COMMISSION
NINETEENTH REGULAR SESSION

Da Nang, Viet Nam
27 November – 3 December 2022

Reference Document for Southwest Pacific Blue Shark (Agenda 8.1.1.1)

WCPFC19-2022-21
11 November 2022

Secretariat

A. INTRODUCTION

1. The purpose of this paper is to provide a quick reference guide to the latest recommendations of the Scientific Committee (SC18) for Southwest Pacific blue shark ((*Prionace glauca*) to be discussed under Agenda 8.1.1.1. This paper includes additional research requested by SC17, brief introduction to Project 107b for additional analyses, and the latest scientific information on stock status and management advice from SC18 for the Southwest Pacific blue shark stock.

B. SCIENTIFIC COMMITTEE RECOMMENDATIONS

B.1 SC17 (2021) – Provision of Scientific Information (*Paragraph 162 - 171, SC17 Summary Report*)

a. Stock status and trends

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

2. 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.

3. 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.

4. 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.

5. 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.

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

7. 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

8. 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.

9. 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

10. SC17 recommended that:

1) increased effort be made to re-construct catch histories for sharks (and other bycatch species) from a range of sources;
2) 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;
3) 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;
4) 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;

5) genetic/genomic studies be undertaken to augment the tagging work to help resolve these stock/sub-stock structure patterns;
6) 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
7) observers (or the vessel) should record number of shark lines deployed per set or the number of floats with shark lines.

B.2 Project 107b – Towards Providing Scientific Advice for Southwest Pacific Blue Shark

11. P. Neubauer presented SC18-SA-WP-03 (*Report on WCPFC project 107b: Improved stock assessment and structural uncertainty grid for Southwest Pacific blue shark*), which is a response to SC17 recommendations to assess performance of each model and evaluate the plausibility of the uncertainty grid before approving the results for providing management advice using several diagnostic tests. These tests include model convergence (the final gradient), stability (Hessian matrix and jitter procedure), goodness-of-fit (residuals patterns of the CPUE and length-frequency distributions), model consistency (retrospective pattern) and prediction skill (hindcasting analysis). The weighting of axes of the grid was also investigated. After applying these tests, the number of models consisting of the uncertainty grid decreased from 3888 to 228. Most (87%) of the 228 (weighted) model runs show that the biomass is above SB/SB_{MSY}. The stock biomass was low throughout the region through the early 2000s following the expansion of longline fishing effort in the region. But the estimates across the uncertainty grid of 228 models largely indicated that the stock has been recovering since then. Fishing mortality has declined over the last decade and is currently relatively low with the median F_{recent}/F_{MSY} = 0.65. These results were qualitatively similar to 2021 assessment grid outcomes.

B.3 SC18 (2022) – Provision of Scientific Information (*Paragraph 32 - 41, SC18 Outcomes Document*)

a. Stock status and trends

12. A description of the structural uncertainty grid with associated weighting that was used to define stock status and characterize uncertainty in the Southwest Pacific blue shark (SBSH) assessment is included in Table SBSH-1.

13. SC18 noted the improvement of the structural uncertainty grid and the use of 228 models, with *a priori* weighting, and the reduced grid complexity compared to the 2021 version.

14. SC18 noted the stock biomass was low throughout the region through the early 2000s following the expansion of longline fishing effort in the region, but the estimates across the uncertainty grid of 228 models largely indicated that the stock has been recovering since then.

15. SC18 noted that the median value of relative recent dynamic spawning biomass depletion for Southwest Pacific blue shark ($SB_{2017\text{-}2020}/SB_{F=0}$) was 0.71 ($90^{th}$ percentiles 0.37 and 0.82). Alternatively, relative recent equilibrium spawning biomass depletion for South Pacific blue shark ($SB_{2017\text{-}2020}/SB_0$) was = 0.80 ($90^{th}$ percentiles 0.43 and 0.90).

16. SC18 noted that the median value of $SB_{2017\text{-}2020}/SB_{MSY}$ was 1.64 (90^{th} percentiles 0.88 and 1.87; Table SBSH-2) with 87% likelihood (according to the 228 weighted models) that the biomass is above SB_{MSY}.

17. SC18 noted that the fishing mortality has declined over the last decade and is currently relatively low with the median $F_{2017\text{-}2020}/F_{MSY}$ = 0.65 (90^{th} percentiles 0.43 and 0.86; Table SBSH-2).

