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AN EVALUATION OF THE MANAGEMENT OPTIONS FOR PURSE SEINE AND LONGLINE FISHERIES DEFINED BY THE TT CMM INTERSESSIONAL MEETING

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Paper by SPC Oceanic Fisheries Programme

[1] Replaces original version issued on 16 November 2017. Details of the changes are explained on the following page.

Details of changes made during the revision to this report

- A correction to Table 8, where the total FAD closure period (months) under '2013-15 conditions' (scalar = 1) was incorrectly indicated as '1' month rather than '4' months.
- Details of emailed questions from CCMs on the report and spreadsheet, and SPC responses, provided below:

Q. On page 4, when it refers to the baseline fishing levels from 2013-2015, can you confirm that these were the baseline levels related to what was assumed to be chosen based on management levels and not the actual catch or effort averages from that period?

A. We project each stock based upon the average levels of fishing over the 2013-2015 period, representing the number of associated 'days' by the purse seine fleets and the average longline catch within the assessment model across those years. So, these are the ACTUAL catch and effort for each stock, as used within the assessments, NOT the expected catch and effort that might arise under the management conditions in place over that period.

Q. Can you provide the number of fishing days that equates to the SKJ TRP?

A. From Table 1 of WCPFC-TCC13-2017-IP08, the average 2013-15 fishing days, including in archipelagic waters = 56,168 (incl ID/PH) or 53,836 (excl ID/PH).

Q. For the BET grid, is it possible to provide instead of the approximate total FAD closure period, what the equivalent is in terms of total FAD sets?

A. We have added a column in the revised version of the Excel output for the BET grid. From Table 3 of WCPFC-TCC13-2017-IP08, the average over 2013-15 = 14,427 sets, which can be applied to the ASS scalar.

Q. Also, for the grids, for relative impacts, is it possible to get a sense of the contribution to depletion for each sector?

A. We cannot in the time available do the equivalent of the 'impact plots' for PS/LL that are presented within the assessment reports (e.g. Figure 46 of the BET assessment report) for each scenario/grid row. As described in the paper and shown in the spreadsheet, we have instead attempted to evaluate the impact contribution of each gear relative to the results of maintaining 2013-15 average conditions. However, following your request we are looking into doing the equivalent of the 'impact plot' calculation specifically for the '2013-15 average' conditions scenario (i.e. scalars of 1). But this will take time.

Q. Is it at all possible to get some higher resolution on the risk levels? I understand the green, yellow and red, but within the yellow, it is at all possible to get it split out at least to 5-10, 10-15 and 15-20?

A. This can be adjusted by the user within the Excel spreadsheet by changing and adding levels defining the colours. When a risk cell is highlighted, this can be changed through: Home > Conditional Formatting > Manage Rules. Also note that the approximated risk levels can be seen when the individual cells are highlighted (as a decimal, where 0.2 = 20% approximated risk). However, as noted, these are approximated risk levels, given the incomplete levels of uncertainty captured within the analysis, and we suggest that evaluations of risk levels at too fine a scale would not be appropriate.

For information, we are also looking into running the 'full' stochastic projection approach for bigeye under the assumption of 2013-15 conditions (scalars of 1) to 'ground truth' the approximated risk we have from the deterministic runs. Again, this will take time.

1. Executive Summary

At the Intersessional Meeting to progress the draft Bridging CMM on Tropical Tuna (Commission Special Session, 22-24th August 2017), a small working group defined management Options for the tropical tuna fishery (purse seine and longline) and performance criteria to evaluate the resulting stock and fishery outcomes. The Science Services Provider (SPC-OFP) was tasked to examine the consequences of these Options for bigeye, skipjack and yellowfin, based upon the latest assessments for each stock.

We use an approach similar to that developed for recent tropical tuna CMM evaluations to:

- Step 1. quantify provisions of each Option – i.e., translating 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 each stock, against the specified evaluation criteria.

Step 1: Quantifying provisions of the Option

We repeated the detailed evaluation approach used within the last CMM 2015-01 evaluation (WCPFC13-2016-15). Within the evaluation, assumptions are made regarding the impact that changes to the FAD closure, FAD set limits and/or high seas effort limits will have on the level of FAD-related effort, and the potential catches of longline fleets. These assumptions are consistent with those made in previous CMM evaluations, and include the pessimistic assumption that any specified effort and catch limits are taken by a flag, even where those limits are higher than recent fishing levels. Under these assumptions, the defined management Options and sub-Options specify levels of future purse seine effort and longline catch.

Step 2: Evaluate the potential consequences of each Option

The consequences of the future fishing levels were evaluated through deterministic projections, to make the process computationally feasible. Results therefore represent the ‘equilibrium’ conditions that would be achieved (on average) in the future, rather than the immediate changes under those fishing levels. The consequences of each management Option, as well as those under baseline ‘2013-15 average’ purse seine effort and longline catch levels, were evaluated against the defined evaluation criteria for each stock. Deterministic stock projections were also performed for combinations of purse seine associated effort and longline catch scalars ranging from 0.5 to 1.5 times 2013-2015 average levels. From this grid, alternative fishery combinations that met the evaluation criteria could be evaluated (Option 3B). Results are summarised within this document and in the accompanying Excel spreadsheet[2].

Key findings

We focus here on the results relative to the key evaluation criteria - spawning biomass depletion ($SB/SB_{F=0}$) and fishing mortality in relation to fishing mortality at maximum sustainable yield (F/F_{MSY}) – as specified by the TT CMM small working group (i.e. no decrease in $SB/SB_{F=0}$ or increase in F/F_{MSY} relative to recent assessed levels). Noting that average conditions over 2013-2015 represent a period in which a 4 month FAD closure, no high seas FAD closure (but high seas effort limits), and tightening bigeye catch limits for key longline fleets have been in place, key findings are:

- For bigeye tuna, a continuation of 2013-15 conditions is expected to:

[2] Consequences are generally calculated as a median across the relevant assessment model runs for each stock. For bigeye specifically, they are weighted according to those used by the Scientific Committee when providing advice.

- maintain the median spawning biomass depletion near to $SB_{recent}/SB_{F=0}$, with a slight decline of 1% estimated (median $SB_{2045}/SB_{F=0}$ = 0.31);
  - increase fishing mortality by 12% (median F_{2045}/F_{MSY} = 0.93), but F remains below F_{MSY};

  Resulting risks of the stock falling below the limit reference point (LRP) and fishing mortality increasing above F_{MSY}, approximated from the deterministic projections, are greater than 20%.
- For skipjack, a continuation of 2013-15 purse seine effort conditions will maintain the spawning biomass depletion around the interim target reference point ($SB/SB_{F=0}$ = 0.50). Median F/F_{MSY} falls slightly compared to that estimated within the assessment, while these is no risk of the stock falling below the LRP, nor of fishing mortality increasing above the F_{MSY} level. For yellowfin, 2013-15 conditions are projected to result in an increase in $SB/SB_{F=0}$, while F/F_{MSY} falls relative to recent levels. For both stocks, approximated risk relative to the LRP and F_{MSY} are low (<5% and 0%, respectively).
- For bigeye, as the majority of specified management options imply increases in purse seine effort and longline catch relative to the 2013-2015 baseline, they do not meet the evaluation criteria of maintaining $SB/SB_{F=0}$ above and F/F_{MSY} below their recent levels. However, Option 4 achieves the spawning biomass depletion criterion where longline catch is maintained at recent levels, while Options 2, 4 and 5 can achieve the evaluation criteria with reductions in longline bigeye catch (longline catch was not specified for these Options by the TT CMM small working group).
- For bigeye, minimum fishery combinations achieving the spawning biomass depletion and fishing mortality evaluation criteria are identified (Table 7, Table 8). As 2013-15 average fishery conditions approximately stabilise spawning biomass depletion at recent levels, increases in the fishing level of one gear must be compensated for by reductions of the other:
  - a 10% increase in **longline bigeye catch**, around a 15-20% decrease in purse seine associated effort is required to compensate; while
  - a 10% increase in **purse seine associated effort** requires a 10% decrease in longline catch to compensate (see Figure 1).

