COMMISSION
EIGTEENTH REGULAR SESSION

Electronic Meeting
1 – 7 December 2021

REFERENCE DOCUMENT FOR BIGEYE, YELLOWFIN AND SKIPJACK TUNA FOR THE REVIEW OF CMM 2020-01 AND DEVELOPMENT OF HARVEST STRATEGIES UNDER CMM 2014-06

WCPFC18-2021-14
5 November 2021

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 latest Scientific Committee (SC) and Technical and Compliance Committee (TCC) of relevance to the discussions in support to the review and development of CMM for tropical tunas. This paper includes SC17 and TCC17 recommendations on bigeye, yellowfin and skipjack target reference points (TRPs), mixed fisheries and other commercial fisheries. The results of the latest stock assessments are attached to this paper for bigeye tuna (**Attachment A**), yellowfin tuna (**Attachment B**) and skipjack tuna (**Attachment C**).

B. SCIENTIFIC COMMITTEE RECOMMENDATIONS

B1. Target reference points for bigeye and yellowfin tuna *(Paragraph 259 - 265, SC17 Summary Report)*

2. Noting the request from WCPFC17 to review any updated information on TRPs for bigeye and yellowfin tuna, SC17 reviewed SC17-MI-WP-01 (*Updated WCPO bigeye and yellowfin TRP evaluations*).

3. SC17 noted that these analyses reflected the original request made by SC16, and the additional request by the Commission for additional information. SC17 also noted the usefulness of these updates as they facilitate an improved understanding of multi-species implications of alternative harvest levels.

4. SC17 noted that impacts on skipjack tuna depletion associated with relative changes to fishing levels to achieve a candidate bigeye tuna TRP are contingent on the proportion of fishing scalars related to purse seine fishing that target skipjack tuna. The relative change in fishing scalars to achieve candidate TRPs assume equal proportionality in purse seine and longline fishing scalars, provided for comparative purposes from the SC16 request.

5. SC17 noted that the analyses will greatly aid in considering candidate TRPs for bigeye and yellowfin tuna.

6. SC17 also noted that the risks of breaching the LRPs outlined in the paper are dependent on the treatment of uncertainty in any assessment and may underestimate uncertainty.

7. SC17 recommended forwarding this working paper to the Commission for its deliberations on target reference points for bigeye and yellowfin tuna and that the results be taken into account at the next Tropical Tuna Workshop.

8. SC17 noted that South Pacific albacore had not been included in the TRP evaluations and asked the Scientific Services Provider (SSP) to update this report to include South Pacific albacore in future evaluations.

B2. Skipjack tuna TRP analyses *(Paragraphs 276-278, SC17 Summary Report)*

9. Noting the request from WCPFC17 to review the updated information provided by the SSP on the performance of candidate TRPs and provide advice to the Commission for its potential update of the skipjack TRP, SC17 reviewed SC17-MI-WP-02 (*Further updates to WCPO skipjack tuna projected stock status to inform consideration of an updated target reference poin*t).

10. SC17 noted the challenges outlined in the paper on interpreting future fishing mortality and several CCMs proposed that additional analyses should be undertaken to consider how the fishing mortality estimated within the analysis is driven by the assumptions, particularly the contributions of the different gear types to the catch in Region 5. To better understand the importance of each sector one CCM also requested yield or spawning biomass per-recruit curves by fishing sector be added to the paper.

11. SC17 recommended forwarding this working paper, and any updates, to the Commission and that the results be taken into account at the next Tropical Tuna Measure Workshop (TTMW2).

B3. Mixed fisheries *(Paragraphs 316 - 321, SC17 Summary Report)*

12. Noting the initial work presented to SC16 in developing a multi-species modelling framework for including mixed fishery interactions when developing and testing harvest strategies for the four main WCPO tuna stocks, SC17 reviewed an update on the development of this framework outlined in SC17-MI-WP-05 (*Mixed-fishery harvest strategy developments*).

13. SC17 noted that in the present ‘proof of concept’ analyses there are differences between the reference year used for the archipelagic waters (2012) whereas the tropical and southern longline fisheries are held to the average of 2016-2018. There will need to be agreement on various assumptions that underpin these simulations noting that as the mixed fishery framework develops, the tropical and southern longline fisheries will not be held constant but will be managed through management procedures.

14. SC17 also noted that while there is agreement on the hierarchical approach, the order of the hierarchy (i.e., the order in which the species-specific management procedures are implemented) has not yet been agreed and that a process to get such an agreement is required.

15. SC17 welcomed the initial work and results of SC17-MI-WP-05 as demonstrating the ‘proof of concept’ and supported continued work by the SSP to further develop this modelling framework as it is critical to the future management of the key tuna stocks in the WCPO.

16. SC17 endorsed the work outlined in SC17-MI-WP-05 and noted the next steps to progress this work, including i) building a full suite of OMs for bigeye and yellowfin, ii) developing candidate MPs for bigeye for the tropical longline fishery, iii) the inclusion of South Pacific albacore in the modelling framework, and iv) agreeing multi-species performance indicators.

17. SC17 recommends that the Commission take note of the progress on the development of a mixed fishery MSE framework and provide advice on the issues listed in the previous paragraph.

B4. Other commercial fisheries for bigeye, yellowfin and skipjack tuna *(Paragraph 45, SC17 Summary Report)*

18. SC17 reviewed information provided by Indonesia and the Philippines to inform a Commission discussion on the application of paragraph 51 of CMM 2020-01.

a) SC17 noted that paragraph 3 of CMM 2020-01 limits the measure to the high seas and EEZs, and based on the information presented recommended that paragraph 51 would not apply to the following fisheries which are restricted to territorial seas and archipelagic waters:
   i) Small-scale hook-and-line fisheries
   ii) Small-scale troll fisheries
   iii) Small-scale gillnet fisheries
   iv) Small-scale pole and line (funai – Indonesia)
   v) Pajeko (Indonesia mini-purse seine)
   vi) Bagnet, beach seine, artisanal longline and other artisanal gears with very minor tuna catch

b) SC17 recommended that paragraph 51 of CMM 2020-01 applies to the following fisheries:
   i) Indonesia pole and line fishery fishing outside archipelagic waters and territorial seas for vessels >30 GT, and
   ii) The "large-fish" handline fishery in Indonesia and the Philippines fishing outside archipelagic waters and territorial seas for vessels >30 GT.

c) SC17 recognized that sufficient data exist to determine a baseline and annual catches for the Indonesia pole-and-line fishery and the Philippines large-fish handline fishery.

d) SC17 recognized that insufficient data exist to derive a baseline for the Indonesia large-fish handline, and suggests that WCPFC consider developing a baseline using years where data are available.

e) Although CMM 2020-01 is not applicable to archipelagic waters, SC17 encouraged Indonesia and the Philippines to provide data from fisheries that operate in those areas for scientific purposes.

C. TECHNICAL AND COMPLIANCE COMMITTEE

19. The relevant recommendations of the TCC17 for WCPFC18 decision with appropriate referencing, are listed below.

i) TCC17 noted for WCPFC18 that there were recommendations in the Provisional CMR relating to the revision of existing Conservation and Management Measures. TCC17 **recommends** that WCPFC18 consider approaches to address challenges identified for the following obligation, noting that more information related to this recommendation is contained in the Provisional CMR:
   a. CMM 2018-01 paragraph 51. (*draft TCC17 Summary Report para 64)*

ii) TCC17 reviewed information provided by Indonesia and the Philippines to inform a Commission discussion on the application of paragraph 51 of CMM 2020-01 and noted the paper TCC17-2021-16 (SC17-2021-ST-WP02). (*draft TCC17 Summary Report para 176)*

iii) TCC17 **supported** the SC17 recommendations related to the application of paragraph 51 CMM 2020-01 noting:

a) that in TCCs view paragraph 51 does not currently affect the following fisheries which are restricted to territorial seas and archipelagic waters:
   i. Small-scale hook-and-line fisheries
   ii. Small-scale troll fisheries
   iii. Small-scale gillnet fisheries
   iv. Small-scale pole and line (funai –Indonesia)
   v. Pajeko (Indonesia mini-purse seine)
   vi. Bagnet, beach seine, artisanal longline and other artisanal gears with very minor tuna catch; and

b) that in TCCs view paragraph 51 of CMM 2020-01 currently affects the following fisheries:
   i. Indonesia Pole and Line Fishery fishing outside archipelagic waters and territorial seas for vessels >30 GT, and
   ii. The "large-fish" Handline fishery in Indonesia and the Philippines fishing outside archipelagic waters and territorial seas for vessels >30 GT. (*draft TCC17 Summary Report para 177)*

iv) TCC17 noted that sufficient data exist to determine a baseline and annual catches for the Indonesia pole-and-line fishery and the Philippines large-fish handline fishery. (*draft TCC17 Summary Report para 178)*

v) TCC17 requested Indonesia and the Scientific Services Provider to provide and present to the Commission, the annual catch estimates for the "large-fish" Handline fishery in Indonesia fishing outside archipelagic waters and territorial sea for vessels >30GT, for this period and the options for the baseline, that is, the average 2013-2016 or the maximum years, due to the absence of data for 2001-2004, for WCPFC18 consideration. This could help advise an appropriate revision of paragraph 51. (*draft TCC17 Summary Report para 179)*

vi) TCC17 reviewed the DRAFT Guidelines for non-entangling and biodegradable FADs prepared by the FAD Management Options IWG, and noted that the Draft Guidelines will be updated by the FAD Management Options IWG prior to WCPFC18. (*draft TCC17 Summary Report para 228)*

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

(Paragraphs 81– 98, SC16 Summary Report)

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	10^{th} percentile	90^{th} 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

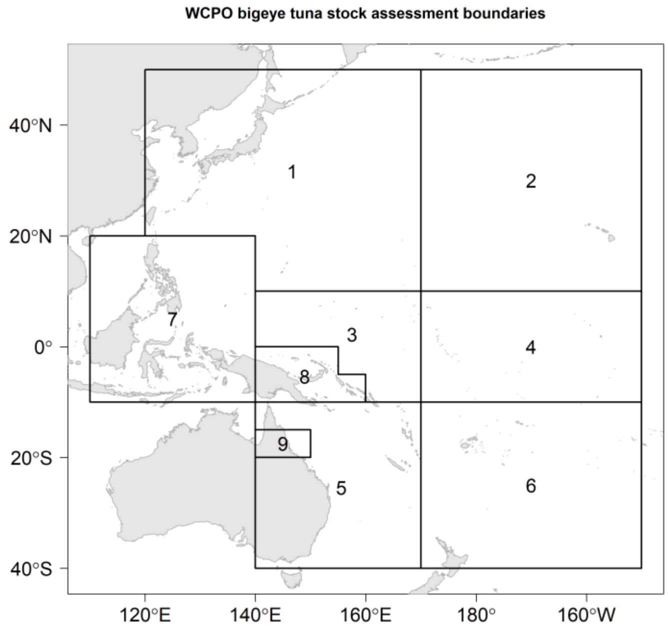


Figure BET-1. Spatial structure for the 2020 bigeye tuna stock assessment.

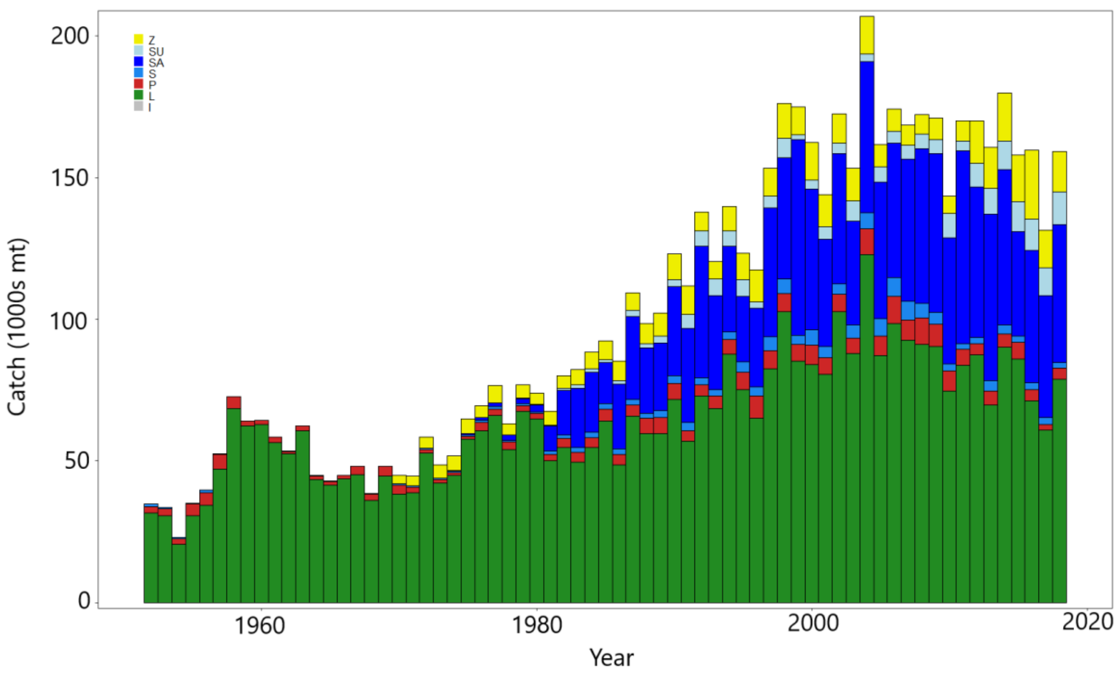


Figure BET-2. Time series of total annual catch (1000s mt) by fishing gear for the diagnostic model over the full assessment period. The different colors refer to longline (green), pole-and-line (red), purse seine (blue), purse seine associated (dark blue), purse seine unassociated (light blue), miscellaneous (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.

