COMMISSION
Twenty-First Regular Session
28 November to 3 December 2024
Suva, Fiji (Hybrid)

Analyses to Inform Discussions on Candidate Bigeye and Yellowfin Target Reference Points

WCPFC21-2024-31
6 November 2024

Submitted by the SPC-OFP

Executive Summary

Under the harvest strategy workplan, WCPFC21 is scheduled to agree target reference points (TRPs) for bigeye and yellowfin this year. To provide some information on which WCPFC21 may base discussions and provide advice, this paper updates analyses presented in WCPFC18-2021-11 using the results of projections developed from the agreed 2023 stock assessments for bigeye and yellowfin.

Two approaches were taken. The first ('equal change') was as in previous analyses, with equal proportional changes in purse seine effort and longline catch made from baseline levels to achieve candidate TRPs. The second ('incorporating CMM 2022-01') reflected the potential implications of CMM 2022-01 for future purse seine effort levels (bigeye, yellowfin and skipjack), and for bigeye specifically the potential implications of CMM 2023-01 for future FAD closure periods. This 'defined' future purse seine fishing levels, and candidate TRPs were then achieved by adjusting future longline catch levels. This scenario may be considered as an example of the balance of fishery controls that will need to be achieved across the stocks as the mixed fishery harvest strategy framework is developed. We highlight that candidate TRP levels can be achieved through a range of different purse seine and longline fishing combinations.

The current analysis reflects the challenges in setting 'common' TRPs for different stocks in a multispecies fishery. The objectives in CMM 2023-01 for bigeye and yellowfin cannot both be met precisely – if achieved for one of the stocks, the other will be above or below that currently specified level. In the examples presented here, TRPs for both bigeye and skipjack could be achieved under specific bigeye recruitment assumptions, but the current objective for yellowfin was not. Compatible TRPs for all stocks may require a trade-off between objectives for the different stocks.

Key decisions remain to be taken for the mixed fishery framework that would help inform analyses:

- Does the Commission wish to identify the bigeye TRP stock level that achieves desirable outcomes, so that an MP can be designed to achieve it on average?
- Does the Commission wish to identify 'baseline' levels for the bigeye management procedure (e.g. FAD closure duration, longline catch levels) that will help define the TRP?
- Could the yellowfin TRP be an emergent property of the other MPs, noting that not all fisheries taking yellowfin will be controlled within the candidate mixed fishery framework?
- How should the catch of relevant components of 'other fisheries' be dealt with within evaluations for yellowfin? In this analysis they have been set consistent with CMM 2022-01, with the implications of an alternative level also evaluated.

WCPFC20 discussed the use of 'threshold' target reference points, representing levels that the stock should remain at or above, which may provide greater flexibility to achieve objectives across stocks within the mixed fishery approach to harvest strategies. However, the status of a threshold TRP would need to be clarified by managers in terms of the risk of falling below that level.

SC20 tasked the SSP to update tables with equivalent depletion levels for South Pacific albacore, provide information on the impact on vulnerable biomass within the tropical longline fishery and southern longline fishery, and re-evaluate the candidate yellowfin and bigeye tuna TRPs using more recent fishing conditions for the domestic 'miscellaneous' fisheries of Indonesia, Philippines, and. Results are included in this paper Vietnam [rather than delivering a separate paper on the alternative fishing conditions for the domestic fisheries as suggested by SC20, we have included the results from this analysis in Appendix 2]. SC20 also:

- recommended that the SMD and Commission take into account the analysis … including the following when considering target reference points for bigeye and yellowfin tuna:
    - Based on the 2023 stock assessment for yellowfin, the miscellaneous fisheries are estimated to account for approximately 37% of the impact on the spawning potential over the period 2016-2018 (see Table 5 of WCPFC20-2023-16), but recent catch for yellowfin is higher.
    - Based on the analysis in SC20-MI-WP-07, the CMM 2023-01 objectives for yellowfin and bigeye tuna cannot both be met simultaneously - if precisely achieved for one stock, the other will be above or below that level.

SMD02 also expressed concern over the increase in yellowfin catches of miscellaneous fisheries in Region 2, noting that this took place mainly in archipelagic waters excluded from the tropical tuna measure. SMD02 noted that the SSP expects to deliver the schedule of work for yellowfin tuna as reflected in the shaded area of Table 1 [of the SMD02 report] for WCPFC21.

WCPFC21 is invited to:

- Discuss the outcomes for bigeye and yellowfin tuna under the different SC16 candidate TRP levels examined to aid their scheduled decisions on bigeye and yellowfin TRPs.
- Note the assumptions made for fisheries (baselines, effort/catch) within these evaluations.
- Consider how a threshold target reference point may be specified.

Introduction

Under the harvest strategy workplan agreed by WCPFC20 in December 2023 (Attachment 4 of the meeting Summary Record), WCPFC21 is scheduled to agree target reference points (TRPs) for WCPO bigeye and yellowfin this year.

In 2023, SC19 provided some comments on TRPs for these stocks within their discussion around SC19-MI-WP-07 (Mixed-fishery harvest strategy update). WCPFC20 discussed these issues further but made no firm decisions. At WCPFC20, specific CCMs did raise a request for the evaluation of a candidate TRP option related to the management objective indicated in CMM 2023-01, being the 2012-15 depletion level but adjusted for the effect of removing the FAD closure (WCPFC20 report, paragraph 329). In the current analysis, this is interpreted as a complete removal of the FAD closure both within EEZs and on the high seas.

SC19 and WCPFC20 also discussed the nature of TRPs for these stocks given the mixed fishery approach for harvest strategies (see paragraph 582 of the SC19 report). Specific CCMs identified the use of 'threshold' reference points as a potential approach, identifying minimum stock levels that would still meet desired objectives. Considerations around this form of TRP are raised within this paper.

In the absence of clear guidance from WCPFC20, but to provide some information on which the Commission may base discussions, this paper repeats and updates the analyses presented in WCPFC18-2021-11 (based on the requests of SC16; see Appendix 3). It uses the results of projections developed from the agreed 2023 stock assessments for bigeye and yellowfin and incorporates recent relevant decisions by the WCPFC, including CMM 2022-01 (the skipjack harvest strategy) and CMM 2023-01 (the tropical tuna CMM that defines FAD closure durations within the purse seine fishery). This paper also addresses the requests of SC20 and SMD02 for additional analyses, with updates including the potential consequences for South Pacific albacore and the potential impacts on the vulnerable biomass (a proxy for CPUE) in tropical and southern longline fisheries (see tables) and higher fishing levels within 'Region 2' of the yellowfin stock assessment (see Appendix 2). The methods behind the analyses can be found in Appendix 1.

Results

The results are presented for the three separate analyses:

- 'equal change', where future purse seine and longline fishing levels (effort and catch, respectively) are changed in equal proportion from baseline levels to achieve the desired stock depletion level,
- 'incorporating CMM 2022-01', where recent decisions on CMMs that influence future purse seine fishing levels are considered. Specifically:
    - Purse seine effort is maintained at 2012 levels (recent outcome of CMM 2022-01).
    - The primary assumption for the FAD closure period is as defined by CMM 2023-01 (1.5 months in EEZs, 2.5 months on the high seas), which specifically affects bigeye.
    - A secondary assumption for the SC16 suggested candidate option of 2012-2015 depletion levels is the removal of the FAD closure, as requested by CCMs at WCPFC20.
    - Longline catch levels are then adjusted to achieve the candidate TRP level suggested by SC16.
- undertaking these two analyses for yellowfin, but assuming more recent higher fishing levels within 'Region 2' of the assessment (ID/PH/VN).

