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Evaluation of CMM 2018-01 for tropical tuna

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[A] This paper represents an update of WCPFC16-2019-17 (and SC15-MI-WP-11),which reflected the potential consequences of the CMM for skipjack tuna, based upon the new stock assessment adopted in 2019, and addressed informational requests raised by CCMs at SC15. The current paper does not present updated tuna stock projection results, given the absence of updated assessments for bigeye and yellowfin that are yet to be adopted by SC16. Changes include:

- Confirmation that scalars under the CMM scenarios remain consistent against the 2013-15 baseline currently used, based upon the updated estimates provided in SC16-MI-IP-19;
- Evaluation of 2019 fishing levels relative to the range of fishing levels expected under the CMM scenarios;
- Removal of the discussion of paragraph 18, given that paragraph applied only in 2019, and was reviewed at WCPFC16;
- Updates where relevant to Appendix 2 to include 2019 values;
- Attempts to address the informational requests made at TCC15 (para 345) – see Appendix 3.

1. EXECUTIVE SUMMARY

This paper evaluates the potential for CMM 2018-01 to achieve its objectives for each of the three WCPO tropical tuna stocks as specified in paragraphs 12 to 14. The evaluation is unchanged from that presented in WCPFC16-2019-17, in that the results are based on the most recent tuna stock assessments. They will be updated once the new assessments for bigeye and yellowfin have been adopted by SC16. The Commission at its 2019 annual session (paragraph 275) considered the development of target reference points for bigeye and yellowfin and agreed that in the interim paragraphs 12 and 14 of CMM 2018-01 be retained and therefore continue to apply to this evaluation.

The evaluation applies a two step approach consistent with recent tropical tuna CMM evaluations:

- Step 1. quantify provisions of each Option – i.e., translate each specified management Option into future potential levels of purse seine effort and longline catch;
- Step 2. evaluate potential consequences of each Option over the long-term for bigeye, yellowfin and skipjack tuna, against the aims specified in CMM 2018-01.

STEP 1: QUANTIFYING PROVISIONS OF THE OPTION

For this evaluation assumptions are required regarding the impact that the FAD closure period and/or high seas effort limits will have on FAD-related effort, and the potential future catches of longline fleets. These assumptions are consistent with those made in previous CMM evaluations and include whether effort and catch limits specified within the CMM are taken by a flag, particularly where those limits are higher than recent fishing levels. Under these assumptions, we define three scenarios of future purse seine effort and longline catch, based upon a baseline average period of 2013-15, the most recent period available in the latest assessments for all three key tropical tuna. Noting that this baseline may be updated when the 2020 assessments for bigeye and yellowfin have been reviewed by SC16. These scenarios are summarised as:

‘2013-2015 avg’: purse seine effort and longline catch levels are maintained at the average levels seen over the years 2013-2015, providing a ‘baseline’ for comparison.

‘Optimistic’: under a 3 month FAD closure, purse seine CCMs make an additional 1/8th FAD sets relative to the average number over 2013-15, when a 4 month closure was in place (i.e. 8 months FAD fishing in those years). The additional 2 month ‘high seas’ FAD closure (5 months in total on the ‘high seas’) reduces the number of FAD sets by 1/8th of those made on the ‘high seas’ in 2013-15 when the 4 month closure was in place. CCMs with longline limits take their 2019 catch limit or 2013-15 average level if lower.

‘Pessimistic’: every CCM fishes the maximum allowed under the Measure. Purse seine CCMs undertake an additional 1/8th FAD sets relative to the average number over the period 2013-15 when the 4 month closure was in operation. The additional 2-month ‘high seas’ FAD closure reduces the number of sets by 1/8th of those set on the high seas in 2013-15, but where specified ‘high seas’’ effort limits allow additional fishing relative to 2013-15, additional FAD sets are assumed on a proportional basis. Limited longline non-SIDS CCMs and US Territories take their entire 2019 specified/2000 mt limits, 2013-2015 average level assumed for other SIDS.

Based on these scenarios and the most recent catch and effort data from SC16-MI-IP-19, catch and effort scalars were calculated relative to 2013-15 and these were applied in the stock projections in step 2. These were confirmed to be consistent with scalars used in WCPFC16-2019-17, based upon values in SC16-MI-IP-19.

The second and third scenarios assume the change in FAD closure periods under CMM 2018-01 equates to a proportional increase/decrease in FAD sets (see also Appendix 1). Other key assumptions across stocks were that total purse seine effort remained constant (increases in FAD sets led to a decrease in free school sets), while for yellowfin, longline catch changes were assumed to proportionally match those evaluated for bigeye tuna. 'Other fisheries', which have a notable impact on yellowfin stock status, were assumed to remain constant at 2013-15 average levels within the analysis.

STEP 2: EVALUATE THE POTENTIAL EFFECTIVENESS OF THE MEASURE ON STOCKS

We use thirty-year stochastic stock projections to evaluate potential long-term consequences of resulting future fishing levels under each scenario, in comparison to 2013-15 average conditions for each of the three tropical tuna stocks. For each, projections were run across the grid of models agreed by SC as the basis for advice.

The stated aims of CMM 2018-01 for bigeye and yellowfin (paragraphs 12 and 14) were to maintain spawning biomass at or above the average $SB/SB_{F=0}$ for 2012-15, while for skipjack tuna (paragraph 13) it was to maintain spawning biomass on average at a level consistent with the interim target reference point ($SB/SB_{F=0}$ = 0.5). The potential long-term performance of the CMM against those objectives varied between stocks.

For bigeye tuna, performance of CMM 2018-01 was strongly influenced by the assumed future recruitment levels (see Table 1). If recent above-average recruitments continue into the future, all scenarios examined achieve the aims of the CMM, in that median spawning biomass is projected to remain stable or increase relative to recent (2012-15) levels, and median fishing mortality is projected to decline slightly (the exception to the latter being the 'pessimistic' CMM scenario, although median fishing mortality remains below F_{MSY}). If lower, longer-term average recruitments continue into the future, spawning biomass depletion worsens relative to recent levels under all scenarios, and the future risk of spawning biomass falling below the limit reference point (LRP) ($SB/SB_{F=0}$ = 0.2) increases to between 17 and 32%, dependent on the scenario. In turn, all three future fishing scenarios imply increases in fishing mortality under those recruitment conditions, more than doubling to median levels well above F_{MSY}.

For yellowfin and skipjack, 'long-term' historical recruitment patterns were assumed to hold into the future. Results for skipjack (Table 2) were consistent across the different CMM 2018-01 scenarios, as overall purse seine effort was assumed to remain constant at 2013-15 average levels, and the impact of longline catch is negligible. Under 2013-15 average fishing levels and 'long term' recruitment, the skipjack stock is projected to stabilise at 41% $SB/SB_{F=0}$, below the interim TRP, while F increases to around 52% F_{MSY}. There was no risk of breaching the adopted LRP, but around a 13% risk of fishing mortality exceeding F_{MSY} by the end of the projection period.

For yellowfin tuna, results under the 2013-15 average and 'optimistic' scenarios are comparable (Table 2), with the stock stabilising at 33% $SB/SB_{F=0}$ (a 1% decrease from recent assessed levels) and F/F_{MSY} reducing to 0.68 (a 7-8% reduction). The 'pessimistic' scenario, which implies a 35% increase in longline yellowfin catch, had a greater impact, with yellowfin biomass falling to 30% $SB/SB_{F=0}$ (an 8% reduction from recent levels), F/F_{MSY} remaining stable at 0.73, and the risk of breaching the adopted LRP increasing to 16%.

2019 purse seine FAD and longline bigeye catch levels were comparable to those anticipated under the 'optimistic' CMM scenario. The total number of FAD sets increased by 8% compared to the baseline, a scalar slightly lower than that anticipated under the 'optimistic' scenario for purse seine. The total 2019 longline bigeye catch was 1% lower than the 2013-15 baseline period, a slightly smaller decline than anticipated under the 'optimistic' scenario for longline. The longline yellowfin catch was 24% higher than the 2013-15 baseline, a level within the range estimated for the 'optimistic' and 'pessimistic' longline scenarios.

Additional analyses were requested by CCMs at the 15th Scientific Committee and 16th Technical and Compliance Committee. These are presented in Appendices 2 and 3, respectively.

Table 1. Median values of reference point levels (adopted limit reference point (LRP) of 20% $SB_{F=0}$; F_{MSY}) and risk[1] of breaching reference points from the 2018 re-assessment of WCPO bigeye tuna incorporating 'updated new growth' models only, and in 2045 under the three future harvest scenarios (2013-15 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2013-2015		Median $SB_{2045}/SB_{F=0}$	Median $SB_{2045}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2041-2044}/F_{MSY}$	Median $F_{2041-2044}/F_{MSY}$ v $F_{2011-14}/F_{MSY}$	Risk	
Recruitment	**Fishing level**	**Purse seine**	**Longline**					**SB_{2045} < LRP**	**$F>F_{MSY}$**
Bigeye assessment ('recent' levels)				0.36	-	0.77	-	0%	6%
Recent	2013-2015 avg	1	1	0.42	1.18	0.73	0.95	0%	11%
	Optimistic	1.11	0.98	0.41	1.15	0.75	0.98	0%	13%
	Pessimistic	1.12	1.35	0.36	1.00	0.89	1.15	5%	30%
Long-term	2013-15 avg	1	1	0.30	0.84	1.60	2.09	17%	93%
	Optimistic	1.11	0.98	0.29	0.82	1.64	2.13	18%	94%
	Pessimistic	1.12	1.35	0.25	0.70	1.84	2.38	32%	98%

[1] note risk within the stock assessment is calculated as the number of models falling below the LRP (X / 36 models). Risk under a projection scenario is the number of projections across the grid that fall below the LRP (X / 3600 (36 models x 100 projections).

