Commission for the Conservation of Southern Bluefin Tuna

みなみまぐろ保存委員会

Report of the Twelfth Operating Model and Management Procedure Technical Meeting

20 – 24 June 2022
Hobart, Australia

Opening

1. Jim Ianelli opened the Twelfth Operating Model and Management Procedure Technical Meeting (OMMP 12) and welcomed participants (**Attachment 1**). It was agreed that he would chair day one of the meeting and that Ana Parma would chair the remainder of the meeting after her arrival. The Chair advised that the meeting is being held as a "hybrid" meeting due to the COVID-19 pandemic. The Chair also advised that the main tasks of the meeting are to complete the analyses required to be in a position to provide advice on a TAC for the period 2024-2026 at the 27th Meeting of the Extended Scientific Committee (ESC 27), including: Reconditioning of the Operating Model (OM) to check the Cape Town Procedure's (CTP) performance in projections using as input a new CPUE series proposed by the intersessional CPUE working group; and Discussion of metarule outcomes to be presented at the ESC. The draft agenda was discussed and amended, and the adopted agenda is shown in **Attachment 2**. The list of documents for the meeting is shown in **Attachment 3**.

Meeting arrangements

2. The Chair advised that, due to the hybrid environment, it is planned to hold two sessions each day. The morning sessions (9-12:30am Hobart time) will be focused on discussion of the most important items that need agreement and on summaries/highlights of results. These are the sessions that everyone should attend (either physically or virtually). The afternoon sessions (2-5:30pm Hobart time) will be for technical work and preliminary review of items. Except for those closely involved in this technical work, it is not necessary for virtual participants to attend these sessions.

3. The group thanked Australia and CSIRO for hosting this meeting and for providing the meeting venue and facilities.

Agenda Item 1. Review progress to date on CPUE analyses

4. The Chair provided a summary of the CPUE modelling group's intersessional work. The link for this presentation is available here. He noted that the base CPUE time series used for conditioning the operating model (OM) used for MP-testing in 2019 had a very high 2018 value which resulted from extremely high CPUE estimates for some strata that had no observations. The CPUE working group was tasked to identify an alternative CPUE methodology that would be more robust to the problems caused by the increased aggregation of fishing effort and consequent data sparsity in some regions. Further, if an improvement could be demonstrated, then the ESC should review the results including implementation within the OM and MP. These points provide focus for the work that is needed on two fronts: for MP implementation and for improving CPUE indices that can be used in the assessment for sensitivities and future potential applications.

5. Simon Hoyle (consultant) presented paper CCSBT-OMMP/2206/04 on validating CPUE model improvements for the primary index of Southern Bluefin Tuna (SBT) abundance. This work was undertaken to validate approaches used in the newly developed primary CPUE index of SBT abundance, based on generalised additive models (GAMs) with spatiotemporal smoothers, and a delta lognormal approach. Map time series showed that the temporal and spatial distributions of both fishing effort and the highest catch rates have changed

appreciably between 1986 and 2020, while the spatial and temporal extents of fishing effort have declined. Simulated data were generated from the best model fitted to the aggregated dataset and used to explore the effectiveness of different model configurations for dealing with these changing distributions. The principal GAM models produced unbiased estimates with the simulated data, while generalised lined models (GLMs) and less flexible GAM smoothers provided biased indices. Manipulating the simulated dataset to produce a large rapid change in fish distribution resulted in moderately biased indices. Increasing the effort concentration through time to focus effort on areas with higher CPUE also resulted in estimation bias, particularly at the end of the time series when concentration was greatest. This bias may be due to loss of information from the dataset rather than model failure, and it may be helpful to increase the information via models that include data from other fleets as well as Japan. In general, GAM models provided less biased indices than either a GAM explicitly equivalent to the variable squares method (GAM_VS) or a combined model (w0.8) approach.

6. The group thanked Simon for his work and clarified that this had been conducted on the aggregated 5x5 data. Furthermore, the implications of implementation on the finer-scale data was explored in CCSBT-OMMP/2206/08 and there was little impact of the number of operations/strata on the results of the standardisation. The group noted that the non-linear relationship of the absolute variance to CPUE and effort indicated that the variance assumptions are violated in models based on aggregated data. The GAM approach is better able than the GLM to accommodate the complex spatio-temporal variation in the data. The simulation comparison indicated that the Variable Square (VS) approach adds some bias and does not improve the reliability of the standardisation, while there was no evidence of bias in the standard implementation. It was noted, however, that the simulated data had been generated from what was judged to be the best model and was not a true representation of the variable squares model. The original impetus for that approach had been the potential for range contraction as abundance declined.

7. Tomoyuki Itoh presented the paper CCSBT-OMMP/2206/08. In the paper he noted that at ESC 26 it had been decided to develop a new CPUE abundance index of SBT to be used in OM and MP. The methodology was examined jointly with Simon Hoyle. A working arrangement was developed regarding use of operational data from Japanese fishermen. Those data are the confidential information belonging to the Japanese fishermen and they were therefore unavailable for broad distribution to Member scientists. Consequently, the analyses were carried out by Japanese scientists. This paper summarised the base case and various robustness tests. The CPUE standardisation applied a two-step GAM approach (the delta lognormal method). The abundance index was the lowest in 2006 and increased in most subsequent years until 2019. In 2020 and 2021, the index decreased to 2015-2017 levels. The results showed that the index was robust to a variety of sensitivity analyses, including model selection approaches, retrospective analysis, vessel ID, area range changes, age range changes, and data and model resolution changes. The authors noted that for future applications, as new data are added the relative values for the past changed when the data for the most recent year was added.

8. In response to a question from the group, Itoh noted that although COVID-19 had an effect on the market, the pandemic and any change to La Nina conditions did not appear to affect the CPUE of Japan's longlining in 2020 and 2021.

9. The group noted that the new standardisation was being applied to a wider selection of data than used in the previous Core Vessel GLM, and that there was generally a high proportion of positive SBT sets across the period covered by the data set (Figure 1 from paper 8 below). It was also noted that the data set included observations from north of 35º only in the Tasman Sea. The standardisation has historically been applied only to Statistical Areas 4-9, as the catches in Statistical Area 2 in the Indian Ocean are generally of a different nature (younger age classes) to those south of 35ºS.

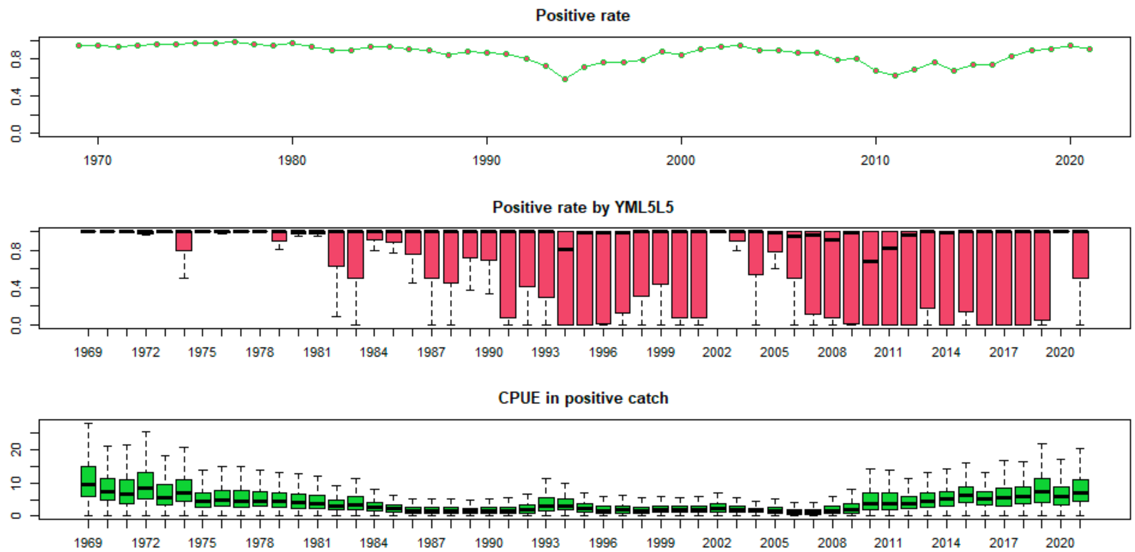

Figure 1. Nominal value of positive catch rate and CPUE by year. Upper panel is the positive rate which is the total number of positive catch operations / the total number of all records. Middle panels are boxplots based on the positive catch rate by year, month, 5 degree latitude and 5 degree longitude. Lower panel is CPUE in positive catch records.

10. The group noted that:
    - the very high 2018 peak in CPUE that initiated the investigation of the CPUE standardisation decreased in scale in the more recent standardisation, even when the same model (e.g. Core Vessel GLM) was used. This is a common phenomenon when new data are added and the updated data series is standardised, as the value of each year is re-estimated with the new model fit and additional data.
    - the retrospective analysis for the new GAM model did not show any evidence of retrospective bias.
    - the decline in the two most recent years (2020, 2021) relative to the peak in 2019, was consistent with the pattern seen in the corresponding 2-year-old year classes observed in the gene-tagging series.
    - regularly checking for any change in the optimal levels of k (relating to the smoothing flexibility) may be a useful regular diagnostic check of the model.
11. Itoh presented paper CCSBT-OMMP/2206/06 on the change in the operation pattern of Japanese southern bluefin tuna longliners in the 2021 fishing season. The Japanese longline data are critically important scientific data for input to the stock assessment of and management procedure for southern bluefin tuna. The change in the operation pattern of the

longline fishing of the most recent year was examined by comparison to the last 10 years. For the 2021 operational pattern, the catch amount, the number of vessels, time and area operated, proportion by area, length-frequency, and spatial concentration of operations were similar to the recent past. The increase in catch quotas over the last decade has had the greatest impact on the increase in CPUE, with the expansion of operating areas and periods. There was also a slight increase in the total number of operations.

