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EVALUATION OF CMM 2018-01 FOR TROPICAL TUNA: 2020 UPDATE

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[1] Rev1 replaces the version issue on 30 November 2020

This paper represents an update of **WCPFC-SC16-2020/MI-IP-23**. The specific changes in this update of the CMM 2018-01 evaluation include:

- Updating the baseline period from 2013-2015 to 2016-2018 due to the new bigeye and yellowfin assessments accepted at SC16, and adjustment of the associated calculations. The final year of data in the most recent assessments of all three tropical tuna stocks is now 2018.
- Applying the new assessment model grids in the evaluations for bigeye and yellowfin agreed by SC16.
- Using the updated catch and effort data as of October 2020.
- Updates of the calculations presented in Appendices 1 to 3.
- Calculation of 'recent' stock status for bigeye and yellowfin relative to 2012-15 levels in Appendix 4.

02/12/20 Amendments in REV1

1. Amendment made to the number of vessels notified to the WCPFC as being exempt from the 3 month FAD closure in 2019 under footnote 1 of CMM 2018-01, revised from 66 to 58 (Appendix 2, Table 10). Number of FAD sets in PNA EEZs during the 3 month FAD closure also revised up from 906 to 938, which resulted in a minor increase in the catches, also updated in Table 10. Footnote also added to Table 10 indicating the number of vessels that actually reported FAD associated sets during the 3 month FAD closures in 2018 and 2019.

2. Additional footnotes added to Table 12.

1. EXECUTIVE SUMMARY

This paper evaluates the potential for CMM 2018-01 to achieve its objectives for each of the three WCPO tropical tuna (bigeye, yellowfin and skipjack) stocks as specified in paragraphs 12 to 14 of that Measure. The evaluations are based on the most recent SC-agreed stock assessments, and for all three tropical tuna stocks these now include data through 2018.

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 2016-2018, the most recent period available in the latest assessments for all three key tropical tuna. In calculating the implications of CMM 2018-01, we calculated adjusted 'CMM equivalent' catches and effort for each baseline year and then averaged those adjusted values, due to differences in annual management arrangements across 2016-2018. The scenarios are summarised as:

'2016-2018 avg': purse seine effort and longline catch levels are maintained at the average levels seen over the years 2016-2018, 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 number in 2016 and 2017, 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 2016 when the 4 month closure was in place. In 2017, when the high seas were closed to FAD fishing all year, an additional 7 months of high seas FAD sets (based on average monthly high seas FAD set levels in 2016 and 2018) were assumed to be made. In 2018, purse seine effort was not adjusted as management arrangements were consistent with those under CMM 2018-01. CCMs with longline limits take their specified catch limit or 2016-2018 average level if lower, and other CCMs take their 2016-2018 average catch.

'Pessimistic': every CCM fishes the maximum allowed under the Measure. Purse seine CCMs undertake an additional 1/8th FAD sets relative to the number over 2016 and 2017 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 2016, but increases them by the equivalent of 7 months for 2017. Where specified 'high seas' effort limits allow additional fishing relative to actual annual levels in 2016, 2017 and 2018, additional FAD sets are assumed on a proportional basis. Limited longline non-SIDS CCMs and US Territories take their entire specified/2000 mt limits, 2016-2018 average level assumed for other SIDS.

Based on these scenarios and the most recent catch and effort data (October 2020), catch and effort scalars were calculated relative to the 2016-2018 baseline and these were applied in the stock projections in step 2.

The 'Optimistic' and 'Pessimistic' 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 2016-2018 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 2016-2018 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 Commission, at its 2019 annual session (WCPFC16 Summary Report, 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. However, we note that the interim TRP for skipjack (CMM 2015-06, referenced in CMM 2018-01 - paragraph 13) was expected to be reviewed no later than 2019. Formal review and a decision on the skipjack TRP are yet be completed. In this paper we therefore do not presume a TRP for skipjack, but express spawning biomass depletion relative to 2012-2015, consistent with bigeye and yellowfin. The potential long-term performance of the CMM against those objectives varied between stocks.

For bigeye tuna, performance of CMM 2018-01 was influenced by the assumed future recruitment levels (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 slightly relative to 2012-2015 levels, and the median fishing mortality is projected to decline slightly for the 2016-2018 average and 'optimistic' scenarios but increase for the 'pessimistic' CMM scenario, although still remaining below F_{MSY}. If the less positive, long-term average recruitment continues into the future, spawning biomass depletion also improves relative to 2012-2015 levels for the 2016-2018 average and 'optimistic' scenarios, but declines under the 'pessimistic' scenario. Under that recruitment assumption, future risk of spawning biomass falling below the limit reference point (LRP) ($SB/SB_{F=0}$ = 0.2) increases to between 5 and 19%, dependent on the CMM scenario. In turn, all three future fishing scenarios imply increases in fishing mortality under the long-term recruitment conditions, and for the 'pessimistic' scenario, F exceeds F_{MSY} at the end of the projection period.

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 2016-2018 average levels, and the impact of longline catch is negligible. Under 2016-2018 average fishing levels and 'long term' recruitment, the skipjack stock is projected to stabilise at 43% $SB/SB_{F=0}$, around 10% lower than the average depletion over 2012-2015, while F increases slightly to around 70% F_{MSY}. There was no risk of breaching the adopted LRP, but a 16-18% risk of F exceeding F_{MSY} by the end of the projection period.

Results for yellowfin tuna, under all scenarios produced similar results (**Table 2**), with the stock stabilising at 57-59% $SB/SB_{F=0}$, a slight increase above the target levels in 2012-2015, and F remaining well below F_{MSY}. For all scenarios there was a 0% risk of breaching the adopted LRP or F exceeding F_{MSY}.

Examining the levels of fishing in 2019, the first year in which CMM 2018-01 applied, purse seine FAD effort levels were lower than those anticipated under the 'optimistic' CMM scenario. The total number of FAD sets decreased by 3% compared to the baseline average. The total 2019 longline bigeye catch was 17% higher than the 2016-2018 baseline average, producing a scalar somewhat higher than the 'optimistic' scenario, but lower than the 'pessimistic' scenario. Similarly, for yellowfin the catch was higher than that anticipated under the 'optimistic' scenario for longline. The longline yellowfin catch was 37% higher than the 2016-2018 baseline, a level still within the range estimated for the 'optimistic' and 'pessimistic' longline scenarios.

The new information incorporated within the 2020 yellowfin tuna stock assessment implies a more robust stock than estimated previously, as seen by the zero risks of depletion falling below the LRP and F increasing above F_{MSY}. It should be noted that key areas for further work on the yellowfin assessment were identified for the coming year, and an external review of the assessment is planned for 2022. While the assessment is viewed as the best scientific information currently available, the further work underway may lead to changes in the perception of stock status and the implications of CMM 2018-01.

Appendices 2 to 4 present the results of additional analyses requested by CCMs at previous Commission meetings and subsidiary body meetings.

