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Further updates to WCPO skipjack tuna projected stock status to inform consideration of an updated target reference point

WCPFC-SC18-2022/MI-WP-09

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Foreword

This paper was prepared for and presented at WCPFC18 in response to recommendations from SC17 (WCPFC18-2021-10), and results were included within WCPFC18-2021-15 to inform tropical tuna CMM discussions. Versions of this paper have been presented at earlier SC and Commission meetings. For SC18, results are also repeated in SC18-MI-IP-09. All analyses were based upon the agreed 2019 skipjack assessment.

The WCPFC18 Summary Report contains a summary of the content of WCPFC18-2021-10, and notes comments by several members. The WCPFC18 outcomes were (p.20):

> 100. The Commission noted the presentation by SPC and advice from SC17 on possible formulations of a TRP for skipjack tuna.
> 101. The Commission noted the importance of agreeing on TRP for skipjack and agreed to progress this work in 2022.

We draw to the attention of SC18 that functionality within MULTIFAN-CL for stochastic projections under the 'catch conditioned' approach taken for the 2022 skipjack assessment is not currently available but is under development. At present, deterministic projections have been performed (see SC18-SA-WP-01, Section 15.3). The 2022 assessment and grid of models used for management advice and the basis for the TRP recalibration also require agreement by SC18. We do not recommend that these results be used as the formal basis for a recalibration of the skipjack TRP value based on the 2022 assessment.

We also take this opportunity to highlight the role of the 'formal stock assessment' and associated recalibrated TRP value within the monitoring strategy where a management procedure has been adopted. Within the harvest strategy framework, the scenarios represented in the operating model (OM) grid will most likely be different from those represented in the most recent stock assessment and it will be unlikely that both sets of models provide the same median estimate of stock status (i.e., the basis of the TRP). Using an historical baseline as the basis of the TRP is therefore a useful approach (e.g. 2012 depletion levels and the depletion reached under 2012 conditions).

When testing and selecting management procedures (MPs), the performance of each candidate MP will be evaluated *relative* to the historical baseline conditions as estimated from the models of the OM grid. When using the 'formal stock assessment' to monitor the performance of an adopted MP the *relative* performance against that same historical baseline will be used, only this time using the estimates from the stock assessment. In this way the stock assessment can be used to monitor the performance of the MP even though the absolute estimates of stock status may differ from those of the OM grid. The table below summarises the *relative* position of the recent stock status from the most recent 3 skipjack assessments to a recalibrated TRP consistent with 2012 levels/status reached under 2012 conditions, and relative to 50%$SB_{F=0}$ (CMM 2015-06).

Assessment Year	SKJ level equivalent to 2012/2012 conditions	Median $SB_{recent}/SB_{F=0}$	$SB_{recent}/SB_{F=0}$ relative to:	
			2012/2012 conditions	50%$SB_{F=0}$
2016	50%	49%[1]	0.98	0.98
2019	42%	44%[2]	1.04	0.88
2022	~55%[3]	51%	0.93	1.02

[1] SB_{recent} used here for consistency with other values

[2] value from weighted grid

[3] preliminary results based on un-adopted 2022 assessment and deterministic projections, as an example. The two objectives here considered to have equal weighting.

Executive Summary

The 2019 agreed WCPO skipjack tuna assessment incorporated new information on stock biology (e.g. the pattern of maturity-at-length), a new spatial structure, and new model settings. In a similar way to the assessment of WCPO bigeye tuna performed in 2017, this changed the perception of stock status and its productivity compared to the model upon which decisions on the skipjack iTRP were based (CMM 2015-06). This paper presents a comparable analysis to that of WCPFC-MOW-WP-03, using the agreed 2019 skipjack assessment, and indicates changes in effort and biomass (depletion) from 2012 and recent (2015-2018 average) levels, and median equilibrium yield (as a proportion of MSY) associated with strategies that maintain a median of spawning biomass depletion ($SB/SB_{F=0}$) at Commission-specified depletion levels. These are compared to the results under 2012 'baseline' fishing levels (2012 effort levels in the purse seine fishery, recent catch levels in Indonesia/Philippines/Vietnam domestic fisheries).

WCPFC17 requested examination of candidate revised interim skipjack TRPs between 36% and 50% of $SB_{F=0}$, which are presented here. In 2021, the TTMW1 requested these analyses also report fishing mortality levels consistent with those % $SB_{F=0}$ levels, along with the change in biomass (depletion) from 2007-2009 average levels. These are presented herein to ensure all information is contained in one place. For brevity, the other information requested by WCPFC16 to aid discussions (paras 258 and 259 of the WCPFC16 Summary Report), which were reported to previous meetings, are not repeated in the main body of this paper but are provided in Annex 3 (covering the formulation of TRPs and the impact of effort creep estimated in relation to TRPs).

Under baseline (2012) fishing levels the stock is predicted, on average, to fall slightly compared to 'recent' (2015-2018) levels (44% $SB_{F=0}$), to 42% $SB_{F=0}$. This is very slightly below 2012 depletion levels but is an equivalent % $SB_{F=0}$ value at 2 decimal places. Examining the four other median depletion levels requested by WCPFC16 (50%, 48%, 46% and 44% $SB_{F=0}$), these levels imply reductions in purse seine effort from 2012 levels of 7 to 25%, lead to predicted increases in spawning biomass from 2012 levels of between 3 and 18%, and either maintained biomass at recent assessed levels, or predict an increase in biomass by 5 to 13%. Total equilibrium yield is predicted to reduce compared to that under 2012 'baseline' levels, to 78-95% of MSY. For the three median depletion levels requested by WCPFC17 (36%, 38% and 40%), these levels imply increases in purse seine effort from 2012 levels of between 5 and 30%, and lead to predicted decreases in spawning biomass from 2012 levels of between 5 and 14%. Total equilibrium yield is predicted to increase very slightly compared to that under 2012 'baseline' levels, to 98% of MSY (reaching the flatter peak of the yield curve). There was no risk of falling below the LRP associated with any of these depletion levels based on the current uncertainty framework.

