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EVALUATION OF CMM 2021-01: TROPICAL TUNA MEASURE

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Rev 1includes a minor correction to the reference to para 17, which is now corrected to para 15 (exemptions from the additional 2 months FAD closure for high seas) consistent with the CMM 2021-01.

1. EXECUTIVE SUMMARY

This paper evaluates the potential for CMM 2021-01 to achieve its objectives for each of the three WCPO tropical tuna (bigeye, yellowfin and skipjack) stocks as specified in paragraphs 11 to 13 of that Measure. The evaluations are based on the most recent SC-agreed stock assessments, that for bigeye and yellowfin were in 2020 (last year of data is 2018) (Ducharme-Barth et al. 2020, Vincent et al. 2020) and for skipjack was in 2022 (last year of data is 2021) (Castillo Jordán et al. 2022). The evaluation is based on updated data in WCPFC19-2022-IP04.

The evaluation applies a two-step approach consistent with the previous 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 2021-01.

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, relative to a baseline average period of 2016-18. This baseline period is retained for this evaluation noting that CMM 2018-01, which preceded CMM 2021-01 came into effect in 2019, and that CMM 2021-01 is essentially the same as CMM 2018-01 for the provisions relevant to this evaluation. Further, 2018 is the last year of the bigeye and yellowfin stock assessments. In calculating the implications of CMM 2021-01, we calculated adjusted 'CMM equivalent' catches and FAD set effort for each baseline year due to differences in management arrangements across 2016-18 and then averaged those annual adjusted values. The scenarios are summarised as:

'2016-18 avg': purse seine effort and longline catch levels are maintained at the average levels seen over the years 2016-18, 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 high seas FAD sets by 1/8th of those made in 2016 when the 4-month high seas 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 FAD set effort was not adjusted as management arrangements were consistent with those implemented under CMM 2018-01 and maintained in CMM 2021-01. Under the 'optimistic' scenario it is assumed CCMs with longline limits take their CMM specified catch limit or 2016-18 average level if lower, and other CCMs take their 2016-18 average catch.

'Pessimistic': every CCM fishes to 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 high seas FAD sets by 1/8th of those in 2016, but increases them by the equivalent of 7 months for 2017. Where the specified high seas effort limits in CMM 2021-01 allow additional fishing effort relative to the actual annual levels in 2016, 2017 and 2018, additional FAD sets are assumed on a proportional basis. The limited longline non-SIDS CCMs and US Territories take their entire specified catch limits or 2000 mt limits where applied, and 2016-18 average levels are assumed for other SIDS.

Based on these scenarios and recent catch and effort data, catch and effort 'scalars' were calculated relative to the 2016-18 baseline and these were applied in stock projections in step 2.

The 'Optimistic' and 'Pessimistic' scenarios assume the changes in FAD closure periods under CMM 2021-01 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 are compensated by decreases 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 2016-18 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 the 2016-18 average (baseline) conditions for each of the three tropical tuna stocks. For each, projections were run across the grid of the most recent models agreed by SC as the basis for management 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 (paragraphs 11 and 13 in CMM 2021-01) be retained and therefore continue to apply to this evaluation. The interim TRP for skipjack, documented in CMM 2015-06 (referenced in CMM 2018-01, paragraph 13), was also retained in CMM 2021-01 (paragraph 12). The potential long-term performance of the CMM against those objectives was evaluated and varied between stocks.

For bigeye tuna, performance of CMM 2021-01 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 2012-15 levels, and the median fishing mortality is projected to decline slightly for the 2016-18 average and 'optimistic' scenarios but increase for the 'pessimistic' CMM scenario, although remaining below F_{MSY}. If the lower, long-term average recruitment continues into the future, spawning biomass depletion also improves relative to 2012-15 levels for the 2016-18 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 lower long-term recruitment conditions, and for the 'pessimistic' scenario, median F exceeds F_{MSY} at the end of the projection period.

For skipjack (Table 2), under the 'long-term' historical recruitment patterns, the performance of the CMM 2021-01 was consistent across the different scenarios. This is largely a result of the assumption that the overall purse seine effort remains at 2016–18 average levels. Changes in the proportions of FAD sets of the level expected under the CMM 2021-01 have limited impact on overall skipjack fishing mortality. For the skipjack stock, under all three scenarios (2016–18 average, 'optimistic', 'pessimistic'), the median $SB/SB_{F=0}$ is projected to stabilize at 0.51, which is marginally higher than the interim TRP of 0.50, while median F is projected to stabilize at 36–37 % F_{MSY}. There was no risk of breaching the adopted LRP, but a 17% risk of F exceeding F_{MSY} by the end of the projection period.

Results for yellowfin tuna were also similar under all scenarios (Table 2), with the stock stabilising at $SB/SB_{F=0}$ of 0.57–0.59, a slight increase above the 2012-15 level, 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}.

To monitor how close the scalars applied to the evaluations are in relation to the actual observed fishing levels the observed fishing levels in 2019, 2020 and 2021 are compared with the average levels for the 2016-18 baselines. These comparisons indicated that:

- **For 2019 purse seine FAD sets**, were 8% lower than the baseline average and, consequently, well below those anticipated under the ‘optimistic’ CMM scenario.
- **For 2020 purse seine FAD sets**, were 7% lower than the baseline average and, consequently, well below those anticipated under the ‘optimistic’ CMM scenario.
- **For 2021 purse seine FAD sets,** effort levels while still below those anticipated under the ‘optimistic’ CMM scenario were 6% higher than the baseline average. This increase may relate to predominant La Niña conditions, in which fleets fishing in the tropical central and western WCPFC have a heavier reliance on drifting FADs.

- **For 2019 longline bigeye,** catches were 11% higher than the baseline average and therefore above those anticipated under the ‘optimistic’ CMM scenario, but well below those expected under the “pessimistic scenario”.
- **For 2020 longline bigeye,** catches were 8% lower than the baseline average and therefore below those anticipated under the ‘optimistic’ CMM scenario.
- **For 2021 longline bigeye,** catches were 20% lower than the baseline average and therefore well below those anticipated under the ‘optimistic’ CMM scenario.