12. The group enquired about Table 3 and "renewal" of vessels (and deletion of "experienced" vessels). Itoh responded that the fishing masters had changed less over recent times than in the past, and that the table in question fails to reflect that change. It is therefore unlikely that this impacts the standardisations. It was also pointed out that the addition of new vessels, in some cases, reflects the replacement of older vessels with new ones by the same operators/companies. It was noted further that individual quotas are allocated to vessels, although some transfer is allowed between vessels within a company.

13. It was noted that the bimodal length frequency distribution for 2021 in Figure 3 (of paper 06) appears to be consistent with the higher abundance of 2-year-old SBT observed in the gene-tagging for 2019 that was followed by two lower abundance year classes in the subsequent two years (see Table 1).

14. Itoh presented the paper CCSBT-OMMP/2206/07. This paper summarises the core vessel CPUE which is an abundance index of SBT used in the MP of CCSBT. It explains data preparation, CPUE standardisation using GLM, as well as generalised linear mixed models (GLMMs) and GAMs used in the 2020 ESC, and area weightings. The data were updated up to 2021. The index values in 2021, in the W0.8 and W0.5 series for the base GLM model, are at the same level as the average over the past 10 years.

15. The group recommended that the ESC could drop specific analyses using the core vessels beyond 2022 since the recommended CPUE series would now use all the vessels. Further, future presentations would follow a similar line as that presented in paper 8 (on the selected GAM standardisation procedure).

16. Korea presented paper CCSBT-OMMP/2206/09. In this study they standardised SBT CPUE from Korean tuna longline fisheries (1996-2021) using GLMs with set by set (operational) data. The authors explored CPUE by area and identified two separate areas (CCSBT Statistical Area 8 and 9) in which Korean vessels have targeted SBT. SBT CPUE was standardised for each of these areas. They applied two alternative approaches, data selection and cluster analysis, to address concerns about target change over time that can affect CPUE indices. GLM results for each area suggested that year, month, location, and targeting effects were the principal factors affecting the nominal CPUE. The standardised CPUEs for both areas decreased until the mid-2000s, and have shown an increasing trend since that time.

17. Based on these papers and discussions, the group recommended that the ESC should adopt the CPUE standardisation approach developed in CCSBT-OMMP/2206/08 with a draft specified in **Attachment 4**. The group noted that:

    - the selected model was robust to a number of sensitivities and improved upon the previous index; it also better reflected the type of index used for simulation-testing the MPs; that is, the CPUE index simulated by the OM lacked data characteristics that would lead to the exceptional circumstances on technical grounds that occurred in the observed base CPUE index.

- the new GAM-based CPUE standardisation approach captured interacting spatio-temporal trends and thus obviated the need to continue with Constant Squares and Variable Squares approaches to contrasting stock and fishery distribution hypotheses.
- the Variable Squares approach was shown to result in biases when tested on simulated data.
- the Korean CPUE indices resulted in broadly similar trends to the recommended Japanese CPUE standardised index.
- the meeting considered incorporating Korean, Taiwanese, and New Zealand longline data for further evaluation of CPUE. This issue will be discussed further at the next ESC.

Agenda Item 2. Reconditioning of operating model: data inputs and results

18. Rich Hillary presented CCSBT-OMMP/2206/05 which includes summaries of the updated data and the operating model fits to the data. It was noted that the results were preliminary as there had been delays in the data exchange that meant the analyses were only completed only immediately prior to the meeting.

2.1. Gene tagging

19. Table 1 provides the available estimates of absolute abundance of two year old SBT from the gene-tagging program for 2016-2019 and Figure 1 illustrates the fits. It was noted that there would not be an estimate for 2020, due to weather conditions and cancellation of the field program due to COVID-19. The estimate for the 2021 cohort will be available for the 2023 data exchange and in time for the next scheduled stock assessment.

Table 1. The results of the gene-tagging programs 2016-2019 that provide the estimate of absolute abundance for the age-2 cohort in the year of tagging.

Year	Age	N Releases	N Harvest	N Matches	*Abundance Est. (Million)*	*CV*
2016	2	2952	15389	20	2.27	0.224
2017	2	6480	11932	67	1.15	0.122
2018	2	6295	11980	66	1.14	0.123
2019	2	4242	11109	31	1.52	0.180

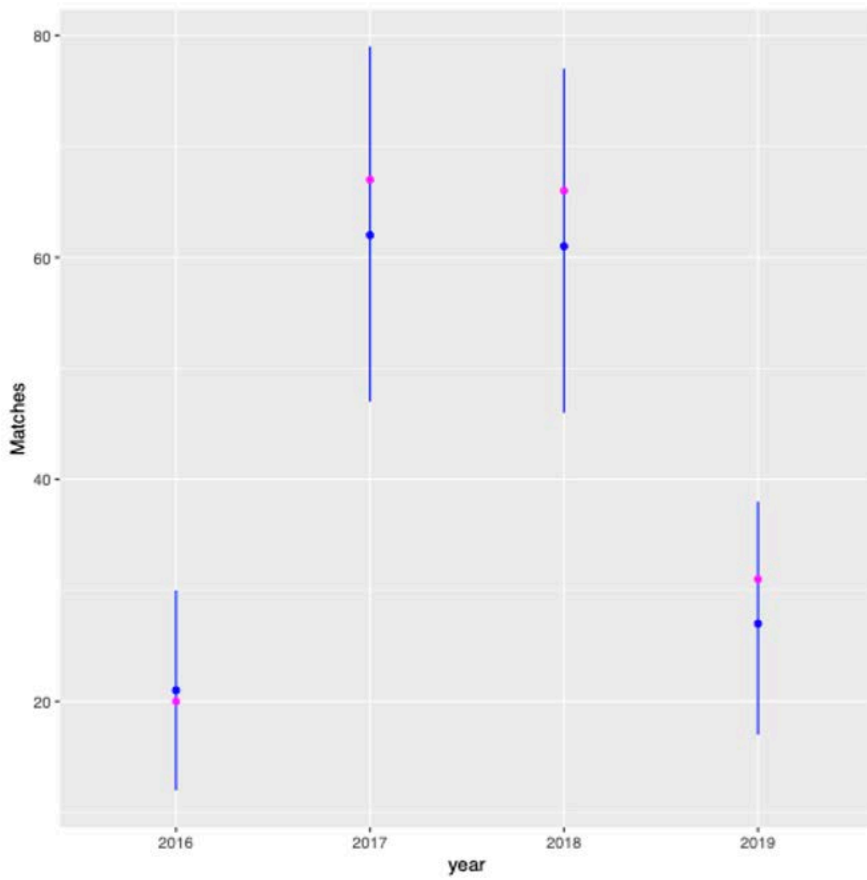

Figure 2. Predictive summary for the gene tagging data (magenta) included in base21 OMs. We plot only the predictive fits to the data as the series is currently too short to calculate a meaningful predictive p-value.

2.2. Close-kin: POPs and half-sibling data

20. It was noted that the adult samples from the spawning ground fishery in Indonesia for the past two years were unavailable due to COVID-19 impacts on international transport out of Bali as well as, more recently, a large institutional restructuring in the Indonesian MMAF and establishment of new national research and innovation agency (BRIN). Notwithstanding this delay, it had still been possible to analyse the juvenile samples for half-sibling pairs (HSP) and compare the new juvenile samples with a reduced window of adults to identify Parent-Offspring Pairs (POPs). Hence, the updated data includes additional POPs as well as HSPs (See Figures in **Attachment 5**), which will be reported in more detail in a specific CKMR update paper at ESC 27.

21. The group noted:
    - The decline in the final three years of the CPUE fit and three most recent year classes from gene-tagging show relatively similar patterns (**Attachment 5** figure on CPUE fit, Table 1 above).
    - That the systematic under-estimation of matches for the gene-tagging (**Attachment 5**) is due to the tension between the estimates from the gene-tagging data and the S-R function.

- The ψ parameter in the grid allows for estimation of the relative reproductive contribution by age. When ψ =1 TRO is equivalent to SSB. ψ values in the grid are 1.5, 1.75 and 2.0.
- The HSP data provide information on both absolute abundance and total mortality, not fishing mortality.
- The POP and HSP absolute abundance are consistent with the model and fit well.

2.3. CPUE

22. Papers CCSBT-OMMP/2206/08, CCSBT-OMMP/2206/09, and CCSBT-OMMP/2206/04 on the progress related to CPUE index were presented under agenda item 1.0 above. The Chair acknowledged the work and support provided by Members and the Secretariat to make progress on this topic.

23. Discussion about developing alternative plausible CPUE series then revolved around sensitivities as presented in CCSBT-OMMP/2206/08. It was noted that there is a parameter “gamma” that affects the “stiffness” of the splines by adjusting the statistical weight given to the model degrees of freedom. Gamma was fixed at 2.0 for all of the current analyses. The group recommended that runs be evaluated with gamma set to 1.4 and 2.6. The group also suggested bootstrapping based on data simulated from the estimation of base case GAM. Itoh carried out both types of runs during the meeting, but the differences were too small to provide a basis for an alternative CPUE series.

