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Minimum Target Reference Points for WCPO yellowfin and bigeye tuna consistent with alternative LRP risk levels, and multispecies implications

WCPFC-SC15-2019/MI-WP-01

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Executive Summary

SC14 reviewed information on the minimum setting for candidate spawning-biomass-depletion-based target reference points (TRPs) for yellowfin tuna that avoided breaching the agreed LRP with a specified level of probability under the current uncertainty framework (SC14-MI-WP-01). The analysis was expanded to bigeye tuna and presented to WCPFC15 (WCPFC15-2018-13_rev1). SC14 noted the main biological consideration for a TRP is that it should be sufficiently above the LRP, and that the choice of a TRP can be based on a combination of biological, ecological and socio-economic considerations. WCPFC15 separately noted it might not be possible to achieve simultaneously precautionary TRPs for all key tuna species in the WCPFC fishery.

In this paper, we re-present median levels of spawning biomass depletion ($SB/SB_{F=0}$) that are consistent with specified risk levels of breaching the limit reference point (LRP) of $0.2SB_{F=0}$. To do this, we used:

- the structural uncertainty grid of models used by SC13 for advice from the 2017 yellowfin tuna assessment, and
- the structural uncertainty grid containing only 'updated new growth' models used by SC14 as the basis for advice from the 2018 update bigeye tuna assessment, under both the 'recent' and 'long term' assumptions for future bigeye recruitment,

to generate 30 year projections that included stochastic variability in future recruitment under a variety of fishing levels scaled to the 2013-2015 averages. These are related to corresponding stock levels estimated in the most recent assessments, and to paragraphs 12 and 14 of CMM 2018-01. The results are summarised in the tables below. Those tables present values of $SB/SB_{F=0}$ that, if achieved on average, are predicted to result in the specified levels of risk of breaching the LRP, and thus may be interpreted as minimum levels of $SB/SB_{F=0}$ consistent with those risk levels, under the current uncertainty framework.

WCPFC15 noted the multispecies considerations involved in TRP discussions. The relative consequences of each minimum TRP level for a stock was therefore examined for the other tropical tuna stock. This was examined across a range of combinations of fishing by the major fishing gears that all achieved the TRP stock level, using deterministic projections. The choice of TRP will depend upon stock management objectives. We used the general objectives detailed in CMM 2018-01 as guidance, specifically that the spawning biomass depletion ratio of both stocks should be maintained at or above the recent average level. Noting there will be a new skipjack assessment agreed at SC15, which was not available at the time of writing, we use the existing assessment to qualitatively infer the implications of these TRP levels for skipjack tuna, relative to paragraph 13 of the CMM.

Maintaining recent fishery conditions implies a very slight decline in yellowfin stock status and a 7% risk of falling below the LRP. For bigeye, those conditions imply either an increase in stock status and no risk (recent recruitment; 2005-2014) or a decline and 17% risk (long-term recruitment; 1962-2014). Status quo management therefore achieves the CMM 2018-01 objective for bigeye if recent recruitment holds, and marginally fails to meet that objective for yellowfin tuna. For skipjack tuna, recent fishery conditions imply stock status slightly below the TRP, and would marginally fail to achieve paragraph 13.

A yellowfin TRP consistent with a 5% risk will achieve the CMM 2018-01 objective for that stock, and implies a small reduction in overall fishery impact. This would lead to improved stock status of bigeye tuna if recent recruitments hold, but a decline if long-term recruitment patterns hold. Both paragraphs 12 and 14 are therefore achieved (under recent bigeye recruitment patterns) under fishery conditions

equivalent to a TRP of 5% risk for yellowfin tuna. For skipjack tuna, if purse seine effort were reduced slightly to achieve the yellowfin TRP, this would have a positive effect on achieving the skipjack TRP.

For bigeye tuna, if recent recruitments hold, minimum TRPs consistent with all levels of risk imply declines in both the bigeye and yellowfin stocks. Paragraphs 12 and 14 are not achieved as a result, and a TRP corresponding to a less depleted bigeye stock level would be required to do so. If long term recruitments occur, only a TRP consistent with a 5% risk leads to an increase in the bigeye stock, which would also lead to increases in the yellowfin stock. This would meet paragraphs 12 and 14. Where levels of reduction occur in the purse seine fishery to achieve that, skipjack tuna would likely meet or exceed its TRP.

We highlight that the results, in particular those from the deterministic projections, are based upon some strong assumptions:

- Comparison between stocks assumes no shift in species targeting to achieve reductions or increases in catch.
- The median stock status implied by specific levels of risk are calculated from stochastic projections where scalars are applied equally across purse seine effort and longline catch. When relating these to the deterministic projection results:
    - We assume that the same stock status from the deterministic projections leads to the same level of risk for all gear-specific combinations. This may not hold if that gear-specific combination leads to a more skewed distribution of estimated results, and hence the actual corresponding risk may be different.
    - Median stock status calculated from the deterministic projections over the assessment grid did not exactly match the median estimate from the stochastic results. We therefore scaled the deterministic estimates to match the values presented in the tables below. The results of the deterministic projection analyses should therefore be viewed as indicative.
- Results are conditioned on the uncertainty framework used.
- Observations for skipjack are qualitative and inferred from results based on the 2016 stock assessment and recent tropical tuna CMM evaluation.

SC15 is invited to:

1. Note the results of the analysis conducted and consider re-providing advice to WCPFC on <u>minimum</u> levels of $SB/SB_{F=0}$ that would be consistent with specific levels of risk of breaching the LRP;
2. Discuss the multispecies implications of these minimum levels of $SB/SB_{F=0}$;
3. Consider if there are relevant ecological and/or socio-economic factors that WCPFC should consider in choosing a specific TRP for yellowfin and bigeye tuna.

