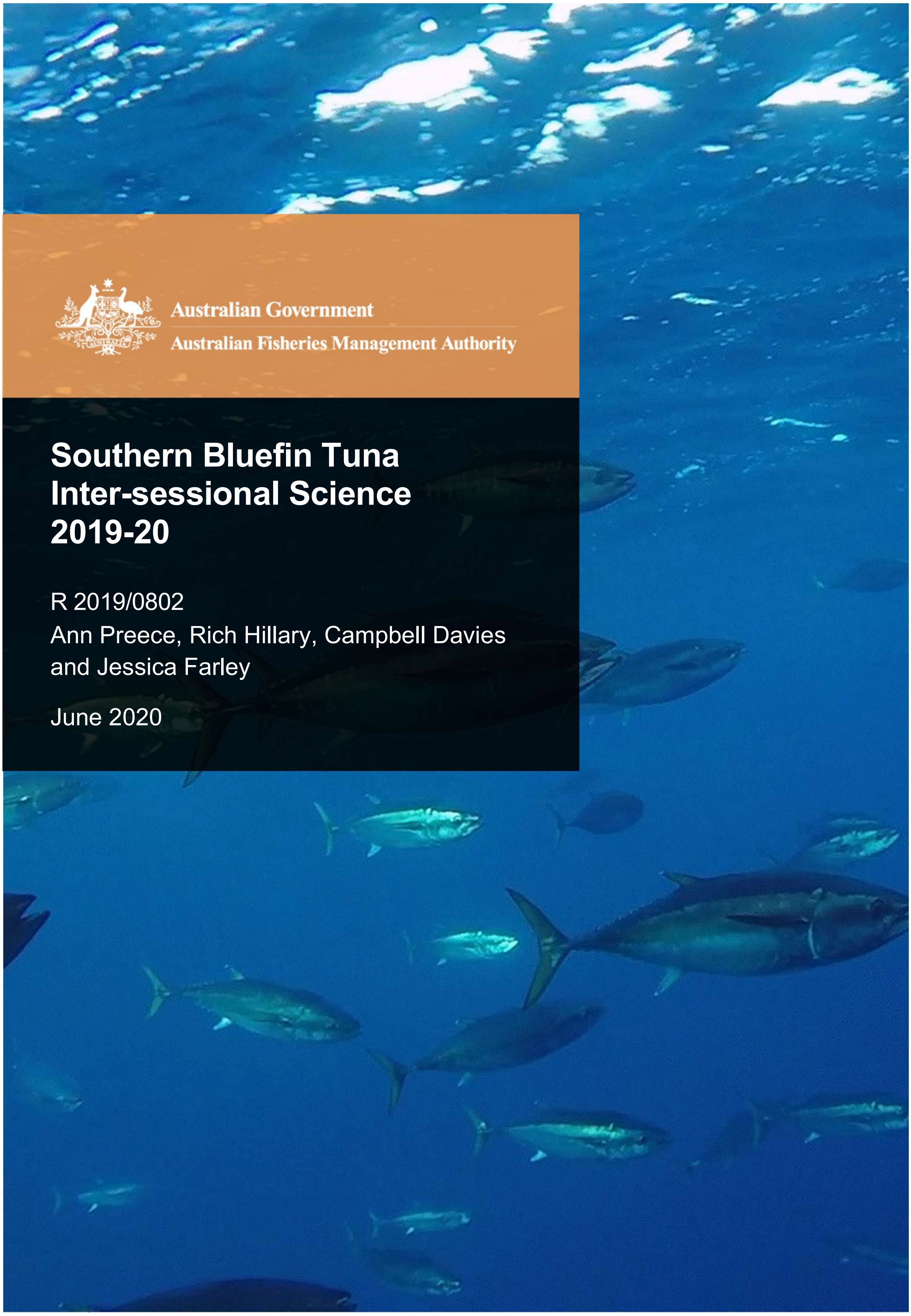

Australian Government
Australian Fisheries Management Authority

Southern Bluefin Tuna Inter-sessional Science 2019-20

R 2019/0802

Ann Preece, Rich Hillary, Campbell Davies and Jessica Farley

June 2020

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Southern Bluefin Tuna Inter-sessional Science 2019-20

Final Report

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AFMA Project Number: R2019/0802
30 May 2020

Final Report to AFMA

Australian Government
Australian Fisheries Management Authority

Citation

Preece AL, Hillary RM, Davies CR and Farley JH (2020) Southern Bluefin Tuna Inter-sessional Science 2019-20. CSIRO, Australia.

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Acknowledgments

This work was funded by AFMA and CSIRO.

The work presented to the 2019 CCSBT meetings was reviewed by ABARES, the CCSBT Advisory Panel and CCSBT member scientists.

The team of CSIRO scientists involved included: Ann Preece, Campbell Davies, Rich Hillary, Jessica Farley, Paige Eveson, Jason Hartog and Scott Cooper.

Non-technical summary

Through the SBT Inter-sessional Science Project CSIRO provides scientific support and advice to AFMA, SBTMAC, Australian Government and Industry and participates in Australian delegation contributions to the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) Extended Scientific Committee.

Consultation and advice are provided to AFMA on the CCSBT work plans, the scientific data exchange, evaluation of exceptional circumstances and indicators, discussion of the CCSBT Scientific Research Program and future planning. The technical work program in 2019-20 reviewed candidate management procedures and the CCSBT adopted a new Management Procedure developed by CSIRO that will be used in 2020 to recommend the global catch for 2021-2023 and beyond.

A full stock assessment is planned for 2020 and preliminary reconditioning of the CCSBT operating models with updated data is underway. The stock assessment will provide a summary of current stock status and progress with rebuilding the SBT stock. The 2020 stock assessment will use the new juvenile abundance estimates from the gene-tagging program for the first time.

Outputs from this inter-sessional science project have been considered in depth by the CCSBT scientific committee and Advisory Panel members and are reflected in recommendations and advice of the ESC to the Commission, and by the Extended Commission in the 2019 funding decisions and approach to the future work program.

This work provides ongoing scientific advice to the Southern Bluefin Tuna MAC and AFMA to support the adequate monitoring, implementation and success of management arrangements in the Southern Bluefin Tuna Fishery.

1 Background

Through the SBT Inter-sessional Science Project CSIRO provides scientific support and advice to AFMA, SBTMAC, Australian Government and Industry and participates in Australian delegation contributions to the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) Extended Scientific Committee.

The main focus of the technical work program in 2019-20 was to review candidate management procedures at the 2019 Extended Scientific Committee meeting and prepare for preliminary reconditioning of the SBT operating models in preparation for the 2020 stock assessment. The 2020 stock assessment will be the first assessment to use the new juvenile abundance estimates from the gene-tagging program. The reconditioned SBT operating models will integrate all available data from the 2020 data exchange.

The technical work for the 2019 ESC also included a regular review of meta-rules consideration of exceptional circumstances and data provided through the CCSBT data exchange, and discussion of the CCSBT's scientific research program.

The development of candidate MPs is part of the CSIRO project with the Department of Agriculture, Water and the Environment, however, the project involves consultation with AFMA, government, Industry and other stakeholders on operational forms of Management Procedure, objectives and trade-offs in performance measures. The AFMA SBT Inter-sessional Science 2019-20 project and CSIRO's Management Procedure project with the Department are strongly linked.

2 Need

This is essential work that provides ongoing scientific advice to the Southern Bluefin Tuna MAC and AFMA to support the adequate monitoring, implementation and success of management arrangements in the Southern Bluefin Tuna Fishery. Consultation and advice are provided to AFMA on the CCSBT work plans, the scientific data exchange, evaluation of exceptional circumstances and indicators, discussion of the 2014-2018 CCSBT Scientific Research Program and future planning. The project covers attendance by key CSIRO staff at ESC and Operating Model and Management Procedure (OMMP) technical meetings, and domestic consultation and planning discussions.

The development of a new MP and the intensive domestic consultation associated with this process is a large piece of work, similar to the work undertaken in the years leading up to the 2011 adoption of the current MP. The development of candidate MPs is covered in a separate project with the Department of Agriculture, Water and the Environment. Consultation with the Department, AFMA and stakeholders is an essential component of the MP process.

The preliminary reconditioning of operating models for the 2020 stock assessment will integrate new data available through the 2020 data exchange and may result in changes to the reference set of operating models. The preliminary reconditioning will include the new gene-tagging data for the first time in the stock assessment.

The SBT inter-sessional science project also includes the work on routine otolith archiving, ageing and developing age-length keys for the Australian SBT surface fishery. Provision of these data is a requirement of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT).

3 Objectives

1. Provide scientific advice and support to AFMA and SBTMAC and participate in the relevant domestic and international meetings. Participate in planning and technical consultation meetings, CCSBT ESC and OMMP meetings, inter-sessional webinars, Scientific Research Program review and planning, and review of exceptional circumstances.
2. Participate in the 2020 CCSBT data exchange.
3. Prepare for the 2020 stock assessment. Commence preliminary reconditioning of the SBT operating models with updated data for the 2020 assessment of stock status.
4. Undertake the routine otolith archiving, ageing and developing age-length keys for the Australian SBT surface fishery and provide data to CCSBT.

4 Results and Discussion

The project has delivered results against each of the objects:

4.1 Objective 1: Scientific advice and support to AFMA and SBTMAC.

Provide scientific advice and support to AFMA and SBTMAC and participate in the relevant domestic and international meetings. Participate in planning and technical consultation meetings, CCSBT ESC and OMMP meetings, inter-sessional webinars, Scientific Research Program review and planning, and review of exceptional circumstances.

CSIRO (Preece, Davies and Hillary) participated at the CCSBT Scientific Committee meeting in Cape Town, South Africa, Sept 2-7, 2019, and the technical meeting 1st September 2019. They contributed to the Australian delegation planning and consultation sessions held prior to the OMMP technical meeting (June 2019) and ESC meeting. Meetings were held with the AFMA, SBT Industry, ABARES and Dept Agriculture (AFMA, ABARES and Dept: 12 June, 16 July (in Canberra), 14 Aug and 27 Aug; Industry meeting 21 Aug Hobart; AFMA briefing 27 Aug Hobart, SBTMAC 25 Sept). A debrief on CCSBT outcomes was held on 22 Nov 2019.

CSIRO provided advice to the Australian delegation on performance of the candidate management procedures (MPs) being considered at the ESC, the updates to the SBT operating models, outcomes of the meta-rules process and consideration of exceptional circumstances, and updates to Australian, CCSBT and international scientific research programs. Briefing notes were provided to AFMA and the Department on alternative tuning levels for Candidate MPs (Preece et al., 2019a) and on the value of the CCSBT research programs (Preece et al., 2019b).

CSIRO were significant participants in the CCSBT meetings providing scientific reports, papers and expertise to the meetings. Preece and Davies rapporteured key sections of the scientific discussions and technical agreements for the meeting reports. Three key papers, planned outputs from this project, were presented in addition to papers funded though other projects.

The integration of the gene-tagging data into the SBT operating model, was described in Hillary et al. (2019a, b). These papers also provided details on and the updates to the operating models and fits to data from inclusion of 2 additional years of data since the 2017 stock assessment. These key updates to the SBT operating models were essential for final tuning and testing of candidate management procedures with the most up-to-date data before selection and recommendation of an MP to the commission in 2019. These changes to the OMs allowed for simulation of the gene-tagging data collection process and use of the simulated data in the candidate MPs. The 2019 update to the OMs did not included full reconditioning to the new data or review of the reference set of models. The full reconditioning will occur for the 2020 stock assessment, with preliminary reconditioning underway for the 2020 OMMP meeting.

Preece et al. (2019c) provided a summary of the meta-rules process and consideration of exceptional circumstances in relation to the 2020 TAC. Exceptional circumstances are events, or observations, that are outside the range for which the CCSBT MP was tested and, therefore, indicate that application of the total allowable catch (TAC) generated by the management procedure (MP) may be highly risky, or highly inappropriate. If exceptional circumstances exist, the “process for action” examines the severity (and implications) of the exceptional circumstances for the operation of the MP, and the types of actions that may be considered. In 2019, the implications of the very high longline CPUE estimate for 2018 were reviewed, in addition to four potential exceptional circumstances issues which had been examined in previous years. The updated CPUE time-series (Itoh and Takahashi, 2019) have shown an increasing trend in CPUE since 2007, with very high estimates for 2018 in the base series. The high estimate for 2018 is affected by catch-rates assumed in unfished squares (which have historically been fished). Investigation of the GLM effects on the series, noted that the historical extent of the fishery has changed substantially over time with contraction of effort to fewer squares. It was noted that the 2018 CPUE estimate has no direct impact on the calculation of the 2020 TAC advice as the TAC was set back in 2016. None of the exceptional circumstances considered by the ESC indicated a need to change the 2020 TAC. The CPUE standardisation is of concern, however, for the implementation of the new Cape Town Management Procedure in 2020 to set the 2021-23 TAC and the 2020 stock assessment.

Meta-rules to accompany the new MP were discussed at the 2019 ESC. The metarules provide a schedule of events for timing of key steps in the implementation of the MP: the annual review of exceptional circumstances, 3-year blocks for TAC recommendations from the MP, 3 yearly assessment of stock status (off-set from year of TAC advice), and 6 -year period for review of MP performance. A draft of updated metarules is in preparation for delivery to the 2020 OMMP meeting or inter-sessional discussion (Preece et al, in prep), as agreed at the 2019 ESC.

CSIRO initiated a technical subgroup of participants to discuss a review of the CCSBT Scientific Research Program (SRP) and enlisted the new Advisory Panel member (Sean Cox) to Chair this group, with the aim of further broadening active engagement by other member scientists in activities funded under the SRP. Further work on the Scientific Research Program will continue through 2019 and 2020, and time for discussion on this was added to the 2020 Operating Models and Management Procedure meeting in June 2020. This has been delayed by COVID-19 travel restrictions to the OMMP meeting, however, and is currently removed from the June 2020 OMMP agenda. AFMA and Industry research needs were discussed at SBTMAC, and a wider research workshop in the 1st half of 2020 was planned, but this has also been disrupted by COVID-19 travel and meeting restrictions. CSIRO is continuing to discuss research ideas with stakeholders and will contribute to discussion inter-sessionally and at the September 2020 ESC.

Preece and Davies participated as observers at SBTMAC 2019 and provided summaries of research programs, scientific committee outcomes and future work plans. CSIRO’s SBT research funded through other agencies, is incorporated into the advice provided to AFMA. These programs of work in 2019-20 have included:

- The development of Candidate Management Procedures, funded by the Department of Agriculture, Water and the Environment. The 2019 Extended Commission has adopted the MP recommended by the ESC which was developed by CSIRO (Hillary et al, 2019c). This major piece of work, funded by the Department, has required regular consultation with AFMA and Industry. Alternative candidate MPs were developed (Hillary et al 2019d), including MPs that are fishery independent (i.e. only used the gene-tagging and close-kin data) to avoid the uncertainties in CPUE data (Preece et al. 2019 d,e).

- The close-kin adult abundance (Farley et al., 2019) and gene-tagging juvenile abundance monitoring programs (Preece et al, 2019f), funded by the CCSBT. Associated work on vertebrae ageing (Clear et al, 2019), and Indonesian age and length monitoring program (Sulistyaningsih et al., 2019). These programs have required the support of Industry for the sampling and data collection components of these programs.
- Contributions to the CCSBT Maturity workshop, Chaired by Jess Farley, CSIRO (Anon, 2019).

Preparation for the 2020 OMMP and ESC meetings, and implications of the COVID-19 related disruptions, was discussed with AFMA and the Department on 7th April and 17th April 2020. CSIRO has also participated in technical CPUE webinar meetings in preparation for the 2020 stock assessment on 18 March, 13th May, and 28th May 2020.

4.2 Objective 2. Participate in the 2020 CCSBT data exchange.

The 2020 CCSBT scientific data exchange has been completed with data provided on time. CSIRO has provided the raised catch at age for the Australian surface and longline fisheries, and the Japanese longline nominal CPUE series to the CCSBT data exchange. Direct ageing data for the Australian Surface Fishery are up to date but no new data have been provided to the CCSBT this year (discussed in 4.4 below).

Additional data were provided to the data exchange in relation to projects funded by the Commission. These included a gene-tagging abundance estimate from year 3 of the program, and new parent-offspring and half-sibling close-kin data.

4.3 Objective 3. Prepare for the 2020 stock assessment.

Prepare for the 2020 stock assessment. Commence preliminary reconditioning of the SBT operating models with updated data, for the 2020 assessment of stock status.

The June 2020 OMMP meeting will be held via video conference due to COVID-19 related travel restrictions. The meeting discussion time will be restricted to only 1.5-2 hours per day because of the participants' very wide range of international time zones and practical constraints of conducting highly technical meetings via video conference. The agenda has been modified only slightly and CSIRO has been involved in discussions on this with AFMA, the Department and CCSBT. There are substantial risks that this shortened discussion and limited interaction will leave some members in a difficult position with respect to fully briefing their Commissioners. A decision on whether the ESC meeting will be held in Tokyo or via webinar is expected in early July. The stock assessment is not essential for TAC advice, as this advice comes solely from the MP, but is still planned to proceed and therefore preliminary reconditioning work is underway.

The preparation of the input data file for running reconditioning of OMs is in progress and will be completed when all the CPUE series to be considered at the OMMP have been provided. The Japanese longline CPUE series which has been standardised using the previously agreed methods shows an unusually high value for 2018, which is not supported by the data. This has been discussed in webinars held in March (18th) and May (13th and 28th) 2020, and alternative CPUE series for the preliminary reconditioning of the OMs for the stock assessment are being investigated.

