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Evaluation of CMM 2021-01: tropical tuna measure

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Revision 1

The 2022 Purse seine effort (FAD sets) and corresponding scalar in Table 9 have been corrected after identifying an issue in the data used to generate this summary information. The text that references the 'observed' 2022 purse seine effort scalar has also been updated accordingly.

The reason for the issue in the previous version of Table 9 was a new source of operational data for 2022 received this year which was erroneously included in the FAD sets for 2022.

A minor correction was also made to the column labels in Table 22

OFP (Oceanic Fisheries Programme)
Pacific Community (SPC), Noumea, New Caledonia

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; those for bigeye and yellowfin were in 2023 (Day et al. 2023, Magnusson et al. 2023) and that for skipjack in 2022 (Castillo Jordán et al. 2022). The last year of data in all three assessments was 2021. The evaluation is based on data in SC19-MI-IP-06.

The evaluation applies a two-step approach consistent with 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. Additionally, the adoption of CMM 2022-01 and implementation of the skipjack management procedure has implications for potential overall purse seine effort levels, which are incorporated here. Under these assumptions, we define four scenarios of future purse seine effort and longline catch, relative to a baseline average period of 2019-21. The period 2019-2021 has in zone/high seas FAD closure periods consistent with those specified in 2021-01, which simplifies the calculations relative to the purse seine fishery. The new baseline period implies different 'scalars' (multipliers) to achieve future fishing levels compared to previous CMM evaluations. The scenarios are summarised as:

'Optimistic': As the FAD closure conditions over the period 2019-2021 are consistent with the FAD clauses within CMM 2021-01, the number of future FAD sets under this scenario is assumed to remain at the average seen over this three-year period. Under the 'optimistic' scenario it is assumed CCMs with longline limits take their CMM specified catch limit or 2019-21 average level if lower, and other CCMs take their 2019-21 average catch.

'Skipjack MP': CMM 2022-01 agrees the implementation of the skipjack management procedure, which indicates the level of purse seine effort (as well as that of other fisheries) in the subsequent three year period. WCPFC SC19 noted the successful running of the skipjack MP and its output, which indicated that maximum total effort in the purse seine fishery should be set at the baseline 2012 effort levels for the period 2024-2026. Under the 'skipjack MP' scenario, future purse seine effort is therefore set at 2012 levels, with a FAD/free school fishing pattern consistent with that seen over the 2019-2021 period. The skipjack MP does not define longline effort or catches. Therefore, scalars estimated for the 'optimistic' and 'fully utilised' scenarios are assumed for that gear, creating two separate 'skipjack MP' scenarios.

'Fully utilised': every CCM fishes to the maximum allowed under the Measure. Effort within the purse seine fishery is increased to 2012 levels, consistent with the output of the skipjack management procedure. Within that overall effort, where the specified high seas flag-based effort limits in CMM 2021-01 allow additional fishing effort relative to the actual annual levels across 2019-2021, additional FAD sets are assumed on a proportional basis. Limited longline non-SIDS CCMs and US Territories take their entire specified catch limits or 2000 mt limits where applied, and 2019-21 average levels are assumed for other SIDS.

Based on these scenarios and recent catch and effort data, 'scalars' were calculated relative to the 2019-21 baseline and were applied in stock projections in step 2.

A key assumption for yellowfin was that the proportion change in longline catch matched 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, consistent with the baseline of the skipjack management procedure, and related to future catch for bigeye and skipjack, and effort for yellowfin. Pole and line fisheries (skipjack) were set at the 2001-2004 average baseline levels, consistent with the output of the skipjack management procedure.

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 for the three stocks. For each, projections were run across the grid of the most recent stock assessment models agreed by SC as the basis for management advice.

CMM 2021-01 specifies objectives for both bigeye and yellowfin stocks, being to maintain their spawning stock depletion ratio ($SB/SB_{F=0}$) at or above the average $SB/SB_{F=0}$ for 2012-2015. These values are 0.34 $SB_{F=0}$ and 0.44 $SB_{F=0}$, for bigeye and yellowfin respectively, based upon the 2023 assessment results. For skipjack, CMM 2022-01 adopted a TRP as described in paragraph 2 of that measure, which equates to a value of 0.50 $SB_{F=0}$ based upon the 2022 assessment results. The potential long-term performance of the CMM against these objectives was evaluated.

The potential long-term performance of CMM 2021-01 for bigeye tuna is primarily influenced by the scenarios assumed for future fishing levels; while absolute levels are influenced by the assumed future recruitment levels, general outcomes relative to the objectives are consistent. Under future fishing levels defined by the 'optimistic' scenario and the first 'skipjack management procedure' scenario (longline catches remain at 2019-2021 levels, purse seine effort increases to 2012 levels), the objective of maintaining the stock at or above 2012-2015 levels is achieved under both future recruitment scenarios. Under the second 'skipjack MP' scenario (longline catches increase to the maximum under the CMM, purse seine effort increases to 2012 levels) and the 'fully utilised' scenario, the stock falls below the objective, and where long-term recruitment is assumed there is over 20% chance of the stock falling below the LRP. We note it is the combination of purse seine and longline fishing levels that lead to this outcome. Relative to recent estimated levels, under the recent recruitment assumption, fishing mortality is projected to decline slightly in the 'optimistic' scenario and increase in the other scenarios, but in all cases median fishing mortality was projected to remain below F_{MSY}. Under the long term recruitment assumption, fishing mortality increases relative to recent levels in all scenarios, and exceeds F_{MSY} on average for the second 'skipjack MP' and 'fully utilised' scenarios, where the risk of exceeding F_{MSY} increases to 66-68%.

Results for skipjack were defined by the assumed level of future purse seine effort. Under the optimistic scenario (2019-2021 average levels), the stock would remain on average above the TRP. Under the 'skipjack MP' scenario, where future overall levels are assumed to return to those seen in 2012, skipjack depletion is projected to stabilise at the level consistent with the TRP (0.50 $SB_{F=0}$), while F is projected to be 31-35% F_{MSY}. There was no risk of breaching the adopted limit reference point, and a 2% chance that F could increase above F_{MSY} under the skipjack MP scenario.

For yellowfin tuna, under all future scenarios examined the stock does not achieve the CMM's current objective of maintaining the stock at or above 2012-2015 levels. The stock falls to levels of 78-93% of that objective, with the stock stabilising on average at 0.34 to 0.41 $SB_{F=0}$. Median F remains well below F_{MSY}. There is a predicted risk of spawning biomass falling below the LRP of 4% and F increasing above F_{MSY} of 2% under the second 'skipjack MP'/'fully utilised' scenario.

To monitor how close the actual fishing levels were to the scalars developed within the evaluations, the actual observed fishing levels in 2020, 2021 and 2022 were compared with the average levels for the 2019-21. These comparisons indicated that:

- **For 2020 purse seine FAD sets** were 4% lower than the 2019-2021 baseline average and, consequently, below those anticipated under the 'optimistic' CMM scenario.
- **For 2021 purse seine FAD sets** were 10% higher than the baseline average, and consequently higher than anticipated under the 'optimistic' CMM scenario, but below that anticipated under the 'skipjack MP'/'fully utilised' scenarios.
- **For 2022 purse seine FAD sets** were 13% higher than the baseline average, and consequently higher than anticipated under the 'optimistic' CMM scenario, but below that anticipated under the 'skipjack MP'/'fully utilised' scenarios.

- **For 2020 longline bigeye,** catches were 5% lower than the 2019-2021 baseline average and, consequently, below those anticipated under the 'optimistic' CMM scenario.
- **For 2021 longline bigeye,** catches were 9% lower than the 2019-2021 baseline average and, consequently, below those anticipated under the 'optimistic' CMM scenario.
- **For 2022 longline bigeye,** catches were 8% lower than the 2019-2021 baseline average and, consequently, below those anticipated under the 'optimistic' CMM scenario.

- **For 2020 longline yellowfin,** catches were 15% lower than the 2019-2021 baseline average and, consequently, below those anticipated under the 'optimistic' CMM scenario.
- **For 2021 longline yellowfin,** catches were 13% lower than the 2019-2021 baseline average and, consequently, below those anticipated under the 'optimistic' CMM scenario.
- **For 2022 longline yellowfin,** catches were 6% higher than the baseline average and therefore above the level anticipated under the 'optimistic' scenario, but below that of the 'fully utilised' scenario.