'Recent conditions', representing the impact of continued average purse seine and longline fishing at the levels seen over 2019-2021 are used as a baseline scenario.

The scalars (multipliers) calculated to represent the different conditions assumed within the purse seine fishery under the different analyses are presented in Table 1. Changes in the purse seine fishery for bigeye can reflect both changes in the FAD closure period duration and increases in purse seine effort (being multiplicative). When calculating the corresponding impact on skipjack or yellowfin, the impact of changes to the FAD closure period (e.g. under CMM 2023-01 or removal of the FAD closure) are 'removed' from the purse seine effort multiplier, given that yellowfin and skipjack tuna are assumed to be affected primarily by overall purse seine effort levels, not the proportion of FAD/free school sets within that effort level. Therefore:

- The change between the baseline period of 2019-2021 effort to represent effort levels in 2012 equates to an increase of 17% (multiplier = 1.17). This multiplier affects bigeye, yellowfin and skipjack where 2012 effort levels are assumed.
- If purse seine effort remains at 2019-2021 levels, but the FAD closure period changes to that specified in CMM 2023-01, a 19% increase in FAD sets is estimated. This affects bigeye specifically.
- Given that increases in purse seine effort and increases in FAD sets due to closure changes are multiplicative, a scenario with 2012 effort and CMM 2023-01 FAD closures equate to an increase in purse seine FAD sets of 40% (multiplier of 1.40) relative to the baseline for bigeye.
- If purse seine effort remains at 2019-2021 levels, but the FAD closure were removed completely, a comparable 39% increase in FAD sets is estimated. When this is combined with the scalar for 2012 effort levels, the resulting FAD set effort is 62% higher (multiplier = 1.62) for bigeye.

Recent conditions

We use 'recent conditions' (2019-2021 levels in purse seine and longline fisheries) as a baseline example of outcomes. This was examined for each stock and each recruitment assumption.

For bigeye tuna, continuing 2019-2021 fishing levels will achieve the objectives of the tropical tuna CMM, in that the stock remains above the 2012-2015 average depletion level (34%$SB_{F=0}$) in the future under both recruitment assumptions. For yellowfin, however, the tropical tuna CMM objective is not met, with the stock declining below the 2012-2015 average depletion level (44%$SB_{F=0}$).

For South Pacific albacore, recent 'baseline' conditions at 2019-2021 levels (with remainder of the EPO catches adjusted to 22,500mt) are generally slightly higher than the 2020-2022 levels examined within WCPFC21-2024-29. However, those conditions still achieve the recalibrated TRP for that stock (50%$SB_{F=0}$).

Equal change

The results where candidate bigeye and yellowfin TRPs are achieved by changing purse seine effort and longline catch by an equal proportion relative to 2019-2021 levels are presented in Table 2, Table 4 and Table 6 (see also Figure 1 and Figure 2), while consequences for vulnerable biomass in the tropical and southern longline fisheries are presented in Table 3, Table 5 and Table 7.

Where recent recruitment patterns are assumed for bigeye tuna, candidate TRPs related to both 2012-2015 depletion levels and risk levels could be achieved with increases in purse seine effort and longline catch (Table 2). This includes the depletion level equivalent to 2012-2015 average levels adjusted for the complete removal of the FAD closure. 2000-2004 average depletion levels are achieved with the continuation of 2019-2021 conditions; note that this does not therefore incorporate the impact of the

shortened FAD closure under CMM 2023-01 and would require a corresponding reduction in purse seine effort to do so. Risks of falling below the LRP are 5% or less, except when specific risk levels are specified as part of the candidate target. Achieving the 2012-2015 average depletion level for bigeye under recent recruitment levels would lead to skipjack depletion being around the adopted TRP of $50\%SB_{F=0}$; the impact of the CMM 2023-01 FAD closure duration on the multiplier for bigeye is removed from the equivalent projections for skipjack. However, this candidate bigeye TRP does not achieve the goal of 2012-2015 average depletion levels for yellowfin, nor that for South Pacific albacore under the baseline assumptions made here.

When less productive longer term recruitment patterns are assumed for bigeye tuna, candidate TRPs related to 2012-2015 depletion levels and risk levels could again be achieved with increases in purse seine effort and longline catch, although those increases in fishing level are lower than where recent recruitments are assumed (Table 4). However, achieving the average depletion level estimated over 2000-2004 would require a 10% reduction in both purse seine effort and longline catch. Corresponding risk levels relative to the LRP are also greater than where recent recruitment levels are assumed. In general, since lower increases in purse seine effort are required to achieve candidate levels - taking into account the multiplier resulting from the shorter FAD closure period relative to that over 2019-2021 – corresponding skipjack depletion levels are generally above the skipjack TRP level. However, only under the bigeye TRP of 2000-2004 average depletion levels, which requires reduced fishing levels, is the 2012-2015 target for yellowfin as well as the recalibrated TRP for South Pacific albacore also achieved.

For yellowfin, purse seine effort and longline catch can only be increased when considering the 2012-2015 average -10% and the two LRP risk level candidate TRPs (Table 6). To achieve all other candidate TRPs, reductions in effort and catch from 2019-2021 average levels are required. For example, if 2012-2015 average depletion levels are desired, a 10% reduction in effort and catch is needed. Both skipjack, bigeye and South Pacific albacore are above the current TRP or CMM 2023-01 objective where options other than the LRP risk levels are considered.

Outcomes for the longline vulnerable biomass (CPUE proxy) relative to average levels over 2019-2021 are presented in Table 3, Table 5 and Table 7 for 'tropical' and 'southern' longline components (see Appendix 1 for fishery definitions) for each stock and bigeye recruitment scenario. Relative trends within fishery groups mirror that of the median depletion levels. Vulnerable biomass in the tropical longline fishery generally declines relative to 2019-2021 average levels across both bigeye and yellowfin TRPs; the exception being at the 2001-2004 average depletion level for yellowfin, which indicates a 5% increase. Impacts on the southern longline vulnerable biomass are less pronounced, with levels increasing relative to the 2019-21 period for both stocks under the bigeye TRP options (Table 3, Table 5). A similar increasing trend is seen for both bigeye and yellowfin southern longline vulnerable biomass under the yellowfin TRP options, except for yellowfin vulnerable biomass for yellowfin TRPs related to risk levels and to the average depletion levels across 2012-2015 minus 10%.