Median levels of yellowfin tuna $SB_{2045}/SB_{F=0}$ for the four nominated levels of risk of breaching the LRP, and the stock level and risk under 2013-15 average fishing levels.

	Risk level	$SB_{2045}/SB_{F=0}$	Future fishing levels relative to 2013-15 average conditions (scalar)	Ratio relative to $SB_{2012\text{-}15}/SB_{F=0}$
	5%	0.34	0.95	1.02
Fishing @ 2013-15 average	7%	0.33	1.00	0.99
	10%	0.32	1.05	0.96
	15%	0.30	1.12	0.91
	20%	0.28	1.20	0.84

Median levels of bigeye tuna $SB_{2045}/SB_{F=0}$ for the four nominated levels of risk of breaching the LRP, and stock level and risk under 2013-15 average fishing levels, under two future stock recruitment hypotheses.

'Recent' recruitment

	Risk level	$SB_{2045}/SB_{F=0}$	Future fishing levels relative to 2013-15 average conditions (scalar)	Ratio relative to $SB_{2012\text{-}15}/SB_{F=0}$
Fishing @ 2013-15 average	(0%)	0.42	1.00	1.18
	5%	0.33	1.23	0.93
	10%	0.30	1.33	0.85
	15%	0.29	1.4	0.82
	20%	0.28	1.46	0.79

'Long term' recruitment

	Risk level	$SB_{2045}/SB_{F=0}$	Future fishing levels relative to 2013-15 average conditions (scalar)	Ratio relative to $SB_{2012\text{-}15}/SB_{F=0}$
	5%	0.38	0.80	1.07
	10%	0.34	0.89	0.96
	15%	0.32	0.97	0.90
Fishing @ 2013-15 average	17%	0.30	1.00	0.84
	20%	0.29	1.06	0.82

Introduction

The specification of target and limit reference points (TRPs and LRPs) are a critical part of the harvest strategy approach. LRPs are places we want to stay away from, while TRPs represent places we want to be. The choice of a LRP is based primarily on biological considerations relating to the resilience of the stock in question, i.e. what is the level of spawning biomass where the risk of recruitment overfishing becomes unacceptable. WCPFC has decided that the LRP for key tuna stocks is 20% of the unfished spawning biomass (0.2 $SB_{F=0}$). The choice of TRP is normally based on a combination of biological, ecological and socio-economic considerations. The main biological consideration is that a TRP should be sufficiently above the LRP so that if the TRP is achieved on average, the risk of breaching the LRP will be acceptably small. To inform WCPFC's consideration of potential TRPs for yellowfin and bigeye tuna, this paper attempts to answer the question "what is the minimum setting for a spawning-biomass depletion-based TRP that on average avoids breaching the LRP with a specified level of probability?"

The paper MOW3-WP-02 (SPC-OFP, 2014) provided preliminary answers to this question for skipjack, yellowfin, bigeye and South Pacific albacore, at 5%, 10%, 15% and 20% levels of probability of breaching the LRP. For that analysis, a small number of models from the respective structural uncertainty grids presented for the 2014 assessments for skipjack, yellowfin and bigeye and the 2012 assessment for South Pacific albacore were used. The models were run in projection mode with future recruitment sampled from the historical estimated time series. Various scalars of fishing effort and/or catch were applied and the results for runs that produced the specified levels of risk of breaching the LRP were recorded, in particular the median level of $SB/SB_{F=0}$. In other words, based on the assessments and their uncertainty frameworks available at the time, it was possible to specify median levels of $SB/SB_{F=0}$ that were consistent with breaching the LRP with the specified probabilities. These median levels could then be interpreted as minimum settings for a spawning-biomass-depletion-based TRP, for each probability level of breaching the LRP.

SC14 reviewed the results of a comparable analysis based upon the latest yellowfin tuna assessment and its current uncertainty framework (SC14-MI-WP-01). That analysis was subsequently expanded to bigeye tuna and presented to WCPFC15 (WCPFC15-2018-13_rev1). SC14 noted that the main biological consideration for a TRP is that it should be sufficiently above the LRP. SC14 also noted that the choice of a TRP can be based on a combination of biological, ecological and socio-economic considerations.

WCPFC15 separately noted that it might not be possible to achieve simultaneously precautionary TRPs for all key tuna species in the complex WCPFC fishery. This is because fishing within the WCPFC is not species-specific; fishing gears influence the status of more than one stock. Hence the selection of management objectives, and ultimately a TRP, for one stock will have implications for another. WCPFC has noted candidate objectives for all fisheries and their stocks. In turn, CMM 2018-01 provides some practical guidance of the desired performance of that Measure for tropical tunas. Specifically for bigeye and yellowfin, paragraphs 12 and 14 specify the aim to maintain the spawning biomass depletion ratio ($SB/SB_{F=0}$) of both stocks at or above the average $SB/SB_{F=0}$ for 2012-2015 ('recent' levels). In turn, paragraph 13 calls for the spawning biomass of skipjack tuna to be maintained on average at the interim TRP level.

In this paper we re-present the results of WCPFC15-2018-13_rev1 for bigeye and yellowfin. Results are compared to the levels of each stock estimated in the most recent assessments, which allows TRP performance to be related to paragraphs 12 and 14 of CMM 2018-01. To begin to address the multispecies issues raised by WCPFC15, we examine the range of purse seine and longline fishery

combinations that can achieve each candidate minimum TRP for one stock, and identify the resulting potential implications of that TRP for trends in the other stock to identify whether multiple objectives can be achieved. Noting there will be a new skipjack assessment agreed at SC15, we use the existing assessment to qualitatively infer the implications of these TRP levels for skipjack tuna, relative to paragraph 13 of the CMM.

Methods

The approach to calculating minimum TRP levels consistent with different levels of risk is first presented. The evaluation of the potential multispecies implications is then described.

