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REFERENCE DOCUMENT FOR THE REVIEW OF CMM 2018-01 AND DEVELOPMENT OF HARVEST STRATEGIES UNDER CMM 2014-06 (BIGEYE, YELLOWFIN AND SKIPJACK TUNA)

WCPFC17-2020-13_rev1
27 November 2020

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) and Technical and Compliance Committee (TCC) of relevance to the stock status, management advice, and fisheries compliance issues fishing for bigeye, yellowfin and skipjack tunas.

2. Recommendations in the following matrix may require the Commission's attention and specific action:

Agenda	Recommendations (Paragraph numbers are from SC16 and TCC16 Summary Report)	Commission's Action
SC16: Bigeye tuna	97. SC16 noted that levels of fishing mortality and depletion differ among regions, and that fishery impact was higher in the tropical regions with particularly high fishing mortality on juvenile bigeye tuna in these regions. …. **SC16 therefore re-iterates that WCPFC17 could continue to consider measures to reduce fishing mortality from fisheries that take juveniles**… 98. Based on those results, **SC16 recommends as a precautionary approach that the fishing mortality on bigeye tuna stock should not be increased from the level that maintains spawning biomass at 2012-2015 levels until the Commission can agree on an appropriate target reference point.**	Note these recommendations
SC16: Yellowfin tuna	135. SC16 also that levels of fishing mortality and depletion differ between regions, and that fishery impact was highest in the tropical region, mainly due to the purse seine fisheries in the equatorial Pacific and the "other" fisheries within the Western Pacific. … **SC16 therefore re-iterates that WCPFC17 could consider measures to reduce fishing mortality from fisheries that take juveniles**…	Note these recommendations

	138. Based on those results, **SC16 recommends as a precautionary approach that the fishing mortality on yellowfin tuna stock should not be increased from the level that maintains spawning biomass at 2012-2015 levels until the Commission can agree on an appropriate target reference point**.	
TCC16: Advice on CMMs to improve compliance and monitoring	89. TCC16 noted for WCPFC17 that there were recommendations in the Provisional CMR relating to the revision of existing Conservation and Management Measures. **TCC16 recommends that WCPFC17 consider approaches to address challenges identified for the following obligations, noting that more information related to these recommendations is contained in the Provisional CMR**: **b. CMM 2018-01 51: for relevant CCMs where there are difficulties in terms of the scope of other commercial fisheries.**	Note the recommendation

B. SCIENTIFIC COMMITTEE RECOMMENDATIONS

3. The following stock status and management advice are extracts from the SC16 and SC15 Summary Reports for the tropical tuna species (bigeye, yellowfin and skipjack).

B1. Stock Status and Management Advice for Bigeye Tuna

4. Refer to **Attachment A** for the detailed description on the latest stock status and management advice for bigeye tuna from SC16.

a. Stock status and trends

5. The median values of relative recent (2015-2018) spawning biomass depletion ($SB_{recent}/SB_{F=0}$) and relative recent (2014-2017) fishing mortality (F_{recent}/F_{MSY}) were used to define stock status over the uncertainty grid of 24 models. A description of the updated structural sensitivity grid used to characterize uncertainty in the assessment is illustrated in Table BET-1, and a summary of reference points over the 24 models in the structural uncertainty grid is provided in Table BET-2.

Table BET-1. Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment. The starred levels denote those assumed in the model diagnostic case.

Axis	Value 1	Value 2	Value 3	Value 4
Steepness	0.65	0.8 *	0.95	
Natural mortality	Diagnostic* (0.112)	M-hi (0.146)		
Size frequency weighting	20*	60	200	500

Table BET-2. Summary of reference points over the 24 models in the structural uncertainty grid. Note that "recent" is the average over the period 2015-2018 for SB and 2014-2017 for fishing mortality, while "latest" is 2018. The values of the upper 90th and lower 10th percentiles of the empirical distributions are also shown. F_{mult} is the multiplier of recent (2014-2017) fishing mortality required to attain MSY.

	Mean	Median	Minimum	10th percentile	90th percentile	Maximum
C_{latest}	159,738	159,288	157,297	157,722	162,033	162,271
$Y_{Frecent}$	136,568	134,940	117,800	124,668	149,424	161,520
f_{mult}	1.45	1.38	0.83	0.98	2.03	2.33
F_{MSY}	0.05	0.05	0.04	0.04	0.07	0.07
MSY	146,715	140,720	117,920	125,628	179,164	187,520
F_{recent}/F_{MSY}	0.74	0.72	0.43	0.49	1.02	1.21
$SB_{F=0}$	1,395,173	1,353,367	903,708	982,103	1,780,138	1,908,636
SB_{MSY}	320,162	321,550	192,500	219,810	443,730	482,700
$SB_{MSY}/SB_{F=0}$	0.23	0.23	0.19	0.2	0.26	0.26
$SB_{latest}/SB_{F=0}$	0.38	0.38	0.23	0.3	0.47	0.51
SB_{latest}/SB_{MSY}	1.7	1.67	0.95	1.23	2.15	2.6
$SB_{recent}/SB_{F=0}$	0.4	0.41	0.21	0.27	0.52	0.55
SB_{recent}/SB_{MSY}	1.78	1.83	0.87	1.18	2.32	2.84

6. SC16 noted that:

- in general, the stock has been continuously declining since the late 1950s;
- the median value of spawning biomass depletion ($SB_{2015-2018}/SB_{F=0}$) was 0.41 with a 10th to 90th percentiles of 0.27 to 0.52;
- there was 0% probability that the recent $SB_{2015-2018}$ had breached the adopted LRP;
- there has been a long-term increase in fishing mortality for both juvenile and adult bigeye tuna;
- the median recent fishing mortality ($F_{2014-2017}/F_{MSY}$) was 0.72 with a 10th to 90th percentile interval of 0.49 to 1.02;
- there was a roughly 12.5% probability that the recent $F_{2014-2017}$ was above F_{MSY};
- stochastic projections with fishing at "status quo" conditions (2016–2018 average longline and other fishery catch and 2018 purse seine effort levels) show that:
  - under short-term recruitment scenario, projections indicate that median $SB_{2025}/SB_{F=0}$ = 0.47; median $SB_{2035}/SB_{F=0}$ = 0.49; median $SB_{2045}/SB_{F=0}$ = 0.49; and the risk that $SB_{2048}/SB_{F=0}$ is less than the LRP is 0%; and
  - under long-term recruitment scenario, projections indicate that median $SB_{2025}/SB_{F=0}$ = 0.42; median $SB_{2035}/SB_{F=0}$ = 0.44; median $SB_{2045}/SB_{F=0}$ = 0.45; and the risk that $SB_{2048}/SB_{F=0}$ is less than the LRP is 5%.

b. Management advice and implications

7. SC16 noted that the preliminary estimate of total catch of WCPO bigeye tuna for 2019 was 135,680 mt, a 9% decrease from 2018 and an 8% decrease from the average 2014-2018. Based on the uncertainty grid adopted by SC16, the WCPO bigeye tuna spawning biomass is above the biomass LRP and recent F is very likely below F_{MSY}. The stock is not overfished (100% probability $SB/SB_{F=0}$>LRP) and likely not experiencing overfishing (87.5% probability $F<F_{MSY}$).

8. SC16 noted that levels of fishing mortality and depletion differ among regions, and that fishery impact was higher in the tropical regions (Regions 3, 4, 7 and 8 in the stock assessment model), with

particularly high fishing mortality on juvenile bigeye tuna in these regions. There is also evidence that the overall stock status is buffered with biomass kept at more elevated level overall by low exploitation in the temperate regions (1, 2, 6 and 9). SC16 therefore re-iterates that WCPFC17 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 biomass for this stock in the tropical regions.

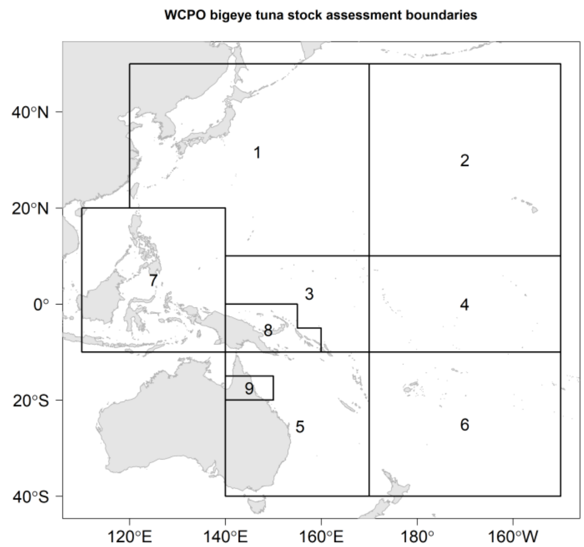

Figure BET-1. Spatial structure for the 2020 bigeye tuna stock assessment.

9. Based on the results, SC16 recommends as a precautionary approach that the fishing mortality on bigeye tuna stock should not be increased from the level that maintains spawning biomass at 2012-2015 levels until the Commission can agree on an appropriate target reference point.

B2. Stock Status and Management Advice for Yellowfin Tuna

10. Refer to **Attachment B** for the detailed description on the latest stock status and management advice for yellowfin tuna from SC16.

a. Stock Status and trends

11. The median values of relative recent (2015-2018) spawning biomass depletion ($SB_{recent}/SB_{F=0}$) and relative recent (2014-2017) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 72 models were used to define stock status. A description of the updated structural sensitivity grid used to characterize uncertainty in the assessment is illustrated in Table YFT-1, and a summary of reference points over the 72 models in the structural uncertainty grid is provided in Table YFT-2.

Table YFT-1. Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment, where * denotes the level assumed in the diagnostic model. Equal weighting was given to all axis values.

Axis	Value 1	Value 2	Value 3	Value 4
Growth	Conditional Age-at-length*	Modal (Size Composition)	Otolith	
Steepness	0.65	0.8 *	0.95	
Size Scalar	20	60 *	200	500
Mixing Period	1 Quarter	2 Quarters *		

Table YFT-2. Summary of reference points over the 72 models in the structural uncertainty grid. Note that "recent" is the average over the period 2015-2018 for SB and 2014-2017 for fishing mortality, while "latest" is 2018. The values of the upper 90th and lower 10th percentiles of the empirical distributions are also shown. F_{mult} is the multiplier of recent (2014-2017) fishing mortality required to attain MSY.

	Mean	Median	Minimum	10th percentile	90th percentile	Maximum
C_{latest}	709,389	711,072	700,358	702,279	712,761	714,073
$Y_{Frecent}$	779,872	784,200	661,600	707,720	877,040	9080,00
f_{mult}	2.87	2.80	1.70	2.12	3.72	4.29
F_{MSY}	0.11	0.10	0.08	0.09	0.12	0.15
MSY	1,090,706	1,091,200	791,600	874,200	1,283,920	1,344,400
F_{recent}/F_{MSY}	0.37	0.36	0.23	0.27	0.47	0.59
$SB_{F=0}$	3,641,228	3,603,980	2,893,274	3,231,353	4,050,429	4,394,277
SB_{MSY}	860,326	858,700	349,100	590,090	1,114,400	1,322,000
$SB_{MSY}/SB_{F=0}$	0.23	0.24	0.12	0.18	0.28	0.30
$SB_{latest}/SB_{F=0}$	0.54	0.54	0.40	0.47	0.60	0.66
SB_{latest}/SB_{MSY}	2.43	2.28	1.47	1.67	3.29	4.89
$SB_{recent}/SB_{F=0}$	0.58	0.58	0.42	0.51	0.64	0.68
SB_{recent}/SB_{MSY}	2.59	2.43	1.58	1.77	3.57	5.27

12. SC16 noted that:

- there has been a long-term decrease in spawning biomass from the 1970s;
- the median value of spawning biomass depletion ($SB_{2015-2018}/SB_{F=0}$) was 0.58 with a 10th to 90th percentile interval of 0.51 to 0.64;
- there was 0% probability that the recent $SB_{2015-2018}$ had breached the adopted LRP;
- there has been a long-term increase in fishing mortality for both juvenile and adult yellowfin tuna;
- the median of relative recent fishing mortality ($F_{2014-2017}/F_{MSY}$) was 0.36 with a 10th to 90th percentile interval of 0.27 to 0.47;
- there was 0% probability that the recent (2014-2017) fishing mortality was above F_{MSY}; and
- stochastic projections with fishing at "status quo" conditions (2016–2018 average longline and other fishery catch and 2018 purse seine effort levels) and long-term recruitment scenario show that median $SB_{2025}/SB_{F=0}$ = 0.58; median $SB_{2035}/SB_{F=0}$ = 0.59; median $SB_{2045}/SB_{F=0}$ = 0.58, and the risk that $SB_{2048}/SB_{F=0}$ is less than the LRP is 0%.

b. Management advice and implications

13. SC16 noted that the preliminary estimate of total catch of WCPO yellowfin tuna for 2019 was 669,362 t, a 5% decrease from 2018 and a 1% increase from the average 2014-2018. Based on the uncertainty grid adopted by SC16, the WCPO yellowfin tuna spawning biomass is above the biomass LRP and recent F is below F_{MSY}. The stock is not experiencing overfishing (100% probability $F<F_{MSY}$) and is not in an overfished condition (0% probability $SB/SB_{F=0}<LRP$).

14. SC16 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. There is also evidence that the overall stock status is buffered with biomass kept at a more elevated level overall by low exploitation in the temperate regions (1, 2, 5, 6, and 9). SC16 therefore re-iterates that WCPFC17 could consider measures to reduce fishing mortality from fisheries that take juveniles, with the goal to increase fishery yields and reduce any further impacts on the spawning potential for this stock in the tropical regions.

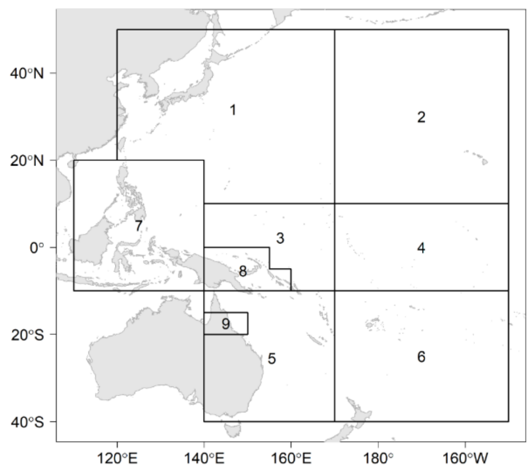

Figure YFT-1. The geographical area covered by the stock assessment and the boundaries for the 9 regions when using the "10N regional structure".

15. SC16 noted that the 2020 stock assessment results indicate the stock is currently exploited at relatively low levels (median $F/F_{MSY} = 0.36$, 10^{th} to 90^{th} percentile interval 0.27-0.47). Nevertheless, SC16 recommends that the Commission notes that further increases in YFT fishing mortality would likely affect other stocks/species which are currently moderately exploited due to the multispecies/gears interactions in WCPFC fisheries taking YFT.

16. Based on the results, SC16 recommends as a precautionary approach that the fishing mortality on yellowfin tuna stock should not be increased from the level that maintains spawning biomass at 2012-2015 levels until the Commission can agree on an appropriate target reference point.

B3. Stock Status and Management Advice for Skipjack Tuna

17. Refer to **Attachment C** for the detailed description on the latest stock status and management advice for skipjack tuna from SC15.

a. Stock status and trends

18. SC15 noted that the total provisional catch in 2018 was 1,795,048 mt, a 10% increase from 2017 and a 1% decrease from 2013-2017.

19. SC15 agreed to use the 8-region model to describe the stock status of skipjack tuna, and stock status was determined over an uncertainty grid of 54 models with assumed weightings as illustrated in Table SKJ-01. The median values of recent (2015–2018) spawning biomass depletion ($SB_{recent}/SB_{F=0}$) and relative recent (2014–2017) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 54 models were used to define stock status (Table SKJ-02).

Table SKJ-01. Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment.

Axis	Value	Relative weight
Steepness	0.65	0.8
	0.80	1.0
	0.95	0.8
Growth	Low	1.0
	Diagnostic	1.0
	High	1.0
Length composition scalar	50	0.8
	100	1.0
	200	1.0
Tag mix	1	1.0
	2	1.0

Table BET-2. Summary of reference points over the 24 models in the structural uncertainty grid. Note that "recent" is the average over the period 2015-2018 for SB and 2014-2017 for fishing mortality, while "latest" is 2018. The values of the upper 90th and lower 10th percentiles of the empirical distributions are also shown. F_{mult} is the multiplier of recent (2014-2017) fishing mortality required to attain MSY.

	Mean	Median	Minimum	10th percentile	90th percentile	Maximum
C_{latest}	159,738	159,288	157,297	157,722	162,033	162,271
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f_{mult}	1.45	1.38	0.83	0.98	2.03	2.33
F_{MSY}	0.05	0.05	0.04	0.04	0.07	0.07
MSY	146,715	140,720	117,920	125,628	179,164	187,520
F_{recent}/F_{MSY}	0.74	0.72	0.43	0.49	1.02	1.21
$SB_{F=0}$	1,395,173	1,353,367	903,708	982,103	1,780,138	1,908,636
SB_{MSY}	320,162	321,550	192,500	219,810	443,730	482,700
$SB_{MSY}/SB_{F=0}$	0.23	0.23	0.19	0.2	0.26	0.26
$SB_{latest}/SB_{F=0}$	0.38	0.38	0.23	0.3	0.47	0.51
SB_{latest}/SB_{MSY}	1.7	1.67	0.95	1.23	2.15	2.6
$SB_{recent}/SB_{F=0}$	0.4	0.41	0.21	0.27	0.52	0.55
SB_{recent}/SB_{MSY}	1.78	1.83	0.87	1.18	2.32	2.84

20. SC15 noted that:

- the median level of spawning potential depletion from the uncertainty grid was $SB_{recent}/SB_{F=0}$ = 0.44 with a probable range of 0.37 to 0.53 (80% probability interval), and the probability that recent spawning biomass was below the LRP was zero;
- the grid median F_{recent}/F_{MSY} was 0.45, with a range of 0.34 to 0.60 (80% probability interval) and there was a zero probability that the recent fishing mortality exceeds F_{MSY};
- the largest uncertainty in the structural uncertainty grid was due to the assumed tag mixing period; and
- the spatial extent of the Japanese pole-and-line fishery has decreased over the time period and that the future use of this standardized CPUE index is uncertain, and further study of alternative indices of abundance is warranted.

b. Management advice and implications

21. SC15 noted that the skipjack assessment continues to show that the stock is currently moderately exploited and the level of fishing mortality is sustainable.

22. SC15 noted that the stock was assessed to be above the adopted LRP and fished at rates below F_{MSY} with 100% probability. Therefore, the skipjack stock is not overfished, nor subject to overfishing. At the same time, it was also noted that fishing mortality is continuously increasing for both adult and juvenile while the spawning biomass reached the historical lowest level.

23. The trajectory of the median spawning biomass depletion (Figure SKJ-08) indicates a long-term trend, and has been under the interim TRP since 2009 (i.e., for 10 years). Since the median spawning biomass has been consistently below the interim TRP, SC15 recommends that the Commission take appropriate management action to ensure that the biomass depletion level fluctuates around the TRP (e.g., through the adoption of a harvest control rule).

