COMMISSION
SIXTEENTH REGULAR SESSION
Port Moresby, Papua New Guinea
5 - 11 December 2019

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

WCPFC16-2019-13
15 November 2019

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 the Technical and Compliance Committee (TCC) of relevance to the discussions in support of the review of CMM 2018-01 and the development of a harvest strategy framework for tropical tunas. This paper includes stock status and management advice for each species, the process of developing the WCPFC harvest strategy framework, and review of the effectiveness of CMM 2018-01 including FAD issues.

B. SCIENTIFIC COMMITTEE RECOMMENDATIONS

2. The following stock status and management advice are extracts from the SC15 Outcomes Document, with a brief summary for skipjack tuna from paragraphs 27 – 40. Refer to **Attachment 1 – 3** for the details of the latest stock assessments.

B1. STOCK STATUS AND MANAGEMENT ADVICE

BIGEYE TUNA
(*Paragraphs 14 – 19, SC15 Outcomes Document*)

a. Stock status and trends

3. SC15 noted that no stock assessment was conducted for WCPO bigeye tuna in 2019. Therefore, the stock status description from SC14 is still current. For further information on the stock status and trends from SC14, please see https://www.wcpfc.int/node/32155

4. SC15 noted that the total bigeye catch in 2018 was 145,402 mt, a 13% increase from 2017 and a 1% decrease from the average 2013-2017.

5. Longline catch in 2018 (71,305 mt) was a 23% increase from 2017 and a 7% increase from the 2013-2017 average. Purse seine catch in 2018 (64,119 mt) was a 10% increase from 2017 and a 4% increase from the 2013-2017 average. Pole and line catch (1,677 mt) was a 3% increase from 2017 and a 60% decrease from the average 2013-2017 catch. Catch by other gear (8,301 mt) was a 25% decrease from 2017 and 45% decrease from the average catch in 2013-2017.

6. SC15 noted that under recent fishery conditions, the bigeye stock is initially projected to increase as recent estimated recruitments support adult stock biomass. Adult stock biomass is then projected to decline slightly before again increasing. Projected fishing mortality is below F_{MSY} (median F_{2020}/F_{MSY} = 0.62, the risk of $F_{2020} > F_{MSY}$ = 0%) and projected median spawning biomass is above the LRP ($SB_{2020}/SB_{F=0}$ = 0.2) (median $SB_{2020}/SB_{F=0}$ = 0.41; median SB_{2020}/SB_{MSY} = 1.79. Risk that SB_{2020} < LRP = 0%). Projections are from the updated model runs of Vincent et al. (2018).

b. Management advice and implications

7. SC15 noted that no stock assessment has been conducted since SC14. Therefore, the advice from SC14 should be maintained, pending a new assessment or other new information. For further information on the management advice and implications from SC14, please see https://www.wcpfc.int/node/32155

c. Research Recommendations

8. SC15 reviewed progresses for the research recommendations from SC14 for bigeye growth and noted that the following research issues need to be addressed further, after classifying these research items as short-term (preferably before SC16) and long-term (preferably before the scheduled 2023 stock assessment).

a) Develop MULTIFAN-CL functionality that can accommodate spatial variation in growth rates and movement between western and eastern Pacific to consider the appropriateness of delineating the two stocks at 150˚W (long-term).
b) Carry out further otolith age validation studies for fish in the western and central Pacific. Consider chemically marking fish at release in future tagging programs and then analyzing otoliths from recaptured marked fish (long-term). Apply other age validation methodology including radiocarbon age validation (short to long-term). SC15 noted potential issues of the spatial pattern of radiocarbon in the Pacific Ocean and its implications for mobile adult tuna.
c) Continue to develop and document protocols for daily and annual ageing by IATTC and WCPFC (short-term).
d) Continue efforts under Project 94 to collect very small bigeye caught by the Indonesian, Vietnamese, and Philippines domestic fisheries in region 7 to aid in the estimation of the size at age-1 qtr-1 parameter (L1) within the assessment model (short to long-term).
e) Compile a high confidence tagging dataset for growth analysis and develop integrated growth models incorporating the tagging data and the otolith data (short-term).
f) Conduct sensitivity analysis using alternative growth models in the stock assessment, if new growth models are developed such as an integrated growth model (short -term), a conditional age-at-length growth model (short-term), and other growth models after conducting further growth analysis listed above.
g) Undertake a genetic stock structure analysis (long-term).

YELLOWFIN TUNA
(*Paragraphs 20 – 26, SC15 Outcomes Document*)

a. Stock status and trends

9. SC15 noted that no stock assessment was conducted for WCPO yellowfin tuna in 2019. Therefore, the stock status description from SC13 is still current. For further information on the stock status and trends from SC13, please see https://www.wcpfc.int/node/29904

10. SC15 noted that the total yellowfin catch in 2018 was 666,971 mt (the second highest catch on record), a 2% decrease from 2017 and a 9% increase from the average 2013-2017.

11. Purse seine catch in 2018 (374,062 mt) was a 22% decrease from 2017 and a 1% increase from the 2013-2017 average. Longline catch in 2018 (94,509 mt) was a 11% increase from 2017 and a 4% increase from the 2013-2017 average. Pole and line catch (12,201 mt) was a 1% decrease from 2017 and a 48% decrease from the average 2013-2017 catch. Catch by other gear (186,199 mt) was a 79% increase from 2017 and 51% increase from the average catch in 2013-2017.

12. SC15 noted that under recent fishery conditions, the yellowfin stock is initially projected to increase as recent estimated recruitments support adult stock biomass. Adult stock biomass is then projected to declines slightly before again increasing. Projected fishing mortality is below F_{MSY} (median $F_{2020}/F_{MSY} = 0.74$, the risk of $F_{2020} > F_{MSY} = 3\%$) and projected median spawning biomass is above the LRP ($SB_{2020}/SB_{F=0} = 0.2$) (median $SB_{2020}/SB_{F=0} = 0.32$; median $SB_{2020}/SB_{MSY} = 1.33$. Risk that $SB_{2020} < LRP = 8\%$).

b. Management advice and implications

13. SC15 noted that no stock assessment has been conducted since SC13. Therefore, the advice from SC13 should be maintained, pending a new assessment or other new information. For further information on the management advice and implications from SC13, please see https://www.wcpfc.int/node/29904

c. Research Recommendations

14. SC15 encouraged the continuation of project 82 on yellowfin tuna age and growth for the next stock assessment.

15. SC15 noted that the following research issues need to be addressed for yellowfin tuna after classifying these research items as short-term (preferably before SC16) and long-term (preferably before the scheduled 2023 stock assessment).

- i) Carry out further otolith age validation studies for yellowfin in the western and central Pacific such as applying radiocarbon age validation (short to long-term).
- ii) Compile a high confidence tagging dataset for growth analysis and develop an integrated growth model incorporating the tagging data and the otolith data (short-term).
- iii) Continue to develop and document protocols for daily and annual ageing by IATTC and WCPFC (short-term).

SKIPJACK TUNA
(*Paragraphs 27 – 40, SC15 Outcomes Document*)

a. Stock status and trends

16. SC15 reviewed the 2019 WCPO skipjack tuna stock assessment conducted by SPC using the 8-region model over an uncertainty grid of 54 models.

17. 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.

18. 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. SC15 also 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}.

b. Management advice and implications

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

20. 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.

21. 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

22. 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;
  v) attempting to provide finalized catch estimates to SPC no later than June 1st.

B2. DEVELOPMENT OF HARVEST STRATEGY FRAMEWORK

TARGET REFERENCE POINTS

a. Yellowfin and bigeye tuna (Paragraphs 114 – 116, SC15 Outcomes Document)

23. SC15 reviewed information on what would be the minimum setting for a candidate spawning-biomass-depletion-based TRP (or maximum fishing-mortality-based TRP) for yellowfin and bigeye tuna that avoids breaching the LRP with a specified level of probability under the current uncertainty framework (SC15-MI-WP-01). While SC15 noted that the main biological consideration for a TRP is that it should be sufficiently above the LRP, SC15 also noted that the choice of a TRP can be based on a combination of biological, ecological and socioeconomic considerations. In this regard consideration of other factors (such as CPUE and the financial performance of typical vessels) in the selection of candidate TRPs would be welcome.

24. SC15 welcomed the consideration of multi-species impacts based on the selection of a minimum TRP based on a given risk of exceeding the LRP for a given species, and whilst desirable noted the difficulty in extending this analysis to include the impact on South Pacific albacore.

25. SC15 recommends that the Science Service Provider update the analysis to incorporate the updated assessment for skipjack, and that WCPFC16 take note of these results when identifying appropriate TRPs for yellowfin tuna and bigeye tuna in 2019 as scheduled in the Harvest Strategy Work Plan. In so doing WCPFC16 should clarify the management objectives for these species.

b. Skipjack tuna (Paragraphs 120 – 122, SC15 Outcomes Document)

26. As requested in the Harvest Strategy Work plan (SC to advise on required analyses to support TRP review), SC15 provided the following advice to the Science Service Provider on technical approaches and analyses which should be undertaken to assist WCPFC16 review the performance of the interim skipjack tuna TRP.

- Table 4 in SC15-MI-IP-09 (*Current and projected stock status of skipjack to inform consideration of target reference points*, MOW3-WP-03) be updated based on the updated skipjack tuna assessment agreed by SC15. This table should indicate changes in effort and biomass from 2012 and the recent levels and median equilibrium yield (as a proportion of MSY) associated with strategies that maintain a median of spawning biomass depletion ($SB/SB_{F=0}$) of 40%, 45%, 50%, and 55%.
- The projection results for skipjack tuna reported in SC15-MI-WP-11 also be updated based on the updated skipjack tuna assessment agreed by SC15.

27. SC15 recommends that WCPFC16 take into consideration the information contained in these updated analyses when reviewing the performance of the interim skipjack tuna TRP.

28. SC15 also notes that WCPFC16 may identify a reference year, or set of years, which may be appropriate to use as a baseline for a skipjack TRP

HARVEST CONTROL RULES AND MANAGEMENT STRATEGY EVALUATION

a. Review of harvest control rules for skipjack tuna (Paragraphs 123 – 128, SC15 Outcomes Document)

29. SC15 reviewed several papers related to ongoing work which is being undertaken by the Scientific Services Provider as specified in the Harvest Strategy Work Plan on the management strategy evaluation (MSE) framework for skipjack.

30. First, SC15 reviewed information on the outputs for the skipjack harvest strategy and the work undertaken to test candidate MPs based upon the latest MSE framework (SC15-MI-WP-05), noting that the technical details of the evaluation framework that underpins the results are documented in a separate information paper (SC15-MI-IP-02). SC15 welcomed the progress on this issue and noted the following:

- The estimation model is model-based as the use of purse-seine CPUE as an index of abundance is problematic due to effort creep associated with technological developments (e.g. acoustic FADs);
- Further work is required so that Performance Indicator 5 (the impact of harvest strategies on Small Island Developing States) can be included;
- Work is progressing on identifying specific El-Nino and La-Nina distribution models so that non-stationary movement can be estimated and help account for possible climate change related impacts.

31. Second, SC15 reviewed information on the range of uncertainty which will need to be considered in the modelling framework when testing a management procedure (MP) (SC15-MI-WP-06). In particular, SC15 reviewed the Reference set of uncertainties (considered to reflect the most plausible hypotheses) which is the primary basis against which all candidate HCRs should be evaluated, and the Robustness set of uncertainties (comprising hypotheses that are considered less likely but still plausible) against which a final sub-set of candidate HCRs would be evaluated in order to determine the 'best' management strategy.

32. SC15 also noted that as part of the monitoring strategy it will be necessary to define 'exceptional circumstances' to identify those situations that fall outside of the range of scenarios against which the implemented MP has been tested. SC15 again welcomed the progress on these issues and in reviewing the Reference set of uncertainties used in the MSE noted that these expand on the set of uncertainties included in the structural grid used in the stock assessment. SC15 recommended that an expanded set of diagnostics be provided so that the plausibility of the fit of each operating model used in the Reference set could be investigated. SC15 also recommended that the Science Service Provider conduct appropriate inter-sessional consultation with CCMs on the conditioning of the operating model and other relevant issues to ensure greater inclusiveness for MSE process.

33. Third, noting that stakeholder engagement is a key component of the harvest strategy approach, SC15 reviewed information on a tool (Performance Indicators and Management Procedures Explorer, PIMPLE) for exploring and comparing the relative performance of alternative candidate MPs and the included HCRs (SC15-MI-WP-09). SC15 noted that PIMPLE was a useful tool and recommends it to mangers and WCPC16 so that they can understand the performance of various MPs for achieving management objectives. CCMs and participants were also encouraged to develop their own HCRs and make them available to the Science Service Provider for possible evaluation and inclusion in PIMPLE.

34. SC15 recommends that WCPFC16 note the progress on the development of the MSE being undertaken under the Harvest Strategy Work Plan for skipjack tuna and provide additional elements, if any, as specified in the Harvest Strategy Work Plan to further progress this work against the scheduled

time-lines noted in this Work-Plan. SC15 also requested the Secretariat create a webpage under the current "Harvest Strategy" tab that compiles the latest information of MSE development so that stakeholders can find the relevant information easily.

b. *Multi-species modeling framework* (Paragraphs 135 – 137, SC15 Outcomes Document)

35. Given that the main target species in the WCPO are caught by an overlapping mix of fisheries, an important consideration when developing harvest strategies is how to account for mixed fishery interactions. Towards this end, SC15 reviewed two potential approaches for modeling mixed fisheries in the WCPO harvest strategy evaluations (SC15-MI-WP-04). Noting the challenges in developing a multi-species modeling framework, and the difficulties and time required to develop a fully integrated multispecies-based operating model, SC15 endorsed the use of a hierarchical approach based on single species operating models.

36. However, SC15 also noted the possible need for the inclusion of PIs from interacting fisheries/stocks in the development of MPs for any single species within such a hierarchical approach. Further consideration was also needed on the framework of MPs within this approach and what species may need to be given a priority, as MPs for healthy stocks may give unintended negative impacts on unhealthy stocks. One CCM suggested that priority may need to be given based on stock status relative to respective reference points. This CCM also emphasized that an MP for bigeye tuna should include control of purse seine fisheries, as currently almost half of the bigeye tuna catch is made by the fleet. One CCM also noted the need for management controls to be applied to all managed species due to the potential of target switching and resource substitution if one or more are left unregulated.

37. SC15 recommends that WCPFC16 note the approaches outlined in the above paper, and the possible implications of the challenges in developing a multi-species modelling framework on this item within the schedule of the Harvest Strategy Work Plan.

B3. IMPLEMENTATION OF CMM 2018-01

EFFECTIVENESS OF CMM 2018-01
(Paragraphs 141 – 147, SC15 Outcomes Document)

38. As requested in paragraph 15 of CMM-2018-01 (The Commission at its 2019 annual session shall review and revise the aims set out in paragraphs 12 to 14 in light of advice from the Scientific Committee), SC15 reviewed information on the likely outcomes in relation to the stated objectives of this measure (SC15-MI-WP-11). Outcomes were evaluated using the 2016 WCPO skipjack assessment and reviewed under three different future catch and effort scenarios which are consistent with this measure: '2013-2015 avg' as well as 'pessimistic' and 'optimistic' scenarios based on the current CMM.