Minimum TRP calculations

For these analyses we used the most recent yellowfin stock assessment presented in 2017 (Tremblay-Boyer *et al.*, 2017) and updated bigeye stock assessment presented in 2018 (Vincent *et al*., 2018):

- For yellowfin tuna, SC13 chose a grid of 48 models to represent the structural uncertainty in the assessment, consisting of five axes – regional structure (2), steepness (3), tag over-dispersion (2), tag mixing (2) and size composition weighting (2).

- For bigeye tuna, SC14 chose a grid of 36 models to represent the structural uncertainty. The grid consisted of four axes – regional structure (2), steepness (3), tag over-dispersion (2) and size composition weighting (3). SC14 agreed that the 'updated new growth' model, which incorporated new age-at-size information collected since 2017, represented the best available science on bigeye growth and that the 'old growth' model should not be used to provide management advice.

For both stocks, the analysis proceeded as follows:

- Run 100 stochastic projections for 30 years (2016-2045) for each model in the grid – each simulation representing a possible 'future' trajectory for recruitment, under a specific level of fishing effort or catch;
- Recruitment trajectories were constructed by computing a mean recruitment resulting from the estimated stock-recruitment relationship and adding recruitment deviations randomly sampled from:
    - For bigeye, the last 10 years of the assessment (2005-2014, 'recent recruitment'), with recruitments then distributed to seasons and regions according to the average distributions within the same 10-year period;
    - For both yellowfin and bigeye, the alternative 'long-term' recruitment assumption where recruitments were sampled across the period used to estimate the stock recruitment relationship (1962-2014).
- Combine the results across model runs and calculate the percentage of projections that had a biomass in the final year below the agreed LRP (20% of the average spawning biomass that would have occurred in the absence of fishing over the penultimate 10-year period of the projections (2035-2044)). Also calculate the median level of terminal spawning biomass compared to $SB_{F=0}$ ($SB_{2045}/SB_{F=0}$); and
- Repeat the above steps with different scalars of effort/catch until the future fishing levels that resulted in risk levels of 5, 10, 15, and 20% were identified. Scalars were applied to the seasonal average of the catch or effort for the last three years of the assessment period for each fishery.

The same scalars were applied to all fisheries simultaneously. Future scenarios for longline fisheries were expressed as constant catch[1], while scenarios for other fisheries were expressed as constant effort.

Multispecies implications

A specific bigeye or yellowfin stock depletion can be achieved through a number of alternative combinations of longline catch and purse seine effort. These were evaluated through deterministic projections (stochastic projections could not be performed due to time constraints) for combinations of purse seine effort[2] and longline catch scalars ranging from 0.5 to 1.5 times 2013-2015 average levels (see for example SPC-OFP, 2017). 30 year deterministic projections were performed across the grid of assessment models and the median $SB_{2045}/SB_{F=0}$ under each purse seine/longline fishery combination calculated. Under deterministic projections, future recruitment is assumed to correspond to the estimated stock recruitment relationship for both stocks, while for bigeye the projections were also run under assumptions equivalent to the 'recent' recruitment scenario.

From the resulting grid of stock status under different fishing levels, alternative fishery combinations that resulted in stock status levels consistent with each minimum TRP were identified[3]. By mapping those fishery combinations onto the equivalent deterministic projection results for the other tuna stock, the implications of a given candidate minimum TRP level for the biomass trend of that other stock were examined. It must be noted that this assumes no change in targeting between the two stocks – i.e. that a decline in the catch of yellowfin tuna within the longline fishery corresponds to an equivalent decline in the catch of bigeye tuna in that fishery.

A new stock assessment for skipjack tuna is scheduled for agreement at SC15, and the TRP for this stock is to be reviewed in 2019. In the absence of agreed assessment results, we draw qualitative inferences of the implications of the alternative bigeye and yellowfin TRPs and the ability to achieve paragraph 13 of CMM 2018-01 (maintaining skipjack at a level consistent with the interim TRP of 50% $SB_{F=0}$). These inferences are based upon the projected stock status achieved under '2013-15 average conditions' from the 2016 skipjack stock assessment, as presented in Pilling et al. (2019).

Results

Minimum TRP calculations

The median $SB_{2045}/SB_{F=0}$ associated with each of the four levels of risk of breaching the LRP for yellowfin and bigeye are provided in Table 1 and 2. These values can be interpreted as the minimum levels of

[1] In a number of projections, the constant-catch scenarios for longline fisheries resulted in some age-classes in some regions tending towards zero abundance. In such cases, the catches of the longline fisheries in those regions were reduced to avoid negative numbers-at-age.

[2] For bigeye tuna, the majority of the stock impact by purse seine is through associated effort. For that stock, effort multipliers can be viewed as associated-set specific. As yellowfin is caught in both associated and unassociated sets, effort multipliers refer to total effort, rather than being associated-set-specific.

[3] Deterministic projection results should be consistent with the average from stochastic projections. However, when calculating across the assessment uncertainty grid, this was not always the case. Therefore the grid of deterministic projection results was scaled by any difference to stock depletion estimated using stochastic projections at each risk level. For example, the yellowfin the grid was scaled downward by 0.01 to 0.02 $SB/SB_{F=0}$, dependent on risk level.

$SB/SB_{F=0}$ that, if achieved on average, would be consistent with remaining above the LRP at each level of risk. Figure 1 presents the distributions of $SB_{2045}/SB_{F=0}$ for each risk level.

For yellowfin tuna:

- The 2017 stock assessment (Tremblay-Boyer *et al.* 2017) estimated the median $SB_{recent}/SB_{F=0}$ to be 0.33 and the 2015 level to be 0.37. These estimated levels of spawning biomass depletion would be consistent with long-term risks of breaching the LRP of 0-10%.
- Continuing to fish under 2013-15 average conditions would lead to a risk of 7%, and the stock would decline very slightly from recent estimated levels (Table 1).