2.4 UAM

24. New Zealand tabled paper CCSBT-OMMP/2206/10: Estimates of unreported longline effort by CCSBT non-cooperating non-Member states between 2007 and 2020.

25. The level of unaccounted mortality (UAM) by non-Members of CCSBT is a key input to assessments of stock status for southern bluefin tuna (SBT). However, there is no reliable information available on SBT catch by non-cooperating non-Members (NCNMs) of the CCSBT. Analysis of the effort data reported to other regional fisheries management organisations (RFMOs), particularly the IOTC (Indian Ocean Tuna Commission) and WCPFC (Western and Central Pacific Fisheries Commission), shows a large degree of overlap with SBT fishing grounds for these tuna fisheries. However, SBT catch is generally not reported to the IOTC, WCPFC or the ICCAT (International Committee for the Conservation of Atlantic Tunas), even though these tuna fleets likely take quantities of SBT bycatch in their albacore, bigeye and yellowfin target fisheries. Some catches may also be targeted, and in general, the extent to which non-Member SBT catches are due to targeted or bycatch fishing is unknown.

26. In 2021, the ESC noted the following in relation to estimates of the UAM:

141. The ESC noted that a "best estimate" of non-Member UAM is required for the stock assessment, while the review of Exceptional Circumstances for the MP only requires an evaluation of whether the non-Member UAM is likely to be larger than that evaluated in the robustness tests.

142. The ESC further noted that an evaluation of changes in the level of non-Member effort since the last estimate would provide a good indication of the relative magnitude of changes in non-Member UAM, and that the level of non-Member UAM would need to be substantially larger than the previous estimate to trigger Exceptional Circumstances.

143. The ESC agreed that the priority work for UAM in 2022 should include an analysis of changes in non-Member effort to support the evaluation of Exceptional Circumstances in 2022.

27. On the basis of these recommendations, this paper documented work undertaken to provide updates to the non-Member effort time series from the IOTC, WCPFC and ICCAT, up to and including 2020.

28. Longline fishing effort reported to the WCPFC, IOTC and ICCAT, by non-cooperating non-Members of the CCSBT was presented. Changes in the non-Member effort provide an indication of likely changes in the magnitude of unaccounted SBT mortality. These data are necessary for a review of Exceptional Circumstances for the current Management Procedure.

29. Overall, total non-Member effort increased from around 26 million hooks per annum in 2007 to around 65 million hooks per annum in 2017. Most of this effort was reported to the WCPFC and concentrated in Statistical Area 12 to the north of New Zealand. Alongside a gradual increase in effort reported to the WCPFC, in 2017 there was an increase in non-Member effort reported to the IOTC in Statistical Area 14, to the east of South Africa. Since 2017 the total effort has been reasonably consistent, although there did seem to have been an uptick in 2020 (see Table 2).

30. The OMMP agreed that, as already planned, a more comprehensive update of UAM estimates should be completed by May 2023 prior to the data exchange for the next full stock assessment. If the 2020 uptick in effort translates into higher estimates of UAM, this may influence assessment inputs and results.

Table 2. *Non-Member effort per year per other tRFMO (million hooks), within grids by quarter with positive SBT catch reported to CCSBT.*

Year	ICCAT	IOTC	WCPFC	Total
2007	4.97	4.00	17.46	26.42
2008	3.56	1.83	14.30	19.69
2009	2.76	4.15	16.83	23.74
2010	2.50	8.78	39.84	51.12
2011	2.40	3.43	21.06	26.89
2012	2.20	4.05	26.73	32.98
2013	8.04	5.42	26.82	40.27
2014	2.47	6.54	29.74	38.75
2015	2.55	9.28	35.71	47.54
2016	2.74	13.51	22.32	38.57
2017	2.50	24.70	31.79	58.98
2018	2.61	23.72	30.40	56.74
2019	2.55	24.59	28.30	55.44
2020	2.65	25.28	36.71	64.64

2.5. Reconditioning of the Operating Model

31. A number of changes were made in the past to the specifications of the reference set of OMs used for different purposes since 2019 when the Cape Town Procedure (CTP) was adopted, as summarised in Table 3. The grid specifications referred to as base2018 were used for testing and tuning candidate management procedures in 2019. Adjustments to the grid were introduced in 2020 when the stock assessment was conducted (base2019), and a new grid (base2021) was defined prior to this meeting to recondition the OMs for the purpose of evaluating the effect of replacing the CPUE series by the one recently developed.

Table 3. Changes in the specification of the reference set of operating models used for different purposes since 2019. These include changes in the grid values used for steepness (h) and natural mortalities at age 0 and 10 (M0 and M10), CPUE series used for conditioning and unaccounted mortalities (UAM) assumed in projections.

Reference set name	Purpose	Most recent data	CPUE series	Steepness (*h*)	M_0	M_{10}	UAM in projections
base2018	2019 CMP testing	2018	2 GLMs W0.5 + W0.8	0.60, 0.70 0.80	0.35, 0.40, 0.45, 0.50	0.050, 0.085, 0.120	LL1: 10% Surf: 39% “UAM1”
base2019	2020 stock assessment	2019	2 “GAM11s” W0.6 + W0.9	0.55, 0.63 0.72, 0.80	0.40 0.45 0.50	0.065, 0.085, 0.105,	LL1: 14% Surf: 20%
base2021	2022 OMMP	2021	Single GAM (recommended)	0.55, 0.63 0.72, 0.80	0.40 0.45 0.50	0.065, 0.085, 0.105	LL1: 14% Surf: 20%

32. The changes from base2018 to base2019 included:

- Replacement of the Core Vessel GLM CPUE series with the temporary GAM11 CPUE series and a change in the values of the weights given to the variable squares and constant squares hypotheses.
- Changes to the range of steepness and natural mortality (both M0 and M10).

- Unaccounted mortalities (UAM) for LL1 based on best estimates of catches from non-cooperating non-Member states and a UAM of 20% for the surface fishery (instead of 39% assumed in the UAM1 scenario used for CMP testing).

33. The changes from base2019 to base2021 included:
    - the new GAM model and CPUE operational data was used to replace the Core Vessel GLM CPUE standardisation; and
    - the VS-CS weights were discontinued, reducing the number of CPUE series used in the grid to one.

34. The group considered that the most appropriate comparison for assessing the impact of the new CPUE series on the performance of the CTP was between base2018 and base2021.

35. The group noted that the recommendation to use the new GAM CPUE series and dropping of the use of CS-VS weights from the reference set resulted in a reduction in the structural uncertainty in the grid and that consideration needed to be given to development of plausible alternative series. The omega = 0.75 scenario used in the past, designed to address the potential for hyperstability in the CPUE-abundance relationship, was considered unsuitable in the rebuild/range contraction context. The group agreed that the development of alternative series (ideally one higher and one lower than the selected series) for inclusion in the reference set would not be possible prior to the ESC 27, and should be a priority for consideration for the 2023 stock assessment.

36. Rich Hillary presented paper CCSBT-OMMP/2206/05 which summarises the results of the fits of updated data using the base2021 grid. The preliminary examination of results indicated that the fits to the updated data were good, and that the new GAM CPUE series was consistent and fit reasonably well.

Agenda Item 3. Projection results using the Cape Town Procedure (CTP)

3.1. Minimum updates required to run CTP using updated data series

37. The group noted that no changes were required in order to be able to run the CTP using the updated OM and the new CPUE series.

3.2. Evaluate performance of CTP in projections using new CPUE series and updated data inputs (catches, Gene tagging and CK data)

38. A summary of the stock status and rebuilding statistics from projections for each of the base OMs is given in Table 4.

Table 4. Comparison of stock status estimates in 2018 (TRO@2018) and in the final year (TRO@final year), TRO depletion in 2035, and the probability of meeting the interim rebuilding objective of the CCSBT ($Pr(TRO/TRO_0>0.2)$ in 2035. All relative TRO estimates are medians.

Base OM	TRO/TRO_0 @ 2019	TRO/TRO_0 final year	TRO/TRO_0 @ 2035	$Pr(TRO>0.2TRO_0)$ @ 2035
base2018	0.17 (0.15-0.21)	0.17 (0.15-0.21)	0.30	0.90
base2019	0.17 (0.14-0.20)	0.20 (0.16-0.24)	0.28	0.86
base2021	0.18 (0.15-0.20)	0.22 (0.19-0.26)	0.28	0.87

39. Figure 3 compares the projection envelopes for base2018 and base 2021, which was considered the most relevant comparison in relation to providing management advice.

