NORTHERN COMMITTEE
SEVENTEENTH REGULAR SESSION
ELECTRONIC MEETING
5 – 7 October 2021

SC17 Outcomes Document

WCPFC-NC17-2021/IP-02

The 17th Regular Session of the Scientific Committee

INTRODUCTION

1. The Seventeenth Regular Session of the Scientific Committee of the Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (SC17) took place for eight days during 11–19 August 2021 as an electronic meeting in response to the global coronavirus disease 2019 (COVID-19) pandemic. The meeting was chaired by the Vice-Chair Dr Tuikolongahau Halafihi (Tonga) as SC Chair Mr Matai'a Ueta Faasili Jr. (Samoa) was unable to attend.

2. The plenary of the Scientific Committee includes four key theme sessions: Data and Statistics, Stock Assessment, Management Issues, and Ecosystem and Bycatch Mitigation Themes. This information paper compiles all theme recommendations and other administrative decision points adopted by the SC17.

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

SCIENTIFIC COMMITTEE
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SC17 OUTCOMES DOCUMENT

WCPFC18-2021-SC17-01
26 August 2021

AGENDA ITEM 1 OPENING OF THE MEETING

1.1 Welcome address

1.2 Meeting arrangements

1.3 Adoption of agenda

1.4 Reporting arrangements

AGENDA ITEM 2 DATA AND STATISTICS THEME

2.1 Data gaps of the Commission

2.1.1 Data gaps

1. SC17 encouraged Members, Cooperating Non-Members and Participating Territories (CCMs) to resume observer coverage in their fisheries as soon as safe and logistically feasible to restore an important flow of scientific information to the Commission.

2. SC17 recommended the Scientific Services Provider (SSP) enhance the scientific data submission guidelines by preparing operational data field tables for longline, purse seine and pole and line operational data for SC18 review.

3. SC17 recommended publishing aggregated size data (data fields as listed in SC17-ST-WP-01, section 4.1) via the WCPFC public domain web page, after CCMs have advised the SSP on which of their size data submissions should be excluded. In this regard, CCMs are requested to advise the SSP of the size data to be excluded before 31 December 2021, after which time the SSP will proceed to publish the WCPFC public domain size data based on this advice.

4. SC17 recommended that the SSP add a new annex to the data gaps paper to include a breakdown of the coverage levels for each operational data field by year and fleet.

2.1.2 Potential use of cannery data

5. SC17 recommended the endorsement of the Draft *Guidelines for the Voluntary Submission of Purse Seine Processor Data by CCMs* to the Commission, and that the draft guidelines be forwarded to TCC17 and WCPFC18 for consideration. SC17 also recommended that TCC17 and WCPFC18 consider how to handle cannery data under the current WCPFC data rules, including updating the WCPFC data rules to include processor data as non-public domain (high risk classification) data.

2.2 Other commercial fisheries for bigeye, yellowfin and skipjack tuna

6. 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.

2.3 Consideration of SC17-ST-IP-06 and SC17-ST-IP-10 (From Agenda Item 8.2)

7. SC17 recommends that Tables 6 – 9 on estimates of all purse seine bycatch (as presented in SC17-ST-IP-06) should be made publicly available in electronic format (EXCEL file on the WCPFC Public domain Bycatch Data web page) to facilitate extraction and use of data.

8. SC17 recommends that future analyses providing estimates of purse seine bycatch include estimates of marine mammal bycatch to the species level, where possible, to allow for additional monitoring of bycatch and bycatch rates of marine mammal species.

AGENDA ITEM 3 STOCK ASSESSMENT THEME

3.1 WCPO tunas

3.1.1 South Pacific albacore tuna (*Thunnus alalunga*)

3.1.1.1 Review of 2021 South Pacific albacore tuna stock assessment

3.1.1.2 Provision of scientific information

a. Stock status and trends

9. The median values of relative recent (2016-2019) spawning biomass depletion (SB_{recent}/ $SB_{F=0}$) and relative recent (2015-2018) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 72 models (Table SPA-01) were used to define South Pacific albacore 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.

10. A description of the updated structural sensitivity grid used to characterize uncertainty in the assessment is illustrated in Table SPA-01. Tables SPA-02, SPA-03, and SPA-04 show reference points for South Pacific-wide, WCPFC-CA (Convention Area) and IATTC-CA, respectively, including the median values of relative 'recent' (2016-2019) and 'latest' (2019) spawning biomass depletion ($SB_{recent}/SB_{F=0}$) and relative recent (2015-2018) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 72 models used to define stock status. These values are based on the uncertainty grid with the downweighted SEAPODYM (M2) movement hypothesis. 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.

11. The spatial structure used in the 2021 stock assessment is shown in Figure SPA-01. Time series of total annual catch by fishing gear over the full assessment period and by regions is shown in Figure SPA-02. Estimated annual average recruitment, spawning potential, and total biomass by model region for the diagnostic case model are shown in Figure SPA-03. Estimated trends in spawning potential by region for the diagnostic case is shown in Figure SPA-04, and juvenile and adult fishing mortality rates from the diagnostic model is shown in Figure SPA-05. Time series of estimated spawning potential for the 72 models are shown in Figure SPA-06. Time-dynamic percentiles of depletion ($SB_t/SB_{t,F=0}$) for the 72 models are shown in Figure SPA-07. Majuro and Kobe plots summarizing the results for each of the 72 models in the weighted structural uncertainty grid are shown in Figures SPA-08 and SPA-09 for the 'recent' and 'latest' periods, respectively.

12. The most influential axis of uncertainty with respect to estimated stock status was movement, where assuming SEAPODYM derived movement was more pessimistic.

13. SC17 noted that the median value of relative recent (2016-2019) spawning biomass depletion for South Pacific albacore ($SB_{2016-2019}/SB_{F=0}$) was 0.52 with a 10th to 90th percentile interval of 0.41 to 0.57.

14. SC17 further noted that there was 0% probability (0 out of 72 models) that the recent (2016-2019) spawning biomass had breached the adopted limit reference point (LRP).

15. SC17 noted that there has been a long-term increase in fishing mortality for adult South Pacific albacore, with a notable steep increase in fishing mortality since 2000.

16. SC17 noted that the median of relative recent fishing mortality for South Pacific albacore ($F_{2015-2018}/F_{MSY}$) was 0.24 with a 10th to 90th percentile interval of 0.15 to 0.37.

17. SC17 further noted that there was 0% probability (0 out of 72 models) that the recent (2015-2018) fishing mortality was above F_{MSY}.

18. SC17 noted the results of stochastic projections (based on the weighted grid, SC17-SA-WP-02a, Figures 1 and 2) from the 2021 assessment, which indicated the potential stock consequences of fishing at "status quo" conditions (2017–2019 or 2020 average catch or, separately, fishing effort) using the uncertainty framework approach endorsed by SC17. These results are provided for both South Pacific-wide and for the WCPFC Convention area only. All projections show a steep and rapid decline in biomass towards the LRP in the year 2021 followed by an increase in biomass thereafter.

Table SPA-01. Description of the structural uncertainty grid used to characterize uncertainty in the management quantities derived from this assessment. Note that the M2-SEAPODYM hypothesis was downweighted by 50% by the SC17.

Axis	1	2	3
Steepness (S)	0.65	**0.80**	0.95
Movement (M)	**M1-Estimated, age-dependent**	M2-SEAPODYM	
Size data weight (D)	Low (50)	**Medium (25)**	High (10)
Recruitment distribution (R)	**R1-SEAPODYM**	R2-Regions 3 and 4	
Growth/M (G/M)	**Fixed otolith, Nat-M1**	Estimated from length frequency, Nat-M2	

Table SPA-02. South Pacific-wide (all regions) reference point estimates from the assessment based on the weighted grid.

	Mean	Median	Min	10%	90%	Max
C_{latest}	87,184	86,827	83,519	85,092	87,633	130,936
F_{MSY}	0.06	0.06	0.05	0.05	0.07	0.08
f_{mult}	4.37	4.25	2.11	2.69	6.62	7.84
F_{recent} / F_{MSY}	0.25	0.24	0.13	0.15	0.37	0.47
MSY	115,661	120,020	68,200	75,584	158,600	166,240
SB_0	623,542	660,200	361,800	392,590	845,100	929,300
$SB_{F=0}$	675,861	678,345	524,886	537,740	824,855	873,278
SB_{latest} / SB_0	0.41	0.41	0.34	0.37	0.46	0.48
$SB_{latest} / SB_{F=0}$	0.37	0.40	0.25	0.27	0.45	0.46
SB_{latest} / SB_{MSY}	2.50	2.33	1.45	1.69	3.92	4.28
SB_{MSY}	109,710	104,100	48,040	61,497	157,500	190,000
SB_{MSY} / SB_0	0.18	0.18	0.11	0.11	0.22	0.23
$SB_{MSY} / SB_{F=0}$	0.16	0.16	0.09	0.11	0.22	0.23
$SB_{recent} / SB_{F=0}$	0.50	0.52	0.37	0.41	0.57	0.59
SB_{recent} / SB_{MSY}	3.34	3.22	2.07	2.24	5.18	5.33
$Y\ F_{recent}$	81,998	85,020	58,440	63,656	94,720	101,400

Table SPA-03. WCPFC-CA reference point estimates from the assessment based on the weighted grid.

	Mean	Median	Min	10%	90%	Max
C_{latest}	78,788	78,455	75,673	76,959	79,126	118,706
$SB_{F=0}$	459,648	463,424	415,746	431,617	491,092	501,602
$SB_{latest} / SB_{F=0}$	0.37	0.39	0.26	0.28	0.43	0.45
$SB_{recent} / SB_{F=0}$	0.51	0.52	0.39	0.42	0.58	0.61

Table SPA-04. IATTC-CA reference point estimates from the assessment based on the weighted grid.

	Mean	Median	Min	10%	90%	Max
C_{latest}	8,396	8,242	7,845	8,074	8,760	12,229
$SB_{F=0}$	216,213	233,755	92,190	98,063	356,491	379,718
$SB_{latest} / SB_{F=0}$	0.38	0.42	0.22	0.25	0.46	0.48
$SB_{recent} / SB_{F=0}$	0.47	0.52	0.28	0.32	0.56	0.57

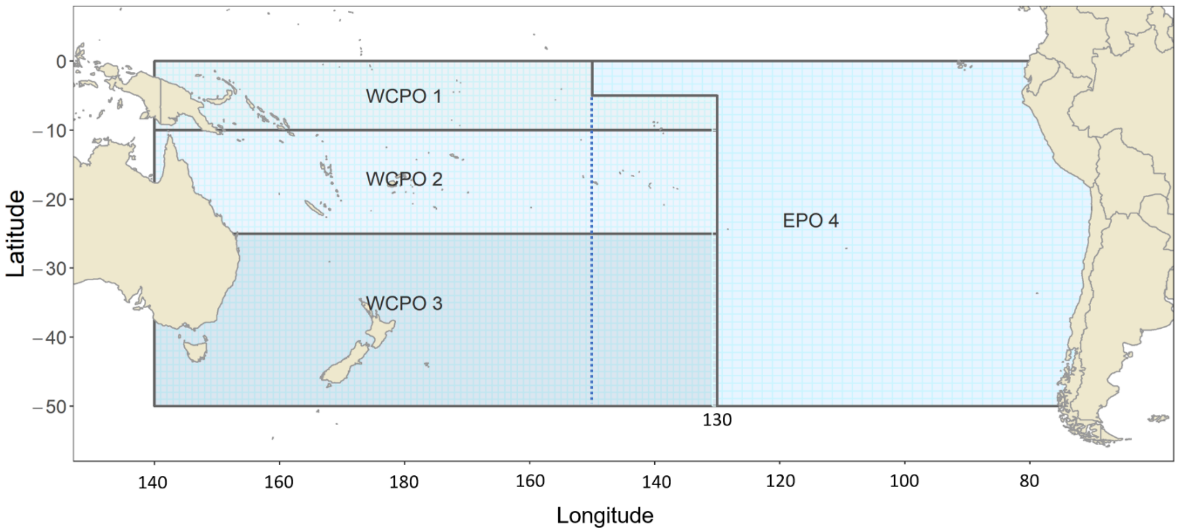

Figure SPA-01. The geographical area covered by the stock assessment and the boundaries of the four model regions used for South Pacific-wide 2021 albacore assessment. The overlap region between the WCPFC and IATTC convention areas is the area between 130º - 150º west demarcated by the dashed line. The catch from the ‘overlap’ area is included within the WCPFC-CA for this assessment.

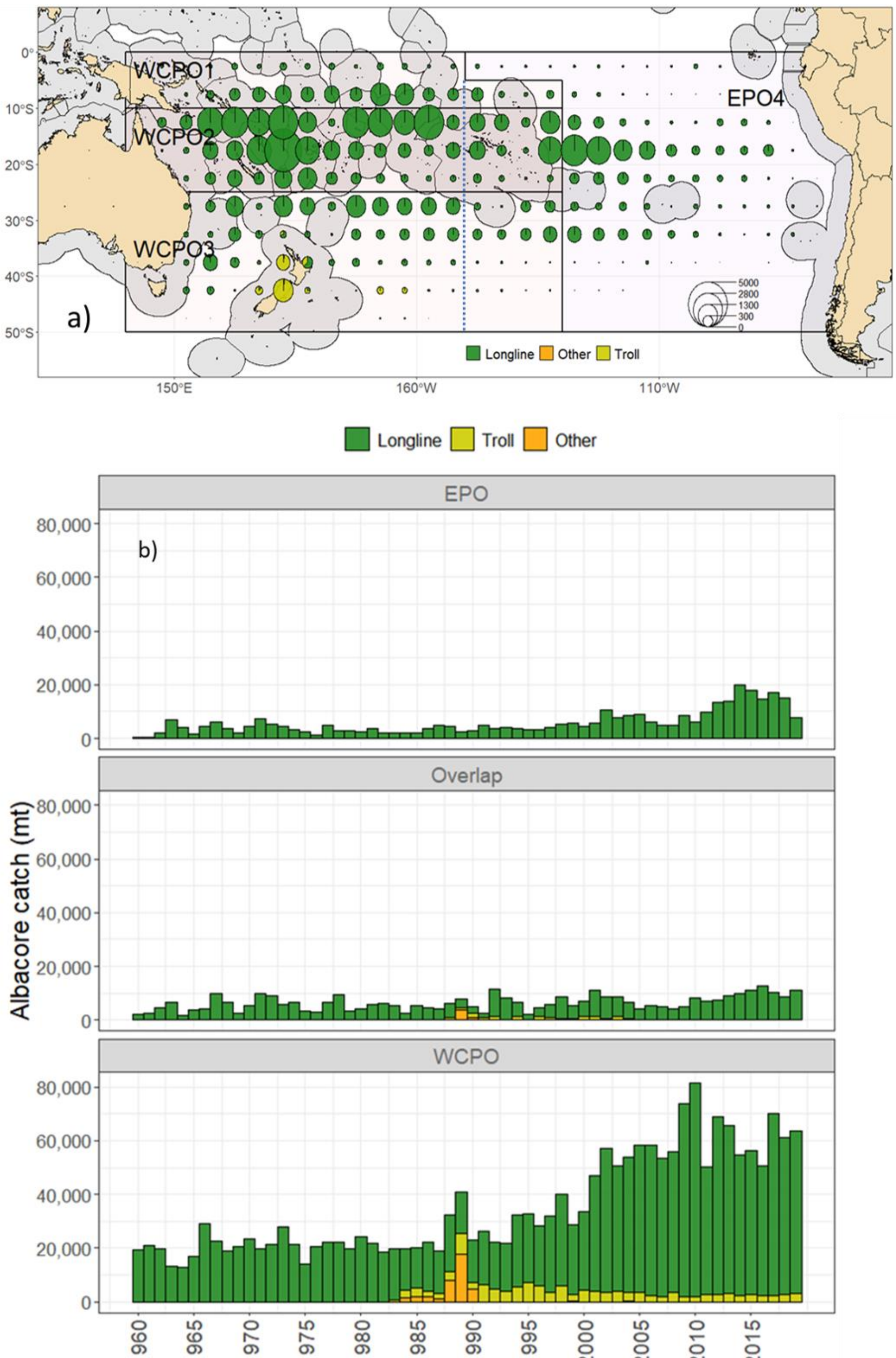

Figure SPA-02. a) Spatial pattern of albacore catch by gear type over the last decade, and b) historical catches of albacore across the model region from 1952-2019 by gear type.