  Skipjack and yellowfin generally meet their evaluation criteria under these conditions.

  To maintain a stable level of bigeye tuna F/F_{MSY}, reductions in fishing relative to 2013-15 conditions are required:
  - with **purse seine associated effort** at 2013-15 levels, a 30% reduction in longline bigeye catch is required; while
  - with **longline catch** at 2013-15 levels, a 50% reduction in purse seine associated effort is required.

  Where a stable level of bigeye tuna F/F_{MSY} is achieved, the approximated risk of the spawning biomass depletion falling below the LRP is less than 20% (5-20% range), while the approximated risk of fishing mortality increasing above F_{MSY} remains greater than 20%.

OTHER OBSERVATIONS

Consistent with previous tropical tuna CMM evaluations, assumptions of future fishing levels and fishing behaviour are required to evaluate the defined Options. These are detailed within this report. They should be considered when interpreting the results.

For bigeye tuna, results are based upon the full uncertainty grid of stock assessments identified by the 13th Scientific Committee meeting, which includes the more pessimistic ‘old growth’ assessment models, which are down-weighted consistent with SC13 decisions. Further research into bigeye growth has been mandated by SC13. If the results of that research further support the plausibility of the ‘new growth’ model, the ‘old growth’ model runs may be excluded from future management advice.

2. QUANTIFYING THE MANAGEMENT OPTIONS

The evaluation of the management Options specified by the small working group (see Appendix 1) uses projections from the relevant stock assessment model ('uncertainty grid' of bigeye, yellowfin or skipjack assessments selected by Scientific Committee for management advice) under particular future levels of either longline catch or purse seine effort. The two steps are:

1. Estimate the levels of associated (FAD) and unassociated (free school) set purse seine effort and longline catch that would result from a given Option. This estimation requires interpretation of the Option to estimate the likely purse seine effort and longline catch levels that would result.
2. Express those purse seine effort and longline catch levels as scalars relative to an observed baseline level of these quantities.

The same detailed approach used in recent evaluations of the tropical tuna CMM (e.g. CMM 2015-01 presented to WCPFC13, WCPFC13-2016-15) was used. These were based upon data provided to TCC13 (WCPFC-TCC13-2017-IP07, WCPFC-TCC13-2017-IP08[3]) and decisions made at WCPFC13 (e.g. related to CMM 2015-01 footnote 5). The assumptions necessary to convert the management Options into specific levels of assumed future purse seine associated effort and longline catch levels are detailed in Appendix 2. They include the 'pessimistic' assumption that specified flag-based effort and catch limits (e.g. annual FAD set limits, longline catch limits under Option 1) are taken, even where those limits are higher than recent fishing levels by that flag state.

Resulting fishing levels, specified as scalars relative to the selected baseline fishing levels of 2013-2015 average purse seine effort and longline catch, are presented in Table 1. This baseline period was chosen as it was a period of stable management within the purse seine fishery (all years had a 4 month FAD closure or equivalent in operation), and avoided the use of a single and potentially 'anomalous' year (e.g. 2015, when purse seine effort in particular was low). We stress the baseline period chosen does not affect the results of the projections – all options can be mapped onto an equivalent FAD closure/longline catch level.

Note that where Options specify an alternative FAD closure duration, we assume a proportional decrease or increase in the overall number of FAD sets, relative to the 2013-2015 baseline level; i.e. there is a direct relationship between the number of FAD sets and the length of the closure, and hence no increase in the number of sets made per day outside the FAD closure period.

Where purse seine associated effort was scaled, in the majority of Options overall total purse seine effort was maintained at the average level from 2013-2015. Therefore, where scalars indicated an increase in purse seine associated effort, there was a corresponding decrease in unassociated effort to ensure effort overall remained constant. The exception was where management options limited total purse seine effort (e.g. limits on overall effort on the high seas), in which case overall effort was reduced (see Appendices 2 and 3).

To address management Option 3B, a grid of future purse seine effort and longline catch combinations was projected. To ensure a sufficient range of future fishery combinations were examined to meet the evaluation criteria, multipliers of associated purse seine effort and longline catch ranged from 0.5 to 1.5 times the 2013-15 baseline, in increments of 0.1. The grid therefore represented 121 unique combinations of future fishery conditions.

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[3] Note: This information is available in terms of annual numbers of FAD sets by flag. Within the stock assessment, and hence projections performed here, we model effort in days (divided into associated and unassociated effort). We therefore assume that the number of sets of each type made per day remains constant into the future.

Longline scalars in Table 1 represent the change in bigeye catch under each scenario. For simplicity, we apply the same longline scalars to yellowfin, which implies an assumed direct relationship between longline bigeye and yellowfin catches.

Table 1. Summary of the range of purse seine/longline scalars estimated from each of the management Options defined by the TT CMM small working group. See Appendix 2 for details.

		Purse Seine		Longline
Option	Sub-option	Associated	Unassociated	
1	a	1.06	-	1.04
	b	1.10	-	1.11
	c	1.06	-	1.11
2	a-e	1.08,1.08,1.08,1.08,1.05	0.92	Not specified*
	f-j	1.10,1.10,1.09,1.09,1.05	0.94	Not specified*
	k-o	1.11,1.10,1.09,1.09,1.05	0.97	Not specified*
3	a	1.16,1.04,1.10,1.22,1.27	-	1.17,1.24,1.31,1.37,1.44
	b	'SPC to define levels that meet the evaluation criteria'		
4		0.96	-	Not specified*
5		1.04	0.96	Not specified*

* In this case, a range of longline catch scalars were examined (being 0.5 to 1.5 at intervals of 0.1), allowing corresponding longline catch levels that achieved the evaluation criteria to be identified.

As an indication of the potential impact of different management Option components on overall purse seine (associated) effort and longline catch, the scalar relative to 2013-2015 average fishing levels resulting from a specific unit of change within each element is presented in Table 2. It should be noted that combinations of Option components are not necessarily additive – there are interactions between the components when calculating the resulting scalar.

Table 2. Impact of a specific level of change in an individual management Option component.

Management option component	**Unit of change**	**Resulting fishery component scalar relative to 2013-2015 average**
PS FAD closure	3 month closure (one month less)	1.13
	5 month closure (one month more)	0.88
PS High seas FAD closure	Total closure, no exemptions	0.91
	Total closure with exemptions[1]	0.96
Longline catch	5000 mt total reduction	0.92
	5000 mt total addition	1.08

[1] Footnote 5 exemptions and KI exemption

An indication of recent fishing levels relative to the corresponding 2013-2015 average baseline is presented in Table 3.

Table 3. Indication of recent annual fishing levels relative to the 2013-2015 baseline.

Year	Purse seine FAD sets/2013-2015 avg	Longline catch/2013-2015 avg
2013	1.05	0.94
2014	1.11	1.04
2015	0.84	1.03
2016*	0.92	0.88

* 2016 values preliminary

3. Evaluation of the potential effectiveness of each option

We use the purse seine associated (FAD) effort and longline catch scalars estimated in Step 1 within projections for each tropical tuna stock to evaluate the outcomes in relation to the stated evaluation criteria. This approach is summarised below (see also Appendix 3).

Stocks were projected forward for 30 years based upon the most recent assessments, which provided information on the status of each stock in 2015 (bigeye: McKechnie et al., 2017; yellowfin: Tremblay-Boyer et al., 2017; skipjack: McKechnie et al., 2016). Key features of the projection approach were:

- Deterministic stock projections were performed (due to time and computational constraints), with future recruitment defined by the stock recruitment relationship as estimated within each assessment model run[4];
- The deterministic projections were performed from each of the stock assessment models within the 'uncertainty grid' used by the Scientific Committee to provide advice (bigeye: 72 models, yellowfin: 48 models, skipjack: 54 models). This was to capture the uncertainty within the stock assessments, consistent with the uncertainty framework approach endorsed by SC10. In the case of bigeye tuna, results were weighted as defined by SC13 (see below);
- The future catchability of each fleet within the model was assumed to be constant at the level estimated in the final year of the stock assessment. This assumes there is no future effort creep, nor increases or decreases in fishing efficiency resulting from management actions (e.g. limiting associated purse seine fishing effort);
- All other fisheries, including the small scale fisheries in Indonesia and Philippines, were kept constant at 2013-2015 average levels.