Table 2. Median and relative values of reference points and risk of breaching reference points levels (adopted limit reference point (LRP) of 20% $SB_{F=0}$; F_{MSY}) in 2045 from the 2019 skipjack and 2017 yellowfin stock assessments, under the three future harvest scenarios (2013-15 average fishing levels, optimistic, and pessimistic) and long-term recruitment patterns.

Stock	Fishing level	Scalars relative to 2013-2015		Median $SB_{2045}/SB_{F=0}$	Median $SB_{2045}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2041-2044}/F_{MSY}$	Median $F_{2041-2044}/F_{MSY}$ v $F_{2011-14}/F_{MSY}$	Risk	
		Purse seine	**Longline**					**SB_{2045} < LRP**	**$F>F_{MSY}$**
Skipjack tuna	2013-2015 avg	1	1	0.41	NA[1]	0.52	1.18[2]	0%	13%
	Optimistic	1.11	0.98	0.41	NA[1]	0.53	1.19[2]	0%	14%
	Pessimistic	1.12	1.35	0.41	NA[1]	0.53	1.19[2]	0%	14%
Yellowfin tuna	2013-2015 avg	1	1	0.33	0.99	0.68	0.92	7%	2%
	Optimistic	1.11	0.98	0.33	0.99	0.68	0.93	7%	2%
	Pessimistic	1.12	1.35	0.30	0.92	0.73	0.99	16%	9%

[1] Stated aim of CMM 2018-01 for skipjack was to maintain the stock on average around the TRP of 50%$SB_{F=0}$ (CMM para 13). We note skipjack TRP discussions continue.
[2] For skipjack, comparison is Median $F_{2041-2044}/F_{MSY}$ v $F_{2014-2017}/F_{MSY}$

2. QUANTIFYING THE PROVISIONS OF THE MEASURE

This CMM 2018-01 evaluation is based upon the latest SC-agreed stock assessment models for the three tropical tuna species (Vincent et al., 2018; Tremblay-Boyer et al., 2017; Vincent et al. 2019), using those models SC selected as representing the best scientific information available. Abundance of each stock is projected into the future (30 years) under particular levels of either catch or effort within the different fisheries modelled in the assessment.

Therefore, the two parts of Step 1 are:

1. Estimate the levels of associated (FAD) and unassociated (free school) set purse seine effort and longline bigeye catch that would result from the provisions of the Measure. This estimation requires interpretation of the CMM text to estimate the most likely purse seine effort and longline catch levels that would result.
    i) Assumptions must then be made for scalars of the longline catch of skipjack and yellowfin. While longline skipjack catch is negligible, and hence ignored within the analysis, assumptions must be made on the impact of longline bigeye catch multipliers on resulting yellowfin catch levels for the evaluation. The assumption was made that changes in bigeye catch estimated under each scenario also applied to future yellowfin tuna catch levels (i.e. a 1:1 relationship was assumed between changes in bigeye catch and yellowfin catch). Under a specific scenario, therefore, yellowfin longline catches are increased or decreased by the same percentage as that for bigeye catch.
2. Express these levels of purse seine effort and longline catch as scalars relative to reported levels of these quantities for 2013-2015 (the last years of the bigeye and yellowfin assessments). This average period was selected to reduce the impact of FAD set fluctuations in individual years on evaluation results, while ensuring the FAD closure period (4 months) was consistent across those years.

We repeated the detailed approach used in the evaluation of CMM 2015-01 which was presented to WCPFC13 (WCPFC13-2016-15). Table 3 outlines the approach taken in relation to the relevant paragraphs of CMM 2018-01.

Table 3. Evaluation of the relevant paragraphs of CMM 2018-01.

Relevant CMM 2018-01 paragraphs	Evaluation Approach
Principles	
2	F/F_{MSY} is included as a performance indicator.
Area of application	
3 and 10	The area of application does not include archipelagic waters (AW). The evaluation will necessarily be for the WCPO (west of 150°W) rather than the WCPFC Convention Area because of the structure of the assessment model, which does not include catch and effort data from the overlap area. This should not significantly impact the results of the evaluation.
4	No guidance is given regarding level of any AW changes; we assume 2013-2015 average levels of effort will continue.
Harvest strategies and interim objectives	
11	While the measure acts as a bridge to the adoption of a harvest strategy for tropical tuna stocks, for the purpose of this evaluation we have examined where the stock would end up under longer-term application of this measure.
12-14	We use the spawning biomass depletion ratio ($SB/SB_{F=0}$) as a performance indicator, consistent with the limit reference point (LRP) formally adopted by WCPFC ($0.2SB_{F=0}$) for all three tropical tuna stocks, and the interim TRP for skipjack tuna, and relate the longer-term outcome of CMM2018-01 measures (over 30 years) to the average $SB_{2012\text{-}2015}/SB_{F=0,\ 2005\text{-}2014}$.
FAD set management	
16-17	CCMs apply an in-zone/high seas FAD closure of 3 months in 2019 (Jul-Sept). This was modelled as (1+1/8) x average FAD sets in 2013-2015. As a four month closure (or equivalent) was in operation over those years, a 3 month closure would allow on average 1/8th more FAD sets than were seen in the remaining 8 months

	of the year in which FAD sets were allowed. We note this does not take into account the potentially different pattern of fishing by those CCMs that selected FAD set limits in those years, but have assumed that the impact on the number of FAD sets performed was roughly equivalent for those CCMs. In addition, the reduction in FAD set numbers due to the specified 2-month additional high seas FAD closure was estimated (5 months in total). The impact of CCMs choosing different two-month pairs for the closure was assumed to be negligible for this evaluation. We have assumed that **high seas FAD sets were not transferred into EEZs, but were removed from the fishery.** We based the number of high seas FAD sets on the recent average sets in the high seas by CCM over 2013-2015 (a 4 month closure), and calculated the impact of removing 1/8th of those FAD sets at the CCM level, noting the exemption for Kiribati, and for Philippines in HSP1. Two options for future conditions were examined: • **Optimistic**: FAD sets were limited through the 3-month FAD closure and additional 2-month high seas closure as calculated above. High seas effort was maintained at 2013-2015 average levels. • **Pessimistic**: FAD sets were limited through the 3-month FAD closure and additional 2-month high seas closure as calculated above. Those CCMs with high seas effort limits were assumed to fish to their day limits, and corresponding additional high seas FAD sets were estimated (see 'purse seine effort control', below), incorporating the closure; 2013-2015 average levels were assumed for other fleets.
18	Paragraph 18 modified the definition of a FAD in 2019 to exclude "small amounts of plastic or small garbage that do not have a tracking buoy attached". An evaluation of this paragraph was presented in WCPFC16-2019-17. This paragraph applied only in 2019, and was reviewed at WCPFC16. It is not considered further in the current analysis.
19-24	No impact on the evaluation is expected due to the use of reduced-entanglement risk FAD designs. In the absence of information, the practical impact on the number of FAD sets made under the CMM through active instrumented buoy limits (para 23) was assumed to be negligible.
Purse seine effort control	
25-30	For simplicity, we did not assume that purse seine total effort in EEZs and high seas would increase as permitted under nominated EEZ effort levels (e.g. Pilling and Harley, 2015). We assumed overall effort (including within archipelagic waters) would remain at 2013-2015 effort levels (with the exception of the high seas effort limits, below). This assumption means that we do not expect EEZs where purse seine effort has been less than 1500 days annually over recent years to attract additional effort. Flag-based high seas effort limits are unchanged from CMM 2016-01. Many limited CCMs would be able to increase their high seas effort marginally under the CMM. This is incorporated within the 'pessimistic' scenario detailed above. Deletion of CMM 2017-01 paragraph 29 is assumed not to affect the overall level of fleet effort, and for the purposes of this analysis the impact was assumed to be negligible.
Longline fishery – bigeye and yellowfin catch limits	
39-44	Longline catch limits are not completely specified for all CCMs. Two options for future conditions were therefore examined: • **Optimistic**: Limited CCMs took their specified catch limit/2,000 mt catch limit, or their 2013-2015 average catch level whichever was <u>lower</u>, other CCMs took their 2013-2015 average catch level. • **Pessimistic**: Limited CCMs took their specified catch limit/2,000 mt catch limit, other CCMs took their 2013-2015 average catch level. A 2,000 mt limit is currently applied to US Territories in US domestic legislation, although there have been recent recommendations for this limit to be removed. Here the 2,000 mt limits have been applied under the pessimistic scenario, consistent with the approach taken for other CCMs with a 2,000 mt limit. We have assumed that non-limited fleets (those without limits specified in CMM Attachment 1, or the upper limit of 2,000 mt) will continue to operate at 2013-2015 levels, although those fleets could legitimately increase to any level under the CMM. If this occurs, then the extent of any reduction of longline catch will be over-estimated, or any increase under-estimated. As noted, the assumption is made that proportional changes in the longline catch of bigeye relative to the 2013-15 average catch will also apply to the longline yellowfin catch, relative to the same baseline.