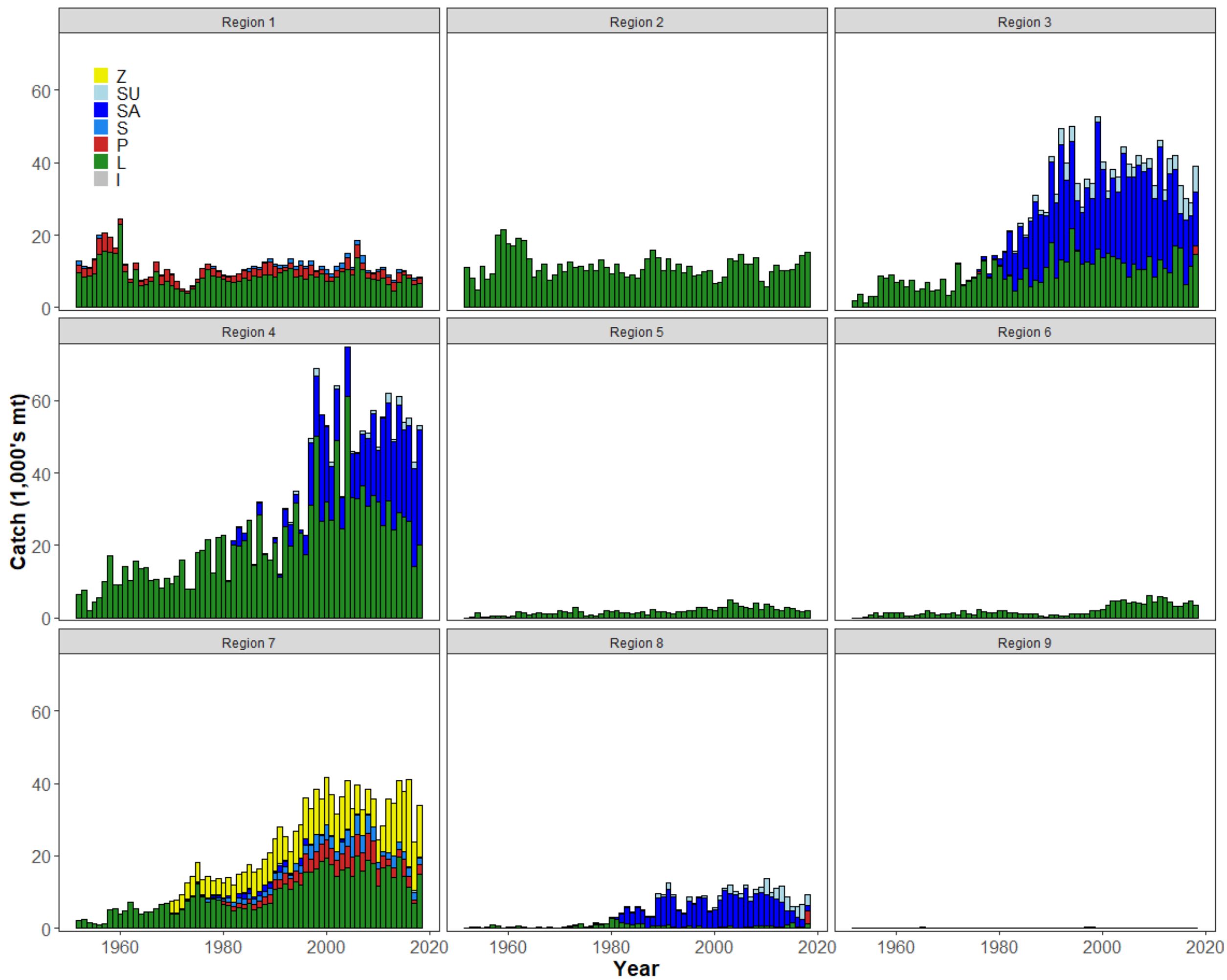


Figure BET-3. Time series of total annual catch (1000s mt) by fishing gear and assessment region for the diagnostic model over the full assessment period. The different colors refer to longline (green), pole-and-line (red), purse seine (blue), purse seine associated (dark blue), purse seine unassociated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

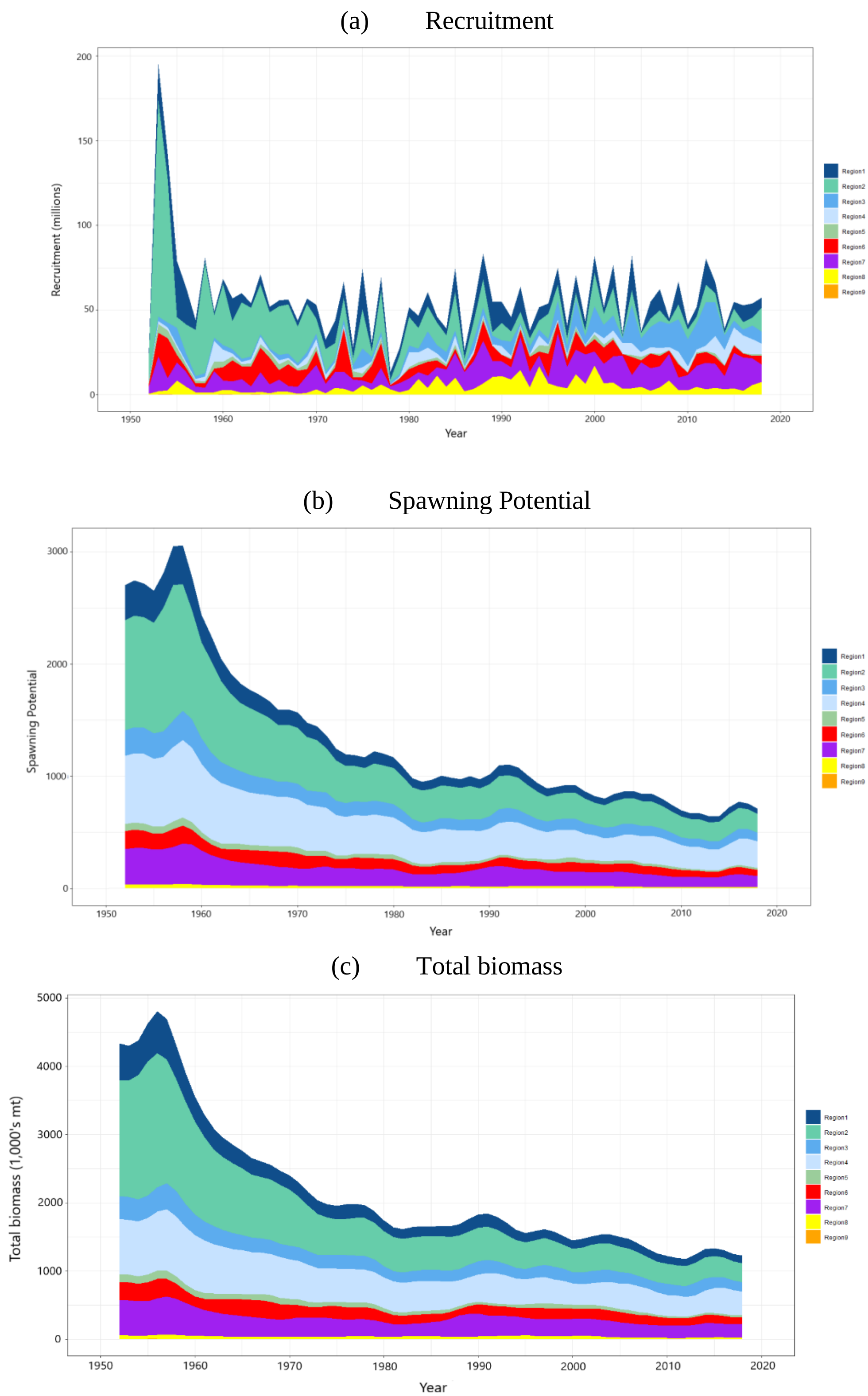


Figure BET-4. Estimated (a) annual average recruitment, (b) spawning potential and (c) total biomass by model region for the diagnostic model, showing the relative sizes among regions.

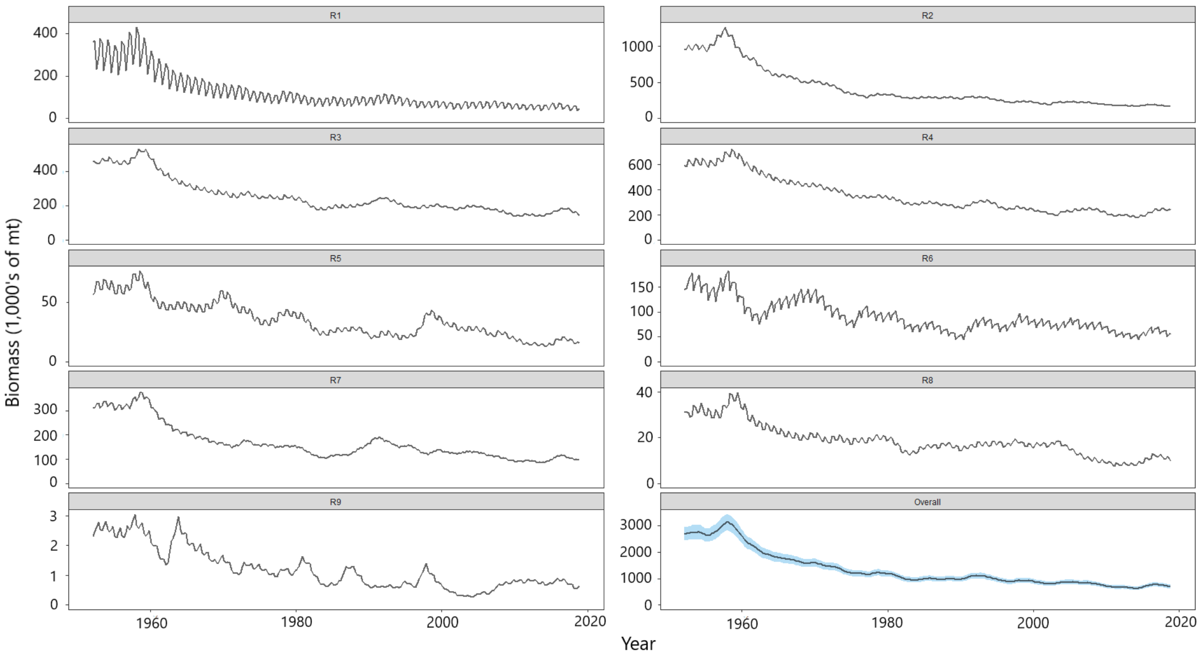


Figure BET-5. Estimated seasonal, temporal spawning potential by model region for the diagnostic model. The asymptotic 95% confidence interval as calculated using the delta-method is shown for the "Overall" region. Note that the scale of the y-axis is not constant across regions.

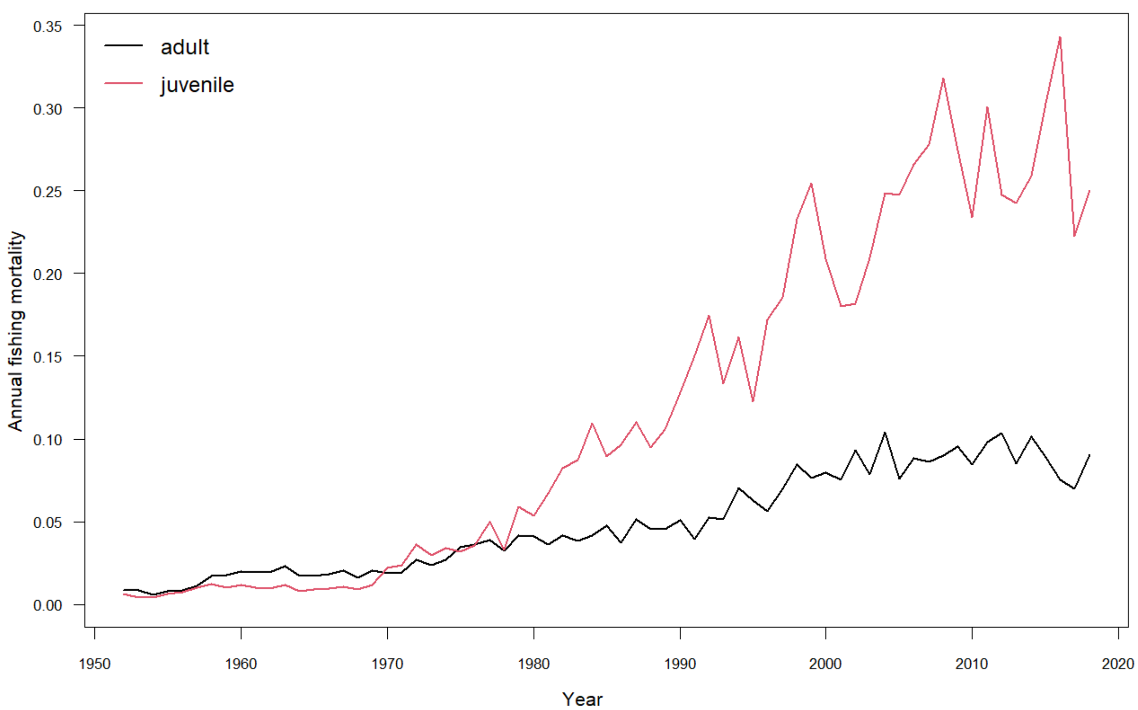


Figure BET-6. Estimated annual average juvenile and adult fishing mortality for the diagnostic model.

