SCIENTIFIC COMMITTEE
EIGHTEENTH REGULAR SESSION

ELECTRONIC MEETING

10-18 August 2022

Updated WCPO bigeye and yellowfin TRP evaluations

WCPFC-SC18-2022/MI-IP-04
(Paper presented to WCPFC as WCPFC18-2021-21)

6 July 2022

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Foreword

This paper was prepared for, and presented at, WCPFC18 in response to recommendations from SC17. An earlier version of this paper first presented at SC16 (SC16-2020/MI-WP-01) and updated with additional information for SC17 (SC17-MI-WP-01) where equivalent depletion levels for skipjack were included. That version of the paper was further updated to also include equivalent depletion levels for albacore, thus giving full consideration of the multispecies impacts of varying TRP levels based on either bigeye or yellowfin. Projections for all requested TRP levels and species impacts were made and summarized in the paper.

The WCPFC18 Summary Report contains a summary of the content of the paper, notes comments by several members, and made the recommendation that the work be further progressed in 2022 (p.22):

> 107. The Commission noted the presentation by SPC of the results of analyses on candidate TRPs for bigeye and yellowfin.
>
> 108. The Commission noted the importance of agreeing on TRP for bigeye and yellowfin and agreed to progress this work in 2022.

Executive Summary

SC16 agreed new stock assessments for WCPO bigeye and yellowfin tuna that indicated both stocks are on average not overfished nor subject to overfishing. This paper presents results of analyses requested by SC16, based upon those new assessments, to assist WCPFC17 in the identification of interim target reference points for WCPO bigeye and yellowfin tuna stocks. It presents the consequences for each stock and fishery of SC16-defined stock depletion levels ($SB/SB_{F=0}$) consistent with specified historical conditions and stock risk levels (paragraphs 76 to 78 of the SC16 Outcomes Document). For each depletion level, results are presented comparably to those in Pilling (2021) for skipjack tuna, indicating changes in biomass from both 2012-2015 and recent (2015-2018 average) levels, changes in fishing from baseline (2016-2018 average) levels, median equilibrium yield (as a proportion of MSY), risk relative to the agreed limit reference point, and SC16-requested per-recruit metrics. Full results are summarised in the tables below. In response to a request from WCPFC17, additional analyses were conducted to facilitate multi-species implications of harvest levels that achieve the different target reference points (TRPs) for each species (yellowfin and bigeye under the two recruitment assumptions). The resultant depletion levels for skipjack and yellowfin (under bigeye TRP calculations), and for skipjack and bigeye (under yellowfin TRP calculations) are computed and provided. Note that within this analysis the overall purse seine effort (and longline catch) is increased or decreased by the scalar specified; this is a different assumption to that of (for example) the evaluation of the tropical tuna CMM for skipjack, where overall purse seine effort is assumed to remain constant. In turn, SC17 requested that the potential consequences of the candidate TRPs for South Pacific albacore depletion be examined, and these are presented.

Under baseline (2016-2018 average) fishing conditions, both bigeye and yellowfin stocks were projected to increase relative to 2012-2015 average levels, and either remain at recent (2015-2018 average) levels (yellowfin) or increase (bigeye).

For both bigeye and yellowfin, CMM 2020-01 specifies that, pending agreement on a TRP, the spawning biomass depletion ratio ($SB/SB_{F=0}$) is to be maintained at or above the average $SB/SB_{F=0}$ for 2012-2015. Achieving that depletion level for bigeye implied increases in fishing from 2016-2018 levels by 38% (recent recruitment) and 22% (assuming long-term recruitment) and resulted in a risk of falling below the limit reference point (LRP) of 3% or 14% (recent and long-term recruitment, respectively). For yellowfin, it implied increased fishing by 29%, and no calculated risk of falling below the LRP. The implications of achieving depletion levels +/- 10% from the 2012-2015 average levels are presented in the tables.

An alternative SC16-specified candidate reference point was equivalent to 2000-2004 average depletion levels. For bigeye, this depletion level required fishing to be reduced by 4% (recent recruitment) or 17% (long-term recruitment), and resulted in no, or a minimal (1% assuming long-term recruitment patterns), risk of falling below the LRP. For yellowfin, 2000-2004 average depletion levels implied increasing fishing by 34% from baseline levels, and there was no risk of falling below the LRP calculated at that level.