To address the request of the TTMW1 for estimated fishing mortality under each candidate depletion level, resulting stock-wide age-averaged F for juvenile and adult components of the population and median fishing mortality-at-age are presented. Interpretation of the results is challenging given that future fishing mortality is strongly influenced by the required settings within the projection, in particular that future domestic fishery and pole-and-line catches continue at set levels (2016-2018 and 2012 respectively), while purse seine is projected on effort. The composition of gears within the projected fishery and their impacts on the stock will therefore change relative to that in the historical (2012) period. This is clear when examining the relative change in fishing mortality in juvenile and adult segments of the population, with that on juveniles increasing notably at all examined depletion levels. This was driven by significant increases in fishing mortality within Region 5 of the skipjack assessment model (western tropical WCPO encompassing Indonesia and Philippines), where future domestic fishery catches continue at 2016-2018 levels.

Median depletion levels of skipjack tuna (SB/SBF=0) and corresponding change1 in biomass from 2007-2009, 2012, 2012-15 and 2015-18 average levels, change in purse seine effort (scalar), resulting median total equilibrium yield (as a percentage of MSY) and the risk of falling below the LRP. Results under baseline fishery conditions indicated by shaded row.

Median depletion level (%$SB_{F=0}$)	Change in spawning biomass (%$SB_{F=0}$) from 2007-2009 levels	Change in spawning biomass (%$SB_{F=0}$) from 2012 levels	Change in spawning biomass (%$SB_{F=0}$) from 2012-2015 average	Change in spawning biomass (%$SB_{F=0}$) from 2015-2018 average	Change in PS effort from 2012 levels*	Median total equilibrium yield (%MSY)**	Risk $SB/SB_{F=0}$ < LRP
50%	-17%	+18%	+2%	+13%	-25%	78%	0%
48%	-19%	+14%	-1%	+10%	-21%	81%	0%
46%	-23%	+9%	-6%	+5%	-15%	87%	0%
44%	-27%	+3%	-10%	0%	-7%	95%	0%
42%	-30%	-2%	-15%	-5%	0%	97%	0%
40%	-32%	-5%	-18%	-8%	+5%	98%	0%
38%	-35%	-10%	-22%	-13%	+20%	98%	0%
36%	-39%	-14%	-25%	-16%	+30%	98%	0%

* '2012' conditions as described in the main text. No future 'effort creep' assumed, i.e. CPUE is assumed proportional to abundance.

** Recalculated using estimated equilibrium catch at defined fishing level

Fishing mortality estimated under each median skipjack tuna depletion level ($SB/SB_{F=0}$), calculated as the stock-wide age-averaged F for juveniles and adults in 2048, presented as a multiplier from that estimated in 2012, or the average estimated over 2012-2015.

Median depletion level (%$SB_{F=0}$)		Juvenile F_{2048}/F_{2012}	Juvenile $F_{2048}/F_{2012-2015}$		Adult F_{2048}/F_{2012}	Adult $F_{2048}/F_{2012-2015}$
50%		1.20	1.06		0.89	0.90
48%		1.24	1.10		0.92	0.93
46%		1.31	1.15		0.97	0.98
44%		1.39	1.22		1.02	1.04
42%		1.48	1.30		1.08	1.09
40%		1.53	1.35		1.11	1.13
38%		1.74	1.54		1.22	1.24
36%		1.92	1.69		1.29	1.31

Introduction

Target reference points, in conjunction with limit reference points (i.e. TRPs and LRPs), a management procedure (data collection, estimation ('assessment') model and harvest control rule (HCR)) and acceptable levels of risk, form critical components of a harvest strategy. In 2015, WCPFC defined the interim target reference point level for WCPO skipjack tuna at 50% of the estimated recent median spawning biomass in the absence of fishing ($SB_{F=0,\ t1\text{-}t2}$). This decision was based upon analyses presented in MOW3-WP/03 (SPC-OFP, 2014), which estimated catch, effort and stock status against a potential range of TRPs from 40-60% $SB_{F=0}$. CMM 2015-06 required that the target reference point be reviewed by the Commission no later than 2019.

In 2019, a new assessment of the WCPO skipjack stock was agreed at the 15th Scientific Committee meeting (Vincent et al., 2019). This assessment included a number of changes when compared to the previous assessments in 2014 (Rice et al., 2014) and 2016 (McKechnie et al., 2016). Changes included:

- the incorporation of a new spatial structure;
- incorporation of new information on the pattern of maturity of the stock; and
- some new model settings.

In a similar way to the incorporation of new knowledge of growth for WCPO bigeye tuna, the incorporation of this new information changed the perception of the status of the skipjack stock, although to a smaller degree than for bigeye tuna.