39. The minor adjustments to the CMM 2017-01 text contained in CMM 2018-01, including the inclusion of paragraph 18, were found to not materially affect the management conditions assumed under this evaluation. SC15 noted, however, the difficulty in evaluating the impacts of paragraph 18 because of the need for clearer guidance on the interpretation of "small garbage". SC15 recommends that the Commission revise paragraph 18 to include a more quantifiable and precise definition, so that a more meaningful evaluation of impacts may be undertaken.

40. SC15 noted that the results are comparable to the results previously presented for bigeye and yellowfin. For bigeye tuna the results are strongly influenced by the assumed future recruitment levels and the time period of the projections. If recent positive recruitments continue into the future, all scenarios examined achieve the aims of the CMM, in that median spawning biomass is projected to

remain stable or increase relative to recent levels, and median fishing mortality is projected to decline slightly (the exception to the latter being the pessimistic CMM scenario, although median fishing mortality remains below F_{MSY}). If less positive longer-term recruitments continue into the future, spawning biomass depletion worsens relative to recent levels under all scenarios, and the future risk of spawning biomass falling below the limit reference point (LRP) is around 20% or greater dependent on the scenario. In turn, all three future fishing scenarios imply increases in fishing mortality under those recruitment conditions more than doubling to median levels well above F_{MSY}.

41. For yellowfin long-term recruitment patterns were assumed to hold into the future. Results under the 2013-2015 average and 'optimistic' scenarios are comparable, with the stock stabilising at 33% $SB/SB_{F=0}$ (a 1% decrease from recent assessed levels) and F/F_{MSY} reducing to 0.68 (a 7%-8% reduction). The 'pessimistic' scenario, which implies a 35% increase in longline yellowfin catch, had a greater impact, with yellowfin biomass falling to 30% $SB/SB_{F=0}$ (an 8% reduction from recent levels), F/F_{MSY} remaining stable at $0.73F/F_{MSY}$, and the risk of breaching the adopted limit reference point increasing to 16%.

42. Although results based on 2016 skipjack assessment were reviewed by SC15, the analysis of skipjack based on the 2019 assessment was not provided due to the timing of the assessment.

43. Several CCMs questioned how much emphasis should be placed on the pessimistic scenarios, given that these seem dependent on LL fisheries fishing at their maximum catch limits allowed under the CMM regardless of the biomass levels. Several CCMs also suggested that future revisions of CMM 2018-01 could include measures that are more precautionary with regard to possible variations in bigeye recruitment.

44. SC15 recommended that the working paper be updated based on the WCPO skipjack tuna assessment agreed by SC15, including the additional analyses requested by CCMs, and forwarded to WCPFC16.

MANAGEMENT ISSUES RELATED TO FADS
(*Paragraphs 148 – 158, SC15 Outcomes Document*)

a. FAD tracking

45. SC15 reviewed information on analyses of the PNA's FAD tracking program (SC15-MI-WP-12). Consistent with previous meetings, SC15 expressed its strong support for this type of research and its continuation, noting that this program is adding substantial value to the scientific understanding of WCPO fisheries.

46. SC15 again noted the ongoing practice of SC not receiving full data (through practices such as geo-fencing) which undermines the scientific value of the information and prevents the SC from being able to provide comprehensive advice to the Commission on FAD dynamics, economics and management. However, SC15 was informed that PNA was finalising a new measure that will require full tracking data be made available that should fix this problem.

47. Based on analysis of the available data (estimated to cover 30%-40% of all FAD trajectories, including FADs completely absent and FADs with some portion of trajectories missing, within the WCPFC convention area) SC15 noted:

- the number of individual FAD buoys active has continually increased since 2016, with estimates of 10,918 buoys in 2016; 18,357 in 2017; and 20,319 in 2018, likely due to the increase in data provision.

- that over 90% of the FAD sets in the WCPO were made in PNA waters.
- the number of both associated and unassociated sets increases with FAD density, while skipjack, bigeye, and total CPUE show a slight decrease with increasing FAD density. Similarly, CPUE from all unassociated sets decreases slightly with increasing FAD densities. Additional work is needed to validate these initial findings.
- simulated FAD tracks based on ocean currents show the dispersion of FADs across a wide area of the equatorial WCPO.

48. Several CCMs expressed concern about the high FAD densities in some areas (400 to 500 FADs in a 1-degree square per month). Also, SC15 again expressed concern about the estimated high rate (6.7%) of tracked FAD beaching events, resulting in pollution and safety issues with respect to navigation, together with the estimated high rate of 'lost' FADs (up to 52%) (defined as when a FAD drifts outside the fishing ground of the company owning it). SC15 was informed that some pending analyses (these will be published soon) identify areas of FAD deployments that are more likely to result in beaching events.

49. SC15 recommends that this paper be forwarded to WCPFC16 who may wish to support the continuation of this work.

50. SC15 also recommends more comprehensive work at the Pacific-wide level as EPO FADs may drift into the WCPFC Convention area, and encourages CCMs to collect additional data on FAD beaching occurrences in their EEZs to enable the Science Services Provider to develop a database for further work.

b. Acoustic FAD analysis

51. SC15 reviewed information on preliminary analyses of acoustic data from echo-sounder buoys deployed on FADs (SC15-MI-WP-13 and SC15-EB-WP-08).

52. With regards to SC15-MI-WP-14, SC15 noted that:

- the deployment of echo-sounder buoys on FADs has increased in recent years, from around 76% in 2016 to 98% in 2019.
- the estimates of biomass were found to be influenced by i) the time of the day, with maximum biomass estimated before sunrise, and ii) the lunar phase, with a slight increase in biomass detected during and just after the full moon.
- biomass estimates showed a significant increase up to around 30 days drifting.
- while an increasing trend in estimated biomass was detected over the two to five days before a fishing set, in general, high variability was detected and no clear pattern could be identified between catch and echo-sounder biomass estimates.
- the acoustic buoys currently cannot differentiate species, although new buoys being used by some fleets can potentially estimate biomass per species which in future may be able to be used to reduce bycatch of bigeye.
- access to a larger dataset covering the whole WCPO would improve these analyses and the potential, over the longer-term, to derive an index of abundance from these data that could be used in stock assessments.

53. With regards to EB-WP-08 SC noted the following preliminary results:

- Juvenile bigeye tuna departures from FADs were higher when skipjack tuna biomass was low, as estimated from FAD-attached echo-sounder buoys.
- Lower SST and greater changes in sea surface height were associated with a lower probability of departure of bigeye tuna from a FAD.

- Quarter and full moon periods, lower sea surface temperatures, and higher local FAD density were all associated with a greater probability of presence of tagged bigeye tuna at the FAD during pre-dawn.

54. SC15 endorsed the continued cooperative relationship with the fishing community to obtain business confidential data for analysis by regional scientists, particularly with regard to FADs, and the fishing strategies involved in their use.

55. SC15 indicated strong support for these projects, identifying the need for improved information on skipjack abundance and that this work can also serve several other research purposes. SC15 recommends that WCPFC16 support the continuation of this work.

C. TECHNICAL AND COMPLIANCE COMMITTEE RECOMMENDATIONS

56. TCC15 draws to the attention of WCPFC16 that there were several recommendations in the Provisional CMR relating to revision of existing Conservation and Management Measures. TCC15 recommended that WCPFC16 review and revise, as appropriate, the following obligations, noting that more information related to these recommendations is contained in the Provisional CMR:

a. CMM 2017-01 51: for fisheries where there are limited catch and effort data; and
b. CMM 2017-01 25: for relevant CCMs who are yet to notify their catch or effort limits.

(TCC15 draft summary report, para 85)

57. TCC15 noted that there are presently nine quantitative limits where there are limited or no additional data presently available to WCPFC to verify the CCM's report on their implementation against the limit. [CMM 2005-03 02 (NP albacore), CMM 2006-04 01 (SW Striped Marlin), CMM 2009-03 01, 02 (Swordfish), CMM 2010-01 05 (NP striped marlin), CMM 2017-01 45, 47, 48 (Tropical tuna vessel limits), CMM 2017-01 51, CMM 2017-08 (Pacific Bluefin)]. TCC15 recommended that the Commission consider whether additional reporting or revised formulations of quantitative limits should be considered so that WCPFC has more ready access to data that can be used to verify a CCM's implementation of a quantitative limit. *(TCC15 draft summary report, para 125)*

58. TCC15 acknowledged ongoing difficulties in evaluating compliance with limits related to the other commercial fisheries for bigeye, yellowfin and skipjack tuna (paragraph 51 of CMM 2017-01, subsequently replaced by CMM 2018-01). TCC15 noted that the fisheries are complex and available data for these fisheries are limited which has led to uncertainties and difficulties in determining appropriate limits, including in determining which fisheries should be included. TCC15 recognised that significant work is underway under the continuation of the West Pacific East Asia (WPEA) project and acknowledges the generous support of New Zealand to facilitate this work through WPEA-ITM. *(TCC15 draft summary report, para 348)*

59. TCC15 tasked the Scientific Services Provider to develop a working paper in conjunction with Indonesia and the Philippines to assist WCPFC16 to interpret (and if necessary clarify) paragraph 50 and 51 of the tropical tuna measure (CMM 2018-01) in a way that makes it possible to evaluate compliance with the purpose of paragraph 51, which is: to ensure that in other commercial fisheries, the total catch of a CCM's bigeye, skipjack and yellowfin catch does not exceed either the average level for the period of 2001-2004 or the level of 2004. *(TCC15 draft summary report, para 349)*

Attachment 1

The Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean

Scientific Committee
Fourteenth Regular Session

Busan, Republic of Korea
8 – 16 August 2018

WCPO BIGEYE TUNA STOCK ASSESSMENT
(Paragraphs 158 – 184, SC14 Summary Report)

Provision of scientific information

a. Stock status and trends

1. The median values of relative recent (2012-2015) spawning biomass depletion ($SB_{recent}/ SB_{F=0}$) and relative recent (2011-2014) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 36 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 set out in Table BET-1. Time series of total annual catch by fishing gear over the full assessment period is shown in Figure BET-1. Estimated trends in spawning biomass depletion for the 36 models in the structural uncertainty grid is shown in Figure BET-2, and juvenile and adult fishing mortality rates from the diagnostic case model is show in BET-3. Figure BET-4 displays Majuro plots summarising the results for each of the models in the structural uncertainty grid. Figures BET-5 show Kobe plots summarising the results for each of the models in the structural uncertainty grid. Table BET-2 provides a summary of reference points over the 36 models in the structural uncertainty grid.

3. SC14 agreed to use the "updated new growth" model to describe the stock status of bigeye tuna because SC14 considered it to be the best available scientific information. By removing results using the old growth model, the stock status becomes considerably more optimistic. However, SC14 also notes that questions remain regarding the "updated new growth" model.

4. Therefore, SC14 acknowledges that further study is warranted related to the new growth model, in particular as to the cause of the difference of growth between EPO and WCPO. An inter-laboratory ageing workshop is planned for late 2018 to review ageing approaches in the WCPO and EPO and to resolve differences, if they exist.

5. In addition, SC14 acknowledges that further study is warranted to refine the tagging dataset in the WCPO to assist validating age estimates of bigeye in the WCPO. SC14 further notes that adopting the updated new growth curve generates new broader questions related to the bigeye tuna stock assessment and agreed that several aspects need to be investigated further to inform future assessments.

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

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

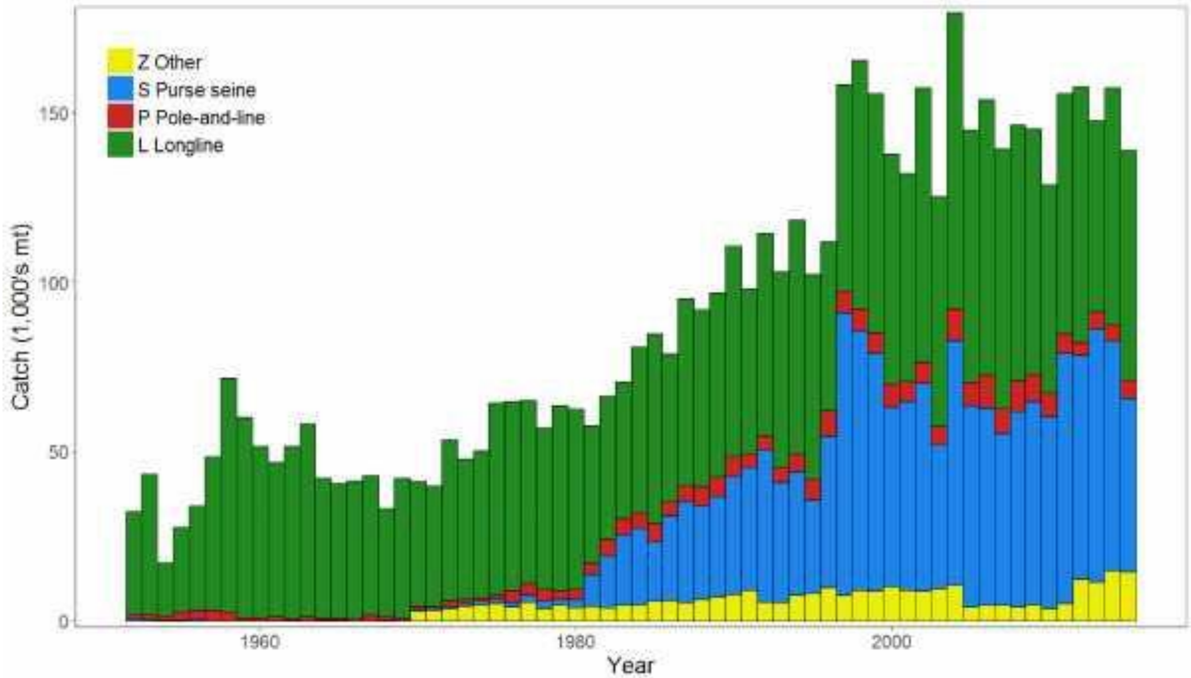


Figure BET-1. Time series of total annual catch (1000's mt) by fishing gear over the full assessment period.

