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RESULTS OF ANALYSES REQUESTED BY TTMW2 and TTMW1

WCPFC18-2021-15
4 November 2021

SPC-OFP
Pacific Community (SPC), Noumea, New Caledonia

Summary

The 1st workshop on the Development of New WCPFC Tropical Tuna Measure (TTMW1) requested specific analyses from the SSP to help inform Commission members on options for the new Measure (Attachment 2 of the TTMW1 report). Similarly, the 2nd workshop (TTMW2) requested further specific analyses from the SSP (Attachment 1 of the TTMW2 report).

The results of all analyses are presented here, grouped into the different categories provided in the Chair's report of the two TTMWs (see Appendix 1 and 2 of this paper, and the summary provided at the beginning of each section).

For each analysis, a short methodological summary is provided where necessary, particularly where interpretation of the request by the SSP was necessary to perform the analysis. This is then followed by the results and where appropriate, key points for CCMs to note when interpreting those results.

TRPs

Source	Request
TTMW1	**BET** TRP as **average depletion 2000-2004**, determine MSY, and F, as a proportion of recent levels (2014-2017), projected to achieve this TRP. Overall, region, fish size (juv/ad).
TTMW1	**BET** TRP as **median depletion 2000-2004**, determine MSY, and F, as a proportion of recent levels (2014-2017), projected to achieve this TRP. Overall, region, fish size (juv/ad).
TTMW1	**BET** Evaluate **2007-2009 fishing level** in terms of median depletion level and the corresponding change in spawning biomass from 2012-2015 average, recent and long-term recruitment conditions
TTMW1	**SKJ** Evaluate applying purse seine effort 2007-2009 average, equilibrium yield v MSY, LRP risks for **50%, 48%, 46%, 44% and 42%$SB_{F=0}$, plus 36, 38 and 40%** (Tokelau).
SC17	**BET and YFT** Development of yield and spawning biomass per recruit curves by fisheries sector for bigeye and yellowfin tuna (SC17 draft summary report, para 271).
SC17	**SPA** Calculate SPA outcomes for different candidate BET/YFT TRP levels presented in MI-WP-01 (SC17 draft summary report, para 265).

For the analysis of bigeye, an approach comparable to that described in SC17-MI-WP-01 was used to identify the identical scalars on purse seine effort and longline catch off 2016-2018 average fishing levels that led to the bigeye stock achieving on average the stock depletion level (%$SB_{F=0}$) specified in the request. Corresponding change from the 2012-2015 average biomass level, yield as a % of MSY, F/F_{MSY}, and risk of falling below the limit reference point (20%$SB_{F=0}$) were identified. Stock-wide fishing mortality at age was computed and adjusted by the corresponding population juvenile/adult numbers-at-age and time period to calculate the average fishing mortality across those age groups. Further technical details are provided in SC17-MI-WP-02.

For skipjack, a full description of the work is provided in SC17-MI-WP-02. In summary, stock projections were performed under different future scenarios for purse seine fishing effort. For each, the stock was projected into the future using the following procedure:

1. Run 100 simulations for 30 years into the future for each of the 54 stock assessment models - each simulation representing a possible 'future' trajectory for recruitment;
2. Run those simulations assuming long-term recruitment patterns (future recruitment is defined by the estimated stock recruitment relationship, with variability around it defined by recruitment estimates from the stock assessment over the period 1982-2017);
3. Assume catchability remains constant into the future – i.e. no effort creep occurs in WCPO fisheries;
4. Taking into account the SC15 plausibility weightings, combine the results across each assessment model run and calculate the median level of terminal spawning biomass compared to $SB_{F=0}$;
5. Adjust the level of purse seine fishing in the future from the 2012 baseline level so that the median stock size was equivalent to the candidate TRP level at the end of the projection period, while maintaining other fisheries at 2012 levels with the exception of domestic fisheries in Indonesia/Philippines/Vietnam which were maintained at 2016-2018 average levels in the assumption that recent estimates better reflected improvements in data collection.

Results and figures for bigeye (under recent and long-term recruitment assumptions) are provided first, then those for skipjack.

Bigeye

Requested results are presented for bigeye under the assumption of 'recent' (Table 1, Figure 1) and 'long-term' (Table 2, Figure 2) recruitment patterns. All requested depletion levels imply stock sizes larger than those in the 'recent' period estimated within the stock assessment, by between 16 and 30%.

Under 'recent' recruitment assumptions, for the first two levels, purse seine effort and longline catch was either maintained at 2016-2018 average levels or decreased slightly, while to achieve the third level (median depletion over 2007-2009), effort and catch needed to be increased by 17% relative to that baseline (Table 1).

Under 'long term' recruitment assumptions, for the first two levels, purse seine effort and longline catch needed to be reduced relative to 2016-2018 average levels, by up to 17%, while to achieve the third level (median depletion over 2007-2009), effort and catch could be maintained at 2016-2018 levels (Table 2).

Table 1. Fishery metrics under specified bigeye tuna depletion levels ($SB/SB_{F=0}$) where recent recruitments were assumed to continue.

Request	Depletion level ($SB/SB_{F=0}$)	PS/LL scalar (cf 2016-18)	Change in spawning biomass (%$SB_{F=0}$) from 2012-2015 average	Median total equilibrium yield (%MSY)	F/F_{MSY}	Risk $SB/SB_{F=0}$ < LRP	Juvenile $F_{2048}/F_{2014\text{-}2017}$	Adult $F_{2048}/F_{2014\text{-}2017}$
Average depletion 2000-2004	0.48	1	+30%	95%	0.69	0	1.18	0.81
Median depletion 2000-2004	0.49	0.96	+34%	94%	0.67	0	1.13	0.77
Median depletion 2007-2009	0.43	1.17	+17%	97%	0.81	0	1.50	1.01

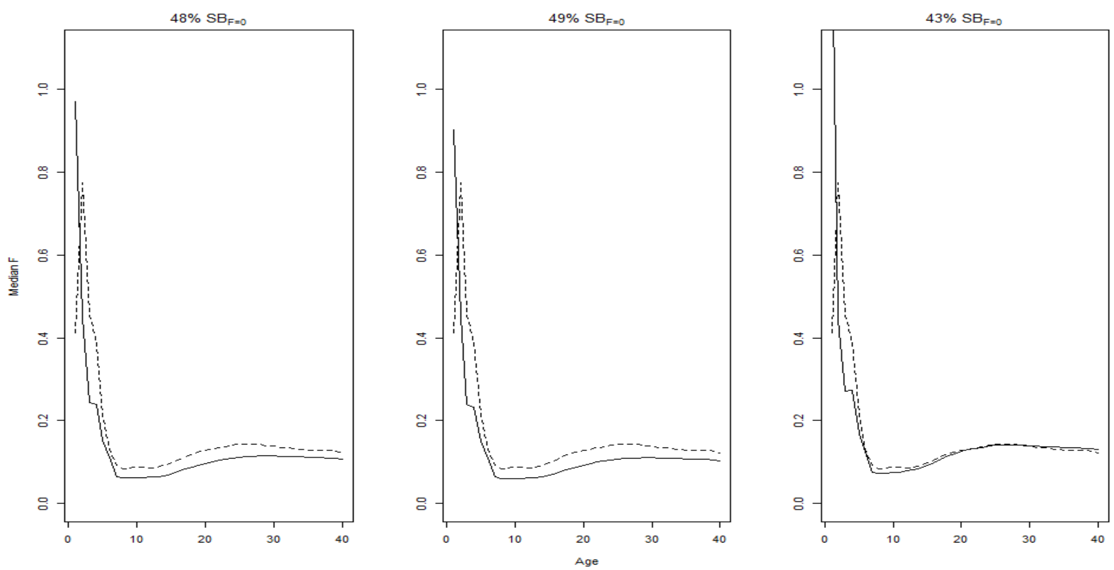

Figure 1. Pattern of (median) overall fishing mortality-at-age (quarter) for the three bigeye proposed depletion levels. Dashed line presents estimated 2014-2017 F-at-age, solid line the projected 2048 F-at-age under the assumption that recent recruitment levels continue.

Table 2. Fishery metrics under specified bigeye tuna depletion levels ($SB/SB_{F=0}$) where long-term recruitments were assumed to continue.

Request	Depletion level ($SB/SB_{F=0}$)	PS/LL scalar (from 2016-18)	Change in spawning biomass ($\%SB_{F=0}$) from 2012-2015 average	Median total equilibrium yield (%MSY)	F/F_{MSY}	Risk $SB/SB_{F=0}$ < LRP	Juvenile $F_{2048}/F_{2014\text{-}2017}$	Adult $F_{2048}/F_{2014\text{-}2017}$
Average depletion 2000-2004	0.48	0.85	+30%	96%	0.79	2%	1.52	0.78
Median depletion 2000-2004	0.49	0.83	+34%	96%	0.78	1%	1.50	0.76
Median depletion 2007-2009	0.43	1	+17%	97%	0.89	5%	1.65	0.97

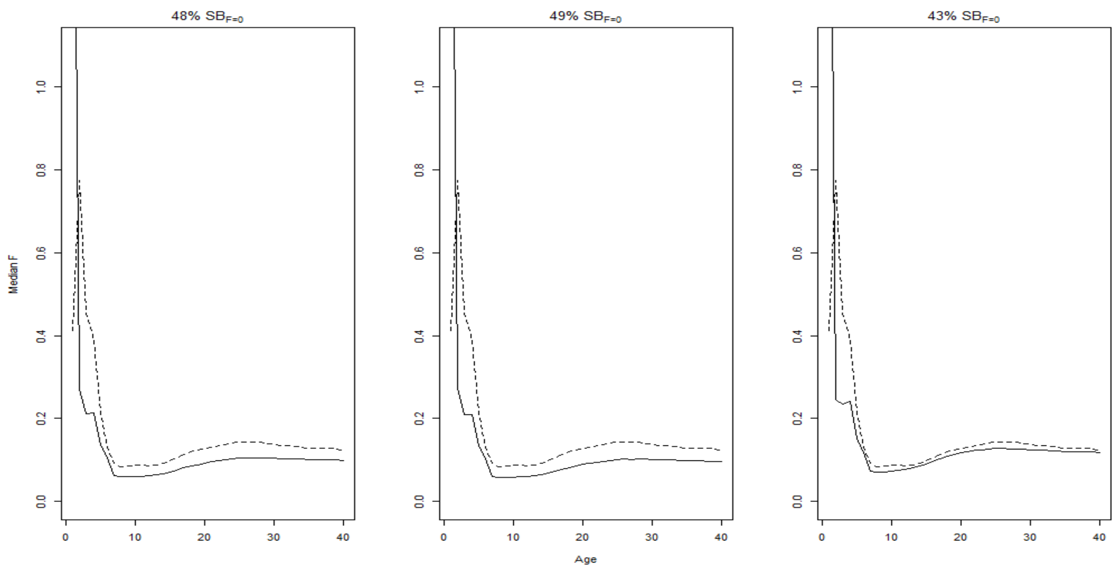

Figure 2. Pattern of (median) overall fishing mortality-at-age (quarter) for the three bigeye proposed depletion levels. Dashed line presents estimated 2014-2017 F-at-age, solid line the projected 2048 F-at-age under the assumption that long-term recruitment levels continue.

Skipjack

The summary of results is presented in Table 4. Under baseline (2012) fishing levels the stock is predicted, on average, to fall slightly compared to 'recent' (2015-2018) levels (44% $SB_{F=0}$), to 42% $SB_{F=0}$. This is very slightly below 2012 depletion levels but is an equivalent % $SB_{F=0}$ value at 2 decimal places. Examining the four other median depletion levels requested by WCPFC16 (50%, 48%, 46% and 44% $SB_{F=0}$), these levels imply reductions in purse seine effort from 2012 levels of 7 to 25%, lead to predicted increases in spawning biomass from 2012 levels of between 3 and 18%, and either maintained biomass at recent assessed levels, or predict an increase in biomass by 5 to 13%. Total equilibrium yield is predicted to reduce compared to that under 2012 'baseline' levels, to 78-95% of MSY. For the three median depletion levels requested by WCPFC17 (36%, 38% and 40%), these levels imply increases in purse seine effort from 2012 levels of between 5 and 30%, and lead to predicted decreases in spawning biomass from 2012 levels of between 5 and 14%. Total equilibrium yield is predicted to increase very slightly compared to that under 2012 'baseline' levels, to 98% of MSY (reaching the flat peak of the yield curve). There was no risk of falling below the LRP associated with any of these depletion levels based on the current uncertainty framework.

Resulting stock-wide age-averaged F for juvenile and adult components of the population and median F-at-age are presented in Table 3 and Figure 3. Interpretation of the results is challenging given that future fishing mortality is strongly influenced by the required settings within the projection, in particular that future domestic fishery and pole-and-line catches continue at specified levels (2016-2018 and 2012 respectively), while purse seine is projected on effort. The composition of gears within the projected fishery and their impacts on the stock will therefore change relative to that in the historical (2012) period. This is clear when examining the relative change in fishing mortality in juvenile and adult segments of the population, with that on juveniles increasing notably at all examined depletion levels. This was driven by significant increases in fishing mortality within Region 5 of the skipjack assessment model (western tropical WCPO encompassing Indonesia and Philippines), where future domestic fishery catches continue at 2016-2018 levels (Figure 4, Figure 5).

Table 3. Fishing mortality estimated under each median skipjack tuna depletion level ($SB/SB_{F=0}$), calculated as the stock-wide age-averaged F for juveniles and adults in 2048, presented as a multiplier from that estimated in 2012, or the average estimated over 2012-2015.

Median depletion level (%$SB_{F=0}$)		Juvenile F_{2048}/F_{2012}	Juvenile $F_{2048}/F_{2012-2015}$		Adult F_{2048}/F_{2012}	Adult $F_{2048}/F_{2012-2015}$
50%		1.20	1.06		0.89	0.90
48%		1.24	1.10		0.92	0.93
46%		1.31	1.15		0.97	0.98
44%		1.39	1.22		1.02	1.04
42%		1.48	1.30		1.08	1.09
40%		1.53	1.35		1.11	1.13
38%		1.74	1.54		1.22	1.24
36%		1.92	1.69		1.29	1.31

As requested by SC17, Table 5 provides the Annual Catch Estimates (ACE) for key Region 5 fisheries by flag and gear in 2012 and 2016-2018 (average), as used within the stock assessment model for these fisheries.

Table 4. Median depletion levels of skipjack tuna ($SB/SB_{F=0}$) and corresponding change in biomass from 2007-2009, 2012, 2012-15 and 2015-18 average levels, change in purse seine effort (scalar), resulting median total equilibrium yield (as a percentage of MSY) and the risk of falling below the LRP. Results under baseline fishery conditions indicated by shaded row.

Median depletion level ($\%SB_{F=0}$)	Change in spawning biomass ($\%SB_{F=0}$) from 2007-2009 levels	Change in spawning biomass ($\%SB_{F=0}$) from 2012 levels	Change in spawning biomass ($\%SB_{F=0}$) from 2012-2015 average	Change in spawning biomass ($\%SB_{F=0}$) from 2015-2018 average	Change in PS effort from 2012 levels*	Median total equilibrium yield (%MSY)**	Risk $SB/SB_{F=0}$ < LRP
50%	-17%	+18%	+2%	+13%	-25%	78%	0%
48%	-19%	+14%	-1%	+10%	-21%	81%	0%
46%	-23%	+9%	-6%	+5%	-15%	87%	0%
44%	-27%	+3%	-10%	0%	-7%	95%	0%
42%	-30%	-2%	-15%	-5%	0%	97%	0%
40%	-32%	-5%	-18%	-8%	+5%	98%	0%
38%	-35%	-10%	-22%	-13%	+20%	98%	0%
36%	-39%	-14%	-25%	-16%	+30%	98%	0%

* ‘2012’ conditions as described in the main text. No future ‘effort creep’ assumed, i.e. CPUE is assumed to be consistently proportional to abundance.