Following agreement of the 2019 WCPO skipjack tuna assessment, and as requested in the Harvest Strategy Workplan ("SC to advise on required analyses to support TRP review"), the SSP undertook the SC15 requested work to assist WCPFC16 in its review of the performance of the interim skipjack tuna TRP. This formed the results presented in WCPFC16-2020-14. Following discussions, WCPFC16 and subsequently WCPFC17 requested examination of specific candidate revised interim skipjack TRPs of between 36% and 50% of $SB/SB_{F=0}$. As part of the development of information to inform objectives for the new tropical tuna CMM in 2021, the TTMW1 also requested that analyses include evaluations of fishing mortality levels consistent with these depletion levels. While those requests were not directed at SC17, they are presented here to allow discussion of the outcomes relative to the technical assumptions made during the analyses. For brevity, the further information requested by WCPFC16 to aid discussions (paras 258 and 259 of the WCPFC16 Summary Report) are not repeated in the main body of the paper, but are provided in Annex 3 and cover information on:

- the formulation of TRPs for skipjack tuna, noting:
    - the SC15 advice on a skipjack tuna TRP "that the Commission may identify a reference year, or set of years, which may be appropriate to use as a baseline for a skipjack TRP."; and
    - the approach to the formulation of a skipjack tuna TRP proposed in WCPFC162019-DP01.
- [the impact of] effort creep estimated in relation to the TRPs.

This paper aims to:

1. Summarise current skipjack stock status from the 2019 assessment.
2. Provide projections of the skipjack stock to compare fishery performance metrics for stock levels requested by the Commission, as well as possible levels of future abundance under 'baseline' fishing levels.
3. Provide further information to underpin discussions, as requested by the Commission, SC and the TTMW1.

Approach

We used the 2019 stock assessment for skipjack tuna, incorporating a grid of the 54 model runs selected by the Scientific Committee (SC15) as the basis for reporting the uncertainty in current and historical stock status. SC15 also provided plausibility weights for each of these models based on expert opinion of how plausible they were relative to the diagnostic case model (see Annex 1 for details of the models and plausibility weights).

Evaluation of current skipjack stock status

We summarise current WCPO skipjack stock status relative to the agreed TRP level defined by CMM 2015-06, based upon the SC15 report and associated figures. The trajectory of skipjack stock depletion over time ($SB/SB_{F=0}$) from the 2019 assessment is also compared to that estimated within the 2014 and 2016 assessments.

Projections of the skipjack stock under 'baseline' fishing levels and four specific stock levels

Stock projections were performed under five different future scenarios for purse seine fishing effort. For each, the stock was projected into the future using the following procedure:

1. Run 100 simulations for 30 years into the future for each of the 54 stock assessment models - each simulation representing a possible 'future' trajectory for recruitment;
2. Run those simulations assuming long-term recruitment patterns (future recruitment is defined by the estimated stock recruitment relationship, with variability around it defined by recruitment estimates from the stock assessment over the period 1982-2017);
3. Assume catchability remains constant into the future – i.e. no effort creep occurs in WCPO fisheries;
4. Taking into account the SC15 plausibility weightings, combine the results across each assessment model run and calculate the median level of terminal spawning biomass compared to $SB_{F=0}$.

The potential future skipjack stock and fishery implications under a 'baseline' fishing level were used to provide a comparison to the four specific stock levels requested by SC15. Fishing levels equivalent to those in 2012 (effort levels for purse seine fisheries, catch levels for all other fisheries in the assessment model) were selected as requested by SC15, and consistent with the baseline used in SPC-OFP (2014) and key purse seine management regimes within the WCPO. However, we note that catch estimates for domestic fisheries in Indonesia/Philippines/Vietnam have indicated higher catches of skipjack in recent years compared to those in 2012. As a result, we have assumed levels equivalent to the 2016-2018 average for those fisheries continue into the future in this analysis (see Annex 2 for further details).

To examine the consequences for the skipjack stock and fishery of the specific stock levels requested by the Commission, the level of purse seine fishing in the future was adjusted from the baseline so that the median stock size was equivalent to the candidate TRP level at the end of the projection period. The level of change in average spawning biomass depletion and effort from 2012 and more recent levels, the risk to the stock relative to the agreed limit reference point level[2] and the total equilibrium yield relative to MSY, were estimated. For the current analysis, yield was estimated from equilibrium calculations relative to MSY, rather than the sum of the estimated 'equilibrium' fleet regional catch presented in previous

[2] The level of risk is defined by the current level of uncertainty captured through the range of models included within the assessment grid, and modelled variability in future recruitment levels. However, this likely underestimates the uncertainty within the assessment and in future conditions.

analyses. This approach was felt more consistent with the approach to estimating MSY[3]. Resulting changes in biomass (depletion) from 2007-2009 average levels are also provided as requested by the 1st 2021 workshop on the development of New WCPFC Tropical Tuna Measure (TTMW1).

The TTMW1 requested an indication of the fishing mortality (aggregate and by fish size (juvenile/adult)) resulting under each depletion level, relative to 2012 and 2012-15 levels. Stock-wide fishing mortality at age by time period was computed as a weighted average of the region-specific values, using the estimated region-specific population numbers at age at the beginning of the time period as the weights, i.e.

$$\tilde{F}_{at} = \frac{\sum_{r=1}^{R} F_{atr} N_{atr}}{\sum_{r=1}^{R} N_{atr}}$$

where *a*=age, *t*=time period, *r*=region and *R*=number of regions. The median of this vector was weighted across assessment models. For juvenile/adult F, the stock-wide $\tilde{F}_{at}$ was adjusted by the corresponding population juvenile/adult numbers-at-age and time period (based upon the population maturity-at-age), e.g. for juveniles (*juv*)

$$\tilde{F}_{juv,t} = \frac{\sum_{a=1}^{A} \tilde{F}_{at} N_{juv,at}}{\sum_{a=1}^{A} N_{juv,at}}$$

where *A* is the number of ages (quarters), and the weighted median calculated across assessment models.