	While the one-off transfer of 500 mt of bigeye from Japan to China (Table 3 of CMM 2018-01) will continue for the life of the existing CMM, for the purposes of this long-term evaluation the transfer is not assumed to continue beyond February 2021. For information, this transfer would increase the longline catch scalar of the optimistic scenario only, from 0.98 to 0.99.
Capacity management	
45-49	Not relevant to the evaluation, assuming that total effort and catch measures are adhered to.
Other commercial fisheries	
50-51	There are neither estimates of capacity nor effort for the majority of fisheries in this category; therefore, we assume continuation of 2013-2015 average catch levels.

Estimation of scalars for purse seine associated effort and longline catch

The interpretation of the CMM provisions detailed within Table 3 define future levels of purse seine associated effort and longline catch for each scenario ('optimistic' and 'pessimistic'). Resulting scalars (Table 4) are calculated relative to 2013-2015 average fishing levels[2], and represent aggregate scalars across all CCMs.

Table 4. Scalars for purse seine effort and longline bigeye and yellowfin catch under alternative CMM 2018-01 scenarios, relative to 2013-2015 average conditions.

	Purse Seine	Longline[3]
Optimistic	1.11	0.98
Pessimistic	1.12	1.35

For purse seine, as noted, overall effort was assumed to remain constant at 2013-15 average levels. Therefore, where future scenarios assumed that purse seine FAD (associated) set effort increased, purse seine free school set effort was reduced to maintain constant overall effort. This assumption was applied for all three stocks.

3. Evaluation of the potential effectiveness of the measure

We use the purse seine associated effort and longline catch scalars estimated in Step 1 within projection analyses to evaluate the outcomes in relation to the stated objectives of the CMM regarding each tropical tuna stock. The main indicators used are:

- the spawning biomass at the end of the 30 year projection in relation to the average unfished level ($SB_{2045}/SB_{F=0}$[4]) compared to both the agreed limit reference point of 0.2 $SB_{F=0}$, $SB_{2012\text{-}2015}/SB_{F=0}$, and skipjack interim TRP[5]; and

[2] The tables used to estimate these values are presented in Appendix 1 and are based upon data in WCPFC15-2018-IP06. Updates in SC16-MI-IP-19 do not impact scenario scalars.
[3] If the assumption was made that all CCMs with longline limits took those limits, but that all other fleets caught at the 2013-2015 average catch level, the resulting longline scalar was 1.11 (see Appendix 1). This additional level was not analysed here, but potential outcomes can be inferred from the analysed scenarios.
[4] $SB_{F=0}$ was calculated consistent with the approach defined in CMM 2015-06, and as used within recent stock assessments, whereby the 10 year averaging period was shifted relative to the year in which the SB was evaluated; i.e. spawning biomass in future year *y* was related to the spawning biomass in the absence of fishing averaged over the period *y*-10 to *y*-1 (e.g. $SB_{2045}/SB_{F=0,\ 2035\text{-}2044}$).
[5] CMM 2018-01 specifies the interim target reference point of 50% of the spawning biomass in the absence of fishing, adopted in accordance with CMM 2015-06. We note that given the changed understanding of the stock's biology and perception of stock status provided by the 2019 assessment, discussions on the appropriate TRP value for skipjack tuna continue.

- the median fishing mortality at the end of the projection period (2041-2044) in relation to the fishing mortality at maximum sustainable yield (F/F_{MSY}) and to the estimated level $F_{2011-2014}/F_{MSY}$.

Additional indicators requested by SC are also calculated.

Analysis of the impact of potential future purse seine associated effort and longline catch is conducted using the full uncertainty framework approach as endorsed by SC:

- Projections are conducted from each assessment model within the uncertainty grid selected by SC for management advice for each stock.
- For each model, 100 stochastic projections, which incorporate future recruitments randomly sampled from historical deviates, are performed for the estimated purse seine associated effort and longline catch provisions of CMM 2018-01 (scalars estimated in Step 1, applied to 2013-2015 average fishing conditions). The outputs of the projections ($SB_{2045}/SB_{F=0}$ and F/F_{MSY}) are combined across the relevant uncertainty grid.
- For bigeye tuna, two scenarios for future recruitment in the projection period were examined:
  - Future recruitment was determined by randomly sampling from ONLY the 2005-2014 recruitment deviations from the stock-recruitment relationship estimated in each assessment model, consistent with previous WCPFC SC decisions for bigeye tuna. This effectively assumes that the above-average recruitment conditions of the past 10 years, in particular those in the most recent years, will continue into the future.
  - As requested by SC12, a sensitivity analysis assuming relatively more pessimistic long-term recruitment patterns (sampled from 1962-2014) continue into the future.
- For yellowfin and skipjack tuna, future recruitment in the projection period was based upon long-term recruitment patterns (sampled from 1962-2014 and 1982-2015, respectively).
- For skipjack, outputs across models were weighted according to the levels agreed by SC15 when calculating the results.

Results

Results are described by stock.

Bigeye tuna

Table 5 summarises the median values of $SB/SB_{F=0}$ and F/F_{MSY} achieved in the long-term, along with the potential risk of breaching the limit reference point (LRP) and exceeding F_{MSY}, under each of the future fishing and recruitment combinations. Figure 1 presents the corresponding distributions of long-term $SB/SB_{F=0}$ and Figure 2 those for F/F_{MSY}. At the request of SC, Table 6 provides equivalent information at different time periods within the projection for bigeye, while Figure 3 presents the overall spawning biomass trajectories of the projections.

Potential outcomes under 2013-15 average and CMM scenario conditions were strongly influenced by the assumed future recruitment levels.

Under the assumption that recent above-average recruitments will continue into the future, spawning biomass relative to unfished levels is predicted to increase from recent levels under all examined future scenarios by 0-18% ($SB_{2045}/SB_{F=0}$ ranges from 0.36 to 0.42; Table 5, Figure 1). There is a 0 to 5% risk of future spawning biomass falling below the LRP. Fishing mortality falls slightly under both the 2013-15 average and 'optimistic' scenarios, assuming recent recruitment. However, fishing mortality increases under the 'pessimistic scenario', but mostly remains below F_{MSY} (30% risk of $F > F_{MSY}$[6]; Table 5, Figure 2).

[6] Future MSY levels are influenced by changes in the gear-specific future effort and catch defined under the optimistic and pessimistic scenarios.

Under the assumption that lower, long-term average recruitments are experienced in the future, spawning biomass relative to unfished levels will decline under all scenarios ($SB_{2045}/SB_{F=0}$ ranges from 0.25 to 0.30). The risk of spawning biomass falling below the LRP increases to between 17% and 32% (Table 5). In all fishing scenarios, fishing mortality increases relative to recent levels (by 109-138%) and is well above F_{MSY}. Risk of fishing mortality exceeding F_{MSY} ranges from 93% to 98%.

Skipjack tuna

Results for skipjack are consistent across the different CMM 2018-01 scenarios, as overall purse seine effort is assumed to remain constant at 2013-15 average levels within the analysis, and the impact of longline fisheries is negligible (Table 7, Figure 4, Figure 5, Table 8). Under 'long term' recruitment, the skipjack stock is projected to stabilise at 41% $SB/SB_{F=0}$, below the specified interim TRP, while F increases to around 52% F_{MSY}. There was no risk of breaching the adopted limit reference point, but around a 13% chance that fishing mortality may increase above F_{MSY}. The latter is influenced by the recent pattern of fishing within 'region 5' of the model (Indonesia/Philippines). Small differences between CMM scenarios result from the relative impact of free school and associated sets on skipjack tuna; there is a small negative impact on skipjack status where there is an increased proportion of associated sets, as those sets tend to catch smaller skipjack tuna (see Hampton and Pilling, 2015).

Yellowfin tuna

For yellowfin tuna, results under the 2013-15 average and 'optimistic' scenarios are comparable, with the stock stabilising at 33% $SB/SB_{F=0}$ (a 1% decrease from recent assessed levels), F/F_{MSY} falling to 0.68 (a 7-8% reduction), and a 7% risk of falling below the LRP (Table 7, Figure 6, Figure 7, Table 8). Again, as overall purse seine effort is assumed to remain constant, differences between these two CMM scenarios largely result from the small relative impact of increased associated set proportions on yellowfin tuna (see Hampton and Pilling, 2014), which are comparable to those seen for skipjack, offset by the small reduction in longline catch. The 'pessimistic' scenario, which implies a 35% increase in longline yellowfin catch, has a more notable impact, with yellowfin biomass falling to 30% $SB/SB_{F=0}$ (an 8% reduction from recent levels), F/F_{MSY} remaining stable at 0.73 F/F_{MSY} and a 16% risk of breaching the adopted limit reference point. It should be noted that 'other fisheries', which have a notable impact on yellowfin stock status, are assumed to remain constant at 2013-15 average levels within this analysis.

3. Comparison of 2019 fishing levels with expectations under the CMM 2018-01 evaluation

To evaluate whether recent fishing patterns under CMM 2018-01 reflect the levels forecast under this evaluation, we compared overall 2019 purse seine effort in FAD set numbers and total longline catch relative to 2013-15 baseline levels. These values are drawn from SC16-MI-IP-19 (longline bigeye catch: Table 4; longline yellowfin catch: Table 5) and Figure A4 of SC16-GN-WP-01 (which best reflects the assumptions of the CMM evaluation for tropical FAD set numbers). Resulting scalars are presented in Table 9.