** Recalculated using estimated equilibrium catch at defined fishing level

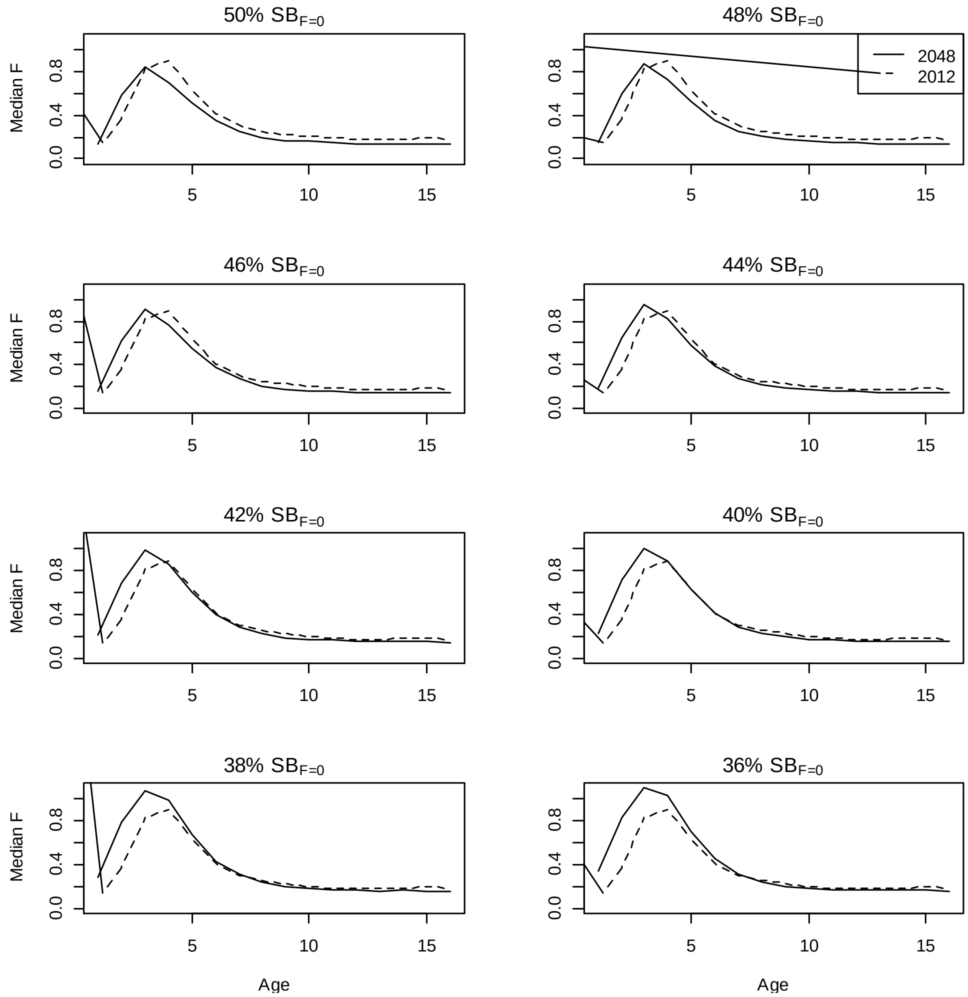

Figure 3. Pattern of (median) overall fishing mortality-at-age (quarter) for each candidate TRP depletion level. Dotted line presents estimated 2012 F-at-age, solid line the projected 2048 F-at-age.

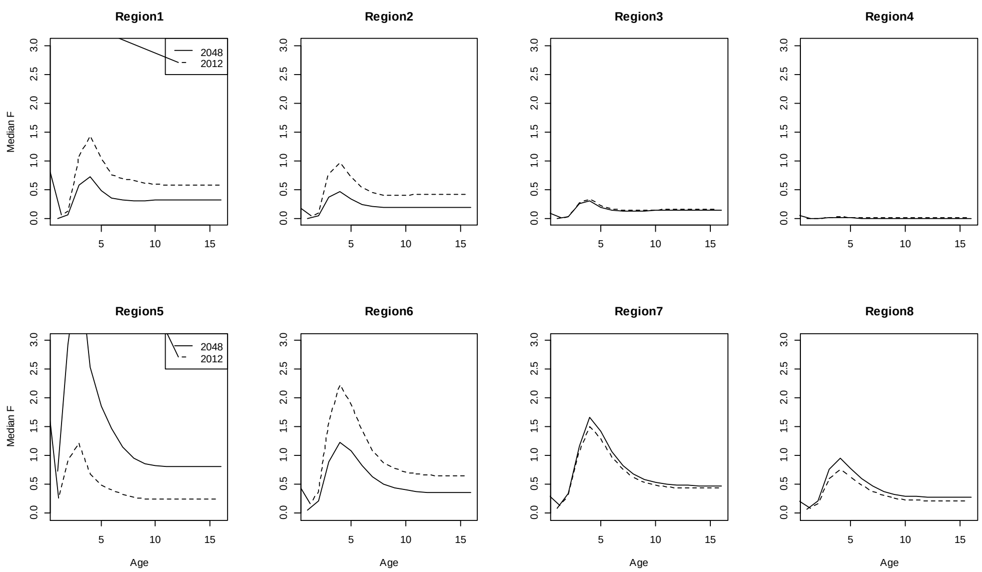

Figure 4. Pattern of (median) fishing mortality-at-age (quarter) by skipjack model region under conditions achieving 42% $SB_{F=0}$ depletion. Dotted line presents estimated 2012 F-at-age, solid line the projected 2048 F-at-age.

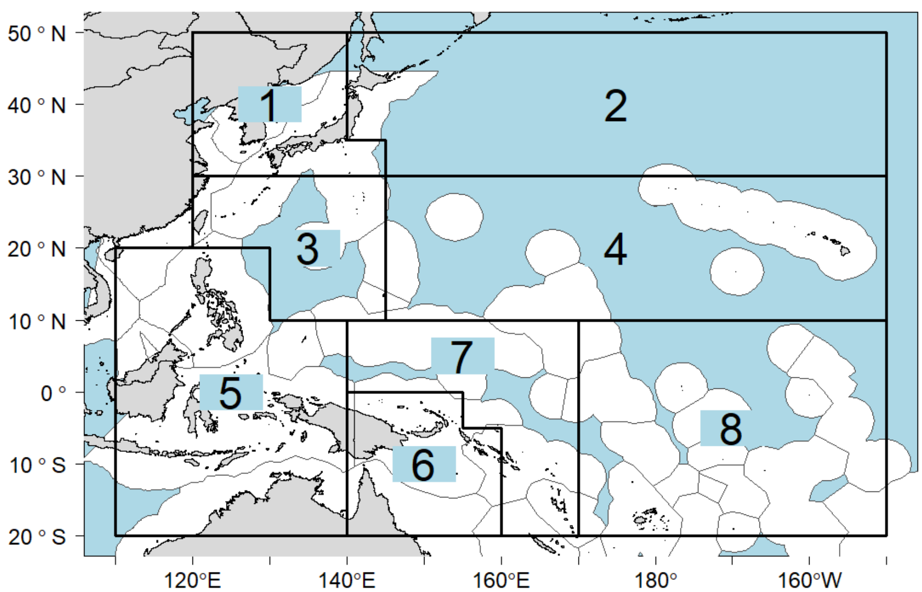

Figure 5. The geographical area covered by the stock assessment and the boundaries for the 8 region assessment model.

Table 5. Table of Annual Catch Estimates for key fisheries within Region 5 of the skipjack stock assessment model for 2012 and averaged over the period 2016-2018 period.

		Skipjack catch (t.) used in assessments from Annual catch estimates				
flag_id	**Gear**	**2012**	**Average 2016-2018**	**Increase / Decrease**	**%**	**% of total**
ID	Gillnet	0	0	0		
	Handline	0	0	0		
	Hook-and-line	0	38,817	38,817		
	Longline	0	2,185	2,185		
	OTHER Small-scale gears	109,732	93,993	-15,739		
	Pole-and-line	100,857	83,027	-17,830		
	Purse seine	69,058	91,985	22,927		
ID Total		279,647	310,006	30,359	11%	8%
PH	Handline	439	2,639	2,200		
	Hook-and-line	10,600	9,418	-1,182		
	Longline	0	0	0		
	OTHER Small-scale gears	3,078	5,136	2,058		
	Ringnet	23,255	26,738	3,483		
	Purse seine	39,062	37,229	-1,833		
PH Total		76,434	81,161	4,727	6%	1%
VN	Gillnet	20,998	39,836	18,838		
	Longline	0	0	0		
	Purse seine	22,638	50,672	28,034		
VN Total		43,636	90,507	46,871	107%	12%
				0		
Total		**399,717**	**481,674**	**81,957**	**21%**	**21%**

Bigeye and yellowfin yield and spawning biomass per recruit curves

SC17 requested yield and spawning biomass per recruit curves by fisheries sector for bigeye and yellowfin tuna (SC17 draft summary report, para 271). Isopleths of equilibrium mean yield per recruit (YPR) and spawning potential ratio (SPR) by fishery sector (longline and purse seine) were calculated across the 2020 grid of assessment models for bigeye tuna (24 models) and yellowfin tuna (72 models) with the following settings:

1. Average, fishery specific, fishing mortality was calculated over the period 2016 to 2018.
2. Recruitment was determined from the estimated SRR for each assessment in the grid of models (i.e. the fit of the relationship to the long-term recruitment pattern for bigeye).
3. Figures are based on terminal values from 30 year deterministic projections with all fisheries projected on effort.
4. All other fisheries (PL and domestic fisheries) set at a scalar of 1.
5. YPR = Yield in terminal year divided by recruitment in terminal year (both summed over quarters).

6. SPR = $SB/SB_{F=0}$ with MULTIFAN-CL age flag 171 = 0. This is identical to $(SB/R_{fished})/(SB/R_{unfished})$ where SB/R is adult biomass in terminal year (averaged over quarters) divided by recruitment in terminal year (summed over quarters).

Note that these figures will differ from those shown in the stock assessment report because:

1. The YPR analysis shown in the stock assessment report is based on a single area approximation of the stock assessment model and uses an aggregate fishing mortality for scaling.
2. The year range for averaging F differs for the stock assessment YPR analysis.
3. In this analysis, the fishing mortality scalers have been applied either to one fishery sector or another and not uniformly across all fisheries.

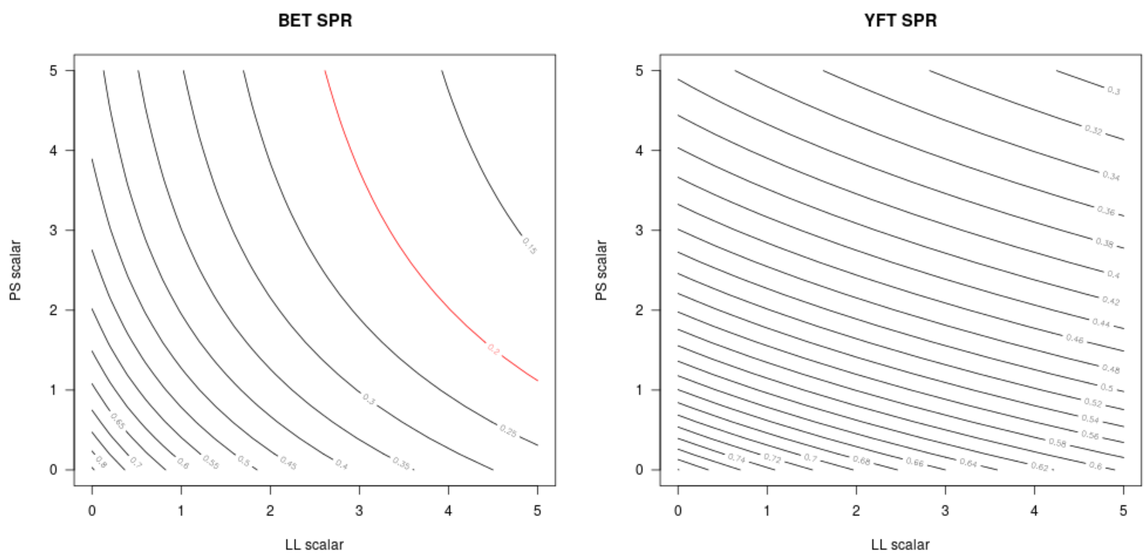

Figure 6. Isopleths of spawning potential ratio for longline and purse seine effort scalars between 0 and 5. As a guide, the red line (left hand panel) shows SPR = 0.2.

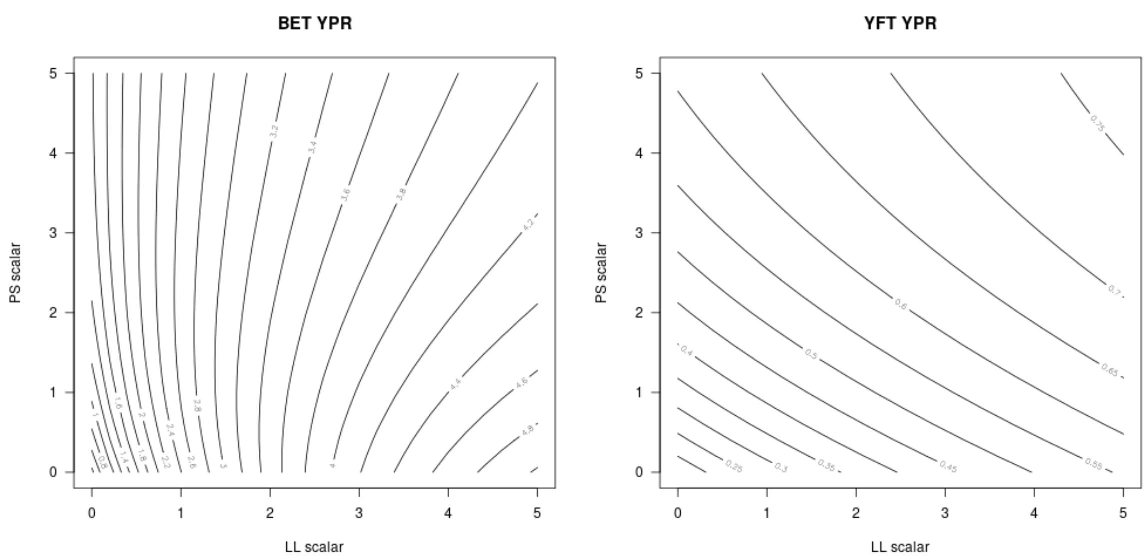

Figure 7. Isopleths of yield per recruit for longline and purse seine effort scalars between 0 and 5

South Pacific albacore outcomes of candidate bigeye and yellowfin TRPs

To evaluate the potential impact on South Pacific albacore stock status of changes in tropical longline catch under each of the candidate TRP levels presented in SC17-MI-WP-01, changes in longline fisheries to achieve each candidate bigeye or yellowfin TRP level were assumed to affect South Pacific albacore only through those longline fisheries operating in 'Region 1' of the albacore assessment model (the region between the equator and 10°S of the WCPFC-CA). About 4% of the total bigeye catch has been taken south of 10°S in recent years, so for simplicity that region is assumed to be unaffected by tropical longline effort changes. We assume that albacore catches in Region 1 of that assessment increase by the same amount as those of bigeye or yellowfin required to achieve their candidate TRP levels. This may be considered a 'worst case' scenario; refined approaches will be undertaken through the harvest strategy's multispecies framework. Resulting South Pacific albacore stock status is presented in tables below for each candidate bigeye (Table 6, Table 7) and yellowfin TRP (Table 8) in the final column.

Table 6. Median <u>bigeye</u> tuna depletion levels ($SB/SB_{F=0}$) assuming 'recent' recruitment conditions, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2015-2018) average levels, change in purse seine effort and longline catch (scalar) from baseline (2016-2018) levels, median equilibrium yield (total yield as % of MSY), and risk of falling below the LRP (20% $SB_{F=0}$) under baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent depletion levels that would result for skipjack, yellowfin and South Pacific albacore for each of the candidate bigeye TRPs is provided in the last three columns.

BET: recent recruitment						Notes	Equiv. SKJ $SB/SB_{F=0}$	Equiv. YFT $SB/SB_{F=0}$	Equiv. SPA $SB/SB_{F=0}$
Median depletion level (% $SB_{F=0}$)	Change in SB (% $SB_{F=0}$) from 2012-2015 average	Change in SB (% $SB_{F=0}$) from 2015-2018 average	Change in fishing from 2016-2018 levels	Median total equilibrium yield (%MSY)	Risk $SB/SB_{F=0}$ < LRP				
48%	+30%	+17%	0%	95%	0%	Base 2016-2018 conditions	43%	59%	43%
33%	-10%	-20%	+54%	98%	10%	Avg. 2012-2015 – 10%	35%	43%	39%
37%	0%	-10%	+38%	98%	3%	Avg. 2012-2015	37%	46%	40%
41%	+10%	0%	+24%	98%	0%	Avg. 2012-2015 + 10%	39%	48%	41%
49%	+34%	+21%	-4%	94%	0%	Avg. depletion 2000-04	44%	54%	43%
32%	-12%	-21%	+55%	98%	10%	10% risk re LRP	35%	43%	39%
29%	-23%	-30%	+70%	98%	20%	20% risk re LRP	34%	41%	38%

Table 7. Median bigeye tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2015-2018) average levels, change in purse seine effort and longline catch (scalar) from baseline (2016-2018) levels, median equilibrium yield (total yield as % of MSY), and risk of falling below the LRP (20% $SB_{F=0}$) under baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent depletion levels that would result for skipjack, yellowfin and South Pacific albacore for each of the candidate bigeye TRPs is provided in the last three columns.