Incorporating CMM 2022-01

In these scenarios for bigeye, purse seine effort is defined by CMM 2022-01 (at 2012 levels) and the specified FAD closure period (as under CMM 2023-01 or a total removal). Under both future bigeye recruitment scenarios (Table 8 and Table 10; see also Figure 1), candidate TRP depletion levels for bigeye tuna can be achieved – with the exception of 2000-04 average stock depletion conditions – with increased longline bigeye catches relative to 2019-2021 levels. To achieve 2001-04 average depletion conditions, however, longline bigeye catches would need to decrease by 35% or 45% relative to the average catch over those years under the alternative recruitment scenarios. Risk levels relative to the LRP (for candidate TRPs where risk levels were not specified) were generally low under the recent recruitment scenario but reached 16% when considering the '2012-2015 average -10%' objective under the long-term recruitment scenario. Where purse seine effort is at 2012 levels and

the FAD closure is removed completely, to achieve the CMM 2023-01 objective of 2012-15 average stock levels, longline catch could increase by 50% or 25%, dependent upon the recruitment assumption. The CMM 2023-01 objective for yellowfin was not achieved under any candidate TRP for bigeye under these assumptions. Given the assumption of 2012 purse seine effort levels and the associated assumptions for pole and line and domestic fishing levels, the skipjack TRP is achieved under all TRP scenarios. The South Pacific albacore stock is at or above the recalibrated TRP where a bigeye TRP reflecting average 2001-2004 depletion levels (both recruitment scenarios) or 2012-2015 +10% (long term recruitment) are selected.

For yellowfin where purse seine effort is assumed to increase to 2012 levels, few of the SC16 TRP scenarios can be achieved with levels of future longline catch within the range examined (from 0.5 to 2 times the baseline longline catch level; Table 12). Only the candidate TRP of 2012-2015 depletion level minus 10% objective can be achieved with future longline yellowfin catches within that range, with a 10% reduction in longline catch. The bigeye CMM 2023-01 objective was also achieved under this scenario. All other candidate yellowfin levels require decreases or increases (in the case of risk levels) in longline catch outside the catch range examined, i.e. more than a 50% reduction in catch, or a greater than 100% increase in catch. For skipjack, the assumption of 2012 effort levels within the scenario meant that the stock was maintained around the TRP on average across all scenarios. For South Pacific albacore, the stock is slightly above the recalibrated TRP at the 2012-2015 depletion level minus 10% objective.

Outcomes for the longline vulnerable biomass (CPUE proxy) relative to average levels over 2019-2021 are presented in Table 9, Table 11 and Table 13 for 'tropical' and 'southern' longline components, for each stock and bigeye recruitment scenario. Patterns are comparable to that seen for the 'equal change' scenario, with tropical longline vulnerable biomass falling relative to the 2019-2021 average across all TRPs examined, and generally increases in vulnerable biomass for the southern longline fishery.

Assuming higher recent fishing levels in Region 2 for yellowfin tuna

Small scale fisheries in Region 2 were modelled at more recent levels, and the resulting purse seine and longline fishing levels that achieved the candidate yellowfin TRP depletion levels were re-evaluated for the 'equal change' and 'Incorporating CMM 2022-01' scenarios. The results are shown in Appendix 2, Table 14 and Table 15.

Assuming higher levels of effort within Region 2 had relatively little impact on the levels of future purse seine and longline fishing required to achieve the median depletion levels specified – only in the case of achieving the average 2012-2015 depletion level (0.44 $SB_{F=0}$) with equal proportional changes in purse seine effort and longline catch was a 5% greater decrease in fishing required. This might seem surprising, as one would expect that the higher recent levels of fishing would lead to greater depletion in Region 2, requiring other regions of the WCPO to fish less to compensate. However, this outcome appears the result of two factors: 1) the depletion in Region 2 is already relatively large (this region is assessed to be the most depleted within the assessment; see Figure 59 of SC19-SA-WP-04) and 2) given the level of depletion, increases in effort to achieve greater catches sufficient to impact the stock further appear greater than assumed within this modelling. This is not likely to be the case if the actual recent increases in catch were modelled; however we note that the use of effort within these projection analyses for Region 2 was necessary as assuming constant 2016-2018 average reported levels of catch within Region 2 fisheries led to the model crashing as there were insufficient fish to allow that catch to be taken within that region.

Discussion

Two approaches were taken to evaluate the consequences of achieving alternative candidate TRP depletion levels within this analysis. The first was that used in previous analyses, with equal proportional changes in purse seine effort and longline catch from 2019-2021 average levels to achieve the candidate TRPs. The second reflected the adoption of CMM 2022-01 and potential implications for future purse seine effort levels (bigeye, yellowfin and skipjack), and also for bigeye the adoption of CMM 2023-01 and potential implications for future FAD closure periods, and discussions at WCPFC20. This 'defined' the future level of purse seine fishing, and candidate TRPs are achieved by adjustments to future longline catch levels. These evaluations therefore assume that this pattern of fishing will continue, and the basis for the TRPs would need to be considered if these patterns changed.

We highlight that candidate TRP levels can be achieved through a range of different purse seine and longline fishing combinations, as shown in Figures 1 to 6 of WCPFC20-2023-16. Alternative purse seine effort/longline catch combinations would have implications for the metrics calculated. For example, in the current study there are differences in the risk of falling below the LRP under a given candidate TRP where equal change or CMM 2022-01 scenarios are examined, reflecting the different impacts gears have on components of the stock.

Skipjack stock status is driven by the level of overall purse seine effort (and associated assumptions made for the level of fishing in pole and line and 'other' fisheries), while that for South Pacific albacore is defined by the baseline conditions (2019-2021 average longline fishing levels being slightly higher than the levels in WCPFC21-2024-29, but still achieve the recalibrated iTRP) and the change in longline fishing assumed under each scenario within the equator to 10°S region of the 'tropical longline fishery'.

Risk-related depletion level objectives represent 'minimum' TRP values consistent with those risk levels; 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.

The values examined are based upon those developed by SC16 to support discussions by managers. However, objectives and the TRPs that reflect them should ultimately be developed by managers rather than scientists, as detailed in SC14-MI-WP-05. Previous papers have highlighted that there is a need to have specific language defining the TRP level, based upon the management objective that the TRP is designed to achieve, rather than identifying a specific level of stock depletion. The language defining the TRP 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.

Implications for the mixed fishery approach

The modelling framework for the mixed fishery approach to harvest strategy development for WCPFC key tuna stocks remains tractable and paves the way for all four tuna stocks to be included in the modelling framework. Under the current mixed fishery harvest strategy framework, yellowfin tuna does not have an MP and effectively relies on the MPs of the other stocks to achieve its goals. As noted in SC19-MI-WP-07, this approach is regarded as an initial attempt at considering multi-species and mixed fisheries with the harvest strategy approach and if found to be unsuccessful in terms of achieving objectives for all four stocks, alternative approaches will need to be developed.

The current analysis reflects the challenges in setting 'common' TRPs for different stocks in a multispecies fishery, and hence in achieving objectives for all stocks at the same time. The objectives in CMM 2023-01 for bigeye and yellowfin cannot both be met precisely – if achieved for one of the stocks, the other will be above or below that level. In the examples presented here, the TRPs for both bigeye and skipjack could be achieved, under specific bigeye recruitment assumptions, but the current objective for yellowfin was not achieved. Under the current framework to manage mixed fisheries within the harvest strategy approach, where yellowfin is managed through MPs for the other stocks, achieving CMM 2023-01 objectives for that stock may not be possible. That does not mean that TRPs cannot be identified for all stocks that are compatible, but this may require a trade-off between objectives for the different stocks.