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 2020 assessment of WCPO <u>bigeye tuna</u>, and in 2048 under the three future harvest scenarios (2016-2018 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2016-2018		Median $SB_{2048}/SB_{F=0}$	Median ratio $SB_{2048}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2044-2047}/F_{MSY}$	Median ratio $F_{2044-2047}/F_{MSY}$ v $F_{2014-17}/F_{MSY}$	Risk[1]	
Recruitment	**Fishing level**	**Purse seine**	**Longline**					**SB_{2048} < LRP**	**F>F_{MSY}**
2020 Bigeye assessment ('recent' levels)				0.41	-	0.72	-	0%	13%
Recent	2016-2018 avg	1	1	0.48	1.30	0.69	0.96	0%	10%
	Optimistic	1.11	1	0.47	1.27	0.71	0.99	0%	12%
	Pessimistic	1.13	1.51	0.40	1.08	0.88	1.22	1%	32%
Long-term	2016-2018 avg	1	1	0.43	1.17	0.89	1.23	5%	37%
	Optimistic	1.11	1	0.42	1.13	0.91	1.26	6%	40%
	Pessimistic	1.13	1.51	0.34	0.91	1.08	1.50	19%	58%

Table 2. Median and relative values of reference points and risk[1] of breaching reference point levels (adopted limit reference point (LRP) of 20% $SB_{F=0}$; F_{MSY}) in 2048 from the 2019 <u>skipjack</u> and 2020 <u>yellowfin</u> stock assessments, under the three future harvest scenarios (2016-2018 average fishing levels, optimistic, and pessimistic) and long-term recruitment patterns.

Stock	Fishing level	Scalars relative to 2016-2018		Median $SB_{2048}/SB_{F=0}$	Median ratio $SB_{2048}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2044-2047}/F_{MSY}$	Median ratio $F_{2044-2047}/F_{MSY}$ v $F_{2014-17}/F_{MSY}$	Risk[1]	
		Purse seine	**Longline**					**SB_{2048} < LRP**	**F>F_{MSY}**
Skipjack tuna	2016-2018 avg	1	1	0.43	0.89	0.68	1.56	0%	16%
	Optimistic	1.11	1	0.43	0.88	0.70	1.57	0%	18%
	Pessimistic	1.13	1.51	0.43	0.88	0.70	1.57	0%	18%
Yellowfin tuna	2016-2018 avg	1	1	0.59	1.09	0.29	0.82	0%	0%
	Optimistic	1.11	1	0.59	1.08	0.30	0.83	0%	0%
	Pessimistic	1.13	1.51	0.57	1.04	0.32	0.89	0%	0%

[1]Risk within the stock assessment is calculated as the (weighted – if weights applied) number of models falling below the LRP (X / No. models). Risk under a projection scenario is the number of projections across the grid that fall below the LRP (X / (No. models x 100 projections) in the terminal projection year (2048).

2. QUANTIFYING THE PROVISIONS OF THE MEASURE

This CMM 2018-01 evaluation is based upon the latest SC-agreed stock assessments for the three tropical tuna species (Ducharme-Barth et al., 2020; Vincent et al., 2019; Vincent et al., 2020), 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. To do this, we:

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 2016-2018 (the last three years of the assessments for the three species/stocks).

Table 3 outlines the approach taken in relation to the relevant paragraphs of CMM 2018-01 and describes how the different arrangements regarding in-zone and high seas closure to FAD fishing across 2016, 2017 and 2018 are accounted for.

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 models, which do 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 2016-2018 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 relate the longer-term outcome of CMM2018-01 measures (over 30 years) to the average $SB_{2012\text{-}2015}/SB_{F=0,\ 2005\text{-}2014}$. Note: as the skipjack TRP referenced in paragraph 13 of CMM 2018-01 was due for review in 2019, and a new TRP has not been defined, we do not make reference to a TRP for skipjack, but for comparison apply the same approach as for bigeye and yellowfin.
FAD set management	
16-17	CCMs apply an in-zone/high seas FAD closure of 3 months from 2018 (Jul-Sept), and an additional 2 months high seas closure (choice of April-May or November-December).

	Because of the different FAD set management arrangements in the baseline years of 2016, 2017 and 2018, we first estimated the numbers of FAD sets that would be expected in each of these years had CMM 2018-01 been in place (described below). To evaluate the implications of CMM 2018-01, we averaged the estimates of the expected FAD sets in each year under CMM 2018-01 and then divided by the average of the actual observed FAD sets over 2016-2018 to determine scalars to be used in stock projections. In 2018 the FAD set management arrangements that were in place were essentially the same as under CMM 2018-01 so the FAD sets were unadjusted for this evaluation. In 2017 there was a 4-month in-zone and high seas FAD closure. Furthermore, the high seas were closed to FAD fishing for the remaining 8 months for all CCMs except Kiribati and those that qualified for an exemption by showing a verifiable reduction of bigeye catch to 55% or less of that reported in 2010-2012. To evaluate the CMM 2018-01 against 2017 conditions the number of FAD sets was modelled as (1+1/8) x average FAD sets/year in 2016-2018. This accounted for the 4-month closure that was in operation in 2017 (i.e. 8 months FAD fishing), and the 3-month closure as per CMM 2018-01 which would have allowed on average 1/8th more FAD sets. To account for the year-long high seas closure in 2017, compared to the 5 months high seas closure under CMM 2018-01, we added an additional 7 months of FAD sets based on the average monthly high seas FAD sets by CCMs in 2016 and 2018, noting any high seas sets reported in 2017 would not be representative given the various clauses of the Measure for that year. In 2016, there was also a 4-month in-zone and high seas FAD closure for all CCMs, however, unlike 2017, outside this closure high seas were open to FAD fishing. To account for the CMM 2018-01 measure for 2016 we therefore made the same adjustment of (1+1/8) x average FAD sets/year in 2016-2018, but then subtracted 1 month of high seas FAD sets (based on 2016 and 2018 monthly averages) due to the additional month of high seas closure under CMM 2018-01. The impact of CCMs choosing different two-month pairs for the high seas closure under CMM 2018-01 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 also note the exemption for Kiribati on the high seas FAD closures, and for Philippines in High Seas Pocket 1. This has been consistent across the baseline period and under CMM 2018-01 and hence is incorporated within this evaluation. 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 average of 2016 and 2018 levels, if less than the CMM-specified day limits. Where fishing by a CCM exceeded those limits over those years, high seas sets were calculated up to the high seas limit only. • **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; 2016-2018 average levels were assumed for other fleets. While we note this does not take into account the potentially different pattern of fishing by those CCMs that selected FAD set limits in particular baseline years, we have assumed that the impact on the number of FAD sets performed was roughly equivalent for those CCMs.
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 2016-2018 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.
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 2016-2018 average catch level whichever was lower, other CCMs took their 2016-2018 average catch level. • **Pessimistic**: Limited CCMs took their specified catch limit/2,000 mt catch limit, other CCMs took their 2016-2018 average catch level. A 2,000 mt limit is currently applied to US Territories in US domestic legislation. 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 2016-2018 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 2016-2018 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) may 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 and it has negligible implications for the longline catch scalars.
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 2016-2018 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 **FAD associated** effort and **longline catch** for each scenario ('optimistic' and 'pessimistic'). Resulting scalars (Table 4) are calculated relative to 2016-2018 average fishing levels[2], and represent aggregate scalars across all CCMs.

Table 4 Scalars for purse seine associated effort (sets) and longline bigeye and yellowfin catch under alternative CMM 2018-01 scenarios, relative to 2016-2018 average conditions.

	Purse Seine	Longline[3]
Optimistic	1.11	1.00
Pessimistic	1.13	1.51

For purse seine, as noted, overall effort was assumed to remain constant at 2016-2018 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.