The OM code was updated in 2019 to allow for inclusion of the gene-tagging data. The 2020 assessment will be the first assessment to include these data. A paper on the preliminary reconditioning and fit to data is in preparation for the OMMP meeting (Hillary et al, in prep).

4.4 Objective 4. Otolith archiving, ageing and age-length keys.

Undertake the routine otolith archiving, ageing and developing age-length keys for the Australian SBT surface fishery and provide data to CCSBT.

Over 200 otoliths were received from the Australian surface fishery in 2019. Of the otoliths received, 100 were selected and read by Fish Ageing Services. A small age bias was detected in 2019, which is being investigated, and the most recent years data has not yet been exchanged.

The direct ageing data exchanged to the CCSBT are up to date, as the CCSBT requirement is to provide data at least up to 2017 calendar year. The 2019 otoliths have been read by Fish Ageing Services and CSIRO and, when travel restrictions are lifted, they will collaborate to further examine the bias and interpretation of otolith edge formation.

5 Benefits / management outcomes

Stakeholders in the Southern Bluefin Tuna Fishery benefit from the implementation of a scientifically designed and tested management procedure (Hillary et al, 2016). The CCSBT MP is used to recommend the global TAC and encompasses meta-rules that provide a regular schedule and agreed processes for review of data, methods, and MP performance. The Bali Procedure (MP) adopted in 2011 has provided stability, increased certainty and increases in the Australian TAC, over the past 9 years. These benefits have been attested to by Industry, fisheries managers and E-NGOs. An additional benefit has been the time and strategic focus this orderly science and management process has provided to concentrate on planning, prioritising and securing the necessary funding for future inter-sessional science work plans as well as addressing strategic science needs. A new MP has been adopted in 2019, the Cape Town Procedure, which will provide TAC advice for rebuilding the stock beyond the interim rebuilding target. The 2020 stock assessment for which preliminary reconditioning is underway, will provide an update on stock status and progress in rebuilding of the stock.

Through this project, CSIRO has provided substantial input to the 2019 OMMP and ESC meetings; presenting papers (Appendix 1) and leading discussions that informed decisions made at the ESC and Extended Commission, providing technical input to meetings, summarising technical model changes and runs, rapporteured meeting reports and encouraging and broadening engagement in the ESC's activities.

The 2019 review of meta-rules identified several potential exceptional circumstances for consideration of actions to modify TAC. No actions to modify the 2020 TAC were recommended.

The 2019 changes to the operating models included new code for incorporation of juvenile abundance estimates from the gene-tagging program.

The 2019 ESC reviewed monitoring and research priorities. The CCSBT Scientific Research Program has made substantial investment in projects providing monitoring data for recruitment (gene-tagging) and adult abundance (close-kin mark recapture). CSIRO's development of cost-effective methods for monitoring the stock have been incorporated into the CCSBT Scientific Research Program and included in the Commission's budget in 2020. These research programs often have flow on effects for other Australian and International fisheries, potentially leading to improved monitoring, assessment and management of other global stocks.

The direct benefits of this project include: government, industry and community confidence that the SBT rebuilding strategy and MP implementation program is based on the best scientific advice; that previous TAC reductions and current TAC settings have been effective in reducing fishing mortality on the stock and are providing for rebuilding consistent with the Commission's rebuilding plan; and increases in the TAC, with associated economic returns to the Australian Industry and wider community.

Extension of results has been achieved through:

1) Submission of working papers and attendance at the CCSBT Extended Scientific committee (South Africa, September 2019), and the 1-day OMMP technical meeting (prior to the ESC) and the June 2019 OMMP meeting.

2) Communication with industry, stakeholders and government in meeting throughout the project.

3) Briefing papers and advice have been provided to AFMA, ABARES and the Department of Agriculture, and CSIRO has participated as observers at SBTMAC.

6 Conclusions

This SBT Inter-sessional Science 2019-20 project has covered the identified priority items of SBTMAC for the 2019 CCSBT work program, and the work up to June 2020. All the objectives of the project have been met.

CSIRO has delivered thorough, rigorous scientific advice on the key agenda items at the 2019 OMMP technical meeting and ESC meeting, and provided briefings, consultation and advice to AFMA, ABARES, Industry and SBTMAC. The CSIRO components of the CCSBT 2020 data exchange are complete, and preparation for preliminary reconditioning of operating models for the 2020 stock assessment has commenced. The work on development of a new scientific Research Program is now being supported by the Advisory Panel but will have to proceed inter-sessionally because it has been dropped from the June 2020 OMMP meeting agenda. The agenda has been reduced because of COVID-19 travel restrictions and the difficult international time zones that mean that the web meeting can only be conducted 1.5-2 hours each day.

A new MP, developed by CSIRO, has been adopted and will be used to recommend the TAC in 2020 for the 2021-2023 TAC block. TAC advice is usually offset from the years when stock status advice from the stock assessment is updated, but both will occur in 2020.

Outputs from this inter-sessional science project have been considered in depth by the OMMP and ESC scientist and are reflected in recommendations and advice of the ESC to the Commission, and by the Extended Commission in the 2019 funding decisions and approach to the future work program.

7 References

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Hillary RM, Preece AL and Davies CR. (2019a). Changes to SBT OM conditioning code. CCSBT-OMMP/1906/04

Hillary RM, Preece AL, Davies CR. (2019b) Updates to the SBT OM. CCSBT-ESC/1909/17

Hillary RM, Preece AL and Davies CR. (2019c). Performance of a revised candidate MP using all 3 input data sources. CCSBT-ESC/1909/16.

Hillary RM, Preece AL and Davies CR. (2019d). Updated candidate MP performance summary on reconditioned grid. CCSBT-OMMP/1906/5.

Hillary, R. M., Preece, A. L., Davies, C. R., Kurota, H., Sakai, O., Itoh, T., Parma, A. M., Butterworth, D. S., Ianelli, J. and Branch, T. A. (2016), A scientific alternative to moratoria for rebuilding depleted international tuna stocks. Fish Fish, 17: 469–482. doi:10.1111/faf.12121

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Sulistyaningsih R, Proctor C, Farley H. 2019. Update on the length and age distribution of southern bluefin tuna (SBT) in the Indonesian longline catch. CCSBT-ESC/1909/09

Appendix A Key Papers 2019-20

Key papers on the development of a new management procedure are included here. The papers marked ** were funded by CSIRO and the Department of Agriculture, Water and the Environment.

A.1 Hillary RM, Preece AL and Davies CR. (2019a). Changes to SBT OM conditioning code. CCSBT-OMMP/1906/04

A.2 Hillary RM, Preece AL, Davies CR (2019b) Updates to the SBT OM. CCSBT-ESC/1909/17

A.3 Preece AL, Davies CR, Hillary RM (2019c) Meta-rules: consideration of exceptional circumstances in 2019 and meta-rules for the new MP. CSIRO, Australia. CCSBT-ESC/1909/14

A.4 ** Hillary RM, Preece AL and Davies CR. (2019c). Performance of a revised candidate MP using all 3 input data sources. CCSBT-ESC/1909/16.

A.5 ** Preece AL, Hillary RM, Davies CR. (2019e). A candidate MP that uses only fishery independent data. CSIRO, Australia. CCSBT-ESC/1909/15.

Appendix A1

Hillary RM, Preece AL and Davies CR. (2019a). Changes to SBT OM conditioning code. CCSBT-OMMP/1906/04

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Changes to SBT OM conditioning code

Rich Hillary, Ann Preece, Campbell Davies

18th June 2019

CSIRO Oceans & Atmosphere
Battery Point, Hobart 7000, Tasmania, Australia.

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Contents

Abstract

The SBT operating models (OMs) are being reconditioned this year for MSE testing of candidate MPs. In addition to updating existing data,we also have two gene tagging estimates for 2016 and 2017 to include for the first time. This paper details the technical specifications of how the gene-tagging data are included in the SBT OM, and the relevant settings and fixed parameters required in the various OM configuration files.

1 Background

This year the OMMP and ESC will be resuming the MSE work begun in 2018 to develop a new MP for the CCSBT. A reconditioning update of the OM is required in 2019 and will include two gene tagging data points for 2016 and 2017 in the conditioning code. These data have already been included in projection code [1, 2] and the same assumptions about the generation of these data in the projections will be mirrored in the conditioning part of the OM.

2 Gene tagging process

The gene tagging data collection process is as follows:

1. In year y, T_y (assumed to be) 2 year old fish are tissue-sampled and re-released off Port Lincoln in South Australia **after** the surface fishery has caught all its fish
2. In year $y+1$, S_{y+1} (assumed to be) 3 year old fish are tissue-sampled in the post-processing facilities in Port Lincoln
3. In year $y+2$, R_{y+2} recaptures are found

We don't go into specifics about the length distribution of tagging and resampling, save that we do this to ensure the maximum chance of tagging 2 year old and resampling 3 year old fish.

3 Likelihood function

In the MP work, we use the simple Petersen estimator for the age 2 abundance in year y, $\widehat{N}_{y,2}$:

$$\widehat{N}_{y,2} = \frac{T_y S_{y+1}}{R_{y+2}},$$

with the Poisson approximation to the variance where the CV in abundance is assumed to be approximated by $1/\sqrt{R_{y+2}}$. For the conditioning of the OM we assume a more flexible distribution: the beta-binomial distribution. The underlying probability of recapturing a biopsied fish is as follows:

$$\pi^r_{y+2} = \frac{T_y}{q^{\mathrm{gt}} N_{y,2}},$$

where q^{gt} represents the fraction of age 2 juveniles available to be tagged in the GAB (default is 1). The other key parameter for the gene tagging likelihood is the over-dispersion coefficient, φ^{gt}: the degree to which the variance in the recaptures exceeds that assumed in the vanilla binomial distribution (i.e $\varphi^{\mathrm{gt}} \geq 1$). With the binomial ($\varphi^{\mathrm{gt}} \equiv 1$), we have the following likelihood:

$$\Lambda^{\mathrm{gt}}\left(R_{y+2} \,|\, S_{y+1}, \pi^r_{y+2}\right) \propto \left(\pi^r_{y+2}\right)^{R_{y+2}} \left(1-\pi^r_{y+2}\right)^{S_{y+1}-R_{y+2}}$$

For the over-dispersed case, $\varphi^{\text{gt}} > 1$, the likelihood is as follows:

$$\alpha^{\text{gt}} = \frac{\left(S_{y+1} - \varphi^{\text{gt}}\right)\pi^r_{y+2}}{\left(1-\pi^r_{y+2}\right)\left(\pi^r_{y+2} + \left(1-\pi^r_{y+2}\right)\left(\varphi^{\text{gt}}-1\right)\right)}$$

$$\beta^{\text{gt}} = \frac{\left(S_{y+1} - \varphi^{\text{gt}}\right)\pi^r_{y+2}}{\pi^r_{y+2} + \left(1-\pi^r_{y+2}\right)\left(\varphi^{\text{gt}}-1\right)}$$

$$\Lambda^{\text{gt}}\left(R_{y+2}\,|\,S_{y+1},\alpha^{\text{gt}},\beta^{\text{gt}}\right) \propto \frac{\Gamma\left(R_{y+2}+\alpha^{\text{gt}}\right)\Gamma\left(S_{y+1}-R_{y+2}+\beta^{\text{gt}}\right)\Gamma\left(\alpha^{\text{gt}}+\beta^{\text{gt}}\right)}{\Gamma\left(S_y+\alpha^{\text{gt}}+\beta^{\text{gt}}\right)\Gamma\left(\alpha^{\text{gt}}\right)\Gamma\left(\beta^{\text{gt}}\right)}$$

and $\Gamma()$ is the gamma function.

4 Settings required in OM configuration files

The data are included as follows in the `sbtdata20XX.dat` file as a table with the following columns: year of release, age of release, year of recapture, number of releases, number of resamples, number of matches. Table 4.1 shows the current data set.

Year of rel.	Age of rel.	Year of recap.	T	S	R
2016	2	2017	2,952	15,389	20
2017	2	2018	6,480	11,932	67

Table 4.1: *Summary of current gene tagging data.*

The remaining control parameters are located in the `sqrt.dat` file:

- `qgt` (q^{gt}): default is set to 1 (and assumed that $q^{\text{gt}} \leq 1$)
- `gtOD` (φ^{gt}): default is set to 1 (and $\varphi^{\text{gt}} \geq 1$)
- `gtsw`: 0/1 switch flag to turn GT data off/on (default set to 1)

5 Fits given reconditioned reference set of OMs

A full diagnostic check of the fits for all updated data sets will be undertaken for the stock assessment in 2020. However, given this is the first time the gene tagging data have been included in the OM, we do summarise how the reconditioned OM fits to these data. The approach taken in the past few years [3] is to simulate a particular data set from its predictive distribution (simulate from the likelihood while integrating across the model ensemble contained in the reference set). If the reference set of OMs was a true posterior, this would be the posterior predictive distribution; given we use the reference set as a proxy for the posterior we refer to it as the predictive distribution.

Figure 5.1 shows the observed and predictive distribution of (in terms of median and 95% credible interval) matches in the 2016 and 2017 gene tagging data (year we denote as year of release/year of abundance estimate). In both cases the median number of matches is slightly below the observed number, indicating a preference for lower age 2 abundance in the gene tagging data, but the credible interval easily encapsulates the data in both cases.

It might seem odd that these data are not fitted effectively perfectly, given there are no other data sets that currently observe these year-classes at the present time. There is, however, a reason-

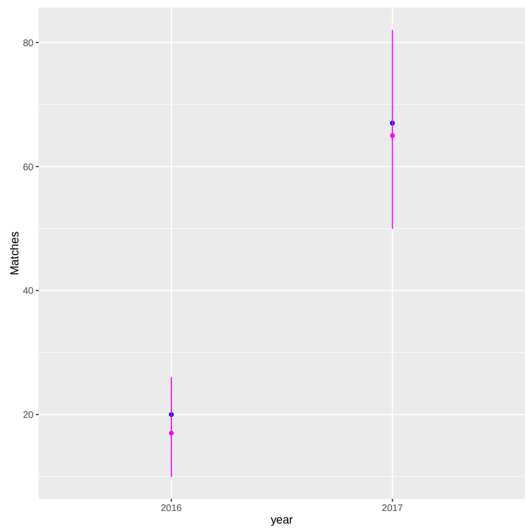

Figure 5.1: *Observed (blue) and predictive median and 95% credible interval (magenta) for the 2016 and 2017 gene tagging recaptures.*

ably informative prior on the year-class strength deviations in the OM, and with auto-correlation built in. The estimates of recruitment prior to 2016 were well above average (especially age 2 abundance in 2015), so built in to the recruitment deviation prior in 2016 and 2017 is a preference for above-average recruitment deviations. This is why the effect looks more obvious for 2016 (which follows the highest recruitment estimate for decades) than for 2017 (as the 2016 age 2 abundance was estimated closer to the expected level). The summary though would be that:

- The conditioning part of the OM has been modified to incorporate the gene tagging data using a flexible beta-binomial likelihood and is implemented as the data are simulated in projection part of the OM
- The data from 2016 and 2017 are fitted well by the reconditioned OM, but suggesting *slightly* lower 2016 and 2017 estimates of age 2 abundance coming from the previous OM and the recruitment deviation prior
- While being cautious about infering too much from only 2 estimates, the gene tagging data does seem to suggest that the previous run of above-average recruitment might be over

6 Acknowledgements

This work was funded by CSIRO and the Australian Fisheries Management Authority.

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[1] R. M Hillary, A. Preece, and C. R. Davies (2016) Methods for data generation in projections. *CCSBT–OMMP/1609/07*

[2] R. M Hillary, A. Preece, and C. R. Davies (2017) Updates required for new data sources and reconditioning of the CCSBT OM. *CCSBT–OMMP/1706/04*.

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Appendix A2

Hillary RM, Preece AL, Davies CR (2019b) Updates to the SBT OM. CCSBT-ESC/1909/17

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Updates to the SBT OM

Rich Hillary, Ann Preece, Campbell Davies

CCSBT-ESC/1909/17

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Copyright and disclaimer

Important disclaimer

Contents

Abstract

The SBT operating models (OMs) are being reconditioned this year for MSE testing of candidate MPs. In addition to updating existing data, we also have gene tagging estimates of abundance of 2 year olds for 2016 and 2017 to include for the first time. This paper details the technical specifications of how the gene-tagging data are included in the SBT OM, and the relevant settings and fixed parameters required in the various OM configuration files. It also explores the fits to the data sources for the reconditioned OM. Finally, we explore the LL1 size data as used in the OM for evidence of the strength of the large estimated 2013 year-class.

1 Background

This year the OMMP and ESC have resumed the MSE work begun in 2018 to develop a new MP for the CCSBT. A reconditioning update of the OM is required in 2019. This update will include two gene tagging data points, one for for 2016 and for 2017, in the conditioning code. These data have already been included in projection code [1, 2] and the same assumptions about the generation of these data in the projections are mirrored in the conditioning part of the OM.