Final SC16-specified depletion levels related to those equivalent to a 10% and 20% risk of falling below the LRP. For bigeye, this implied increases in fishing by 55% and 70% (recent recruitment) and 12% and 33% (long-term recruitment), respectively. Under recent recruitments, those risk levels were achieved at stock sizes 12-23% lower than 2012-2015 levels. Under the less productive long-term recruitment assumption those risk levels implied a 6% less depleted stock and 10% more depleted stock respectively, relative to 2012-2015 average depletion. For yellowfin, 200% greater fishing than baseline levels (a scalar of 3) was

required to achieve a 10% risk level; this was considered unrealistic, and a 20% risk-based depletion level was therefore not pursued further for this stock.

With reference to the risk-related depletion levels, which represent 'minimum' TRP values consistent with those risk levels, as noted in previous papers the choice of a TRP can be based on a combination of biological, ecological, and socio-economic considerations, which would likely imply higher TRP levels than the 'minimum' TRPs calculated here.

As agreed at SC16, within this analysis purse seine effort and longline catch are 'scaled' equally relative to baseline levels. Scalars are applied to overall purse seine effort – i.e. both associated and unassociated sets are increased or decreased, with the relative pattern reflecting that over the 2016-2018 baseline period. Results will therefore generally differ from that in the CMM 2018-01 evaluation that was presented to WCPFC17 (SPC-OFP, 2020). It should be noted that candidate TRP levels can be achieved under different combinations of future purse seine and longline catch/effort levels, which will have implications for the other metrics calculated. If desired, identification of a limited sub-set of candidate interim TRP levels is strongly recommended before that style of analysis is undertaken.

As noted in previous papers discussing TRP formulation, there is a need to have specific language defining the TRP level, based upon the management objective that the TRP is designed to achieve. That language needs to be suitably specific so that the TRP can be recalculated in the case that in the future, new biological or fishery knowledge leads to an updated perception of stock status from the stock assessments.

The new information incorporated within the 2020 yellowfin tuna stock assessment implies a more robust stock than estimated previously, as seen by the minimal risks of falling below the LRP identified at the levels identified here. It should be noted that key areas for further work on the yellowfin assessment were identified for the coming year, and an external review of the assessment is planned for 2022 (SPC-OFP, 2021). While the assessment is viewed as the best scientific information currently available, the further work underway may lead to changes in the perception of stock status and robustness.

Median bigeye tuna depletion levels ($SB/SB_{F=0}$) assuming 'recent' recruitment conditions, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2015-2018) average levels, change in purse seine effort and longline catch (scalar) from baseline (2016-2018) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP and spawner- and yield-per-recruit levels relative to that under 'baseline' (2016-2018 average conditions), under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent depletion levels that would result for skipjack, yellowfin and South Pacific albacore for each of the candidate bigeye TRPs are provided in the last three columns.

BET: recent recruitment								Notes	Equiv. SKJ $SB/SB_{F=0}$	Equiv. YFT $SB/SB_{F=0}$	Equiv. SPA $SB/SB_{F=0}$
Median depletion level ($\%SB_{F=0}$)	Change in SB ($\%SB_{F=0}$) from 2012-2015 average	Change in SB ($\%SB_{F=0}$) from 2015-2018 average	Change in fishing from 2016-2018 levels	Median total equilibrium yield (%MSY)	Risk $SB/SB_{F=0}$ < LRP	Rel. YPR	Rel. SPR				
48%	+30%	+17%	0%	95%	0%	1	1	Base 2016-2018 conditions	43%	59%	43%
33%	-10%	-20%	+54%	98%	10%	1.21	0.65	Avg. 2012-2015 – 10%	35%	43%	39%
37%	0%	-10%	+38%	98%	3%	1.17	0.76	Avg. 2012-2015	37%	46%	40%
41%	+10%	0%	+24%	98%	0%	1.12	0.86	Avg. 2012-2015 + 10%	39%	48%	41%
49%	+34%	+21%	-4%	94%	0%	0.98	1.02	Avg. depletion 2000-04	44%	54%	43%
32%	-12%	-21%	+55%	98%	10%	1.22	0.64	10% risk re LRP	35%	43%	39%
29%	-23%	-30%	+70%	98%	20%	1.24	0.54	20% risk re LRP	34%	41%	38%

Median bigeye tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2015-2018) average levels, change in purse seine effort and longline catch (scalar) from baseline (2016-2018) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP and spawner- and yield-per-recruit levels relative to that under 'baseline' (2016-2018 average conditions), under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent depletion levels that would result for skipjack, yellowfin and South Pacific albacore for each of the candidate bigeye TRPs are provided in the last three columns.