In 2019, the total number of FAD sets increased by 8% compared to the baseline. This scalar is slightly lower than the scalar anticipated under the 'optimistic' scenario for purse seine. The total longline bigeye catch was 1% lower than the 2013-15 baseline period. This is a slightly smaller decline than anticipated under the 'optimistic' scenario for longline (0.98). The longline yellowfin catch was 24% higher than the 2013-15 baseline. While this is within the range estimated for the 'optimistic' and 'pessimistic' longline scenarios, is indicates that the assumption of a direct relationship between bigeye and yellowfin longline catch scalars may not hold.

For both gears, therefore, 2019 fishing patterns of key relevance for bigeye tuna were comparable to that anticipated under the 'optimistic' CMM scenario.

4. Discussion

We have evaluated CMM 2018-01 using stochastic projections (incorporating variation in future recruitment), across the SC-agreed assessment grids as used for advice. This evaluation provides an indication of whether the CMM as it currently stands will achieve the objective of paragraphs 12 to 14 in the long-term.

The potential long-term performance of CMM 2018-01 for bigeye tuna is strongly influenced by assumed future recruitment levels. If recent above-average recruitments continue into the future, all scenarios examined achieve the aims of the CMM, in that spawning biomass is projected to increase relative to recent levels, and fishing mortality is projected to decline (the exception to the latter being the 'pessimistic' CMM scenario). If lower, longer-term average recruitments continue into the future, spawning biomass depletion worsens relative to recent levels under all scenarios, and the future risk of spawning biomass falling below the LRP increases to 17-32%, dependent on the scenario. In turn, all three future fishing scenarios imply notable increases in fishing mortality under those recruitment conditions, to median levels well above F_{MSY}.

Results for skipjack were consistent across the different CMM 2018-01 scenarios, as overall purse seine effort was assumed to remain constant at 2013-15 average levels, and the impact of any change in proportional longline catch is negligible. Under 2013-15 average levels and 'long term' recruitment, skipjack depletion is projected to stabilise at 41% $SB/SB_{F=0}$, below the interim specified TRP, while F increases to around 52% F_{MSY}. There was no risk of breaching the adopted limit reference point, but around a 13% chance that fishing mortality may increase above F_{MSY}.

For yellowfin tuna, results under the 2013-15 average and 'optimistic' scenarios are comparable, with the stock stabilising at 33% $SB/SB_{F=0}$ (a 1% decrease from recent assessed levels) and F/F_{MSY} reducing to 0.68 (a 7-8% reduction). The pessimistic scenario, which implies a 35% increase in longline yellowfin catch, had a greater impact, with yellowfin biomass falling to 30% $SB/SB_{F=0}$ (an 8% reduction from recent levels), F/F_{MSY} remaining stable at 0.73F/F_{MSY}, and the risk of breaching the adopted limit reference point increasing to 16%.

As in previous CMM evaluations (e.g. SPC, 2018), it is not possible to define precisely what levels of future fishing will result from CMM provisions. Estimating future levels for the purse seine fishery requires the assumption that the number of future FAD sets performed in a year is proportional to the additional month of FAD fishing allowed, and that the choice of paired high seas FAD closure months will not affect the assumption of a proportional decrease in high seas FAD sets. We also assume that the potential increase in purse seine fishing effort permissible under recently nominated EEZ effort levels will not occur, under the logic that we do not expect EEZs where purse seine effort has been less than 1500 days annually over recent years to attract additional effort. However, those increases are theoretically permitted under the CMM. For the longline fishery, future fishing levels will depend on the degree to which those fleets recently under-fishing their defined catch limits continue to do so, and the future levels of fishing undertaken by currently unlimited fleets.

5. References

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6. TABLES

Table 5. Median values of reference point levels (adopted limit reference point (LRP) of 20% $SB_{F=0}$; F_{MSY}) and risks[1] of breaching reference points from the 2018 <u>bigeye</u> stock assessment incorporating 'updated new growth' models only, and in 2045 under the three future harvest scenarios (2013-2015 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2013-2015		Median $SB_{2045}/SB_{F=0}$	Median $SB_{2045}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2041-2044}/F_{MSY}$	Median $F_{2041-2044}/F_{MSY}$ v $F_{2011-14}/F_{MSY}$	Risk	
Recruitment	Fishing level	Purse seine	Longline					SB_{2045} < LRP	F>F_{MSY}
Bigeye assessment ('recent' levels)				0.36	-	0.77	-	0%	6%
Recent	2013-2015 avg	1	1	0.42	1.18	0.73	0.95	0%	11%
	Optimistic	1.11	0.98	0.41	1.15	0.75	0.98	0%	13%
	Pessimistic	1.12	1.35	0.36	1.00	0.89	1.15	5%	30%
Long-term	2013-15 avg	1	1	0.30	0.84	1.60	2.09	17%	93%
	Optimistic	1.11	0.98	0.29	0.82	1.64	2.13	18%	94%
	Pessimistic	1.12	1.35	0.25	0.70	1.84	2.38	32%	98%

[1] note risk within the stock assessment is calculated as the number of models falling below the LRP (X / 36 models). Risk under a projection scenario is the number of projections across the grid that fall below the LRP (X / 3600 (36 models x 100 projections)).

Table 6. Median $SB/SB_{F=0}$ values and associated risk of breaching the adopted limit reference point (LRP) of 20% $SB_{F=0}$ for the bigeye stock in 2020, 2025 and 2045 under the three future harvest scenarios (2013-2015 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses. Note: Only 'Updated new growth' models used.

Scenario		Scalars relative to 2013-2015		Median $SB_{2020}/SB_{F=0}$	Median $SB_{2025}/SB_{F=0}$	Median $SB_{2045}/SB_{F=0}$	Risk SB_{2020} < LRP	Risk SB_{2025} < LRP	Risk SB_{2045} < LRP
Recruitment	Fishing level	Purse seine	Longline						
Recent	2013-2015 avg	1	1	0.42	0.41	0.42	0%	1%	0%
	Optimistic	1.11	0.98	0.41	0.40	0.41	0%	1%	0%
	Pessimistic	1.12	1.35	0.38	0.35	0.36	0%	4%	5%
Long-term	2013-2015 avg	1	1	0.35	0.30	0.30	2%	12%	17%
	Optimistic	1.11	0.98	0.35	0.30	0.29	2%	13%	18%
	Pessimistic	1.12	1.35	0.32	0.26	0.25	7%	26%	32%

Table 7. Median and relative values of reference points and risks of breaching reference points levels (adopted limit reference point (LRP) of 20% $SB_{F=0}$; F_{MSY}) in 2045 from the 2016 skipjack and 2017 yellowfin stock assessments, under the three future harvest scenarios (2013-2015 average fishing levels, optimistic, and pessimistic).

Stock	Fishing level	Scalars relative to 2013-2015		Median $SB_{2045}/SB_{F=0}$	Median $SB_{2045}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2041-2044}/F_{MSY}$	Median $F_{2041-2044}/F_{MSY}$ v $F_{2011-14}/F_{MSY}$	Risk	
		Purse seine	Longline					SB_{2045} < LRP	$F>F_{MSY}$
Skipjack tuna	2013-2015 avg	1	1	0.41	NA[1]	0.52	1.18[2]	0%	13%
	Optimistic	1.11	0.98	0.41	NA[1]	0.53	1.19[2]	0%	14%
	Pessimistic	1.12	1.35	0.41	NA[1]	0.53	1.19[2]	0%	14%
Yellowfin tuna	2013-2015 avg	1	1	0.33	0.99	0.68	0.92	7%	2%
	Optimistic	1.11	0.98	0.33	0.99	0.68	0.93	7%	2%
	Pessimistic	1.12	1.35	0.30	0.92	0.73	0.99	16%	9%

[1] Stated aim of CMM 2018-01 for skipjack was to maintain the stock on average around the TRP of 50%$SB_{F=0}$ (CMM para 13).
[2] For skipjack, comparison is Median $F_{2041-2044}/F_{MSY}$ v $F_{2014-2017}/F_{MSY}$.

Table 8. Median $SB/SB_{F=0}$ values and associated risk of breaching the adopted limit reference point (LRP) of 20% $SB_{F=0}$ for the yellowfin and skipjack stocks in 2020, 2025 and 2045 under the three future harvest scenarios (2013-2015 average fishing levels, optimistic, and pessimistic).

Stock	Fishing level	Scalars relative to 2013-2015		Median $SB_{2020}/SB_{F=0}$	Median $SB_{2025}/SB_{F=0}$	Median $SB_{2045}/SB_{F=0}$	Risk SB_{2020} < LRP	Risk SB_{2025} < LRP	Risk SB_{2045} < LRP
		Purse seine	Longline						
Skipjack tuna	2013-2015 avg	1	1	0.39	0.40	0.41	0%	0%	0%
	Optimistic	1.11	0.98	0.39	0.40	0.41	0%	0%	0%
	Pessimistic	1.12	1.35	0.39	0.40	0.41	0%	0%	0%
Yellowfin tuna	2013-2015 avg	1	1	0.32	0.31	0.33	9%	10%	7%
	Optimistic	1.11	0.98	0.32	0.32	0.33	9%	10%	7%
	Pessimistic	1.12	1.35	0.30	0.29	0.30	15%	18%	16%

Table 9. Pattern of purse seine effort (FAD sets) and longline bigeye and yellowfin catch in 2019 and scalar from 2013-15 levels.