- **For 2019 longline yellowfin,** catches were 24% higher than the baseline average and therefore above those anticipated under the ‘optimistic’ CMM scenario, but below those expected under the “pessimistic scenario”.
- **For 2020 longline yellowfin,** catches were 18% lower than the baseline average and therefore below those anticipated under the ‘optimistic’ CMM scenario.
- **For 2021 longline yellowfin,** catches were again 18% lower than the baseline average and therefore below those anticipated under the ‘optimistic’ CMM scenario.

The new information incorporated within the 2020 yellowfin tuna stock assessment implied a more robust stock than estimated previously, as seen by the zero risks of depletion falling below the LRP or the F increasing above F_{MSY}. It should be noted that key areas for further work on the yellowfin assessment were identified including an external peer review of the assessment that was recently conducted in 2022 and will be reported to SC19. 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 2021-01. The next yellowfin and bigeye assessments are scheduled to be in 2023.

Appendices 2 to 4 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 (2016-18 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2016-18		Median	Median ratio	Median	Median ratio	Risk[1]	
Recruitment	**Fishing level**	**Purse seine**	**Longline**	**$SB_{2048}/SB_{F=0}$**	**$SB_{2048}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$**	**$F_{2044-2047}/F_{MSY}$**	**$F_{2044-2047}/F_{MSY}$ v $F_{2014-17}/F_{MSY}$**	**SB_{2048} < LRP**	**$F>F_{MSY}$**
2020 Bigeye assessment ('recent' levels)				0.41	-	0.72	-	0%	13%
Recent	2016-18 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	2016-18 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 / 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

Table 2. Median and relative values of reference points and risk of breaching limit reference points levels (adopted limit reference point (LRP) of 20% $SB_{F=0}$; F_{MSY}) in 2048 from the 2022 skipjack and 2020 yellowfin stock assessments, under the three future harvest scenarios (2016-18 average fishing levels, optimistic, and pessimistic) and long-term recruitment patterns.

Stock	Fishing level	Scalars relative to 2016-18		Median $SB_{2048}/SB_{F=0}$	Median $SB_{2048}/SB_{F=0}$ v $SB/SB_{F=0}$ = 0.50	Median $F_{2044-2047}/F_{MSY}$	Median $F_{2044-2047}/F_{MSY}$ v F_{recent}[1]$/F_{MSY}$	Risk	
		Purse seine	**Longline**					**SB_{2048} < LRP**	**$F>F_{MSY}$**
Skipjack tuna	2016-18 avg	1	1	0.51	1.02	0.36	1.13	0%	17%
	Optimistic	1.11	1	0.51	1.02	0.37	1.15	0%	17%
	Pessimistic	1.13	1.51	0.51	1.02	0.37	1.15	0%	17%
					Median $SB_{2048}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$				
Yellowfin tuna	2016-18 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] The actual 'recent' time period is specific to the assessment, recent = 2018-2021 for skipjack and 2015-2018 for yellowfin.

2. Quantifying the provisions of the measure

This CMM 2021-01 evaluation is based upon data updated in WCPFC19-2022-IP04 and the latest SC-agreed stock assessments for the three tropical tuna species (Ducharme-Barth et al., 2020; Vincent et al., 2019; Castillo-Jordán et al., 2022), 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 2016-18 (the last three years of the assessments for bigeye and yellowfin, and the period immediately prior to the implementation of CMM 2018-01, noting the provisions considered in this evaluation of CMM 2021-01 remain consistent with CMM 2018-01).

Table 3 outlines the approach taken in relation to the relevant paragraphs of CMM 2021-01 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 2021-01.

Relevant CMM 2021-01 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 2016-18 average levels of effort will continue.
Harvest strategies and interim objectives	
1	Acknowledging that harvest strategies are being developed for bigeye, yellowfin and skipjack, for the purpose of this evaluation we have examined where the stock would end up under longer-term application of this measure.
11-13	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 (0.2 $SB_{F=0}$) for all three species/stocks. For bigeye and yellowfin stocks, we relate the longer-term outcome of CMM 2021-01 measures (over 30 years) to the average $SB_{2012\text{-}2015}/SB_{F=0,\ 2008\text{-}2017}$ as specified in paras 11 and 13. For skipjack we relate the longer-term outcome of CMM 2021-01 measures to the interim TRP of 0.5 $SB_{F=0}$ referenced in para 12, adopted in accordance with CMM 2015-06.
FAD set management	
14-15	CCMs apply an in-zone/high seas FAD closure of 3 months from 2019 (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 2021-01 been in place (described below). To evaluate the implications of CMM 2021-01, we averaged the estimates of the expected FAD sets in each year under CMM 2021-01 and then divided by the average of the actual observed FAD sets over 2016-18 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 2021-01 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 2021-01 against 2017 conditions the number of FAD sets was modelled as (1+1/8) x average FAD sets/year in 2016-18. 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 2021-01 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 2021-01, 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 2021-01 measure for 2016 we therefore made the same adjustment of (1+1/8) x average FAD sets/year in 2016-18, 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 2021-01. The impact of CCMs choosing different two-month pairs for the high seas closure under CMM 2021-01 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 2021-01 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, calculated as described 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; 2016-18 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.
16	The provisions of paragraphs 3 to 7 of CMM 2009-02 apply to the high seas FAD closures. This has been maintained after recent evaluations (WCPFC18-2021-15) showed it would have negligible impact on calculations of FAD set numbers.
17-23	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 (paras 21, 22) was assumed to be negligible.
Purse seine effort control	
24-28	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 2016-18 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	
37-41	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 2016-18 average catch level whichever was lower, other CCMs took their 2016-18 average catch level. • **Pessimistic**: Limited CCMs took their specified catch limit/2,000 mt catch limit, other CCMs took their 2016-18 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 2016-18 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 2016-18 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 2021-01) 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	
42-46	Not relevant to the evaluation, assuming that total effort and catch measures are adhered to.
Other commercial fisheries	
47	There are neither estimates of capacity nor effort for the majority of fisheries in this category; therefore, we assume continuation of 2016-18 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 2016-18 average fishing levels[1], and represent aggregate scalars across all CCMs.