18. SC18 noted that there was a 1% likelihood (according to the 228 weighted models) that the recent fishing mortality ($F_{2017-2020}$) was above F_{MSY}.

Table SBSH-1. Description of the seven axes for the updated 2022 structural uncertainty grid. Base settings used under the diagnostic case are highlighted in bold. Weights used for alternative values in the weighting of the grid axes are given in parentheses.

Axis	Description
Catch scenario	**Base (0.9)**, high (0.1)
Discard scenario	Low (0.25), **base (0.5)**, high (0.25)
Initial F	**base (0.9)**, high (0.1)
High latitude CPUE	**New Zealand (1),** low weight (0.5), remove (RM) early New Zealand (0.5)
Low latitude CPUE	**Japan (1)**, Australia (0.5), remove EU CPUE
Survival fraction	**Base**, low, high
Growth	**Manning and Francis (2005)**, Joung et al. (2018)

Table SBSH-2. Summary of reference points and stock status for the subset of 228 grid model in the structural uncertainty grid, after sub-setting the grid for model runs that showed acceptable retrospective patterns and estimates for natural mortality. Grid axes are weighted by prior input weights. The symbols used in the yield and stock status are described in Table 3 of SC18-SA-WP03.

	Mean	Median	Min	10%	90%	Max
C_{latest}	5,965	5671	3707	3978	7593	9601
C_{recent}	6,912	6744	4322	4596	8926	9577
MSY	11,413	9993	8968	9313	16333	25629
SB_0	22,772	20603	15686	18524	32263	53503
$SB_{F=0}$	25,894	22658	17559	20161	38033	66434
SB_{MSY}	11,104	9985	7564	9008	15854	26684
SB_{latest}	18,420	17904	12973	15902	20424	38004
SB_{recent}	16,344	15907	11320	14000	17670	33654
SB_{latest}/SB_0	0.85	0.90	0.42	0.49	1.01	1.19
SB_{recent}/SB_0	0.76	0.80	0.37	0.43	0.90	1.05
$SB_{latest}/SB_{F=0}$	0.76	0.79	0.32	0.43	0.93	1.29
$SB_{recent}/SB_{F=0}$	0.67	0.71	0.29	0.37	0.82	1.15
SB_{latest}/SB_{MSY}	1.75	1.84	0.85	1.00	2.10	2.47
SB_{recent}/SB_{MSY}	1.55	1.64	0.76	0.88	1.87	2.19
F_{MSY}	0.144	0.142	0.134	0.136	0.158	0.181
$F_{lim,AS}$	0.228	0.225	0.211	0.214	0.248	0.291
$F_{crash,AS}$	0.325	0.320	0.299	0.304	0.351	0.419
F_{latest}	0.073	0.072	0.039	0.051	0.093	0.120
F_{recent}	0.094	0.094	0.048	0.065	0.117	0.160
F_{latest}/F_{MSY}	0.51	0.52	0.24	0.35	0.67	0.78
F_{recent}/F_{MSY}	0.65	0.65	0.30	0.43	0.86	1.06
$F_{latest}/F_{lim,AS}$	0.32	0.33	0.15	0.22	0.43	0.50
$F_{recent}/F_{lim,AS}$	0.41	0.41	0.19	0.27	0.55	0.68
$F_{latest}/F_{crash,AS}$	0.23	0.23	0.11	0.15	0.30	0.35
$F_{recent}/F_{crash,AS}$	0.29	0.29	0.13	0.19	0.39	0.48

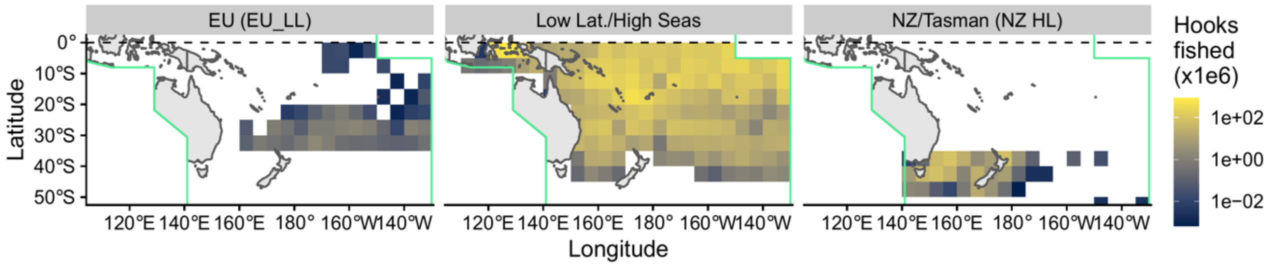

Figure SBSH-1. Spatial structure used in the 2022 stock assessment model.

