4 and 5. Applications of F_{y+1} yield a noticeably more stable outcome than applications of C_{y+1}. This is because, when calculating C_{y+1}, the biomass from the previous year is being used (i.e. B_y), which introduces an additional lag compared to direct application of F_{y+1} to the biomass in year $y+1$. Nevertheless, the dynamics appear to oscillate and converge on the target values in both instances.

4.2 Diagnostics

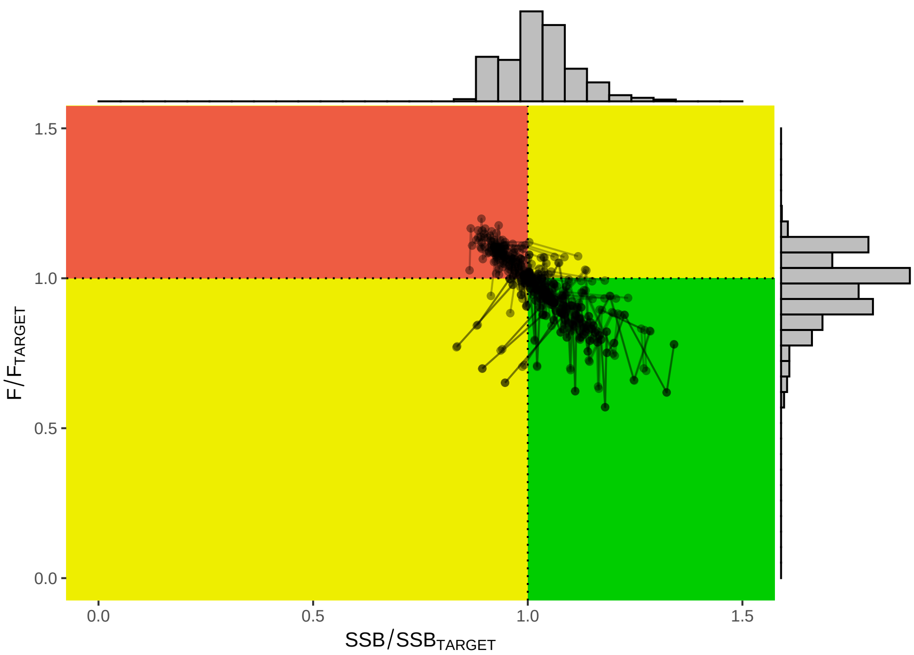
Diagnostics appropriate for evaluation of a given control rule or MP include the graphical summaries given in Figures 4 and 5. In addition, the diagnostic outputs from Bentley and Adam (2016) are listed in Table 4. They included catch, abundance, fishing mortality, and biomass-based summary statistics. For the catch, summaries were used to measure the total absolute level as well as inter-annual variability and the distribution between fleets.

Table 4: Diagnostic outputs for evaluation of F_{y+1} and C_{y+1} control rules. Each performance statistic is generated by first calculating the mean value per run across projection years, and then reporting the median and 80% CI values across these mean values – unless the statistic is a probability (Pr.), in which case it is calculated across all projection years and runs simultaneously. A full description of each performance statistic is given in Table 8 of Bentley and Adam (2016).