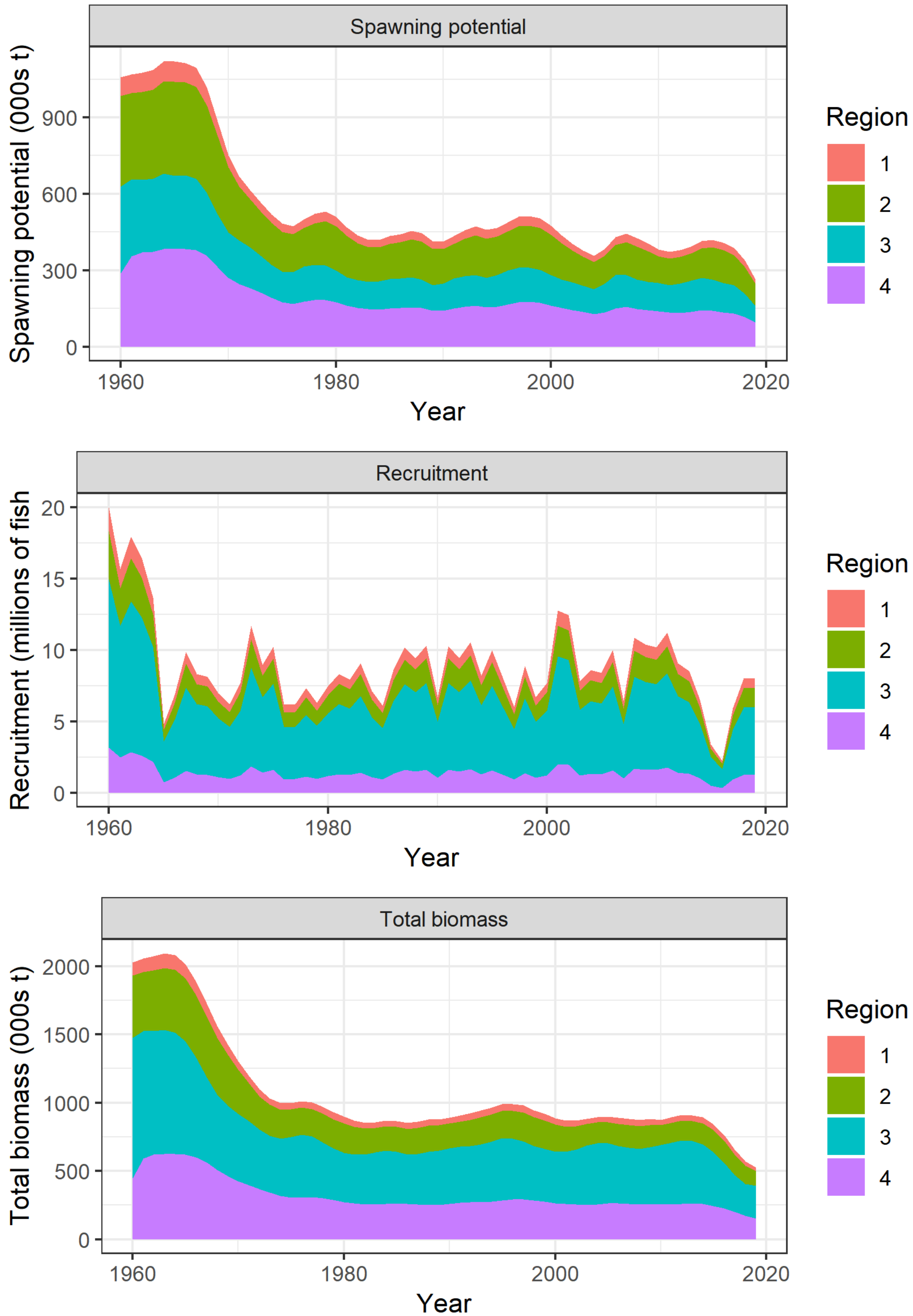

Figure SPA-03. Estimated annual average a) spawning potential, b) recruitment, and c) total biomass by model region for the diagnostic case model, showing the relative levels among regions.

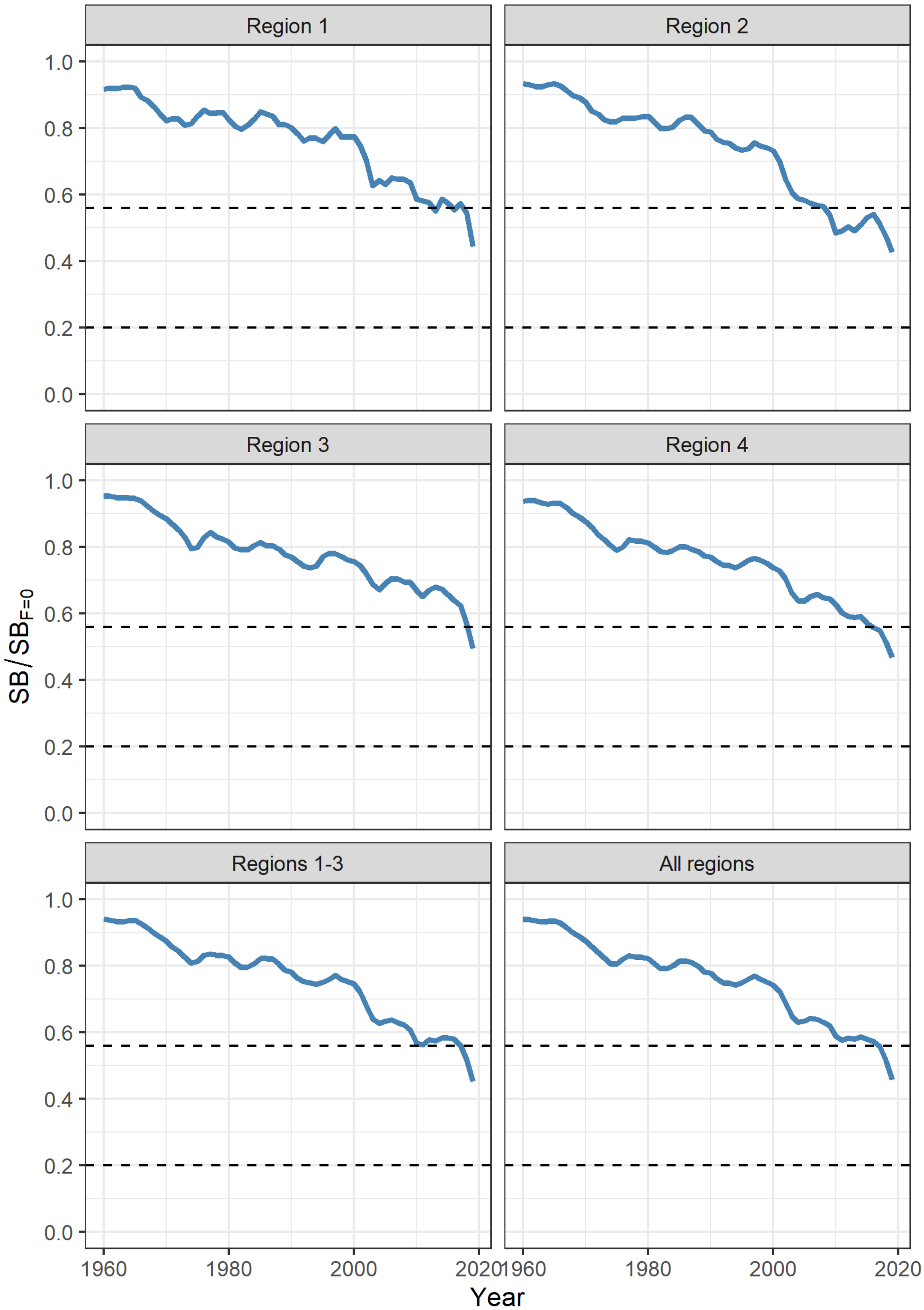

Figure SPA-04. Estimated temporal spawning potential by model region, grouped by region (WCPFC-CA, EPO) and South Pacific as a whole for the diagnostic case model. The dotted lines are included to indicate the $SB/SB_{F=0}$ interim target reference point (TRP)=0.56 and the LRP=0.2 for the WCPFC-CA albacore fishery. Regions 1-3 represent the WCPFC-CA (including the "overlap"), region 4 is the IATTC-CA.

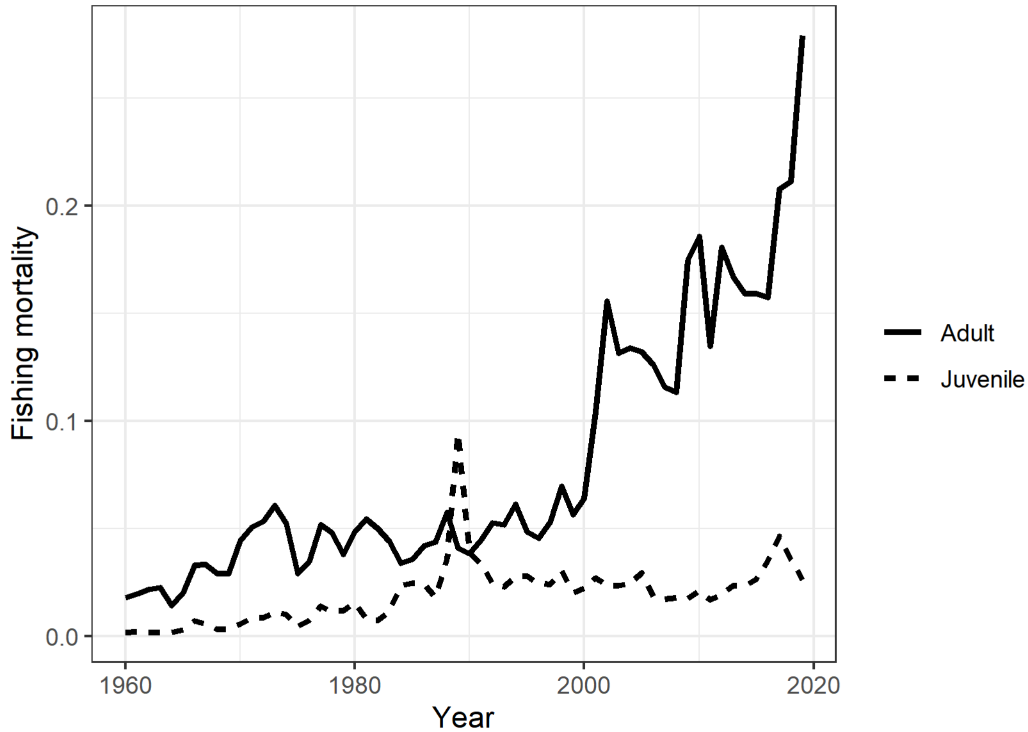

Figure SPA-05. Estimated annual average juvenile and adult fishing mortality for the diagnostic case model.

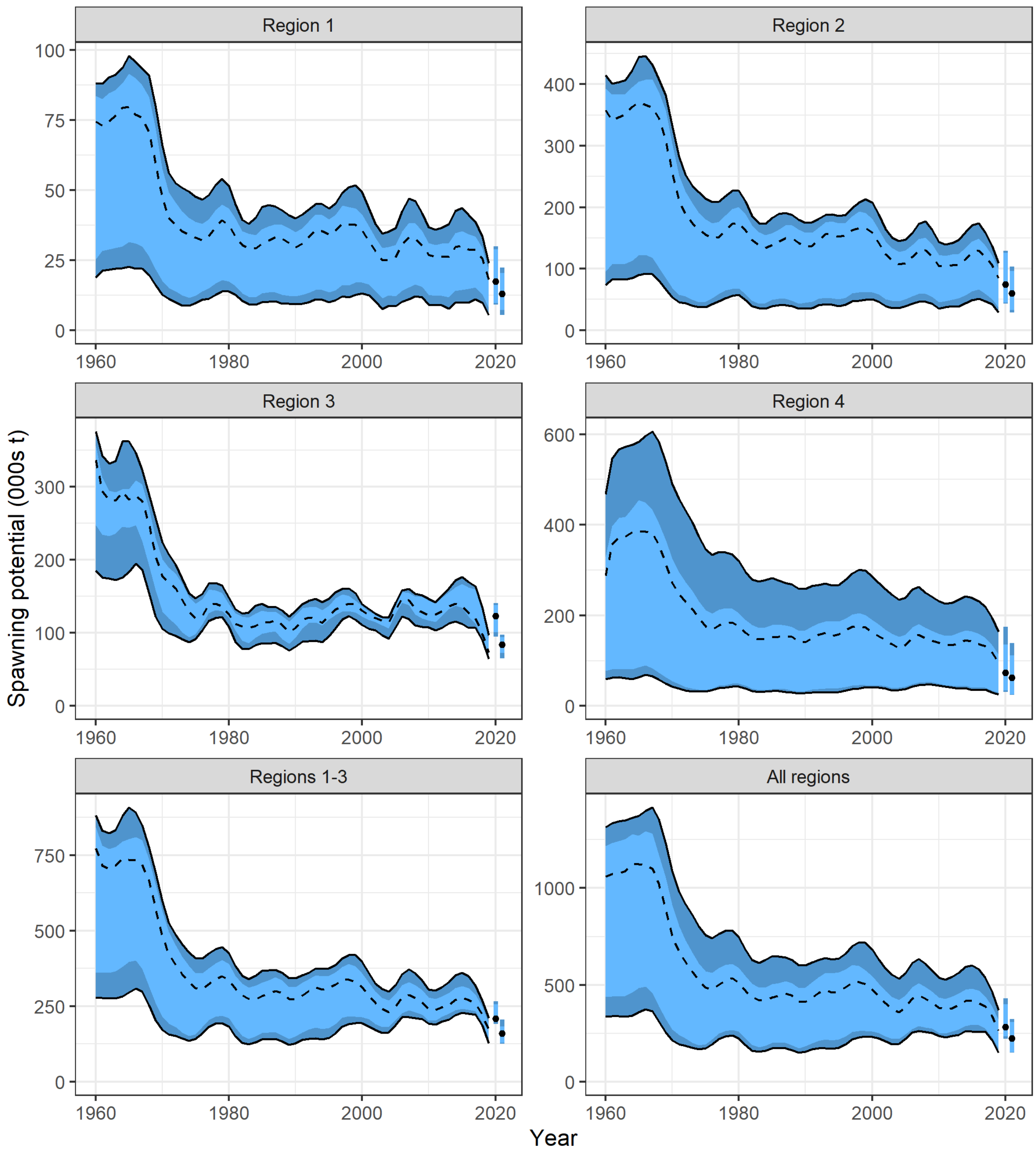

Figure SPA-06. Estimated spawning potential across all models in the structural uncertainty grid over the period 1960-2019. The dashed line represents the median. The darker band shows the 10th-90th percentile, and the lighter band shows the 25th-75th percentile of the model estimates. Regions 1-3 represent the WCPFC-CA (including the "overlap"), region 4 is the IATTC-CA. The bars at right in each plot are the median values (points) and percentiles for recent (left) and latest (right) spawning potential.

