COMMISSION
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3 – 7 December, 2017

REFERENCE DOCUMENT FOR REVIEW OF CMM 2016-01
(Bigeye, Yellowfin, and Skipjack Tuna)

WCPFC14-2017-12
15 November 2017

Paper prepared by the Secretariat

A. Introduction

1. The purpose of this paper is to provide a quick reference guide to the recommendations of the Scientific Committee (SC) of relevance to the discussions in support of the review of CMM 2016-01. The Summary Reports of the annual meetings are part of the meeting documentation and readily available for access, and they provide the context and discussion in support of the recommendations.

B. Scientific Committee Recommendations

2. Brief descriptions on stock status and management advice from SC13 on bigeye, yellowfin and skipjack tuna are listed below. Full recommendations from SC12 and SC13 on each of the three species are annexed to this document as attachments.

Bigeye Tuna (*SC13 Paragraphs 219 – 241*)

Stock status and management advice (*see* **Attachment A** *for the details*)

1. Based on the uncertainty grid adopted by SC13, the WCPO bigeye tuna spawning biomass is likely above the biomass LRP and recent F is likely below F_{MSY}, and therefore noting the level of uncertainties in the current assessment it appears that the stock is not experiencing overfishing (77% probability) and it appears that the stock is not in an overfished condition (84% probability).

2. Based on those results, SC13 recommends as a precautionary approach that the fishing mortality on bigeye tuna stock should not be increased from current level to maintain current or increased spawning biomass until the Commission can agree on an appropriate target reference point (TRP).

3. SC13 recognized that future work is required to improve the assessment and to reduce uncertainty. Future research should concentrate on the two axes (e.g. growth, regional structure) of uncertainty which are the most influential. The growth analysis should continue with the emphasis on

providing length at age estimates for larger fish between 130 and 180 cm FL. Additional research is also required for the regional structure uncertainty to consider options in addition to the structures used in the 2014 and 2017 assessments, for example, by using statistical approaches (e.g. tree models).

Table BET. Summary of reference points over the 72 models in the structural uncertainty grid where the models using the new growth function are given three times the weighting of the models using the old growth function. Note that $SB_{recent}/SB_{F=0}$ is calculated where SB_{recent} is the mean SB over 2012-2015 instead of 2011-2014 (used in the stock assessment report), at the request of the Scientific Committee.

	Mean	Median	Min	10%	90%	Max
C_{latest}	149,178	153,137	130,903	131,597	156,113	157,725
MSY	156,765	158,040	124,120	137,644	180,656	204,040
$Y_{Frecent}$	150,382	148,920	118,000	133,400	168,656	187,240
F_{mult}	1.21	1.20	0.57	0.76	1.63	1.85
F_{MSY}	0.05	0.05	0.04	0.04	0.05	0.06
$F_{recent}/F_{\mathrm{MSY}}$	0.89	0.83	0.54	0.61	1.32	1.76
SB_{MSY}	457,162	454,100	219,500	285,530	598,210	710,000
SB_0	1,730,410	1,763,000	1,009,000	1,279,300	2,148,200	2,509,000
SB_{MSY}/SB_0	0.26	0.26	0.22	0.24	0.29	0.29
$SB_{\mathrm{F=0}}$	1,915,184	1,953,841	1,317,336	1,584,593	2,170,899	2,460,411
$SB_{\mathrm{MSY}}/SB_{F=0}$	0.24	0.24	0.17	0.18	0.27	0.29
SB_{latest}/SB_0	0.37	0.40	0.11	0.19	0.49	0.53
$SB_{latest}/SB_{F=0}$	0.34	0.37	0.08	0.15	0.46	0.49
$SB_{latest}/SB_{\mathrm{MSY}}$	1.42	1.45	0.42	0.86	1.97	2.12
$SB_{recent}/SB_{F=0}$	0.30	0.32	0.08	0.15	0.41	0.44
$SB_{recent}/SB_{\mathrm{MSY}}$	1.21	1.23	0.32	0.63	1.66	1.86

Implementation of CMM 2016-01 – Bigeye hotspot analysis (*SC13 Paragraphs 525 – 536*)

4. SC13 reviewed the draft final report from Project 77: *Development of potential measures to reduce interactions with bigeye tuna in the purse seine fishery in the western and central Pacific Ocean ('bigeye hotspots analysis')* (SC13-MI-WP-07) funded by the EU. The aims of this study were i) to identify factors linked to high purse seine bigeye catch; ii) to identify top bigeye tuna catching purse seiners; and iii) to examine spatial management considerations.

5. As highlighted in previous studies it is clear that many factors influence bigeye catch by the purse seine fishery, which therefore makes it challenging to gauge the effect of each factor separately. SC13 noted several factors influencing bigeye catches, such as vessel size and thermocline depth, and that top vessel lists were different between areas, likely linked to the fact that many fleets mostly operate in one of the three areas analysed during a specific year. SC13 also noted the presence of two types of 'bigeye hotspot' areas: i) an area of high overall bigeye tuna catch, with small bigeye catch per set but high effort on associated sets; and ii) an area of high bigeye CPUE, but with lower average catches.

6. SC13 made a number of suggestions to clarify aspects of the report (e.g. enumerating the proportion of the identified hot-spots within each national jurisdiction, providing similar estimates based on those used in the stock assessment to check for potential biases in the observers' visual estimations, noting the concerns expressed by some CCMs regarding potential difficulties of applying time/area closures in areas of national jurisdiction) and these will be incorporated into the final report to be provided to the WCPFC Secretariat, and subsequently to be made generally available[1]. SC13 also noted

[1] The final report SC13-MI-WP-07 Rev.02 was posted on SC13 website on 31 October 2017.

the need for improved information on FAD designs, deployments and type of buoy use within the WCPO, together with the importance of detailed information on the characteristics of vessels fishing in the WCPO, to improve future analyses.

7. SC13 recommends that the upcoming Intersessional Meeting to progress the Draft Bridging CCM on Tropical Tuna and both TCC13 and WCPFC14 takes note, among other elements, of the preliminary results contained in this report when framing the 'bridging' CMM to replace CMM-2016-01 and that mechanisms be considered to help facilitate further analyses as indicated above.

Yellowfin tuna (*SC13 Paragraphs 265 – 279*)

Stock status and management advice (*see* **Attachment B** *for the details*)

8. Based on the uncertainty grid adopted by SC13 the spawning biomass is highly likely above the biomass LRP and recent F is highly likely below F_{MSY}, and therefore noting the level of uncertainties in the current assessment, it appears that the stock is not experiencing overfishing 96% probability) and it appears that the stock is not in an overfished condition (92% probability).

9. SC13 reiterates its previous advice from SC10 that WCPFC could consider measures to reduce fishing mortality from fisheries that take juveniles, with the goal to increase to maximum fishery yields and reduce any further impacts on the spawning potential for this stock in the tropical regions.

10. SC13 also reiterates its previous advice from SC10 that measures should be implemented to maintain current spawning biomass levels until the Commission can agree on an appropriate target reference point (TRP).

Table YFT. Summary of reference points over the 48 models in the structural uncertainty grid retained for management advice using divisors of 20 and 50 for the weighting on the size composition data. Note that $SB_{recent}/SB_{F=0}$ is calculated where SB_{recent} is the mean SB over 2012-2015 instead of 2011-2014 (used in the stock assessment report), at the request of the Scientific Committee.