Performance Statistic	F_{y+1} HCR	C_{y+1} HCR
Catch		
C	526.59 (438.94 - 633.72)	526.39 (439.66 - 635.51)
$C_{[PL]}$	81.05 (70.11 - 95.7)	80.87 (68.33 - 97.14)
$C_{[PSFS]}$	7.72 (6.37 - 9.39)	7.72 (6.39 - 9.45)
$C_{[PSLS]}$	201.61 (158.23 - 249.55)	202.21 (166.77 - 243.54)
$C_{[OTHER]}$	235.84 (204.16 - 280.13)	235.58 (198.18 - 285.38)
Catch stability		
Pr. catch decrease	0.46	0.51
Pr. catch increase	0.54	0.49
$\lvert C_{y+1}/C_y - 1\rvert$	0.01 (0 - 0.08)	0.06 (0 - 0.23)
Pr. $C > 425$ kt	0.94	0.83
Pr. $C = 0$	0	0
Catch rate		
$A_{[PL]}$	7.59 (6.75 - 9.78)	7.63 (6.74 - 9.79)
$A_{[PSLS]}$	7.23 (6.67 - 8.36)	7.23 (6.67 - 8.33)
$A_{[OTHER]}$	335.22 (297.5 - 431.84)	336.7 (297.29 - 432.01)
Exploitation rate		
F/F_{2036}	0.97 (0.83 - 1.1)	0.95 (0.82 - 1.1)
Stock biomass		
Pr. $SSB > SSB_{10\%}$	1	1
Pr. $SSB > SSB_{20\%}$	1	1
SSB/SSB_0	0.41 (0.38 - 0.45)	0.41 (0.38 - 0.45)
Min. SSB/SSB_0	0.38 (0.36 - 0.42)	0.38 (0.34 - 0.41)
Kobe Quadrants		
Pr. Green	0.05	0.14
Pr. Red	0.05	0.11

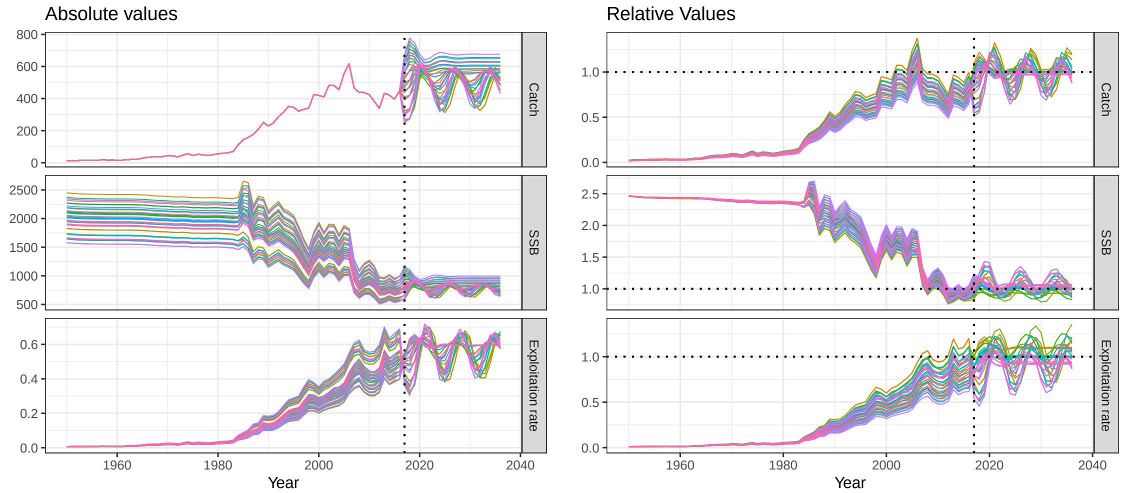


(a) Dynamics over time for the total catch (C_y), spawning stock biomass (SSB_y) and exploitation rate (F_y).