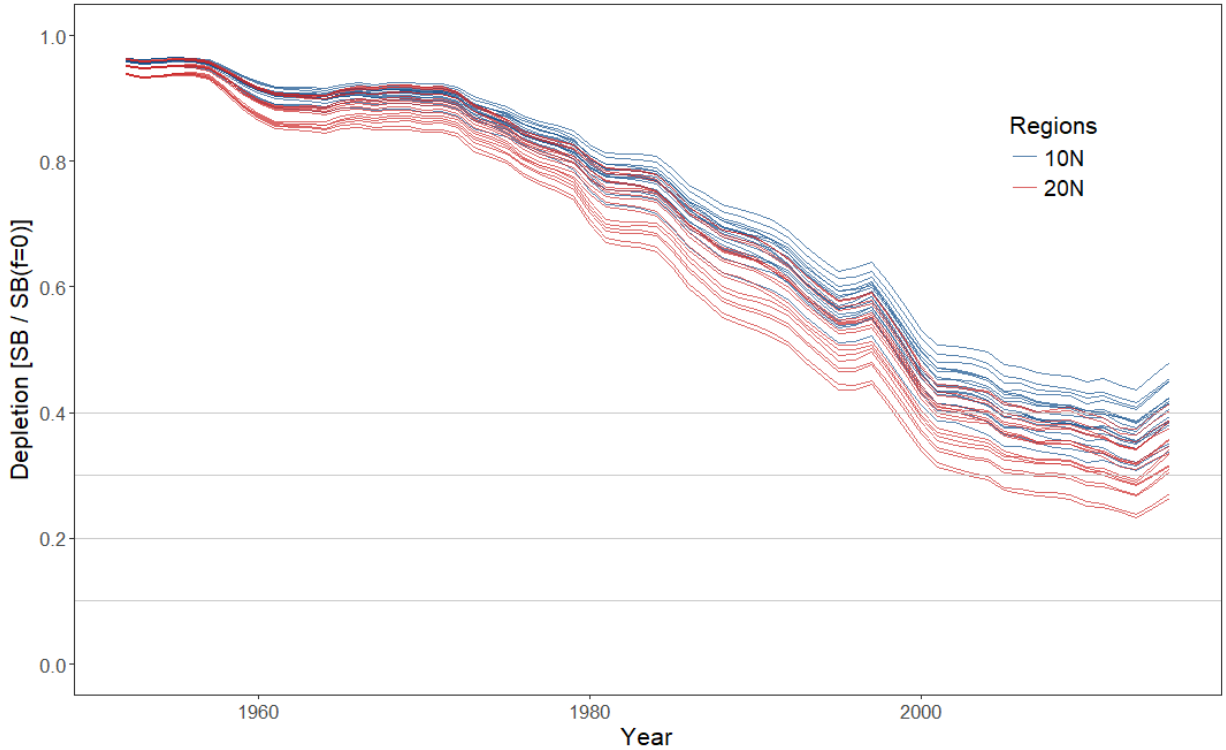


Figure BET-2. Plot showing the trajectories of spawning biomass depletion for the 36 model runs included in the structural uncertainty grid. The colours depict the models in the grid with the 10°N and 20°N spatial structures.

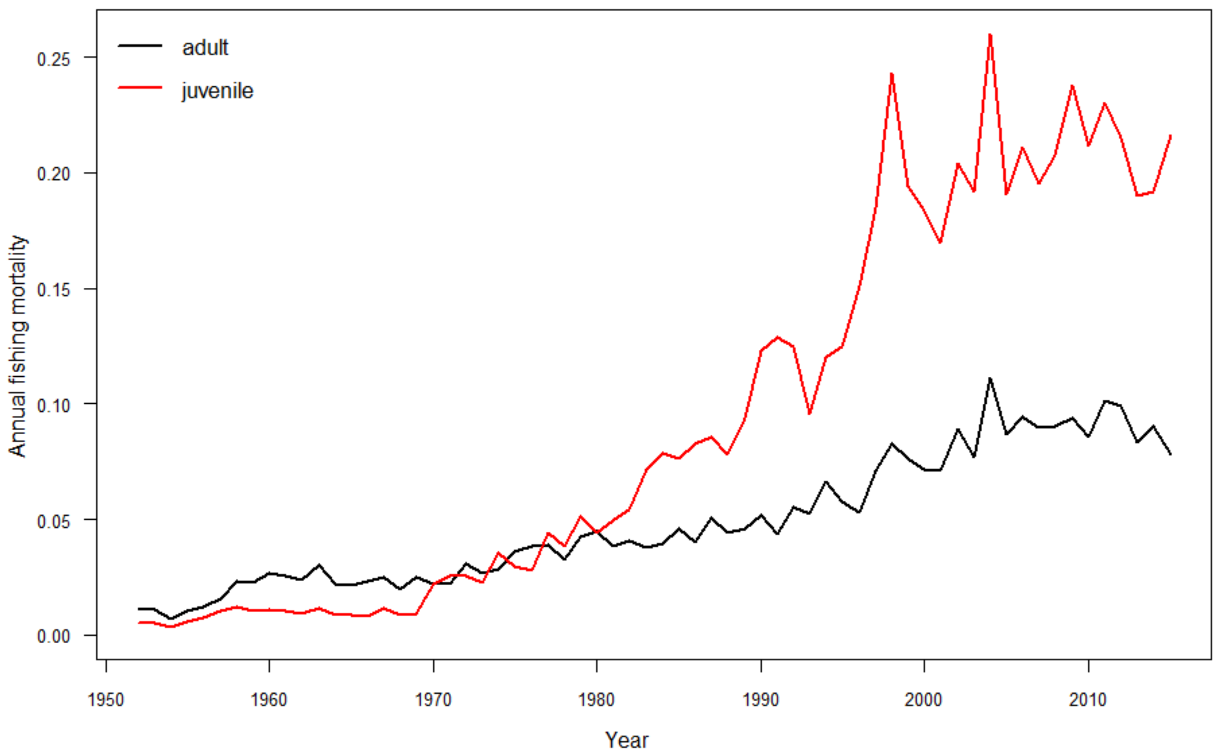
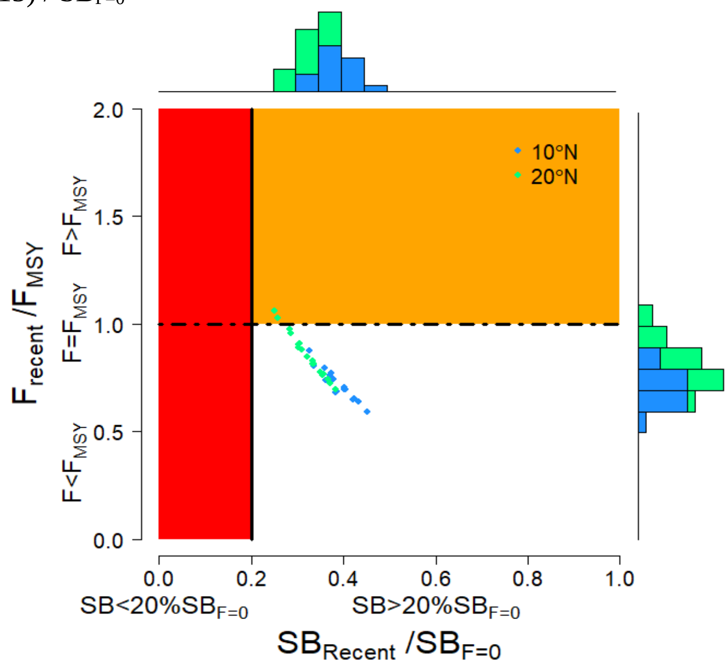


Figure BET-3. Estimated annual average juvenile and adult fishing mortality for the diagnostic case model.

SB$_{recent}$ (2012-2015) / SB$_{F=0}$



SB$_{latest}$ (2015) / SB$_{F=0}$

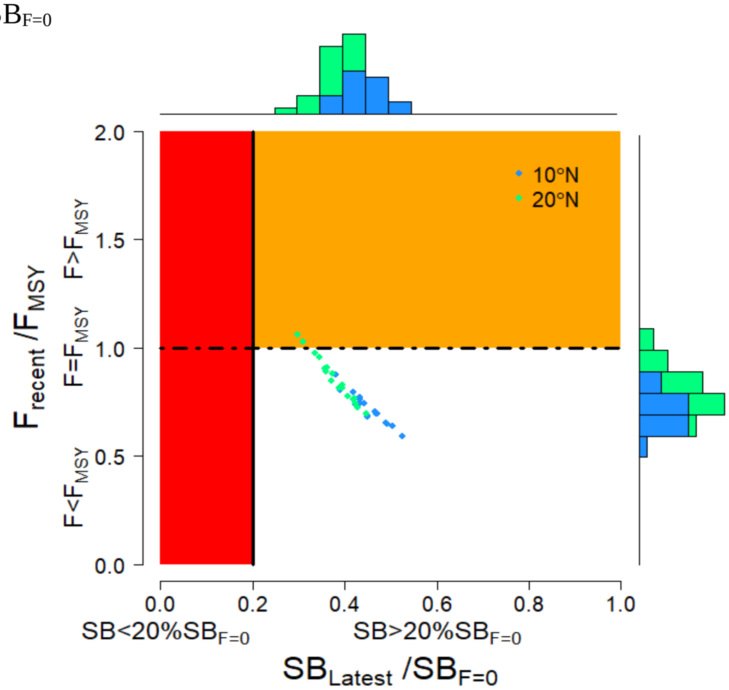
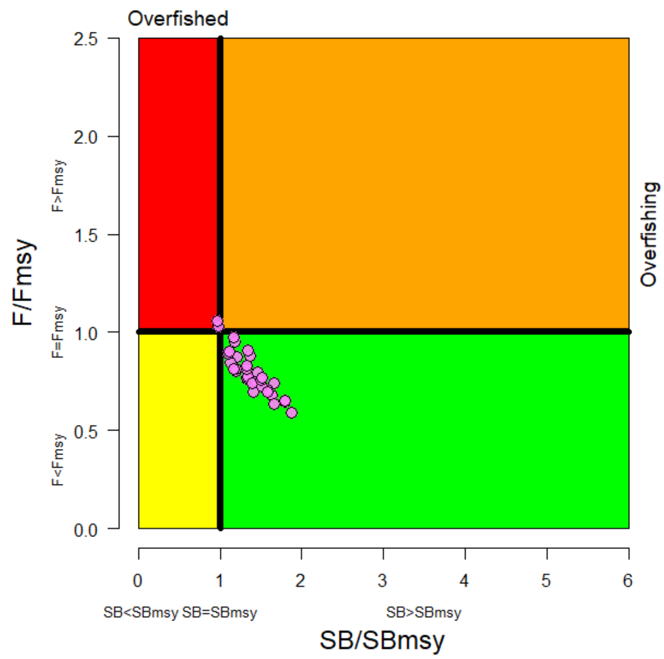


Figure BET-4. Majuro plot summarising the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality. The red zone represents spawning biomass levels lower than the agreed limit reference point, which is marked with the solid black line. The orange region is for fishing mortality greater than FMSY (FMSY is marked with the black dashed line). In the upper panel, the points represent $SBrecent/SBF=0$, where $SBrecent$ is the mean SB over 2012-2015. In the lower panel, the points represent $SB_{latest}/SB_{F=0}$, where SB_{latest} is from 2015. In both panels the colors depict the models in the grid with the 10°N and 20°N regional structures.

SB_{recent} (2012-2015) / SB_{MSY}



SB_{latest} (2015) / SB_{MSY}

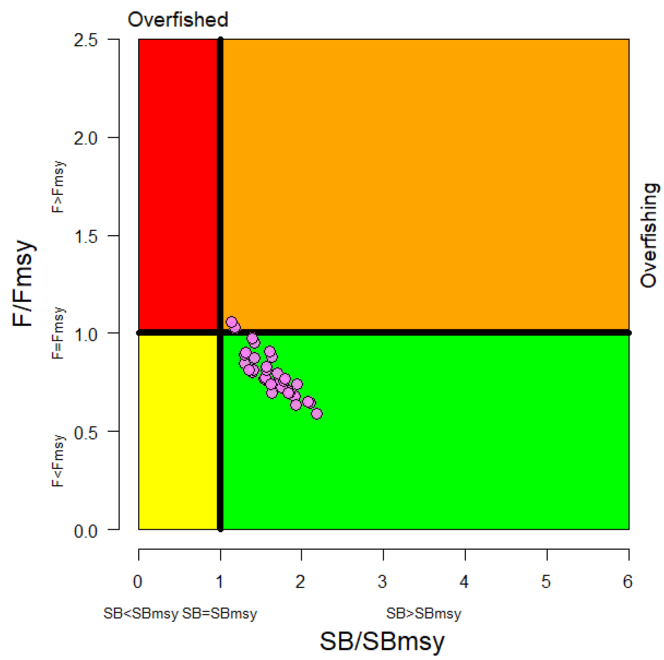


Figure BET-5. Kobe plot summarising the results for each of the models in the structural uncertainty grid. In the upper panel, the points represent *SBrecent/SBMSY*, where *SBrecent* is the mean *SB* over 2012-2015. In the lower panel, the points represent SB_{latest}/SB_{MSY}, where SB_{latest} is from 2015.

Table BET-2. Summary of reference points over the 36 models in the structural uncertainty grid. Note that *SBrecent/SBF=0* is calculated where *SBrecent* is the mean *SB* over 2012-2015 at the request of the Scientific Committee.

	Mean	Median	Min	10%	90%	Max
C_{latest}	152,148	151,846	148,888	148,936	154,971	155,577
YF_{recent}	154,180	153,220	133,120	141,140	170,720	172,280
f_{mult}	1.291	1.301	0.946	1.075	1.499	1.690
F_{MSY}	0.050	0.049	0.044	0.045	0.054	0.056
MSY	158,551	159,020	133,520	143,040	173,880	180,120
F_{recent}/F_{MSY}	0.789	0.768	0.592	0.667	0.931	1.058
SB_0	1,674,833	1,675,500	1,261,000	1,415,500	1,941,000	2,085,000
$SB_{F=0}$	1,841,609	1,858,775	1,509,007	1,632,014	2,043,108	2,139,644
SB_{MSY}	471,956	476,050	340,700	386,600	577,400	614,200
SB_{MSY}/SB_0	0.281	0.280	0.260	0.262	0.300	0.302
$SB_{MSY}/SB_{F=0}$	0.255	0.255	0.226	0.235	0.280	0.287
SB_{latest}/SB_0	0.456	0.456	0.346	0.392	0.523	0.568
$SB_{latest}/SB_{F=0}$	0.414	0.420	0.298	0.351	0.480	0.526
SB_{latest}/SB_{MSY}	1.633	1.624	1.146	1.306	1.933	2.187
$SB_{recent}/SB_{F=0}$	0.353	0.358	0.251	0.295	0.412	0.452
SB_{recent}/SB_{MSY}	1.394	1.377	0.963	1.117	1.659	1.879

6. SC14 noted that there has been a long-term decrease in spawning biomass from the 1950s to the present for bigeye tuna and that this is consistent with previous assessments.

7. SC14 also noted that the central tendency of relative recent (2012-2015) spawning biomass depletion was median ($SB_{recent}/SB_{F=0}$) = 0.36 with a range of 0.30 to 0.41 (80% probability interval).

8. SC14 further noted that there was 0% probability (0 out of 36 models) that the recent spawning biomass had breached the adopted LRP.

9. SC14 noted that there has been a long-term increase in fishing mortality for both juvenile and adult bigeye tuna (Figure BET-3), consistent with previous assessments.

10. SC14 also noted that the central tendency of relative recent fishing mortality was median (F_{recent}/F_{MSY}) = 0.77 with an 80% probability interval of 0.67 to 0.93.