BET: long-term recruitment								Notes	Equiv. SKJ $SB/SB_{F=0}$	Equiv. YFT $SB/SB_{F=0}$	Equiv. SPA $SB/SB_{F=0}$
Median depletion level ($\%SB_{F=0}$)	Change in SB ($\%SB_{F=0}$) from 2012-2015 average	Change in SB ($\%SB_{F=0}$) from 2015-2018 average	Change in fishing from 2016-2018 levels	Median total equilibrium yield (%MSY)	Risk $SB/SB_{F=0}$ < LRP	Rel. YPR	Rel. SPR				
43%	+17%	+6%	0%	97%	5%	1	1	Base 2016-2018 conditions	43%	59%	43%
33%	-10%	-20%	+33%	98%	20%	1.14	0.75	Avg. 2012-2015 – 10%	38%	46%	41%
37%	0%	-10%	+22%	97%	14%	1.10	0.82	Avg. 2012-2015	39%	48%	42%
41%	+10%	0%	+8%	97%	8%	1.04	0.93	Avg. 2012-2015 + 10%	42%	51%	43%
49%	+34%	+21%	-17%	96%	1%	0.91	1.14	Avg. depletion 2000-04	48%	62%	44%
40%	+6%	-4%	+12%	97%	10%	1.05	0.90	10% risk re LRP	41%	50%	42%
33%	-10%	-19%	+33%	98%	20%	1.14	0.75	20% risk re LRP	38%	46%	41%

Median yellowfin tuna depletion levels (SB/$SB_{F=0}$) assuming 'long-term' recruitment conditions, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2015-2018) average levels, change in purse seine effort and longline catch (scalar) from baseline (2016-2018) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP and spawner- and yield-per-recruit levels relative to that under 'baseline' (2016-2018 average conditions), under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent depletion levels that would result for skipjack, South Pacific albacore and bigeye (under recent (R) and long-term (L) recruitment scenarios) for each of the candidate yellowfin TRPs are provided in the last three columns.

YFT: long-term recruitment								Notes	Equiv. SKJ SB/$SB_{F=0}$	Equiv. BET-R/L SB/$SB_{F=0}$	Equiv. SPA SB/$SB_{F=0}$
Median depletion level (%$SB_{F=0}$)	Change in SB (%$SB_{F=0}$) from 2012-2015 average	Change in SB (%$SB_{F=0}$) from 2015-2018 average	Change in fishing from 2016-2018 levels	Median total equilibrium yield (%MSY)	Risk SB/$SB_{F=0}$ < LRP	Rel. YPR	Rel. SPR				
59%	+7%	0%	0%	63%	0%	1	1	Base 2016-2018 conditions	43%	48%/43%	43%
49%	-10%	-16%	+65%	77%	0%	1.32	0.83	Avg. 2012-2015 – 10%	34%	30%/26%	38%
55%	0%	-6%	+29%	70%	0%	1.15	0.92	Avg. 2012-2015	38%	40%/34%	41%
60%	+10%	+3%	-5%	62%	0%	0.97	1.01	Avg. 2012-2015 + 10%	45%	50%/45%	43%
54%	-1%	-8%	+34%	71%	0%	1.17	0.91	Avg. depletion 2000-2004	38%	38%/30%	40%
31%	-43%	-47%	+200%	88%	10%	1.61	0.47	10% risk re LRP	26%	8%/3%	35%
NA	-	-	-	-	-	-	-	20% risk re LRP	-	-	-

Introduction

Target reference points, in conjunction with limit reference points (i.e. TRPs and LRPs), a management procedure (data collection, estimation model and harvest control rule (HCR)) and acceptable levels of risk, form critical components of a harvest strategy.

