SCIENTIFIC COMMITTEE
SIXTEENTH REGULAR SESSION
Online
11–20 August 2020

Results of re-evaluations of management procedures for skipjack tuna in the WCPO.

WCPFC-SC16-2020/MI-IP-03

R. Scott[1], F. Scott, G. M. Pilling, P. Hamer and J. Hampton

[1]Oceanic Fisheries Programme, The Pacific Community

Contents

Executive Summary

This paper, along with the information presented in supporting papers to this SC, provides the latest information on the MSE framework for WCPO skipjack and the work undertaken to test candidate management procedures (MPs). It presents a summary of the results of recent evaluations and considers the next steps that will need to be taken as scheduled in the harvest strategy work-plan as updated by WCPFC16.

MSE results have previously been presented to WCPFC-SC15 using an evaluation framework based on the 2016 skipjack assessment. We present a similar set of the results available to date, based on the updated OM grid of the 2019 skipjack stock assessment described in SC16-MI-IP08. Of particular interest is whether the changes made to update the OM grid lead to a very different set of results with regards the performance of the MPs. The uncertainty included in the OM grid should span the likely range of values resulting from new assessments. If the results differ markedly from previous evaluations it might indicate that important sources of uncertainty are not adequately represented in the reference set of MSE scenarios. However, the results of the updated evaluations presented here are similar to those obtained under the previous OM grid.

In addition we outline assumptions for how archipelagic waters are treated within the evaluations. Guidance is sought from relevant CCMs on the specific assumptions that should be made within the MSE regarding management arrangements for archipelagic waters.

Under the revised harvest strategy workplan, the WCPFC is scheduled to agree 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:

- Input into candidate HCR designs;
- Feedback on presentational approaches to enhance decision making;
- 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;
- Procedures for selecting the ‘best performing’ MP.

1 Introduction

In accordance with the workplan for the adoption of harvest strategies under CMM2014-06, SC16 is scheduled to provide advice on the performance of candidate management procedures (MPs) for skipjack. This paper, along with the information presented in supporting papers to this SC, provides the latest information on the MSE framework for WCPO skipjack and the work undertaken to test candidate MPs. It presents a summary of the results of recent evaluations and considers the next steps that will need to be taken as scheduled in the harvest strategy work-plan as updated by WCPFC16. This paper should be considered alongside a number of other papers presented to this SC:

- MI-IP-08 describes the current status of the management strategy evaluation (MSE) modeling framework for skipjack in the WCPO. The framework has been updated in accordance with the most recent assessment of WCPO skipjack (Vincent et al., 2019). The most recent assessment for WCPO skipjack made a number of changes to the assessment model including a shift from a 5-region to an 8-region spatial structure.
- 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.
- MI-IP-10 describes the model settings currently 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.
- 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.

MSE results have previously been presented to WCPFC-SC15 (Scott et al., 2019c) using an evaluation framework based on the 2016 skipjack assessment (McKechnie et al., 2016). In this paper we present a similar set of the results available to date, based on the updated OM grid of the 2019 skipjack stock assessment (see SC16-MI-IP08). Of particular interest is whether the changes made to update the evaluation framework lead to a very different set of results with regards the performance of the MPs. When evaluating MPs we test their robustness to uncertainty. This uncertainty should span the likely range of values resulting from new assessments. If the results differ markedly from previous evaluations it might indicate that important sources of uncertainty may not be adequately represented in the reference set of MSE scenarios.

Similar to last year we present here 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 results of evaluations conducted for WCPFC harvest strategies. Work to complete the full set of evaluations continues. The information available in PIMPLE will be progressively updated as new results become available.

2 The MSE Framework for WCPO Skipjack

2.1 MSE Uncertainty Grid

The revised skipjack OM grid based on the updated 2019 assessment is very similar to the previous OM grid based on the 2016 stock assessment. The axes of uncertainty considered in the reference set (Table 1) and their respective settings have changed very little.

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 candidate subset of management procedures. Work continues to finalise the outstanding elements of the robustness set (Scott et al., 2019b).

Performance indicators are calculated for the reference set of model scenarios and are the primary source of information for selecting the 'best' management procedure (see Section 3.2). At present, performance indicators are calculated assuming equal weighting for all scenarios across the grid. Alternative weighting can be applied where considered appropriate.

