DEVELOPMENT OF A NEW TROPICAL TUNA MEASURE
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This paper provides updates to the previous version of the evaluation of CMM 2018-01 (now CMM 2020-01), known as the "Tropical Tuna Measure". The most recent version of this evaluation was provided to the first WCPFC meeting for developing the new "Tropical Tuna Measure" (Development of New WCPFC Tropical Tuna Measure Workshop 1). The recent version "Evaluation of CMM 2018-01 for tropical tuna - revision 3" included an update of all components, based on the recently completed stock assessments for skipjack, bigeye and yellowfin tuna, that all included data up to 2018. These evaluations, which are the core of this paper, are necessarily unchanged from the previous version.

This version differs from WCPFC-TTMW1-2021-01_rev3 primarily in that it updates tables covering the various additional request from CMMs at SC15 (included as appendices). These tables are updated with the latest data reports for 2019 and 2020. We also update Table 9 and relevant text (executive summary, and section 4) in the main body of the report which compares predicted FAD set and longline catch scalars under the CMM with those actually observed in 2019 and 2020.

Note: there are some differences to the calculations provided in this update compared to the version provided to the 'Tropical Tuna Measure Workshop 1', based upon the latest update to the 2019 data. These are due to recompilation of those data, that required some corrections and adjustments to account for some misreporting issues. These have minor implications for findings.

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 $1/8^{th}$ 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 $1/8^{th}$ 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 $1/8^{th}$ 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 $1/8^{th}$ 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 recent catch and effort data, 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 to 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}.

Comparison of the levels of fishing in 2019 and 2020 (updated data as of April 2021) with those predicted by the CMM scalars and the 2016-2018 baselines, showed that:

- **For 2019 purse seine FAD sets**, effort levels were lower than those anticipated under the 'optimistic' CMM scenario and were 9% less than the baseline average.
- **For 2020 purse seine FAD sets**, effort levels were lower than those anticipated under the 'optimistic' CMM scenario and were 7% less than the baseline average.

- **For 2019 longline bigeye,** catches were 10% higher than those anticipated under the ‘optimistic’ CMM scenario, but well below that under the “pessimistic scenario”, and 10% higher than the baseline average.
- **For 2020 longline bigeye,** catches were 6% lower than those anticipated under the ‘optimistic’ CMM scenario and 6% lower than the baseline average.
- **For 2019 longline yellowfin,** catches were 28% higher than those anticipated under the ‘optimistic’ CMM scenario, but well below that under the “pessimistic scenario”, and 28% higher than the baseline average.
- **For 2020 longline yellowfin,** catches were 14% lower than those anticipated under the ‘optimistic’ CMM scenario and 14% lower than the baseline average.

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 5 present the results of the 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 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[2]	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[2]	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 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[2]	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[2]	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] Note – inclusion of Canadian limits, as requested at WCPFC17, raises this scalar to 1.54.

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 $SB_{2012-2015}/SB_{F=0, 2005-2014}$. 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[1], 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[2]
Optimistic	1.11	1.00
Pessimistic	1.13	1.51[3]

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

[1] 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.
[2] 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] Inclusion of Canadian limits (2,000 mt) as requested at WCPFC17 applies to the pessimistic scenario only and would raise this scalar to 1.54. This updated scalar is not evaluated within this paper.

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 ($SB_{2048}/SB_{F=0}$[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.

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

[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 and 2020 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, the overall 2019 and 2020 purse seine effort in FAD set numbers and total longline catches for bigeye and yellowfin are compared relative to the 2016-18 average baseline levels and the 'optimistic' and 'pessimistic' scalars. The data used for these comparisons is updated in this paper based on SC17-MI-IP11 - Table 3, but with the addition of archipelagic waters FAD sets to be consistent with the assumptions in the CMM evaluation. Longline bigeye catch is from Table 5; and longline yellowfin catch is from Table 6 of SC17-MI-IP11. Resulting scalars are presented in Table 9.

Based on the updated data, the total number of FAD sets in 2019 was 9% lower than the baseline, and in 2020, was 7% lower than the baseline. Both years were lower than the scalar anticipated under the 'optimistic' scenario.

In 2019, the total longline bigeye catch was 10% higher than the 2016-18 baseline period, but in 2020 was 6% lower. For yellowfin, the longline catch in 2019 was 28% higher than the 2016-18 baseline, but in 2020 was 14% lower. In 2019 the catches for both species were higher than anticipated under the 'optimistic' scenario but lower than the 'pessimistic' scenario, and in 2020 both were lower than the 'optimistic' scenario. However, despite the generally consistent pattern of catch increase and decrease in each year, the differences in the actual catch changes relative to the 2016-18 baseline for bigeye and yellowfin suggest that the assumption of a direct relationship between bigeye and yellowfin longline catch scalars may not hold.