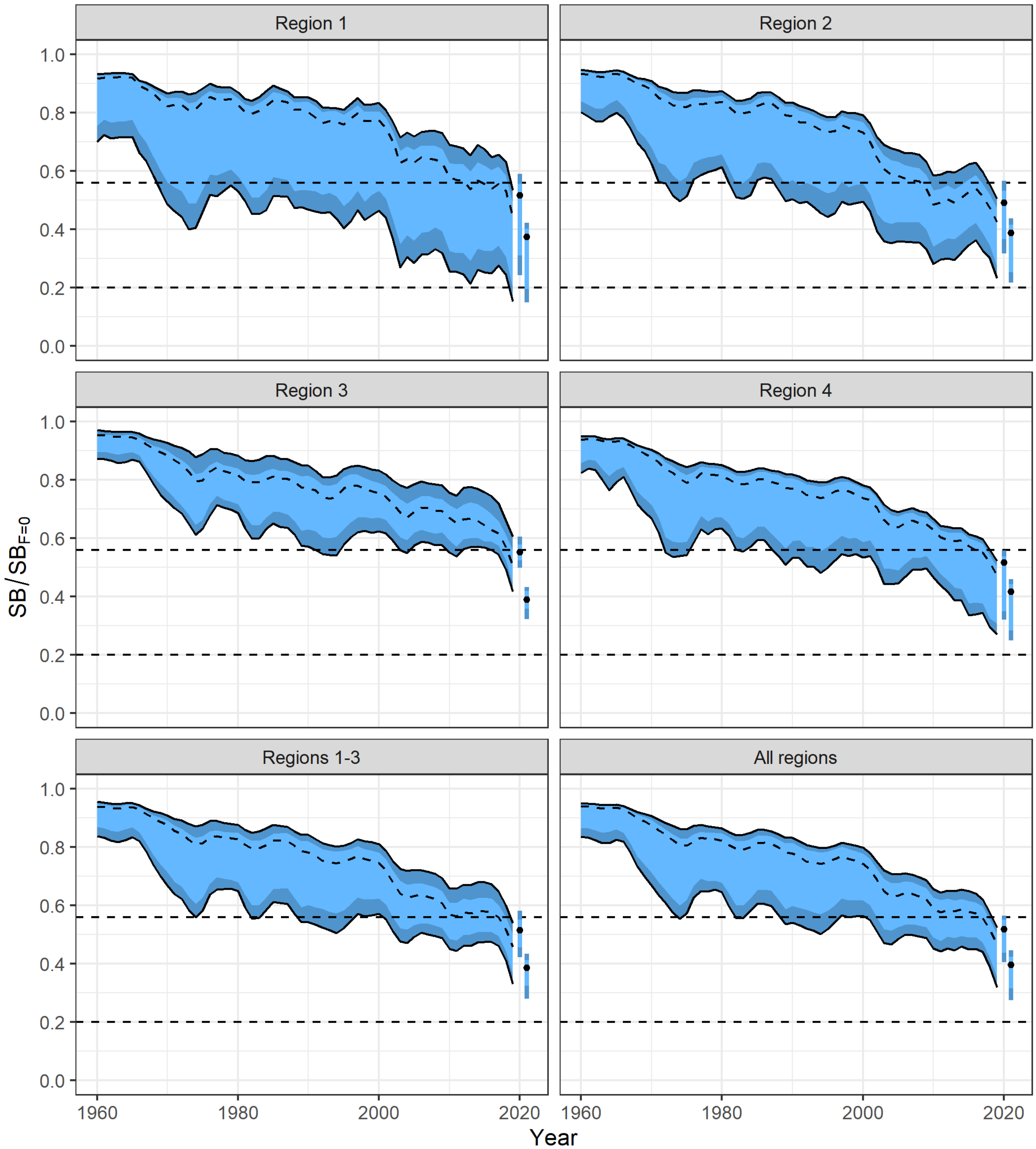

Figure SPA-07. Estimated spawning depletion across all models in the structural uncertainty grid over the period 1960-2019. The dashed line represents the median. The darker band shows the 10th-90th percentile, and the lighter band shows the 25th-75th percentile of the model estimates. Regions 1-3 represent the WCPFC-CA (including the "overlap"), region 4 is the IATTC-CA. The dashed horizontal lines indicate the depletion LRP (0.2) and the WCPFC-CA TRP for $SB/SB_{F=0}$ (0.56). The bars at right in each plot are the median values (points) and percentiles for $SB_{recent}/SB_{F=0}$ (left) and $SB_{latest}/SB_{F=0}$ (right).

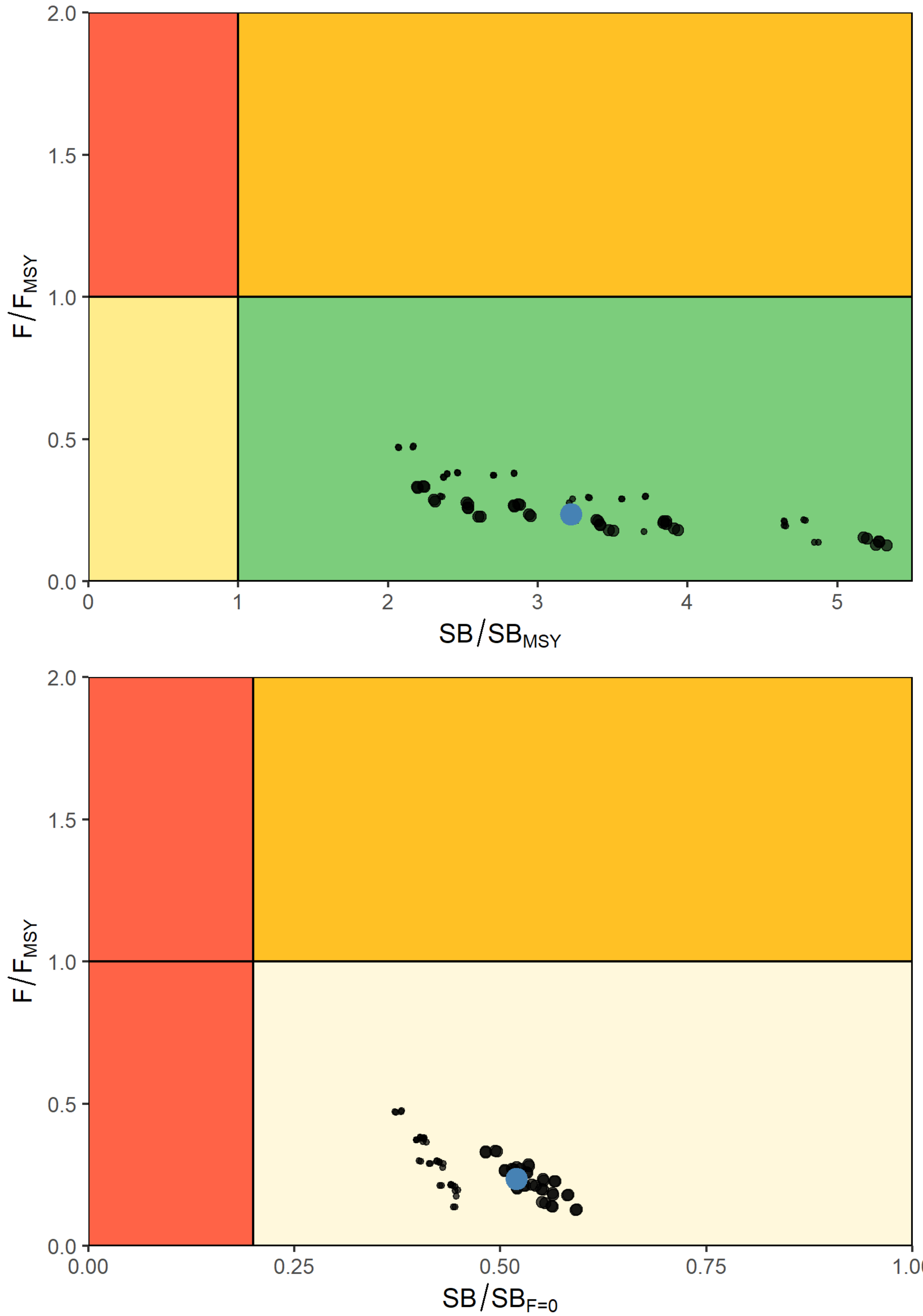

Figure SPA-08. Majuro (bottom) and Kobe (top) plots summarizing the Pacific-wide results for each of the models in the structural uncertainty grid for the 'recent' (2016-2019) period. The blue point is the median value based on the weighted grid models, with the more heavily weight models indicated by the larger black dots.

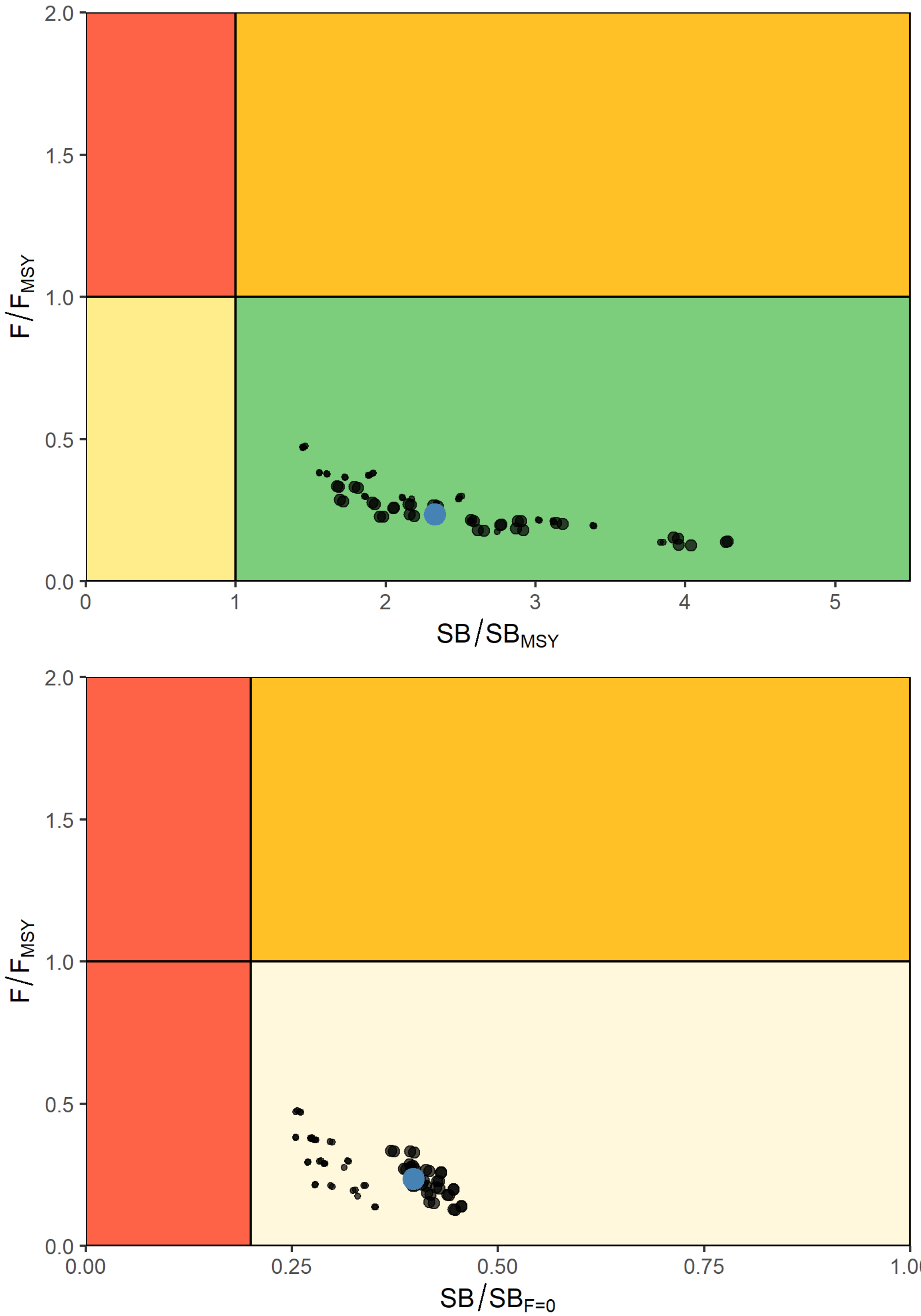

Figure SPA-09. Majuro (bottom) and Kobe (top) plots summarizing the Pacific-wide results for each of the models in the structural uncertainty grid for the 'latest' (2019) period. The blue point is the median value based on the weighted grid models, with the more heavily weighted models indicated by the larger black dots.

b. Management advice and implications

19. Annual catch estimates for albacore in the South Pacific peaked at 93,835 mt (all gears) in 2017 (SC17-SA-IP-04). Catch by longliners represented 93% of the catch weight in 2020 at 64,963 mt and represented a 21% decrease from 2019 despite a shift of effort from the tropical to the southern longline fishery in 2020. By comparison, the 2020 total albacore catch within the southern part of the WCPFC-CA was 61,778 mt and the longline catch was 57,006 mt.

20. The 2021 South Pacific albacore stock assessment provided results consistent with the 2018 assessment. The addition of the EPO region into the current entire South Pacific assessment did not notably alter the main assessment outcomes, and similar trajectories and terminal depletion were estimated in both RFMO regions.

21. The spawning stock biomass has become more depleted across the model period (1960-2019), with a notable increase in depletion in the most recent years. Based on the set of models in the SC endorsed structural uncertainty grid the South Pacific albacore assessment indicates the stock is not overfished, and, there was zero estimated risk of the stock being below the Limit Reference Point of $20\%SB_{F=0}$. However, the decline in the latest estimated $SB_{latest}/SB_{F=0}$ (year 2019; median 0.40; 10^{th} and 90^{th} percentiles 0.27 - 0.45) is notably more pessimistic than those of $SB_{recent}/SB_{F=0}$ (years 2016-2019; median 0.52; 10^{th} and 90^{th} percentiles 0.41 - 0.57) indicating that there has been a substantial decline in stock status estimated over the last three years. The general trends are consistent for estimates across all regions of the South Pacific stock, and for the WCPFC-CA only.

22. For the WCPFC-CA region, the ‘recent’ and ‘latest’ SB estimates are on average both below the interim TRP of 0.56. Further, 86% of models (62 out of 72 models) in the structural uncertainty grid endorsed by SC17 estimated that $SB_{recent}/SB_{F=0}$ was below the interim TRP. In relation to management objectives for the WCPFC-CA longline fishery, this assessment estimated that the median `latest' (2019) and `recent' (2016-2019) longline vulnerable biomass for the WCPFC-CA are 56% and 76% of the 2013+8% target level that defined the interim TRP.

23. SC17 noted CPUE declines in many domestic longline fisheries in the southern portion of the WCPFC-CA.

24. SC17 noted that depletion is greatest in regions north of 25ºS, specifically in assessment Regions 1 and 2 where most domestic Pacific Island Countries and Territories (PICTs) fleets operate, including Small Island Developing States (SIDS) and Participating Territories that may have no high seas access. These are areas mostly unaffected by current management measure for South Pacific albacore (CMM 2015-02), which prescribe effort controls and reporting provisions south of 20ºS.

25. SC17 expressed great concern with the projected status of South Pacific albacore if recent catch or effort levels are maintained (SC17-SA-WP-02a REV2). Projections indicated that South Pacific albacore stock has a greater than 20% risk of falling below the LRP in 2021 under both catch and effort scenarios. These projections indicate an extended period where biomass is below the current interim TRP and in most cases the TRP is not achieved within the 30-year projection period.

26. Recalling its previous advice from SC11, SC12, and SC13, SC17 recommended that longline catch be reduced to avoid further and extended declines in the vulnerable biomass so that economically viable catch rates can be maintained, especially for longline catch of adult albacore.

27. SC17 recommended a recalibration of the interim TRP for review at WCPFC18 in accordance with the process agreed at WCPFC15 (WCPFC15 Summary Report, para 207). Further, SC17 recommended projections be undertaken to estimate the constant catch levels that would achieve that TRP on average over the long-term. SC17 recommended that these analyses be provided to WCPFC18 to guide its consideration of reductions in longline fishing mortality that will be required to return the vulnerable biomass to the 2013 +8% level as agreed.

c. Future research recommendations

28. SC17 noted with concern that the standardized CPUE indices do not show linear contrast with catches over the past 20 years when the catch has increased by 2 to 3-fold and also that the fit to the indices show a residual pattern over time. SC17 supported the assessment scientist's suggestion to consider split indices in future assessments, which might allow for the incorporation of more informative catchability and density covariates during the contemporary period, which is more important for estimates of recent status.

29. SC17 noted a possible a nonlinear relationship between catch and effort or a time-varying relationship with changing fishing power and catchability. The next assessment could investigate such nonlinear relationships and explore alternative effort metrics.

30. SC17 noted with concern that the standardized CPUE model with hooks between floats (HBF) did not converge. The time-series is almost 70 years with substantial shifts to deploy more HBF though time. These gear changes have probably altered South Pacific albacore catchability and require additional research. HBF is one characteristic of longline gear that could affect catchability; operational longline data are largely absent of detailed vessel and gear characteristics that could be valuable in a standardization model. Reliably collecting additional gear characteristics will better inform these models on variability in catchability among vessels and fleets and over time and these data enhancements could be achieved by revisiting the minimum logsheet data standards, increasing observer coverage, or expanding electronic monitoring applications. Without this additional information the large uncertainties associated with the use of standardised-CPUE in assessments will remain unresolved and continue to impact on future assessments.

31. SC17 noted the need to both recalibrate the interim TRP according to the procedure agreed at WCPFC15 (WCPFC15 Summary Report, para 207) and estimate the constant catch levels that would achieve that TRP on average over the long-term. Specifically, based upon the SC-agreed 2021 South Pacific albacore stock assessment:

a) re-calibrate the WCPFC interim TRP (the median depletion in the WCPFC-CA, $SB/SB_{F=0}$) that would on average achieve the agreed objective of an 8 % increase in vulnerable biomass (CPUE proxy) for the southern longline fishery as compared to 2013 levels.
b) undertake projections to estimate the constant catch levels that would achieve the recalibrated TRP, on average, over the long-term
c) within that projection-based analysis, WCPFC-CA longline and troll fisheries should be modelled based upon catch, and fishing levels within the EPO should be adjusted in the same way as the WCPO for one scenario and fixed at recent catch levels for another scenario. Future recruitment should be sampled from the long-term recruitment pattern.

