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EVALUATIONS OF CANDIDATE MANAGEMENT PROCEDURES FOR SKIPJACK TUNA IN THE WCPO (SC17-MI-WP-04)

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Evaluations of candidate management procedures for skipjack tuna in the WCPO.

WCPFC-SC17-2021/MI-WP-04

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Executive Summary

This paper provides the latest information on the management strategy evaluation (MSE) framework for WCPO skipjack. It presents an overview of the MSE framework and a summary of the results of recent evaluations and considers the next steps that will need to be taken in order to select and agree on a final management procedure (MP). Specific details of the framework are provided in a number of annexes to this report including:

- the components of the management procedure (data collection, estimation model settings and harvest control rule formulation);
- the procedure for determining how the archipelagic waters are currently treated by the management procedure (assumed constant at 2012 levels);
- information on where the relevant data objects, source code and software used to run the evaluations can be obtained.

The modeling framework for WCPO skipjack is well advanced. Many of the key technical challenges have been addressed and are documented in papers submitted to this, and previous, meetings of the Scientific Committee. Work will continue to further refine some of the technical components of the framework, in particular the specification of the operating models (OMs) that will comprise the robustness set and also to evaluate any additional management procedures (including harvest control rule (HCR) designs) that may be proposed by members. The results of these evaluations will be made available online and members can be kept appraised of progress through regular updates.

Under the revised harvest strategy workplan, the WCPFC is scheduled to agree on a management procedure for the WCPO skipjack / tropical purse seine fishery in 2022. To support the necessary discussions and decisions towards this, we seek from SC:

- input into candidate HCR designs;
- feedback on presentational approaches to enhance decision making; and
- discussion on how advice on the scientific aspects of candidate HCRs should be delivered to managers.

To progress the development of harvest strategies for the skipjack/tropical purse seine fishery, SC may wish to seek advice from the Commission on the following issues:

- definition of fisheries and fishery controls within the harvest strategy;
- input into candidate HCR designs;
- feedback on presentational approaches to enhance decision making; and
- procedures for selecting the ‘best performing’ MP.

1 Introduction

In accordance with the updated WCPFC workplan for the adoption of harvest strategies under CMM2014-06, SC17 is scheduled to provide advice on the performance of candidate management procedures (MPs) for skipjack tuna in the Western and Central Pacific Ocean (WCPO). The adoption of an agreed harvest strategy for WCPO skipjack is scheduled for 2022.

This paper provides the latest information on the management strategy evaluation (MSE) framework for WCPO skipjack. It presents an overview of the MSE framework and a summary of the results of recent evaluations and considers the next steps that will need to be taken in order to select and agree on a final MP. This paper is similar in both content and format to WCPFC-SC16-2020/MI-IP-03 and should be considered alongside a number of other papers presented to this meeting that consider the next stages of implementing the harvest strategy workplan:

- SC17-MI-WP-05 outlines preliminary evaluations of the mixed fishery framework specifically with regard to the impact of skipjack management procedures on stocks of bigeye and yellowfin tuna.
- SC17-MI-WP-03 and SC17-MI-IP-02 which consider the progress of stakeholder engagement and processes for communication, engagement and capacity building with respect to the technical development of the harvest strategy approach.

and papers submitted to previous meetings of the SC that describe the evaluation framework in greater detail:

- SC16-MI-WP-08 describes the technical details and status of the MSE modeling framework for skipjack in the WCPO.
- SC16-MI-IP-07 provides an overview of a common set of diagnostics and model outputs for MULTIFAN-CL. It presents a simple user interface for exploring the diagnostic outputs of the grid of operating models (OMs) that form the basis of the evaluations. These diagnostics and model outputs can be accessed at https://ofp-sam.shinyapps.io/hierophant/.
- SC16-MI-IP-10 describes the model settings adopted for simulating catch, effort, size composition and tag release and recapture information within the evaluation framework. It outlines the basis for these settings and provides a number of examples and simple comparisons to illustrate the extent to which the simulated data resemble true observations.
- SC16-MI-IP-09 describes work undertaken to test and validate the estimation model (EM) within the management procedure. The EM is used to determine a reliable and unbiased estimate of stock status that can be used by the harvest control rule (HCR) to determine future fishing opportunities.

Specific information on key model settings has been included in a number of annexes to the current report to formally document the framework structure, modeling approaches and parameter values used in the evaluations, particularly with respect to the implementation of the MP.

We present only a brief summary of the evaluation results. A more comprehensive set of results can be accessed via the PIMPLE software `https://ofp-sam.shinyapps.io/pimple`, developed specifically to allow members to review and compare the MSE results for WCPO skipjack.

2 The MSE Framework for WCPO Skipjack

The evaluation framework for WCPO skipjack is largely unchanged from last year. The two main updates are that:

- the software version of MULTIFAN-CL has been upgraded from version 2.0.7.2 to version 2.0.8.0. The more recent version of MULTIFAN-CL employs a more efficient minimisation procedure but achieves almost identical results to previous evaluations conducted using the earlier version.
- the interim catch and effort levels assumed for the starting period (i.e. the period between the last year of the assessment (2018) and the first year in which the MP is applied (2022) is now set to the average of 2016-18 levels (previously set to 2012 levels) since these more accurately reflect fishery conditions in the recent period (see Figure 5, Appendix A).

2.1 MSE Uncertainty Grid

The operating models (OMs) are divided into a reference set and a robustness set. The reference set is considered to reflect the most plausible hypotheses of fishery and stock dynamics and forms the primary basis for selecting the 'best performing' MP. The sources of uncertainty included in the reference set (Table 1) and their respective settings are unchanged from last year.

Performance indicators are calculated from the reference set of model scenarios (see Section 3.2). At present, performance indicators are calculated assuming equal weighting for all scenarios across the grid. Alternative weighting can be applied if considered appropriate.