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 depletion and fishing mortality values for WCPO bigeye tuna in 2051 relative to reference point levels (adopted limit reference point (LRP) of 0.2 $SB_{F=0}$; CMM 2021-01 objective; F_{MSY}) and risk[1] of breaching reference points under four future harvest scenarios (optimistic, SKJ MP, and fully utilised) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2019-2021		Median $SB_{2048-2051}/SB_{F=0}$	Median $SB_{2048-2051}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2047-2050}/F_{MSY}$	Median ratio $F_{2047-2050}/F_{MSY}$ v $F_{2017-20}/F_{MSY}$	Risk (%)[1]	
Recruitment	Fishing level	Purse seine	Longline					$SB_{2048-2051}$<LRP	$F>F_{MSY}$
Recent	Optimistic[2]	1	1	0.46	1.35	0.57	0.97	0%	26%
	SKJ MP	1.19	1	0.43	1.27	0.62	1.05	0%	29%
		1.19	1.62	0.34	0.99	0.87	1.47	0%	43%
	Fully utilised	1.22	1.62	0.34	0.99	0.90	1.53	0%	44%
Long-term	Optimistic[2]	1	1	0.43	1.26	0.79	1.34	0%	38%
	SKJ MP	1.19	1	0.41	1.19	0.89	1.51	0%	44%
		1.19	1.62	0.30	0.88	1.39	2.36	22%	66%
	Fully utilised	1.22	1.62	0.30	0.88	1.44	2.44	22%	68%

[1] Risk within the stock assessment is calculated as the 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 20 projections) at the end of the projection (estimated over 2048-2051).

[2] As the purse seine FAD closure period over 2019-2021 is equivalent to that specified within CMM 2021-01, and longline catches over that period are below limits within the CMM, the optimistic scenario off the 2019-2021 baseline is a scalar of 1 for both gears.

Table 2. Median depletion and fishing mortality values for WCPO skipjack and WCPO yellowfin tuna in 2051 relative to reference point levels (adopted limit reference point (LRP) of 0.2 $SB_{F=0}$; CMM 2021-01 objective; F_{MSY}) and risk of breaching reference points under the four future harvest scenarios (optimistic, SKJ MP, and fully utilised).

Stock	Fishing level	Scalars relative to 2019-2021		Median $SB_{2048-2051}/SB_{F=0}$	Median $SB_{2048-2051}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2047-2050}/F_{MSY}$	Median ratio $F_{2047-2050}/F_{MSY}$ v $F_{2017-20}/F_{MSY}$	Risk (%)	
		Purse seine	Longline					$SB_{2048-2051}$<LRP	$F>F_{MSY}$
Yellowfin	Optimistic	1	1	0.41	0.93	0.57	1.14	0%	0%
	SKJ MP	1.19	1	0.38	0.87	0.61	1.22	0%	0%
	SKJ MP/Fully utilised	1.19	1.62	0.34	0.78	0.67	1.34	4%	2%
					Median $SB_{2048-2051}/SB_{F=0}$ v $SB/SB_{F=0}$ = 0.50				
Skipjack	Optimistic	1	1	0.53	1.07	0.31	0.97	0%	0%
	SKJ MP/Fully utilised	1.19	1.62	0.50	1	0.35	1.09	0%	2%

2. QUANTIFYING THE PROVISIONS OF THE MEASURE

This CMM 2021-01 evaluation is based upon data in SC19-MI-IP-06 and the latest SC-agreed stock assessments for the three tropical tuna species (Day et al. 2023, Magnusson et al. 2023, 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 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 2019-21 (the last three years of the assessments).

Table 3 outlines the approach taken in relation to the relevant paragraphs of CMM 2021-01 and describes how the arrangements regarding in-zone and high seas closure to FAD fishing across the period 2019-21 are accounted for.

A new element for this evaluation is the adoption by the Commission of CMM 2022-01. This CMM agrees the implementation of the skipjack management procedure, which indicates the level of purse seine effort (as well as that of other fisheries) in the subsequent three year period. Following SC19's noting of the successful running of the skipjack MP and its output, which indicated that maximum effort in the purse seine fishery should be set at its baseline level as specified in CMM 2022-01 (2012 effort levels) for the period 2024-2026, we have developed additional scenarios to reflect the implications of long term future purse seine effort being set at 2012 levels, with a FAD/free school fishing pattern consistent with that seen over the 2019-2021 period.

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 2019-21 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. The implications of the recent implementation of the skipjack management procedure is incorporated within two of the future scenarios evaluated herein.

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 TRP adopted as part of CMM 2022-01, which under the current assessment equals a value of 0.5 $SB_{F=0}$.
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). The updated 'baseline' period of 2019-2021 reflects a period where the FAD closure regime in place was consistent with that specified in CMM 2021-01. As per previous evaluations, 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 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 implicitly incorporated within this evaluation. Three options for future conditions in the purse seine fishery were examined: • **Optimistic**: FAD sets were limited through the 3-month FAD closure and additional 2-month high seas closure. High seas effort was maintained at average of 2019 - 2021 levels, if less than the CMM-specified day limits. The optimistic scenario therefore equated to the average conditions over the period 2019-2021. • **Skipjack management procedure**: This scenario assumed the output of the skipjack management procedure (MP) was fully utilised, reflecting a level of future overall purse seine effort equal to that seen in 2012. The assumption was made that the pattern of FAD and free school sets increased proportionally, and hence FAD sets were scaled up using the ratio between 2012 and 2019-2021 average total effort levels. • **Fully utilised**: FAD sets were limited through the 3-month FAD closure and additional 2-month high seas closure, calculated as described above. Overall effort was allowed to increase to 2012 levels, consistent with the output of the skipjack MP. However, those CCMs with high seas effort limits were assumed to fish to their day limits (see 'purse seine effort control', below), and corresponding additional high seas FAD sets were estimated, incorporating the closure, using a flag-specific FAD set rate per day on the high seas over the period 2019-2021.
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 (e.g. 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 in CMM 2021-01 Attachment 1, Table 1 (e.g., Pilling and Harley, 2015), particularly given the adoption of CMM 2022-01. We assumed overall effort (including within archipelagic waters) would occur as described under each of the scenarios described above: 2019-21 effort levels or 2012 effort levels. 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 specified in CMM 2021-01 Attachment 1, Table 2. Many limited CCMs would be able to increase their high seas effort marginally under the CMM. This is incorporated within the 'fully utilised' scenario detailed above.
Longline fishery – bigeye and yellowfin catch limits	
37-41	Longline catch limits are not 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 2019-21 average catch level whichever was lower, other CCMs took their 2019-21 average catch level. • **Fully utilised**: Limited CCMs took their specified catch limit/2,000 mt catch limit, other CCMs took their 2019-21 average catch level. A 2,000 mt limit has been applied to US Territories in US domestic legislation. Here the 2,000 mt limits have been applied under the fully utilised 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 2019-21 levels, although those fleets could legitimately increase to any level under the CMM. If this occurs, then the extent of any increase in longline catch will be under-estimated. As noted, the assumption is made that proportional changes in the longline catch of bigeye relative to the 2019-21 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 purposes of this long-term evaluation the transfer is not assumed to continue beyond February 2023 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. However, for consistency with the skipjack MP we have assumed these catches will remain at 2016-2018 average levels in the future. A caveat is for yellowfin, where for the majority of these fisheries the assumption has been made that the corresponding estimated effort will remain at 2016-2018 average levels in the future (see also WCPFC20-2023-16).

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 'fully utilised'). As noted, we have also developed scenarios to reflect the potential implications of the implementation of outputs of the skipjack management procedure for the purse seine fishery. As the skipjack MP has no influence on longline catches, the scalars estimated for the 'optimistic' and 'fully utilised' scenarios are assumed for that fishery component, creating two separate scenarios. Resulting scalars (Table 4) are calculated relative to 2019-21 average fishing levels[1], and represent aggregate scalars across all CCMs. For bigeye, the impact is through the number of FAD sets. For skipjack and yellowfin, the impact is through overall effort (all sets). For these stocks, the 'fully utilised' scenario purse seine scalar is 1.19, as the additional high seas FAD sets estimated under this scenario are assumed to be offset by reduced free school sets to maintain overall 2012 effort levels, with the assumption that sets per day do not change.

Table 4 Scalars for purse seine associated effort (FAD sets), and longline bigeye and yellowfin catch under alternative CMM 2021-01 scenarios, relative to 2019-21 average conditions.

	Purse Seine	Longline
Optimistic	1.00	1.00
SKJ MP	1.19	1.00
	1.19	1.62
Fully utilised[a]	1.22	1.62

[a] As noted, for skipjack and yellowfin, the impact is through overall effort (sets). For these stocks, the fully utilised scenario purse seine scalar is 1.19. For bigeye the impact is through the FAD sets and the fully utilised scalar includes the additional FAD sets due to CCMs in attachment 1, table 2 fishing to the full limits.

3. EVALUATION OF THE POTENTIAL EFFECTIVENESS OF THE MEASURE

We use the purse seine 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:

[1] The tables or calculations used to estimate these values are presented in Appendix 1 and are based upon data in SC19-MI-IP-06.

- the 'recent' spawning biomass at the end of the 30 year projection in relation to the average unfished level ($SB_{2048\text{-}2051}/SB_{F=0}$[2]) compared to both the agreed limit reference point of 0.2 $SB_{F=0}$, and $SB_{2012\text{-}2015}/SB_{F=0}$ for yellowfin and bigeye and 0.5 $SB_{F=0}$ for skipjack.
- the median fishing mortality at the end of the projection period (2047-2050) in relation to the fishing mortality at maximum sustainable yield (F/F_{MSY}) and to the estimated level $F_{2017\text{-}2020}/F_{MSY}$.