For bigeye tuna:

- The 2018 updated stock assessment (Vincent *et al.* 2018) estimated the median $SB_{recent}/SB_{F=0}$ to be 0.36 and the 2015 level to be 0.46. These estimated levels of spawning biomass depletion would be consistent with risks of breaching the LRP of 0-10% under the long-term recruitment scenario, and zero risk under recent recruitments.
- Continuing to fish under 2013-15 average conditions would lead to the stock increasing and zero risk if recent recruitments continue, and the stock declining and a risk of 17% under the long-term recruitment scenario (Table 2).

Multispecies implications

A minimum TRP stock level consistent with a given level of risk can be achieved under a range of purse seine and longline fishing combinations. These generally involve trade-offs between purse seine and longline fishing levels, and result in the diagonal patterns seen in Figure 2a and b for yellowfin TRPs, and Figure 3a and b for bigeye. The smaller the level of risk a TRP corresponds with, the closer to the top left of the Figure the band of fishing combinations is found. The consequences of different minimum candidate TRPs of one stock for the other are also summarised in those figures, based upon the colouration of the bands.

When considering minimum TRP levels for yellowfin tuna:

- A TRP consistent with a 5% risk level generally implies a small reduction in the fishing level of purse seine, longline or both gears, and would allow a small increase in yellowfin stock status relative to recent levels.
- TRPs consistent with higher risk levels allow overall increases in fishing (with trade-offs between one gear and the other), but imply declines in yellowfin stock status from recent levels.
- Only minimum TRPs consistent with lower risk levels (primarily 5 and 10% risk) are consistent with concurrent increases in the bigeye stock across the majority of compatible longline and purse seine fishing combinations if recent recruitments continue. As risk levels increase, the bigeye stock will decline if longline catch levels increase above 2013-15 average levels, while purse seine effort levels could be allowed to increase.
- If the long term recruitment assumption holds for bigeye, all minimum TRP levels for yellowfin imply declines in the bigeye stock from recent levels. The objective to maintain bigeye at or above the average $SB/SB_{F=0}$ for 2012-2015 (para 12, CMM 2018-01) would not be met at any minimum yellowfin TRP level in this case.
- Recent conditions are forecast to result in a skipjack stock just below the TRP. If achieving the 5% TRP for yellowfin implies a small reduction in purse seine effort, this would have a positive effect on achieving paragraph 13 of the CMM.

For bigeye tuna:

- if recent recruitments continue, achieving all minimum TRPs implies allowable increased fishing levels, but also declines in bigeye stock status from recent levels.
- If long term recruitments occur, achieving TRPs consistent with 5-15% risk levels generally require reduced overall fishing levels. Only for the 5% risk level are those reductions sufficient to lead to increases in bigeye stock status from recent levels under those recruitment conditions.
- Fishing at levels consistent with all minimum bigeye TRPs under the recent recruitment assumption imply declines in the yellowfin stock from recent levels.
- Under the long-term recruitment assumption for bigeye, minimum TRPs consistent with 15% or lower risks generally require reductions in fishing from one or both gears. Those minimum TRP levels will result in increases in, or maintenance of, the yellowfin stock at recent levels, except at the higher purse seine effort scalar levels compatible with a 15% risk. At the 20% TRP level for bigeye, the yellowfin stock will generally decline where purse seine effort, and to a lesser extent longline catch, is increased.
- For skipjack, minimum bigeye TRPs under the long term recruitment assumption consistent with 15% or lower risks would help to meet paragraph 13 under the assumption of an overall reduction in purse seine effort (rather than transference of effort from associated to unassociated sets), while none of the minimum TRPs under the recent recruitment assumption would meet paragraph 13 where overall purse seine effort was increased.

Discussion

The method used here to estimate minimum TRPs is consistent with that used in the past (MOW3-WP-02) and seems to be generally accepted by WCPFC. However, it should be noted that the results of such analyses are conditioned on the uncertainty framework used. In this analysis, the structural uncertainty frameworks in the 2017 yellowfin and 2018 bigeye tuna assessments, plus stochastic variability in future recruitment, were used. The amount of uncertainty incorporated will impact the 'spread' of the future distributions of $SB/SB_{F=0}$, which in turn will affect the estimated risks of breaching the LRP. In general, more uncertainty = greater risk, and higher median $SB/SB_{F=0}$ levels would be required to meet a particular risk of breaching the LRP.

In order to recommend a specific level of $SB/SB_{F=0}$ as a TRP, it is necessary to:

- Agree on an acceptable level of risk of breaching the LRP in order to define the minimum TRP in terms of $SB/SB_{F=0}$. This issue was summarised previously (SPC-OFP, 2014) in the following terms:
  - "The acceptable level of risk is a management decision and will be strongly influenced by the severity of the consequences of exceeding the LRP, be those consequences biological, economical, ecological or social. Low stock size is likely to be associated with lower production (catches) and higher variability in productivity, along with the increased potential for other unexpected but bad consequences that we have not experienced in the past ('unknown unknowns'). When considering the acceptable level of risk, the importance of the stock to the people of the region and to the ecosystem may be important factors to consider."
- Consider other ecological and socio-economic factors that might be relevant in recommending specific TRPs that may be more conservative than the risk-based 'limiting' levels described in this paper.

As the choice of TRP depends upon the management objectives for stocks, we have related results to the current general objectives detailed in CMM 2018-01. Specifically, that the spawning biomass depletion ratio of both bigeye and yellowfin should be maintained at or above the recent average level. We also infer results for skipjack, noting the upcoming agreement of a new stock assessment and review of the current interim TRP.

Maintaining recent fishery conditions implies a very slight decline in yellowfin stock status and a 7% risk of falling below the LRP. Skipjack is projected to settle at a level just below the interim TRP. The same conditions for bigeye imply either an increase in stock status and no risk (recent recruitment) or a decline and 17% risk (long-term recruitment). Management at 2013-15 average levels therefore achieves the CMM 2018-01 objective for bigeye if recent recruitment holds, and marginally fails to meet objectives for yellowfin tuna and skipjack tuna.