2 Gene tagging process & likelihood

The gene tagging data collection process is as follows:

1. In year y, T_y (assumed to be) 2 year old fish are tissue-sampled and re-released in the Great Australian Bight, South Australia **after** the surface fishery has caught all its TAC
2. In year $y+1$, S_{y+1} (assumed to be) 3 year old fish are tissue-sampled in the processing facilities in Port Lincoln through-out the harvest period
3. In year $y+2$, R_{y+2} recaptures are detected and data are available for inclusion in models

We don't go into specifics about the length distribution of tagging and resampling, here, save that we do this to ensure the maximum chance of tagging 2 year old and resampling 3 year old fish [3, 4] . In the MP work, we use the simple Petersen estimator for the age 2 abundance in year y, $\widehat{N}_{y,2}$:

$$\widehat{N}_{y,2} = \frac{T_y S_{y+1}}{R_{y+2}},$$

with the Poisson approximation to the variance where the CV in abundance is assumed to be approximated by $1/\sqrt{R_{y+2}}$. For the conditioning of the OM we assume a more flexible distribution: the beta-binomial distribution. The underlying probability of recapturing a biopsied fish is as follows:

$$\pi^r_{y+2} = \frac{T_y}{q^{\text{gt}} N_{y,2}},$$

where q^{gt} represents the fraction of age 2 juveniles available to be tagged in the GAB (default is 1). The other key parameter for the gene tagging likelihood is the over-dispersion coefficient, φ^{gt}: the degree to which the variance in the recaptures exceeds that assumed in the vanilla binomial distribution (i.e $\varphi^{\text{gt}} \geq 1$). With the binomial ($\varphi^{\text{gt}} \equiv 1$), we have the following likelihood:

$$\Lambda^{\text{gt}}\left(R_{y+2} \,|\, S_{y+1}, \pi^r_{y+2}\right) \propto \left(\pi^r_{y+2}\right)^{R_{y+2}} \left(1-\pi^r_{y+2}\right)^{S_{y+1}-R_{y+2}}$$

For the over-dispersed case, $\varphi^{\text{gt}} > 1$, the likelihood is as follows:

$$\alpha^{\text{gt}} = \frac{\left(S_{y+1} - \varphi^{\text{gt}}\right)\pi^r_{y+2}}{\left(1-\pi^r_{y+2}\right)\left(\pi^r_{y+2} + \left(1-\pi^r_{y+2}\right)\left(\varphi^{\text{gt}}-1\right)\right)}$$

$$\beta^{\text{gt}} = \frac{\left(S_{y+1} - \varphi^{\text{gt}}\right)\pi^r_{y+2}}{\pi^r_{y+2} + \left(1-\pi^r_{y+2}\right)\left(\varphi^{\text{gt}}-1\right)}$$

$$\Lambda^{\text{gt}}\left(R_{y+2}\,|\,S_{y+1},\alpha^{\text{gt}},\beta^{\text{gt}}\right) \propto \frac{\Gamma\left(R_{y+2}+\alpha^{\text{gt}}\right)\Gamma\left(S_{y+1}-R_{y+2}+\beta^{\text{gt}}\right)\Gamma\left(\alpha^{\text{gt}}+\beta^{\text{gt}}\right)}{\Gamma\left(S_y+\alpha^{\text{gt}}+\beta^{\text{gt}}\right)\Gamma\left(\alpha^{\text{gt}}\right)\Gamma\left(\beta^{\text{gt}}\right)}$$

and $\Gamma()$ is the gamma function.

3 Settings required in OM configuration files

The data are included as follows in the `sbtdata2018.dat` file as a table with the following columns: year of release, age of release, year of recapture, number of releases, number of resamples, number of matches. Table 4.1 shows the current data set.

Year of rel.	Age of rel.	Year of recap.	T	S	R
2016	2	2017	2,952	15,389	20
2017	2	2018	6,480	11,932	67

Table 3.1: *Summary of current gene tagging data.*

The remaining control parameters are located in the `sqrt.dat` file:

- `qgt` (q^{gt}): default is set to 1 (and assumed that $q^{\text{gt}} \leq 1$)
- `gtOD` (φ^{gt}): default is set to 1 (and $\varphi^{\text{gt}} \geq 1$)
- `gtsw`: 0/1 switch flag to turn GT data off/on (default set to 1)

4 Abundance fits given reconditioned reference set of OMs

The following updated and new sources of data have been included in the 2019 reconditioning:

- Catch biomass, composition and Japanese longline CPUE up to and including 2018
- CKMR POP and HSP data up to and including sampling year 2017, which would observe the adult population up to and including 2014
- The two gene tagging estimates of age 2 abundance in 2016 and 2017

A full diagnostic check of the fits for all updated data sets will be undertaken for the stock assessment scheduled for 2020. However, given this is the first time the gene tagging data have been included in the OM, we do summarise how the reconditioned OM fits to these data. The approach taken in the past few years [5] is to simulate a particular data set from its predictive distribution (simulate from the likelihood while integrating across the model ensemble included in the reference set). If the reference set of OMs was a true posterior, this would be the posterior predictive distribution; given we use the reference set as a proxy for the posterior we refer to it as the predictive distribution.

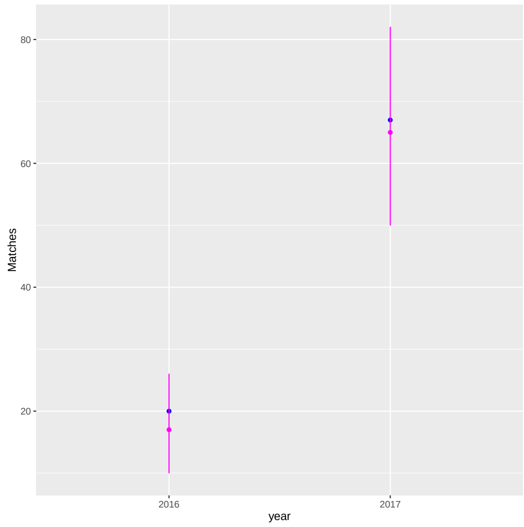

Figure 4.1: *Observed (blue) and predictive median and 95% credible interval (magenta) for the 2016 and 2017 gene tagging recaptures.*

Figure 5.1 shows the observed and predictive distribution of (in terms of median and 95% credible interval) matches in the 2016 and 2017 gene tagging data (year is denoted as year of release/year of abundance estimate). In both cases the median number of matches is slightly below the observed number, indicating a slight preference for lower age 2 abundance in the gene tagging data, but the credible interval easily encapsulates the data in both cases.

It might seem odd that these data are not fitted effectively perfectly, given no other data sets in the OMs observe these year-classes at the present time. There is, however, a reasonably informative prior on the year-class strength deviations in the OM, and with auto-correlation built in. The estimates of recruitment prior to 2016 were well above average (especially age 2 abundance in 2015), so built in to the recruitment deviation prior in 2016 and 2017 is a preference for above-average recruitment deviations. This is why the effect lis more apparent for 2016 (which follows the highest recruitment estimate for decades) than for 2017 (as the 2016 age 2 abundance was estimated closer to the expected level). In summary:

- The conditioning part of the OM has been modified to incorporate the gene tagging data using a flexible beta-binomial likelihood and is implemented in the same manner as the data are simulated in projection part of the OM
- The data from 2016 and 2017 are fitted well in the reconditioned OM, but suggest *slightly* lower 2016 and 2017 estimates of age 2 abundance than those coming from the previous OM and the recruitment deviation prior
- The 2017 gene tagging estimate is below the previous run of above-average recruitment.

The grid configuration agreed to in 2017 for MP testing is detailed in Table 3.1 and, in line with previous reconditionings, we sample 2,000 times from the current suite of 432 using the resampling scheme outlined in Table 3.1. We summarise the `base18UAM1` grid of operating models, given this is our current reference case for the MSE work. For the best fitting grid element, the fits to the abundance data (CPUE, aerial survey and gene-tagging) are shown in Figure 3.1. The fits to the conventional tagging data are provided in Figure 3.2; and the aggregated fits to the CKMR POP and HSP data (as per [5]) are detailed in Figure 3.3.

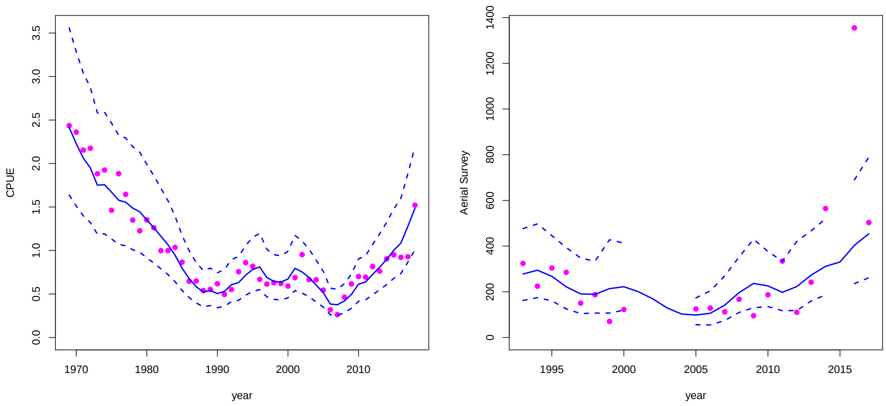

Figure 4.2: *Observed (magenta) and predicted median and 95% CI (blue) for the Japanese longline CPUE (left) and aerial survey (right) indices.*

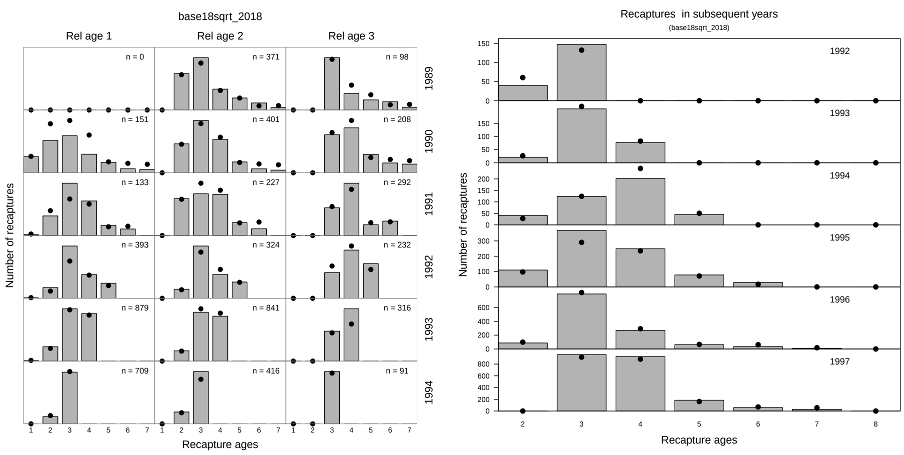

Figure 4.3: *Disaggregated (left) and pooled (right) 1990s tagging data fitting summaries.*

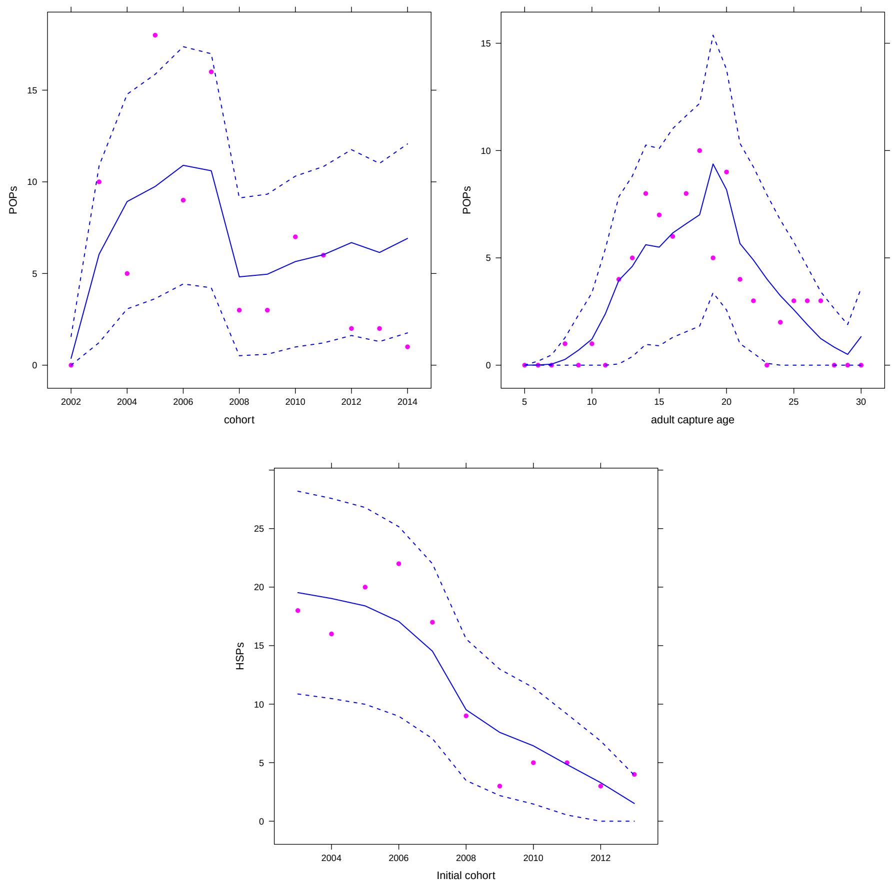

Figure 4.4: *Observed (magenta) and predicted median and 95% CI (blue) for fits to the POP data aggregated to the cohort (top left) and adult capture age (top right) levels, and the HSP data aggregated to the initial comparison cohort level (bottom).*

Parameter	Values	Prior	Resampling	CumulN
Steepness	$\{0.6, 0.7, 0.8\}$	Uniform	Prior	3
M_0	$\{0.35, 0.4, 0.45, 0.5\}$	Uniform	Objf	12
M_{10}	$\{0.0.5, 0.085, 0.12\}$	Uniform	Objf	36
ω	$\{1\}$	Uniform	Prior	36
CPUE ind.	$\{2, 3\}$	Uniform	Prior	72
CPUE ages	$\{4, 18\}$ & $\{8, 12\}$	$\{0.67, 0.33\}$	Prior	144
ψ	$\{1.5, 1.75, 2\}$	$\{0.25, 0.5, 0.25\}$	Prior	432

Table 4.1: *Summary of the agreed grid configuration for the 2019 reconditioning*

The fits to the CPUE are similar to previous years, and the notable increase in CPUE in 2018 is fitted well (driven by the already large estimate of recruitment in 2013 driven by the 2016 aerial survey). The fits to the aerial survey haven't changed since the previous assessment [5] and the fit to conventional tagging data are also similar to previous years. The fits to the aggregated POP data are similar to previous years but there is a slight trend in number of POPs for the most recent juvenile birth years (2012–2014) being over-estimated. Apart from the last point which is just outside the bounds, there is no clear significant misfit, and the data for these cohorts will be not be static - in the coming years we will compare new adults to juveniles born in these years and so could detect more matches which will change this trend. The fits to the adult capture age lof the POPs is good as are the HSP fits when aggregated to the initial cohort level. It is also worth noting the sample sizes for the CKMR monitoring are based on previous OMs. Given the updated estimates of status and population dynamics since the original design study and the use of CKMR for stock assessment, monitoring the rebuilding plan and input to candidate MPs, a review of this monitoring program and associated sample sizes should be a priority to ensure appropriate samples sizes in the future.

Variable	TRO depletion	B_{10+} depletion	F/F_{msy}	B/B_{msy}	B_{msy}/B_0
Summary	0.17 (0.15–0.21)	0.14 (0.12–0.17)	0.55 (0.41–0.74)	0.64 (0.47–0.91)	0.27 (0.22–0.32)

Table 4.2: *Population dynamic summaries (median and 90% CI) for the reconditioned OM.*

The main population dynamic summaries can be found in Table 3.2 (for the reference set which includes the UAM1 scenario). Current TRO depletion has a median (and 90% CI) of 0.17 (0.15–0.21) so higher than the 0.13 estimate of 2017 [5] but consistent with the projections done in both 2017 and 2018. Current estimates of F are just above half of F_{msy} with a very low probability of exceeding it. The ratio of the adult biomass at MSY relative to the unfished level is also consistent with previous estimates: 0.27 (0.22–0.32).

5 Effect of large 2013 recruitment on LL1 OM data

An issue that arose at the OMMP meeting was that the recent run of good recruitment - and in particular the 2013 year class - seemed consistent with the signals in both the aerial survey data and the Japanese long-line CPUE abundance index [6] but was seemingly not apparent in the LL1 size frequency or, specifically, the Japanese long-line data [7]. In this section we explore whether it is reasonable to *expect* the LL1 (or Japanese) size data to show consistent tracking of an individual strong year class, given the large variation in length at age for SBT.

It is true for almost all teleost fish that length tends to become a poor indicator of individual, age as the overall growth of the fish slows down and the variability in individual length given age increases. In the case of SBT, after age 3 it becomes increasingly difficult to define a size range that would be expected to include *only* one age-class. So, either visually inspecting length data or cohort-slicing the length data to obtain estimates of the underlying age distribution will become increasingly uninformative as the size of the animals increases. Only by collecting direct age data can one get a sense of the actual age distribution within a given set of length data above around 100cm - which is where the vast majority of the LL1 data are reported to be.