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

Ducharme-Barth, N., Vincent, M., Hampton, J., Hamer, P., Williams, P. and Pilling, G. (2020). Stock assessment of bigeye tuna in the western and central Pacific Ocean. WCPFC-SC16-2020/SA-WP-03 [REV3]

Hampton, J. and Pilling, G. (2014). Relative impacts of FAD and free-school purse seine fishing on yellowfin tuna stock status. WCPFC-SC10-2014/MI-WP-05.

Hampton, J. and Pilling, G. (2015). Relative impacts of FAD and free-school purse seine fishing on skipjack tuna stock status. WCPFC-SC11-2015/MI-WP-05.

Pilling, G. and Harley, S. (2015). Estimating potential tropical purse seine fleet sizes given existing effort limits and candidate target stock levels. WCPFC-SC11-2015/ MI-WP-10.

SPC (2018). Evaluation of CMM 2017-01 for bigeye tuna with additional evaluations for skipjack and yellowfin tuna. WCPFC15-2018-12_rev2.

Vincent, M., Ducharme-Barth, N., Hamer, P., Hampton, J., Williams, P. and Pilling, G. (2020). Stock assessment of yellowfin tuna in the western and central Pacific Ocean. WCPFC-SC16-2020/SA-WP-04-Rev2

Vincent, M. T., Pilling, G. and Hampton, J. (2019). Stock assessment of skipjack tuna in the western and central Pacific Ocean. WCPFC-SC15-2019/SA-WP-05-Rev2.

WCPFC Secretariat & SPC-OFP (2021). Catch and effort data summaries to support discussions on the TROPICAL TUNA CMMS. Information Paper MI–IP–11. Seventeenth Regular Session of the Scientific Committee of the WCPFC (SC17). Online Meeting, 11–19 August 2021.

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[2]	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[2]	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).

[2] Note – inclusion of Canadian limits, as requested at WCPFC17, raises this scalar to 1.54

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[1]	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[1]	0.39	0.34	0.34	0%	11%	19%

[1] Note – inclusion of Canadian limits, as requested at WCPFC17, raises this scalar to 1.54

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[2]	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[2]	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).

[2] Note – inclusion of Canadian limits, as requested at WCPFC17, raises this scalar to 1.54

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[1]	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[1]	0.63	0.58	0.57	0%	0%	0%

[1] Note – inclusion of Canadian limits, as requested at WCPFC17, raises this scalar to 1.54

Table 9 Pattern of purse seine effort (FAD sets) and longline bigeye catch in 2019 and 2020, and corresponding scalars from 2016-2018 levels.

	Average 2016-18	2019	Scalar 2019[3]	2020	Scalar 2020
Purse seine effort (FAD sets)[1]	16,316	14,918	0.91[3]	15,225	0.93
Longline bigeye catch (mt)[2]	59,312	65,267	1.10	55,882	0.94
Longline yellowfin catch (mt)[2]	67,653	86,417	1.28	58,239	0.86

[1] in the tropical purse seine fishery according to updated data as available April 2021
[2] longline catch data available up until April 2021
[3] the scalar for 2019 FAD sets is lower than the previous version of this report due to an issue where a CCMs FAD sets were double counted because they were reported both under their flag country and the chartering nation. Minor differences in the 2016-2018 baseline average also occurred due to the inclusion of additional logbook data (minor changes occurred to 2018 estimates).