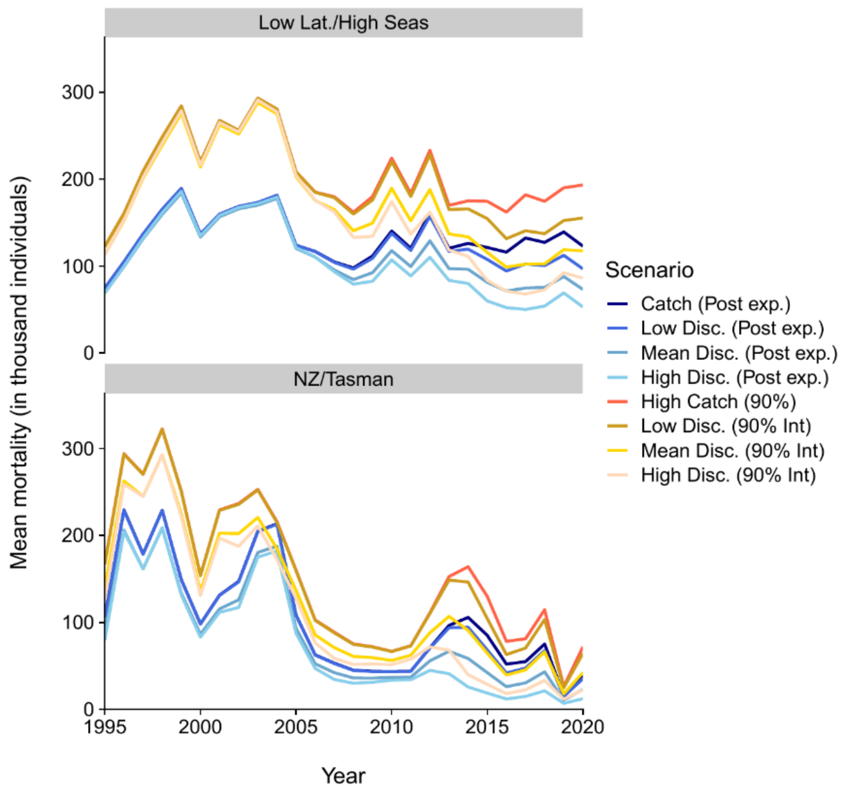

Figure SBSH-2. Top panel: Time series of total reported annual Southwest Pacific BSH catch for the EU-SP fleet (mt), Bottom panels: Predicted total fishing related mortality by latitudinal stratum (high [≥ 35 degree South] and low latitude [< 35 degree South]), including 17% post release mortality for live-discarded blue sharks. Interactions refer to the posterior median (50%) and 90th percentile (90%) of the predicted catch from the observer catch rate model. Low, median and high discard scenarios refer to the 25%, 50% (median) and 75% discard estimates. All discard estimates were applied at flag and latitudinal stratum level to overall interactions.