The robustness set comprises scenarios that are considered less likely though still plausible and are used to give a secondary indication of the performance of a reduced subset of management procedures. Work continues to finalise the outstanding elements of the OMs that will comprise the robustness set for WCPO skipjack (Scott et al., 2019).

Table 1: Skipjack OM uncertainty grid (reference set, 96 model scenarios). ‡ denotes those scenarios for which a dedicated fit of MULTIFAN-CL is required.

Axis	Levels	Options		
		0	**1**	**2**
Process Error				
Recruitment variability	**2**	**1982-2018**	**2005-2018**	
Observation Error				
Catch and effort	**1**	**20%**		
Size composition (ESS)	**1**	**estimated**		
Tag recaptures	**1**	**status quo**		
Model Error				
Steepness ‡	**3**	**0.8**	**0.65**	**0.95**
Mixing period (qtr) ‡	**2**	**1**	**2**	
Growth ‡	**2**		**low**	**high**
Movement	**1**	**estimated**		
Hyperstability in CPUE (k) ‡	**2**	**0**	**-0.5**	
Implementation Error				
Effort creep	**2**	**0%**	**2%**	

2.2 WCPO skipjack management procedures

Following SC discussions, model based management procedures (MPs) are initially being considered for WCPO skipjack. For the MPs considered here MULTIFAN-CL is used as the estimation model (EM) to determine stock status that will then be used as an input to the HCR. An examination of the performance of the EM is described in SC16-MI-IP09.

A 3 year management cycle has been assumed whereby the MP will be run once every 3 years. The management action determined by the HCR will apply for the following 3 years until the MP is run again. This assumed management cycle replicates, more or less, the timescale of the current management approach for WCPFC tuna stocks and fisheries. Note that the modeling implementation also preserves the time lag that occurs between the last year of available data (year $y-1$), running the EM (year y) and implementing the management action (year $y+1$).

3 Evaluation of Candidate Management Procedures

The MSE uncertainty grid comprises a total of 96 scenarios across the different levels of observation, process and model uncertainty. Ten iterations were run for each scenario, each having different random seeds for the generation of stochastic recruitment, catch, effort, length composition and tag recapture information. In total 960 evaluations were run for each MP.

An MP comprises the data collection protocols, an estimation method and an HCR. For the MPs considered here the data collection and estimation model do not change. It is assumed that future catch and effort reporting; biological sampling; tag release and the reporting of recaptured tags continue at their current levels. As such, the alternative MPs evaluated here differ only in the HCR.

3.1 Harvest Control Rules

The HCRs presented in this report include those considered in previous analyses as well as two additional HCRs that have been proposed by members.

The results for 6 HCRs (Table 6, Figure 1) are briefly summarised here. In each case, the output of the HCR scales catch and effort relative to 2012 levels to set fishing opportunities in the next management period. The scalar resulting from the HCR has been applied equally to effort for purse seine fisheries and to catch for all other fisheries, reflecting current management approaches.

The current assumption is that all fisheries are subject to the HCR with the exception of fisheries in archipelagic waters (specifically within assessment regions 5 and 6) for which status quo 2012 catch and effort has been assumed. Assumptions regarding the quantity of catches taken in archipelagic waters are outlined in Appendix B.

Some HCRs have additional meta-rules that constrain the magnitude of changes in catch and effort from one management period to the next. These constraints can have a large influence on the performance of an HCR particularly during the initial transition period when moving from assumed status quo fishing conditions to the management procedure. Meta-rules to constrain changes in catch and effort between management periods have been applied at the individual fishery level so that the catch or effort of any individual fishery (as defined in the OMs) does not vary by more than the specified amount. Alternative application of these constraints is possible within the evaluation framework and can be tested if so desired.

We seek further guidance and advice from SC17 on the design and scope of candidate HCRs to be considered in future evaluations, and from WCPFC17 on the control mechanism (e.g. effort) and the fisheries being controlled (e.g. all key fisheries taking skipjack).

3.2 Performance Indicators

Currently six performance indicators (PIs) are calculated for the skipjack evaluations. A further four indicators, requested by members, remain under consideration pending further discussion on how they might best be calculated or approximated. The six PIs presented here are listed in Table 2. The full list of PIs currently being developed for skipjack is detailed in Scott et al. (2018).