32. A number of key research needs were identified in undertaking the assessment that should be investigated either internally or through directed research.

33. As with the previous South Pacific albacore assessment, the fishery dependent CPUE-based indices of abundance lacked contrast to inform population responses to increased fishing pressure. This continues to be a significant concern for the reliability of estimates of population size. The CPUE analysis has been a major focus of preparatory work for this and previous assessments, and despite the attempts of various

scientists, application of new approaches including attempts at splitting time series and testing various covariates, the CPUE continues to lack contrast. It is recommended that alternative fishery independent estimates of population size be explored, especially the genetic method of Close-Kin Mark-Recapture (CKMR).

34. The implications of uncertainty in movement were clearly evident in this year's assessment, with this being the most influential uncertainty for management advice. In the absence of strong empirical data to inform decisions on alternative movement hypotheses, the SC decided to downweight one of the two movement hypothesis for provision of management advice. This is an unsatisfactory situation and there is a clear need to improve understanding of connectivity among albacore populations across the South Pacific, and, in particular, the fishery regions in the WCPFC and IATTC convention areas. This is particularly critical if South Pacific-wide assessments are to continue. The CKMR method as a byproduct can also address this uncertainty.

35. Despite applying the new growth data to this assessment, the modal structure in the New Zealand troll fishery size composition was still not fit adequately. Further work on growth modelling is required. It should also be noted that otolith-based growth data being used is mostly derived for otolith samples collected in 2009 -2010. Further, to update the growth information for albacore, samples from the IATTC-CA are needed. Again, samples required to address this issue could be collected as part of a CKMR project that would also include a component to develop (tissue-based) epigenetic ageing methods and sex determination. This would be a major advance in including more contemporary growth information in tuna assessments.

36. Follow-up studies to assess the reliability of size composition data for providing information on recruitment and population trends, and if necessary, develop better stratification methods to improve the representativeness of size composition data should be considered.

37. Finally, the current model is highly parameterized, and reducing model parameters and complexity should be considered to improve model fits and diagnostics. One key advancement would be the application of the "catch conditioned" approach that will be available in MULTIFAN-CL for the next assessment.

3.2 WCPO sharks

3.2.1 Southwest Pacific blue shark (*Prionace glauca*)

3.2.1.1 Review of 2021 Southwest Pacific blue shark stock assessment (Project 107)

3.2.1.2 Provision of scientific information

<u>Provision of information about indicators</u>

38. SC17 noted that in 2021, the three major CPUE time series (high-latitude fisheries around New Zealand and South-East Australia; mid-latitude EU-Spain fishery; and the high latitude and high seas Japan fishery) for blue shark in the Southwest Pacific from 1995 to 2020 indicated a consistent trend of increasing CPUE in the recent decade.

39. SC17 noted that the CPUE of the low latitude/high seas Japanese fishery suggested a declining trend in biomass from relatively high values of CPUE in the 1990s, reflecting increasing effort during that time, followed by a steady increase of biomass since around 2010 as effort plateaued and discard rates increased, and returned to biomass levels estimated at the beginning of the assessment period.

40. SC17 noted that blue sharks are relatively productive with fast growth and high fecundity compared to other sharks. In addition, the population is structured spatially with smaller fish in the higher latitudes.

a. Stock status and trends

41. SC17 noted that WCPFC has not yet agreed on any reference points for Southwest Pacific blue shark.

42. SC17 noted that Southwest Pacific blue shark assessment was undertaken using the Stock Synthesis model framework and the structural uncertainty grid approach with 9 structural uncertainties (Catch, Discard, Initial-F, Rec. dev., High latitude CPUE, Low latitude CPUE, Natural mortality, survival function, growth) resulting in 3,888 models. In addition, a surplus production model was run. SC17 noted that both assessment methods produced similar results.

43. SC17 agreed that the assessment was an improvement on the 2016 assessment, in particular, the catch reconstruction, CPUE time series, and re-parameterization of biological parameters using combined information from south and north Pacific assessments.

44. SC17 noted that 90% of model runs indicated that F_{2020} was below F_{MSY} and 96% of model runs shows that SB_{2020} was above SB_{MSY}. However, the model grid was not adopted by SC17 due to the views of some CCMs that a more thorough investigation of diagnostics across the grid of models was required. These CCMs recommended that residual pattern and retrospective analysis, among other approaches, would be informative, and a deeper investigation into the grid model selection and uncertainty was advised.

45. SC17 noted that fishing mortality has likely declined over the last decade and is currently relatively low due to the fact that most sharks are released upon capture in most longline fleets.

46. SC17 requested several diagnostics (i.e., CPUE's residuals, retrospective analysis, jitter analysis, and recruitment deviations) for the diagnostic case.

47. These diagnostics showed that the model convergence was reasonable for the models in the uncertainty grid with low maximum gradient and positive definite of hessian matrix, but the model fitting of the CPUEs and recruitment deviations were contended by some members of the SC.

b. Management advice and implications

48. SC17 noted, based on the above information, that stock biomass is likely increasing, and fishing pressure has declined through the recent decade. The results indicate that, if assessed against conventional reference points, it is likely that the stock will not be found to be overfished nor would overfishing be occurring.

49. SC17 recommended improving the manner in which the grid was selected before approving the results for providing management advice and proposed developing objective criteria for evaluating the plausibility of the grid. It was suggested that an attempt be made to use diagnostic tests as criteria for determining the final grid of results to inform management advice and uncertainty in the assessment. The performance of each model would be assessed against the following four criteria.

1) Model convergence and stability: the analysis should assess the final gradient (the final gradient should be relatively small; $<1e^4$), and check that the Hessian matrix is definite. Apply the jitter procedure to verify the stability of the model to evaluate whether the model has converged to a global solution rather than a local minimum.

2) Goodness-of-fit evaluate whether residuals patterns of the CPUE and length-frequency distributions were normally distributed or/and had temporal trends.
3) Model consistency: retrospective analysis to check the consistency of model estimates, for example, the invariance in SB and F as the model is updated with new data in retrospect.
4) Prediction skill: hindcasting analysis could be done to evaluate the model prediction skill of the CPUE. When conducting hindcasting, a model is fitted to the first part of a time series and then projected over the period omitted in the original fit. Prediction skill can then be evaluated by comparing the predictions from the projection with the observations.

c. Future research recommendations

50. SC17 recommended that:

a) increased effort be made to re-construct catch histories for sharks (and other bycatch species) from a range of sources;
b) dynamic/non-equilibrium reference points, such as $SB_{F=0}$ be investigated for shark stock status, as they may be more appropriate for fisheries with uncertain early exploitation history and strong environmental influences;
c) additional tagging be carried out using satellite tags in a range of locations, especially known nursery grounds in South-East Australia and New Zealand, as well as high seas areas to the north and east of New Zealand, where catch-rates are high;
d) additional growth studies from a range of locations be undertaken to help build a better understanding of typical growth, as well as regional growth differences;
e) genetic/genomic studies be undertaken to augment the tagging work to help resolve these stock/sub-stock structure patterns;
f) aggregated data for key sharks are submitted as by ocean area not simply as WCPO and, where possible, these data should be retrospectively corrected; and
g) observers (or the vessel) should record number of shark lines deployed per set or the number of floats with shark lines.

3.3 WCPO billfishes

3.3.1 Southwest Pacific swordfish (*Xiphias gladius*)

3.3.1.1 Research and information

a. Structural uncertainty grids and projections

b. Review of 2021 Southwest Pacific swordfish stock assessment

3.3.1.2 Provision of scientific information

a. Stock status and trends

51. The median values of relative latest (2019) spawning potential depletion (SB_{latest}/ $SB_{F=0}$), spawning potential relative to MSY (SB_{latest}/ SB_{MSY}) and relative recent (2015-2018) fishing mortality (F_{recent}/F_{MSY}) over the 25-model ensemble (Table SWO-03) were used to define Southwest Pacific swordfish stock status. The values of the upper 90th and lower 10th percentiles of the empirical distributions of relative spawning potential depletion, spawning potential relative to MSY and relative fishing mortality from the uncertainty ensemble (that included both structure and estimation uncertainty) were used to characterize the probable range of stock status.

52. A description of the model ensemble used to characterize uncertainty in the assessment is illustrated in Tables SWO-01 and SWO-02. Table SWO-03 shows reference points for Southwest Pacific swordfish, including the median values of relative 'latest' (2019) spawning biomass depletion ($SB_{latest}/SB_{F=0}$), spawning potential relative to spawning potential at MSY (SB_{latest}/SB_{MSY}), and relative recent (2015-2018) fishing mortality (F_{recent}/F_{MSY}) over the final 25-model ensemble used to define stock status. These values present a more holistic view of uncertainty, accounting for both model (structural) and estimation (statistical) uncertainty.

53. The spatial structure used in the 2021 stock assessment is shown in Figure SWO-01. Time series of total annual catch by fishing gear over the full assessment period and by regions is shown in Figure SWO-02. Estimated annual average recruitment, spawning potential, and total biomass by model region for the diagnostic case model are shown in Figure SWO-03. Estimated trends in fishing mortality rates by age and region from the diagnostic model are shown in Figure SWO-04. Time-dynamic median and percentiles of depletion ($SB_t/SB_{t,F=0}$) for the 25 models are shown in Figure SWO-05. Majuro and Kobe plots summarizing the results for each of the 25 models in the ensemble are shown in Figures SWO-06 and SWO-07, respectively.

54. Estimated stock status was most impacted by the uncertainties in movement and natural mortality. Low natural mortality and higher rates of movement from Region 1 into Region 2 resulted in more pessimistic stock status.

55. SC17 noted that the stock is estimated to have gradually declined from the 1950s to the mid-1990s before rapidly declining to an overall low point near 2010. Current stock status is estimated to be at a similar level as the overall low with a declining trend in the terminal 4 years of the model.

56. SC17 noted that latest spawning potential depletion levels estimated by this assessment ($SB_{latest}/SB_{F=0}$) indicated a median of 0.39 (10^{th} and 90^{th} percentiles 0.18 - 0.79).

57. SC17 noted that there was 13% risk that the latest (2019) spawning potential was lower than 20% $SB/SB_{F=0}$ when considering structural + estimation uncertainty. Omitting the estimation uncertainty as was done in the previous assessment, although this is known to exist, would have resulted in an 8% risk.

58. SC17 noted that the stock is estimated to have spawning potential above the MSY level (SB_{latest}/SB_{MSY} median 2.95; 10^{th} and 90^{th} percentiles 0.99 – 6.78) and SB_{recent}/SB_{MSY} has a median value of 3.61, 10^{th} and 90^{th} percentiles 1.23–7.39.

59. SC17 noted that there was 10% risk that $SB_{latest}/SB_{MSY} < 1$ when considering model and estimation uncertainty. Using only model-based uncertainty would have resulted in an 4% risk.

60. SC17 noted that fishing mortality is predicted to have increased gradually across the assessment region through the mid-1990s. Fishing mortality is estimated to have sharply increased in the early-2000s and appears to have stabilized at high levels in the last decade.

61. SC17 noted that the median of relative recent fishing mortality for Southwest Pacific swordfish F_{recent}/F_{MSY} is 0.47 and 10^{th} and 90^{th} percentiles are 0.25 – 1.29.

62. SC17 noted that there was 20% risk that $F/F_{MSY} > 1$ when considering structural + estimation uncertainty. Omitting the estimation uncertainty, as was done in the previous assessment, although this is known to exit, would not have changed the level of risk.

Table SWO-01. Summary of fixed assumptions made in the final model ensemble. The minimum, maximum, median and 10th and 90th percentiles are given for the ensemble parameters.

	Mean	Median	Min	10	90	Max
σ_{Age}	29.51	28.50	25.76	26.13	34.10	40.66
σ_{Length}	0.39	0.37	0.18	0.24	0.60	0.85
Steepness	0.89	0.90	0.71	0.85	0.94	0.98
α_{LW}	0.0000130	0.0000131	0.0000117	0.0000121	0.0000139	0.0000154
β_{LW}	3.00	3.00	2.97	2.98	3.01	3.02
k	0.20	0.19	0.16	0.17	0.22	0.26
L_{∞}	241.13	242.02	228.62	235.17	248.09	250.59
t_0	-2.07	-2.12	-2.60	-2.39	-1.74	-1.15
Average M	0.27	0.27	0.11	0.17	0.35	0.39
L_{50} Female maturity	179.85	179.90	176.78	177.81	181.62	182.55
$Region\ 1 \rightarrow\ 2$	0.036	0.036	0.008	0.011	0.065	0.096
$Region\ 2 \rightarrow\ 1$	0.017	0.015	0.002	0.006	0.034	0.044
LF scalar	33.04	32.00	20.00	22.00	46.60	49.00
WF scalar	30.24	30.00	11.24	13.40	45.20	47.76
Recruitment CV	0.52	0.50	0.29	0.29	0.71	0.71
AU index CV	0.46	0.37	0.11	0.13	0.78	0.80
NZ index CV	0.43	0.42	0.11	0.19	0.71	0.78

Table SWO-02. Percentage of models remaining across the ensemble (Aggregate) and for each factorial level following each post-hoc filtration step.

	Aggregate	DWFN - EU	DWFN - JP	DWFN - TW	DWFN - None	BH CV - 0.7	BH CV - 0.5	BH CV - 0.3	t_0 prior - Uninformative	t_0 prior- Informative	M prior - VB	M prior - max Age
1	40%	32%	46%	40%	41%	44%	36%	39%	33%	46%	40%	40%
2	29%	31%	18%	25%	41%	30%	26%	30%	24%	33%	30%	28%
3	28%	31%	18%	24%	41%	30%	26%	30%	24%	32%	30%	27%
4	27%	31%	18%	21%	40%	29%	25%	28%	23%	31%	29%	26%
5	14%	20%	5%	5%	27%	16%	14%	13%	18%	11%	15%	14%
6	11%	18%	3%	4%	18%	11%	11%	10%	18%	4%	11%	10%
7	7%	13%	2%	2%	9%	9%	4%	7%	12%	1%	6%	7%

Table SWO-03. Summary of reference points (measures of central tendency, min, max and relevant percentiles, 10th and 90th) including model and estimation uncertainty from the 25 models in the final ensemble. Models were equally weighted in the ensemble.

	Mean	Median	Min	10	90	Max
C_{latest}	7,772	7,723	7,364	7,524	8,259	8,453
$Y\ F_{recent}$	6,558	6,608	3,351	4,964	8,106	9,347
MSY	9,922	9,543	3,869	5,470	14,738	22,278
F_{recent}/F_{MSY}	0.67	0.47	0.16	0.25	1.29	2.34
SB_0	83,853	69,390	16,491	31,472	145,944	334,518
SB_{latest}	38,287	31,517	10,588	16,096	69,370	125,681
SB_{recent}	41,916	38,106	14,975	18,956	68,550	99,304
SB_{MSY}	12,507	11,480	2,427	5,212	21,722	29,297
SB_{latest}/SB_{MSY}	3.7	2.95	0.44	0.99	6.78	18
SB_{recent}/SB_{MSY}	4.1	3.61	0.64	1.23	7.39	16
SB_{latest}/SB_0	0.59	0.46	0.1	0.2	1.09	2.49
$SB_{latest}/SB_{F=0}$	0.45	0.39	0.08	0.18	0.79	1.42

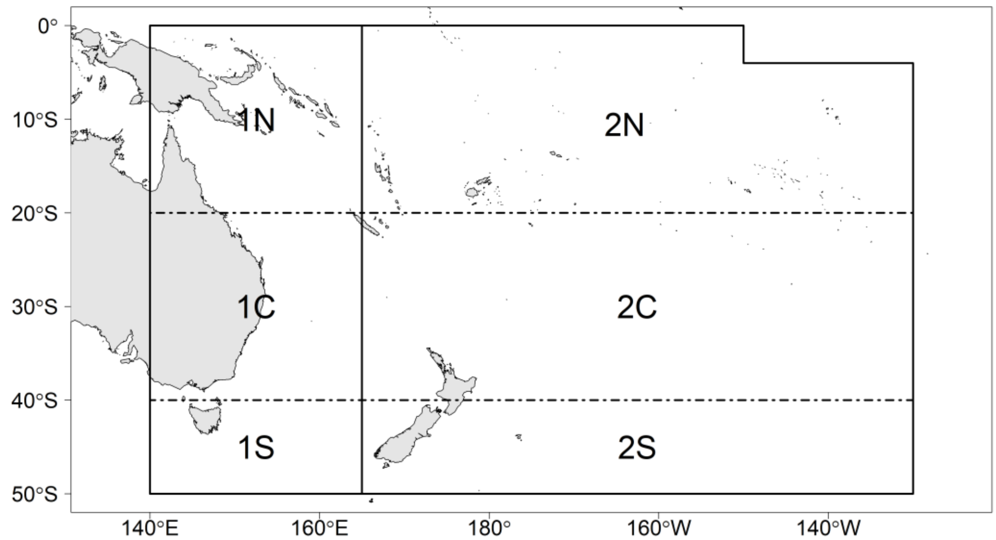

Figure SWO-01. Spatial structure for the 2021 Southwest Pacific swordfish stock assessment. Sub-regions used to differentiate fisheries are shown with the dotted lines.