Results

Evaluation of current skipjack stock status.

SC15 noted that the 2019 assessment for WCPO skipjack indicated the stock was not overfished, and not subject to overfishing (Figure 1). The median depletion level from the weighted uncertainty grid of the agreed SC15 WCPO skipjack assessment was 44% ($SB_{recent}/SB_{F=0}$, where recent is the average SB over the period 2015-2018), and a probable range of 37% to 53% (80% of runs fell within this range). The median is therefore below the interim TRP (50% $SB_{F=0}$), while the range of estimates spans that interim TRP.

To illustrate the influence of changes in the 2019 assessment model assumptions to the perception of stock status, Table 1 and Figure 2 compare the depletion estimates across time and in specific years from the 2014, 2016 and 2019 stock assessments. The change in perception of stock productivity resulting from new biological information, changes in model assumptions and settings implies a lower stock status for recent years within the 2019 assessment compared to the historical assessments.

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[3] In the current analysis, the catch (and MSY estimate) is an equilibrium calculation based upon a single region, with overall recruitment, and averaged fishing mortality over a specified period. There is obviously no movement. The previous fleet-estimated catch was a dynamic model calculation that achieved equilibrium after 30 years of projection. However, total recruitment in that case was assigned to regions according to mean region-specific proportion parameters, with fishing mortality also being region-specific. Yield-per-recruit therefore varied among regions. Movement also occurred among regions that re-distributed recruitments, impacting on the region-specific YPR and hence the total spawning biomass among regions, compared to the equilibrium approach now used.

Projections of the skipjack stock under 'baseline' fishing levels and specified stock levels

The baseline projections illustrate where the stock may end up on average if those baseline fishing levels continue (2012 effort levels in the purse seine fishery, 2012 catches in other fisheries except for Indonesia/Philippines/Vietnam domestic fisheries where recent catch levels were assumed). The stock will on average fall slightly compared to 'recent' levels, to 42% $SB_{F=0}$. This is marginally below 2012 levels, but is an equivalent % $SB_{F=0}$ value at 2 decimal places, and has no associated risk of falling below the LRP (Table 2).

Examining the other depletion levels requested by the Commission, the median depletion levels requested by WCPFC16 (50%, 48%, 46% and 44% $SB_{F=0}$), implied reductions in purse seine effort from 2012 levels of between 7 to 25%, led to increases in spawning biomass from 2012 levels of between 3 and 18%, and either maintained biomass at recent (2015-2018 average) levels, or implied an increase by 5 to 13%. Total equilibrium yield would reduce compared to the baseline levels, to 78-95% of MSY. There was no risk of falling below the LRP associated with any of these depletion levels based on the current uncertainty framework (Table 2).

The median depletion levels requested by WCPFC17 (36%, 38% and 40%) implied increases in purse seine effort from 2012 levels by 5 to 30%, and led to predicted decreases in spawning biomass from 2012 levels of between 5 and 14%. Total equilibrium yield was predicted to increase very slightly compared to that under 2012 'baseline' levels, to 98% of MSY (having reached the flat peak of the yield curve). There was again no risk of falling below the LRP associated with any of these depletion levels based on the current uncertainty framework.

To address the request of the TTMW1 for estimated fishing mortality under each candidate depletion level, resulting stock-wide age-averaged F for juvenile and adult components of the population and median fishing mortality-at-age are presented (Table 3; Figure 3; Figure 4). Interpretation of the results is challenging given that future fishing mortality is strongly influenced by the settings within the projection, in particular that future domestic fishery and pole-and-line catches continue at specified levels (2016-2018 and 2012 respectively), while purse seine is projected on effort. The composition of gears within the projected fishery and their impacts on the stock will therefore change relative to that in the historical (2012) period. This is clear when examining the relative change in fishing mortality in juvenile and adult segments of the population, with that on juveniles increasing notably at all examined depletion levels (Table 3; Figure 3). This was driven by increases in fishing mortality within Region 5 of the skipjack assessment model (western tropical WCPO encompassing Indonesia and Philippines; Figure 4, Figure 5), where future domestic fishery catches continue at 2016-2018 levels (Table 4). For depletion levels from 46% to 50%, stock-wide age-averaged F for adults decreased relative to 2012 or 2012-15 average levels, while stock depletion levels greater than 46% imply increases in adult F relative to those baselines.

As requested at TTMW1, Figure 6 presents a time series of median juvenile and adult skipjack fishing mortality from the agreed model grid of the 2019 stock assessment (1972 to 2018), and for the projection period (2019 to 2048) where stock depletion outcomes are consistent with a candidate TRP of 42%$SB_{F=0}$. Weighting of individual assessment model outputs, as adopted by SC15, are applied here. Table 5 presents the ratio of 'recent' fishing mortality levels (assumed to be the average over 2014-2017, as defined by SC15 when providing management advice) relative to estimated levels in 2012, and the average over 2012-2015. Estimated (weighted) median fishing mortality levels for all stock components were lower in 2012 or 2012-2015 relative to the recent period (values are less than 1).

References

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Rice, J., Harley, S., Davies, N. and Hampton, J. (2014). Stock assessment of skipjack tuna in the western and central Pacific Ocean. WCPFC-SC10-2014/SA-WP-05.

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Tables and figures

Table 1. Summary of median depletion levels for the reference case model (2014) and across the uncertainty grids of the 2016 and 2019 WCPO skipjack stock assessments in specific years, weighted as specified by Scientific Committee.