The scenario incorporating the settings of CMM 2022-01 and CMM 2023-01 highlights the timing of decisions for the different stocks. It may be considered as an example of the balance of fishery controls that will need to be achieved across the stocks as the mixed fishery framework is developed.

As noted in SC19-MI-WP-07, there are considerations for both bigeye and yellowfin TRPs:

- Does the Commission wish to identify the bigeye TRP stock level that achieves desirable outcomes, so that an MP can be designed to achieve it on average? The type of analysis presented here can inform those considerations.
- In a similar approach to that for skipjack, does the Commission wish to identify 'baseline' levels for the management procedure (e.g. FAD closure duration, longline catch levels) that will help define the TRP?
- Given that most of the fisheries taking bigeye are proposed to be under MP control, either directly or through the mixed fishery approach, it is anticipated that a single TRP value will represent the level around which the stock should fluctuate. However, the points made below for yellowfin may also apply.
- Could the yellowfin TRP largely be an emergent property of the other MPs, noting that not all fisheries taking yellowfin will be controlled within the candidate mixed-fishery framework?
- How should the catch of relevant components of 'other fisheries' be dealt with within evaluations for yellowfin? For example, in the current analysis they have been set at levels consistent with the years defined in CMM 2022-01, with a separate evaluation of the impact of an alternative assumption for future fishing levels.

Based upon the points raised in SC19-MI-WP-07, WCPFC20 discussed the use of 'threshold' levels as target reference points for some stocks, representing levels that the stock should remain at or above. This approach may provide greater flexibility to achieve objectives across stocks within the mixed fishery approach to harvest strategies. However, the status of a threshold TRP would need to be clarified by managers. A target reference point is generally to be achieved on average – i.e. with a 50% probability of being below or above it through time, and which interacts with the maximum permissible risk of falling below the LRP (i.e. the threshold would need to be sufficiently far away from the LRP so that the risk of breaching the LRP is acceptable within the uncertainty framework used). Alternatively, a threshold TRP could represent a level that the stock must remain above with 100% probability, thereby functioning as a type of 'hard limit' within the evaluations. For example, under the dynamic management decision making of a harvest strategy framework, candidate mixed fishery MPs that led to a stock falling below that threshold target within an evaluation more often than the specified probability could be discarded. However, this probability would also need to be specified by managers as part of the threshold level definition.

SC20:

- recommended that the SSP include the following updates to SC20-MI-WP-07 for presentation to the Commission:
    - Update tables 2-7 with the equivalent depletion levels for South Pacific albacore based on the 2024 South Pacific albacore stock assessment;
    - Include additional columns in the evaluation of candidate TRPs for YFT and BET which provide the impact on vulnerable biomass within the tropical longline fishery and the southern longline fishery.
- recommended that the SMD and Commission take into account the analysis contained in SC20-MI-WP-07 including the following when considering target reference points for bigeye and yellowfin tuna:
    - Based on the 2023 stock assessment for yellowfin, the miscellaneous fisheries are estimated to account for approximately 37% of the impact on the spawning potential over the period 2016-2018 (see Table 5 of WCPFC20-2023-16), but recent catch for yellowfin is higher.
    - Based on the analysis in SC20-MI-WP-07, the CMM 2023-01 objectives for yellowfin and bigeye tuna cannot both be met simultaneously - if precisely achieved for one stock, the other will be above or below that level.
- recommended that an additional working paper be submitted to WCPFC21, which will include a re-evaluation of the candidate yellowfin and bigeye tuna TRPs using more recent fishing conditions for the domestic fisheries of Indonesia, Philippines, and Vietnam. The 2016-18 average catches are significantly lower than the recent fishing level, likely leading to a more optimistic projected stock status for yellowfin tuna.

SMD02:

- expressed concern over the increase in yellowfin catches in Region 2, noting that this took place mainly in archipelagic waters excluded from the tropical tuna measure. SMD02 noted the request of SC20 for analysis from the SSP to be submitted to WCPFC21, which will include a re-evaluation of the candidate yellowfin and bigeye tuna TRPs using more recent fishing conditions for the domestic fisheries of Indonesia, Philippines, and Vietnam. SMD02 noted that the SSP expects to deliver the schedule of work for yellowfin tuna as reflected in the shaded area of Table 1 [of the SMD02 report] for WCPFC21.

WCPFC21 is invited to:

- Discuss the outcomes for bigeye and yellowfin tuna under the different SC16 candidate TRP levels examined to aid their scheduled decisions on bigeye and yellowfin TRPs.
- Note the assumptions made for fisheries (baselines, effort/catch) within these evaluations.
- Consider how a threshold target reference point may be specified.

References

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1 Tables and figures

Table 1. Purse seine multipliers (scalars) from 2019-2021 levels under future effort and FAD closure assumptions, and the stock for which they are 'relevant'.

Purse seine assumption	Multiplier off 2019-2021	Stock impacted		
		Bigeye	Yellowfin	Skipjack
2019-2021 effort levels	1	x	x	x
2012 effort levels, 2019-2021 FAD closure period	1.17	x	x	x
2019-2021 effort levels, CMM 2023-01 FAD closure period	1.19	x		
2019-2021 effort levels, no FAD closure period	1.39	x		
2012 effort levels, CMM 2023-01 FAD closure period	1.40	x		
2012 effort levels, removal of FAD closure	1.62	x		

Table 2. Median bigeye tuna depletion levels ($SB/SB_{F=0}$) assuming 'recent' recruitment conditions and proportional changes in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions. Corresponding change in spawning biomass from 2012-2015 and 'recent' (2018-2021) average levels ($0.35SB_{F=0}$) and risk of falling below the LRP under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent median depletion levels that may 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 2018-2021 average	Change in fishing from 2019-2021 levels		Risk $SB/SB_{F=0}$ < LRP				
			Purse seine	Longline					
0.46	+35%	+31%	0%	0%	0%	Base 2019-2021 conditions	53%	41%	50%
0.30	-12%	-14%	+60%	+60%	5%	Avg. 2012-2015 – 10%	48%	33%	47%
0.34	0%	-3%	+45%	+45%	0%	Avg. 2012-2015	50%	36%	48%
0.37	+9%	+6%	+30%	+30%	0%	Avg. 2012-2015 + 10%	52%	38%	49%
0.32	-6%	-9%	+50%	+50%	1%	Avg. 2012-2015 minus FAD closure	52%	37%	47%
0.46	+35%	+31%	0%	0%	0%	Avg. depletion 2000-04	53%	41%	50%
0.29	-15%	-17%	+65%	+65%	10%	10% risk re LRP	46%	32%	47%
0.26	-24%	-26%	+80%	+80%	20%	20% risk re LRP	45%	30%	46%

* assumption that FAD closure duration does not affect SKJ or YFT stock status (see WCPFC20-2023-16). Therefore, purse seine impact is estimated using the assumed future total effort level, taking into account the impact of the FAD closure period under CMM 2023-01 into the purse seine effort scalar.

Table 3. Average trend in bigeye and yellowfin vulnerable biomass (CPUE proxy) for tropical and southern longline vessels at each median bigeye tuna depletion level (recent recruitment; $SB/SB_{F=0}$), assuming proportional changes in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions.