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**		
DD catchability (k) ‡	**2**		**0**	**-0.5**
Implementation Error				
Effort creep	**2**		**0%**	**2%**

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

2.2 WCPO skipjack management procedures

Model based management procedures (MPs) are, in the first instance, being considered for WCPO skipjack. For the MPs considered here MULTIFAN-CL is used as the estimation model (EM) to determine an estimate of stock status that will be used to 'drive' the HCR. An examination of the performance of the EM is described in SC16-MI-IP09.

3 Re-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. The alternative MPs evaluated here differ only in the HCR.

3.1 Harvest Control Rules

The HCRs considered in this report are the same as those considered in previous analyses. They have been primarily selected by SPC to try to show a range of potential outcomes and to achieve some contrast in the performance indicators. The results for five HCRs (Table 2, Figure 1) are summarised here. In each case, the output of the HCR scales the 2012 catch or effort to determine fishing opportunities in the next management period. The scaler 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 assumption has currently been made 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 effort has been assumed. Assumptions regarding the quantity of catches taken in archipelagic waters are outlined in Appendix A. We seek further guidance and advice from SC16 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

HCR	Type	Parameters				
		$SB/SBF0_{min}$	$SB/SBF0_{max}$	$scaler_{min}$	$scaler_{max}$	$constraint$
1	threshold	0.2	0.6125	0.2	1.3	
2	threshold	0.2	0.4	0.2	1.0	
3	-					
4	threshold	0.2	0.8	0.2	1.2	
5	threshold	0.2	0.4	0.5	1.0	
6	-					
7	threshold	0.2	0.6125	0.2	1.3	15%

Table 2: 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.

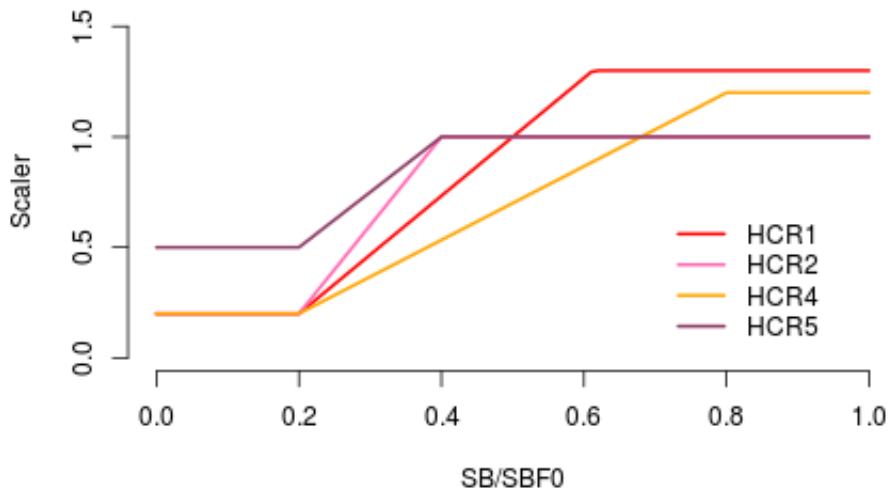


Figure 1: The harvest control rules (1,2,4 and 5) that have been evaluated to date under the revised MSE framework for WCPO skipjack. A further HCR, based on HCR1 but including a ±15% constraint on maximum changes to the scaler between management periods was also evaluated (HCR7).

how they might best be calculated or approximated. The six PIs presented here are listed in Table 3. The full list of PIs currently being developed for skipjack are detailed in Scott et al. (2018).

3.3 Results

The results for the skipjack harvest strategy evaluations presented here, based on the updated (8-region) OM grid, represent an almost complete set of evaluations for HCR1, HCR2 and HCR5. At the time of compiling this report the results for HCR4 comprised only 672 of the 960 iterations.

We provide only a very brief commentary on the results obtained so far to highlight particular features for SC16 consideration. For a more comprehensive investigation of the results we encourage members to use the PIMPLE software which can be accessed at the following address https://ofp-sam.shinyapps.io/pimple. The evaluation of additional HCRs continues and results will be added to PIMPLE on an ongoing basis.