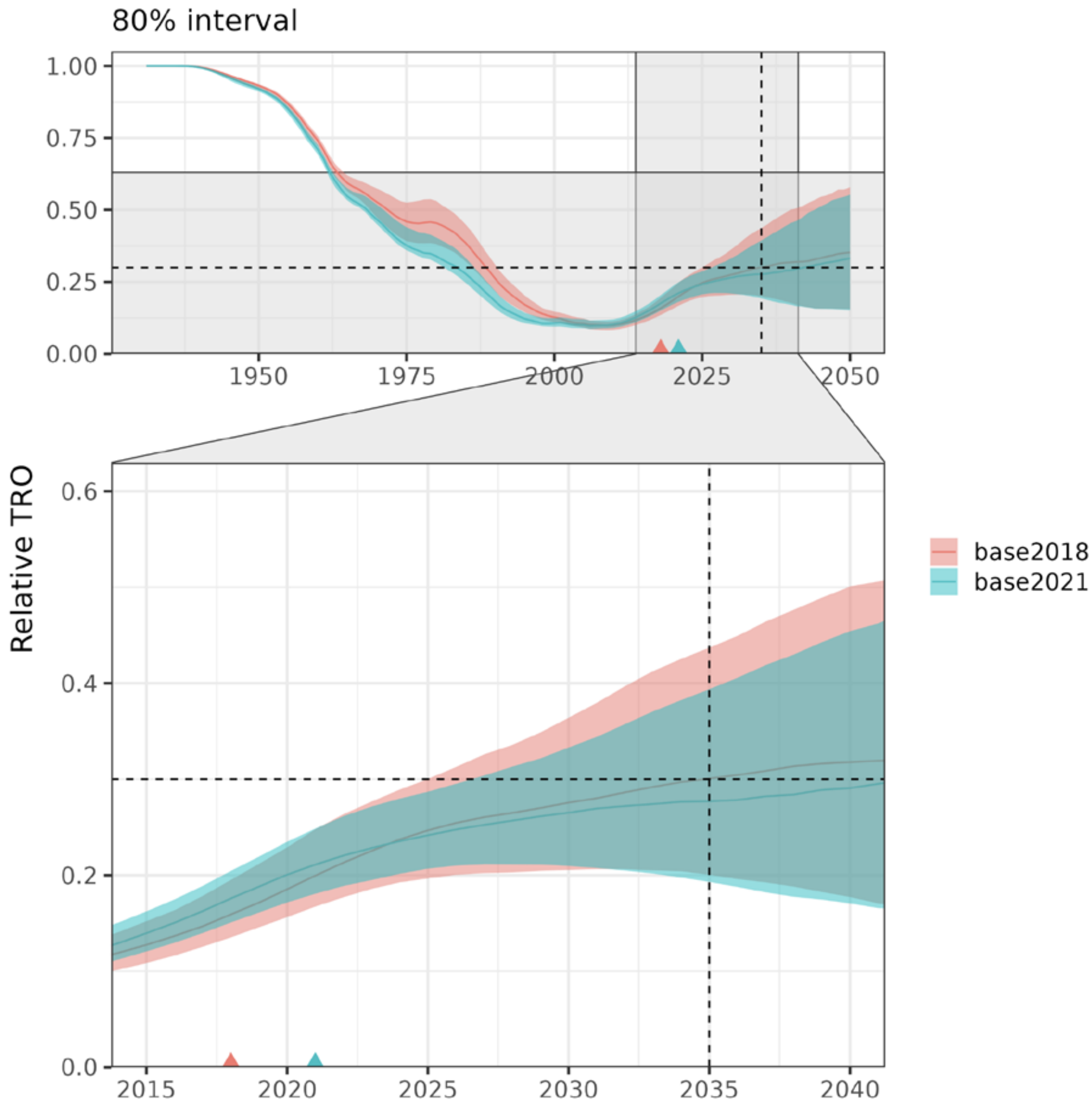

Figure 3. Projections of relative TRO (medians and 80% probability intervals) calculated using the Cape Town Procedure and the OM developed in 2019 (base 2018) and the updated OM (base2021) conditioned to the new CPUE series. Top figure shows the full period covered by the OM and the bottom figure is focussed on the recent period. The small triangles on the horizontal axis indicate the end of the data and the start of projections in each case.

40. The group noted that the difference in projections appears to be mostly driven by the updated data and the change to the CPUE series, as the differences are generally consistent across the two sets of grid parameters. Furthermore, the probability of achieving 0.3TRO/TRO0 by 2035 is 0.39 using the updated CPUE series. This result is consistent for both the base2019 and base2021 reference grids when using updated data.

41. The estimated stock status for the updated base2021 grid is 0.22 (0.19-0.26) compared to 0.2 (0.16-0.24) estimated in the 2020 stock assessment.

42. The probability envelopes for projections conducted in 2019, when the CTP was adopted, substantially overlap with those obtained after updating the data and replacing the CPUE series.

43. It is important to note that it is expected that there will be differences in the estimated probability of the median TRO meeting the rebuilding target for the CTP between the original CTP tuning in 2019 and subsequent updates of the OMs. This results from: i) the fact that TAC decisions have been made and the catches taken constrain the range of future TAC trajectories at each subsequent TAC decision and the impact on the stock; and ii) new data have been included in the conditioning of the OMs used for projections and also as input to the CTP. The new data provide information on variables such as recent recruitments which would differ from assumptions made in 2019. Both constrain the future possible trajectories of TAC and TRO in model projections.

Agenda Item 4. Discuss advice to ESC based on metarule process

4.1. Apply meta-rules process

44. The technical problems described under Agenda item 1 with the conventional GLM-based standardisation approach used for CTP implementation, and the need to develop a more robust CPUE index, triggered exceptional circumstances.

45. The meta-rules process required an evaluation of the consequences of replacing the CPUE series in terms of CTP performance.

46. In this context, the question was raised of how different the projected performance of the CTP needed to be before there was a need to retune or revise the CTP. The group noted that the meta-rules adopted together with the CTP were deliberately general and process orientated, which allow for consideration of the context and implications of individual exceptional circumstances. The meta-rules do not define specific criteria or risk levels, beyond the specification that the values of observed or projected monitoring series are within the probability bounds of the projections under base2018. In that context, the relevant initial tests for evaluating the consequences of the use of a new CPUE series are:
    - Is the new CPUE series within the bounds of the 2019 projections of the Core Vessel GLM CPUE?
    - Are the projections of the CTP using the new CPUE series and updated data (base2021) similar/within the bounds of the original projections?
    - Has the interim rebuilding target agreed in 2011 been met? (Pr(TRO/TRO0>0.20)=0.70 by 2035)?

47. The group considered that the focus on the median rebuilding tuning criteria for the CTP of Pr(TRO/TRO0>0.3)=0.5 was inappropriate because of the impacts of decisions that have been made since CTP adoption – as described in paragraph 46 above.

48. The group noted that the experience with the application of the meta-rules had served the CCSBT well and allowed the ESC and Extended Commission to address a range of exceptional circumstances in a structured and considered manner. This has been an important contribution to the stability and consistency of decision making since the implementation of

the Bali Procedure in 2011. The group agreed that it was generally undesirable to need to retune or modify the MP outside the review schedule specified in the meta-rules, and that the level of diversion from the original performance criterion before retuning is required is, ultimately, a question for the Extended Commission.

49. In terms of the first test above, Norio Takahashi presented a comparison of the new GAM and Core Vessel CPUE series and the range of projected CPUE values calculated in 2019 when the CTP was adopted (using base2018) (Figure 4). The group noted that the new CPUE series fell within the 95% probability bounds of the 2019 projections.

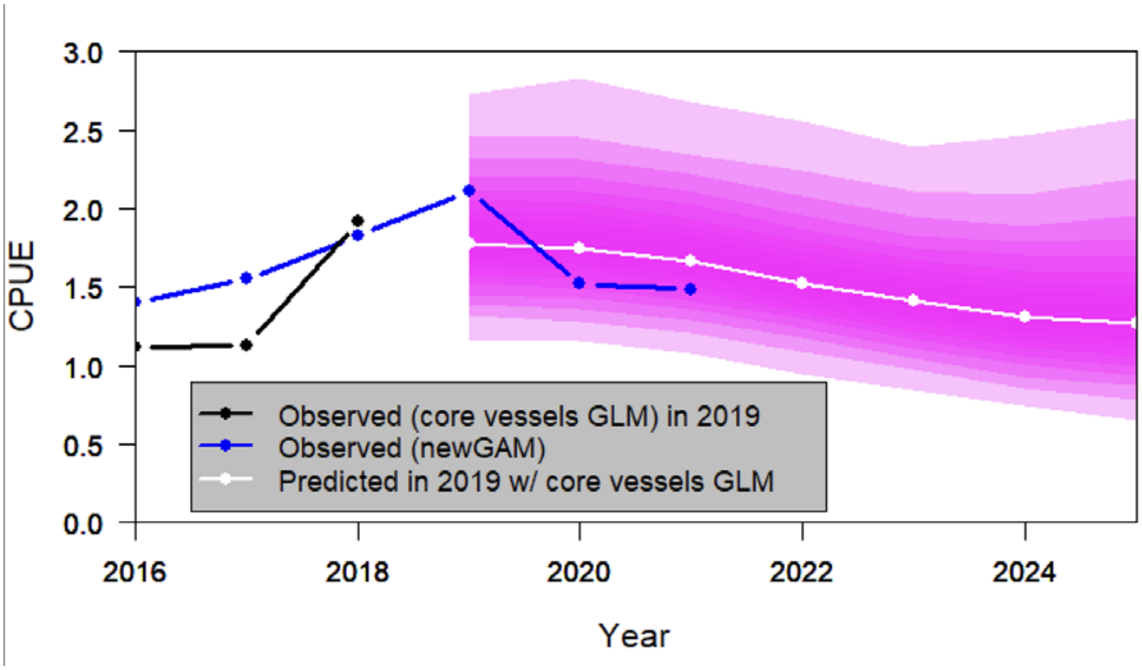

Figure 4. Comparison of the new GAM CPUE series with the 95% probability intervals of the CPUE values projected in 2019 (using base2018) when the Cape Town Procedure was adopted.

50. The 80% uncertainty envelopes of biomass projections conducted with the updated OM (using base2021) overlap substantially with those calculated in 2019 when the CTP was adopted (Figure 3).