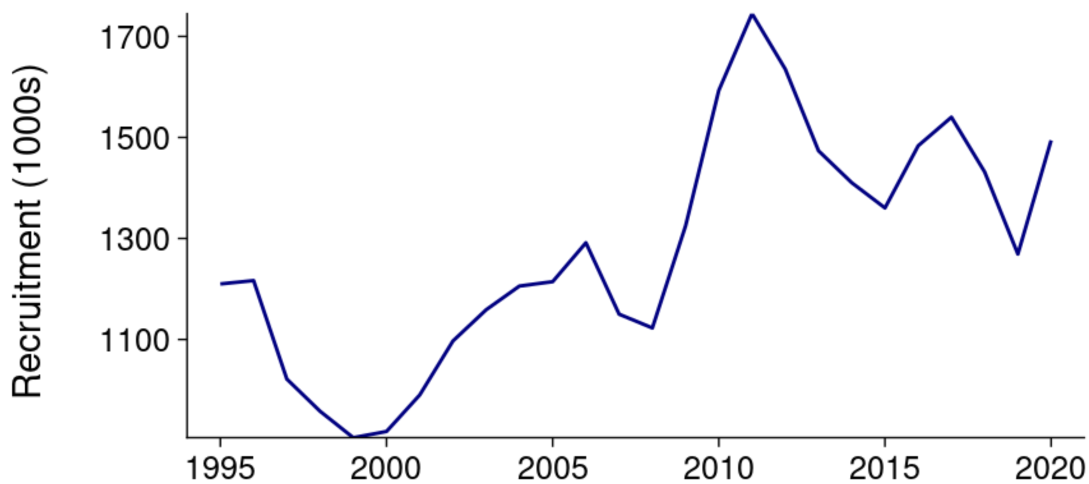

Figure SBSH-3. Estimated annual recruitment for the diagnostic case model

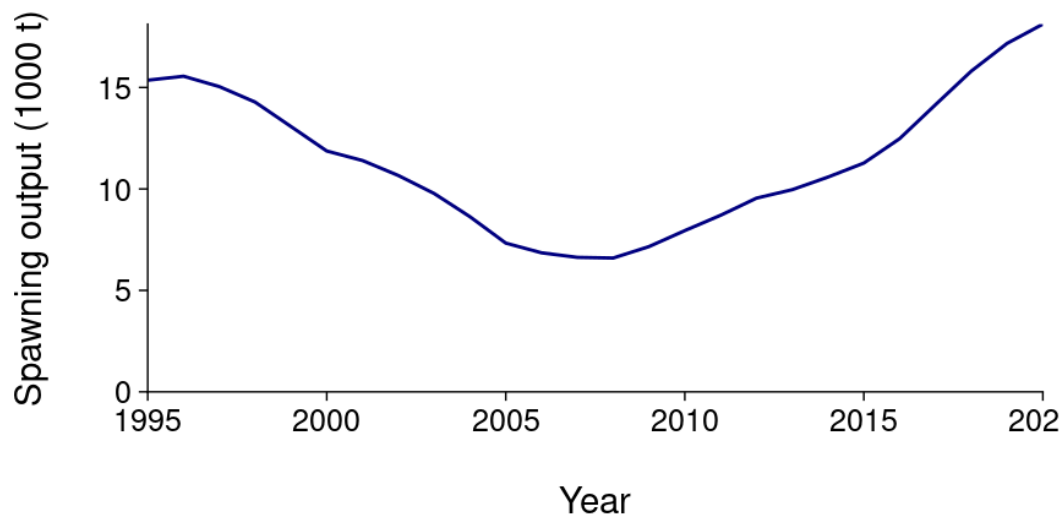

Figure SBSH-4. Estimated annual spawning potential by model region for diagnostic case model