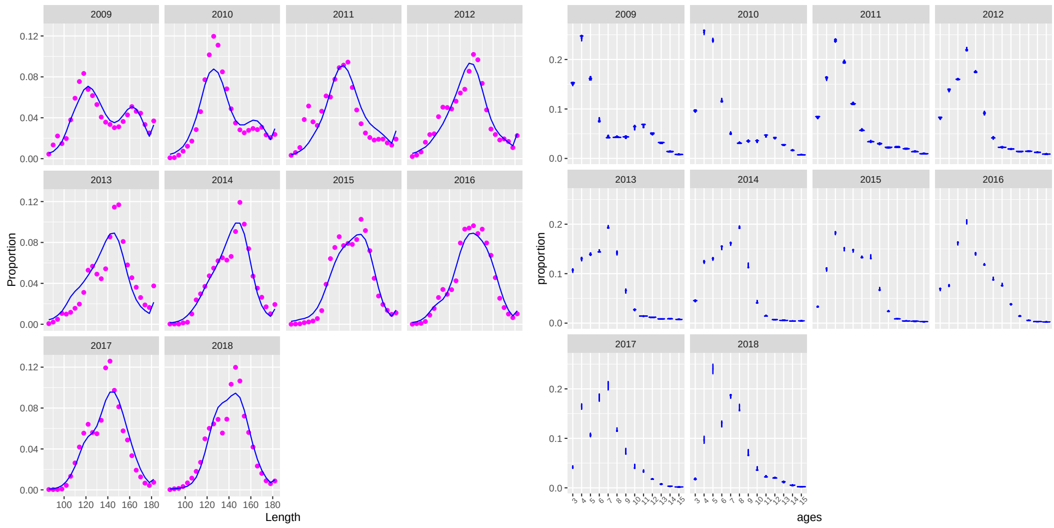

Figure 5.1: *On the left the observed (magenta points) and predicted (blue lines) LL1 size frequency from 2009 to 2019. On the right violin plot summaries of the predicted age distribution in the long-line size data for the same years for ages 3–15.*

To make this point quantitatively, Figure 5.1 shows the observed and predicted LL1 data from 2009 to 2018. It also shows the predicted age distribution within the LL1 size data across all grid runs: the distribution-at-age derived from multiplying the true numbers-at-age in the population by the LL1 selectivity-at-age. The effect can be seen across several different years, but focussing on 2017 and 2018 when the 2013 age class would be 4 and 5 years old, respectively, and approaching full selectivity in the LL1 data. In the observed and - importantly - predicted length data there are no obvious peaks around 117cm and 127cm - the mean lengths at age 4 and 5, respectively. Looking at the predicted age distribution, however, it is apparent that the 2013 year class in 2017 makes up over 10% of the LL1 catch-at-age and in 2018 that increases to almost 25% of the LL1 catch-at-age.

The OM clearly estimates a large year-class for 2013 - with or without the 2016 aerial survey and the 2018 CPUE index. When both are included it is by far the largest estimate of recruitment seen over the last 4 decades. Yet, in the predicted length data there is no obvious peak centred around the mean length of this age-class - the argument essentially being made in [7] in terms of questioning why this year-class doesn't appear to be obvious in the observed size data. The point is really that we would not *expect* to see such a peak, given the variability in length-at-age for the ages likely being currently exploited by the LL1 fleet. Only by collecting direct age data representative (spatiotemporally) of the LL1 catch would we be able to make some kind of statement on the size of the 2013 recruitment using the LL1 size data. So, we don't think we can conclude that the LL1 size data do not appear to confirm the large estimated 2013 year-class. At most, the data are compatible with the large estimate as there are no obvious issues with the fits to the 2017 and 2018 LL1 size data. The important point is that we would not expect these data to be informative for specific **individual** year-class strength. Where they have been informative, for example, was in the extreme case of the run of very low year-classes from 1999–2002, as they were quite clearly seen to be absent for a number of years in the left-hand side of the LL1 length frequency data.

6 Discussion

The CCSBT OM has been reconditioned for data up to and including 2018 as well as the first inclusion of the two gene tagging data points. The new likelihood function for the gene tagging data was described - with the current default being a binomial distribution. We have, however, programmed in the option for the more flexible beta-binomial distribution to allow for over-dispersion in these data, very similar to how this is done for the 1990s tagging data. It will take a number of years, however, before we can in-principle estimate of the potential over-dispersion factor as with only two data points the estimate would be highly uncertain. In any case the two data points are fitted very well, given little else in the data sets observes those year-classes currently, so it would be not just uncertain but effectively zero (i.e. reduced to a binomial anyway). The base grid agreed at the previous ESC (and subsequently confirmed at the 2019 OMMP) was used and the UAM1 unaccounted mortality scenario was used to create the reference set of OMs used in the MSE work. The data were generally fitted well - including the new gene tagging data - and there were no obvious issues with the resulting OM that would suggest it could not be used in the MP testing work this year.

One issue relating to the large estimated 2013 year-class, largely driven by first the 2016 aerial survey index and then the 2018 LL1 CPUE index, is why it does not appear to give a strong signal in the LL1 (and Japanese) length frequency data [7]. We demonstrated that even the model predicted size frequency data do not show obvious peaks centered around the mean length of this 2013 year class in both 2017 and 2018 (when it would be 4 and 5 years old, respectively) yet the year-class is the largest one estimated for over 4 decades. What *is* very apparent is that the model predicted age distribution in the LL1 data show this year class as fairly strong at age 4 (more than 10% of the total catch) and very strong at age 5 (almost a quarter of the total catch).The variability in size-at-age at the sizes caught in the LL1 and Japanese fleets means that length frequency data are essentially uninformative on **individual** year-class strength - clearly so even for very large estimated recruitments. So we do not think it is appropriate to say that the LL1 and Japanese size frequency data do not appear to confirm the presence of a large 2013 year-class. The data are consistent with the model estimated 2013 year-class - the data are fitted fine in both 2017 and 2018 - but could not be expected to be informative on a single year-class.

7 Acknowledgements

This work was funded by CSIRO and the Australian Fisheries Management Authority.

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[7] Itoh, T. (2019) Change in operation pattern of Japanese southern bluefin tuna longliners in the 2018 fishing season. *CCSBT–OMMP/1906/08*.

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Appendix A3

Preece AL, Davies CR, Hillary RM (2019c) Meta-rules: consideration of exceptional circumstances in 2019 and meta-rules for the new MP. CSIRO, Australia. CCSBT-ESC/1909/14

CCSBT-ESC/1909/14
(ESC Agenda item 11,1)

Australia's National
Science Agency

Meta-rules: consideration of exceptional circumstances in 2019 and meta-rules for the new MP

Preece AL, Davies CR, Hillary RM
CCSBT-ESC/1909/14

Prepared for the CCSBT Extended Scientific Committee for the Twenty Fourth Meeting of the Scientific Committee

2-7 September 2019, Cape Town, South Africa

Citation

Preece AL, Davies CR, Hillary RM (2019) Meta-rules: consideration of exceptional circumstances in 2019 and meta-rules for the new MP. CSIRO, Australia. CCSBT-ESC/1909/14.

Acknowledgments

This work was funded by AFMA and CSIRO

Contents

Abstract

The annual review of the CCSBT Management Procedure (MP) input data series, and stock and fishery indicators, is intended to identify conditions and/or circumstances that may represent a substantial departure from conditions against which the MP was tested, termed "exceptional circumstances", and where appropriate recommend action. In 2019, the ESC will review MP implementation in the context of the TAC set for 2020, which was recommended using the MP at the 2016 meeting of the ESC.

A potential new exceptional circumstance in 2019 is the very high Japanese longline CPUE estimate for 2018. Exceptional circumstances that have been identified and assessed in previous years and continue to exist are: 1) the planned absence of the index of recruitment from the scientific aerial survey in 2018 and 2019; 2) changes in estimates of the population dynamics and productivity of the stock identified in 2017 through the updated stock assessment; 3) the shift in size distribution, towards small fish, in the Indonesian spawning ground fishery since 2013; 4) the potential for total catches (members and non-members) to be greater than the TAC (either annually or over the 3 year quota block). These issues, and their cumulative impacts, will need to be considered by the ESC and principles and process for action agreed, if required.

As part of the recommendation of a new MP in 2019, the ESC will need to consider adopting meta-rules that will provide a schedule of activities and a safety-net around the MP TAC recommendations for circumstances or events not included in the MSE testing phase. The meta-rules schedule of activities would include the frequency of: evaluation of exceptional circumstances, TAC setting, assessment of stock status and periodic review of MP performance. The meta-rules will continue to be an essential component of the MP that provides structure and confidence for CCSBT members and stakeholders and transparency in the TAC decisions of the CCSBT.

1 Introduction

The SBT MP meta-rules' schedule of activities includes an annual process for identifying exceptional circumstances. Exceptional circumstances are events, or observations, that are outside the range for which the CCSBT MP was tested and, therefore, indicate that application of the total allowable catch (TAC) generated by the management procedure (MP) may be highly risky, or highly inappropriate.

The exceptional circumstances process under the meta-rules involves the following three steps:

1. Determining whether exceptional circumstances exist;

2. A "process for action" that examines the severity (and implications) of the exceptional circumstances for the operation of the MP, and the types of actions that may be considered;

3. "Principles for action" that determine how recommendations from the MP might be altered, if at all, based on the most recent reconditioning of the Operating Model (OM).

The meta-rules process as adopted by CCSBT can be found at Attachment 10 of the 2013 ESC report (Anon, 2013).

The meta-rules schedule of activities for implementation of the MP TAC specifies frequency of TAC setting, stock assessment, MP review and the consideration of exceptional circumstances. The consideration of exceptional circumstances has identified issues that the Commission or ESC have subsequently responded to, where required, e.g. action on accounting for all sources of mortality and dealing with missing data. The meta-rules provide a safety-net around the MP TAC recommendations and will continue to be an essential component of the implementation of the new MP being developed to replace the Bali Procedure.

2 Potential exceptional circumstances in 2019

The following items may represent exceptional circumstances:

1. The very high longline CPUE estimate in 2018;
2. the pre-arranged absence of aerial survey data for 2018 and 2019;
3. changes in estimates of the population dynamics and productivity of the stock since the tuning and implementation of the MP in 2011;
4. the shift in size distribution towards small fish in the Indonesian spawning ground fishery since 2013; and,
5. potential for fishing mortality (from members and non-members) to be greater than the TAC recommended by the MP.

The first item is new in 2019, and the remaining four were reviewed at the 2017 and 2018 ESCs (Preece et al., 2017, 2018a; Anon, 2017, 2018) and are only briefly addressed again here.

In considering the potential for exceptional circumstances arising from these issues, we examine whether: 1) the inputs to the MP are affected, 2) the population dynamics are potentially significantly different from those for which the MP was tested (as defined by the 2011 Reference and Robustness sets of OMs), 3) the fishery or fishing operations have changed substantially, 4) total removals are greater than the MP's recommended TACs, and 5) if there are likely to be impacts on the performance of the SBT rebuilding plan as a result.

The events are considered individually, however, the implications of the combination of events for the performance of the MP and the ability of the ESC to provide robust advice on the status and trends of the stock should also be considered. It is possible that additional exceptional circumstances may also be identified at the ESC's annual review of stock and fishery indicators.

2.1 High longline CPUE estimate in 2018

The updated CPUE time-series (Itoh and Takahashi, 2019) have shown an increasing trend in CPUE since 2007, with very high estimates for 2018 in the base series. The 2018 data point appears to be highly influenced by high catch rates in statistical area 8, which affect the catch-rates assumed in unfished squares (which have historically been fished). Investigation of the GLM effects on the series, noted that the historical extent of the fishery has changed substantially over time with contraction of effort to fewer squares. Takahashi (2019, pers. comm.) has noted that the high value is not outside of the range against which the MP was tested, and therefore it would not trigger exceptional circumstances. This 2018 data point (and the CPUE trend), is a positive indicator for the fishery and has no direct impact on the calculation of the 2020 TAC advice as the TAC was set back in 2016. Therefore, we do not recommend any modification of the 2020 TAC. We do note that these data are being considered for use in the new MP and will therefore need to be further evaluated at the 2019 ESC, and in preparation for the next stock assessment in 2020.

2.2 Absence of scientific aerial survey data

The scientific aerial survey was discontinued after completion of the 2017 survey. This was a planned cessation, agreed by the Commission in 2016. Members recognised the risks involved in foregoing future aerial survey results (Anon, 2016a,b), and that this cessation would mean that a new recruitment monitoring program and management procedure would need to be developed.

The gene-tagging program was developed and adopted as the replacement recruitment monitoring program. A pilot study commenced in 2016 and the program is now ongoing (Preece et al, 2018b). Two abundance estimates (the age 2 cohort in 2016 and 2017) from the gene-tagging program have been submitted through the CCSBT scientific data exchange. The gene-tagging and aerial survey abundance estimates are not directly comparable but there is some over-lap in the age classes surveyed (i.e. the aerial survey index is estimates of relative abundance of 2-4-year-olds, and gene-tagging data provides an absolute abundance of 2-year-olds).

In the context of the TAC recommended for 2020 and advice on exceptional circumstance, the absence of the aerial survey index in 2018 and 2019 means that there is no information on whether the aerial survey index would have been inside or outside the bounds of the trajectories from the operating models used when testing and tuning the MP adopted in 2011. To examine the potential impact of this exceptional circumstance, we can look at recent information on recruitment: 1) the last 3 points in the aerial survey index (2014, 2016-17) are substantially higher than the long term average of the series; 2) there is an increasing trend in stock assessment recruitment estimates since 2002; 3) the gene-tagging program has been established and has delivered the first two estimates of abundance of 2 year-olds, the first is similar to recent high recruitment estimates in the 2017 stock assessment and the second is below recent recruitment estimates, but not as low as the very low cohorts observed in 1999-2002. In summary, these recruitment indicators are primarily positive and suggest that the absence of the 2018 and 2019 aerial survey data does not require action with respect to the MP recommended TAC for 2020.

2.3 Changes in population dynamics and productivity of the stock

The 2017 stock assessment (Hillary et al., 2017; Anon 2017) indicated that there were substantial differences in the rebuilding timeframe and estimates of stock productivity from the 2011 operating models used to test and tune the current MP. The 2017 assessment indicated the improvement in stock status (relative depletion) over the most recent years and the potential for much earlier rebuilding to the interim target (70% probability of rebuilding to 20%B_0 by 2035) than previously anticipated. Sensitivity tests identified that recent high aerial survey results (2014 and 2016) were the most influential factors in the change in population dynamics since the 2014 assessment[1].

This potential exceptional circumstance was reviewed at the 2017 ESC, and noted the following:

1. Changes to the operating model do not affect the operation of the MP;
2. The changes in population dynamics are positive and lead to earlier rebuilding, even when the 2016 Aerial Survey data are excluded in sensitivity tests (Hillary et al., 2017);
3. The TAC increase recommended by the MP for the 2018-20 quota block was driven by the sustained positive trend in CPUE, with the aerial survey index having a relatively minor influence (Anon, 2016b).

The 2017 and 2018 ESCs concluded there was no reason to modify the 2018 and 2019 TAC recommendations (respectively). We suggest that this reasoning also applies to the 2020 TAC for this exceptional circumstance. The operating models were updated in 2019 for further testing of candidate management procedures. The updated population dynamics and results are consistent with the 2017 stock assessment, with further improvement in estimates of stock status (Hillary et al, 2019).

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[1] Close-kin parent-off-spring pair data were included in the operating models in 2014 which resulted in changes to the reference set. These were the influential factors in changes in population dynamics in 2014.

2.4 Potential changes in the Indonesian fishery selectivity

Since 2013, unusually large numbers of small fish have been recorded in the Indonesian catch monitoring data from Benoa, Bali (see Sulistyaningsih et al., 2018; Fahmi et al. 2019). New analysis of data covering the most recent years indicates that most of the small fish <160cm were caught off the spawning ground (Fahmi et al., 2019). Updating data back to 2013 is on-going and it is anticipated that any updated data will be available for the 2020 stock assessment. Until the data analysis is completed, the potential change in selectivity remains of concern in terms of their potential influence on the operating models for stock assessment and MP testing and, also, as input for Close-Kin Mark-Recapture abundance estimation. As these data do not directly influence the operation of the MP, we do not recommend modification to the MP TAC for 2020.

2.5 Total fishing mortalities exceeding the TAC

The design and simulation testing of the current MP (the Bali Procedure) assumed that all removals from the stock were accounted for, i.e. the implementation of the TAC was exact. Additional unaccounted mortality by members and non-members has the potential to undermine the MP-based rebuilding strategy of the Commission. Sensitivity tests, using the reconditioned models for the 2017 stock assessment and an additional catch scenario (UAM1) developed in 2014 (Anon, 2014), indicated that additional catches would impact rebuilding of the stock, but the rebuilding target would likely still be met (given the more optimistic population dynamics resulting from the 2017 reconditioning). The conclusion at previous ESC meetings were that if these unaccounted catches are occurring, they would trigger exceptional circumstances. The 2018 ESC agreed that the UAM1 additional catch scenario was still considered plausible (Anon, 2018). The ESC has agreed that an unaccounted mortality scenario (UAM1) will be included in the base set of operating models used for testing and tuning candidate MPs. This mechanism is intended to improve the robustness of the new MP to uncertainty in total catches and, ideally, avoid the triggering of exceptional circumstances due to this uncertainty in the future.

Accounting for sources of additional mortalities by members has progressed, with the Extended Commission's common definition for member's "attributable catch". Members have been required to account for all sources of mortality, as defined by the Commission, within their TAC since 2018 and report on their attributable catches to the ESC and Compliance Committee. If the catch quantities to be attributed to total catch by members do not account for their total fishing mortality, then the potential for impact on the rebuilding plan for SBT will remain.

Potential non-member catches are difficult to quantify (Anon, 2017; Edwards et al., 2016; 2019). The Commission has deducted 306t from the annual TAC available for allocation to members for the 2018-2020 TAC block as a temporary 'direct approach' aimed at mitigating the impact of unaccounted fishing mortality in this period on performance of the MP. This direct approach is applied only for the 2018-2020 block while a new MP is being developed that will be more robust to a certain level of unaccounted mortality.

The new estimates of potential non-member UAM provided by Edwards et al (2019) are larger than the estimates considered at the 2016 ESC due to changes in the data used (additional historical data, change in use of Japanese RTMP and ADJ (logbook) data to ADJ only, change in spatial allocation in IOTC and ICCAT data (5° square shift)). The new estimates for the more recent years (2015-2017) are substantially larger than the estimates for earlier years. This estimated increase in potential non-member catch is of concern, however as noted above, catches of this scale would impact on the level of rebuilding but the rebuilding target may still be met, given the optimistic population dynamics from the 2017 assessment. Therefore, we do not recommend that the MP TAC for 2020 needs to be adjusted. We do note, however, that the continued potential for total removals to be in excess of the TAC recommended by the MP and set by the Commission is a concern as, if they are in fact occurring, they will reduce the rate of stock rebuilding and undermine confidence in the monitoring, control and surveillance systems of the members and Commission.