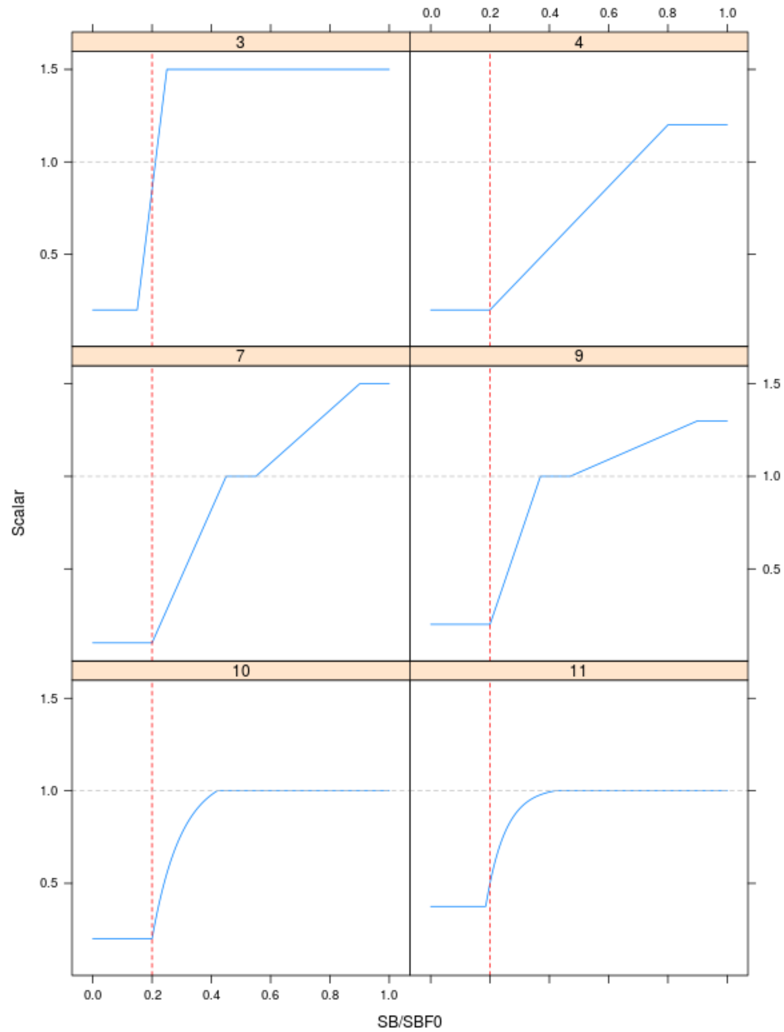

Figure 1: A selection of the harvest control rules that have been evaluated to date under the revised MSE framework for WCPO skipjack. A further HCR, based on HCR 10 but including a ±10% constraint on maximum changes to the scaler between management periods was also evaluated but is not illustrated here.

Table 2: Performance indicators examined

Indicator 1	Maintain SKJ, YFT, BET biomass at or above levels that provide fishery sustainability throughout their range.
Indicator 3	Maximise economic yield from the fishery (average expected catch).
Indicator 4	Maintain acceptable CPUE.
Indicator 6	Catch stability.
Indicator 7	Stability and continuity of market supply (effort variation relative to a reference period).
Indicator 8	Stability and continuity of market supply (probability of and deviation from $SB/SB_{F=0} > 0.5$).

3.3 Results

We provide only a brief commentary on the results to highlight particular features of the HCRs examined to date. For a more comprehensive investigation of the results we encourage members to use the PIMPLE software `https://ofp-sam.shinyapps.io/pimple/`. The updates to the evaluation framework described in section 2 have had very little impact on the results and the results presented here are very similar to those obtained from previous analyses. The evaluation of additional HCRs continues and results will be added to PIMPLE on an ongoing basis.

The HCRs considered in this report share a common basic form to reduce fishing as stock abundance approaches the LRP, although the point at which the decline in fishing starts and the rate at which it occurs differs in each case. A comparison of the performance of HCRs 10 and 4 is shown in Figure 2 which presents the overall distribution of stock status ($SB/SB_{F=0}$) resulting from the 960 evaluations of each management procedure (MP) along with trajectories of two individual runs.

The results of single model runs would not normally be investigated as there are simply too many of them in a full MSE analysis to interrogate each one individually. However, a select subset are useful in this instance to highlight a number of points, in particular, the level of expected variability in stock and fishery arising from the actual implementation of the MP; the likely behaviour of the HCR and the influence of environmental factors such as recruitment variability.

The dynamics of the fishery under the MP are likely to be more variable than the average values implied when all of the runs are plotted together. Whilst the median estimate of, for example, depletion might be very close to a target value throughout the simulations, the trajectory of depletion for individual runs will vary around this value. Performance indicators (PIs) are calculated to measure the extent of this variation. PIs 6 and 7 measure the relative inter-annual variability in catch and effort (Table 2). These PIs measure variability (or stability) for one MP relative to the other MPs being evaluated (i.e. MP 1 achieves greater stability in catch than MP 2).

The individual runs are also useful for highlighting the different characteristics and likely behavior of the HCRs. They clearly show that HCR 10 achieves much greater stability in effort than HCR 4 (Figure 2). HCR 4 maintains effort levels lower than HCR 10 resulting in reduced catches initially and a corresponding increase in stock abundance. As abundance increases, catches progressively increase eventually reaching similar levels to those achieved under HCR 10, but at lower, and more variable, effort.

Although stock abundance under HCR 4 is greater than under HCR 10 (see Figure 2, depletion plots), the inter-annual variability in depletion is quite similar because of the impact of variability in recruitment. For relatively short-lived, fast maturing species such as skipjack, variability in recruitment will rapidly manifest as variability in adult stock abundance and may, for some scenarios, be the primary driver of stock status and catch levels regardless of the HCR being employed. As a consequence, two very different HCRs (e.g. HCR 7 and HCR 11) can have almost identical performance (Figure 3). Although these HCRs have very different forms, their overall performance is quite similar and in some some instances almost exactly the same because, for the majority of runs, both HCRs maintain the stock at depletion levels close to the range at which they share a similar form ($0.4 < SB/SB_{F=0} > 0.5$). At this range of depletion, effort is held constant and any variability in stock abundance and catch results primarily from variability in recruitment.

Once an MP is adopted and implemented it should be monitored to check that it is performing as expected. As part of the monitoring strategy a stock assessment will be periodically conducted to monitor performance in terms of expected stock status. Figures 2 and 3 show that the inter-annual variability evident from the individual trajectories is greater than the relatively smooth and constant trends implied by the median values calculated across all model and iteration scenarios and in some cases individual runs fall outside the range of values plotted (Figure 4). In the examples presented here we show the 95th percentiles of estimated depletion (i.e. there is a 5% chance of exceeding the range, either above or below). In the event that the monitoring strategy shows values deviating from their expected ranges, the SC will need to provide advice to the Commission on the best course of action. Depending on the extent of the deviation, the SC may advise either to continue with the existing MP without modification; to begin exploring alternative, improved MPs or, in extreme cases, to abandon the MP immediately and pursue an alternative management arrangement.