11. SC14 further noted that there was a roughly 6% probability (2 out of 36 models) that the recent fishing mortality was above F_{MSY}.

12. SC14 also noted that, regardless of the choice of uncertainty grid, the assessment results show that the stock has been continuously declining for about 60 years since the late 1950's, except for the recent small increase.

13. SC14 also noted the continued relatively higher levels of depletion in the equatorial and western Pacific (specifically Regions 3, 4, 7 and 8) and the associated higher levels of impact, especially on juvenile bigeye tuna, in these regions due to the associated purse-seine fisheries and the 'other' fisheries within the western Pacific (as shown in Figures 46 and 47 of SC13-SA-WP-03).

14. Table BET-3 summarises the median values of $SB/SB_{F=0}$ and F/F_{MSY} achieved in the long term, along with the potential risk of breaching the limit reference point (LRP) and exceeding F_{MSY}, under each of the future fishing and recruitment combinations. Figure BET-6 presents the corresponding distributions of long term $SB/SB_{F=0}$ and Figure BET-7 those for F/F_{MSY}.

15. Potential outcomes under the 2013-15 average and CMM scenario conditions were strongly influenced by the assumed future recruitment levels.

16. Under the assumption that recent positive recruitments will continue into the future, spawning biomass relative to unfished levels is predicted to increase from recent levels under all examined future scenarios by 0-18% ($SB_{2045}/SB_{F=0}$ ranges from 0.36 to 0.42; Table BET-3, Figure BET-6). While future uncertainty in stock status increases due to stochastic future recruitment levels, the risk of future spawning biomass falling below the LRP falls to between 0 and 5%, due to the improved overall stock size. Fishing mortality falls slightly under both the status quo and optimistic scenarios, assuming recent recruitment. However, fishing mortality increases under the pessimistic scenario, but remains below F_{MSY} (30% risk of $F > F_{MSY}$ Table BET-3, Figure BET-7).

17. Under the assumption that less positive long-term recruitments are experienced in the future, spawning biomass relative to unfished levels will decline under all scenarios ($SB_{2045}/SB_{F=0}$ ranges from 0.25 to 0.30). The risk of spawning biomass falling below the LRP increases to between 17 and 32% (Table BET-3). In all fishing scenarios, fishing mortality increases relative to recent levels (by 109-138%) and is well above F_{MSY}. Risk of fishing mortality exceeding F_{MSY} ranges from 93 to 98%.

18. It should be noted that even under assumption of long term recruitment levels, the risk of exceeding the LRP in the short term ranges between 2% and 7% (2020) and 12 and 26% (2025), with only the pessimistic scenario exceeding the 20% level of risk in 2025. (Table BET-4 and Figure BET-8)

Table BET-3. Including '2013-2015 average levels'
Median values of reference point levels (adopted limit reference point (LRP) of 20% $SB_{F=0}$; F_{MSY}) and risk[1] of breaching reference points from the 2018 bigeye stock assessment incorporating updated new growth information, and in 2045 under the three future harvest scenarios (2013-2015 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses. 'Updated new growth' runs only.

Scenario		Scalars relative to 2013-2015		Median $SB_{2045}/SB_{F=0}$	Median $SB_{2045}/SB_{F=0}$ v $SB_{2012-15}/SB_{F=0}$	Median $F_{2041-2044}/F_{MSY}$	Median $F_{2041-2044}/F_{MSY}$ v $F_{2011-14}/F_{MSY}$	Risk	
Recruitment	**Fishing level**	**Purse seine**	**Long line**					**SB_{2045} < LRP**	**$F>F_{MSY}$**
Bigeye assessment ('recent' levels)				0.36	-	0.77	-	0%	6%
Recent	2013-2015 average	1	1	0.42	1.18	0.73	0.95	0%	11%
	Optimistic	1.11	0.98	0.41	1.15	0.75	0.98	0%	13%
	Pessimistic	1.12	1.35	0.36	1.00	0.89	1.15	5%	30%
Long-term	2013-2015 average	1	1	0.30	0.84	1.60	2.09	17%	93%
	Optimistic	1.11	0.98	0.29	0.82	1.64	2.13	18%	94%
	Pessimistic	1.12	1.35	0.25	0.70	1.84	2.38	32%	98%

[1] note risk within the stock assessment is calculated as the (weighted) number of models falling below the LRP (X / 36 models). Risk under a projection scenario is the number of projections across the grid that fall below the LRP (X / 3600 (36 models x 100 projections).

Table BET-4. Median values of $SB/SB_{F=0}$ and associated risk of breaching the adopted limit reference point (LRP) of 20% SBF=0 in 2020, 2025 and 2045 under the three future harvest scenarios (2013-2015 average fishing levels, optimistic, and pessimistic) and alternative recruitment hypotheses. 'Updated new growth' runs only.

Scenario		Scalars relative to 2013-2015		Median $SB_{2020}/SB_{F=0}$	Median $SB_{2025}/SB_{F=0}$	Median $SB_{2045}/SB_{F=0}$	Risk SB_{2020} < LRP	Risk SB_{2025} < LRP	Risk SB_{2045} < LRP
Recruitment	**Fishing level**	**Purse seine**	**Long line**						
Recent	2013-2015 average	1	1	0.42	0.41	0.42	0%	1%	0%
	Optimistic	1.11	0.98	0.41	0.40	0.41	0%	1%	0%
	Pessimistic	1.12	1.35	0.38	0.35	0.36	0%	4%	5%
Long-term	2013-2015 average	1	1	0.35	0.30	0.30	2%	12%	17%
	Optimistic	1.11	0.98	0.35	0.30	0.29	2%	13%	18%
	Pessimistic	1.12	1.35	0.32	0.26	0.25	7%	26%	32%

Recent recruitments | Long-term recruitment

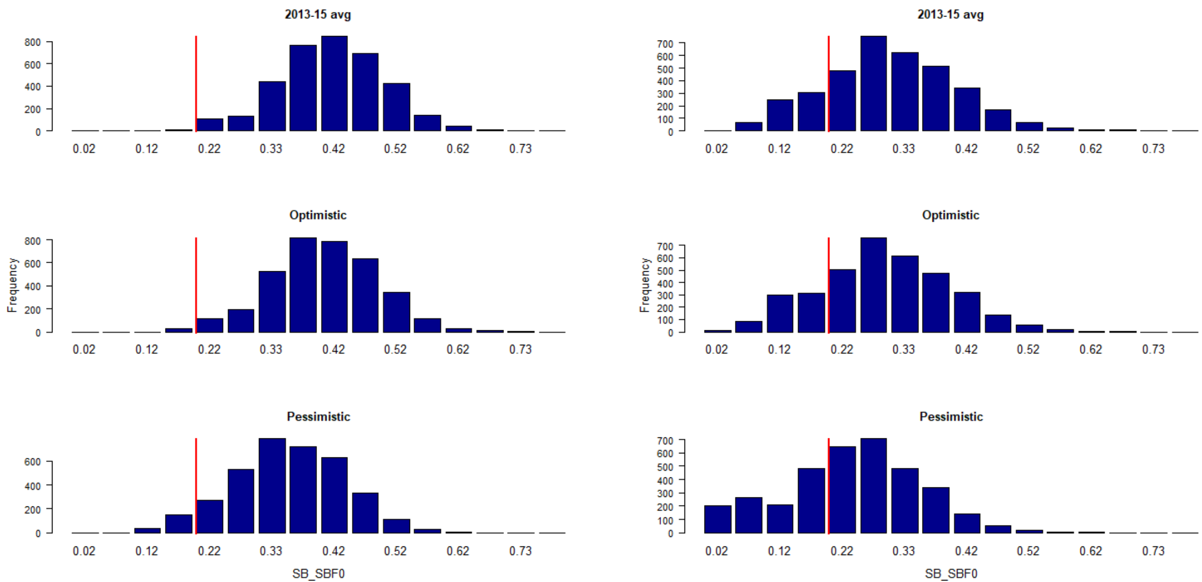


Figure BET-6. Distribution of $SB_{2045}/SB_{F=0}$ assuming recent and long term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2013-15 average (2013-15 average conditions, top row); optimistic conditions (middle row); and pessimistic conditions (bottom row). Projection results from 'updated new growth' models (3,600 projections) only where the red line indicates the LRP.

Recent recruitments | Long-term recruitment

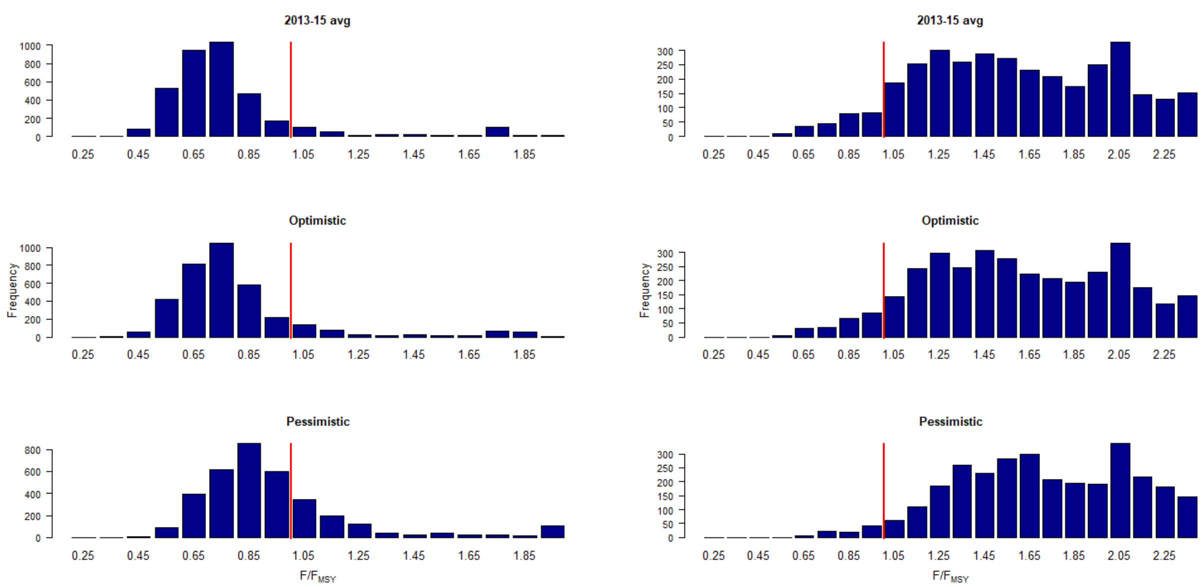
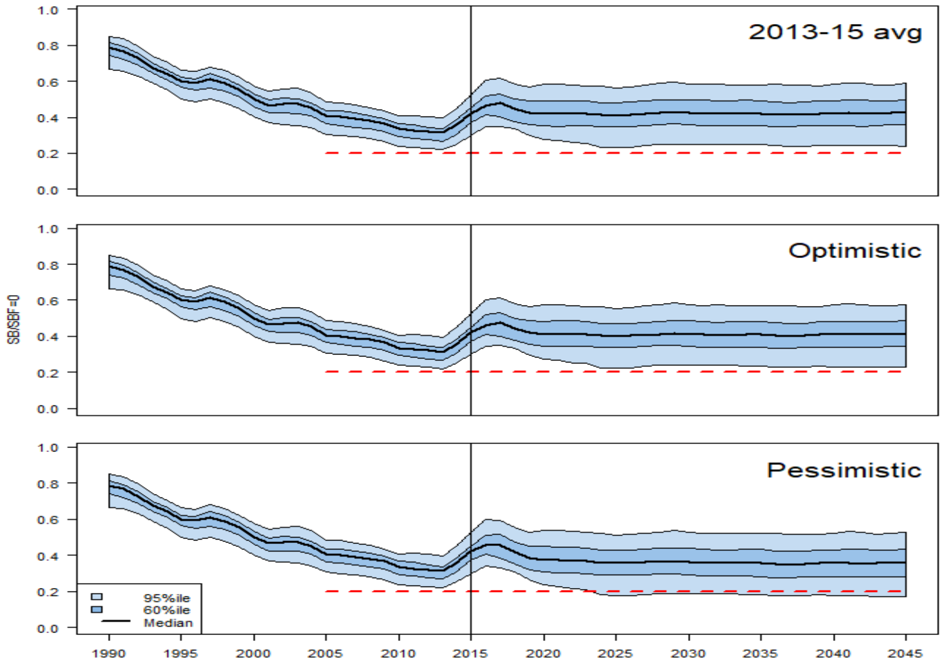


Figure BET-7. Distribution of F/F_{MSY} assuming recent and long term recruitment conditions (left and right columns, respectively), under the three future fishing scenarios: 2013-15 average (2013-15 average conditions, top row); optimistic conditions (middle row); and pessimistic conditions (bottom row). Projection results from 'updated new growth' models (3,600 projections) only.

Recent recruitments



Long-term recruitment

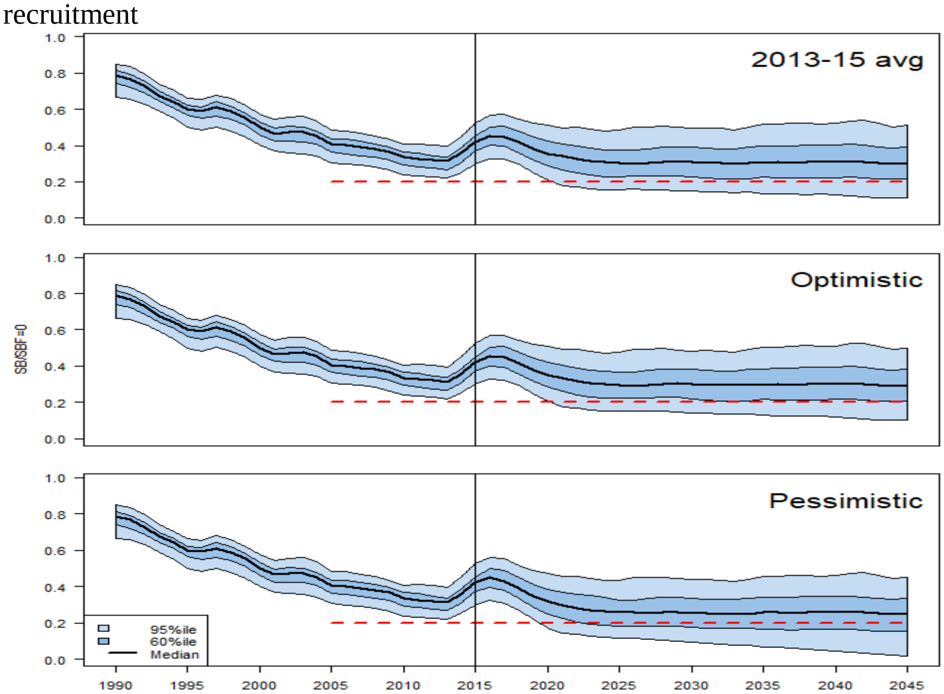


Figure BET-8. Time series of WCPO bigeye tuna spawning biomass ($SB/SB_{F=0}$) from the uncertainty grid of assessment model runs for the period 1990 to 2015 (the vertical line at 2015 represents the last year of the assessment), and stochastic projection results for the period 2016 to 2045 under the three future fishing scenarios ("2013-15 average", "Optimistic" and "Pessimistic"; rows). During the projection period (2016-2045) levels of recruitment variability are assumed to match those over the "recent" time period (2005-2014; left panel) or the time period used to estimate the stock-recruitment relationship (1962-2014; right panel). The red dashed line represents the agreed limit reference point.

b. Management advice and implications

19. SC14 noted that the preliminary estimate of total catch of WCPO bigeye tuna for 2017 was 126,929 mt, a 17% decrease from 2016 and a 19% decrease from the average 2012-2016. Longline catch in 2017 (58,164 mt) was an 8% decrease from 2016 and a 19% decrease from the 2012-2016 average. Purse seine catch in 2017 (56,194 mt) was a 12% decrease from 2016 and a 13% decrease from the 2012-2016 average. Pole and line catch (1,411 mt) was a 65% decrease from 2016 and a 70% decrease from the average 2012-2016 catch. Catch by other gear (11,160 mt) was a 48% decrease from 2016 and 28% decrease from the average catch in 2012-2016.