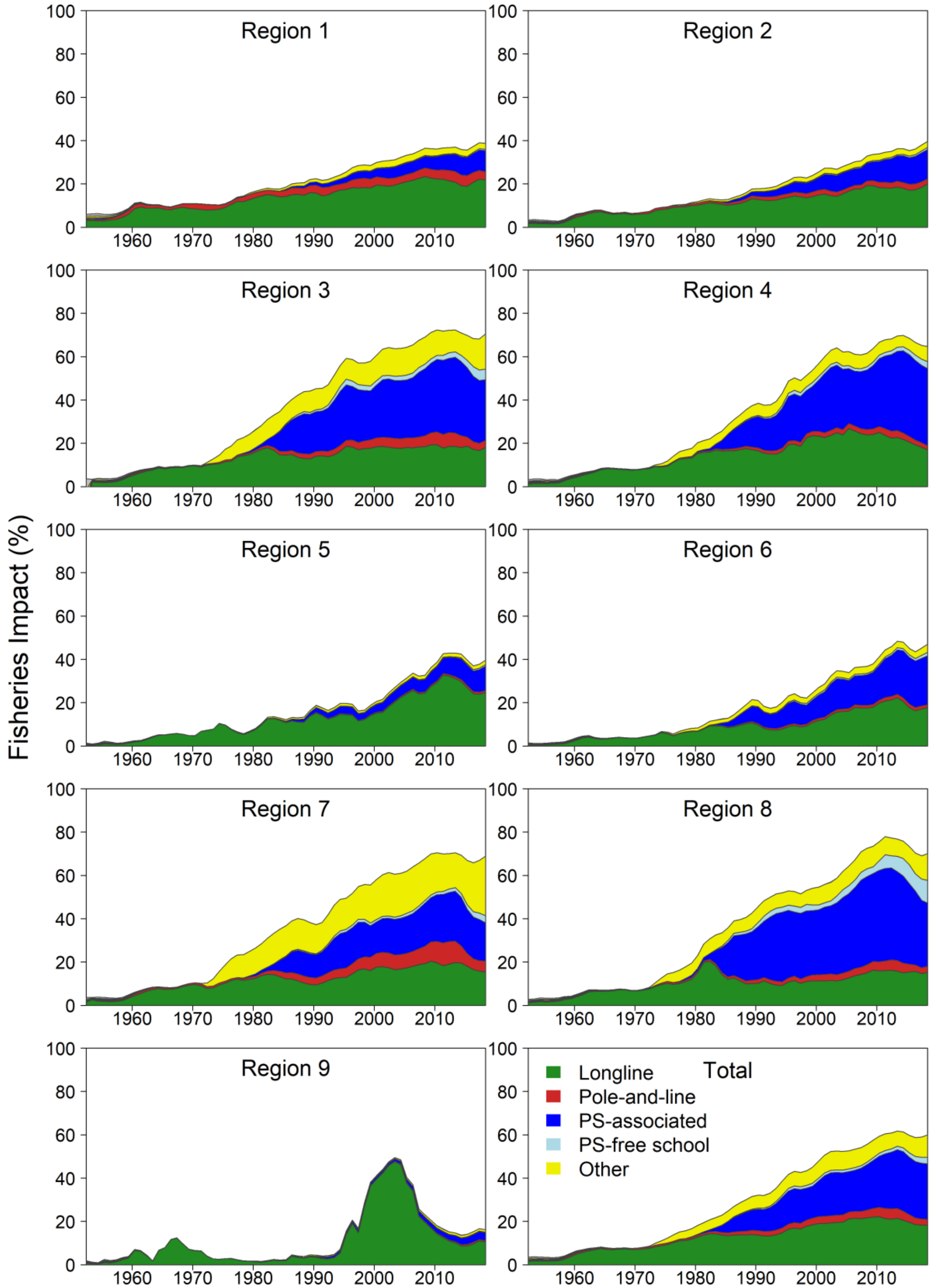


Figure BET-7. Estimates of reduction in spawning potential due to fishing (fishery impact = $(1-SB_t/SB_{t;F=0}) * 100\%$) by region, and over all regions (lower right panel), attributed to various fishery groups for the diagnostic model.

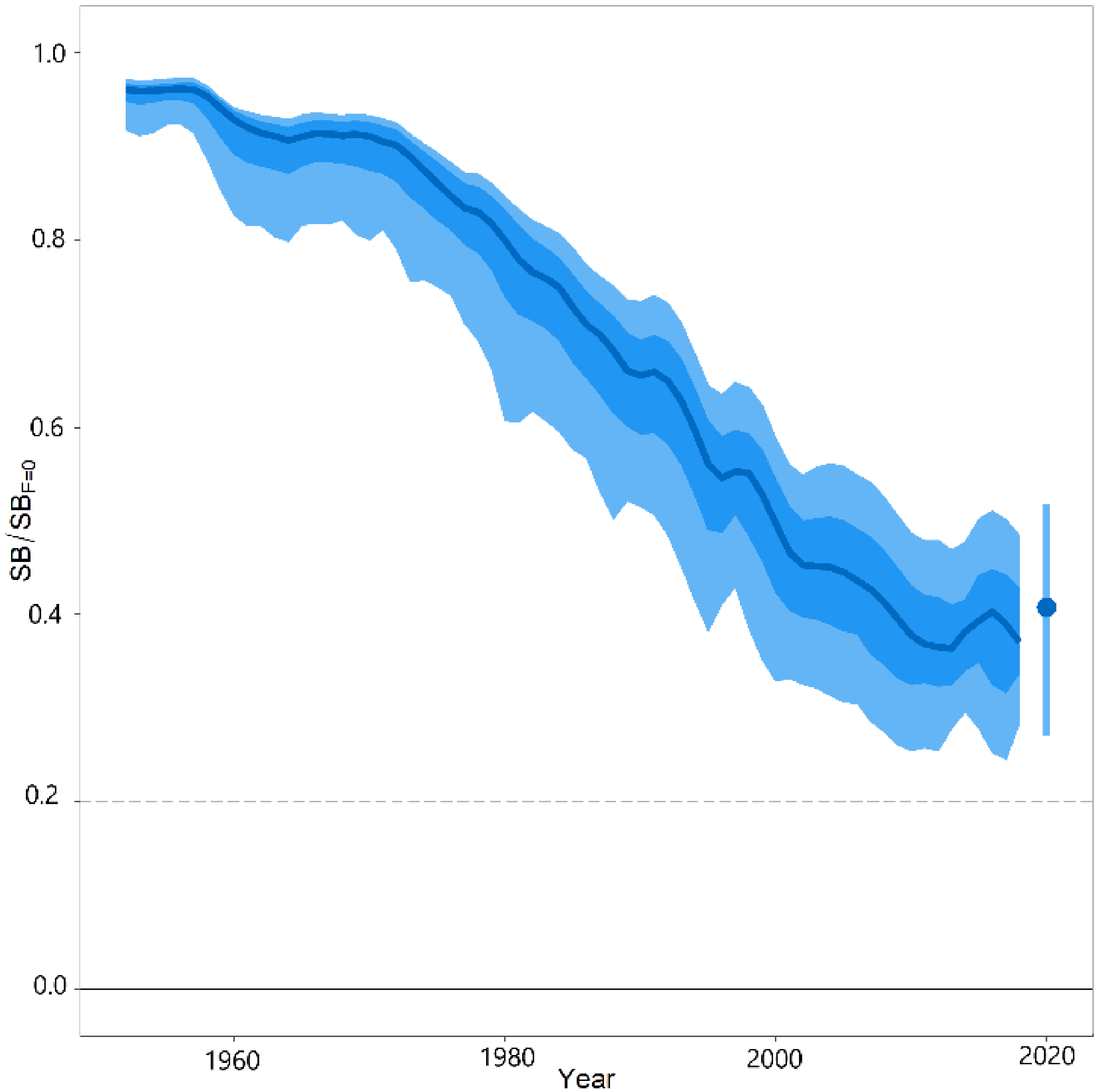


Figure BET-8. Time-dynamic percentiles of depletion ($SB_t/SB_{t;F=0}$) and median (dark line) across all 24 models in the structural uncertainty grid. The lighter band shows the 10th to 90th percentiles around the median, and the dark band shows the 50th percentile around the median. The median $SB_{recent}/SB_{F=0}$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

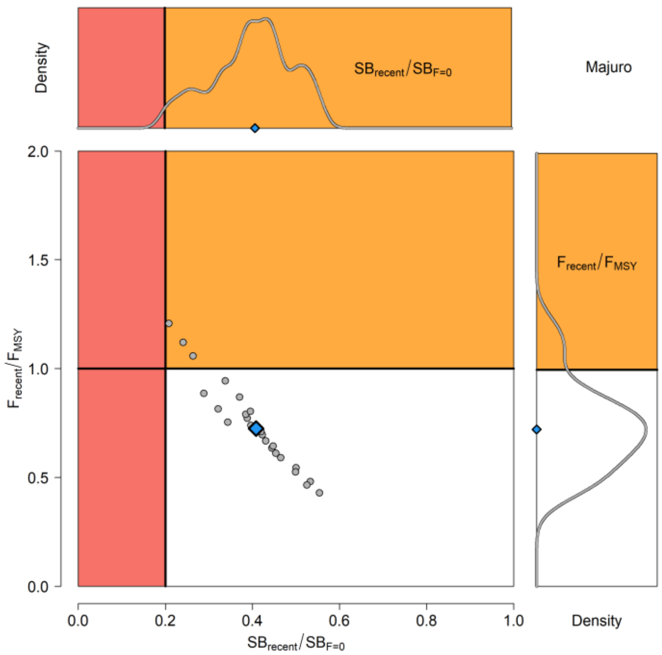


Figure BET-9. Majuro plot for the recent spawning potential (2015–2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality, and marginal distributions of each are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

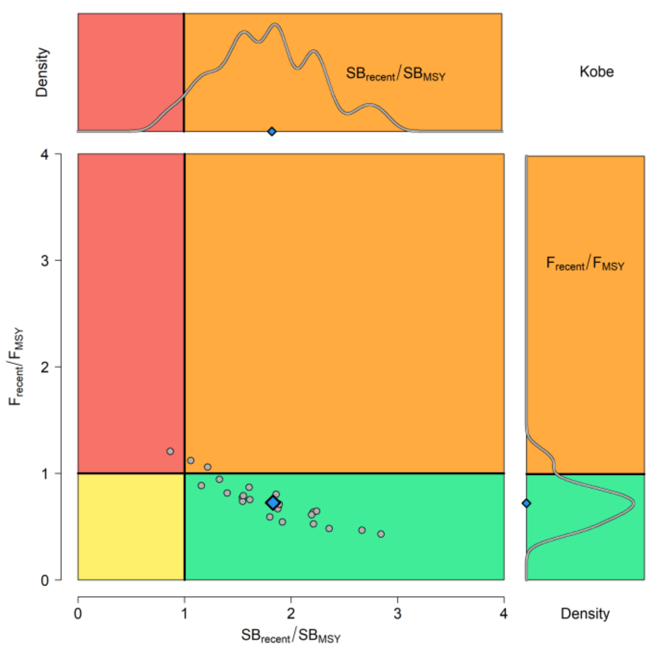


Figure BET-10. Kobe plot for the recent spawning potential (2015–2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality. Marginal distributions of each are presented.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

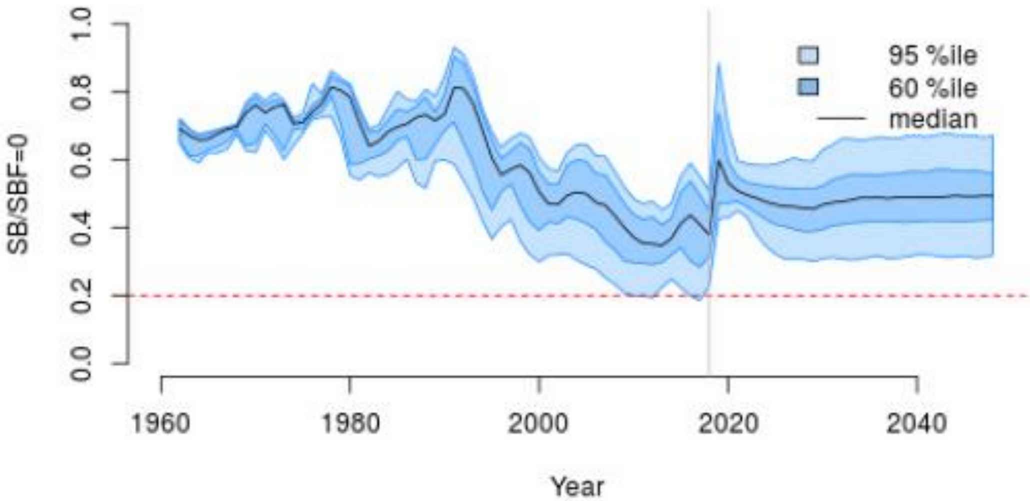


Figure BET-11. Time series of bigeye tuna spawning potential SB_t=$SB_{F=0}$, where $SB_{F=0}$ is the average SB from t-10 to t-1, relative to the current year t, from the uncertainty grid of assessment models for the period 2000 to 2018, and stochastic projection results for the period 2019 to 2048 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.

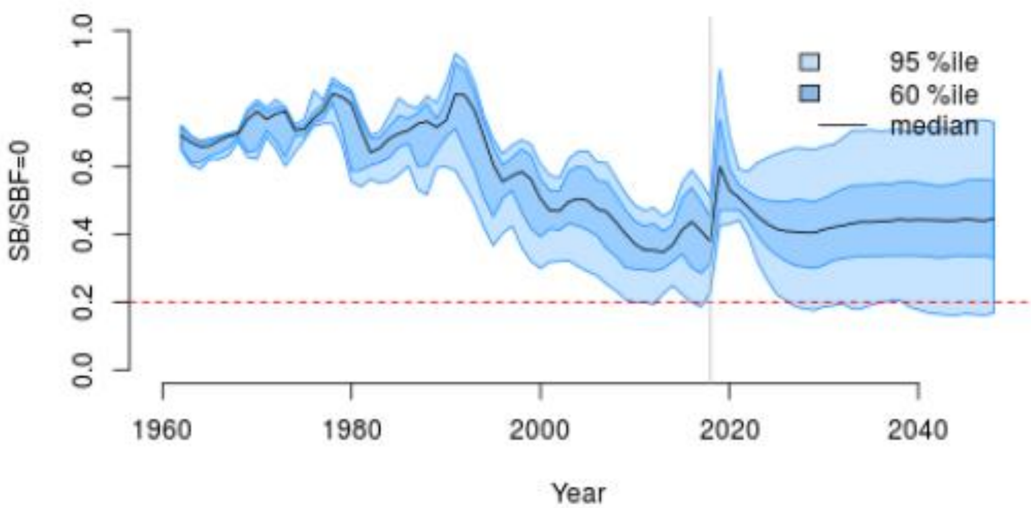


Figure BET-12. Time series of bigeye tuna spawning potential SB_t=$SB_{F=0}$, where $SB_{F=0}$ is the average SB from t-10 to t-1, relative to the current year t, from the uncertainty grid of assessment models for the period 2000 to 2018, and stochastic projection results for the period 2019 to 2048 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 ($SB_{2015-2018}$/ $SB_{F=0}$) 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 ($F_{2014-2017t}/F_{MSY}$) 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 $SB_{2025}/SB_{F=0}$ = 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
(Paragraphs 122 – 138, SC16 Summary Report)

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

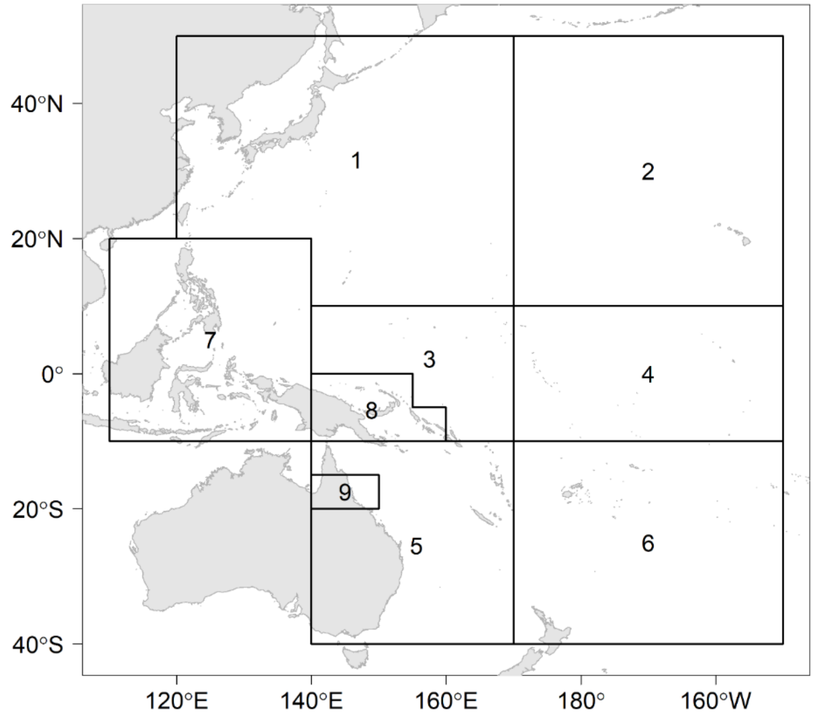


Figure YFT-1. The geographical area covered by the stock assessment and the boundaries for the 9 regions when using the "10N regional structure".