	Average 2013-15	2019	Scalar
Purse seine effort (FAD sets)[1]	16,729	18,124	1.08
Longline bigeye catch (mt)[2]	66,554	65,875	0.99
Longline yellowfin catch (mt)[2]	71,178	88,020	1.24

[1] in the tropical purse seine fishery
[2] in WCPFC-CA

7. Figures

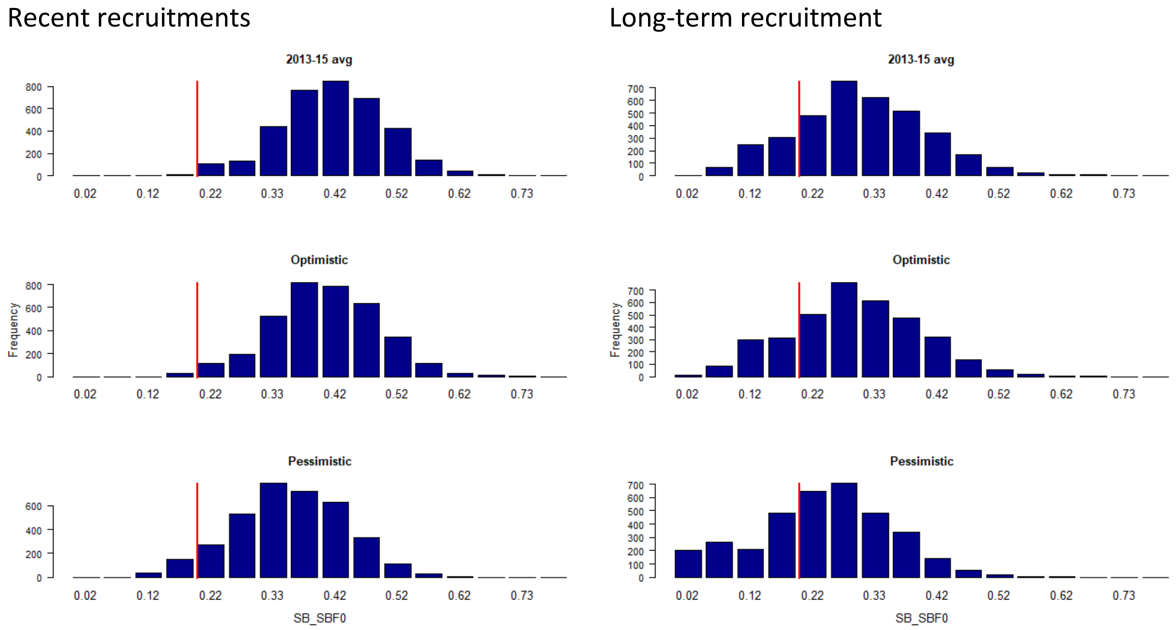

Figure 1. Distribution of $SB_{2045}/SB_{F=0}$ for <u>bigeye</u> tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2013-15 avg (2013-15 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions (bottom row). Projection results from 'updated new growth' models (3,600 projections) only. Red line indicates the LRP (20%$SB_{F=0}$).

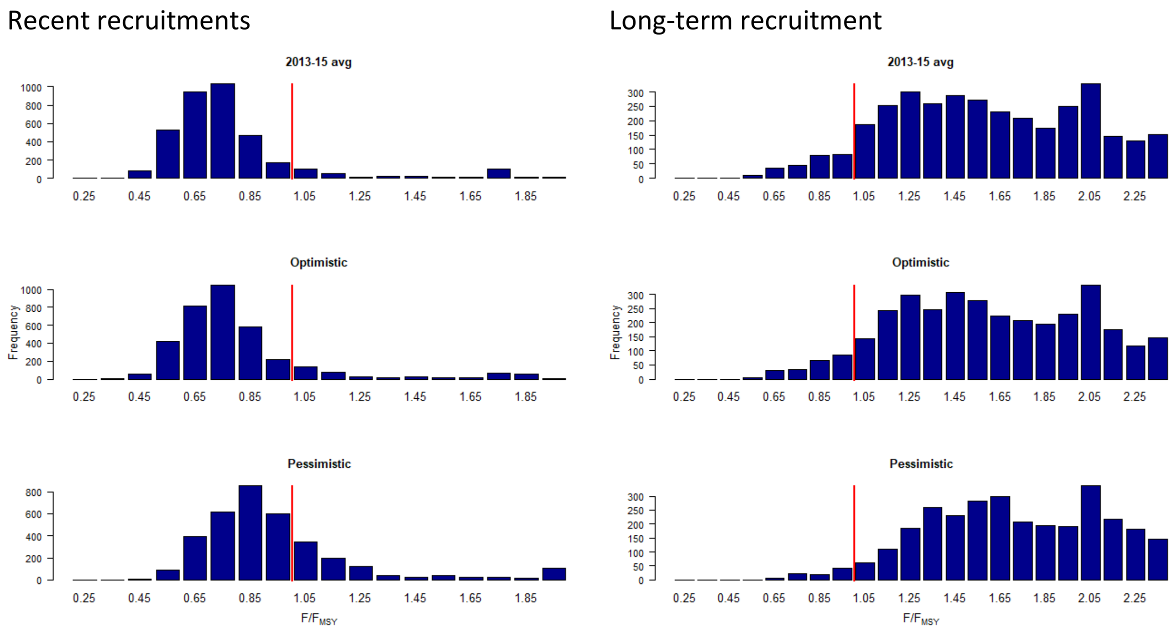

Figure 2. Distribution of F/F_{MSY} for <u>bigeye</u> tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2013-15 avg (2013-15 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions (bottom row). Projection results from 'updated new growth' models (3,600 projections) only. Red line indicates $F = F_{MSY}$.

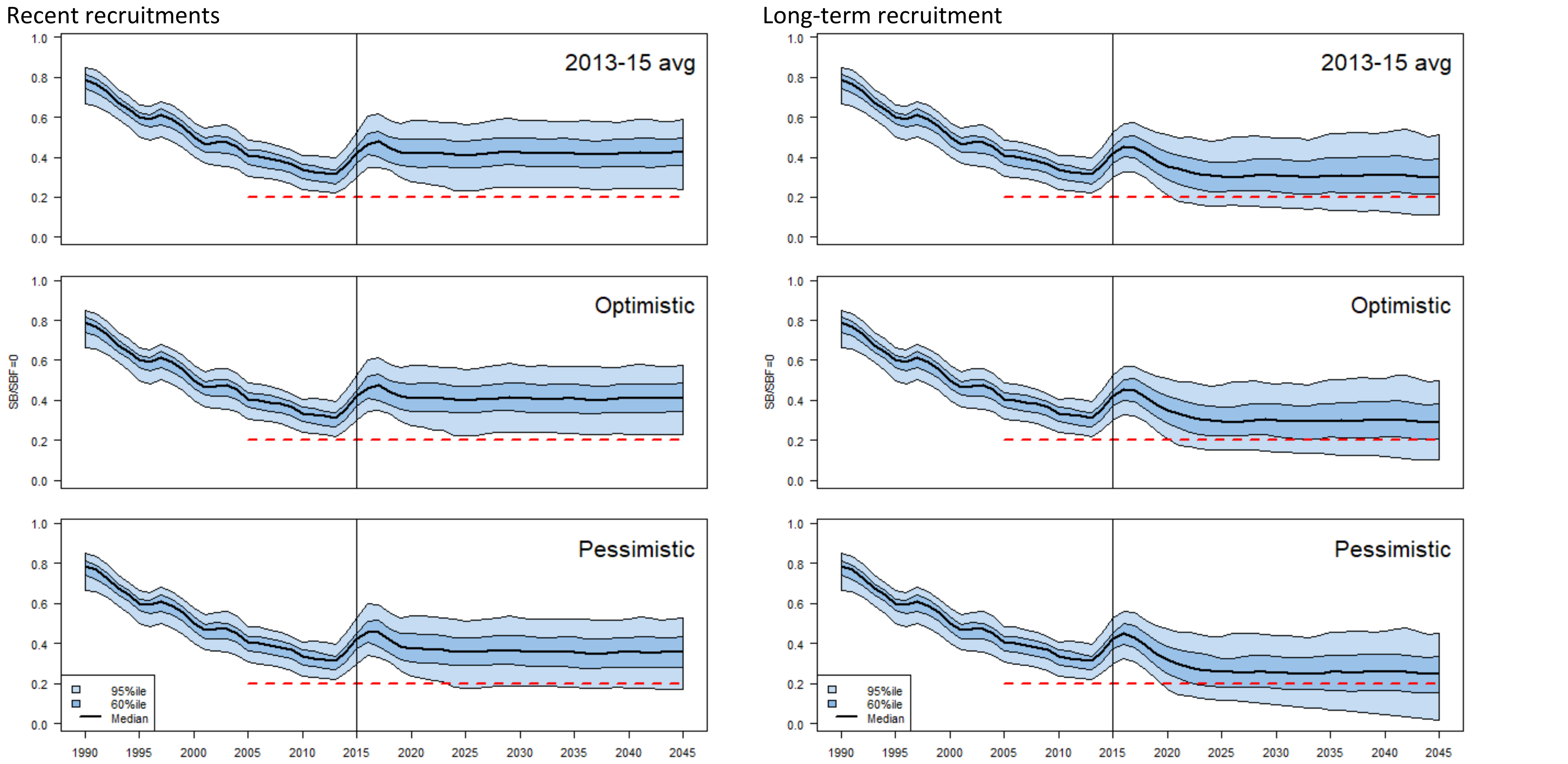

Figure 3. Time series of WCPO bigeye tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2015 (the vertical line at 2015 represents the last year of the assessment), and stochastic projection results for the period 2016 to 2045 under the three future fishing scenarios ('2013-15 avg', 'Optimistic' and 'Pessimistic'; rows). During the projection period (2016-2045) levels of recruitment variability are assumed to match those over the "recent" time period (2005-2014; left panel) or the time period used to estimate the stock-recruitment relationship (1962-2014; right panel). The red dashed line represents the agreed limit reference point.