The defined evaluation criteria for each stock (see Appendix 1) were calculated from the last year of the projection (2045). These results therefore represent where the stock would be – on average – in equilibrium with the fishery conditions defined by each management Option. We do not examine the trajectory of stocks to those equilibrium levels. Key indicators used are the spawning biomass in relation to

[4] We also examined a specific bigeye tuna recruitment scenario where future recruitment was fixed at the average of the last 10 years of estimated recruitments, to approximate the assumption that recent relatively positive bigeye recruitments would continue. Preliminary results were comparable to those under the stock-recruitment relationship assumption. This similarity was influenced by improvements within the 2017 bigeye assessment that reduced the temporal trend in the recruitment time series compared to previous assessments, as well as consequences of that recruitment assumption for the calculation of future unfished biomass ($SB_{F=0}$). This alternative bigeye recruitment option was not therefore pursued further.

the average unfished level (e.g. $SB_{2045}/SB_{F=0}$[5]) and the fishing mortality at the end of the projection period in relation to the fishing mortality at maximum sustainable yield (e.g. F_{2045}/F_{MSY}).

An average (median) value for these evaluation criteria, and for vulnerable biomass, was calculated across the results from the 'uncertainty grid' of assessment model runs for a stock. For bigeye tuna, the medians across the model runs based upon the two alternative growth assumptions were weighted as defined by Scientific Committee. Resulting median values were compared to median $SB_{recent}/SB_{F=0}$ and F_{recent}/F_{MSY} values from the most recent stock assessments[6]. Median purse seine and longline vulnerable biomass levels, and skipjack catch, were reported relative to the projected level that resulted under 2013-2015 fishing conditions.

As these evaluations are necessarily based upon deterministic (rather than stochastic) projections, the risk indicator is based only on the uncertainty captured by different stock assessment runs. No other sources of future uncertainty, such as variability in the level of future recruitments, are included. Therefore, the expectation is that the risk presented herein is understated. Rather than provide specific values for the resulting approximated level of risk, a 'traffic light' indicator is provided whereby red = greater than 20% approximated risk; amber = between a 5% and 20% risk; green = less than a 5% risk. These should be viewed as arbitrary cut offs.

For bigeye specifically, the relative impact of each gear on changes in the bigeye $SB/SB_{F=0}$ level was calculated relative to the level projected under 2013-15 conditions. The contribution of a gear to the relative change in spawning biomass depletion was estimated by sequentially setting the scalar of one gear to that specified within the Option, the scalar for the other gear at 1, and examining the relative implication of those fishing conditions for the spawning biomass depletion ratio ($SB/SB_{F=0}$). The relative impact is then the gear-specific change, relative to the absolute change resulting from both gears. Negative contributions represent a reduction in spawning biomass depletion relative to that under 2013-15 conditions, and positive contributions an increase. Under 2013-15 conditions, there is therefore no contribution to change by either gear.

For bigeye under Option 3B (the grid of purse seine effort and longline catch levels), an indication of the approximate total FAD closure period and longline bigeye catch level equivalents is estimated, based upon the scalars applied relative to the 2013-15 average conditions.

POTENTIAL CONSEQUENCES OF THE MANAGEMENT OPTIONS

The resulting evaluation criteria under each of the potential management Options defined by the TT CMM small working group in Hawaii are presented in Table 4 to Table 6, by stock. The outputs for these Options, and for Option 3B, are also available in the accompanying Excel spreadsheet. This spreadsheet allows Commission members to filter on specific columns to identify those purse seine and longline scalars that achieve desired evaluation criteria. It also contains the additional information on the approximate equivalent purse seine total FAD closure period and longline (bigeye) catch level defined by the corresponding fishery scalars, as well as the estimated gear-specific impacts.

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[5] $SB_{F=0}$ was calculated consistent with the approach defined in CMM 2015-06, 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. $SB_{2045}/SB_{F=0, 2035\text{-}2044}$).

[6] Recent values are defined as the average over 2012-2015 for spawning biomass ($SB_{2012\text{-}2015}$) and 2011-2014 for fishing mortality ($F_{2011\text{-}2014}$).

Table 4. Weighted median outcomes for bigeye tuna arising from each management Option.

All values rounded to 2dp. Shading for display purposes only.

Option	Sub-option	Resulting scalars		$SB_{2045}/SB_{F=0}$	$SB_{2045}/SB_{F=0}$ relative to $SB_{2012-2015}/SB_{F=0}$	F_{2045}/F_{MSY}	F_{2045}/F_{MSY} relative to $F_{2011-2014}/F_{MSY}$	Vulnerable biomass (relative to 2013-2015 outcomes)		Approximated risk** of		Relative gear impact on $SB/SB_{F=0}$	
		PS ASS	LL					PS	LL	SB <LRP	F > F_{MSY}	PS	LL
'2013-15 conditions'		1.00	1.00	0.31	0.99	0.93	1.12	1.00	1.00			-	-
1	a	1.06	1.04	0.30	0.94	0.96	1.16	0.96	0.95			-46	-54
	b	1.10	1.11	0.28	0.89	0.99	1.20	0.94	0.91			-33	-67
	c	1.06	1.11	0.29	0.90	0.98	1.19	0.95	0.92			-18	-82
2	a-d	1.08	1*	0.30	0.96	0.95	1.14	0.97	0.97			-100	0
	e	1.05	1*	0.31	0.97	0.94	1.13	0.98	0.98			-100	0
	f-g	1.10	1*	0.30	0.95	0.95	1.15	0.96	0.96			-100	0
	h-i	1.09	1*	0.30	0.96	0.95	1.14	0.96	0.96			-100	0
	j	1.05	1*	0.31	0.97	0.94	1.13	0.98	0.98			-100	0
	k	1.11	1*	0.30	0.95	0.96	1.15	0.95	0.95			-100	0
	l	1.10	1*	0.30	0.95	0.95	1.15	0.95	0.96			-100	0
	m, n	1.09	1*	0.30	0.95	0.95	1.15	0.96	0.96			-100	0
	o	1.05	1*	0.31	0.97	0.94	1.13	0.97	0.98			-100	0
3	a.i	1.16	1.17	0.26	0.83	1.03	1.24	0.88	0.86			-35	-65
	a.ii	1.16	1.24	0.25	0.79	1.05	1.27	0.86	0.83			-27	-73
	a.iii	1.16	1.31	0.24	0.75	1.07	1.29	0.85	0.79			-22	-78
	a.iv	1.16	1.37	0.23	0.72	1.10	1.32	0.85	0.76			-19	-81
	a.v	1.16	1.44	0.22	0.69	1.13	1.36	0.82	0.73			-16	-84
	a.vi	1.04	1.17	0.28	0.87	1.00	1.21	0.94	0.90			-5	-95

	a.vii	1.04	1.24	0.26	0.83	1.02	1.23	0.91	0.86			-4	-96
	a.viii	1.04	1.31	0.25	0.79	1.05	1.26	0.89	0.83			-3	-97
	a.ix	1.04	1.37	0.24	0.76	1.07	1.29	0.88	0.80			-2	-98
	a.x	1.04	1.44	0.23	0.72	1.10	1.32	0.87	0.76			-2	-98
	a.xi	1.10	1.17	0.27	0.85	1.01	1.22	0.91	0.88			-23	-77
	a.xii	1.10	1.24	0.26	0.81	1.04	1.25	0.88	0.85			-17	-83
	a.xiii	1.10	1.31	0.24	0.77	1.06	1.28	0.87	0.81			-13	-87
	a.xiv	1.10	1.37	0.23	0.74	1.08	1.31	0.86	0.78			-11	-89
	a.xv	1.10	1.44	0.22	0.70	1.11	1.34	0.85	0.75			-10	-90
	a.xvi	1.22	1.17	0.26	0.81	1.04	1.25	0.86	0.84			-44	-56
	a.xvii	1.22	1.24	0.25	0.78	1.06	1.28	0.85	0.81			-35	-65
	a.xviii	1.22	1.31	0.23	0.73	1.09	1.31	0.84	0.77			-29	-71
	a.xix	1.22	1.37	0.22	0.70	1.12	1.34	0.82	0.74			-25	-75
	a.xx	1.22	1.44	0.21	0.67	1.14	1.38	0.80	0.71			-22	-78
	a.xxi	1.27	1.17	0.25	0.80	1.05	1.26	0.84	0.83			-49	-51
	a.xxii	1.27	1.24	0.24	0.76	1.07	1.29	0.83	0.79			-40	-60
	a.xxiii	1.27	1.31	0.23	0.72	1.10	1.33	0.82	0.75			-34	-66
	a.xxiv	1.27	1.37	0.22	0.69	1.13	1.36	0.80	0.73			-30	-70
	a.xxv	1.27	1.44	0.21	0.66	1.15	1.39	0.78	0.70			-26	-74
	b	See Excel spreadsheet and next section of this paper											
4		0.96	1*	0.32	1.00	0.92	1.11	1.02	1.02			100	0
5		1.04	1*	0.31	0.97	0.94	1.13	0.98	0.98			-100	0