8. FIGURES

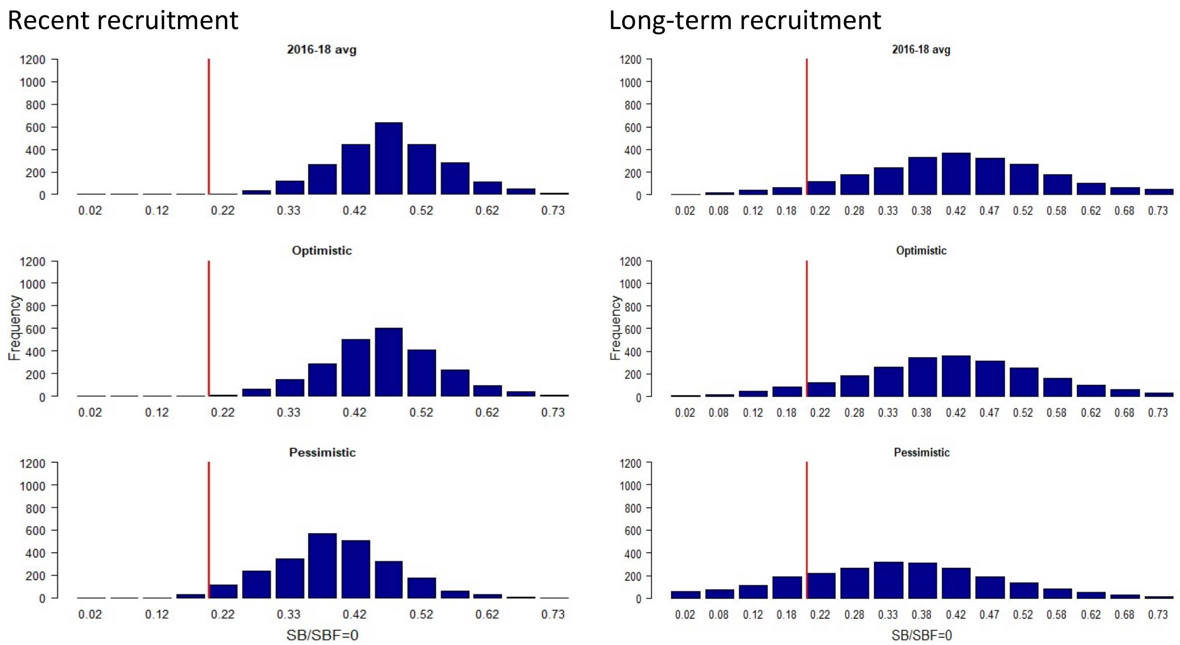

Figure 1 Distribution of $SB_{2048}/SB_{F=0}$ for <u>bigeye</u> tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic'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

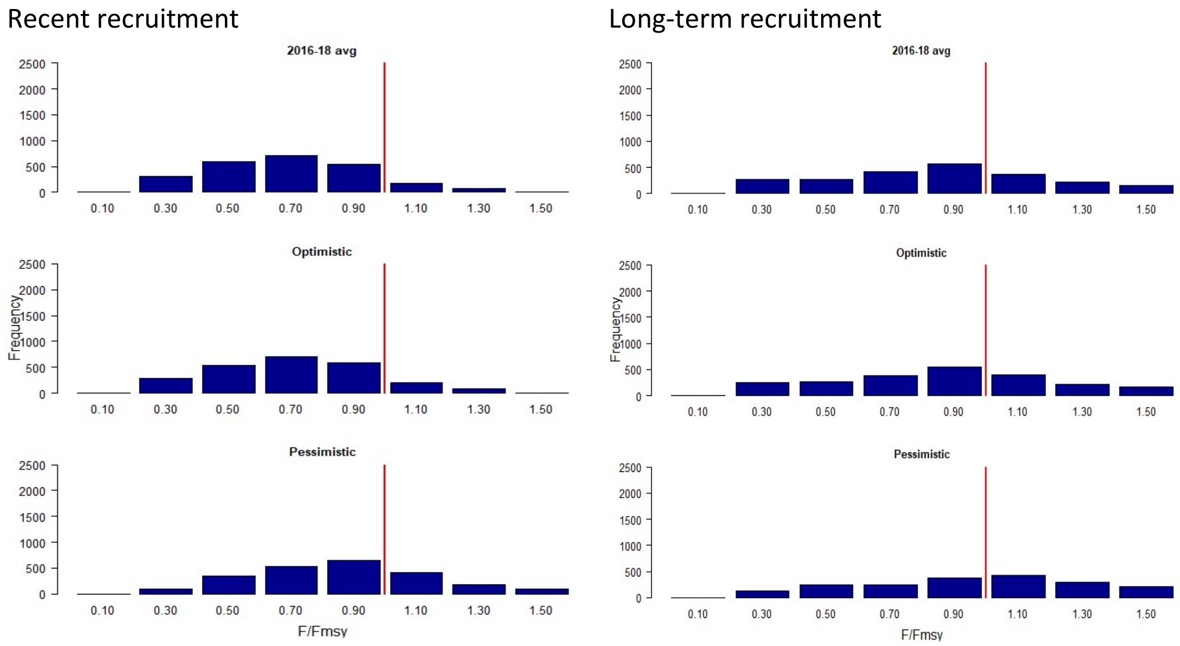

Figure 2 Distribution of F/F_{MSY} for <u>bigeye</u> tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions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

