Commission for the Conservation of
Southern Bluefin Tuna

みなみまぐろ保存委員会

Report of the Eleventh Operating Model and Management Procedure Technical Meeting

15 – 19, 22 and 24 June 2020

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Opening

1. The Chair of the Eleventh Operating Model and Management Procedure Technical Meeting (OMMP 11), Dr. Ana Parma, opened the web meeting and welcomed participants (**Attachment 1**). The Chair advised that the meeting this year is being held as a web meeting due to the COVID-19 pandemic and that the main tasks of the meeting are to prepare for this year's full stock assessment and running the Cape Town Management Procedure (MP).
2. The draft agenda was discussed and amended, and the adopted agenda is shown in **Attachment 2**.
3. The list of documents for the meeting is shown at **Attachment 3**.
4. Rapporteurs were chosen in advance of the meeting for preparing different parts of the report.

Agenda Item 1. Review of data inputs

1.1. Gene tagging

5. CSIRO presented paper CCSBT-OMMP/2006/05 on gene-tagging data for the MP and stock assessment. The third full cycle of the CCSBT gene-tagging program has been completed to provide an estimate of absolute abundance of the age 2-cohort in 2018. Over 8,000 fish were tagged in March 2018, and tissue samples were collected from over 11,500 fish during the surface fishery harvest in August 2019. DNA extraction, sequencing and estimation of abundance was completed in April 2020. The analysis identified 66 matches (recaptures) from 75.4 million comparisons. The estimate of abundance of age 2 fish in 2018 is 1.14 million fish with a coefficient of variation (CV) of 0.123. The 2018 abundance estimate is very similar to the 2017 estimate (1.15 million fish age 2, CV 0.122), and is close to half of the estimate of age 2 fish in 2016. The data from each year of the gene-tagging program will be used in the stock assessment in 2020 and in the Cape Town MP to recommend the TAC for 2021-2023.
6. CSIRO advised that seasonal fishing circumstances and the impact of COVID-19 meant that the release sampling for 2020 had been poor (a very low number of releases), so that there would not be an estimate for the 2020 2-year-old cohort to report in 2022. Nevertheless, at this stage, it is expected that the 2020 harvest sample for the 2019 releases will proceed as planned with the estimate for the 2019 2-year-old cohort reported to next year's ESC.
7. The group drew attention to the low CVs (circa 0.12) associated with the estimates for the 2017 and 2018 cohorts and asked if there is any reason to suspect these CVs are underestimated. CSIRO responded that a number of potential sources of bias had

been explored in the design study for the gene tagging program (CCSBT-ESC/1509/18), and that the CVs were consistent with expectation from this design and simulation work. CSIRO also advised that a number of checks had been completed recently. This included an investigation of the length bins used to distinguish 2 and 3-year-olds (using vertebrae counts as well as otolith readings) – see the earlier reports to ESC24 (CCSBT-ESC/1909/10 &11). There are no indications of any problems with the methods or analyses. It was noted that, at present, the time series is too short to estimate directly the degree of over-dispersion associated with the estimates, but this should be possible in the future.

8. The group asked whether the recent lower recruitment estimates from the gene-tagging program are an indication of poor recruitment. It was noted that while the two most recent estimates (2017 and 2018) are below the recent levels of recruitment estimated from the reference set, they are well above the historically low recruitments observed in the early 2000s. The group considered it would be useful to make a direct comparison of the absolute estimates with the OMs for the particular year classes and recent average recruitment. This was conducted during the meeting and is reported under item 2 (paragraph 46).

1.2. Close-kin: POPs and half-sibling indices

9. Australia presented papers CCSBT-OMMP/2006/06 and CCSBT-OMMP/2006/14 on CKMR POPs and half-sibling-pairs (HSPs) data for the MP and stock assessment. In 2019 there were around 101 million comparisons and 82 detected POPs; in the 2020 data this has increased to around 112 million comparisons with 89 detected POPs. The "hit-rate" (ratio of detected POPs to comparisons) decreased by 2.2% from 0.812 per million in 2019 to 0.795 per million in 2020 - this is qualitatively commensurate with a slightly more optimistic view of total reproductive output, especially in the most recent years. The adult age distribution in the POPs is essentially the same as 2019, with a clear peak in the POP adult ages at around age 16, very few adult POPs less than 8 and none above 26. In the case of HSPs, in 2019 about 78 million comparisons resulted in 145 cross-cohort HSPs (note within cohort HSPs are not used in the estimation process); for 2020, about 88 million comparisons yielded 155 HSPs, which is about a 4% increase from 2019. As noted in previous meetings, as total sample sizes increase, there is greater potential for overlap between true HSPs and unrelated (or weakly-related) pairs. In order to keep the risk of false positives very low, it proved necessary to increase the lower cut-off on the statistic used for determining HSPs. This resulted in fewer HSPs, and a higher false negative rate, than for 2019. In future, the aim is to make use of a genome assembly for SBT to improve the separation and "reclaim" some of the HSPs currently being excluded. In the meantime, however, the number of HSPs is sufficiently large to provide reliable estimates for the MP and stock assessment purposes.

10. It was noted that the use of these data in the MP and stock assessment would be discussed in more detail under subsequent agenda items; therefore, such discussion was held over for items 2 and 6.

1.3. CPUE

11. The Chair of the CPUE Working Group, Dr. Jim Ianelli, presented a brief summary of work conducted through four intersessional webinars. This work addressed problems identified in 2019 with the then-Base CPUE model, which produced a very high index value for 2018, identified as anomalous and requiring further examination. He acknowledged the work and support provided by Members and the Secretariat to make progress on this topic. This included updated analyses from Korea and extensive new analyses by Japan.

12. CPUE indices are used in both the CCSBT stock assessment and as an input to the Management Procedure (MP). After discussing the results of the robustness tests conducted in 2019 when testing candidate management procedures, the webinars concluded that, as in the past, the use of the standard average of the two weighted CPUE series (W0.8 and W0.5) would be used for the implementation of the MP at the Extended Scientific Committee (ESC) meeting. However, these standard series were not considered adequate for use in the stock assessment, given the extremely high CPUE values predicted for strata that had zero observations. Further analyses were conducted intersessionally in order to improve the CPUE standardisation.

13. The attention of the group was drawn to three documents that had been presented in the CPUE working group. CCSBT-OMMP/2006/10 reported changes in the pattern of operation of Japanese SBT longliners in the 2019 fishing season by comparing the most recent year to the past 10 years. The author reported that no remarkable change was found in the 2019 operational pattern in terms of catch amount, the number of vessels, time and area covered by operations, proportion by area, length frequency, and concentration of operations, and concluded that the CPUE for the 2019 Japanese longline fishery can be regarded as reflecting stock abundance to the same extent as in previous years. In terms of the increase in the catch landed in 2019, the increase in CPUE contributed the most, while the expansion of the time and space of operation and the number of operations contributed to a lesser extent.

14. CCSBT-OMMP/2006/11 was presented. This paper summarises the core vessel CPUE which is an abundance index for SBT used in the MP. It explains the data preparation, CPUE standardisation using GLM, and area weighting. The core vessel data were updated up to 2019. The index values in 2019, for W0.5 and W0.8 in terms of the base GLM model, are higher than the average over the past 10 years.

15. CCSBT-OMMP/2006/12 was presented. Attempts had been made to determine the cause of the anomalously large increase in the 2018 value of the abundance index for SBT calculated from the CPUE of the core vessels. It was found that the cause was an abnormal estimate of a year-area interaction term due to an imbalance in the amount of data by latitude in areas 8 and 9. This conclusion was confirmed by a slight manipulation of the dataset. The GLM model without the year-area interaction term and a GLMM with a year-area interaction term treated as a random effect eliminated the anomalously high value.

16. Korea presented paper CCSBT-OMMP/2006/13 on CPUE standardisation for the Korean SBT longline fisheries. The CPUE from Korean tuna longline fisheries (1996-2019) was standardised using Generalised Linear Models (GLMs) with set-by-set

data. The data used for these GLMs were catch (number), effort (number of hooks), number of hooks between floats (HBF), fishing location (5° cell), and vessel identifier by year, month, and area. Areas 8 and 9 were identified as those in which Korean vessels have targeted SBT. SBT CPUE was standardised for each of these areas using two alternative approaches: data selection and cluster analysis, to address concerns about changes in targeting through time. Explanatory variables for the GLM were year, month, vessel identifier, location, cluster (in some models), moon phase and number of hooks. GLM results for each area suggested that location, year, targeting and month 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. The group noted it would be useful to examine the Korean CPUE plotted in conjunction with the Japanese CPUE for areas 8 and 9 so that they can be compared more readily. Additionally, during the discussion of the high CPUE value in 2015, clarification was offered that the high CPUE likely relates to low effort and reduced fishing areas.

18. New Zealand presented paper CCSBT-OMMP/2006/15 which describes the exploratory analyses conducted for the Japanese longline CPUE index. This paper explored reasons for the high 2018 estimate and found that increasing effort concentration had produced increasingly sparse coverage in some areas within the catch and effort dataset. This led to unstable predictions from the 'Base' GLM model in strata without observed CPUE values. A diagnostic for the magnitude of this issue was developed based on the number of extreme values predicted by the model. Spatio-temporal smoothing in a generalised additive model (GAM) provided more stable predictions for areas with no, or sparse, data and fitted the data better as measured by the AIC. A model was recommended for the purposes of the OMMP (GAM11). Work to further develop the model and continue to explore alternative CPUE approaches in the future was recommended for discussion at the ESC as part of the Scientific Research Program (SRP).

19. The group noted that a new criterion of 15 year-month records per 5° cell used to identify cells to include in the index was based on records across the whole time series from 1986 to the present. This filtering process does not exclude many spatial cells but avoided including those with few observations. To this end, a direct comparison of the spatio-temporal coverage of the two data sets being used in the different analyses (core fleet and all vessels) would be worthwhile for future research. The group recommended that future work be undertaken to evaluate an objective criterion for CPUE model selection—including, in particular, approaches that need to be explored when anomalously-high predictions occur for certain cells that had no fishing operations.

20. It was noted that the nominal CPUE trend differs from the GAM11 trend in recent years. New Zealand agreed to investigate this and to revise Paper CCSBT-OMMP/2006/15 for the coming ESC meeting, which will provide an approach that will investigate the drivers of the different trends. During the meeting, it was possible to examine the progression of terms in GAM11 and the preliminary summary was that the trend change since 2015 is associated with fishing location, as there was a

large change when the smoother for latitude and longitude was introduced. The group recommended that this work be elaborated upon in order to clarify how the different factors affect the nominal CPUE trends in standardising the series.

21. A discussion of constant squares (CS) and variable squares (VS) in the context of the new GAM models ensued. Advice was given that the GAM spatial smoother models extrapolate into unfished areas akin to the CS approach and that when data are missing, uncertainty in those spatial predictions increases. The extent that uncertainty is appropriately reflected in the confidence intervals for the estimated CPUE series is unclear because of violations of the assumptions of independence amongst observations. It was noted that the preferred model, GAM11, could be used to construct either kind of index: constant squares, using the same 5° cells throughout the time series; or variable squares, using only the cells that have fishing activity in a particular year and assuming zero abundance elsewhere in that year.

22. It was agreed that the CS version of GAM11 was an improved index relative to the GLM Base-CS model. In terms of the VS hypothesis, however, the GAM interpolation would still result in an upward bias if the contraction in the area fished was in part a reflection of a contraction of area occupied by the stock. Hence, the VS version of GAM11 would still need to be included to address this concern.