4 Next Steps

Work will continue to further refine some of the technical components of the framework, in particular the specification of the OMs that will comprise the robustness set. However, the evaluation framework for testing candidate management procedures for WCPO skipjack is now considered to be established. Work will also continue to evaluate any additional management procedures. This will include any additional HCR designs that may be proposed. The results of these evaluations will be made available online and members can be kept appraised of progress through regular updates.

Under the revised harvest strategy workplan, the WCPFC is scheduled to agree on a management procedure for the WCPO skipjack / tropical purse seine fishery in 2022. To support the necessary discussions and decisions towards this, we seek advice from SC on:

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- Input into candidate HCR designs;
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- Procedures for selecting the 'best performing' MP.

Acknowledgments

We gratefully acknowledge funding for this work from the New Zealand Ministry of Foreign Affairs and Trade (MFAT) funded project "Pacific Tuna Management Strategy Evaluation". In addition we thank both the Center for High Throughput Computing (CHTC UW-Madison) and the New Zealand eScience Infrastructure (NeSI) for generously providing access to their computing resources.

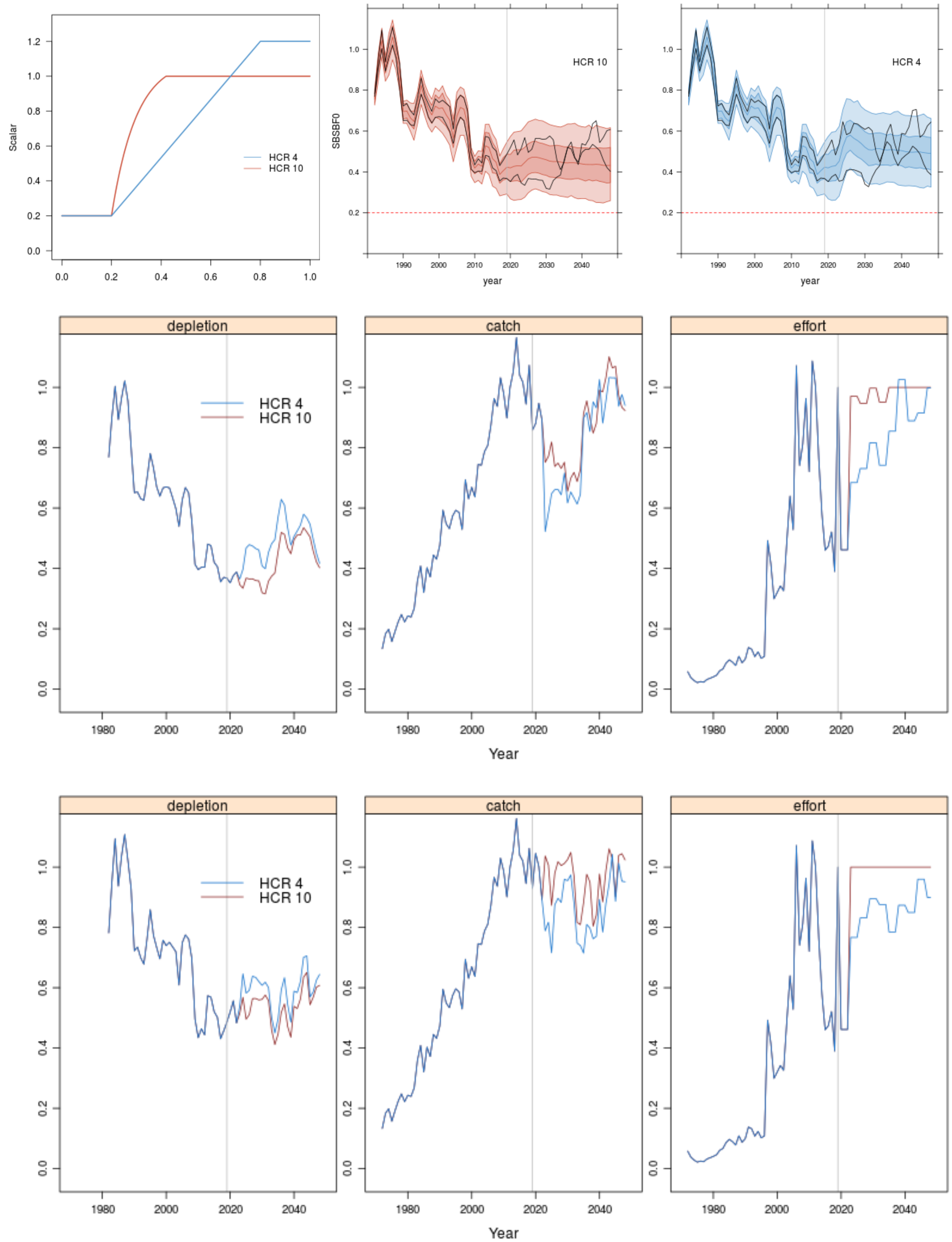

Figure 2: Comparative output for two MPs showing the form of the HCRs and the distributions (95th and 60th percentiles) of stock status as calculated across the full suite of OM and iteration scenarios (top row), black lines show the individual trajectories of stock status for individual runs (iterations 27 and 707) for each MP. Middle and bottom rows show stock status, total catch and purse-seine effort (relative to 2012) for the same two individual runs (OM and iteration combination, iterations 27 and 707).