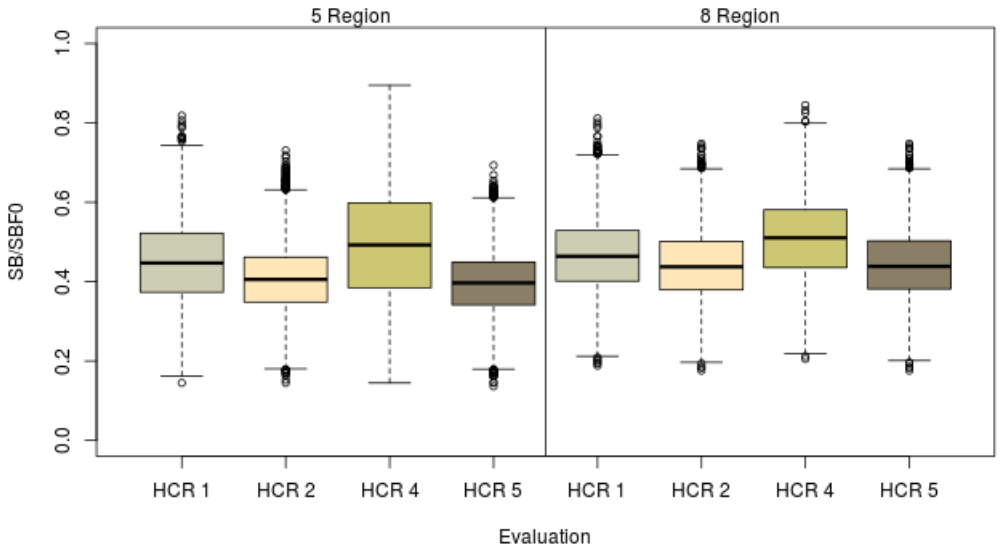
Of particular interest is whether the results of the evaluations differ substantially between the current and previous evaluation frameworks. The scenarios included in the MSE uncertainty grid (Table 1) should span the likely range of values, including those resulting from new assessments.

The results of the updated evaluations are similar to those obtained under the previous (5-region) OM grid. Although the results may differ slightly in terms of absolute levels it is the difference in the relative performance of the HCRs that is of greatest interest since, ultimately, the basis for selecting an MP will be based on how well it performs in relation to other candidate MPs.

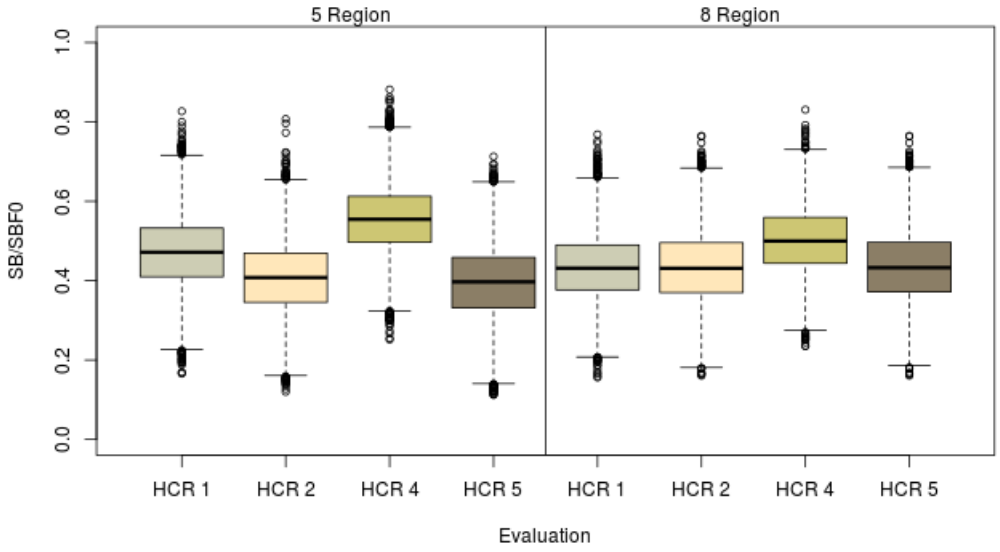
Estimates of stock depletion (Figure 2a) show similar relative performance between the two sets of evaluations particularly in the short-term. In the long-term the relative performance of HCR1 differs slightly to previous evaluations but overall the difference is small. Although some small differences are apparent and a full set of results has not yet been obtained, the very similar pattern of results to the previous evaluations shows that, even with the new stock assessment and the updated OM grid, the HCRs exhibit similar relative performance and the ultimate choice of the 'best' HCR would be the same (or at least not radically different).

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 $SB/SB_{F=0} > 0.5$).

Table 3: Performance indicators examined



(a) Short-term results.



(b) Long-term results.

Figure 2: Comparison of depletion ratios under the four HCRs from the previous OM grid (based on the 5 region, 2016 assessment) and the updated OM grid (based on the 8 region, 2019 assessment).