51. Finally, these new projections indicate that there is a 0.87 probability that TRO in 2035 exceeds 0.20 the initial TRO_0, thus fully meeting the original rebuilding performance criterion established by the Extended Commission in 2011 (Pr(TRO/TRO0>0.20)=0.70 by 2035).

52. In addition, the existence of exceptional circumstances in terms of UAM were evaluated based on the results presented in paper CCSBT-OMMP/2206/10 described in paragraphs 24-30. The findings in that paper were that the estimates of unreported longline effort by CCSBT non-cooperating non-Member states were generally consistent with previous estimates, although some increase was estimated for 2020 (see Table 2 above). The group considered that that increase was not sufficiently large to trigger exceptional circumstances based on UAM.

4.2. Advice to ESC

53. Based on the results summarised under Agenda item 4.1 the group agreed that

- there is no need to retune the CTP;
- the recommended TAC for 2024-2026 can be based on the application of the CTP as it was adopted, using the new GAM-based CPUE series as input.

54. The resulting TAC for 2024-2026 is shown in Figure 5, together with the TAC for 2021-2023 (red vertical lines), compared to the corresponding distributions of projected TACs calculated during the 2019 simulation testing of the CTP (blue histograms). These comparisons indicate that the TAC values are consistent with projections made when the CTP was adopted. The group noted that the values in the figure are the outputs from the CTP application and do not include subsequent adjustments made by the Extended Commission when the actual TAC is set (e.g., for carryover reasons).

55. As explained earlier, TAC decisions already made constrain the range of future possible TACs. For example, in Figure 2 the fact that the MP TAC recommendation was 17,647 in 2020, constrains the upper and lower levels of possible TACs in 2024-2026 to 17,647 +/- 3,000. In turn, the outcome of the decision for future TACs will constrain the future projections.

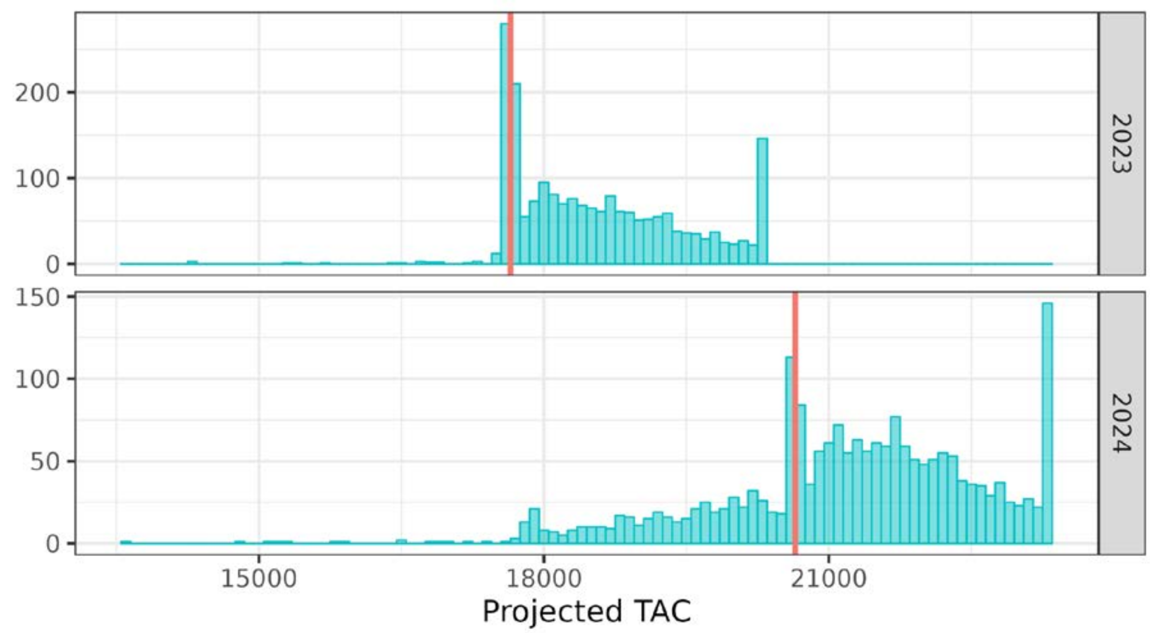

Figure 5. Values of TACs for 2021-2023 (top) and 2024-2026 (bottom) as calculated by the Cape Town Procedure (CTP; red lines) compared to the distributions of TACs projected in 2019 when the CTP was adopted.

Agenda Item 5. OM code re-writing/reformulation

56. The OM that has been used for SBT stock assessments and testing of candidate management procedures was developed more than 20 years ago using AD Model Builder (ADMB). Over this time, the SBT model has increased in components and complexity as new data types, uncertainties and modelling challenges arose. Creating a new SBT model within a new

software platform would improve assessment and MP-testing capability in a number of ways. First, the current ADMB model lacks an overarching design, which would be helpful for addressing contemporary challenges related to old and new data and uncertainties. Second, based on experience with other fisheries, alternative platforms such as Template Model Builder (TMB) and *Stan* provide faster, more stable estimation performance in both maximum likelihood and Bayesian estimation contexts, which allows for development of more robust models that can be simulation-tested for reliability. Third, future considerations for SBT such as sex, fleet, spatial, and temporal structure, as well as possible roles of climate change could be more easily implemented in TMB and *Stan* platforms, if necessary. Finally, although there are costs to transitioning the SBT model from ADMB to an alternative, such costs are justified based on the anticipated decades of useful life of a new model, as well as efficiency savings in being able to perform triennial assessments faster and more reliably.

57. ADMB is supported by NOAA at the University of Hawaii. However, the level of support is likely to be reduced in the next few years. Consequently, the group noted that other software platforms have a much larger community and are likely to persist. Additionally, these platforms have a number of other advantages including better diagnostic checks and speed advantages for evaluating model uncertainties in a Bayesian context (important for OM and assessment models).

58. The group considered three different aspects related to the code rewriting and model reformulation: the choice of a software platform, the characteristics of the model itself, and the process that would be implemented to advance this work.

59. In terms of software, three alternatives were discussed: ADMB (the platform currently used platform), TMB, and *Stan*. While ADMB has the advantage of being more transparent and familiar to SBT modelers, TMB and *Stan* are more efficient for dealing with complexities related to random effects and evaluating Bayesian posterior distributions. The group noted that the initial OMs developed for MP testing by the OMMP technical group used a combination of a discrete grids with MCMC conducted within each grid cell. This approach was abandoned mainly due to issues with MCMC convergence. While a model reformulation together with the much more informative datasets available now might improve MCMC performance within ADMB, the group agreed that moving to TMB or *Stan* would offer many advantages in terms of adding flexibility and improved diagnostics.

60. There are pros and cons to using either Stan or TMB. Comparison of the features available in the software platforms Stan and TMB include:

Feature	**ADMB**	**Stan**	**TMB**
Higher priority wrt SBT			
Penalised maximum likelihood optimisation routine	Yes	Yes	Yes
Documentation/help	Poor	Excellent	Good
Developer/community support	Poor	Excellent	Good
NUTS/HMC MCMC	Yes	Yes	Yes
Parameter bounds dealt with well	Ok	Excellent	Ok
Ability to sample from prior (rather than posterior) for some parameters within MCMC	No	No	Yes
Leave one out information criterion (LOO IC) support	No	Yes	Yes

Other desirable features			
Variational inference	No	Yes	No
Laplace approximation	Yes	No	Yes
Sparse matrix algebra	No	Yes	Yes

61. In the group discussions it was clear that, whatever the software framework chosen, there was agreement that the philosophy behind the existing grid approach should be preserved. The grid provided a tractable way to integrate across uncertainty in parameters (e.g., steepness) or processes (e.g. CPUE indices) to avoid spurious data trends informing key parameters, or over-interpreting how certain overall estimates of key variables may be. Currently, there are several statistical ways to deal with this issue (e.g., Bayesian model averaging) so that whatever the selected software framework, the development process will ensure that the underlying idea behind the grid approach flows through to the eventual replacement.

62. The group pointed out that, while the estimation of a full posterior by MCMC would be a main goal, it was important to retain the capability to use an efficient and fast optimisation routine to obtain point estimates for models to facilitate model development and sensitivity analyses.

63. In terms of the model, the group agreed that the model structure and code should be kept SBT-specific instead of applying a more general modelling platform (e.g., CASAL).

64. The possibility of incorporating spatial and/or sex structure was discussed. The general consensus was that given limitations in the data available to inform a more complex model, it would be preferable to maintain the current model structure in terms of the fleets considered and the lack of explicit spatial structure and sex structure. This is a decision that was made in terms of OMs to be used for stock assessment and CMP evaluation. The group emphasised the value of developing a spatially-explicit model that could be used to evaluate scenarios in a more strategic sense.

65. Some desirable model modifications were proposed by participants and discussed in very general terms. These are listed below, but they should be interpreted as an initial set of ideas to be expanded or refined as necessary.

66. There was agreement that bycatch fleets could be treated more effectively as fish removals instead of modelling their variable selectivity as is done in the current model. The rationale for this suggested change was that there is no information in the limited size composition data from these fleets, which nevertheless fit poorly even though highly flexible selectivities are allowed at the expense of many model parameters. An alternative treatment for these fisheries could involve cohort-slicing and removals of fish by age similar to what is done in a virtual population analysis (VPA) model.