23. The meeting agreed that the VS version of GAM11 was too extreme, given the increased contraction of the area fished in recent years, and that the previous standard weighting referred to as W0.5 (equal weights given to CS and VS) and W0.8 (0.8 CS + 0.2 VS) would need to be reconsidered. After a review of the GAM11 CS and VS indices provided by Japan, it was agreed that re-weightings of W0.6 (0.6 CS + 0.4 VS) and W0.9 (0.9 CS + 0.1 VS) would be used for the stock assessment for the ESC. It was also agreed that these two series would be sampled with equal weight for the reference set.

24. The meeting recommended that further CPUE analyses be given high priority among Member scientists. Specifically, further examination of spatio-temporal models that may improve upon the GAMs conducted for this meeting was encouraged.

1.4. Unaccounted sources of mortality

25. The issue of unaccounted catches by non-cooperating non-Members (NCNMs) was discussed in advance of OMMP11 during a webinar conducted on 9 June 2020. The main purpose of the webinar was to specify the scenario for unaccounted mortalities (UAM) to be used in the reference set of models for the stock assessment, and to propose alternative scenarios to be run as sensitivities.

26. The webinar noted that the reference set of Operating Models (OMs) used for MP testing in 2019 was based on the scenario called UAM1 (this scenario involved added UAM in conditioning: 1000 t of small fish + 1000 t of large fish, ramping up linearly from zero in 1990 to these levels in 2013; in addition to a 20% increase in the surface fishery from zero in 1992 to 20% in 1999). This corresponds to what has been called the “MP approach” for TAC setting. This approach involves adjusting the simulation models used in MP testing for plausible extra catches (i.e., UAM1) so that the

selected MP is robust to that level of potential UAM and hence the MP-derived TAC can be implemented as calculated.

27. For the purpose of stock assessment, on the other hand, the best available estimates of UAM need to be added to the reported historical catches for fitting the models. The values used in the stock assessment conducted in 2017 correspond to estimates of the catches by NCNMs provided in document CCSBT-ESC/1609/BGD02 for 2007-2014, based on the "targeted" method (applying Japanese LL catch rates to the NCNM effort to estimate potential catches). For 2015-2016, an average equal to 306 t was added to the LL1 catches. In addition, the catches from the surface fishery were increased by 20% (ramping up from 0 in 1992 to 20% in 1999).

28. Paper CCSBT-ESC/1909/33 presented by New Zealand at ESC24 revised and updated the previous analysis, resulting in catch estimates that were considerably higher than the estimates presented in 2016. A number of the requests for clarification and issues raised at ESC24 were resolved during that meeting, but it was agreed that two issues needed further analysis and documentation: (1) a quantitative evaluation of the relative impacts of the main data changes on the results, and (2) a revision of the method for estimating the average weight of individual fish to account for the different weights of discarded and retained individuals.

29. New Zealand tabled paper CCSBT-OMMP/2006/04 which addressed those issues. The paper was presented at the webinar. Results showed that changes to the code used in processing the IOTC effort data had the most substantial impact on the revised estimates, increasing the predicted average catch for the Indian/Atlantic Oceans by 70 to 500 tonnes, with the range bounded by whether bycatch (assuming Taiwanese catchability) or targeted catch rates (assuming Japanese catchability) were assumed for the NCNM effort. Estimates of catches increased by 500 - 900% due to this single change to the analysis alone, which was by far the most substantial effect detected. In the Pacific Ocean, changes were much smaller, with the most notable being an increase of around 20 - 70% (1 - 20 tonnes more) following from changes to the WCPFC effort data, and a decrease of 20% (around 20 tonnes less) as a result of changes to the Japanese CCSBT data extract. The effect of changing the average weight estimation for Japanese catches led to a small decrease in the predicted catch rates for targeted fishing, with no noticeable consequences for the prediction of NCNM catches.

30. It should also be noted that the analysis was substantially influenced and improved by the incorporation of much more complete effort data collected by the CCSBT Secretariat, rather than simply using publically-available data as had been the case in the past.

31. The group thanked New Zealand and Australia for their effort to update estimates of potential NCNM catch of SBT.

32. The webinar concluded that in order to maintain consistency with the approach used for the 2017 stock assessment, the best currently available estimates of UAM should be used in the Reference Set. Furthermore, the webinar decided to use the sum of the Indian/Atlantic Ocean and Pacific Ocean estimates for NCNM catches based on the GLM method and targeted (assuming Japanese) catch rates provided in Table 12 of

paper CCSBT-OMMP/2006/04 to provide the UAM LL1 catch in a similar fashion to the approach taken in 2017. The actual values of estimated UAM are provided in Table 1, where they are compared to values used in 2017. As before, a 20% overcatch was also added to the Australian surface fishery catches.

Table 1. Estimates of annual catches in tonnes by NCNMs of CCSBT, provided by the GLM method using the Japanese catchability targeted effort, from paper CCSBT-OMMP/2006/04.

Year	Value used for 2017 stock assessment	Value to be used for 2020 stock assessment
2007	81	244
2008	35	124
2009	224	418
2010	372	756
2011	246	333
2012	476	613
2013	293	668
2014	210	443
2015	306	950
2016		1173
2017		1402
2018		1402
2019		1402

33. Some concern was expressed that the reported effort by NCNMs could be underestimated which would result in an underestimate of UAM. Countering this potential bias, the use of the catch rates corresponding to a fleet that targets SBT (Japanese LL) to calculate SBT catches by NCNM fleets could lead to bias in the opposite direction. The group agreed to use these estimates for the current stock assessment, but expressed reservations about accepting them as definitive estimates that might be used in other contexts.

34. There are a number of issues in addition to the potential biases in both directions mentioned above. These include a) is it most appropriate to apply the targeted (Japanese) catch rate, the bycatch (Taiwanese) catch rate, or something in between; b) if indeed the estimated catches were made, were they retained or discarded (including potentially being released alive); c) if estimated catch is actually being discarded, is it of undersized fish or of adults; and d) would it be better to combine the catchability for all major fleets (Japan, Korea and Taiwan), rather than using the Japanese catchability alone? The difference in size composition between the Taiwanese and Japanese catches was also noted. In addition, Taiwan indicated that Taiwanese vessels have various fishing strategies for targeting SBT, albacore and oilfish, which differ from those used by other fleets; hence it would not be appropriate to apply Taiwanese catch rates to other fleets. The OMMP agreed that these issues should be designated as future research to be conducted next time the UAM analysis is updated.

35. The group also acknowledged these concerns by agreeing to include a sensitivity run using UAM estimated assuming Taiwanese catch rates (a bycatch fishery) for the purpose of bracketing the uncertainty. A sensitivity test with no NCNM UAM was also proposed to assess impact of these potential catches on rebuilding.

36. The webinar also agreed to use scenario UAM1 as a sensitivity run, for comparison with the projections used to tune the Cape Town MP in 2019.

Agenda Item 2. Review of model runs: diagnostics and likelihood weights

37. Due to delays in the processing of input data, particularly those associated with CPUE analyses, results of OM fits were available only a few days prior to the OMMP meeting, so there was no time to prepare meeting papers. The output from different model fits conducted prior and during the meeting were uploaded to the web and results were explored using the new Shiny application developed by the consultant, Dr. Darcy Webber.

38. Australia presented an overview of preliminary reconditioning of the OMs with the updated data and reported the following:

- Many runs conducted while fixing M_0 (natural mortality at age 0) to the lowest value specified in the grid used for MP testing in 2019 (M_0 = 0.35) had crashed. This was identified prior to the meeting and agreement had been reached among analysts and the Chair to revise the lower bound for M_0 to 0.4. With this revision the 2019 grid could be run without problems. All results presented in this report have this modification to the M_0 values in the grid.
- In the case of M_{10} there was a tendency for the highest value (M_{10} = 0.12) not to be sampled very often (Fig. 1). This is due to a tension in the fits between the conventional tagging data (2-4 year olds, late 1990s-early 2000s) and the parent offspring pair (POP) data (which observes those same cohorts as parents), both of which provide information on absolute abundance of the same cohorts at different ages. The tagging data have a preference for lower M_{10}, while the POP data have a preference for the mid to high levels of M_{10} (Fig. 2; and see paragraph 41 below).
- The close-kin mark-recapture (CKMR) POP and half-sibling pair (HSP) data were consistent with each other and indicated a small positive increase in TRO since the 2019 reconditioning, of the order of 2%.
- The fits to each of the other data series were generally good with no obvious evidence of mis-fits (e.g., Fig. 3, fit to the Aerial survey).
- The revised CPUE series (GAM11) has substantially reduced the estimated abundance of the 2013 cohort (Fig. 4). It is still well above average, but not as extreme as in Base2016 and Base2018.

39. The group noted the low level of variation between model fits to the GAM11-Constant-Squares CPUE series for Base19 and the same grid with a modified range for M_{10}. While it was acknowledged that these plots do not represent the full range of

uncertainty (they represent the range of maximum-likelihood point estimates across the respective grids and do not include within-cell uncertainty), this relatively low level of uncertainty arises because the SBT fishery is relatively data rich and, in particular, includes several independent data sources which provide absolute abundance information. As noted above, these include:

- the conventional tagging and CKMR POP data, which cover the same cohorts,
- the CKMR HSP data, which provides information on absolute abundance and the total mortality of parents, independent of the POP data, and
- the gene-tagging data, which provide absolute abundance estimates for 2-year-olds.

40. The comparison of TRO between Base18 and Base19, with the new GAM11 CPUE series, indicates a further reduction in the level of uncertainty and a slightly more positive stock status.

41. In considering the revisions to M_0 and M_{10} (rates of natural mortality at ages 0 and 10) and the impact of the incorporation of the CKMR data on the OMs, the group recalled the rationale for the relatively complex form of the mortality function, which includes a higher value of M for juveniles, as estimated from specifically designed tagging studies (Polacheck et al. 2002[1]; CCSBT_MPTM/0502/05; Attachment 6, Report of OMMP2), an intermediate level of M for sub-adults and adults and a higher senescence mortality for fish age 25 and older (Attachment 7, reports of OMMP2; OMMP4 and ESC18). It was suggested that, given the complex nature of the mortality function and the improvements in information over the past decade, it would be useful to undertake a more in-depth review. The group agreed that this would be worthwhile to consider as part of the development of the new SRP at the ESC. The group examined the impact of a) the incorporation of the new CPUE series based on model GAM11 using alternative weightings of the Constant Squares (CS) and Variable Squares (VS) hypotheses, referred to as W0.6 (0.6 CS, 0.4 VS) and W0.9 (0.9 CS, 0.1 VS), and b) the removal of the highest level of M_{10}, which was seldom sampled in the original Base19 grid (Figs. 5 and 6). The group noted that the tension between the preference for lower M_{10} for conventional tags and the preference for higher M_{10} based on the HSP remained. The group recalled that this issue had been identified in the previous full assessment (Report of OMMP8 and ESC22) when the HSP information was incorporated into the OMs for the first time. Two sensitivities were evaluated at ESC18 by alternatively removing the tagging or the CKMR data from the fits. Results of these sensitivities indicated that only when both sets of data were present did the tagging data favour the lower M_{10} values; when the CKMR data were removed, the higher M_{10} values were preferred.

42. Figure 7 illustrates the time-series of TRO for the different values of M_{10} estimated using the updated W6W9 grid based on the two new CPUE series (W0.6 and W0.9). The banding pattern that was evident in the likelihood profiles is also evident in the

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[1] Polacheck , T., J.P. Eveson, and G.M. Laslett. 2002. Estimation of mortality rates from tagging data for pelagic fisheries: analysis and experimental design. FRDC Final Report 2002/015.

SSB time-series, being strongest for the years following the commencement of the CPUE series (1969 through to the mid-late 1970's). This suggests that the banding may be the result of an interaction between the two CPUE series and the age range used to normalise selectivity (qAgeRange 4-18 vs 8-12; Fig. 6). The group agreed that more specific diagnostics are needed to understand the underlying cause clearly, and in particular whether it may be arising from some model misspecification.