* longline scalar was not specified within the TT CMM small working group management options. A scalar of 1 is used here for illustrative purposes. Refer to the accompanying Excel spreadsheet for the full results.

** risk approximated from the results of the deterministic projections. Colours represent: green = risk < 5%, amber = risk between 5% and 20%, red = risk over 20%. Note this risk is expected to be underestimated.

Table 5. Median outcomes for skipjack tuna arising from each management option (for skipjack, the longline scalar is not relevant).

Option	Sub-option	Resulting scalars		$SB_{2045}/SB_{F=0}$ (TRP=0.5)	F_{2045}/F_{MSY}	F_{2045}/F_{MSY} relative to $F_{2011-2014}/F_{MSY}$	PS vulnerable biomass (relative to 2013-2015 outcomes)	Approximated risk** of		PS catch (relative to 2013-2015 outcomes)
		PS ASS	LL					SB <LRP	F > F_{MSY}	
'2013-15 conditions'		1.00	-	0.50	0.43	0.90	1.00	green	green	1.00
1	a	1.06	-	0.50	0.44	0.91	1.00	green	green	1.00
	b	1.10	-	0.50	0.44	0.91	0.99	green	green	1.00
	c	1.06	-	0.50	0.44	0.91	1.00	green	green	1.00
2*	a-d	1.08	-	0.50	0.43	0.90	1.00	green	green	0.99
	e	1.05	-	0.50	0.43	0.89	1.01	green	green	0.98
	f-g	1.10	-	0.50	0.44	0.91	0.99	green	green	1.00
	h-i	1.09	-	0.50	0.44	0.91	1.00	green	green	1.00
	j	1.05	-	0.50	0.43	0.90	1.00	green	green	0.99
	k	1.11	-	0.49	0.44	0.92	0.99	green	green	1.01
	l	1.10	-	0.50	0.44	0.92	0.99	green	green	1.01
	m, n	1.09	-	0.50	0.44	0.92	0.99	green	green	1.01
	o	1.05	-	0.50	0.44	0.91	1.00	green	green	1.00
3	a.i to v	1.16	-	0.50	0.44	0.91	0.99	green	green	1.00
	a.vi to x	1.04	-	0.50	0.44	0.91	1.00	green	green	1.00
	a.xi to xv	1.10	-	0.50	0.44	0.91	0.99	green	green	1.00
	a.xvi to xx	1.22	-	0.49	0.44	0.92	0.98	green	green	1.00
	a.xxi to xxv	1.27	-	0.49	0.44	0.92	0.98	green	green	1.01
	b	See Excel spreadsheet and next section of this paper								
4		0.96	-	0.50	0.43	0.90	1.00	green	green	1.00
5*		1.04	-	0.51	0.43	0.89	1.01	green	green	0.98

* note: overall purse seine effort is reduced in these Options.

** risk approximated from the results of the deterministic projections. Colours represent: green = risk < 5%, amber = risk between 5% and 20%, red = risk over 20%. Note this risk is expected to be underestimated.

Table 6. Median outcomes for yellowfin tuna arising from each management option.

Option	Sub-option	Resulting scalars		$SB_{2045}/SB_{F=0}$	$SB_{2045}/SB_{F=0}$ relative to $SB_{2012-2015}/SB_{F=0}$	F_{2045}/F_{MSY}	F_{2045}/F_{MSY} relative to $F_{2011-2014}/F_{MSY}$	Vulnerable biomass (relative to 2013-2015 outcomes)		Approximated risk** of	
		PS ASS	LL					PS	LL	SB <LRP	F > F_{MSY}
'2013-15 conditions'		1.00	1.00	0.37	1.13	0.61	0.82	1.00	1.00		
1	a	1.06	1.04	0.37	1.11	0.62	0.83	0.99	0.99		
	b	1.10	1.11	0.36	1.10	0.63	0.85	0.98	0.98		
	c	1.06	1.11	0.36	1.10	0.62	0.84	0.98	0.98		
2	a-d	1.08	1*	0.37	1.13	0.61	0.82	1.00	1.00		
	e	1.05	1*	0.37	1.14	0.61	0.82	1.00	1.01		
	f-g	1.10	1*	0.37	1.12	0.61	0.83	0.99	0.99		
	h-i	1.09	1*	0.37	1.12	0.61	0.83	0.99	1.00		
	j	1.05	1*	0.37	1.13	0.61	0.82	1.00	1.00		
	k	1.11	1*	0.37	1.11	0.62	0.84	0.98	0.99		
	l	1.10	1*	0.37	1.11	0.62	0.83	0.99	0.99		
	m, n	1.09	1*	0.37	1.12	0.62	0.83	0.99	0.99		
	o	1.05	1*	0.37	1.12	0.61	0.83	1.00	1.00		
3	a.i	1.16	1.17	0.35	1.08	0.64	0.86	0.96	0.96		
	a.ii	1.16	1.24	0.35	1.06	0.64	0.87	0.96	0.95		
	a.iii	1.16	1.31	0.35	1.05	0.65	0.88	0.95	0.94		
	a.iv	1.16	1.37	0.34	1.04	0.66	0.89	0.95	0.93		
	a.v	1.16	1.44	0.34	1.02	0.67	0.90	0.94	0.92		
	a.vi	1.04	1.17	0.36	1.09	0.63	0.85	0.97	0.97		
	a.vii	1.04	1.24	0.35	1.07	0.64	0.86	0.97	0.96		
	a.viii	1.04	1.31	0.35	1.06	0.65	0.87	0.96	0.95		

	a.ix	1.04	1.37	0.34	1.05	0.65	0.88	0.96	0.94		
	a.x	1.04	1.44	0.34	1.03	0.66	0.89	0.95	0.93		
	a.xi	1.10	1.17	0.36	1.08	0.63	0.86	0.97	0.97		
	a.xii	1.10	1.24	0.35	1.07	0.64	0.87	0.96	0.96		
	a.xiii	1.10	1.31	0.35	1.06	0.65	0.88	0.96	0.95		
	a.xiv	1.10	1.37	0.34	1.04	0.66	0.89	0.95	0.94		
	a.xv	1.10	1.44	0.34	1.03	0.67	0.90	0.94	0.93		
	a.xvi	1.22	1.17	0.35	1.07	0.64	0.86	0.96	0.96		
	a.xvii	1.22	1.24	0.35	1.06	0.65	0.87	0.95	0.95		
	a.xviii	1.22	1.31	0.34	1.05	0.66	0.89	0.95	0.94		
	a.xix	1.22	1.37	0.34	1.03	0.66	0.90	0.94	0.93		
	a.xx	1.22	1.44	0.34	1.02	0.67	0.91	0.93	0.92		
	a.xxi	1.27	1.17	0.35	1.07	0.64	0.87	0.96	0.96		
	a.xxii	1.27	1.24	0.35	1.06	0.65	0.88	0.95	0.95		
	a.xiii	1.27	1.31	0.34	1.04	0.66	0.89	0.94	0.93		
	a.xxiv	1.27	1.37	0.34	1.03	0.67	0.90	0.94	0.93		
	a.xxv	1.27	1.44	0.33	1.02	0.67	0.91	0.93	0.92		
	b	See Excel spreadsheet and next section of this paper									
4		0.96	1*	0.37	1.13	0.61	0.82	1.00	1.00		
5		1.04	1*	0.37	1.13	0.61	0.82	1.00	1.00		

* longline scalar was not specified within the TT CMM small working group management options. A scalar of 1 is used here for illustrative purposes. Refer to the accompanying Excel spreadsheet for the full results.