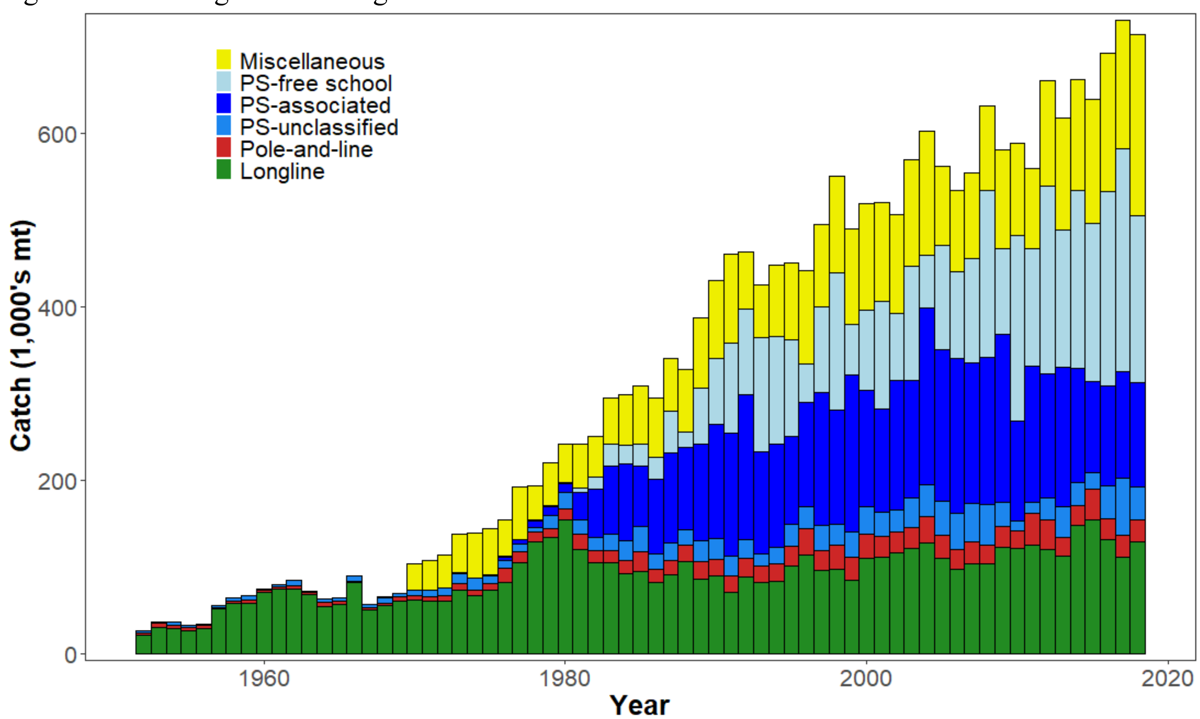


Figure YFT-2. Time series of total annual catch (1000s mt) by fishing gear over the full assessment region and time period. The different colours denote longline (green), pole-and-line (red), purse seine unclassified (blue), purse seine-associated (dark blue), purse seine-unassociated (light blue), miscellaneous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

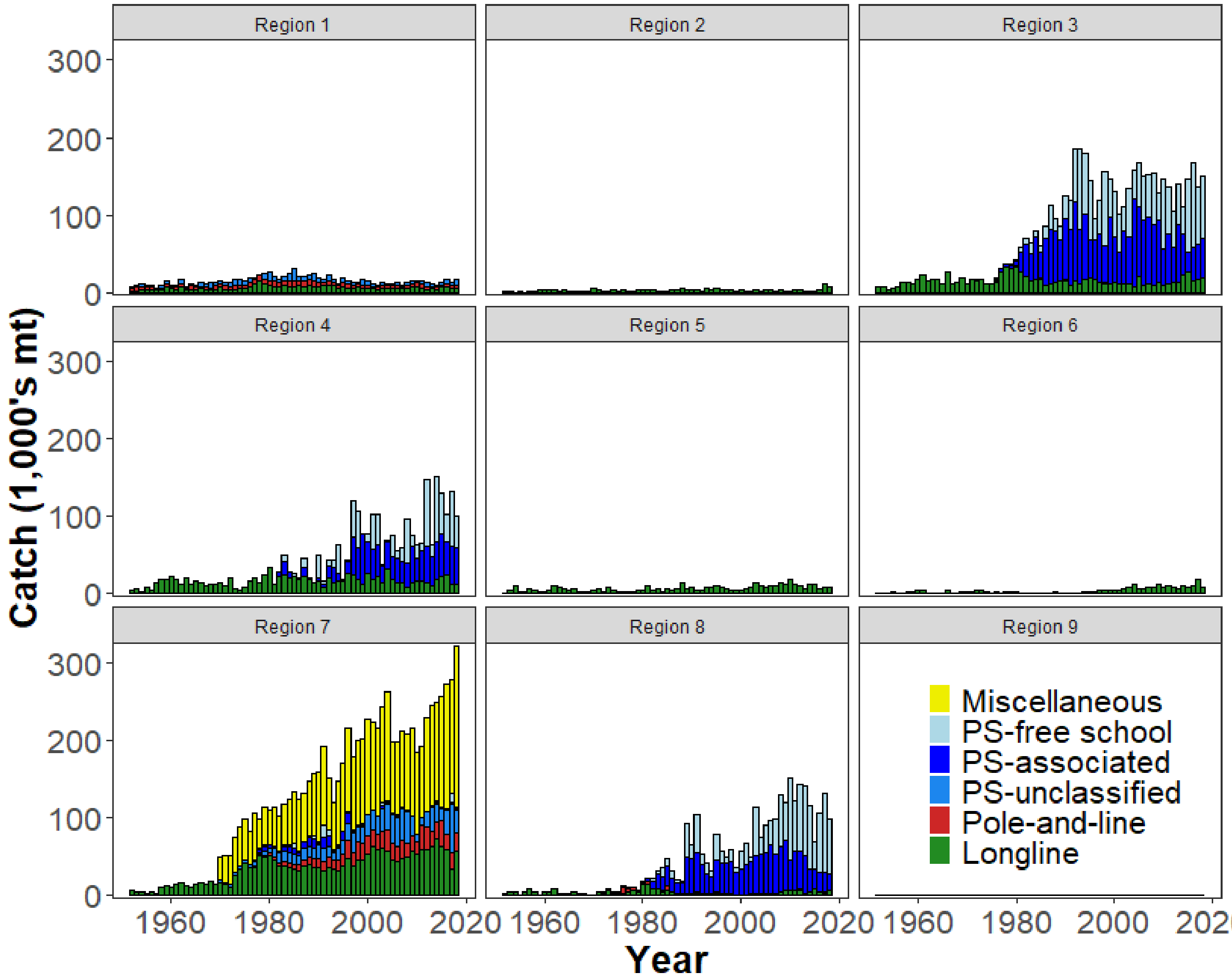


Figure YFT-3. Time series of total annual catch (1000s mt) by fishing gear and assessment region over the full assessment period. The different colours denote longline (green), pole-and-line (red), purse seine unclassified (blue), purse seine-associated (dark blue), purse seine-unassociated (light blue),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

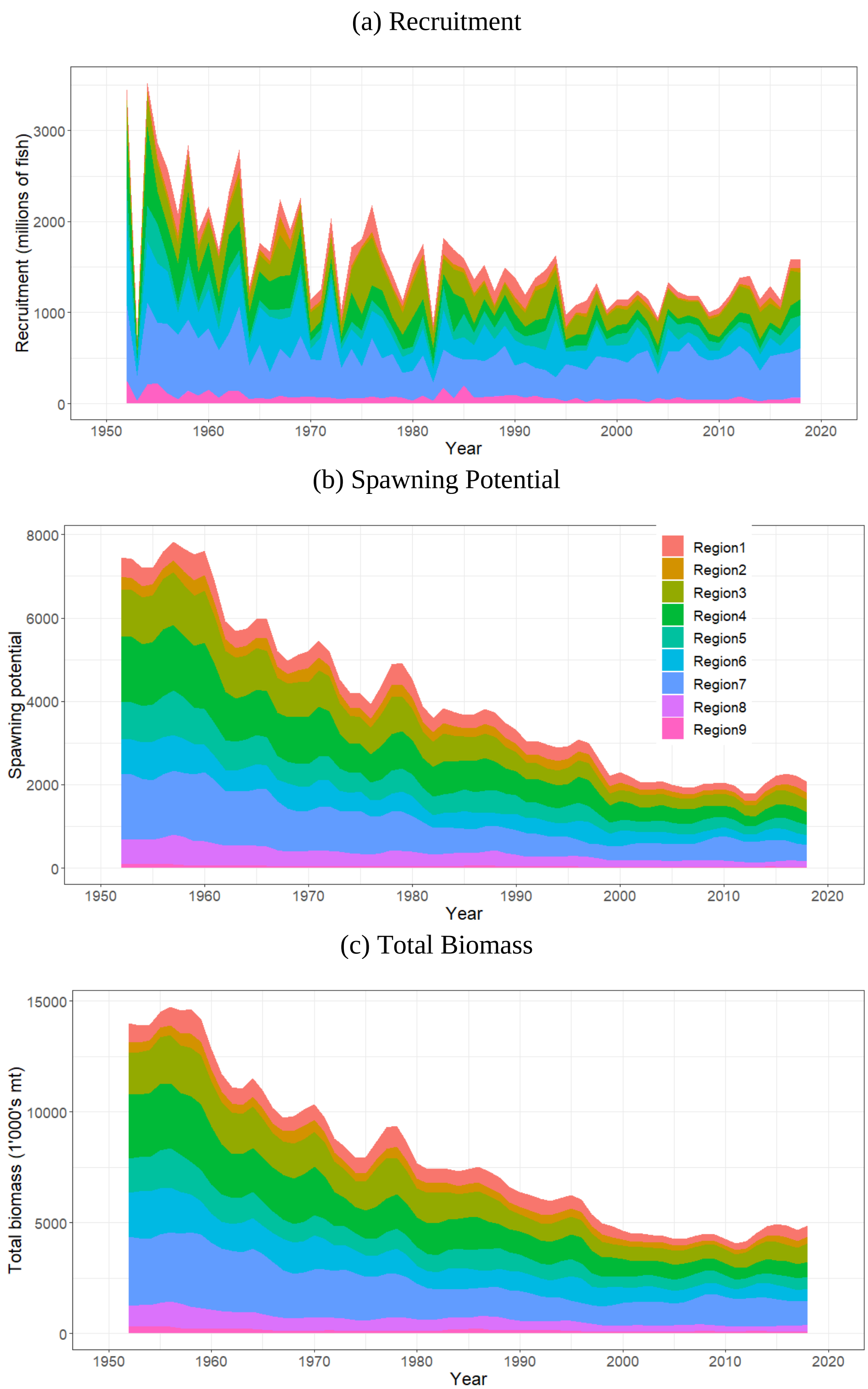


Figure YFT-4. Estimated annual average, (a) recruitment (b) spawning potential (c) total biomass by model region for the diagnostic model, showing the relative sizes among regions.