20. Based on the uncertainty grid adopted by SC14, the WCPO bigeye tuna spawning biomass is above the biomass LRP and recent F is very likely below F_{MSY}. The stock is not experiencing overfishing (94% probability $F<F_{MSY}$) and it is not in an overfished condition (0% probability $SB/SB_{F=0}$<LRP).

21. Although SC14 considers that the updated assessment is consistent with the previous assessment, SC14 also advises that the amount of uncertainty in the stock status results for the 2018 assessment update is lower than for the previous assessment due to the exclusion of old information on bigeye tuna growth.

22. SC14 noted that levels of fishing mortality and depletion differ among regions, and that fishery impact was higher in the tropical region (Regions 3, 4, 7 and 8 in the stock assessment model), with particularly high fishing mortality on juvenile bigeye tuna in these regions. SC14 therefore recommends that WCPFC15 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.

23. SC14 noted that according to CMM 2017-01 bigeye tuna $SB/SB_{F=0}$ is to be maintained above the 2012-2015 level ($SB_{recent}/SB_{F=0}$ = 0.36; Table BET-3) pending the agreement on a TRP. SC14 also noted that the projection results based on scenarios estimating CMM 2017-01 indicated a high level of uncertainty on the levels of spawning stock biomass relative to the LRP and the objective of CMM 2017-01 in 2045. Under the scenario assuming long-term average recruitment continues into the future there was a high risk (18-32%) of breaching the LRPs and a zero probability of achieving the objective of CMM 2017-01, while under the scenario which assumes higher more recent recruitments continues into the future there was a low risk (0-5%) of breaching the LRPs and a 100% probability of achieving the objective of CMM 2017-01.

24. However, SC14 also noted that the projections assume that longline catches would be maintained regardless of the decrease in biomass. This may result in unlikely high levels of effort. Therefore, the catch estimates under the long term recruitment scenario, especially in the longer term projections, are more uncertain.

25. Based on these results, SC14 recommends that WCPFC15 takes note of the results of the projections in relation achieving CMM 2017-01 and as a precautionary approach that the fishing mortality on bigeye tuna stock should not be increased from the recent average (2011-2014) level to maintain spawning biomass at or above the 2012-2015 average, until the Commission can articulate the management objectives and agree on an appropriate TRP for bigeye, although one CCM considers that SC14 could provide more options for the commission to consider.

c. Research Recommendations

26. SC14 noted that the acceptance of the updated new growth model for BET raises a number of issues in relation to patterns of growth and stock structure of BET across the Pacific Ocean and recommended that the following research issues need to be addressed:

1) Two different growth models separated at 150˚W effectively means that Pacific BET should be assessed as a two-stock resource between the WCPO and EPO. However, catch information indicates that the fishing grounds near 150˚W are a core area of BET catch, thus influencing the assessments of both the WCPFC and IATTC. Also, tagging information suggests movement of BET between the WCPO and EPO. Therefore, the appropriateness off delineating the two stocks at 150˚W needs to be investigated.
2) The updated new growth analysis suggests area variant growth across the Pacific. While the level of variation is seen to be relatively small within the WCPO (and possibly within the margins of observation error), there is a suggestion of substantial change in growth around the boundary between the WCPO and the EPO (c.f. Figure 14 in SC14-SA-WP-01). The reasons for this suggested change in growth remains unknown, but SC14 noted the utility of collecting more information from the regions either side of this boundary to inform a greater understanding of possible changes in growth around this area. While the incorporation of area-variant growth within the assessment model would also help explore this issue, SC14 noted the difficulty of this task.
3) SC11 concluded that the stock status of WCPO BET from the Pan-Pacific assessment and the WCPO-only assessment were similar when the growth models were similar in the EPO and WCPO. This conclusion needs to be revisited in light of the different growth between EPO and WCPO by adopting the new growth.

27. The following additional research activities were also recommended by SC14 in order to improve the understanding of the age and growth of BET across the Pacific:

1) A WCPO growth model based on size composition and tagging data, as well as the use of additional modeling approaches (e.g., length-conditional), should also be evaluated.
2) Collaboration with the IATTC to analyze bigeye growth from otolith and tagging data collected across the entire Pacific, to better characterize the apparent regional difference in growth between the WCPO and EPO, and possible environmental determinants of such differences.
3) Analyzing the same otoliths by different laboratories, to build confidence in ageing estimates and to estimate ageing error.
4) Continued development of a high-confidence tagging dataset for growth analysis, with particular focus on larger bigeye tuna and events with reliable measurements at release. Such data would assist with the validation of the age estimates of large bigeye in the WCPO, and could potentially be incorporated directly into the assessment model as an additional data set. However, a reliable measurement of both length at release and recapture are necessary to accurately estimate incremental growth.
5) Collect otoliths of very small bigeye that are captured by the Indonesian, Vietnamese, and Philippines domestic fisheries in region 7 and estimate age through daily ring counts to aid in the estimation of the size at age-1 qtr^{-1} parameter (L1) within the assessment model.

Attachment 2

The Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean

Scientific Committee
Thirteenth Regular Session

Rarotonga, Cook Islands
9 – 17 August 2017

WCPO YELLOWFIN TUNA STOCK ASSESSMENT
(Paragraphs 265 – 279, SC13 Summary Report)

Provision of scientific information

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

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

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

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

a. Status and trends

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

6. Descriptions of the updated structural sensitivity grid used to characterize uncertainty in the assessment are provided in Table YFT-1. Catch trend data is presented in Figure YFT-1. Estimated annual average recruitment, biomass, fishing mortality and depletion are shown in Figures YFT-2 – YFT-5. Majuro plots summarizing the results for each of the models in the structural uncertainty grid retained for management advice are represented in Figures YFT-6 and YFT-7. Figure YFT-8 and YFT-9 present

Kobe plots summarizing the results for each of the models in the structural uncertainty grid. Figure YFT-10 provides estimated time-series (or "dynamic") Majuro and Kobe plots from the yellowfin 'diagnostic case' model run. Figure YFT-11 shows estimates of reduction in spawning potential due to fishing by region, and over all regions attributed to various fishery groups (gear-types) for the diagnostic case model. Table YFT-2 provides a summary of reference points over the 48 models in the structural uncertainty grid (based on the SC decision to include size frequency weighting levels 20 and 50 only).

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

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

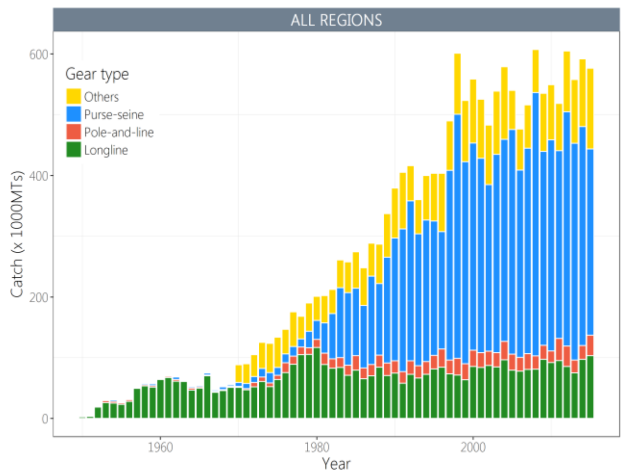


Figure YFT-1. Time series of total annual catch (1000's mt) by fishing gear for the diagnostic case model over the full assessment period.

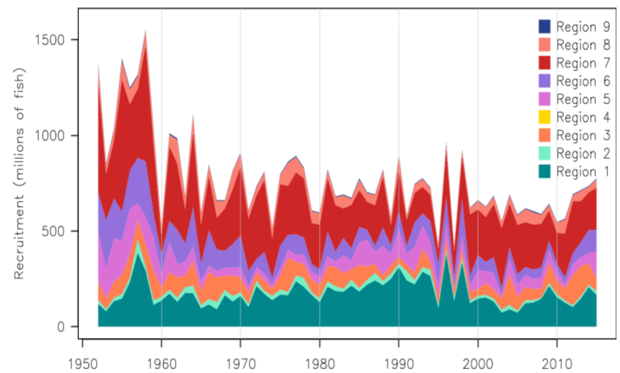


Figure YFT-2. Estimated annual average recruitment by model region for the diagnostic case model, showing the relative sizes among regions.

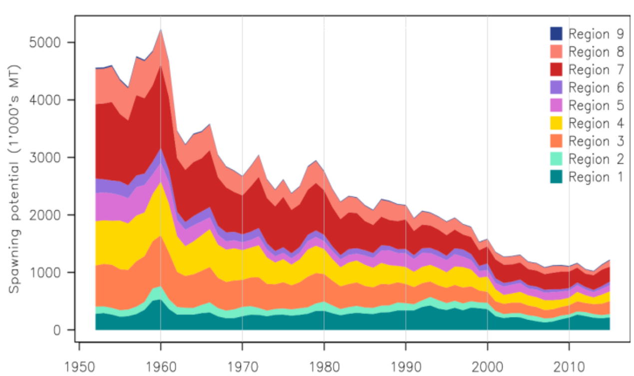


Figure YFT-3. Estimated annual average spawning potential by model region for the diagnostic case model, showing the relative sizes among regions.

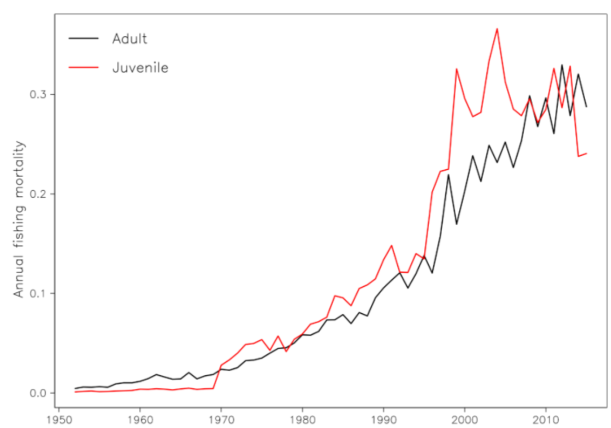


Figure YFT-4. Estimated annual average juvenile and adult fishing mortality for the diagnostic case model.

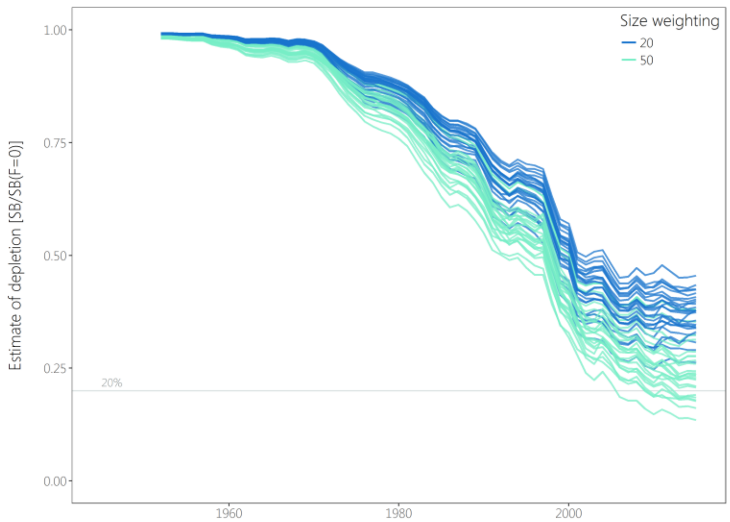


Figure YFT-5: Plot showing the trajectories of fishing depletion (of spawning potential) for the 48 model runs retained for the structural uncertainty grid used for management advice. The colours depict the models in the grid with the size composition weighting using divisors of 20 and 50.

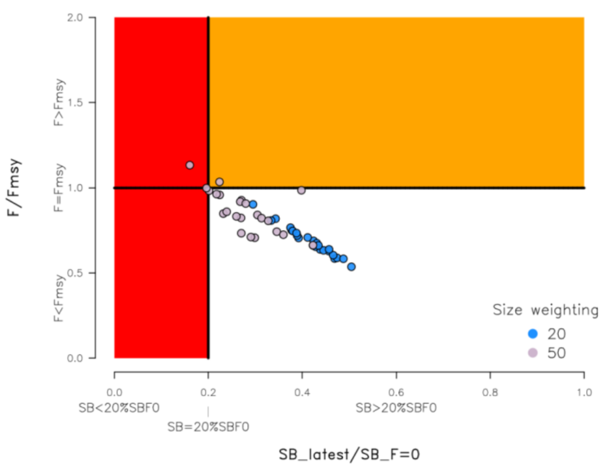


Figure YFT-6. Majuro plot summarising the results for each of the models in the structural uncertainty grid retained for management advice. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality. The red zone represents spawning potential levels lower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

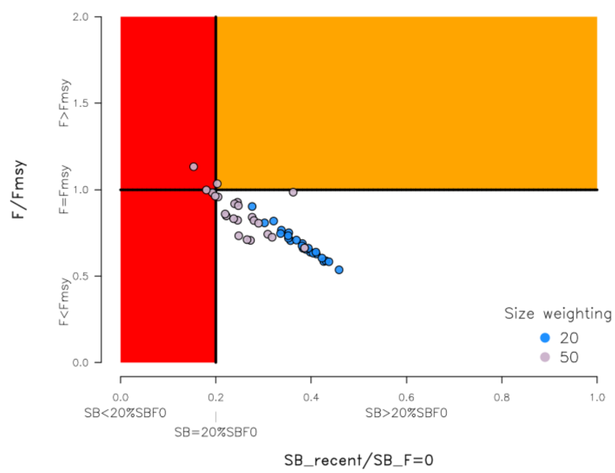


Figure YFT-7: Majuro plot summarising the results for each of the models in the structural uncertainty grid retained for management advice. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality. The red zone represents spawning potential levels lower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

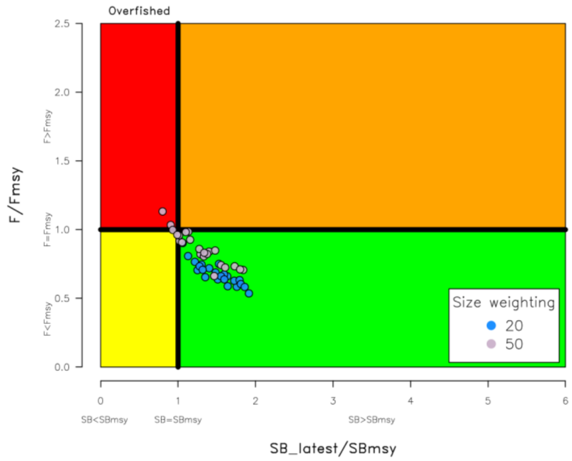


Figure YFT-8. Kobe plot summarising the results for each of the models in the structural uncertainty grid. The points represent SB_{latest}/SB_{MSY}, the colours depict the models in the grid with the size composition weighting using divisors of 20 and 50.