	Mean	Median	Min	10%	90%	Max
C_{latest}	611,982	612,592	606,762	607,517	614,237	614,801
MSY	670,658	670,800	539,200	601,480	735,280	795,200
$Y_{Frecent}$	646,075	643,400	534,400	586,120	717,880	739,600
F_{mult}	1.34	1.36	0.88	1.03	1.61	1.86
F_{MSY}	0.12	0.12	0.07	0.10	0.14	0.16
F_{recent}/F_{MSY}	0.77	0.74	0.54	0.62	0.97	1.13
SB_{MSY}	544,762	581,400	186,800	253,320	786,260	946,800
SB_0	2,199,750	2,290,000	1,197,000	1,366,600	2,784,500	3,256,000
SB_{MSY}/SB_0	0.24	0.24	0.15	0.18	0.28	0.34
$SB_{F=0}$	2,083,477	2,178,220	1,193,336	1,351,946	2,643,390	2,845,244
$SB_{MSY}/SB_{F=0}$	0.25	0.26	0.16	0.19	0.30	0.35
SB_{latest}/SB_0	0.33	0.34	0.18	0.23	0.42	0.45
$SB_{latest}/SB_{F=0}$	0.35	0.37	0.16	0.22	0.46	0.50
SB_{latest}/SB_{MSY}	1.40	1.39	0.80	1.02	1.80	1.91
$SB_{recent}/SB_{F=0}$	0.32	0.33	0.15	0.20	0.41	0.46
SB_{recent}/SB_{MSY}	1.40	1.41	0.81	1.05	1.71	1.93

WCPO skipjack tuna (*SC13 Paragraphs 300 – 306*)

Stock status and management advice (*see* **Attachment C** *for the details, including scientific information from SC12*)

11. SC13 noted that no stock assessment was conducted for WCPO skipjack tuna in 2017. Therefore, the stock status description from SC12 is still current.

12. SC13 noted that under recent fishery conditions (2016 catch level for LL and other fisheries and effort level for purse seine), the skipjack stock was initially projected to decrease for a short period and then to increase as recent relatively high recruitments move through the stock. Median $F_{2018}/F_{MSY} = 0.37$; median $SB_{2018}/SB_{F=0} = 0.47$.

13. SC13 noted that no stock assessment has been conducted since SC12. Therefore, the advice from SC12 should be maintained, pending a new assessment or other new information.

Attachment A

WCPO bigeye tuna (*SC13 Paragraphs 219 – 241*)

Provision of scientific information

1. SC13 noted that the preliminary total bigeye tuna catch in 2016 (154,045 mt) was a 9% increase over 2015 but a 2% decrease over 2011-2015. Longline catch (65,371 mt) was 5% lower than in 2015 and 11% lower than the 2011-2015 average. Pole and line catch (3,700 mt) was 35% lower than in 2015 and 26% lower than 2011-2015 average. Purse seine catch (63,304 mt) was 22% higher than in 2015, but 5% lower than 2011-2015 average. Catches from other gears (21,670 mt) were 44 % higher than in 2015 and 76% higher than the 2011-2015 average (see SC13-SA-WP-02).

2. SC13 endorsed the 2017 WCPO bigeye tuna stock assessment as the most advanced and comprehensive assessment yet conducted for this species.

3. SC13 also endorsed the use of the assessment model uncertainty grid to characterize stock status and management advice and implications but noted the large variance in the assessment results, mainly due to the inclusion of the old and new regional structures and growth curves, for which some CCMs considered further investigation is necessary.

4. SC13 reached consensus on the weighting of assessment models in the uncertainty grid for bigeye tuna. The consensus weighting considered all options within the four axes of uncertainty for steepness, tagging dispersion, size frequency and regional structure to be equally likely. For the growth axis of uncertainty, the new growth curve models (n=36 models, weight=3, 108 model weight units) were weighted three times more than the old growth curve models (n=36 models, weight=1, 36 model weight units). In total there were 144 model weight units. The resulting uncertainty grid was used to characterize stock status, to summarize reference points as provided in the assessment document SC13-SA-WP-05, and to calculate the probability of breaching the adopted spawning biomass limit reference point ($0.2*SB_{F=0}$) and the probability of F_{recent} being greater than F_{MSY}. It should be noted that the results would vary depending on the choice and/or weighting of grids, in particular the growth curve model, thus those characterizations of central tendency of stock status need to be interpreted with caution.

a. Stock status and trends

5. The median values of relative recent (2012-2015) spawning biomass ($SB_{recent}/ SB_{F=0}$) and relative recent fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid were used to measure the central tendency of stock status. The values of the upper 90th and lower 10th percentiles of the empirical distributions of relative spawning biomass and relative fishing mortality from the uncertainty grid were used to characterize the probable range of stock status.

6. A description of the updated structural sensitivity grid used to characterize uncertainty in the assessment was set out in Table BET-1. Time series of total annual catch by fishing gear for the diagnostic case model over the full assessment period is shown in Figure BET-1. Estimated annual average recruitment, spawning potential, juvenile and adult fishing mortality and fishing depletion for the diagnostic case model are shown in Figures BET-2 – BET-5. Figures BET-6 and BET-7 display Majuro plots summarising the results for each of the models in the structural uncertainty grid. Figures BET-8 and BET-9 show Kobe plots summarising the results for each of the models in the structural uncertainty grid. Figure BET-10 provides estimated time-series (or "dynamic") Majuro and Kobe plots from the bigeye 'diagnostic case' model run. Figure BET-11 provides estimates of reduction in spawning potential due to

fishing by region, and over all regions attributed to various fishery groups (gear-types) for the diagnostic case model. Table BET-2 provides a summary of reference points over the 72 models in the structural uncertainty grid.

Table BET-1. Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment.

Axis	Levels	Option
Steepness	3	0.65, 0.80, 0.95
Growth	2	'Old growth', 'New growth'
Tagging over-dispersion	2	Default level (1), fixed (moderate) level
Size frequency weighting	3	Sample sizes divided by 10, 20, 50
Regional structure	2	2017 regions, 2014 regions

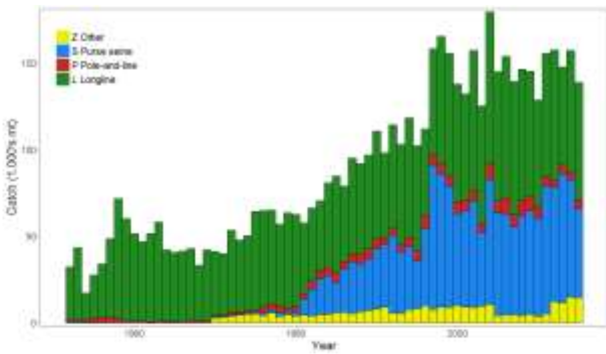

Figure BET-1. Time series of total annual catch (1000's mt) by fishing gear for the diagnostic case model over the full assessment period.

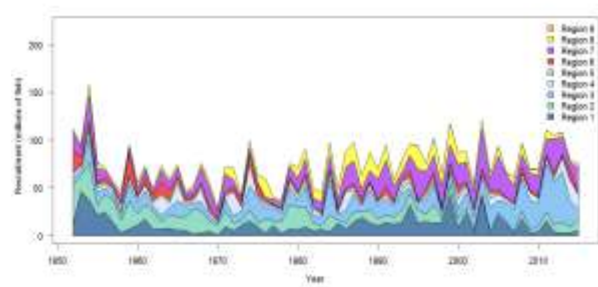

Figure BET-2. Estimated annual average recruitment by model region for the diagnostic case model, showing the relative sizes among regions.

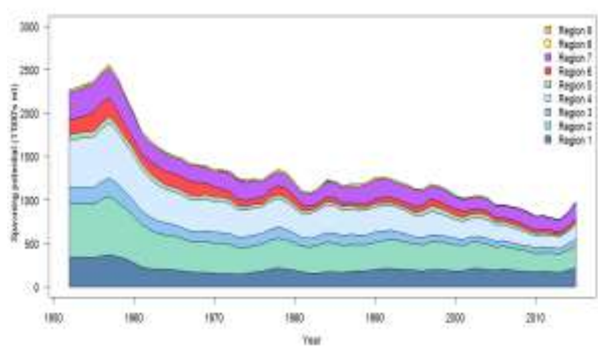

Figure BET-3. Estimated annual average spawning potential by model region for diagnostic case model, showing the relative sizes among regions

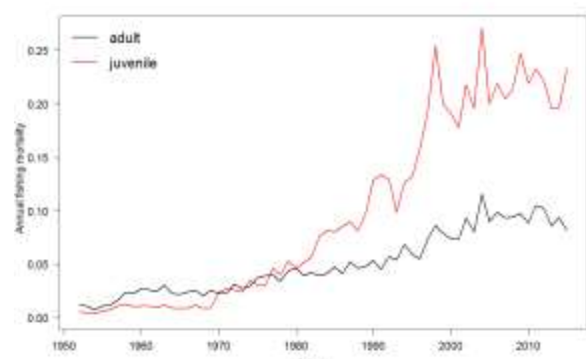

Figure BET-4. Estimated annual average juvenile and adult fishing mortality for the diagnostic case model.