Year	$SB_{year}/SB_{F=0, \text{year-1 to year-10}}$		
	2014 assessment	2016 assessment	2019 assessment
2012	51%	48%	42%
2015	-	51%	47%
2018	-	-	42%

Table 2. Median depletion levels of skipjack tuna ($SB/SB_{F=0}$) and corresponding change[1] in biomass from 2007-2009, 2012, 2012-15 and 2015-18 average levels, change in purse seine effort (scalar), resulting median total equilibrium yield (as a percentage of MSY) and the risk of falling below the LRP. Results under baseline fishery conditions indicated by shaded row.

Median depletion level (%$SB_{F=0}$)	Change in spawning biomass (%$SB_{F=0}$) from 2007-2009 levels	Change in spawning biomass (%$SB_{F=0}$) from 2012 levels	Change in spawning biomass (%$SB_{F=0}$) from 2012-2015 average	Change in spawning biomass (%$SB_{F=0}$) from 2015-2018 average	Change in PS effort from 2012 levels*	Median total equilibrium yield (%MSY)**	Risk $SB/SB_{F=0}$ < LRP
50%	-17%	+18%	+2%	+13%	-25%	78%	0%
48%	-19%	+14%	-1%	+10%	-21%	81%	0%
46%	-23%	+9%	-6%	+5%	-15%	87%	0%
44%	-27%	+3%	-10%	0%	-7%	95%	0%
42%	-30%	-2%	-15%	-5%	0%	97%	0%
40%	-32%	-5%	-18%	-8%	+5%	98%	0%
38%	-35%	-10%	-22%	-13%	+20%	98%	0%
36%	-39%	-14%	-25%	-16%	+30%	98%	0%

* 2012 conditions assumed for purse seine (effort) and most other fisheries (catch), 2015-18 average levels assumed for domestic ID/PH. This also assumes no 'effort creep' occurs and hence CPUE is assumed proportional to stock abundance.

[1] 'Change' calculated as a percentage, as: [Median level of indicator at defined stock depletion] / [Defined base level of indicator]

** Recalculated using estimated equilibrium catch at defined fishing level

Table 3. Fishing mortality estimated under each median skipjack tuna depletion level ($SB/SB_{F=0}$), calculated as the stock-wide age-averaged F for juveniles and adults in 2048, presented as a multiplier from that estimated in 2012, or the average estimated over 2012-2015.

Median depletion level (%$SB_{F=0}$)		Juvenile F_{2048}/F_{2012}	Juvenile $F_{2048}/F_{2012\text{-}2015}$		Adult F_{2048}/F_{2012}	Adult $F_{2048}/F_{2012\text{-}2015}$
50%		1.20	1.06		0.89	0.90
48%		1.24	1.10		0.92	0.93
46%		1.31	1.15		0.97	0.98
44%		1.39	1.22		1.02	1.04
42%		1.48	1.30		1.08	1.09
40%		1.53	1.35		1.11	1.13
38%		1.74	1.54		1.22	1.24
36%		1.92	1.69		1.29	1.31

Table 4. Table of Annual Catch Estimates for key fisheries within Region 5 of the skipjack stock assessment model for 2012 and averaged over the period 2016-2018 period.

		Skipjack catch (t.) used in assessments from Annual catch estimates				
flag_id	**Gear**	**2012**	**Average 2016-2018**	**Increase / Decrease**	**%**	**% of total**
ID	Gillnet	0	0	0		
	Handline	0	0	0		
	Hook-and-line	0	38,817	38,817		
	Longline	0	2,185	2,185		
	OTHER Small-scale gears	109,732	93,993	-15,739		
	Pole-and-line	100,857	83,027	-17,830		
	Purse seine	69,058	91,985	22,927		
ID Total		279,647	310,006	30,359	11%	8%
PH	Handline	439	2,639	2,200		
	Hook-and-line	10,600	9,418	-1,182		
	Longline	0	0	0		
	OTHER Small-scale gears	3,078	5,136	2,058		
	Ringnet	23,255	26,738	3,483		
	Purse seine	39,062	37,229	-1,833		
PH Total		76,434	81,161	4,727	6%	1%
VN	Gillnet	20,998	39,836	18,838		
	Longline	0	0	0		
	Purse seine	22,638	50,672	28,034		
VN Total		43,636	90,507	46,871	107%	12%
				0		
Total		**399,717**	**481,674**	**81,957**	**21%**	**21%**

Table 5. Table of 'recent' fishing mortality levels (average over the period 2014-2017, consistent with the definition of the 'recent' period used by SC15) relative to that in 2012 and that averaged over 2012-2015.

Fishing mortality ratio	Stock component		
	Juvenile	Adult	Total
$F_{2012}/F_{2014-2017}$	0.79	0.94	0.80
$F_{2012-2015}/F_{2014-2017}$	0.89	0.94	0.90

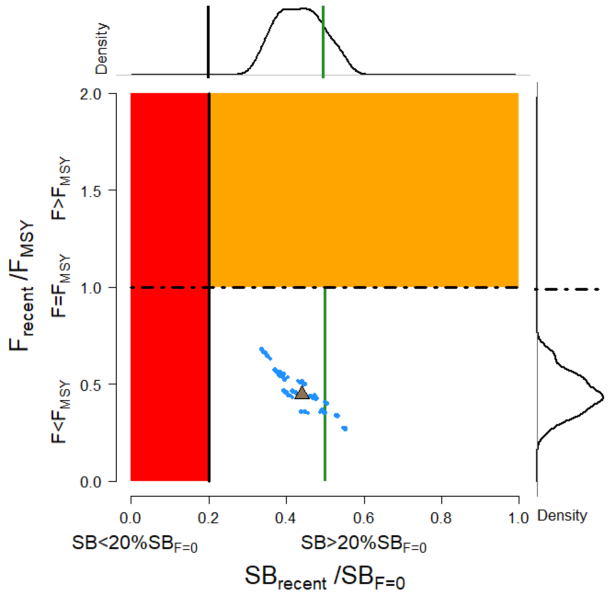

Figure 1. Majuro plot of the recent spawning potential (2015 – 2018) summarizing the results for each of the models in the structural uncertainty grid with weighting. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality, and marginal distributions of each are presented. Vertical green line denotes the interim TRP. Brown triangle indicates the weighted median of the estimates.