67. Alternatives for modelling time-varying selectivities for fisheries LL1 and LL5 (Indonesian LL fishery) would be desirable to avoid problems that became apparent with the non-parametric approach during MCMC evaluations of the posterior distribution for the model fit.

68. There is a series of tag mortality parameters that are estimated separately from the population mortality parameters to account for the tags that are recovered the same year of tagging when

complete mixing cannot be assumed. These parameters could be eliminated and the tags could be removed directly instead.

69. The advantages of modelling the joint age-size dynamics (instead of modelling the dynamics of cohorts and using pre-specified size-at-age distributions as done in the current model) was discussed. This would allow for an improved treatment of CKMR-related processes and size-based mortalities (i.e., selectivity could be age or size based). Growth parameters would still be fixed externally rather than being estimated internally by the model.

70. In terms of process, in the past CCSBT hired a consultant to develop the code following model specifications developed as part of the OMMP technical group process. The advantage of having one person writing the code initially would be to improve internal consistency of the code and its documentation, which in turn should improve transparency. The group noted the need to have a product that all SBT modelers could follow and modify in the future.

71. The group suggested that some of the simpler model modifications (such as those suggested in paragraphs 70 and 72) might be better introduced into the current ADMB code to help with bridging between the old and new approach/software. The proposal is that the two models would be run in parallel for some period to assure consistency of results.

Agenda item 6. Other issues

6.1 Development of the new Scientific Research Program (SRP)

72. As agreed at ESC 26, Sean Cox (Scientific Advisory Panel) convened a 1.5-hour meeting on the Strategic Research Program (SRP) background document that aims to provide relevant information about the SRP process for assessing and prioritising research areas, identifying potential new research, and ranking research proposals.

73. The group revised, updated, and prioritised the Research Priority areas related to (1) Characterisation of Catch, (2) Abundance indices, (3) Biological Parameters, (4) MP Implementation, and (5) Stock Assessment and OM development.

74. The group agreed that a second meeting of the SRP Working Group will be scheduled in the coming weeks in time for developing specific research proposals for ESC 27 (using Attachment 8 from the ESC 26 report).

6.2 Discussion of Indonesian Length and Age data, and the Benoa catch monitoring program

75. Jessica Farley presented OMMP12_BGD01 paper on behalf of CSIRO and Indonesia authors. The paper provides a preliminary review of the SBT size data collected in Indonesia and the effect of the dataset choice on estimates of the age distribution of the spawning population. To monitor changes in the SBT spawning population, it is important to obtain length data from a random sample of the Indonesian longline catch in Statistical Area 1 only. Until recently, the primary source of size data for SBT caught by Indonesia was from the catch monitoring program in Benoa. Recent investigations, however, suggest that a proportion of the fish monitored are likely to have been caught south of the SBT spawning ground. To improve the SBT length frequency data analysed, the DGCF provided SBT length and weight data from the CDS for SBT caught in Statistical Area 1 for the last five spawning seasons. The size data from the two sources analysed (catch monitoring and CDS)

provide different age composition results for the five years compared. There could be several explanations for these differences and further work is needed to examine the uncertainties identified and to refine and improve the quality control of the data.

76. The group recommended this work be considered as an immediate priority under the Scientific Research Plan.

77. Fayakun Satria acknowledged the long timeseries of data and cooperative research described in this joint paper and indicated that Indonesia would like the collaboration to continue. The Indonesian Ministry of Marine Affairs and Fisheries is currently undergoing a large transition to the new BRIN National Institute for Research and Innovation.

78. The group noted that resolving the uncertainty in location of catches and consistency of sampling from the monitoring program have been priorities for a number of years, as they are important inputs to both the conditioning of the OMs and close-kin mark recapture data used for the MP. The following items were identified as requiring further investigation:
    1. Previous reviews determined that there was no bias in length frequency of fish classified as 'reject' and 'export quality' fish, with the reject quality fish being sampled for biological samples in Benoa. It has been some time since the original study, and this should be revisited as the length frequency for fish from which otoliths are collected is slightly smaller than the LF for all fish in the landed sample monitoring program.
    2. The length-weight data from the CDS has been 'trimmed' to remove outliers, and alternative statistical methods should be considered to remove outliers.
    3. Length measurements in the CDS data needs to be improved. There appears to be aggregation into 5 cm bins.
    4. Length frequency from the CDS and catch monitoring do not match, and it is not clear which data set should be used for age-length keys.
    5. Location of catches (whether on or off the spawning ground) still needs further investigation.

79. The group agreed that addressing these issues is a high priority and that it would be advantageous to have the review of the data collection program coincide with the Indonesian institutional restructure. Refining and consolidating the standard operating procedures for this monitoring program is important.

6.3 OMMP Workplan

80. The group noted that the workplan from the past ESC will be updated at the 2022 ESC with consideration of details highlighted in this report. In particular, leading up to the ESC, the group anticipates:
    - Finalising the draft CPUE standardisation method (**Attachment 4**) for inclusion in the MP specification document (replacing that of the core vessel GLM W0.8 / W0.5).
    - Preparation of a proposal for OM and assessment model software development
    - That the consultant discusses separately with Korea, Taiwan, and New Zealand the possibility of including their longline data in the CPUE series standardisation
    - The SRP will meet prior to ESC 27 to develop proposals that relate to important OMMP activities.

Agenda item 7. Close of meeting and adoption of Meeting Report

81. The report was adopted.

82. The meeting closed at 15:45 pm in Canberra time on 24 June 2022.

List of Attachments

Attachments

1 List of Participants

2 Agenda

3 List of Documents

4 Draft CPUE Specification

5 Updated fits of data within the OM (reference set: base2021)

Attachment 1

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Attachment 2

Agenda
Twelfth Operating Model and Management Procedure Technical Meeting

Attachment 3

List of Documents

1. Provisional Agenda
2. List of Participants
3. List of Documents
4. (CCSBT) Validating CPUE model improvements for the primary index of Southern Bluefin Tuna abundance (OMMP Agenda Item 1)
5. (Australia) Update of SBT OM given revised CPUE and MP implications (OMMP Agenda Item 2)
6. (Japan) Change in operation pattern of Japanese southern bluefin tuna longliners in the 2021 fishing season (OMMP Agenda Item 1 and 2.3)
7. (Japan) Update work of the core vessel data and CPUE for southern bluefin tuna in 2022 (OMMP Agenda Item 1 and 2.3)
8. (Japan) Development of the new CPUE abundance index using GAM for southern bluefin tuna in CCSBT (OMMP Agenda Item 1 and 2.3)
9. (Korea) Data Exploration and CPUE Standardization for the Korean Southern Bluefin Tuna Longline Fishery (1996-2021) (OMMP Agenda Item 2.3)
10. (New Zealand and CCSBT) Estimates of unreported longline effort by CCSBT non-cooperating non-Member states between 2007 and 2020 (OMMP Agenda Item 4)

(CCSBT-OMMP/2206/BGD)

1. (CCSBT) Review of data to estimate the length and age distribution of SBT in the Indonesian longline catch (OMMP Agenda Item 2.4) (Previously CCSBT-ESC/2108/07)

(CCSBT-OMMP/2206/Rep)

1. Report of the Twenty Eighth Annual Meeting of the Commission (October 2021)
2. Report of the Twenty Sixth Meeting of the Scientific Committee (August 2021)
3. Report of the Twenty Seventh Annual Meeting of the Commission (October 2020)
4. Report of the Twenty Fifth Meeting of the Scientific Committee (August/September 2020)
5. Report of the Eleventh Operating Model and Management Procedure Technical Meeting (June 2020)
6. Report of the Twenty Sixth Annual Meeting of the Commission (October 2019)
7. Report of the Twenty Fourth Meeting of the Scientific Committee (September 2019)
8. Report of the Tenth Operating Model and Management Procedure Technical Meeting (June 2019)
9. Report of the Twenty Third Meeting of the Scientific Committee (September 2018)
10. Report of the Ninth Operating Model and Management Procedure Technical Meeting (June 2018)
11. Report of the Fifth Meeting of the Strategy and Fisheries Management Working Group (March 2018)

Attachment 4

Specification of the GAM model for OMMP and assessment

Dataset used

The dataset was extracted from logbook data for the Japanese longline fishery, which include the period from 1969 to the latest year (currently 2021). Following procedures for the conventional CPUE abundance index, records in Statistical Areas between 4 and 9 and from April to September were selected. From the logbooks, year, month, latitude (in 1 degree), longitude (in 1 degree), vessel ID (available from 1979), number of hooks used, number of fish caught of southern bluefin tuna (SBT), bigeye tuna (*T. obesus*, BET), yellowfin tuna (*T. albacares*, YFT), albacore (*T. alalunga*, ALB) and swordfish (*Xiphias gladius*, SWO) data were used. At the stage of trial and error examination, the number of hooks between floats (HBF; available since 1975) and other fish species (several species of marlins, and butterfly kingfish (*Gasterochisma melampus*; available since 1994)) were also included.

From the size data in the CCSBT database, the age composition of Japanese commercial catch was calculated and converted into the number of fish caught over four years old (age-4 plus). The age composition information was first applied to the fork length composition of 50 or more individuals measured in the same month, 5 degrees longitude, and 5 degrees latitude. At this stage, 97% of the number of SBT caught was incorporated, and the ratio of age-4 plus was calculated. If the conditions for 50 or more individuals were not met, the time and space were gradually expanded to correspond to fork length composition, such as the same month - longitude 15 degrees - latitude 5 degrees, the same moon phase - longitude 15 degrees - latitude 15 degrees, the same quarter - longitude 15 degrees - latitude 5 degrees, the same quarter - Statistical Area, the same year - Statistical Area, and the same year. The fork length was converted to age by the age-length relationship used by CCSBT.