Table 4 Scalars for purse seine associated effort (FAD sets) and longline bigeye and yellowfin catch under alternative CMM 2021-01 scenarios, relative to 2016-18 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 at 2016-18 average levels. Therefore, where future scenarios assumed that purse seine FAD (associated) set effort increased, purse seine free

[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. Despite some minor changes in data tables with annual updates, the scalars remain consistent with data updated in WCPFC19-2022-IP04

[2] If the assumption was made that all CCMs with longline limits took those limits, but that all other fleets caught at the 2016-18 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.

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 $SB_{2012-2015}/SB_{F=0}$ for yellowfin and bigeye and 0.5 $SB_{F=0}$ for skipjack.
- 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 2021-01 (scalars estimated in Step 1, applied to 2016-18 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 <u>2007-2016</u> 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 1982-2020, respectively).
- For skipjack, outputs across models were equally weighted according to SC18 when calculating the results. Equal weighting across models was also 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. $SB_{2048}/SB_{F=0,\ 2038\text{-}2047}$).

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 2016-18 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 $F > F_{MSY}$[5] (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 2016-18 average and 'optimistic' scenarios relative to 2012-15 ($SB_{2048}/SB_{F=0}$ 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 2021-01 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). For each scenario, the skipjack stock is projected to stabilise at an $SB_{2048}/SB_{F=0}$ of 0.51, with F at 36-37 % of F_{MSY} (Table 7). There was no risk of breaching the limit reference point, but a 17% chance that fishing mortality may increase above F_{MSY} (Table 7).

Yellowfin tuna

For yellowfin tuna, results under all scenarios are comparable, with the stock stabilising at $SB_{2048}/SB_{F=0}$ of 0.57-0.59 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).

4. COMPARISON OF 2019, 2020 AND 2021 FISHING LEVELS WITH EXPECTATIONS UNDER THE CMM 2021-01 EVALUATION

To evaluate whether recent fishing patterns under CMM 2021-01 reflect the levels forecast under this evaluation, the actual 2019, 2020 and 2021 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

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

on estimates available to the SPC as of November 2022 (WCPFC19-2022-IP04), with the inclusion of archipelagic waters FAD sets to be consistent with the assumptions in the CMM evaluation. Resulting scalars are presented in Table 9.

Based on the updated data, the total number of FAD sets in 2019 was 8% 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. However, in 2021 the observed FAD sets were estimated to be 6% higher than the 2016-18 baseline, but with a scalar that remained below the 'optimistic' scenario. The increased in FAD sets in 2021 is thought to be related to the La Niña conditions, in which fleets fishing in the tropical central and western WCPFC have a heavier reliance on drifting FADs.

In 2019, the total longline bigeye catch was 11% higher than the 2016-18 baseline period, but in 2020 was 8% lower. In 2021, the bigeye catch dropped further to be 20% lower than the 2016-18 baseline. For yellowfin, the longline catch in 2019 was 24% higher than the 2016-18 baseline, but in 2020 and 2021 was 18% 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 and 2021 both were well below 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 2021-01 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 11 to 13 in the long-term.

The potential long-term performance of CMM 2021-01 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 2012-15, 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 applying the new 2022 assessment were consistent across the different CMM 2021-01 scenarios. Under 2016-18 average levels and 'long-term' recruitment, skipjack depletion is projected to stabilise at 51% $SB_{F=0}$, marginally higher than the interim TRP of 50%, while F is projected to be 36-37% F_{MSY}. There was no risk of breaching the adopted limit reference point, but a 17% chance that F could increase above F_{MSY}.

For yellowfin tuna, results under all scenarios are comparable, with the stock stabilising at 57-59% $SB_{F=0}$, slightly higher than the 2012-15 levels, 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}.

The FAD set effort levels that have been observed since 2019 are within the range expected under the CMM 2021-01 evaluation scenarios as are the longline catches of bigeye and yellowfin, which since 2020 are well below the expectations from the evaluation.

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

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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 <u>bigeye tuna</u>, and in 2048 under the three future harvest scenarios (2016-18 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2016-18		Median	Median ratio	Median	Median ratio	Risk[1]	
Recruitment	**Fishing level**	**Purse seine**	**Longline**	$SB_{2048}/SB_{F=0}$	$SB_{2048}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	$F_{2044-2047}/F_{MSY}$	$F_{2044-2047}/F_{MSY}$ v $F_{2014-17}/F_{MSY}$	SB_{2048} < LRP	F>F_{MSY}
2020 Bigeye assessment ('recent' levels)				0.41	-	0.72	-	0%	13%
Recent	2016-18 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[1]	0.40	1.08	0.88	1.22	1%	32%
Long-term	2016-18 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. Risk under a projection scenario is the number of projections across the grid that fall below the LRP in the terminal projection year (2048). There are 24 models in the bigeye assessment grid. 100 stochastic projections are conducted for each grid model.
[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 (2016-18 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2016-18		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	2016-18 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	2016-18 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 2022 skipjack and 2020 yellowfin stock assessments grids, under the three future harvest scenarios (2016-18 average fishing levels, optimistic, and pessimistic) and long-term recruitment patterns.

Stock	Fishing level	Scalars relative to 2016-18		Median $SB_{2048}/SB_{F=0}$	Median $SB_{2048}/SB_{F=0}$ v $SB/SB_{F=0} = 0.50$	Median $F_{2044\text{-}2047}/F_{MSY}$	Median $F_{2044\text{-}2047}/F_{MSY}$ v F_{recent}^{1}/F_{MSY}	Risk[2]	
		Purse seine	**Longline**					**SB_{2048} < LRP**	**$F>F_{MSY}$**
Skipjack tuna	2016-18 avg	1	1	0.51	1.02	0.36	1.13	0%	17%
	Optimistic	1.11	1	0.51	1.02	0.37	1.15	0%	17%
	Pessimistic	1.13	1.51	0.51	1.02	0.37	1.15	0%	17%
					Median $SB_{2048}/SB_{F=0}$ v $SB_{2012\text{-}15}/SB_{F=0}$				
Yellowfin tuna	2016-18 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] The 'recent' time period is specific to the assessment, recent = 2018-2021 for skipjack and 2015-2018 for yellowfin.