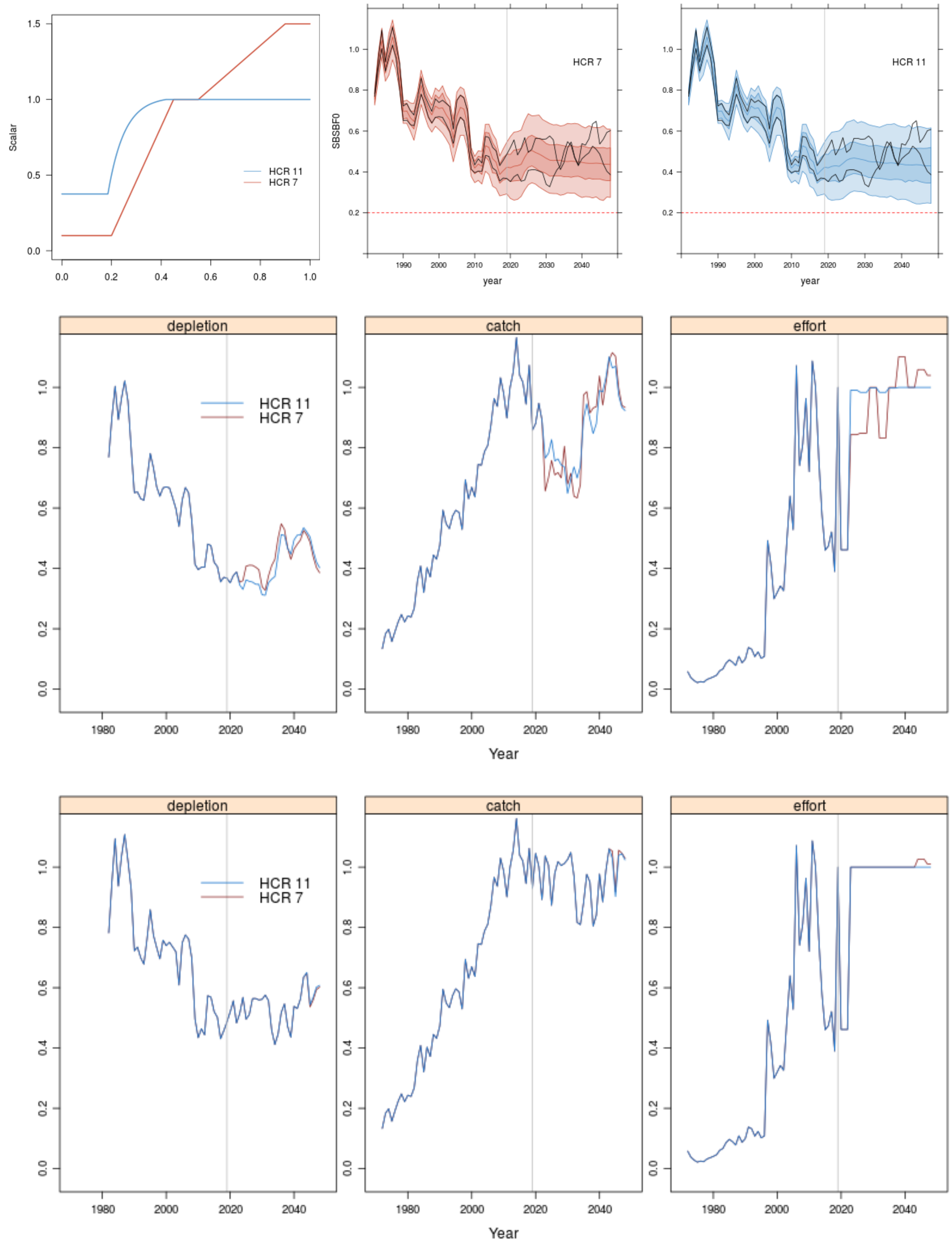

Figure 3: Comparative output for two MPs showing the form of the HCRs and the distributions (95th and 60th percentiles) of stock status as calculated across the full suite of OM and iteration scenarios (top row), black lines show the individual trajectories of stock status for individual runs (iterations 27 and 707) for each MP. Middle and bottom rows show stock status, total catch and purse-seine effort (relative to 2012) for the same two individual runs (OM and iteration combination, iterations 27 and 707).

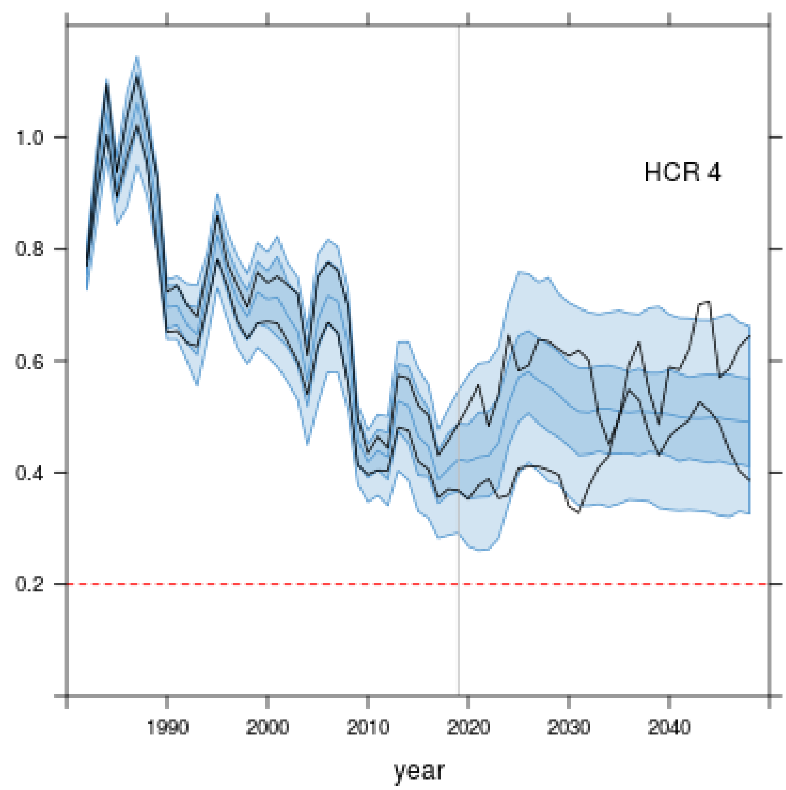

Figure 4: (Inset from Figure 2) Distribution of expected stock status ($SB/SB_{F=0}$) resulting from HCR 4. Blue ribbons show the 95th and 60th percentiles and median values. Black squiggly lines show the individual trajectories for two OM iteration combinations (iteration 27, OM A1B0C1D0E0F0 and iteration 707, OM A2B1C2D0E0F1). Vertical grey line denotes the start of the evaluation period.