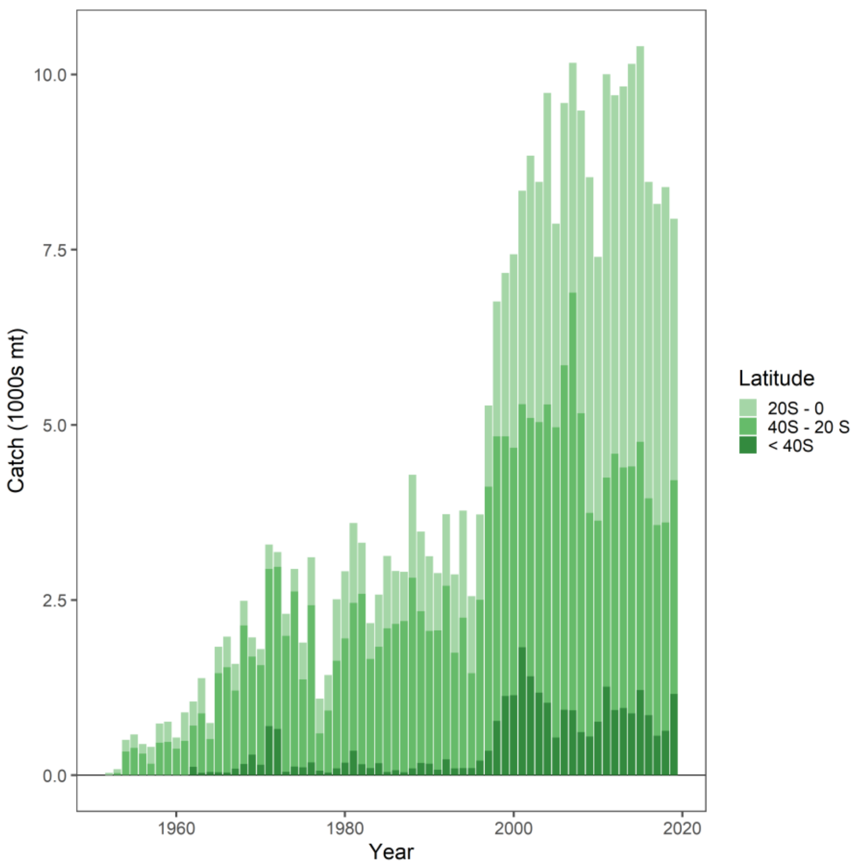

Figure SWO-02. Annual catch (mt) where the colors indicate latitudinal location of the catch.

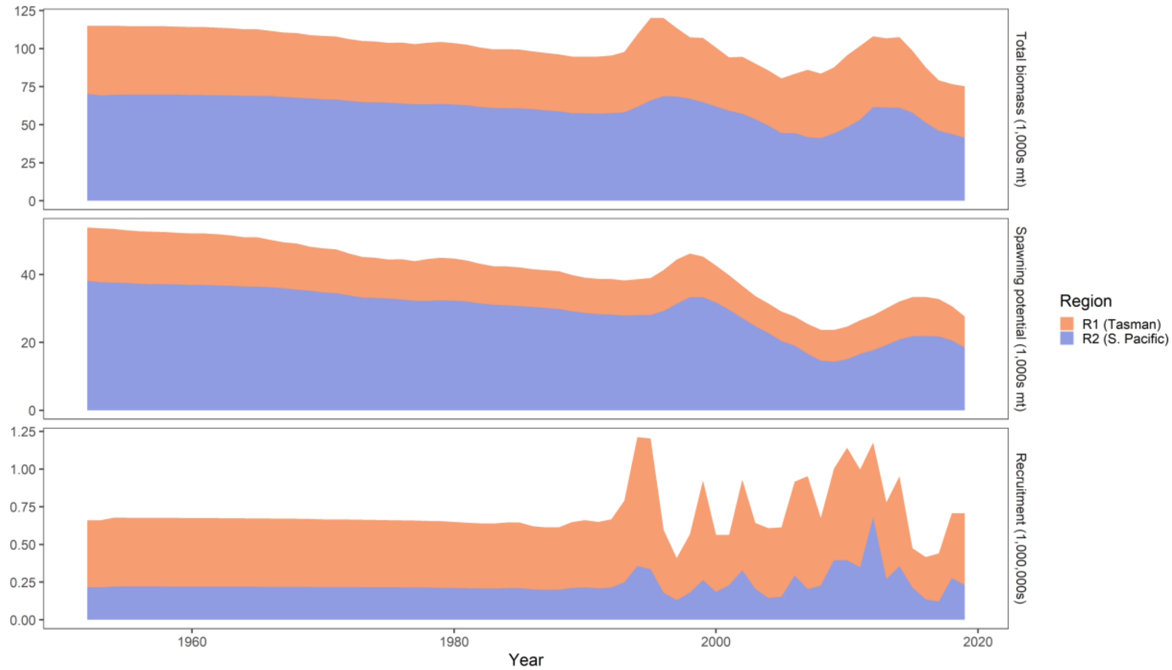

Figure SWO-03. Estimated total biomass (top panel), spawning potential (middle panel), and recruitment (lower panel) for the diagnostic case model. Color indicates the model region: Region 1 (orange) and Region 2 (blue).

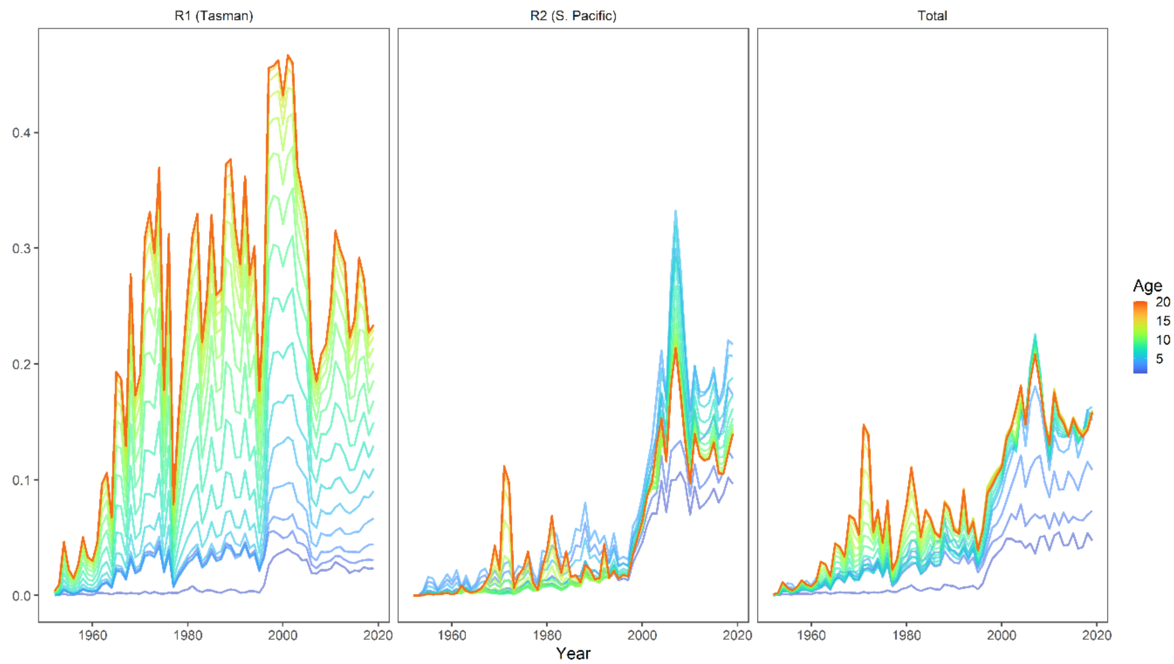

Figure SWO-04. Annual fishing mortality by age (color) and region (panel: Region 1 - left, Region 2 - center, and total - right).

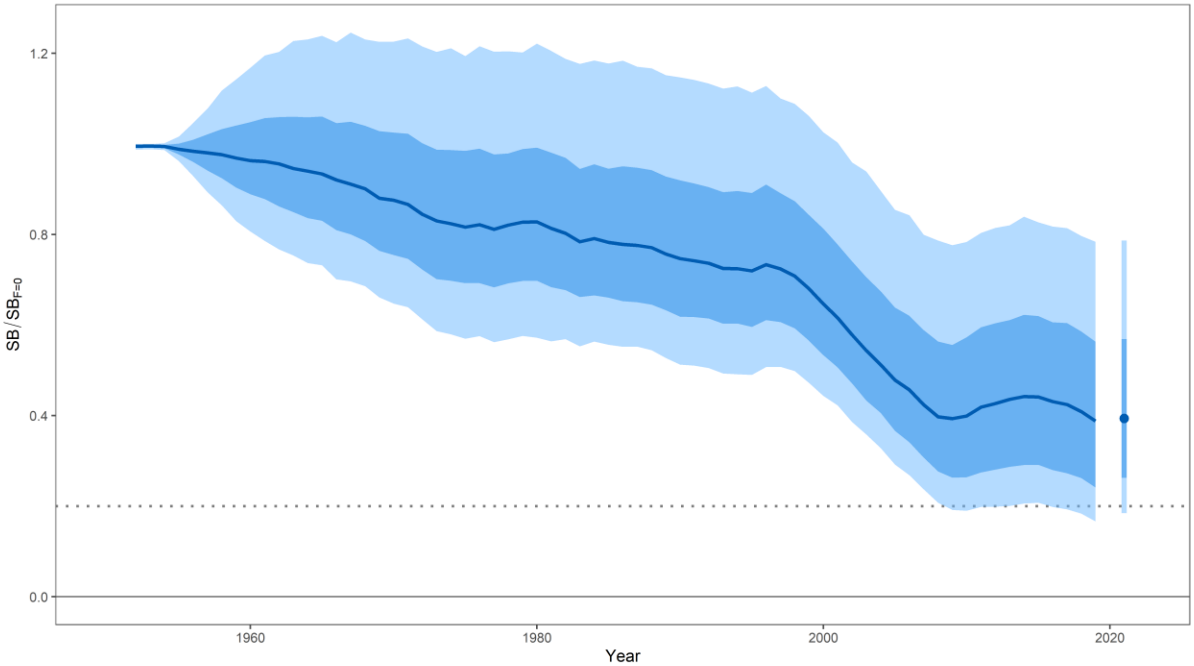

Figure SWO-05. Uncertainty in depletion where uncertainty is characterized as structural + estimation uncertainty. The median is showed by the dark line, the 25th-75th percentiles shown by the dark band, and the 10th-90th percentiles by the light band. The median and percentiles for total $SB_{latest}/SB_{F=0}$ are shown to the right of the figure. For reference, the WCPFC tropical tuna LRP $20\%SB_{F=0}$ is shown with the dotted line.

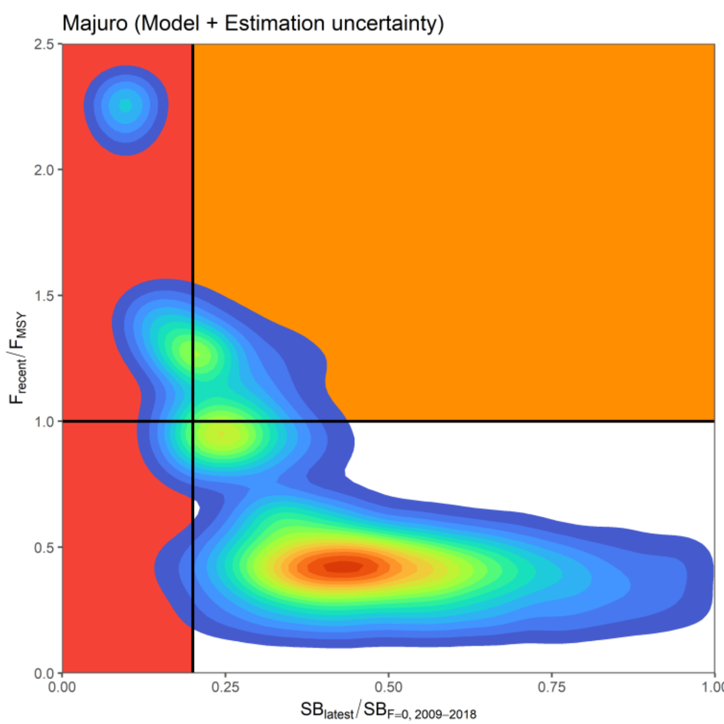

Figure SWO-06. Uncertainty in terminal stock status, based on the 12,500 bootstrap samples characterizing the structural + estimation uncertainty. Warmer colors indicate a greater density of samples, while cooler colors show the fringe of the distribution.

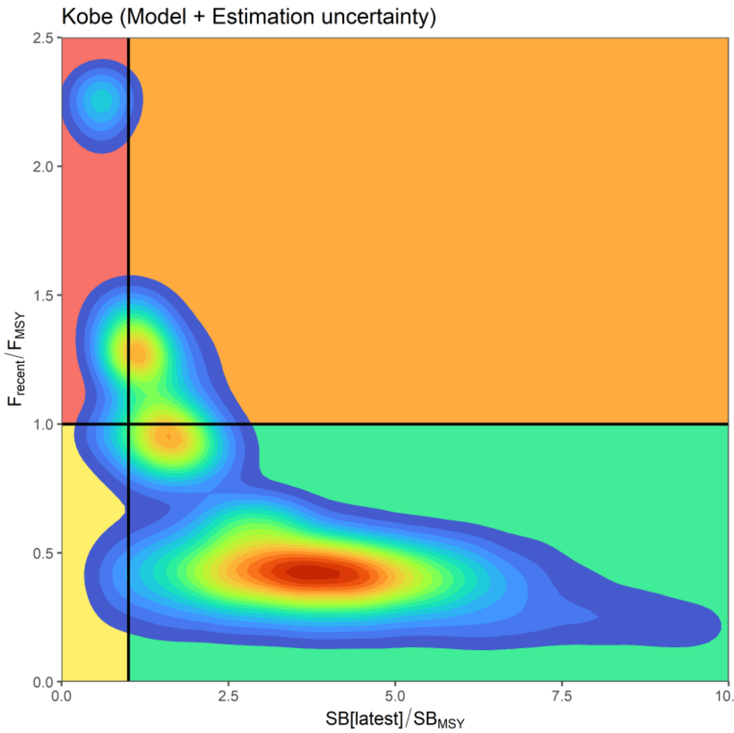

Figure SWO-07. Uncertainty in terminal stock status, based on the 12,500 bootstrap samples characterizing the structural + estimation uncertainty. Warmer colors indicate a greater density of samples, while cooler colors show the fringe of the distribution.

b. Management advice and implications

63. Annual catch estimates for Southwest Pacific swordfish peaked at 11,128 mt in 2012 (SC17-ST-IP-01). Catch by longline vessels in 2020 was 5,373 mt compared to 5,812 mt in 2019, a decline of 7.6%.

64. SC17 supported the new model ensemble approach for developing management advice for this stock, noting that this approach, including the process for review of priors and decisions on post-hoc filtering rules, would continue to be refined and improved in future. SC17 also noted this new approach may result in significant changes in the level of uncertainty assumed so far. This may have implications in the perception of risks, particularly when applied to species with adopted LRPs.

65. The outcomes of the assessment are on average more optimistic in relation to the 2017 assessment, but the estimated uncertainty has increased. Noting that a LRP for Southwest Pacific swordfish has not yet been adopted by WCPFC, SC17 noted that the median recent Southwest Pacific swordfish spawning biomass is above both SB_{MSY} and the LRP $20\%SB_{F=0}$ applied to tunas, and recent fishing mortality is below F_{MSY}. The stock is likely not experiencing overfishing (80% probability $F<F_{MSY}$ and 20% probability $F>F_{MSY}$) and is likely not in an overfished condition (13% probability that $SB_{latest}/SB_{MSY} < 1$ and a 10% probability that $SB_{latest}/SB_{F=0}<0.2$).