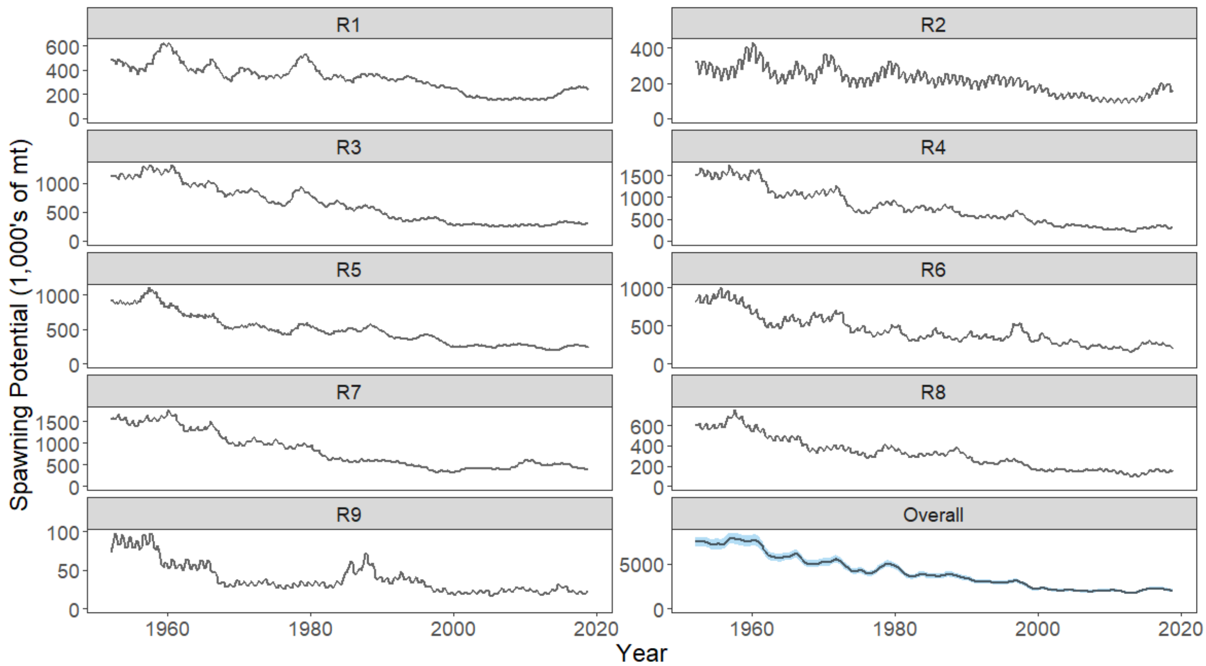


Figure YFT-5. The temporal trend in estimated spawning potential by model region for the diagnostic model, where the blue shaded region for the overall spawning potential shows the estimated 95% confidence interval based on statistical uncertainty estimated for the diagnostic model. Note that the y-axis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

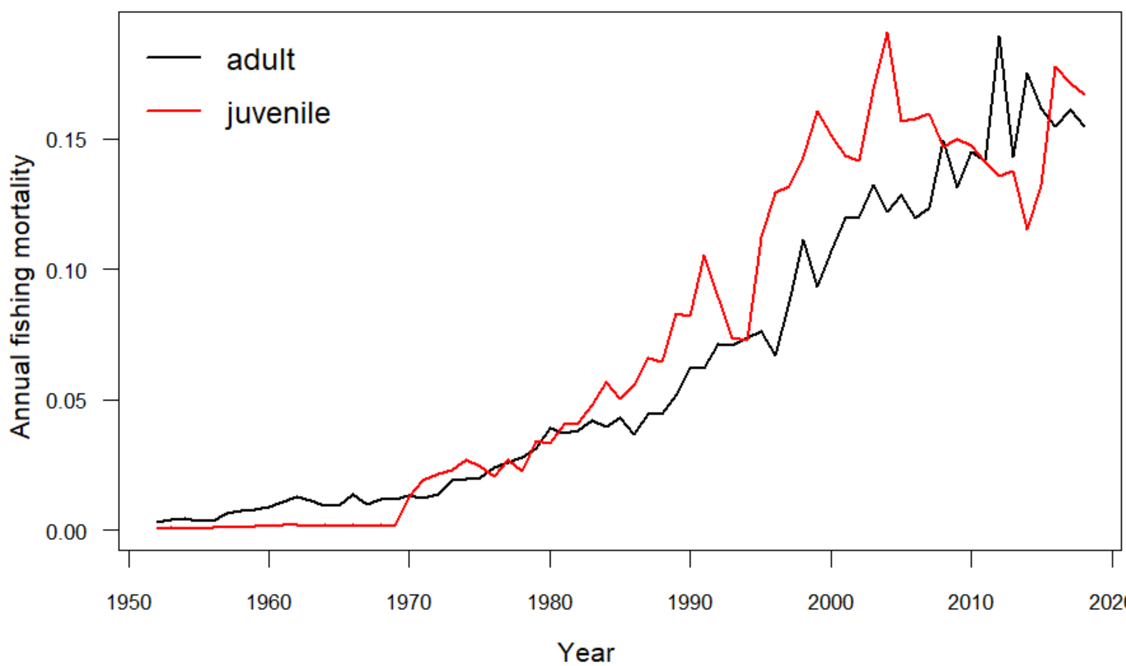


Figure YFT-6. Estimated annual average juvenile and adult fishing mortality for the diagnostic model.

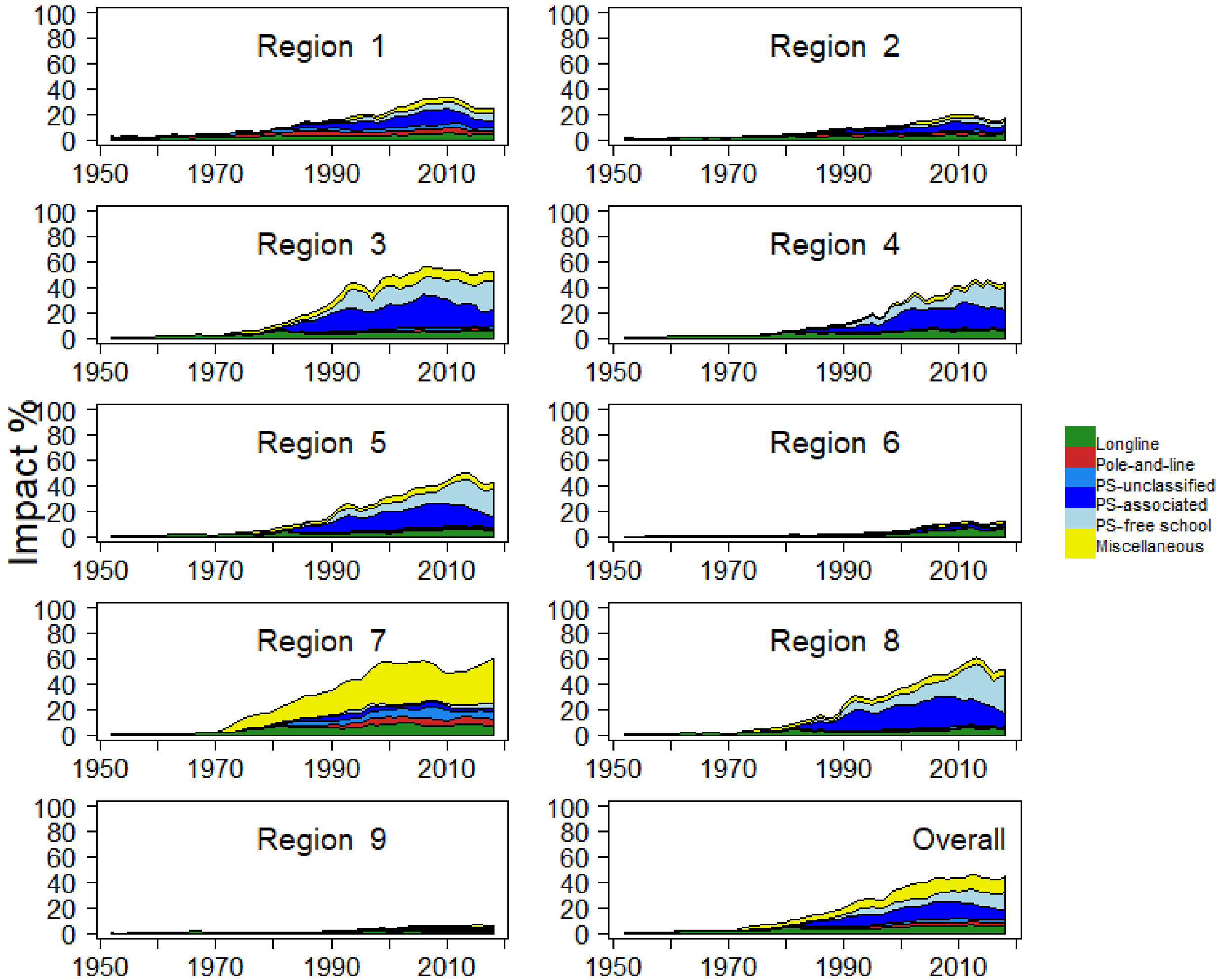


Figure YFT-7. Estimates of reduction in spawning potential due to fishing by region (Fishery Impact = $(1\text{-}SB_t/SB_{t;F=0}) * 100\%$) and over all regions (lower right panel), attributed to various fishery groups for the diagnostic model.

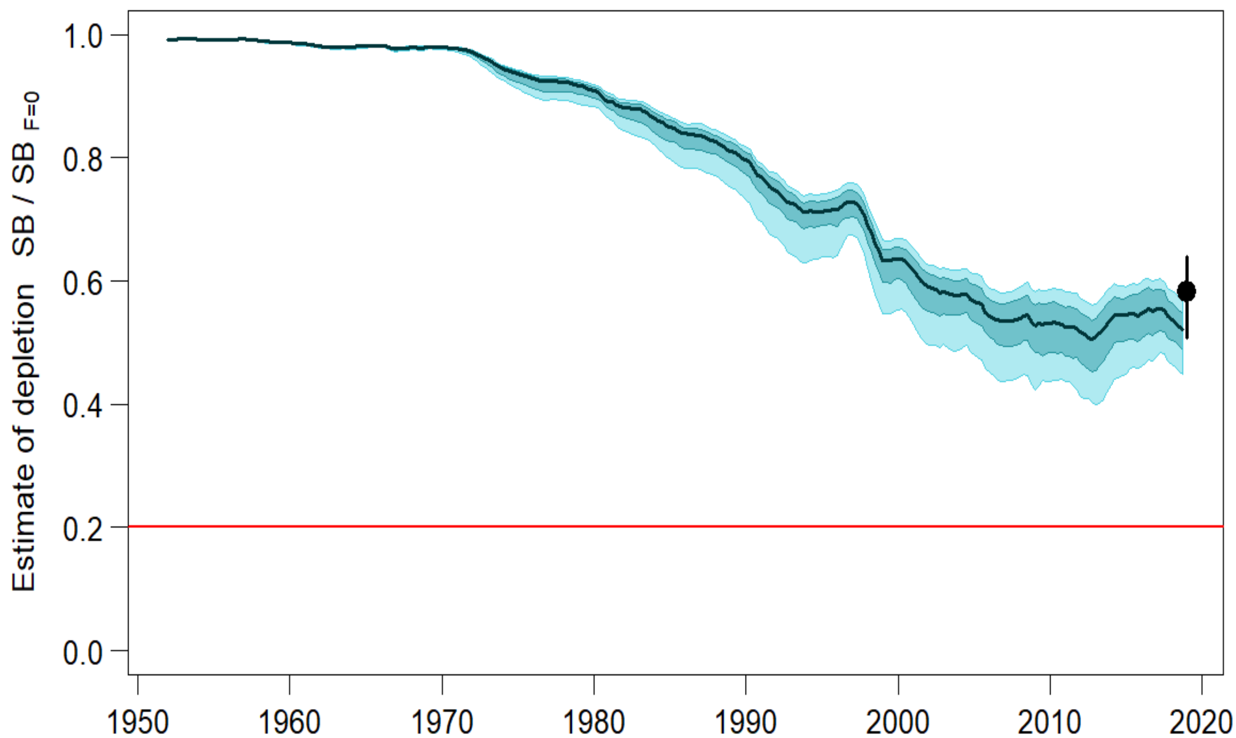


Figure YFT-8. Plot showing the trajectories of fishing depletion of spawning potential for the models in the structural uncertainty grid for the median, 50% quantile, and 80% quantile of instantaneous depletion across the structural uncertainty grid and the point and error bars is the median and 10th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

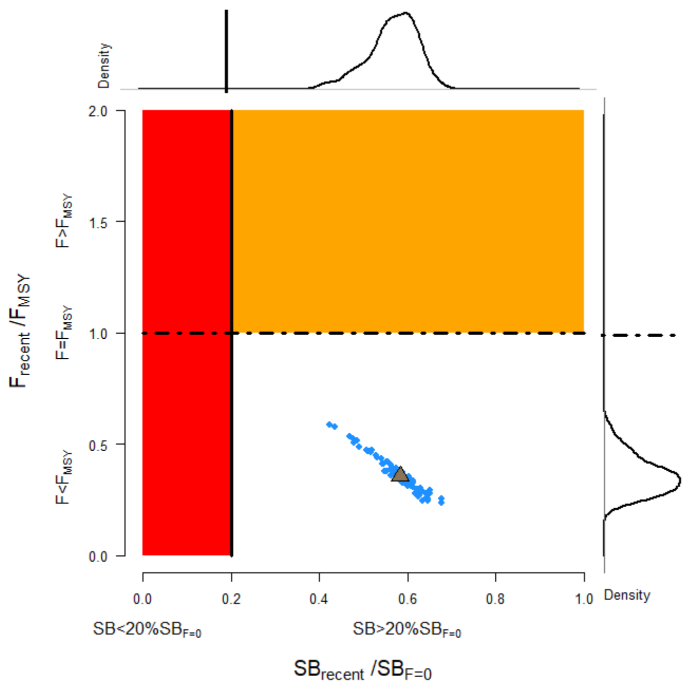


Figure YFT-9. Majuro plot representing stock status in terms of recent spawning potential depletion (2015–2018) and fishing mortality. The plots summarize the results for each of the models in the structural uncertainty grid with marginal distributions for spawning potential depletion and fishing mortality,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

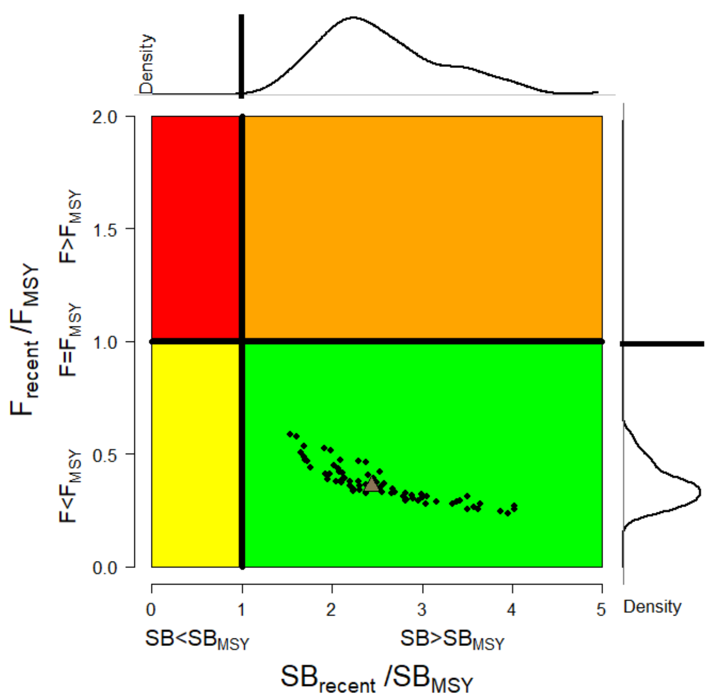


Figure YFT-10. Kobe plot for the recent spawning potential (2015–2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality relative to MSY quantities and marginal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