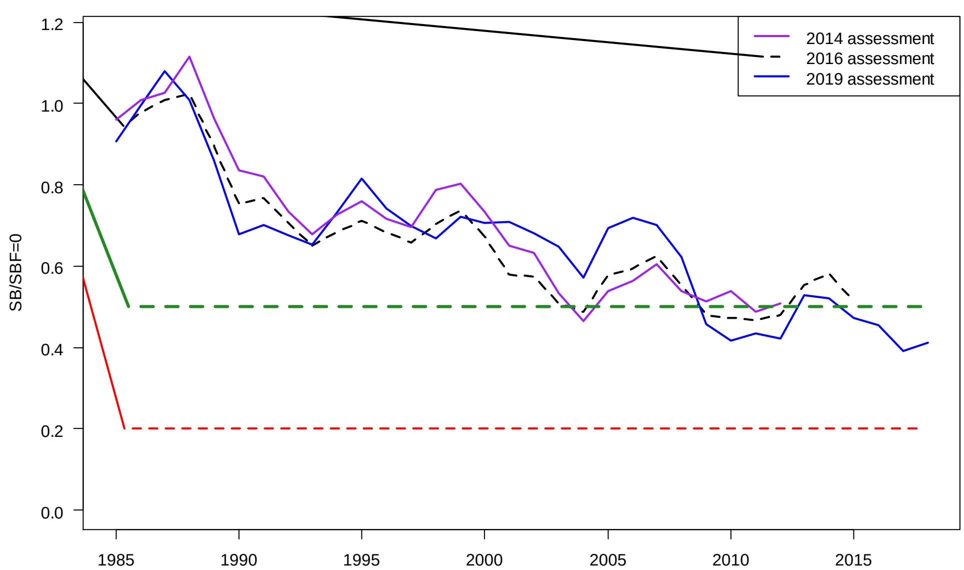

Figure 2. Comparison of depletion trajectories from the 2014, 2016 and 2019 assessments over the period 1985 to the end of each assessment. $SB_{F=0}$ calculated consistent with the approach defined for the limit (red horizontal line) and previous interim target (green horizontal line) reference points (i.e. $SB_{F=0, t-1 \text{ to } t-10}$).