66. SC17 noted that the levels of fishing mortality and depletion in the diagnostic case differ between the two model regions, with fishing mortality higher in Region 1 but spawning biomass depletion greater (more depleted) in Region 2. SC17 noted that over the past two decades, the majority of catch has been taken by a combination of swordfish targeting fleets (in the area south of 20°S; 42% of catches) and fleets

taking swordfish as a bycatch on the high seas (in particular in the eastern stock area north of 20°S; 34% of catches).

67. While SC17 advocated for the adoption of the new ensemble approach, it is nevertheless important that the Commission understand the implications of the new approach and that additional work is required to refine this approach.

68. SC17 noted the significant unresolved uncertainties in the assessment relating to the reliability of CPUE indices, longitudinal movements, spatial connectivity and absolute population size. These uncertainties, combined with the need to further refine and review the new ensemble approach, suggest additional caution may be appropriate when interpreting the current assessment outcomes to guide management decisions. SC17 recommended that research priorities for this stock include directed longitudinal tagging of swordfish and a feasibility study on the utility of CKMR.

69. SC17 noted the current measure (CMM 2009-03) for this stock does not contain provisions to limit total fishing mortality on the stock and emphasized the continued importance of WCPFC to develop a revised and strengthened CMM that will ensure the ongoing future sustainability of the Southwest Pacific swordfish. SC17 noted that the suite of catch projections requested by WCPFC16, which are to be undertaken by the SSP post-SC17 and prior to WCPFC18, are intended to test the future likely state of the stock under a range of potential future catch or effort scenarios. This information will inform the revision of the future measure.

70. SC17 recommended that a number of additional projection runs be explored alongside the WCPFC16 requested projections to be presented for consideration at WCPFC18:

1) No change to recent catch and effort levels.
2) 10% and 20% reduction in total swordfish catch.

71. SC17 noted that the current CMM does not cover catches north of 20°S. SC17 recommends that the Commission take note of the swordfish projections in framing any future CMM.

c. Future research recommendations

72. Contingent on the collection of comprehensive sex-specific catch and size composition data, SC17 recommended to continue progress on developing a sex-disaggregated model to better account for the significant differences in life history between male and female swordfish. Implementation of a sex-disaggregated model applied to comprehensive sex-specific data could reduce bias in the model results. The Scientific Services Provider however did note that lack of sex specific size composition data was a major limitation to a sex disaggregate approach that would need to be improved.

73. The SPC investigated the application of a length-weight relationship bias correction factor during SC17. The analysis concluded that applying the bias-correction factor would not qualitatively change the management advice in this instance as it resulted in a 2-3% reduction in the risks to both the SW swordfish stock undergoing overfishing and being overfished. The co-convener advocated not to change the assessment runs for SC17 and to consider the correction for the next assessment.

74. The following three key research needs were identified in undertaking the assessment that should be investigated either internally or through directed research.

1) Directed longitudinal tagging of swordfish to reduce the uncertainty in movement rates, and a feasibility study to explore applying CKMR techniques to Southwest Pacific swordfish are the two most critical research items.

2) Development of a statistically robust sampling plan for the collection of fisheries dependent biological samples (by sex), including but not limited to age, catch, size frequency data, and genetic samples.
3) In order to improve quality of abundance indices there is a need to expand minimum reporting requirements for longline operational characteristics to include: *a priori* target species, light stick use, bait type, setting time (or fraction of night-time soak), and gear settings that influence fishing depth (e.g. hooks between floats, branch line length, float line length, and/or line setting speed).

3.3.2 Pacific blue marlin (*Makaira nigricans*)

3.3.2.1 Review of 2021 Pacific blue marlin stock assessment

3.3.2.2 Provision of scientific information

a. Stock status and trends

75. SC17 noted that ISC[1] provided the following conclusions on the stock status of Pacific blue marlin:

Stock status, biomass trends, and recruitment of Pacific blue marlin (*Makaira nigricans*) for both models in the ensemble had equal weights and similar trends, although the estimates of initial conditions are different. All reported results are the model-averaged estimates from the ensemble model unless otherwise noted.

Estimates of population biomass declined until the mid-2000s, increased again until 2019, and were relatively flat until the present. The minimum spawning stock biomass is estimated to be 17,592 mt (95% C.I. 14,512-20,703 mt) in 2006 which corresponds to 5% above SB_{MSY}, the spawning stock biomass to produce MSY, (i.e., SB/SB_{MSY} = 1.05; 95% C.I. 0.70-1.01, Figure PBUM-1). In 2019, SB = 24,272 mt and the relative SB/SB_{MSY} = 1.17 (95% C.I. 0.87-1.51).

Combined median fishing mortality on the stock (average F on ages 1-10) is currently below F_{MSY} (Figure PBUM-1). It averaged roughly F = 0.13 during 2017-2019, or 40% below F_{MSY}, and in 2019, F=0.11 with a relative fishing mortality of F/F_{MSY} = 0.50 (95% C.I. 0.37-0.69). Median fishing mortality has been below F_{MSY} in all years except the period 2003 to 2006.

The predicted value of the spawning potential ratio (SPR, the predicted spawning output at current *F* as a fraction of unfished spawning output) is currently $SPR_{2017\text{-}2019}$ = 31% for the average of the ensemble model, which is above the SPR required to produce MSY (17%). Recruitment was relatively consistent throughout the assessment time horizon, with occasional pulses in recruitment, but no notable periods of below-average recruitment.

No target or limit reference points have been established for Pacific blue marlin under the auspices of the WCPFC. Blue marlin is expected to be highly productive due to its rapid growth and high resilience to reductions in spawning potential. Although fishing mortality has approached F_{MSY} and exceeded MSY from 2003 to 2006, the biomass of the stock has remained above SB_{MSY} since this time. With continued decreases in fishing effort and associated catches of Pacific blue marlin, the stock is expected to remain within MSY limits. When the status of blue marlin is evaluated relative to MSY-based reference points, the 2019 spawning stock biomass of 24,272 mt is 17% above

[1] International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

SSB_{MSY} (20,677 mt, 95% C.I. -13% to +50%) and the 2017-2019 fishing mortality is 50% of F_{MSY} (95% C.I. 37% to 69%). Therefore, relative to MSY-based reference points, overfishing was very likely not occurring (>90% probability) and Pacific blue marlin is likely not overfished (81% probability, Figure PBUM-2).

Deterministic stock projections were conducted with Stock Synthesis to evaluate the impact of alternative future levels of harvest intensity on female spawning stock biomass, fishing mortality, and yield for Pacific blue marlin. Future recruitment was predicted based on the stock- recruitment curve. These projections used all the multi-fleet, multi-season, size- and age- selectivity, and complexity in the assessment model to produce consistent results. The stock projections started in 2020 and continued through 2029 (10 years) under 4 levels of constant fishing mortality: (1) constant fishing mortality equal to the 2003-2005 average ($F_{2003-2005}$); (2) constant fishing mortality equal to F_{MSY}; (3) constant fishing mortality equal to the 2016-2018 average defined as current; and (4) constant fishing mortality equal to F30% (F30% corresponds to the fishing mortality that produces 30% of the spawning potential ratio). Stock projections for each F scenario were run for both growth models in the ensemble and combined using the multivariate lognormal method. Using the deterministic projection result, the multivariate lognormal approximation was applied to generate 10,000 trajectories of SSB and F to calculate the model-averaged results of the new and old growth models. Results showing the projected female spawning stock biomasses, fishing mortality, and the catch biomasses under each of the combined scenarios are provided in Table PBUM-3 and Figure PBUM-3.

76. SC17 noted the following stock status from ISC:

Based on these findings, the following information on the status of the WCNPO blue marlin stock is provided:

1. No target or limit reference points have been established for Pacific blue marlin by the WCPFC;
2. Female spawning stock biomass was estimated to be 24,241 mt in 2019, or about 17% above SSB_{MSY} and 17% above $20\%SSB_0$.
3. Fishing mortality on the stock (average F, ages 1 to 10) averaged roughly F = 0.13 during 2016-2019, or about 40% below F_{MSY} and 28% below F20% SSB_0.
4. Blue marlin stock status from the ensemble model indicates that relative to MSY- based reference points, overfishing was very likely not occurring (>90% probability) and Pacific blue marlin is likely not overfished (81% probability, Figure PBUM-2).

77. SC17 noted that this result is predicated on the use of the Japanese and Taiwanese longline CPUE indices in the assessment, and the exclusion of the Hawaii longline CPUE index, which shows a somewhat different trend (declining by about 50% from 1995-2005, then flat) to the Taiwanese CPUE index in particular. The ISC Billfish Working Group (BILLWG) doesn't believe that the Hawaii longline CPUE index was representative of the Pacific-wide relative abundance of Pacific blue marlin due to the small area it represents, rather a measure of local density. In addition, The CPUE index was in conflict with both Taiwanese and Japanese indices over the same time period. Further, the decision to remove the Hawaii longline CPUE index was consistent with the model decisions made for the 2016 assessment.

b. Management advice and implications

78. SC17 noted the following conservation information from ISC:

The Pacific blue marlin stock has produced annual yields of around 18,800 mt per year since 2015, or about 90% of the MSY catch (Table PBUM-1). Blue marlin stock status from the ensemble model indicates that the current median spawning biomass is above SSB_{MSY} and that the current median fishing mortality is below F_{MSY}. However, uncertainty in the stock status indicates a 19% chance of Pacific blue marlin being overfished relative to SSB_{MSY}. Both the old and new growth models show evidence of spawning biomass being above SSB_{MSY} and fishing mortality being below F_{MSY} during the last 5 years. Catch biomass has been declining for the last 5 years, and therefore the stock has a low risk of experiencing overfishing or being overfished unless fishing mortality increases to above F_{MSY} based upon stock projections (Table PBUM-3 and Figure PBUM-3). However, it is also important to note that retrospective analyses show that the assessment model tends to overestimate biomass and underestimate fishing mortality in recent years, in part due to rapid changes in longline CPUE.

Based on these findings, the following conservation information is provided:

1. There is no evidence of excess fishing mortality above F_{MSY} ($F_{2016\text{-}2019}$ is 40% of F_{MSY}) or substantial depletion of spawning potential (SSB_{2019} is 17% above SSB_{MSY});
2. It is important to note that retrospective analyses show that the assessment model tends to overestimate spawning stock biomass in recent years; and
3. The results show that projected female spawning biomass is expected to increase under the Fstatus quo and $F_{30\%}$ harvest scenarios and decline to SSB_{MSY} under the High F and F_{MSY} harvest scenarios. The probability that the stock is overfished or overfishing occurring by 2029 under each harvest scenario is low.

Special Comments

1. Uncertainty regarding the choice of BUM growth curve led to the ensemble model approach for this assessment. The BILLWG recognized that there is considerable uncertainty in input CPUE data in the recent years and life history parameters, especially growth. The BILLWG considered an extensive suite of model formulations and associated diagnostics for developing the assessment models. Overall, the BILLWG found issues with both the new growth and old growth model diagnostics and sensitivity runs that are consistent with the presence of data conflicts, but none of the model diagnostics show that the results of either model were invalid. It is recommended model development work to reduce data conflicts and modeling uncertainties continue and that input assessment data be reevaluated to improve the time series.
2. It is recommended that biological sampling to improve life history parameter estimates continue to be collected and ISC countries participate in the BILLWG International Biological Sampling program to improve those estimates.

Table PBUM-1. Reported catch (mt) used in the stock assessment along with annual model-averaged estimates of female spawning biomass (mt), relative female spawning biomass (SSB/SSB_{MSY}), recruitment (thousands of age-0 fish), fishing mortality (average F, ages 1 – 10), relative fishing mortality (F/F_{MSY}), and spawning potential ratio (SPR) of Pacific blue marlin.

Year	2013	2014	2015	2016	2017	2018	2019	Mean[1]	Min[1]	Max[1]
Reported Catch	22,166	23,741	21,861	22,644	14,443	18,589	16,503	18,873	10,882	26,138
Spawning Biomass	27,707	26,321	25,476	23,693	22,942	23,222	24,279	35,007	17,601	69,331
Relative Spawning Biomass	1.33	1.26	1.22	1.15	1.11	1.12	1.18	1.70	0.84	3.51
Recruitment (thousands of age 0 fish)	960	785	608	862	870	1,399	876	895	502	1,399
Fishing Mortality	0.18	0.19	0.19	0.21	0.13	0.16	0.11	0.16	0.08	0.25
Relative Fishing Mortality	0.81	0.85	0.83	0.95	0.58	0.71	0.50	0.71	0.35	1.11
Spawning Potential Ratio	0.26	0.24	0.25	0.22	0.33	0.27	0.34	0.33	0.17	0.60

[1]During 1971-2019

Table PBUM-2. Estimates of biological reference points along with estimates of fishing mortality (F), spawning stock biomass (SSB), recent average yield (C), and spawning potential ratio (SPR) of Pacific blue marlin, derived from the assessment ensemble model, where "MSY" indicates reference points based on maximum sustainable yield.

Reference Point	Estimate
F_{MSY} *(age 1-10)*	0.23
F_{2019} *(age 1-10)*	0.11
$F_{20\%SSB0}$	0.18
SSB_{MSY}	20,677 mt
SSB_{2019}	24,241 mt
$SSB_{20\%SSB0}$	20,729 mt
MSY	24,600 mt
$C_{2017-2019}$	16,512 mt
SPR_{MSY}	17%
SPR_{2019}	34%
$SPR_{20\%SSB0}$	23%

Table PBUM-3. Projected median values of Pacific blue marlin spawning stock biomass (SSB, mt) and catch (mt) under four constant fishing mortality rate (F) scenarios during 2020-2029.

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Scenario 1: $F = F_{2003-2005}$										
SSB	25,459	23,462	21,752	20,498	19,262	18,689	18,252	17,835	17,583	17,475
Catch	33,111	30,527	28,638	27,331	26,431	25,806	25,363	25,044	24,811	24,641
Scenario 2: $F = F_{MSY}$										
SSB	25,318	23,351	21,583	20,255	19,216	18,405	18,186	17,809	17,513	17,466
Catch	32,875	30,436	28,662	27,439	26,606	26,037	25,645	25,370	25,177	25,039
Scenario 3: $F = F_{2016-2018}$										
SSB	26,930	28,182	28,764	28,675	28,428	28,731	28,052	28,142	27,861	28,081
Catch	23,321	23,546	23,591	23,561	23,513	23,472	23,443	23,422	23,407	23,397
Scenario 4: $F = F_{30\%}$										
SSB	27,757	30,064	30,624	30,976	31,072	31,624	31,415	31,800	31,753	32,132
Catch	20,828	21,404	21,764	22,001	22,167	22,294	22,393	22,471	22,532	22,580