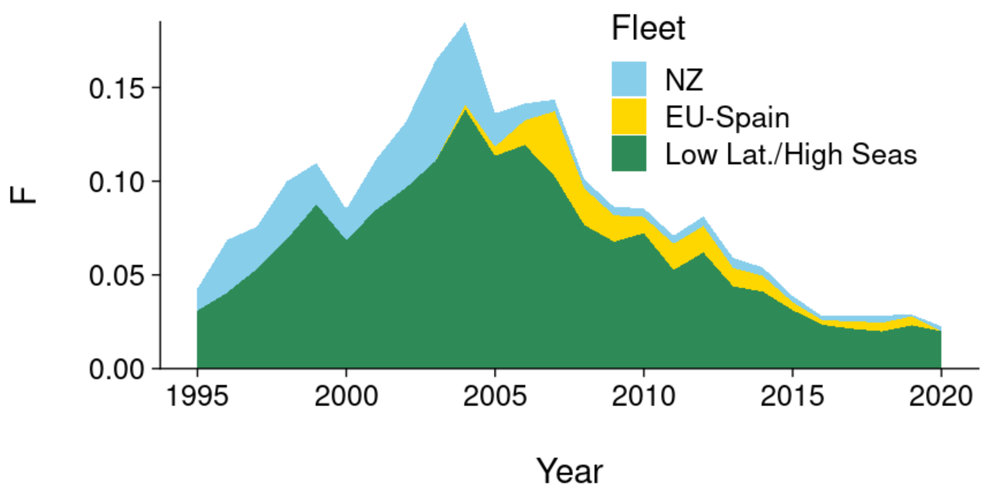

Figure SBSH-5. Estimated annual fishing mortality for the diagnostic case model

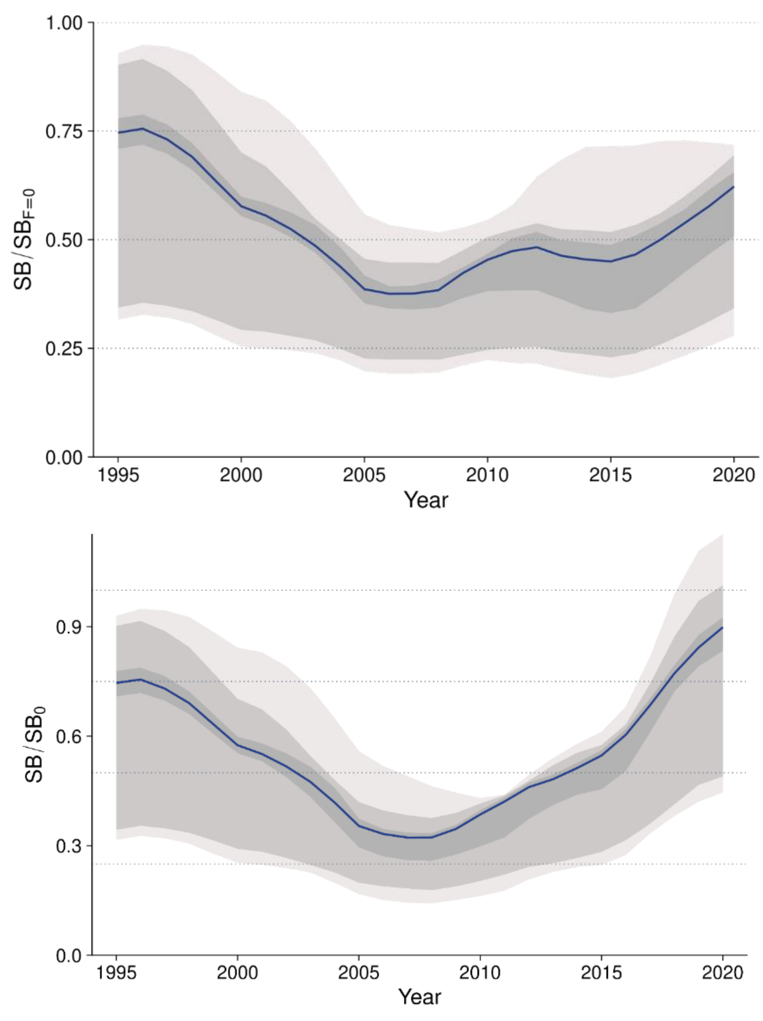

Figure SBSH-6. Plot showing the quantiles of trajectories of fishing depletion (of spawning potential) for the 228 model runs included in the structural uncertainty grid

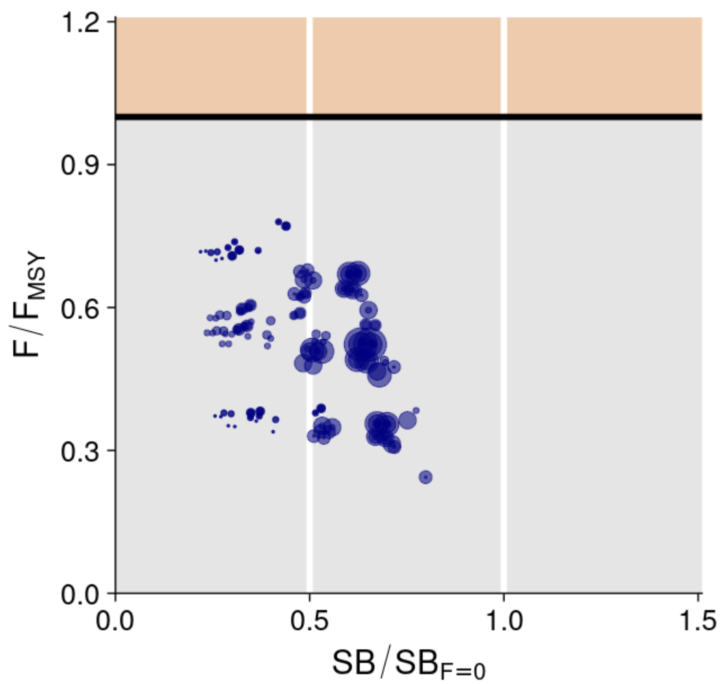

Figure SBSH-7. Majuro plot summarising the results for each of the models in the structural uncertainty grid. Size indicates weight of each model in the grid, darker shading indicates multiple models with similar outcomes.