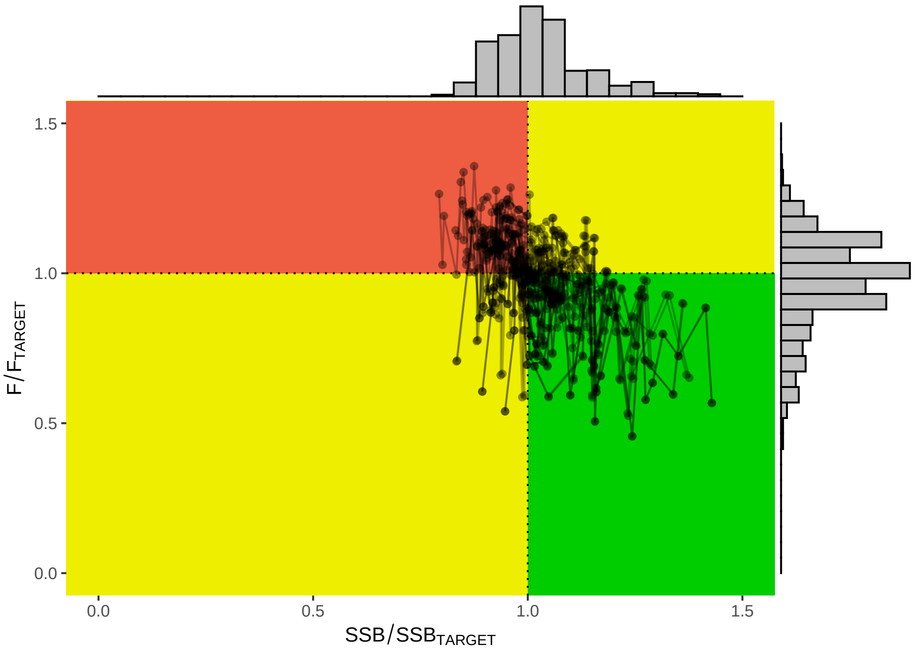


(b) Kobe phase plot. Each point represents a projection year ($y \geq 2017$), with years from the same model run joined by a line.

Figure 4: Application of F_{y+1} control rule assuming median values of SSB_{TARGET} = 808 thousand tonnes and F_{TARGET} = 0.6 across all runs (Equations 2a and 2b). Relative values per run are calculated using the C_{2036}, SSB_{2036} and F_{2036} reference points listed in Table A1 and applied in Figure 2.



(a) Dynamics over time for the total catch (C_y), spawning stock biomass (SSB_y) and exploitation rate (F_y).



(b) Kobe phase plot. Each point represents a projection year ($y \geq 2017$), with years from the same model run joined by a line.

Figure 5: Application of C_{y+1} control rule assuming median values of $SSB_{TARGET} =$ 808 thousand tonnes and $F_{TARGET} = 0.6$ across all runs (Equation 2). Relative values per run are calculated using the C_{2036}, SSB_{2036} and F_{2036} reference points listed in Table A1 and applied in Figure 2.

5 Summary and further work

A basic framework for evaluation of a HCR using an SS3 OM has been presented. The framework is capable of performing closed-loop, annual projections using catch or exploitation rates calculated from an external HCR input. Furthermore, it can project the abundance index per fleet, meaning that the simulated feedback loop could include generation of the data needed for annual iterations of a simple stock assessment.

Applications of the simulation framework demonstrated that previous iteration of Resolution 16/02 in 2017 likely yielded a suitable catch recommendation (IOTC, 2017a). However evaluations also showed that the use of median values for constructing reference point inputs for the control rule is likely flawed. Instead control rule input values should be selected that allow performance criteria to be met for a minimum quantile of the model runs being examined. This is particularly important given likely over catch of the recommendation, which will also need to be included in future developments of coding framework.

Further work will focus on the specification of a full MP, which includes an annual assessment model for setting of the catch limit. Evaluation will require the simulation of future abundance data and automation of the assessment model fit, as well as uncertainty in implementation of the recommended catch.

6 Model code

Reference code developed for implementation of the current project is stored in `https://github.com/cttedwards/skj`.

7 Acknowledgements

I am grateful for discussions with Teresa A'mar (NIWA, New Zealand), Dale Kolody (CSIRO, Australia) and Iago Mosquiera (Wageningen Marine Research, Netherlands) who facilitated in drafting the original plan of work, to Dan Fu (IOTC, Seychelles) for his assistance in interpreting the SS3 files and updating the assessment to SS3.30, and to Nathan Vaughan (NOAA, Southeast Fisheries Science Center, USA) for assistance with coding the closed loop simulations.