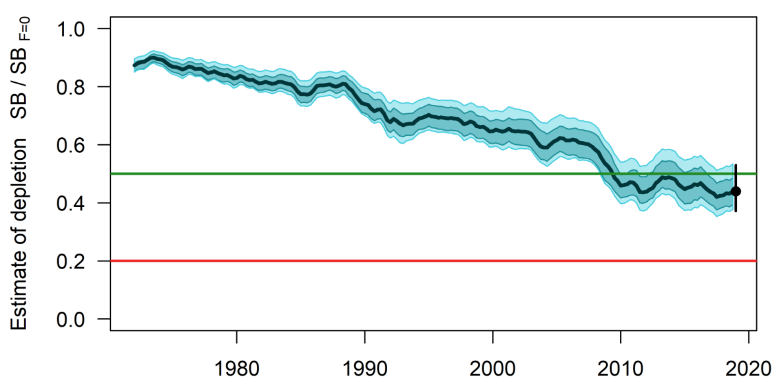


Figure SKJ-08. Plot showing the trajectories of spawning potential depletion for the model runs included in the structural uncertainty grid weighted by the values given in Table SKJ-01. Red horizontal line indicates the agreed limit reference point, the green horizontal line indicates the interim target reference point.

c. Research recommendations

24. In order to maintain the quality of stock assessments for this important stock SC15 recommends:

i) continuing work to develop an index of abundance based on purse seine data and from FAD acoustic sensors;
ii) evaluating the possibility of conducting fishery independent surveys to provide relative abundance indices;
iii) conducting regular large-scale tagging cruises and expanding the infrastructure for rapid return of recaptured tags in a manner that provides the best possible data for stock assessment purposes;
iv) investigating skipjack growth by validation studies of otolith readings and/or estimation of growth within MFCL from tag recapture data; and
v) attempting to provide finalized catch estimates to SPC no later than June 1st.

B4. Development of Harvest Strategies under CMM 2014-06

25. Refer to Paragraphs 200 – 255 of the SC16 Summary Report for the detailed discussions on the progress of developing the WCPFC harvest strategy framework.

a. Target reference points for bigeye and yellowfin tuna

26. Noting the request from WCPFC16 for the Scientific Committee to provide advice on the formulation of TRPs for bigeye and yellowfin tuna, and for the Scientific Service Provider to conduct an analysis for bigeye and yellowfin tuna similar to that undertaken in working paper WCPFC16-2019-14 (*Current and projected stock status of WCPO skipjack tuna to inform consideration of an updated target reference point*), as outlined in para. 273-275 of the WCPFC16 Summary Report, SC16 reviewed SC16-MI-WP-01 (*Further consideration of candidate target reference points for bigeye and yellowfin tuna in the WCPO*) and requested the Scientific Services Provider undertake the analyses for bigeye and yellowfin tuna according to the criteria outlined in the table below:

Issue	Requested Scenario
Model settings and the uncertainty grid	The SC16 agreed structural uncertainty grid.
Additional scenarios	To use both short- and long-term recruitment for bigeye tuna.
The range of candidate TRPs to be explored:	There are some advantages to defining candidate target stock depletion relative to the average biomass within a recent time period. This is consistent with the approach taken for development of the South Pacific Albacore interim TRP and serves to "future proof" the candidate TRP from changes in the biomass time series that have been noted with updated assessments. Specifying a time period also allows reference to some fisheries performance metrics within that period, such as CPUE. The following candidate TRPs are specified: • Average $SB/SB_{F=0}$ for 2012-2015 (consistent with the Aims of CMM 2018-01) • 10% above Average $SB/SB_{F=0}$ for 2012-2015 • 10% below Average $SB/SB_{F=0}$ for 2012-2015 • TRPs at intermediate steps between the candidates outlined above (e.g. at 5% intervals) were also recommended. • An alternative TRP based on the average SB for 2000-2004 should also be explored.

	• Additional candidate TRPs can be identified in terms of the risk of breaching the LRPs; in particular: the $SB/SB_{F=0}$ levels associated with 10% and 20% risks of breaching the LRP based on an updated analysis using the SC16 adopted structural uncertainty grid.
Time period of the projections	30 years, consistent with the earlier skipjack analyses. Intervals of 10 years will be presented within this period. The rationale is to have a period to allow the population to reach equilibrium.
Use of catch or effort	• purse seine– effort • longline – catch • Other fisheries – catch SC16 noted that this is for the purposes of these analyses and without prejudice to preferred management arrangements.
The baseline catch and effort levels	A recent period is preferable because it is more relevant to recent activity levels and also a more realistic reflection of IDN/PHL fisheries catches.
Limits to the range of the fishery scalars	SC16 noted that if scalars are too constrained then it might not be possible to achieve the different biomass TRP levels and some guidance on this issue was sought from the SSP. Scalars would be applied equally to purse seine effort and longline catch. For other fleets, recent catch levels would be assumed. SC16 also noted that this is an exploratory exercise to see what the consequences could be for different TRP choices and not a management recommendation that sets up any kind of precedent.
Reporting the output of the analysis:	Similar outputs to the skipjack work reported in WCPFC16-2019-14. In addition, SC16 recommended reporting against the Aims of CMM 2018-01 paras 12 and 14 being "average $SB/SB_{F=0}$ for 2012-2015". SC16 also noted the request from one CCM that the Scientific Service Provider produce information on the projected yield per recruit and spawning biomass per recruit under the various harvest scenarios.

27. Noting the large number of scenarios included in the above request, possible analytical challenges that may arise, and the heavy workload of the Scientific Service Provider due to other requests, the following priority was placed on the TRPs to be evaluated.

a) The initial average and +/- 10% proposal (3 scenarios)
b) The additional runs for 10% and 20% risk and the average SB for 2000-2004 (3 scenarios)
c) Intermediate values based upon the results of the above work (e.g., 2-5 scenarios)

28. SC16 recommends that the above analyses be completed by the Scientific Service Provider and a paper summarizing both the analyses undertaken and the tentative results be forwarded to the TCC16 and final results to WCPFC17.

b. Target reference point for skipjack tuna

29. Noting the request from WCPFC16 to revise the working paper WCPFC16-2019-14 using candidate interim skipjack TRPs of 42%,44%, 46%, 48% and 50% of $SB/SB_{F=0}$ (para. 259 of the WCPFC16 Summary Report), SC16 reviewed SC16-MI-WP-02 (*Updates to WCPO skipjack tuna projected stock status to inform consideration of an updated target reference point*) and noted the following:

i) In response to a query from one CCM as to whether based on the presented results that the TRP could be changed from the current interim 50% $SB/SB_{F=0}$ TRP to a lower level, the Scientific Services Provider noted that 50% $SB/SB_{F=0}$ was the equilibrium depletion level achieved when projecting under 2012 effort levels from the 2016 skipjack assessment, and was equivalent to the 2012 stock status identified in that assessment. Using the 2019 stock assessment, and performing the same analysis, a TRP of 42% $SB/SB_{F=0}$ would be consistent with this logic (i.e. would be achieved in the equilibrium under 2012 effort levels and was equivalent to 2012 stock status). In response to a related question as to why 2012 was chosen as the reference year given that catches were made available in recent years in ID, PH and VN, the Scientific Services Provider informed SC16 that as part of this analysis the increased catch levels in these countries in recent years had been included.

ii) One CCM noted that in CMM 2018-01 the interim management objective adopted was using the 2012-2015 average as the base line years and requested that an additional table be included in the working paper based on an analysis using these reference years. Another CCM also requested that an indication of the recent effort levels relative to the 2012 effort also be included.

iii) In response to a request from one CCM to make the projections based on recent fisheries mortality rather than the 2012 effort (i.e. number of purse seine sets), the Scientific Services Provider noted that this may be difficult but would investigate the possibility of doing so.

30. Noting the additional requests from WCPFC16 for advice on the formulation of TRPs for skipjack tuna and effort creep estimated in relation to the TRPs (para. 258 of the WCPFC16 Summary Report), SC16 noted that advice pertaining to these requests are also contained in SC16-MI-WP-02.

31. SC16 recommends that SC16-MI-WP-02 be revised to include the additional analyses requested in (ii) and (iii) above, and that this revised paper be forwarded to WCPFC17.

32. SC16 recommends that the Commission take into consideration the information contained in this revised paper when discussing a TRP for skipjack tuna.

c. Performance indicators, monitoring strategy harvest control rules and management strategy evaluation

33. Noting the request by WCPFC16 to review the progress on the technical development of WCPFC harvest strategies for the key WCPO tuna stocks, SC16 reviewed SC16-MI-WP-03 (*Overview of recent developments and key decisions for harvest strategies for WCPFC stocks and fisheries*) and received a very brief summary of ten (10) related Information Papers (SC16-MI-IP-01 to SC16-MI-IP-10) and provides the following advice to the Commission:

a) SC16 noted the difficulties in structuring the discussions for this large amount of work due to the virtual nature of the meetings format.

b) SC16 also noted the constraints that COVID-19 has had on ongoing capacity building with the result that not all CCMs were as well placed as they would have liked to have been to provide feedback on all aspects of this work.

c) Despite these limitations, SC16 welcomed the work presented by the Science Service Provider on skipjack management procedures and the south pacific albacore MSE framework.

d) SC16 noted that the Operating Model for skipjack tuna had been updated to take account of the updated assessment presented in 2019 and that there were no substantial changes between the model outputs compared to those from the previous model.

e) In response to a question about how and when the elements of the Operating Models for skipjack and SP-albacore would be agreed and adopted to allow testing of Management Procedures (MPs) under a final set of diagnostics, SC16 noted that with further input from CCMs over the coming year (see recommendations below) that adoption of the Operating Models could be undertaken at SC17 with the review of a final suite of MPs to be undertaken by SC18. This would align with the schedule for the adoption of a MP for both skipjack and South Pacific albacore as outlined in the current Harvest Strategy Workplan.

f) SC16 noted that the current Operating Model for skipjack conditioning includes an additional growth element that was not included in the previous model, and there may be a need to expand the grid of uncertainties in relation to the occurrence of exceptional circumstances.

g) One CCM noted the need for Performance Indicators (PI) for the impact on small-scale fisheries, but SC16 was informed that currently it would be difficult to include these fisheries within the Operating Model and unless further information/data pertaining to these fisheries is provided the development of a PI (or a proxy) would also be difficult.

h) Several CCMs also noted the need for a PI to meet requirements of para 12 in CMM 2014-06 (Harvest Strategy CMM), specifically to avoid overfishing and not to transfer a disproportionate burden to developing state parties and territories. They also noted that while such a PI may not be informative in the skipjack MSE it was seen as critical in the multispecies framework. The Scientific Services Provider advised SC16 that input from members on alternative PI options to be included within the framework was welcome.

i) SC16 noted the inclusion of a length-based indicator in the suite of empirical Harvest Control Rules (HCRs) tested for South Pacific albacore and that this had been undertaken to explore different ways of constructing a HCR using empirical data approaches that are not based on CPUE. The limitations of such length-based indicators were noted. SC16 also noted that unless effort creep can be accounted for, the utility of empirical HCRs that are CPUE-based can also be compromised. SC16 noted that model-based approaches might also be appropriate.

j) In relation to the multispecies approach being developed, SC16 noted that it may not be possible to achieve all the TRPs at the same time, and mixed fisheries harvest strategies may lead to one or two stocks being fished above or below the TRP. The Scientific Services Provider advised SC16 that options to support discussion on such issues will be developed within the mixed fishery framework.

34. Noting the key findings and challenges summarised above, SC16 provides the following advice and recommendations to the Scientific Services Provider (SSP) and the Commission:

a) SC16 recommends that WCPFC17 note the progress on the development of the Harvest Strategy Workplan as outlined in SC16-MI-WP-03 (and related Information Papers) and provide additional elements, if any, as specified in the Harvest Strategy Workplan to further progress this work against the scheduled timelines noted in this Workplan.

b) Noting that the virtual SC16 meeting had not provided enough time to consider the ten information papers (SC16-MI-IP-01 to SC16-MI-IP-10) related to the progress of developing the WCPFC harvest strategy framework, and the ongoing needs of the SSP to get further feedback from CCMs on this work, SC16 agreed to continue discussions on these ten papers through the WCPFC Online Discussion Forum (ODF). The purpose of the ODF would be to:
    i) facilitate feedback on technical aspects related to the issues covered by the ten information papers presented to SC16;
    ii) enable CCMs to make suggestions to the SSP on alternative HCRs to consider;
    iii) get benefit from participant's feedback on the progress on the SSP's work;
    iv) assist with the mutual understanding of this work; and
    v) assist with capacity building of the participants.

The ODF should remain open for as long as required.

c) SC16 noted that this ODF activity is outside of the Scientific Committee and any discussions on this ODF will not constitute formal recommendations to the Commission or the SSP.

d) SC16 also noted that given the large range of technical issues included in the ongoing development of the WCPFC harvest strategy framework, and limitations for the SC to undertake a thorough review of these issues, that progress on many of the technical aspects related to this framework would be enhanced through an intersessional workshop, which could be held in conjunction with the annual Pre-Assessment Workshop (PAW) hosted by the SSP. Like the PAW, the aim is for this workshop to be a technical meeting of scientists who have a common interest in providing feedback to the SSP on technical issues related to the development of the harvest strategy framework. The outcomes of the meeting would be documented, and the report of the meeting and other analyses would be submitted to the WCPFC Scientific Committee either as a stand-alone paper or within other relevant papers. SC16 requests the Commission to consider the utility of holding such a workshop.

e) Finally, noting that the development of the WCPFC harvest strategy framework is reaching a mature stage, and the increasing number of issues that require the attention of, and feedback from, managers in order to progress the Harvest Strategy Workplan, SC16 again reiterates its previous recommendations for a Science-Management Dialogue to be convened. In addition, SC16 calls attention to the importance of such a dialogue to ensure the input of managers and stakeholders to the MSE process and to ensure timely execution of the Commission's harvest strategies workplan.

B5. Implementation of CMM 2018-01

35. SC16 requested the Scientific Services Provider to provide additional information as described below to the Commission for discussions on the implementation of CMM 2018-01 (Paragraph 256 of the SC16 Summary Report):

> To provide additional information to the Commission on options for CMM2018-01, SC16 recommends that the Scientific Services Provider provide to the Commission as early as reasonable, the following:
>
> (i) Any updates to SC15-MI-WP-01, "minimum target reference points for WCPO yellowfin and bigeye tuna consistent with alternative LRP risk levels, and multispecies implications," and the following additions to the deterministic projections in Figure 3a and 3b for bigeye tuna (and to Figures 2a and 2b for yellowfin tuna if possible) (as in the original paper, the purse seine scalar should scale overall purse seine fishing effort, including both associated and unassociated fishing effort):
>
> a) Inclusion on the x axis (purse seine scalar) and y axis (longline scalar) of the absolute quantities that correspond to the scalars (for purse seine scalar, numbers of both associated sets and unassociated sets, and for longline scalar, longline catch in mt).
>
> b) Inclusion on the x axis and y axis of the expected fishery impact of the sector on SSB (SB2045/SBF=0) that correspond to the scalars, assuming the other sectors' (e.g., pole-and-line and other) impacts are as they were in 2013-2015, on average.
>
> c) Extension of the ranges of the x and y axes to scalars as high as 2.0 (from 1.5).
>
> d) Indications of the expected purse seine scalars for the purse seine management regime under CMM 2018-01.
>
> (ii) One or more tables showing as long a time series as possible, of fishery impact on WCPO bigeye tuna SSB, by fishery sector (for just the diagnostic case, and including at a minimum: longline, purse seine associated, purse seine unassociated, pole-and-line, and other).

C. TECHNICAL AND COMPLIANCE COMMITTEE RECOMMENDATIONS

36. TCC16 noted for WCPFC17 that there were recommendations in the Provisional CMR relating to the revision of existing Conservation and Management Measures. TCC16 recommends that WCPFC17 consider approaches to address challenges identified for the following obligations, noting that more information related to these recommendations is contained in the Provisional CMR:

b. CMM 2018-01 51: for relevant CCMs where there are difficulties in terms of the scope of other commercial fisheries. (*Paragraph 89 of the TCC16 Summary Report*)

Attachment A

The Commission for the Conservation and Management of
Highly Migratory Fish Stocks in the Western and Central Pacific Ocean
Scientific Committee
Sixteenth Regular Session
Electronic Meeting
12 – 19 August 2020

WCPO BIGEYE TUNA STOCK ASSESSMENT
(Refer to Paragraphs 53 – 98 of the SC16 Summary Report for the detailed discussions)

Provision of scientific information

a. Stock status and trends

1. The median values of relative recent (2015-2018) spawning biomass depletion (SB_{recent}/ $SB_{F=0}$) and relative recent (2014-2017) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 24 models (Table BET-1) were used to define 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.

2. A description of the updated structural sensitivity grid used to characterize uncertainty in the assessment is illustrated in Table BET-1. The spatial structure used in the 2020 stock assessment is shown in Figure BET-1. Time series of total annual catch by fishing gear over the full assessment period is shown in Figure BET-2. The time series of total annual catch by fishing gear and assessment region is shown in Figure BET-3. Estimated annual average recruitment, spawning potential and total biomass by model region is shown in Figure BET-4. Estimated trends in spawning potential by region for the diagnostic case is shown in Figure BET-5, and juvenile and adult fishing mortality rates from the diagnostic model is shown in Figure BET-6. Estimates of the reduction in spawning potential due to fishing by region is shown in Figure BET-7. Time-dynamic percentiles of depletion ($SB_t/SB_{t,F=0}$) for the 24 models are shown in Figure BET-8. A Majuro and Kobe plot summarising the results for each of the 24 models in the structural uncertainty grid are shown in Figures BET 9 and 10, respectively. Projections are illustrated in Figures BET-11 and BET-12. Table BET-2 provides a summary of reference points over the 24 models in the structural uncertainty grid.

3. A number of investigative models were run with growth, such as: 1) *Oto-Only*, a growth curve that was a fixed Richards growth curve based on high-readability otoliths, 2) *Tag-Int*: a growth curve that was a fixed Richards growth curve based on the same high-readability otolith data-set in addition to bigeye tuna tag-recapture data, and 3) *Est-Richards*: A conditional age-length data-set was constructed from the combined daily and annual otolith dataset. The *Oto-Only* growth model predicted very high levels of biomass and corresponding low level of depletion. The *Est Richards* growth model showed sensitivity to the initial values given for the estimated growth parameters. The implausible results from the *Oto-Only* growth and differing results from the *Est-Richards* indicate questions still remain regarding bigeye tuna growth.

4. SC16 requested the bigeye tuna assessment to try and fit the data for those small bigeye tuna as they are increasingly caught by domestic fisheries in region 7, but the current diagnostic model does not fit those fish that well because the L1 parameter is larger than most of those fish. SPC could consider additional developments to Multifan-CL to model greater variability in size around the growth curve at small ages.

5. The most influential grid axis is the size-frequency data-weighting axis and further research is required to develop model diagnostics and objective criteria for model inclusion.