BET: recent recruitment		Bigeye vulnerable biomass (rel. 2019-2021 average)		Yellowfin vulnerable biomass (rel. 2019-2021 average)	
Median depletion level ($\%SB_{F=0}$)	Change in SB ($\%SB_{F=0}$) from 2012-2015 average	'Tropical' longline	'Southern' longline	'Tropical' longline	'Southern' longline
0.46	+35%	0.97	1.64	0.84	1.01
0.30	-12%	0.45	1.34	0.57	1.40
0.34	0%	0.57	1.42	0.69	1.48
0.37	+9%	0.70	1.51	0.82	1.55
0.32	-6%	0.53	1.40	0.75	1.49
0.46	+35%	0.97	1.64	0.97	1.64
0.29	-15%	0.40	1.30	0.51	1.35
0.26	-24%	0.30	1.21	0.40	1.27

Table 4. Median bigeye tuna depletion levels ($SB/SB_{F=0}$) assuming 'long term' recruitment conditions and proportional changes in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions. Corresponding change in spawning biomass from 2012-2015 and 'recent' (2018-2021) average levels ($0.35SB_{F=0}$) and risk of falling below the LRP under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent median depletion levels that may 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 2018-2021 average	Change in fishing from 2019-2021 levels		Risk $SB/SB_{F=0}$ < LRP				
			Purse seine	Longline					
0.43	+26%	+23%	0%	0%	0%	Base 2019-2021 conditions	53%	41%	50%
0.30	-12%	-14%	+45%	+45%	16%	Avg. 2012-2015 – 10%	50%	36%	48%
0.34	0%	-3%	+30%	+30%	3%	Avg. 2012-2015	52%	38%	49%
0.37	+9%	+6%	+20%	+20%	1%	Avg. 2012-2015 + 10%	53%	40%	49%
0.32	-6%	-9%	+40%	+40%	10%	Avg. 2012-2015 minus FAD closure	53%	39%	48%
0.46	+35%	+31%	-10%	-10%	0%	Avg. depletion 2000-04	58%	46%	51%
0.32	-6%	-9%	+40%	+40%	10%	10% risk re LRP	50%	36%	48%
0.30	-12%	-14%	+50%	+50%	20%	20% risk re LRP	48%	35%	47%

* assumption that FAD closure duration does not affect SKJ or YFT stock status (see WCPFC20-2023-16). Therefore, purse seine impact is estimated using the assumed future total effort level, taking into account the impact of the FAD closure period under CMM 2023-01 into the purse seine effort scalar.

Table 5. Average trend in bigeye and yellowfin vulnerable biomass (CPUE proxy) for tropical and southern longline vessels at each median bigeye tuna depletion level (long term recruitment; $SB/SB_{F=0}$), assuming proportional changes in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions.

BET: long term recruitment		Bigeye vulnerable biomass (rel. 2019-2021 average)		Yellowfin vulnerable biomass (rel. 2019-2021 average)	
Median depletion level ($\%SB_{F=0}$)	Change in SB ($\%SB_{F=0}$) from 2012-2015 average	'Tropical' longline	'Southern' longline	'Tropical' longline	'Southern' longline
0.43	+26%	0.85	1.50	0.84	1.01
0.30	-12%	0.43	1.22	0.54	1.28
0.34	0%	0.56	1.32	0.67	1.37
0.37	+9%	0.65	1.37	0.76	1.43
0.32	-6%	0.48	1.25	0.68	1.35
0.46	+35%	0.95	1.55	1.05	1.59
0.32	-6%	0.48	1.25	0.68	1.35
0.30	-12%	0.39	1.18	0.50	1.24

Table 6. Median yellowfin tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions and proportional changes in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions. Corresponding change in spawning biomass from 2012-2015 and 'recent' (2018-2021) average levels ($0.47SB_{F=0}$) and risk of falling below the LRP under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent median depletion levels that may result for skipjack, bigeye (under recent (R) and long-term (L) recruitment scenarios) and South Pacific albacore 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 2018-2021 average	Change in fishing from 2019-2021 levels		Risk $SB/SB_{F=0}$ < LRP				
			Purse seine	Longline					
0.41	-7%	-13%	0%	0%	0%	Base 2019-2021 conditions	53%	46%/43%	50%
0.39	-11%	-17%	+10%	+10%	0%	Avg. 2012-2015 – 10%	52%	41%/38%	50%
0.44	0%	-6%	-10%	-10%	0%	Avg. 2012-2015	55%	46%/44%	51%
0.48	+9%	+2%	-30%	-30%	0%	Avg. 2012-2015 + 10%	60%	53%/51%	52%
0.50	+14%	+6%	-40%	-40%	0%	Avg. depletion 2000-2004	63%	57%/55%	52%
0.31	-30%	-34%	+50%	+50%	10%	10% risk re LRP	44%	30%/27%	47%
0.27	-39%	-43%	+70%	+70%	20%	20% risk re LRP	42%	26%/23%	46%

* note assumption of FAD closure period affects bigeye stock status outcomes. Assumption for closure made here is CMM 2023-01 FAD closure duration

Table 7. Average trend in bigeye (both recruitment assumptions) and yellowfin tuna vulnerable biomass (CPUE proxy) for tropical and southern longline vessels at each median yellowfin tuna depletion level ($SB/SB_{F=0}$), assuming proportional changes in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions.

YFT: long-term recruitment		Yellowfin vulnerable biomass (rel. 2019-2021 average)		Bigeye vulnerable biomass (rel. 2019-2021 average)			
				Recent recruitment		Long term recruitment	
Median depletion level ($\%SB_{F=0}$)	Change in SB ($\%SB_{F=0}$) from 2012-2015 average	'Tropical' longline	'Southern' longline	'Tropical' longline	'Southern' longline	'Tropical' longline	'Southern' longline
0.41	-7%	0.84	1.01	0.97	1.64	0.85	1.50
0.39	-11%	0.80	0.97	0.69	1.48	0.67	1.37
0.44	0%	0.89	1.05	0.82	1.55	0.76	1.43
0.48	+9%	0.99	1.14	0.75	1.49	0.68	1.35
0.50	+14%	1.04	1.18	0.97	1.64	1.05	1.59
0.31	-30%	0.63	0.81	0.51	1.35	0.68	1.35
0.27	-39%	0.55	0.73	0.40	1.27	0.50	1.24

Table 8. Median bigeye tuna depletion levels ($SB/SB_{F=0}$) assuming 'recent' recruitment conditions and setting purse seine effort based upon recent CMMs, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2018-2021) average levels ($0.35SB_{F=0}$), change in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent median depletion levels that may 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 2018-2021 average	Change in fishing from 2019-2021 levels		Risk $SB/SB_{F=0}$ < LRP				
			Purse seine	Longline					
0.46	+35%	+31%	0%	0%	0%	Base 2019-2021 conditions	53%	41%	50%
0.30	-12%	-14%	+40%	+70%	4%	Avg. 2012-2015 – 10%	50%	34%	46%
0.34	0%	-3%	+40%	+50%	0%	Avg. 2012-2015		35%	47%
0.37	+9%	+6%	+40%	+25%	0%	Avg. 2012-2015 + 10%		37%	49%
0.32	-6%	-9%	+62%	+50%	1%	Avg. 2012-2015 minus FAD closure		34%	47%
0.46	+35%	+31%	+40%	-35%	0%	Avg. depletion 2000-04		36%	52%
0.29	-15%	-17%	+40%	+85%	10%	10% risk re LRP		33%	46%
0.26	-24%	-26%	+40%	+100%	20%	20% risk re LRP		32%	45%

* assumption that FAD closure duration does not affect SKJ or YFT stock status (see WCPFC20-2023-16). Therefore, purse seine impact is estimated using the assumed future total effort level.