BET: long-term recruitment						Notes	Equiv. SKJ $SB/SB_{F=0}$	Equiv. YFT $SB/SB_{F=0}$	Equiv. SPA $SB/SB_{F=0}$
Median depletion level (% $SB_{F=0}$)	Change in SB (% $SB_{F=0}$) from 2012-2015 average	Change in SB (% $SB_{F=0}$) from 2015-2018 average	Change in fishing from 2016-2018 levels	Median total equilibrium yield (%MSY)	Risk $SB/SB_{F=0}$ < LRP				
43%	+17%	+6%	0%	97%	5%	Base 2016-2018 conditions	43%	59%	43%
33%	-10%	-20%	+33%	98%	20%	Avg. 2012-2015 – 10%	38%	46%	41%
37%	0%	-10%	+22%	97%	14%	Avg. 2012-2015	39%	48%	42%
41%	+10%	0%	+8%	97%	8%	Avg. 2012-2015 + 10%	42%	51%	43%
49%	+34%	+21%	-17%	96%	1%	Avg. depletion 2000-04	48%	62%	44%
40%	+6%	-4%	+12%	97%	10%	10% risk re LRP	41%	50%	42%
33%	-10%	-19%	+33%	98%	20%	20% risk re LRP	38%	46%	41%

Table 8. Median yellowfin tuna depletion levels ($SB/SB_{F=0}$) assuming 'long-term' recruitment conditions, and corresponding change in spawning biomass from 2012-2015 and 'recent' (2015-2018) average levels, change in purse seine effort and longline catch (scalar) from baseline (2016-2018) levels, median equilibrium yield (total yield as % of MSY), and risk of falling below the LRP (20% $SB_{F=0}$) under baseline fishery conditions (shaded row) and SC16-nominated depletion and risk levels. The equivalent depletion levels that would result for skipjack, South Pacific albacore and bigeye (under recent (R) and long-term (L) recruitment scenarios) for each of the candidate yellowfin TRPs is provided in the last three columns.

YFT: long-term recruitment						Notes	Equiv. SKJ $SB/SB_{F=0}$	Equiv. BET (R/L) $SB/SB_{F=0}$	Equiv. SPA $SB/SB_{F=0}$
Median depletion level (%$SB_{F=0}$)	Change in SB (%$SB_{F=0}$) from 2012-2015 average	Change in SB (%$SB_{F=0}$) from 2015-2018 average	Change in fishing from 2016-2018 levels	Median total equilibrium yield (%MSY)	Risk $SB/SB_{F=0}$ < LRP				
59%	+7%	0%	0%	63%	0%	Base 2016-2018 conditions	43%	48%/43%	43%
49%	-10%	-16%	+65%	77%	0%	Avg. 2012-2015 – 10%	34%	30%/26%	38%
55%	0%	-6%	+29%	70%	0%	Avg. 2012-2015	38%	40%/34%	41%
60%	+10%	+3%	-5%	62%	0%	Avg. 2012-2015 + 10%	45%	50%/45%	43%
54%	-1%	-8%	+34%	71%	0%	Avg. depletion 2000-2004	38%	38%/30%	40%
31%	-43%	-47%	+200%	88%	10%	10% risk re LRP	26%	8%/3%	35%
NA	-	-	-	-	-	20% risk re LRP	-	-	-

FAD closure

Source	Request
TTMW1	Adding months, projected change in **future depletion** for **SKJ, BET, YFT; HS x 6 months, EEZ x 3 months**
TTMW1	Adding months, projected change in **future depletion** for **SKJ, BET, YFT; HS x 5 months, EEZ x 4 months**
TTMW1	Adding months, projected change in **future depletion** for **SKJ, BET, YFT**; **HS x 6 months, EEZ x 4 months**
TTMW1	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion; **status quo (3 months EEZ/HS + 2 months HS)** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion; **1 month reduction (EEZ and HS)** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion; **complete removal (both EEZ and HS** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion; **2 months EEZ, 3 months HS** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion; **2 months HS, 2 months EEZ** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion; **1 month HS, 1 month EEZ** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Changed FAD closure implications on **SKJ, BET, YFT** future depletion; **5 months HS, 5 months EEZ** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Changed FAD closure implications on **SKJ, BET, YFT** future depletion; **4 months HS, 4 months EEZ** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Changed FAD closure implications on **SKJ, BET, YFT** future depletion; **3 months HS, 3 months EEZ** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Changed FAD closure implications on **SKJ, BET, YFT** future depletion; **2 months HS, 3 months EEZ** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Changed FAD closure implications on **SKJ, BET, YFT** future depletion; **3 months HS, 4 months EEZ** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Changed FAD closure implications on **SKJ, BET, YFT** future depletion; **3 months HS, 5 months EEZ** **+ a sensitivity with the 2019 effort and catch levels.**
TTMW1	Assess the trade-off between increases in longline bigeye catch and length of FAD closure, include results for SKJ, BET, YFT

Alternative in-zone and high seas FAD closure durations

To evaluate the impact of changing the FAD closure on purse seine effort, an approach comparable to the analysis of the existing tropical tuna CMM was undertaken (see SC17-MI-IP-03 for full details).

Baseline purse seine effort levels were set at the 2016-2018 average unless otherwise requested as a sensitivity. Increases in FAD sets were therefore compensated for by decreases in free school sets (and vice versa) to maintain overall effort levels. Within these settings, the impact of the purse seine fishery component on the three tropical tuna stocks varied.

The changes in amount of FAD sets primarily affect the results for bigeye. For this stock, the change in FAD closure period and variations in overall effort from the 2016-2018 average baseline are assumed to be multiplicative – e.g. a decrease in the number of 'days fished' and a decrease in the period within which FAD sets can be made both reduce the number of FAD sets. We therefore assume that the general pattern of fishing remains consistent into the future, and the number or proportion of FAD sets made outside the closure is not increased, despite specified changes in FAD closure length (see column 'Overall PS scalar' in Table 9 and Table 10).

Depletion outcomes resulting from the different combinations of FAD closure periods are presented in Table 9 and Table 10 for bigeye under recent and long-term recruitment assumptions, respectively. Longline and other fishery levels were assumed as specified in the table for each scenario (we interpreted the request for a sensitivity analysis of 2019 levels as applying to both purse seine and longline fisheries and applied this variation to ALL requested scenarios detailed in the request table above).

For yellowfin and skipjack, previous analyses (SC10-MI-WP-05; SC11-MI-WP-05) have indicated that with regards to purse seine impacts, it is the overall effort by this gear that is the primary influence on stock status rather than the proportion of FAD sets. Therefore, in these analyses we only account for the impact of overall purse seine effort changes for these stocks (see column 'PS effort and HS PS effort v 2016-18 avg' in Table 9 and Table 10).

Results for each stock are interpreted based upon the relevant scalars estimated, with reference to Tables 1 to 6 in WCPFC-TTMW1-2021-02_rev1 (bigeye and yellowfin) and Table 2 in WCPFC-TTMW1-2021-04_rev1 (skipjack).

We note that in this and other spatial FAD-related analyses presented within this document, we do not specifically apply, for example, the high seas FAD closure only to those regions of the bigeye stock assessment model where the high seas are primarily located. For simplicity, the change is distributed across the tropical regions. However, we note that the impact of changes in high seas FAD closure duration would primarily be felt in the eastern region of the tropics where bigeye catch-per-set is generally above the average for the tropical region (see Figure 11). To an extent, the impact of the high seas FAD closure on the bigeye stock will be under-estimated within this analysis as a result.

Table 9. Combinations of specified EEZ and high seas FAD closure periods, purse seine effort and longline catch scenarios, and resulting depletion levels and risk of breaching the LRP (20% $SB_{F=0}$) for bigeye (recent recruitment assumption), yellowfin and skipjack tuna.

Scenario combinations					Resulting Scalars					BET outcomes			YFT outcomes			SKJ outcomes	
EEZ PS effort	EEZ FAD closure	HS FAD closure	LL catch	Other catch	PS effort & HS PS effort v 2016-18 avg	FAD closure scalar	Overall PS scalar	LL catch scalar	Other catch scalar	BET depletion	Result v 2012-15 avg	LRP risk	YFT depletion	Result v 2012-15 avg	LRP risk	SKJ depletion	LRP risk
2016-18 levels	3mth	6mth	2016-18 levels	2016-18 levels	1	1.1	1.1	1	1	0.47	1.27	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	4mth	5mth	2016-18 levels	2016-18 levels	1	1	1	1	1	0.48	1.30	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	4mth	6mth	2016-18 levels	2016-18 levels	1	0.99	0.99	1	1	0.48	1.30	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	3mth	5mth	2016-18 levels	2016-18 levels	1	1.11	1.11	1	1	0.47	1.27	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	2mth	4mth	2016-18 levels	2016-18 levels	1	1.24	1.24	1	1	0.44	1.19	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	0mth	0mth	2016-18 levels	2016-18 levels	1	1.51	1.51	1	1	0.41	1.10	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	2mth	3mth	2016-18 levels	2016-18 levels	1	1.25	1.25	1	1	0.44	1.19	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	2mth	2mth	2016-18 levels	2016-18 levels	1	1.26	1.26	1	1	0.44	1.19	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	1mth	1mth	2016-18 levels	2016-18 levels	1	1.38	1.38	1	1	0.42	1.14	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	5mth	5mth	2016-18 levels	2016-18 levels	1	0.88	0.88	1	1	0.5	1.35	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	4mth	4mth	2016-18 levels	2016-18 levels	1	1.01	1.01	1	1	0.48	1.30	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	3mth	3mth	2016-18 levels	2016-18 levels	1	1.13	1.13	1	1	0.46	1.24	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	3mth	2mth	2016-18 levels	2016-18 levels	1	1.14	1.14	1	1	0.46	1.24	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	4mth	3mth	2016-18 levels	2016-18 levels	1	1.01	1.01	1	1	0.48	1.30	0%	0.59	1.07	0%	0.44	0%
2016-18 levels	5mth	3mth	2016-18 levels	2016-18 levels	1	0.9	0.90	1	1	0.5	1.35	0%	0.59	1.07	0%	0.44	0%
2019 levels	3mth	6mth	2019 levels	2016-18 levels	0.93	1.1	1.02	1.1	1	0.47	1.27	0%	0.59	1.07	0%	0.46	0%
2019 levels	4mth	5mth	2019 levels	2016-18 levels	0.93	1	0.93	1.1	1	0.48	1.34	0%	0.59	1.07	0%	0.46	0%
2019 levels	4mth	6mth	2019 levels	2016-18 levels	0.93	0.99	0.92	1.1	1	0.49	1.34	0%	0.59	1.07	0%	0.46	0%
2019 levels	3mth	5mth	2019 levels	2016-18 levels	0.93	1.11	1.03	1.1	1	0.46	1.27	0%	0.59	1.07	0%	0.46	0%
2019 levels	2mth	4mth	2019 levels	2016-18 levels	0.93	1.24	1.15	1.1	1	0.44	1.19	0%	0.59	1.07	0%	0.46	0%
2019 levels	0mth	0mth	2019 levels	2016-18 levels	0.93	1.52	1.41	1.1	1	0.41	1.10	0%	0.59	1.07	0%	0.46	0%
2019 levels	2mth	3mth	2019 levels	2016-18 levels	0.93	1.25	1.16	1.1	1	0.44	1.19	0%	0.59	1.07	0%	0.46	0%
2019 levels	2mth	2mth	2019 levels	2016-18 levels	0.93	1.26	1.17	1.1	1	0.44	1.19	0%	0.59	1.07	0%	0.46	0%
2019 levels	1mth	1mth	2019 levels	2016-18 levels	0.93	1.39	1.29	1.1	1	0.42	1.14	0%	0.59	1.07	0%	0.46	0%
2019 levels	5mth	5mth	2019 levels	2016-18 levels	0.93	0.88	0.82	1.1	1	0.5	1.35	0%	0.59	1.07	0%	0.46	0%
2019 levels	4mth	4mth	2019 levels	2016-18 levels	0.93	1.01	0.94	1.1	1	0.48	1.30	0%	0.59	1.07	0%	0.46	0%
2019 levels	3mth	3mth	2019 levels	2016-18 levels	0.93	1.13	1.05	1.1	1	0.46	1.24	0%	0.59	1.07	0%	0.46	0%
2019 levels	3mth	2mth	2019 levels	2016-18 levels	0.93	1.14	1.06	1.1	1	0.46	1.24	0%	0.59	1.07	0%	0.46	0%
2019 levels	4mth	3mth	2019 levels	2016-18 levels	0.93	1.02	0.95	1.1	1	0.48	1.30	0%	0.59	1.07	0%	0.46	0%
2019 levels	5mth	3mth	2019 levels	2016-18 levels	0.93	0.9	0.84	1.1	1	0.49	1.34	0%	0.59	1.07	0%	0.46	0%

Table 10. Combinations of specified EEZ and high seas FAD closure periods, purse seine effort and longline catch scenarios, and resulting depletion levels and risk of breaching the LRP (20% $SB_{F=0}$) for bigeye (long-term recruitment assumption), yellowfin and skipjack tuna