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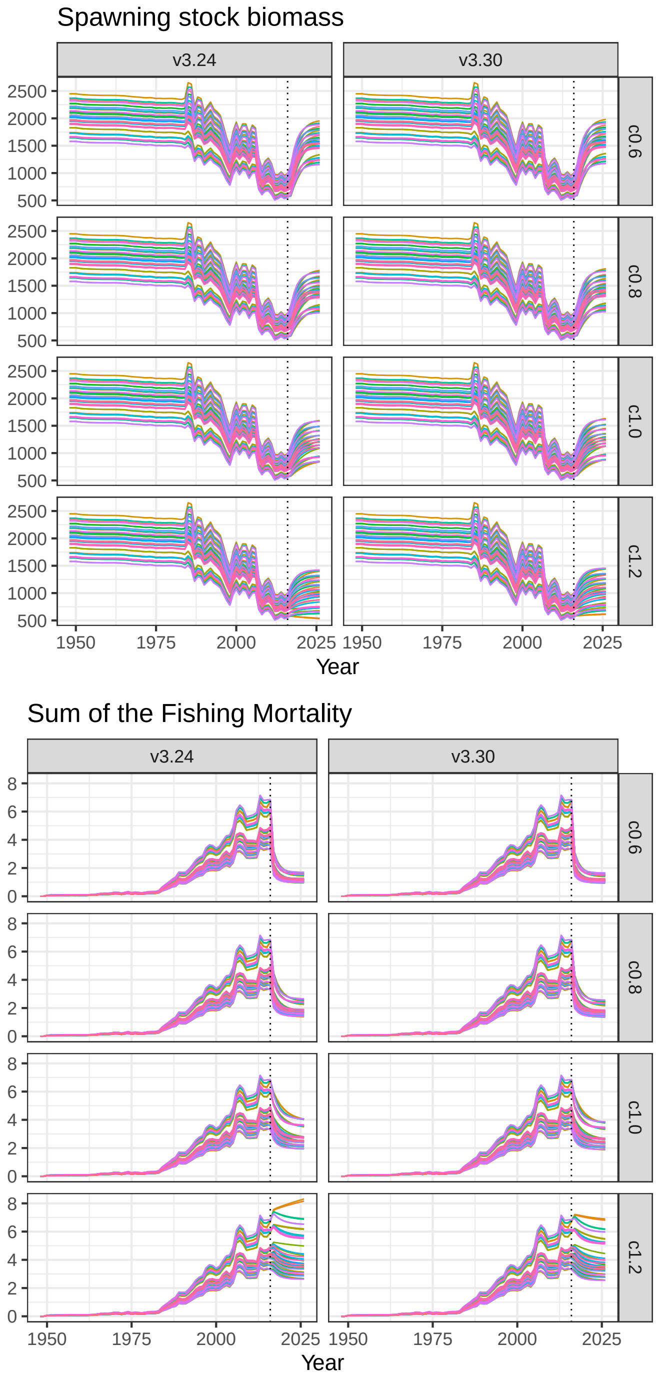

Figure A1: Comparative runs for SS3.24z (used in the 2017 assessment IOTC, 2017b) and SS3.30 (to be used in the 2020 assessment). The spawning stock biomass and fishing morality trajectories between 1950 and 2026 are shown, with catch multipliers of between 0.6 and 1.2. The catch multiplier of 1.4 is not shown, since it produced unusually high fishing mortality values. The fishing mortality is reported as the sum of apical values (`starter::F_report_units = 3`).

Table A1: Reference point estimates for each of 36 model runs used in the 2017 stock assessment (IOTC, 2017b,c).