The following records were deleted: hooks 500 or less, hooks 4500 or more, and CPUE 200 or higher. As a result of subsequent examination, with the agreement of the CPUE working group, the records of 50S (50S to 54S), which had a small number of data, were also deleted.

Cluster analysis

A cluster analysis was performed to consider the target species of the fishing operations. The clust_PCA_run function of the R package cpue.rfmo was used. Cluster analysis was performed using the number of fish caught for five species, SBT, BET, YFT, ALB and SWO as data.

Standardisation by GAM

Standardisation by the generalised additive model (GAM) was carried out by use of the delta log normal approach. The mgcv package of R was used. The bum function, which is suitable for large volumes of data, was used. Based on the results of the study by the consultant, a binomial submodel (hereinafter referred to as BSM) and a positive catch submodel (hereinafter referred to as PCSM) were used, and gamma = 2, binomial distribution and gauss distribution are used respectively (Hoyle 2022). For the smoother, s (spline) was used for the offset term (hook logarithmic value), and ti (tenor product suitable when there was an interaction with the main effect) was used for the others. cs (cubic regression spline with shrinkage) was used for the basis function (bs) of ti. Gamma is a coefficient multiplied by EDF (described later) and promotes smoothing with values set to 1> (= 1.5 is common).

Binomial submodel:

cpue > 0 ~ yf +ti(month) + ti(lon) + ti(lat) +
ti(lon, lat) + ti(month, lat) + ti(lon, month) + ti(year, lat) + ti(year, lon) + ti(year, month) + cl + s(log(hook))

Positive catch submodel:

log(cpue) ~ yf +ti(month) + ti(lon) + ti(lat) +
ti(lon, lat) + ti(month, lat) + ti(lon, month) + ti(year, lat) + ti(year, lon) + ti(year, month) + ti(lat, month, year) + ti(lat, lon, month) + ti(lat, lon, year) + ti(year, lon, month) + cl + s(log(hook))

where, “yf” and “cl” indicate year and cluster factors and all other covariates are provided in number (centered on latitude or longitudinal bounds.

The R code used is as follows:

Binomial submodel:

```
modA2 <- cpue > 0 ~ yf +
        ti(month,         k=kA.month11,bs="cs")+
        ti(lon,           k=kA.lon11,bs="cs")+
        ti(lat,           k=kA.lat11,bs="cs")+
        ti(lon,  lat,     k=c(kA.lon21,  kA.lat21), bs="cs")+
        ti(month, lat,    k=c(kA.month22,kA.lat22), bs="cs")+
        ti(lon, month,    k=c(kA.lon23,  kA.month23), bs="cs")+
        ti(year, lat,     k=c(kA.year24, kA.lat24), bs="cs")+
        ti(year, lon,     k=c(kA.year25, kA.lon25), bs="cs")+
        ti(year, month, k=c(kA.year26, kA.month26), bs="cs")+
        cl        +       s(log(hook))
mgcv::bam(modA2, data =data, gamma = 2, method = 'fREML', family = binomial, discrete=F)
```

Positive catch submodel

```
modB3 <- log(cpue) ~ yf +
        ti(month,               k=kB.month11,bs="cs")+
        ti(lon,                 k=kB.lon11,bs="cs")+
        ti(lat,                 k=kB.lat11,bs="cs")+
        ti(lon,  lat,           k=c(kB.lon21,  kB.lat21), bs="cs")+
        ti(month,lat,           k=c(kB.month22,kB.lat22), bs="cs")+
        ti(lon,  month,         k=c(kB.lon23,  kB.month23), bs="cs")+
        ti(year, lat,           k=c(kB.year24, kB.lat24), bs="cs")+
        ti(year, lon,           k=c(kB.year25, kB.lon25), bs="cs")+
        ti(year, month,         k=c(kB.year26, kB.month26), bs="cs")+
        ti(lat,  month,year,    k=c(kB.lat31, kB.month31,kB.year31), bs="cs")+
        ti(lat,  lon, month,    k=c(kB.lat32, kB.lon32, kB.month32), bs="cs")+
        ti(lat,  lon, year,     k=c(kB.lat33, kB.lon33, kB.year33), bs="cs")+
        ti(year, lon, month,    k=c(kB.year34, kB.lon34, kB.month34), bs="cs")
            +  cl + s(log(hook))
mgcv::bam(modB3, data = data.positive, gamma = 2, method ="fREML", discrete=F)
```

The larger the k value (basis dimension for smoothing flexibility) of the interaction, the better, but the longer the calculation time. The effective degrees of freedom for a model term (EDF) value is calculated by the k.check function in mgcv package, and when EDF was close to k' (the maximum possible EDF for the term), “and” the p-value of k-index was < 0.05, a larger k value was set. The k values were determined by trial and error. Since the k value of the interaction is treated as the value of 2 multiplications (3 multiplications for 3 interactions), it is not necessary to set them separately. k was set separately, however, for the purpose of organising the work, and the k value for each variable in the interaction was set to the same value (i.e. k for year = 20 is used for all interaction terms which include year).

The software R (R4.0.5) was used to make the dataset. Microsoft R Open 4.0.2 was used to calculate GAM.

Calculation of abundance index

After creating data with all combinations of year / month / latitude / longitude (using R's expand.grid function), we made a dummy data set limited to the month / latitude / longitude where the fishing was operated in the past. The predicted value was calculated for each submodel for the dummy data set, and the product was calculated. Since the expected value is biased when the logarithmic normal distribution is restored, the predicted value was corrected by adding mean squared error (MSE) / 2 in the case of the positive catch submodel.

Furthermore, the area weighting coefficient was calculated in consideration of the fact that the distance of 1 degree of longitude differs depending on the latitude and the number of 1 degree squares that SBT have been caught in the past within the 5 degree x 5 degree squares. The abundance index can be calculated by the following formula.

Σ(predicted value of binomial submodel of dummy data set × predicted value of positive catch submodel of dummy data set * Area weighting coefficient) / Overall average value.

Attachment 5

Updated data fits for base2021 from paper CCSBT-OMMP/2206/05

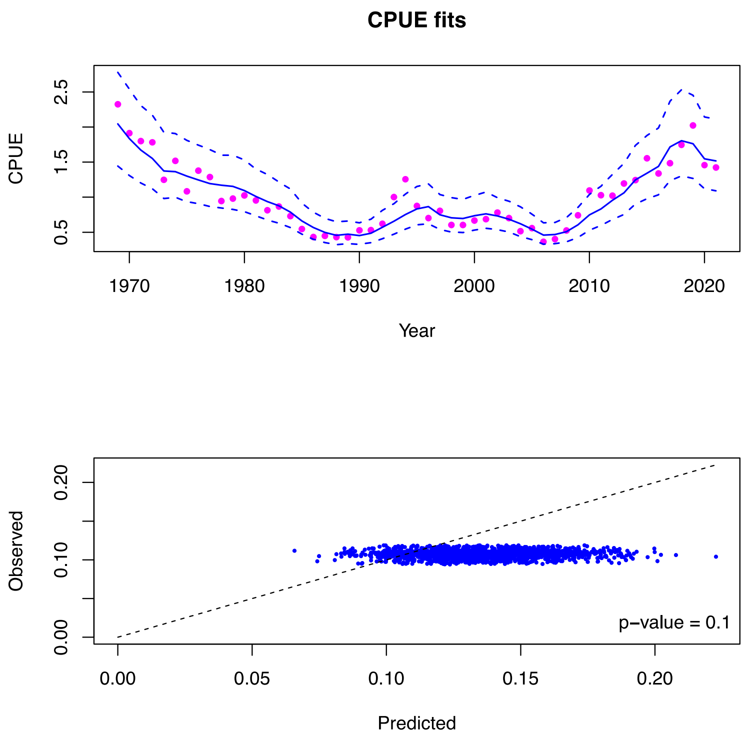

Figure A5-1: Predictive summary for the new CPUE series used in reference set of OMs. The upper panel shows the fits to the data (magenta); the lower panel the overall predictive p-value for the series.

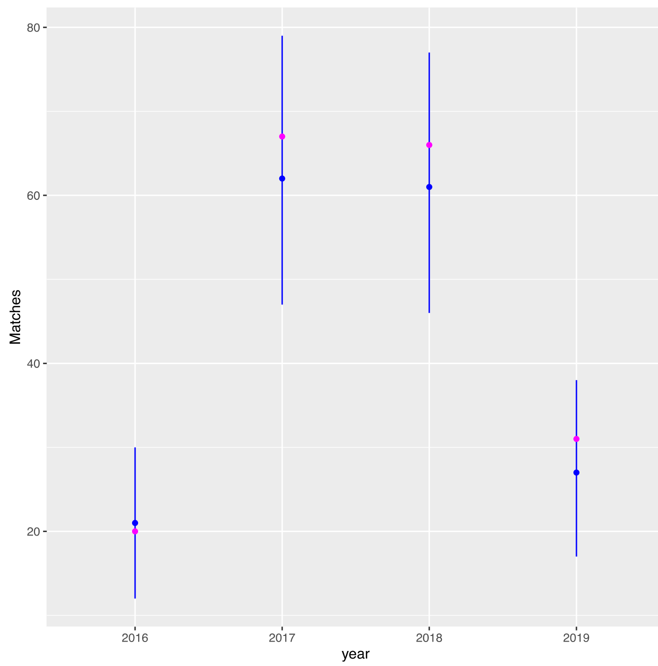

Figure A5-2: Predictive summary for the gene tagging data (magenta) included in the reference set of OMs. We plot only the predictive fits to the data as the series is currently too short to calculate a meaningful predictive p-value.