[2] The tables used to estimate these values are presented in Appendix 1 and are based upon data in SC16-MI-IP-19 and its update WCPFC17-2020-IP04.

[3] If the assumption was made that all CCMs with longline limits took those limits, but that all other fleets caught at the 2016-2018 average catch level, the resulting longline scalar was 1.26 (see Appendix 1). This additional level was not analysed here, but potential outcomes can be inferred from the analysed scenarios.

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 ($SB_{2048}/SB_{F=0}$[4]) compared to both the agreed limit reference point of 0.2 $SB_{F=0}$, and $SB_{2012-2015}/SB_{F=0}$[5]; and;
- the median fishing mortality at the end of the projection period (2044-2047) in relation to the fishing mortality at maximum sustainable yield (F/F_{MSY}) and to the estimated level $F_{2014-2017}/F_{MSY}$.

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 2016-2018 average fishing conditions). The outputs of the projections ($SB_{2048}/SB_{F=0}$ 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 2007-2016 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 more recent years, will continue into the future.
  - As requested by SC12, a sensitivity analysis assuming relatively more pessimistic long-term recruitment patterns (sampled from 1962-2016) continue into the future.
- For yellowfin and skipjack tuna, future recruitment in the projection period was based upon long-term recruitment patterns (sampled from 1962-2016 and 1982-2017, respectively).
- For skipjack, outputs across models were weighted according to the levels agreed by SC15 when calculating the results. Equal weighting across models was applied to yellowfin and bigeye as agreed by SC16.

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[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. $SB_{2048}/SB_{F=0,\ 2038-2047}$).

[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, and we have chosen not to evaluate against a specific TRP for skipjack.

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 2016-18 average and CMM scenario conditions were 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 2012-15 levels under all examined future scenarios by 8-30% ($SB_{2048}/SB_{F=0}$ ranges from 0.40 to 0.48; Table 5**,** Figure 1). There is a 0 to 1% risk of future spawning biomass falling below the LRP. Fishing mortality falls slightly under both the 2016-2018 average and 'optimistic' scenarios, assuming recent recruitment. However, fishing mortality increases under the 'pessimistic' scenario, but remains below F_{MSY} , with a 32% risk of $F > F_{MSY}$[6] (Table 5**,** Figure 2).

Under the assumption that lower, long-term average recruitments are experienced in the future, spawning biomass relative to unfished levels is predicted to increase under the 2016-2018 average and 'optimistic' scenarios relative to 2012-2015 ($SB_{2048}/SB_{F=0}$ 0.42 to 0.43), but decrease for the 'pessimistic' scenario ($SB_{2048}/SB_{F=0}$ 0.34) (Table 5). The risk of spawning biomass falling below the LRP increases to between 5% and 19% (Table 5). In all fishing scenarios, fishing mortality increases relative to recent levels (by 23-50%) and exceeds F_{MSY} for the 'pessimistic' scenario. Risk of F exceeding F_{MSY} ranges from 37% to 58%.

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 2016-18 average levels within the analysis, and the impact of longline fisheries is negligible (Table 7**,** Figure 4**,** Table 8**,** Figure 5). The skipjack stock is projected to stabilise at 43% $SB/SB_{F=0}$, with F at around 70% of F_{MSY}. There was no risk of breaching the adopted limit reference point, but around a 16-18% 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, 2014, 2015).

Yellowfin tuna

For yellowfin tuna, results under all scenarios are comparable, with the stock stabilising at 57-59% $SB/SB_{F=0}$, and F/F_{MSY} at 0.29-0.32. There is 0% risk of spawning biomass falling below the LRP, or F increasing to levels above F_{MSY} (Table 7**,** Figure 6**,** Table 8**,** Figure 7).

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

4. 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 2016-18 baseline levels. These values are drawn from WCPFC17-2020-IP04 (longline bigeye catch: Table 4; longline yellowfin catch: Table 5) and a data extract comparable to that for 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 decreased by 3% compared to the baseline. This scalar is lower than the scalar anticipated under the 'optimistic' scenario for purse seine. The total longline bigeye catch was 17% higher than the 2016-18 baseline period. This is higher than anticipated under the 'optimistic' scenario for longline, but lower than the 'pessimistic' scenario. The longline yellowfin catch was 37% higher than the 2016-18 baseline. While this is within the range estimated for the 'optimistic' and 'pessimistic' longline scenarios, it 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 more comparable to that anticipated under the 'optimistic' than the 'pessimistic' CMM scenario.

5. Discussion

We have evaluated CMM 2018-01 using stochastic projections (incorporating variation in future recruitment), across the SC-agreed assessment grids as used for management advice. This evaluation provides an indication of whether the CMM as it currently stands is likely to 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 moderately 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 remain above the levels in 2012-2015, although only marginally so for the 'pessimistic' scenario. Fishing mortality is projected to remain similar and below F_{MSY}, or increase slightly under the 'pessimistic' CMM scenario. If lower, longer-term average recruitments continue into the future, spawning biomass depletion worsens relative to recent levels only for the 'pessimistic' CCM scenario, and the future risk of spawning biomass falling below the LRP increases to 5-19%, dependent on the scenario. In turn, all three future fishing scenarios imply increases in fishing mortality to be close to F_{MSY}, but only the 'pessimistic' scenario exceeded 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 2016-18 average levels, and the impact of any change in proportional longline catch is negligible. Under 2016-18 average levels and 'long-term' recruitment, skipjack depletion is projected to stabilise at 43% $SB/SB_{F=0}$, slightly lower than levels in 2012-15, while F increases to around 70% F_{MSY}. There was no risk of breaching the adopted limit reference point, but a 16-18% chance that F could increase above F_{MSY}.

For yellowfin tuna, results under all scenarios are comparable, with the stock stabilising at 57-59% $SB/SB_{F=0}$, and F remaining well below F_{MSY}. There is no predicted risk of spawning biomass falling below the LRP, or F increasing to levels above F_{MSY}.

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 that recently under-fishing their defined catch limits continue to do so, and the future levels of fishing undertaken by currently unlimited fleets.

6. References

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7. TABLES

Table 5 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 2020 assessment of WCPO bigeye tuna, and in 2048 under the three future harvest scenarios (2016-2018 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2016-2018		Median $SB_{2048}/SB_{F=0}$	Median ratio $SB_{2048}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2044-2047}/F_{MSY}$	Median ratio $F_{2044-2047}/F_{MSY}$ v $F_{2014-17}/F_{MSY}$	Risk[1]	
Recruitment	**Fishing level**	**Purse seine**	**Longline**					**SB_{2048} < LRP**	**$F>F_{MSY}$**
2020 Bigeye assessment ('recent' levels)				0.41	-	0.72	-	0%	13%
Recent	2016-2018 avg	1	1	0.48	1.30	0.69	0.96	0%	10%
	Optimistic	1.11	1	0.47	1.27	0.71	0.99	0%	12%
	Pessimistic	1.13	1.51	0.40	1.08	0.88	1.22	1%	32%
Long-term	2016-2018 avg	1	1	0.43	1.17	0.89	1.23	5%	37%
	Optimistic	1.11	1	0.42	1.13	0.91	1.26	6%	40%
	Pessimistic	1.13	1.51	0.34	0.91	1.08	1.50	19%	58%

[1] Risk within the stock assessment is calculated as the (weighted – if weights applied) number of models falling below the LRP (X / 24 models). Risk under a projection scenario is the number of projections across the grid that fall below the LRP (X / 2400 (24 models x 100 projections) in the terminal projection year (2048).