While an interim TRP has been specified for South Pacific albacore, and discussions are ongoing on the updated interim TRP level for skipjack, discussions and analyses for bigeye and yellowfin tuna have not progressed past identification of 'minimum' TRP levels that are consistent with specified risks of the stock falling below the LRP (e.g. SPC-OFP, 2019). As noted in previous papers, the choice of a TRP can be based on a combination of biological, ecological and socio-economic considerations, which would likely imply higher TRP levels than the 'minimums' calculated therein.

Within CMM 2020-01, interim objectives for the bigeye and yellowfin stock were specified as: 'pending agreement on a target reference point the spawning biomass depletion ratio ($SB/SB_{F=0}$) is to be maintained at or above the average $SB/SB_{F=0}$ for 2012-2015'. This provides some guidance against which candidate TRP levels can be viewed.

In 2020, new assessments of the WCPO bigeye and yellowfin stocks were discussed and agreed at the 16th Scientific Committee meeting (Ducharme-Barth et al., 2020; Vincent et al., 2020). These assessments incorporated a number of changes when compared to the previous assessments, including new information on the biological characteristics of the stocks, and some new model settings. For yellowfin tuna, in particular, the incorporation of this new information changed the perception of the status of this stock.

The Harvest Strategy Work plan indicated that in 2020 the Scientific Committee should provide advice on a range of issues pertaining to the formulation of a TRP for bigeye and yellowfin tuna, and the Commission consider that advice. To this end, SC16 requested that the Scientific Services Provider undertake analyses to inform discussions at WCPFC17 (paragraphs 76 to 78 of the SC16 outcomes document; see Annex 1). This paper presents the results of those analyses and responds to additional requests made at WCPFC17.

Approach

We used the 2020 stock assessments for bigeye and yellowfin tuna, incorporating a grid of 24 and 72 model runs, respectively, selected by the Scientific Committee (SC16) as the basis for reporting the uncertainty in current and historical stock status.

Stock projections were performed under different future scenarios for purse seine fishing effort and longline catch for each stock. 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 stock assessment models within the uncertainty grid - each simulation representing a possible 'future' trajectory for recruitment;
2. Run the simulations assuming future recruitment is defined by the estimated stock recruitment relationship, with variability around it defined by recruitment estimates from:
    a. the stock assessment over the period 1962-2016 (yellowfin, and 'long-term' recruitment for bigeye);
    b. the stock assessment over the period 2007-2016 ('recent' recruitment for bigeye);

3. Assume catchability remains constant into the future – i.e. no effort creep occurs;
4. Combine the results across each assessment model run and calculate the median level of terminal spawning biomass compared to $SB_{F=0}$.

To examine the consequences of the specific stock levels requested by SC16 for the relevant stock and fishery, the levels of purse seine effort and longline catch in the future were adjusted equally from the baseline so that the median stock size was equivalent to the candidate TRP level at the end of the 30-year projection period. Therefore, the future 'scalars' on purse seine effort and longline catch were identical in this analysis, relative to the 2016-2018 baseline.

The potential future stock and fishery implications under a 'baseline' fishing level were used to provide a comparison to the stock levels specified by SC16. Fishing levels equivalent to the average of those in 2016-2018 were used as this baseline period, reflecting the more recent years in the stock assessments.

The level of change in average spawning biomass and effort from 2012-2015 and 'recent' (2015-2018) levels, the risk to the stock relative to the agreed limit reference point level[1], the total equilibrium yield relative to MSY, and SC16-requested 'per recruit' levels were estimated under each depletion level.

In response to a request from WCPFC17 and SC17, additional analyses were conducted to facilitate multi-species implications of harvest levels that achieve the different TRPs for each of the species (yellowfin and bigeye under the two recruitment assumptions). The resultant depletion levels for skipjack, South Pacific albacore[2] and yellowfin (under bigeye TRP calculations), and for skipjack, South Pacific albacore and bigeye (under yellowfin TRP calculations) are computed and provided.

Results

The baseline projections (2016-2018 average levels in all fisheries) illustrate where the stocks would end up if those fishing levels continued into the future. The depletion levels that would result in 2048 are: bigeye 48% (recent recruitment) and 43% (long-term recruitment), yellowfin 59% and both skipjack and South Pacific albacore 43%.