** risk approximated from the results of the deterministic projections. Colours represent: green = risk < 5%, amber = risk between 5% and 20%, red = risk over 20%. Note this risk is expected to be underestimated.

Identify other fishery combinations that meet bigeye evaluation criteria (Option 3b)

A set of minimum fishery scalar combinations within the range examined that maintain median bigeye $SB_{2045}/SB_{F=0}$ specifically at recent levels (ratio ~ 1) are presented in Table 7. In turn, minimum scalar combinations that maintain median F_{2045}/F_{MSY} levels at those estimated within the recent assessment are presented in Table 8. They provide an indication of the minimum relative changes in purse seine effort and longline catch that maintain recent biomass and fishing mortality levels, noting that the different gear combinations lead to different F_{MSY} values. Also note that these are selected from the specific scalar combination values examined – other options at a finer scalar resolution would also be feasible. Combinations that result in greater reductions in fishing impact can be identified using the Excel spreadsheet.

Table 7. Summary table of purse seine and longline scalars that maintain the bigeye median $SB_{2045}/SB_{F=0}$ around 'recent' levels in the stock assessment ($SB_{2012-2015}/SB_{F=0}$).

Scalars		$SB_{2045}/SB_{F=0}$	$SB_{2045}/SB_{F=0}$ relative to $SB_{2012-2015}/SB_{F=0}$	F_{2045}/F_{MSY}	F_{2045}/F_{MSY} relative to $F_{2011-2014}/F_{MSY}$	Approximated Risk		Approximate equivalent	
PSASS	LL					SB<LRP	F>F_{MSY}	Total FAD closure period (mths)	LL catch (mt)
0.5	1.3	0.32	1.00	0.91	1.10			8	85,700
0.6	1.2	0.32	1.02	0.91	1.09			7.2	79,100
0.8	1.1	0.32	1.00	0.92	1.11			5.6	72,500
1	1	0.31	0.99	0.93	1.12			4	65,900
1.1	0.9	0.32	1.01	0.91	1.10			3.2	59,300
1.3	0.8	0.32	1.00	0.92	1.10			1.6	52,700

Table 8. Summary table of purse seine and longline scalars that maintain the bigeye median F_{2045}/F_{MSY} around 'recent' levels in the stock assessment ($F_{2011-2014}/F_{MSY}$).

Scalars		$SB_{2045}/SB_{F=0}$	$SB_{2045}/SB_{F=0}$ relative to $SB_{2012-2015}/SB_{F=0}$	F_{2045}/F_{MSY}	F_{2045}/F_{MSY} relative to $F_{2011-2014}/F_{MSY}$	Approximated Risk		Approximate equivalent	
PSASS	LL					SB<LRP	F>F_{MSY}	Total FAD closure period (mths)	LL catch (mt)
0.5	1	0.37	1.17	0.82	0.99			8	65,900
0.7	0.9	0.37	1.15	0.83	1.00			6.4	59,300
0.8	0.8	0.37	1.16	0.82	0.99			5.6	52,700
0.9	0.8	0.36	1.13	0.84	1.01			4.8	52,700
1	0.7	0.36	1.14	0.82	0.99			4	46,100
1.1	0.7	0.35	1.11	0.84	1.01			3.2	46,100
1.2	0.6	0.36	1.12	0.82	0.99			2.4	39,500
1.3	0.6	0.35	1.09	0.84	1.01			1.6	39,500
1.5	0.5	0.35	1.09	0.83	0.99			0	32,900

3. Key observations

Implications of '2013-15' conditions

Management conditions represented by 2013-2015 average levels are a 4 month FAD closure, no high seas FAD closure (but high seas purse seine effort limits), and for some key longline fleets, a tightening of bigeye catch limits.

For bigeye tuna, the continuation of average 2013-15 conditions are predicted to maintain the spawning biomass depletion near to the $SB_{recent}/SB_{F=0}$ estimated by the 2017 stock assessment. A slight decline of 1% (weighted median long term $SB/SB_{F=0}$ = 0.31) is forecast. Fishing mortality is estimated to increase by 12% on average over the period, but remain below F_{MSY} (median long term F/F_{MSY} = 0.93). This increase is in part influenced by the fact that future catchability is assumed to remain constant at levels estimated in the final year of the assessment (catchability varied across the years represented by the 'recent' period). Risk of both the stock falling below the LRP and fishing mortality increasing above F_{MSY}, approximated from the deterministic projections, is greater than 20%. This result is influenced by those model runs in which the bigeye stock is assumed to be of lower productivity (low SRR steepness and 'old growth', for example).

For skipjack, 2013-15 purse seine effort conditions (longline fishing levels have little influence on skipjack stock status) are predicted to maintain the spawning biomass depletion around the interim target reference point ($SB/SB_{F=0}$ = 0.50). Median F/F_{MSY} falls slightly compared to that estimated within the assessment, while there is no risk of the stock falling below the LRP, or of fishing mortality increasing above F_{MSY} levels.

For yellowfin tuna, 2013-15 conditions are predicted to result in an increase in $SB/SB_{F=0}$ relative to that estimated within the 2017 assessment (by 13%), while median F/F_{MSY} falls by 18% compared to that estimated within the assessment. There is a low approximated risk of the stock falling below the LRP, or of fishing mortality increasing above F_{MSY} levels (<5% and 0%, respectively).

Do any specified management Options meet the evaluation criteria?

For bigeye, as specified management Options generally imply increases in purse seine effort and longline catch relative to 2013-2015 conditions, the majority of those Options fail to meet the evaluation criteria of maintaining spawning biomass depletion and fishing mortality at recent levels (Table 4). Furthermore, under Option 3, fishing mortality tends to increase above F_{MSY} levels. However for Options 2, 4 and 5 - where longline catch levels were not specified by the small working group - there are fishery combinations that achieve the objectives for bigeye, which can be identified using the accompanying Excel spreadsheet:

- For Option 2, an accompanying reduction of at least 10% in longline catch (scalar = 0.9) will maintain or increase $SB/SB_{F=0}$ relative to recent assessed levels. In some combinations, this reduced the approximated risk of the stock falling below the LRP to below 20%. More than a 30% reduction in longline catch (scalar < 0.7) is required under this Option to maintain fishing mortality at around recent levels, but corresponding risk of $F > F_{MSY}$ is always greater than 20% unless further longline catch reductions are taken.
- For Option 4, the $SB/SB_{F=0}$ criterion is met where 2013-15 average longline levels are maintained (Table 4). Under this Option, a reduction in longline catch of over 20% is required to maintain fishing mortality at recent levels. This reduces the approximated risk of the stock falling below the LRP to less than 15%, but greater longline reductions are required to reduce the approximated risk of $F > F_{MSY}$ below 20%.

- For Option 5, a reduction in longline catch of less than 10% is required to maintain $SB/SB_{F=0}$ at recent levels (and LRP approximated risk to just less than 20%), while a 30% reduction is required to maintain fishing mortality at recent levels (at that level, LRP approximated risk falls to just less than 10%, but $F > F_{MSY}$ risk remains above 20%).

For skipjack tuna, as the assumption has been made that overall purse seine effort is unchanged from 2013-2015 average levels unless specified, the Options have minimal impact on stock status and fishing mortality. Where an Option assumes lower associated purse seine effort, and hence increased unassociated effort, there are small benefits in terms of spawning biomass depletion and fishing mortality, due to an increased focus on relatively larger individuals within the catch. This is consistent with the findings of previous analyses (e.g. Hampton and Pilling, 2015)[7]. Where Options define an overall purse seine effort reduction (Options 2 and 5), a slightly improved stock status results.