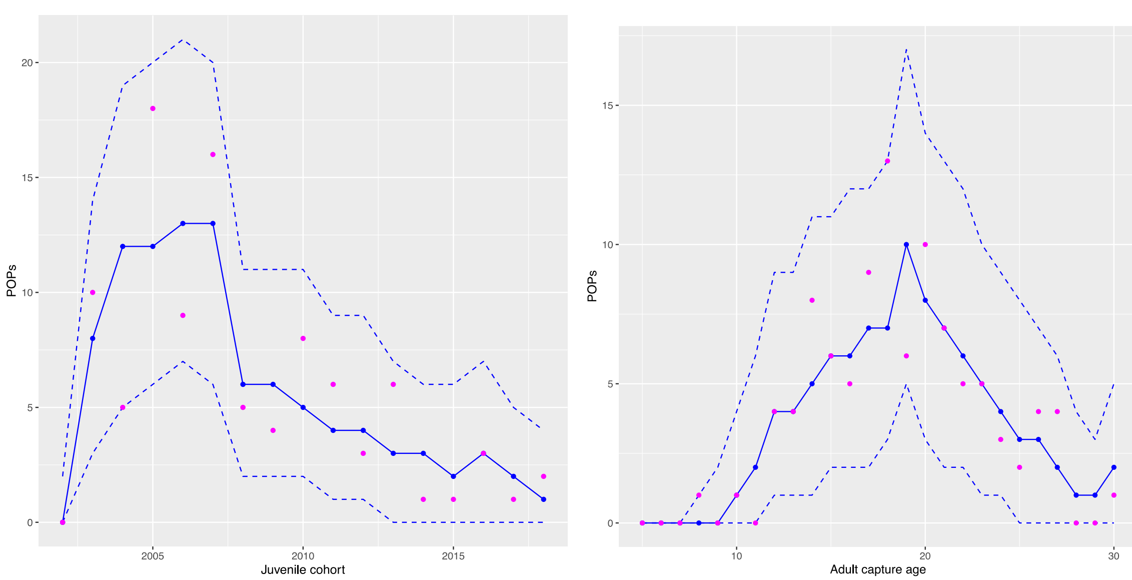

Figure A5-3: Predictive fits to the POP data (magenta) for the juvenile cohort aggregation level (top left), adult capture age level (top right),

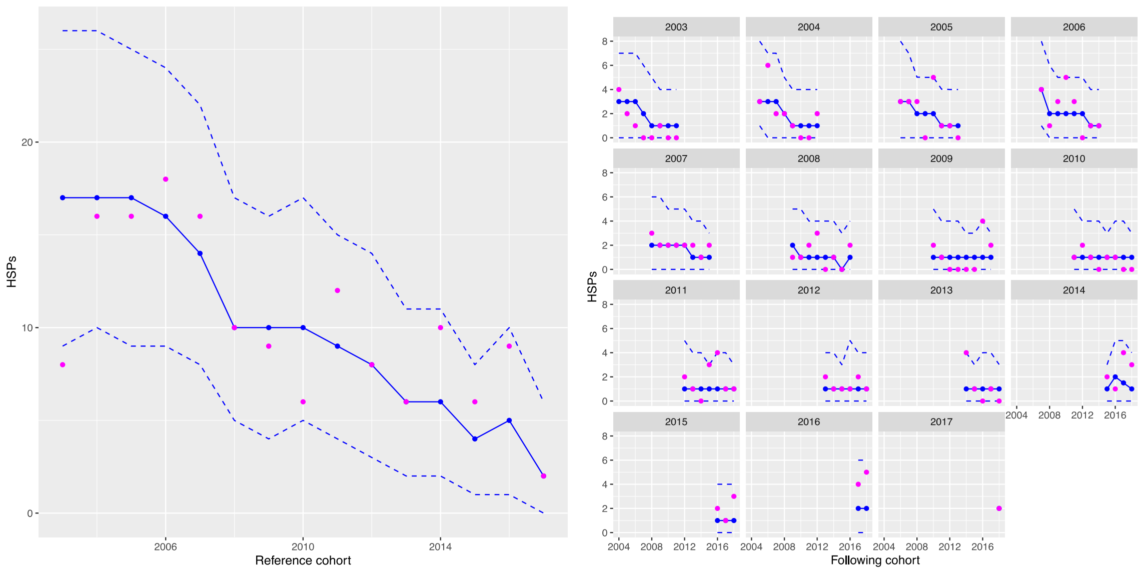

Figure A5-4: Predictive fits to the HSP data (magenta) for the initial cohort aggregation level (left), and the full disaggregation level (right).

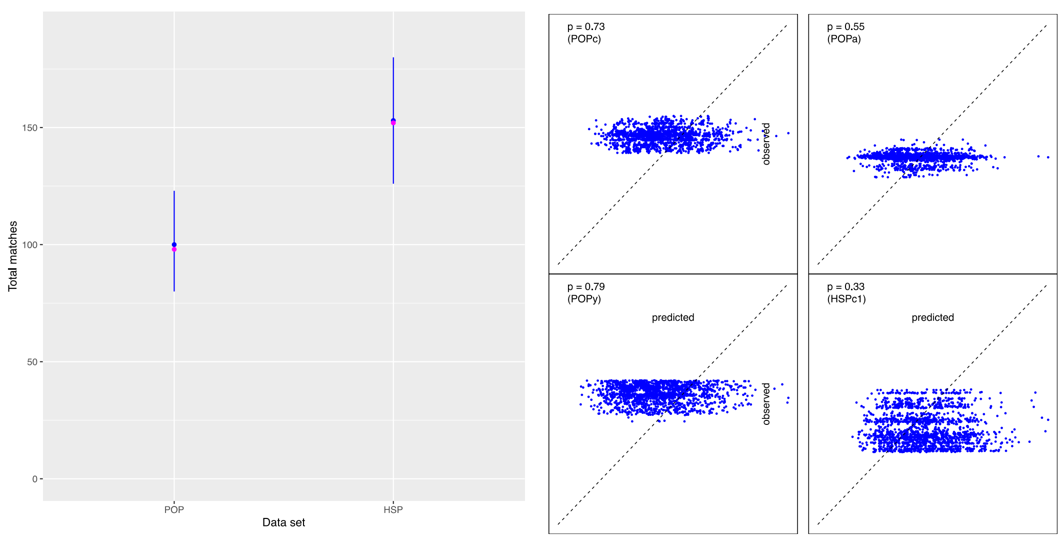

Figure A5-5: Left hand panel - Estimated and observed matches for POP (left) and HSP (right) for CKMR data. Right-hand panel - *Predictive p-value summary for the CKMR data: POPs at initial cohort level (top left); POPs at adult capture age level (top right);* POPs at the adult capture year level (bottom left) *HSPs at initial cohort level (bottom right).*

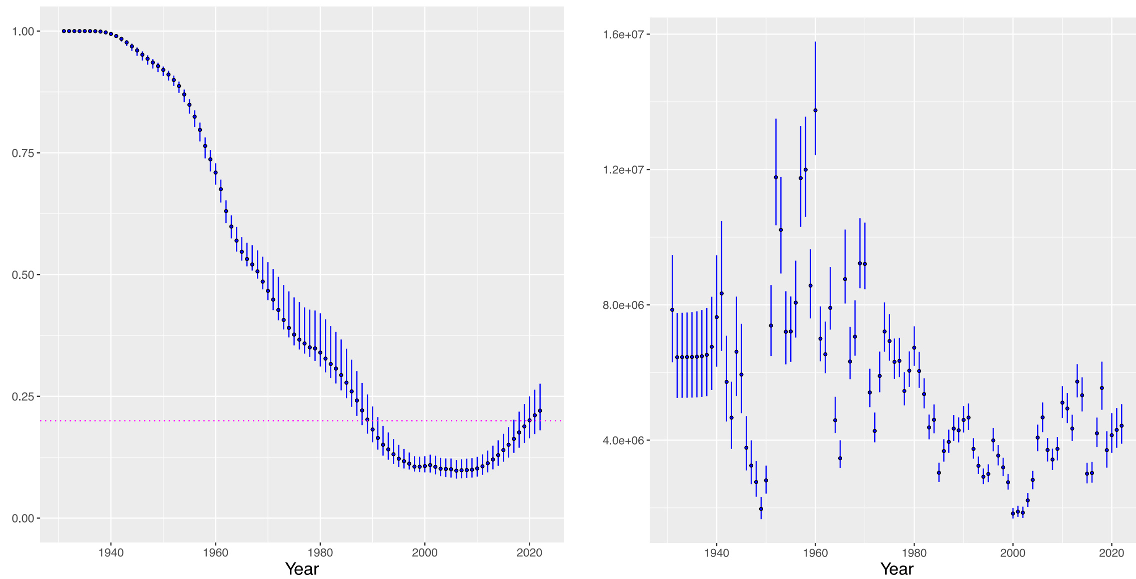

Figure A5-6: Relative TRO (left) and recruitment (right) summaries – median and 80% CI – for the base21 reference set of OMs.