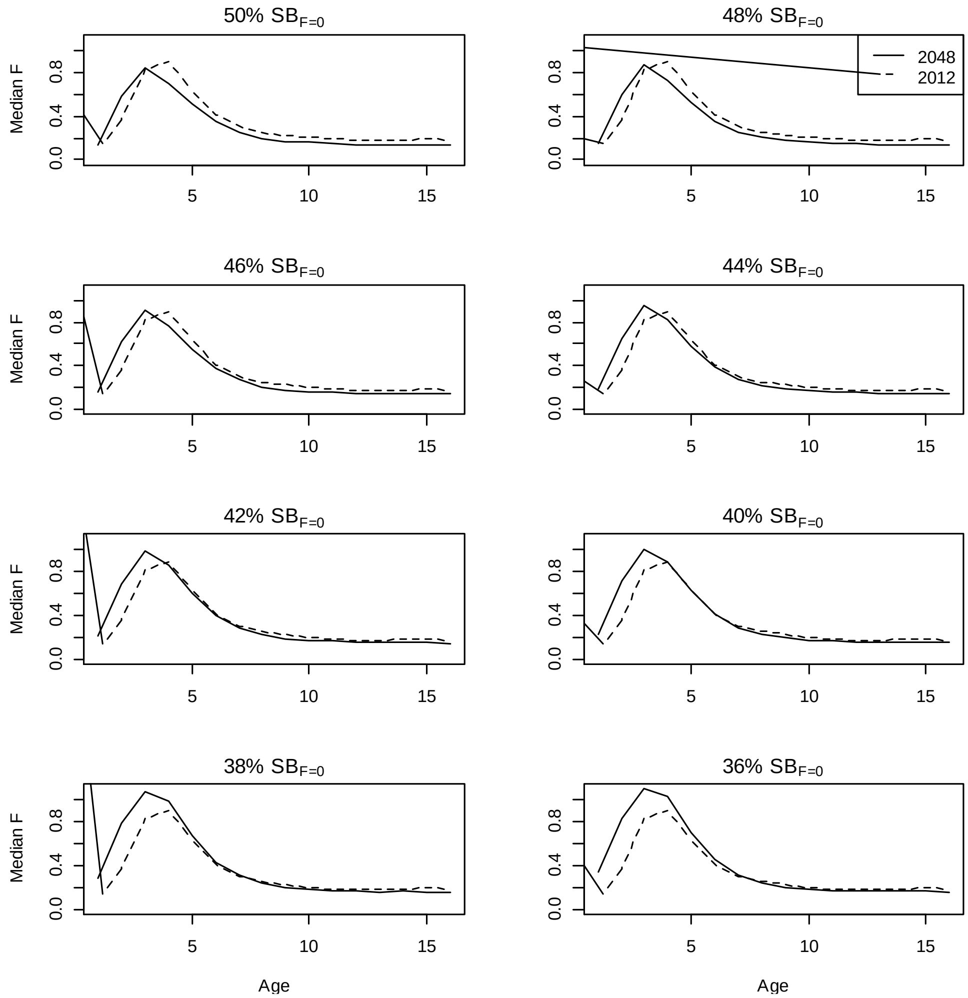

Figure 3. Pattern of (median) overall fishing mortality-at-age (quarter) for each candidate TRP depletion level. Dotted line presents estimated 2012 F-at-age, solid line the projected 2048 F-at-age.

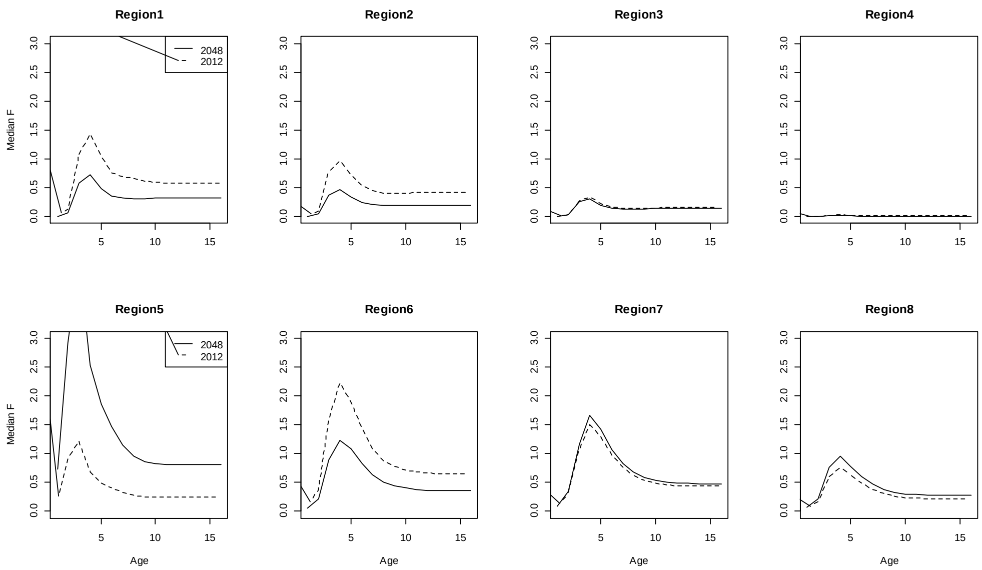

Figure 4. Pattern of (median) fishing mortality-at-age (quarter) by skipjack model region under conditions achieving 42% $SB_{F=0}$ depletion. Dotted line presents estimated 2012 F-at-age, solid line the projected 2048 F-at-age.

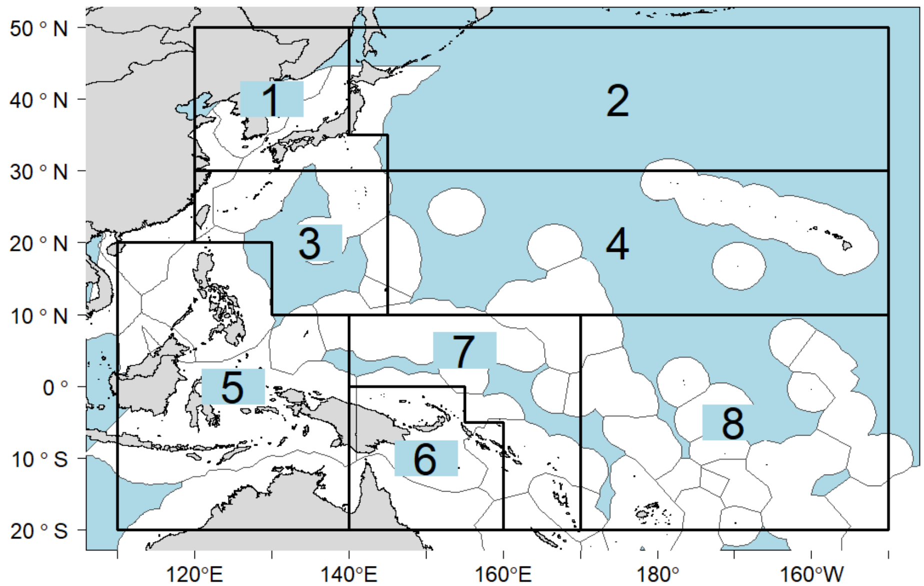

Figure 5. The geographical area covered by the stock assessment and the boundaries for the 8 region assessment model.