Table 9. Average trend in bigeye and yellowfin vulnerable biomass (CPUE proxy) for tropical and southern longline vessels at each median bigeye tuna depletion level (recent recruitment; $SB/SB_{F=0}$) and setting purse seine effort based upon recent CMMs and modifying longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions.

BET: recent recruitment		Bigeye vulnerable biomass (rel. 2019-2021 average)		Yellowfin vulnerable biomass (rel. 2019-2021 average)	
Median depletion level ($\%SB_{F=0}$)	Change in SB ($\%SB_{F=0}$) from 2012-2015 average	'Tropical' longline	'Southern' longline	'Tropical' longline	'Southern' longline
0.46	+35%	0.97	1.64	0.84	1.01
0.30	-12%	0.50	1.35	0.61	1.40
0.34	0%	0.58	1.42	0.69	1.47
0.37	+9%	0.67	1.50	0.79	1.55
0.32	-6%	0.48	1.37	0.69	1.47
0.46	+35%	0.87	1.66	0.98	1.70
0.29	-15%	0.43	1.28	0.54	1.33
0.26	-24%	0.37	1.22	0.48	1.28

Table 10. Median bigeye tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions and setting purse seine effort based upon recent CMMs, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2018-2021) average levels ($0.35SB_{F=0}$), change in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent median depletion levels that may 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 2018-2021 average	Change in fishing from 2019-2021 levels		Risk $SB/SB_{F=0}$ < LRP				
			Purse seine	Longline					
0.43	+26%	+23%	0%	0%	0%	Base 2019-2021 conditions	53%	41%	50%
0.30	-12%	-14%	+40%	+45%	16%	Avg. 2012-2015 – 10%	50%	36%	48%
0.34	0%	-3%	+40%	+25%	2%	Avg. 2012-2015		37%	49%
0.37	+9%	+6%	+40%	+10%	0%	Avg. 2012-2015 + 10%		38%	50%
0.32	-6%	-9%	+62%	+25%	8%	Avg. 2012-2015 minus FAD closure		37%	49%
0.46	+35%	+31%	+40%	-45%	0%	Avg. depletion 2000-04		41%	53%
0.32	-6%	-9%	+40%	+40%	10%	10% risk re LRP		36%	48%
0.30	-12%	-14%	+40%	+50%	20%	20% risk re LRP		35%	47%

* assumption that FAD closure duration does not affect SKJ or YFT stock status (see WCPFC20-2023-16). Therefore, purse seine impact is estimated using the assumed future total effort level.

Table 11. Average trend in bigeye and yellowfin vulnerable biomass (CPUE proxy) for tropical and southern longline vessels at each median bigeye tuna depletion level (long term recruitment; $SB/SB_{F=0}$) and setting purse seine effort based upon recent CMMs and modifying longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions.

BET: long term recruitment		Bigeye vulnerable biomass (rel. 2019-2021 average)		Yellowfin vulnerable biomass (rel. 2019-2021 average)	
Median depletion level ($\%SB_{F=0}$)	Change in SB ($\%SB_{F=0}$) from 2012-2015 average	'Tropical' longline	'Southern' longline	'Tropical' longline	'Southern' longline
0.43	+26%	0.85	1.50	0.84	1.01
0.30	-12%	0.46	1.23	0.56	1.29
0.34	0%	0.54	1.31	0.64	1.36
0.37	+9%	0.60	1.37	0.70	1.42
0.32	-6%	0.44	1.25	0.64	1.36
0.46	+35%	0.79	1.53	0.90	1.58
0.32	-6%	0.47	1.24	0.57	1.29
0.30	-12%	0.43	1.19	0.53	1.25

Table 12. Median <u>yellowfin</u> tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions and setting purse seine effort based upon recent CMMs, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2018-2021) average levels ($0.47SB_{F=0}$), change in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent median depletion levels that may result for skipjack, bigeye (under recent (R) and long-term (L) recruitment scenarios) and South Pacific albacore 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 2018-2021 average	Change in fishing from 2019-2021 levels		Risk $SB/SB_{F=0}$ < LRP				
			Purse seine	Longline					
0.41	-7%	-13%	0%	0%	0%	Base 2019-2021 conditions	53%	46%/43%	50%
0.39	-11%	-17%	+17%	-10%	0%	Avg. 2012-2015 – 10%	50%	43%/40%	51%
0.44	0%	-6%	+17%	> -50%	0%	Avg. 2012-2015		-/-	-
0.48	+9%	+2%	+17%	> -50%	0%	Avg. 2012-2015 + 10%		-/-	-
0.50	+14%	+6%	+17%	> -50%	0%	Avg. depletion 2000-2004		-/-	-
-*	-	-	+17%	> +100%	10%	10% risk re LRP		-/-	-
-*	-	-	+17%	> +100%	20%	20% risk re LRP		-/-	-

* not reached under these purse seine effort/longline catch settings and baseline levels for other fisheries

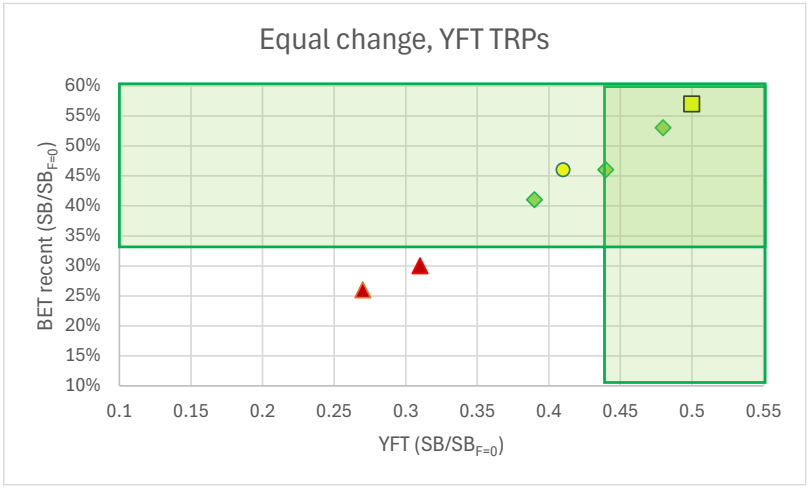
** note assumption of FAD closure period affects bigeye stock status outcomes. Assumption for closure made here is CMM 2023-01 FAD closure duration

Table 13. Average trend in bigeye (both recruitment scenarios) and yellowfin tuna vulnerable biomass (CPUE proxy) for tropical and southern longline vessels at each median yellowfin tuna depletion level ($SB/SB_{F=0}$) and setting purse seine effort based upon recent CMMs and modifying longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions.