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 2025, 2035 and 2048 under the three future harvest scenarios (2016-2018 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2016-2018		Median $SB_{2020}/SB_{F=0}$	Median $SB_{2025}/SB_{F=0}$	Median $SB_{2048}/SB_{F=0}$	Risk SB_{2020} < LRP	Risk SB_{2025} < LRP	Risk SB_{2048} < LRP
Recruitment	Fishing level	Purse seine	Longline						
Recent	2016-2018 avg	1	1	0.41	0.45	0.48	0%	0%	0%
	Optimistic	1.11	1	0.41	0.45	0.47	0%	0%	0%
	Pessimistic	1.13	1.51	0.39	0.39	0.40	0%	1%	1%
Long-term	2016-2018 avg	1	1	0.41	0.40	0.43	0%	4%	5%
	Optimistic	1.11	1	0.41	0.39	0.42	0%	4%	6%
	Pessimistic	1.13	1.51	0.39	0.34	0.34	0%	11%	19%

Table 7 Median and relative values of reference points and risk[1] of breaching reference points levels (adopted limit reference point (LRP) of 20% $SB_{F=0}$; F_{MSY}) in 2048 from the 2019 skipjack and 2020 yellowfin stock assessments, under the three future harvest scenarios (2016-2018 average fishing levels, optimistic, and pessimistic) and long-term recruitment patterns.

Stock	Fishing level	Scalars relative to 2016-2018		Median $SB_{2048}/SB_{F=0}$	Median ratio $SB_{2048}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2044-2047}/F_{MSY}$	Median ratio $F_{2044-2047}/F_{MSY}$ v $F_{2014-17}/F_{MSY}$	Risk[1]	
		Purse seine	Longline					SB_{2048} < LRP	$F>F_{MSY}$
Skipjack tuna	2016-2018 avg	1	1	0.43	0.89	0.68	1.56	0%	16%
	Optimistic	1.11	1	0.43	0.88	0.70	1.57	0%	18%
	Pessimistic	1.13	1.51	0.43	0.88	0.70	1.57	0%	18%
Yellowfin tuna	2016-2018 avg	1	1	0.59	1.09	0.29	0.82	0%	0%
	Optimistic	1.11	1	0.59	1.08	0.30	0.83	0%	0%
	Pessimistic	1.13	1.51	0.57	1.04	0.32	0.89	0%	0%

[1] Risk within the stock assessment is calculated as the (weighted – if weights applied) number of models falling below the LRP (X / 72 and 54 models for yellowfin and skipjack, respectively). Risk under a projection scenario is the number of projections across the grid that fall below the LRP (X / 7,200 and 5,400 (72 and 54 models x 100 projections) for yellowfin and skipjack respectively) in the terminal projection year (2048).

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 2048 under the three future harvest scenarios (2016-2018 average fishing levels, optimistic, and pessimistic).

Stock	Fishing level	Scalars relative to 2016-2018		Median $SB_{2020}/SB_{F=0}$	Median $SB_{2025}/SB_{F=0}$	Median $SB_{2048}/SB_{F=0}$	Risk SB_{2020} < LRP	Risk SB_{2025} < LRP	Risk SB_{2048} < LRP
		Purse seine	Longline						
Skipjack tuna	2016-2018 avg	1	1	0.40	0.42	0.43	0%	0%	0%
	Optimistic	1.11	1	0.40	0.42	0.43	0%	0%	0%
	Pessimistic	1.13	1.51	0.40	0.42	0.43	0%	0%	0%
Yellowfin tuna	2016-2018 avg	1	1	0.65	0.60	0.59	0%	0%	0%
	Optimistic	1.11	1	0.65	0.60	0.59	0%	0%	0%
	Pessimistic	1.13	1.51	0.63	0.58	0.57	0%	0%	0%

Table 9 Pattern of purse seine effort (FAD sets) and longline bigeye catch in 2019 and corresponding scalars from 2016-2018 levels.

	Average 2016-18	2019	Scalar
Purse seine effort (FAD sets)[1]	15,075	14,593	0.97
Longline bigeye catch (mt)[2]	59,312	69,460	1.17
Longline yellowfin catch (mt)[2]	67,653	92,632	1.37

[1] in the tropical purse seine fishery according to updated data reported by SPC October 2020
[2] longline catch data available up until October 2020

8. FIGURES

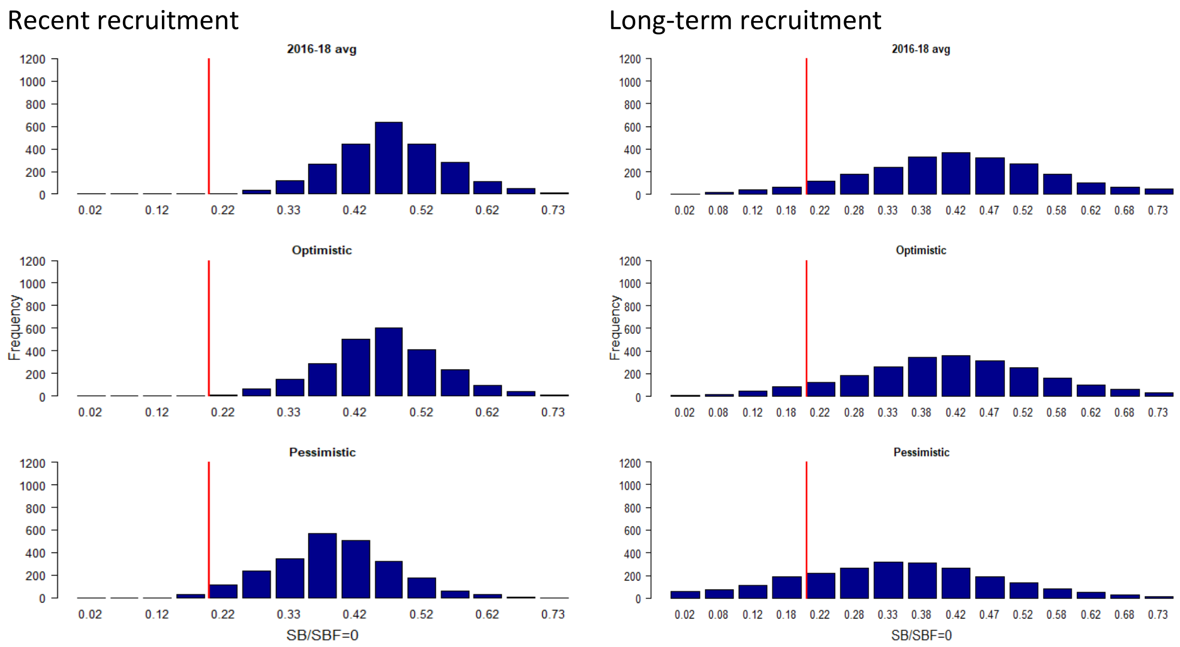

Figure 1 Distribution of $SB_{2048}/SB_{F=0}$ for <u>bigeye</u> tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions (bottom row). Red line indicates the LRP ($20\%SB_{F=0}$).