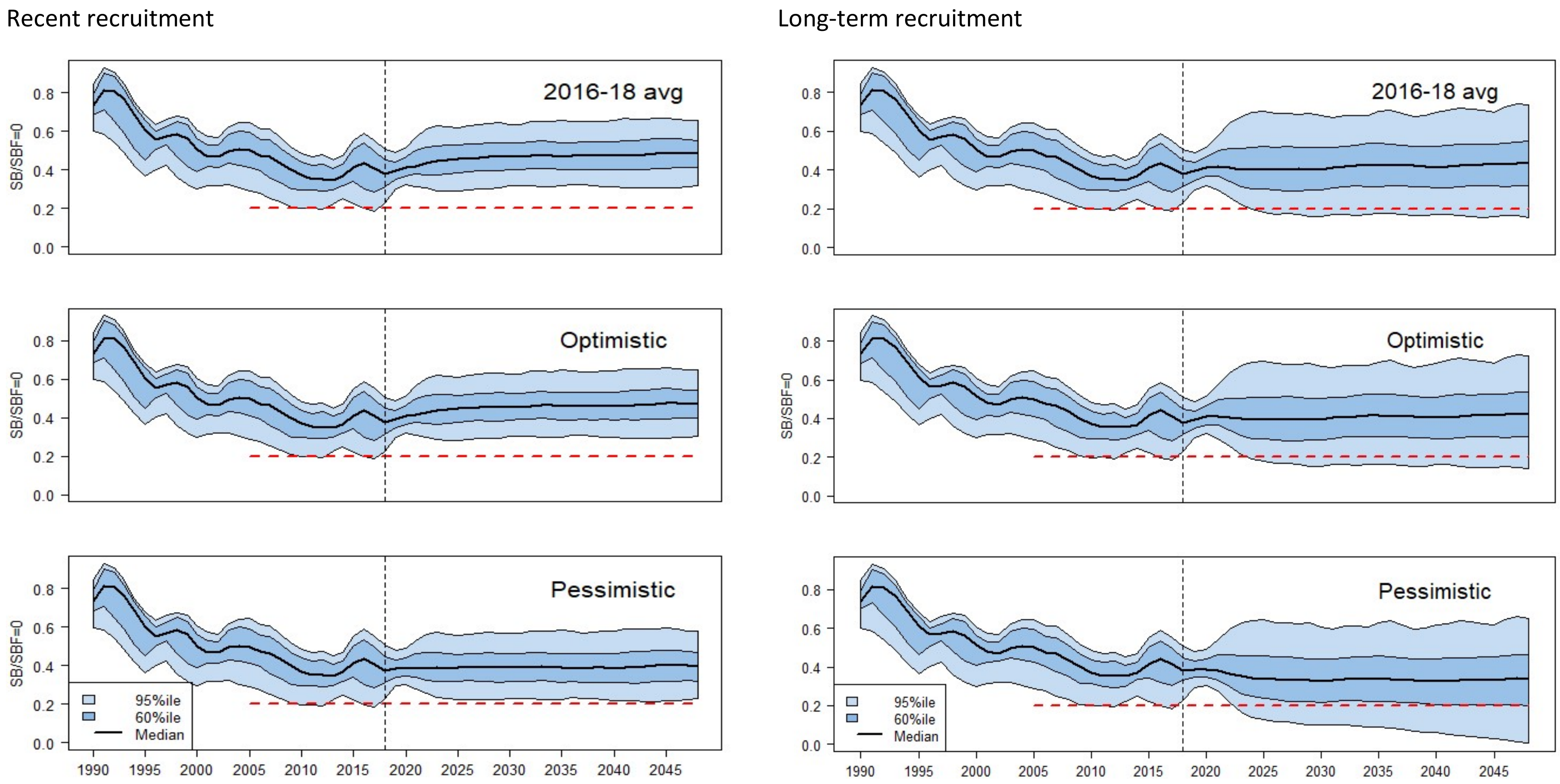

Figure 3 Time series of WCPO bigeye tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2018 (the vertical line at 2018 represents the last year of the assessment), and stochastic projection results for the period 2019 to 2048 under the three 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.

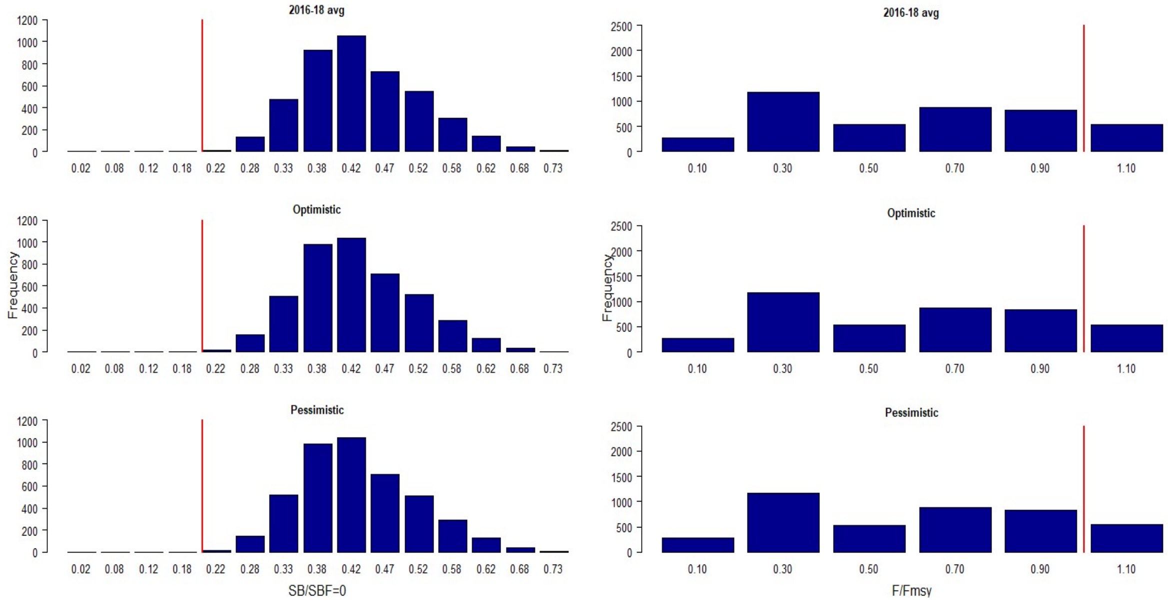

Figure 4 Distribution of $SB_{2048}/SB_{F=0}$ (left column), and F/F_{MSY} for skipjack tuna assuming long-term recruitment conditions, under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions (bottom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