3 Meta-rules for the new Management Procedure for TACs 2021 and beyond

The meta-rules for the MP adopted in 2011, have been an essential framework for orderly implementation and review of performance of the MP. They provide for structured examination of the potential existence of exceptional circumstances, their likely impacts on the MP and the process for action. They have been used by the ESC as part of providing TAC advice from 2012 through to the current year. The thorough and systematic annual examination of exceptional circumstances has assisted the ESC to provided transparent and clearly reasoned TAC recommendations to the Commission in the context of the objectives of the MP and the conditions under which it was tested. As they are currently documented, the meta-rules for the MP are intentionally not too particular or prescriptive and therefore could be adopted as part of the new meta-rules associated with the new MP.

The metarules also provide a schedule of events for timing of key steps in the implementation of the MP: the annual review of exceptional circumstances, 3-year blocks for TAC recommendations from the MP, 3 yearly assessment of stock status (off-set from year of TAC advice), and 6 -year period for review of MP performance. This schedule has provided structure for ESC planning and more time and resources to focus on specific research and monitoring priorities (e.g. CKMR and gene-tagging; refinements of the operating models). The ESC and Commission would be well served by carrying over an updated and revised schedule of activities for the implementation of the new MP. Assuming this proposal is adopted, in 2020 this would involve the annual review of exceptional circumstances, TAC advice via the MP (2020 with no lag, then resuming normal schedule in 2022, 2025, and onwards) and a full stock assessment.

The 3-year frequency for provision of stock status advice is short enough for relatively up-to-date advice on current stock status, given the relative slow dynamics of the SBT spawning stock, and long enough to see changes in key indicators from the previous assessment. The review of performance of the adopted MP could be considered in 2026 at which time the TAC will have been set for a period of 9 years, through to 2029 (i.e. in 2020 TAC will be set for 2021-23, in 2022 TAC will be set for 2024-26 and in 2025 TAC will be set for 2027-29). A review may be triggered earlier via the normal consideration of exceptional circumstances, if required.

The consideration of exceptional circumstances requires the specification of the operating models and test conditions used during the selection and final tuning of the adopted MP, as these are used as a reference in future years to determine whether indicators, our understanding of population dynamics, and MP inputs are still within the range considered during testing. Therefore, the current code, inputs and outputs need to be carefully archived as a reference for future comparisons. The operating model code is likely to be changed and reference sets altered for the provision of stock assessment advice, which for the CCSBT is a separate process to the TAC advice generated from MP models. The latter are not altered once adopted.

4 Conclusion

Through the meta-rules process we have examined: 1) changes in the (most likely) population dynamics since the MP was adopted in 2011, 2) the potential shift in selectivity in the Indonesian fishery, 3) the potential for total catches to be greater than the TAC, 4) the absence of the aerial survey data and impact on MP, and 5) the recent very high CPUE data point in the timeseries. The impacts of these issues have been considered in the context of the 2020 TAC (as recommended in 2016).

In summary, the change in the estimates of the population dynamics in the reconditioned operating models does not affect running of the MP or the 2020 TAC recommendation.

The Indonesian selectivity change is in the process of being investigated, and similarly, does not directly impact on the running of the MP or TAC advice.

The potential for total catches to be greater than the TAC remains a concern, although the CCSBT has made progress on accounting for these. Members now account for attributable catches, and an allowance (a reduction of the MP recommended TAC by 306t) for non-cooperating non-member catches has been made in the 2018-2020 TAC block. Estimates of potential non-member catches based on effort reported to IOTC and WCPFC are substantially larger than previous estimates.

The absence of aerial survey data in 2018 and 2019 technically triggers exceptional circumstances, however, it is mitigated by the high levels of recruitment in the most recent years of the survey and development of a replacement recruitment monitoring program, which has provided abundance estimates for use in candidate MPs (Hillary et al., 2019).

The high 2018 CPUE data point is understood to be within the range of values used to test the MP in 2011 and does not affect the 2020 TAC recommendation.

On the basis of this review, no change is recommended for the 2020 TAC.

The meta-rules process has provided a schedule of activities for the implementation and review of performance of the MP. We recommend that the existing meta-rules be considered for adoption with the new MP, to ensure continuity of review and transparency of TAC advice by the CCSBT under the new MP.

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Appendix A4

Hillary RM, Preece AL and Davies CR. (2019c). Performance of a revised candidate MP using all 3 input data sources. CCSBT-ESC/1909/16

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Performance of a revised candidate MP using all 3 input data sources

Rich Hillary, Ann Preece, Campbell Davies

CCSBT-ESC/1909/16

CSIRO Oceans & Atmosphere
Battery Point, Hobart 7000, Tasmania, Australia.

Contents

1 Background

This paper details the revised structure and performance of a candidate MP using all three of the input data sources (gene-tagging, close-kin, and LL CPUE). The revised MP is very similar to the one presented at the OMMP10 [1], but with some alterations to the CPUE part of the HCR. From the OMMP summary it was clear the previous version of the MP was prone to high probabilities of increasing the TAC in the first 2 decisions, then decreasing it again. This is one of the performance statistics that has been outlined as something we want to minimise for an MP tuned to the reference set of OMs [2].

The candidate MPs are tuned to the agreed reference set of OMs [2] for the current two tuning objectives:

1. Attain a TRO depletion level of 30% of the unfished level by 2035 and with probability 0.5
2. Attain a TRO depletion level of 35% of the unfished level by 2040 and with probability 0.5

and we assumed a tuning tolerance of $\pm 1\%$.

2 Revised MP structure

As noted, the previous **rh12** [1] CMP had a propensity to result in higher probabilities of two initial TAC increases then a decrease in the first three decision years [2]. Given this has been considered undesirable behaviour for CMPs - at least for the reference set of OMs - we needed to determine what was causing the behaviour, then redesign the CMP in a manner that addressed the issue.

The cause of this behaviour was clear: in the **rh12** HCR there was a trend term for the CPUE data and, as the strong year classes of recent years moved through the CPUE in the first 5–10 years of the projections a strong “up then down” trend is apparent in the CPUE. With a trend term, and the time-frame over which this “up then down” trend moves through the data (basically coincidental with the TAC decision years with the lag accounted for), the trend term in the HCR basically hard-wired in the “2 up then 1 down” TAC behaviour.

To fix the problem we modified the CPUE part of the HCR, by replacing the trend term with a functional response more like that used for the gene tagging part of the HCR. That is, within a threshold range of recent mean CPUE do not change the TAC, and when below/above the threshold range decrease/increase the TAC (with an asymmetric response allowed). The main difference between the CPUE implementation and the gene tagging component is that we attach a weighting to the functional response for the CPUE, as we want it to be more subtle than the gene tagging part of the HCR. The mathematical specification of the revised MP - **rh13** - is given in the Appendix.

Below we provide a high-level (relatively) explanation of the operation of the revised MP (**rh13**):

- **CPUE**: as described above, if the recent average CPUE is within a specified range it does nothing; above/below this range it tries to increase/decrease the TAC. The reactivity of this part of the HCR is directly linked to how close we are to the estimated rebuilding level (as estimated by the CKMR population model in the CMP). Prior to attaining the target rebuilding level, the CPUE part of the HCR is *more* reactive than when close to the target and after it has been achieved.

- **CKMR**: below the rebuilding objective level the HCR enforces a minimum rate of TRO rebuilding; for values above/below this rate it tries to increase/decrease the TAC. As the stock is estimated (from the CKMR model within the CMP) to approach the target rebuilding level the minimum increase rate is effectively reduced to to zero; this encourages TAC changes to keep the TRO at the rebuilding level
- **Gene tagging**: similar to the CPUE part of the HCR, there is a target range for the average 2 year old absolute abundance over recent years from the gene tagging. Below this specified range the HCR reduces the TAC strongly; above this range it is increases the TAC more slowly. The main difference for this part of the HCR, relative to the CPUE implementation, is there is no weighting on the reactivity. This is to allow the MP to respond rapidly enough to poor (or very good) recruitments detected in the gene tagging data.

3 Robustness tests

The priority robustness tests as agreed at OMMP10 were [2]:

1. **lowR5** (reclow5): reduce future recruitment by half during the first n years. For 2018, n was set to 5 (H)
2. **h=0.55** (h55): reduced grid with steepness of 0.55 *only* (and the two highest M_0 values in the full grid are also excluded) (M)
3. **IS20** (fis20): Indonesian selectivity flat from age 20+ (M)
4. **Upq2008** (cpueupq): permanent 25% increase in LL1 catchability from 2008 (H)
5. **Omega75** (cpueom75): power function for biomass-CPUE relationship with power set at 0.75 (i.e. hyper-stable) (H)
6. **Var sq. CPUE** (cpuew0): variable squares (L)
7. **Aerial2016** (as2016): remove 2016 aerial survey data point (H)
8. **CPUE2018** (cpue18): remove 2018 LL1 abundance index data point (M)

The first terms in brackets are their respective codes; the second terms are their relative ranking: high (H), medium (M), or low (L). This covers the individual robustness tests but a number of "crossed" tests were also recommended: reclow5as2016 (H), reclow5cpuew0 (L), as2016cpue18 (H).

While not strictly robustness tests, the OMMP also agreed that developers tune their respective MPs to the 30% by 2035 objective *but* for a 2,000 and 4,000 maximum TAC change to investigate the impact of changing the maximum TAC increase/decrease on CMP performance as requested by the SFMWG5. This was to be done only for the reference set of OMs, and these tuned MPs were not to be run on the suite of robustness tests outlined above. This was considered sufficient to explore the likely impact of these alternative relative to the 3,000 maximum TAC change, which is the specification of the Bali Procedure, and used as the default in CMP testing to date. We also tuned the MP to the 30% by 2040 tuning option that, while not included in the main tuning objectives, has not yet actually been ruled out.

4 Results

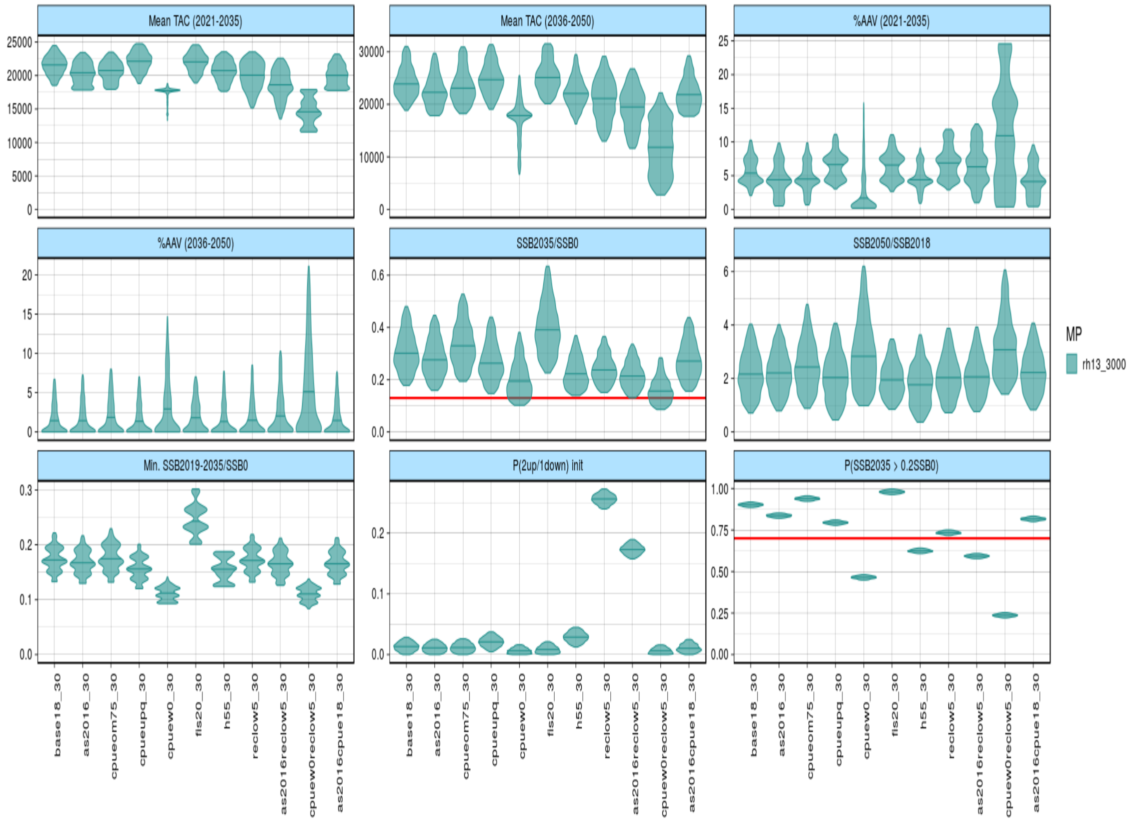

Figure 4.1: *Performance summary for the 30% by 2035 tuning objective.*

4.1 30% by 2035 tuning level

Figure 4.1 shows the SBT shiny app violin plot performance summary for this tuning level. Figure 4.2 shows the associated TAC and TRO worm plots for the reference grid. For the base tuning average TACs (for the 2021–2035 period) range from 19,000 to 24,000t; AAV is low (median of 5%) and never seems to exceed 11%; for the period after the tuning the AAV is even lower as build into the MP structure; the probability of 2 TAC increases then a decrease is very low; and the probability of being above 20% of the unfished level in 2035 is just above 0.9 (so well above the previous 0.7 tuning objective).

For the **as2016** robustness test, this generally results in slightly lower average TACs over the tuning period, slightly lower AAV (as big 2013 recruitment is reduced in influence in projections), and just misses the actual tuning objective getting to around 28% with probability 0.5. The original tuning objective is still exceeded (around 0.85). The crossed **as2016cpue18** test appears *very* similar to the **as2016** test. The mean TACs are marginally smaller, and the 2035 median depletion level is a little higher. The reason is that removing the 2018 CPUE point, as well as the 2016 survey, does not change the reduction in the size of the estimated 2013 year-class (as a result of removing the 2016 aerial survey data point). All it really does is make the mean average CPUE at the start of the projection period somewhat smaller, which results in slightly lower TACs in the first decision year.

For the **reclow5** robustness test, this results in lower TACs over the tuning period and specifically an asymmetric distribution in the average TAC to levels down to around 15,000t at the lowest given the limit-type nature of the gene tagging part of the HCR. The median value of depletion

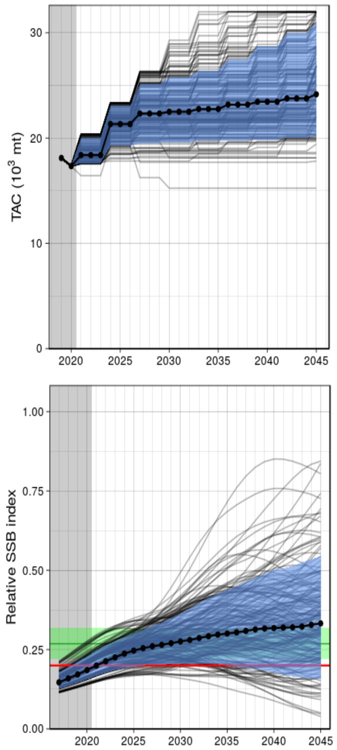

Figure 4.2: *Worms plots for the base UAM1 grid (tuned to 30% by 2035) for TAC (top) and TRO (bottom) and 20 random worms are shown.*

by 2035 is around 0.24 and the original tuning objective is still achieved.

For the **as2016reclow5** combination robustness test this results in the most pessimistic projections, as one might expect. Average TAC levels are similar but a little lower than the **reclow5** case, wIth median TRO levels of around 0.21 by 2035 - so it misses the original tuning objective but does get the relative TRO to 20% with a greater than 50% probability by 2035.

For the **cpueom75** test we actually see slightly lower average TACs over the tuning period and a greater than 50% probability of being above 30% by 2035. This might seem odd for what is, ostensibly, a pessimistic robustness test (hyperstable CPUE). The reasons are twofold: (i) the starting conditions for this test are actually very similar to the reference case, and (ii) the hyperstable relationship means CPUE increases *slower* than true abundance and results in a more conservative MP (lower TACs) and, as a result, a higher level of relative TRO by the target year. For the **cpueupq** test we see higher than average catches, given the step-shift change in q from 2008 onwards, and a resultant median depletion level of around 0.27 by 2035. The MP still easily meets the previous tuning objective (probability of 0.78). The **cpuew0** and **cpue0reclow5** tests are by far the most pessimistic in terms of rebuilding relative to the current and previous objectives and average catch levels. This is because this scenario is *very* pessimistic in terms of current (2019) depletion levels (below 0.1 TRO).In terms of relative level of rebuilding for these two robustness test, the CMP actually increases the TRO by almost a factor of 3 between 2019 and 2050. So, while the MP does very poorly in terms of the the tuning objectives (current and previous), it does act to rebuild the stock - and does increase it substantially in relative terms.