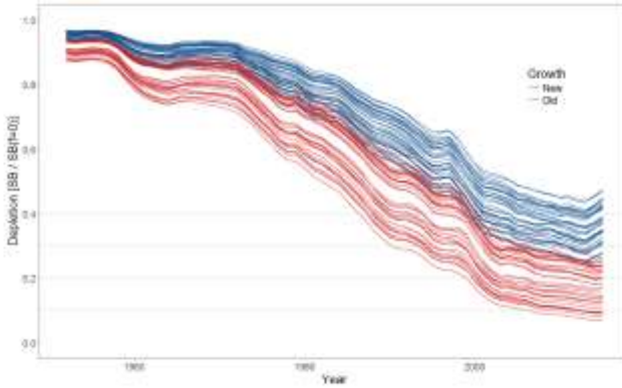

Figure BET-5. Plot showing the trajectories of fishing depletion (of spawning potential) for the 72 model runs included in the structural uncertainty grid. The colours depict the models in the grid with the new and old growth functions.

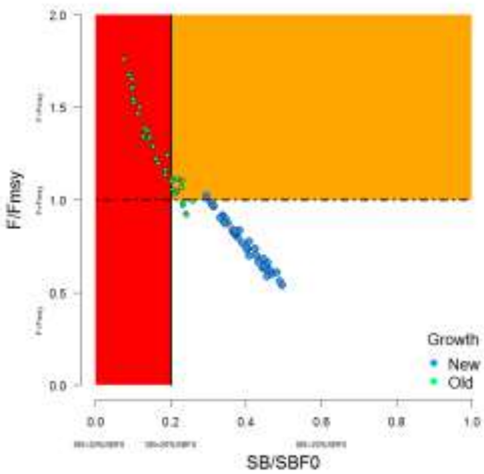

Figure BET-6. Majuro plot summarising the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality. The red zone represents spawning potential levels lower than the agreed limit reference point which is marked with the solid black line. The orange region is for fishing mortality greater than F_{MSY} (F_{MSY} is marked with the black dashed line). The points represent $SB_{latest}/SB_{F=0}$ (labelled as $\mathrm{SB/SB_{F=0}}$ above), and the colours depict the models in the grid with the new and old growth functions with the size of the points representing the decision of the SC to weight the new growth models three times higher than the old growth models.

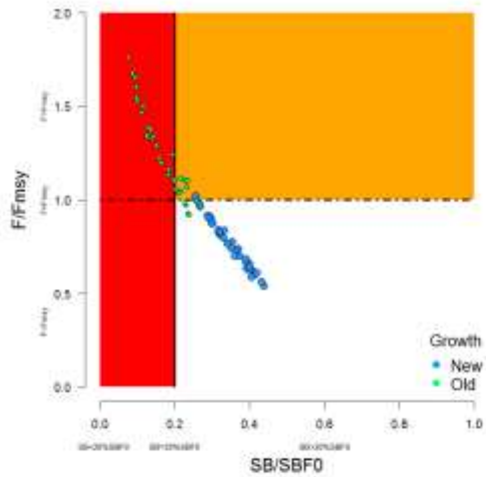

Figure BET-7. Majuro plot summarising the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality. The red zone represents spawning potential levels lower than the agreed limit reference point which is marked with the solid black line. The orange region is for fishing mortality greater than F_{MSY} (F_{MSY} is marked with the black dashed line). The points represent $SB_{recent}/\mathrm{SB}_{\mathrm{F=0}}$ (labelled as $\mathrm{SB/SB_{F=0}}$ above), where SB_{recent} is the mean *SB* over 2012-2015 instead of 2011-2014 (used in the stock assessment report), at the request of the Scientific Committee. The colours depict the models in the grid with the new and old growth functions with the size of the points representing the decision of the SC to weight the new growth models three times higher than the old growth models.

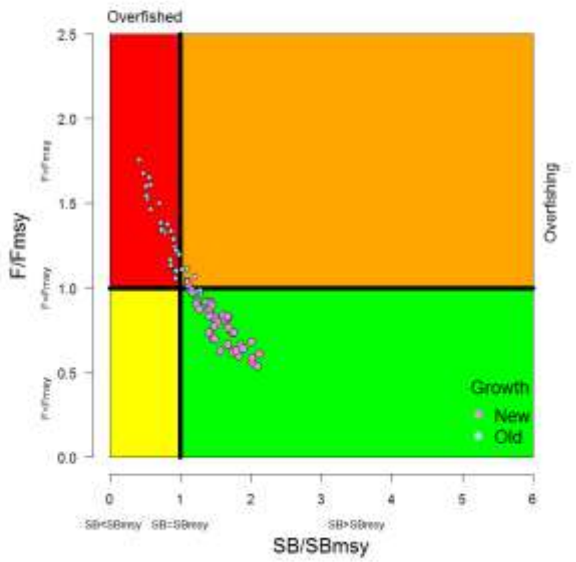

Figure BET8. Kobe plot summarising the results for each of the models in the structural uncertainty grid. The points represent $SB_{latest} / SB_{\mathrm{MSY}}$, with the colours depicting the models in the grid with the new and old growth functions, and the size of the points representing the decision of the SC to weight the new growth models three times higher than the old growth models.

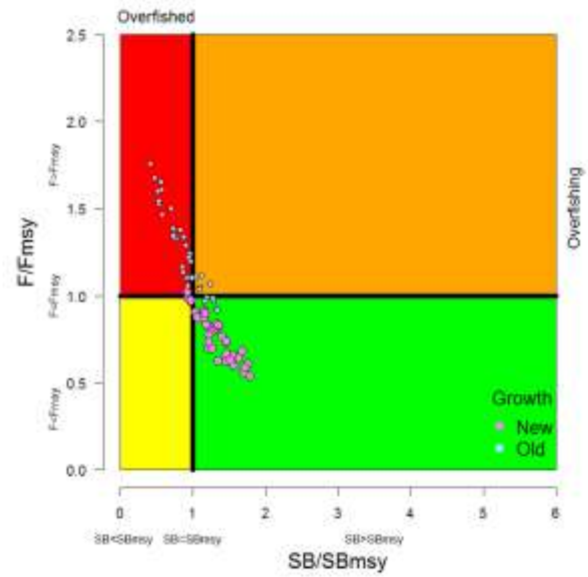

Figure BET-9. Kobe plot summarising the results for each of the models in the structural uncertainty grid. The points represent SB_{recent}/SB_{MSY}, with the colours depicting the models in the grid with the new and old growth functions, and the size of the points representing the decision of the SC to weight the new growth models three times higher than the old growth models.