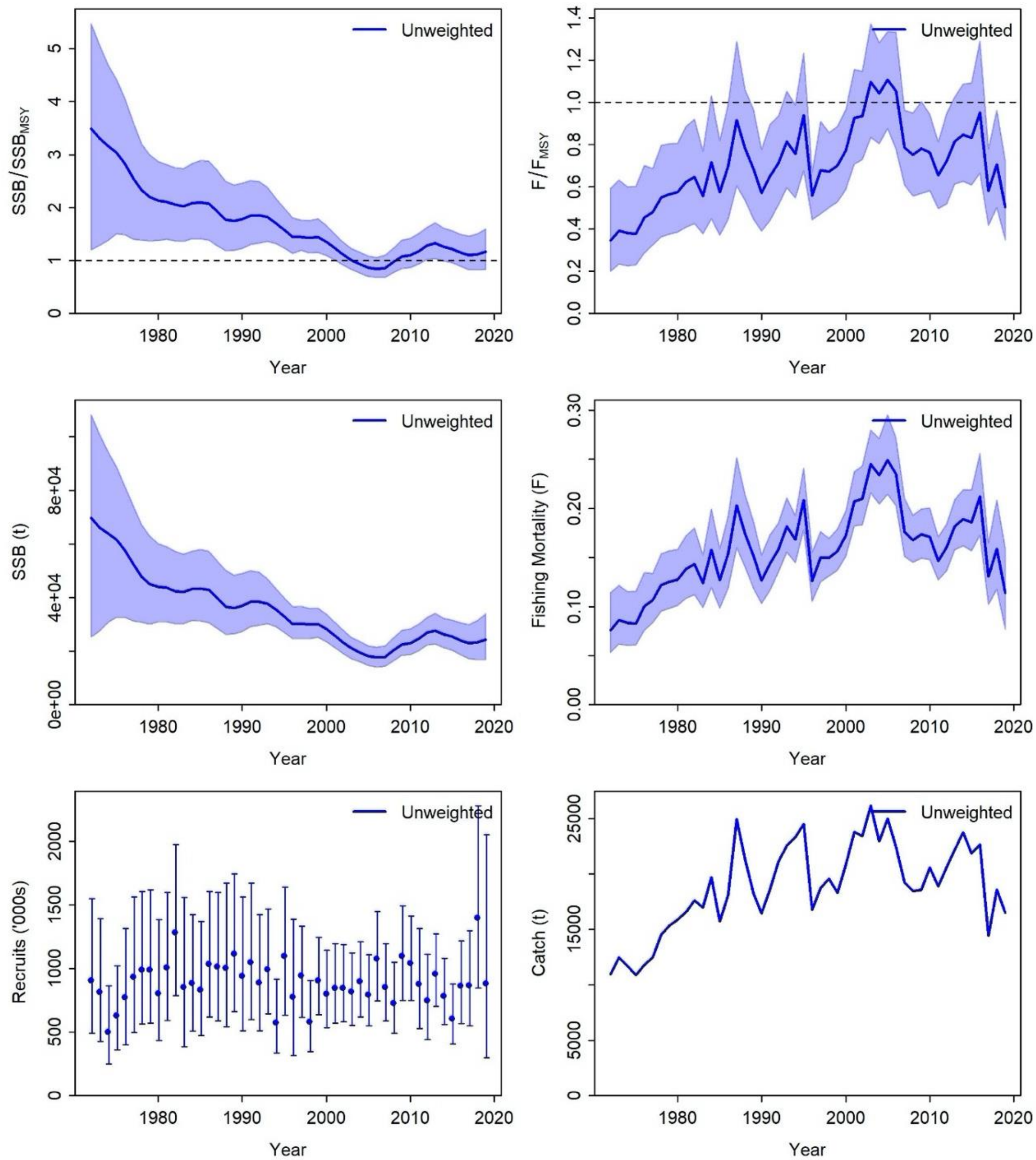

Figure PBUM-1. Time series of estimates of female spawning stock biomass over female spawning stock biomass at MSY (top left), fishing mortality over fishing mortality at MSY (top right), spawning stock biomass (center left), instantaneous fishing mortality (ages 1-10 $year^{-1}$, center right), recruitment (age-0 fish, bottom left), and catch (bottom right) for Pacific blue marlin (*Makaira nigricans*) derived from the 2021 stock assessment model ensemble. Lines (or points for recruitment) indicate the median value estimated from the joint multivariate delta-lognormal estimation, shaded areas (or error bars for recruitment) indicate the 95% confidence intervals. Unweighted indicates that both models have equal weights in the ensemble.

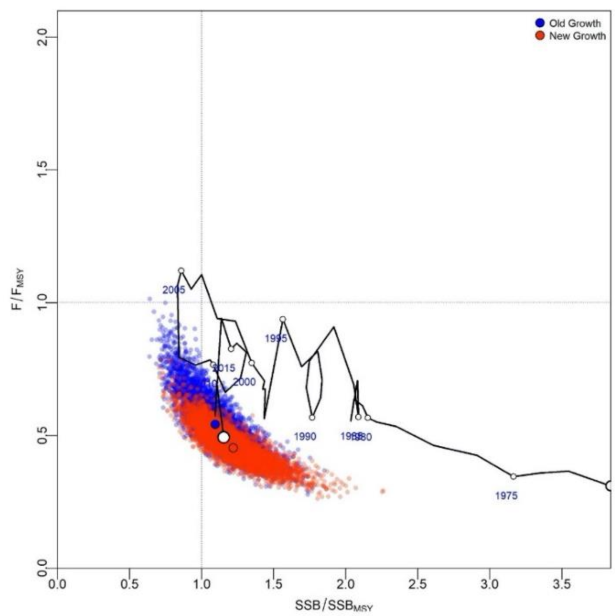

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Figure PBUM-2. Kobe plot of the time series of estimates of relative fishing mortality (average of age 1-10) and relative spawning stock biomass of Pacific blue marlin (*Makaira nigricans*) during 1971-2019. The white circle denotes the delta-lognormal multivariate estimate of the combined models in 2019, blue dots indicate the final year stock status of the old growth model with the 10,000 multivariate draws, and red dots indicate the final year stock status of the new growth model with the 10,000 multivariate draws.

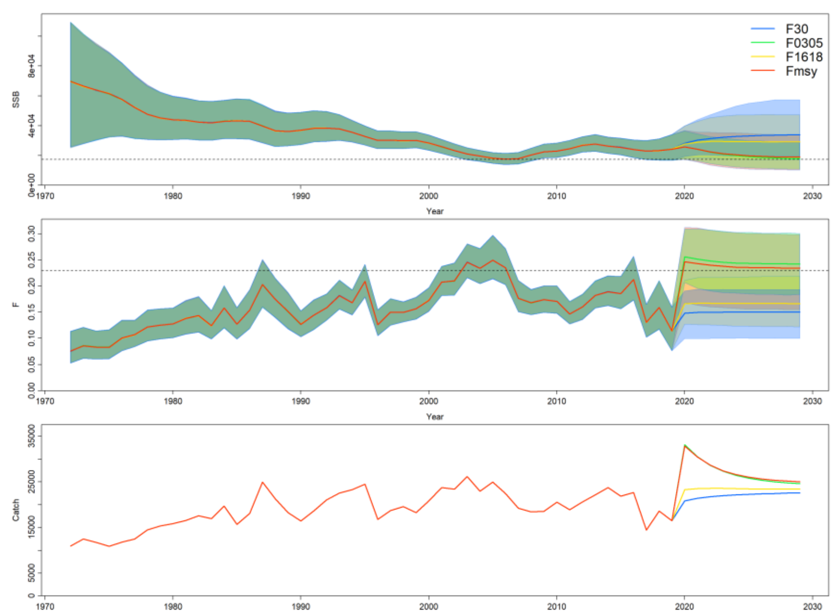

Figure PBUM-3. Historical and projected trajectories of spawning biomass and total catch from the Pacific blue marlin combined models based upon the four F scenarios: projected spawning biomass, dotted line indicates SSB_{MSY}, shading indicates 95% confidence intervals (top); projected instantaneous fishing mortality (ages 1-10 $year^{-1}$), dotted line indicates F_{MSY}, shading indicates 95% confidence intervals (center); and projected catch (mt. bottom). Green indicates scenario 1, $F_{2003\text{-}2005}$; red indicates scenario 2, F_{MSY}; yellow indicates scenario 3, $F_{2016\text{-}2018}$; and blue indicates scenario 4, $F_{30\%}$. The list of projection scenarios can be found in Table 3.

3.4 Peer Review

AGENDA ITEM 4 MANAGEMENT ISSUES THEME

4.1 Development of the Harvest Strategy Framework for key tuna species

4.1.1 Overview on the progress and updates to the harvest strategy workplan

4.1.2 Target reference points (TRPs)

4.1.2.1 Bigeye and yellowfin tuna TRP analyses

79. 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*).

80. 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.

81. 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.

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

83. 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.

84. 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.

85. 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.

4.1.2.2 Skipjack tuna TRP analyses

86. Noting the request from WCPFC17 to review the updated information provided by the SSP on the performance of candidate target reference points 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).

87. 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.

88. 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 Workshop.

4.1.3 Review of the overall harvest strategy work

89. Noting the revised work plan for the adoption of the WCPFC Harvest Strategy under CMM 2014-06 (Attachment H, WCPFC17 Summary Report), SC17 reviewed the overall progress to date in the development of the harvest strategy covered by this workplan as outlined in SC17-MI-WP-03 (*Recent progress in the technical development of harvest strategies for WCPFC stocks and fisheries*).

90. SC17 noted several difficulties with the use of CPUE to inform a management procedure for South Pacific albacore and supported the continuing investigation of simple model-based alternatives. Incorporation of the new treatment of uncertainty (as included in the updated assessment for Southwest Pacific swordfish reviewed by SC17) should also be investigated.

91. SC17 continued to encourage a focus on capacity building workshops, particularly for SIDS and developing states, on understanding of harvest strategy functioning and implications. Building such capacity will assist all CCMs to participate fully in this complex process and have the confidence in the harvest strategy development process and its outcomes when implemented. It will also assist the effective participation of all CCMs in any future Science-Management Dialogue.

92. SC17 endorsed the work outlined in MI-WP-03 and to progress the Harvest Strategy Workplan recommends that the Commission take note of this work and provide advice on the following issues:

- Definition of fisheries and fishery controls within the harvest strategy.
- Procedures for identifying, selecting, and implementing the ‘best’ management procedure.

93. Finally, SC17 noted that while the current Harvest Strategy Workplan only goes through 2022, the funding support from New Zealand for the associated project (Pacific Tuna Management Strategy Evaluation) has been extended to the beginning of 2024. SC17 noted that the current timeline for completing the harvest strategy is ambitious.

4.1.4 Skipjack management strategy evaluation (MSE) framework

94. Noting the planned schedule of adopting the management procedure for skipjack tuna in 2022, SC17 reviewed the progress on analysing the performance of candidate management procedures outlined in SC17-MI-WP-04 (*Evaluations of candidate management procedures for skipjack tuna in the WCPO*).

95. SC17 noted the SC14 recommendation to retain the full list of performance indicators for skipjack even for those that may be difficult to estimate. SC17 also noted that a scenario which assumes an annual 3% effort creep in the purse-seine fishery will be included in the robustness set for skipjack.

96. SC17 also noted that current candidate Management Procedures are developed using a single schedule applicable for both effort-controlled fisheries (PS) and catch-controlled (non-PS) fisheries, resulting in different projected yield patterns between two types of fisheries. For PS, the catch will increase if stock increases even if the effort is kept constant, while for non-PS fisheries catch will be kept constant even if the stock increases. This could cause problems as this may be seen as unequitable among stakeholders.

97. SC17 also commended the SSP for the PIMPLE app as it has served an important role in enhancing understanding of Management Procedures (MPs) and encouraged its use with managers in providing advice on the scientific aspects of candidate MPs. SC17 noted there are some MSY indicators presented within the PIMPLE software as this tool now includes both Kobe and Majuro plots.

98. SC17 noted that evaluations of candidate management procedures for skipjack tuna were based on a grid of operating models that was initially proposed at SC15 and subsequently revised at SC16. However, no formal agreement on the range of OMs to be used has been made by the SC. SC17 further noted that the details of the OMs including model diagnostics were available for inspection online at https://ofp-sam.shinyapps.io/hierophant but more detailed presentation and discussion are warranted at SC18.

99. SC17 noted the continuing high quality of the work on a skipjack MSE framework.

100. To progress the development of harvest strategies for skipjack, SC17 recommends that the Commission take note of the analyses outlined in SC17-MI-WP-04 and requests the Commission to provide advice on the following issues:

- Multispecies impacts on other tropical tuna related harvest strategies;
- Definition of fisheries and fishery controls within the harvest strategy;
- Input into candidate MP designs;
- Feedback on presentational approaches to enhance decision making;
- Procedures for selecting the 'best performing' MP.

101. SC17 saw much value in presenting this work to managers and other stakeholders, and to achieve this and help address the requests made above a Science-Management Dialogue to be held in 2022 was strongly supported.

4.1.5 Mixed fisheries

102. 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*).

103. 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.

104. 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.

105. 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.

106. 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.

107. 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.

4.1.6 Review of future progress of the WCPFC Harvest Strategy Workplan

108. SC17 noted the request from the Commission to review the steps required to further progress the Harvest Strategy Workplan and highlight issues for further guidance by the Commission, including how decisions on Management Procedures can be made and what the role of the SC might be in this process. This includes continuing to consider options to convene a Science-Management Dialogue to assist this process.

109. SC17 noted that while substantial progress has been made on the technical work to support harvest strategies according to the workplan, the workplan does not currently extend beyond 2022 and that it will require amendment to encompass future technical work and decision making, particularly on bigeye, yellowfin and the multispecies framework. Toward this end SC17 noted Australia's intention to again take a leading role in amending the HS workplan to reflect decisions made, progress to date, and to cover the work and decisions for years 2023 and beyond for the consideration of the Commission this year.

110. While SC17 noted that the technical work by the SSP has generally kept pace with the Harvest Strategy Workplan, it was also noted that capacity-building initiatives, as well as WCPFC consideration, engagement and decision-making has perhaps not kept pace. SC17 noted that greater input from WCPFC bodies in general, but particularly commissioners, managers and stakeholders, will be vital over the coming years to inform the testing of candidate management procedures for skipjack and South Pacific albacore in the WCPO, and in the iterative process of their review and refinement prior to formal adoption.

111. Finally, noting that the development of the WCPFC harvest strategy framework is reaching a mature stage, and the increasing number of issues that require the attention of, and feedback from, managers in order to progress the Harvest Strategy Workplan (as noted in several recommendations above). SC17 again reiterates its previous recommendations for a Science-Management Dialogue to be convened in 2022. In addition, SC17 calls attention to the importance of such a dialogue to ensure the input of managers and stakeholders to the MSE process and to ensure timely execution of the Commission's harvest strategies workplan.

112. SC17 also recommended that greater priority should be given during 2022 to Harvest Strategy work within the Commission Workplan.

4.2 Limit Reference Points for Species other than Tuna

4.2.1 Limit reference points for elasmobranchs

113. Noting the request from WCPFC16 to identity appropriate LRPs for elasmobranchs in the WCPO, SC17 reviewed the outcomes of Project 103 outlined in SC17-MI-WP-07 (*Appropriate Limit Reference Points for WCPO Elasmobranchs*).

114. SC17 noted the comprehensive scope of the project report and that this work had built on the results of several other reports previously reviewed by the SC (SC10-MI-WP-07; SC11-EB-IP-13; SC14-MI-WP-07).

115. SC17 noted and discussed the recommendations made in SC17-MI-WP-07 and conveyed the following conclusions to the Commission:

- SC17 continued to support the tier-based approach first recommended by SC10:
  - For stocks assessed using a stock assessment model (i.e., data-rich stocks), reference points estimated in the same stock-assessment should be adopted.
  - For stock without a stock assessment (i.e., data-poor stocks), or when the results are not robust, risk-based RPs should be used.
- SC17 noted that the data rich approach might not necessarily have lower uncertainty than the data poor approach.
- While an LRP for WCPO elasmobranchs equivalent to $B_{lim}=0.25B_o$ (consistent with $20\%SB_{unfished}$ for target species) and the corresponding $F_{lim}=1.5F_{MSY}$ was supported by a number of CCMs, several other CCMs did not support the use of this LRP, instead suggesting that a broader range of reference points should be appraised (such as outlined in Table 7 of SC17-MI-WP-08) to assess their applicability to WCPO elasmobranchs, and that these be considered under a broader banner of reference points for non-tuna species. However, there was some concern expressed that such a review of other metrics had already been undertaken by earlier reports (e.g., SC10-MI-WP-07).
- The use of a constant percentage of SPR (spawning potential ratio) such as $F_{60\%}SPR$ (i.e., F that produces an SPR of 60% of unfished) as a reference point for all stocks was not supported.
- It was noted that continued fishing at or above F_{crash} would lead to stock collapse. In the long term, an LRP should constrain fishing mortality to below this level.
- Finally, SC17 noted that it is important to continue research to provide or improve estimates of life-history parameters and gear selectivity to improve the determination of risk-based reference points.
- SC17 noted that a management strategy evaluation approach could be helpful in determining what LRPs would work best when there is uncertainty in the input assessment data, population dynamics, model structure and other dynamic features of the WCPO fishery system.

116. SC17 agreed that Project 103, and the other projects that had preceded it, had provided a good framework for progressing the development and identification of appropriate LRP for WCPO elasmobranchs. However, SC17 expressed disappointment that after such lengthy consideration that the SC was at this time unable to make a final recommendation on appropriate LRPs to the Commission.

117. SC17 recommended that the Commission take note of the work and recommendations outlined in SC17-MI-WP-07 together with the conclusions reached by SC17 and the need for further work as noted above.

4.2.2 Review of appropriate LRPs for Southwest Pacific striped marlin and other billfish (Project 104)

118. Noting the agreed outcome from WCPFC16 to revisit the identification of an appropriate limit reference point for South Pacific Striped marlin, SC17 reviewed the outcomes of Project 104 outlined in SC17-MI-WP-08 (*Appropriate LRPs for Southwest Pacific Ocean Striped Marlin and Other Billfish*).