Table BET-1. Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment. The starred levels denote those assumed in the model diagnostic case.

Axis	Value 1	Value 2	Value 3	Value 4
Steepness	0.65	0.8 *	0.95	
Natural mortality	Diagnostic* (0.112)	M-hi (0.146)		
Size frequency weighting	20*	60	200	500

Table BET-2. Summary of reference points over the 24 models in the structural uncertainty grid. Note that "recent" is the average over the period 2015-2018 for SB and 2014-2017 for fishing mortality, while "latest" is 2018. The values of the upper 90th and lower 10th percentiles of the empirical distributions are also shown. F_{mult} is the multiplier of recent (2014-2017) fishing mortality required to attain MSY.

	Mean	Median	Minimum	10th percentile	90th percentile	Maximum
C_{latest}	159,738	159,288	157,297	157,722	162,033	162,271
$Y_{Frecent}$	136,568	134,940	117,800	124,668	149,424	161,520
f_{mult}	1.45	1.38	0.83	0.98	2.03	2.33
F_{MSY}	0.05	0.05	0.04	0.04	0.07	0.07
MSY	146,715	140,720	117,920	125,628	179,164	187,520
F_{recent}/F_{MSY}	0.74	0.72	0.43	0.49	1.02	1.21
$SB_{F=0}$	1,395,173	1,353,367	903,708	982,103	1,780,138	1,908,636
SB_{MSY}	320,162	321,550	192,500	219,810	443,730	482,700
$SB_{MSY}/SB_{F=0}$	0.23	0.23	0.19	0.2	0.26	0.26
$SB_{latest}/SB_{F=0}$	0.38	0.38	0.23	0.3	0.47	0.51
SB_{latest}/SB_{MSY}	1.7	1.67	0.95	1.23	2.15	2.6
$SB_{recent}/SB_{F=0}$	0.4	0.41	0.21	0.27	0.52	0.55
SB_{recent}/SB_{MSY}	1.78	1.83	0.87	1.18	2.32	2.84

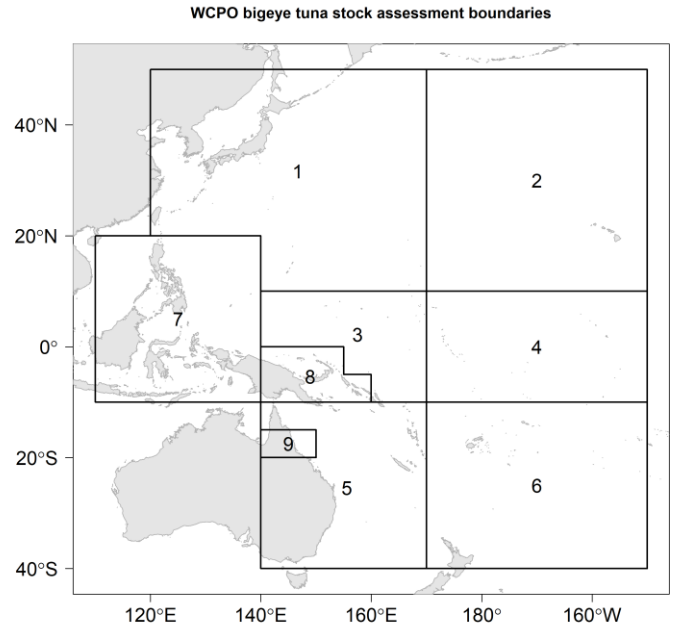


Figure BET-1. Spatial structure for the 2020 bigeye tuna stock assessment.

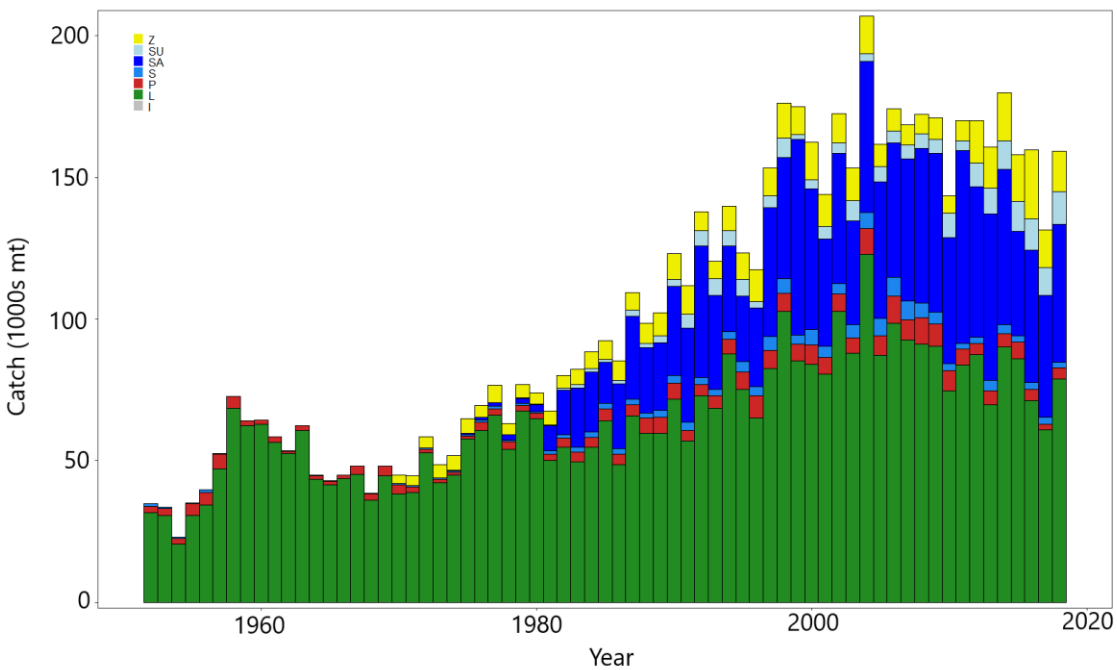


Figure BET-2. Time series of total annual catch (1000s mt) by fishing gear for the diagnostic model over the full assessment period. The different colors refer to longline (green), pole-and-line (red), purse seine (blue), purse seine associated (dark blue), purse seine unassociated (light blue), miscellaneous (yellow), and index (gray). Note that the catch by longline gear has been converted into catch-in-weight from catch-in-numbers and so may differ from the annual catch estimates presented in (Williams et al., 2020), however these catches enter the model as catch-in-numbers.

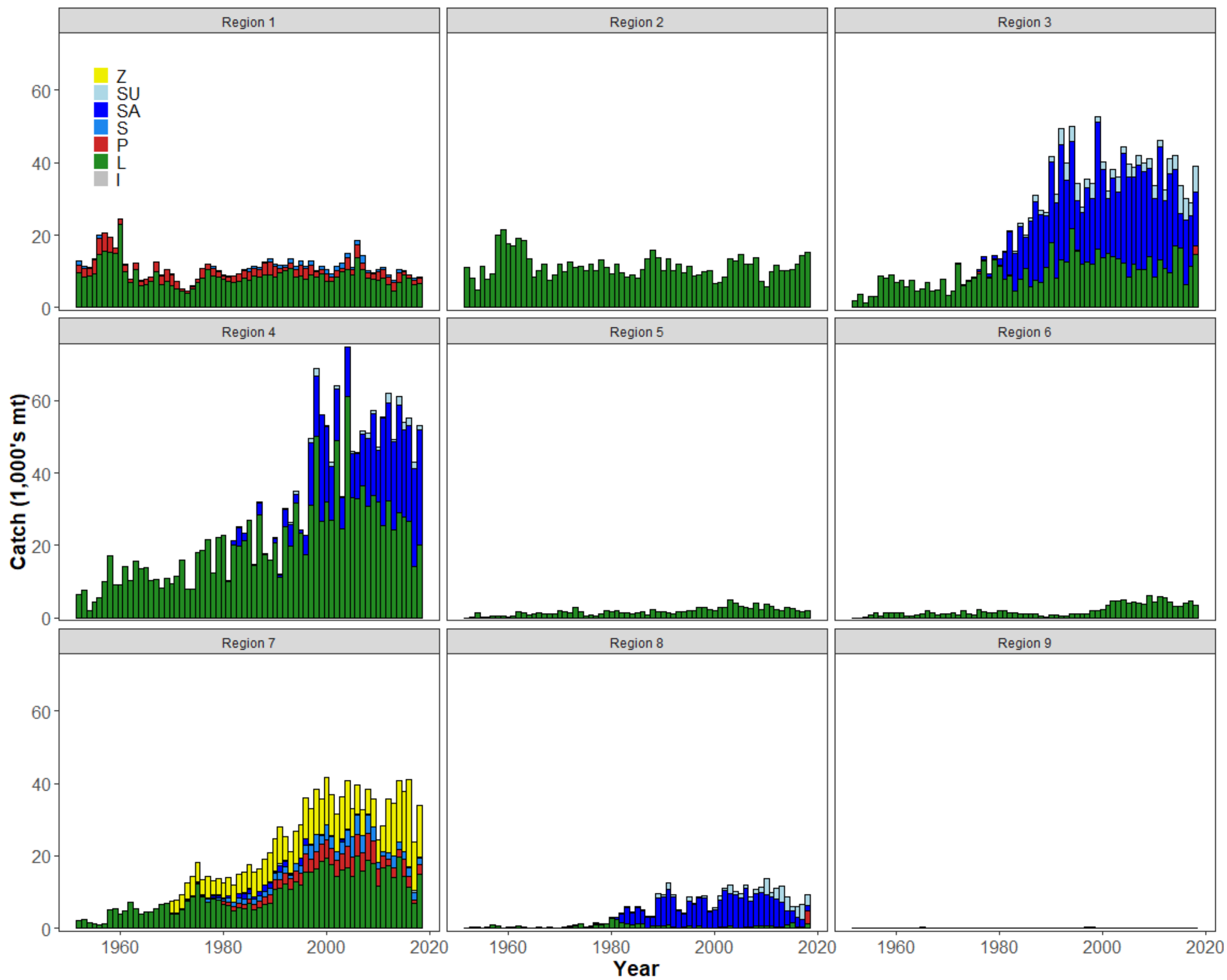


Figure BET-3. Time series of total annual catch (1000s mt) by fishing gear and assessment region for the diagnostic model over the full assessment period. The different colors refer to longline (green), pole-and-line (red), purse seine (blue), purse seine associated (dark blue), purse seine unassociated (light blue), miscellaneous (yellow), and index (gray).

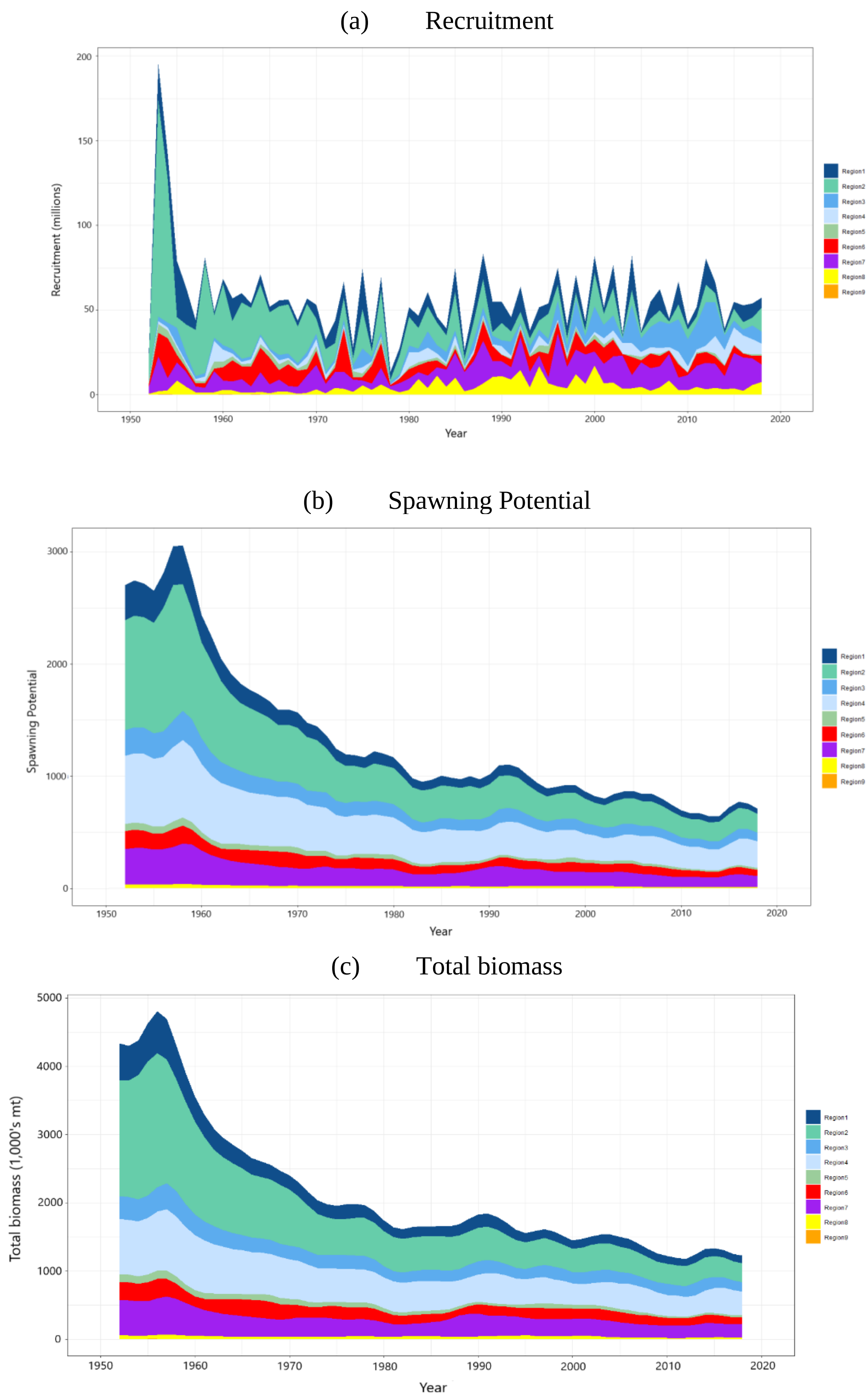


Figure BET-4. Estimated (a) annual average recruitment, (b) spawning potential and (c) total biomass by model region for the diagnostic model, showing the relative sizes among regions.

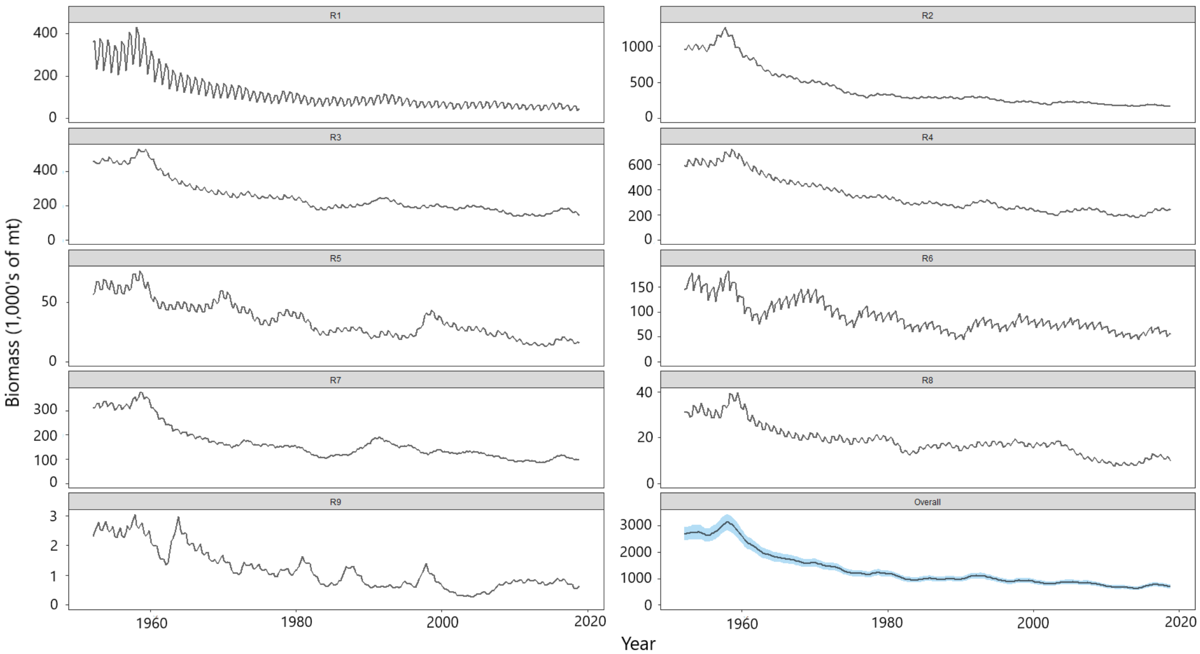


Figure BET-5. Estimated seasonal, temporal spawning potential by model region for the diagnostic model. The asymptotic 95% confidence interval as calculated using the delta-method is shown for the “Overall” region. Note that the scale of the y-axis is not constant across regions.

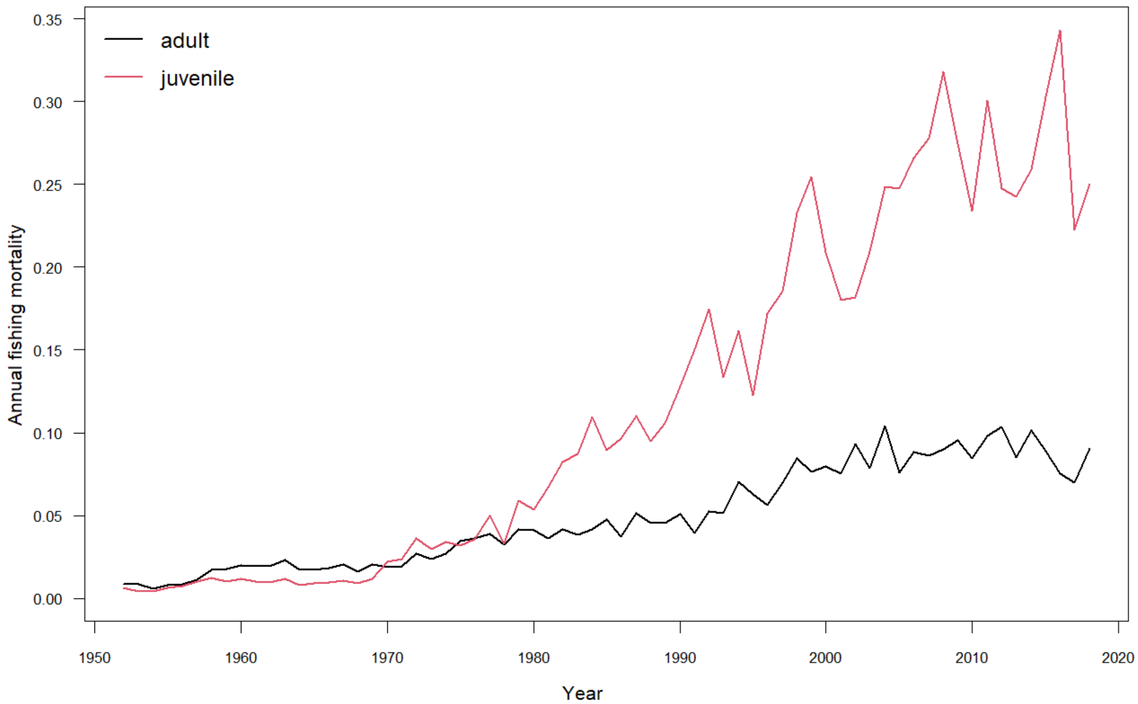


Figure BET-6. Estimated annual average juvenile and adult fishing mortality for the diagnostic model.