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, 20 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 2019-21 average fishing conditions). The outputs of the projections ($SB_{2048\text{-}2051}/SB_{F=0}$ 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 2010-2020 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 will continue into the future.
  - As requested by SC12, a sensitivity analysis assuming relatively more pessimistic long-term recruitment patterns (sampled from 1962-2020) continue into the future.
- For yellowfin and skipjack tuna, future recruitment in the projection period was based upon long-term recruitment patterns (sampled from 1962-2020 and 1982-2020, respectively).
- For all stocks, outputs across models were equally weighted consistent with SC decisions when calculating the results.

RESULTS

Results are provided 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 CMM scenario conditions were less influenced by the assumed future recruitment levels than in previous evaluations; the major influence was through the assumed scenario for future fishing levels.

[2] $SB_{F=0}$ was calculated consistent with the approach defined in CMM 2022-01, 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. $SB_{2051}/SB_{F=0,\ 2041\text{-}2050}$). We have also used the 'SBrecent' calculation, as used in SC advice, calculating this depletion averaged over the most recent four years.

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 the optimistic and first skipjack MP scenario (where longline catch remains at 2019-2021 levels). However, it falls just below this objective under the second skipjack MP scenario and the 'fully utilised' scenario by 1% ($SB_{2048-2051}/SB_{F=0}$ across all scenarios ranges from 0.34 to 0.46; Table 5**,** Figure 1). There is no estimated risk of future spawning biomass falling below the LRP. Fishing mortality falls slightly under the 'optimistic' scenario relative to recent levels, assuming recent recruitment, with a 26% chance of fishing mortality being greater than F_{MSY}. For the other scenarios, fishing mortality increases relative to recent levels, notably for the second 'skipjack MP' and 'fully utilised' scenarios, but all remain below F_{MSY} on average, with a maximum 44% risk of $F > F_{MSY}$[3] (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 remain above 2012-15 levels under the 'optimistic' and first 'skipjack MP' scenarios ($SB_{2048-2051}/SB_{F=0}$ 0.41 to 0.43) with no estimated risk of falling below the LRP. However, the stock is estimated to fall below the objective under the second 'skipjack MP' scenario and the 'fully utilised' scenario ($SB_{2048-2051}/SB_{F=0}$ = 0.30) (Table 5). The risk of spawning biomass falling below the LRP also increases to 22% (Table 5). In all fishing scenarios, fishing mortality increases relative to recent levels (by 34-144%) and exceeds F_{MSY} for the second 'skipjack MP' and 'fully utilised' scenarios. Risk of F exceeding F_{MSY} ranges from 38% to 68%.

Skipjack tuna

Results for skipjack are driven by the future purse seine effort assumed, given that the impact of longline fisheries on the stock is negligible. Under the optimistic scenario (essentially 2019-2021 average conditions), the stock on average increases above the target reference point ($SB_{2048-2051}/SB_{F=0}$ 0.53), while under the skipjack MP/fully utilised scenarios, the stock remains on average at the TRP ($SB_{2048-2051}/SB_{F=0}$ is 0.50). Fishing mortality is estimated to be 31-35 % of F_{MSY} (Table 7), increasing by 9% relative to the recent level under the 'skipjack MP'/'fully utilised' scenarios. There was no risk of breaching the limit reference point, and a 2% chance that fishing mortality may increase above F_{MSY} under the 'skipjack MP'/'fully utilised' scenarios (Table 7).

Yellowfin tuna

For yellowfin tuna, results under all scenarios are qualitatively comparable, with the stock falling below 2012-2015 levels and fishing mortality increasing (but still lower than F_{MSY}) under all scenarios ($SB_{2048-2051}/SB_{F=0}$ from 0.34 to 0.41 and F/F_{MSY} at 0.57-0.67). There is 4% risk of spawning biomass falling below the LRP, and a 2% risk or F increasing to levels above F_{MSY} under the second 'skipjack MP'/'fully utilised' scenario (Table 7**,** Figure 6**,** Table 8**,** Figure 7).

4. Comparison of 2020, 2021 and 2022 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 2020, 2021 and 2022 purse seine effort in FAD set numbers and total longline catches for bigeye and yellowfin are compared relative to the 2019-21 average baseline levels and the scalars under the different CMM 2021-01 scenarios. The data used for these comparisons is updated in this paper based on estimates available to the SPC as of October 2023, 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 2020 was 4% lower than the baseline, and below that anticipated in the 'optimistic' scenario. However, in 2021 and 2022 FAD sets increased to

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

10% and 13% above the baseline respectively. This may be influenced by ENSO conditions, in particular the recent relatively extended La Niña period. The impact of the shift to El Niño conditions in 2023 may be identified in the 2024 tropical tuna CMM review. During La Niña periods there tends to be a greater reliance on FAD fishing when skipjack are more concentrated in the western equatorial Pacific.

The total longline bigeye catches in 2020, 2021 and 2022 have been below the 2019-2021 baseline, and hence the 'optimistic' scenario by 5%, 9% and 8% respectively. For yellowfin, the longline catch in both 2020 and 2021 has been below the 2019-2021 baseline and hence the optimistic scenario by 15% and 13% respectively, and 6% above in 2022 - higher than anticipated under the 'optimistic' scenario but lower than the 'full utilised' scenario. Despite the generally consistent pattern of increase and decrease of the catch of the two stocks in each year, there are differences suggesting that the assumption of a direct relationship between bigeye and yellowfin longline catch scalars may not always 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 primarily influenced by the scenarios assumed for future fishing levels; while absolute levels are influenced by the assumed future recruitment levels, general outcomes relative to the objectives are consistent. Under future fishing levels defined by the 'optimistic' scenario and the first 'skipjack management procedure' scenario (longline catches remain at 2019-2021 levels, purse seine effort increases to 2012 levels), the objective of maintaining the stock at or above 2012-2015 levels is achieved under both future recruitment scenarios. Under the second 'skipjack MP' scenario (longline catches increase to the maximum under the CMM, purse seine effort increases to 2012 levels) and the 'fully utilised' scenario, the CMM objective is not met, and where long-term recruitment patterns are assumed for the future there is more than a 20% chance of falling below the LRP. We note it is the combination of purse seine and longline fishing levels that lead to this outcome. Relative to recent estimated levels, under the recent recruitment assumption, fishing mortality is projected to decline slightly in the 'optimistic' scenario and increase for the other scenarios, but in all cases median fishing mortality remains below F_{MSY}. Under the long term recruitment assumption, fishing mortality increases relative to recent levels in all scenarios, and exceeds F_{MSY} on average for the second 'skipjack MP' and 'fully utilised' scenarios, where the risk of exceeding F_{MSY} increases to 66-68%.

Results for skipjack were defined by the assumed level of future purse seine effort (assumptions for other key fisheries being consistent with levels under the skipjack management procedure output). Under the optimistic scenario (2019-2021 average levels), the stock would remain on average above the TRP. Under the 'skipjack MP' scenario, where future overall levels are assumed to return to those seen in 2012, skipjack depletion is projected to stabilise at the level consistent with the TRP (0.5 $SB_{F=0}$), while F is projected to be 31-35% F_{MSY}. There was no risk of breaching the limit reference point, and a 2% chance that F could increase above F_{MSY}.

For yellowfin tuna, under all future scenarios examined the stock does not achieve the CMM's current objective of maintain the stock at or above 2012-2015 levels, falling to levels of 78-93% of that objective, with the stock stabilising on average at 0.34 to 0.41 $SB_{F=0}$. Median F remains well below F_{MSY}. There is a predicted risk of spawning biomass falling below the LRP of 4% and F increasing above F_{MSY} of 2% under the second skipjack MP/fully utilised scenario.

The FAD set effort levels in 2020 were below that expected under the 'optimistic' scenario; 2021 and 2022 levels were within the range of scenarios examined. Longline bigeye catches over 2020-2022 have been below the level expected under the 'optimistic' scenario, while those of yellowfin are below or within the range of scenarios evaluated.

As in previous CMM evaluations 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 changes in overall purse seine effort, and that the choice of paired high seas FAD closure months will not affect the number of sets performed. We also assume that the potential increase in purse seine fishing effort permissible under recently nominated EEZ effort levels (CMM 2021-01, attachment 1, table 1) 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, and that the overall limit resulting from the implementation of CMM 2022-01 will occur. 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 depletion and fishing mortality values for WCPO bigeye tuna in 2051 relative to reference point levels (adopted limit reference point (LRP) of 0.2 $SB_{F=0}$; CMM 20221-01 objective; F_{MSY}) and risk[1] of breaching reference points under four future harvest scenarios (optimistic, SKJ MP, and fully utilised) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2019-2021		Median $SB_{2048-2051}/SB_{F=0}$	Median $SB_{2048-2051}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2047-2050}/F_{MSY}$	Median ratio $F_{2047-2050}/F_{MSY}$ v $F_{2017-20}/F_{MSY}$	Risk (%)[1]	
Recruitment	Fishing level	Purse seine	Longline					SB_{2051}<LRP	$F>F_{MSY}$
Recent	Optimistic[2]	1	1	0.46	1.35	0.57	0.97	0%	26%
	SKJ MP	1.19	1	0.43	1.27	0.62	1.05	0%	29%
		1.19	1.62	0.34	0.99	0.87	1.47	0%	43%
	Fully utilised	1.22	1.62	0.34	0.99	0.90	1.53	0%	44%
Long-term	Optimistic[2]	1	1	0.43	1.26	0.79	1.34	0%	38%
	SKJ MP	1.19	1	0.41	1.19	0.89	1.51	0%	44%
		1.19	1.62	0.30	0.88	1.39	2.36	22%	66%
	Fully utilised	1.22	1.62	0.30	0.88	1.44	2.44	22%	68%

[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 20 projections) at the end of the projection (2048-2051).