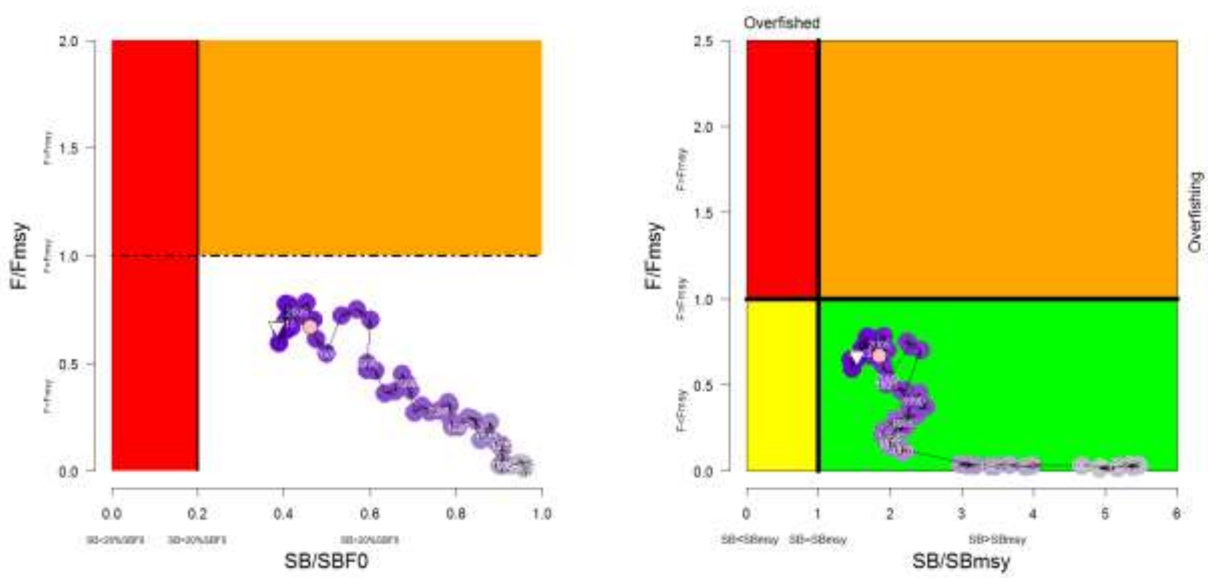

Figure BET-10. Estimated time-series (or "dynamic") Majuro and Kobe plots from the bigeye 'diagnostic case' model run.

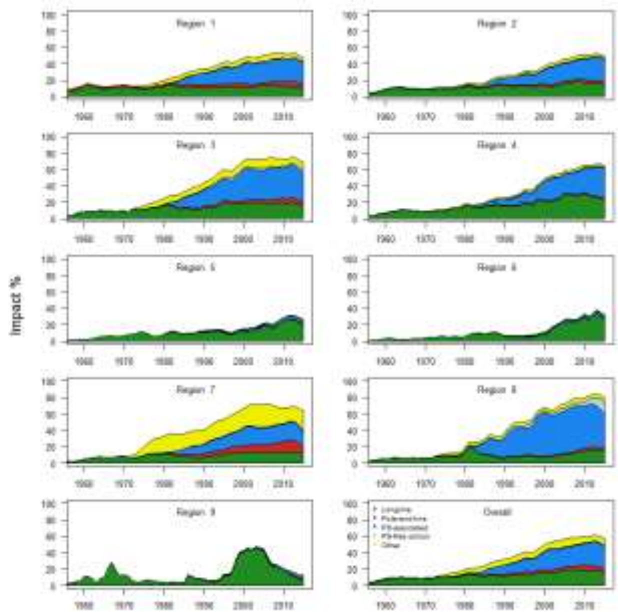

Figure BET-11. Estimates of reduction in spawning potential due to fishing by region, and over all regions (lower right panel), attributed to various fishery groups (gear-types) for the diagnostic case model.

Table BET-2. Summary of reference points over the 72 models in the structural uncertainty grid where the models using the new growth function are given three times the weighting of the models using the old growth function. Note that $SB_{recent}/SB_{F=0}$ is calculated where SB_{recent} is the mean SB over 2012-2015 instead of 2011-2014 (used in the stock assessment report), at the request of the Scientific Committee.

	Mean	Median	Min	10%	90%	Max
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SB_{latest}/SB_0	0.37	0.40	0.11	0.19	0.49	0.53
$SB_{latest}/SB_{F=0}$	0.34	0.37	0.08	0.15	0.46	0.49
$SB_{latest}/SB_{\mathrm{MSY}}$	1.42	1.45	0.42	0.86	1.97	2.12
$SB_{recent}/SB_{F=0}$	0.30	0.32	0.08	0.15	0.41	0.44
$SB_{recent}/SB_{\mathrm{MSY}}$	1.21	1.23	0.32	0.63	1.66	1.86

7. SC13 noted that the central tendency of relative recent spawning biomass under the selected new and old growth curve model weightings was median ($SB_{recent}/SB_{F=0}$) = 0.32 with a probable range of 0.15 to 0.41 (80% probability interval). This suggested that there was likely a buffer between recent spawning biomass and the LRP but that there was also some probability that recent spawning biomass was below the LRP.

8. SC13 also noted that there was a roughly 16% probability (23 out of 144 model weight units) that the recent spawning biomass had breached the adopted LRP with Prob(($SB_{recent}/SB_{F=0}$) < 0.2) = 0.16. This suggested that there was a high probability (roughly 5 out of 6) that recent bigeye tuna spawning biomass had not breached the adopted spawning biomass limit reference point of $0.2*SB_{F=0}$.

9. SC13 noted that the central tendency of relative recent fishing mortality under the selected new and old growth curve model weightings was median(F_{recent}/F_{MSY}) = 0.83 with an 80% probability interval of 0.61 to 1.31. While this suggested that there was likely a buffer between recent fishing mortality and F_{MSY}, it also showed that there was some probability that recent fishing mortality was above F_{MSY}.

10. SC13 also noted that there was a roughly 23% probability (33 out of 144 model weight units as described in para. 6) that the recent fishing mortality was above F_{MSY} with Prob((F_{recent}/F_{MSY}) > 1) = 0.23. While this suggested that recent fishing mortality was likely below F_{MSY}, there was also a moderate probability (~ 1 out of 4) that recent fishing mortality has exceeded F_{MSY}.

11. SC13 noted that the best available information on the stock status of WCPO bigeye tuna has changed in two ways from the previous assessment under the selected weighting of the 2017 assessment uncertainty grid. First, the stock status condition is more positive with a higher central tendency for $SB_{recent}/SB_{F=0}$ in the 2017 assessment (median($SB_{recent}/SB_{F=0}$) = 0.32) in comparison to the 2014 assessment (($SB_{current}/SB_{F=0}$) = 0.20) and a lower ratio of relative recent F in the 2017 assessment (median(F_{recent}/F_{MSY}) = 0.83) in comparison to the 2014 assessment ($F_{current}/F_{MSY}$ = 1.57). Second, there is much greater uncertainty in the stock status of bigeye tuna in 2017 due to the fuller technical treatment of structural uncertainty through the use of the model uncertainty grid.

12. SC13 noted that the positive changes for bigeye tuna stock status in the 2017 assessment are primarily due to three factors: the inclusion of the new growth curve information, the inclusion of the new regional assessment structure, and the estimated increases in recruitment in recent years. In terms of the cause of the recent increases in recruitment, SC13 commented that it was unclear whether the recent improvement was due to positive oceanographic conditions, effective management measures to conserve spawning biomass, some combination of both, or other factors. SC13 also noted the recent recruitment improvements for yellowfin and skipjack tunas. SC13 also noted recent recruitment improvements for bigeye tuna in the Eastern Pacific Ocean.

13. SC13 also noted that, regardless of the choice of uncertainty grid, the assessment results show that the stock has been continuously declining for about 60 years since the late 1950's, except for the recent small increase suggested in the new growth curve model grid.

14. SC13 also noted the continued higher levels of depletion in the equatorial and western Pacific (specifically Regions 3, 4, 7 and 8 of the stock assessment) and the associated higher levels of impact, especially on juvenile bigeye tuna, in these regions due to the associated purse-seine fisheries and the 'other' fisheries within the western Pacific (as shown in Figures 35 and 46 of SC13-SA-WP-05).

15. SC13 noted that there has been a long-term increase in fishing mortality for both juvenile and adult bigeye tuna, consistent with previous assessments.

16. SC13 noted that there has been a long-term decrease in spawning biomass from the 1950s to the present for bigeye tuna and that this is consistent with previous assessments.

b. Management advice and implications

17. Based on the uncertainty grid adopted by SC13, the WCPO bigeye tuna spawning biomass is likely above the biomass LRP and recent F is likely below F_{MSY}, and therefore noting the level of uncertainties in the current assessment it appears that the stock is not experiencing overfishing (77% probability) and it appears that the stock is not in an overfished condition (84% probability).

18. Although SC13 considers that the new assessment is a significant improvement in relation to the previous one, SC13 advises that the amount of uncertainty in the stock status results for the 2017 assessment is higher than for the previous assessment due to the inclusion of new information on bigeye tuna growth and regional structures.