[2] Risk within the stock assessment is calculated as the (weighted – if weights applied) % of models falling below the LRP. Risk under a projection scenario is the number of projections across the grid that fall below the LRP in the terminal projection year (2048). There are 18 models in the skipjack assessment grid and 72 models in the yellowfin assessment grid. 100 stochastic projections are conducted for each grid model.

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 (2016-18 average fishing levels, optimistic, and pessimistic), based on 2022 stock assessment grid for skipjack and 2020 assessment grid for yellowfin.

Stock	Fishing level	Scalars relative to 2016-18		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_{2045} < LRP
		Purse seine	Longline						
Skipjack tuna	2016-18 avg	1	1	*	0.47	0.51	0%	0%	0%
	Optimistic	1.11	1	*	0.46	0.51	0%	0%	0%
	Pessimistic	1.13	1.51[1]	*	0.46	0.51	0%	0%	0%
Yellowfin tuna	2016-18 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%

*Not included in the evaluation as within the time period included in the 2022 skipjack assessment

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

Table 9 Patterns of purse seine effort (FAD sets) and longline bigeye and yellowfin catches in 2019, 2020, and 2021 with corresponding scalars from 2016-18 levels[1]. Predicted optimistic and pessimistic scalars under CMM 2021-01 are 1.11 and 1.13 for FAD sets and 1.00 and 1.51 for longline catches.

	Average 2016-18	2019	Scalar 2019[3]	2020	Scalar 2020	2021	Scalar 2021
Purse seine effort (FAD sets)[1]	16,316	14,934	0.92[3]	15,250	0.93	17,247	1.06
Longline bigeye catch (mt)	58,593	64,772	1.11	53,824	0.92	46,904	0.80
Longline yellowfin catch (mt)	68,940	85,940	1.24	56,693	0.82	56,533	0.82

[1] In the tropical purse seine fishery according to updated data as available from November 2022. The purse seine FAD sets are inclusive of sets in archipelagic waters that are assumed to continue at 2016-18 average levels for the CMM evaluation.

Note: Minor differences to previous versions of this table may occur due to receival of outstanding log sheets and the annual recalculation of the raised catch and effort estimates.

8. FIGURES

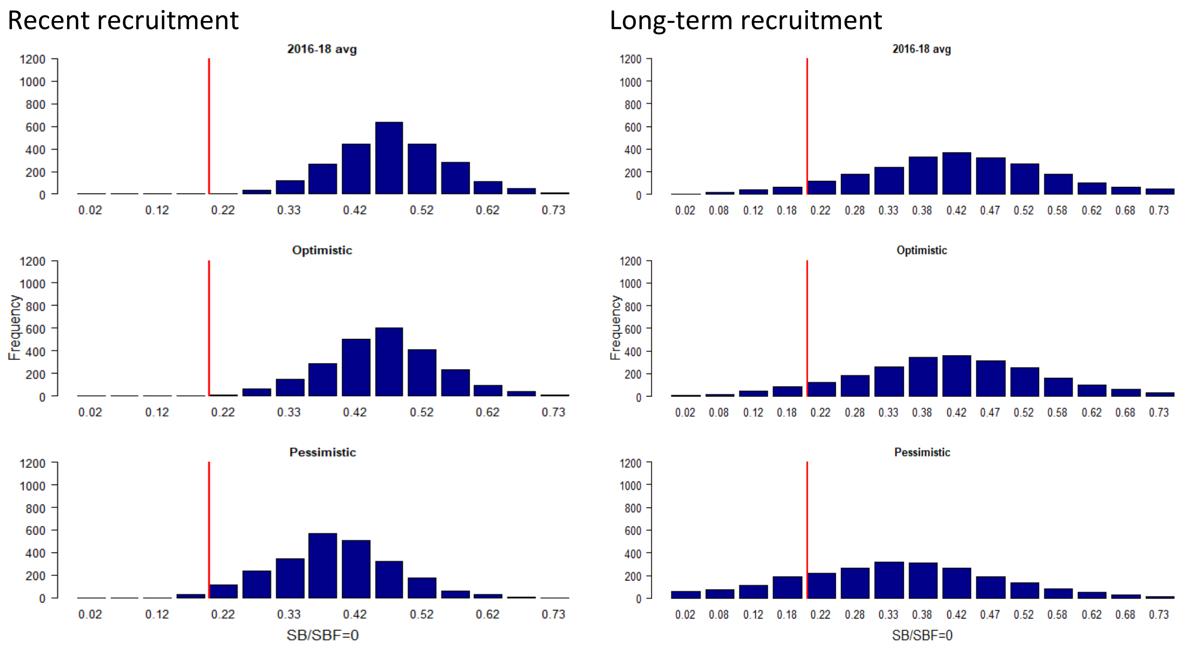

Figure 1 Distribution of $SB_{2048}/SB_{F=0}$ for <u>bigeye</u> tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic'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