[2] As the purse seine FAD closure period over 2019-2021 is equivalent to that specified within CMM 2021-01, and longline catches over that period are below limits within the CMM, the optimistic scenario off the 2019-2021 baseline is a scalar of 1 for both gears.

Table 6 Median $SB/SB_{F=0}$ values and associated risk of breaching the adopted limit reference point (LRP) of 0.2 $SB_{F=0}$ for the bigeye stock in 2026, 2035 and 2051 under the four future harvest scenarios (optimistic, skipjack MP and fully utilised) and alternative recruitment hypotheses.

Scenario		Scalars relative to 2019-21		Median $SB_{2023-2026}/SB_{F=0}$	Median $SB_{2032-2035}/SB_{F=0}$	Median $SB_{2048-2051}/SB_{F=0}$	Risk SB_{2026} < LRP	Risk SB_{2035} < LRP	Risk SB_{2051} < LRP
Recruitment	**Fishing level**	**Purse seine**	**Longline**						
Recent	Optimistic	1	1	0.39	0.45	0.46	0%	0%	0%
	SKJ MP	1.19	1	0.39	0.43	0.43	0%	0%	0%
		1.19	1.62	0.34	0.34	0.34	0%	0%	0%
	Fully utilised	1.22	1.62	0.34	0.34	0.34	0%	0%	0%
Long-term	Optimistic	1	1	0.38	0.40	0.43	0%	0%	0%
	SKJ MP	1.19	1	0.38	0.38	0.41	0%	0%	0%
		1.19	1.62	0.34	0.29	0.30	0%	8%	22%
	Fully utilised	1.22	1.62	0.33	0.28	0.30	0%	9%	22%

Table 7. Median depletion and fishing mortality values for WCPO skipjack and WCPO yellowfin tuna in 2051 relative to reference point levels (adopted limit reference point (LRP) of 0.2 $SB_{F=0}$; CMM 2021-01 objective; F_{MSY}) and risk of breaching reference points under the four future harvest scenarios (optimistic, SKJ MP, and fully utilised).

Stock	Fishing level	Scalars relative to 2019-2021		Median $SB_{2048-2051}/SB_{F=0}$	Median $SB_{2048-2051}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2047-2050}/F_{MSY}$	Median ratio $F_{2047-2050}/F_{MSY}$ v $F_{2017-20}/F_{MSY}$	Risk (%)	
		Purse seine	Longline					SB_{2051}<LRP	F>F_{MSY}
Yellowfin	Optimistic	1	1	0.41	0.93	0.57	1.14	0%	0%
	SKJ MP	1.19	1	0.38	0.87	0.61	1.22	0%	0%
	SKJ MP/Fully utilised	1.19[1]	1.62	0.34	0.78	0.67	1.34	4%	2%
					Median $SB_{2048-2051}/SB_{F=0}$ v $SB/SB_{F=0}$ = 0.50				
Skipjack	Optimistic	1	1	0.53	1.07	0.31	0.97	0%	0%
	SKJ MP/Fully utilised	1.19[1]	1.62	0.50	1	0.35	1.09	0%	2%

[1] Note that the major impact from the purse seine fishery on the yellowfin and skipjack stocks is based upon the overall effort, rather than the FAD/free school set combination. As a result, the SKJ MP/fully utilised scenarios result in comparable scalars for this fishery component.

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 2026, 2035 and 2051 under the four future harvest scenarios (optimistic, skipjack MP and fully utilised).

Scenario		Scalars relative to 2019-21		Median $SB_{2023-2026}/SB_{F=0}$	Median $SB_{2032-2035}/SB_{F=0}$	Median $SB_{2048-2051}/SB_{F=0}$	Risk SB_{2026} < LRP	Risk SB_{2035} < LRP	Risk SB_{2051} < LRP
Stock	**Fishing level**	**Purse seine**	**Longline**						
Yellowfin	Optimistic	1	1	0.43	0.40	0.41	0%	0%	0%
	SKJ MP	1.19	1	0.42	0.37	0.38	0%	0%	0%
	SKJ MP/Fully utilised	1.19[1]	1.62	0.40	0.34	0.34	0%	0%	4%
Skipjack	Optimistic	1	1	0.50	0.54	0.53	0%	0%	0%
	SKJ MP/Fully utilised	1.19[1]	1.62	0.46	0.50	0.50	0%	0%	0%

[1] Note that the major impact from the purse seine fishery on the yellowfin and skipjack stocks is based upon the overall effort, rather than the FAD/free school set combination. As a result, the SKJ MP/fully utilised scenarios result in comparable scalars for this fishery component.

Table 9 Patterns of purse seine effort (FAD sets) and longline bigeye and yellowfin catches in 2020, 2021, and 2022 with corresponding scalars from 2019-21 levels[1]. Predicted scalars under CMM 2021-01 scenarios are 1.00, 1.19 and 1.21 for FAD sets and 1.00 and 1.62 for longline catch.

	Average 2019-21	2020	Scalar 2020	2021	Scalar 2021	2022	Scalar 2022
Purse seine effort (FAD sets)[1]	15,869	15,271	0.96	17,383	1.10	18,428	1.13
Longline bigeye catch (mt)	56,083	53,298	0.95	51,054	0.91	51,873	0.92
Longline yellowfin catch (mt)	66,099	56,260	0.85	57,836	0.87	70,257	1.06

[1] In the tropical purse seine fishery according to updated data as available from October 2023. The purse seine FAD sets in this table are 'inclusive' of sets in archipelagic waters that are assumed to continue at 2019-21 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

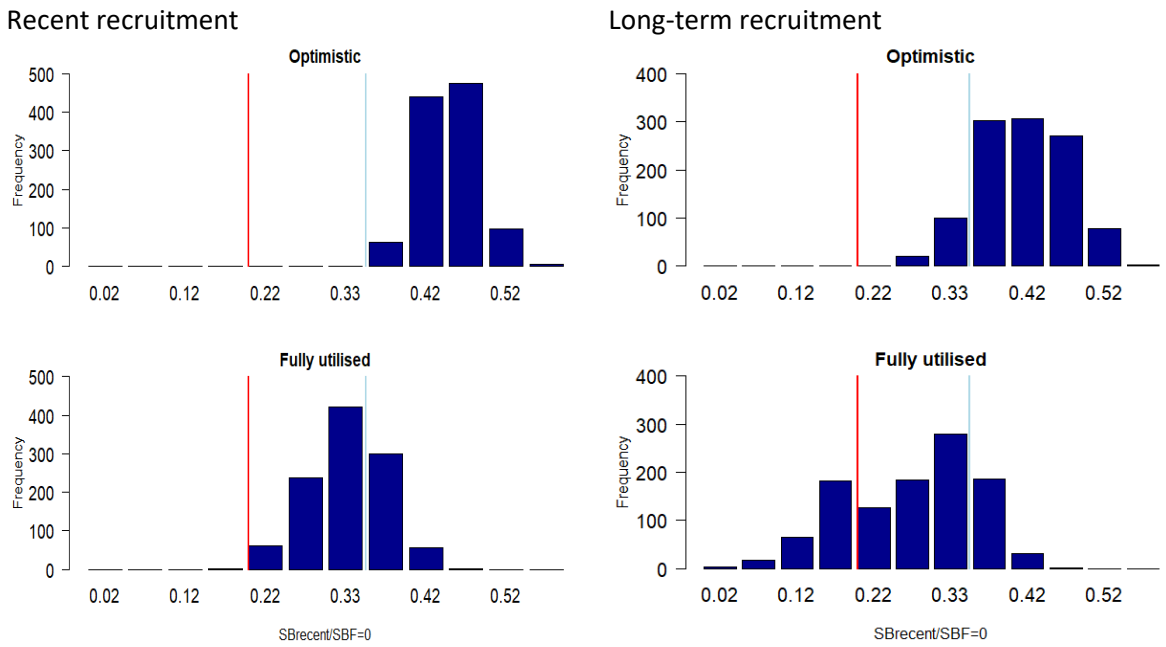

Figure 1 Distribution of $SB_{2048-2051}/SB_{F=0}$ for bigeye tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under two specific future fishing scenarios ("optimistic", "fully utilised"; top and bottom rows, respectively). Red line indicates the LRP ($0.2SB_{F=0}$). Blue line indicates 2012-2015 average depletion levels.