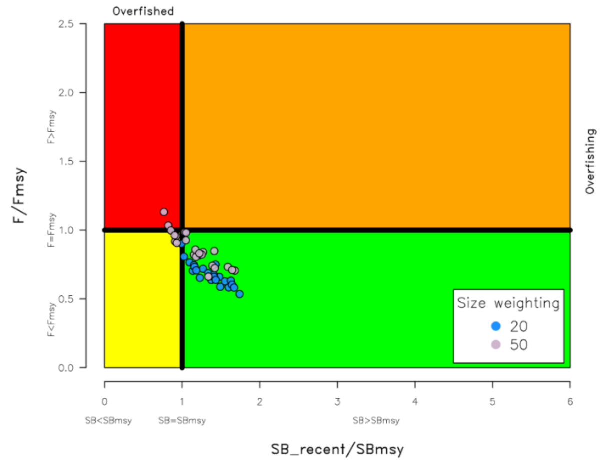


Figure YFT-9. Kobe plot summarising the results for each of the models in the structural uncertainty grid. The points represent SB_{recent}/SB_{MSY}, the colours depict the models in the grid with the size composition weighting using divisors of 20 and 50.

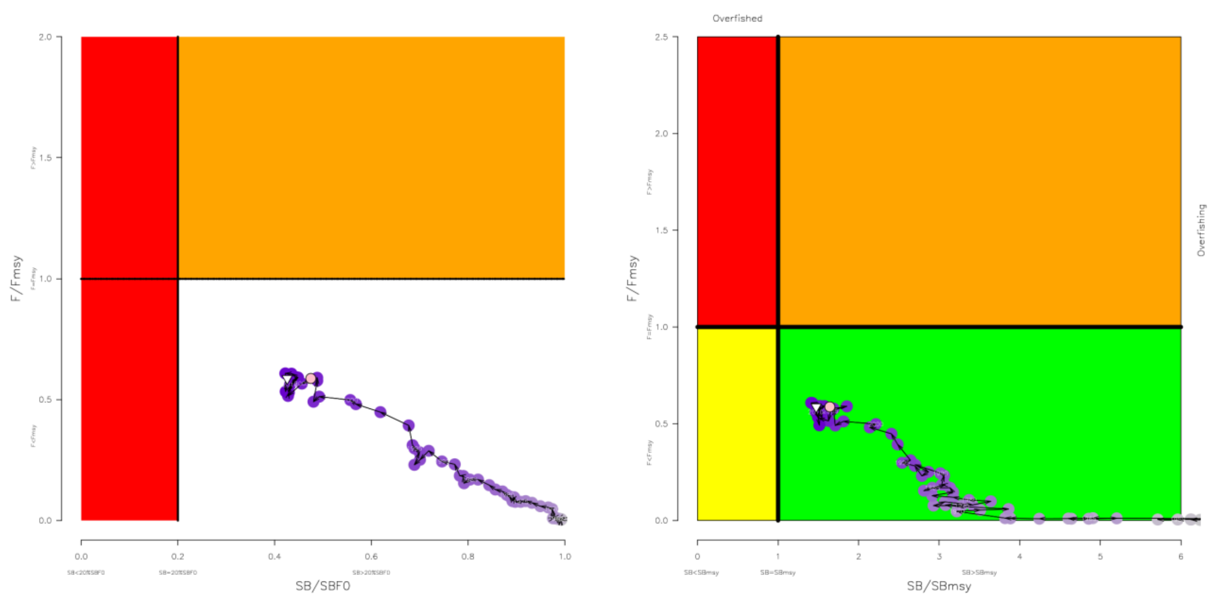


Figure YFT-10. Estimated time-series (or "dynamic") Majuro and Kobe plots from the yellowfin 'diagnostic case' model run.

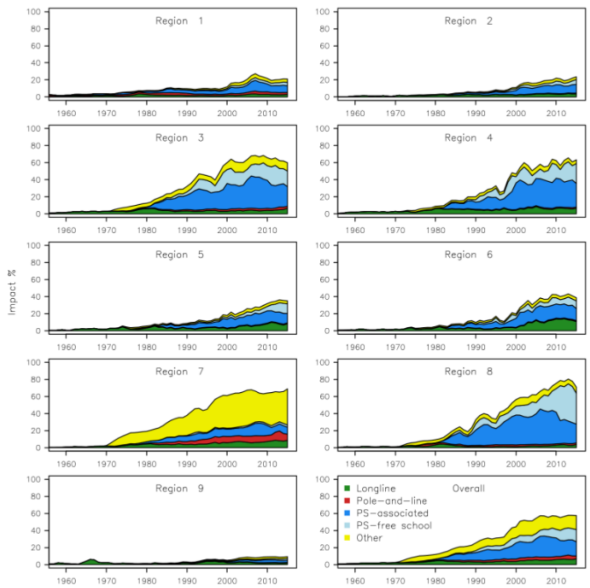


Figure YFT-11. Estimates of reduction in spawning potential due to fishing by region, and over all regions (lower right panel), attributed to various fishery groups (gear-types) for the diagnostic case model.

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

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

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

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

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

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

b. Management advice and implications

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

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

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

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

c. Research Recommendations

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

Attachment 3

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 27 – 40, SC15 Outcomes Document)

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

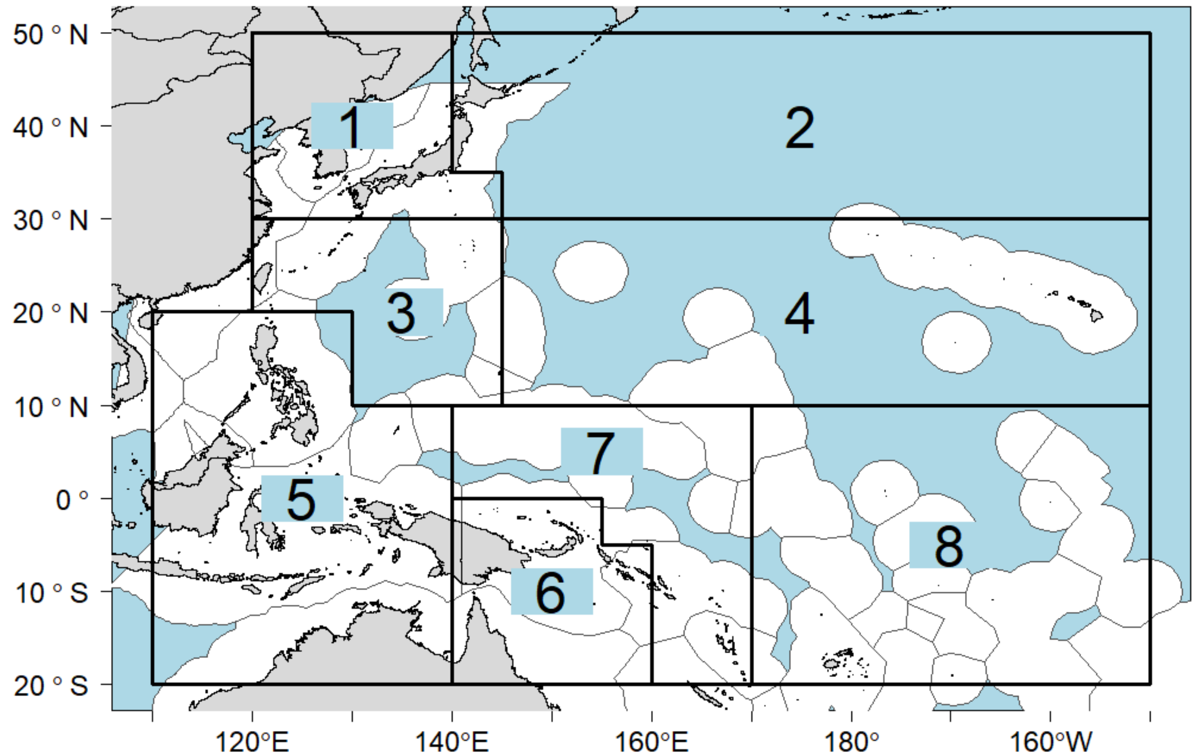


Figure SKJ-01. Eight region spatial structure used in the 2019 stock assessment model.

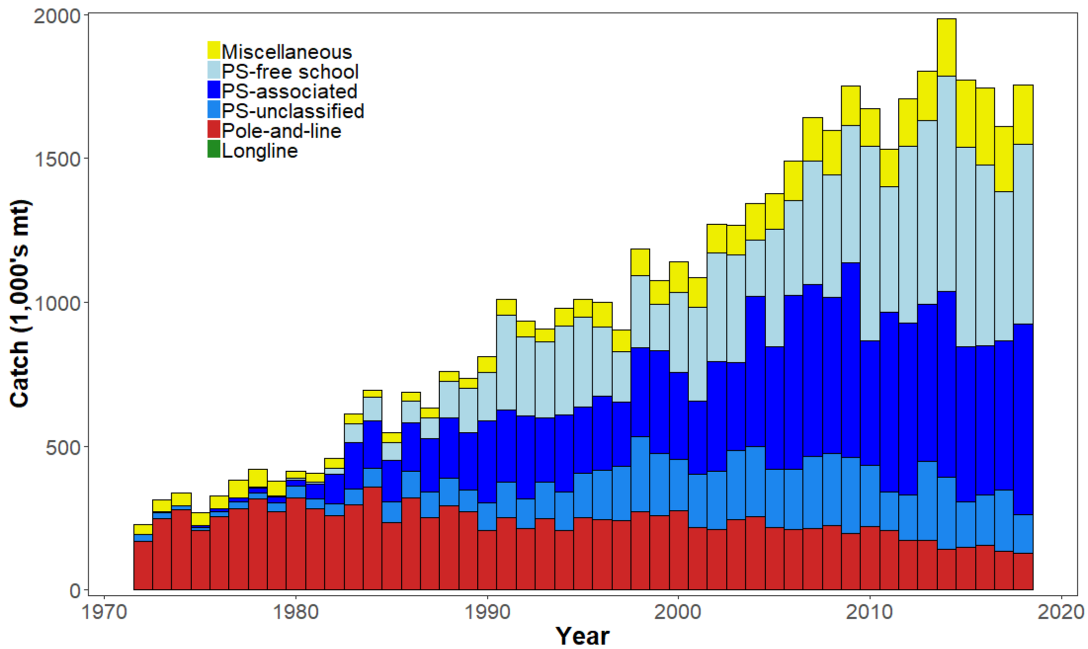


Figure SKJ-02. Time series of total annual catch (1000's mt) by fishing gear over the full assessment period.

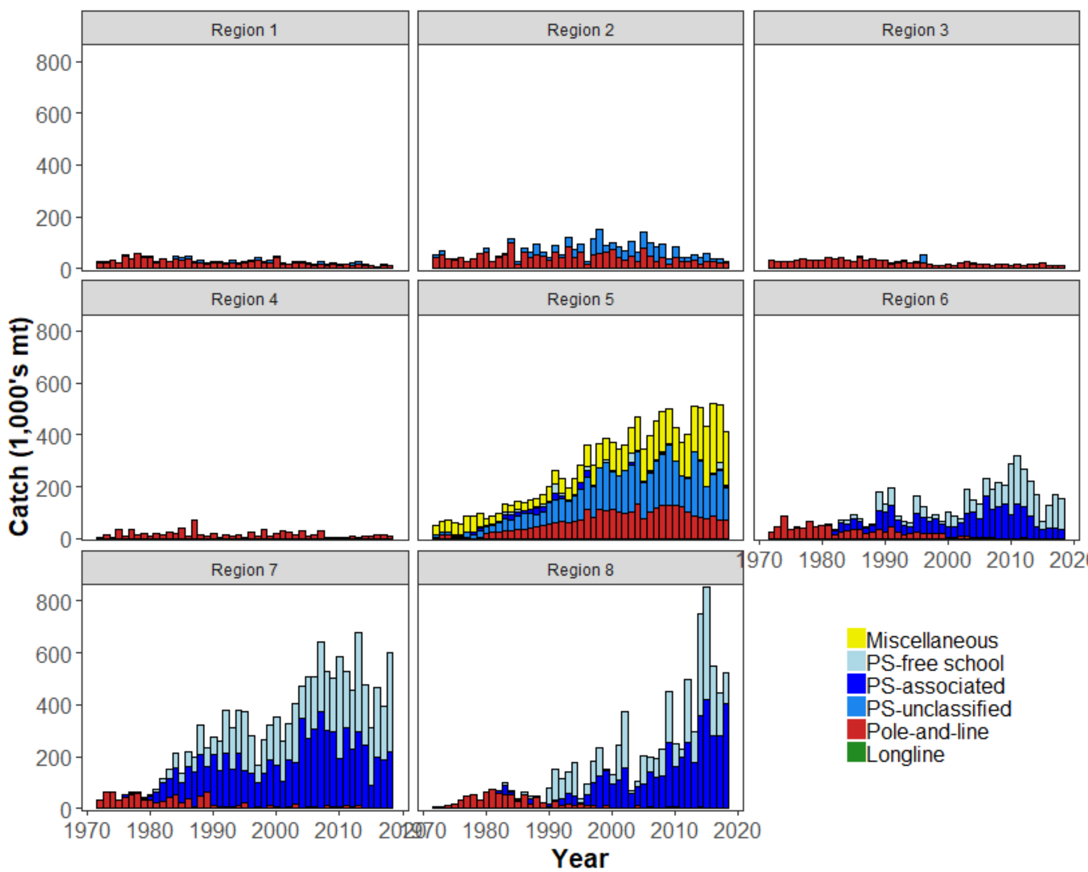
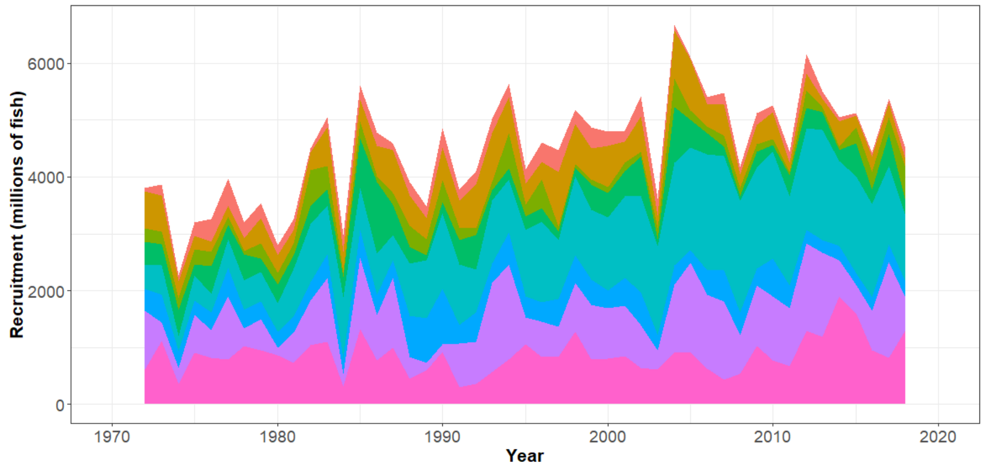
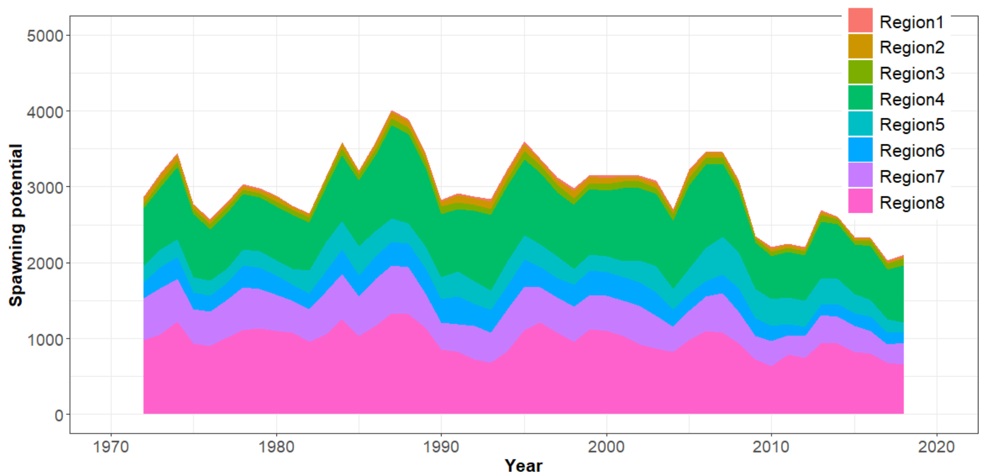