For bigeye, under both recent and long term recruitment assumptions, the stock increases relative to both 2012-2015 average and 'recent' levels, by 17-30% (recent recruitment) and 6-17% (long term recruitment), while there is zero and 5% risk of falling below the LRP, respectively (**Table 1** and **Table 2**).

[1] 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.

[2] For longline fisheries, changes in the catch of one stock that achieve the candidate TRP are assumed to proportionally apply to the other stock. For bigeye and yellowfin, the longline fisheries within the assessments are consistent across the WCPO in the assessment models. For South Pacific albacore, proportional catch changes are applied specifically in the WCPFC-CA region between the equator and 10°S (Region 1 of the albacore assessment model), while albacore catches in other areas of that assessment are maintained constant at recent levels. Approximately 4% of the total bigeye catch has been taken south of 10°S in recent years, so for simplicity that region is assumed to be unaffected by tropical longline effort changes. The proportional catch change may be considered a 'worst case' scenario; refined approaches will be undertaken through the harvest strategy's multispecies framework.

For yellowfin, baseline fishing levels lead to an increase from 2012-2015 average levels (by 7%) and maintains the stock at higher than recent (2015-2018) levels (**Table 3**). There is zero risk of falling below the LRP under the baseline fishing levels.

Levels relative to 2012-2015 average stock sizes

The first set of SC16 requested levels related to 2012-2015 average conditions as referenced in CMM 2018-01.

For bigeye, these represented depletion levels of 33% ("2012-2015 average – 10%"), 37% ("2012-2015 average") and 41% ("2012-2015 average + 10%") $SB_{F=0}$. 'Recent' depletion levels were equivalent to that at "2012-2015 average + 10%", while other levels were 10% or 20% lower than 'recent' levels. Achieving these 2012-2015 average-related depletion levels implied increases in fishing from 2016-2018 levels by 24% to 54% (recent recruitment) and 8 to 33% (long-term recruitment). The risk of falling below the LRP was 3% at "2012-2015 average levels" (14% assuming long-term recruitment), rising to 10% (20% assuming long term recruitment) at "2012-2015 average – 10%" levels (**Table 1** and **Table 2**). At the fishing levels that achieved these three bigeye TRPs, depletion levels for skipjack ranged from 35-39% (recent recruitment) and 38-42% (long-term recruitment), while yellowfin depletion ranged from 43-48% (recent recruitment) and 46-51% (long-term recruitment), and South Pacific albacore depletion ranged from 39-41% (recent recruitment) and 41-43% (long-term recruitment).

For yellowfin, these represented depletion levels of 49% ("2012-15 average – 10%"), 55% ("2012-15 average") and 60% ("2012-15 average + 10%") $SB_{F=0}$ (**Table 3**). To achieve the higher ("2012-15 average + 10%") level, effort and catch would need to decrease by 5% relative to baseline levels. To achieve "2012-15 average" depletion levels, effort and catch could increase by 29%, and for the lower ("2012-15 average – 10%") by 65%. Across those levels, there was no risk of falling below the LRP. At the fishing levels that achieved these three yellowfin TRPs, depletion levels for skipjack ranged from 34-45%, while bigeye depletion ranged from 30-50% (recent recruitment) and 26-45% (long-term recruitment), and South Pacific albacore depletion ranged from 38-43%.

Levels relative to average stock sizes over 2000-2004

The second SC16 requested TRP level related to the average depletion level over the period 2000-2004.

For bigeye, this represented a level of 49% $SB_{F=0}$, an increase of 34% from 2012-2015 levels, and 21% from 2015-2018 levels. To achieve this depletion, fishing was reduced by 4% (recent recruitment) or 17% (long-term recruitment) (**Table 1** and **Table 2**). There was no, or a minimal (1% assuming long-term recruitment patterns), risk of falling below the LRP calculated at this stock size. The equivalent skipjack depletion levels were 44% and 48%, under recent and long-term bigeye recruitment, respectively. Yellowfin depletion levels were 54% (recent recruitment) and 62% (long-term recruitment). South Pacific albacore depletion levels were 43% (recent recruitment) and 44% (long-term recruitment).