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A Management procedure details

A.1 Data collection

The evaluations assume that current data collection protocols (including catch and effort reporting, biological sampling, tag release programs, tag recapture reporting and, where relevant, CPUE standardisation) will continue into the future.

A.2 Estimation model settings

The estimation model provides an estimate of stock status based on an update assessment using MULTIFAN-CL (version 2.0.8.0). The settings of the update model are based on those of the 2019 diagnostic case assessment for WCPO skipjack.

Table 3: Fixed model settings for the estimation model.

Model Setting		**Value**
Region structure		8 regions
Steepness		0.8
Length comp wtg		100
Tag mixing period		1 qtr
VonB growth params	L_{min}	25.7051
	L_{max}	78.0308
	k	0.212
Hyperstability in CPUE		0

The estimation model is run in 3 phases with the catch penalty weighting (age flag 144) being successively increased (100, 10,000, 100,000) in each phase. Phases 1 and 2 are each run for 100 function evaluations and phase 3 for 1000 function evaluations. Stock status is determined from the results of phase 3 as $SB/SBF0_{latest}$.

A.3 HCR parameterisation

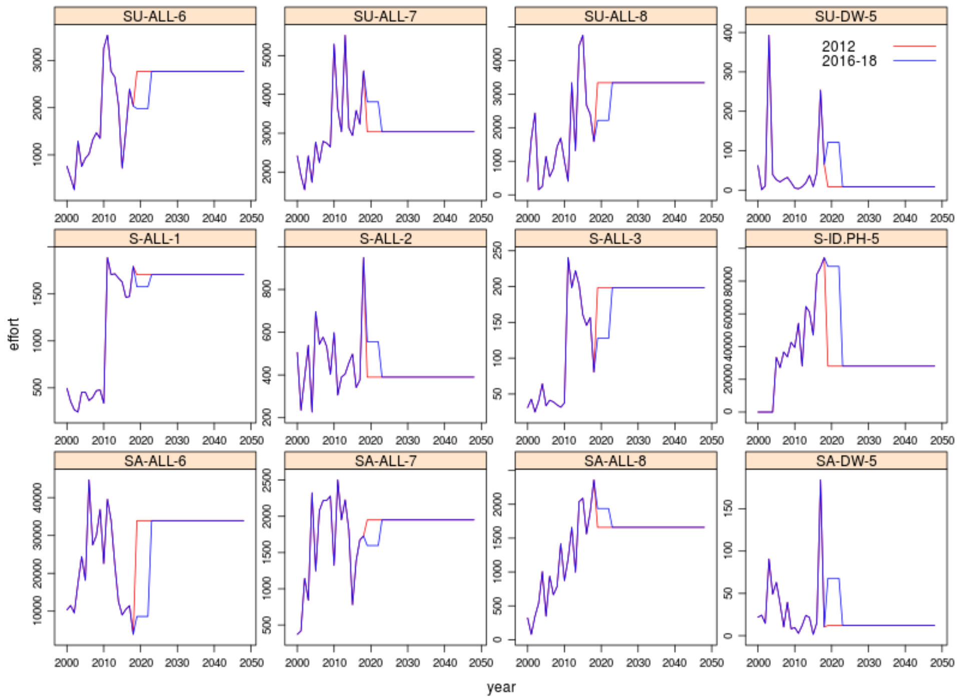
For each 3 year management period, the harvest control rule uses the estimate of stock status ($SB/SB_{F=0}$ in the terminal year, as determined by the estimation model) to calculate a value that scales catch and effort up or down relative to 2012 catch and effort levels. The resulting scaled catch and effort values set the fishing opportunities for the next 3 years (Table 4).

This implementation preserves the time lag between the last year for which data are available ($year = y - 1$), the year in which the management procedure is run ($year = y$) and the year in which the prescribed management action is implemented ($year = y + 1$).

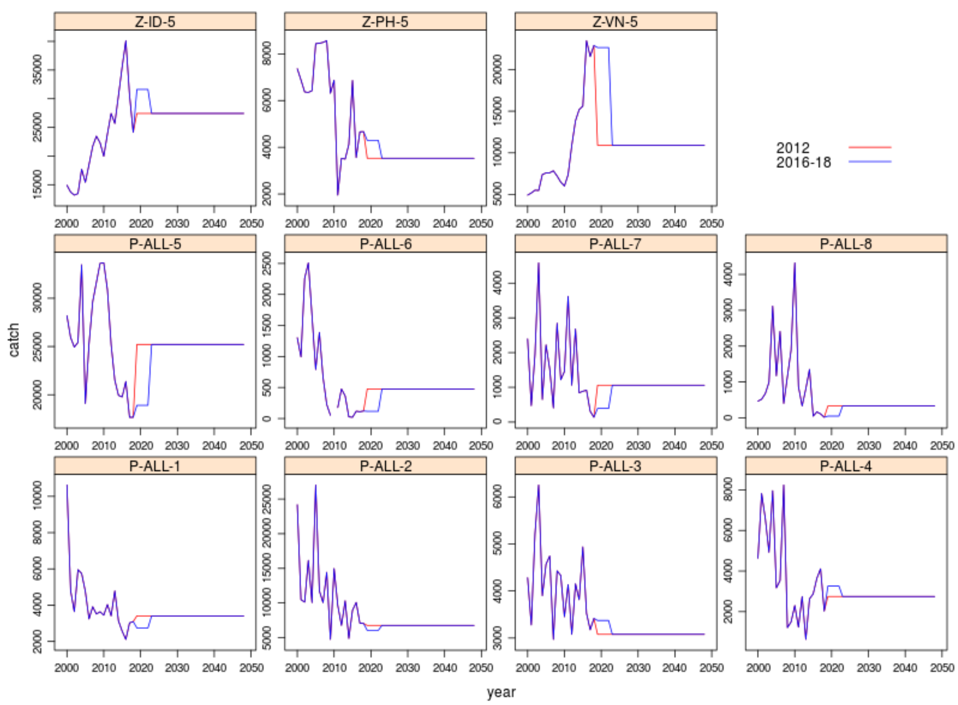
Table 4: Management cycle.