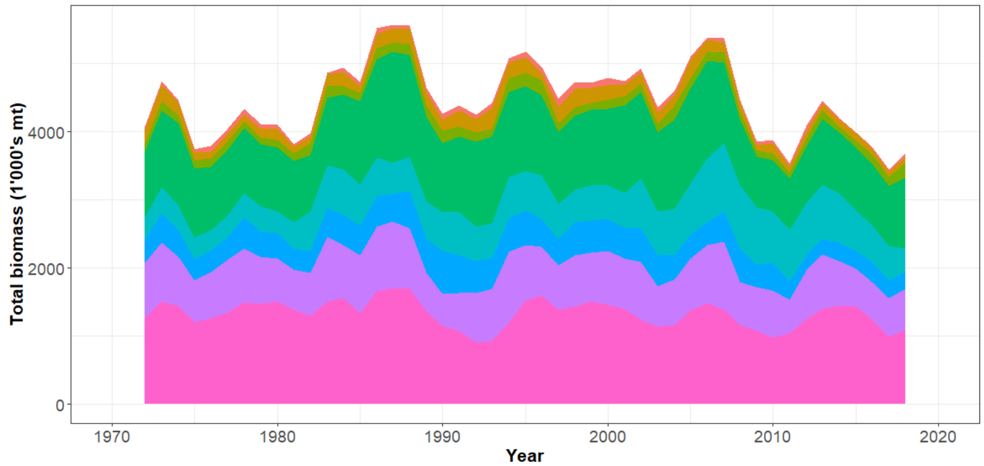
Figure SKJ-03. Time series of total annual catch (1000's mt) by fishing gear and assessment region over the full assessment period.



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.

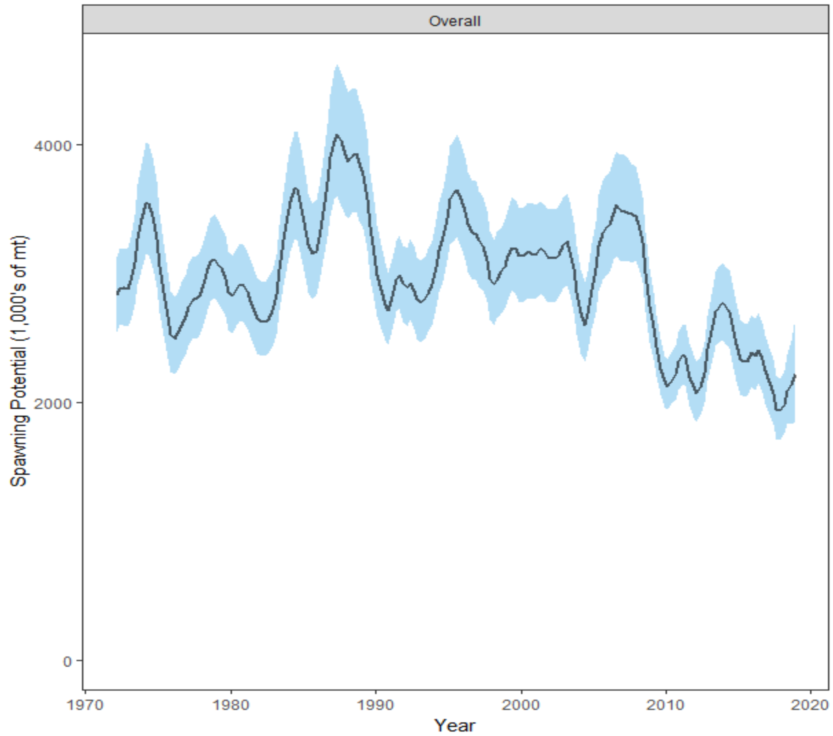


Figure SKJ-05. Estimated temporal overall spawning potential summed across regions from the diagnostic model, where the shaded region is ± 2 standard deviations (i.e., 95% CI).

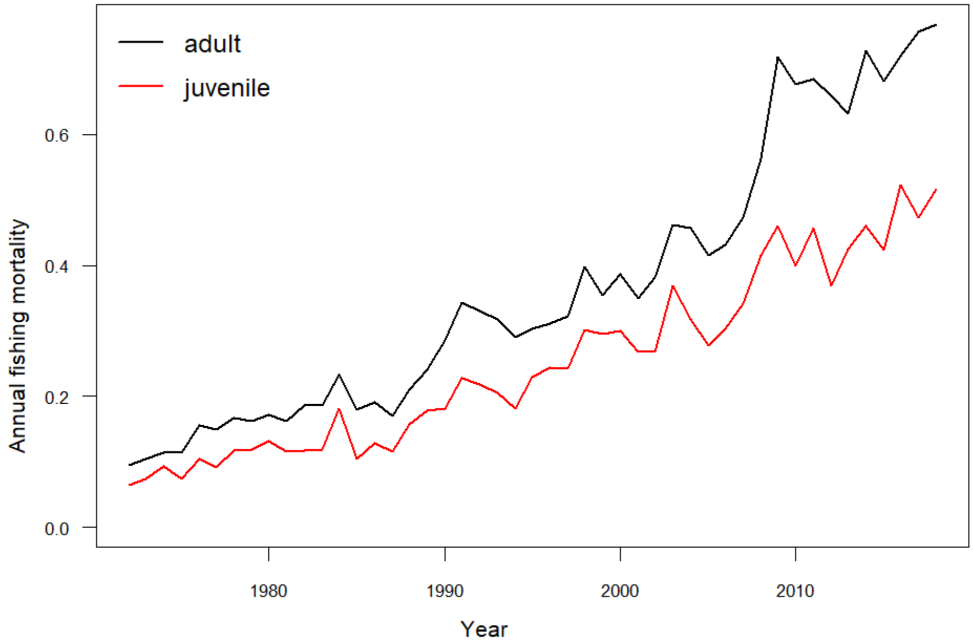


Figure SKJ-06. Estimated annual average juvenile and adult fishing mortality for the diagnostic model.

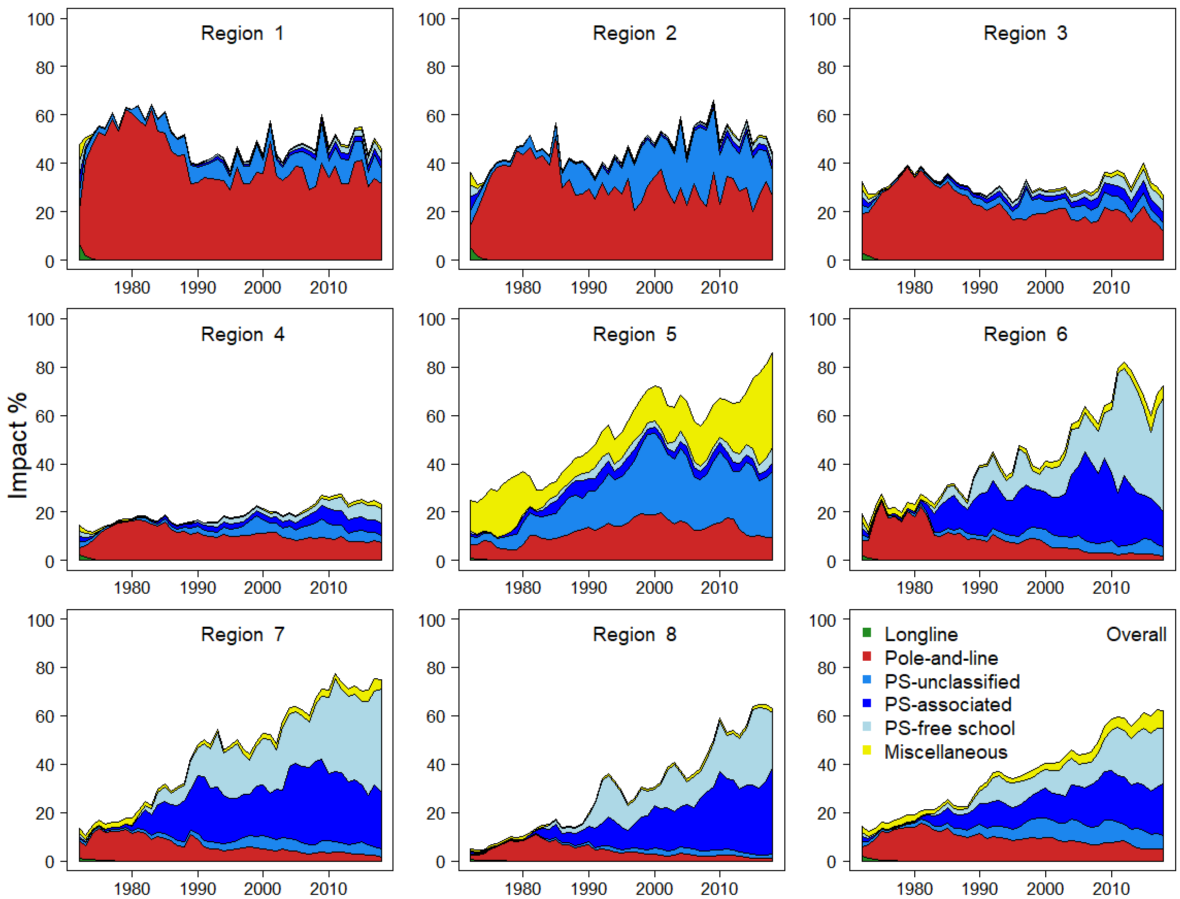


Figure SKJ-07. Estimates of reduction in spawning potential due to fishing (fishery impact = 1-SB_{latest}/$SB_{F=0}$) by region for the diagnostic model.

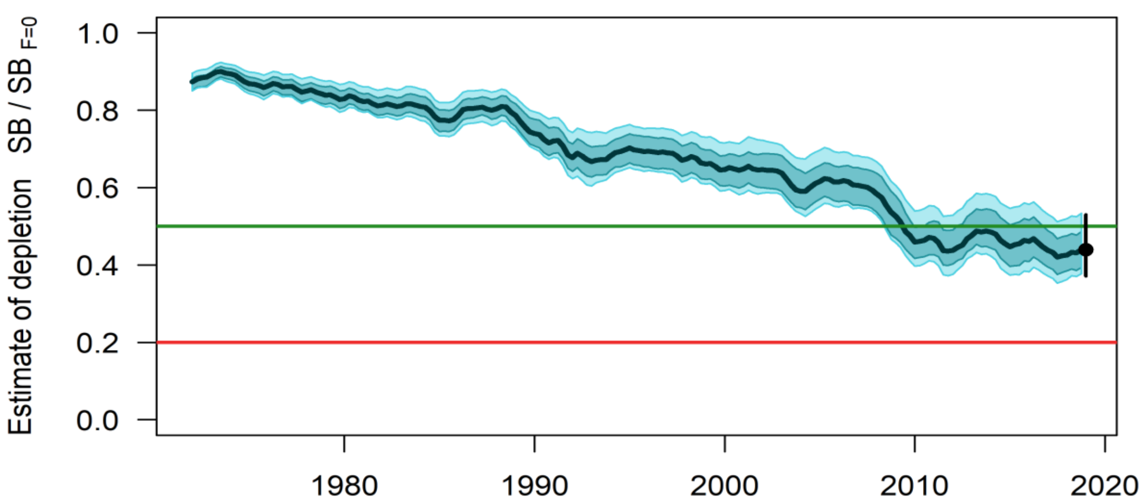


Figure SKJ-08. Plot showing the trajectories of spawning potential depletion for the model runs included in the structural uncertainty grid weighted by the values given in Table SKJ-01. Red horizontal line indicates the agreed limit reference point, the green horizontal line indicates the interim target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