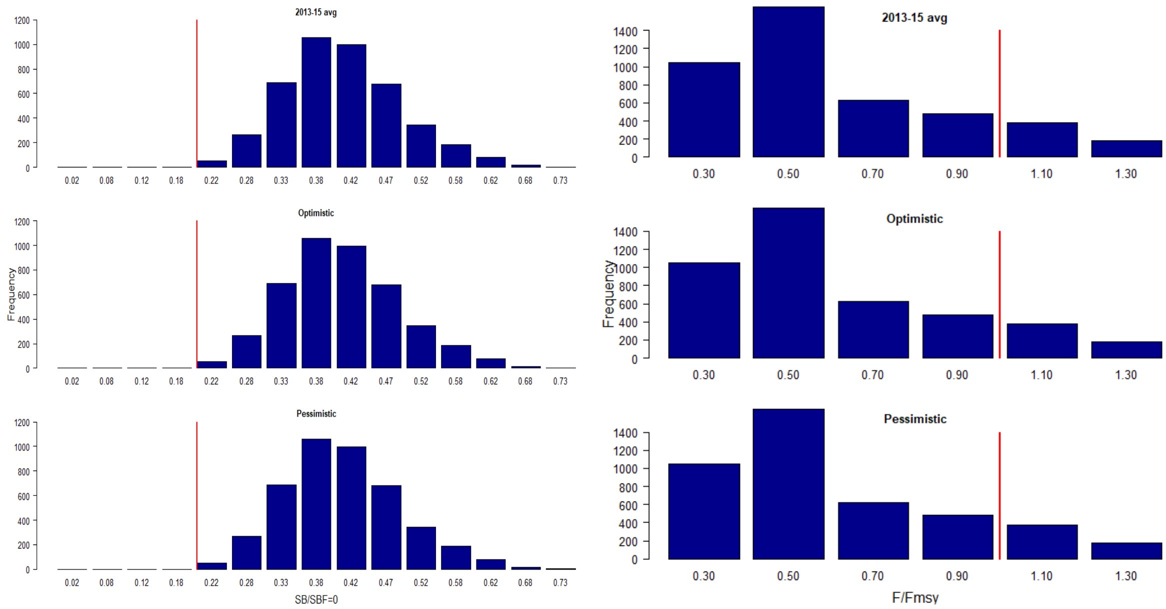

Figure 4. Distribution of $SB_{2045}/SB_{F=0}$ (left column), and F/F_{MSY} for skipjack tuna assuming long-term recruitment conditions, under the three future fishing scenarios: 2013-15 avg (2013-15 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions (bottom row). Red line indicates the LRP ($20\%SB_{F=0}$) and $F=F_{MSY}$, respectively.

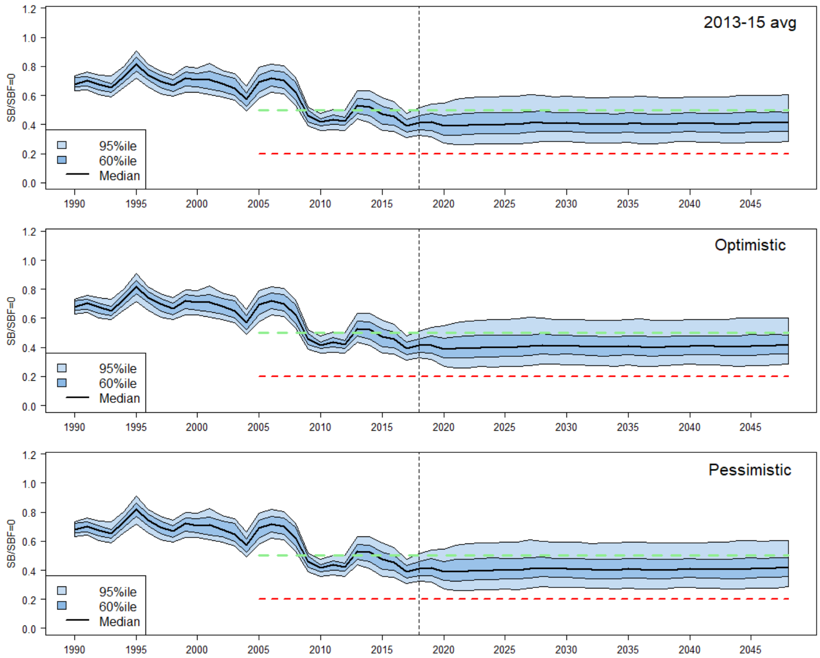

Figure 5. Time series of WCPO skipjack tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2018 (the vertical line at 2018 represents the last year of the assessment), and stochastic projection results for the period 2019 to 2045 under the three future fishing scenarios ('2013-15 avg', 'Optimistic' and 'Pessimistic'; rows). During the projection period (2019-2045) levels of recruitment variability are assumed to match those over the time period used to estimate the stock-recruitment relationship (1982-2017). The red dashed line represents the agreed limit reference point, the green dashed line the interim specified target reference point.

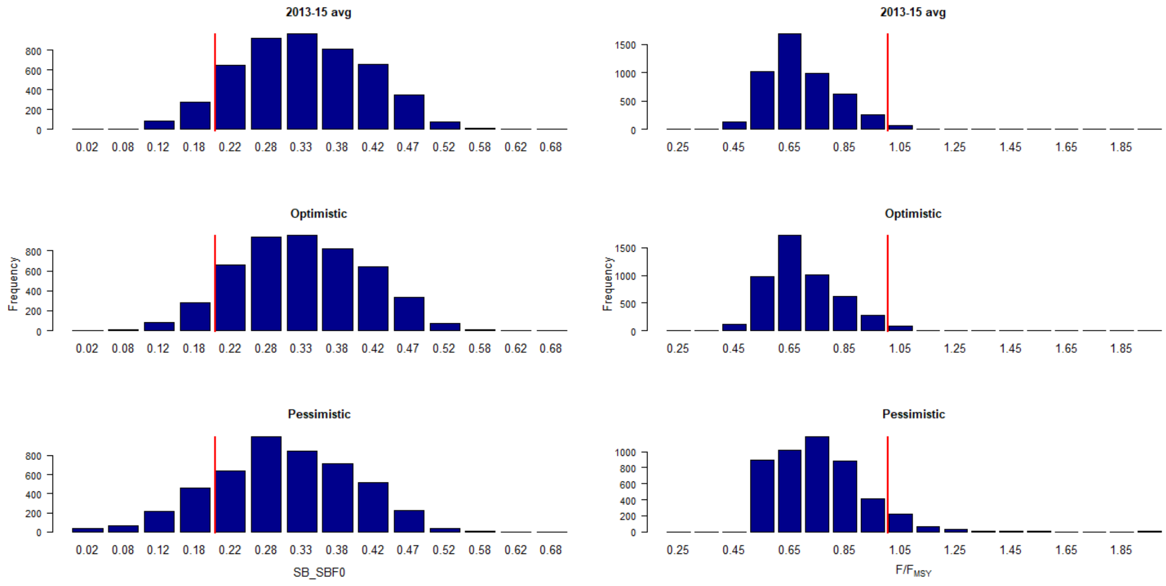

Figure 6. Distribution of $SB_{2045}/SB_{F=0}$ (left column), and F/F_{MSY} for yellowfin tuna assuming long-term recruitment conditions, under the three future fishing scenarios: 2013-15 avg (2013-15 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions (bottom row). Red line indicates the LRP ($20\%SB_{F=0}$) and $F=F_{MSY}$, respectively.