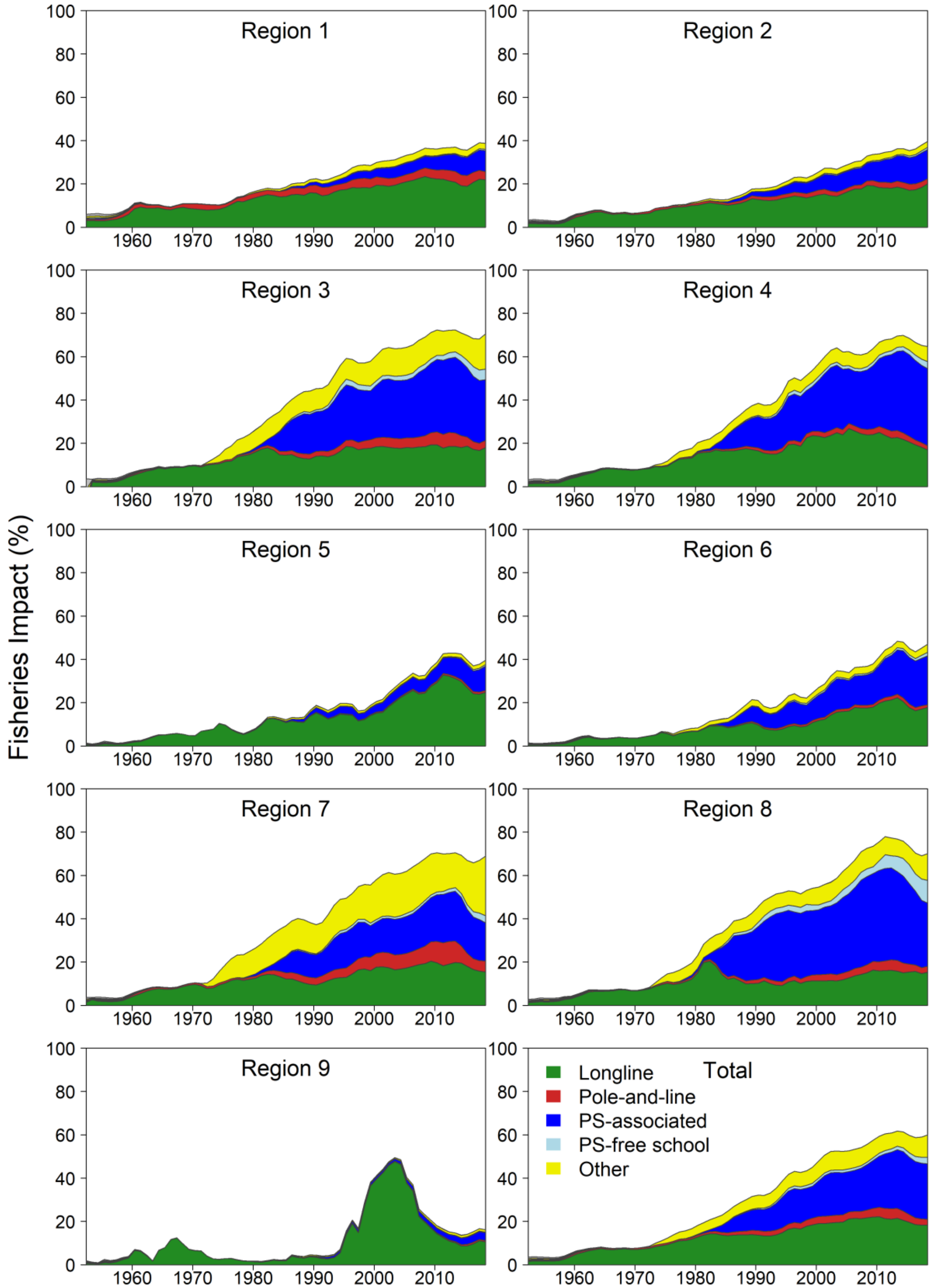


Figure BET-7. Estimates of reduction in spawning potential due to fishing (fishery impact = $(1\text{-}SB_t/SB_{t;F=0})$ * 100%) by region, and over all regions (lower right panel), attributed to various fishery groups for the diagnostic model.

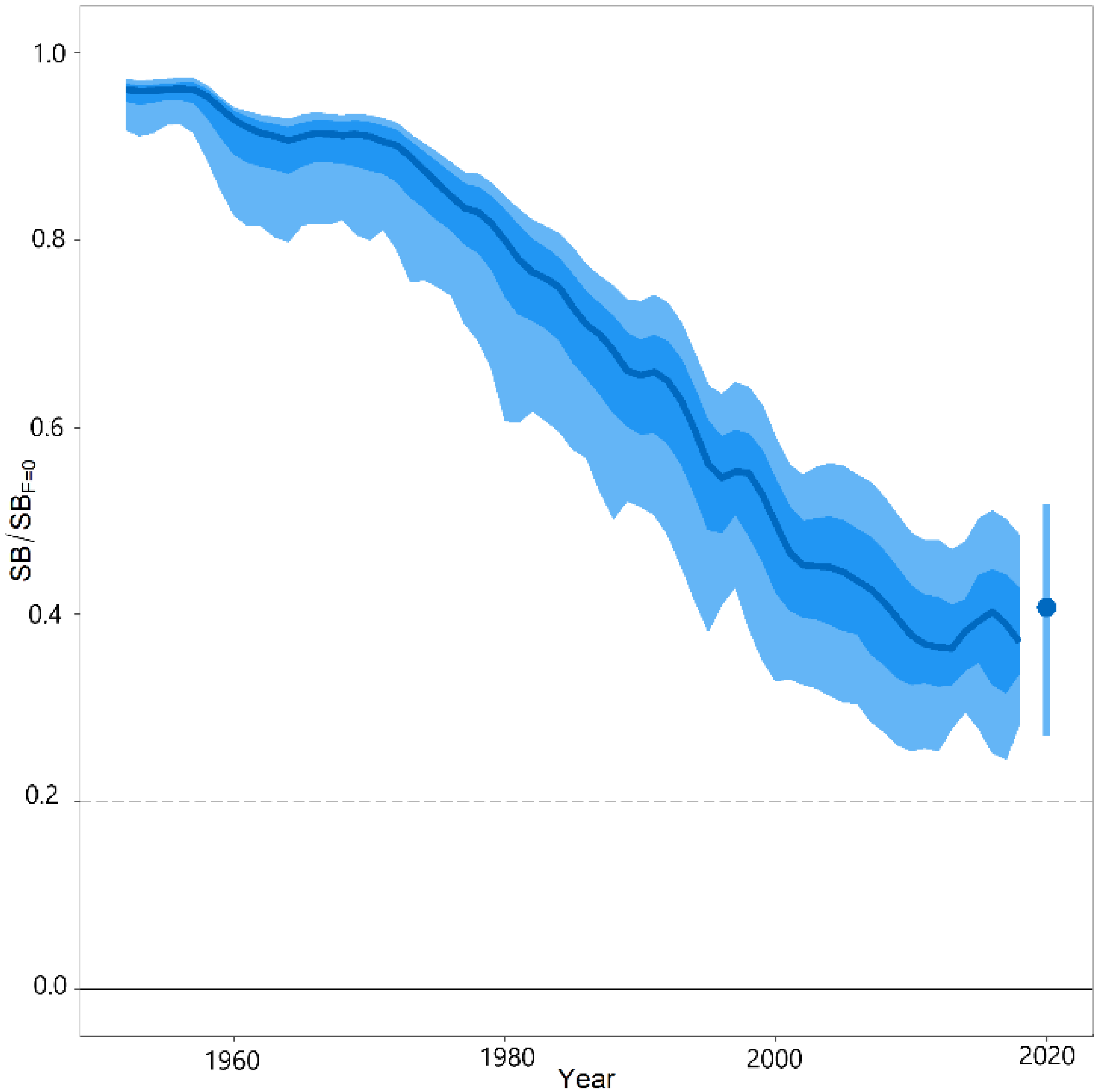


Figure BET-8. Time-dynamic percentiles of depletion ($SB_t/SB_{t;F=0}$) and median (dark line) across all 24 models in the structural uncertainty grid. The lighter band shows the 10th to 90th percentiles around the median, and the dark band shows the 50th percentile around the median. The median $SB_{recent}/SB_{F=0}$ and 80th percentile is shown on the right by the dot and line.

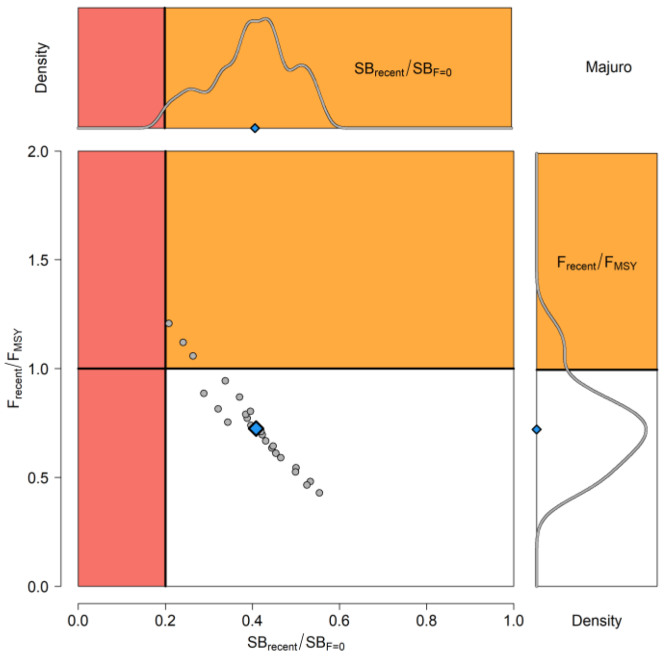


Figure BET-9. Majuro plot for the recent spawning potential (2015–2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality, and marginal distributions of each are presented. The median is shown in blue.

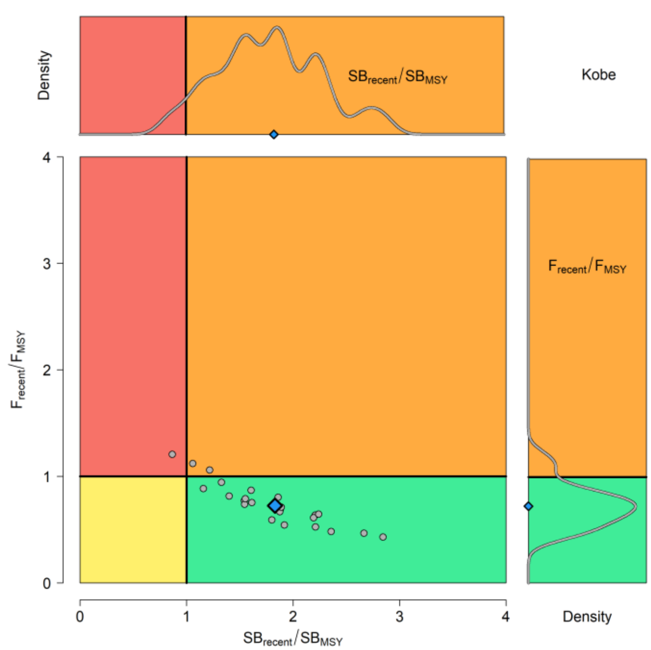


Figure BET-10. Kobe plot for the recent spawning potential (2015–2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality. Marginal distributions of each are presented. The median is shown in blue.

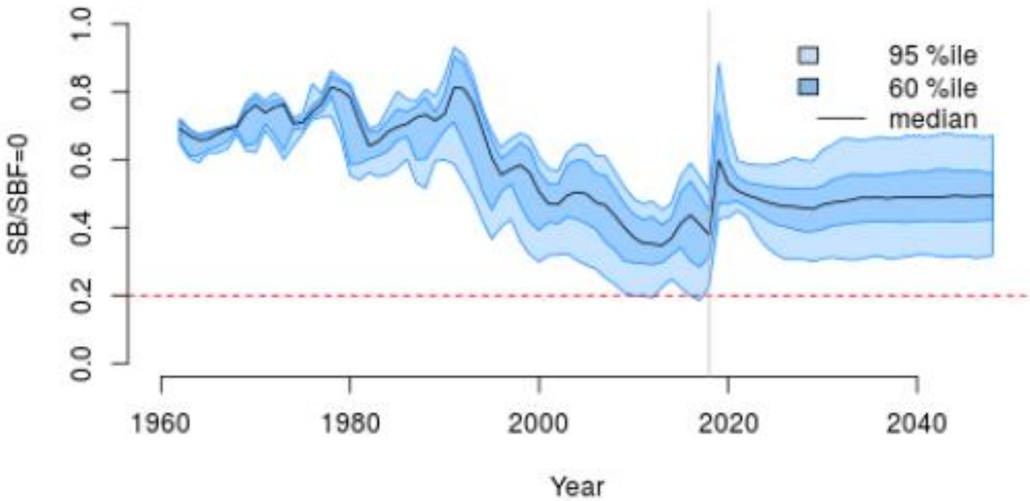


Figure BET-11. Time series of bigeye tuna spawning potential SB_t=$SB_{F=0}$, where $SB_{F=0}$ is the average SB from t-10 to t-1, relative to the current year t, from the uncertainty grid of assessment models for the period 2000 to 2018, and stochastic projection results for the period 2019 to 2048 assuming 2016-2018 average catches in LL and other fisheries and 2018 effort in PS fisheries continue. Vertical gray line at 2018 represents the last year of the assessment. During the projection period (2019-2048) levels of recruitment variability are assumed to match those over the short-term period (2008-2017). The red horizontal dashed line represents the agreed limit reference point.

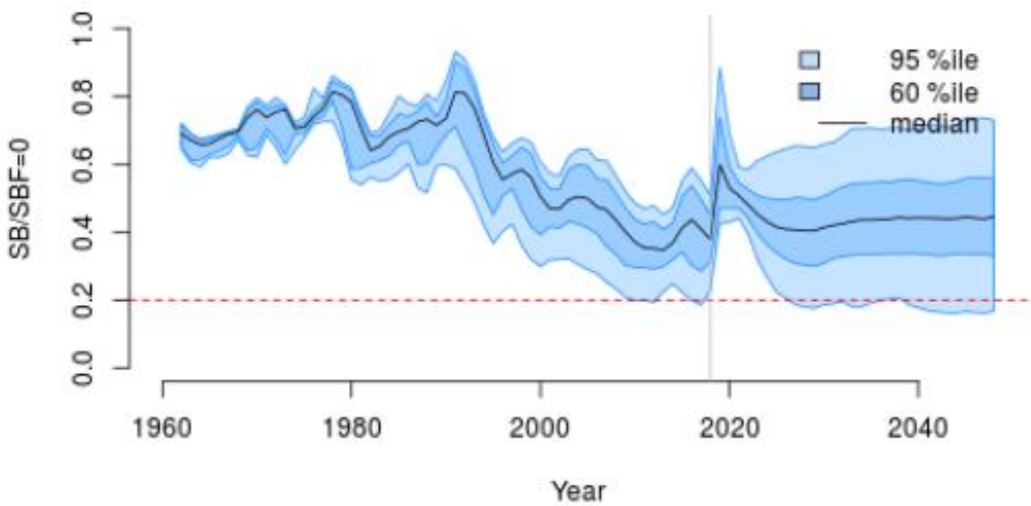


Figure BET-12. Time series of bigeye tuna spawning potential SB_t=$SB_{F=0}$, where $SB_{F=0}$ is the average SB from t-10 to t-1, relative to the current year t, from the uncertainty grid of assessment models for the period 2000 to 2018, and stochastic projection results for the period 2019 to 2048 assuming 2016-2018 average catches in LL and other fisheries and 2018 effort in PS fisheries continue. Vertical gray line at 2018 represents the last year of the assessment. During the projection period (2019-2048) levels of recruitment variability are assumed to match those over the long-term period (1962-2017). The red horizontal dashed line represents the agreed limit reference point.

6. **SC16 noted** that the results from the uncertainty grid adopted by SC16 show that the stock has been continuously declining for about 60 years since the late 1950s, except for the recent small increase from 2015 to 2016 with biomass declining thereafter.

7. SC16 also noted that the median value of relative recent (2015-2018) spawning biomass depletion ($SB_{2015\text{-}2018}/ SB_{F=0}$) was 0.41 with a 10th to 90th percentiles of 0.27 to 0.52.

8. SC16 further noted that there was 0% probability (0 out of 24 models) that the recent (2015-2018) spawning biomass had breached the adopted limit reference point (LRP).

9. SC16 noted that there has been a long-term increase in fishing mortality for both juvenile and adult bigeye tuna and while juvenile fishing mortality is higher than that of the adult fish, both adult and juvenile fishing mortality rates have stabilised somewhat since 2008 and have fluctuated without trend since that time.

10. SC16 noted that the median recent fishing mortality ($F_{2014\text{-}2017t}/F_{MSY}$) was 0.72 with a 10^{th} to 90^{th} percentile interval of 0.49 to 1.02.

11. SC16 noted that there was a roughly 12.5% probability (3 out of 24 models) that the recent (2014-2017) fishing mortality was above F_{MSY}.

12. SC16 noted the results of stochastic projections (Figures BET 11 and BET 12) from the 2020 assessment which indicated the potential stock consequences of fishing at "status quo" conditions (2016–2018 average longline and other fishery catch and 2018 purse seine effort levels) and short-term recruitment scenario using the uncertainty framework approach endorsed by SC. Projections indicate that median $SB_{\mathbf{2025}}/SB_{F=0}$ = 0.47; median $SB_{2035}/SB_{F=0}$ = 0.49 and median $SB_{2045}/SB_{F=0}$ = 0.49. The risk that $SB_{2048}/SB_{F=0}$ is less than the Limit Reference Point is 0%.

13. SC16 noted the results of stochastic projections from the long-term recruitment scenario using the uncertainty framework approach endorsed by SC. Projections indicate that median $SB_{2025}/SB_{F=0}$ = 0.42; median $SB_{2035}/SB_{F=0}$ = 0.44 and median $SB_{2045}/SB_{F=0}$ = 0.45. The risk that $SB_{2048}/SB_{F=0}$ is less than the Limit Reference Point is 5%.

b. Management advice and implications

14. SC16 noted that the preliminary estimate of total catch of WCPO bigeye tuna for 2019 was 135,680 mt, a 9% decrease from 2018 and an 8% decrease from the average 2014-2018. Longline catch in 2019 (68,371 mt) was a 0% decrease from 2018 and a 2% increase from the 2014-2018 average. Purse seine catch in 2019 (50,819 mt) was a 22% decrease from 2018 and a 17% decrease from the 2014-2018 average. Pole and line catch (1,400 mt) was a 66% decrease from 2018 and a 66% decrease from the average 2014-2018 catch. Catch by other gear totalled 15,090 mt and was a 33% increase from 2018 and 1% increase from the average catch in 2014-2018.