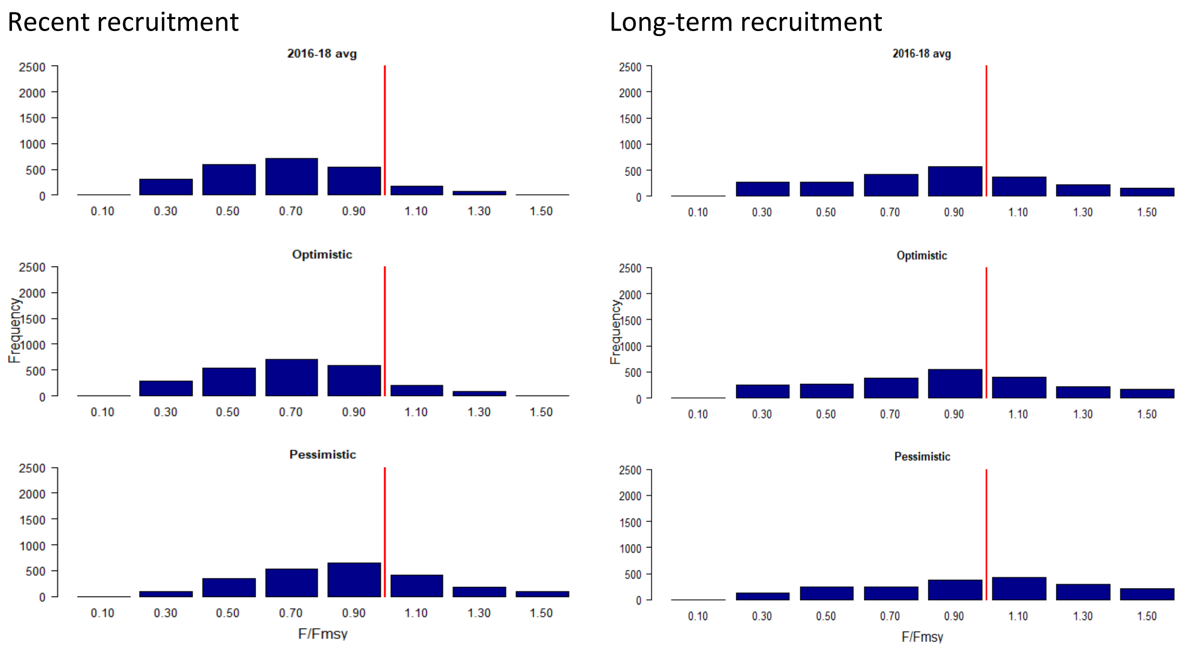

Figure 2 Distribution of F/F_{MSY} for <u>bigeye</u> tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions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

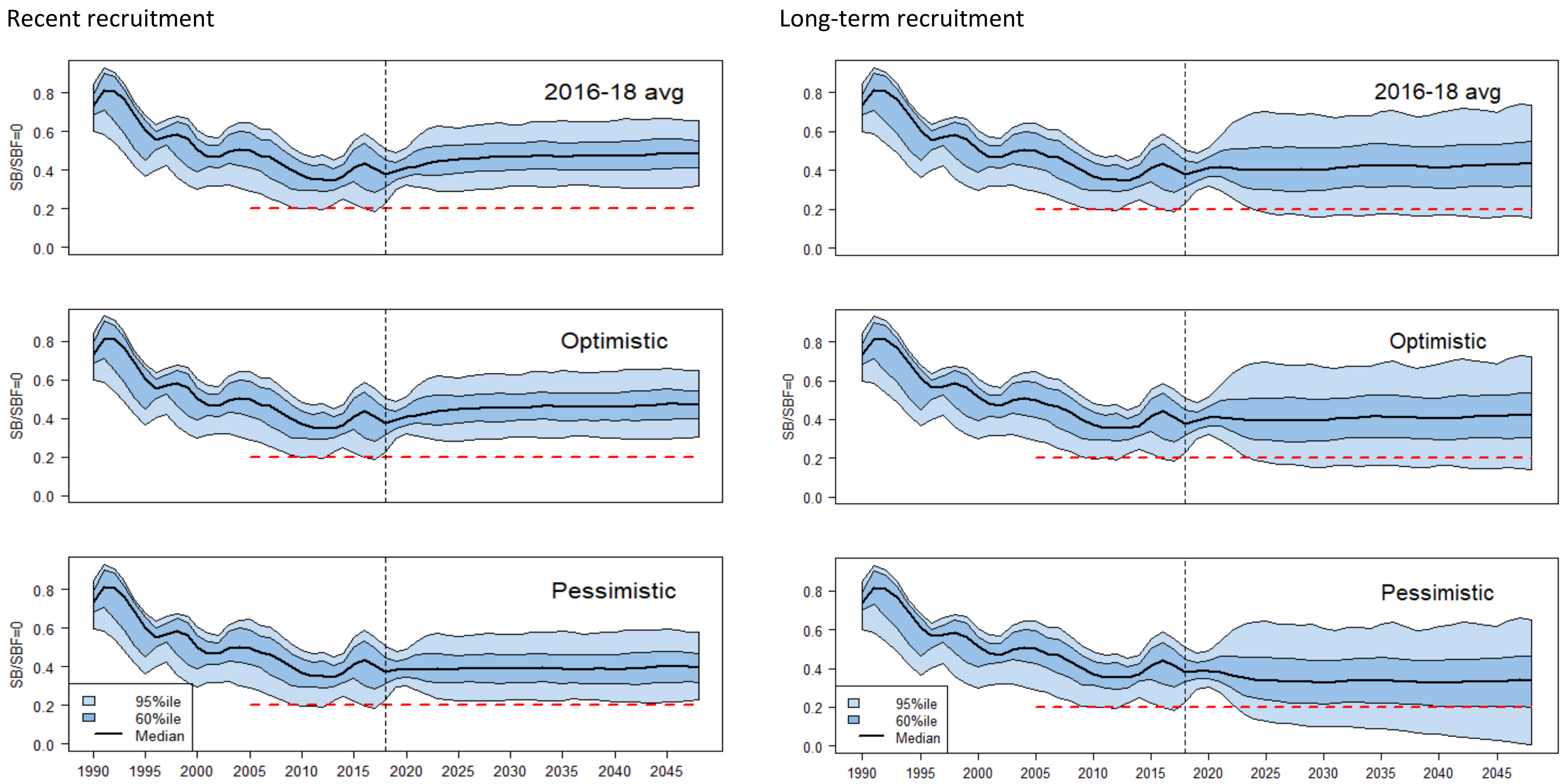

Figure 3 Time series of WCPO bigeye tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2018 (the vertical line at 2018 represents the last year of the assessment), and stochastic projection results for the period 2019 to 2048 under the three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