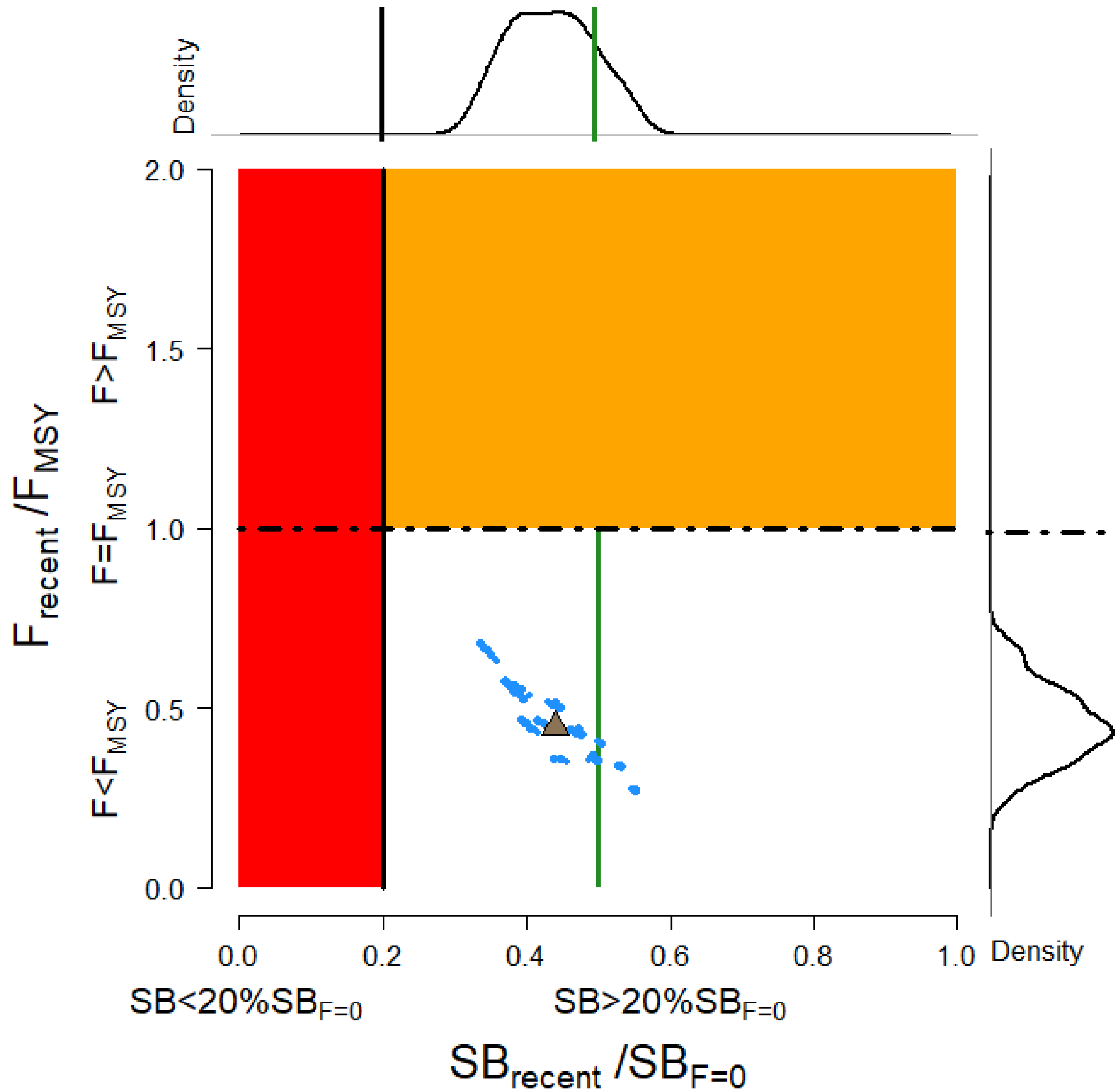


Figure SKJ-09. Majuro plot for the recent spawning potential (2015 – 2018) summarizing the results for each of the models in the structural uncertainty grid with weighting. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality, and marginal distributions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

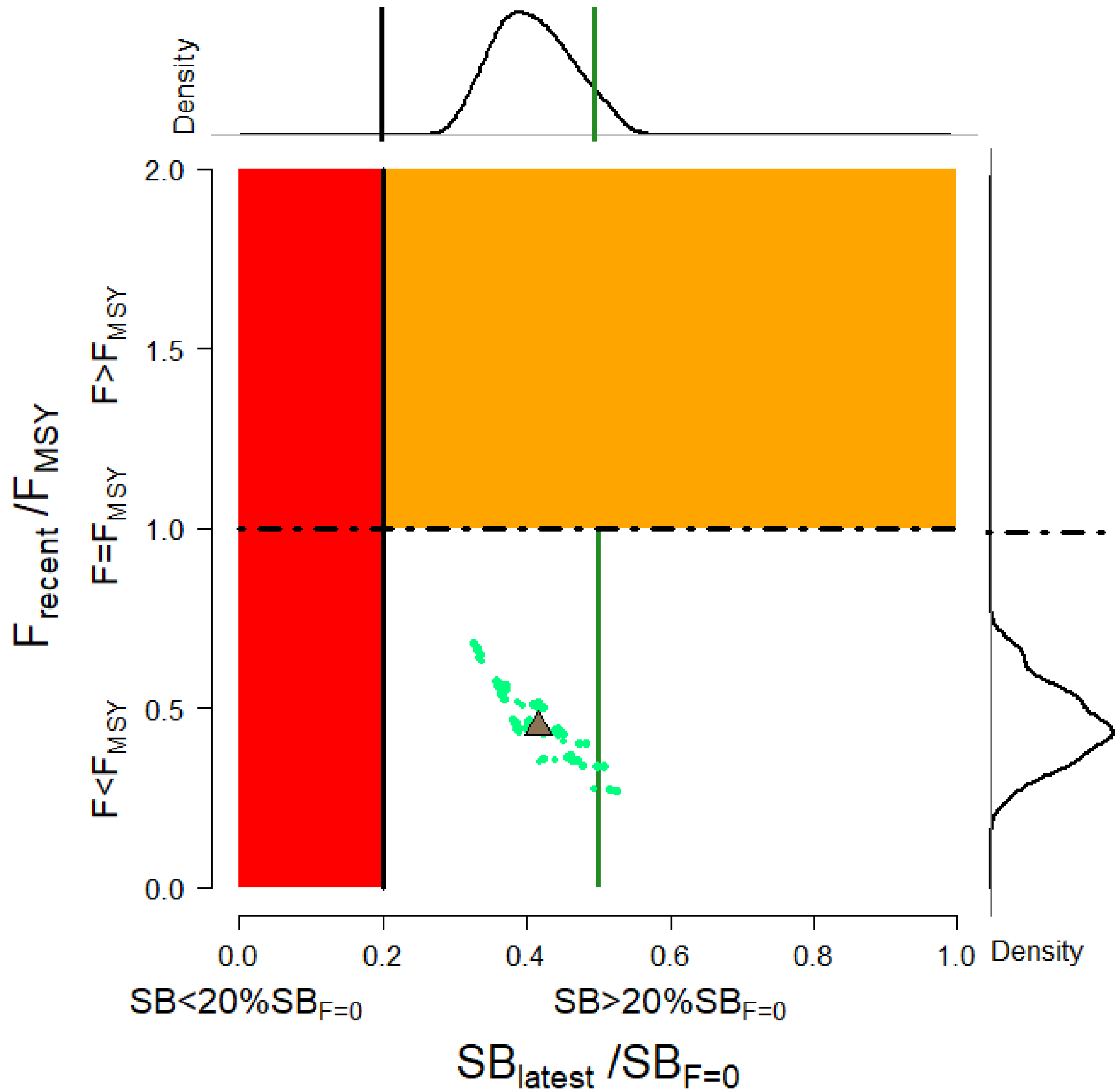


Figure SKJ-10. Majuro plot for the latest spawning potential (2018) summarizing the results for each of the models in the structural uncertainty grid with weighting. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality, and marginal distributions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

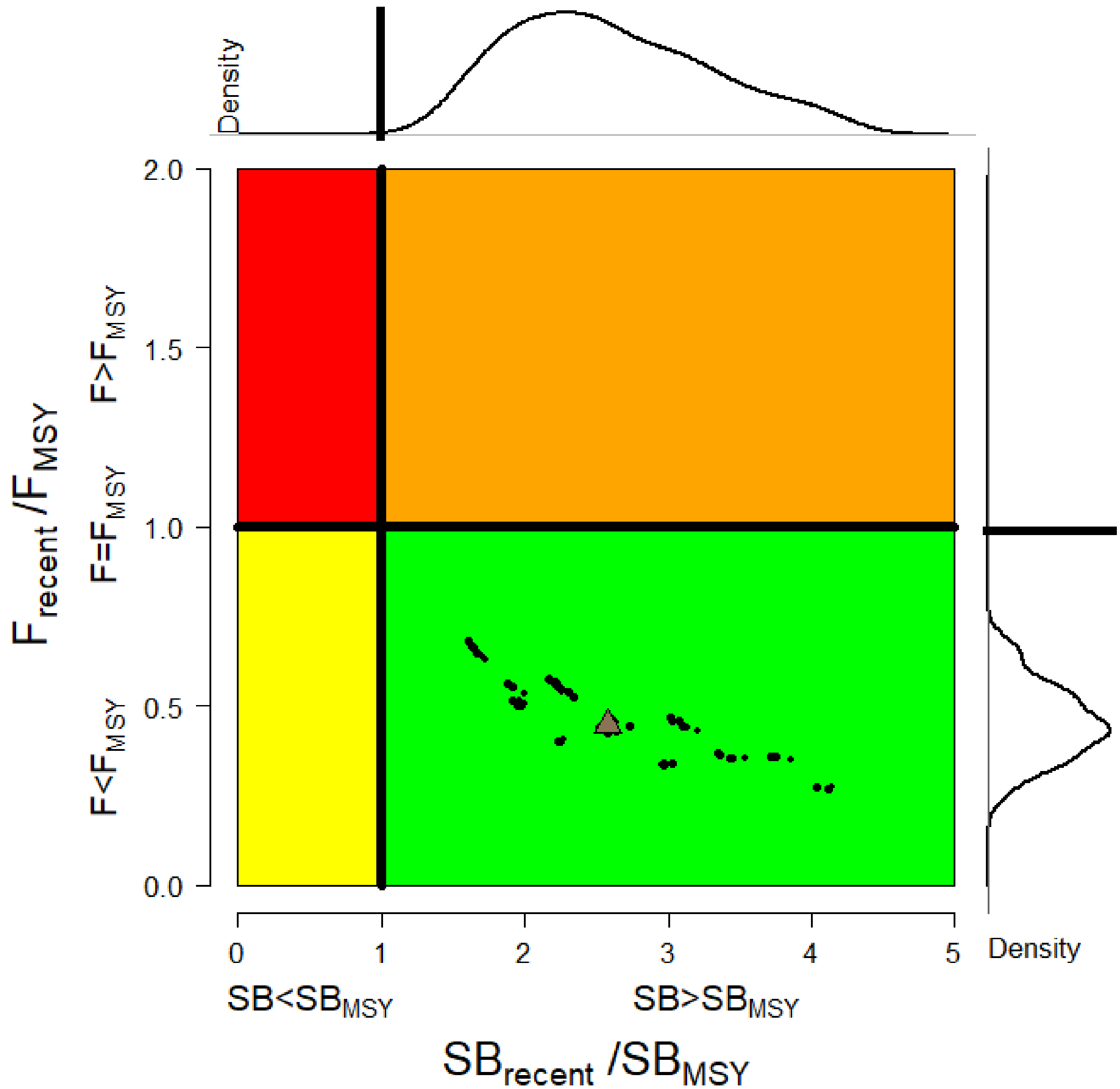


Figure SKJ-11. Kobe plot for the recent spawning potential (2015 – 2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality and marginal distributions of each are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

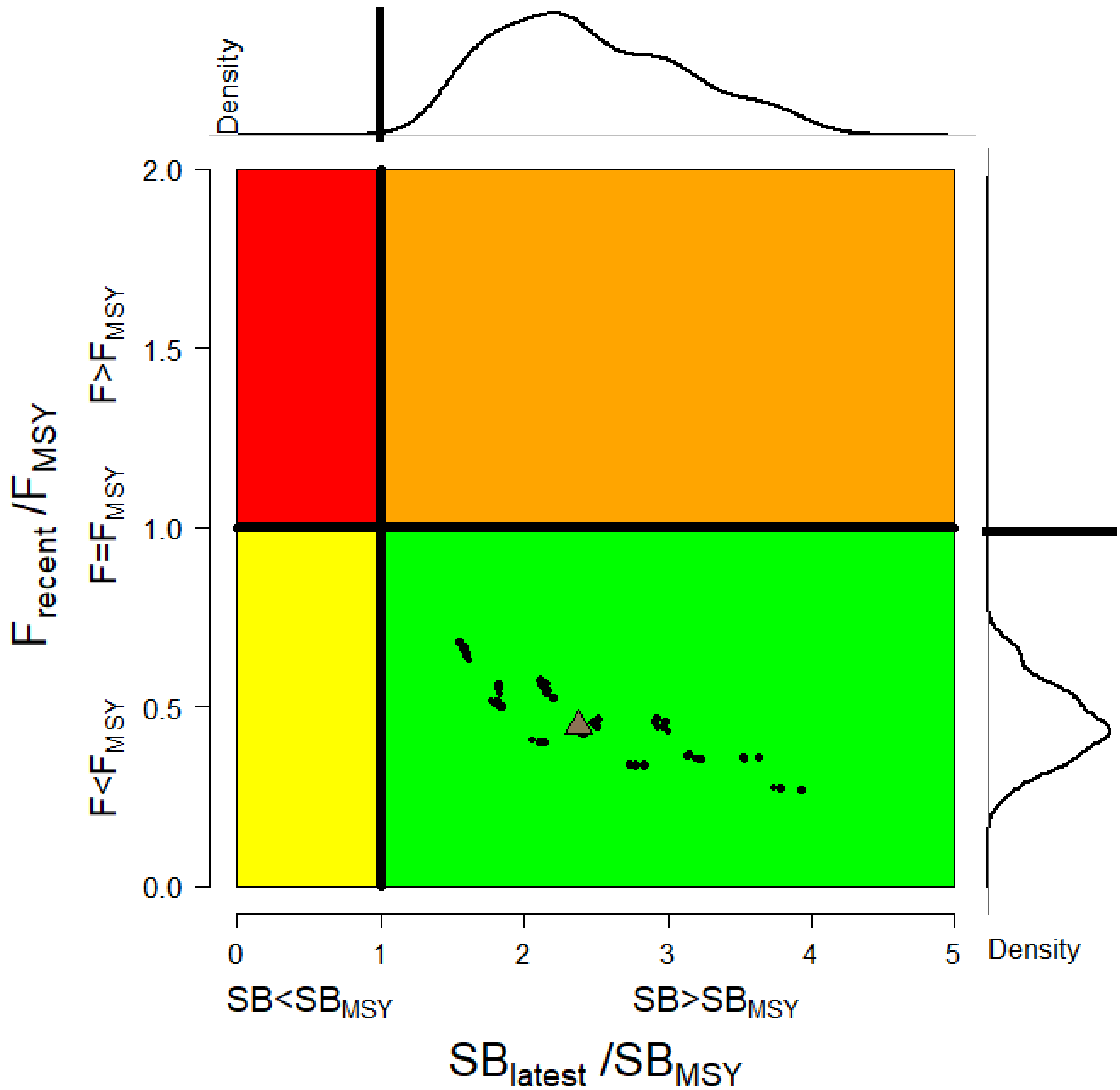


Figure SKJ-12. Kobe plot for the latest spawning potential (2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning potential depletion and fishing mortality and marginal distributions of each are presented.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