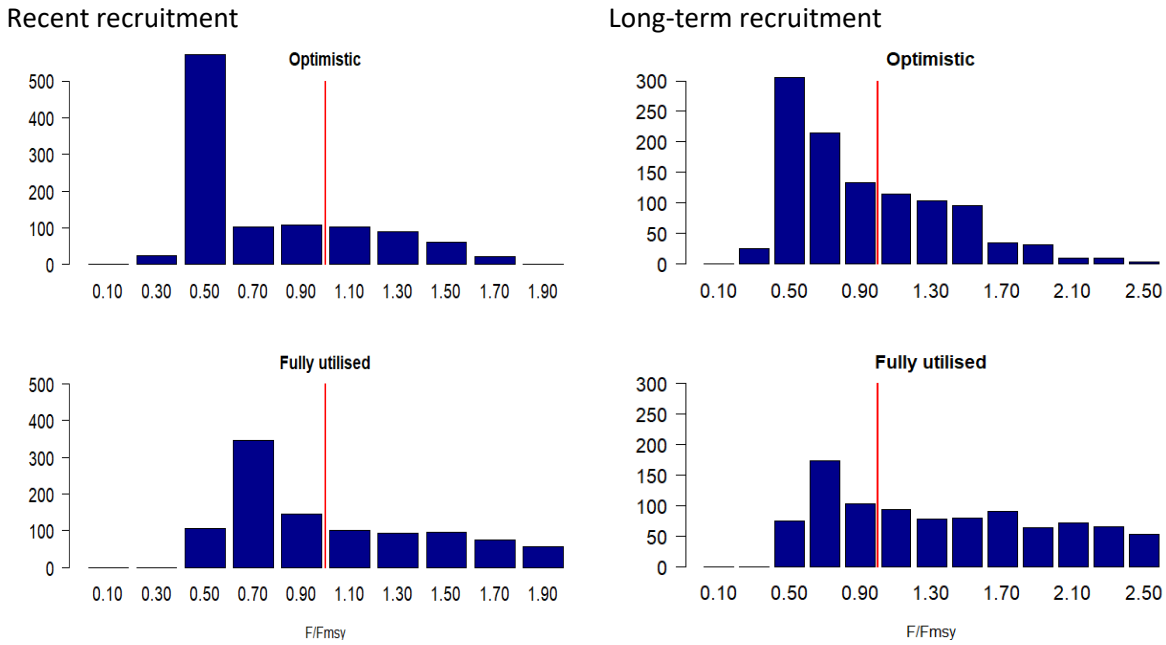

Figure 2 Distribution of F/F_{MSY} for bigeye tuna assuming recent and long-term recruitment conditions (left and right columns, respectively), under two specific future fishing scenarios ("optimistic", "fully utilised"; top and bottom rows, respectively). Red line indicates $F = F_{MSY}$.

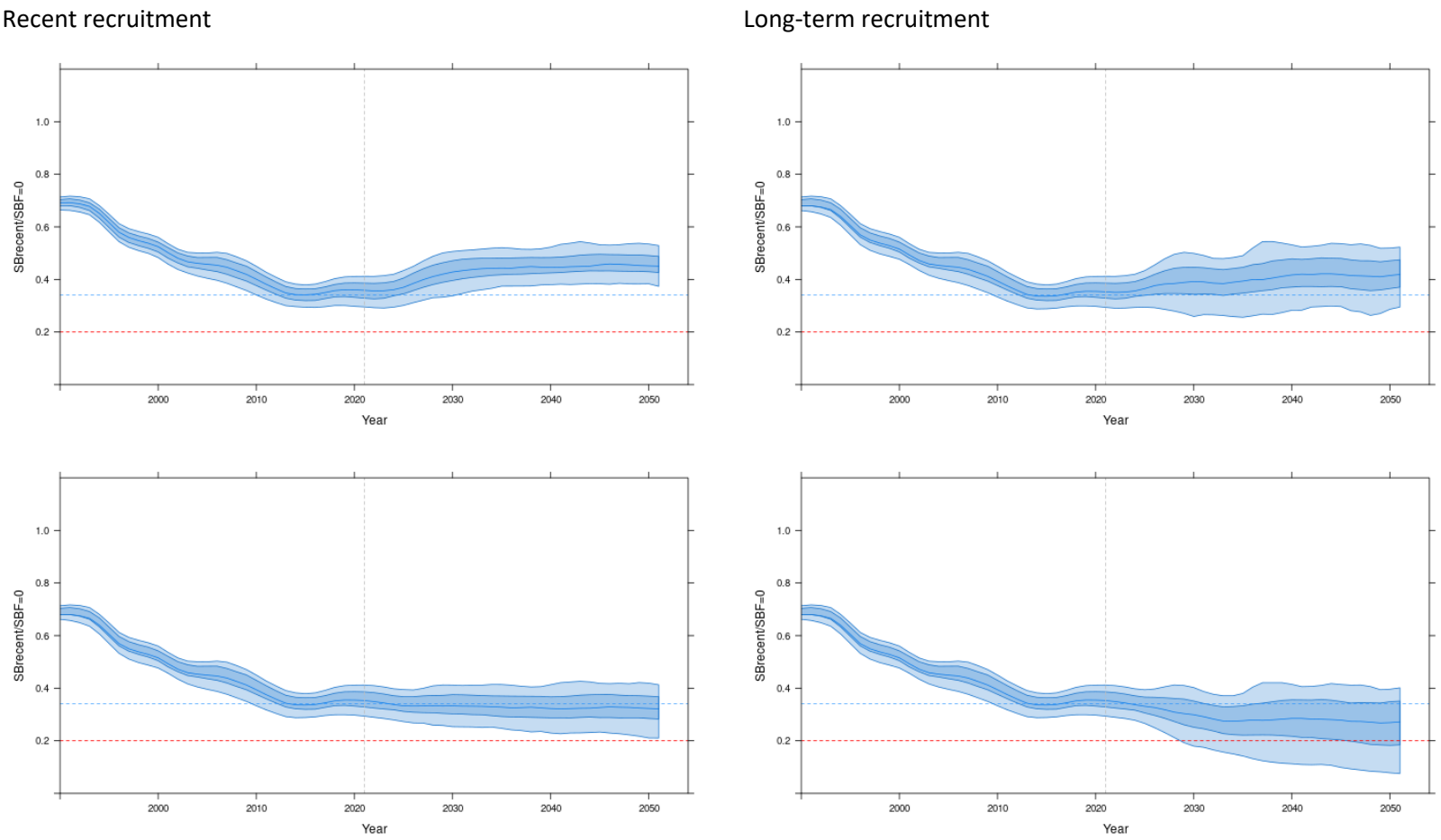

Figure 3 Time series of WCPO bigeye tuna spawning biomass ($SB_{recent}/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2021 (the vertical line at 2021 represents the last year of the assessment), and stochastic projection results for the period 2022 to 2051 under two specific future fishing scenarios ("optimistic", "fully utilised"; top and bottom rows, respectively). During the projection period (2022-2051) levels of recruitment variability are assumed to match those over the "recent" time period (2011-2020; left panel) or the time period used to estimate the stock-recruitment relationship (1962-2020; right panel). The red dashed line represents the agreed limit reference point. The blue dashed line represents the 2012-2015 average depletion level.

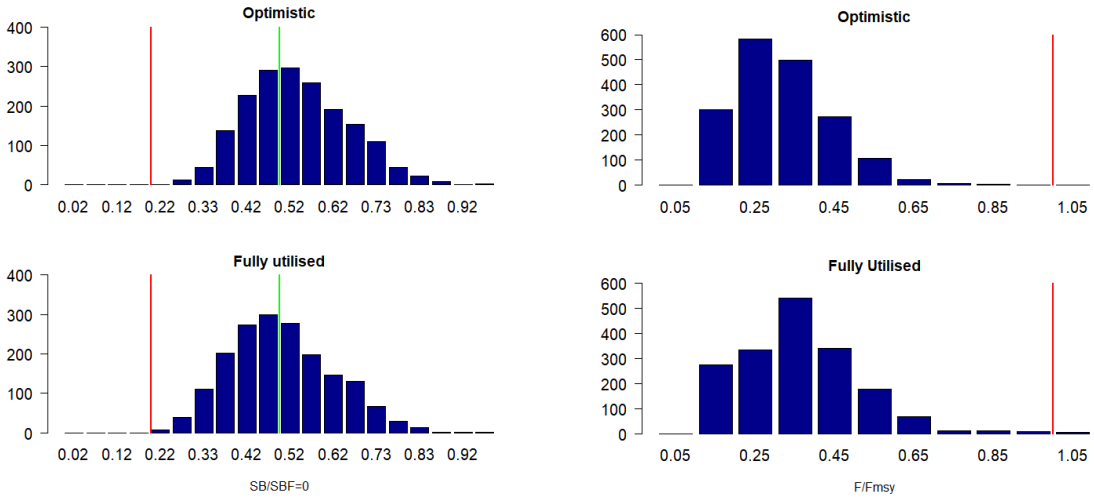

Figure 4 Distribution of $SB_{2048\text{-}2051}/SB_{F=0}$ (left column), and F/F_{MSY} for <u>skipjack</u> tuna assuming long-term recruitment conditions, for the 2022 assessment uncertainty grid, under two specific future fishing scenarios ("optimistic", "fully utilised"; top and bottom rows, respectively). Red line indicates the LRP ($0.2SB_{F=0}$) and $F=F_{MSY}$, respectively. Green line indicates the TRP on the depletion plot.