119. SC17 noted the comprehensive scope of the project report and discussed the nine recommendations made in MI-WP-08 and while broadly supporting these recommendations conveys the following conclusions to the Commission:

- The WCPFC should develop interim objectives for Southwest Pacific striped marlin to guide the appropriate levels for any agreed LRP and the associated maximum risk levels for breaching this LRP.
- While an LRP equivalent to $20\% SB/SB_{F=0}$ for Southwest Pacific striped marlin was supported by several CCMs (consistent with the logic behind the application to key tuna stocks), several other CCMs pointed out that the life-history of billfish are substantially different to key tuna

species and therefore did not support this LRP. Several CCMs also noted that in adopting the tuna LRPs, in their view the Commission took into account factors such as the risk of greater fluctuations in recruitment and smaller fish sizes and values as biomass declined, and these factors may not be as applicable to setting LRPs for billfish.

- Several CCMs supported the development of billfish LRPs based on MSY criteria with appropriate risk choices.
- For WCPO billfish species the identification of appropriate LRPs should be guided by developing management objectives for different species divided into the following groups: target species (swordfish); data-rich bycatch species (striped and blue marlin); medium information bycatch species with levels of catch (black marlin); and data-poor low-catch bycatch species (shortbilled spearfish and sailfish). Having agreed objectives would help clarify which approach to use and inform selection of the acceptable risk of breaching the LRP.
- Each billfish species should initially be assessed against the potential LRPs listed in Table MI-1. The SC should also work towards developing a minimum list of metrics that should appear in any future billfish assessment reports and a preferred metric for each WCPO billfish stock. For example, several CCMs suggested the addition of F_{MSY} and SB_{MSY}-related values, as it is related to the spirit of the Convention in their view and is the reference point used by other RFMOs for billfish species. In the interim SC agreed to retain Table MI-1 as an interim list of candidate LRPs for billfish.
- The applicability of LRPs should be evaluated, whenever possible, at the stock level. Some CCMs noted that for some species, like the south Pacific swordfish, the adopted LRP for tropical tuna species (20%$SB_{F=0}$) is significantly above $SB_{MSY.}$
- There was support for the proposed additions to the hierarchical approach, originally endorsed by WCPFC8 for key target species and SC10 for elasmobranchs, to cater for empirical and risk-based reference points of medium and low data stocks. The updated table is presented in Table MI-2.
- These decisions should be incorporated into the Billfish Research Plan that is scheduled to be developed in 2022 and focus that work on developing objectives, assessing LRPs for each species, and determining if a pathway to a higher level of information and knowledge should be developed. This Plan should also consider a request that the SSP compile a table based on existing assessments of billfish and sharks that shows SB_{MSY}, SB_0 and $SB_{F=0}$ levels and the percentage of SB_{MSY} relative to the other two metrics, with associated uncertainty.
- The risk-based fishing mortality benchmarks should be defined as dependent variables in the two main assessment platforms used (Stock Synthesis and MFCL) so that statistical uncertainty of the estimates can be calculated.

120. SC17 agreed that Project 104 had developed a good framework for progressing the development and identification of appropriate LRP for WCPO billfish and recommends that the Commission take note of the above conclusions reached by SC17 and the need for further work as outlined above.

Table MI-1. Proposed list of potential Limit Reference Points for consideration for WCPFC billfish, categorized as Target and Bycatch and by assessment type. Grey shading is simply for easy separation of LRP groups.

LRP	Group	Assessment type	Comments
x% F/F_{MSY}	Target & Bycatch	Data rich	Choose the level of x based on an evaluation.
x% $SB/SB_{F=0}$	Target & Bycatch	Data rich	Choose the level of x based on an evaluation.
x% SB_0	Target & Bycatch	Data rich	Choose the level of x based on an evaluation.
SPR x% $SB_{F=0}$	Bycatch	Medium data or data poor	Choose the level of x based on an evaluation.
x% $CPUE_0$	Target & Bycatch	Data rich or Medium data	Choose the start of a reliable CPUE series and the level of x.
$SB/SB_{F=0,\ t1-t2}$	Target & Bycatch	Data rich	Choose a time period where the stock was considered in an undesirable state (and should be avoided in future), but recovered back to suitable levels.
SB_{t1-t2}	Target & Bycatch	Data rich	Choose a time period where the stock was considered in an undesirable state (and should be avoided in future), but recovered back to suitable levels.
$CPUE_{t1-t2}$	Target & Bycatch	Data rich or Medium data	Choose a time period where the stock was considered in an undesirable state (and should be avoided in future), but recovered back to suitable levels.
$SB/SB_{F=0}$_ low	Target & Bycatch	Data rich	Choose a low year where the stock was considered in an undesirable state (and should be avoided in future), but recovered back to suitable levels.
SB_low	Target & Bycatch	Data rich	Choose a low year where the stock was considered in an undesirable state (and should be avoided in future), but recovered back to suitable levels.
CPUE_low	Target & Bycatch	Data rich or Medium data	Choose a low year where the stock was considered in an undesirable state (and should be avoided in future), but recovered back to suitable levels. Note CPUEt1−t2 is more precautionary.
F/F_{lim} >1	Bycatch	Data poor	Use as an interim LRP until a more reliable metric can be generated.
F/F_{crash} >1	Bycatch	Data poor	Use as an interim LRP until a more reliable metric can be generated.

Table MI-2. The 5-level hierarchical approach for defining LRPs for bycatch species modified from that endorsed by WCPFC8.

Level	Condition	LRP metrics
Level 1	A reliable estimate of steepness is available.	F_{MSY} and B_{MSY}
Level 2	Steepness is not known well, if at all, but the key biological (natural mortality, maturity) and fishery (selectivity) variables are reasonably well estimated.	$Fx\%_{SPR\_F=0}$ and either x% SB_0 or x% $SB_{current,F=0}$
Level 3	The key biological and fishery variables are not well estimated or understood.	x% SB_0 or x% $SB_{current,F=0}$
Level 4	Poor biological information, fishery data sparse or patchy with no ability to estimate parameters noted above, or other metrics considered important. But a reliable CPUE index is available.	$CPUE_{t1-t2}$ or CPUE_low
Level 5	The key biological variables (age, reproduction, intrinsic rate of increase and carrying capacity) are reliably estimated.	F/F_{crash} >1 or F/F_{lim} >1

AGENDA ITEM 5 ECOSYSTEM AND BYCATCH MITIGATION THEME

5.1 Review of potential mitigation measures to reduce fishing-related mortality on silky and oceanic whitetip sharks (Project 101)

121. SC17 recommends that the Project 101 be continued with the following modifications:

- Relevant CCMs should consider authorizing the release of their non-ROP longline data (facilitated through SPC) for this study, specifically to provide more complete gear configurations by flag, or collaborating to conduct such an analysis for their flagged vessels, and allow analyses similar to Caneco et al. (2014) to estimate factors affecting shark catchability and condition on longline retrieval to be conducted using a more complete dataset;
- Conduct the Monte Carlo analyses with inputs on catchability, condition on longline retrieval and gear configurations by flag;
- Conduct updated projections with inputs on the impact of banning shark lines and wire leaders or both and estimates of the probability of post release mortalities of silky and oceanic whitetip sharks (as based on Hutchinson et al. 2021 or other new information);

Additionally, results of the analyses should be shared to CCMs that made contributions to those analyses for their review and comments in advance of SC18.

122. SC17 also noted the result contained in SC17-EB-WP-01 and recommends that the Commission to be alerted to them, including:

- Banning shark lines has the potential to reduce fishing mortality by 2.6% and 5.4% for silky shark and oceanic whitetip shark, respectively. These percentages are lower than predicted estimates from Harley et al. (2015) which may be explained by a decrease in use of shark lines in more recent observer data; and]
- Banning branchline wire leaders has the potential to reduce fishing mortality by 28.2% and 35.8% for silky shark and oceanic whitetip shark, respectively. These percentages are higher than estimates from Harley et al. (2015) and are due to a better representation of wire leader use in distant water fisheries.

123. Shark conservation and management measure (CMM 2019-04 paragraph 14) contains the option to either ban the carrying and use of wire leaders as branchlines or ban the use of branchlines directly off the longline floats or drop lines, known as shark lines, is currently in effect in many CCMs.

5.2 Best handling practices for the release of cetaceans

124. SC17 recommends the *Draft Best Handling Practices for the Safe Handling and Release of Cetaceans* be forwarded to TCC17 and WCPFC18 for consideration.

125. SC17 further recommends that the Commission develop graphics to be included with the *Best Handling Practices for the Safe Handling and Release of Cetaceans* for consideration at WCPFC19.

5.3 Other issues

5.3.1 Seabird Mitigation Measures on Small-Scale Longline Vessels North of 23º North (SC17-EB-IP-15)

126. SC17 recommends that Commission CCMs with small-scale longline vessels (< 24m) operating north of 23° North provide the SC with information, such as the results of scientific research or EM-based commercial vessel survey, as well as the specific mitigation measures used by those vessels and the

associated seabird interaction rates for each mitigation measure, if available, including streamer-less tori lines, and that SC18 review such information, to make findings and recommendations with respect to the effectiveness of the streamer-less tori line designs to inform the Commission's review under CMM 2015-03 (and its successor measures).

127. SC17 encourages further experimental investigation of 'strategic' offal discharge and blue-dyed bait to determine the relative efficacy of these seabird bycatch mitigation methods.

AGENDA ITEM 6 FUTURE WORK PROGRAM AND BUDGET

6.1 Development of the 2022 work programme and budget, and projection of 2023-2024 provisional work programme and indicative budget

a) Review of *Scoring of the Proposed Scientific Committee Projects* (SC17-GN-WP-01)

128. SC17 agreed that Table WP-01 be used to score and then rank SC projects. SC agreed to implement this approach at SC17 and thereafter. Ranking is derived from the average of the scores allocated by CCMs.

Table WP-01. SC project scoring table. Colours represent priority rankings (6,9 = High; 3,4 = Medium; 1,2 = Low):

<table>
<tr><td></td><td></td><td colspan="3">Importance to WCPFC Management Outcomes or to the functioning of the SC</td></tr>
<tr><td></td><td>Rank</td><td>Low</td><td>Moderate</td><td>High</td></tr>
<tr><td rowspan="3">Feasibility: Likelihood of Success</td><td>Low</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Moderate</td><td>2</td><td>4</td><td>6</td></tr>
<tr><td>High</td><td>3</td><td>6</td><td>9</td></tr>
<tr><td colspan="5">Notes:
Importance criteria evaluate the significance of the outcomes of the proposal in contributing to the successful management of the WCPFC stocks or the functioning of the SC (e.g. is the proposal aligned with the WCPFC research and/or management priorities; does the proposal contribute to the effective planning and functioning of the SC; are the intended outputs/benefits well-defined and relevant; what is the level of impact and likelihood that the proposal outputs will be adopted; is the proposal cost effective). High= Essential; Moderate=Important but not essential; Low=Not Important.

Feasibility criteria evaluate the proposal's potential for success i.e., how likely is the proposal to achieve its stated objectives (e.g. are the objectives clearly stated, is the methodology sound, are the project objectives realistic and likely to be achieved, does the research team [if identified] have the ability, capacity and track record to deliver the outputs).</td></tr>
</table>

b) Review of 2021 SC Projects and the results of the SC17 Online Discussion Forum

129. SC17 noted the progress of 2021 project outputs detailed in SC17-GN-IP-06 (*Intersessional activities of the Scientific Committee*). SC17 also noted that there were no objections raised regarding the results of 2021 projects through the Online Discussion Forum, as detailed in SC17-ODF-01 (*Summary of Online Discussion Forum*).

c) Review of *SPC assessment-related activities under the SSP standard SPC and additional resourcing budget* (SC17-GN-WP-02)

130. SC17 agreed that the Commission's 2022 scientific services from SPC would comprise (i) the skipjack stock assessment; (ii) the YFT peer review and additional analyses; and (iii) continuing work to develop the new ensemble approach. Other additional priority work areas beyond the current agreed 2021 scientific services were identified for the remainder of 2021, including the requested stock projections for Southwest Pacific swordfish, and requested analyses related to the South Pacific albacore TRP and implications of the work presented in SC17-MI-WP-01 for that stock.

d) Review of proposed projects for 2022 – 2024

131. SC17 recommended the proposed work program and budget for 2022 and indicative budget for 2023 – 2024 in Table WP-02 to the Commission.

Table WP-02. Recommended Future Work Program and Budget for 2022 – 2024, ordered by CCM's averaged score. (Essential projects are in gray; P17Xy represents a new project)

Project Title	TOR	2022 (SC18)	2023 (SC19)	2024 (SC20)	Responsibility	Avg. score	# CCMs
SPC-OFP scientific services[2]		961,874	981,112	1,000,734	SPC	**8.8**	18
SPC Additional resourcing[2]	MFCL work	173,206	176,670	180,204	SPC	**8.2**	18
P35b. WCPFC Tissue Bank[2]	SC15-Att.G	103,204	105,268	107,373	SPC	**8.7**	19
P42. Pacific Tuna Tagging Program	SC15-Att.G	730,000	730,000	730,000	SPC	**8.9**	19
P65. Peer review	SC17-GN-IP-07	50,000			SPC	**9.0**	20
P17X4. Further development of ensemble model approaches for presenting SA uncertainty	TOR - TBC		20,000		SPC	**7.9**	20
P17X1. Billfish Research Plan 2023 - 2027	SC17-GN-IP-07	55,000			SPC	**7.8**	20
P90. Length weight conversion	SC16-GN-IP-08	75,000			SPC	**7.6**	20
P17X3. Preparing WCP tuna fisheries for application of CKMR methods to resolve key SA uncertainties.	SC17-GN-IP-07	40,000			SPC; Contingent on EU support	**6.9**	20
P17X2. SWP mako shark SA	SC17-GN-IP-07	105,000			SPC	**6.5**	20
P17X5. Scientific Advice for Southwest Pacific blue shark	SC17-GN-IP-07	40,000			SPC	**6.2**	20
P108. WCPO silky shark assessment	SC17-GN-IP-07	50,000	50,000		SPC; Report to SC19	**5.6**	14
P68. Seabird mortality	SC17-GN-IP-07	25,000	40,000	10,000	SPC	**5.2**	20
P60. PS Species Composition (Carry over 2000 budget to 2022)	SC15-Att.G				SPC	**N/A**	
Total Project Budget		**1,446,410**	**1,121,938**	**1,027,577**			
Total Project Budget + SPC		**2,408,284**	**2,103,050**	**2,028,311**			

[2] Budget – 2% annual increase

AGENDA ITEM 7 ADMINISTRATIVE MATTERS

7.1 Election of Officers of the Scientific Committee

132. The Vice-Chair noted the discussion held at the HOD meeting prior to SC17 regarding the need for a SC Chair, Vice-Chair, and co-conveners for the EB and MI themes for SC18. No nominations were made at SC17. The Executive Director advised that nominations for these positions would remain open until WCPFC18.

7.2 Next meeting

133. SC17 recommended to the Commission that SC18 would be held from 10–18 August 2022, and that it had not identified a host country for the meeting if held in person. Tonga offered to host SC19 in 2023.

AGENDA ITEM 8 OTHER MATTERS

8.1 Review of Online Discussion Forum outputs

134. SC17 noted the results of the Online Discussion Forum (SC17-ODF-01, *Summary of Online Discussion Forum*).

8.2 Consideration of SC17-ST-IP-06 and SC17-ST-IP-10

135. Addressed under Agenda Item 2.3.

AGENDA ITEM 9 ADOPTION OF THE SUMMARY REPORT OF THE SEVENTEENTH REGULAR SESSION OF THE SCIENTIFIC COMMITTEE

136. SC17 adopted the recommendations of the Seventeenth Regular Session of the Scientific Committee.

137. SC agreed that the SC17 Summary Report would be adopted intersessionally according to the following schedule:

Tentative Schedule	Actions to be taken
19 August	Close of SC17. By 30 August, SC17 Outcomes Document will be distributed to all CCMs and observers (within 7 working days, Rules of Procedure).
26 Aug – 6 Sep	Secretariat will receive Draft Summary Report from the lead rapporteur and review the Draft Report
6-14 September	Secretariat will distribute the Report to all Theme Convenors for review.
14-21 September	Secretariat will clear the Report for posting and distribution
21 Sep -30 Oct	The Secretariat will post/distribute the draft Summary Report to all for CCMs and Observers for their review. Deadline for submission of comments by 30 October
Early November	Intersessional process for the adoption of the SC17 Summary Report

AGENDA ITEM 10 CLOSE OF MEETING

138. The Vice-Chair closed SC17 at 12:10 Pohnpei time on Thursday, 19 August 2021.