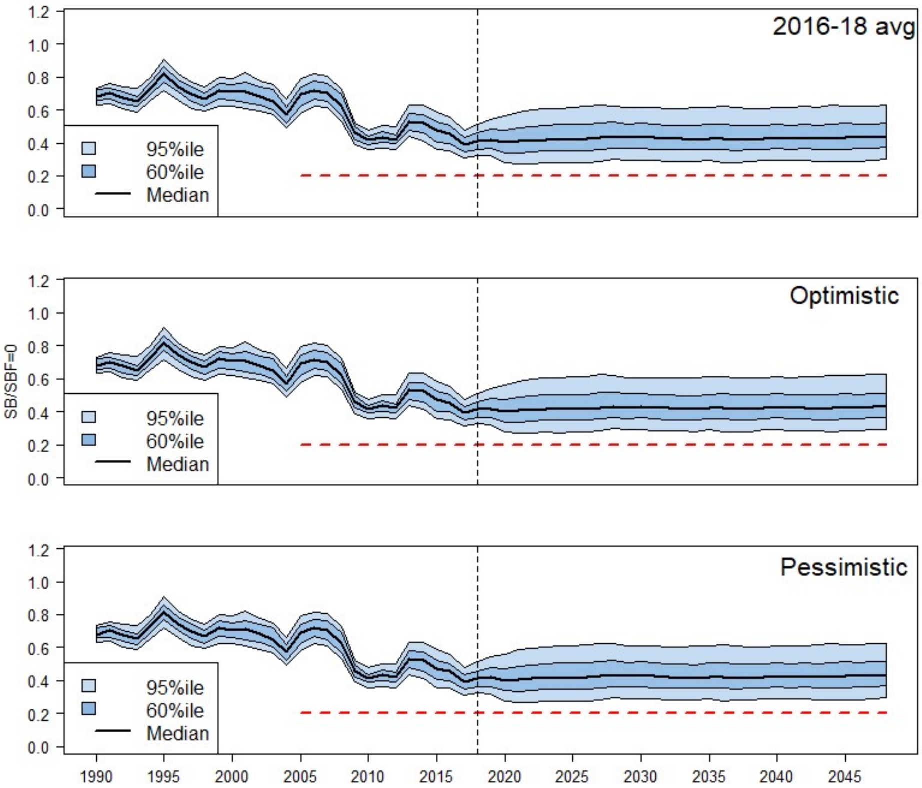

Figure 5 Time series of WCPO skipjack tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2018 (the vertical line at 2018 represents the last year of the assessment), and stochastic projection results for the period 2019 to 2048 under the three 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.

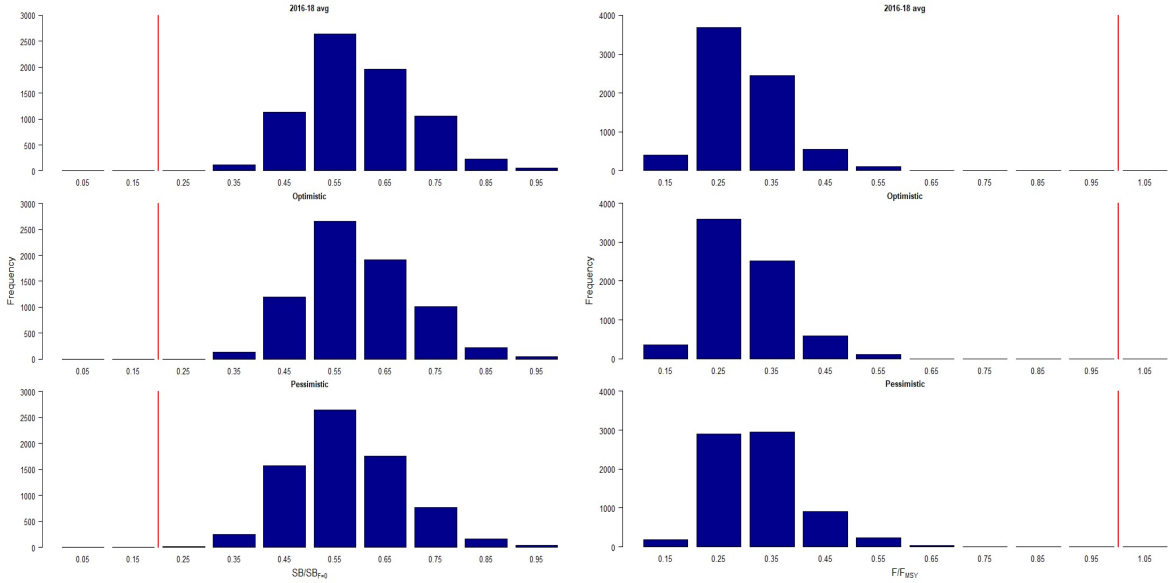

Figure 6 Distribution of $SB_{2048}/SB_{F=0}$ (left column), and F/F_{MSY} for yellowfin tuna assuming long-term recruitment conditions, under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); optimistic conditions (middle row); and pessimistic conditions (bottom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