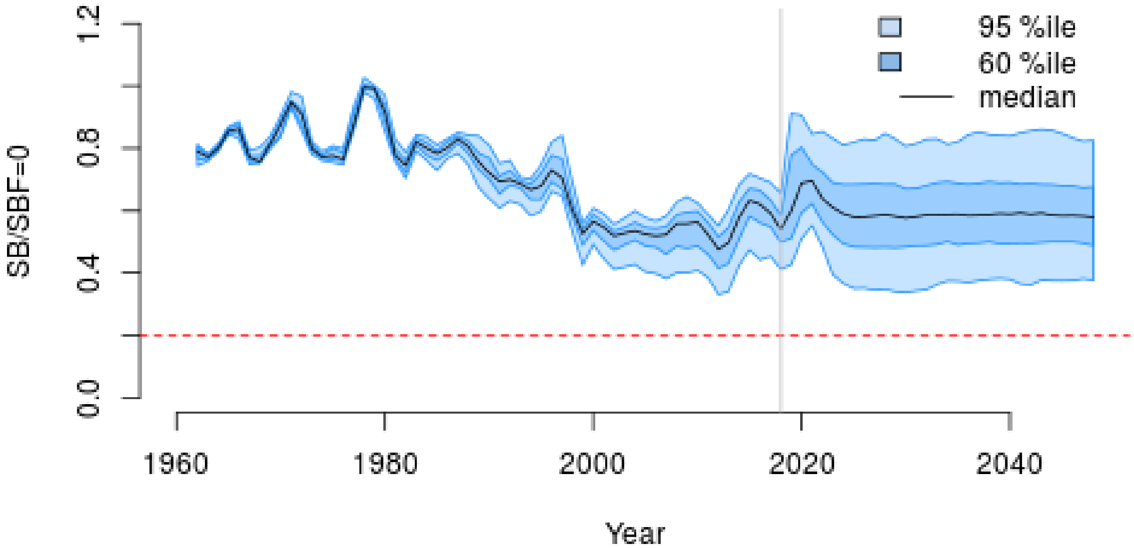


Figure YFT-11. Time series of yellowfin tuna spawning biomass ($SB_t/SB_{t,F=0}$, where $SB_{t,F=0}$ is the average SB from t-10 to t-1) from the uncertainty grid of assessment models for the period 2000 to 2018, and stochastic projection results for the period 2019 to 2048 assuming 2016-2018 average 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.
20.

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

(Paragraphs 210 – 223, SC15 Summary Report)

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	10^{th} %ile	90^{th} %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

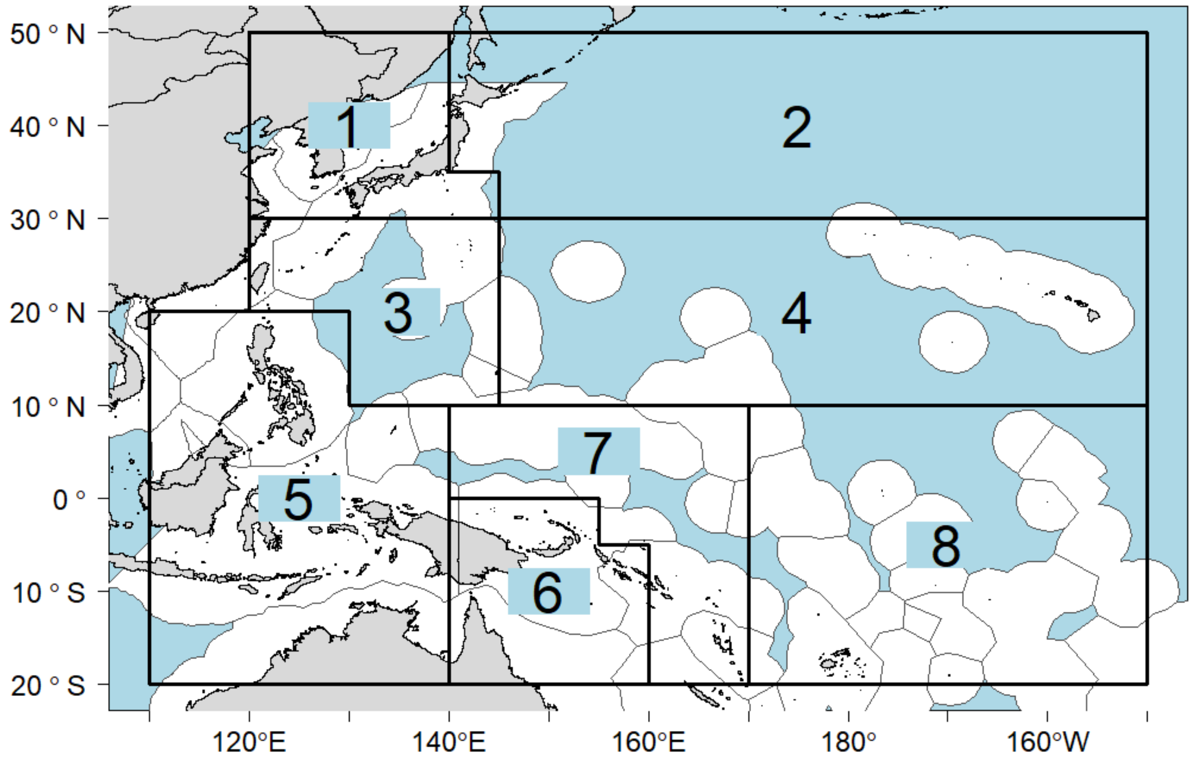


Figure SKJ-01. Eight region spatial structure used in the 2019 stock assessment model.

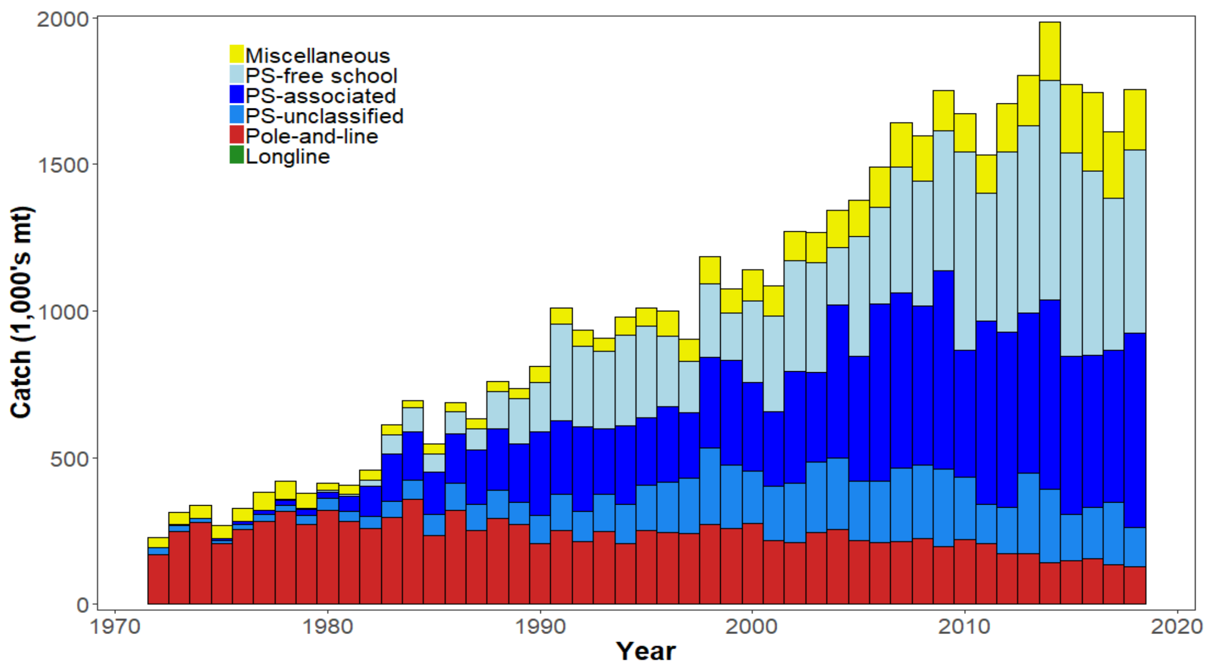


Figure SKJ-02. Time series of total annual catch (1000's mt) by fishing gear over the full assessment period.

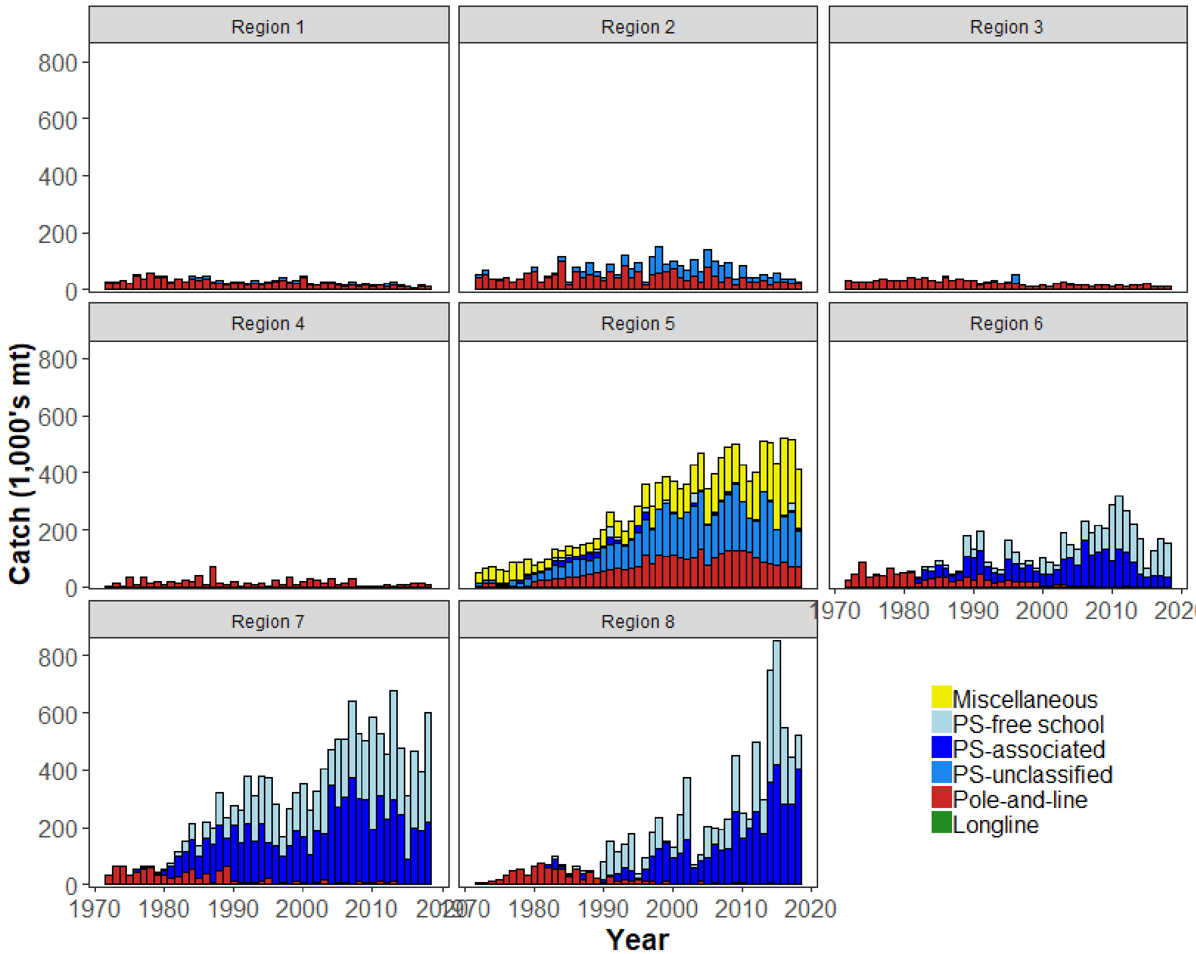
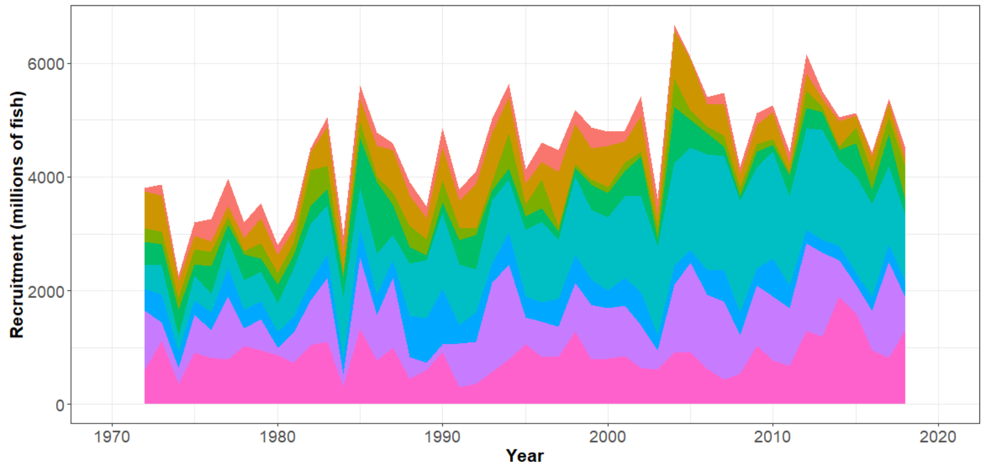
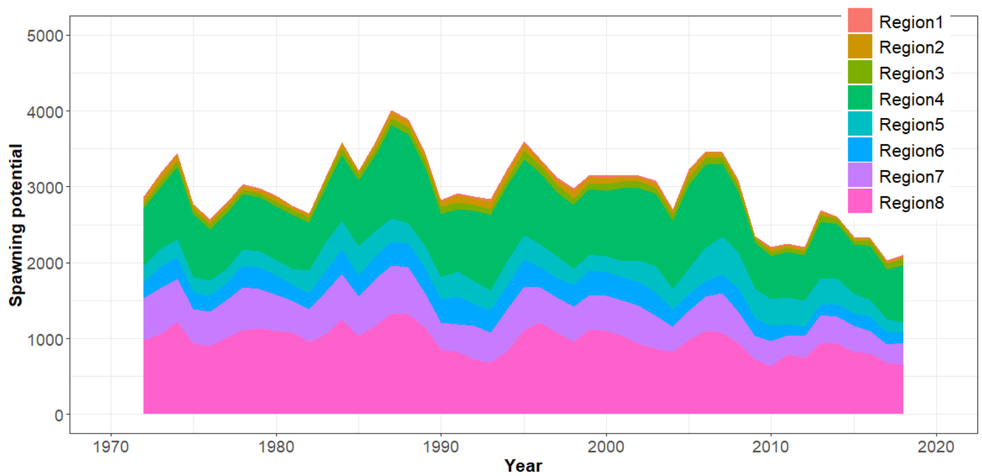