19. SC13 also noted that levels of fishing mortality and depletion differ between regions, and that fishery impact was higher in the tropical region (Regions 3, 4, 7 and 8 in the stock assessment model), with particularly high fishing mortality on juvenile bigeye tuna in these regions. SC13 therefore recommends that WCPFC14 could continue to consider measures to reduce fishing mortality from fisheries that take juveniles, with the goal to increase bigeye fishery yields and reduce any further impacts on the spawning potential for this stock in the tropical regions.

20. Based on those results, SC13 recommends as a precautionary approach that the fishing mortality on bigeye tuna stock should not be increased from current level to maintain current or increased spawning biomass until the Commission can agree on an appropriate target reference point (TRP).

Research Recommendations

21. SC13 recognized that future work is required to improve the assessment and to reduce uncertainty. Future research should concentrate on the two axes (e.g. growth, regional structure) of uncertainty which are the most influential. The growth analysis should continue with the emphasis on providing length at age estimates for larger fish between 130 and 180 cm FL. Additional research is also required for the regional structure uncertainty to consider options in addition to the structures used in the 2014 and 2017 assessments, for example, by using statistical approaches (e.g. tree models).

22. In addition, SC13 considers that the model ensemble or weighting will be increasingly important as SC moves to uncertainty grid approaches in stock assessments and requests the Scientific Services Provider to study those methods further.

23. SC13 requested that SPC undertake projections of potential changes in spawning biomass in the future under current levels of fishing mortality. This would be similar to the projections delivered in SC13-SA-IP-22, but would be based on the weighted uncertainty grid as described above.

Attachment B

WCPO yellowfin tuna (*SC13 Paragraphs 265 – 279*)

Provision of scientific information

1. SC13 noted that preliminary total yellowfin tuna catch in 2016 (651,575 mt) was a 12% increase over 2015 and a 14% increase over 2011-2015. Longline catch (91,635 mt) was 10% lower than in 2015 and 1% lower than the 2011-2015 average. Pole and line catch (23,074 mt) was 36% lower than in 2015 and 25% lower than 2011-2015 average. Purse seine catch (394,756 mt) was 29% higher than in 2015, and 17% higher than 2011-2015 average. Catches from other gears (142,110 mt) were 2% higher than in 2015 and 26% higher than the 2011-2015 average. (see SC13-SA-WP-02).

2. SC13 endorsed the 2017 WCPO yellowfin tuna stock assessment as the most advanced and comprehensive assessment yet conducted for this species.

3. SC13 also endorsed the use of the assessment model uncertainty grid to characterize stock status and management advice and implications.

4. SC13 reached consensus on the weighting of assessment models in the uncertainty grid for yellowfin tuna. The consensus weighting considered all options within five axes of uncertainty for steepness, tagging dispersion, tag mixing, size frequency (with two levels), and regional structure to be equally likely. The resulting uncertainty grid was used to characterize stock status, to summarize reference points as provided in the assessment document SC13-SA-WP-06, and to calculate the probability of breaching the adopted spawning biomass limit reference point ($0.2*SB_{F=0}$) and the probability of F_{recent} being greater than F_{MSY}.

a. Status and trends

5. The median values of relative recent spawning biomass (2012-2015) ($SB_{recent}/SB_{F=0}$) and relative recent fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid were used to measure the central tendency of stock status. The values of the upper 90th and lower 10th percentiles of the empirical distributions of relative spawning biomass and relative fishing mortality from the uncertainty grid were used to characterize the probable range of stock status.

6. Descriptions of the updated structural sensitivity grid used to characterize uncertainty in the assessment are provided in Table YFT-1. Catch trend data is presented in Figure YFT-1. Estimated annual average recruitment, biomass, fishing mortality and depletion are shown in Figures YFT-2 – YFT-5. Majuro plots summarizing the results for each of the models in the structural uncertainty grid retained for management advice are represented in Figures YFT-6 and YFT-7. Figure YFT-8 and YFT-9 present Kobe plots summarizing the results for each of the models in the structural uncertainty grid. Figure YFT-10 provides estimated time-series (or “dynamic”) Majuro and Kobe plots from the yellowfin ‘diagnostic case’ model run. Figure YFT-11 shows estimates of reduction in spawning potential due to fishing by region, and over all regions attributed to various fishery groups (gear-types) for the diagnostic case model. Table YFT-2 provides a summary of reference points over the 48 models in the structural uncertainty grid (based on the SC decision to include size frequency weighting levels 20 and 50 only).

Table YFT-1: Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment

Axis	Levels	Option
Steepness	3	0.65, 0.80, 0.95
Tagging overdispersion	2	Default level (1), fixed (moderate) level
Tag mixing	2	1 or 2 quarters
Size frequency weighting	3	Sample sizes divided by 10, 20, 50
Regional structure	2	2017 regions, 2014 regions

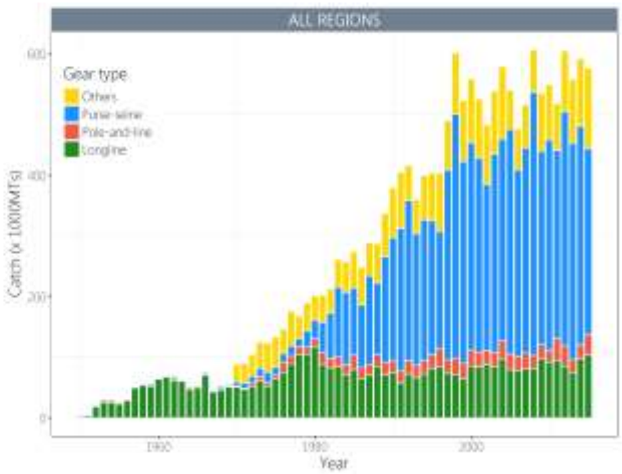

Figure YFT-1. Time series of total annual catch (1000's mt) by fishing gear for the diagnostic case model over the full assessment period.

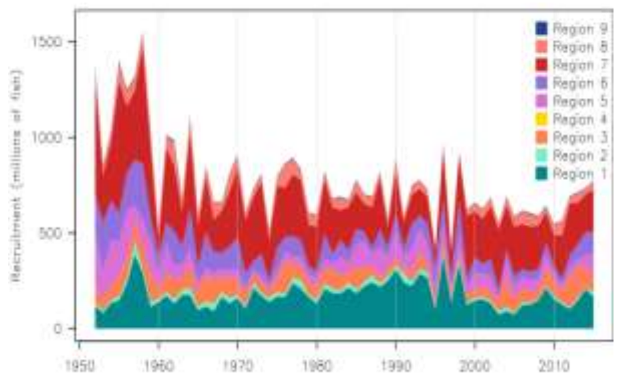

Figure YFT-2. Estimated annual average recruitment by model region for the diagnostic case model, showing the relative sizes among regions.

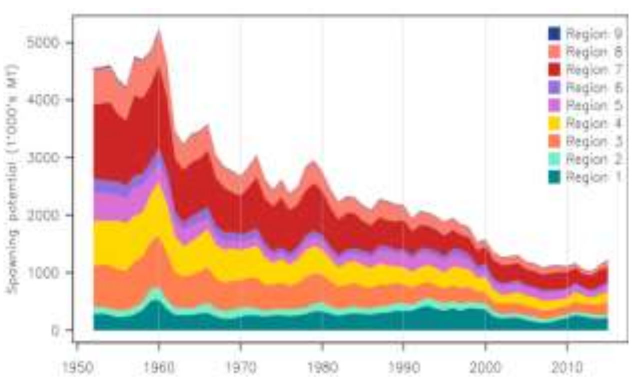

Figure YFT-3. Estimated annual average spawning potential by model region for the diagnostic case model, showing the relative sizes among regions.