For yellowfin, this represented a level of 54% $SB_{F=0}$, a small reduction from 2012-2015 levels, and 8% lower than 2015-2018 levels. To achieve that depletion, fishing could increase by 34% from baseline levels (**Table 3**). There was no risk of falling below the LRP calculated at that level. The equivalent skipjack depletion level was 38%, bigeye depletion levels were 38% (recent recruitment) and 30% (long-term recruitment), and South Pacific albacore depletion levels were 40%.

‘Minimum’ TRP levels consistent with different LRP risks

The final SC16 requested levels related to the risk of falling below the LRP, specifically 10% and 20% risk levels.

For bigeye, achieving depletion levels consistent with a 10% and 20% risk of falling below the LRP implied increases in fishing by 55-70% (recent recruitment) and 12-33% (long-term recruitment). Under recent recruitments, those risk levels were achieved at stock sizes 12-23% lower than 2012-2015 levels. Under the less productive long-term recruitment assumption, this required a larger stock (by 6%) relative to 2012-2015 average depletion levels to achieve a 10% risk, but a decline in stock size relative to the 2012-2015 average to achieve a 20% risk level. The equivalent skipjack depletion levels for the 10% and 20% bigeye TRP risk levels (for recent recruitment) were 35% and 34%, and (for long-term recruitment) were 41% and 38%). Yellowfin depletion levels were 43% and 41% (recent recruitment) and 40% and 46% (long-term recruitment). South Pacific albacore depletion levels were 39% and 38% (recent recruitment), and 41% and 42% (long-term recruitment).

For yellowfin, initial analyses indicated significantly greater levels of future purse seine and longline fishing were required to drive the stock to levels where risk increased. A scalar of 3 (200% more purse seine effort and longline catch) achieved a risk of 10% of falling below the LRP (**Table 3**). Analyses for a 20% risk were therefore not attempted. The equivalent skipjack depletion level (at 10% risk to yellowfin TRP) was 26%, while bigeye depletion levels were 8% (recent recruitment) and 3% (long-term recruitment), and South Pacific albacore depletion levels 35%.

Formulation of TRPs for bigeye and yellowfin tuna

Target reference points, through definition of the management objectives (and trade-offs) that they enable, are primarily defined by managers. Currently, WCPFC has adopted a ‘de facto’ minimum TRP level for these two stocks through paragraphs 12 and 14 of CMM 2018-01, being to maintain the spawning biomass depletion ratio at or above the average $SB/SB_{F=0}$ for 2012-2015. Consideration of the objectives for these stocks and associated fisheries would enable more refined analyses to be performed.

In relation to this, as noted in more detail in the equivalent paper for skipjack (see Pilling (2021)), the text describing the TRP level 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. 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 felt achieved the most important management objectives or represented the best trade-off between them.

Other comments

The new information that was incorporated within the 2020 yellowfin tuna stock assessment implies a more robust stock than estimated previously. This is clearly seen by the minimal risks of falling below the LRP identified at the levels identified here, and the significant increases in fishing levels required to result in stock sizes equivalent to risk levels greater than zero. It should be noted that key areas for further work on the yellowfin assessment were identified for the coming year, and an external review is planned for 2022 (SPC-OFP, 2021).

References

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Tables and figures

Table 1. Median <u>bigeye</u> tuna depletion levels ($SB/SB_{F=0}$) assuming 'recent' recruitment conditions, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2015-2018) average levels, change in purse seine effort and longline catch (scalar) from baseline (2016-2018) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP and spawner- and yield-per-recruit levels relative to that under 'baseline' (2016-2018 average conditions), under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent depletion levels that would result for skipjack, yellowfin and South Pacific albacore for each of the candidate bigeye TRPs are provided in the last three columns.