Period		**interim**			**1**			**2**			
Year	2019	2020	2021	2022 run MP	2023	2024	2025 run MP	2026	2027	2028 run MP	...

The harvest control rule returns a single scalar that is used to increase or decrease the allowable catch or effort for the following management period. Fisheries are managed either by catch or effort according to table 5



(a) Purse seine fisheries managed through effort.



(b) Non-purse seine fisheries managed through catch.

Figure 5: Annual catch and effort for WCPO skipjack fisheries under two alternative assumptions (average 2012 or average 2016-18) for the interim year period (2019 to 2022). After the interim period the catch and effort level is scaled up or down by the HCR using average 2012 catch and effort as the baseline.

A.3.1 Threshold

$$gradient = \frac{S_{max} - S_{min}}{D_{max} - D_{min}}$$

$$intercept = S_{min} - (gradient.D_{min})$$

$$S = min\left(max\left(\text{SBSBF0}.gradient + intercept, S_{min}\right), S_{max}\right) \tag{1}$$

A.3.2 Asymptotic

$$p = \frac{S_{max}}{e^{-\theta.D_{max}}} - \frac{S_{min}}{e^{-\theta.D_{min}}}$$

$$q = \frac{1 - S_{max}/e^{-\theta.D_{max}}}{S_{max}/e^{-\theta.D_{max}}}$$

$$r = \frac{1 - S_{min}/e^{-\theta.D_{min}}}{S_{min}/e^{-\theta.D_{min}}}$$

$$a = \frac{p}{q - r}$$

$$b = \frac{S_{min} - a.\left(1 - e^{-\theta.D_{min}}\right)}{e^{-\theta.D_{min}}}$$

$$S = max\left(min\left(a - (a - b) * e^{-\theta.\text{SBSBFO}}, S_{max}\right), S_{min}\right) \tag{2}$$

A.3.3 Hillary Step

The Hillary step HCR is constructed using the same formulation as the threshold HCR. It comprises two threshold HCRs with parameter values set depending on whether SBSBF0 is greater or less than the $step_{min}$ value.

Table 5: Management metric (catch or effort) for fisheries under control of the WCPO skipjack management procedure .

	Name	Region	Metric	MP Control
1	P-ALL-1	1	catch	full
2	S-ALL-1	1	effort	full
3	L-ALL-1	1	catch	none - assumed constant
4	P-ALL-2	2	catch	full
5	S-ALL-2	2	effort	full
6	L-ALL-2	2	catch	none - assumed constant
7	P-ALL-3	3	catch	full
8	S-ALL-3	3	effort	full
9	L-ALL-3	3	catch	none - assumed constant
10	Z-PH-5	5	catch	full
11	Z-ID-5	5	catch	none - AW assumed constant
12	S-ID.PH-5	5	effort	partial - AW correction
13	P-ALL-5	5	catch	partial - AW correction
14	SA-DW-5	5	effort	full
15	SU-DW-5	5	effort	full
16	Z-VN-5	5	catch	full
17	L-ALL-5	5	catch	none - assumed constant
18	P-ALL-6	6	catch	full
19	SA-ALL-6	6	effort	partial - AW correction
20	SU-ALL-6	6	effort	partial - AW correction
21	L-ALL-6	6	catch	none - assumed constant
22	P-ALL-4	4	catch	full
23	L-ALL-4	4	catch	none - assumed constant
24	P-ALL-7	7	catch	full
25	SA-ALL-7	7	effort	full
26	SU-ALL-7	7	effort	full
27	L-ALL-7	7	catch	none - assumed constant
28	P-ALL-8	8	catch	full
29	SA-ALL-8	8	effort	full
30	SU-ALL-8	8	effort	full
31	L-ALL-8	8	catch	none - assumed constant

A.3.4 HCR parameters

Table 6: Settings for the HCRs. HCR7 is the same as HCR1 but incorporates an additional meta-rule to constrain the scaler to no more than a 15% change from one management period to the next. The numbering of the HCRs has been retained from previous reports to aid comparison.

HCR	**Type**	**Parameters**								
		$SB/SBF0_{min}$	$SB/SBF0_{max}$	$scaler_{min}$	$scaler_{max}$	$curve$	$step_{min}$	$step_{max}$	$height$	$constraint$
3	threshold	0.2	0.25	0.2	1.5					
4	threshold	0.2	0.8	0.2	1.2					
9	stepped	0.2	0.9	0.2	1.3		0.37	0.47	1.0	
10	asymptotic	0.2	0.42	0.2	1.0	1.0				
10	asymptotic	0.2	0.42	0.2	1.0	1.0				10%
11	stepped	0.2	0.9	0.2	1.5		0.45	0.55	1.0	
12	asymptotic	0.185	0.42	0.375	1.0	15				

B Archipelagic waters

In some instances, fisheries operating within archipelagic (sovereign) waters may be subject to alternative management arrangements, either through a formal management strategy developed at a local level, or through national legislation. Those fisheries will not be subject to direct control by the regional WCPFC wide harvest strategy. It is therefore necessary to exclude those fisheries that operate in archipelagic waters from the control of the management procedure.