43. CPUE indices for two intermediate cells are given as examples of the W0.6 and W0.9 fits in Figure 8. This illustrates differences in residual patterns between the two CPUE weighting series.

44. The group noted that the current runs do not account for within-cell uncertainty. In the recent past the focus of stock assessment and MP testing has been on incorporating the plausible range of structural uncertainty (between cells in the grid), as this was considered to be more important (i.e. to lead to results showing greater differences) than the within-cell uncertainty. The improvements in information content of the data with the addition of the CKMR, in particular, have seen the structural uncertainty reduced substantially over the past decade. The group considered that it would be timely to revisit within-cell uncertainty, if this can be implemented with reasonable run time, to provide for a more comprehensive representation of the uncertainty.

45. In a similar vein, the group also agreed that it would be valuable to have analyses of the predicted confidence intervals (e.g. CCSBT-ESC/1708/14) for the fitted data series for evaluation at the ESC, if possible.

46. Following discussion of the high precision associated with the estimates of 2-year-old abundance from the gene-tagging, the group reviewed a specific comparison of the direct estimates from gene-tagging with the maximum-likelihood estimates of the abundance of 2-year-olds for the W6W9 grid and the corresponding expected values predicted from the stock-recruitment function (Fig. 9). The group noted that the GT estimates have a strong influence on the OM estimates and that the confidence intervals of the OM and GT estimates overlap. The 2016 estimate is well above the recent average estimates from the OMs, while the two more recent estimates (2017-2018) are somewhat below the recent average level but about 50% higher than the lowest historical year classes estimated as age 2-year-olds in 2002-2004. It was noted that the last two estimates in the plot (2019-2020) are predictions based on the stock-recruitment relationship and that they are above the recent average. This reflects the autocorrelation in the recruitment deviates from the stock-recruitment function: as the most recent observations have been below average the expectation is that the coming year classes are likely to be above those recent values.

47. The group reviewed the fits to the other data series (length compositions, age data for the surface and Indonesian longline fisheries, conventional tags, POPs, HSPs and gene-tagging). The group agreed there was no evidence of systematic mis-fits or other issues that would motivate a change in the choice to the reference set.

48. The group examined the posterior sampling distributions obtained using objective function weights for steepness (*h*) rather than the uniform prior used in the base grid. The group noted that when the constant-squares version of GAM11 was used as the

single CPUE series the distributions showed a central mode for steepness and slightly more skewed distribution for M_{10} in the resampling distributions, with little difference in the likelihood profiles.

49. To examine this issue further the posterior sampling distribution of the updated grid (W6W9, with the revised values for M_{10}) with a uniform prior on steepness was compared with the same grid using objective function weights. With objective function weighting, there was a strong preference for lower levels of steepness (amongst 0.6, 0.7 and 0.8), which was attributed to the increased weight assigned to the GAM11-variable squares hypothesis in the W6W9 grid compared to the initial grid based on GAM11-constant-squares. In particular, the subset corresponding to models fitted to the W0.6 CPUE series showed a strong preference for the lowest steepness value and hardy any support for the value of $h = 0.8$.

50. Given the strong preference for lower values of steepness in the W6W9 grid, the group agreed to examine whether a value of steepness lower than 0.6 could be fit to the data with this grid and, if so, to consider whether the reference set should include a wider range of steepness values, or rather whether the lower value of steepness should be examined as a sensitivity test. The group agreed that the focus of this additional exploration was on the range of steepness values to include in the reference set and that the uniform prior on steepness would be retained.

51. The group recalled that the previous revision to the range of steepness values included in the grid was decided in 2017, when the two extreme values, $h = 0.55$ and $h = 0.9$, were dropped from the grid because they received very little support from the objective function (log likelihoods plus penalties). Based on retrospective analyses (Report of ESC22, Fig. 22) the ESC22 concluded that the support provided to values of h less than 0.6 had diminished since the 2014 assessment because of the upturn in estimated recent recruitments to levels well above those predicted by any of the stock-recruitment models considered (paragraphs 82-86, Report of ESC22). Those increases in recruitment estimates were partly driven by an observation of very high abundance from the aerial survey data (2016) and increases in the old Base CPUE indices. The revisions to the CPUE and the addition of the gene-tagging data have resulted in a substantially reduced estimates of these recent recruitments.

52. The new runs focused on a lower bound for steepness of $h = 0.55$, consistent with the lower bound used in the 2014 stock assessment. That value had been defined based on in-depth analysis of the influence of the recruitment penalty on preferences for steepness (OMMP2; ESC17 and ESC22). The group noted that while it was possible to complete runs for values of steepness lower than 0.55, the fits for these runs would be worse. The sampling distributions obtained using a steepness grid equal to $h = \{0.55, 0.6, 0.7, 0.8\}$, sampled using both uniform weights and posterior weights (Figs. 10 and 11), show that the addition of the lower 0.55 value for h resulted in a relatively balanced, domed distribution of steepness when using posterior weights, with very little influence on other grid elements when compared with the uniform prior. The corresponding likelihood plot illustrates that the strong preference for lower levels of steepness is driven by the recruitment penalty term and the data fitted are not strongly informative about steepness (Fig. 12). This preference is moderated somewhat for the overall objective function, which reflects the influence of the data sets on the fits.

Figure 13 illustrates that the lower levels of steepness are resampled more frequently for the W0.6 CPUE series compared to the W0.9 series (Fig. 14). The group agreed that these results were sufficient to justify extension of the lower end of the range of steepness in the reference set grid to 0.55 and recommended the use of equally spaced values between 0.55 and 0.8. The group agreed that it would be important to complete additional diagnostic analyses for consideration at the ESC so as to provide a comprehensive summary of the factors contributing to the revised range for steepness in Reference Set.

53. An evaluation of posterior weights on Psi indicated a minor level of aliasing of Psi with M_{10}, when both Psi and h were sampled using posterior weights. The group agreed that this was consistent with expectations and sufficient to remove the Psi sensitivity run from the initial list considered for the ESC (Table 4).

Agenda Item 3. Discussion of projection results

54. Projection results from the preliminary reconditioning of the operating models (not the reference set proposed for the ESC) were run during the meeting and presented. Two sets of conditioned OMs were examined:
    1) using the average of the old Base W0.5 and Base W0.8 CPUE series, which were the specified series to be used in the Cape Town MP, and
    2) using the average of the GAM11 W0.6 and W0.9 series, which are planned to be used for the reference set of models for the 2020 stock assessment.
55. The preliminary results indicate that the rebuilding objective of the Cape Town MP (30% SSB_0 by 2035) is likely to be met with either preliminary grid combination.
56. The group discussed which of the CPUE series should be used in the projections. In both sets of projections results presented, the CPUE series used in conditioning was the same used in the data file for the MP, creating consistency between the historical and the simulated CPUE estimates in the projections.
57. The group agreed that for consistency with testing and implementation of the Cape Town MP, it would be preferable to use the average of the old Base W0.5-W0.8 series as input to the MP in the projections. However, given that subsequent discussions (see paragraph 23) concluded that the GAM11 CPUE series are now regarded as providing more reliable indices of the underlying abundance, these series should be used for the stock assessment that in turn provides the numbers-at-age estimates from which the projections are initiated. This creates a discontinuity between conditioning and projections, which will be examined prior to the ESC.

Agenda Item 4. Specification of reference set and sensitivity runs to be presented to the ESC

58. Based on the review of model runs (Agenda Item 2), the group selected a final grid of OMs to be used as reference set for the stock assessment (Table 2). The grid comprises 432 cells resulting from the crossing of four values of steepness (h), three values of natural mortality at age 0 (M_0), three values of mortality at age 10 (M_{10}), a single value of Ω (implying a linear relationship between CPUE and LL1 exploitable biomass), two choices of the age range used to standardise LL1 selectivity over time,

two alternative series of CPUE (W0.6 and W0.9 based on model GAM11), and three values of ψ (power parameter for relative reproductive contribution by age).

59. The aim of the reference set of models is to provide stock status advice that encapsulates these key uncertainties.

Table 2. Revised reference set grid for the stock assessment to be presented at the ESC. Sampling weight refers to how the grid of models is sampled to generate a distribution from 2000 parameter draws. Note that the values for M_0, M_{10} and h below differ from those used in 2019 for MP testing, and also differ from the reference set used in the last full stock assessment in 2017. The lower values for M_0 = 0.35 and M_{10} = 0.05 used before were increased prior to OMMP to 0.4 and 0.065, respectively, because of convergence issues. The upper M_{10} = 0.12 was dropped during the meeting (but was included in the figures for the W6W9 reference set) and the third highest value was increased. The h grid was expanded to include a lower value (see paragraph 51).

Parameter	Value	Cumul N	Prior	Sampling weight
H	0.55, 0.63, 0.72, 0.80	4	Uniform	Prior
M_0	0.4 0.45 0.5	12	Uniform	Posterior
M_{10}	0.065, 0.085, 0.105	36	Uniform	Posterior
Omega (Ω)	1	36	Uniform	Prior
CPUE	W0.6, W0.9 (weighting of CS:VS, GAM11)	72	Uniform	Prior
CPUE age range	4-18, 8-12	144	0.67, 0.33	Prior
Psi (ψ)	1.5, 1.75, 2.0	432	0.25, 0.5, 0.25	Prior

60. Other assumptions made for the Reference Set of OMs include:

- Non-member estimates of UAM: estimated catches in Table 1 are added to LL1 historical catches. These values were estimated with the GLM method and assuming targeted catch rates documented in CCSBT-OMMP/2006/04. These equate to a 14% NCNM-UAM catch to be added to LL1 catches in projections.
- A 20% overcatch is added to the Australian surface fishery in conditioning (ramping up from 0 in 1992 to 20% in 1999 and beyond (in projections).
- Maintain the increased flexibility for Indonesian selectivity, commencing in 2012, to accommodate the sharp increase in abundance of younger fish (<age 7 yr) in the catch.
- The recruitment deviate simulated for the first year of projections is uncorrelated to historical deviates from the conditioned model; future recruitment deviates are simulated using an empirical estimate of autocorrelation.
- Allocation of catches for 2021 and beyond is specified in Table 3, corresponding to CCSBT's resolution on the nominal Allocation of the Global Total Allowable Catch to countries (Table 1 in report of EC26, nominal catch proportion) converted to the four OM fisheries considered in the projections.

Table 3. Catch allocation to be used in projections.

Fishery in OM projections	LL1	LL2	Indonesia	Surface
Allocation	0.5752	0.0713	0.0607	0.3091

61. The group discussed the sensitivity runs to be reported for the ESC and recommended the following list:

Table 4. List of sensitivity runs to be conducted for discussion at the ESC.