15. SC16 noted that the catch in the last year of the assessment (2018) was median 159,288 mt which was greater than the median MSY (140,720 mt).

16. Based on the uncertainty grid adopted by SC16, the WCPO bigeye tuna spawning biomass is above the biomass LRP and recent F is very likely below F_{MSY}. The stock is not overfished (100% probability $SB/SB_{F=0}$>LRP) and likely not experiencing overfishing (87.5% probability $F<F_{MSY}$).

17. SC16 noted that levels of fishing mortality and depletion differ among regions, and that fishery impact was higher in the tropical regions (Regions 3, 4, 7 and 8 in the stock assessment model), with particularly high fishing mortality on juvenile bigeye tuna in these regions. There is also evidence that the overall stock status is buffered with biomass kept at more elevated level overall by low exploitation in the temperate regions (1, 2, 6 and 9). SC16 therefore re-iterates that WCPFC17 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 biomass for this stock in the tropical regions.

18. Based on those results, SC16 recommends as a precautionary approach that the fishing mortality on bigeye tuna stock should not be increased from the level that maintains spawning biomass at 2012-2015 levels until the Commission can agree on an appropriate target reference point.

Attachment B

The Commission for the Conservation and Management of
Highly Migratory Fish Stocks in the Western and Central Pacific Ocean
Scientific Committee
Sixteenth Regular Session
Electronic Meeting
12 - 19 August 2020

WCPO YELLOWFIN TUNA STOCK ASSESSMENT
(Refer to Paragraphs 99 – 138 of the SC16 Summary Report for the detailed discussions)

Provision of scientific information

a. Stock Status and trends

1. The median values of relative recent (2015-2018) spawning biomass depletion (SB_{recent}/ $SB_{F=0}$) and relative recent (2014-2017) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 72 models (Table YFT-1) were used to define 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.

2. A description of the updated structural sensitivity grid used to characterize uncertainty in the assessment is illustrated in Table YFT-1. The spatial structure used in the 2020 stock assessment is shown in Figure YFT-1. Time series of total annual catch by fishing gear over the full assessment period is shown in Figure YFT-2. The time series of total annual catch by fishing gear and assessment region is shown in Figure YFT-3. Estimated annual average recruitment, spawning potential, and total biomass by model region is shown in Figure YFT-4. Estimated trends in spawning biomass depletion for the 72 models in the structural uncertainty grid is shown in Figure YFT-5, and juvenile and adult fishing mortality rates from the diagnostic model is shown in Figure YFT-6. Estimates of the reduction in spawning potential due to fishing by region are shown in Figure YFT-7. Time-dynamic percentiles of depletion ($SB_t/SB_{t,F=0}$) for the 72 models are shown in Figure YFT-8. A Majuro and Kobe plot summarising the results for each of the 72 models in the structural uncertainty grid are shown in Figures YFT-9 and 10, respectively. Projections are illustrated in Figure YFT-11. Table YFT-2 provides a summary of reference points over the 72 models in the structural uncertainty grid.

3. The most influential axis of uncertainty with respect to estimated stock status was growth. The most pessimistic model estimates occurred with models that assumed growth estimated from the modal progression information in the size composition data. The most optimistic stock status estimates were obtained from models that used the growth curve estimated externally from otolith data. Models where growth was estimated by the conditional age-at-length data resulted in estimates that were in between the other two, but were more consistent with the otolith growth curve models. Further research is required to develop alternative growth estimates at the regional spatial scale and develop model diagnostics and objective criteria for model inclusion.

Table YFT-1. Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment, where * denotes the level assumed in the diagnostic model. Equal weighting was given to all axis values.

Axis	Value 1	Value 2	Value 3	Value 4
Growth	Conditional Age-at-length*	Modal (Size Composition)	Otolith	
Steepness	0.65	0.8 *	0.95	
Size Scalar	20	60 *	200	500
Mixing Period	1 Quarter	2 Quarters *		

Table YFT-2. Summary of reference points over the 72 models in the structural uncertainty grid. Note that "recent" is the average over the period 2015-2018 for SB and 2014-2017 for fishing mortality, while "latest" is 2018. The values of the upper 90th and lower 10th percentiles of the empirical distributions are also shown. F_{mult} is the multiplier of recent (2014-2017) fishing mortality required to attain MSY.

	Mean	Median	Minimum	10th percentile	90th percentile	Maximum
C_{latest}	709,389	711,072	700,358	702,279	712,761	714,073
$Y_{Frecent}$	779,872	784,200	661,600	707,720	877,040	9080,00
f_{mult}	2.87	2.80	1.70	2.12	3.72	4.29
F_{MSY}	0.11	0.10	0.08	0.09	0.12	0.15
MSY	1,090,706	1,091,200	791,600	874,200	1,283,920	1,344,400
F_{recent}/F_{MSY}	0.37	0.36	0.23	0.27	0.47	0.59
$SB_{F=0}$	3,641,228	3,603,980	2,893,274	3,231,353	4,050,429	4,394,277
SB_{MSY}	860,326	858,700	349,100	590,090	1,114,400	1,322,000
$SB_{MSY}/SB_{F=0}$	0.23	0.24	0.12	0.18	0.28	0.30
$SB_{latest}/SB_{F=0}$	0.54	0.54	0.40	0.47	0.60	0.66
SB_{latest}/SB_{MSY}	2.43	2.28	1.47	1.67	3.29	4.89
$SB_{recent}/SB_{F=0}$	0.58	0.58	0.42	0.51	0.64	0.68
SB_{recent}/SB_{MSY}	2.59	2.43	1.58	1.77	3.57	5.27

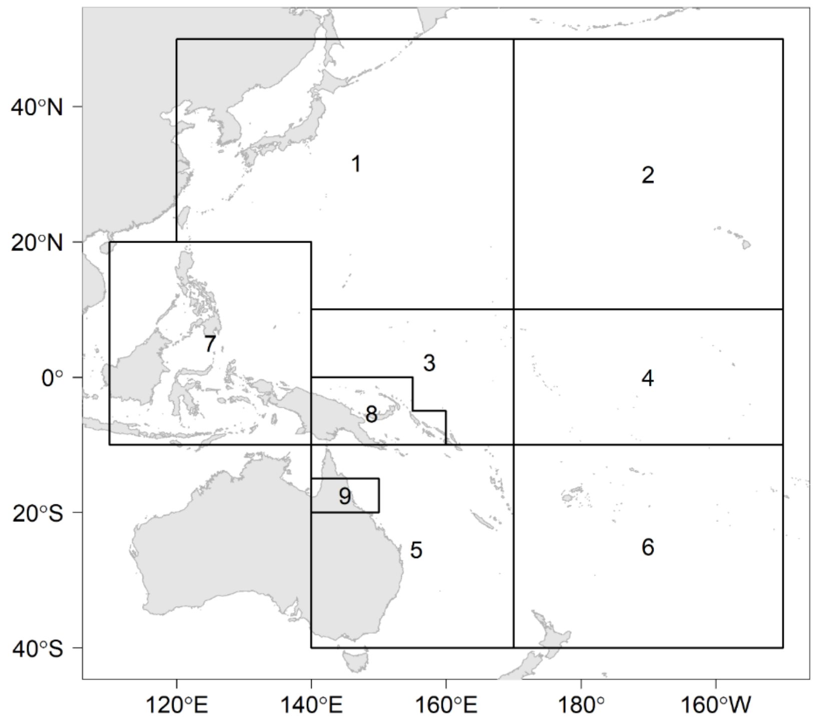


Figure YFT-1. The geographical area covered by the stock assessment and the boundaries for the 9 regions when using the "10N regional structure".

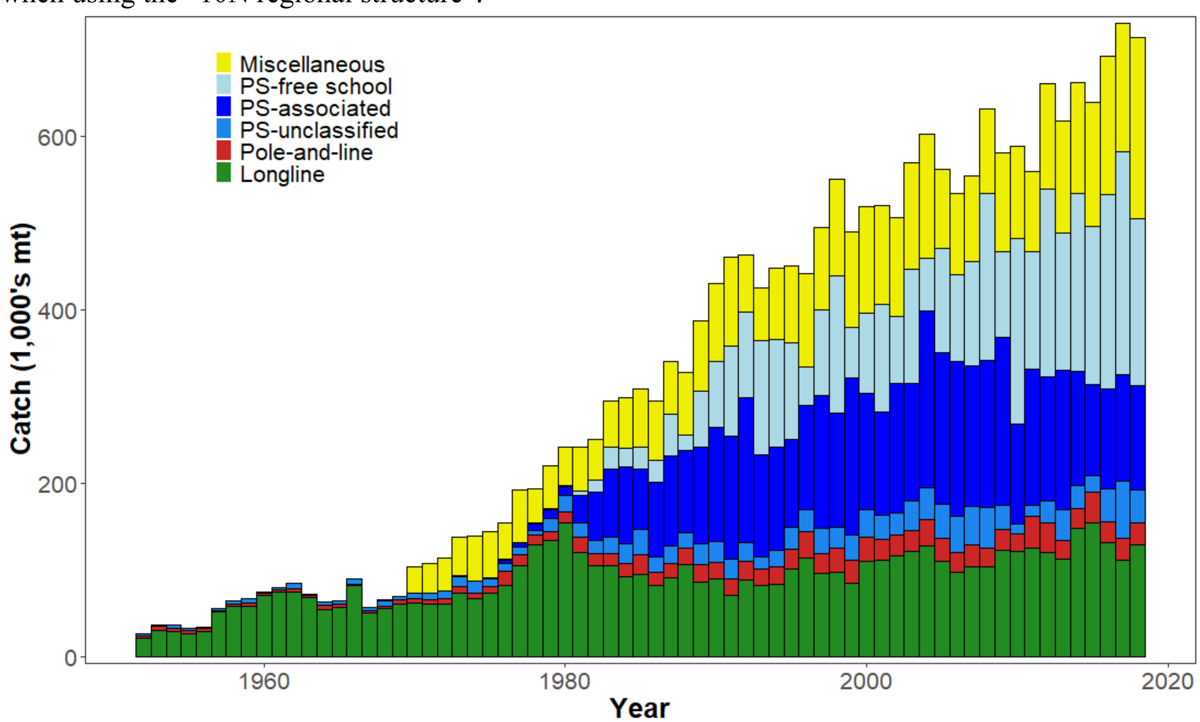


Figure YFT-2. Time series of total annual catch (1000s mt) by fishing gear over the full assessment region and time period. The different colours denote longline (green), pole-and-line (red), purse seine unclassified (blue), purse seine-associated (dark blue), purse seine-unassociated (light blue), miscellaneous (yellow).

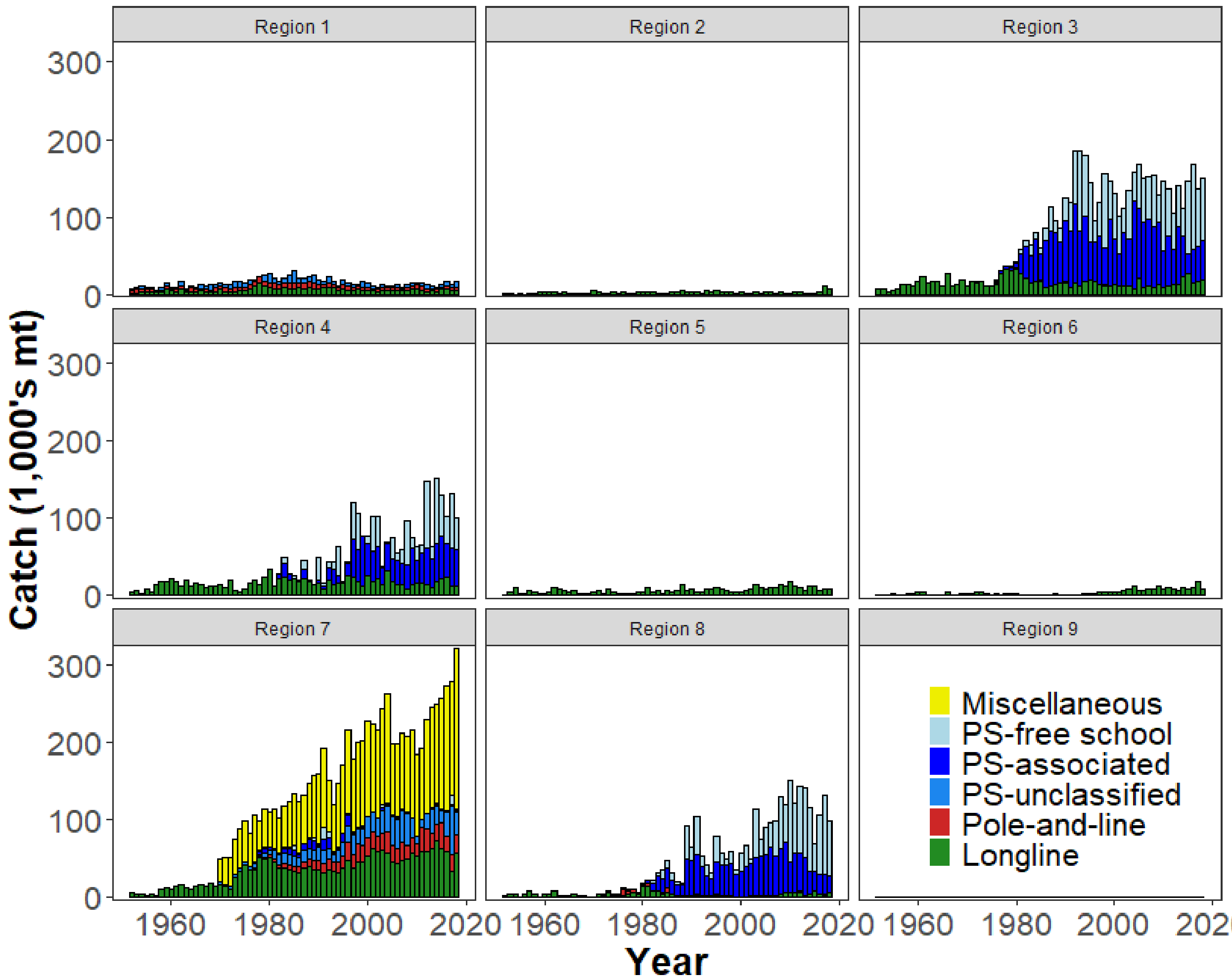


Figure YFT-3. Time series of total annual catch (1000s mt) by fishing gear and assessment region over the full assessment period. The different colours denote longline (green), pole-and-line (red), purse seine unclassified (blue), purse seine-associated (dark blue), purse seine-unassociated (light blue), miscellaneous (yellow).

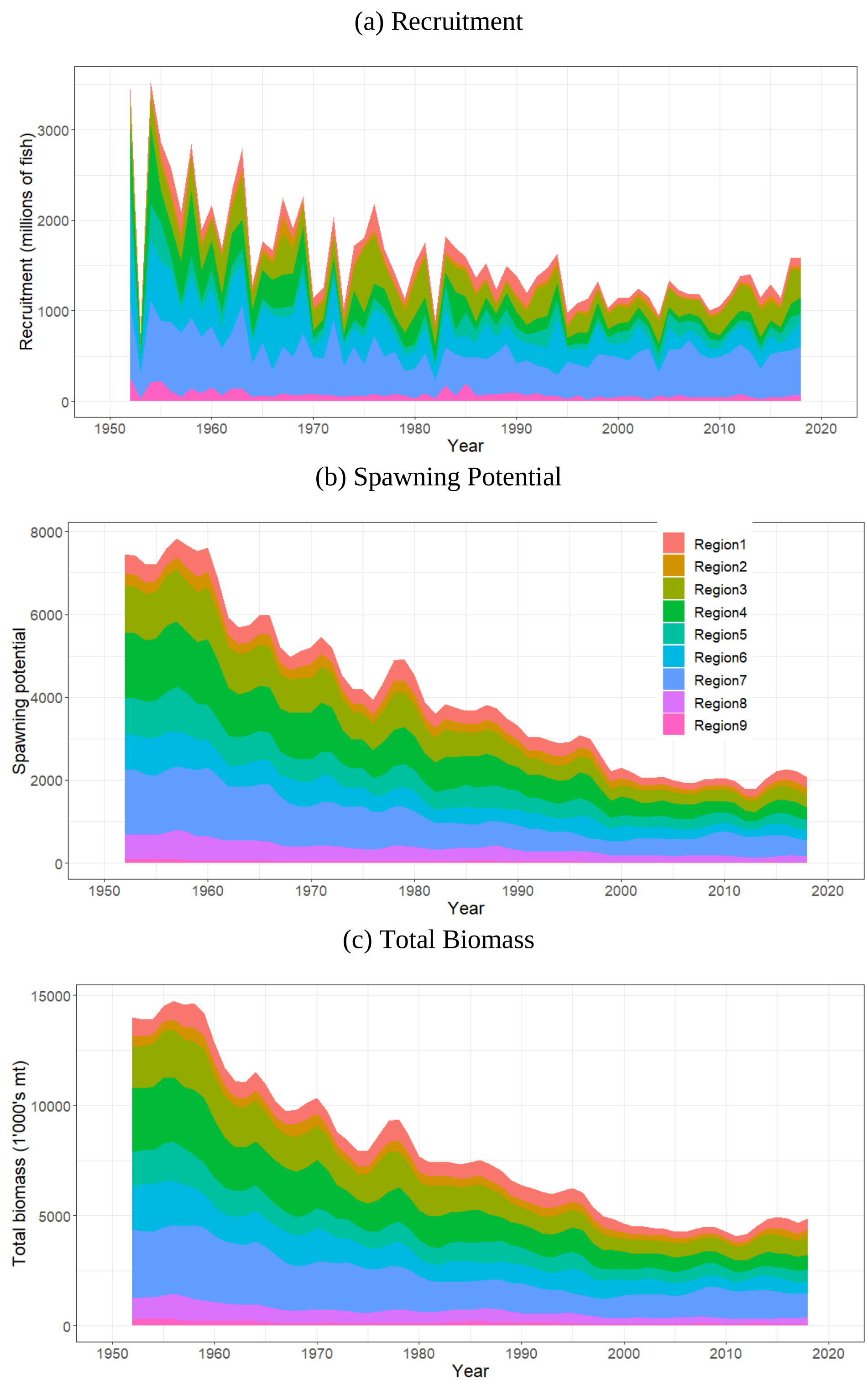


Figure YFT-4. Estimated annual average, (a) recruitment (b) spawning potential (c) total biomass by model region for the diagnostic model, showing the relative sizes among regions.