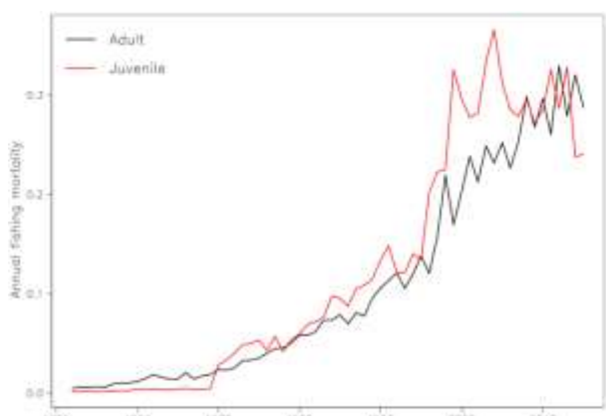

Figure YFT-4. Estimated annual average juvenile and adult fishing mortality for the diagnostic case model.

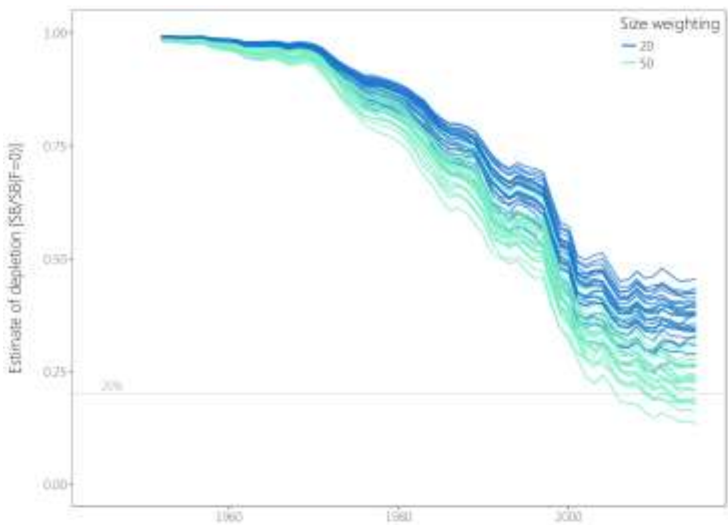

Figure YFT-5 : Plot showing the trajectories of fishing depletion (of spawning potential) for the 48 model runs retained for the structural uncertainty grid used for management advice. The colours depict the models in the grid with the size composition weighting using divisors of 20 and 50.

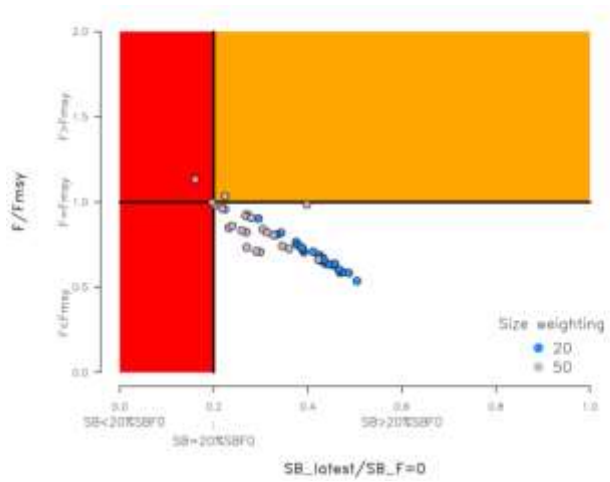

Figure YFT-6. Majuro plot summarising the results for each of the models in the structural uncertainty grid retained for management advice. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality. The red zone represents spawning potential levels lower than the agreed limit reference point which is marked with the solid black line. The orange region is for fishing mortality greater than F_{MSY} (F_{MSY} is marked with the black horizontal line). The points represent $SB_{latest}/SB_{F=0}$, and the colours depict the models in the grid with the size composition weighting using divisors of 20 and 50.

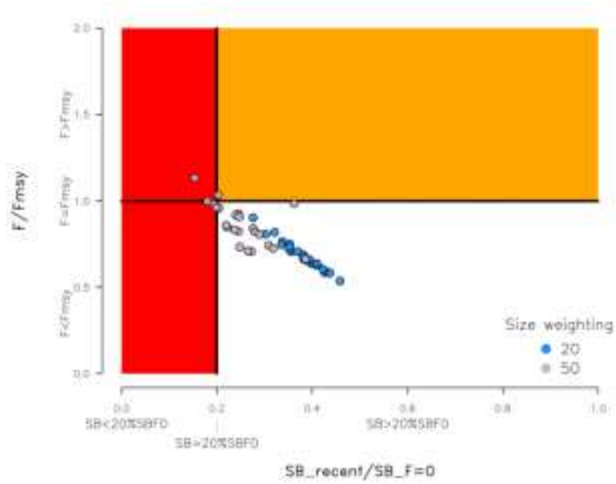

Figure YFT-7: Majuro plot summarising the results for each of the models in the structural uncertainty grid retained for management advice. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality. The red zone represents spawning potential levels lower than the agreed limit reference point which is marked with the solid black line. The orange region is for fishing mortality greater than F_{MSY} (F_{MSY} is marked with the black horizontal line). The points represent $SB_{recent}/SB_{F=0}$, and the colours depict the models in the grid with the size composition weighting using divisors of 20 and 50.

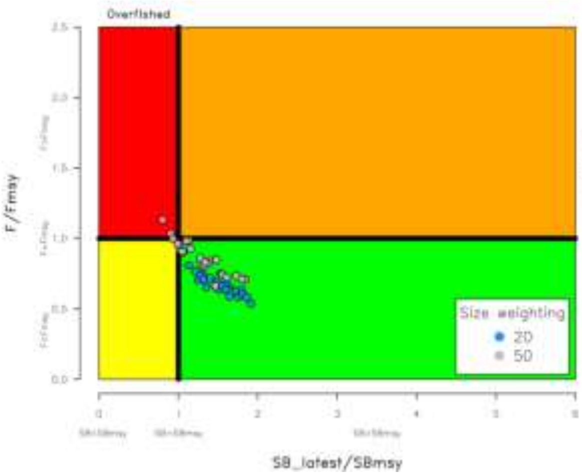

Figure YFT-8. Kobe plot summarising the results for each of the models in the structural uncertainty grid. The points represent SB_{latest}/SB_{MSY}, the colours depict the models in the grid with the size composition weighting using divisors of 20 and 50.

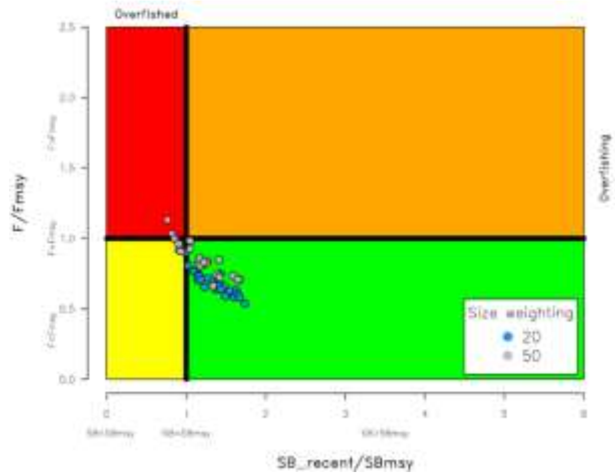

Figure YFT-9. Kobe plot summarising the results for each of the models in the structural uncertainty grid. The points represent SB_{recent}/SB_{MSY}, the colours depict the models in the grid with the size composition weighting using divisors of 20 and 50.