Test name	Code	Conditioning and projection notes	Priority
UAM1	UAM1	Same UAM scenario as used for MP testing: add 1000 tonnes to LL1, ramping up from 1990 to 2013, and increase surface catches by 1% in 1992 to 40% in 1999 and onwards, and shift age composition as was done for the 20% overcatch. Projected catches: 14% overcatch in LL1 and 40% overcatch in surface fishery	H
UAMbycatch	UAMbycatch	Replace LL1 NCNM catches estimated using Japanese catch rates by estimates calculated using Taiwanese catch rates.	H
No UAM	noUAM	Remove NCNM catches from conditioning and projections.	H
LL1 Case 2 of MR	case2	LL1 overcatch based on Case 2 of the 2006 Market Report	L
Alternative overcatch	TBD	Possible sensitivity on an alternative overcatch estimate, to be specified at ESC25	?
SFO00	sfo00	No overcatch in surface fishery	L
Old CPUE series	CPUE.old.base	Use of W0.5 and W0.8 CPUE series estimated using the old Base GLM model	H
S50CPUE	cpues50	50% of LL1 overcatch associated with reported effort	M
Omega75	cpueom75	Power function for biomass-CPUE relationship with power = 0.75	H
Upq2008	cpueupq	CPUE q increased by 25% (permanent in 2008)	H
GLMM	glmm	Area-year mixed-model CPUE standardisation	M
Q age range	cpue59	Age range for q equal to 5-9	M
Bridging		To the extent practical, conduct a run with settings close to the most recent assessment, noting that some aspects will be difficult as the grids differ due to changes in the data and assumptions.	
IS20	fis20	Indonesian selectivity flat from age 20+	M
Aerial2016	as2016	Remove the 2016 aerial survey data point	H
NoPOP&HSP		Exclude both close-kin data (Parent-Offspring and Half-Sibling Pairs)	H
Omit GT	getout	Omit Gene Tagging data	H
GTI	troll	Includes the grid-type trolling index as additional recruitment index. Increase CV of aerial survey to preclude aerial survey dominating the fit, given apparent conflicts in the data	M
Psi		Grid sampling using objective function weighting on psi instead of prior weights	Discarded (paragraph 52)
POPs only		Implemented by increasing the variance on other trend data or some other approach	If practical

Agenda Item 5. Preparation of input data/code and review of steps for implementation of the Cape Town MP at the ESC

62. Australia presented paper CCSBT-OMMP/2006/08 which describes the Cape Town MP formulae. The paper describes the key data inputs to the 2019 Cape Town MP, and the effect of each data component on the MP calculation for the 2021-2023 TAC recommendation. The data inputs to the MP are: 1) the gene tagging abundance estimates of the age 2 cohorts for 2016-2018 and the number of matches associated with each estimate, 2) the arithmetic mean of the individual w0.5 and w0.8 Base CPUE series, 3) the updated CKMR parent-offspring pairs (POP) data, and 4) the updated CKMR half-sibling pairs (HSP) data.

63. The group discussed how each of the components affected the MP output. A detailed description is provided in CCSBT-OMMP/2006/08.

64. The POP and HSP data provide information on adult abundance and mortality, from which the log-linear trend in total reproductive output (TRO) is estimated in the MP model component. The trend in TRO is used to determine TAC changes. TAC increases occur only for positive trends above a minimum level required to achieve the rebuilding objective. A density dependent effect is built in so that the MP becomes less reactive when the TRO estimates are closer to the rebuilding objective.

65. The CPUE component of the MP uses the average of the most recent four years of CPUE data relative to upper and lower threshold values. TAC changes are asymmetrical, with a stronger response to reduce the TAC when below the lower threshold, and slower increases in the TAC when above the upper threshold. The CPUE component, like the CKMR component, becomes less reactive as the rebuilding target is approached or reached. This helps to create stability over time in the TAC.

66. The gene-tagging component of the MP uses a recent average of the gene-tagging estimates and specified lower and upper bounds which determine the direction and strength of changes to TAC. There is a very strong reaction when the recent average age-2 abundance estimate is below the lower bound, resulting in a decrease of the TAC. When the average of the estimates is above the upper bound, the TAC increase is relatively small, and when within the bounds, there is no change to the TAC.

67. The group noted that even when there are positive trends in the data inputs, a minimum rebuilding rate is required before TACs will increase. This is because the MP's primary design objective is to rebuild the stock.

68. The MP code and data files will be available to Members on Github site or can be requested directly from Dr. Richard Hillary.

Agenda Item 6. Update of the Metarules for the Cape Town Procedure

69. ESC 24 agreed that the Metarules for the Bali Procedure should be updated to reflect the Cape Town MP adopted by the Extended Commission (EC) in 2019.

70. Australia presented paper CCSBT-OMMP/2006/09 which provided an initial draft of the Metarules for the Cape Town MP based on intersessional work by Australia and Japan. The Metarules adopted for the Bali Procedure (Attachment 10, Report of

ESC18) were used as the basis for the draft Metarules for the Cape Town MP. These metarules provide a safety net for implementation of the MP. The existing metarules have assisted the ESC and EC to assess the impacts, severity and actions in relation to exceptional circumstances and have provided a valuable framework for an orderly and considered approach to such events.

71. The group noted that the metarules and, in particular, the sections dealing with exceptional circumstances, were, by design, not especially prescriptive and that this has served the ESC and EC well for the implementation of the Bali Procedure. The question was raised as to whether there would be benefit in refining the definition of "severity" and the specification of what constituted "action" under the Principles for Action. It was also suggested that it would be useful to clarify who was responsible (ESC or EC) for different steps, where that was not already clearly stated. In relation to the desire to build and maintain the orderly philosophy that has developed with respect to the implementation of the metarules, it was suggested that a small number of concise case-studies covering a range of previous events that had triggered exceptional circumstances and the response of the ESC and EC might be useful, particularly for new participants. Finally, the suggestion was made that text for Principles for Action should be revised.

72. The group agreed that a small inter-sessional working group should consider the feedback provided and continue to develop a revised draft for consideration at the ESC, noting that the metarules constitute part of the EC Resolution for the adoption of the Cape Town MP and, hence, also need to be reviewed and adopted by the EC later this year. The group also noted that the full technical specification and other details of the Cape Town MP (i.e. three input data series and the population model within the MP) need to be updated for review and recommendation at this year's ESC meeting.

Agenda Item 7. Workplan

7.1. Preparation of stock assessment sensitivity runs

73. The group agreed to divide the workload among the analysts to complete the list of sensitivity runs (Table 4) prior to the ESC. The Chair agreed to distribute a spreadsheet for that purpose after the meeting.

74. The group agreed to convene a small group web meeting to discuss structure of the Github.

7.2. Other issues

75. No other issues were discussed.

Adoption of Meeting Report

76. The report was adopted.

Close of meeting

77. The meeting closed at 10:15 hrs (Canberra time) on 24 June 2020.

List of Attachments

Attachments

1 List of Participants

2 Agenda

3 List of Documents

4 Figures

Attachment 1

List of Participants

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Attachment 2

Agenda
Eleventh Operating Model and Management Procedure Technical Meeting

1. Review of data inputs

1.1 Gene tagging

1.2 Close-kin: POPs and half-sibling indices

1.3 CPUE

1.4 Unaccounted sources of mortality (to be discussed prior to OMMP)

2. Review of model runs: diagnostics and likelihood weights

3. Discussion of projection results

4. Specification of reference set and sensitivity runs to be presented to the ESC

5. Preparation of input data/code and review of steps for implementation of the Cape Town MP at the ESC

6. Update of the Metarules for the Cape Town Procedure

7. Workplan

7.1 Preparation of stock assessment sensitivity runs.

7.2 Other?

Attachment 3

List of Documents
The Eleventh Operating Model and Management Procedure Technical Meeting

(CCSBT-OMMP/2006/)

1. Provisional Agenda (Rev.2)
2. List of Participants
3. List of Documents
4. (New Zealand) Estimates of SBT catch by CCSBT non-cooperating non-member states between 2007 and 2017 (OMMP Agenda Item 1.4)
5. (CCSBT) Gene-tagging data for the MP and stock assessment (OMMP Agenda Item 1.1)
6. (CCSBT) Notes on the close-kin analysis for 2020 (OMMP Agenda Item 1.2)
7. ~~(Australia) OM update and fit to data (OMMP Agenda Item 2)~~
8. (Australia) Running the Cape Town Procedure for 2020 (OMMP Agenda Item 5)
9. (Australia) Draft metarules for the Cape Town Management Procedure (OMMP Agenda Item 6)
10. (Japan) Change in operation pattern of Japanese southern bluefin tuna longliners in the 2019 fishing season (OMMP Agenda Item 1.3)
11. (Japan) Update of the core vessel data and CPUE for southern bluefin tuna in 2020 (OMMP Agenda Item 1.3)
12. (Japan) Examination of an anomalously high value of the core vessel CPUE in 2018 for southern bluefin tuna (OMMP Agenda Item 1.3)
13. (Korea) Data Exploration and CPUE Standardisation for the Korean Southern Bluefin Tuna Longline Fishery (1996-2019) (Rev.1) (OMMP Agenda Item 1.3)
14. (Australia) Summary of updated CKMR data and model performance in the Cape Town Procedure (OMMP Agenda Item 5)
15. (New Zealand) Exploratory analyses for primary CCSBT CPUE index (OMMP Agenda Item 1.3)

(CCSBT-OMMP/2006/Rep)

1. Report of the Twenty Sixth Annual Meeting of the Commission (October 2019)
2. Report of the Twenty Fourth Meeting of the Scientific Committee (September 2019)
3. Report of the Tenth Operating Model and Management Procedure Technical Meeting (June 2016)
4. Report of the Twenty Fifth Annual Meeting of the Commission (October 2018)
5. Report of the Twenty Third Meeting of the Scientific Committee (September 2018)
6. Report of the Ninth Operating Model and Management Procedure Technical Meeting (June 2018)
7. Report of the Fifth Meeting of the Strategy and Fisheries Management Working

Group (March 2018)

8. Report of the Twenty Second Meeting of the Scientific Committee (August - September 2017)
9. Report of the Eighth Operating Model and Management Procedure Technical Meeting (September 2017)

Attachment 4

Figures

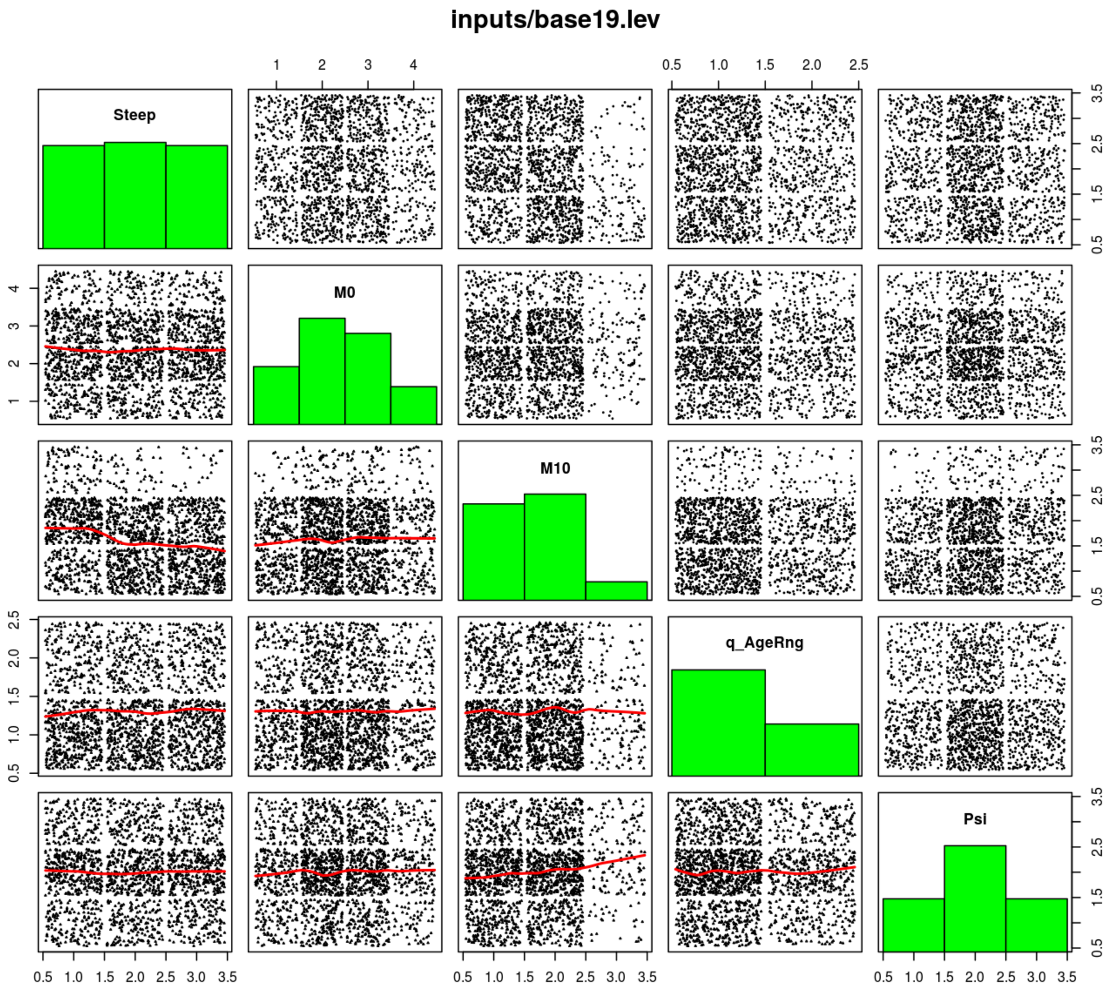

Figure 1. Sampling distributions (“Level plots”) for the initial reference set based on the GAM11-constant squares CPUE series, sampled using uniform weights for h = {0.6, 0.7, 0.8}, posterior weights for M0 = {0.4,0.433,0.467,0.5} and M10 = {0.065, 0.085, 0.12}, and prior weights for q-age-range and for Psi. Values on the horizontal and vertical axes correspond to the levels of the different grid factors (not the actual parameter values) jittered within each level.