Archipelagic waters are declared within the EEZs of several WCPFC members but in many instances the catches taken within them are comparatively small. However, catches of skipjack tuna within the archipelagic waters of PNG and the Solomon Islands and also in the archipelagic waters of Indonesia and the Philippines represent a larger proportion of total catches and need to be treated appropriately within the evaluations.

The evaluations described in this report have been based on the assumptions outlined below. However, guidance is sought from relevant CCMs on the specific assumptions that should be made within the MSE regarding management arrangements for archipelagic waters.

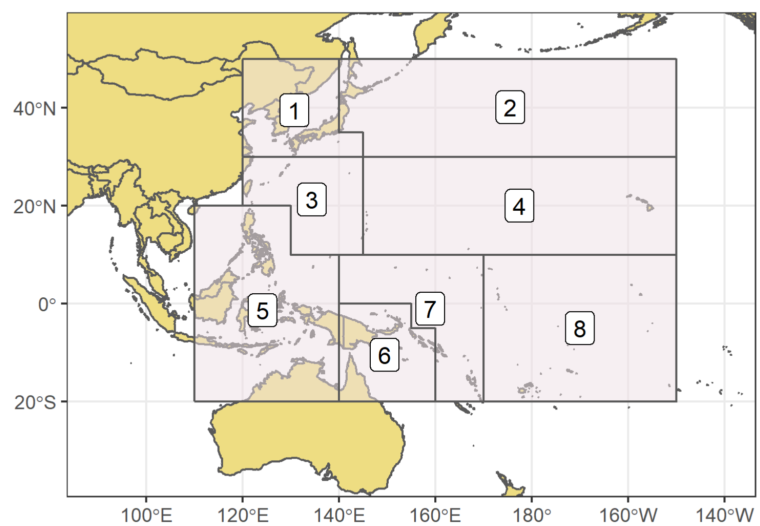


Figure 6: Spatial structure of the 2019 WCPO skipjack assessment.

B.1 PNG and Solomon Island archipelagic waters

The archipelagic waters correction is based on the total fishing effort in 2012 and on the effort of the purse seine fisheries in region 6 of the 2019 assessment (SA-ALL-6 and SU-ALL-6 prior to standardisation). The effort correction is a simple scaler based on the proportion of 2012 fishing effort inside and outside AWs (Eqn.1). This is exactly the same approach as that used for the first round of evaluations.

$$S_6 = \frac{S_{HCR}.E_{EEZ-AW} + E_{AW}}{E_{EEZ-AW} + E_{AW}} \tag{3}$$

where:

S_6	adjusted effort scaler to be applied to Region 6 purse seine fisheries
S_{HCR}	effort scaler determined from the harvest control rule
E_{EEZ-AW}	fishing effort outside of AWs in 2012
E_{AW}	fishing effort inside of AWs in 2012

B.2 Indonesian archipelagic waters

The Indonesian archipelagic waters correction is based on catch because effort data for this region are considered less reliable and cannot be separated into inside and outside AW components. Approximately 65% of catches within the Indonesian EEZ are taken from archipelagic waters for which a separate harvest strategy is being developed (Hoshino et al., 2020). The fishery definitions used in both the stock assessment and the operating models for this region separates the purse seine fisheries into distant water (associated and unassociated) and a combined Indonesia and Philippines purse seine fishery. The pole and line fishery also operates throughout the area and takes significant catches.

Calculation of the percentage split (inside to outside AW) to be applied to the fisheries is difficult due to high levels of inter-annual variability in catch statistics for this assessment area. For the evaluations presented in this report it has been assumed that skipjack catches within archipelagic waters comprise:

- All catches from the Indonesian domestic fishery (fishery 11)
- 50% of the catches from the combined Indonesia and Philippines PS fishery (fishery 12)
- 50% of the catches from the pole and line fishery (fishery 13)

These assumptions are broadly consistent with those of Hoshino et al. (2020) but can be modified if other values are considered more appropriate. We note also that the domestic fisheries of the Philippines will also occur predominantly in archipelagic waters and may also need to be included in the above.

C Evaluation software and input data

The evaluations are run from R (R Core Team, 2020) and use MULTIFAN-CL as the principle data generator to modify and update the operating models at each time increment. The R package FLR4MFCL is used extensively to manage the associated input and output files from MFCL and to calculate the performance indicators from the evaluation results. The run-time for a single evaluation (OM, MP, iteration) is quite long (around 15 hours depending on processing power) and the evaluations are therefore run over a distributed computing network. Currently these include The CHTC HTCondor facilities at the University of Wisconsin and the HPC platform of the New Zealand eScience Infrastructure (NeSI).

All of the input objects, data files, code and software necessary to run the evaluations can be accessed via a number of repositories. These repositories are either public and freely accessible, or can be accessed with login credentials available on request from OFP-SAM, SPC (contact the authors for more information).

- FLR4MFCL `https://github.com/PacificCommunity/ofp-sam-flr4mfcl` can be downloaded from a public github repository, including information on how to install package dependencies.
- MULTIFAN-CL is available on request via the website `https://mfcl.spc.int/`. Both MULTIFAN-CL and FLR4MFCL are under continued development. The current set of evaluations have been run using MULTIFAN-CL version 2.0.8.0. and FLR4MFCL version 1.3.2.
- the input objects, data files and code necessary to run the evaluations is hosted on GitHub and can be accessed at `https://github.com/PacificCommunity/ofp-sam-MSE`.