A yellowfin TRP consistent with a 5% risk will achieve the CMM 2018-01 objective for that stock, and implies a small reduction in overall fishery impact. This would lead to improved stock status of bigeye tuna if recent recruitments hold, but a decline if long-term bigeye recruitment patterns hold. If decreased fishing impact included slight reductions in purse seine effort, the skipjack objective may also be met. All three paragraphs (12 to 14) may therefore be achieved (under recent bigeye recruitment patterns) under fishery conditions equivalent to a TRP of 5% risk for yellowfin tuna.

For bigeye tuna, if recent recruitments hold, TRPs consistent with all levels of risk imply declines in bigeye and yellowfin stocks, and likely also for skipjack. Paragraphs 12, 13 and 14 are not achieved as a result, and a TRP corresponding to a less depleted stock level would be required to do so. If long term recruitments occur, only a TRP consistent with a 5% risk leads to an increase in the bigeye stock, which would also lead to increases in the yellowfin stock, and likely also for skipjack (assuming overall purse seine effort reductions). This would meet paragraph 12, 13 and 14 objectives.

We highlight that the results, in particular those of the deterministic projections, are based upon some strong assumptions:

- As noted earlier, the comparison between stocks assumes that there is no shift in species targeting to achieve reductions or increases in catch. For example, a 10% increase in bigeye catch will correspond to a 10% increase in yellowfin catch.
- To estimate the median stock status that leads to specific levels of risk calculated from the stochastic projections, scalars are applied equally across purse seine effort and longline catch. When relating these to the deterministic projection results:
    - We assume that the same stock status from the deterministic results will lead to the same level of risk for all gear-specific combinations. However unequal gear-specific scalars may lead to different distributions of stock status outcomes (i.e. the gear-specific combination that results in a given median may be from a more skewed distribution of estimated results, and hence the actual corresponding risk may be different).
    - The median stock status calculated from the deterministic results over the assessment grid did not exactly match the median estimate from the stochastic results. We therefore scaled the deterministic estimates (by maximum +0.04 and -0.03) to match the values presented in Tables 1 and 2. The results of the deterministic projection analyses should therefore be viewed as indicative.
- Results are conditioned on the uncertainty framework used.
- Observations for skipjack are qualitative and inferred from results based on the 2016 stock assessment and recent tropical tuna CMM evaluation.

SC15 is invited to:

1. Note the results of the analysis conducted and consider re-providing advice to WCPFC on minimum levels of $SB/SB_{F=0}$ that would be consistent with specific levels of risk of breaching the LRP;
2. Discuss the multispecies implications of these minimum levels of $SB/SB_{F=0}$;
3. Consider if there are relevant ecological and/or socio-economic factors that WCPFC should consider in choosing a specific TRP for yellowfin and bigeye tuna.

Acknowledgements

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Tables and figures

Table 1. Median levels of yellowfin tuna $SB_{2045}/SB_{F=0}$ for the four nominated levels of risk of breaching the LRP, and the stock level and risk resulting from fishing at 2013-15 average levels.

	Risk level	$SB_{2045}/SB_{F=0}$[1]	Future fishing levels relative to 2013-15 average conditions (scalar)	Ratio relative to $SB_{2012\text{-}15}/SB_{F=0}$
	5%	0.34	0.95	1.02
Fishing @ 2013-15 average	7%	0.33	1.00	0.99
	10%	0.32	1.05	0.96
	15%	0.30	1.12	0.91
	20%	0.28	1.20	0.84

[1] note: these values are slightly different from those presented in SC14-MI-WP-01. They have been re-calculated using the long-term recruitment assumption, which is consistent with that used within the tropical tuna CMM evaluation.

Table 2. Median levels of bigeye tuna $SB_{2045}/SB_{F=0}$ for the four nominated levels of risk of breaching the LRP, and the stock level and risk resulting from fishing at 2013-15 average levels, under the two future recruitment assumptions of 'recent' (sampling from the last 10 years) and 'long term' (sampling across 1962 to 2014).

'Recent' recruitment

	Risk level	$SB_{2045}/SB_{F=0}$	Future fishing levels relative to 2013-15 average conditions (scalar)	Ratio relative to $SB_{2012\text{-}15}/SB_{F=0}$
Fishing @ 2013-15 average	(0%)	0.42	1.00	1.18
	5%	0.33	1.23	0.93
	10%	0.30	1.33	0.85
	15%	0.29	1.4	0.82
	20%	0.28	1.46	0.79

'Long term' recruitment

	Risk level	$SB_{2045}/SB_{F=0}$	Future fishing levels relative to 2013-15 average conditions (scalar)	Ratio relative to $SB_{2012\text{-}15}/SB_{F=0}$
	5%	0.38	0.80	1.07
	10%	0.34	0.89	0.96
	15%	0.32	0.97	0.90
Fishing @ 2013-15 average	17%	0.30	1.00	0.84
	20%	0.29	1.06	0.82