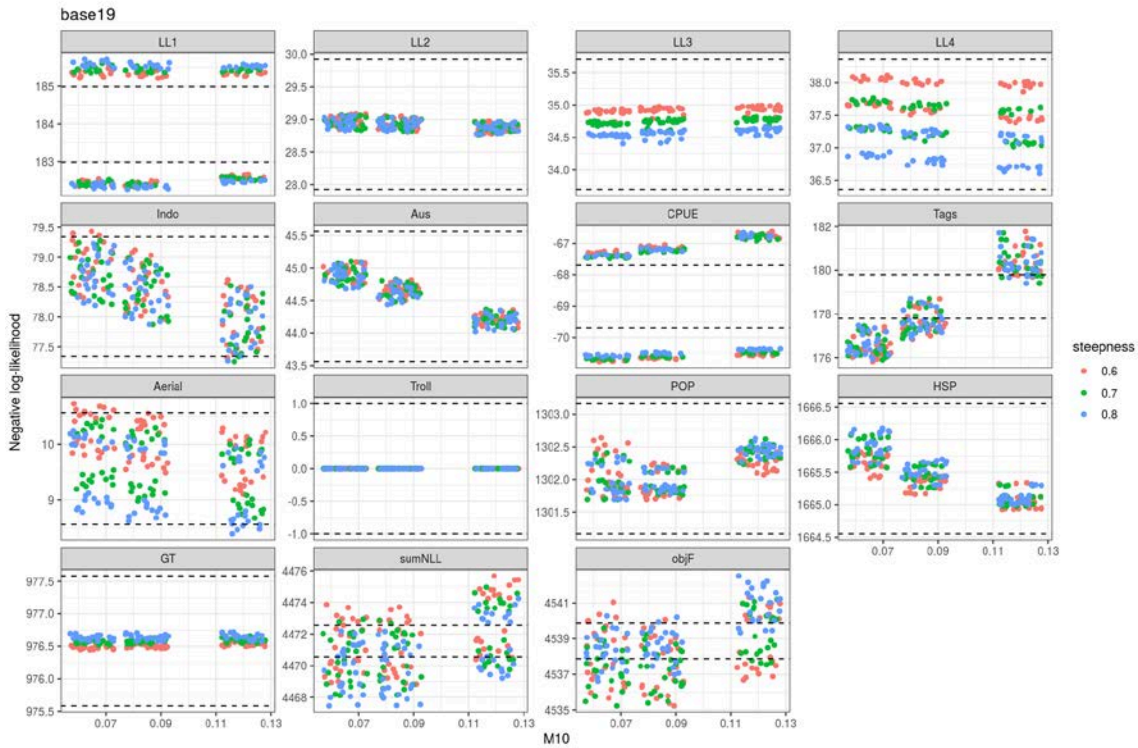

Figure 2. Initial set of the negative log-likelihood (NLL) components for base19; the sum of the negative log-likelihood components (sumNLL), and the total objective function (objF) plotted by M10 on the x-axis and coloured by steepness. The M10 values are randomly jittered (within a category) so that values do not all sit on top of each other. The dashed horizontal lines represent ± 2 units of NLL.

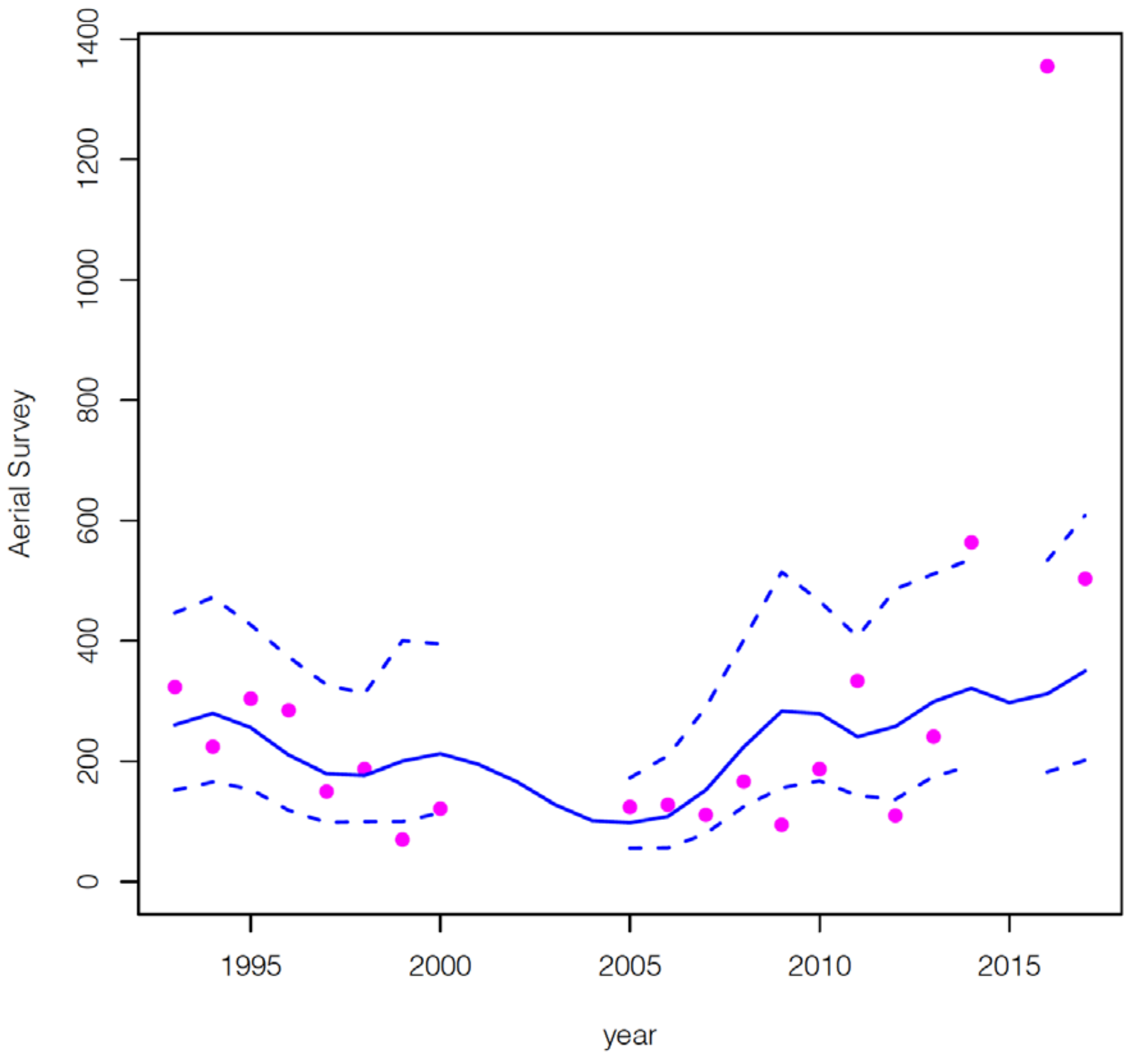

Figure 3. Model fit to aerial survey estimates of 2-year-olds for the "best fitting" cell from the Base19 OM, fitted to GAM11 constant squares CPUE index .

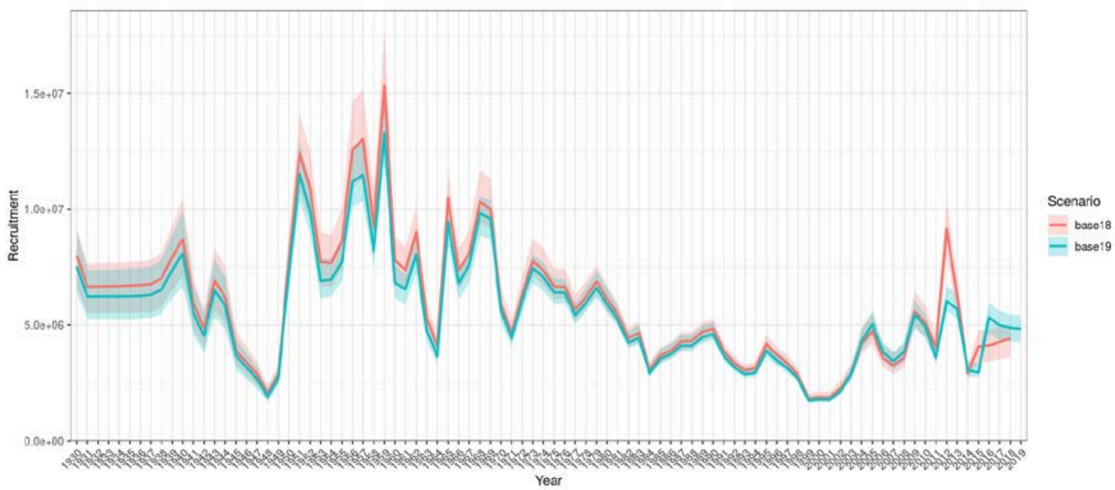

Figure 4. Estimated time series of recruitment for Base19 compared to the OMs updated in 2019 at ESC24 (Base18).