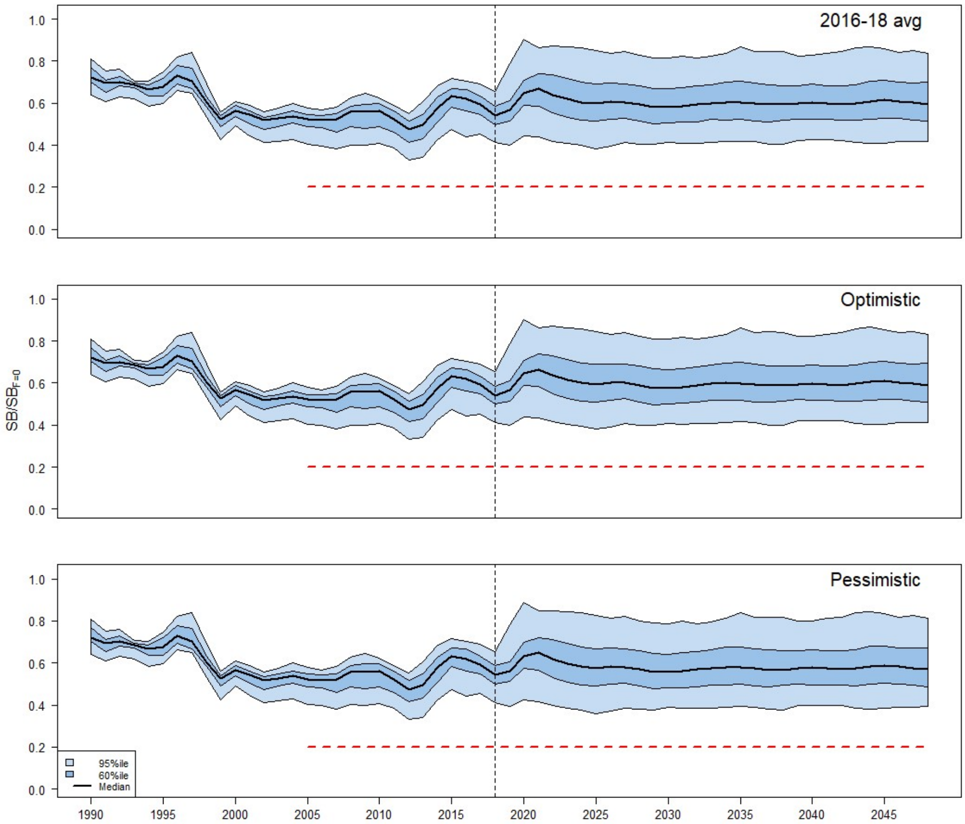

Figure 7 Time series of WCPO yellowfin tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2018 (the vertical line at 2018 represents the last year of the assessment), and stochastic projection results for the period 2019 to 2048 under the three 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 seine 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	-	-
CANADA	[2,000][1]	-	-
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** [91,500[1]]	**74,440**	**59,312**
Scalar	**1.51** [1.54[1]]	**1.26**	**1.00**

[1] As notified to the WCPFC Secretariat on 8th December, and raised at WCPFC17, Canada requested the appropriate allocation be added to the analysis. This influences the pessimistic scenario only.

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 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, 2019 and 2020 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, 2019 and 2020 three-month FAD closure by 'footnote 1' vessels.

Year	Number of vessels		Total	Total catch (mt)			
	Notifying	Fishing	FAD sets	Skipjack	Yellowfin	Bigeye	Total
2018	49	47	747	34,921	2,062	872	37,855
2019	55	55	638	35,484	1,670	394	37,548
2020	92	87	1,072	52,674	6,513	1,541	60,728

1. Excludes Archipelagic waters
2. FAD sets and Tuna species catch as reported on logbooks
3. Based on vessels notifying under tropical tuna measure footnote 1
4. Represents the total FAD sets during the three-month closure period and the catch by species were summed across vessels

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, 2019, and 2020 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 set effort and adjusted species catch taken within both additional two month high seas FAD closure periods, and the average fishing that might result, by Kiribati vessels in adjacent high seas areas (top) and Philippines vessels in HSP#1 (bottom) for 2018, 2019, 2020.