$F_{40\%}$	F_{2016}	F_{2036}	SSB_0	$SSB_{40\%}$	SSB_{2016}	SSB_{2036}	B_0	B_{2016}	B_{2036}	$C_{40\%}$	C_{2016}	C_{2036}
0.55	0.53	0.54	2344.36	937.75	1033.08	951.71	2499.18	1161.69	1078.89	583.79	620.38	585.77
0.55	0.54	0.55	2182.75	873.10	913.11	886.11	2327.09	1031.40	1004.76	546.85	559.71	548.70
0.57	0.58	0.56	1739.04	695.62	589.90	706.03	1853.97	679.07	800.77	447.64	392.35	449.17
0.57	0.58	0.56	1733.93	693.57	587.03	703.95	1848.76	676.09	798.61	446.64	390.87	448.16
0.55	0.53	0.54	2448.92	979.57	1110.78	994.14	2611.28	1246.68	1127.46	606.83	658.19	608.89
0.55	0.54	0.54	2273.59	909.44	980.43	922.98	2424.48	1105.06	1046.94	566.70	592.84	568.62
0.56	0.57	0.56	1826.21	730.48	653.34	741.41	1946.95	748.34	840.85	466.42	425.56	468.01
0.56	0.57	0.56	1828.14	731.26	655.68	742.20	1949.21	751.01	841.90	466.98	426.84	468.57
0.53	0.53	0.53	2026.07	810.43	767.00	822.02	2169.46	882.52	940.60	494.18	470.97	495.80
0.50	0.51	0.50	2056.27	822.51	720.50	833.50	2186.55	823.46	941.29	466.57	420.50	467.99
0.55	0.54	0.54	2096.46	838.59	851.33	850.81	2249.86	976.94	977.47	525.91	527.50	527.66
0.51	0.52	0.51	2122.05	848.82	805.38	860.44	2262.29	918.37	976.29	496.21	474.21	497.76
0.61	0.58	0.60	2269.49	907.80	1058.38	920.34	2419.56	1191.48	1050.20	627.01	691.85	628.23
0.61	0.59	0.60	2105.00	842.00	934.72	853.64	2244.39	1057.11	974.34	585.17	624.27	586.31
0.63	0.63	0.62	1645.02	658.01	596.73	667.16	1753.88	688.47	761.71	470.61	435.20	471.54
0.63	0.63	0.62	1641.93	656.77	595.18	665.90	1750.81	686.94	760.48	469.96	434.35	470.88
0.60	0.57	0.60	2369.43	947.77	1133.28	960.86	2526.73	1273.47	1096.92	651.53	731.17	652.80
0.61	0.58	0.60	2191.36	876.54	999.13	888.66	2336.99	1127.67	1014.70	606.21	658.46	607.39
0.62	0.62	0.61	1726.40	690.56	655.92	700.16	1840.68	753.15	799.34	490.23	468.71	491.19
0.62	0.62	0.61	1731.91	692.76	660.72	702.39	1846.75	758.51	802.06	491.71	471.48	492.68
0.58	0.58	0.58	1945.77	778.31	778.82	788.62	2083.01	897.80	908.36	521.90	518.66	522.87
0.55	0.55	0.54	1968.42	787.37	728.63	797.10	2092.49	834.65	905.43	490.10	461.47	490.96
0.60	0.58	0.59	2015.20	806.08	861.45	816.96	2162.18	990.29	944.99	556.49	578.91	557.55
0.56	0.56	0.56	2033.31	813.32	811.58	823.62	2167.06	927.40	940.21	522.49	518.63	523.42
0.65	0.62	0.65	2219.65	887.86	1084.22	899.43	2366.61	1221.23	1032.15	665.19	755.12	665.76
0.66	0.63	0.65	2052.54	821.01	957.16	831.73	2188.62	1083.14	954.71	618.97	681.51	619.50
0.68	0.68	0.67	1579.58	631.83	606.27	640.13	1684.24	700.34	735.02	490.83	473.57	491.25
0.68	0.68	0.67	1577.93	631.17	605.62	639.45	1682.69	699.79	734.46	490.48	473.21	490.91
0.65	0.61	0.64	2318.86	927.54	1159.25	939.63	2473.01	1303.42	1078.77	691.72	796.87	692.31
0.65	0.62	0.65	2137.16	854.86	1020.78	866.01	2279.36	1152.87	994.46	641.44	717.28	641.99
0.67	0.67	0.66	1657.30	662.92	663.07	671.62	1767.14	762.42	771.14	511.27	507.64	511.72
0.67	0.66	0.66	1665.29	666.11	669.57	674.85	1775.84	769.65	775.01	513.54	511.61	513.98
0.62	0.61	0.62	1890.22	756.09	793.72	765.53	2023.21	915.80	886.78	546.64	561.90	547.09
0.59	0.59	0.58	1905.89	762.36	739.79	771.23	2025.55	848.54	880.43	510.72	498.33	511.12
0.64	0.62	0.63	1960.38	784.15	876.15	794.12	2103.01	1008.00	923.92	584.01	625.73	584.50
0.60	0.59	0.60	1972.36	788.95	823.00	798.35	2101.65	941.50	916.12	546.03	559.27	546.46