Scenario combinations					Resulting Scalars					BET outcomes			YFT outcomes			SKJ outcomes	
EEZ PS effort	EEZ FAD closure	HS FAD closure	LL catch	Other catch	PS effort & HS PS effort v 2016-18 avg	FAD closure	Overall PS scalar	LL catch scalar	Other catch scalar	BET depletion	Result v 2012-15 avg	LRP risk	YFT depletion	Result v 2012-15 avg	LRP risk	SKJ depletion	LRP risk
2016-18 levels	3mth	6mth	2016-18 levels	2016-18 levels	1	1.1	1.1	1	1	0.42	1.14	6%	0.59	1.07	0%	0.44	0%
2016-18 levels	4mth	5mth	2016-18 levels	2016-18 levels	1	1	1	1	1	0.43	1.16	5%	0.59	1.07	0%	0.44	0%
2016-18 levels	4mth	6mth	2016-18 levels	2016-18 levels	1	0.99	0.99	1	1	0.43	1.16	5%	0.59	1.07	0%	0.44	0%
2016-18 levels	3mth	5mth	2016-18 levels	2016-18 levels	1	1.11	1.11	1	1	0.42	1.14	6%	0.59	1.07	0%	0.44	0%
2016-18 levels	2mth	4mth	2016-18 levels	2016-18 levels	1	1.24	1.24	1	1	0.39	1.05	9%	0.59	1.07	0%	0.44	0%
2016-18 levels	0mth	0mth	2016-18 levels	2016-18 levels	1	1.52	1.52	1	1	0.36	0.97	12%	0.59	1.07	0%	0.44	0%
2016-18 levels	2mth	3mth	2016-18 levels	2016-18 levels	1	1.25	1.25	1	1	0.39	1.05	9%	0.59	1.07	0%	0.44	0%
2016-18 levels	2mth	2mth	2016-18 levels	2016-18 levels	1	1.26	1.26	1	1	0.39	1.05	9%	0.59	1.07	0%	0.44	0%
2016-18 levels	1mth	1mth	2016-18 levels	2016-18 levels	1	1.39	1.39	1	1	0.37	1.00	11%	0.59	1.07	0%	0.44	0%
2016-18 levels	5mth	5mth	2016-18 levels	2016-18 levels	1	0.88	0.88	1	1	0.45	1.22	4%	0.59	1.07	0%	0.44	0%
2016-18 levels	4mth	4mth	2016-18 levels	2016-18 levels	1	1.01	1.01	1	1	0.43	1.16	5%	0.59	1.07	0%	0.44	0%
2016-18 levels	3mth	3mth	2016-18 levels	2016-18 levels	1	1.13	1.13	1	1	0.41	1.10	7%	0.59	1.07	0%	0.44	0%
2016-18 levels	3mth	2mth	2016-18 levels	2016-18 levels	1	1.14	1.14	1	1	0.41	1.10	7%	0.59	1.07	0%	0.44	0%
2016-18 levels	4mth	3mth	2016-18 levels	2016-18 levels	1	1.02	1.02	1	1	0.43	1.16	5%	0.59	1.07	0%	0.44	0%
2016-18 levels	5mth	3mth	2016-18 levels	2016-18 levels	1	0.9	0.90	1	1	0.45	1.22	4%	0.59	1.07	0%	0.44	0%
2019 levels	3mth	6mth	2019 levels	2016-18 levels	0.93	1.1	1.02	1.1	1	0.42	1.14	7%	0.59	1.07	0%	0.46	0%
2019 levels	4mth	5mth	2019 levels	2016-18 levels	0.93	1	0.93	1.1	1	0.43	1.16	5%	0.59	1.07	0%	0.46	0%
2019 levels	4mth	6mth	2019 levels	2016-18 levels	0.93	0.99	0.92	1.1	1	0.43	1.16	5%	0.59	1.07	0%	0.46	0%
2019 levels	3mth	5mth	2019 levels	2016-18 levels	0.93	1.11	1.03	1.1	1	0.41	1.10	7%	0.59	1.07	0%	0.46	0%
2019 levels	2mth	4mth	2019 levels	2016-18 levels	0.93	1.24	1.15	1.1	1	0.39	1.05	9%	0.59	1.07	0%	0.46	0%
2019 levels	0mth	0mth	2019 levels	2016-18 levels	0.93	1.52	1.41	1.1	1	0.36	0.97	13%	0.59	1.07	0%	0.46	0%
2019 levels	2mth	3mth	2019 levels	2016-18 levels	0.93	1.25	1.16	1.1	1	0.39	1.05	9%	0.59	1.07	0%	0.46	0%
2019 levels	2mth	2mth	2019 levels	2016-18 levels	0.93	1.26	1.17	1.1	1	0.39	1.05	9%	0.59	1.07	0%	0.46	0%
2019 levels	1mth	1mth	2019 levels	2016-18 levels	0.93	1.39	1.29	1.1	1	0.37	1.00	11%	0.59	1.07	0%	0.46	0%
2019 levels	5mth	5mth	2019 levels	2016-18 levels	0.93	0.88	0.82	1.1	1	0.45	1.22	4%	0.59	1.07	0%	0.46	0%
2019 levels	4mth	4mth	2019 levels	2016-18 levels	0.93	1.01	0.94	1.1	1	0.42	1.14	6%	0.59	1.07	0%	0.46	0%
2019 levels	3mth	3mth	2019 levels	2016-18 levels	0.93	1.13	1.05	1.1	1	0.41	1.10	7%	0.59	1.07	0%	0.46	0%
2019 levels	3mth	2mth	2019 levels	2016-18 levels	0.93	1.14	1.06	1.1	1	0.41	1.10	7%	0.59	1.07	0%	0.46	0%
2019 levels	4mth	3mth	2019 levels	2016-18 levels	0.93	1.02	0.95	1.1	1	0.42	1.14	6%	0.59	1.07	0%	0.46	0%
2019 levels	5mth	3mth	2019 levels	2016-18 levels	0.93	0.9	0.84	1.1	1	0.44	1.19	5%	0.59	1.07	0%	0.46	0%

Trade-off between bigeye longline catch and the FAD closure period

The trade-off request was interpreted in two ways.

The first component evaluated the level of change required in one gear, relative to 2016-2018 baseline conditions, to maintain the depletion of bigeye tuna (under the two recruitment scenarios) at a specific level. For this analysis, the depletion level under 'baseline' 2016-2018 levels was used, to reflect the differing impacts of the recruitment assumptions being examined on future stock productivity. This therefore mirrored a specific 'diagonal line' of Figures 1 and 3 in WCPFC-TTMW1-2021-02_rev1 (maintaining BET depletion at 'baseline' 0.48 and 0.43 $SB_{F=0}$ for 'recent' and 'long-term' recruitment scenarios, respectively). The request indicated increases in longline catch, so additional catch increments of approximately +6,000 mt (10% of the 2016-2018 average) were evaluated, up to a set of scalars that fell within the 0.5 - 2 range examined within WCPFC-TTMW1-2021-02_rev1.

The approach identifies trade-offs in terms of the impact on the bigeye stock, i.e. maintaining the stock at specific depletion levels, to best reflect the differential impacts purse seine and longline fishing has on that stock. An approach that equated to the impact in terms of equal catch, for example, would ignore the fact that to take a comparable level of catch (mt), the longline fleet would take fewer and larger fish given its selectivity, and hence would have a different impact on the stock to the removal of an equivalent weight of smaller fish by the purse seine fishery.

The request asked for the corresponding impacts on yellowfin and skipjack stocks. An assumption of this evaluation is that overall purse seine effort remains constant at 2016-2018 levels, with increased FAD closure duration equating to an increased number of sets being transferred to free school sets to maintain the overall effort. Under this assumption there is no differential impact on skipjack tuna, and hence the consequences for this stock are not presented. For yellowfin, this assumption means that the main impact is through the change in longline catch. For this analysis, the assumption is made that changes in yellowfin longline catch are equal to the assumed change in bigeye longline catch. Under that strong assumption, the consequences for yellowfin are included within Table 11 and Table 12.

Table 11. Evaluation of the change in FAD sets (and equivalent FAD closure period) required to maintain bigeye depletion at levels resulting under 'baseline' conditions given set increases in longline bigeye catch, where 'recent' recruitment is assumed. Potential consequences for the yellowfin stock where changes in longline catch mirror those for bigeye are shown.

Approximate LL BET catch (mt)	LL scalar from 2016-18 average	Scalar for PS FAD sets to maintain BET at 'recent' depletion levels	Approximate equivalent additional months of PS FAD closure period (and approx. total*)	Resulting yellowfin $SB/SB_{F=0}$
65,000	1.1	0.95	0.42 (4.12)	0.59
71,000	1.2	0.85	1.25 (4.95)	0.58
77,000	1.3	0.80	1.67 (5.37)	0.58
83,000	1.4	0.70	2.50 (6.2)	0.57
89,000	1.5	0.65	2.92 (6.62)	0.57
95,000	1.6	0.60	3.33 (7.03)	0.56
101,000	1.7	0.50	4.17 (7.87)	0.56
107,000	1.8	-	-	0.56

* assumes approximate average FAD closure period of 3.7 months over 2016-2018

Table 12. Evaluation of the change in FAD sets (and approximate equivalent FAD closure period) required to maintain bigeye depletion at levels resulting under 'baseline' conditions given set increases in longline bigeye catch, where 'long-term' recruitment is assumed. Potential consequences for the yellowfin stock where changes in longline catch mirror those for bigeye are shown.

Approximate LL BET catch (mt)	LL scalar from 2016-18 average	Scalar for PS FAD sets to maintain BET at 'long term' depletion levels	Approximate equivalent additional months of PS FAD closure period (and approx. total*)	Resulting yellowfin $SB/SB_{F=0}$
65,000	1.1	0.90	0.83 (4.53)	0.59
71,000	1.2	0.80	1.67 (5.37)	0.58
77,000	1.3	0.75	2.08 (5.78)	0.58
83,000	1.4	0.65	2.92 (6.62)	0.57
89,000	1.5	0.6	3.33 (7.03)	0.57
95,000	1.6	0.50	4.17 (7.87)	0.56
101,000	1.7	-	-	0.56

* assumes approximate average FAD closure period of 3.7 months over 2016-2018

The second component evaluated the length of FAD closure that would have an equivalent impact on the stock as a specified increase in longline catch. To examine this, the impact of the specified change in longline catch in terms of bigeye depletion was evaluated, assuming the purse seine effort remained at the 2016-2018 average level. Then the corresponding change in purse seine FAD effort required to achieve the same level of bigeye depletion was identified, assuming longline catch remained at the 2016-2018 average level. This was evaluated under 'recent' and 'long-term' recruitment scenarios (Table 13). As the FAD closure was the focus, the implications were evaluated for bigeye only (under the assumption that overall purse seine effort remains constant, results for yellowfin would be as detailed in Table 12).

Table 13. Evaluation of the equivalent change in FAD sets (and approximate equivalent FAD closure period) that had the same impact on bigeye stock depletion as set increases in longline bigeye catch, under 'recent' and 'long-term' recruitment assumptions.

Approximate LL BET catch (mt)	LL scalar from 2016-18 average	Resulting bigeye tuna depletion ($SB/SB_{F=0}$)		Equivalent purse seine effort scalar (and approx. FAD duration*)	
		Recent recruitment	Long term recruitment	Recent recruitment	Long term recruitment
65,000	1.1	0.47	0.42	1.1 (2.87)	1.1 (2.87)
71,000	1.2	0.45	0.40	1.2 (2.04)	1.2 (2.04)
77,000	1.3	0.44	0.38	1.3 (1.21)	1.35 (0.80)
83,000	1.4	0.43	0.37	1.35 (0.80)	1.4 (0.38)
89,000	1.5	0.41	0.35	1.5 (0)	1.6 (0)
95,000	1.6	0.40	0.34	1.6 (-)	1.7 (-)
101,000	1.7	0.38	0.32	1.7 (-)	1.95 (-)

* assumes approximate average FAD closure period of 3.7 months over 2016-2018

High seas effort

Source	Request
TTMW1	Maintaining EEZ PS effort, evaluate the impact of varying effort on the high seas between **0** and **10,000** days (increment by **2,000** days)

The analysis assumed that changes on the high seas occurred relative to the patterns of fishing over the period 2016 to 2018. Within those patterns, the effort in EEZs was assumed to remain at the 2016-2018 level, while effort on the high seas changed as specified by the TTMW1 request. Changes in high seas effort were not therefore assumed to lead to increased or decreased fishing within EEZs.

To calculate the number of FAD sets that resulted, the specified number of days available on the high seas in each year were proportioned to each flag operating in 2016-2018, relative to the pattern of effort between flags seen in each year (e.g. WCPFC-TTMW1-2021-IP02, Table 2), and the average flag-level FAD sets per day (averaged over 2016 and 2018, given the high seas closure in 2017) were applied to those days to get the overall change in FAD sets (EEZ + high seas) relative to the 2016-2018 baseline. Given the aim of the analysis is to evaluate the potential impact on the bigeye stock (in particular), this approach was taken for all flags and ignores allocation issues or exemptions.

The scalar for purse seine reflected the estimated change in the number of FAD sets relative to the 2016-2018 average level. Longline and other fisheries were assumed to maintain 2016-2018 average catches (scalar = 1). Impacts are therefore due to changes in the purse seine fishery only.

Changes in effort on the high seas may also lead to impacts for skipjack tuna. To simplify that analysis, we assumed that the relative pattern of (FAD and free school) sets per day would remain constant at the average over 2016-2018. Hence the scalar influencing skipjack status could be calculated using the change in the annual number of fishing days relative to that seen over the 2016-2018 period, where again the number of days fished within EEZs remained constant, and those on the high seas changed as specified by the TTMW1 request (see WCPFC-TTMW1-2021-IP02, Table 1).

Table 14. Implications of alternative levels of high seas purse seine effort on overall purse seine fishing levels and consequences for bigeye tuna (under the two hypotheses of future recruitment) and skipjack tuna depletion levels, with a 2016-18 average baseline EEZ effort level.

HS effort (days)	PS FAD set scalar relative to 2016-2018 average	Resulting BET $SB/SB_{F=0}$		PS (days) scalar relative to		Resulting SKJ $SB/SB_{F=0}$
		Recent recruitment	Long-term recruitment	2016-2018 average	2012	
0	0.92	0.50	0.45	0.87	0.80	0.48
2,000	0.95	0.49	0.44	0.91	0.84	0.46
4,000	0.98	0.48	0.43	0.94	0.87	0.46
6,000	1.01	0.48	0.43	0.98	0.91	0.44
8,000	1.04	0.47	0.42	1.02	0.94	0.44
10,000	1.07	0.47	0.42	1.06	0.98	0.42

Table 15. Implications of alternative levels of high seas purse seine effort on overall purse seine fishing levels and consequences for bigeye tuna (under the two hypotheses of future recruitment) and skipjack tuna depletion level, with 2012 EEZ effort levels.

HS effort (days)	PS FAD set scalar relative to 2016-2018 average	Resulting BET $SB/SB_{F=0}$		PS (days) scalar relative to		Resulting SKJ $SB/SB_{F=0}$
		Recent recruitment	Long-term recruitment	2016-2018 average	2012	
0	1.12	0.47	0.42	1.04	0.96	0.43
2,000	1.15	0.46	0.41	1.08	1.00	0.42
4,000	1.18	0.45	0.40	1.11	1.03	0.41
6,000	1.21	0.45	0.40	1.15	1.07	0.40
8,000	1.23	0.44	0.39	1.19	1.10	0.39
10,000	1.26	0.44	0.39	1.23	1.14	0.38

FAD definitions

Source	Request
TTMW1	Impact of the exclusion of floating objects that do not have a tracking buoy attached from the definition of FAD
TTMW2	Update on evaluation re-small floating objects (garbage)

Impact of excluding floating objects without a tracking buoy

The assumption was made that the exclusion of floating objects that do not have a tracking buoy attached from the definition of a FAD would equate to the removal of logs from that definition (e.g. see Figure 3.2.2 of SC17-GN-IP-01). For 2016-2018, the raised annual number of log sets (excluding archipelagic waters and the domestic fisheries of Philippines, Indonesia and Vietnam) within the tropical region of the WCPFC-CA was calculated. The corresponding average number of sets per month (considering the variable annual FAD closures over that period) was estimated. The resulting average number of log sets per month was then applied to the length of the FAD closure period in each year (Table 16). The resulting increased number of sets was estimated as a scalar applied to the 2016-2018 average, and the corresponding impact on bigeye tuna depletion assessed under the two future recruitment scenarios (Table 17).

Table 16. Estimation of the purse seine FAD set scalar resulting from the exclusion of 'log sets' from the definition of a FAD, for the years 2016-2018.

Year	Estimated raised log sets per year (excl. AW)	FAD closure period (approx.)	Log sets per remaining month	Increased sets per annum	Annual 'updated' total FAD sets
2016	1,864	4months	233	932	13,547
2017	1,374	4months	172	687	16,099
2018	1,741	3months	193	580	17,742
				Average:	15,796
				Scalar from 2016-2018:	1.05

The resulting BET depletion level, assuming the catch of longline and other fisheries remain at 2016-18 average levels, is presented in Table 17.

Table 17. Implications for bigeye tuna of the exclusion of 'log sets' from the definition of a FAD (under the two hypotheses of future recruitment).

PS FAD set scalar relative to 2016-2018 average	Resulting BET $SB/SB_{F=0}$	
	Recent recruitment	Long term recruitment
1	0.48	0.43
1.05	0.47	0.42

This analysis assumes that the pattern of log sets seen over the 2016-2018 period remains consistent into the future, and that the exclusion of these sets from the definition of a FAD does not change the behaviour of vessels in the future. We also note that the number of log sets will be affected by the overall level of purse seine effort – assumed to be constant at the 2016-2018 average level here – as well as the location of fishing within the tropical WCPO.

To examine how well the recent period reflects the potential levels of log fishing that might occur during the FAD closure period if definitions were changed, the historical trend in the number of log sets made per annum, and both the proportion of log sets to total purse seine sets and proportion of log sets to days fishing in the tropical WCPFC-CA are plotted in Figure 8. The number of log sets declined and the proportion of sets on drifting FADs increased over the period, with the 2016-2018 average being 37% of the 2000-2019 average level. If vessels changed fishing behaviour and returned to historical long-term average levels of log setting within the FAD closure period, this would equate to a scalar of 1.07 (2000-2019 average).