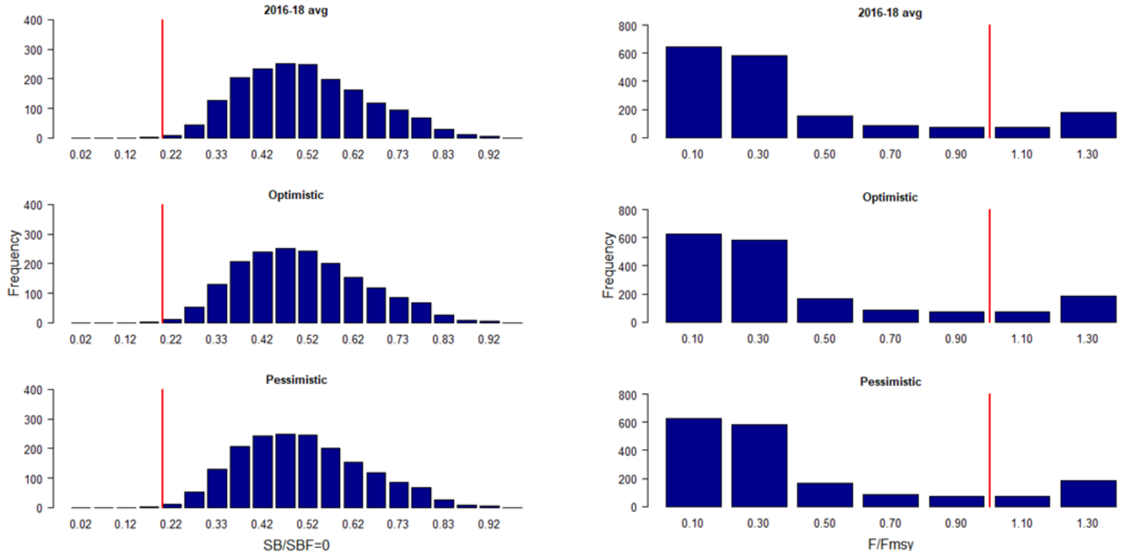

Figure 4 Distribution of $SB_{2048}/SB_{F=0}$ (left column), and F/F_{MSY} for skipjack tuna assuming long-term recruitment conditions, for the 2022 assessment uncertainty grid, under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); 'optimistic' conditions (middle row); and 'pessimistic' conditions (bottom row). Red line indicates the LRP ($20\%SB_{F=0}$) and $F=F_{MSY}$, respectively.

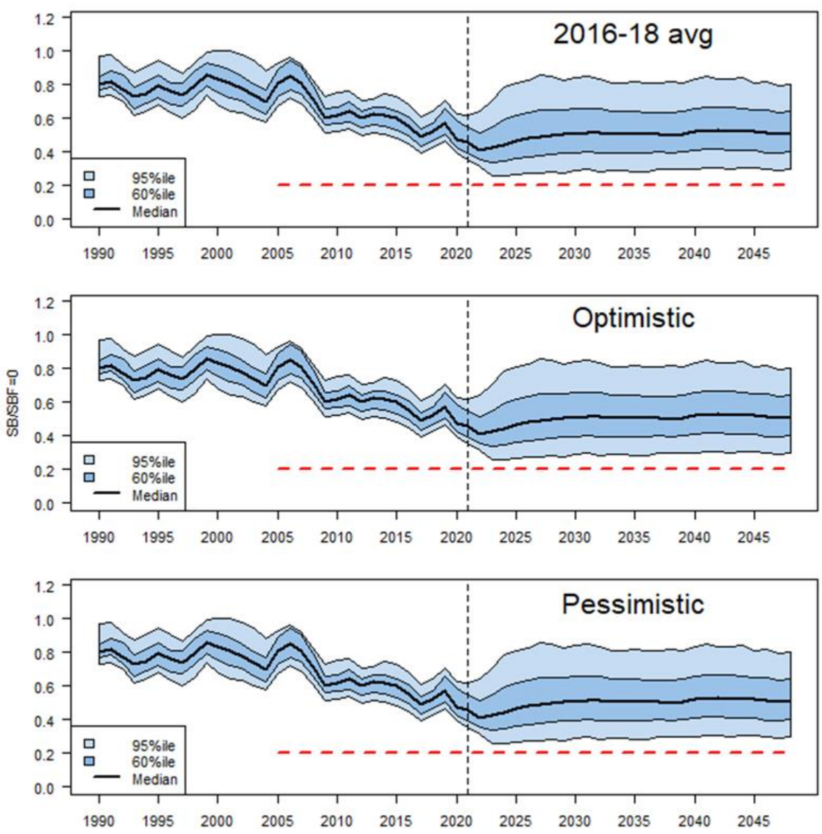

Figure 5 Time series of WCPO skipjack tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2021 (the vertical line at 2021 represents the last year of the assessment), and stochastic projection results for the period 2022 to 2048 under the three future fishing scenarios ("2016-18 avg", 'Optimistic' and 'Pessimistic'; rows). During the projection period (2022-2048) levels of recruitment variability are assumed to match those over the time period used to estimate the stock-recruitment relationship (1982-2020). The red dashed line represents the agreed limit reference point.