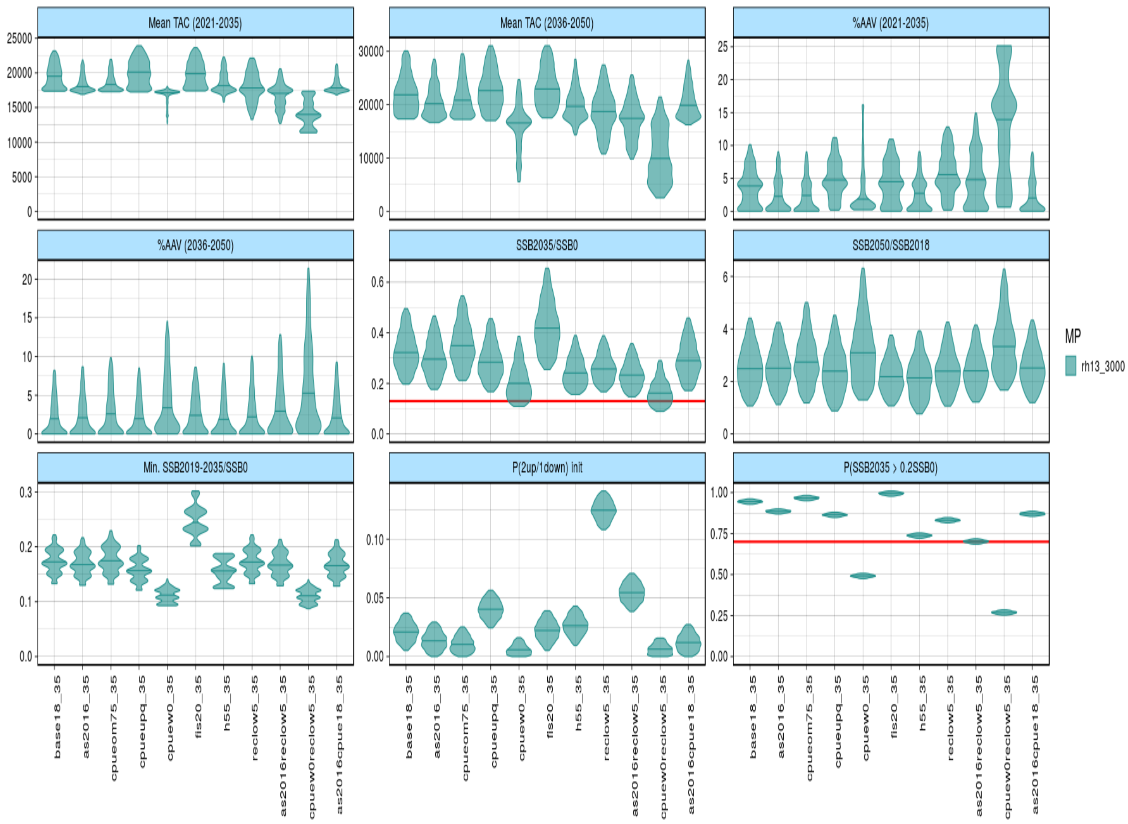

Figure 4.3: *Performance summary for the 35% by 2040 tuning objective.*

4.2 35% by 2040 tuning level

Figure 4.3 shows the SBT shiny app violin plot performance summary for this tuning level. Figure 4.4 shows the associated TAC and TRO worm plots for the **base2018** grid. For the base tuning average TACs (for 2021–2035 period) range from 17,500 to 22,000t; AAV is low (median of 4%) and never seems to exceed 10%; for the period after the tuning year the AAV is even lower, which reflects the reduced level of reactivity built into the MP; the probability of 2 TAC increases then a decrease is low (0.06); and the probability of being above 20% of the unfished level in 2035 is around 0.95 (so well above the 0.7 probability specified for the interim rebuilding objective).

For the **as2016** robustness test, this generally results in slightly lower average TACs over the tuning period, slightly lower AAV (as big 2013 recruitment is reduced in influence in projections), and just misses the actual tuning objective getting to around 32% with probability 0.5 by 2040. The original tuning objective is still exceeded (just over 0.87).

For the **reclow5** robustness test, this results in lower TACs over the tuning period and specifically an asymmetric distribution in the average TAC to levels down to around 13,000t at the lowest given the limit-type nature of the gene tagging part of the HCR. The median value of depletion by 2035 is around 0.26 and the original tuning objective is still easily achieved.

For the **as2016reclow5** combination robustness test this results in the most pessimistic projections, as one might expect. Average TAC levels are similar but a little lower than the **reclow5** case, wth median TRO levels of around 0.23 by 2035 but still *just* meets the original tuning objective. The qualitative features of the performance of the MP tuned to the 35% by 2040 objective

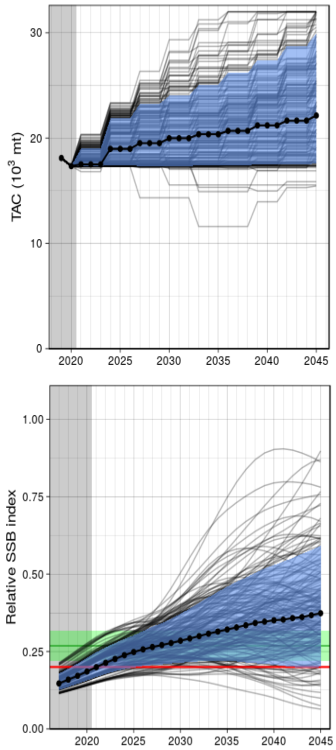

Figure 4.4: *Worms plots for the base UAM1 grid (tuned to 35% by 2040) for TAC (top) and TRO (bottom) and 200 random worms are shown.*

on the CPUE-related robustness tests are basically the same as those of the MP tuned to the 30% by 2035 objective.

4.3 Alternative maximum TAC change levels

Figure 4.5 summarises the effect of the 2,000t and 4,000t maximum TAC change levels, relative to the current 3,000t maximum change. Average TACs between 2021–2035 are around 500t less for the 2,000t, relative to the 3,000, but the same for the 4,000t. As might expected, there is an increasing trend in AAV as the maximum TAC change increases though it still never exceeding 13% even for 4,000t. Minimum TRO levels are basically the same across the three levels, and there is an increasing trend in the 2-up/1-down statistic as the maximum change increases but it never exceeds 0.05 for the levels examined.

4.4 30% by 2040 tuning objective

We tuned the MP described herein to the 30% by 2040 tuning objective because this variant has not been ruled out by the Commission, and to see if it really differs at all to the 30% by 2035 objective. Figure 4.6 shows the reference set performance for all three tuning objectives, and Figure 4.7 shows the TAC and TRO worms for this tuning objective. Basically, this tuning objective is *very* similar to the 30% by 2035 tuning objective. The average catch over the 2021–2035 period is around 400-500t higher, AAV is fractionally higher, the 2-up/1-down probabilities are basically the same, and the median level fo relative TRO by 2035 in this case is 0.29 (which is why they are so similar). In terms of short-term differences, looking at the TAC worms all one can really say is that, in median terms, the first TAC decision is a slightly larger increase and the

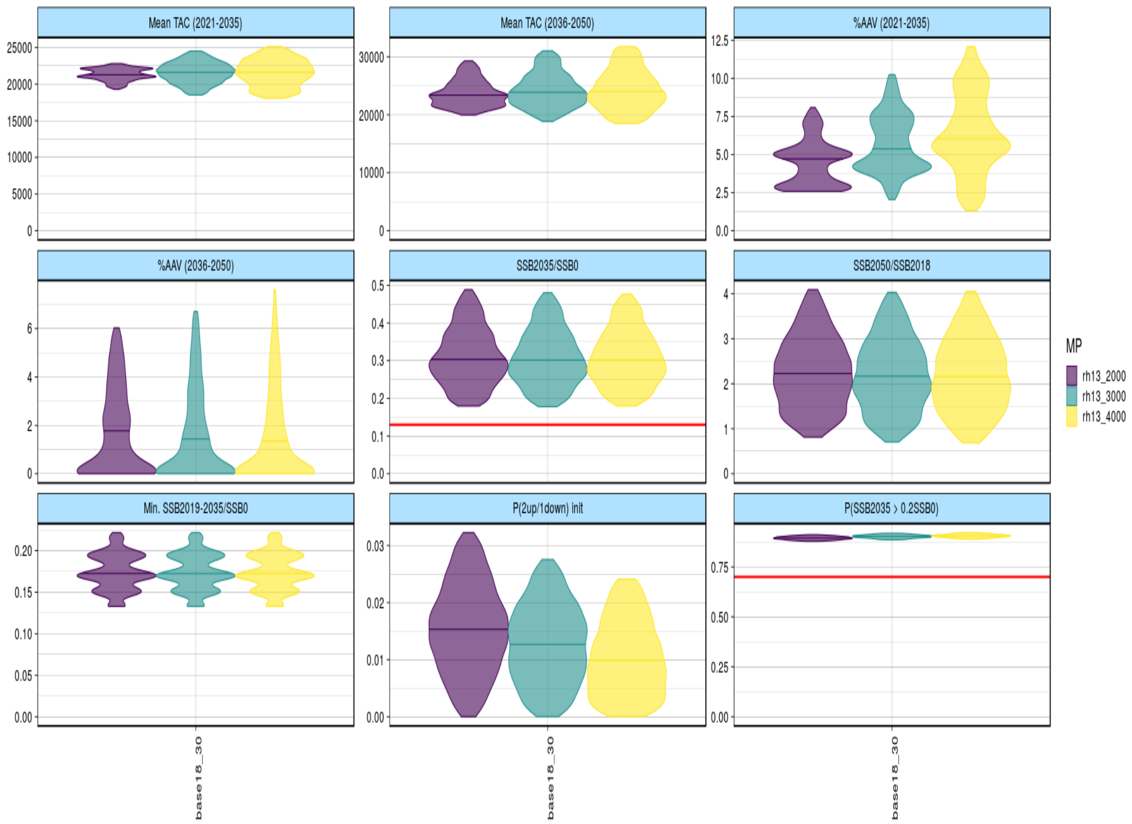

Figure 4.5: *Performance summary for the 30% by 2035 tuning objective and with the 2,000t (purple) and 4,000t (yellow) maximum TAC changes alongside the base 3,000t level.*

second a slightly smaller increase, relative to the 30% by 2035 tuning objective.

5 Discussion

The candidate MP presented at OMMP10 (**rh12** [1]) - which used the gene tagging, CPUE and CKMR data - was revised based on the feedback received from the meeting [2]. The main change to the CMP's HCR was to remove the trend-driven CPUE component and replace it with something similar to the gene tagging functional response. This includes an "OK" zone for mean CPUE within which the TAC does not change, and "good" and "bad" threshold levels which, when breached, result in (potentially asymmetric) increases and decreases in TAC, respectively (see Appendix for details). The modification was implemented to address the higher probability of this CMP, relative to the others, of two initial increases in TAC then a decrease in the third [2]. The revised MP was tuned to the two tuning levels and run on all the key robustness trials. It was also tuned to the 30% by 2035 objective with maximum TAC changes of 2,000t and 4,000t to explore the potential effect of changing from the current default of 3,000t maximum TAC change. For tuning objective completeness, we also included the 30% by 2040 option but only for the reference set of OMs (no robustness trials).

For the 30% by 2035 tuning objective average TACs over the 2021–2035 period had a median of 22,000t and a range of around 19,000-24,000t. AAV levels over the same period were low: median values of 5% and very rarely exceeding 10%. The probability of a 2-up/1-down dynamic

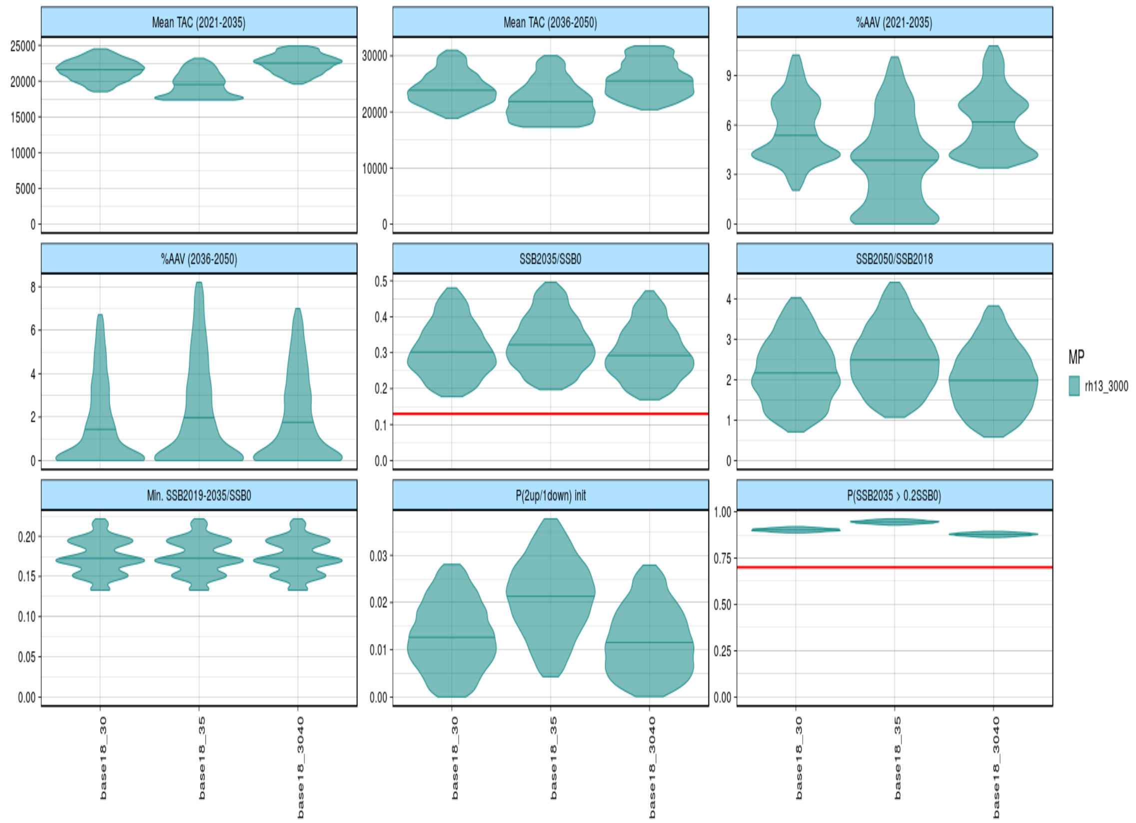

Figure 4.6: *Performance summary on the reference set for the three tuning objectives.*

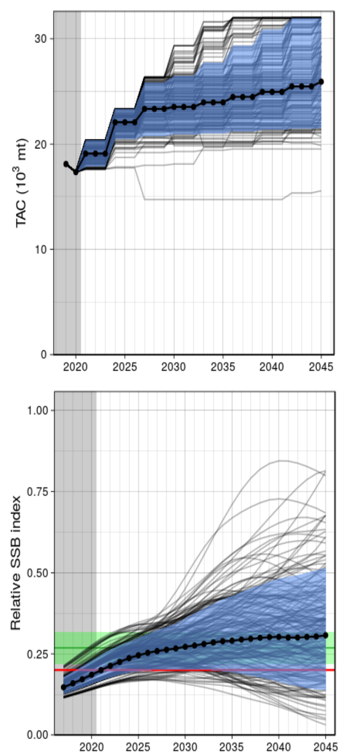

Figure 4.7: *Worms plots for the base UAM1 grid (tuned to 30% by 2040) for TAC (top) and TRO (bottom) and 200 random worms are shown.*

in the first three TACs was very low (0.02) so the modified HCR seems to have addressed the poorer performance of the previous version of the CMP for this statistic. The probability of achieving the interim rebulding objective was 0.94, so well above the 0.7 required level. The MP performs satisfactorily on the high-ranking robustness tests (low recruitment, removing the 2016 aerial survey and 2018 CPUE data points), as well as the Upq2008 and Omega75 CPUE tests. By far the worst performance was on the **cpuew0** because of the very low starting relative TRO level (below 0.1). Notwithstanding this performance against the specified rebuilding objective, the MP does rebuild (in relative terms) the TRO by a factor of almost 3 (relative to a factor of 2 for the more optimistic grids).

For the 35% by 2040 tuning objective the average TACs had a median value of 19,000t (17,500–23,000t range). The AAVs are low - median value of 4% and never exceeding 10% - and a little lower than for the MP tuned to the 30% by 2035 tuning objective. The qualitative performance of this MP tuned to this objective on the robustness tests is the same as for the MP tuned to the 30% by 2035 objective, just slightly more conservative across the board.

Changing the maximum TAC increase/decrease to 2,000 or 4,000t didn't strongly change the behaviour of the MP, at least when tuned to the 30% by 2035 objective. For the 2,000t limit the average TACs (2021–2035) were at most 500t lower than the other two options; and there was no obvious difference in mean TACs for the 3,000t and 4,000t options, just higher variability in the latter. There were small but clear trends in both AAV and the 2-up/1-down TAC probability statistics - increasing with increasing size of maximum TAC - but still at good performance levels. At most, and without running the variants on the robustness test, one could conclude that increasing the maximum TAC change to 4,000t would not be expected to result in higher TACs on average.

When looking at the 30% by 2040 tuning objective, the performance of the MP on the reference set of OMs was *very* similar to that of the MP tuned to the same depletion level but by 2035. This is not necessarily surprising, given how the TRO flattens out after 2035 for this tuning year. At most, there is a 400-500t higher average catch over the 2021–2035 period and a slightly higher TAC increase then slightly lower TAC increase (relative to the 30% by 2035 objective) for the first two TAC decisions.

The revised structure of the CMP presented at the OMMP10 [1] appears to have improved the poor performance on the 2-up/1-down TAC statistic. Given no change to the rest of the structure or major parametric changes in the MP itself, it is perhaps not a major surprise that it performs similarly to before on the other performance statistics. It performs satisfactorily on the high priority robustness tests, and does so with good AAV and other catch related performance criteria. The alternative maximum TAC changes (2,000 and 4,000t) did not appear to have a major effect - in particular there was no obvious significant increase in average TACs for the between the 3000t and 4000t values, but there was a small associated increase in catch variability.