For yellowfin tuna, Options tended, by varying degrees, to increase $SB/SB_{F=0}$ and reduce fishing mortality relative to recent assessed levels (Table 6). Median fishing mortality remains below F_{MSY} for all Options. Fishing mortality and spawning biomass depletion risk levels are generally less than 5%, although specific runs (e.g. frequently within Option 3, and in Options 2, 4 and 5 where longline effort increases by more than 10-20% relative to the 2013-15 average) can imply approximated risk levels above 5%, but still less than 20%. As found for skipjack, the assumption that overall purse seine effort remains unchanged from 2013-2015 average levels means that Options influencing associated set proportions have minimal impact on stock status and fishing mortality (e.g. see Options 2, 4 and 5 displayed in Table 6). Options assuming lower associated purse seine effort again provide small benefits in terms of spawning biomass depletion and fishing mortality, due to an increased focus on relatively larger individuals within the catch through increased unassociated purse seine sets (see also Hampton and Pilling, 2014)[6].

WHAT OTHER FISHERY CONDITIONS ACHIEVE THE EVALUATION CRITERIA?

For bigeye tuna, minimum combinations of purse seine effort and longline catch that maintain spawning biomass depletion or fishing mortality at recent levels are presented in Table 7 and Table 8.

As 2013-15 average fishery conditions are estimated to stabilise spawning biomass depletion around recent levels (a small decrease is projected), increases in the level of fishing in one gear from the baseline must therefore be compensated for by reductions in that of the other. From the scalars identified, for a 10% increase in longline bigeye catch, around a 15-20% decrease in purse seine associated effort is required to compensate, while a 10% increase in purse seine associated effort requires a 10% decrease in longline effort to compensate (Table 7).

Under scenarios that maintain bigeye spawning biomass depletion at recent assessed levels, corresponding fishing mortality increases by around 10% relative to that estimated within the assessment, although average fishing mortality remains below F_{MSY}. To maintain a stable level of fishing mortality, therefore, reductions in fishing levels relative to 2013-15 conditions are generally required (Table 8). If purse seine associated effort levels remain at 2013-15 levels, a 30% reduction in longline bigeye catch is required relative to that baseline, while if longline catch remains at 2013-15 levels, a 50% reduction in purse seine associated effort is required. Under those conditions, the approximated risk of $SB/SB_{F=}0$ falling below the LRP is less than 20% (5-20% range), while the approximated risk of fishing mortality increasing above F_{MSY}

[7] This result is dependent on the assumptions noted earlier: that overall purse seine effort remains constant at the average of 2013-15 levels, i.e. that purse seine associated sets foregone are taken up by unassociated fishing; and that the increased unassociated fishing can occur at current levels of catchability.

remains greater than 20%. The sensitivity of $SB/SB_{F=0}$ and F/F_{MSY} to changes in purse seine associated effort or longline bigeye catch is shown in Figure 1. These plots suggest that outcomes are slightly more sensitive to percentage changes in longline catch than equivalent percentage changes in purse seine associated effort.

Under the assumption that overall purse seine effort remains at 2013-15 average levels and that effort creep does not occur, the skipjack stock appears robust to the range of fishing levels being examined. Spawning biomass depletion remains on average around the interim TRP, fishing mortality decreases slightly, and there is no approximated risk of the stock falling below the LRP, or fishing mortality exceeding F_{MSY}.

Yellowfin tuna spawning biomass depletion remains at least at recent assessed levels within the examined range of fishing levels, and $SB/SB_{F=0}$ is generally forecast to increase relative to recent levels and for fishing mortality to fall, under the assumptions made within the projections. Approximated risk of the stock falling below the LRP, or fishing mortality exceeding F_{MSY} is projected to be less than 20% under all examined fishing levels, increasing to around 15% and 10% respectively in the most extreme fishing levels evaluated (scalars of 1.5 on both purse seine and longline fisheries).

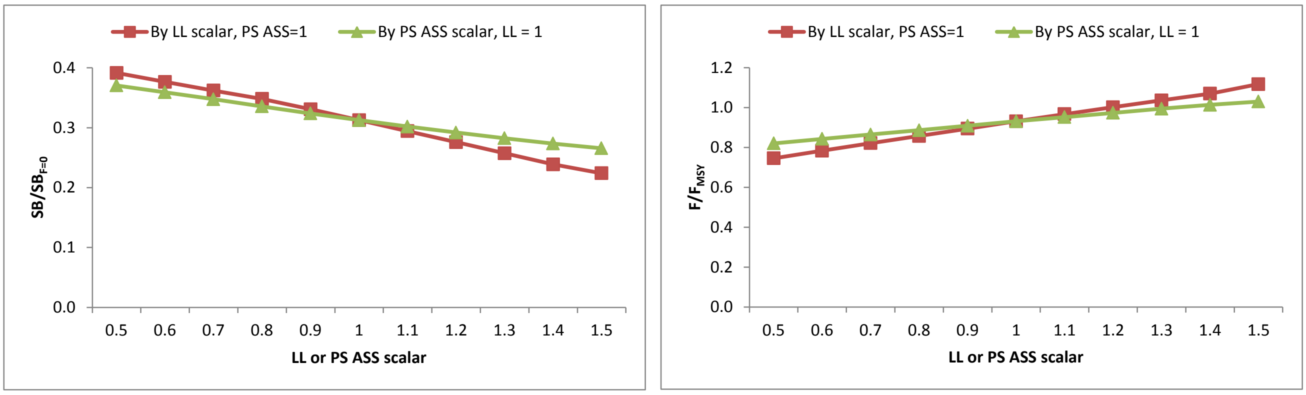

Figure 1. Sensitivity of bigeye $SB/SB_{F=0}$ and F/F_{MSY} to specific changes in purse seine associated fishing effort, or longline bigeye catch.

Other observations

For the bigeye analyses performed here, the results are based upon the full uncertainty grid of stock assessments identified by the 13th Scientific Committee meeting, which includes the more pessimistic 'old growth' assessment models. Within this analysis, the results from the 'old growth' models are down-weighted as specified by SC13. It should be noted that SC13 mandated further research into bigeye growth. If the results of that research further support the plausibility of the 'new growth' model, 'old growth' model runs may be excluded from future management advice.

4. References

Hampton, J. and Pilling, G. 2014. Relative impacts of FAD and free-school purse seine fishing on yellowfin tuna stock status. WCPFC-SC10-MI-WP-05. https://www.wcpfc.int/node/19013

Hampton, J. and Pilling, G. 2015. Relative impacts of FAD and free-school purse seine fishing on skipjack tuna stock status. WCPFC-SC11-MI-WP-05. https://www.wcpfc.int/node/21793

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Tremblay-Boyer L., S. McKechnie, G. Pilling and J. Hampton. 2017. Stock assessment of yellowfin tuna in the western and central Pacific Ocean. WCPFC-SC13-2017/SA-WP-06. https://www.wcpfc.int/node/29519

Appendix 1. Tasking to Scientific Services Provider for WCPFC14

See also Attachment G of the report from the Intersessional Meeting to progress the draft Bridging CMM on Tropical Tuna - Commission Special Session (https://www.wcpfc.int/meetings/intersessional-meeting-progress-draft-bridging-cmm-tropical-tuna).