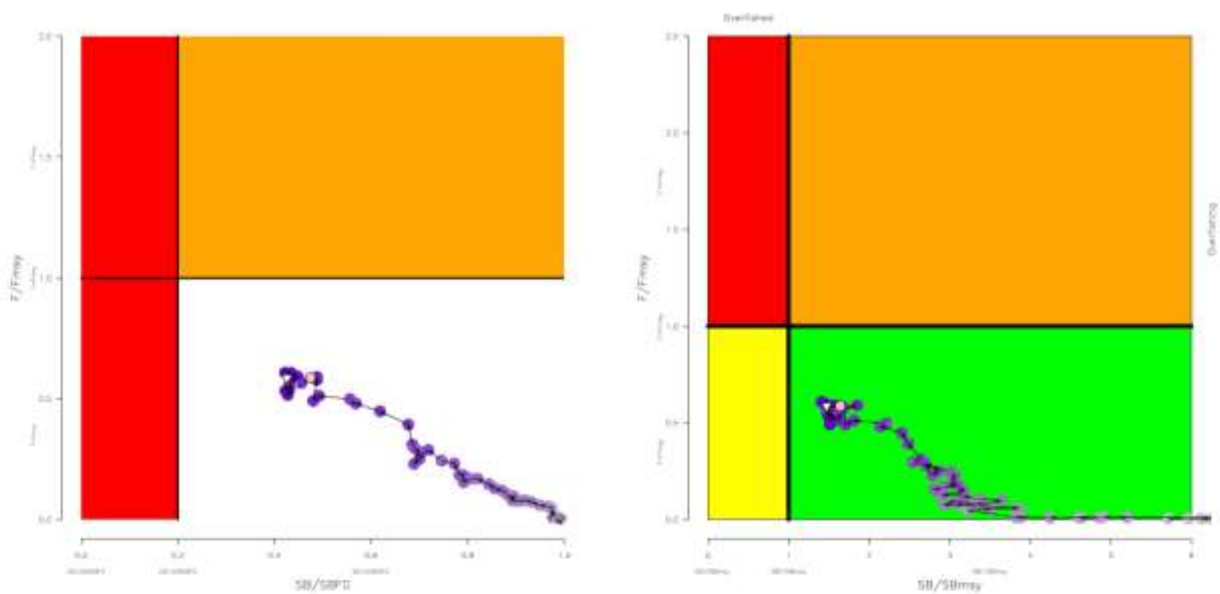

Figure YFT-10. Estimated time-series (or "dynamic") Majuro and Kobe plots from the yellowfin 'diagnostic case' model run.

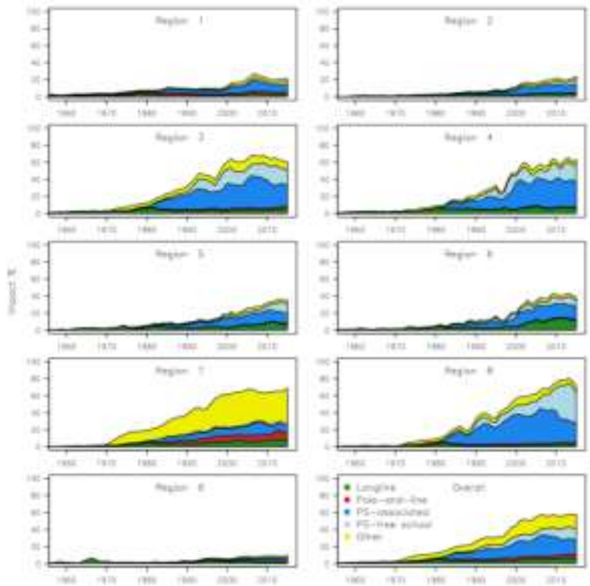

Figure YFT-11. Estimates of reduction in spawning potential due to fishing by region, and over all regions (lower right panel), attributed to various fishery groups (gear-types) for the diagnostic case model.

Table YFT-2. Summary of reference points over the 48 models in the structural uncertainty grid retained for management advice using divisors of 20 and 50 for the weighting on the size composition data. Note that $SB_{recent}/SB_{F=0}$ is calculated where SB_{recent} is the mean SB over 2012-2015 instead of 2011-2014 (used in the stock assessment report), at the request of the Scientific Committee.

	Mean	**Median**	**Min**	**10%**	**90%**	**Max**
C_{latest}	611,982	612,592	606,762	607,517	614,237	614,801
MSY	670,658	670,800	539,200	601,480	735,280	795,200
$Y_{Frecent}$	646,075	643,400	534,400	586,120	717,880	739,600
F_{mult}	1.34	1.36	0.88	1.03	1.61	1.86
F_{MSY}	0.12	0.12	0.07	0.10	0.14	0.16
$F_{recent}/F_{\mathrm{MSY}}$	0.77	0.74	0.54	0.62	0.97	1.13
SB_{MSY}	544,762	581,400	186,800	253,320	786,260	946,800
SB_0	2,199,750	2,290,000	1,197,000	1,366,600	2,784,500	3,256,000
SB_{MSY}/SB_0	0.24	0.24	0.15	0.18	0.28	0.34
$SB_{F=0}$	2,083,477	2,178,220	1,193,336	1,351,946	2,643,390	2,845,244
$SB_{\mathrm{MSY}}/SB_{F=0}$	0.25	0.26	0.16	0.19	0.30	0.35
SB_{latest}/SB_0	0.33	0.34	0.18	0.23	0.42	0.45
$SB_{latest}/SB_{F=0}$	0.35	0.37	0.16	0.22	0.46	0.50
$SB_{latest}/SB_{\mathrm{MSY}}$	1.40	1.39	0.80	1.02	1.80	1.91
$SB_{recent}/SB_{F=0}$	0.32	0.33	0.15	0.20	0.41	0.46
$SB_{recent}/SB_{\mathrm{MSY}}$	1.40	1.41	0.81	1.05	1.71	1.93

68. SC13 noted that the central tendency of relative recent spawning biomass was median ($SB_{recent}/SB_{F=0}$) = 0.33 with a probable range of 0.20 to 0.41 (80% probable range), and there was a roughly 8% probability (4 out of 48 models) that the recent spawning biomass had breached the adopted LRP with Prob(($SB_{recent}/SB_{F=0}$)<0.2) = 0.08. The median estimate (0.33) is below that estimated from the 2014 assessment grid (($SB_{current}/SB_{F=0}$) = 0.41, see SC10-SA-WP-04), noting the differences in grid uncertainty axes used in that assessment.

8. SC13 noted that the central tendency of relative recent fishing mortality was median (F_{recent}/F_{MSY}) = 0.74 with an 80% probability interval of 0.62 to 0.97, and there was a roughly 4% probability (2 out of 48 models) that the recent fishing mortality was above F_{MSY} with Prob((F_{recent}/F_{MSY})>1) = 0.04. The median estimate (0.74) is also comparable to that estimated from the 2014 assessment grid ($F_{current}/F_{MSY}$ = 0.76, see SC10-SA-WP-04).

9. SC13 noted that the assessment results show that the stock has been continuously declining for about 50 years since the late 1960's.

10. SC13 also noted that levels of fishing mortality and depletion differ between regions, and that fishery impact was highest in the tropical region (Regions 3, 4, 7 and 8 in the stock assessment model), mainly due to the purse seine fisheries in the equatorial Pacific and the "other" fisheries within the Western Pacific (as shown in Figure 44 of SC13-SA-WP-06).

b. Management advice and implications

11. Based on the uncertainty grid adopted by SC13 the spawning biomass is highly likely above the biomass LRP and recent F is highly likely below F_{MSY}, and therefore noting the level of uncertainties in the current assessment is appears that the stock is not experiencing overfishing 96% probability) and it appears that the stock is not in an overfished condition (92% probability).

12. Based on the diagnostic case, both juvenile and adult fishing mortality show a steady increase since the 1970s. Adult fishing mortality has increased continuously over most of the time series, while juvenile fishing mortality has stabilized since the late 1990s at a level similar to that now estimated for adult yellowfin.

13. SC13 reiterates its previous advice from SC10 that WCPFC could consider measures to reduce fishing mortality from fisheries that take juveniles, with the goal to increase to maximum fishery yields and reduce any further impacts on the spawning potential for this stock in the tropical regions.

14. SC13 also reiterates its previous advice from SC10 that measures should be implemented to maintain current spawning biomass levels until the Commission can agree on an appropriate target reference point (TRP).

Research Recommendations

15. SC13 recognized that reviewing yellowfin growth through a study of yellowfin otoliths collected from the WCPO and incorporating this into future assessments should be encouraged.

Attachment C

WCPO skipjack tuna (*SC13 Paragraphs 300 – 306*)

Provision of scientific information

a. Status and trends

1. SC13 noted that no stock assessment was conducted for WCPO skipjack tuna in 2017. Therefore, the stock status description from SC12 is still current.