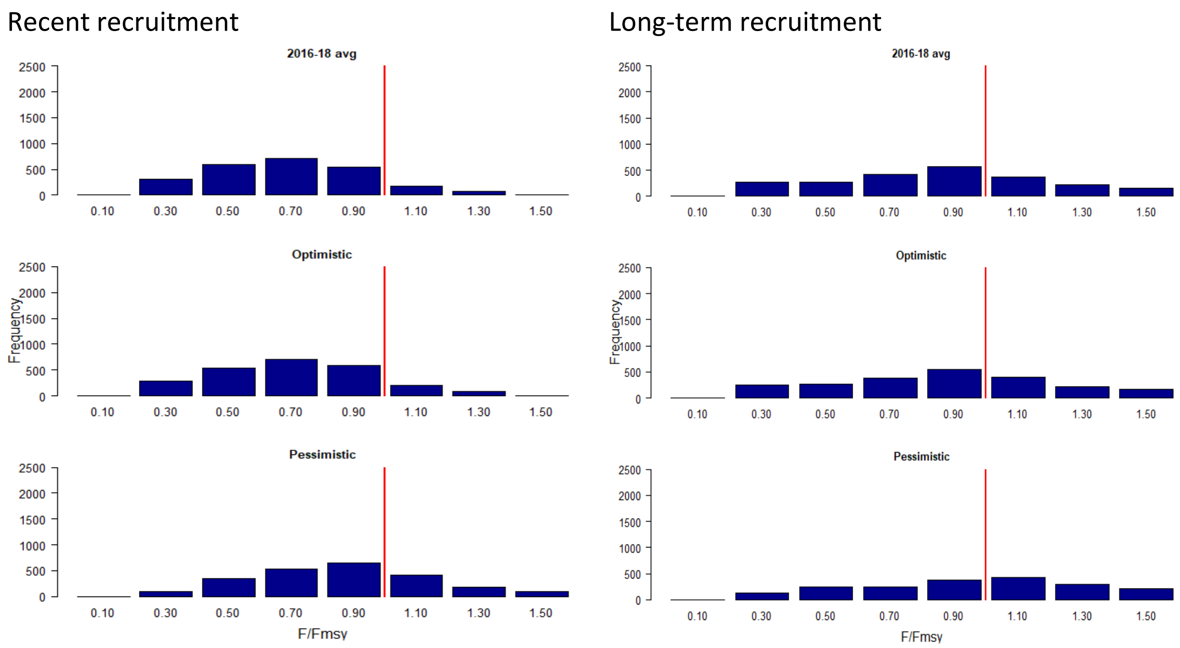

Figure 2 Distribution of F/F_{MSY} for <u>bigeye</u> tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions (bottom row). Red line indicates $F = F_{MSY}$.

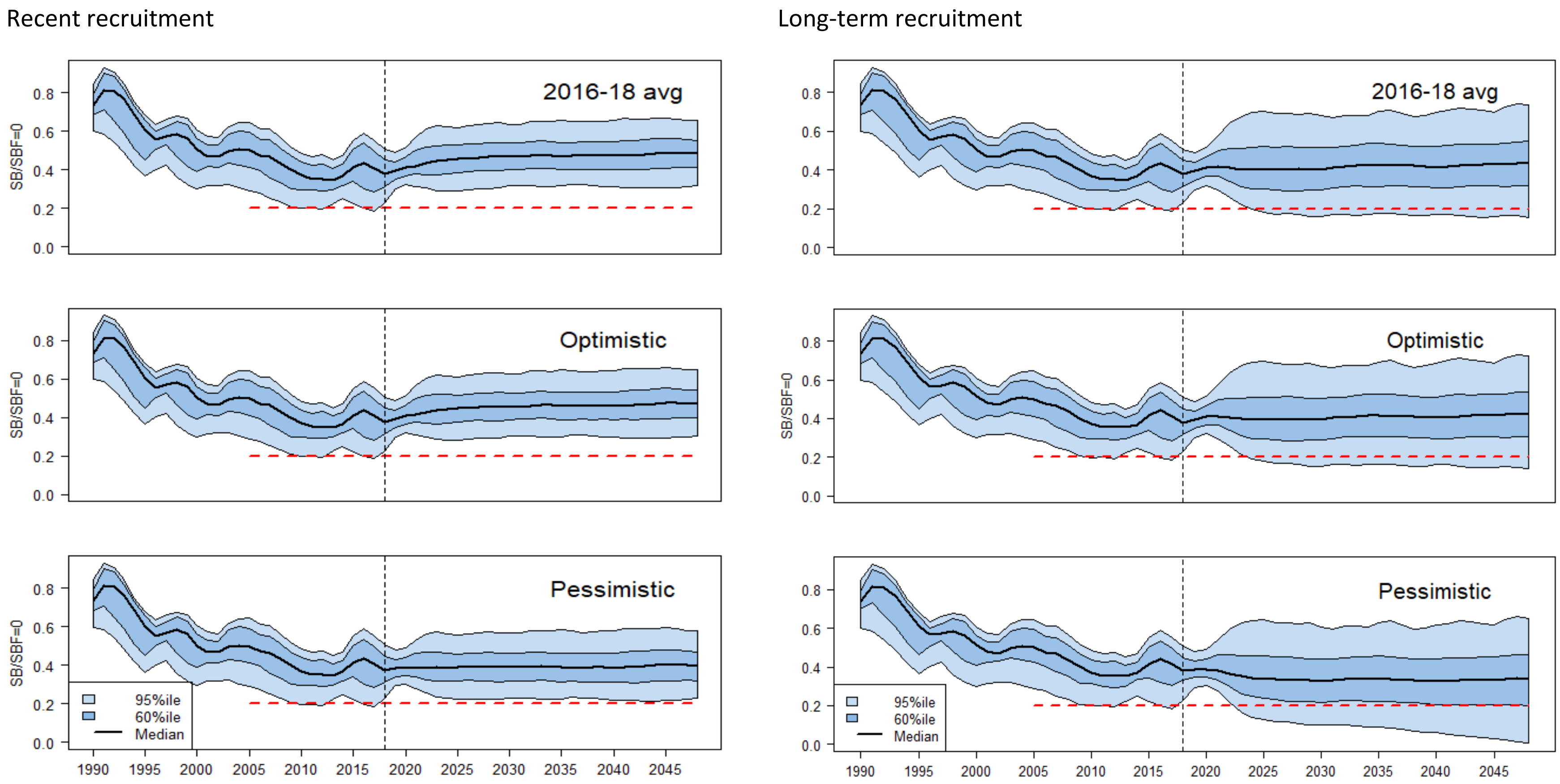

Figure 3 Time series of WCPO <u>bigeye</u> tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2018 (the vertical line at 2018 represents the last year of the assessment), and stochastic projection results for the period 2019 to 2048 under the three future fishing scenarios ("2016-18 avg", 'Optimistic' and 'Pessimistic'; rows). During the projection period (2019-2048) levels of recruitment variability are assumed to match those over the "recent" time period (2007-2016; left panel) or the time period used to estimate the stock-recruitment relationship (1962-2016; right panel). The red dashed line represents the agreed limit reference point.