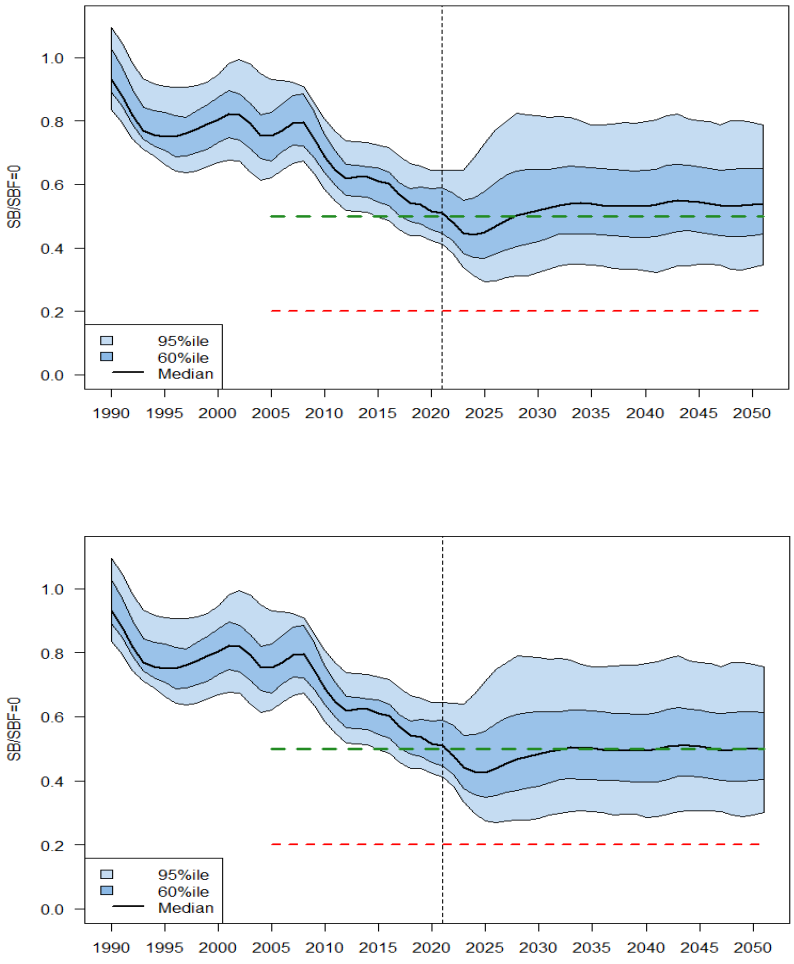

Figure 5 Time series of WCPO skipjack tuna spawning biomass ($SB_{recent}/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2021 (the vertical line at 2021 represents the last year of the assessment), and stochastic projection results for the period 2022 to 2051 under two specific future fishing scenarios ("optimistic", "fully utilised"; top and bottom rows, respectively). During the projection period (2022-2051) 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, the green dashed line the target reference point.

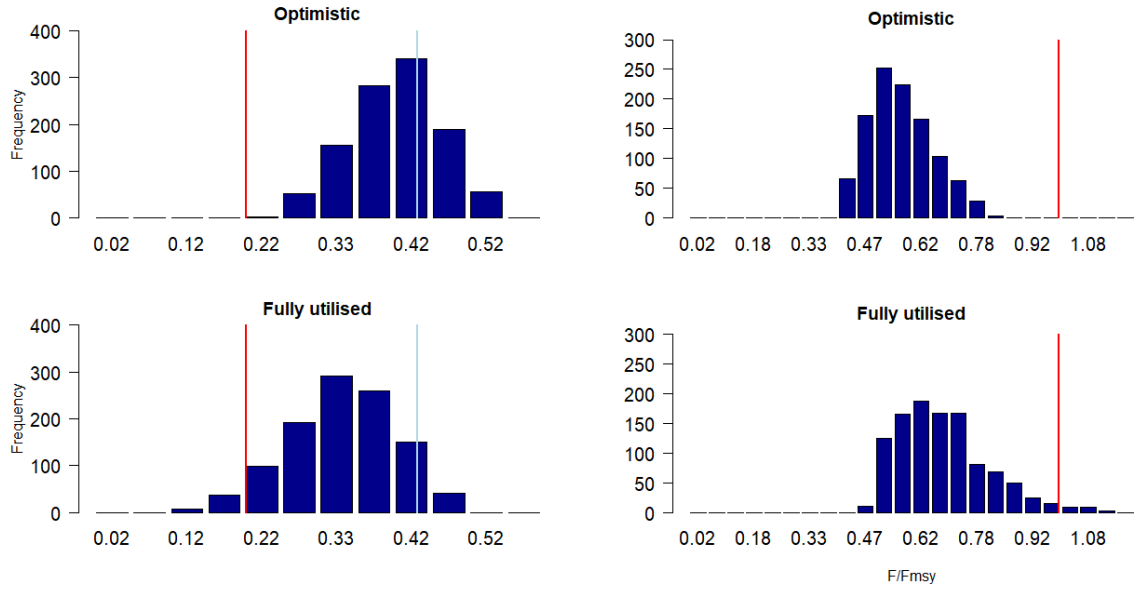

Figure 6 Distribution of $SB_{2051}/SB_{F=0}$ (left column), and F/F_{MSY} for <u>yellowfin</u> tuna assuming long-term recruitment conditions, under two specific future fishing scenarios ("optimistic", "fully utilised"; top and bottom rows, respectively). Red line indicates the LRP ($0.2SB_{F=0}$) and $F=F_{MSY}$, respectively. Blue line indicates 2012-2015 average depletion levels on the depletion plot.

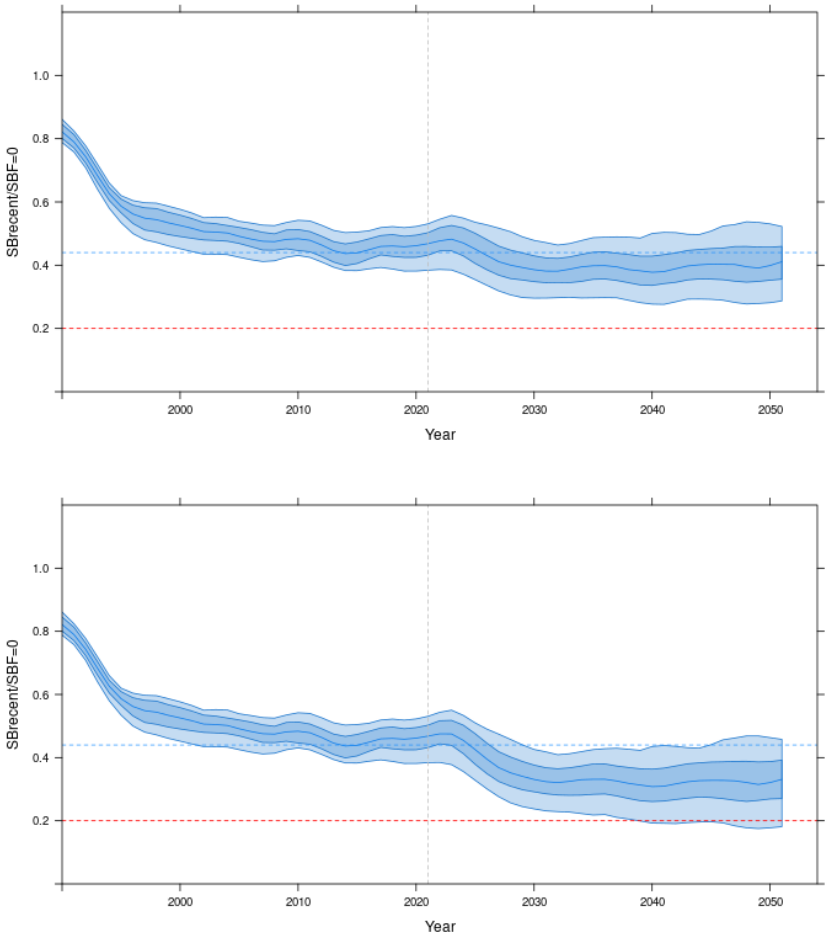

Figure 7 Time series of WCPO <u>yellowfin</u> tuna spawning biomass ($SB_{recent}/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2021 (the vertical line at 2021 represents the last year of the assessment), and stochastic projection results for the period 2022 to 2051 under two specific future fishing scenarios ("optimistic", "fully utilised"; top and bottom rows, respectively). During the projection period (2022-2051) levels of recruitment variability are assumed to match those over the time period used to estimate the stock-recruitment relationship (1962-2020). The red dashed line represents the agreed limit reference point. The blue dashed line represents the 2012-2015 average depletion level.