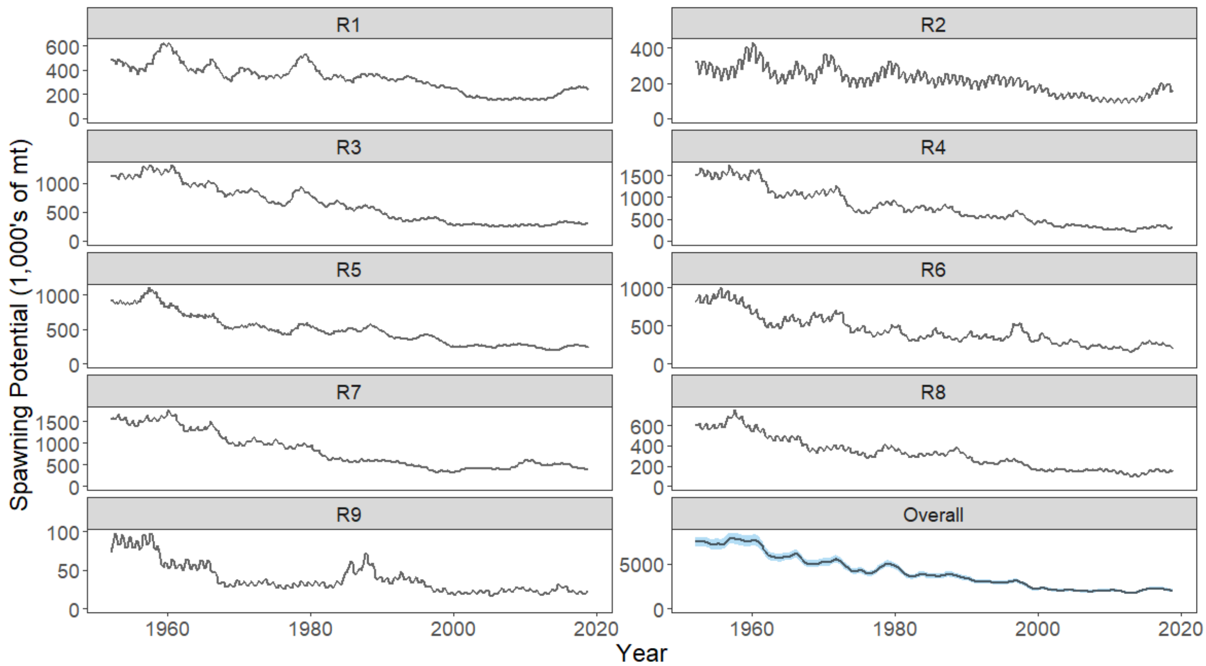


Figure YFT-5. The temporal trend in estimated spawning potential by model region for the diagnostic model, where the blue shaded region for the overall spawning potential shows the estimated 95% confidence interval based on statistical uncertainty estimated for the diagnostic model. Note that the y-axis scale among panels are not consistent.

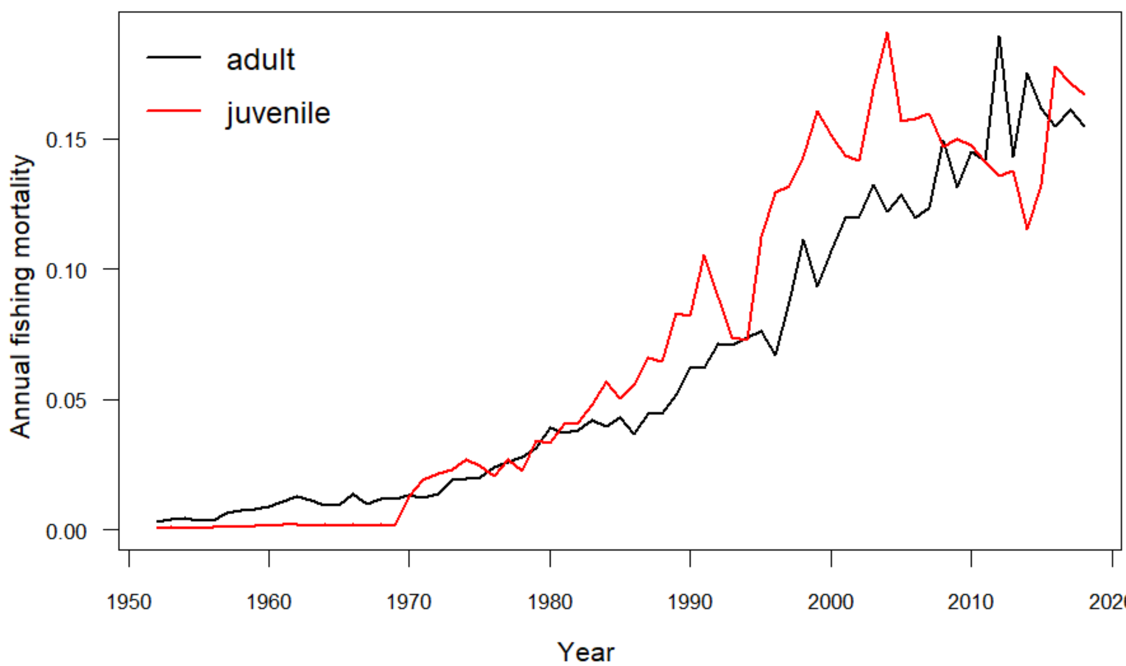


Figure YFT-6. Estimated annual average juvenile and adult fishing mortality for the diagnostic model.

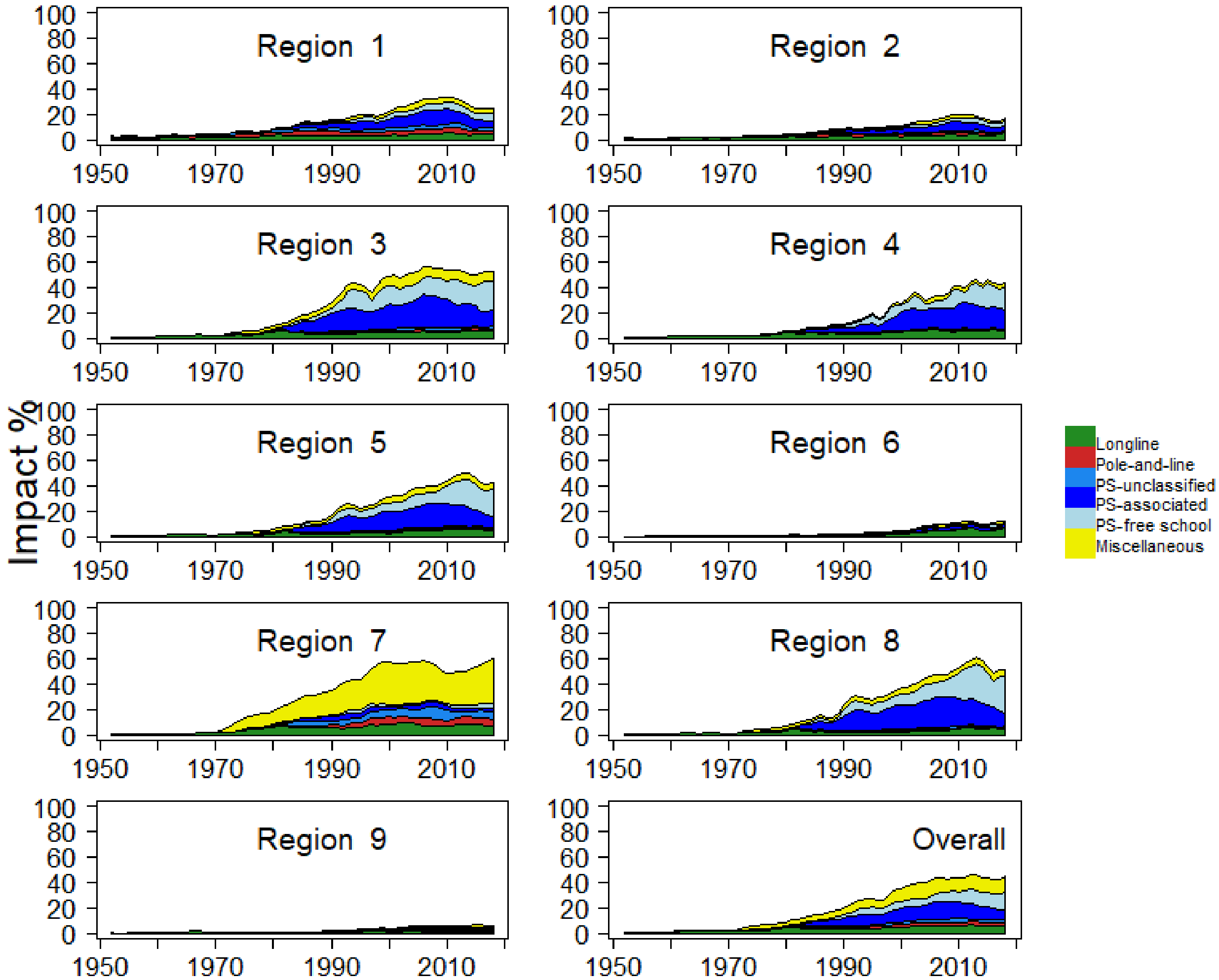


Figure YFT-7. Estimates of reduction in spawning potential due to fishing by region (Fishery Impact = ($1-SB_t/SB_{t;F=0}$) * 100%) and over all regions (lower right panel), attributed to various fishery groups for the diagnostic model.

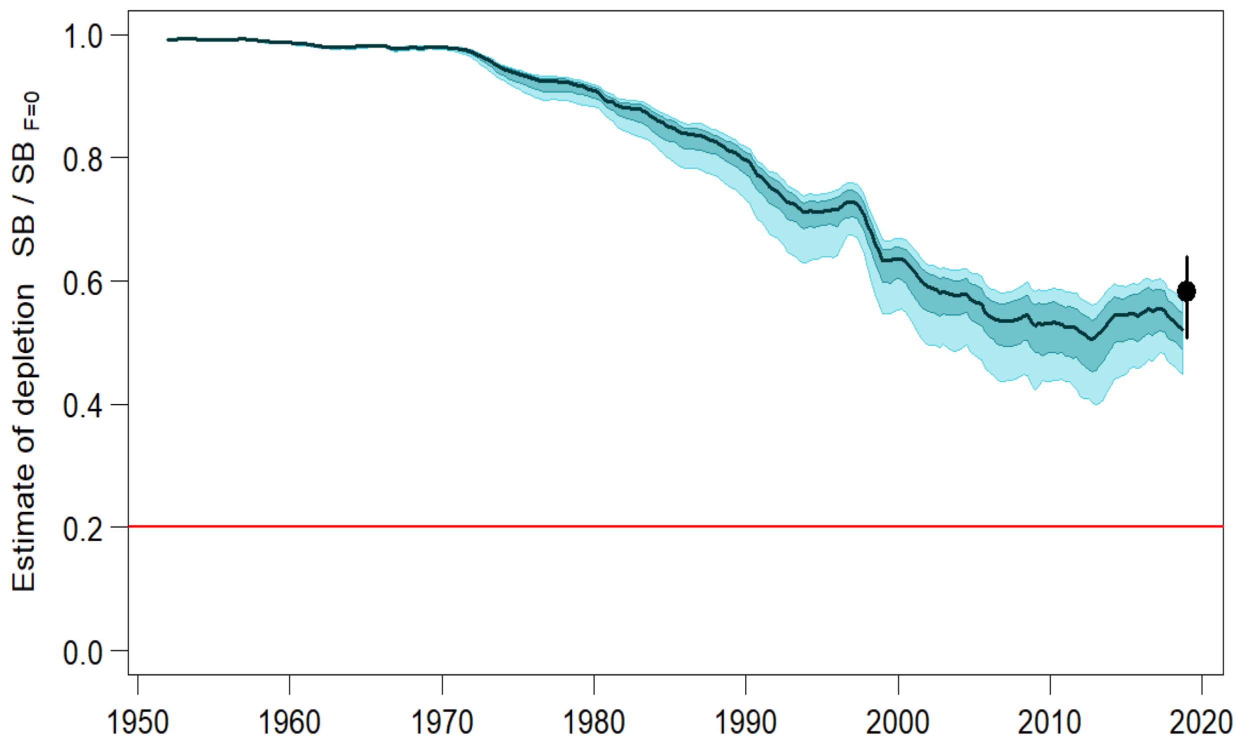


Figure YFT-8. Plot showing the trajectories of fishing depletion of spawning potential for the models in the structural uncertainty grid for the median, 50% quantile, and 80% quantile of instantaneous depletion across the structural uncertainty grid and the point and error bars is the median and 10th and 90th percentile of estimates of $SB_{recent}/SB_{F=0}$.

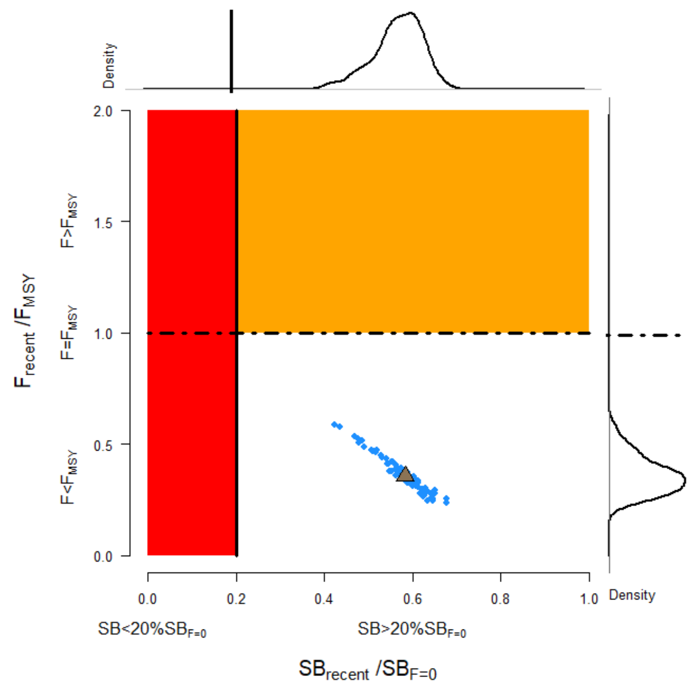


Figure YFT-9. Majuro plot representing stock status in terms of recent spawning potential depletion (2015–2018) and fishing mortality. The plots summarize the results for each of the models in the structural uncertainty grid with marginal distributions for spawning potential depletion and fishing mortality, where the brown triangle is the median of the structural uncertainty grid.

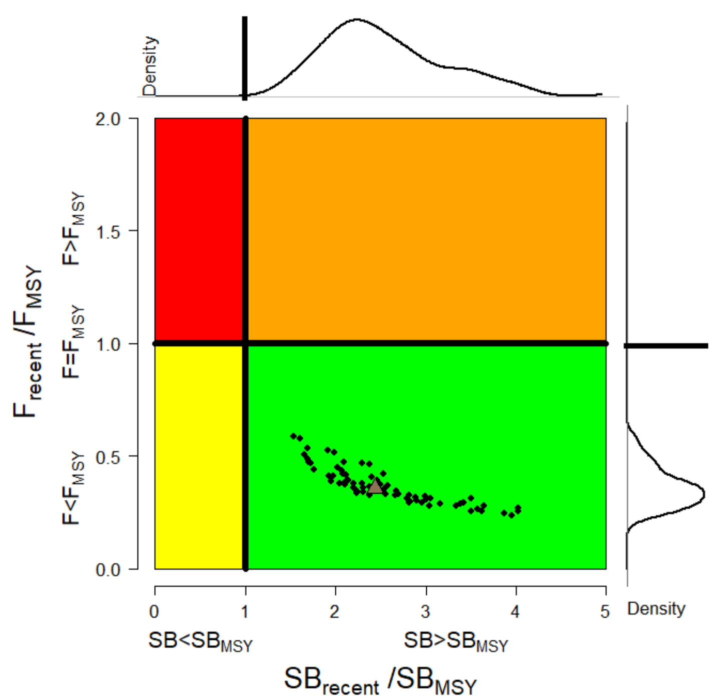


Figure YFT-10. Kobe plot for the recent spawning potential (2015–2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality relative to MSY quantities and marginal distributions of each are presented with the median of the structural uncertainty grid displayed as a brown triangle.

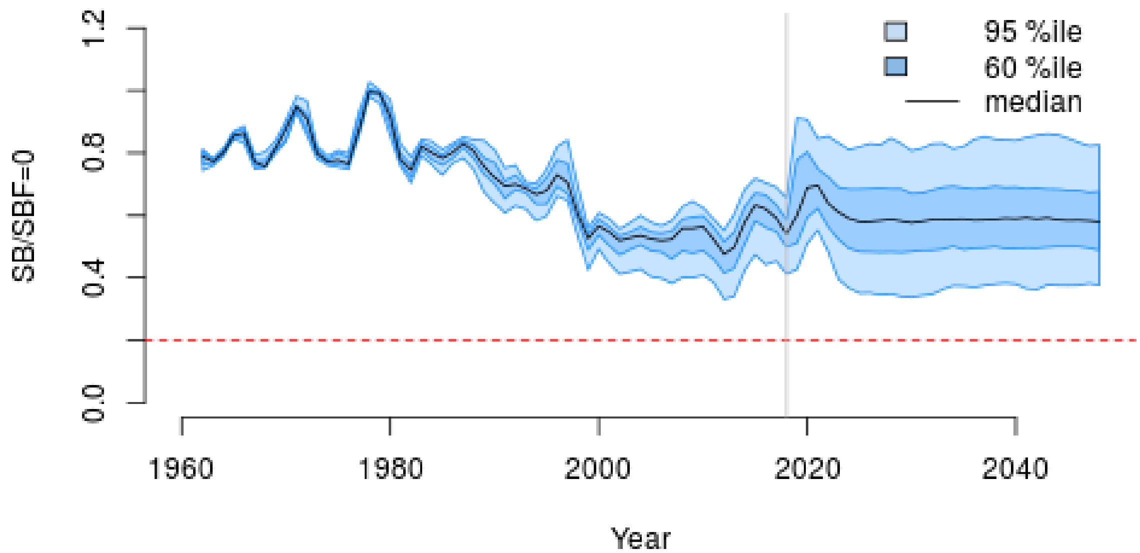


Figure YFT-11. Time series of yellowfin tuna spawning biomass ($SB_t/SB_{t,F=0}$, where $SB_{t,F=0}$ is the average SB from t-10 to t-1) from the uncertainty grid of assessment models for the period 2000 to 2018, and stochastic projection results for the period 2019 to 2048 assuming 2016-2018 average catches in LL and other fisheries and 2018 effort in PS fisheries continue. Vertical gray line at 2018 represents the last year of the assessment. During the projection period (2019-2048) levels of recruitment variability are assumed to match those over the time period used to estimate the stock-recruitment relationship (1962-2017). The red horizontal dashed line represents the agreed limit reference point.

4. SC16 noted that there has been a long-term decrease in spawning biomass from the 1970s for yellowfin tuna but that the depletion rates have been relatively stable over the last decade.

5. SC16 also noted that the median value of relative recent (2015-2018) spawning biomass depletion ($SB_{2015\text{-}2018}/SB_{F=0}$) was 0.58 with a 10^{th} to 90^{th} percentile interval of 0.51 to 0.64.

6. SC16 further noted that there was 0% probability (0 out of 72 models) that the recent (2015-2018) spawning biomass had breached the adopted LRP.