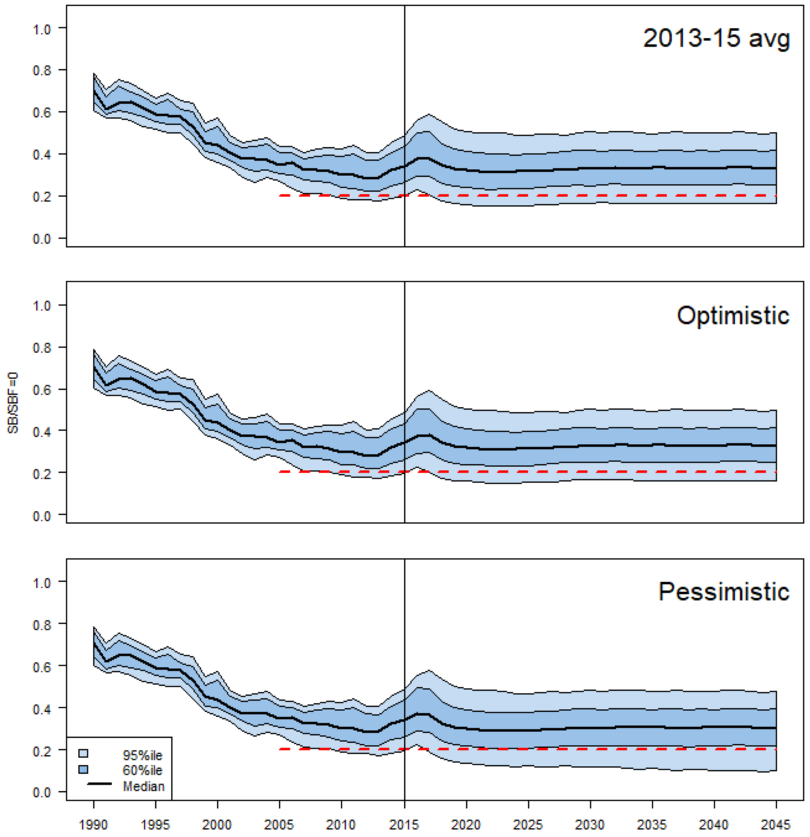

Figure 7. Time series of WCPO yellowfin tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2015 (the vertical line at 2015 represents the last year of the assessment), and stochastic projection results for the period 2016 to 2045 under the three future fishing scenarios ('2013-15 avg', 'Optimistic' and 'Pessimistic'; rows). During the projection period (2016-2045) levels of recruitment variability are assumed to match those over the time period used to estimate the stock-recruitment relationship (1962-2014). The red dashed line represents the agreed limit reference point.

8. APPENDIX 1. ESTIMATION OF SCENARIOS

Purse seine FAD set numbers assumed for CCMs, and corresponding scalars relative to 2013-2015 average conditions under the two scenarios.

'Optimistic' PS scenario

	Non-SIDS		SIDS				
	3 mth FAD closure	Additional 2mth high seas removes:	3mth FAD closure	Additional 2mth high seas removes:	Non-SIDS	SIDS	Total
CHINA	1365	0			1365		1365
ECUADOR	285	8			277		277
EL SALVADOR	292	14			279		279
FSM			661	3		658	658
JAPAN	1019	0			1019		1019
KIRIBATI			963	0		963	963
MARSHALL ISLANDS			1285	7		1278	1278
NEW ZEALAND	110	2			107		107
PAPUA NEW GUINEA			1585	7		1578	1578
PHILIPPINES (distant-water)	464	0			464		464
REPUBLIC OF KOREA	1422	4			1418		1418
SOLOMON ISLANDS			128	0		128	128
EU (SPAIN)	477	29			449		449
CHINESE TAIPEI	2591	3			2588		2588
TUVALU			61	0		61	61
USA	3330	59			3271		3271
VANUATU			230	0		230	230
					11236	**4895**	**16131**
			Scalar V 2013-15 avg				**1.11**

'Pessimistic' PS scenario: additional high seas sets under specified effort limits

	CMM HS day limit	Avg 13-15HS days	Avg HS sets/day	Additional HS sets
CN	26	15.3	0.04	0.5
ES	403	327.7	0.62	46.7
JP	121	39.3	0.08	6.9
NZ	160	59.3	0.28	28.2
KR	207	146.0	0.20	12.4
TW	95	67.3	0.36	10.0
US	1270	1279.3	0.37	0.0
			Additional HS sets	**105**

Longline bigeye catch assumed for CCMs, and corresponding scalars relative to 2013-15 average conditions under the two scenarios, plus intermediate analysis of consequences where CCMs limited to 2000mt take their recent average catch levels.

	Pessimistic		**Optimistic**
CCM	2018 CMM levels if limited, otherwise 2000mt (non sids) or 2013-2015 avg	2018 CMM levels if limited, otherwise 2013-2015 avg	2018 CMM levels or 2013-15 if lower
AMERICAN SAMOA	2,000	421	421
AUSTRALIA	2,000	588	588
BELIZE	2,000	72	72
CHINA	8,224	8,224	8,224
COOK ISLANDS	181	181	181
EU-PORTUGAL	2,000	65	65
EU-SPAIN	-	47	47
FSM	1,377	1,377	1,377
FIJI	1,300	1,300	1,300
FRENCH POLYNESIA	776	776	776
GUAM	2,000	277	277
INDONESIA	5,889	5,889	3,411
JAPAN	18,265	18,265	14,290
KIRIBATI	469	469	469
MARSHALL ISLANDS	27	27	27
NAURU	0	0	0
NEW CALEDONIA	57	57	57
NEW ZEALAND	2,000	118	118
NIUE	0	0	0
NORTHERN MARIANAS	2,000	831	831
PALAU	0	0	0
PAPUA NEW GUINEA	33	33	33
PHILIPPINES	2,000	77	77
REPUBLIC OF KOREA	13,942	13,942	12,095
SAMOA	44	44	44
SENEGAL	2,000	0	0
SOLOMON ISLANDS	2,481	2,481	2,481
TONGA	18	18	18
TUVALU	128	128	128
CHINESE TAIPEI	10,481	10,481	10,017
USA	3,554	3,554	3,554
VANUATU	3,670	3,670	3,670
WALLIS AND FUTUNA	0	0	0
Total	88,916	73,411	64,649
Scalar from 2013-15	**1.35**	**1.11**	**0.98**

9. Appendix 2. Additional analyses requested by CCMs at the 15th Scientific Committee

Three CCMs raised requests at SC15 for further evaluation within this paper, as detailed within the SC15 summary report:

1. [Para 480] The United States in seeking to fully understand the expected effects of CMM 2018-01, requested the science provider to explicitly consider and evaluate the expected effects of footnote 1 of CMM 2018-01, which relates to exemptions from the three-month FAD closure. The evaluation could be expressed in comparative fashion, such as comparing the effects of zero vessels taking the exemption versus 49 vessels taking the exemption, as occurred in 2018. The United States also requested the science provider to explicitly evaluate the expected effects of the exemptions for vessels of Kiribati and the Philippines under paragraph 17 of CMM 2018-01, which relates to exemptions from the additional two-month FAD closure for the high seas. It may be helpful to scale these evaluations relative to the effects of the FAD closures more generally; for example, what are the respective magnitudes of the effects of footnote 1 and paragraph 17 relative to the expected effects of the FAD closure? Ideally, these analyses would be incorporated into future routine evaluations of tropical tunas CMMs.

2. [Para 485] Palau asked for an analysis of the effect of overshooting of the high seas effort limits shown in Table 2 of SC15-MI-IP-06.

3. [Para 481] The EU inquired whether the purse seine effort repeatedly observed in the HS in recent years by CCMs not bound by HS effort limits was captured by the scenarios, and requested that it is addressed in future simulations.

To address the SC15 requests, we break the evaluation down into specific elements:

1. Footnote 1
2. Paragraph 17
3. Purse seine high seas effort relative to 2018-01 limits
4. Patterns of high seas effort

For each element, the consequences of the potential change in the number of FAD sets that could result, if patterns found in 2018 (and 2019 where relevant) were to continue into the future, were evaluated for the purse seine fishery scalars under the 'optimistic' and 'pessimistic' scenarios. We also relate the change in the number of FAD sets to 'FAD closure month' equivalents.

The CMM evaluation assumes overall effort is constant at 2013-15 average levels, and a key issue is the pattern of FAD setting within that overall effort (e.g. through the impact of FAD closure periods). Where SC15 elements refer to effort, to which the corresponding specific number of FAD sets is impossible to identify (elements 3 and 4), we apply recent patterns of FAD setting per day for each flag to estimate the potential FAD sets that may result. Where necessary, we assume that all other CCMs maintain levels consistent with the 'optimistic' and 'pessimistic' scenarios.

Where species catch are presented, these are adjusted based upon the species composition from observer sampling, or for Philippines fishing in HSP #1 directly sourced from observer data.

Footnote 1

Footnote 1 states "Members of the PNA may implement the FAD set management measures consistent with the Third Arrangement Implementing the Nauru Agreement of May 2008. Members of the PNA shall provide notification to the Commission of the domestic vessels to which the FAD closure will not apply."

The pattern of fishing of the 49 domestic vessels to which this footnote applied in 2018 was summarised based upon logsheet data. Total FAD sets during the three month closure period and the catch by species were summed across vessels. The resulting total sets and species catch is summarised in Table 10.

Table 10. Summary of FAD effort and adjusted species catch taken within the 2018 FAD closure by 'footnote 1' vessels.

Total FAD sets	Total catch (mt)			
	Skipjack	Yellowfin	Bigeye	Total
765	31,851	4,926	1,991	38,768

Paragraph 17

Paragraph 17 details the additional 2 month high seas-specific FAD closure period, with the exemption for those vessels flying the Kiribati flag when fishing in the high seas adjacent to the Kiribati exclusive economic zone, and Philippines' vessels operating in HSP1 in accordance with Attachment 2. To evaluate the potential impact of fishing by vessels of these flags, we identified the level of fishing within each of the 2 month high seas closure periods in 2018, and calculate the average across them (Table 11). For Kiribati vessels, fishing activity in those months reflects that in neighbouring high seas areas.