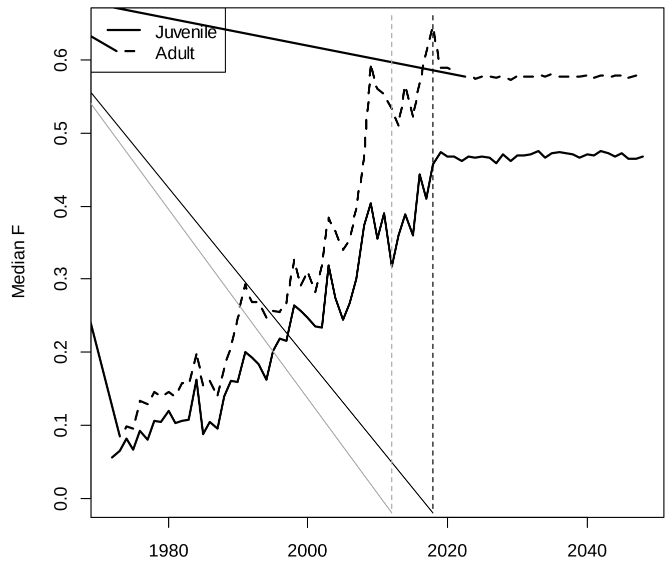

Figure 6. Time series of median (weighted) fishing mortality for juvenile and adult skipjack tuna across the WCPO model region. Vertical dotted black line = 2018 (last year of the assessment period). Vertical dotted grey line = 2012.

Annex 1: Model runs and weights defined by SC15 and used for the analysis

Axis	Value	Relative weight
Steepness	0.65	0.8
	0.80	1.0
	0.95	0.8
Growth	Low	1.0
	Diagnostic	1.0
	High	1.0
Length composition scalar	50	0.8
	100	1.0
	200	1.0
Tag mix	1	1.0
	2	1.0

Annex 2. Pattern of catches estimates for the domestic fisheries of Indonesia, Philippines and Vietnam within the 2019 skipjack stock assessment.

The table below presents the catch scalar for the three domestic fleets in the western tropical region (Region 5) within the 2019 skipjack stock assessment. This scalar represents the multiplier required to scale the 2012 catch levels up to the average catch estimated over the period 2016 to 2018.

Fishery number	Fishery description	Scalar from 2012 catch to match 2016-18 average catches
F10	Domestic Philippines in Region 5	1.22
F11	Domestic Indonesia in Region 5	1.23
F16	Domestic Vietnam in Region 5	2.03

Annex 3. Additional requests from WCPFC16

The formulation of TRPs for skipjack tuna

WCPFC16 requested SC16 provide advice on the appropriate formulation of text for the skipjack TRP, noting:

- SC15 advice "that the Commission may identify a reference year, or set of years, which may be appropriate to use as a baseline for a skipjack TRP."; and
- the approach to the formulation of a skipjack tuna TRP proposed in WCPFC16-2019-DP01.

Text defining a TRP should refer to the balance of management objectives that the TRP value achieves. This means the text should be sufficiently explicit to allow the technical re-estimation of the appropriate TRP-consistent stock depletion value (or other stock/fishery value) when new knowledge is obtained, as for skipjack within the 2019 assessment. Text should therefore avoid open statements such as '… the risk of falling below the limit reference point should be very low'.

The use of a specific year, or set of years, within a TRP definition provides a tangible reference to a stock size or fishery condition that managers and stakeholders feel achieved the most important management objectives or represented the best trade-off between them. Where the year refers to fishery levels or conditions (e.g. 'the level of purse seine effort in 2012'), testing needs to be undertaken to ensure that those conditions do not drive the stock to undesirable levels, which would mean that the fishery performance in that reference year would not then be achieved.

The formulation as specified in WCPFC16-2019-DP01 is tied to the specific objectives for the fishery highlighted by that stakeholder group. WCPFC16-2019-DP01 uses a baseline year of 2012, noting that the TRP should be "…consistent with the level of fishing effort for skipjack in 2012 and the condition of the skipjack stock in 2012". It is broadly consistent with the approach adopted for South Pacific albacore.

The formulation is suitably explicit in that it has allowed the re-estimation of the skipjack TRP ($SB/SB_{F=0}$ level), but we note two things:

- The assumption has been made that 2012 fishing effort levels are those in the purse seine fishery specifically, as this is not specified within the text.
- As examined within this paper, this formulation is consistent (2012 fishing conditions lead to a stock status equal to that in 2012), but care must be taken if the incorporation of improved biological or fishery understanding within the skipjack assessment meant this consistency was then lost. Therefore, the weighting of each objective (the fishing effort and 2012 stock status) should be specified.

Effort creep estimated in relation to the TRPs

WCPFC16 requested SC16 provide advice on whether effort creep should be considered when identifying TRP levels.

In theory, where the primary management objective was to maintain a level of CPUE within the fishery, effort creep might be considered since effort creep could maintain fishery CPUE in the face of a declining stock (i.e. the CPUE would be maintained at more depleted stock levels in the future due to increases in fishing efficiency). If effort creep were sufficient, the stock (and TRP) may decline until it reached the ‘minimum TRP’ level defined by the maximum permissible level of risk of falling below the limit reference point, as defined by an over-riding stock sustainability management objective.

In practice, considering effort creep within the TRP calculation is not feasible. This is because the future level of effort creep within the purse seine fishery is not known. Estimates of historical trends (if available) do not necessarily indicate future fishery performance, while assuming some arbitrary level of effort creep within an analysis could lead to an inappropriate TRP level if that assumption proves incorrect. Therefore, effort creep within the purse seine fishery has not been included when estimating the skipjack TRP within this paper. To ensure objectives are met if effort creep occurs, an adaptive approach where the management settings are reviewed as required over time is viewed as the most appropriate. This would occur automatically within the harvest strategy framework, where management procedures robust to effort creep can be identified, and the monitoring strategy can identify whether the adopted management procedure is being effective.

Finally, given the witnessed advances in technology, effort creep is currently considered likely to be most significant within the WCPO purse seine fishery (Vidal et al., 2019) rather than the longline fishery. Balancing this when calculating TRPs where both gears are exploiting a stock would further limit the feasibility of including effort creep when considering TRPs.