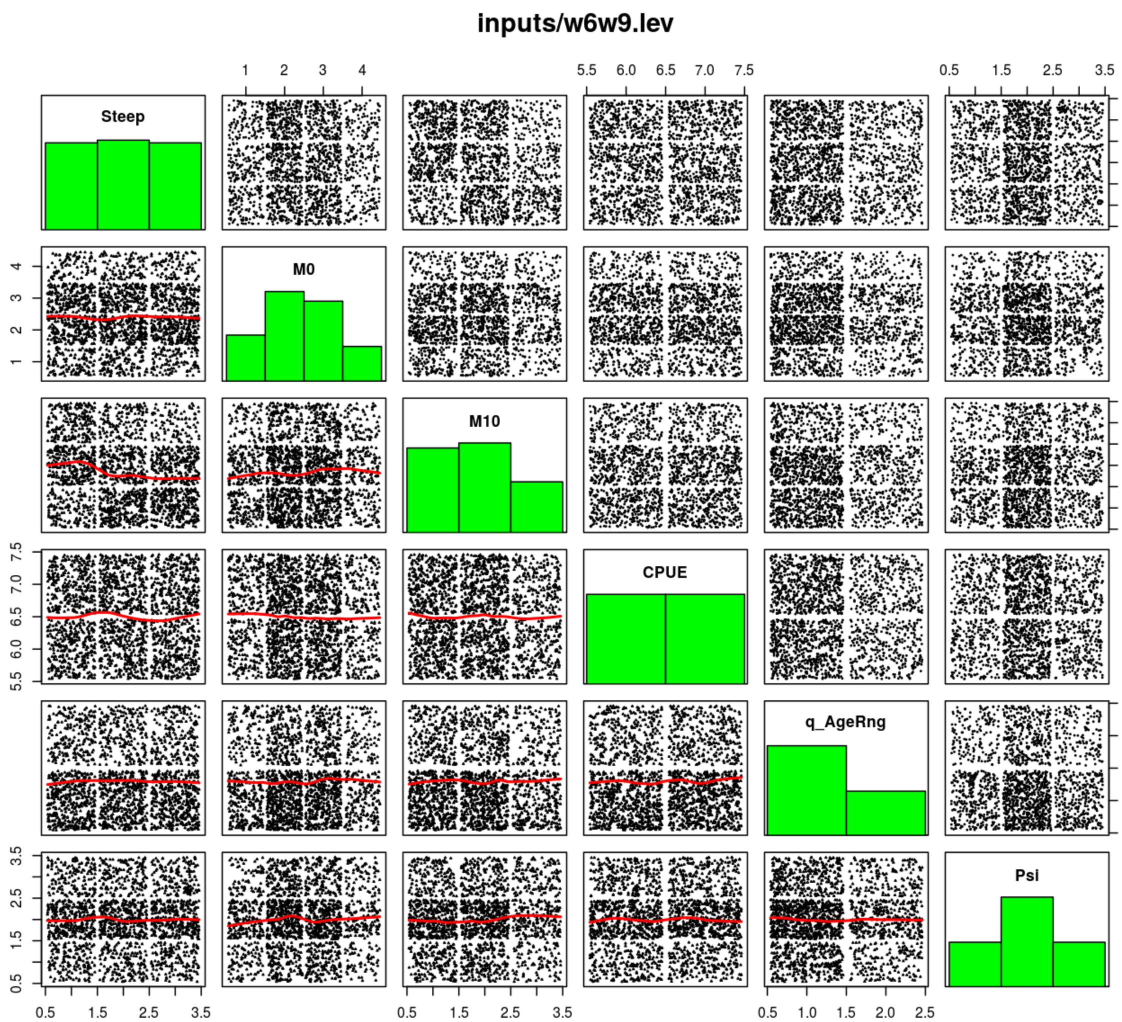

Figure 5. Level plots for the W6W9 reference set fitted to the W0.6 and W0.9 CPUE series, corresponding to different weightings of the CS vs VS hypothesis, whereby W0.6 refers to 60:40 CS:VS and W0.9 refers to a 90:10 CS:VS weighting. Grid cells were sampled using uniform weights for $h = \{0.6, 0.7, 0.8\}$, posterior weights for $M_0 = \{0.4, 0.433, 0.467, 0.5\}$ and $M_{10} = \{0.065, 0.085, 0.105\}$, and prior weights for q-age-range and for Psi. Values on the horizontal and vertical axes correspond to the levels of the different grid factors (not the actual parameter values) jittered within each level.

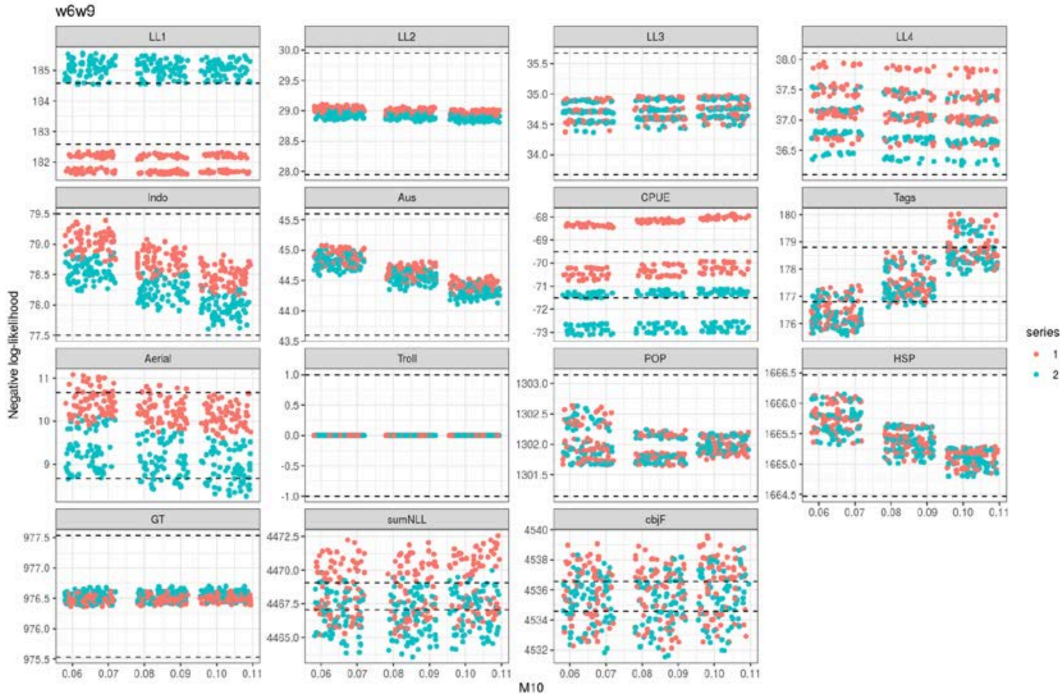

Figure 6. Negative log-likelihood (NLL) components for W6W9 set; the sum of the negative log-likelihood components (sumNLL), and the total objective function (objF) plotted by M10 on the x-axis and coloured by CPUE series (series 1 = W0.9, series 2 = W0.6). The M10 grid values equal to {0.065, 0.085, 0.105} are randomly jittered (within a category) so that values do not all sit on top of each other. The dashed horizontal lines represent ± 2 units of NLL.

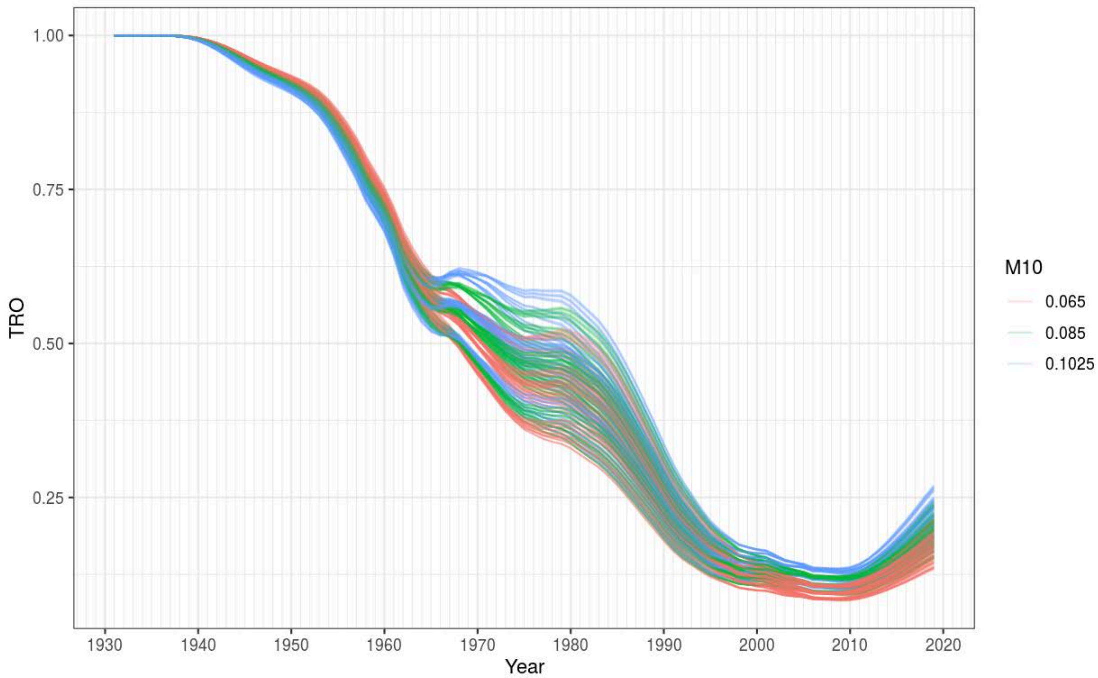

Figure 7. Total Reproductive Output (TRO) time series estimated using the W6W9 grid with colours by M_{10} (red is lowest, blue highest).

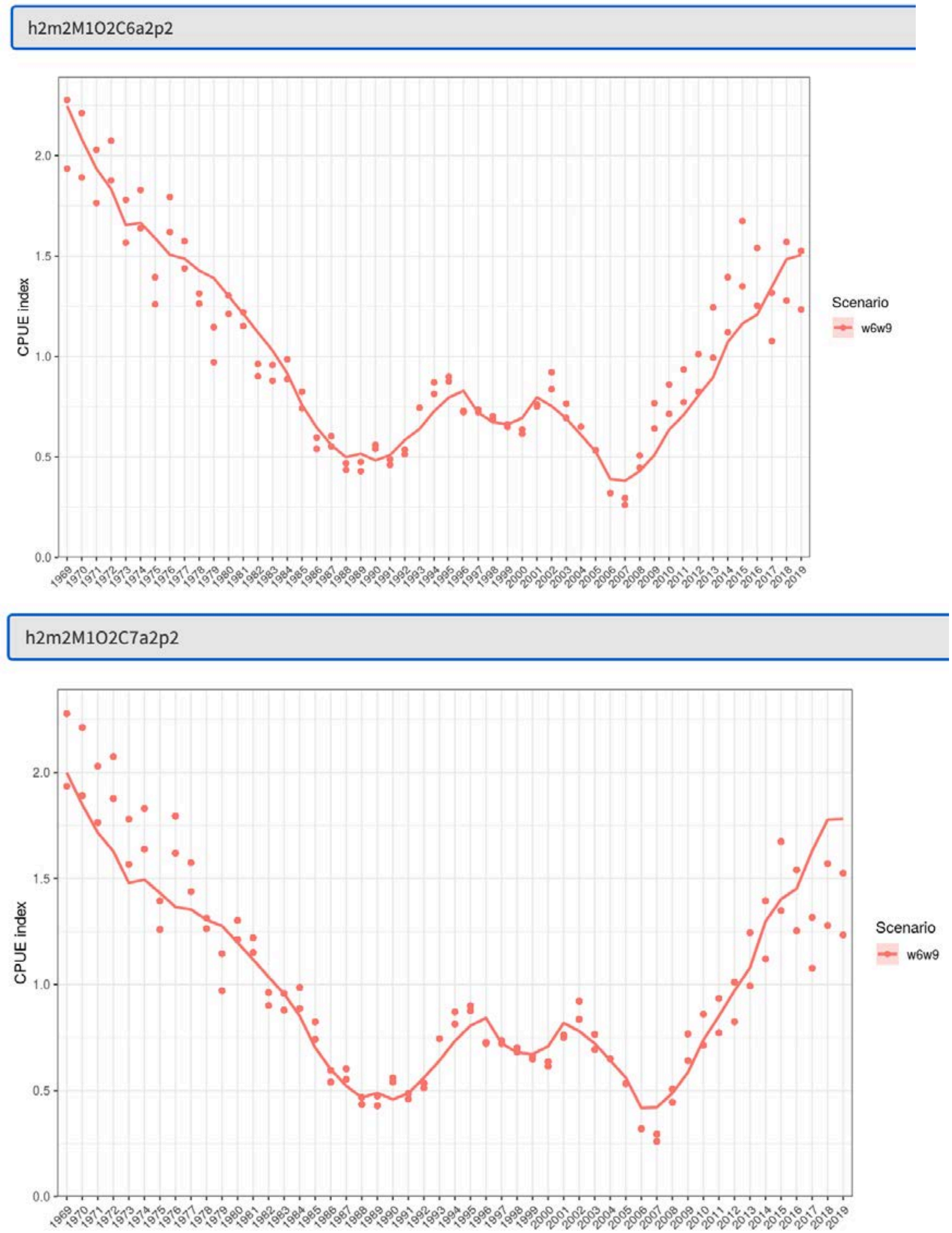

Figure 8. Model fit to catch per unit effort (CPUE) for two selected intermediate grid cells. Note that two observations (points) are shown per year but the top figure shows the CPUE fitted to the W0.6 CPUE (lower values) and the bottom figure shows the CPUE fitted to the W0.9 CPUE (higher values). W0.6 and W0.9 correspond to different weightings of the constant squares and variable squares GAM11 CPUE series, whereby W0.6 refers to a 60:40 CS:VS and W0.9 to a 90:10 CS:VS weighting.