Evaluation Criteria defined by the SWG

In evaluating the performance of management measures in relation to the interim objectives for **bigeye and yellowfin** the following evaluation criteria will be considered:

- the spawning biomass depletion ratio ($SB/SB_{F=0}$) is to be maintained at or above the average $SB/SB_{F=0}$ for 2012-2015
- the fishing mortality is to be maintained at or below the average fishing mortality level in 2011-2014
- the fishing mortality at F_{MSY}
- the risk of breaching the adopted limit reference point of 20% of the estimated recent average spawning biomass in the absence of fishing
- Vulnerable biomass
- [relative impact on spawning biomass by fishery sector/gear]

In evaluating the performance of management measures in relation to the interim objectives for **skipjack** the following evaluation criteria will be considered:

- Catches
- Vulnerable biomass
- the spawning biomass depletion ratio ($SB/SB_{F=0}$) to be maintained on average at the target reference point
- the fishing mortality to be maintained at or below the average fishing mortality level in 2011-2014
- the fishing mortality at F_{MSY}
- the risk of breaching the adopted limit reference point of 20% of the estimated recent average spawning biomass in the absence of fishing
- [relative impact on spawning biomass by fishery sector/gear]

Management Options defined by the SWG

Option	Sub-option	Description for purse seine	Description for longline
1	**a**	CCM 2016-01 (2017 FAD closure limits) - 4 month FAD closure/flag state options for 4th month + high seas FAD closure (KI exemption and footnote3)	Assumed TT CMM specified catch levels for 2017 for constrained flags, non-constrained flags assumed to take their average catch over 2013-2015.
	b	2015-16 measures – 4 month FAD closure/ flag state options for 4th month	Assumed TT CMM specified catch levels for 2015/2016 for constrained flags, non-constrained flags assumed to take their average catch over 2013-2015.
	c	2012-15 measures = 3.5 month FAD closure	Baseline longline catch from CMM 2008-01 minus 31.25%
2	**a**	3 months FAD closure + (3/4/5/6/9/12 month) high seas FAD closure (KI exempt); + total effort equals 3/4/5000 days on the high seas.	Not specified
3	**a**	No FAD closure, hard FAD set limits option (USA provided hard limits: the average FAD set numbers from 2011-2014, 90% of that number, 95% of that number, 105% of that number and 110% of that number)	Catch limits of 77,400, 81,700, 86,000, 90,300 and 94,600 mt
	b	SPC calculate limits necessary to meet objectives	SPC calculate limits necessary to meet objectives
4	**-**	4 month closure/flag state option for 4th month + high seas FAD closure, 5th month FAD closure for non-SIDS fleets averaging >500mt of bigeye per purse seiner (average 2010-2013).	Not specified
5	**-**	3 month FAD closure, zero effort (PS) for 3 months in the high seas	Not specified

APPENDIX 2. DEVELOPMENT OF FISHERY SCALARS BASED UPON THE SPECIFIED MANAGEMENT OPTIONS

This section documents the approach and assumptions necessary to translate the management options into fishing levels for purse seine (associated and unassociated) effort and longline catch within the tropical WCPO, for use within the stock projections. The approach for each option/sub-option is described.

Option 1. Recent tropical tuna CMM provisions

- **Sub-Option a: CCM 2016-01 (2017 FAD closure limits), 4 month FAD closure/flag state options for 4^{th} month + high seas FAD closure (KI exemption and footnote 3).**

Note in comparison to previous CMM evaluations, the assumptions made here for purse seiners are comparable to '2017 choices' (based upon choices detailed at TCC13), plus a high seas closure (with exemptions). Note these scalars are based on a different baseline to previous CMM evaluations (i.e. not 2012 fishing levels).

Gear	Element	Approach	Resulting scalar v 2013-2015 avg
PS ASS	4 month FAD closure/flag state options for 4^{th} month	Flags adopting 4^{th} month closure in 2017: effort at flag level assumed average 2013-2015 Flags adopting FAD set limit in 2017: as defined in Attachment A, column A	1.06
	High seas FAD closure	Flags not exempt: proportion of FAD sets made in the high seas over 2013-2015 removed from those calculated above Exempt flags: values calculated above used	
LL	Not specified	Assumed TT CMM specified catch levels for 2017 taken for constrained flags, non-constrained flags assumed to take their average catch over 2013-2015.	1.04

- **Sub-Option b: 2015-16 measures (no high seas closure, alternative specified longline limits assumed to be taken)**

Gear	Element	Approach	Resulting scalar v 2013-2015 avg
PS ASS	4 month FAD closure/flag state options for 4th month	Flags adopting 4th month closure in 2017: effort at flag level assumed average 2013-2015 Flags adopting FAD set limit in 2017: as defined in Attachment A, column A	1.10
LL	Not specified	Assumed TT CMM specified catch levels for 2015/2016 taken for constrained flags, non-constrained flags assumed to take their average catch over 2013-2015.	1.11

- **Sub-Option c: 2012-15 measures**

In consultation, evaluated as a merger of recent CMM elements, being:

- 3.5 month FAD closure
- Baseline longline catch from CMM 2008-01 minus 31.25%

Gear	Element	Approach	Resulting scalar v 2013-2015 avg
PS ASS	3.5 month FAD closure	Calculated by flag as 1/16th more FAD sets than the average over 2013-2015 (that represented a 4th month FAD closure)	1.06
LL	Baseline longline catch from CMM 2008-01 minus 31.25%	As defined by CMM 2008-01 Attachment F, flags catching > 2000mt reduced by 31.25%, other flags assumed to catch average 2013-2015 levels.	1.11

Option 2. 3 month FAD closure (in zone) + 3/4/5/6/12 month high seas FAD closure (KI exempt) + total effort equals 3/4/5000 days on the high seas.

The assumptions behind this evaluation were:

- High seas FAD sets are constrained by the greater of the FAD closure period or the total effort limits (assuming that this effort limit reduction implies a proportional reduction in FAD sets by flag).
- High seas effort (2013-2015 average) was 6,506 fishing days (calculated from Table 2, WCPFC-TCC13-2017-IP08), implying a 3,000 day limit was a reduction to 46% of the baseline level.

Sub-Options a-e: 3000 day high seas effort limit, 3/4/5/6/12 month HS FAD closure.

Gear	**Element**	**Approach**	**Resulting scalar v 2013-2015 avg**
PS ASS	3 month FAD closure	Calculated by flag as $1/8^{th}$ more FAD sets than the average over 2013-2015 (which represented a 4^{th} month FAD closure)	1.08 (3 to 6mth – day limit constraining), 1.05 (12 month closure constraining)
	3/4/5/6/12 month FAD closure 3000 day high seas effort limit	Appropriate proportion of FAD sets made in the high seas over 2013-2015 removed (3/12, 4/12, etc.) **OR if reduction greater** 54% of high seas FAD sets removed ((6506-3000)/6506) from those calculated above	
PS UNA	3000 day high seas effort limit	Overall unassociated effort reduced through high seas effort limit in proportion. Average 2013-2015 total effort taken from Table 1 WCPFC-TCC13-2017-IP08, excluding archipelagic waters. Reduction of 1-((6,506-3,000)/43,350).	0.92
LL	Not specified	-	SPC to identify scalars that achieve the objectives.

Sub-Options f-j: 4000 day high seas effort limit, 3/4/5/6/12 month HS FAD closure.

Gear	Element	Approach	Resulting scalar v 2013-2015 avg
PS ASS	3 month FAD closure	Calculated by flag as 1/8th more FAD sets than the average over 2013-2015 (that represented a 4th month FAD closure)	1.10 (3 and 4mth – day limit constraining), 1.09 (5 and 6mth constraining), 1.05 (12 month constraining)
	3/4/5/6/12 month FAD closure 4000 day high seas effort limit	Appropriate proportion of FAD sets made in the high seas over 2013-2015 removed (3/12, 4/12, etc.) **OR if reduction greater** 39% of high seas FAD sets removed ((6506-4000)/6506) from those calculated above	
PS UNA	4000 day high seas effort limit	Overall unassociated effort reduced through high seas effort limit in proportion. Average 2013-2015 total effort taken from Table 1 WCPFC-TCC13-2017-IP08, excluding archipelagic waters. Reduction of 1-((6,506-4,000)/43,350).	0.94
LL	Not specified	-	SPC to identify scalars that achieve the objectives.

Sub-Options k-o: 5000 day high seas effort limit, 3/4/5/6/12 month HS FAD closure.