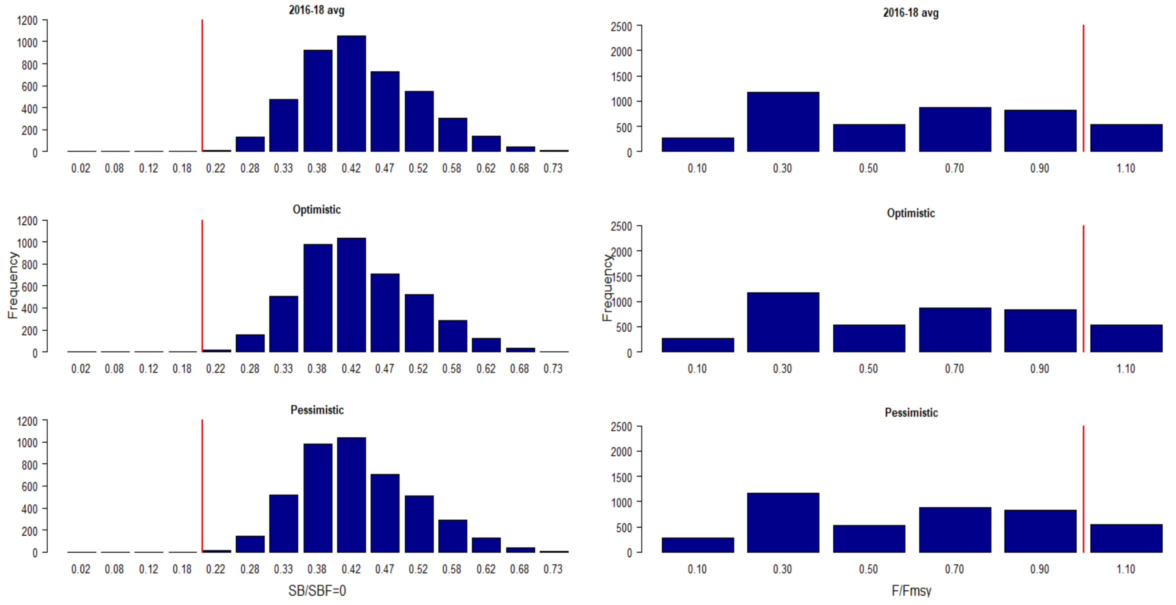

Figure 4 Distribution of $SB_{2048}/SB_{F=0}$ (left column), and F/F_{MSY} for skipjack tuna assuming long-term recruitment conditions, under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions (bottom row). Red line indicates the LRP (20%$SB_{F=0}$) and $F=F_{MSY}$, respectively.

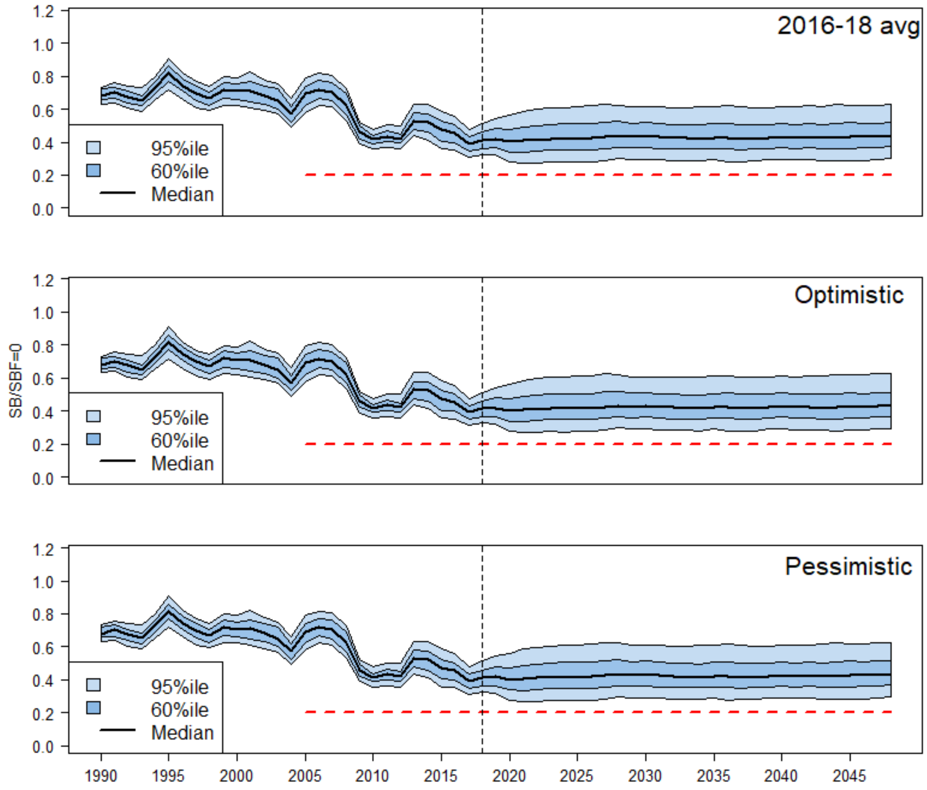

Figure 5 Time series of WCPO skipjack tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2018 (the vertical line at 2018 represents the last year of the assessment), and stochastic projection results for the period 2019 to 2048 under the three future fishing scenarios ("2016-18 avg", 'Optimistic' and 'Pessimistic'; rows). During the projection period (2019-2048) 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.

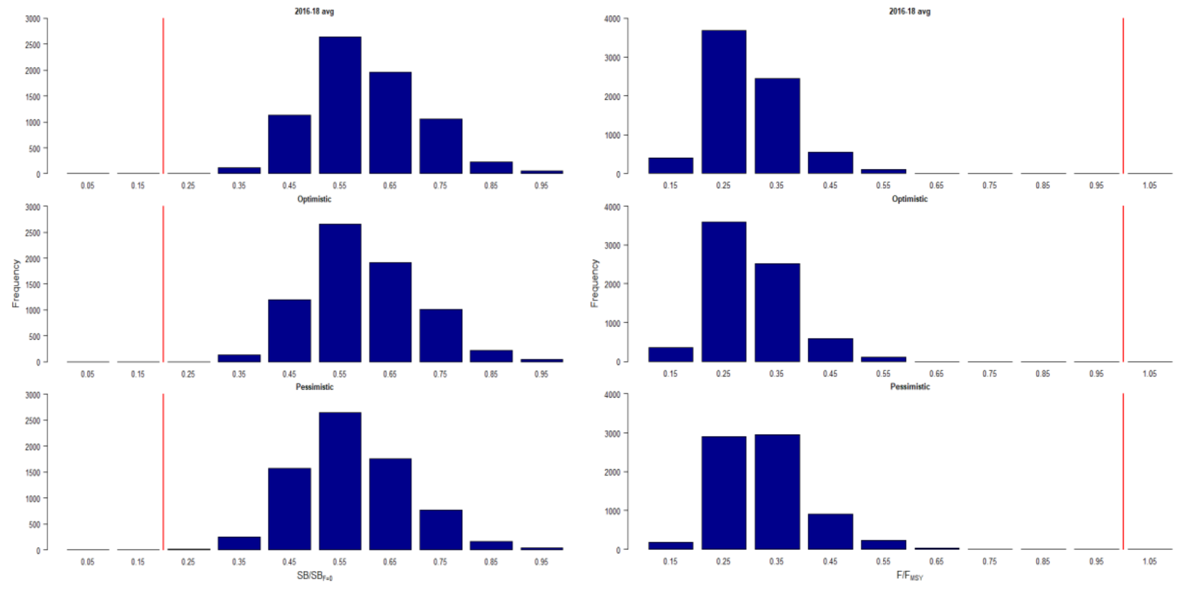

Figure 6 Distribution of $SB_{2048}/SB_{F=0}$ (left column), and F/F_{MSY} for yellowfin tuna assuming long-term recruitment conditions, under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); optimistic conditions (middle row); and pessimistic conditions (bottom row). Red line indicates the LRP (20%$SB_{F=0}$) and $F=F_{MSY}$, respectively.