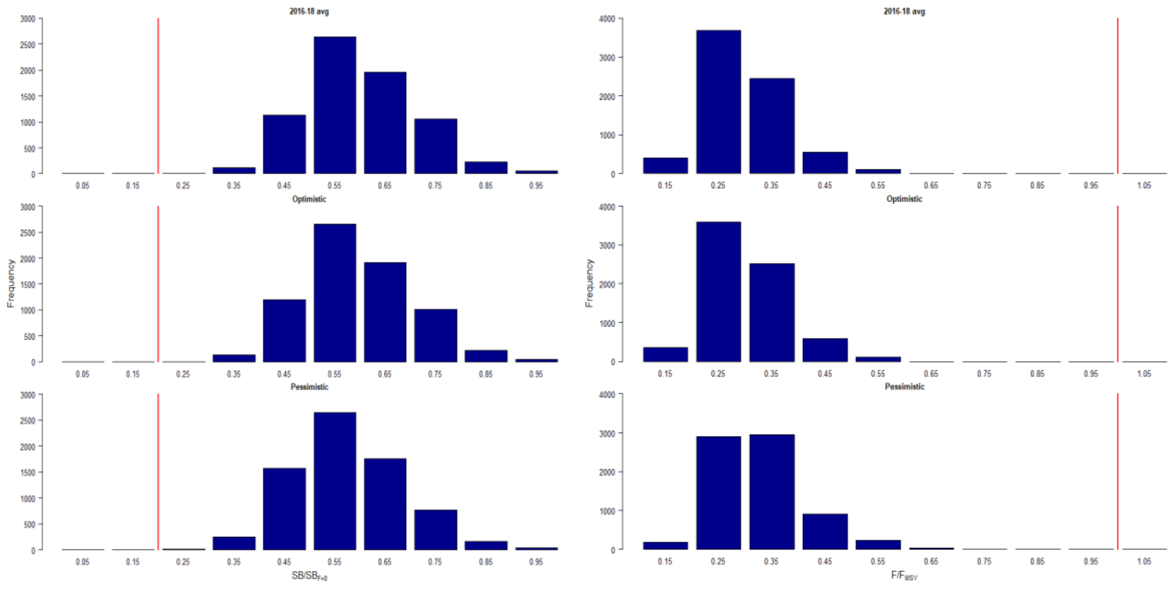

Figure 6 Distribution of $SB_{2048}/SB_{F=0}$ (left column), and F/F_{MSY} for yellowfin tuna assuming long-term recruitment conditions, under the three future fishing scenarios: 2016-18 avg (2016-18 average conditions, top row); optimistic conditions (middle row); and pessimistic conditions (bottom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

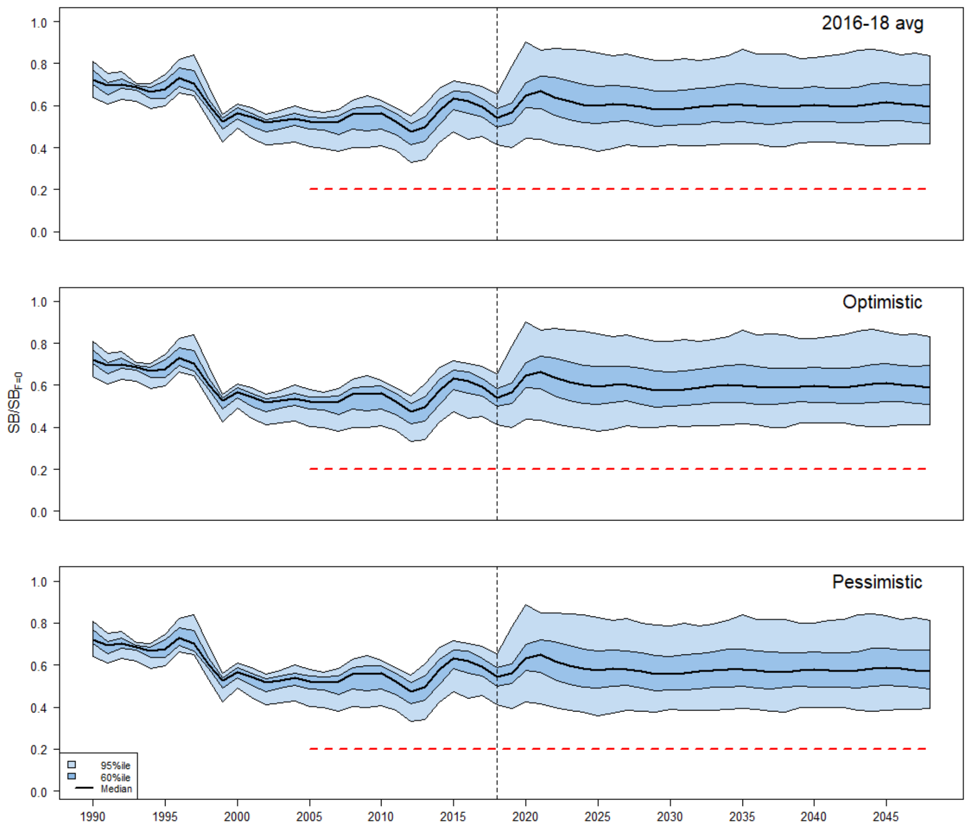

Figure 7 Time series of WCPO yellowfin tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2018 (the vertical line at 2018 represents the last year of the assessment), and stochastic projection results for the period 2019 to 2048 under the three 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 2016-18 average conditions if CMM 2021-01 was applied under the two scenarios.

'Optimistic' PS scenario

CCM	**FAD sets per year under CMM 2021-01**		
	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 2016-18 under CMM 2021-01	16,717		
Actual average FAD sets/year 2016-18	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 2016-18 as assumed would occur under the CMM 2021-01

[2] Nauru only recently (from 2018) reported FAD sets so we applied the 2019 set number in 2016-18 as assumed would occur under the CMM 2021-01

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

CCM	**FAD sets per year under CMM 2021-01**		
	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 2016-18 under CMM 2021-01	16,985		
Actual average FAD sets/year 2016-18	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 2021-01. We assume that under the CMM 2021-01 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 FAD sets/year.
[2]Minor changes to the FAD set baseline data have occurred.

Longline bigeye catch assumed for CCMs, and corresponding scalars relative to 2016-18 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 2021-01 levels if limited, otherwise 2000mt (non-SIDS) or 2016-18 average	2017 CMM levels if limited, otherwise 2016-18 average	CMM 2021-01 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

This appendix has been updated to include data for the year 2021, minor changes to data for prior years may occur due to updates of source data in WCPFC19-2022-IP04.

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 15 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 15 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 15
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 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 the apply the average of the 2016 and 2018 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, 2020 and 2021 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, 2020 and 2021 three-month FAD closure by 'footnote 1' vessels.

Year	Number of vessels		Total FAD sets	Total catch (mt)			
	Notifying	Fishing		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	1,116	52,525	6,570	1,553	62,648
2021	92	82	770	21,708	8,915	503	31,126

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 15

Paragraph 15 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, 2020 and 2021 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 estimated 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 and 2021.

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	50	5,566	2,358	486	170	496	97	6,548	2,625
2021	47	71	1,180	2,113	115	109	55	84	1,350	2,306
Average	**105**	**78**	**4455**	**3207**	**236**	**151**	**382**	**136**	**5073**	**3494**

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	6,534	1,728	2,382	291	94	9,078	9,009
2021	495	553	3,627	2,157	1,473	1,431	266	104	5,366	3,693
Average	**629**	**599**	**3,842**	**3,537**	**1,587**	**1,827**	**445**	**216**	**5,874**	**5,580**

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 high seas effort limits within CMM 2021-01 (Table 2) with the patterns of actual fishing in 2018, 2019, 2020, and 2021 which includes the effort in the 'overlap' area for USA in 2018 and 2019, but not in 2020 and 2021[4].