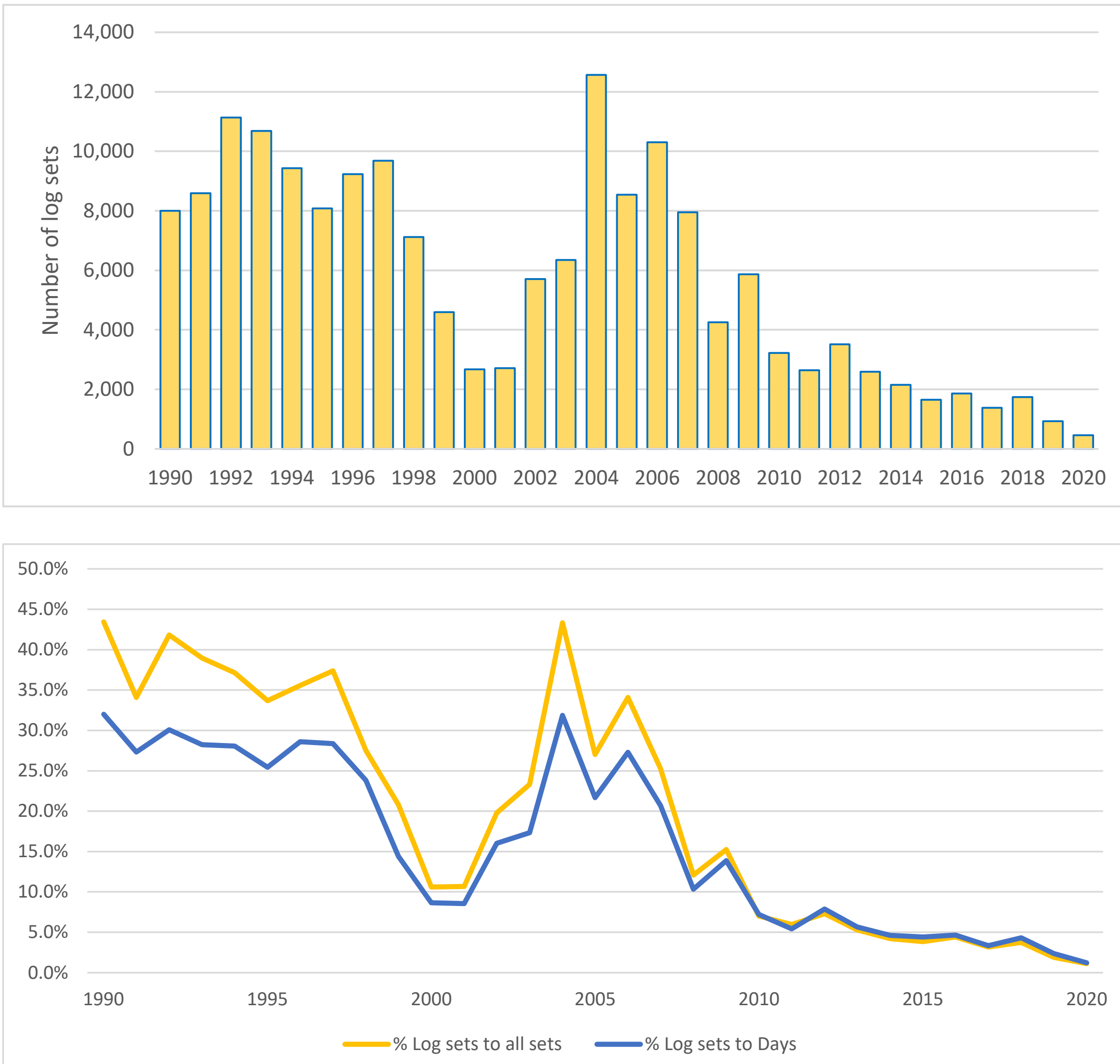

Figure 8. Number of log sets per annum (top), and log sets as a proportion of total sets and proportion of log sets to the total number of days fishing (bottom) in the tropical WCPFC purse seine fishery since 1990 (excludes AWs and domestic fisheries of Philippines, Indonesia and Vietnam).

Update on evaluation re-small floating objects ('small amounts of garbage')

Paragraph 18 of CMM 2018-01 specified that "any set where small amounts of plastic or small garbage that do not have a tracking buoy attached are detected shall not be considered to be a FAD set for the purposes of the FAD closure". An evaluation of the implications of this paragraph was presented in WCPFC16-2019-17.

At the request of TTMW2, we re-examined the potential implications of this form of paragraph using observer data from January 2005 to June 2021. The analysis aimed to quantify the frequency of 'associated' sets that under Paragraph 18 could be considered 'unassociated' if they met the specified criteria. The results from this analysis are then used to estimate the potential occurrence of such sets over a 3-month FAD closure period.

Using the observer comment section of reports, we searched for activities leading up to a set (i.e., activity ID #8 –investigate free school; #9 –investigate floating object/log) where specific keywords were included within the observer comment section: 'garbage'; 'flotsam'; 'debris'; 'detritus'; 'branch'; 'rubbish'; 'paper'; 'pollution'; 'bag'; 'litter'; 'chopstick'; 'plastic', 'net', 'wrapper' and 'waste'. Where these activities were followed by an associated set by that vessel (on log or drifting FAD) within 90 minutes and typically within 5 km of the position where the investigation activity leading up the set was reported, those activities were assumed to relate to that subsequent set. Under this analysis, those sets would be considered non-FAD sets under Paragraph 18.

Natural logs did not fall under the Paragraph 18 definition and sets that were clearly associated with 'natural logs' were excluded. All objects where an observer noted an attached buoy were also excluded. Many activity records included combinations of the terms: "log", "branch" and or "debris" in the same record. "Debris" was noted frequently by observers and could be related to logs/natural objects rather than man-made waste. To account for the uncertainty in what these sets were associated with we include separate data for any sets with a preceding activity record that included the term "debris". Where notes on investigation activities contained the keywords but the subsequent set was considered unassociated by the observer, it was not included within the current analysis as it would not be subject to the FAD closure given that unassociated set designation.

We present the evaluation for two sets of results:

1) Where only those records that specified 'plastic', 'rubbish', 'bag', 'net', 'food wrappers' and 'garbage' were included (these were the specific keywords used by observers over this period that were identified within the evaluation); and
2) Where 'debris' was assumed to relate to objects that would fall within the Paragraph 18 definition.

For **(1)**, there were 35 records across the approximate 198-month period over which the observer records were evaluated. This equates to 0.18 sets per month, or 0.54 sets within a 3-month FAD closure that would no longer be counted as a FAD set. We note the same analysis was also conducted previously as part on an earlier evaluation on CMM 2018-01 using data from March 2010 to June 2019, and found similar results of 0.2 sets per month, or 0.6 sets within a 3-month FAD closure.

For **(2)**, there were 319 records when 'debris' was included within the keywords, equating to 1.6 sets per month or 4.8 sets within a 3-month FAD closure. Again, this is similar to the results of the previous analysis for data from March 2010 to June 2019 that found there were 2.2 sets per month or 6.7 sets within a 3 month FAD closure period.

The results of this analysis in the context of the evaluation of CMM 2020-01 can be considered in terms of the scalar applied to FAD sets. Each of the analyses would imply a negligible increase in the FAD set scalar of < 0.001.

It is challenging to evaluate the potential impact of Paragraph 18 language on the performance of the tropical tuna CMM. While the current calculations imply a negligible impact resulting from this paragraph, we do not know how consistently observers have noted various key words over the historical period. Sets were often classified as set type 3 (drifting log, debris or dead animal) but with no associated preceding activity record, and these are assumed to be associated sets as that is how they are reported.

We also had to interpret keywords that the observers have used primarily in relation to 'plastic or garbage'. We are unable to identify whether these records relate to 'small amounts'. In turn, there may have been times when the observer may not have seen 'small amounts of garbage', or seen it and not reported it, and continued to record the set type as an unassociated set.

Finally, while we have mainly been considering isolated occurrences of 'garbage', the potential for tuna associations with large aggregations of garbage to become more frequent in future, particularly in convergence zones, is a concern.

If language comparable to that in CMM 2018-01 Paragraph 18 is added, its evaluation would be improved by a more precise and quantifiable definition. The current description is open to interpretation of:

- what constitutes 'garbage',
- what is the definition of 'small'.

Improved precision of these definitions, along with data collection protocols and training, is needed to help observers collect consistent and appropriate information to allow the impact of any Paragraph 18 style language to be more accurately evaluated.

While the impact of language comparable to that in CMM 2018-01 Paragraph 18 may be assumed to be negligible, any increase in the number of 'FAD sets' due to adoption of this paragraph will 'result in increased catches of bigeye and small yellowfin tuna' (Paragraph 18).

Exemptions

Source	Request
TTMW1	Consequence on the projected stock status on the exemption from 20% of the 35% cuts applied to the bigeye catch limits of other major longline fleets from the baseline limits in CMM 2008-01 for any fleet in accordance with para 35 of CMM 2008-01.

Paragraph 35 of CMM 2008-01 states "Further to paragraph 34, the reductions specified in paragraph 33 for 2010 and 2011 shall not apply to fleets of members with a total longline bigeye tuna catch limit as stipulated in Attachment F of less than 5,000 tonnes and landing exclusively fresh fish, provided that the details of such fleets and their operational characteristics are registered with the Commission by 31 December 2008 and that the number of licenses authorized in such fisheries does not increase from current levels. In such cases, catch limits specified in Attachment F shall continue to be applied." The specification of landing fresh fish focuses this Paragraph on specific CCMs.

The pattern of longline bigeye catches over time by relevant CCMs, and the tropical tuna CMM limits in accordance with paragraph 35 of CMM 2008-01 are presented in Table 19. Using this as the basis, the level of catch that would have been taken under CMM 2008-01 conditions relative to actual catch levels over that period (on average a difference of 652 mt) is calculated as a scalar relative to 2016-2018 average conditions, and the resulting bigeye stock status estimated assuming purse seine and other gears continued at 2016-2018 average fishing levels (scalar=1; Table 18).

Table 18. Longline catch scalar relative to 2016-2018 average conditions that would have been taken under CMM 2008-01 Para 35 limits.

Scenario	LL bigeye catch (mt)	Longline scalar	Resulting bigeye depletion ($SB/SB_{F=0}$)	
			Recent recruitment	Long term recruitment
2016-2018 average	59,312	1	0.48	0.43
CMM 2008-01 Para 35	58,661	0.99	0.48	0.43

Table 19. Reported total longline bigeye catches (mt) and TT CMM limits in accordance with para 35 of CMM 2008-01 for affected CCMs.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Reported BET catches	4,649	3,741	3,577	3,565	3,660	3,612	3,823	3,427	3,747	2,968	3,393	3,460	3,548
TT CMM Limits (Para 35 CMM 2008-01)	4,181	3,763	3,345	2,927	2,927	2,927	2,927	2,927	2,718	2,718	2,718	2,718	2,718

Additional metrics/scalars

Source	Request
TTMW1	**SKJ** WP04 – A calculation of recent fishing mortality levels as proportions of 2012 and 2012-2015 levels, overall region, fish size (juv/ad)
TTMW1	Alternative values for estimating future depletion levels against alternative catch and effort baselines **Purse seine** 1-month EEZ FAD closure; 1-month High seas FAD closure 1-month High seas + EEZ FAD closure; and
TTMW1	Alternative values for estimating future depletion levels against alternative catch and effort baselines **Longline catch equivalents for:** 1-month EEZ FAD closure; 1-month High seas FAD closure 1-month High seas + EEZ FAD closure; and
TTMW1	Current equivalent scalars - what scalars should apply relative to the 2016-18 “starting point” for 2019 conditions (for both catch and effort).
TTMW2	Include time series data for the US LL fleet in Figure 12 of TTMW2-01_REV4

Skipjack

Figure 9 presents a time series of median juvenile and adult skipjack fishing mortality from the agreed model grid of the 2019 stock assessment (1972 to 2018), and for the projection period (2019 to 2048) where stock depletion outcomes are consistent with a candidate TRP of 42%$SB_{F=0}$. Weighting of individual assessment model outputs, as adopted by SC15, are applied here.

Note that for period of the stock assessment (1972-2018), fishing mortality (F) calculated at a specific time is based upon the estimated recruitment patterns and variable patterns of fishing seen in the region’s fisheries. In the projection period (2019-2048), purse seine effort and other fisheries are assumed ‘constant’ rather than varying as seen in the assessment period, and the projection results conform to a pattern of ‘average’ future recruitment, leading to the less variable median fishing mortality estimated within the projection period.

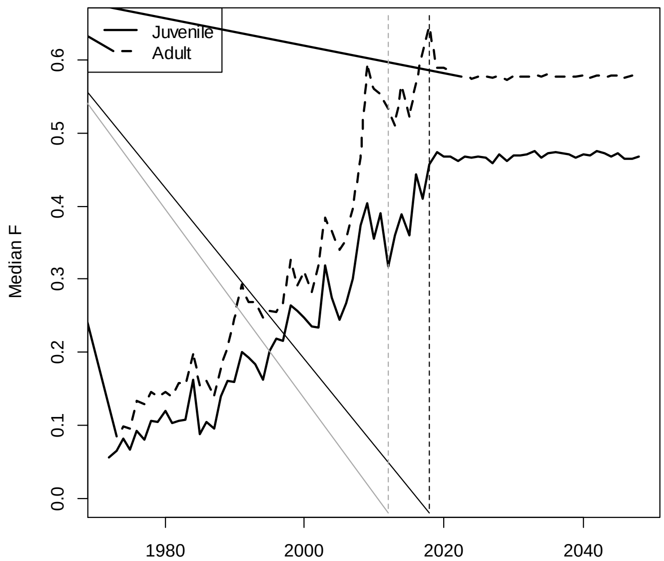

Figure 9. Time series of median (weighted) fishing mortality for juvenile and adult skipjack tuna across the WCPO model region. Vertical dotted black line = 2018 (last year of the assessment period). Vertical dotted grey line = 2012.

Table 20 presents the ratio of 'recent' fishing mortality levels (assumed to be the average over 2014-2017, as defined by SC15 when providing management advice) relative to estimated levels in 2012, and the average over 2012-2015. Estimated (weighted) median fishing mortality levels for all stock components were lower in 2012 or 2012-2015 relative to the recent period (values are less than 1).

Table 20. Table of recent fishing mortality levels (average over the period 2014-2017, consistent with the definition of the 'recent' period used by SC15) relative to that in 2012, and the average over 2012-2015.

Fishing mortality ratio	Stock component		
	Juvenile	Adult	Total
$F_{2012}/F_{2014\text{-}2017}$	0.79	0.94	0.80
$F_{2012\text{-}2015}/F_{2014\text{-}2017}$	0.89	0.94	0.90

Purse seine/longline equivalents

Scalars on purse seine associated effort resulting from changes in the FAD closure arrangement were calculated relative to 2016-2018 average conditions, using the same approach as described for the 'FAD closure' analyses above. Under the assumption that the longline catch remains constant at 2016-2018 average levels, the resulting bigeye depletion level was calculated.

To estimate the longline catch change 'equivalent' to each FAD closure arrangement, the reduction in longline catch necessary to achieve that same resulting bigeye depletion level was estimated under the assumption that the purse seine associated effort was maintained at 2016-2018 average levels.

Evaluations were performed under the two assumptions of future bigeye recruitment (Table 21).

Table 21. Purse seine scalar resulting from different FAD closure characteristics, resulting depletion level, and equivalent scalar on longline bigeye catch that would lead to the same stock depletion level, under the two assumptions for future bigeye recruitment.

Increase in FAD closure duration	Approx PS FAD set scalar (relative to 2016-18 levels)	Recent recruitment			Long term recruitment		
		Resulting BET $SB/SB_{F=0}$	Approx equivalent longline BET catch scalar	Approx longline BET catch (mt)*	Resulting BET $SB/SB_{F=0}$	Approx equivalent longline BET catch scalar	Approx longline BET catch (mt)*
1 month EEZ FAD closure	0.89	0.50	0.87	51,600	0.45	0.90	53,400
1 month HS FAD closure	0.99	0.48	1.00	59,300	0.43	1.00	59,300
1 month EEZ and HS FAD closure	0.87	0.51	0.80	47,500	0.46	0.85	50,400

* Calculated based upon Table 5 of SC17-MI-IP-11, and excluding Vietnam

Current equivalent scalars

The scalars representing overall purse seine effort in 2019, and the pattern of purse seine associated and unassociated set numbers in that year, and for longline bigeye catch levels under 2019 conditions were calculated relative to the 2016-2018 baseline, based upon information available in SC17-MI-IP-11 adjusted to best reflect the calculations made within the TT CMM evaluation (Table 22).

Table 22. Scalars of fishery components in 2019 relative to the 2016-2018 average baseline.

Fishery component	Scalar 2019 v 2016-2018 avg
PS total effort (days)	0.93
PS ASS effort (sets)	0.91
PS UNA effort (sets)	1.13
LL bigeye catch (mt)	1.10

CPUE

Source	Request
TTMW1	**Request during WS1**: compile informative BET CPUE time series

To address this request, we present a range of nominal and standardised bigeye CPUE time series for the key fishing gears from recent papers (SC17-SA-IP-15; SC16-SA-WP-03; SC16-SA-IP-07), and provide further information on the spatial pattern of bigeye CPUE in the WCPO relative to the stock assessment's tropical regions (Figures 10-14). The spatial pattern will influence the time series of specific fleets, particularly those that have shifted activities from east (higher CPUE) to west (lower CPUE) within the region over time.