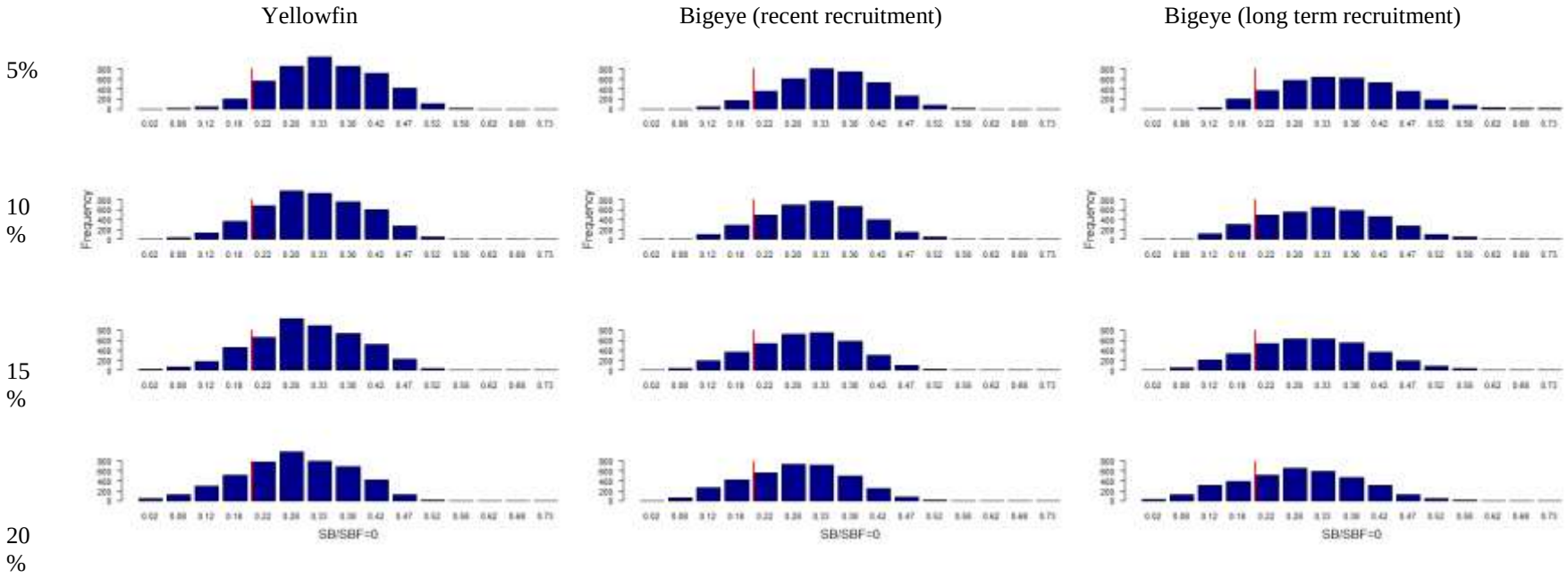

Figure 1. The distribution of $SB_{2045}/SB_{F=0}$ for the four nominated levels of risk of breaching the LRP for yellowfin and bigeye (for the latter, two SRR assumptions). Red vertical line in each panel represents 20% of $SB_{F=0}$

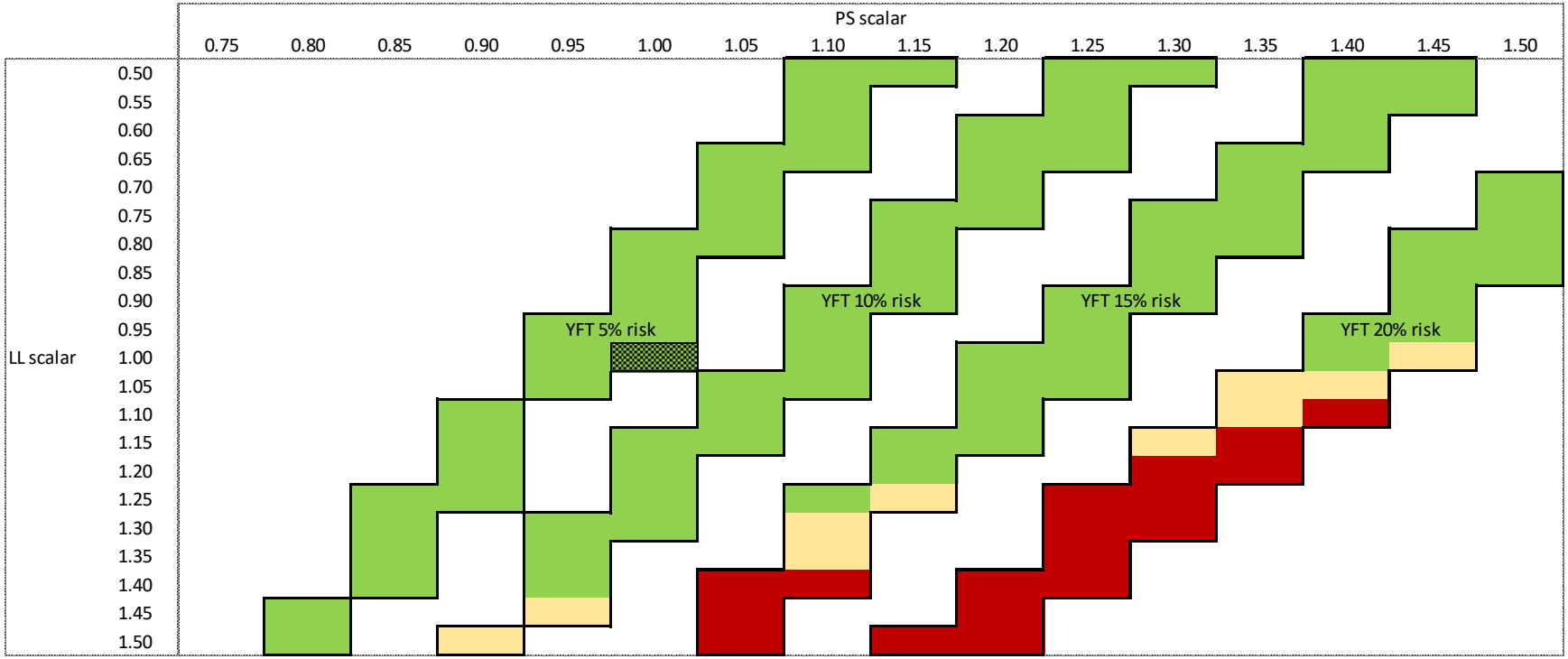

Figure 2a. For yellowfin tuna, the combination of longline catch and purse seine effort (scaled off 2013-15 average levels) that achieve the 'minimum TRP' $SB/SB_{F=0}$ consistent with each of the four levels of risk examined (5%, 10%, 15%, 20% risk of falling below the LRP). For each PS/LL fishing combination, the colour indicates the corresponding future trend in the bigeye stock relative to recent assessed levels ($SB_{2012-2015}/SB_{F=0}$ = 0.36) under 'recent' recruitment assumptions (red = decline, yellow=maintained, green = increased). Greyed square indicates the location of yellowfin '2013-15 average conditions'. Note this point is scaled to 0.33 (see Table 1)