Table 11. Summary of FAD effort and adjusted species catch taken within both additional two month high seas FAD closure periods, and the average fishing that might result, by Philippines vessels in HSP#1 (top) and Kiribati vessels in adjacent high seas areas (bottom).

Philippines (HSP#1)

Months	Total FAD sets	Total catch (mt)			
		Skipjack	Yellowfin	Bigeye	Total
April-May	710	2,367	1,397	603	4,367
November-December	696	2,816	2,193	471	5,480
Average	**703**	**2,591**	**1,795**	**537**	**4,923**

Kiribati (adjacent high seas)

Months	Total FAD sets	Total catch (mt)			
		Skipjack	Yellowfin	Bigeye	Total
April-May	109	2,845	206	753	3,804
November-December	103	4,835	420	309	5,565
Average	**106**	**3,840**	**313**	**531**	**4,684**

Purse seine high seas effort relative to CMM limits

To address the third SC15 request element, Table 12 below compares the agreed high seas effort limits within CMM 2018-01 (Table 2) with the patterns of actual fishing in 2018 and 2019 from SC16-MI-IP-19 (Table 2).

Table 12. Comparison of CMM high seas purse seine effort limits (see CMM 2018-01, Table 2) with days fished in tropical international waters[1] (20°N to 20°S) in 2018 and 2019.

Flag	CMM limits	Days fished in international waters 20°N-20°S in:	
		2018	**2019**
China	26	3	1
Ecuador	**	0	0
El Salvador	**	28	10
European Union	403	158	141
Indonesia	(0)	0	0
Japan	121	5	22
New Zealand	160	57	32
Philippines	#	2,749	2,654
Republic of Korea	207	198	222
Chinese Taipei	95	62	84
USA	1,270	1,584	1,525

**subject to CNM on participatory rights
Measures that Philippines would take are in Attachment 2 of CMM 2018-01
[1] WCPFC region or WCPO, dependent upon flag notifications on application of IATTC rules in the overlap area

The approximate additional number of FAD sets resulting from the additional days fished on the high seas when compared to the 'optimistic' scenario would be 107 sets in 2018 and 82 sets in 2019, and when compared to the 'pessimistic' scenario, 18 more sets in 2018 and 8 fewer sets in 2019.

Patterns of high seas effort

To examine the fourth SC15 request element, we use the data available from Table 2 of SC16-MI-IP-19 to calculate the average pattern of effort (days fished) in the high seas over the 2013-15 baseline period, and relate to the levels seen in 2018 and 2019 (Table 13).

Table 13. Comparison of average high seas purse seine effort by flag over 2013-15 with days fished in tropical international waters (20°N to 20°S) in 2018 and 2019.

Flag	Days fished in international waters 20°N-20°S		
	Average 2013-15	**in 2018**	**In 2019**
China	15	3	1
Cook Islands	0	0	72
Ecuador	1	0	0
El Salvador	42	28	10
European Union	332	158	141
FSM	162	619	1,208
Indonesia	0	0	0
Japan	41	5	22
Kiribati	563	817	978
Marshall Is.	285	303	954
Nauru	0	130	188
New Zealand	58	57	32
PNG	381	11	0
Philippines	3,066	2,749	2,654
Republic of Korea	128	198	222

Solomon Is.	0	102	103
Tuvalu	29	57	52
Chinese Taipei	71	62	84
USA	1,277	1,584	1,525
Vanuatu	3	123	165
Total	**6,515**	**7,006**	**8,411**

Applying a flag-specific high seas FAD setting rate from recent years for all fleets, the additional overall effort in 2018 and 2019 compared to the baseline could result in an additional 188 to 393 FAD sets under the 'optimistic' scenario and 99 to 304 FAD sets compared to the 'pessimistic' scenario.

IMPACT OF SC15 ELEMENTS ON PURSE SEINE SCALARS

The potential impact of each SC15 element has been expressed as the potential change in the overall number of FAD sets. We subtract or add those estimated FAD sets to the overall number under the CMM 'optimistic' and 'pessimistic' scenarios, and re-calculate the purse seine scalars (Table 14). Based upon the assumed impact of a month of FAD closure on the purse seine effort scalar (a month's closure being equivalent to a scalar of $1/8^{th}$, i.e. 0.125, relative to the 2013-15 baseline), we also relate the number of FAD sets thus estimated to the equivalent primary FAD closure period.

Table 14. Future purse seine scalars (under the CMM two scenarios) that may result where the equivalent number of FAD sets are removed from or added to from the calculations.

	Approx. FAD set change	Optimistic scenario	Pessimistic scenario	Approximate equivalent main FAD closure period
CMM evaluation scalars		1.11	1.12	3 months
Footnote 1	-765	1.06	1.07	~ 2.6 months
Paragraph 17[1]	-809	1.08	1.08	~ 2.75 months
High seas CMM limits	-8/+107	1.11/1.12	1.12/1.13	~3 - 3.1 months
Patterns of effort	+99 to +393	1.13-1.14		~3.1 - 3.2 months

[1] Note that removal of 703 sets from Philippines (distant water) effort would lead to a negative number of sets (cf Table 11 and Appendix 1). We have assumed that the impact would be that no sets were made by this flag, which would lead to the reduction in purse seine effort scalar indicated in the table for 'Paragraph 17'.

10. APPENDIX 3. ADDITIONAL ANALYSES REQUESTED BY PNA MEMBERS AT THE 15TH TECHNICAL AND COMPLIANCE COMMITTEE

PNA members raised requests at TCC15 for further evaluation within this paper, as detailed within the TCC15 summary report (para 345):

> *PNA members ... requested that the SPC analysis cover all special provisions in the measure, including the high seas purse seine effort limits set for the EU and the United States, the special provision (CMM 2017-01 paragraph 29) for the United States' purse seine fleet to transfer some of their days to U.S. territories, and the special provision that resulted in the United States' longline fleet taking a lower reduction in longline bigeye catch limits than other fleets.*

The intent of this request was subsequently clarified with the PNA, and the impact on fishing of the following three specific 'special provisions' are evaluated below:

- *i)* *High seas purse seine effort limits set out in Table 2 of CMM 2018-01;*
- *ii)* *Longline bigeye catch limits set out in Table 3 of CMM 2018-01;*
- *iii)* *Fishing conducted under charter arrangements referred to in para 9 of CMM 2018-01.*

HIGH SEAS PURSE SEINE EFFORT LIMITS

Table 2 of CMM 2018-01 specifies the high seas purse seine effort levels (days) relating to paragraphs 26-28 of the Measure. The request was to examine the impact on the purse seine scalar if those limits were set to zero. The number of FAD sets that may be performed within those specified days were calculated based upon a flag-specific rate of FAD sets/high seas day (see table in Appendix 1). The resulting number of FAD sets were removed from each flag's total, i.e. we assume they were not transferred into EEZs. Where flags were included that did not have a high seas effort limit, the FAD closure was assumed to still apply. The resulting scalar is compared to that under the 'pessimistic' scenario (where the scalar is calculated assuming all high seas days allowed under the Measure are used).

Table 15. Purse seine scalar under the 'pessimistic' scenario, and under the assumption that high seas effort limits for flags in Table 2 of the Measure were set to zero.

Scenario	'Pessimistic' scenario	Table 2 effort set to zero
Scalar	1.12	1.06

LONGLINE BIGEYE CATCH LIMITS

Table 3 specifies the longline catch limits for specific CCMs. To evaluate the impact of those specified limits on the longline scalar, the request was to examine the resulting impact if those limits were set to zero. The resulting scalars were calculated with settings for other CCMs equivalent to the 'optimistic' and 'pessimistic' scenarios.

Table 16. Longline catch scalar under 'optimistic' and 'pessimistic' scenarios, and under the assumption that Table 3 limits were set to zero.

	'Optimistic' scenario		'Pessimistic' scenario	
Scenario	As main text	Table 3 catches set to zero	As main text	Table 3 catches set to zero
Scalar	0.98	0.20	1.35	0.43

Fishing under charter arrangements

Paragraph 9 of CMM 2018-01 notes that "*for purposes of paragraphs 39-41* [longline bigeye catches] *and 45-49* [purse seine and longline vessel limits], *catches and effort of United States flagged vessels operating under agreements with its Participating Territories shall be attributed to the Participating Territories*."

According to the US Federal Register, a 2019 limit of 2,000 metric tons (t) of longline-caught bigeye tuna was applied for each U.S. Pacific territory (American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI)). Each territory could allocate up to 1,000 t each year to U.S. longline fishing vessels in a specified fishing agreement that meets established criteria.

To evaluate the impact, longline bigeye catches up to 1000 mt in American Samoa, Guam and CNMI flags in 2019 (SC16-MI-IP-19) were assumed to be removed, and US fleet catches maximised at the level specified in Table 3. The resulting scalars were compared to the 'optimistic' scenario, since the 'pessimistic' scenario assumed territories expanded their catches to 2,000 mt as permitted under Paragraph 43.

Table 17. Longline catch scalar under the optimistic scenario, and under the assumption that Paragraph 9 did not apply.

Scenario	'Optimistic' scenario	Paragraph 9 excluded
Scalar	0.98	0.97