6 Acknowledgements

This work was funded by CSIRO, the Department of Agriculture and the Australian Fisheries Management Authority.

References

[1] R. M. Hillary, A. Preece, C. R. Davies (2019) Updated candidate MP performance summary on reconditioned grid. *CCSBT–OMMP/1906/4*.

[2] Anonymous. Report of the 10th Operating Model and Management Procedure workshop. CCSBT, Canberra, Australia.

[3] R. M. Hillary, A. Preece, C. R. Davies (2019) Updates to the SBT OM. *CCSBT–OMMP/1909/17*.

Appendix

We explored a modified version of the original adult-focused age-structured population model, now with auto-correlated “recruitment” deviations:

$$
\begin{aligned}
N_{y_{\min},a_{\min}} &= \bar{R}\exp\left(\xi_{y_{\min}} - \sigma_R^2/2\right),\\
N_{y,a_{\min}} &= \bar{R}\exp\left(\epsilon_y - \sigma_R^2/2\right),\\
\epsilon_y &= \rho\epsilon_{y-1} + \sqrt{1-\rho^2}\xi_y,\\
\xi_y &\sim N(0,\sigma_R^2),\\
N_{y+1,a+1} &= N_{y,a}\exp\left(-Z_{y,a}\right) \qquad a \in (a_{\min}, a_{\max}),\\
N_{y+1,a_{\max}} &= N_{y,a_{\max}-1}\exp\left(-Z_{y,a_{\max}-1}\right) + N_{y,a_{\max}}\exp\left(-Z_{y,a_{\max}}\right),\\
Z_{y,a} &= Z_y \qquad a \leq 25,\\
Z_{y,a} &= Z_y + \frac{a-25}{a_{\max}-25}\left(Z_{a_{\max}} - Z_y\right) \qquad a \in [26, a_{\max}],\\
Z_y &= \frac{Z_{\max}e^{\chi_y} + Z_{\min}}{1+e^{\chi_y}},\\
\chi_{y+1} &= \chi_y + \zeta_y,\\
\zeta_y &\sim N(0,\sigma_\chi^2),\\
TRO_y &= \sum_a N_{y,a}\varphi_a
\end{aligned}
$$

The estimate parameters of this model are:

1. The mean adult recruitment, $\bar{R}$
2. The adult recruitment deviations, ϵ_y
3. The initial value, χ_{init}, that ”starts” the random walk for Z_y (with an associated normal prior mean and SD)
4. The random walk deviations ζ_y

This is similar to the number of parameters estimated in the Bali Procedure population model. There are not a large number of model parameters, and many of them are going to be constrained deviation parameters. The likelihood model for the POP and HSP data are basically the same as those used in the SBT OM, but where M_a and the harvest rates are replaced by $Z_{y,a}$ to estimate cumulative survival in the HSP likelihood. The assumed settings for the CKMR MP population model are detailed in Table 8.1.

The general structure of the revised MP is as follows:

$$
TAC_{y+1} = TAC_y\left(1 + \Delta_y^{\text{cpue}} + \omega^{\text{ck}}\left(\Delta_y^{\text{ck}} - 1\right)\right) \times \Delta_y^{\text{gt}},
$$

where the inertial terms for the CPUE and CKMR parts of the HCR are now additive, not multiplicative as previously explored. This avoids the quadratic term in the multiplicative case where both trends are consistently positive consistently making the TAC increases larger than for the additive case, despite the trends being the same in both cases.

Before detailing the changed form of the HCR we recap some useful variables:

Parameter	Value
$a_{\min}$	6
$a_{\max}$	30
σ_R	0.25
ρ	0.5
σ_χ	0.1
$Z_{\min}$	0.05
$Z_{\max}$	0.4
$Z_{a_{\max}}$	0.5
$\mu_{\chi_{\text{init}}}$	-1.38
$\sigma_{\chi_{\text{init}}}$	0.15
q_{hsp}	0.9

Table 6.1: Settings for CKMR MP population model

- I_y^{ck}: moving average of the estimated TRO from the MP population model (now pushed forward to the current year using the model to project forward for 4 years to avoid too much intertia in the signal when you need it)
- $\tilde{I}$: average estimated TRO from 2003 to 2012 (reference period w.r.t. relative rebuilding criterion)
- γ: proportional amount of TRO rebuilding we wish to achieve

We are interested in the following ratio: $\delta = I_y^{\text{ck}}/(\gamma\tilde{I})$. To get from the current average level of TRO to the 30% level we would consider $\gamma \approx 2$; for the 35% level $\gamma \approx 2.5$. As the ratio δ approaches 1 (i.e. we *think* we are at or close to the target TRO), we would like to have the potential to morph (continuously and possibly smoothly) the behaviour of the MP. It seems that MPs need to be fairly reactive in the first 10–15 years (3–4 TAC decisions) of the projections to be able to tune to the 30% target by 2035, but afterwards that embedded reactivity might be giving rise to continued TAC increases to levels likely to cause the TRO to come back down again post-target year. For the CPUE trend part of the HCR we explore a density-dependent gain parameter:

$$k^{\text{cpue}}(\eta) = w_1^{\text{cpue}}\left(1 - \left(1 + e^{-2\kappa\eta}\right)^{-1}\right) + w_2^{\text{cpue}}\left(1 + e^{-2\kappa\eta}\right)^{-1}$$

where $\eta = \delta - 1$. This is using the logistic function approximation to the Heaviside step function $H[\eta]$ ($H[\eta < 0] = 0$, $H[\eta \geq 0] = 1$). We set $\kappa = 20$ so the transition between the two gain parameters, given η, happens within $\pm 5\%$ of $\delta = 1$. The CPUE multiplier is then just defined as follows:

$$\Delta_y^{\text{cpue}} = k^{\text{cpue}}(\eta)\left(\delta_y^{\text{cpue}} - 1\right)$$

and δ_y^{cpue} is actually very similar in form to the gene tagging part of the HCR

$$\begin{aligned}
\delta_y^{\text{cpue}} &= \left(\frac{\bar{I}_{\text{cpue}}}{I_{\text{low}}}\right)^{\alpha_1} && \forall \bar{I}_{\text{cpue}} \leq I_{\text{low}}, \\
\delta_y^{\text{cpue}} &= 1 && \forall \bar{I}_{\text{cpue}} \in \left(I_{\text{low}}, I_{\text{high}}\right), \\
\delta_y^{\text{cpue}} &= \left(\frac{\bar{I}_{\text{cpue}}}{I_{\text{low}}}\right)^{\beta_1} && \forall \bar{I}_{\text{cpue}} \geq I_{\text{high}},
\end{aligned}$$

where $\bar{I}_{\text{cpue}}$ is the (4 year) moving average LL1 CPUE, $\bar{I}_{\text{low}}$ and $\bar{I}_{\text{high}}$ are upper and lower threshold CPUE values, and α_1 and β_1 allow for an asymmetric response above or below the threshold zone.

For the CKMR part of the HCR we try to preserve the main elements of the previous candidate MP (**rh12**): ensure a minimum rate of increase in the TRO *beneath* the target level, and once it is achieved we would like to maintain the TRO at that level. To include this kind of behaviour in the HCR we also include some density-dependence in the log-linear growth rate at which the HCR moves from a TAC increase to a TAC decrease:

$$
\begin{aligned}
\Delta_y^{\rm ck} &= 1 + k^{\rm ck}(\eta)\left(\tilde{\lambda}(\eta) - \lambda^{\rm ck}\right),\\
k^{\rm ck}(\eta) &= k_1^{\rm ck}\left(1 - \left(1 + e^{-2\kappa\eta}\right)^{-1}\right) + k_2^{\rm ck}\left(1 + e^{-2\kappa\eta}\right)^{-1},\\
\tilde{\lambda}(\eta) &= \lambda_{\min}\left(1 - \left(1 + e^{-2\kappa\eta}\right)^{-1}\right)
\end{aligned}
$$

The threshold level at which a trend goes from a TAC decrease to an increase essentially begins at $\lambda_{\min} > 0$ and, as the estimated TRO approaches the target level, this rapidly dercreases to zero (in a similar way to the CPUE trend term). This is to ensure that a minimum level of rebuilding is encouraged for **all** trajectories below the target, and where above the target the *status quo* is preferred.

In the last several incarnations of this MP we use the absolute nature of the GT data then the general principles would be something like:

- Below the limit level the HCR should act strongly to reduce the TAC
- Above the limit level and up to some pre-specified upper level the GT part of the HCR maintains the TAC where it is
- If recent mean recruitment has been suitably elevated (i.e. above a pre-specified level) then the HCR should act to increase the TAC

To calculate the recent mean age 2 abundance from the GT data consider a weighted moving average approach:

$$
\bar{N}_{y,2} = \sum_{i=y-1-\tau}^{y-2} \omega_i \widehat{N}_{i,2}
$$

where ω_i is a weighting proportional to the number of matches used to produce the GT estimate $\widehat{N}_{i,2}$ (basically inverse variance weighting). The 2 year delay between having the estimate and what year it actually refers to is factored into the calculation. The multiplier for the GT part of the HCR would then be:

$$
\begin{aligned}
\Delta_y^{\rm gt} &= \left(\frac{\bar{N}_{y,2}}{N_{\rm low}}\right)^{\alpha} \quad \text{if} \quad \bar{N}_{y,2} \leq N_{\rm low},\\
\Delta_y^{\rm gt} &= 1 \qquad\qquad\quad \text{if} \quad \bar{N}_{y,2} \in (N_{\rm low}, N_{\rm high}),\\
\Delta_y^{\rm gt} &= \left(\frac{\bar{N}_{y,2}}{N_{\rm high}}\right)^{\beta} \quad \text{if} \quad \bar{N}_{y,2} \geq N_{\rm high}
\end{aligned}
$$

with $N_{\rm low}$ the limit level and $N_{\rm high}$ the upper level at where TAC inrceases are permitted. The exponents α and β are to allow for differential responses depending on the situation: we might expect $\alpha > 1$ as we would want to act strongly on poor recruitment levels; alternatively we might have $\beta < 1$ so that TAC inreases based on increased recruitment are more modest, given increased recruitment does not guarantee the TRO will increase (especically if we increase the Fs they experience as they mature).

Along with embedding a kind of switching mechanism in both **rh11** and **rh12**, in terms of behaviour once the target is met, we also continue with the idea of a maximum TAC value. This is again to avoid short-term increases to levels of TAC (and, hence, total catch including UAM) that are not sustainable in the long-term, even for the most optimistic grid combinations and future trajectories, and will definitely require large TAC decreases in the future. The value chosen for the maximum TAC was 32,000t. Including UAM (which is approximately and consistently 20% of the TAC) this value would be a total catch of around 36,000t.

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Appendix A5

Preece AL, Hillary RM, Davies CR. (2019e). A candidate MP that uses only fishery independent data. CSIRO, Australia. CCSBT-ESC/1909/15

Australia's National
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A candidate MP that uses only fishery independent data

Preece, Hillary, Davies
CCSBT-ESC/1909/15
September 2019

Citation

Preece AL, Hillary RM, Davies CR (2019). A candidate MP that uses only fishery independent data. CSIRO, Australia. CCSBT-ESC/1909/15

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Acknowledgments

This work was funded by the Department of Agriculture and Water Resources and CSIRO.

Contents

Abstract

Our aim is to explore the performance of an MP which is reliant only on fishery-independent data. This candidate MP uses data from the gene-tagging and close-kin mark-recapture programs, and no CPUE data. The rationale for this is that these fishery-independent data sets are from scientific monitoring programs designed to provide data with specific precision and for which the design process has examined the possible sources of bias. In contrast, for CPUE data there are concerns (in fisheries worldwide) regarding the accuracy of the catch and effort data used in CPUE standardisation, and the ability of CPUE indices to reflect population abundance.

The close-kin and gene-tagging data sources encompass two important aspects of the fishery. The close-kin program monitors adult abundance, which we are aiming to rebuild, whereas the gene-tagging program monitors juvenile abundance, which provides an early warning of periods of low recruitment that will affect future adult abundance. It also recognizes periods of higher recruitment that a clever MP may be able to take advantage of in a feedback decision rule.

This fishery-independent candidate MP has been simulation tested in a full management strategy evaluation (MSE) framework. The MP has been tuned to several tuning objectives and performance tested for the base set of operating models and the suite of robustness tests.

1 Introduction

The CCSBT Extended Scientific Committee (ESC) is exploring the performance of candidate Management Procedures (MPs) to inform selection and adoption of a single MP by the Commission in 2019. Three data sets have been agreed for use in the candidate MPs; the Japanese longline CPUE index, juvenile abundance estimates from the gene-tagging program and adult abundance data from the close-kin mark-recapture program (Anon, 2016). The latter two are formally designed monitoring programs that are largely fishery independent (Preece et al., 2015; Bravington et al., 2016; Davies et al., 2018), and the CPUE index of abundance is derived from fishery-dependent data (Itoh and Takahashi, 2019).

The candidate MP described here uses only the fishery-independent data sets, i.e. data from the gene-tagging program and the close-kin mark-recapture program. The reasons for pursuing an MP that does not include CPUE data are that the fishery-independent data sets are from scientific monitoring programs which have been designed to provide estimates with specific precision and for which the design process has examined the possible sources of bias. For SBT and other fisheries worldwide, there have been concerns regarding the accuracy of the catch and effort data used in CPUE standardisation, and the ability of CPUE indices to reflect population abundance (e.g. Harley et al, 2001). The SBT CPUE data unfortunately has a history of unreported catches and associated uncertainty in the underlying effort data (Davies et al., 2008), and the relationship with abundance is uncertain and subject to potential biases that are difficult to account for in the standardisation or in the use of the index e.g. effects of range contraction, hyperstability (e.g. Maunder et al., 2006).

The three data sets considered for use in the MP represent different components of the stock, with the gene-tagging data proving an absolute abundance estimate of 2-year-old fish, the CKMR providing information on the spawning component of the stock, and the CPUE data providing information primarily on the sub-adult component of the stock i.e. ~4-10 year-olds. The strength of the two fishery-independent data sources is that they encompass two important aspects of the fishery: the spawning component that we are aiming to rebuild, and the juveniles which provide an early warning system of periods of low recruitment that will inevitably affect future adult abundance. The gene-tagging data will also provide data on periods of strong recruitment, which a clever MP may be able to take advantage of by allowing for higher catches through the feedback decision rule, while still meeting the rebuilding objective.

The candidate MPs are simulation tested in a full management strategy evaluation (MSE) framework, using complex operating models that include a much wider range of data than that used in the MPs (Hilary et al., 2019, 2015). A reference/base set of operating models are used to test performance of the MP against a combination of hypotheses for existing uncertainties (e.g. productivity via steepness in the stock recruitment relationship, natural mortality at age, CPUE age classes). The candidate MPs are tuned to a common target so that they can be compared against additional performance criteria (other than the target) for the base set of operating models, and against a robustness set of more extreme but plausible hypotheses. The preliminary results for the candidate MPs considered at OMMP 2019 were reasonably similar for the base set of operating models; performance distinctions between them were quite small. It is likely that differences will be more apparent in the results from testing them against the suite of robustness tests.

2 Description of the fishery-independent candidate MP

The fishery-independent MP evaluated here has been presented previously as D25 to the 2018 OMMP and ESC (Hillary et al., 2018, Anon 2018a,b) and A49 and A60 in 2019 (Addendum to Hillary et al., 2019; Anon 2019). The code was provided by Rich Hillary and has been shared and used by CCSBT ESC members as C1GT1CK4.tpl (11/6/2019 and earlier versions; Hillary et al., 2019).

In the MP, the gene-tagging abundance estimates of 2-year-olds are used as an indicator for recent recruitment. A low and high level of (age 2) juvenile abundance are specified, and asymmetrical response parameters are used to smoothly adjust the TAC above and below these levels. If average recent (5-year) juvenile abundance falls close to or below a limit level, which is similar to the estimates related to very poor recruitments observed in 1999-2002, then the MP will act strongly to reduce the TAC. If recent average juvenile abundance is near to or higher than the upper level, then the MP will act to slowly increase the TAC. The aim of this component of the MP is to respond to poor recruitments quickly enough to minimise later impacts on spawning biomass, and if there is a period of very strong recruitment, to slowly increase the TAC to take advantage of this improvement without impacting rebuilding of the spawning biomass.

The close-kin mark-recapture component of the MP uses the Parent-Offspring-Pair (POP) data and Half-Sibling-Pair (HSP) data in a relatively simple age-structured population dynamics model that accounts for changes in recruitment of sub-adults to the adult population and changes in total mortality on adults in stronger and weaker cohorts (Hillary et al., 2018, 2019). The population dynamics model provides an index of abundance of reproductive adults (or Total Reproductive Output (TRO), also referred to here as SSB as this is more familiar and a CCSBT convention) which is then used in the Harvest Control Rule component of the MP to modify the TAC. The simulation trials of this population model demonstrated very strong correlations between the modelled and simulated abundance estimates (see Hillary et al 2018 for the detailed description and testing). The MP uses adult abundance estimates relative to a target rebuilding level, and trends in abundance over a 3-year period, to modify the TAC (Hillary et al, 2018). The aim of this component of the MP is to rebuild the adult abundance to the target level, adjust the TAC if the trend is in the wrong direction or the rate of rebuilding is not fast enough, and once the target has been reached, to maintain the adult abundance around the specified rebuilding SSB level.

The code is described in Hillary et al, 2018 and 2019.