YFT: long-term recruitment		Yellowfin vulnerable biomass (rel. 2019-2021 average)		Bigeye vulnerable biomass (rel. 2019-2021 average)			
				Recent recruitment		Long term recruitment	
Median depletion level ($\%SB_{F=0}$)	Change in SB ($\%SB_{F=0}$) from 2012-2015 average	'Tropical' longline	'Southern' longline	'Tropical' longline	'Southern' longline	'Tropical' longline	'Southern' longline
0.41	-7%	0.84	1.01	0.97	1.64	0.85	1.50
0.39	-11%	0.79	0.97	0.79	1.60	0.66	1.42
0.44	0%	-	-	-	-	-	-
0.48	+9%	-	-	-	-	-	-
0.50	+14%	-	-	-	-	-	-
-*	-	-	-	-	-	-	-
-*	-	-	-	-	-	-	-

Figures

Figure 1. Yellowfin depletion outcomes (y-axis) corresponding to the candidate bigeye TRP depletion levels (x-axis) assuming recent (top row) and long term (bottom row) bigeye recruitment levels, under equal change in fishing between gears (left column) and when incorporating CMM-defined levels for purse seine (right column). Points indicate status quo conditions (yellow circle), avg 2012-2015 related TRPs (green diamonds), 2001-2004 levels (yellow square) and risk-related TRPs (red triangles). Bigeye objective of being at or above 2012-2015 levels is met when to the right of the vertical green line (green zone), corresponding yellowfin objective is met when above the horizontal green line (green zone), and both objectives are met when in the overlapping green zone in the top right of the figures.



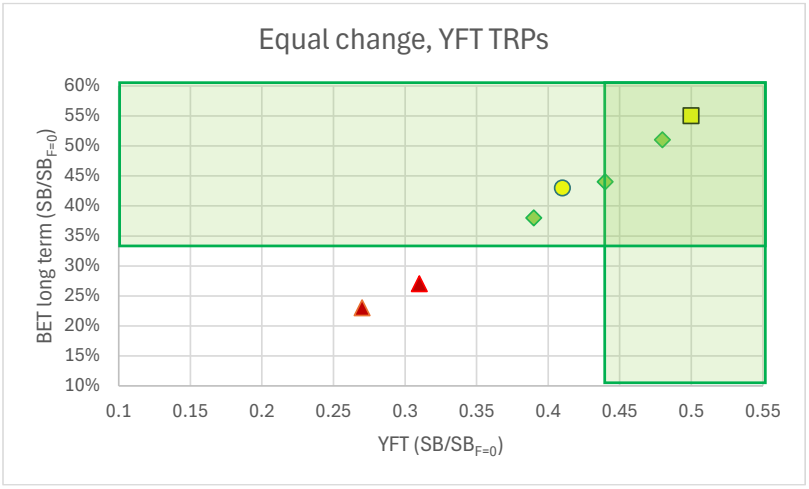


Figure 2. Bigeye depletion outcomes (y-axis) assuming recent (left) and long term (right) recruitments corresponding to the candidate yellowfin TRP depletion levels (x-axis) where there was equal change in fishing between gears only. Points indicate status quo (yellow circle), avg 2012-2015 related TRPs (green diamonds), 2001-2004 levels (yellow square) and risk-related TRPs (red triangles). Yellowfin objective of being at or above 2012-2015 levels is met when to the right of the vertical green line (green zone), corresponding bigeye objective is met when above the horizontal green line (green zone), and both objectives are met when in the overlapping green zone in the top right of the figures

Appendix 1: Methods

The 2023 stock assessments for bigeye and yellowfin tuna (Day et al., 2023; Magnusson et al., 2023 respectively) were used as the basis for projection analyses, incorporating a grid of 54 model runs in each case, as used by Scientific Committee (SC19) as the basis for reporting the uncertainty in current and historical stock status. These underpinned the results of projection analyses presented in WCPFC20-2023-16_Rev01. Those projections were performed for each stock under different future scenarios for purse seine fishing effort and longline catch using the following procedure:

- Stocks were projected for 30 years into the future for each of the stock assessment models (2022 to 2051).
- Scalars (multipliers) were applied to average longline catch and purse seine effort over the period 2019-2021. For longline and purse seine fisheries, a range of catch and effort scalars (0.5 to 2.0 in increments of 0.05) were applied[1].
- Twenty stochastic projections were run for each of the 54 models in the uncertainty grids of the recent yellowfin and bigeye assessments under each scalar combination.
- Future recruitment in each projection was defined by the estimated stock recruitment relationship, with variability around it defined by:
    - the 'long term' historical period (1962 - 2020 q2; for (yellowfin, and 'long-term' recruitment for bigeye);
    - the additional 'recent recruitment' scenario for bigeye tuna with future recruitment resampled from the last 10 years (2010 q3 – 2020 q2).
- Catchability assumed to remain constant into the future – i.e. no effort creep occurs.
- For each scalar combination, the median terminal depletion level (spawning biomass in 2051 relative to the corresponding $SB_{F=0}$) was calculated across the projections. These represented 'equilibrium' depletion outcomes under the range of future purse seine effort/longline catch levels combinations examined.

For the current analysis, the potential future stock and fishery implications under a 'baseline' fishing level were first examined. Fishing levels in the purse seine and longline fisheries and the duration of the FAD closure period equivalent to the average of those in 2019-2021 were used as this baseline period, where pole and line and domestic fisheries (ID/PN/VN) were maintained at the levels indicated in footnote 2.

The consequences of specific candidate TRP stock depletion levels requested by SC16 were evaluated. A specific bigeye or yellowfin stock depletion level can be achieved through different combinations of purse seine effort and longline catch, and hence there was a need to constrain the scenarios examined. Two approaches were taken for these stocks, where the specific depletion level was achieved through: 1) *equal*

[1] For all other fisheries (pole and line fisheries and domestic fisheries of Indonesia, Philippines, Vietnam) fixed scalars were applied corresponding to the catch or effort change necessary to achieve baseline fishing levels as specified under the interim skipjack tuna management procedure (CMM 2022-01). These baseline levels are 2001-2004 effort levels for pole and line fisheries, and 2016-2018 average catches for domestic ID/PH/VN fisheries. These baselines were applied to be consistent with the skipjack management procedure assumptions. For the yellowfin model, constant effort at 2016-18 levels for the domestic ID/PH/VN fisheries in 'Region 2' of the 2023 yellowfin assessment are assumed within these projections, the exception being the Indonesian 'large fish' handline fishery where the constant catch assumption is maintained. A constant effort assumption implies that the resulting catch will vary dependent upon the underlying stock size, rather than assuming a constant catch is taken despite declines in the stock in that region under many of the future scenarios.

change in purse seine effort and longline catch from baseline levels (comparable to the previous analyses) and 2) *incorporating the potential impact of CMM 2022-01* for skipjack tuna on the purse seine fishing component, and adjusting the longline catch to achieve the candidate TRP. These are described in more detail below.

For each scenario, a cut down summary of results is included under each target depletion level, being: the level of change in average spawning biomass and effort from 2012-2015 and 'recent' (2019-2021) levels and the risk to the stock relative to the agreed limit reference point level[2] were estimated. In response to requests 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 and yellowfin (under bigeye TRP calculations), and for skipjack and bigeye (under yellowfin TRP calculations) are provided. Note that specific FAD closure duration assumptions are necessary for bigeye, as detailed below, and should be considered when reviewing those results. In addition, in response to the request from SC20 the resultant depletion levels for South Pacific albacore[3] are computed and provided, using the agreed 2024 stock assessment.