7. SC16 noted that there has been a long-term increase in fishing mortality for both juvenile and adult yellowfin tuna, which is consistent with previous assessments, but since 2010 there has been no directional trend.

8. SC16 noted that the median of relative recent fishing mortality ($F_{2014\text{-}2017}/F_{MSY}$) was 0.36 with a 10^{th} to 90^{th} percentile interval of 0.27 to 0.47.

9. SC16 further noted that there was 0% probability (0 out of 72 models) that the recent (2014-2017) fishing mortality was above F_{MSY}.

10. SC16 noted the results of stochastic projections (Figure YFT-11) from the 2020 assessment which indicated the potential stock consequences of fishing at "status quo" conditions (2016–2018 average

longline and other fishery catch and 2018 purse seine effort levels) and long-term recruitment scenario using the uncertainty framework approach endorsed by SC. Projections indicate that median $SB_{2025}/SB_{F=0}$ = 0.58; median $SB_{2035}/SB_{F=0}$ = 0.59 and median $SB_{2045}/SB_{F=0}$ = 0.58. The risk that $SB_{2048}/SB_{F=0}$ is less than the Limit Reference Point is 0%.

b. Management advice and implications

11. SC16 noted that the preliminary estimate of total catch of WCPO yellowfin tuna for 2019 was 669,362 mt, a 5% decrease from 2018 and a 1% increase from the average 2014-2018. Purse seine catch in 2019 (364,571 mt) was a 4% decrease from 2018 and an 8% decrease from the 2014-2018 average. Longline catch in 2019 (104,440 mt) was a 7% increase from 2018 and a 9% increase from the 2014-2018 average. Pole and line catch (37,563 mt) was a 43% increase from 2018 and a 40% increase from the average 2014-2018 catch. Catch by other gear totalled 162,788 t and was an 18% decrease from 2018 and a 16% increase from the average catch in 2014-2018.

12. SC16 noted that the catch in the last year of the assessment (2018) was 711,072 mt which was less than the median MSY (1,091,200 mt).

13. Based on the uncertainty grid adopted by SC16, the WCPO yellowfin tuna spawning biomass is above the biomass LRP and recent F is below F_{MSY}. The stock is not experiencing overfishing (100% probability $F<F_{MSY}$) and is not in an overfished condition (0% probability $SB/SB_{F=0}<LRP$). Additionally, stochastic projections predict there to be no risk of breaching the LRP (0% probability $SB_{2048}/SB_{F=0}<LRP$).

14. SC16 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. There is also evidence that the overall stock status is buffered with biomass kept at a more elevated level overall by low exploitation in the temperate regions (1, 2, 6, and 9). SC16 therefore re-iterates that WCPFC17 could consider measures to reduce fishing mortality from fisheries that take juveniles, with the goal to increase fishery yields and reduce any further impacts on the spawning potential for this stock in the tropical regions.

15. SC16 noted that the 2020 stock assessment results indicate the stock is currently exploited at relatively low levels (median F/F_{MSY} = 0.36, 10^{th} to 90^{th} percentile interval 0.27-0.47). Nevertheless, SC16 recommends that the Commission notes that further increases in YFT fishing mortality would likely affect other stocks/species which are currently moderately exploited due to the multispecies/gears interactions in WCPFC fisheries taking YFT.

16. SC16 also noted that although the structural uncertainty grid presents a positive indication of stock status, the high level of unresolved conflict amongst the data inputs used in the assessment suggests additional caution may be appropriate when interpreting assessment outcomes to guide management decisions.

17. Based on those results, SC16 recommends as a precautionary approach that the fishing mortality on yellowfin tuna stock should not be increased from the level that maintains spawning biomass at 2012-2015 levels until the Commission can agree on an appropriate target reference point.

Attachment C

The Commission for the Conservation and Management of
Highly Migratory Fish Stocks in the Western and Central Pacific Ocean
Scientific Committee
Fifteenth Regular Session
Pohnpei, Federated States of Micronesia
12 – 20 August 2019

WCPO SKIPJACK TUNA STOCK ASSESSMENT

(Refer to Paragraphs 164 – 223 of the SC15 Summary Report for the detailed discussions)

Provision of scientific information

a. Stock status and trends

1. SC15 noted that the total provisional catch in 2018 was 1,795,048 mt, a 10% increase from 2017 and a 1% decrease from 2013-2017. Purse seine catch in 2018 (1,469,520 mt) was a 15% increase from 2017 and a 2% increase from the 2013-2017 average. Pole and line catch (138,534 mt) was a 4% increase from 2017 and a 9% decrease from the average 2013-2017 catch. Catch by other gear (182,888 mt) was a 16% decrease from 2017 and 19% decrease from the average catch in 2013-2017.

2. SC15 agreed to use the 8-region model to describe the stock status of skipjack tuna because SC15 considers that it better captures the biology of skipjack tuna than the existing 5-region structure. Stock status was determined over an uncertainty grid of 54 models with assumed weightings as illustrated in Table SKJ-01.

3. The median values of recent (2015–2018) spawning biomass depletion ($SB_{recent}/SB_{F=0}$) and relative recent (2014–2017) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 54 models (Table SKJ-02) were used to define stock status. The values of the upper 90th and lower 10th percentile 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.

4. The spatial structure used in the assessment model is shown in Figure SKJ-01. Time series of total annual catch (1000's mt) by fishing gear for all regions is shown in Figure SKJ-02 and by region separately is shown in Figure SKJ-03. The annual average recruitment, spawning potential, and total biomass by model region for the diagnostic model are shown in Figure SKJ-04. The overall spawning potential summed across region for the diagnostic model is shown in Figure SKJ-05. The estimated annual average juvenile and adult fishing mortality for the diagnostic model is shown in Figure SKJ-06. The estimated impact of fishing (1 – $SB_{latest}/SB_{F=0}$) by region and overall regions for the diagnostic model is shown in Figure SKJ-07. The median and 80th percent quantile trajectories of fishing depletion for models in the weighted structural uncertainty grid in Table SKJ-01 is shown in Figure SKJ-08, where it can be seen that the median has been below the target since 2009. The Majuro plot shows the recent fishing mortality and spawning potential relative to the unfished spawning potential for all models in the structural uncertainty grid for (i) spawning potential in the recent time period (2015–2018) in Figure SKJ-09, and (ii) spawning potential in the latest time period (2018) in Figure SKJ-10. The Kobe plot shows the recent fishing mortality and spawning potential relative to spawning potential at MSY for all models in the structural uncertainty grid for (i) spawning potential in the recent time period (2015–2018) in Figure SKJ-11, and (ii) spawning potential in the latest time period (2018) in Figure SKJ-12.

5. SC15 noted that the median level of spawning potential depletion from the uncertainty grid was $SB_{recent}/SB_{F=0}$ = 0.44 with a probable range of 0.37 to 0.53 (80% probability interval). There were no individual models where $SB_{recent}/SB_{F=0} < 0.2$, which indicated that the probability that recent spawning biomass was below the LRP was zero.

6. SC15 noted that the grid median F_{recent}/F_{MSY} was 0.45, with a range of 0.34 to 0.60 (80% probability interval) and that no values of F_{recent}/F_{MSY} in the grid exceed 1. Therefore, SC15 noted that there was a zero probability that the recent fishing mortality exceeds F_{MSY}.

7. SC15 noted that the largest uncertainty in the structural uncertainty grid was due to the assumed tag mixing period. In addition, SC15 acknowledges that further study is warranted to investigate the uncertainty surrounding the appropriate mixing period for the tagging data.

8. SC15 acknowledges that the spatial extent of the Japanese pole-and-line fishery has decreased over the time period and that the future use of this standardized CPUE index within future stock assessments is uncertain.

9. Therefore, SC15 acknowledges that further study of alternative indices of abundance is warranted, such as investigation of standardizing the purse seine fishery and evaluation of the feasibility of conducting fishery independent surveys.

Table SKJ-01. Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment.

Axis	Value	Relative weight
Steepness	0.65	0.8
	0.80	1.0
	0.95	0.8
Growth	Low	1.0
	Diagnostic	1.0
	High	1.0
Length composition scalar	50	0.8
	100	1.0
	200	1.0
Tag mix	1	1.0
	2	1.0

Table SKJ-02. Summary of reference points over the various models in the structural uncertainty grid. F_{mult} is the multiplier of recent (2014-2017) fishing mortality required to attain MSY, F_{recent} is the average fishing mortality of recent (2014-2017), SB_{recent} is the average spawning potential of recent years (2015-2018) and SB_{latest} is the spawning potential in 2018.

	Mean	Median	Minimum	10th %ile	90th %ile	Maximum
C_{latest}	1,755,328	1,755,693	1,749,846	1,753,471	1,757,057	1,757,083
$Y_{Frecent}$	1,877,914	1,864,040	1,679,600	1,737,702	2,043,556	2,135,200
F_{mult}	2.282	2.258	1.472	1.757	2.957	3.705
F_{MSY}	0.223	0.222	0.180	0.189	0.264	0.270
MSY	2,296,566	2,294,024	1,953,600	1,995,987	2,767,083	2,825,600
F_{recent}/F_{MSY}	0.461	0.447	0.270	0.343	0.600	0.679
$SB_{F=0}$	6,220,675	6,299,363	5,247,095	5,580,942	6,913,431	7,349,557
SB_{MSY}	1,100,947	1,064,400	631,900	723,742	1,544,060	1,688,000
$SB_{MSY}/SB_{F=0}$	0.175	0.176	0.117	0.131	0.225	0.23
$SB_{latest}/SB_{F=0}$	0.414	0.415	0.325	0.36	0.487	0.525
SB_{latest}/SB_{MSY}	2.468	2.382	1.551	1.779	3.356	3.925
$SB_{recent}/SB_{F=0}$	0.440	0.440	0.336	0.372	0.530	0.551
SB_{recent}/SB_{MSY}	2.623	2.579	1.601	1.892	3.613	4.139

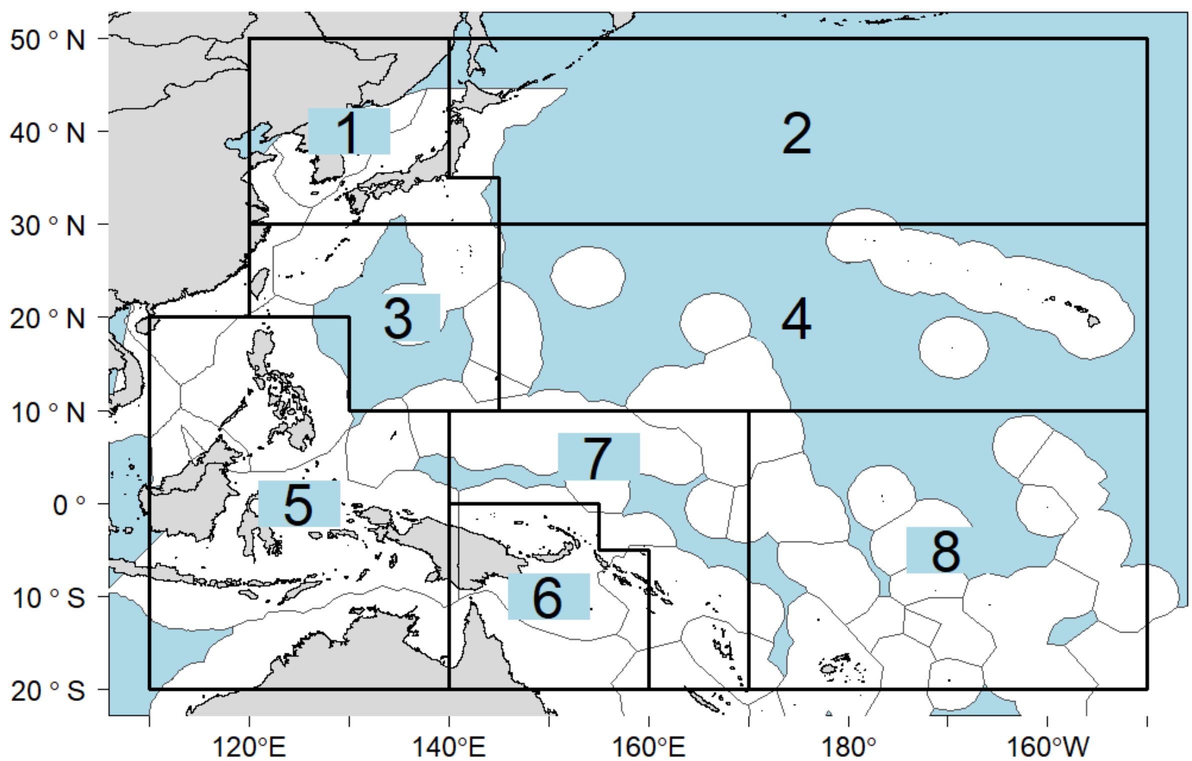


Figure SKJ-01. Eight region spatial structure used in the 2019 stock assessment model.

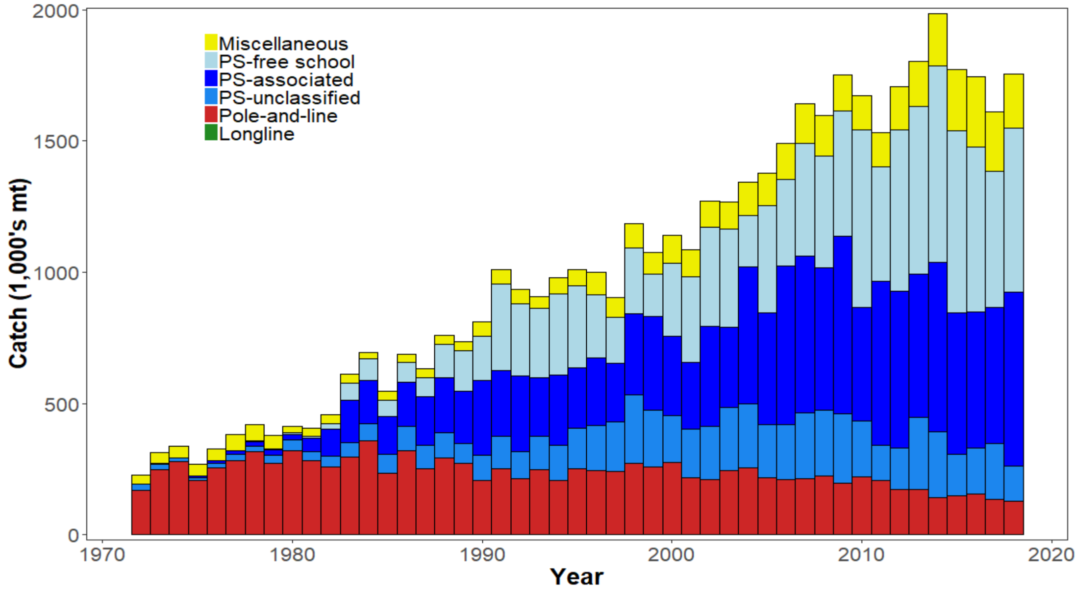


Figure SKJ-02. Time series of total annual catch (1000's mt) by fishing gear over the full assessment period.

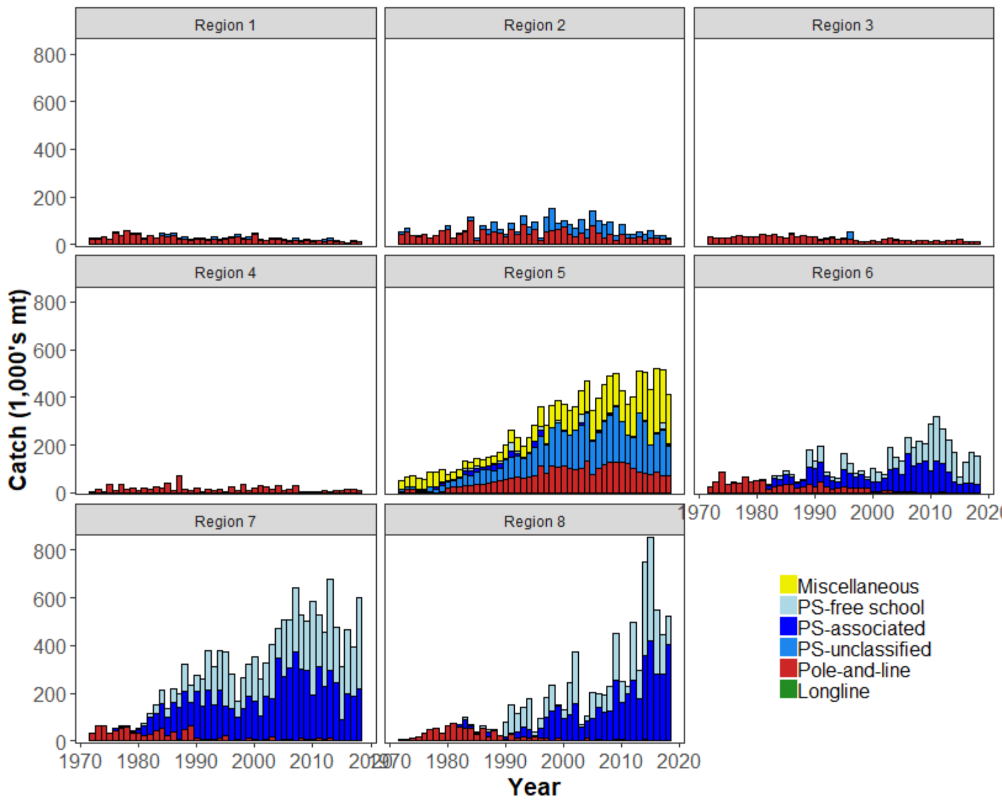
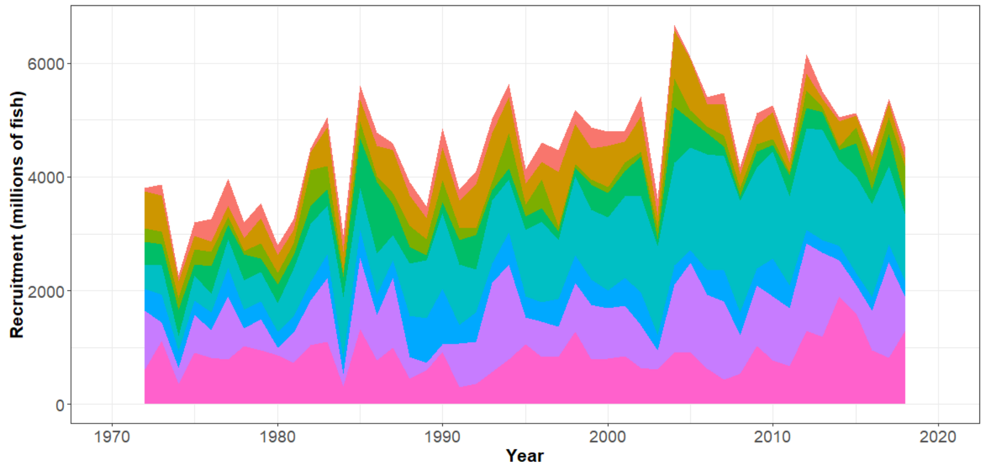
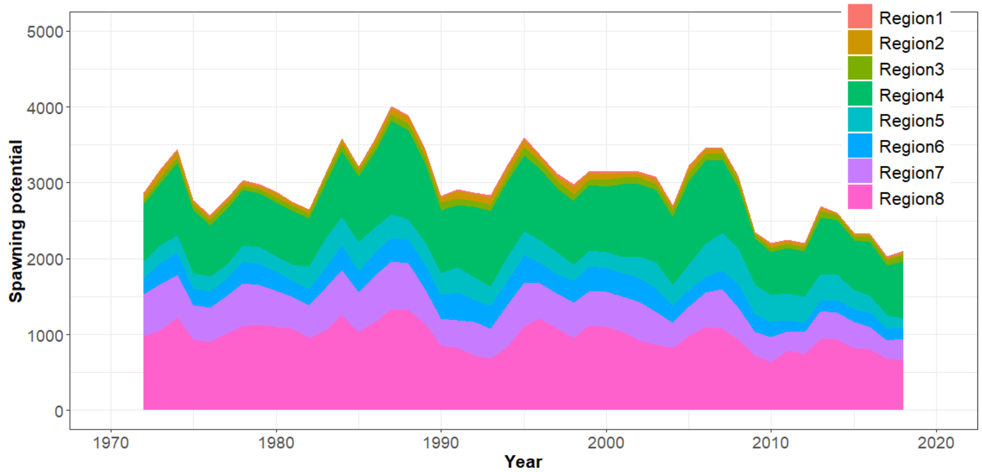