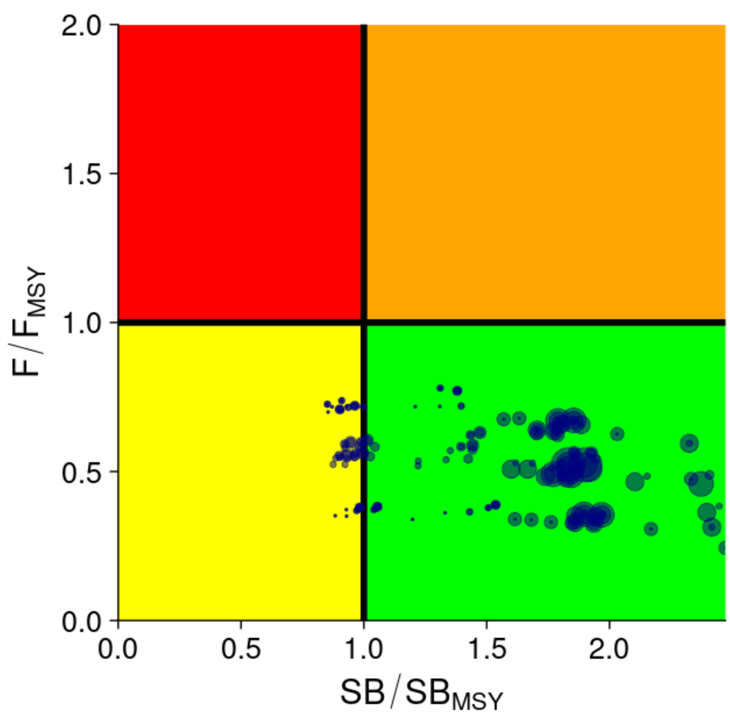

Figure SBSH-8. Kobe plot summarising the results for each of the models in the structural uncertainty grid. Size indicates weight of each model in the grid, darker shading indicates multiple models with similar outcomes.

b. Management advice and implications

19. SC18 welcomed the reduction and refinement of the grid of models for Southwest Pacific blue shark as well as the approach to the weighting of the model.

20. Based on the above information, SC18 advised the Commission that the Southwest Pacific blue shark is unlikely to be overfished and it is unlikely that overfishing is occurring when considered against MSY and depletion-based reference points.

c. Future research recommendations

21. SC18 noted the following research recommendations to achieve improvement in future shark assessments:

(i) Providing more time, either as inter-session projects, or by extending time-frames for shark data analyses. This will allow more thorough investigation of input data quality and trends, which shape assessment choices. In addition, it would allow input analyses to be completed in time to be presented to the SPC's Pre-Assessment Workshop prior to the stock assessment. In addition, allowing more time for the assessments themselves will allow a more thorough investigation of alternative model structures, which may include comparisons with low-information methods such as spatial risk assessments.

(ii) Increased effort to reconstruct catch histories for sharks (and other bycatch species) from a range of sources. Our catch reconstruction models showed that model assumptions and formulation can have important implications for reconstructed catches. Additional data sources, such as log-sheet reported captures from reliably reporting vessels, may be incorporated into integrated catch-reconstruction models to fill gaps in observer coverage.

(iii) 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. Such tagging may help to resolve questions about the degree of natal homing and mixing of the stock.

(iv) Tagging may also help to obtain better estimates of natural mortality, if carried out in sufficient numbers. This could be taken up as part of the WCPFC Shark Research Plan to assess the feasibility and scale of such an analysis.

(v) Additional growth studies from a range of locations could help build a better understanding of typical growth, as well as regional growth differences. Current growth data are conflicting, despite evidence that populations at locations of current tagging studies are likely connected or represent individuals from the same population.

(vi) Genetic/genomic studies could be undertaken to augment the tagging work to help resolve these stock/sub-stock structure patterns. To support this work, a strategic tissue sampling program for sharks is recommended with samples to be stored and curated in the Pacific Marine Specimen Bank.