9. APPENDIX 1. ESTIMATION OF SCENARIOS

Purse seine FAD set numbers for CCMs are as presented in SC19-MI-IP-06, implying 2019-21 average conditions (excluding archipelagic waters) equate to 14,746 sets ('optimistic' scenario). Please refer to the footnotes for Table 3 of that paper.

The 'skipjack MP' scenario is related to purse seine effort (Table 1 of SC19-MI-IP-06), including archipelagic water effort (consistent with the use of the relevant stock assessments) but excluding Indonesia and Philippines values. The scalar of 2012 effort (55,205 days) to 2019-2021 average effort (46,443 days) is therefore 1.19. Please refer to the footnotes for Table 1 of that paper.

The 'fully utilised' scenario takes into account the potential increase in high seas effort that could occur within the skipjack MP output (2012 levels). This was calculated from the difference between high seas days in 2019-2021 by flag and the limits in CMM 2021-01 Table 2 and a flag-level FAD sets per day, using Tables 2 and 5 of SC19-MI-IP-06. Please refer to the footnotes for those tables of that paper.

Longline bigeye catch assumed for CCMs, and corresponding scalars relative to 2019-21 average conditions under the two scenarios. Refer to Table 6 of SC19-MI-IP-06 and associated footnotes.

CCM	**'Fully utilised'**	**'Optimistic'**
	CMM 2021-01 levels if limited, otherwise 2000mt (non-SIDS) or 2019-21 average	CMM 2021-01 levels or 2019-21 if lower
AMERICAN SAMOA	2,000	1,186
AUSTRALIA	2,000	303
BELIZE	2,000	-
CANADA	2,000	-
CHINA	8,224	7,180
COOK ISLANDS	101	101
EU-PORTUGAL	2,000	-
EU-SPAIN	2,000	58
FSM	2,441	2,441
FIJI	800	800
FRENCH POLYNESIA	958	958
GUAM	2,000	-
INDONESIA	5,889	1,521
JAPAN	18,265	9,305
KIRIBATI	1,162	1,162
MARSHALL ISLANDS	1,050	1,050
NAURU	-	-
NEW CALEDONIA	50	50
NEW ZEALAND	2,000	67
NIUE	-	-
NORTHERN MARIANAS	2,000	1,142
PALAU	285	285
PAPUA NEW GUINEA	60	60
PHILIPPINES	2,000	-
REPUBLIC OF KOREA	13,942	13,469
SAMOA	142	142
SOLOMON ISLANDS	885	885
TONGA	14	14
TUVALU	28	28
CHINESE TAIPEI	10,481	7,786
USA	3,554	3,554
VANUATU	2,499	2,499
WALLIS AND FUTUNA	-	-
Total	90,830	56,047
Scalar	**1.62**	**1.00**

10. APPENDIX 2. ADDITIONAL ANALYSES REQUESTED BY CCMS

This appendix has been updated to include data for the year 2022. Minor changes to data for prior years may occur due to updates of source data in SC19-MI-IP-06.

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 (para 15 in updated CMM 2021-01), 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 (para 15 in updated CMM 2021-01) 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 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 and summarised as scalars on the 2019-21 baseline average levels. We also determine what the reduction in the full FAD closure would be to compensate for removing the exemptions.

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 2019, 2020, 2021 and 2022 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 11 provides a summary of the implications if the FAD sets conducted under the Footnote 1 exemption not been conducted for the years 2019-2022. For this analysis we have not included FAD sets by the Philippines in HSP1. This is to ensure that the impact of the removal of the Footnote 1 exemption on the FAD sets scalar is not biased by including Philippines HSP1 FAD set that are not equivalent to 'typical' high seas sets on drifting FADs. Typical highs seas FAD sets harvest 5-6 times more tuna that the Philippines HSP1 FAD sets, that are on anchored FADs with smaller nets and smaller vessels (see WCPFC20-2023-16).

Table 10. Summary of FAD effort and adjusted species catch taken within the 2019, 2020, 2021 and 2022 three-month FAD closure by 'footnote 1' vessels.

Year	Vessels		FAD sets	Total catch (MT)			
	Notifying	Fished		Skipjack	Yellowfin	Bigeye	Total
2019	55	55	638	35,484	1,670	394	37,548
2020	92	87	1,116	54,525	6,570	1,553	62,648
2021	92	82	770	21,708	8,915	503	31,126
2022	71	62	775	28,763	1,560	930	31,253

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

Table 11. Estimated implications for the FAD set scalar based on the 2019-2021 baseline period if the Footnote 1 exemption was removed, and the potential reduction of the full 3 month FAD fishing closure that could compensate for the removal of the Footnote 1 exemption.

Evaluation		Approx. FAD set change	Scalar relative to 2019-21	Approximate equivalent main (full) FAD closure period (months)
1	CMM evaluation scalars (2019-21 baseline = 14,746 FAD sets, **excludes Phil HSP1**)			
2	Footnote 1 (2019)	**-638**	0.96	~ 2.7
3	Footnote 1 (2020)	**-1,116**	0.92	~ 2.5
4	Footnote 1 (2021)	**-770**	0.95	~ 2.6
5	Footnote 1 (2022)	**-775**	0.95	~ 2.6

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 2019, 2020, 2021 and 2022 and calculate the average across them. For Kiribati vessels, fishing activity in those months reflects that in neighbouring high seas areas.

For this analysis the difference between FAD sets conducted by the Philippines vessels in HSP1 and vessels fishing in the highs seas adjacent to the Kiribati EEZ is significant and should be taken into account. It is estimated that sets on drifting FADs by the larger vessels in the industrial purse seine fleet take about 5.6 time more tuna per set than for the smaller Philippines vessels who set on anchored FADs in the HSP1. Previously analyses of these exemptions have combined the Kiribati and Philippines components, but for this evaluation we have now considered it is more appropriate to present the analysis for the Kiribati and Philippines HSP1 exemptions separately.

Kiribati exemption from additional 2-month high seas FAD closure

Table 12. Summary of numbers of FAD sets and estimated species catches 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 for 2019, 2020, 2021 and 2022.

Kiribati adjacent HS

Year	Period	FAD sets	Total catch (MT)			
			Skipjack	Yellowfin	Bigeye	Total
2019	Apr-May	178	8,216	139	232	8,587
2019	Nov-Dec	85	2,854	236	213	3,303
2019	**Average**	**132**	**5,535**	**188**	**223**	**5,945**
2020	Apr-May	84	5,566	486	496	6,548
2020	Nov-Dec	50	2,358	170	97	2,625
2020	**Average**	**67**	**3,962**	**328**	**297**	**4,587**
2021	Apr-May	47	1,180	115	55	1,350
2021	Nov-Dec	71	2,113	109	84	2,306
2021	**Average**	**59**	**1,647**	**112**	**70**	**1,828**
2022	Apr-May	12	416	11	13	440
2022	Nov-Dec	91	3,227	59	109	3,395
2022	**Average**	**52**	**1,822**	**35**	**61**	**1,918**

1. Excludes Archipelagic waters
2. KIRIBATI High seas: FAD SETS and Tuna species catch as reported on logbooks

Table 13. Estimated implications for the FAD set scalar based on the 2019-21 baseline period if the Paragraph 15 exemption was removed for the Kiribati adjacent high seas, and the potential reduction of the full 3-month FAD fishing closure that could compensate for the removal of the exemption.

Evaluation		Approx. FAD set change	Scalar relative to 2019-21	Approximate equivalent main (full) FAD closure period (months)
1	CMM evaluation scalars (2019-21 baseline = 14,746 FAD sets, excludes Phil HSP1)			
2	Para 15 Kiribati (2019)	-132	0.99	~ 2.9
3	Para 15 Kiribati (2020)	-67	0.99	~ 2.9
4	Para 15 Kiribati (2021)	-59	0.99	~ 2.9
5	Para 15 Kiribati (2022)	-52	0.99	~ 2.9

Philippines exemption from additional 2-month high seas FAD closure

Table 14. Summary of the numbers of FAD sets reported from the Philippines HSP1 during each of the 2-month additional high seas FAD closure period options and the average FAD sets across the two periods, along with associated catches estimated for the three tropical tuna species for 2019, 2020, 2021 and 2022. Note the much lower tuna catches relative to the numbers of FAD sets in comparison to table 12 for the Kiribati adjacent high seas.