Kiribati adjacent HS

Year	FAD sets		Total catch (mt)							
	April-May	Nov-Dec	Skipjack		Yellowfin		Bigeye		**Total**	
			April-May	Nov-Dec	April-May	Nov-Dec	April-May	Nov-Dec	April-May	Nov-Dec
2018	110	105	2,858	5,505	206	90	745	149	3,809	5,744
2019	178	85	8,216	2,854	139	236	232	213	8,587	3,303
2020	84	45	5,566	2,128	486	145	496	97	6,548	2,370
Average	**124**	**78**	**5,547**	**3,496**	**277**	**157**	**491**	**153**	**6,315**	**3,806**

Philippines (HSP#1)

Year	FAD sets		Total catch (mt)							
	April-May	Nov-Dec	Skipjack		Yellowfin		Bigeye		**Total**	
			April-May	Nov-Dec	April-May	Nov-Dec	April-May	Nov-Dec	April-May	Nov-Dec
2018	674	675	2,225	2,803	1,356	2,021	542	437	4,122	5,261
2019	661	501	2,458	2,655	1,790	1,476	681	228	4,929	4,359
2020	687	667	7,058	6,532	1,728	2,382	291	94	9,077	9,008
Average	**674**	**614**	**3,914**	**3,997**	**1,625**	**1,960**	**505**	**253**	**6,043**	**6,209**

1. Excludes Archipelagic waters
2. KIRIBATI High seas : FAD SETS and Tuna species catch as reported on logbooks
3. PHILIPPINES HSP#1 : FAD Sets and Tuna species catch as reported by OBSERVERS (100% coverage)

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, 2019 and 2020 from WCPFC-SC17-2021-MI-IP-11 (Table 2).

Table 12. Comparison of CMM high seas purse seine effort limits (see CMM 2020-01, Table 2) with days fished in tropical international waters[1] (20°N to 20°S) in 2018, 2019 and 2020. ***Data are updated based on Table 2 of WCPFC-SC17-2021-MI-IP-11.***

Flag	CMM limits[2]	Days fished in international waters 20°N-20°S		
		2018	2019	2020
China	26	26	22	16
Ecuador	**	0	0	0
El Salvador	**	28	10	30
European Union	403	158	146	194
Indonesia	(0)	0	0	0
Japan	121	6	29	21
New Zealand	160	103	95	57
Philippines	#	2,749	2,654	2,635
Republic of Korea	207	198	181	170
Chinese Taipei	95	62	84	62
USA	1,270	1,587[3]	1,543	1,658[4]
Total		4,917	4,764	4,843

**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.
[4] The US notified that 2020 management of high seas effort in the WCPFC-IATTC overlap area will be through the IATTC measures (it was previously WCPFC measures). As such, the 2020 US purse seine high seas days excludes the WCPFC-IATTC overlap area.

For the CCMs with HS (high seas) days limits, the number of additional or reduced FAD sets resulting from the actual days fished on the HS compared to the expectations under the 'optimistic' scenario were: 2018 = + 113, 2019 = +12, 2020 = +372, and compared to the expectations under the 'pessimistic' scenario were: 2018 = -112, 2019 = - 213, 2020 = +147. The expected FAD sets under the 'optimistic' and 'pessimistic' scenarios are based on the number of HS fishing days expected under each scenario multiplied by the average of the FAD sets per HS fishing day for each flag across years 2016 and 2018.

Patterns of high seas effort

To examine the fourth SC15 request element, we use the data available from Table 2 of WCPFC-SC17-2021-IP-11 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 HS closure all year), and relate this to the levels seen in 2019 and 2020 (**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 2019 and 2020. Updated from table 2 of SC17-MI-IP-11.

Flag	Average 2016 and 2018	Reported in 2019	Reported in 2020
China	25	22	16
Cook Islands	0	72	29
Ecuador	0	0	0
El Salvador	27	10	30
European Union	123	146	194
FSM	499	1,053	710
Indonesia	0	0	0
Japan	14	29	21
Kiribati	861	950	653
Marshall Is.	348	955	698
Nauru	65	188	383
New Zealand	126	95	57
PNG	55	0	4
Philippines	2,696	2,654	2,635
Republic of Korea	198	181	170
Solomon Is.	64	91	18
Tuvalu	102	71	122
Chinese Taipei	79	84	62
USA	1,516	1,543	1,658
Vanuatu	143	147	139
Total	6,937	8,291	7,599

Applying an average flag-specific HS FAD setting rate from the 2016 and 2018 years for all flags, the additional overall HS effort in days for 2019 and 2020 resulted in an additional 310 and 704 more HS FAD sets, respectively, than expected under the 'optimistic' scenario. Relative to the expectations under the 'pessimistic' scenario, in 2019 and 2020 an additional 85 and 479 HS FAD sets were estimated to have occurred.

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 expected 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 approximately 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 (Footnote 1 and Para 17) or added (HS CMM limits and Patterns of HS effort) to the calculations. Note: the addition of the scenario where flags with HS limits have those limits set to zero (bottom row).