Gear	Element	Approach	Resulting scalar v 2013-2015 avg
PS ASS	3 month FAD closure	Calculated by flag as 1/8th more FAD sets than the average over 2013-2015 (that represented a 4th month FAD closure)	1.11 (3mth), 1.10 (4mth), 1.09 (5 and 6mth), 1.05 (12 month)
	3/4/5/6/12 month FAD closure 5000 day high seas effort limit	Appropriate proportion of FAD sets made in the high seas over 2013-2015 removed (3/12, 4/12, etc.) **OR if reduction greater** 23% of high seas FAD sets removed ((6506-5000)/6506) from those calculated above	
PS UNA	5000 day high seas effort limit	Overall unassociated effort reduced through high seas effort limit in proportion. Average 2013-2015 total effort taken from Table 1 WCPFC-TCC13-2017-IP08, excluding archipelagic waters. Reduction of 1-((6,506-5,000)/43,350).	0.97
LL	Not specified	-	SPC to identify scalars that achieve the objectives.

Option 3a. No FAD closure, hard FAD set limit option.

The US provided FAD set limits and longline catch limits to the Science Services Provider. These provided 25 different PS/LL scalar combinations.

Gear	Element	Approach	Resulting scalar v 2013-2015 avg
PS ASS	Hard FAD set limits: the average FAD set numbers from 2011-2014, 90% of that number, 95% of that number, 105% of that number and 110% of that number	Average FAD set numbers from 2011-2014 = 16,721 sets (Table 3, WCPFC-TCC13-2017-IP08), scalars calculated relative to the 2013-2015 average of 14,427 sets.	1.04 (90%), 1.10 (95%), 1.16 (100%), 1.22 (105%), 1.27 (110%)
LL	Bigeye catch limits of 77,400, 81,700, 86,000, 90,300 and 94,600 mt	Scalars calculated relative to the average catch of 65,891 mt (Table4, WCPFC-TCC13-2017-IP08).	1.17, 1.24, 1.31, 1.37, 1.44

Option 3b. SPC to calculate limits necessary to meet objective

The projection results from the grid of scalars can be used to identify those purse seine and longline scalar combinations that achieve the evaluation criteria.

Option 4. 4 month FAD closure/flag state option for the 4th month + high seas FAD closure + 5th month FAD closure for non-SIDS fleets averaging > 500mt of bigeye per purse seiner (over 2010-2013).

Gear	Element	Approach	Resulting scalar v 2013-2015 avg
PS ASS	4 month FAD closure/flag state options for 4th month	Flags adopting 4th month closure in 2017: effort at flag level assumed average 2013-2015 Flags adopting FAD set limit in 2017: as defined in Attachment A, column A	0.96
	High seas FAD closure	All FAD sets made in the high seas over 2013-2015 removed (no exemptions specified)	
	5th month closure for non-SIDS fleets averaging > 500mt per purse seiner over 2010-2013	Calculated using data in Table 7 WCPFC-TCC13-2017-IP08 at flag level. Impacts fleets of EU, SV. Modelled as an additional 1/8th FAD sets removed in addition to reductions above.	
LL	Not specified	-	SPC to identify scalars that achieve the objectives.

Option 5. 3 month FAD closure, zero purse seine effort for 3 months on the high seas

Gear	Element	Approach	Resulting scalar v 2013-2015 avg
PS ASS	3 month FAD closure	Calculated by flag as 1/8th more FAD sets than the average over 2013-2015 (that represented a 4th month FAD closure)	1.04
	Zero purse seine effort for 3 months on the high seas	25% of high seas FAD sets removed	
PS UNA	Zero purse seine effort for 3 months on the high seas	Overall unassociated effort reduced through high seas closure. Average 2013-2015 total effort taken from Table 1 WCPFC-TCC13-2017-IP08, excluding archipelagic waters. Reduction of 1-((6,506*0.25)/43,350).	0.96
LL	Not specified	-	SPC to identify scalars that achieve the objectives.

APPENDIX 3. STOCK PROJECTION METHODOLOGY.

This appendix describes the projection approach used in some more detail, with bigeye tuna and the Option 3B analysis used as an example.

Deterministic projections were run for a 30 year period for each of the assessment models in the SC-defined structural uncertainty grid (72 models) and for each combination of eleven scalers (0.5 to 1.5 in increments of 0.1) which were applied to future purse seine associated effort and longline catch. In total 8,712 individual projections were conducted.

Future recruitment was determined from the stock and recruitment relationship estimated within each model run. For bigeye, this relationship was fitted to the estimates for the period 1962 to 2014 (McKechnie et al., 2017).

Fisheries were grouped into four categories for the purpose of scaling (Table 10). Longline (LL) and purse seine associated (PS-ASS) fisheries were scaled according to a grid of scalers with corresponding counter scalers applied to purse seine unassociated (PS-UNA) fisheries so as to maintain total purse seine effort at an overall constant level (Table 11). All other (OTH and IDPH) fisheries were merged into a single category and received a constant scaler of 1 throughout the analysis.

All scalers were applied on an annual basis. The mean of the period 2013 to 2015 was used as the basis for calculating the scalers (such that a scaler of 1.0 would project future catch or effort for each fishery as the mean of the period 2013 to 2015 for that fishery).

The US longline fishery in region 4 is only represented in the 2014 regional structure. Due to the shift in the boundary between regions 2 and 4 in the 2017 regional structure, this fishery becomes merged with the US longline fishery in region 2. In addition, the scalers applied to the purse seine fisheries in region 8 were modified to take account of fishing effort within the archipelagic waters of PNG and Solomon Islands not being subject to WCPFC measures. Approximately 40% of purse seine fishing effort in region 8 is within archipelagic waters over the period 2013-2015. Therefore scalers have been applied only to the 60% of fishing effort that is conducted outside of archipelagic waters.

Table 9. Year ranges used for the fishery scalar average baseline, and for the calculation of the 'recent' period in the fishing mortality and spawning biomass evaluation criteria.

Statistic	Year Range
Catch or Effort scalar	2013 – 2015
F_{recent}	2011 – 2014
SB_{recent}	2012 – 2015

Table 10. Fishery groupings for the bigeye tuna projection settings showing the scaling category (LL=longline, PS=purse seine, IDPH=Indonesia and Philippines, OTH=other) and the scaling metric (C=catch, E=effort) for each fishery represented in the assessment. Note that the L-US-4 fishery is included in the 2014 regional structure but not in the 2017 regional structure. In addition, modified effort scalers were applied to the purse seine fisheries in region 8 to account for fishing effort in archipelagic waters.

	Fishery name	region	metric	category
1	L-ALL-1	1	C	LL
2	L-ALL-2	2	C	LL
3	L-US-2	2	C	LL
4	L-ALL-3	3	C	LL
5	L-OSE-3	3	C	LL
6	L-OSW-7	7	C	LL
7	L-ALL-7	7	C	LL
8	L-ALL-8	8	C	LL
10	L-US-4*	4	C	LL
11	L-AU-5	5	C	LL
12	L-ALL-5	5	C	LL
13	L-ALL-6	6	C	LL
14	S-ASS-ALL-3	3	E	PS-ASS
15	S-UNS-ALL-3	3	E	PS-UNA
16	S-ASS-ALL-4	4	E	PS-ASS
17	S-UNS-ALL-4	4	E	PS-UNA
18	Misc-PH-7	7	E	IDPH
19	HL-IDPH-7	7	E	IDPH
20	S-JP-1	1	E	OTH
21	P-JP-1	1	E	OTH
22	P-ALL-3	3	E	OTH
23	P-ALL-8	8	E	OTH
24	Misc-ID-7	7	E	IDPH
25	S-PHID-7	7	E	IDPH
26	S-ASS-ALL-8**	8	E	PS-ASS
27	S-UNS-ALL-8**	8	E	PS-UNA
28	L-AU-9	9	C	LL
29	P-ALL-7	7	E	OTH
30	L-ALL-9	9	C	LL
31	S-ASS-ALL-7	7	E	PS-ASS
32	S-UNS-ALL-7	7	E	PS-UNA
33	Misc-VN-7	7	E	OTH

* Fishery grouping present only for 2014 regional structure
** Fishery scalers adjusted to take account of archipelagic fishing

Table 11. Annual purse seine un-associated scalers for corresponding purse seine associated scalers.

Associated	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
Unassociated	1.270	1.216	1.161	1.108	1.054	1.0	0.946	0.892	0.838	0.784	0.730