Table 12. Comparison of CMM high seas purse seine effort limits (see CMM 2021-01, Table 2) with days fished in tropical international waters[1] (20°N to 20°S) in 2018, 2019, 2020 and 2021.

Flag	CMM limits[2]	Days fished in international waters 20°N-20°S			
		2018	2019	2020	2021
China	26	26	22	16	0
Ecuador	**	0	0	0	0
El Salvador	**	28	10	30	26
European Union	403	158	146	194	232
Indonesia	(0)	0	0	0	0
Japan	121	6	29	21	0
New Zealand	160	103	95	57	0
Philippines	#	2,749	2,654	2,635	2,539
Republic of Korea	207	198	181	170	105
Chinese Taipei	95	62	84	62	53
USA	1,270	1,587[3]	1,543	1,658[4]	731[4]
Total		4,917	4,764	4,843	3,686

**subject to CNM on participatory rights
Measures that Philippines would take are in Attachment 2 of CMM 2021-01
[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 (para 28 in CMM 2021-01)."
[3] Noting para 29 of CMM 2017-01 is applicable from 2018 onwards.
[4] The US notified that 2020 and 2021 management of high seas effort in the WCPFC-IATTC overlap area will be through the IATTC measures. As such, the 2020, and 2021 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 = + 111, 2019 = +10, 2020 = +373, 2021 = + 354 and compared to the expectations under the 'pessimistic' scenario were: 2018 = -111, 2019 = - 212, 2020 = +150, 2021 = +131. 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 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, 2020 and 2021 (**Table 13**).

Table 13. Comparison of average high seas purse seine effort (days) by flag over 2016 and 2018 with days fished in tropical international waters (20°N to 20°S) in 2019, 2020 and 2021. Updated from data received in November 2022, WCPFC19-2022-IP04.

Flag	Average 2016 and 2018	Reported in 2019	Reported in 2020	Reported in 2021
China	25	22	16	0
Cook Islands	0	72	29	185
Ecuador	0	0	0	0
El Salvador	27	10	30	26
European Union	123	146	194	232
FSM	499	1,053	694	944
Indonesia	0	0	0	0
Japan	14	29	21	0
Kiribati	861	950	654	571
Marshall Is.	348	955	698	394
Nauru	65	188	398	118
New Zealand	138	136	63	0
PNG	55	0	4	2
Philippines	2,696	2,654	2,635	2,539
Republic of Korea	198	182	172	105
Solomon Is.	64	91	19	1
Tuvalu	102	71	127	181
Chinese Taipei	79	84	62	53
USA	1,798	1,543	1,658	731
Vanuatu	143	147	140	112
Total	7,230	8,333	7,614	6,194

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, 2020 and 2021 resulted in an additional 308, 715 and 466 more HS FAD sets, respectively, than expected under the 'optimistic' scenario. Relative to the expectations under the 'pessimistic' scenario, in 2019, 2020 and 2021 an additional 85, 492 and 417 HS FAD sets were estimated to have occurred respectively.

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, and for the high seas (HS) effort scenarios, for the equivalent high seas 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 15) or added (HS CMM limits and Patterns of HS effort) to the calculations. Note: the addition of the scenarios where flags with HS day limits and those without limits specified in table 2 of CMM 2021-01 have their specified limits or CMM 'optimistic' effort levels set to zero (bottom row). Data are updated based on WCPFC19-2022-IP04.

Evaluation		Approx. FAD set change	Optimistic scenario scalar	Pessimistic scenario scalar	Approximate equivalent main (full) FAD closure period (months)	Approximate equivalent HS only closure period (months)
1	CMM evaluation scalars (relative to 2016-18 baseline)		**1.11**	**1.13**	3	5
2	Footnote 1 (2019)	-638	1.07	1.09	~ 2.6	NA
3	Footnote 1 (2020)	-1,116	1.04	1.06	~ 2.4	NA
4	Footnote 1 (2021)	-770	1.06	1.08	~ 2.6	NA
5	Paragraph 15 (2019)	-712	1.07	1.08	~ 2.6	NA
6	Paragraph 15 (2020)	-744	1.07	1.08	~ 2.6	NA
7	Paragraph 15 (2021)	-583	1.08	1.09	~ 2.7	NA
8	High seas CMM limits (2019) (reported – predicted, **limited**)	+10 opt -213 pess	1.11	1.12	~2.9 - 3.0	5.1 3.9
9	High seas CMM limits (2020) (reported – predicted, **limited**)	+373 opt +150 pess	1.13	1.14	~3.1 - 3.2	6.9 5.8
10	High seas CMM limits (2021) (reported – predicted, **limited**)	+354 +131	1.13	1.14	~3.1 - 3.2	6.8 5.7
11	High seas CMM limits (2019) (reported – **it**predicted, **non-limited**)	+298 opt	1.13	1.15	~3.1	6.6
12	High seas CMM limits (2020) (reported – predicted, **non-limited**)	+341 opt	1.13	1.15	~3.2	6.8
13	High seas CMM limits (2021) (reported – predicted, **non-limited**)	+286	1.13	1.15	~3.1	6.5
14	Patterns of high seas effort (2019) (reported -predicted, **all CCMs**)	+308 opt +85 pess	1.13	1.14	~3.0 - 3.2	6.6 5.4
14	Patterns of high seas effort (2020) (reported -predicted, **all CCMs**)	+715 opt +492 pess	1.16	1.16	~3.3 - 3.4	8.7 7.6
16	Patterns of high seas effort (2021) (reported -predicted, **all CCMs**)	+466 +417	1.14	1.16	~3.2 - 3.3	7.4 7.2
17	HS effort limits set to zero for **limited** CCMs	-651 opt -875 pess	1.07	1.07	~ 2.5 – 2.6	1.6 0.4
18	HS effort set to zero for **non-limited** CCMs	-815 opt	1.05	NA	~ 2.5	0.8

11. Appendix 3. Additional analyses requested by PNA members at the 15th Technical and Compliance Committee

Note: appendices 3 and 4 did not require updates for this paper.

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