YEAR	COHORT AGE	N RELEASES	N HARVEST	N MATCHES	ABUNDANCE ESTIMATE (MILLIONS)	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

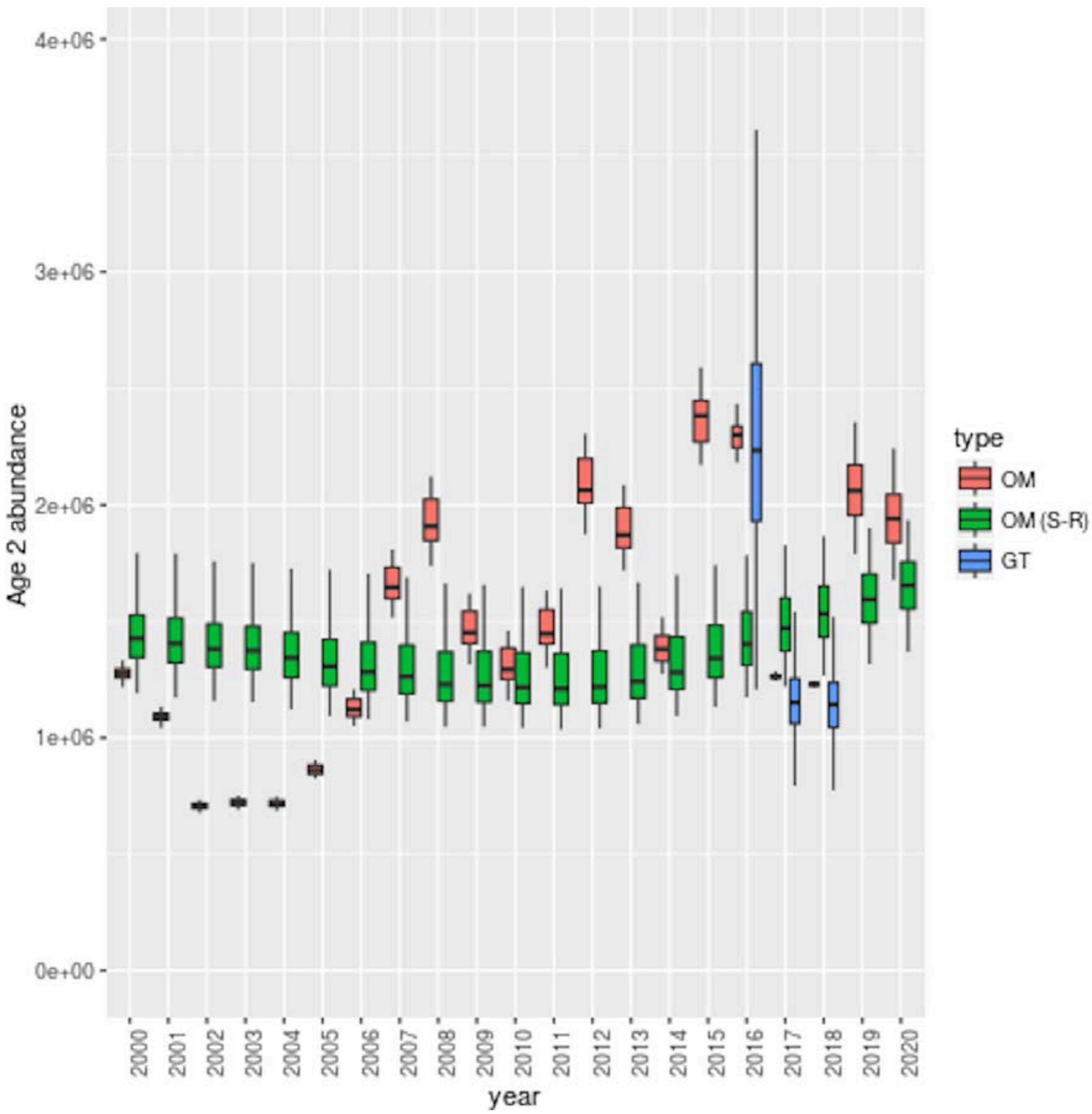

Figure 9. Table of the results of the gene-tagging programs 2016-2018 including absolute abundance estimates for the age-2 cohort in the year of tagging (top) and comparison of gene-tagging age-2 abundance estimates and corresponding age-2 estimates from the OM and those predicted from the stock-recruitment function (OM-(S-R)) (bottom).

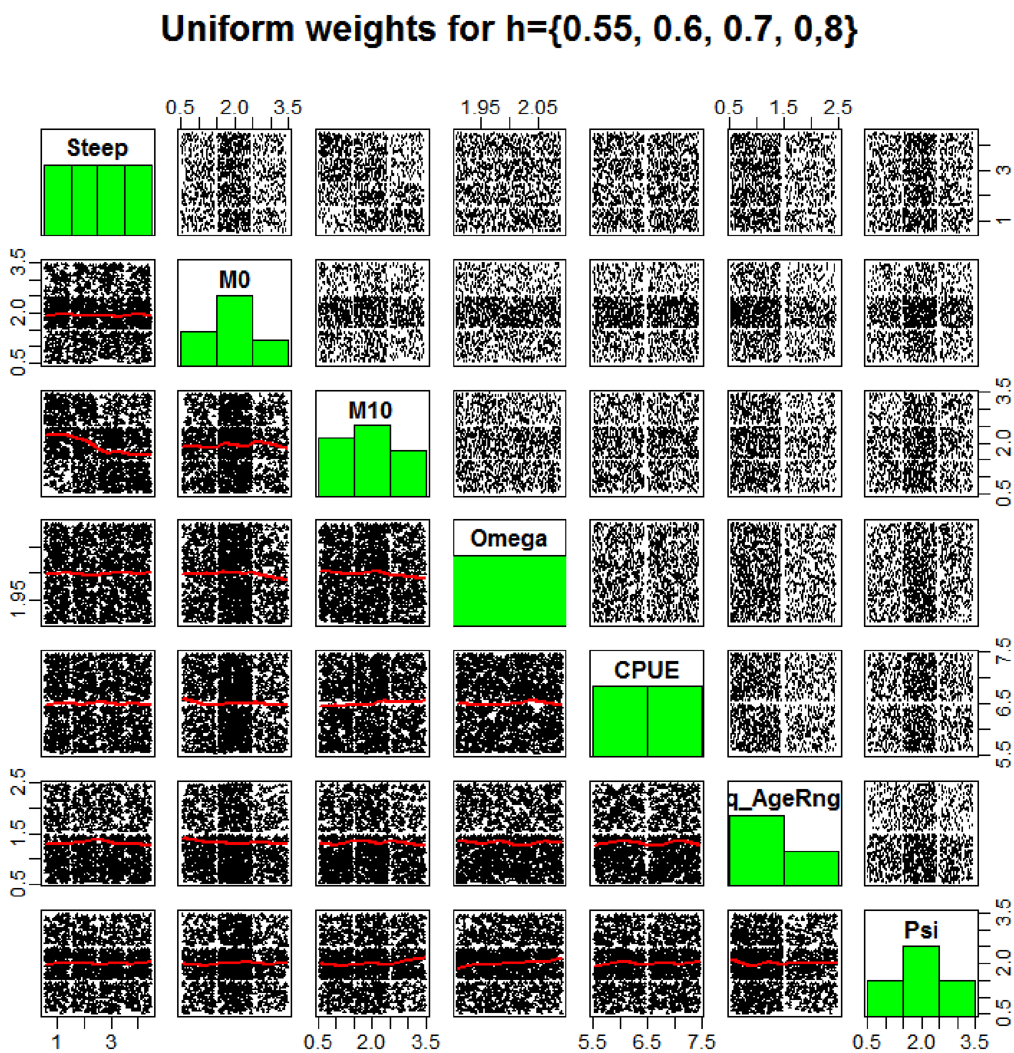

Figure 10. Set of level plots for reference set based on W0.6-W0.9 CPUE indices and an expanded grid on steepness. Grid cells are sampled using uniform weights for h = {0.55, 0.6, 0.7, 0.8}, posterior weights for M0 = {0.4,0.45,0.5} and M10 = {0.065, 0.085, 0.105}, and prior weights for q-age-range and for Psi. Values on the horizontal and vertical axes correspond to the levels of the different grid factors (not the actual parameter values) jittered within each level.

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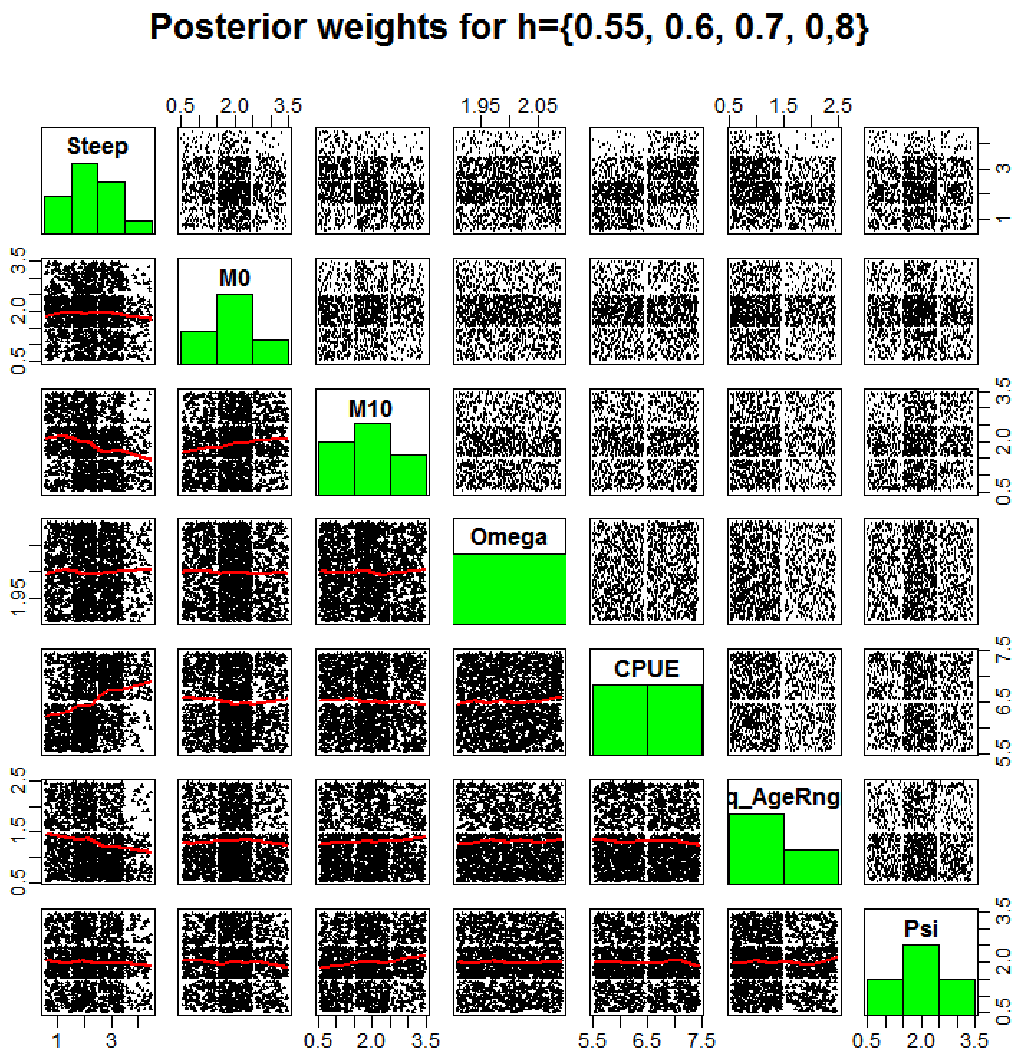

Figure 11. Set of level plots for reference set based on W0.6-W0.9 CPUE indices and an expanded grid on steepness. Grid cells are sampled using posterior weights for h = {0.55, 0.6, 0.7, 0.8}, M0 = {0.4,0.45,0.5} and M10 = {0.065, 0.085, 0.105}, equal weights for the CPUE series, and prior weights for q-age-range and for Psi. Values on the horizontal and vertical axes correspond to the levels of the different grid factors (not the actual parameter values) jittered within each level.