Philippines (HSP#1)

Year	Period	FAD sets	Total catch (MT)			
			Skipjack	Yellowfin	Bigeye	Total
2019	Apr-May	661	2,458	1,790	681	4,929
2019	Nov-Dec	501	2,655	1,476	228	4,359
2019	**Average**	**581**	**2,556**	**1,633**	**455**	**4,644**
2020	Apr-May	687	7,058	1,728	291	9,078
2020	Nov-Dec	667	6,534	2,382	94	9,009
2020	**Average**	**677**	**6,796**	**2,055**	**192**	**9,044**
2021	Apr-May	495	3,627	1,473	266	5,366
2021	Nov-Dec	553	2,157	1,431	104	3,693
2021	**Average**	**524**	**2,892**	**1,452**	**185**	**4,530**
2022	Apr-May	468	2,639	852	110	3,602
2022	Nov-Dec	551	4,156	1,386	158	5,700
2022	**Average**	**510**	**3,398**	**1,119**	**134**	**4,651**

1. Excludes Archipelagic waters
2. PHILIPPINES HSP#1: FAD Sets and Tuna species catch as reported by OBSERVERS (100% coverage)

Table 15 Estimated implications for the FAD set scalar based on the 2019-21 baseline period if the Paragraph 15 exemption was removed for Philippines HSP1, and the potential reduction of the full 3-month FAD fishing closure that could compensate for the removal of the exemption.
Note: For this analysis we present two versions: a) which just indicates the implications of removing the FADs sets for the HSP1 (i.e., Philippines anchored FAD fishery), and, b) which adds the Philippines HSP1 FAD sets to the overall FAD sets analysis but divides the number of Philippines HSP1 FAD sets by 5.6 so that the numbers of sets are more equivalent, in terms of impact, to the high seas FAD sets on drifting FADs.

a) Considering only the Philippines HSP1 anchored FAD fishery, this table show the reduction in FAD sets for the Philippines HSP1, acknowledging that a HSP1 FAD set is not the same as a standard high seas drifting FAD set.

Evaluation		Approx. FAD set change	Scalar relative to 2019-21 HSP1 FAD sets
1	CMM evaluation scalars (2019-21 baseline = 2446 HSP1 FAD sets)		
2	Para 15 Phil HSP1 (2019)	-581	0.76
3	Para 15 Phil HSP1(2020)	-677	0.72
4	Para 15 Phil HSP1 (2021)	-524	0.79
5	Para 15 Phil HSP1 (2022)	-510	0.79

b) Incorporating the adjusted Philippines HSP1 anchored FAD sets (i.e. divided by 5.6) into the wider high seas purse seine effort for the para 15 exemption evaluation.

Evaluation		Approx. FAD set change (Phil HSP1 adjusted)	Scalar relative to 2019-21 all FAD sets (Phil. HSP1 adjusted by 5.6)	Approximate equivalent main (full) FAD closure period (months)
1	CMM evaluation scalars (2019-21 baseline = 15,183 FAD sets, includes Phil HSP1 adjusted sets)			
2	Para 15 Phil HSP1 (2019)	-104	0.99	~ 2.9
3	Para 15 Phil HSP1(2020)	-121	0.99	~ 2.9
4	Para 15 Phil HSP1 (2021)	-94	0.99	~ 2.9
5	Para 15 Phil HSP1 (2022)	-91	0.99	~ 2.9

PURSE SEINE HIGH SEAS EFFORT RELATIVE TO CMM LIMITS

To address the third SC15 request element, Table 16 below compares the high seas effort limits within CMM 2021-01 (Table 2) with the patterns of actual fishing in 2019, 2020, 2021, and 2022 which includes the effort in the 'overlap' area for USA in 2019, but not in 2020 and 2021, 2022[4]. In 2021 and 2022 no HS day limits were breached.

Table 16. Comparison of 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 2019, 2020, 2021 and 2022.

Flag	CMM limits[2]	Days fished in international waters 20°N-20°S			
		2019	2020	2021	2022
China	26	22	16	23	21
Ecuador	**	0	0	0	1
El Salvador	**	10	30	27	27
European Union	403	146	194	226	214
Indonesia	(0)	0	0	0	0
Japan	121	29	21	76	53
New Zealand	160	136	63	0	0
Philippines	#	2654	2635	2539	2562
Republic of Korea	207	182	172	102	50
Chinese Taipei	95	84	62	57	59
USA	1,270	1485	1658	721	700
Total		4,748	4,851	3,771	3,687

**subject to CNM on participatory rights
Measures that Philippines would take are in Attachment 2 of CMM 2022-01
[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 for 2020, 2021 and 2022 management of high seas effort in the WCPFC-IATTC overlap area will be through the IATTC measures. As such, the 2020, 2021 and 2022 US purse seine high seas days excludes the WCPFC-IATTC overlap area.

PATTERNS OF HIGH SEAS EFFORT

To examine the fourth SC15 request element, we show the average pattern of effort (days fished) in the high seas over the 2019-21 baseline and the levels seen in the individual years 2019, 2020, 2021 and 2022 (**Table 17**).

Table 17. Comparison of average high seas purse seine effort (days) by flag over 2019-21 with days fished in tropical international waters (20°N to 20°S) in 2019, 2020, 2021 and 2022.

Flag	Average 2019 to 2021	Reported in 2019	Reported in 2020	Reported in 2021	Reported in 2022
China	20	22	16	23	21
Cook Islands	95	72	29	185	308
Ecuador	0	0	0	0	1
El Salvador	22	10	30	27	27
European Union	189	146	194	226	214
FSM	896	1,053	694	942	404
Indonesia	0	0	0	0	0
Japan	42	29	21	76	53
Kiribati	723	950	654	566	273
Marshall Is.	682	955	698	394	177
Nauru	231	182	397	115	125
New Zealand	66	136	63	0	0
PNG	2	0	4	2	2
Philippines	2,609	2,654	2,635	2,539	2,562
Republic of Korea	152	182	172	102	50
Solomon Is.	37	91	19	1	0
Tuvalu	136	71	127	209	61
Chinese Taipei	68	84	62	57	59
USA	1,288	1,485	1,658	721	700
Vanuatu	137	145	132	133	121
Total	7,391	8,267	7,605	6,318	5,158

IMPACT OF HIGH SEAS EFFORT ON PURSE SEINE SCALARS

The analysis summarised in Table 18 show separately the effects of removing all reported high seas effort by CCMs with limits in table 2 of CMM 2021-01, and the effect of removing all reported effort by CCMs not included in table 2 of CMM 2021-01. The amount of FAD sets that would have been removed is indicated along with the reduction in the full 3 month FAD closure that would compensate for the removal of the high seas effort.

Because the Philippines is listed in table 2 with reference to their HSP1 conditions (attachment 2 of CMM 2021-01), for this evaluation we included the 'adjusted' FAD set numbers (divided by 5.6) for the Philippines HSP1 FAD set.

Table 18 Implications of removing high seas effort on FAD sets.

Evaluation		Approx. FAD set change	Scalar relative to 2019-21	Approximate equivalent main (full) FAD closure period (months)
CMM evaluation scalars (2019-21 baseline = 15,183 FAD sets, includes Phil HSP1 adjusted sets)				
1	Remove table 2 high seas effort (2019)	-1171	0.92	¬2.5
2	Remove table 2 high seas effort (2020)	-1425	0.91	¬2.3
3	Remove table 2 high seas effort (2021)	-1368	0.91	¬2.4
4	Remove table 2 high seas effort (2022)	-1153	0.92	¬2.5
5	Remove non-table 2 high seas effort (2019)	-1072	0.92	¬2.5
6	Remove non-table 2 high seas effort (2020)	-1187	0.92	¬2.5
7	Remove non-table 2 high seas effort (2021)	-1160	0.92	¬2.5
8	Remove non-table 2 high seas effort (2022)	-551	0.96	¬2.7

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 (now 2021-01) 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. The resulting number of FAD sets were removed from each flag's total expected under the 'fully utilised scenario' where we assume all high seas days allowed under the Measure are used and effort was at 2012 levels. The scalar is them recalculated with reduced number set and compared to the scalar under the 'fully utilised' scenario (Table 4). This assumes that effort is not transferred into EEZs.

Table 19. Purse seine scalar under the 'fully utilised' 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	'Fully utilised' scenario	Table 2 effort limits set to zero
Scalar	1.22	1.14

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 'fully utilised' scenarios.

Table 20. Longline catch scalar under 'optimistic' and 'fully utilised' scenarios, and under the assumption that Table 3 limits were set to zero.

	'Optimistic' scenario		'Fully utilised' scenario	
Scenario	As main text	Table 3 catches set to zero	As main text	Table 3 catches set to zero
Scalar	1	0.24	1.62	0.54

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 were assumed to be removed, and US fleet catches maximised at the level specified in CMM 2021-01 Table 3. The resulting scalars were compared to the 'optimistic' scenario, since the 'fully utilised' scenario assumed territories expanded their catches to 2,000 mt as permitted under Paragraph 43.

Table 21. 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 22 below has been updated based upon the agreed 2023 stock assessment results, presenting the median 'recent' depletion levels from the stock assessment, the corresponding levels in 2012-2015, and the depletion ratio of $(SB_{2018\text{-}21}/SB_{F=0}) / (SB_{2012\text{-}15}/SB_{F=0})$.

Table 22. Ratio of the recent median spawning depletion to that of 2012-15 as determined from the most recent stock assessments (2023) for bigeye and yellowfin tuna.

Stock	$SB_{2018\text{-}21}/SB_{F=0}$	$SB_{2012\text{-}15}/SB_{F=0}$	Ratio: $(SB_{2018\text{-}21}/SB_{F=0})/(SB_{2012\text{-}15}/SB_{F=0})$
Bigeye	0.35	0.34	1.03
Yellowfin	0.47	0.44	1.07