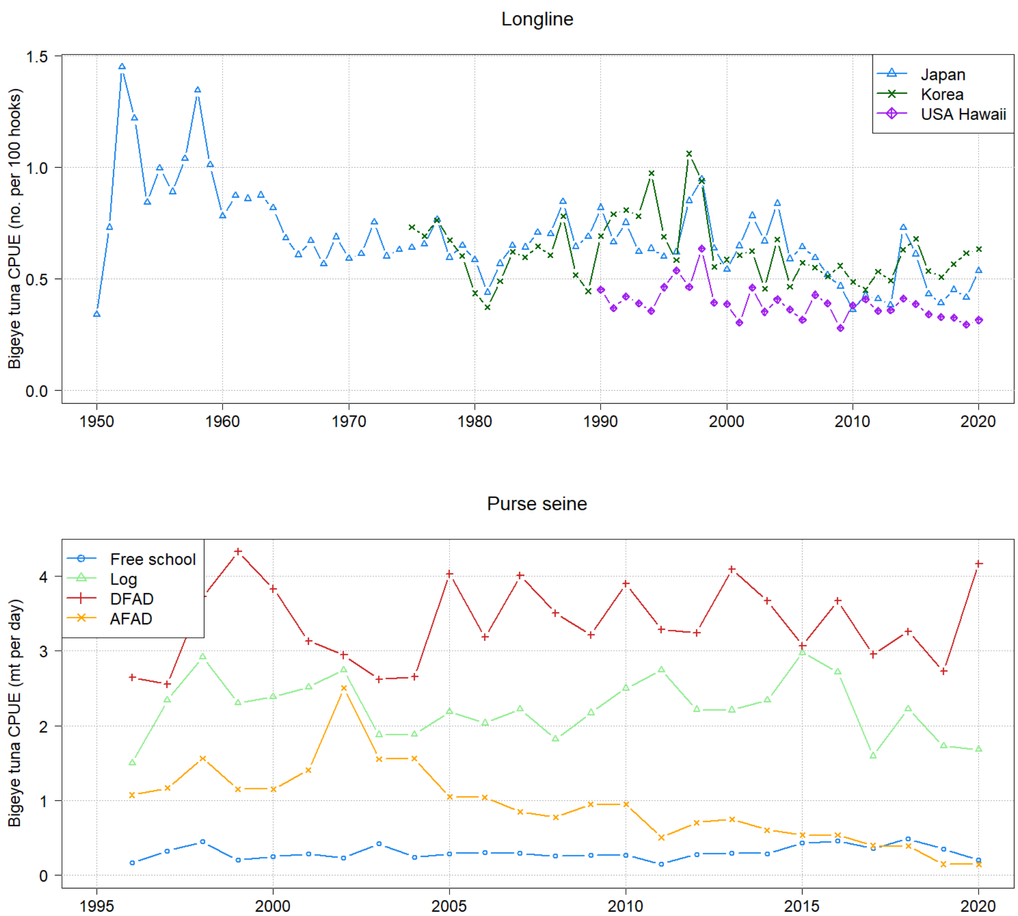

Figure 10. Evolution of bigeye CPUE by key tropical longline (20°N to 10°S) fleets (top) and tropical purse seine (20°N to 20°S) fleets by set type (bottom) over time.

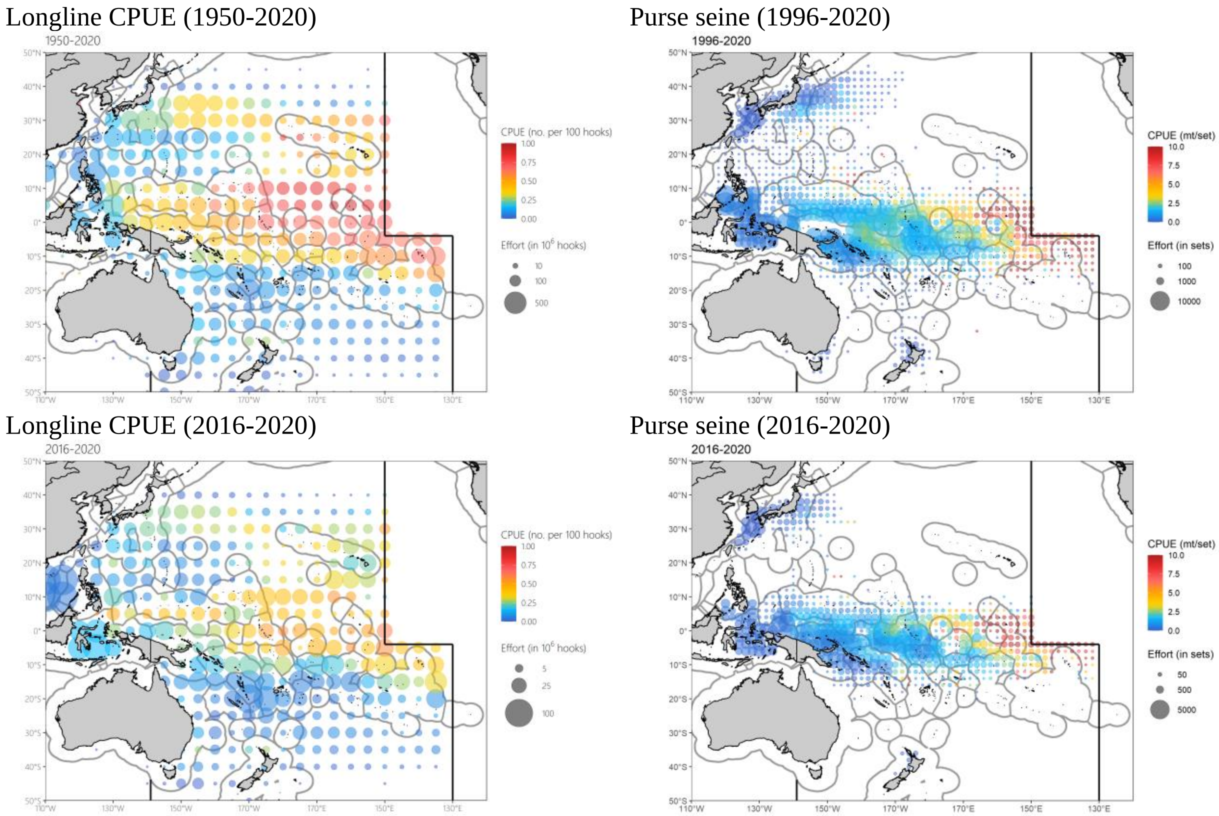

Figure 11. Distribution of 5°x5° longline effort (circle size) and bigeye tuna CPUE (number of fish per 100 hooks; colour) from longline fisheries across different time periods (left), and comparable plot for purse seine fisheries at 2° x 2° (right).

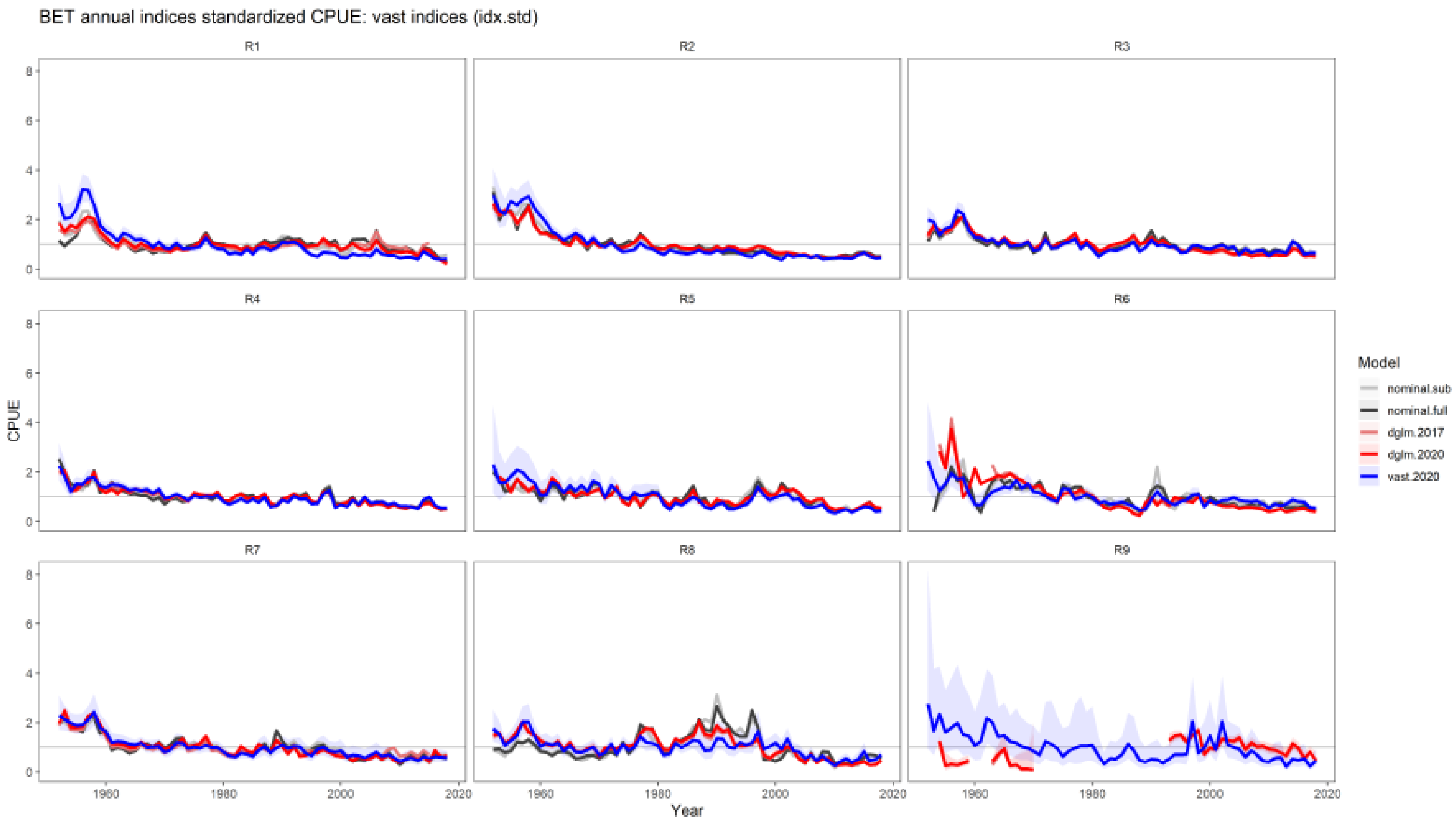

Figure 12. Nominal and standardised abundance indices for bigeye tuna as used within the 2020 WCPO bigeye stock assessment, by model region. The nominal index corresponding to the subset of data that the standardization model was fit to is shown in light gray (nominal.sub). The nominal index from the full data set is shown in dark gray (nominal.full). The delta-GLM index used in the 2017 stock assessment is shown in light red (dglm.2017). The delta-GLM index used in the data update step of the 2020 stock assessment is shown in red (dglm.2020). The VAST spatiotemporal index used in the diagnostic case of the 2020 stock assessment is shown in blue. (vast.2020). The asymptotic 95% confidence intervals are shown via the corresponding shaded polygon.

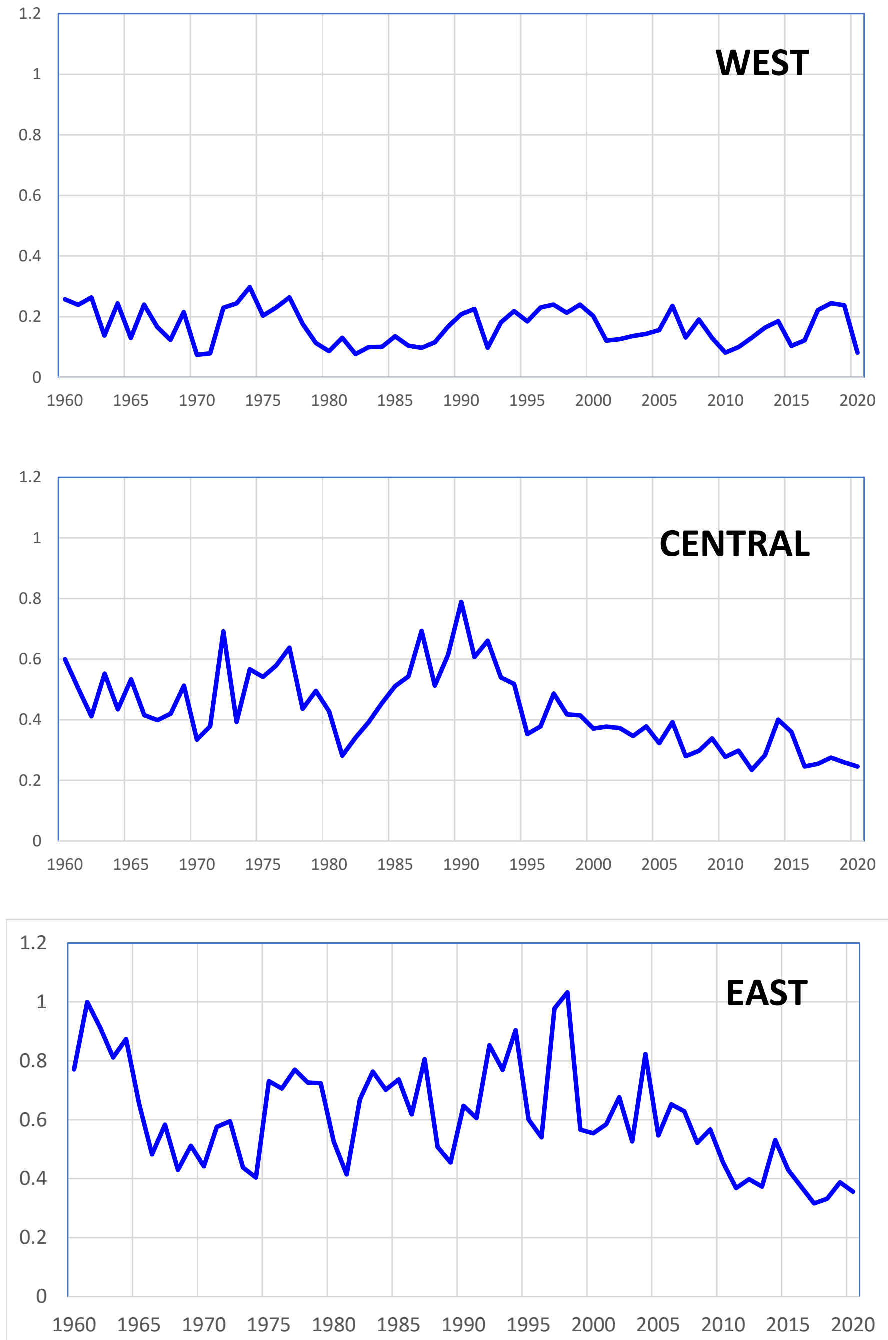

Figure 13. Annual trends in nominal bigeye tuna CPUE (number of fish per 100 hooks) in the tropical WCPFC LONGLINE fishery, by assessment region: "WEST" = Assessment Region 7: 10°S–20°N, 110°–140°E; "CENTRAL" = Assessment Region 3: 10°S–10°N, 130°–170°E; "EAST" = Assessment Region 4: 10°S–10°N, 170°E–150°W).