BET: recent recruitment											
Median depletion level (% $SB_{F=0}$)	Change in SB (% $SB_{F=0}$) from 2012-2015 average	Change in SB (% $SB_{F=0}$) from 2015-2018 average	Change in fishing from 2016-2018 levels	Median total equilibrium yield (%MSY)	Risk $SB/SB_{F=0}$ < LRP	Rel. YPR	Rel. SPR	Notes	Equiv. SKJ $SB/SB_{F=0}$	Equiv. YFT $SB/SB_{F=0}$	Equiv. SPA $SB/SB_{F=0}$
48%	+30%	+17%	0%	95%	0%	1	1	Base 2016-2018 conditions	43%	59%	43%
33%	-10%	-20%	+54%	98%	10%	1.21	0.65	Avg. 2012-2015 – 10%	35%	43%	39%
37%	0%	-10%	+38%	98%	3%	1.17	0.76	Avg. 2012-2015	37%	46%	40%
41%	+10%	0%	+24%	98%	0%	1.12	0.86	Avg. 2012-2015 + 10%	39%	48%	41%
49%	+34%	+21%	-4%	94%	0%	0.98	1.02	Avg. depletion 2000-04	44%	54%	43%
32%	-12%	-21%	+55%	98%	10%	1.22	0.64	10% risk re LRP	35%	43%	39%
29%	-23%	-30%	+70%	98%	20%	1.24	0.54	20% risk re LRP	34%	41%	38%

Table 2. Median <u>bigeye</u> tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2015-2018) average levels, change in purse seine effort and longline catch (scalar) from baseline (2016-2018) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP and spawner- and yield-per-recruit levels relative to that under 'baseline' (2016-2018 average conditions), under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent depletion levels that would result for skipjack, yellowfin and South Pacific albacore for each of the candidate bigeye TRPs are provided in the last three columns.

BET: long-term recruitment								Notes	Equiv. SKJ $SB/SB_{F=0}$	Equiv. YFT $SB/SB_{F=0}$	Equiv. SPA $SB/SB_{F=0}$
Median depletion level (%$SB_{F=0}$)	Change in SB (%$SB_{F=0}$) from 2012-2015 average	Change in SB (%$SB_{F=0}$) from 2015-2018 average	Change in fishing from 2016-2018 levels	Median total equilibrium yield (%MSY)	Risk $SB/SB_{F=0}$ < LRP	Rel. YPR	Rel. SPR				
43%	+17%	+6%	0%	97%	5%	1	1	Base 2016-2018 conditions	43%	59%	43%
33%	-10%	-20%	+33%	98%	20%	1.14	0.75	Avg. 2012-2015 – 10%	38%	46%	41%
37%	0%	-10%	+22%	97%	14%	1.10	0.82	Avg. 2012-2015	39%	48%	42%
41%	+10%	0%	+8%	97%	8%	1.04	0.93	Avg. 2012-2015 + 10%	42%	51%	43%
49%	+34%	+21%	-17%	96%	1%	0.91	1.14	Avg. depletion 2000-04	48%	62%	44%
40%	+6%	-4%	+12%	97%	10%	1.05	0.90	10% risk re LRP	41%	50%	42%
33%	-10%	-19%	+33%	98%	20%	1.14	0.75	20% risk re LRP	38%	46%	41%

Table 3. Median <u>yellowfin</u> tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2015-2018) average levels, change in purse seine effort and longline catch (scalar) from baseline (2016-2018) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP and spawner- and yield-per-recruit levels relative to that under 'baseline' (2016-2018 average conditions), under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent depletion levels that would result for skipjack, South Pacific albacore and bigeye (under recent (R) and long-term (L) recruitment scenarios) for each of the candidate yellowfin TRPs are provided in the last three columns.

YFT: long-term recruitment								Notes	Equiv. SKJ $SB/SB_{F=0}$	Equiv. BET-R/L $SB/SB_{F=0}$	Equiv. SPA $SB/SB_{F=0}$
Median depletion level ($\%SB_{F=0}$)	Change in SB ($\%SB_{F=0}$) from 2012-2015 average	Change in SB ($\%SB_{F=0}$) from 2015-2018 average	Change in fishing from 2016-2018 levels	Median total equilibrium yield (%MSY)	Risk $SB/SB_{F=0}$ < LRP	Rel. YPR	Rel. SPR				
59%	+7%	0%	0%	63%	0%	1	1	Base 2016-2018 conditions	43%	48%/43%	43%
49%	-10%	-16%	+65%	77%	0%	1.32	0.83	Avg. 2012-2015 – 10%	34%	30%/26%	38%
55%	0%	-6%	+29%	70%	0%	1.15	0.92	Avg. 2012-2015	38%	40%/34%	41%
60%	+10%	+3%	-5%	62%	0%	0.97	1.01	Avg. 2012-2015 + 10%	45%	50%/45%	43%
54%	-1%	-8%	+34%	71%	0%	1.17	0.91	Avg. depletion 2000-2004	38%	38%/30%	40%
31%	-43%	-47%	+200%	88%	10%	1.61	0.47	10% risk re LRP	26%	8%/3%	35%
NA	-	-	-	-	-	-	-	20% risk re LRP	-	-	-