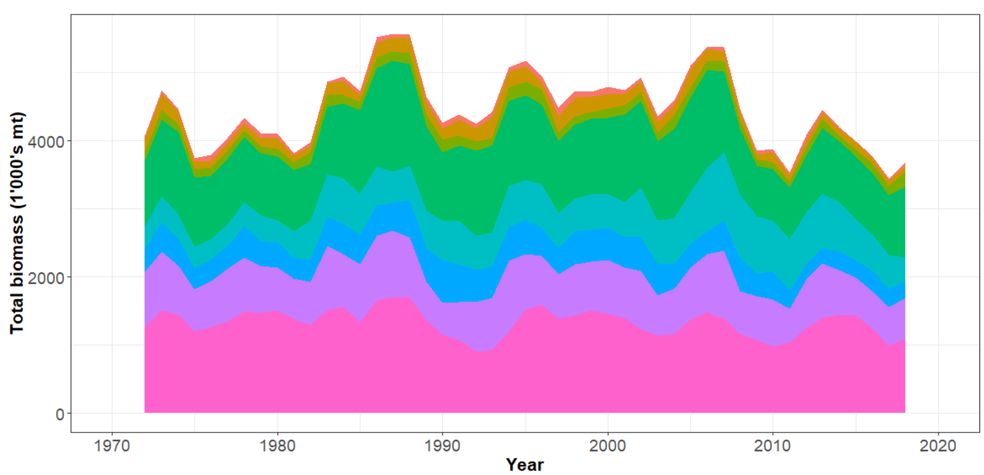
Figure SKJ-03. Time series of total annual catch (1000's mt) by fishing gear and assessment region over the full assessment period.



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.

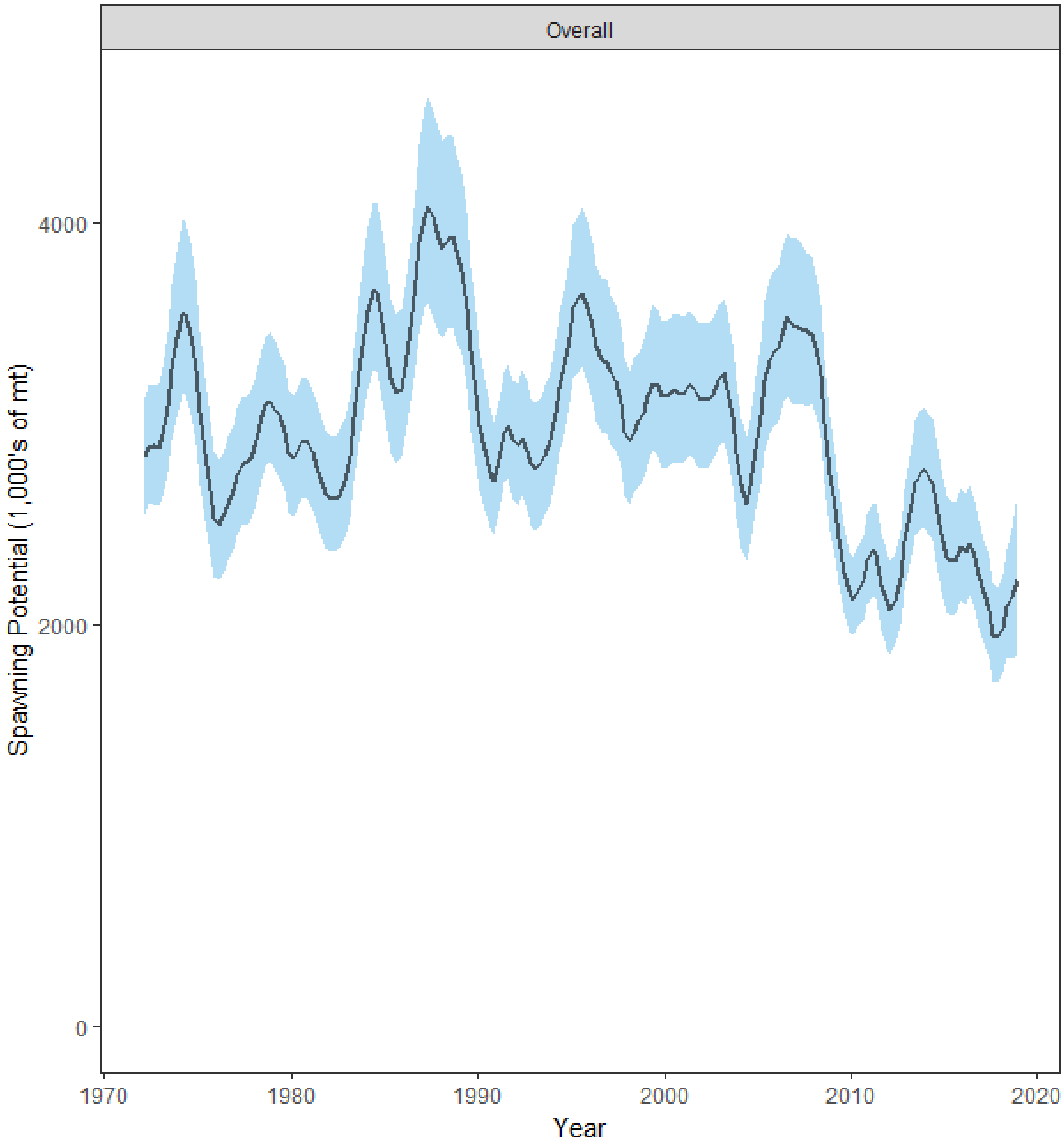


Figure SKJ-05. Estimated temporal overall spawning potential summed across regions from the diagnostic model, where the shaded region is ± 2 standard deviations (i.e., 95% CI).

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

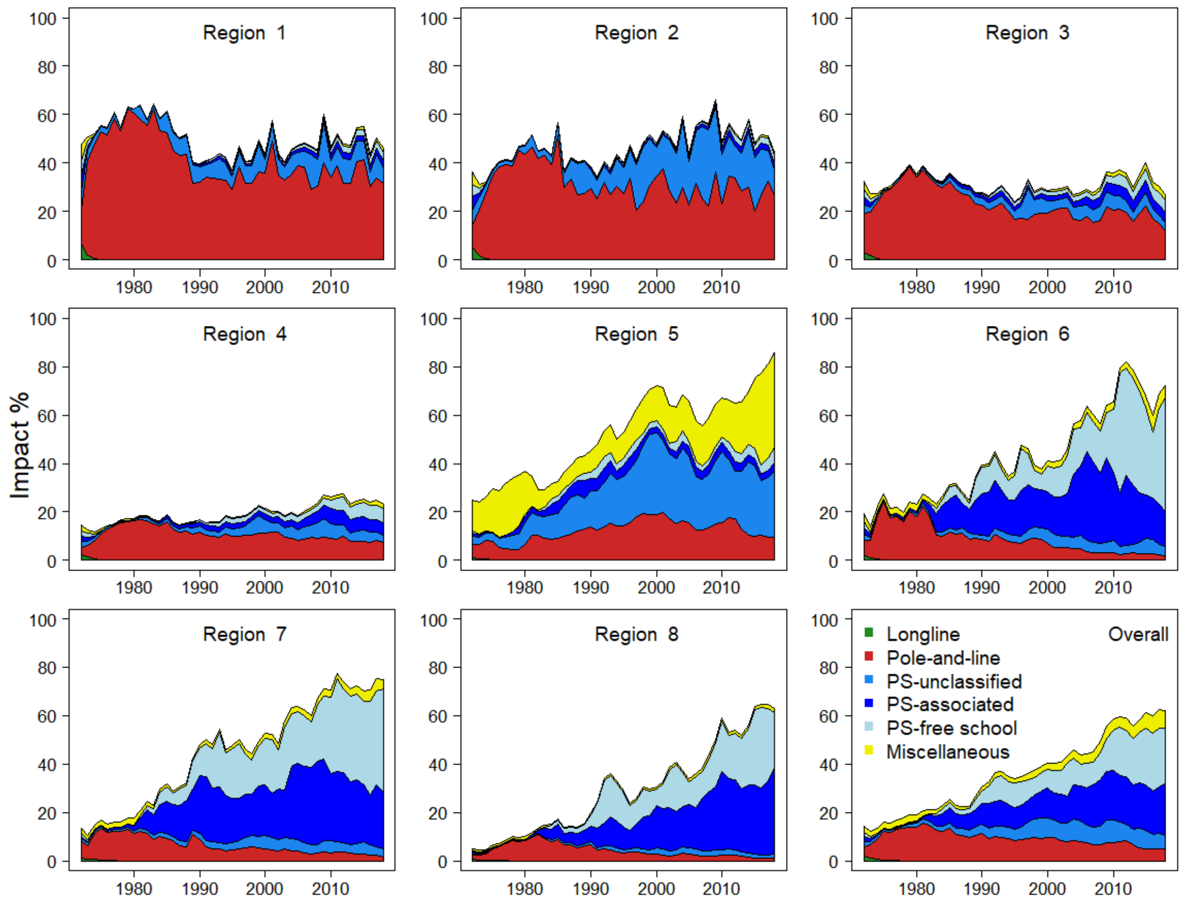


Figure SKJ-07. Estimates of reduction in spawning potential due to fishing (fishery impact = 1-SB_{latest}/$SB_{F=0}$) by region for the diagnostic model.

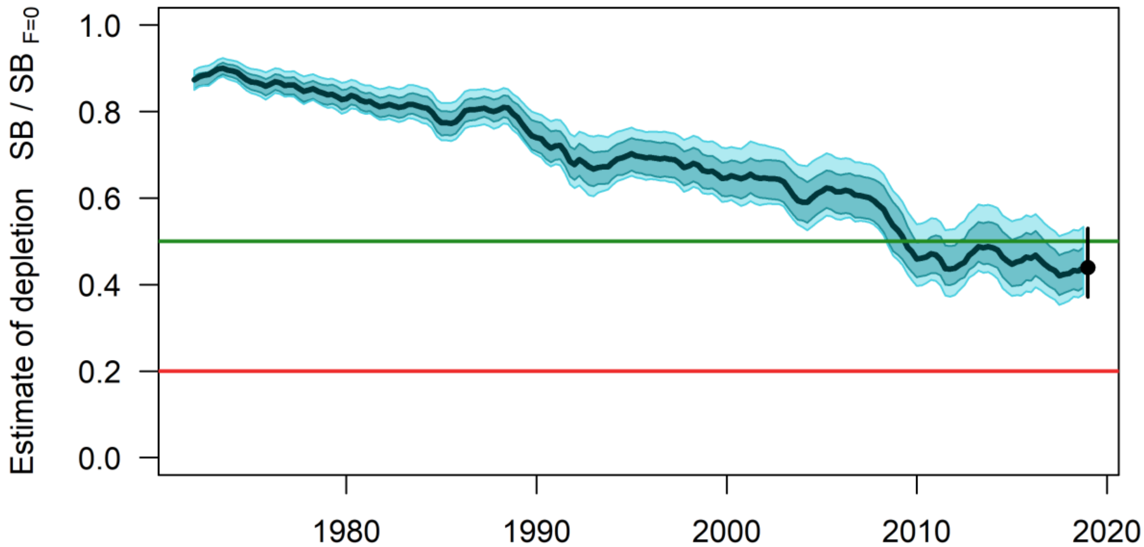


Figure SKJ-08. Plot showing the trajectories of spawning potential depletion for the model runs included in the structural uncertainty grid weighted by the values given in Table SKJ-01. Red horizontal line indicates the agreed limit reference point, the green horizontal line indicates the interim target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