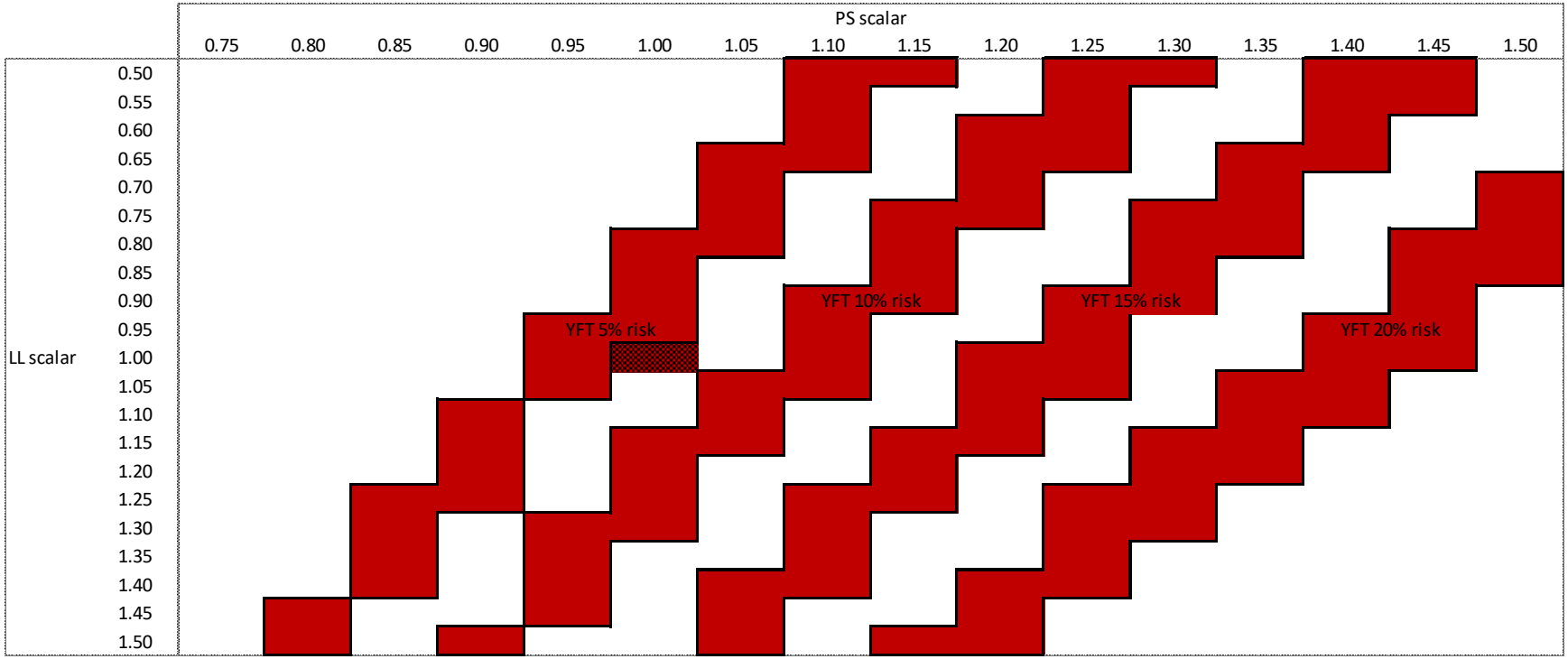

Figure 2b. For yellowfin tuna, the combination of longline catch and purse seine effort (scaled off 2013-15 average levels) that achieve the 'minimum TRP' $SB/SB_{F=0}$ consistent with each of the four levels of risk examined (5%, 10%, 15%, 20% risk of falling below the LRP). For each PS/LL fishing combination, the colour indicates the corresponding future trend in the bigeye stock relative to recent assessed levels ($SB_{2012-2015}/SB_{F=0}$ = 0.36) under 'long term' recruitment assumptions (red = decline, yellow=maintained, green = increased). See caption of Figure 2a for more details.