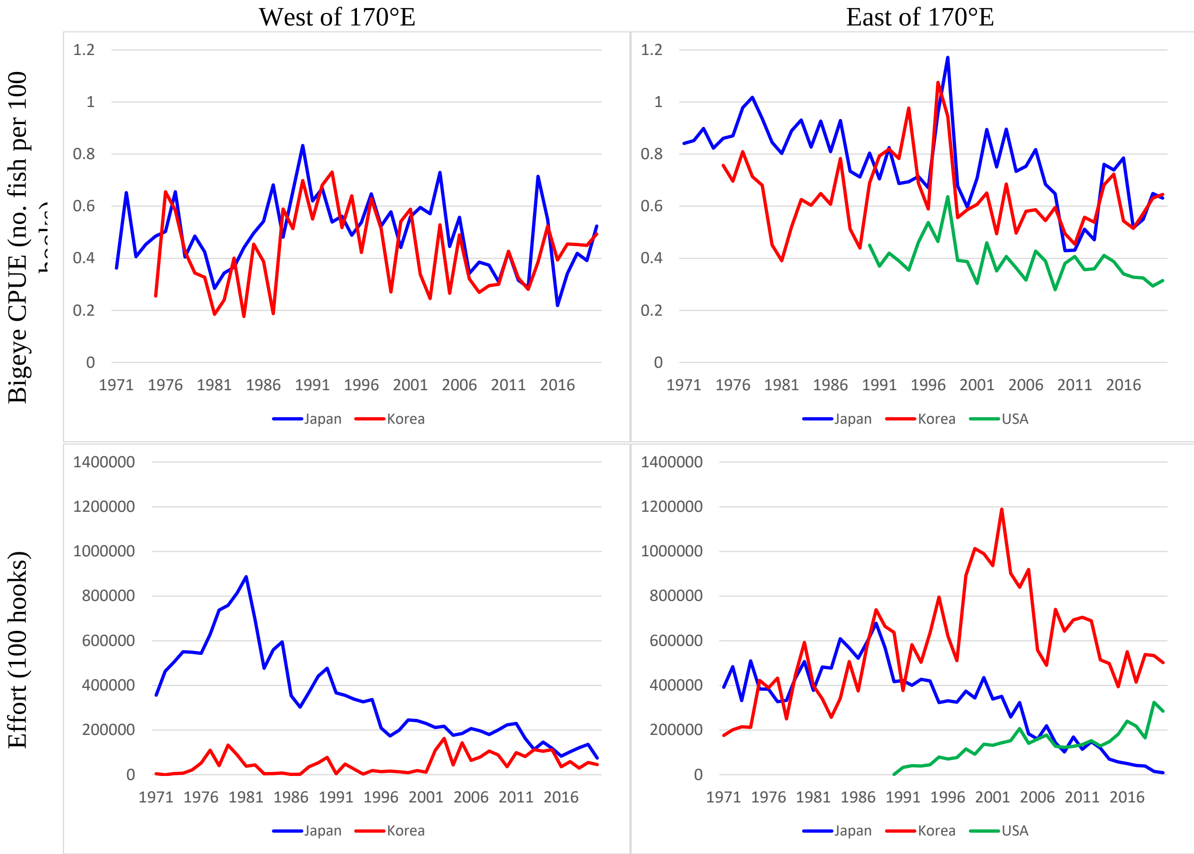

Figure 14. Annual trends in: (top row) nominal bigeye tuna CPUE (number of fish per 100 hooks) for the Japan and Korean longline fleets in the tropical fishery (20°N to 10°S); and (bottom row) effort ('00 hooks) for fishing west of 170°E (left) and east of 170°E (right). Data in the final year of the time series (2020) is likely incomplete. US fleet patterns within the region east of 170°E added as per TTMW2 request.

High seas

Source	Request
TTMW1	Schedule of high seas effort by US vessels against the US limits in applicable CMMs since 2012
TTMW1	Evaluate the removal of the FAD sets in 2019 in the HS for flags not in Table 2 of the measure (i.e., not bound by limits).

US vessel high seas effort

The schedule of high seas effort by US vessels against CMM-specified limits is provided in Table 23.

Table 23. Schedule of HS effort by US vessels from CMM tables, versus US limits in applicable CMMs since 2012.

Category	2012	2013	2014	2015	2016	2017	2018	2019	2020
HS Days	1,241	1,016	1,153	1,664	1,445	842	1,587	1,543	1,658
Limit			1,270	1,270	1,270	1,270	1,370	1,270	1,270

Notes

1. The USA notified WCPFC in November 2020 of their choice of IATTC measures in the overlap area, so the 2020 HS days excludes HS days in the WCPFC-IATTC overlap area

Evaluation of FAD set removal for non-Table 2 flags

To calculate the impact of the removal of high seas FAD sets for those flags not in Table 2 of the Measure, the anticipated number of total FAD sets in 2019 was first calculated using the approach used in the 'FAD closure' section of this report (i.e. under conditions of a 3 month in zone closure and 5 month high seas closure; see also Table 9). The number of high seas FAD sets made by fleets not in Table 2 of the measure in 2019 was then subtracted. This assumes that those fleets do not transfer FAD sets in-zone during the year.

The scalar for the 2019 total FAD sets and FAD sets minus 'non-Table 2' fleets were then calculated relative to the 2016-2018 baseline period. As those scalars are relative to the 2016-18 baseline, a period that had higher overall purse seine effort than in 2019 (Table 22), the same approach as applied in Table 9 was used to scale values back to the overall level of effort in 2019 (Table 24). The potential impact on future bigeye stock status was then evaluated for the two future recruitment scenarios. This therefore assumed that purse seine overall effort and the period available to set on FADs were at 2019 levels, and longline catch was similarly at 2019 levels.

Table 24. Impact of removing high seas FAD sets by non-Table 2 fleets from 2019 fishing levels on future bigeye depletion.

Scenario	2019 PS effort relative to 2016-2018	Expected 2019 PS FAD set scalar relative to 2016-2018	Overall PS scalar relative to 2016-2018	LL 2019 scalar relative to 2016-2018	Resulting bigeye depletion ($SB/SB_{F=0}$)	
					Recent recruitment	Long term recruitment
2019 baseline	0.93	1.11	1.03	1.10	0.46	0.41
2019 minus HS FAD sets from unlimited fleets	0.93	1.04	0.97	1.10	0.48	0.42

Other

Source	Request
TTMW1	Table of the number of purse seine vessels as fishing in the Convention Area between 20N-20S by CCMs listed in Table 2 of Attachment 1 of CMM 2020-01 from 2012
TTMW1	Results shown in table 15 and table 14 in WCPFC-TTMW1-2021-01_rev3 be merged. *This has been superseded by requests at TTMW2.*
TTMW1	IP02: Two plain graphs expressing the percentage of effort in (EEZ+AW) and HS (split between CCMs with limits, PH, CCMs without limits)
TTMW1	IP02: update of figure 3 taking into account the FADs sets estimated for footnote 1 of CMM 2018-01.
TTMW2	Modifications to table 23 of WCPFC-TTMW2-2021-01_rev4: evaluation of the 'patterns of high seas effort' for 2020 and 2019, calculate these comparisons against the 'optimistic' and 'pessimistic' scenarios based on the 'actual reported numbers' of high seas FAD sets (as opposed average high seas days and sets/high seas day by flag) in the 2016/18 baseline period for flags not included in table 2 of CMM 2020-01.
TTMW2	Modifications to table 23 of WCPFC-TTMW2-2021-01_rev4: include information on the impact of high seas effort by CCMs not in table 2 of CMM 2020-01 (i.e., analogous to the evaluation of "HS effort limits set to zero for limited flags" in table 23 of WCPFC-TTMW2-2021-01_rev4
TTMW2	Modifications to table 23 of WCPFC-TTMW2-2021-01_rev4: Include a column with estimates of "Approximate equivalent HS FAD closure period". Caveat: This would only be done for high seas scenarios

The requested tables and figures are provided below.

Table 25. Numbers of purse seine vessels as fishing in the Convention Area between 20N-20S by CCMs listed in Table 2 of Attachment 1 of CMM 2020-01 from 2012 – 2020, by fleet

Fleet	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	13	14	19	20	2	3	3	0	0
Ecuador	8	7	7	7	2	4	4	8	4
EU-Spain	4	4	4	4	2	2	2	2	2
Japan	41	41	40	40	37	38	34	36	36
Republic of Korea	28	27	28	25	25	26	27	26	27
New Zealand	4	4	5	2	2	1	1	1	1
Philippines	21	27	27	23	17	12	12	12	6
El Salvador	2	4	4	2	3	1	1	2	2
Chinese Taipei	34	34	34	34	34	31	27	30	29
USA	39	40	40	39	37	34	34	31	23
	194	202	208	196	161	152	145	148	130

Additional requests at TTMW2 aimed at updating Table 23 of WCPFC-TTMW2-2021-01_rev4 (table now below). Three requests were made:

a) The results for request "evaluation of the 'patterns of high seas effort' for 2020 and 2019, calculate these comparisons against the 'optimistic' and 'pessimistic' scenarios" are included in rows 8, 9 of Table 26**.** This evaluation determines the difference between the number of high seas (HS) FAD sets that were predicted to occur under CMM 2020-01 (with baseline years 2016-2018) with the numbers that were actually reported in logbooks in 2019 and 2020. Rows 8 and 9 were added to allow comparison of these differences between CCMs that have HS purse seine day limits (rows 6, 7) under Table 2 of CMM 2020-01 and those that do not have limits applied (rows 8, 9). Note that for the CCMs that have HS day limits, both optimistic and pessimistic scenarios are presented consistent with the original CMM 2020-01 evaluation (Hamer et al. 2021), where the optimistic scenario is where limited CCMs fish according to their average HS days effort and daily FAD setting rates for the baseline years, and pessimistic is where they all fish to their full day limits with the average daily FAD setting rates as per the baseline period. For CCMs that do not have HS day limits only the optimistic scenario is specified because there are no upper limits to effort to inform a pessimistic scenario. The results in rows 8, 9 show that in 2019 and 2020 non-limited CCMs made 298 and 331 more HS FAD sets, respectively, than expected under the CMM evaluation. Rows 10 and 11 simply show the combined (limited plus non-limited CCMs) HS FAD set differences compared to that predicted by the CMM evaluation.

b) The evaluation of the request “information on the impact of high seas effort by CCMs not in table 2 of CMM 2020-01” was conducted to provide a direct comparison of the expected implications of setting the non-limited CCMs HS effort to zero against the same scenario for the CCMs with HS day limits. Table 26 (rows 12, 13) compares the results for the pessimistic and optimistic scenario predicted by the CMM evaluation for the limited CMMs, but as for the previous analysis, only the optimistic scenario is presented for the non-limited CCMs. The Philippines is excluded from this analysis.

c) “Include a column with estimates of “Approximate equivalent HS FAD closure period”.” The implications of higher or lower reported HS FAD sets compared to those predicted by the CMM evaluation are included as the equivalent total HS only FAD closure required to compensate for the differences (far right column, Table 26). Where more sets were reported than predicted the total HS FAD set closure is increased, and where there were less HS FAD sets than predicted it is reduced.

Table 26. Future purse seine scalars (under the CMM two scenarios) that may result where the equivalent number of FAD sets are removed from (Footnote 1 and Para 17) or added (HS CMM limits and Patterns of HS effort) to the calculations. The bottom two rows include scenarios where CCMs with HS day limits have those limits set to zero, and those without limits have their predicted HS FADs sets under the optimistic scenario set to zero. opt=optimistic scenario, pess= pessimistic scenario.

Evaluation		Approx. FAD set change	Optimistic scenario	Pessimistic scenario	Approximate equivalent main (full) FAD closure period	Approximate equivalent HS only closure period
1	CMM evaluation scalars (relative to 2016-2018 baseline)		**1.11**	**1.13**	3 months	NA
2	Footnote 1 (2019)	-638	1.07	1.09	~ 2.6 months	NA
3	Footnote 1 (2020)	-1072	1.04	1.06	~ 2.4 months	NA
4	Paragraph 17 (2019)	-447	1.08	1.10	~ 2.8 months	NA
5	Paragraph 17 (2020)	-370	1.09	1.11	~ 2.8 months	NA
6	High seas CMM limits (2019) (reported – predicted, **limited**)	+12 opt -213 pess	1.11	1.12	~2.9 - 3.0 months	5.1 3.9
7	High seas CMM limits (2020) (reported – predicted, **limited**)	+372 opt +147 pess	1.14	1.14	~3.1 - 3.2 months	6.9 5.8
8	High seas CMM limits (2019) (reported – predicted, **non-limited**)	+298 opt	1.13	1.15	~3.1 months	6.6
9	High seas CMM limits (2020) (reported – predicted, **non-limited**)	+331 opt	1.14	1.15	~3.2 months	6.7
10	Patterns of high seas effort (2019) (reported - predicted, **all CCMs**)	+310 opt +85 pess	1.14	1.14	~3.0 - 3.2 months	6.6 5.4
11	Patterns of high seas effort (2020) (reported - predicted, **all CCMs**)	+704 opt +479 pess	1.16	1.16	~3.3 - 3.4 months	8.7 7.5
12	HS effort limits set to zero for limited CCMs[1]	-650 opt -875 pess	1.07	1.07	~ 2.5 – 2.6 months	1.6 0.4
13	HS effort set to zero for non-limited CCMs[1]	-815 opt	1.06	NA	~ 2.5 months	0.7

[1]The total reported HS FAD sets by limited CCMs in 2019 and 2020 were 662 and 1022, respectively and for non-limited fleets were 1113 and 1147, respectively.

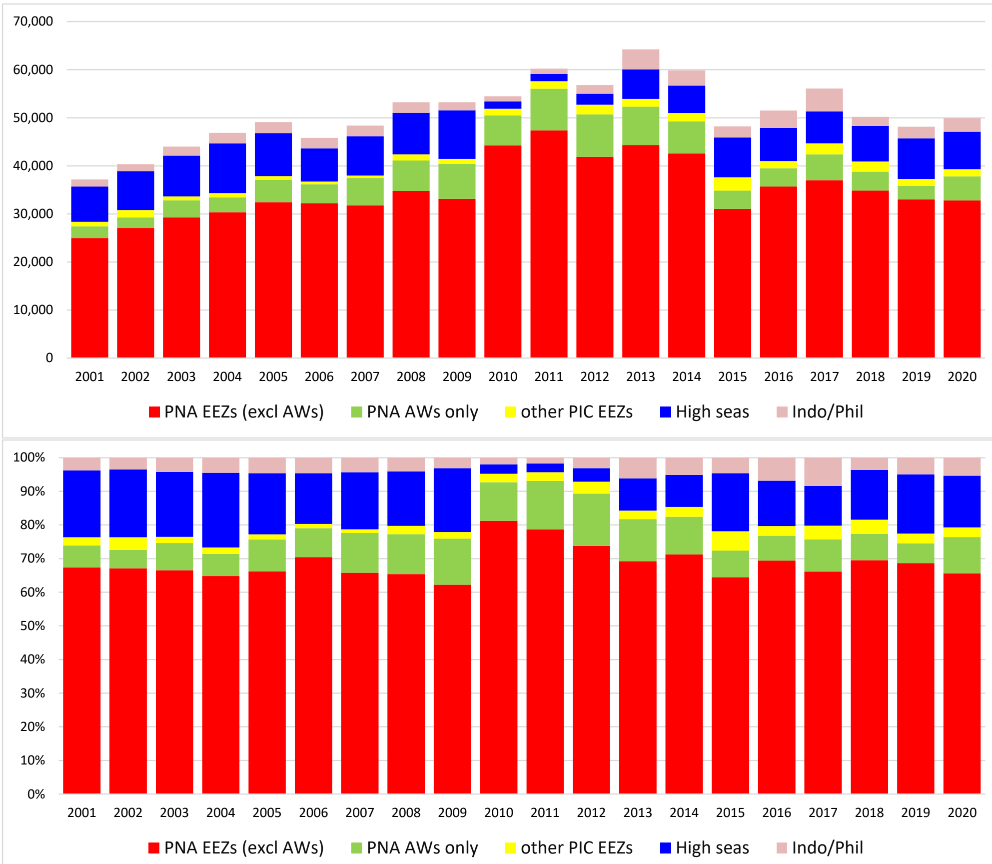

Figure 15. Purse seine effort in waters under national jurisdiction (EEZs and AWs) and in high seas (20°N-20°S). Days fished (top) and percentage of days fished (bottom)

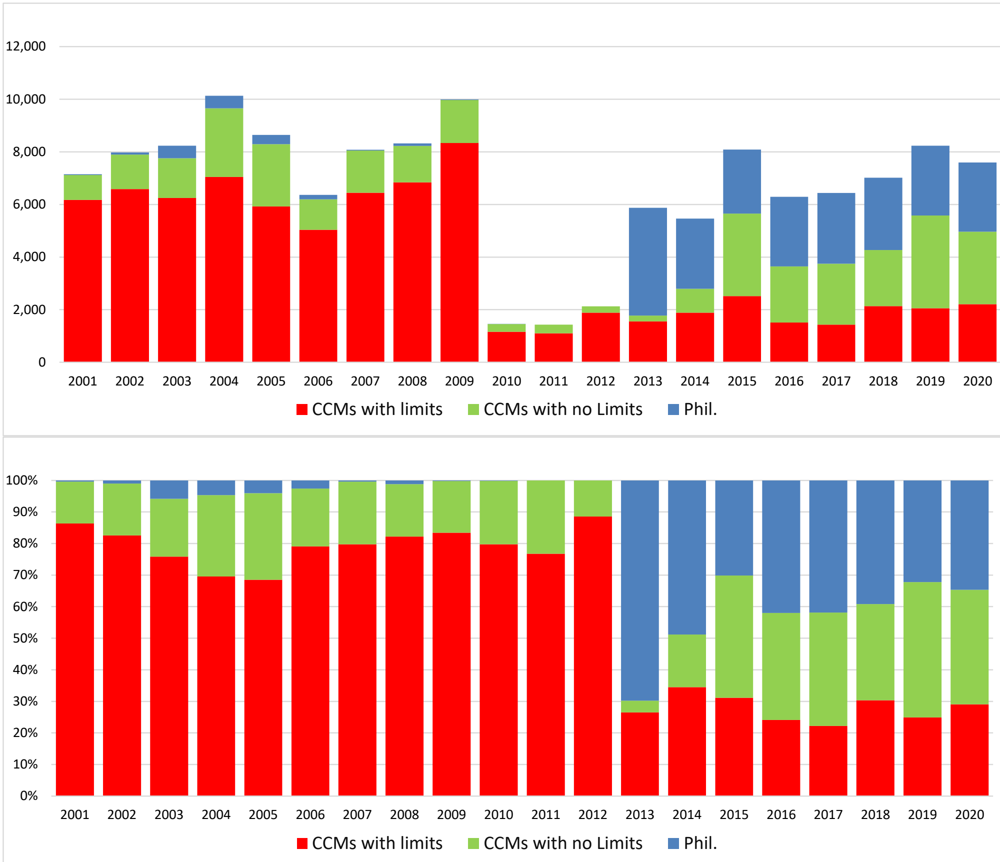

Figure 16. Purse seine effort in high seas (20°N–20°S), by fleet category.