	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)	-638	1.07	1.09	~ 2.6 months
Footnote 1 (2020)	-1072	1.04	1.06	~ 2.4 months
Paragraph 17[1] (2019)	-447	1.08	1.10	~ 2.8 months
Paragraph 17 (2020)	-370	1.09	1.11	~ 2.8 months
High seas CMM limits (2019)	+12 opt -213 pess	1.11	1.12	~2.9 - 3.0 months
High seas CMM limits (2020)	+372 opt +147 pess	1.14	1.14	~3.1 - 3.2 months
Patterns of high seas effort (2019)	+310 opt +85 pess	1.14	1.14	~3.0 - 3.2 months
Patterns of high seas effort (2020)	+704 opt +479 pess	1.16	1.16	~3.3 - 3.4 months
Addition of table 15[1]				
HS effort limits set to zero for limited flags (see table 12)	-875	na	1.07	~ 2.5 months

[1]The estimate of the implication of setting high seas limits for limited flags in table 12 to zero is added for comparison with the other exemptions and high seas scenarios. See below "HIGH SEAS PURSE SEINE EFFORT LIMITS"

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 expected under the 'pessimistic scenario' where we assume all high seas days allowed under the Measure are used. The scalar is them recalculated with reduced number set and compared to the scalar under the 'pessimistic' scenario (Table 15).

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

13. Appendix 5. Additional analyses requested during WCPFC17

The following requests were made at WCPFC17 (see summary report from that meeting) and are addressed as far as possible below.

[Para. 173 WCPFC17 report] The exemptions in CMM 2018-01 and their impact on the CMM's effectiveness, that the number of vessels that benefit from footnote 1 in CMM 2018-01 increased from about 50 in 2018 to about 150 in 2020 that were notified to the Commission and suggested this was more than 50% of the total that could potentially benefit in 2020.
The EU inquired if the following questions could be addressed in similar future work by SPC to help clarify the impact of the exemptions:

(i) Are all the notified vessels setting on FADs during the closure?

We note that some vessels operating under footnote 1 have been notified in each year of the period 2018-2020:

- If we consider those vessels notifying in 2018, 2019 and 2020 continue to be included, this would represent a total of 95 distinct vessels.
- If it is those notifying in 2019 and 2020 (under CMM 2018-01) then it is 92 vessels.
- If it is only those notifying in 2020, then it is 92 vessels.

Out of the 92 vessels notifying for 2019-2020, 48 vessels (52%) fished on FADs during the FAD closure period.

(ii) What is the number of sets on FADs from these vessels during the closures?

Values are reported in Table 10 of WCPFC17-2020-14 CMM2018-01 evaluation. The number of sets on FADs from these vessels during the 2019 closure period was 938 sets, and for 2018, it was 765 sets, according to Table 10. However, updated information obtained since that extract now indicates 815 and 892 sets for 2018 and 2019, respectively.

(iii) Are those sets taken into account in scientific analyses (e.g., evaluation of the performance of CMM 2018-01)?

The baseline period for this analysis – 2016-2018 – is generally outside the period of CMM 2018-01 operation. However, footnote 2 was introduced in CMM 2017-01, which applied in 2018. As a result, only the final year of the baseline period incorporated effort consistent with this exemption. The numbers indicated for 2018 in the response above are therefore captured within the current evaluation.

(iv) Do these vessels use these exemptions on the high seas?

The FAD fishing for these exempted vessels was almost exclusively in their home EEZs. In 2018, only 3 sets (of 815 sets) were outside the home EEZs and in 2019, only 2 sets (of the 892 sets) were outside the home EEZ. On further examination the sets outside of the home EEZs were actually on or very close to the home EEZ boundary used by SPC so there appears to be an intention to remain in the home EEZ.

(v) Do these vessels use compatible measures and have those been tested to demonstrate their compatibility in terms of conservation benefits?

This question cannot be answered by the SSP.

(vi) Does the FADs closure exemption affect the robustness of the regular simulations of future scenarios for purse seine effort when projecting the status of the tropical tuna stocks into the future and in that case, what is the scale of the bias introduced and how can this be overcome in future evaluations?

Based upon evaluation of the resulting scalar presented in Appendix 2, the additional FAD sets seen in recent years are equivalent to 0.5 months of FAD closure; removal of those sets leads to a purse seine scalar ~0.06-0.07 lower than those evaluated in the main body of this paper. This could have a further positive effect on projected bigeye stock status within CMM scenarios, where the other assumptions that are necessary when undertaking the evaluations hold.

As for other components of the CMM, evaluation of this footnote would require assumptions to be made on the potential level of future uptake and the level of fishing those vessels would undertake.

[Para 175 WCPFC17 report] The EU … asked if figures based on the data in WCPFC17-2020-IP04 could be added in the future to allow better visualization of trends. … Regarding data visualization, SPC stated this was possible, but there are significant notes that must be appreciated when viewing trends in the data.

See latest version of the CMM TT data summary paper for April 2021 CMM TT workshop #1

[Para 186] What would the impact on the stock be if the longline catch limit returned to 2014 level?

Using Table 4 of WCPFC17-2020-IP04, 2014 catch = 69,270 mt. When related to the average catch over 2016-18, the 2014 bigeye catch level would result in a scalar of 1.17. This value is within the range of optimistic and pessimistic scenarios for longline examined within the current analysis. However, the specific impact on bigeye and yellowfin stocks would depend on the scenarios being considered for the purse seine fleet.