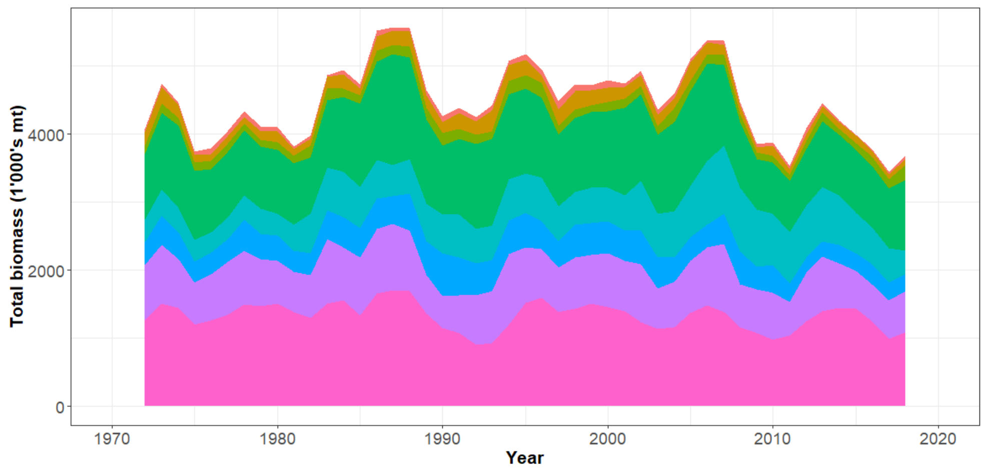
Figure SKJ-03. Time series of total annual catch (1000's mt) by fishing gear and assessment region over the full assessment period.



a) Recruitment



b) Spawning Potential



c) Total biomass

Figure SKJ-04. Estimated annual average recruitment, spawning potential and total biomass by model region for the diagnostic model, showing the relative sizes among regions.

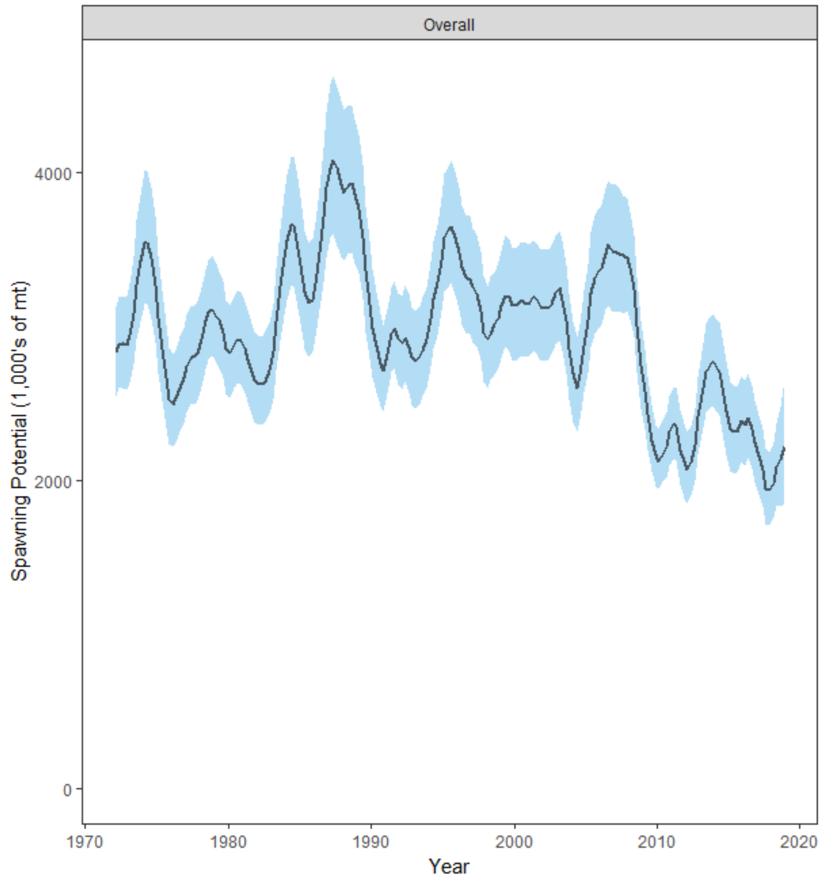


Figure SKJ-05. Estimated temporal overall spawning potential summed across regions from the diagnostic model, where the shaded region is ± 2 standard deviations (i.e., 95% CI).

Figure SKJ-06. Estimated annual average juvenile and adult fishing mortality for the diagnostic model.

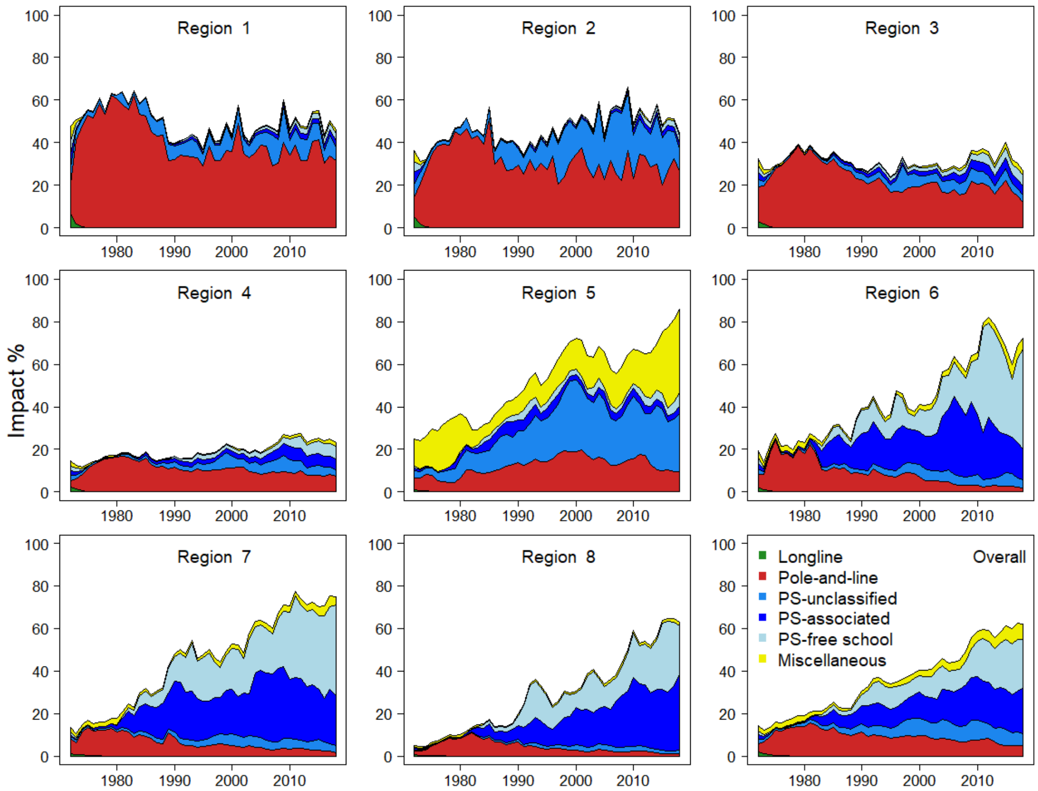


Figure SKJ-07. Estimates of reduction in spawning potential due to fishing (fishery impact = 1-SB_{latest}/$SB_{F=0}$) by region for the diagnostic model.

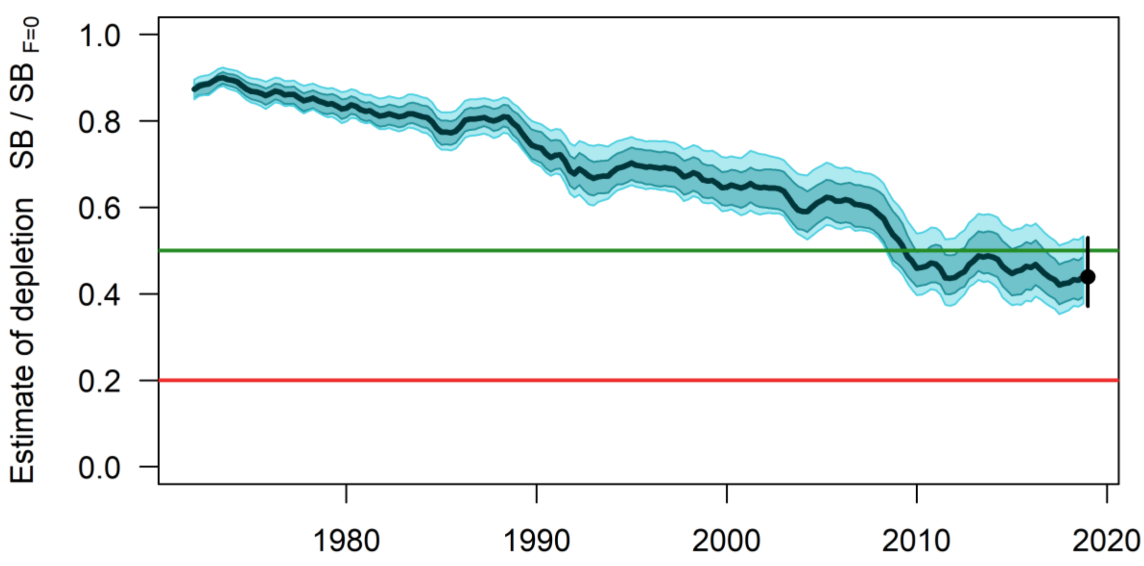


Figure SKJ-08. Plot showing the trajectories of spawning potential depletion for the model runs included in the structural uncertainty grid weighted by the values given in Table SKJ-01. Red horizontal line indicates the agreed limit reference point, the green horizontal line indicates the interim target reference point.

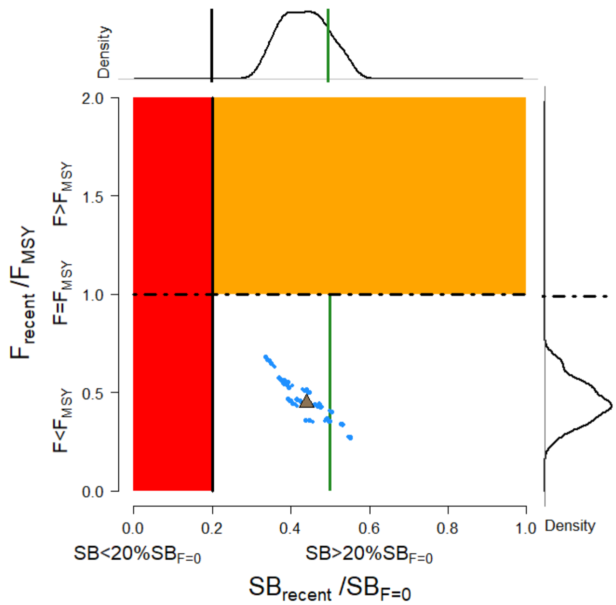


Figure SKJ-09. Majuro plot for the recent spawning potential (2015 – 2018) summarizing the results for each of the models in the structural uncertainty grid with weighting. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality, and marginal distributions of each are presented. Vertical green line denotes the interim TRP. Brown triangle indicates the median of the estimates. The size of the circle relates to the weight of that particular model run.

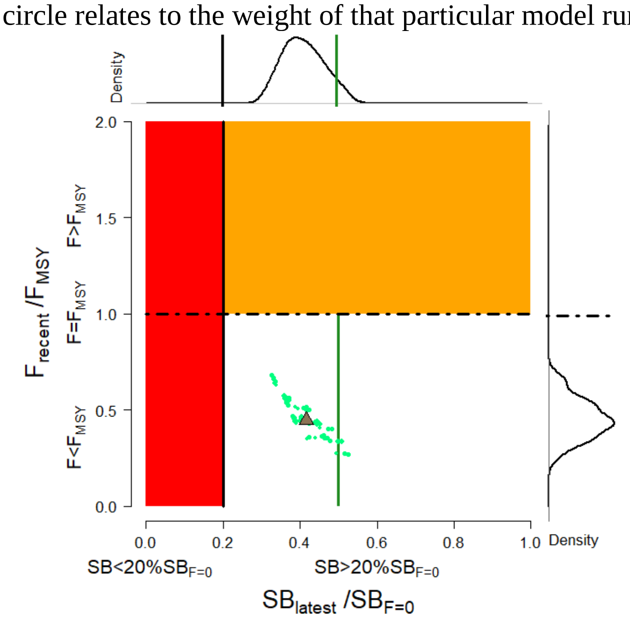


Figure SKJ-10. Majuro plot for the latest spawning potential (2018) summarizing the results for each of the models in the structural uncertainty grid with weighting. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality, and marginal distributions of each are presented. Vertical green line denotes the interim TRP. Brown triangle indicates the median of the estimates. The size of the circle relates to the weight of that particular model run.

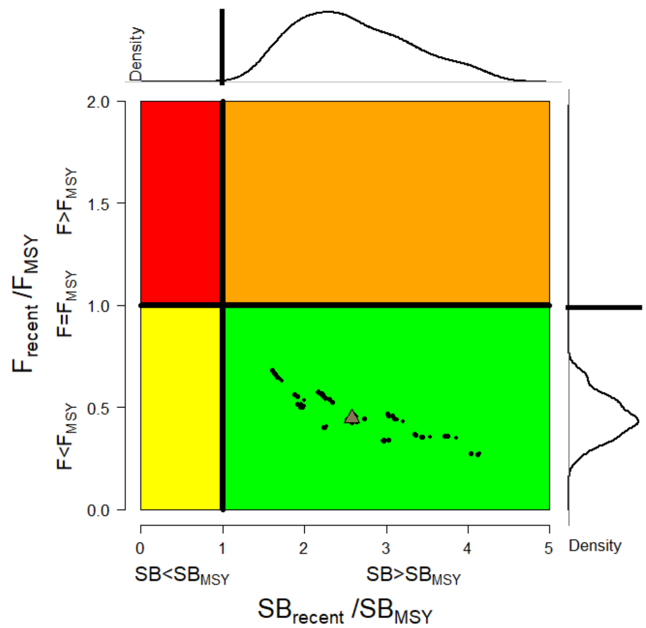


Figure SKJ-11. Kobe plot for the recent spawning potential (2015 – 2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality and marginal distributions of each are presented. Brown triangle indicates the median of the estimates. The size of the circle relates to the weight of that particular model run.

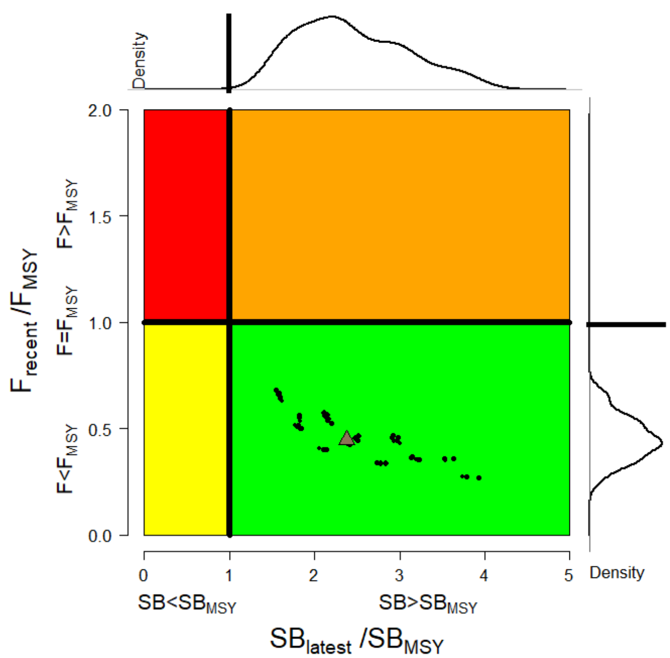


Figure SKJ-12. Kobe plot for the latest spawning potential (2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality and marginal distributions of each are presented. Brown triangle indicates the median of the estimates. The size of the circle relates to the weight of that particular model run.

b. Management advice and implications

10. SC15 noted that the skipjack assessment continues to show that the stock is currently moderately exploited and the level of fishing mortality is sustainable.

11. The 2019 stock assessment includes additional data and a range of model improvements such as a change to the maturity schedule used in this assessment, with length-at-maturity now larger than in the previous assessment, which has resulted in a reduction in the estimate of potential spawning biomass, relative to the 2016 assessment.

12. SC15 noted that the stock was assessed to be above the adopted Limit Reference Point and fished at rates below F_{MSY} with 100% probability. Therefore, the skipjack stock is not overfished, nor subject to overfishing. At the same time, it was also noted that fishing mortality is continuously increasing for both adult and juvenile while the spawning biomass reached the historical lowest level.

13. The skipjack interim Target Reference Point (TRP) is 50% of spawning biomass in the absence of fishing. The trajectory of the median spawning biomass depletion indicates a long-term trend, and has been under the interim TRP since 2009 (i.e., for 10 years). Since the median spawning biomass has been consistently below the interim TRP, SC15 recommends that the Commission take appropriate management action to ensure that the biomass depletion level fluctuates around the TRP (e.g., through the adoption of a harvest control rule).

c. Research recommendations

14. In order to maintain the quality of stock assessments for this important stock SC15 recommends:

a) continuing work to develop an index of abundance based on purse seine data and from FAD acoustic sensors;
b) evaluating the possibility of conducting fishery independent surveys to provide relative abundance indices;
c) conducting regular large-scale tagging cruises and expanding the infrastructure for rapid return of recaptured tags in a manner that provides the best possible data for stock assessment purposes;
d) investigating skipjack growth by validation studies of otolith readings and/or estimation of growth within MFCL from tag recapture data;
e) attempting to provide finalized catch estimates to SPC no later than June 1st.