Annex 1: SC16 request

76. Noting the request from WCPFC16 for the Scientific Committee to provide advice on the formulation of TRPs for bigeye and yellowfin tuna, and for the Scientific Service Provider to conduct an analysis for bigeye and yellowfin tuna similar to that undertaken in working paper WCPFC16-2019-14 (Current and projected stock status of WCPO skipjack tuna to inform consideration of an updated target reference point), as outlined in para. 273-275 of the WCPFC16 Summary Report, SC16 reviewed SC16-MI-WP-01 and requested the Scientific Services Provider undertake the analyses for bigeye and yellowfin tuna according to the criteria outlined in the table below:

Issue	Requested Scenario
Model settings and the uncertainty grid	The SC16 agreed structural uncertainty grid.
Additional scenarios	To use both short- and long-term recruitment for bigeye tuna.
The range of candidate TRPs to be explored:	There are some advantages to defining candidate target stock depletion relative to the average biomass within a recent time period. This is consistent with the approach taken for development of the South Pacific Albacore interim TRP and serves to “future proof” the candidate TRP from changes in the biomass time series that have been noted with updated assessments. Specifying a time period also allows reference to some fisheries performance metrics within that period, such as CPUE. The following candidate TRPs are specified: • Average $SB/SB_{F=0}$ for 2012-2015 (consistent with the Aims of CMM 2018-01) • 10% above Average $SB/SB_{F=0}$ for 2012-2015 • 10% below Average $SB/SB_{F=0}$ for 2012-2015 • TRPs at intermediate steps between the candidates outlined above (e.g. at 5% intervals) were also recommended. • An alternative TRP based on the average SB for 2000-2004 should also be explored. • Additional candidate TRPs can be identified in terms of the risk of breaching the LRPs; in particular: the SB/SBF=0 levels associated with 10% and 20% risks of breaching the LRP based on an updated analysis using the SC16 adopted structural uncertainty grid.
Time period of the projections	30 years, consistent with the earlier skipjack analyses. Intervals of 10 years will be presented within this period. The rationale is to have a period to allow the population to reach equilibrium.
Use of catch or effort	• PS – effort • LL – catch • Other fisheries – catch SC16 noted that this is for the purposes of these analyses and without prejudice to preferred management arrangements.

The baseline catch and effort levels	A recent period is preferable because it is more relevant to recent activity levels and also a more realistic reflection of IND/PHI fisheries catches.
Limits to the range of the fishery scalars	SC16 noted that if scalars are too constrained then it might not be possible to achieve the different biomass TRP levels and some guidance on this issue was sought from the SSP. Scalars would be applied equally to purse seine effort and longline catch. For other fleets, recent catch levels would be assumed. SC16 also noted that this is an exploratory exercise to see what the consequences could be for different TRP choices and not a management recommendation that sets up any kind of precedent.
Reporting the output of the analysis:	Similar outputs to the skipjack work reported in WCPFC16-2019-14. In addition, SC16 recommended reporting against the Aims of CMM-2018-01 paras 12 and 14 being "average $SB/SB_{F=0}$ for 2012-2015". SC16 also noted the request from one CCM that the Scientific Service Provider produce information on the projected yield per recruit and spawning biomass per recruit under the various harvest scenarios.

77. Noting the large number of scenarios included in the above request, possible analytical challenges that may arise, and the heavy workload of the Scientific Service Provider due to other requests, the following priority was placed on the TRPs to be evaluated.

a) The initial average and +/- 10% proposal (3 scenarios)
b) The additional runs for 10% and 20% risk and the average SB for 2000-2004 (3 scenarios)
c) Intermediate values based upon the results of the above work (e.g., 2-5 scenarios)

78. SC16 recommends that the above analyses be completed by the Scientific Service Provider and a paper summarizing both the analyses undertaken and the tentative results be forwarded to the TCC16 and final results to WCPFC17.