2. SC13 noted that the total catch in 2016 (1,816,762 mt) was comparable to that in 2015 and a 2% increase over 2011-2015. (see SC13-SA-WP-02)

3. Purse seine catch (1,408,110 mt) was comparable to both 2015 and the 2011-2015 average. Pole and line catch (151,441 mt) was a 1% decrease from 2015 and an 11% decrease from 2011-2015 average. Catches by other fisheries (251,470 mt) were 2% higher than in 2015 and 26% higher than 2011-2015 average.

4. SC13 noted that under recent fishery conditions (2016 catch level for LL and other fisheries and effort level for purse seine), the skipjack stock was initially projected to decrease for a short period and then to increase as recent relatively high recruitments move through the stock. Median F_{2018}/F_{MSY} = 0.37; median $SB_{2018}/SB_{F=0}$ = 0.47.

b. Management advice and implications

5. SC13 noted that no stock assessment has been conducted since SC12. Therefore, the advice from SC12 should be maintained, pending a new assessment or other new information. For further information on the management advice and implications from SC12, please see https://www.wcpfc.int/node/27769

WCPO skipjack tuna from SC12 (*SC12 - Paras 301-321*)

Provision of scientific information

a. ***Stock status and trends***

6. The SC12 was unable to reach consensus on the description of stock status based on the 2016 stock assessment. So majority and alternative views were provided for the stock status whereas SC12 provided agreed management advice.

> **Note**
> The Science Services Provider conducted additional sensitivity model runs to supplement the 2016 stock assessment. This paper is posted on the SC12 website (SA-WP-04a) on 28 November 2016, which can be considered at WCPFC13:
> http://www.wcpfc.int/system/files/SC12-SA-WP-04a%20%5BAdditional%20analysis%20to%20support%20SKJ%20assessment%5D.pdf

Majority view of stock status and trends

7. A majority of SC12 CCMs selected the reference case model as the base case to represent the stock status of skipjack tuna (column “Ref Case” in Table SKJ2). To characterize uncertainty, those CCMs chose the structural uncertainty grid. Summaries of important model quantities for these models are shown in Table SKJ2.

Table SKJ2: Estimates of management quantities for the selected stock assessment models. For the purpose of this assessment, “recent” is the average over the period 2011–2014 and “latest” is 2015. The column “Ref Case” shows summaries for the reference case and the remaining columns are the quantiles of the structural uncertainty grid, e.g. 5% and 50% are the 5% quantile and the median (50% quantile), respectively. Option 1 in the text recommends basing management advice on the reference case model and considering the uncertainty represented by the 5% and 95% quantile columns. Option 2 recommends basing management advice on the range of model runs in the structural uncertainty grid, as represented by the 5% and 95% quantile columns.

Quantity	Ref Case	50%	5%	25%	75%	95%
C_{latest}	1,679,528	1,679,444	1,678,646	1,679,170	1,679,497	1,679,592
MSY	1,891,600	1,875,600	1,618,060	1,785,400	1,976,700	2,199,880
$Y_{F_{recent}}$	1,594,800	1,607,000	1,486,660	1,533,200	1,755,200	1,808,860
f_{mult}	2.23	2.07	1.57	1.85	2.29	2.62
F_{MSY}	0.24	0.24	0.21	0.22	0.26	0.28
F_{recent}/F_{MSY}	0.45	0.48	0.38	0.44	0.54	0.64
SB_{MSY}	1,626,000	1,628,000	1,258,700	1,425,750	1,852,750	2,166,100
SB_0	6,764,000	6,359,500	5,214,050	5,853,750	7,095,250	8,340,450
$SB_{F=0}$	7,221,135	6,876,526	5,778,079	6,408,578	7,425,353	8,555,240
SB_{latest}/SB_0	0.62	0.55	0.43	0.49	0.59	0.71
$SB_{latest}/SB_{F=0}$	0.58	0.51	0.39	0.47	0.57	0.67
SB_{latest}/SB_{MSY}	2.56	2.15	1.6	1.81	2.43	3.08
$SB_{recent}/SB_{F=0}$	0.52	0.49	0.4	0.46	0.52	0.57

8. Dynamics of most model quantities are relatively consistent with the results of the 2014 stock assessment, although there has been a period of several subsequent years with high recruitments and increased spawning biomass.

9. Fishing mortality of all age-classes is estimated to have increased significantly since the beginning of industrial tuna fishing, but fishing mortality still remains below the level that would result in the MSY (F_{recent}/F_{MSY} = 0.45 for the reference case), and is estimated to have decreased moderately in the last several years. Across the reference case and the structural uncertainty grid F_{recent}/F_{MSY} varied between 0.38 (5% quantile) to 0.64 (95% quantile). This indicates that overfishing is not occurring for the WCPO skipjack tuna stock.

10. The estimated MSY of 1,891,600 mt is moderately higher than the 2014 estimate due to the adoption of an annual, rather than quarterly, stock-recruitment relationship. Recent catches are lower than, but approaching, this MSY value.

11. The latest (2015) estimate of spawning biomass is well above both the level that will support MSY (SBlatest/SBMSY = 2.56, for the reference case model) and the adopted LRP of 0.2 SBF=0 (SBlatest/SBF=0 = 0.58, for the reference case model), and SBlatest/SBF=0 was relatively close to the adopted interim target reference point (0.5 SBF=0) for all models explored in the assessment (structural uncertainty grid: median = 0.51, 5% and 95% quantiles = 0.39 and 0.67).

Alternative view of stock status and trends

12. China, Japan and Chinese Taipei considered it is not possible to select a base-case model from various sensitivity models in the 2016 assessment, given the advice from the Scientific Service Provider that a suite of the sensitivity models were plausible. Therefore, these members considered that it would be more appropriate to provide advice to WCPFC13 on skipjack stock status based on the range of uncertainty expressed by the alternative model runs in the sensitivity analysis rather than based on the single base case model (represented by the 5% and 95% quantiles of the structural sensitivity grid presented in Table SKJ2).

13. The estimated MSY of the WCPO skipjack stock ranges from 1,618,060 mt (5% quantile) to 2,199,880 mt (95% quantile) across the alternative skipjack stock assessment models represented in the sensitivity grid. These CCMs also noted that some alternative models indicate that the 2015 biomass is below the adopted TRP of 0.5SBF=0.

b. *Management advice and implications*

14. SC12 noted that the skipjack assessment continues to show that the stock is currently moderately exploited and fishing mortality level is sustainable. The recent catches are fluctuating around and some models also indicate that the stock is currently under the TRP.

15. SC12 noted that fishing is having a significant impact on stock size and can be expected to affect catch rates. The stock distribution is also influenced by changes in oceanographic conditions associated with El Niño and La Niña events, which impact on catch rates and stock size. Additional purse-seine effort will yield only modest gains in long-term skipjack tuna catches and may result in a corresponding increase in fishing mortality for bigeye and yellowfin tunas. The management of total effort in the WCPO should recognize this.

16. SC12 noted that skipjack spawning biomass is now around the adopted TRP and SC12 recommends that the Commission take action to keep the spawning biomass near the TRP and also advocates for the adoption of harvest control rules based on the information provided.

17. In order to maintain the quality of stock assessments for this important stock, SC12 recommends 1) continued work on developing an index of abundance based on purse seine data; 2) regular large scale tagging cruises and complementary tagging work continue to be undertaken in a way that provides the best possible data for stock assessment purposes.

18. SC12 also notes that the current method of calculating the TRP is based on the most recent 10 years of recruitment information. However, the information on spawning potential, SB_{2015}, which is used to evaluate current stock status relative to the TRP can change very rapidly for skipjack which mature at age 1 and this rapid maturation may provide an optimistic status evaluation when recruitment is estimated have an increasing trend but is estimated with substantial uncertainty, as is currently observed in the case of skipjack which does not have a fishery-independent index of recruitment strength.

19. There is ongoing concern by at least one CCM that high catches in the equatorial region may be causing a range contraction of WCPO skipjack tuna, thus reducing skipjack tuna availability to fisheries conducted at higher latitudes than the Pacific equatorial region. SC12 reiterates the advice of SC11 whereby there is no demonstrated statistical evidence for SKJ range contraction. As a result, SC12 recommends that ongoing research on range contraction of skipjack tuna be continued in the framework of Project 67.