Equal change

In the WCPFC18-2021-11 analysis, TRPs were examined based upon equal changes in purse seine and longline fishing levels (effort and catch, respectively). This approach was repeated for the current analysis, based upon the latest assessments and projection results. The FAD closure period was assumed to be that stated in CMM 2023-01, unless otherwise specified. Based upon previous analyses, the duration of the FAD closure period has little impact on yellowfin or skipjack stock depletion compared to the overall purse seine effort level (e.g. WCPFC20-2023-16). Therefore, specifically when calculating the impact on skipjack and yellowfin of a given bigeye candidate TRP, the corresponding bigeye-equivalent purse seine effort multipliers were scaled downward to reflect overall purse seine effort, rather than number of FAD sets.

Incorporating CMM 2022-01

Since the WCPFC18-2021-11 analysis, a management procedure for skipjack has been adopted that sets the anticipated level of purse seine effort within the WCPO, and through which objectives would be achieved through 2012 purse seine effort levels (CMM 2022-01). In this set of analyses, for each candidate TRP level for bigeye and yellowfin we therefore assume:

[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.

[3] 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 South Pacific albacore, proportional catch changes are applied specifically in the WCPFC-CA region between the equator and 10°S (Sub-regions 1A and 1B of the albacore assessment model), while albacore catches in other areas of that assessment are maintained constant at 2019-2021 levels to be consistent with the assumptions made for the other stocks. However, remainder of the EPO fisheries are assumed to be at 22,500mt to be consistent with levels seen in recent years (see also WCPFC21-2024-29). 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. As for bigeye and yellowfin, longline catches here are in numbers of fish.

- For bigeye:
  - Purse seine effort is maintained at 2012 levels.
  - The primary assumption for the FAD closure period is that under CMM 2023-01 (1.5 months in EEZs, 2.5 months on the high seas).
  - A secondary assumption for the SC16 suggested candidate option of 2012-2015 depletion levels is the removal of the FAD closure, as requested by CCMs at WCPFC20.
  - Longline catch levels are adjusted to achieve the candidate TRP level suggested by SC16.
- For yellowfin:
  - Purse seine effort is maintained at 2012 levels. Based upon previous analyses, the duration of the FAD closure period is ignored as the proportion of FAD versus free school sets was found to have little impact on yellowfin stock depletion compared to the overall effort level (e.g. WCPFC20-2023-16).
  - Longline catch levels are adjusted to achieve the candidate TRP level suggested by SC16.

2012 purse seine effort levels and the FAD closure period in CMM 2023-01 are both different to those in place over the baseline period 2019-2021 (the period representing a purse seine scalar of 1). The scalar for overall purse seine effort was calculated using the approach described in WCPFC20-2023-15 and WCPFC20-2023-16 (see for example, Table 12 of the latter document): changes in FAD closure period and variations in overall purse seine effort relative to baseline levels are assumed to be multiplicative when calculating scalars.

For the 'incorporating CMM 2022-01' scenario, these assumptions constrain the multiplier for purse seine fisheries. As noted above, the longline catch level in each case it then adjusted to achieve the SC16 suggested target depletion level for the stock.

Calculation of vulnerable biomass

As requested by SC20, the median vulnerable biomass (CPUE proxy) for longline fisheries corresponding to 'tropical longline' (regions 3, 4 & 8 of the bigeye assessment model; regions 3 & 4 of the yellowfin assessment model) and 'southern longline' (regions 5, 6 & 9 of the bigeye assessment model; region 5 of the yellowfin assessment model) at the end of the projection period relative to the corresponding 'baseline' average level over 2019-2021 were calculated for each candidate target depletion level for WCPO bigeye and yellowfin. For bigeye, the same recruitment assumption is used within these calculations as defined in the main analysis. Under the yellowfin TRP analyses, the implications for bigeye longline vulnerable biomass are examined under both recruitment scenarios.

Appendix 2: Results of additional analyses where Region 2 fishing levels were at more recent levels for WCPO yellowfin

Table 14. Median yellowfin tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions and proportional changes in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels to achieve those depletions. Effort within small scale fisheries in model region 2 set at recent levels. Corresponding change in spawning biomass from 2012-2015 and 'recent' (2018-2021) average levels ($0.35SB_{F=0}$) and risk of falling below the LRP 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 2018-2021 average	Change in fishing from 2019-2021 levels		Risk $SB/SB_{F=0}$ < LRP				
			Purse seine	Longline					
0.41	-7%	-13%	0%	0%	0%	Base 2019-2021 conditions	53%	46%/43%	50%
0.39	-11%	-17%	+10%	+10%	0%	Avg. 2012-2015 – 10%	52%	41%/38%	50%
0.44	0%	-6%	-15%	-15%	0%	Avg. 2012-2015	55%	48%/45%	51%
0.48	+9%	+2%	-30%	-30%	0%	Avg. 2012-2015 + 10%	60%	53%/51%	52%
0.50	+14%	+6%	-40%	-40%	0%	Avg. depletion 2000-2004	63%	57%/55%	52%
0.31	-30%	-34%	+50%	+50%	10%	10% risk re LRP	44%	30%/27%	47%
0.27	-39%	-43%	+70%	+70%	20%	20% risk re LRP	42%	26%/23%	46%

* note assumption of FAD closure period affects bigeye stock status outcomes. Assumption for closure made here is CMM 2023-01 FAD closure duration

Table 15. Median yellowfin tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions and setting purse seine effort based upon recent CMMs. Effort within small scale fisheries in model region 2 set at recent levels. Corresponding change in spawning biomass from 2012-2015 and 'recent' (2018-2021) average levels ($0.47SB_{F=0}$), change in purse seine effort and longline catch (scalar) from baseline (2019-2021) levels, median equilibrium yield (total yield as % of MSY), risk of falling below the LRP under those baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels presented. 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 2018-2021 average	Change in fishing from 2019-2021 levels		Risk $SB/SB_{F=0}$ < LRP				
			Purse seine	Longline					
0.41	-7%	-13%	0%	0%	0%	Base 2019-2021 conditions	53%	46%/43%	50%
0.39	-11%	-17%	+17%	-10%	0%	Avg. 2012-2015 – 10%	50%	43%/40%	51%
0.44	0%	-6%	+17%	> -50%	0%	Avg. 2012-2015		-/-	
0.48	+9%	+2%	+17%	> -50%	0%	Avg. 2012-2015 + 10%		-/-	
0.50	+14%	+6%	+17%	> -50%	0%	Avg. depletion 2000-2004		-/-	
-*	-	-	+17%	> +100%	10%	10% risk re LRP		-/-	
-*	-	-	+17%	> +100%	20%	20% risk re LRP		-/-	

* not reached under these purse seine effort/longline catch settings and baseline levels for other fisheries

** note assumption of FAD closure period affects bigeye stock status outcomes. Assumption for closure made here is CMM 2023-01 FAD closure duration

Appendix 3: 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.