(days fished–top and percentage days fished–bottom)

(“<u>CCMs with no limits</u>“ are Pacific Island fleets fishing in high seas adjacent to their home waters; Philippines effort data prior to 2013 are not available or underreported)

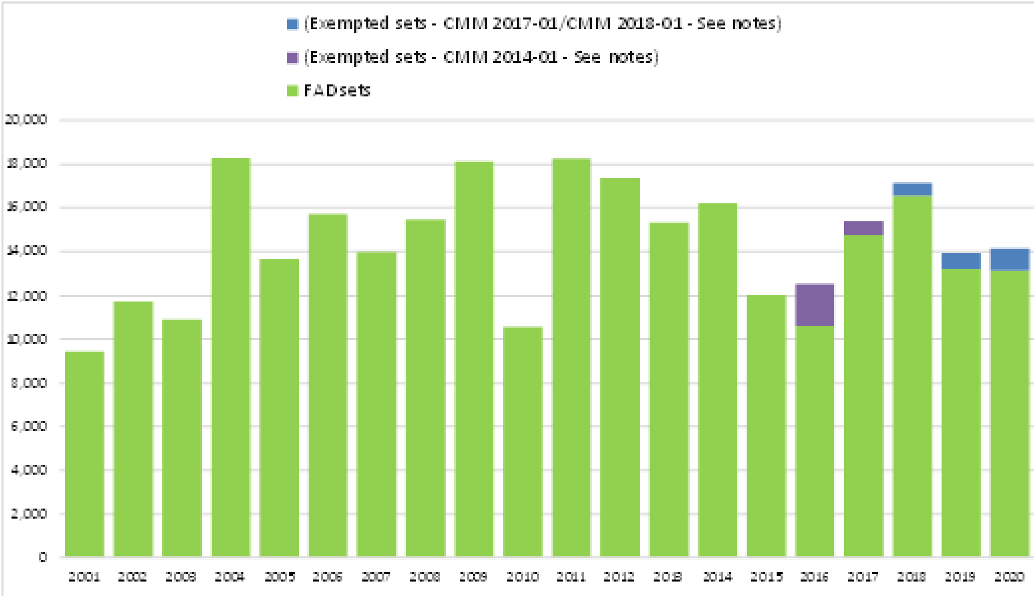

Figure 17. Estimated FAD sets undertaken in the tropical purse seine fishery (20°N-20°S), by fleet category.

Additional evaluations

Source	Request
TTMW2	Assess the projected depletion levels and present the results for skipjack tuna relative to the 2012 levels and for bigeye and yellowfin against the 2012-2015 levels resulting from: Using 2016-18 baseline fishing levels adjusted by appropriate scalars to take into account the changes in the CMM in 2017, as well as 2019 levels as starting points, make the following adjustments: o 8% increase in longline bigeye catch; o FAD closure reduced to 2 months; o High Seas FAD closure reduced by 1/3rd to 40 days; o With no change to the High Seas purse seine effort

For this analysis, the approach taken was comparable to that for the 'FAD closure' analyses detailed earlier (e.g. Table 9). Resulting stock status for the three tropical tuna stocks under this fishing scenario is shown in Table 27 under the two options for future bigeye recruitment.

Table 27. Combinations of specified EEZ and high seas FAD closure periods, purse seine effort and longline catch under the specified scenario, and resulting depletion levels for bigeye (recent and long-term recruitment assumptions), yellowfin and skipjack tuna.

BET recruitment scenario	Fishery scenario combinations					Resulting Scalars					BET outcomes			YFT outcomes			SKJ outcomes	
	EEZ PS effort	EEZ FAD closure	HS FAD closure	LL catch	Other catch	PS effort & HS PS effort v 2016-18 avg	FAD closure scalar	Overall PS scalar	LL catch scalar	Other catch scalar	BET depletion	Result v 2012-15 avg	LRP risk	YFT depletion	Result v 2012-15 avg	LRP risk	SKJ depletion	LRP risk
Recent	2019 levels	2mth	40 days	2019 levels +8%	2016-18 levels	0.93	1.27	1.18	1.19	1	0.42	1.14	0%	0.59	1.07	0%	0.46	0%
Long term	2019 levels	2mth	40 days	2019 levels +8%	2016-18 levels	0.93	1.27	1.18	1.19	1	0.37	1.00	11%	0.59	1.07	0%	0.46	0%

Appendix 1. Summary table of SSP requests from TTMW1

Approved Requests to SSP

Considering the capacity of the SSP it is not possible to complete all the 'Short' requests by the next meeting. With this is mind, the remaining 'Short' requests have been scored by the SSP in relation to their difficulty/time requirements, i.e., the 'Points' column. The meeting selected a priority list of requests that total no more than 20 points. The SSP would expect to complete these requests in the available time before the next meeting.

Category	Request	CCM making request	Technical feasibility	Time scale[1]	Points
TRPs	**BET** TRP as **average depletion 2000-2004**, determine, MSY, F, as a proportion of recent levels (2014-2017), projected to achieve this TRP. Overall, region, fish size (juv/ad)	Japan	**Technically feasible**	Short	2
TRPs	**BET** TRP as **median depletion 2000-2004**, determine, MSY, F, as a proportion of recent levels (2014-2017), projected to achieve this TRP. Overall, region, fish size (juv/ad)	Japan	**Technically feasible**	Short	
TRPs	**SKJ** Evaluate applying purse seine effort 2007-2009 ave., equlib yield v MSY, LRP risks 50%, 48%, 46%, 44% and 42%SBF=0, plus 36, 38 and 40% (Tokelau)	Korea	**Technically feasible**	Short	1
TRPs	**BET** Evaluate 2007-2009 fishing level in terms of median depletion level and the corresponding change in spawning biomass from 2012-2015 average, recent and long-term recruitment conditions	Korea	**Technically feasible**	Short	1
FAD closure	Adding months, projected change in **future depletion** for **SKJ, BET, YFT** **HS x 6 months, EEZ x 3 months**	Japan	**Technically feasible**	Short	~~2~~
FAD closure	Adding months, projected change in **future depletion** for **SKJ, BET, YFT** **HS x 5 months, EEZ x 4 months**	Japan	**Technically feasible**	Short	

[1] **Short** – next meeting; **Medium** – commission; **Long**- 2022?

Category	Request	CCM making request	Technical feasibility	Time scale[1]	Points
FAD closure	Adding months, projected change in **future depletion** for SKJ, BET, YFT **HS x 6 months, EEZ x 4 months**	Japan	**Technically feasible**	Short	
FAD closure	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion **status quo (3 mths EEZ/HS + 2 mths HS)** **+ a sensitivity with the 2019 effort and catch levels.**	PNA	**Technically feasible**	Short	
FAD closure	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion **1 month reduction (EEZ and HS)** **+ a sensitivity with the 2019 effort and catch levels.**	PNA	**Technically feasible**	Short	
FAD closure	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion **complete removal (both EEZ and HS** **+ a sensitivity with the 2019 effort and catch levels.**	PNA	**Technically feasible**	Short	
FAD closure	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion **2 mo EEZ, 3 mo HS** **+ a sensitivity with the 2019 effort and catch levels.**	PNA	**Technically feasible**	Short	
FAD closure	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion **2 mo HS, 2 mo EEZ** **+ a sensitivity with the 2019 effort and catch levels.**	PNA	**Technically feasible**	Short	
FAD closure	Reduce FAD closure implications on **SKJ, BET, YFT** future depletion **1 mo HS, 1 mo EEZ** **+ a sensitivity with the 2019 effort and catch levels.**	PNA	**Technically feasible**	Short	
FAD closure	Changed FAD closure implications on **SKJ, BET, YFT** future depletion **5 mo HS, 5 mo EEZ** **+ a sensitivity with the 2019 effort and catch levels.**	EU	**Technically feasible**	Short	
FAD closure	Changed FAD closure implications on **SKJ, BET, YFT** future depletion **4 mo HS, 4 mo EEZ** **+ a sensitivity with the 2019 effort and catch levels.**	EU	**Technically feasible**	Short	

Category	Request	CCM making request	Technical feasibility	Time scale[1]	Points
FAD closure	Changed FAD closure implications on **SKJ, BET, YFT** future depletion **3 mo HS, 3 mo EEZ** **+ a sensitivity with the 2019 effort and catch levels.**	EU	**Technically feasible**	Short	
FAD closure	Changed FAD closure implications on **SKJ, BET, YFT** future depletion **2 mo HS, 3 mo EEZ** **+ a sensitivity with the 2019 effort and catch levels.**	EU	**Technically feasible**	Short	
FAD closure	Changed FAD closure implications on **SKJ, BET, YFT** future depletion **3 mo HS, 4 mo EEZ** **+ a sensitivity with the 2019 effort and catch levels.**	EU	**Technically feasible**	Short	
FAD closure	Changed FAD closure implications on **SKJ, BET, YFT** future depletion **3 mo HS, 5 mo EEZ** **+ a sensitivity with the 2019 effort and catch levels.**	EU	**Technically feasible**	Short	
FAD closure	Assess the trade-off between increases in longline bigeye catch and length of FAD closure, include results for SKJ, BET, YFT	PNA	**Technically feasible**	Short	1
High Seas effort	Maintaining EEZ PS effort, evaluate the impact of varying effort on the high seas between **0** and **10,000** days (increment by **2000** days)	FFA	**Technically feasible**	Short	1
FAD definitions	Impact of the exclusion of floating objects that do not have a tracking buoy attached from the definition of FAD	Korea	**Technically feasible**	Short	2
Exemptions	Consequence on the projected stock status on the exemption from 20% of the 35% cuts applied to the bigeye catch limits of other major longline fleets from the baseline limits in CMM 2008-01 for any fleet in accordance with para 35 of CMM 2008-01.	PNA	**Technically feasible**	Short	2
Additional metrics/scalars	**SKJ** WP04 – A calculation of recent fishing mortality levels as proportions of 2012 and 2012-2015 levels, overall region, fish size (juv/ad)	Japan	**Technically feasible**	Short	2
Additional metrics/scalars	Alternative values for estimating future depletion levels against alternative catch and effort baselines **Purse seine** 1-month EEZ FAD closure; 1-month High seas FAD closure 1-month High seas + EEZ FAD closure; and	PNA	**Technically feasible**	Short	1

Category	Request	CCM making request	Technical feasibility	Time scale[1]	Points
Additional metrics/scalars	Alternative values for estimating future depletion levels against alternative catch and effort baselines **Longline catch equivalents for:** 1-month EEZ FAD closure; 1-month High seas FAD closure 1-month High seas + EEZ FAD closure; and	PNA	**Technically feasible**	Short	
Additional metrics/scalars	Current equivalent scalars - what scalars should apply relative to the 2016-18 "starting point" for 2019 conditions (for both catch and effort).	PNA	**Technically feasible**	Short	0
CPUE	**Request during WS1**: compile informative BET CPUE time series	**Japan**	**Technically feasible**	Short	1
High seas	Schedule of high seas effort by US vessels against the US limits in applicable CMMs since 2012	**PNA**	**Technically feasible**	Short (SPC or Secretariat)	0
High seas	Evaluate the removal of the FAD sets in 2019 in the HS for flags not in table 2 of the measure (i.e., not bound by limits).	**EU**	**Technically feasible**	Short (SPC or Secretariat)	(1-evaluate?)
Other	Table of the number of purse seine vessels as fishing in the Convention Area between 20N-20s by CCMs listed in Table 2 of Attachment 1 of CMM 2020-01 from 2012	**PNA**	**Technically feasible**	Short (SPC or Secretariat)	1
Other	Results shown in table 15 and table 14 in WCPFC-TTMW1-2021-01_rev3 be merged.	**EU**	**Technically feasible**	Short	1
Other	IP02: Two plain graphs expressing the percentage of effort in (EEZ+AW) and HS (split between CCMs with limits, PH, CCMs without limits)	**EU**	**Technically feasible**	Short	
Other	IP02: update of figure 3 taking into account the FADs sets estimated for footnote 1 of CMM 2018-01.	**EU**	**Technically feasible**	Short	

Appendix 2. Summary table of SSP requests from TTMW2

The table below provides a list of the requests for additional work to the SSP as prioritised and agreed at TTM-W2 to be provided to the WCPFC18 Commission meeting. These included requests carried over from TTM-W1, and relevant requests raised at SC17. The requests are grouped according to the categories used by the SSP for TTM-W1 requests. The meeting selected a priority list of requests that total no more than 13 points.

Source	Category	Request	CCM making request	Technical feasibility	Points
SC17	**TRPs**	Calculate SPA outcomes for different candidate BET/YFT TRP levels presented in MI-WP-01 (SC17 draft summary report, para 265)	FFA	**Technically feasible**	3
SC17	**TRPs**	Development of yield and spawning biomass per recruit curves by fisheries sector for bigeye and yellowfin tuna (SC17 draft summary report, para 271)	US	**Technically feasible**	2
TTMW1	**FAD definitions**	Update on evaluation re-small floating objects	Japan	**Technically feasible**	3
TTMW2	**Other**	Modifications to table 23 of WCPFC-TTMW2-2021-01_rev4: evaluation of the ‘patterns of high seas effort’ for 2020 and 2019, calculate these comparisons against the ‘optimistic’ and ‘pessimistic’ scenarios based on the ‘actual reported numbers’ of high seas FAD sets (as opposed average high seas days and sets/high seas day by flag) in the 2016/18 baseline period for flags not included in table 2 of CMM 2020-01.	EU	**Technically feasible**	1
TTMW2	**Other**	Modifications to table 23 of WCPFC-TTMW2-2021-01_rev4: include information on the impact of high seas effort by CCMs not in table 2 of CMM 2020-01 (i.e., analogous to the evaluation of “HS effort limits set to zero for limited flags” in table 23 of WCPFC-TTMW2-2021-01_rev4	EU	**Technically feasible**	1
TTMW2	**Other**	Modifications to table 23 of WCPFC-TTMW2-2021-01_rev4: Include a column with estimates of “Approximate equivalent HS FAD closure period”.	EU	**Technically feasible**	1

		Caveat: This would only be done for high seas scenarios			
TTMW2	**Additional metrics/scalars**	Include time series data for the US LL fleet in Figure 12 of TTMW2-01_REV4	PNA	**Technically feasible**	1
TTM2	**Additional evaluations**	Assess the projected depletion levels and present the results for skipjack tuna relative to the 2012 levels and for bigeye and yellowfin against the 2012-2015 levels resulting from: Using 2016-18 baseline fishing levels adjusted by appropriate scalars to take into account the changes in the CMM in 2017, as well as 2019 levels as starting points, make the following adjustments: o 8% increase in longline bigeye catch; o FAD closure reduced to 2 months; o High Seas FAD closure reduced by 1/3rd to 40 days; o With no change to the High Seas purse seine effort.	PNA	**Technically feasible**	1