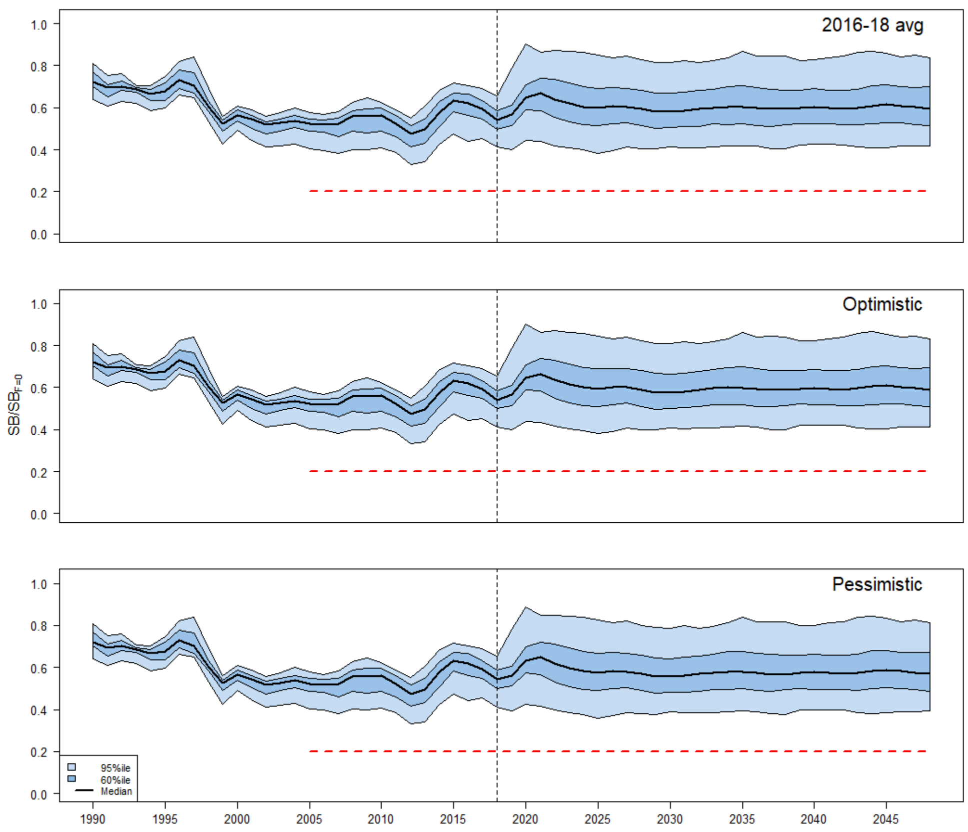

Figure 7 Time series of WCPO yellowfin tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2018 (the vertical line at 2018 represents the last year of the assessment), and stochastic projection results for the period 2019 to 2048 under the three future fishing scenarios ("2016-18 avg", 'Optimistic' and 'Pessimistic'; rows). During the projection period (2019-2048) levels of recruitment variability are assumed to match those over the time period used to estimate the stock-recruitment relationship (1962-2016). The red dashed line represents the agreed limit reference point.

9. APPENDIX 1. ESTIMATION OF SCENARIOS

Purse seine FAD set numbers assumed for CCMs, and corresponding scalars relative to 2016-2018 average conditions if CMM 2018-01 was applied under the two scenarios.

'Optimistic' PS scenario

CCM	FAD sets per year under CMM 2018-01		
	2016	**2017**	**2018**
CHINA	1	567	230
COOK ISLANDS[1]	43	43	43
ECUADOR	56	264	411
EL SALVADOR	105	106	82
EUROPEAN UNION	94	251	190
FSM	1,204	1,674	1,348
JAPAN	998	716	559
KIRIBATI	2,046	2,870	2,998
MARSHALL ISLANDS	740	1,579	1,226
NAURU[2]	256	256	256
NEW ZEALAND	25	101	41
PAPUA NEW GUINEA	2,184	1,943	1,720
PHILIPPINES (distant-water)	347	42	128
REPUBLIC OF KOREA	1,765	2,214	2,390
SOLOMON ISLANDS	262	403	440
CHINESE TAIPEI	1,682	2,160	2,277
TUVALU	62	95	107
USA	2,290	3,104	2,856
VANUATU	38	167	95
Total FAD sets under CMM	14,198	18,555	17,397
Average FAD sets/year 2016-2018 under CMM	16,717		
Actual average FAD sets/year 2016-2018	15,075		
FAD sets scalar 'optimistic'	**1.11**		

[1] Cook Islands only recently (from 2019) reported FAD sets so we applied the 2019 set number in 2016-2018 as assumed would occur under the CMM 2018-01

[2] Nauru only recently (from 2018) reported FAD sets so we applied the 2019 set number in 2016-2018 as assumed would occur under the CMM 2018-01

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

CCM	**FAD sets per year under CMM 2018-01**		
	2016	**2017**	**2018**
CHINA	71	567	230
EUROPEAN UNION	320	452	365
JAPAN	1,003	722	566
NEW ZEALAND	49	129	72
REPUBLIC OF KOREA	1,771	2,219	2,395
CHINESE TAIPEI	1,682	2,166	2,288
USA[1]	2,290	3,104	2,856
Total additional high seas FAD sets	331	246	230
Average FAD sets/year 2016-2018 under CMM	16,985		
Actual average FAD sets/year 2016-2018	15,075		
FAD sets scalar ‘pessimistic’	**1.13**		

[1]For the baseline years 2016 and 2018 the US fleet reported more high seas purse days than their 1270 day limit as specified in CMM 2018-01. We assume that under the CMM 2018-01 the specified day limits would be met with no overshoot in the ‘optimistic’ and ‘pessimistic’ scenarios. The overshoot in high seas purse seine days by the US fleet in 2016 and 2018 was equivalent to approximately 50 associated sets/year.

Longline bigeye catch assumed for CCMs, and corresponding scalars relative to 2016-2018 average conditions under the two scenarios, plus intermediate analysis of consequences where CCMs limited to 2000mt take their recent average catch levels.