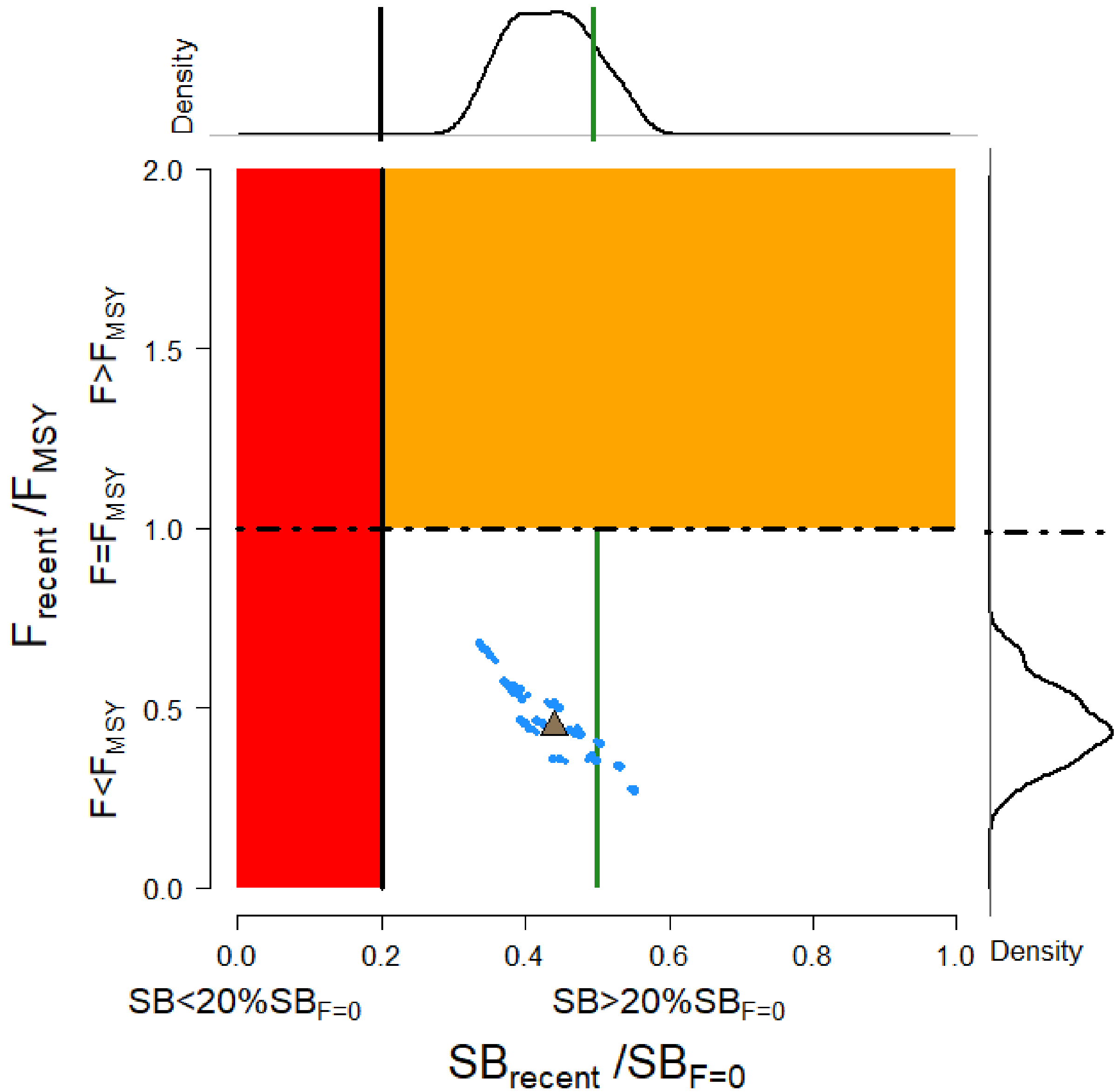


Figure SKJ-09. Majuro plot for the recent spawning potential (2015 – 2018) summarizing the results for each of the models in the structural uncertainty grid with weighting. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality, and marginal distributions 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.

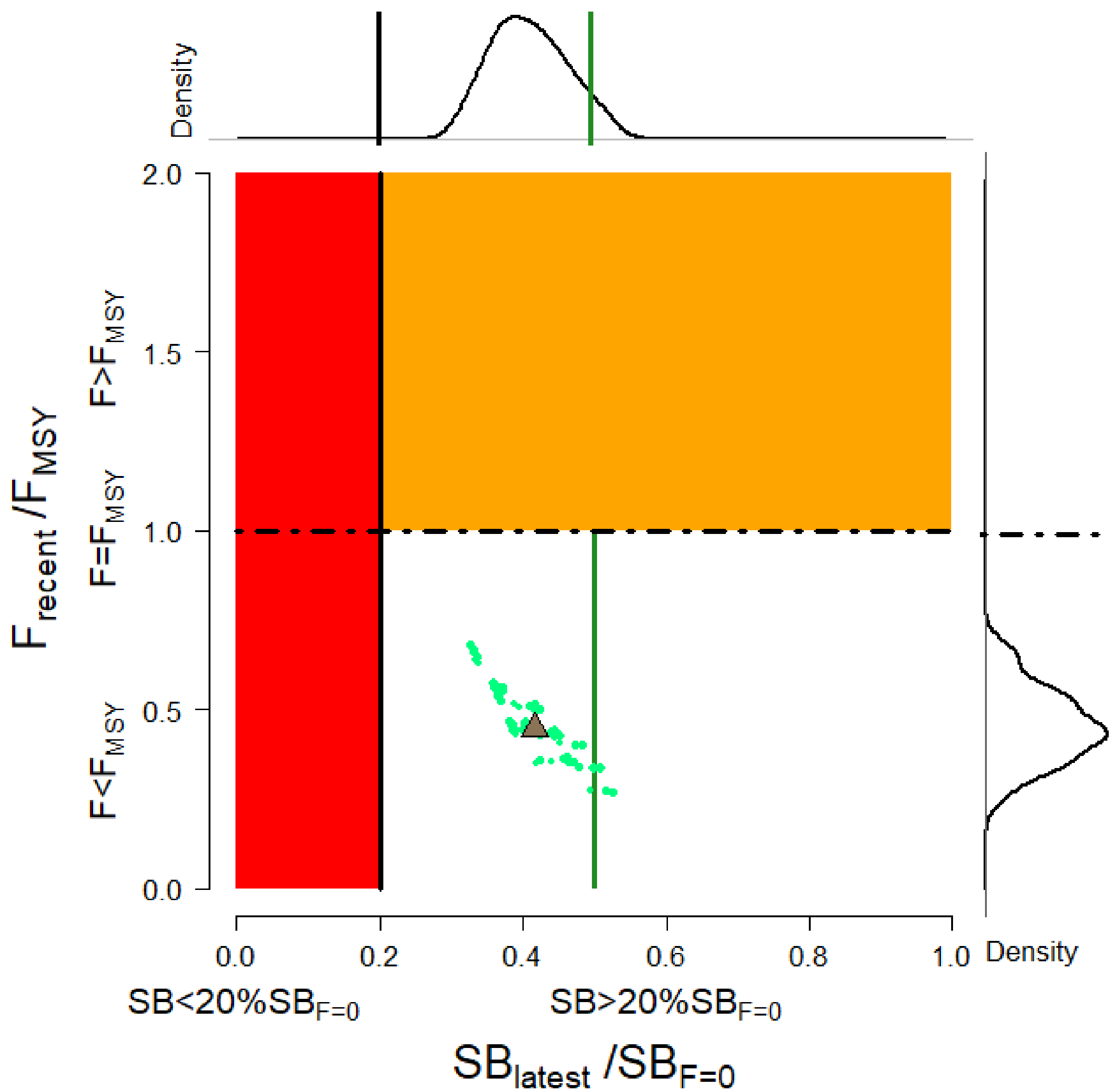


Figure SKJ-10. Majuro plot for the latest spawning potential (2018) summarizing the results for each of the models in the structural uncertainty grid with weighting. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality, and marginal distributions 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.

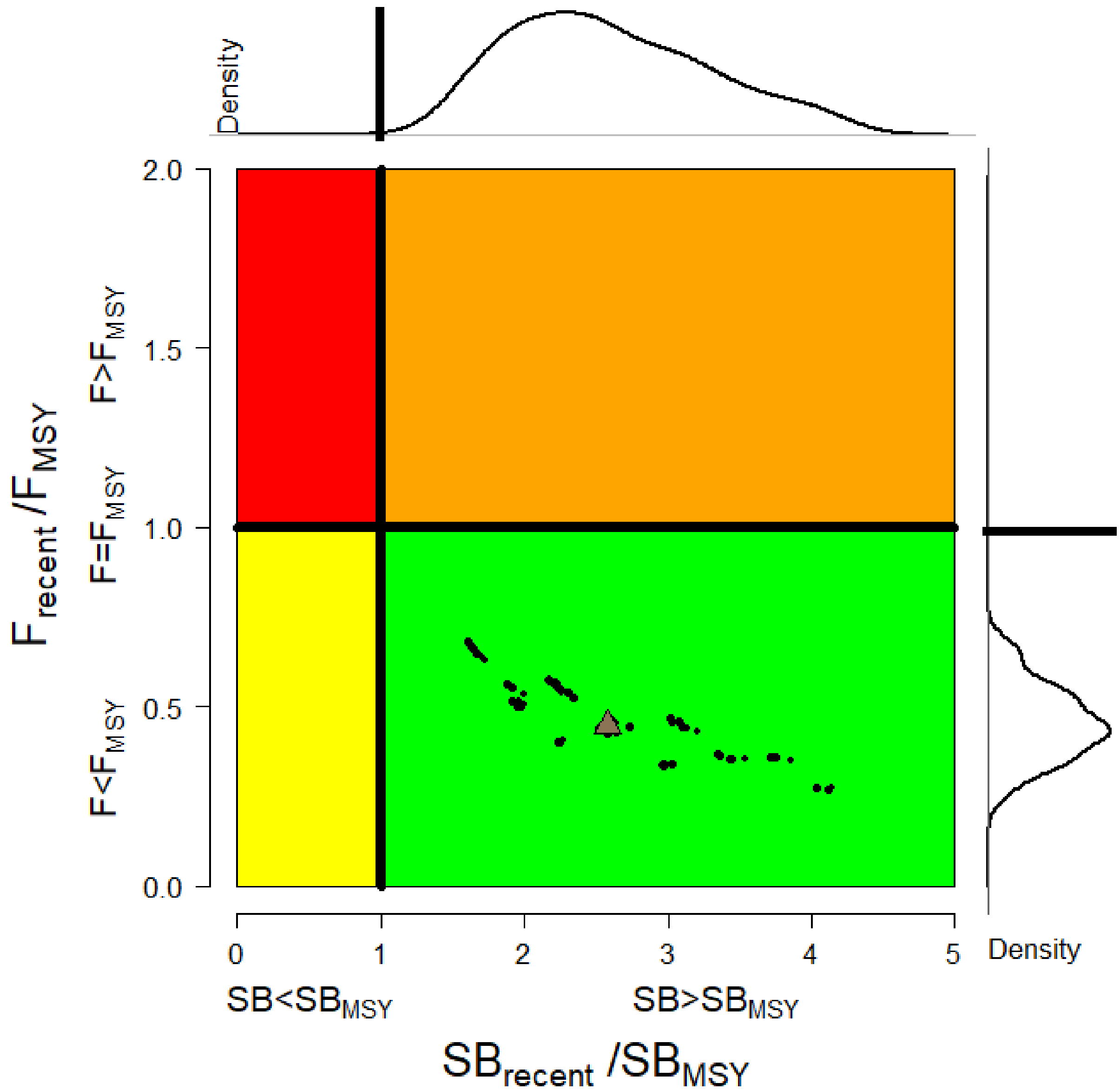


Figure SKJ-11. Kobe plot for the recent spawning potential (2015 – 2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality and marginal distributions of each are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

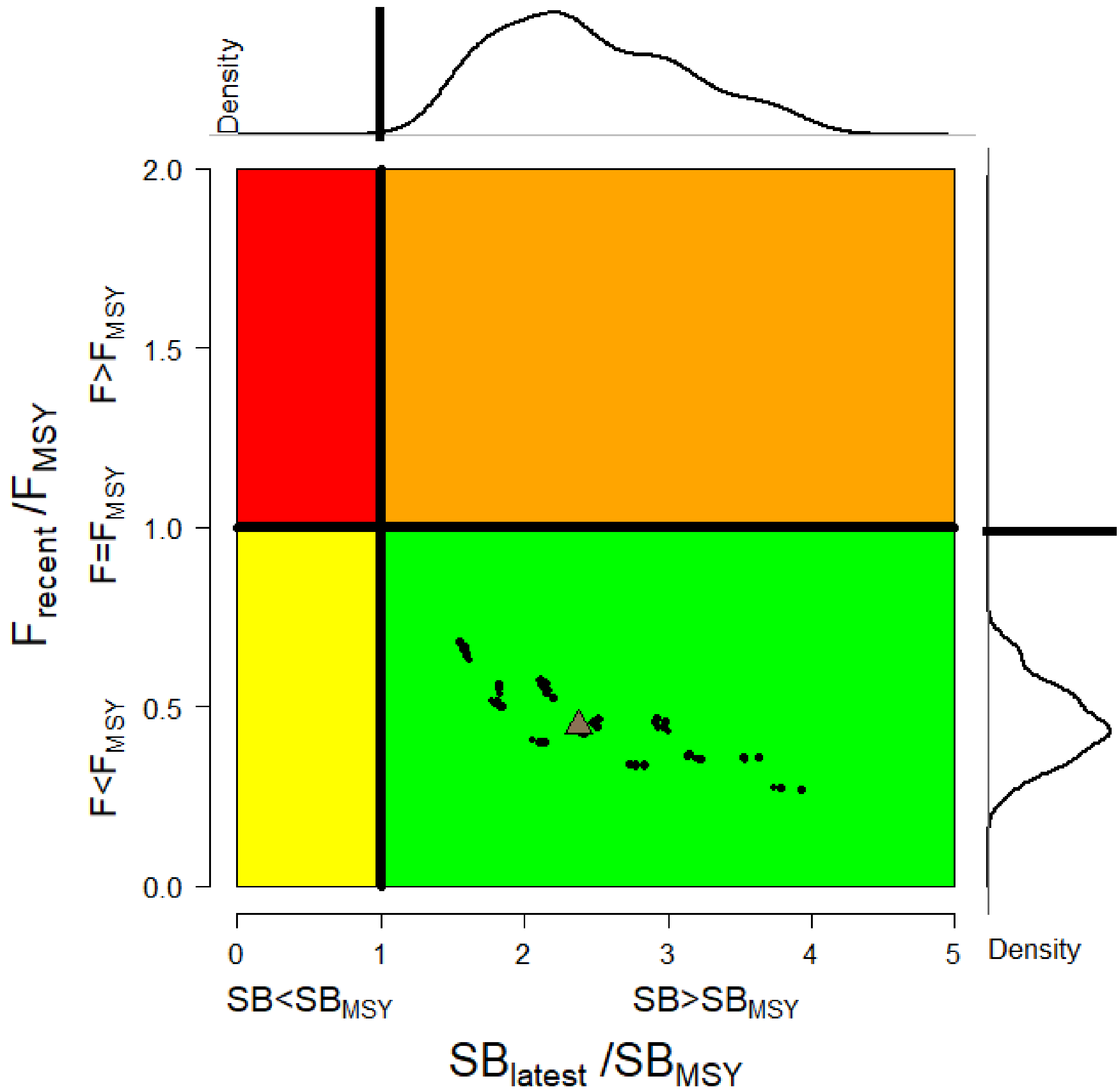


Figure SKJ-12. Kobe plot for the latest spawning potential (2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality and marginal distributions of each are presented. 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.