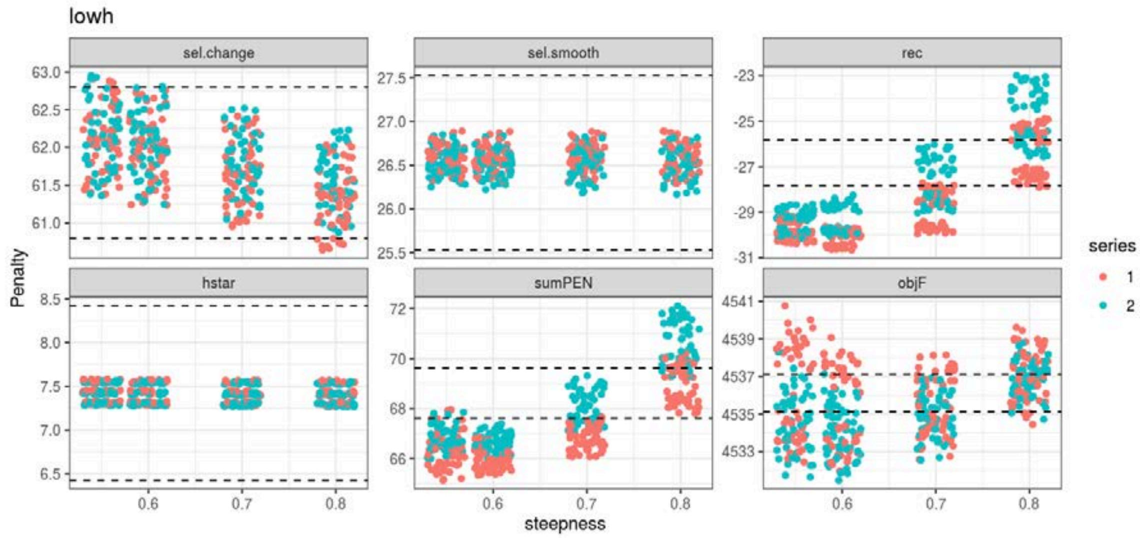

Figure 12. Penalty components, their sum (lower middle) and objective function (lower right) from the W6W9 grid; plotted by steepness on the x-axis and coloured by CPUE series (series 1 = W0.9, series 2 = W0.6). The steepness values are randomly jittered (within a category) so that values do not all sit on top of each other. The dashed horizontal lines represent ± 2 units of NLL (or penalty).

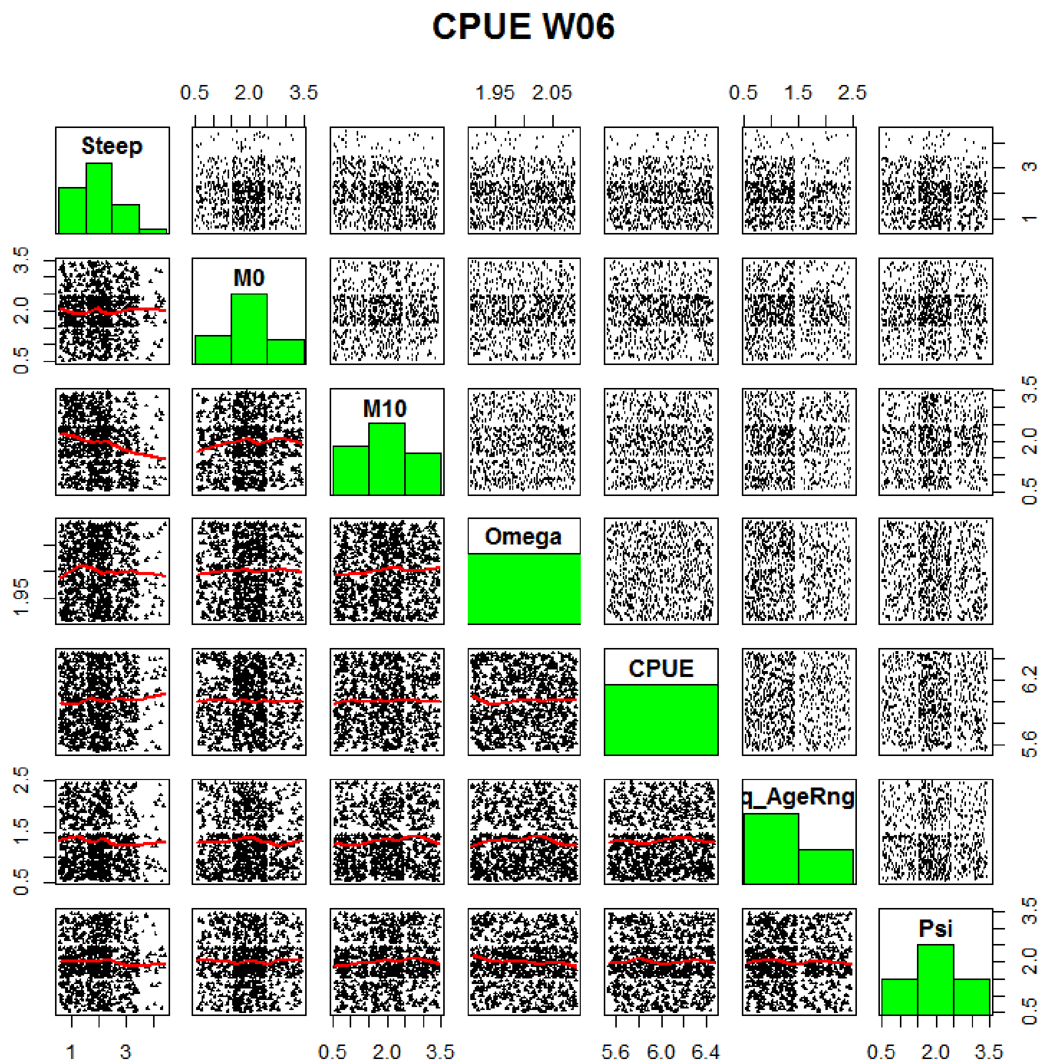

Figure 13. Set of level plots for reference set based on W0.6 CPUE index only and an expanded grid on steepness when grid cells are sampled using posterior weights for h = {0.55, 0.6, 0.7, 0.8}, M0 = {0.4,0.45,0.5} and M10 = {0.065, 0.085, 0.105}, and prior weights for q-age-range and for Psi. Values on the horizontal and vertical axes correspond to the levels of the different grid factors (not the actual parameter values) jittered within each level.

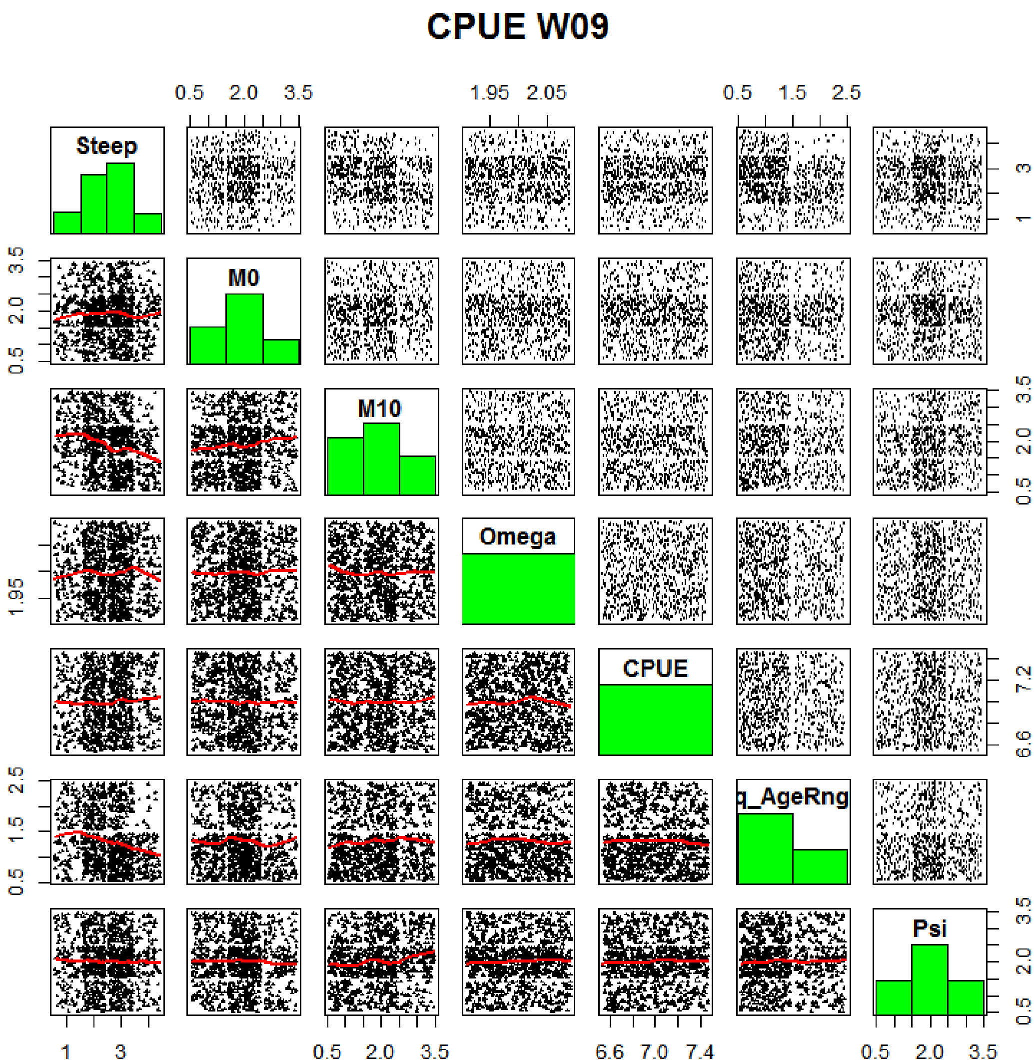

Figure 14. Set of level plots for reference set based on W0.9 CPUE index only and an expanded grid on steepness, when grid cells are sampled using posterior weights for h = {0.55, 0.6, 0.7, 0.8}, M0 = {0.4,0.45,0.5} and M10 = {0.065, 0.085, 0.105}, and prior weights for q-age-range and for Psi. Values on the horizontal and vertical axes correspond to the levels of the different grid factors (not the actual parameter values) jittered within each level.