CCM	**'Pessimistic'**	**'Intermediate'**	**'Optimistic'**
	CMM 2018-01 levels if limited, otherwise 2000mt (non-SIDS) or 2016-2018 average	2017 CMM levels if limited, otherwise 2016-2018 average	CMM 2018-01 levels or 2016-18 if lower
AMERICAN SAMOA	2,000	973	973
AUSTRALIA	2,000	523	523
BELIZE	2,000	-	-
CHINA	8,224	8,224	7,971
COOK ISLANDS	226	226	226
EU-PORTUGAL	2,000	3	3
EU-SPAIN	2,000	38	38
FSM	2,370	2,370	2,370
FIJI	1,132	1,132	1,132
FRENCH POLYNESIA	841	841	841
GUAM	2,000	311	311
INDONESIA	5,889	5,889	1,141
JAPAN	18,265	18,265	11,648
KIRIBATI	438	438	438
MARSHALL ISLANDS	1,025	1,025	1,025
NAURU	-	-	-
NEW CALEDONIA	56	56	56
NEW ZEALAND	2,000	136	136
NIUE	-	-	-
NORTHERN MARIANAS	2,000	957	957
PALAU	706	706	706
PAPUA NEW GUINEA	73	73	73
PHILIPPINES	2,000	-	-
REPUBLIC OF KOREA	13,942	13,942	11,689
SAMOA	91	91	91
SOLOMON ISLANDS	540	540	540
TONGA	28	28	28
TUVALU	93	93	93
CHINESE TAIPEI	10,481	10,481	9,410
USA	3,554	3,554	3,369
VANUATU	3,527	3,527	3,527
WALLIS AND FUTUNA	-	-	-
Total	**89,500**	**74,440**	**59,312**
Scalar	**1.51**	**1.26**	**1.00**

10. APPENDIX 2. ADDITIONAL ANALYSES REQUESTED BY CCMS

Three CCMs raised requests at SC15 for further evaluation, as detailed within the SC15 summary report, these additional evaluations are updated for this 2020 paper:

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 purse seine effort is constant at 2016-18 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 catches 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 domestic vessels to which this footnote applied in 2018 and 2019 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 and 2019 FAD closure by 'footnote 1' vessels.

Number of vessels (2018 / 2019)	Total FAD sets (2018 / 2019)	Total catch (mt) (2018 / 2019)			
		Skipjack	Yellowfin	Bigeye	Total
49 / 58[1]	765 / 938	31,851 / 42,464	4,926 / 5,024	1,991 / 1,647	38,768 / 49,135

[1]Note: of the 58 vessels notified to WCPFC as exempt under footnote 1 in 2019, 48 vessels reported FAD associated sets during the closure months, this number is the same as for 2018.

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 HSP#1 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 2019, and calculate the average across them (**Table 11**). For Kiribati vessels, fishing activity in those months reflects that in neighbouring high seas areas. Species composition is determined from observer data.

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) for 2018 and 2019.

Philippines (HSP#1)

Months	Total FAD sets (2018 / 2019)	Total catch (mt) (2018 / 2019)			
		Skipjack	Yellowfin	Bigeye	Total
April-May	710 / 632	2,367 / 2,422	1,397 / 1,754	603 / 646	4,367 / 4,822
November-December	696 / 460	2,816 / 2,643	2,193 / 1,445	471 / 213	5,480 / 4,301
Average	**703 / 546**	**2,591 / 2,533**	**1,795 / 1,600**	**537 / 430**	**4,923 / 4,562**

Kiribati (adjacent high seas)

Months	Total FAD sets (2018 / 2019)	Total catch (mt) (2018 / 2019)			
		Skipjack	Yellowfin	Bigeye	Total
April-May	109 / 174	2,845 / 7,998	206 / 139	753 / 233	3,804 / 8,370
November-December	103 / 85	4,835 / 2,854	420 / 236	309 / 213	5,565 / 3,303
Average	**106 / 130**	**3,840 / 5,426**	**313 / 188**	**531 / 223**	**4,684 / 5,837**

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 WCPFC17-2020-IP04 (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[2]	Days fished in international waters 20°N-20°S in:	
		2018	2019
China	26	26	17
Ecuador	**	0	0
El Salvador	**	28	9
European Union	403	158	141
Indonesia	(0)	0	0
Japan	121	5	22
New Zealand	160	57	22
Philippines	#	2,749	2,654
Republic of Korea	207	198	223
Chinese Taipei	95	62	84
USA	1,270	1,584[3]	1,526

**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
[2] Noting footnote 13 - Table 2 in WCPFC17-2020-IP04 "A high seas purse seine effort limit may be adjusted in accordance with para 30 of CMM 2017-01 and CMM 2018-01."
[3] Noting para 29 of CMM 2017-01 was applicable in 2018.

For the CCMs with HS days limits, 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 156 sets in 2018 and 64 sets in 2019, but when compared to the 'pessimistic' scenario, there were 73 fewer sets in 2018 and 184 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 WCPFC17-2020-IP04 to calculate the average pattern of effort (days fished) in the high seas over the 2016 and 2018 baseline period (2017 not used due to highs seas closure all year), and relate to the levels seen in 2019 (**Table 13**).

Table 13. Comparison of average high seas purse seine effort by flag over 2016 and 2018 with days fished in tropical international waters (20°N to 20°S) in 2018 and 2019.

Flag	Average 2016 and 2018	In 2019
China	25	17
Cook Islands	0	72
Ecuador	0	0
El Salvador	27	9
European Union	123	141
FSM	499	1,208
Indonesia	0	0
Japan	15	22
Kiribati	861	917
Marshall Is.	348	954
Nauru	65	188
New Zealand	69	22

PNG	55	0
Philippines	2,696	2,654
Republic of Korea	198	223
Solomon Is.	64	103
Tuvalu	102	52
Chinese Taipei	79	84
USA	1,513	1,526
Vanuatu	143	159
Total	**6,877**	**8,351**

Applying an average flag-specific high seas FAD setting rate from the 2016 and 2018 years for all fleets, the additional overall effort in 2019 compared to the baseline could result in 339 FAD sets more than expected under the 'optimistic' scenario, and 93 more FAD sets more than expected under the 'pessimistic' scenario.

IMPACT OF SC15 ELEMENTS ON PURSE SEINE SCALARS

The potential impact of each SC15 additional request 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 0.12, relative to the 2016-18 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 the calculations.

	Approx. FAD set change	Optimistic scenario	Pessimistic scenario	Approximate equivalent main FAD closure period
CMM evaluation scalars		1.11	1.13	3 months
Footnote 1 (2019)	-938	1.05	1.06	~ 2.5 months
Paragraph 17[1] (2019)	-676	1.07	1.08	~ 2.8 months
High seas CMM limits	-184/+156	1.09/1.12	1.11/1.14	~2.9 - 3.1 months
Patterns of high seas effort	+93 to +339	1.11-1.15		~3.0 - 3.2 months

[1] Note that removal of 546 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'.

11. 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 (where specified) for flags in Table 2 of the Measure were set to zero.

Scenario	'Pessimistic' scenario	Table 2 effort limits set to zero
Scalar	1.13	1.07

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	1	0.24	1.51	0.49

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	1.00	0.96

12. APPENDIX 4. ADDITIONAL REQUEST FROM FFA (WCPFC17-2020-DP01 PARA. 2)

As requested in by FFA in WCPFC17-2020-DP01 para. 2: "FFA Members note that the stated aims of CMM 2018-01 for bigeye and yellowfin are to maintain spawning biomass at or above the average $SB/SB_{F=0}$ for 2012-15. FFA Members seek confirmation from the science services provider that the estimated $SB_{recent}/SB_{F=0}$ from the updated 2020 stocks assessments accords with this objective."

Table 18 below present the requested depletion ratio of $(SB_{2015\text{-}18}/SB_{F=0})$ / $(SB_{2012\text{-}15}/SB_{F=0})$.

Table 18. Ratio of the recent median spawning depletion to that of 2012-15 as determined from the most recent stock assessments (2020) for bigeye and yellowfin tuna.

Stock	Ratio: $(SB_{2015\text{-}18}/SB_{F=0})/(SB_{2012\text{-}15}/SB_{F=0})$
Bigeye	1.11
Yellowfin	1.10