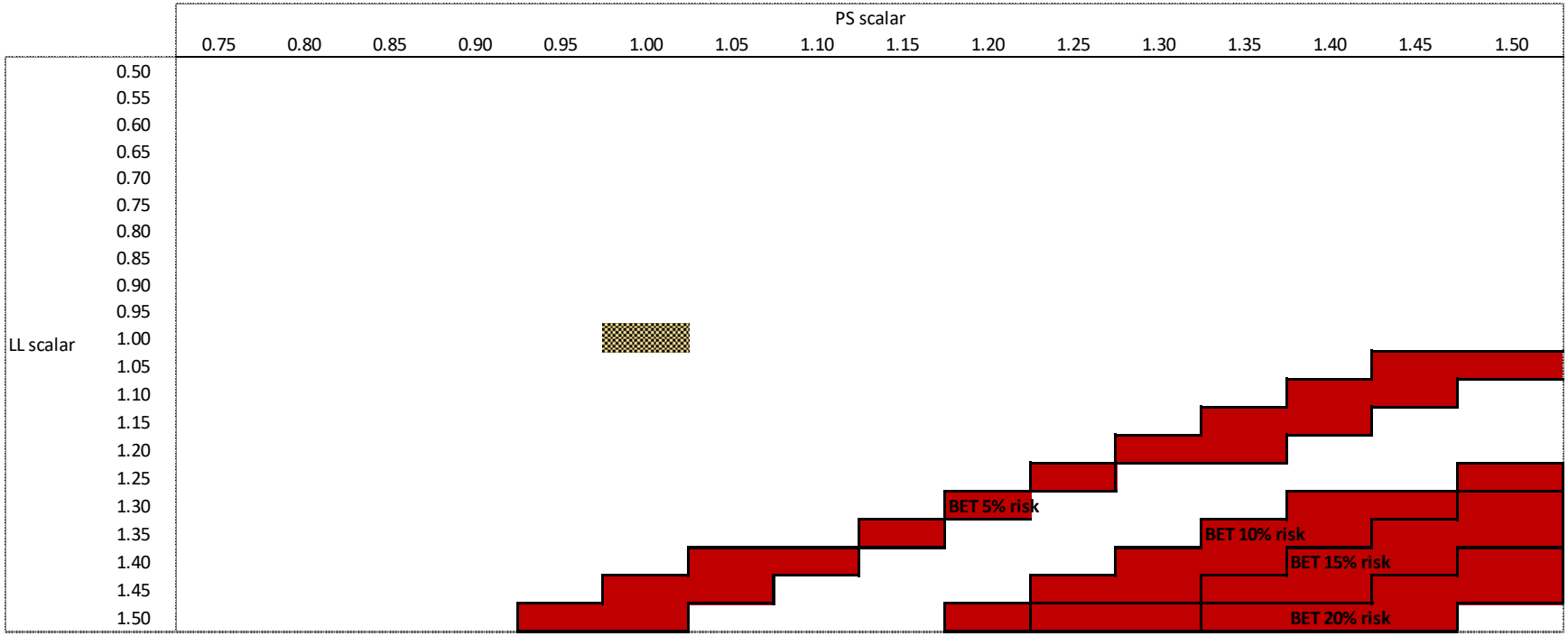

Figure 3a. For bigeye tuna under 'recent recruitment' levels, the combination of longline catch and purse seine effort (scaled off 2013-15 average levels) that achieve the 'minimum TRP' $SB/SB_{F=0}$ consistent with each of the four levels of risk examined (5%, 10%, 15%, 20% risk of falling below the LRP). For each PS/LL fishing combination, the colour indicates the corresponding future trend in the yellowfin stock relative to recent assessed levels ($SB_{2012\text{-}2015}/SB_{F=0}$ = 0.33) (red = decline, yellow=maintained, green = increased). See caption of Figure 2a for more details.

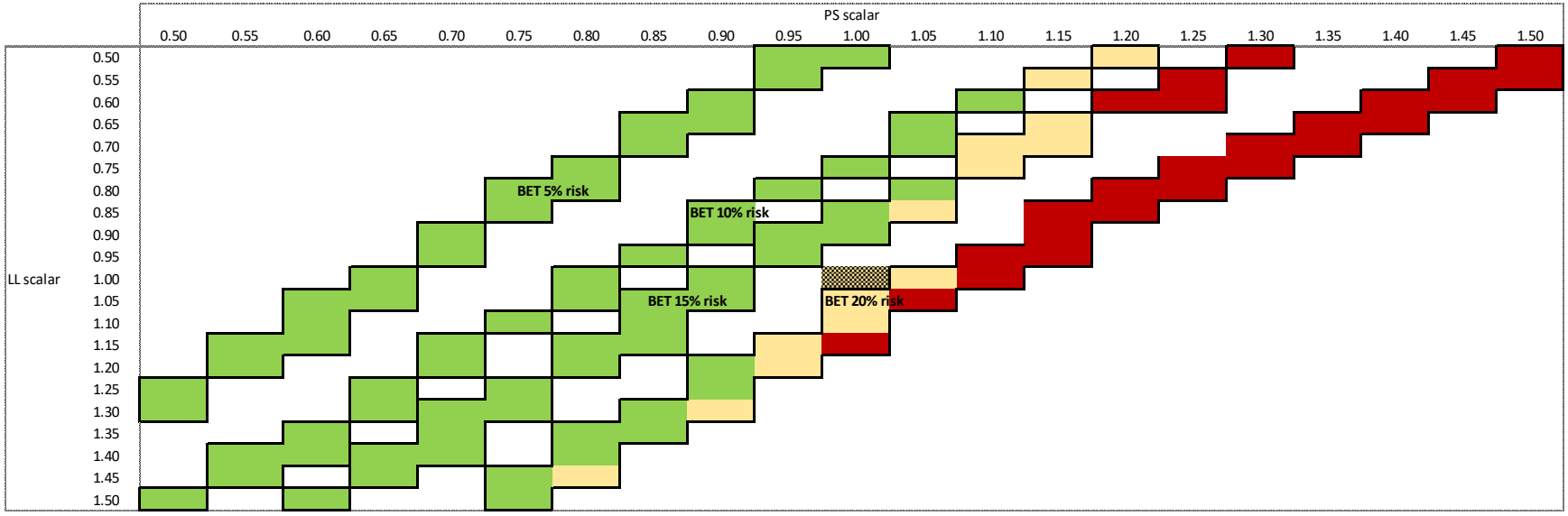

Figure 3b. For bigeye tuna under 'long-term recruitment' levels, the combination of longline catch and purse seine effort (scaled off 2013-15 average levels) that achieve the 'minimum TRP' $SB/SB_{F=0}$ consistent with each of the four levels of risk examined (5%, 10%, 15%, 20% risk of falling below the LRP). For each PS/LL fishing combination, the colour indicates the corresponding future trend in the yellowfin stock relative to recent assessed levels (red = decline, yellow=maintained, green = increased). See caption of Figure 3a for more details.