4 Next Steps

Work will continue to further refine some of the technical components of the framework, in particular for the generation of simulated data (see SC16-MI-IP10), however, the evaluation framework for testing candidate management procedures for WCPO skipjack is now considered relatively well 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 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:

- Input into candidate HCR designs;
- Feedback on presentational approaches to enhance decision making;
- 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;
- 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 the Center for High Throughput Computing (CHTC UW-Madison) for generously providing access to their computing resources.

References

Hoshino, E., Hillary, R., Davies, C., Satria, F., Sadiyah, L., Ernawati, T., and Proctor, C. (2020). Development of pilot Empirical harvest control rules for tropical tuna in Indonesian archipelagic waters: Case studies of skipjack and yellowfin tuna. *Fisheries Research*, 227(doi.org/10.1016/j.fishres.2020.105539).

McKechnie, S., Hampton, J., Pilling, G. M., and Davies, N. (2016). Stock assessment of skipjack tuna in the western and central Pacific Ocean. WCPFC-SC12-2016/SA-WP-04, Bali, Indonesia, 3–11 August 2016.

OFP (2018). Key decisions for managers and stakeholders under the harvest strategy approach for WCPO tuna stocks and fisheries. WCPFC-SC14-2018/MI-WP/05, SPC-OFP, Busan, Republic of Korea, 8-16 August 2018.

Punt, A. E., Butterworth, D., de Moor, C., De Oliveira, J., and Haddon, M. (2014). Management strategy evaluation: best practices. *Fish and Fisheries*, (DOI:10.111/faf12104).

Scott, F., Scott, R., Yao, N., Pilling, G., and Hampton, J. (2019a). Harvest strategy engagement tools. WCPFC-SC15-2019/MI-WP-09, Pohnpei, Federated States of Micronesia, 12–20 August 2019.

Scott, F., Scott, R., Yao, N., Pilling, G., and Hampton, J. (2019b). Modelling key uncertainties in skipjack management strategy evaluation. WCPFC-SC15-2019/MI-WP-06, Pohnpei, Federated States of Micronesia, 12–20 August 2019.

Scott, F., Scott, R. D., Pilling, G., and Hampton, J. (2018). Performance indicators for comparing management procedures using the MSE modelling framework. WCPFC-SC14-2018/MI-WP-04, Busan, South Korea, 5–13 August 2018.

Scott, R. D., Scott, F., Yao, N., Pilling, G., and J., H. (2019c). Results of inital evaluations of management procedures for skipjack. WCPFC-SC15/MI-WP-05, , Pohnpei, Federated States of Micronesia, 12–20 August 2019.

Vincent, M., Pilling, G. M., and Hampton, J. (2019). Stock assessment of skipjack tuna in the western and central pacific ocean. WCPFC-SC15-2019/SA-WP-05 (rev 2), Pohnpei, Federated States of Micronesia. 12-20 August, 2019.

A 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 following assumptions. However, guidance is sought from relevant CCMs on the specific assumptions that should be made within the MSE regarding management arrangements for archipelagic waters.

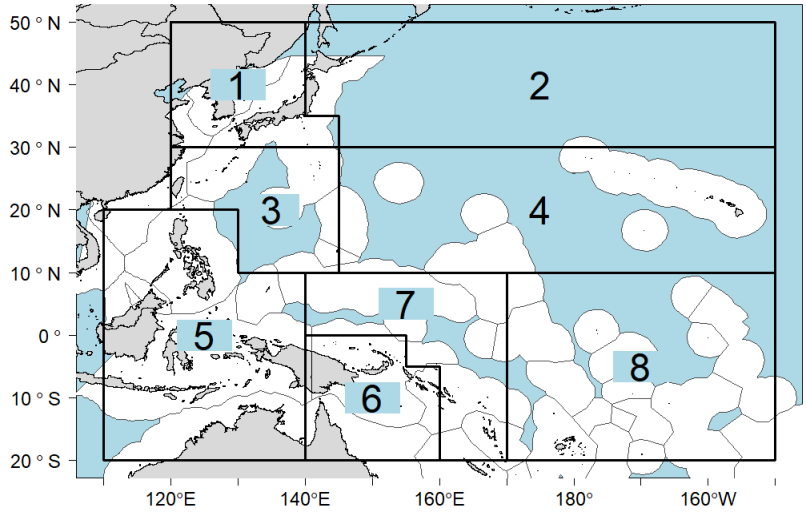


Figure 3: Spatial structure of the 2019 WCPO skipjack assessment.

A.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.

$$S_6 = \frac{S_{HCR}.E_{EEZ-AW} + E_{AW}}{E_{EEZ-AW} + E_{AW}} \quad (1)$$

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

A.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.