3 Tuned candidate MPs

The fishery-independent candidate MP has been tuned to three levels in the cross combination of SSB depletion level and timeframe for rebuilding. The tuning requirement is that 50% of the base set of operating model projections are at the specified SSB depletion level by the tuning year (±1%). The original Commission request was to tune rebuilding to 25, 30, 35 and 40% SSB_0 by 2035. The highest and lowest rebuilding targets were excluded because of poor performance behaviours (Anon 2018). Rebuilding to 30% SSB_0 by 2035 was achievable and rebuilding to 35% SSB_0 was only achievable by increasing the timeframe out to 2040. The third combination explored here is rebuilding to 30% SSB_0 by 2040 as this fills out the remaining cross combination of the two rebuilding targets and timeframes. For these three tuning levels, the minimum TAC change is 100t, the maximum is 3000t and the TAC is set in 3-year blocks, with the first TAC change in 2021.

To examine the impact of the maximum TAC change, the MP was also tuned to 30% SSB_0 by 2035 target with 4000t and 2000t maximum TAC change, and performance compared with the MP with the default setting of 3000t.

The MPs tuned to 30% SSB_0 by 2035 and 35% SSB_0 by 2040 for the base set were also tested for relative performance against the robustness set of more extreme but still plausible hypotheses, as specified by the ESC and OMMP (Anon 2019, table 5).

4 Results and discussion

4.1 MPs tuned to the base set of operating models

The relative performance of the tuned MPs for the base set of operating models are examined first. Figure 1 shows TAC and SSB behaviours for tuning levels 30% SSB_0 by 2035 and 35% SSB_0 by 2040. For both of these MP tuning levels, the median SSB gradually increases to the target and then tapers off. The lower 10% percentile of SSB, once it has increased above the 20% SSB_0 depletion level, does not drop below 20% SSB_0 until 2035 for the MP tuned to 30% SSB_0 by 2035 and not until after the projection period for the MP tuned to 30% SSB_0 by 2040. On average, the median TAC gradually increases above current levels for both tuned MPs. The lower 10%-ile of TAC does not fall below the current TAC for either tuned MP and does not decrease until after 2040 for the MP tuned to 30% SSB_0 by 2035 and not at all for the MP tuned to 35% SSB_0 by 2040. The upper TAC 10%-ile limit of 32,000t is not reached until 2042 for the MP tuned to 30% SSB_0 by 2035 and not at all for the MP tuned to 35% SSB_0 by 2040. The main difference between these two tuned MPs for the base set of models is that for the MP tuned to 35% SSB_0 by 2040 the TAC increases are somewhat slower, as it is required to rebuild to a higher SSB level, than the MP tuned to 30% SSB_0 by 2035. For the few randomly selected trajectories (shown as the grey lines) with TACs below current levels, there are positive signs of TAC increases over the main period of the projections, which demonstrates that the MP is responding to negative signals in the stock and the response is sufficient to remedy the situation. There are no catastrophic SSB trajectories evident in these figures.

The MP was also tuned to 30% SSB_0 by 2040 to demonstrate the full cross combination of tuning year and level (35% SSB_0 by 2035 was excluded in 2018 because of performance and this result confirmed at OMMP10). Figure 2a shows that the 30% SSB_0 by 2040 MP performance is very similar to the 30% SSB_0 by 2035 MP.

The MP tuned to 30% SSB_0 by 2035 was also tuned with maximum TAC change of 2000t and 4000t (the base set maximum TAC change is 3000t). Figure 2b, shows that the TAC and SSB performance of this MP for the different TAC change limits are nearly identical to the MP tuned to 30% SSB_0 by 2035 with 3000t maximum TAC change.

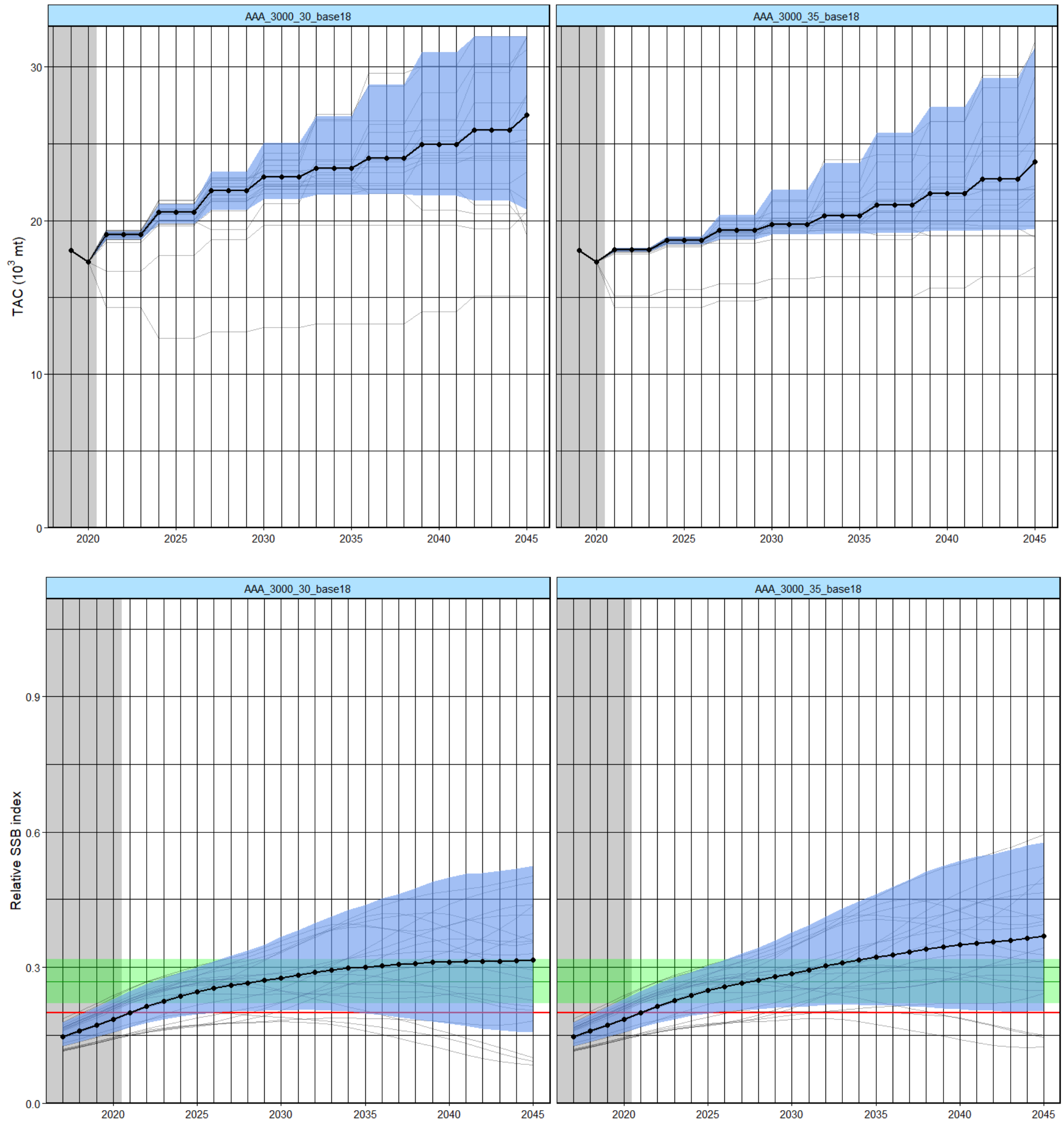

Figure 1. The TAC (top) and relative spawning stock biomass (SSB, bottom) for tuning level 30% SSB_0 by 2035 (left) and 35% SSB_0 by 2040 (right) showing 20 individual iterations, or worms, (thin black lines), the median (bold black line and points), and 80% confidence interval (blue shading). The median and 80% confidence interval for the maximum sustainable yield (MSY) is also presented (horizontal green line and shaded region). The original interim rebuilding target of 20% SSB_0 is indicated on the SSB figures (red line).

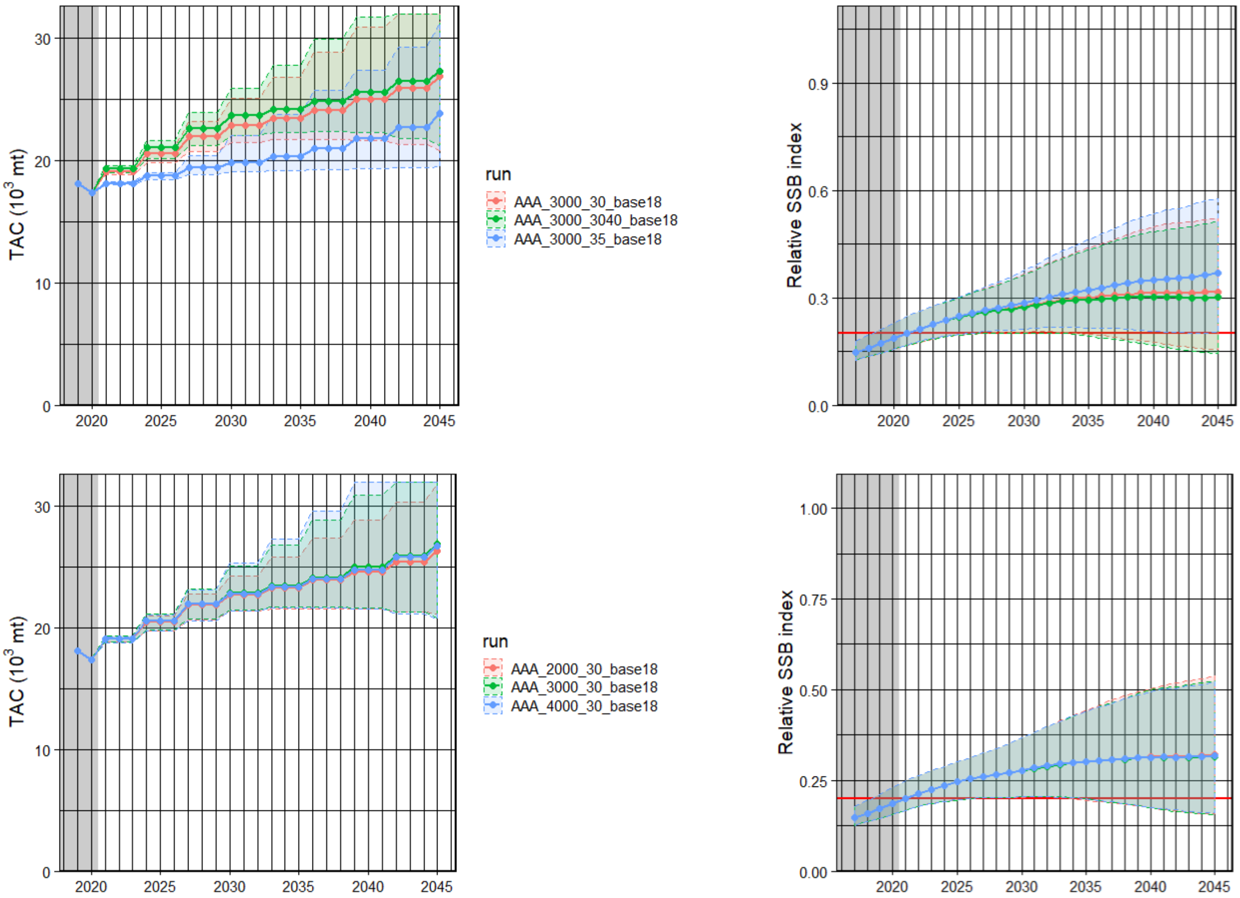

Figure 2. Comparison of MP performance for TAC (left) SSB (right) for three tuning combinations and different levels of maximum TAC change: a) (top) TAC and SSB performance for the MP tuned to 30% SSB_0 by 2040 MP (green), 30% SSB_0 by 2035 (red) and 35% SSB_0 by 2040 (blue); b) (bottom) maximum TAC change 2000t (red), 4000t (blue) and default level 3000t (green) for the MP tuned to 30% SSB_0 by 2035.

4.2 Robustness tests

The full set of robustness tests specified at the 2019 OMMP meeting (Anon 2019, Att 1) have been run for the MP tuned to 30% SSB_0 by 2035 (Figure 3) and to 35% SSB_0 by 2040 (Figure 4). The TAC and SSB trajectories of the tuned MPs under the conditions of these robustness tests are provided in Figure 5 and 6. The high priority robustness tests are: reclow5, cpueupq, cpueom75, as2016, as2016reclow5, as2017cpue18.

The performance of the tuned MPs in the robustness tests are similar (Figure 3 and Figure 4). Both MPs respond to a period of low recruitment (reclow5) and have good probability of rebuilding SSB to target levels. Removal of the high aerial survey 2016 point (as2016) has only a small negative impact on TACs and rebuilding. For the combination robustness test of AS2016reclow5 (no 2016 aerial survey point and 5 years of low recruitment), both MPs exhibit poorer performance for the probability of two TAC increases followed by a decrease (P2up1down) and for the probability of rebuilding above 20% SSB_0 by 2035 (P(SSB2035 > 0.2SSB0)). The median TAC and rebuilding performance were poor for the cpuew0 robustness test, and the other tests in combination with this scenario e.g. cpuew0reclow5 (Figures 3 and 4).

The TAC and SSB trends in Figure 5 for the MP tuned to 30% SSB_0 by 2035 indicates that the MP responds to robustness test conditions by cutting TAC when necessary to rebuild SSB. In nearly all cases the median TAC trajectory has an upward trend in the long term. The exceptions to this are in the cpuew0 test (flat TAC), cpuew0reclow5 (TAC declines) and as2016reclow5 (possibly small TAC decline). Apart from the severe cpuew0reclow5 test results, all median TACs are above the current TAC throughout the timeseries. In all the robustness tests the median of the SSB trajectories indicates there is rebuilding towards the target SSB level. The median SSB trajectories are above (sometimes well above) or are closely approaching 20% SSB_0 by the end of the projection period shown (2045), even in the worst-case scenarios.

Similar performance is seen for the MP tuned to 35% SSB_0 by 2040 under these robustness tests (Figure 6). Median TAC trajectories are generally flatter than those in Figure 5 as this is a more conservative MP. All median TACs trend upwards in the latter part of the projection period, apart from under the cpuew0 and cpuew0reclow5 tests which have a flat median TAC trend after initial TAC changes. All median SSB trajectories show positive rebuilding and are above or well above the 20% SSB threshold at the end of the projection period, even under the worst-case scenarios.

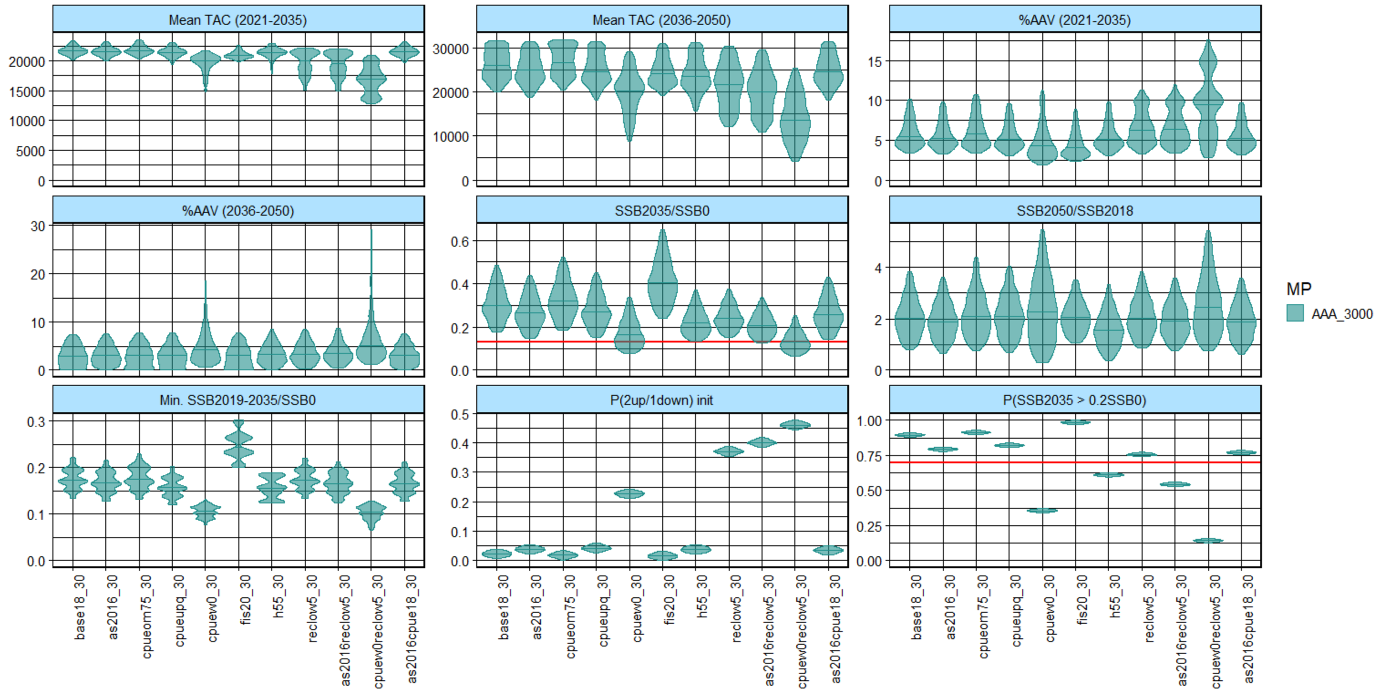

Figure 3. Output statistics for the MP tuned to 30% SSB_0 by 2035 for the base set and robustness tests. The horizontal line within each violin represents the median. The red horizontal line on the SSB2035 > 0.2SSB0 panel indicates the 70% probability level which was the interim rebuilding target for the Bali Procedure MP adopted in 2011: being above this level is a minimum requirement for the new MP.

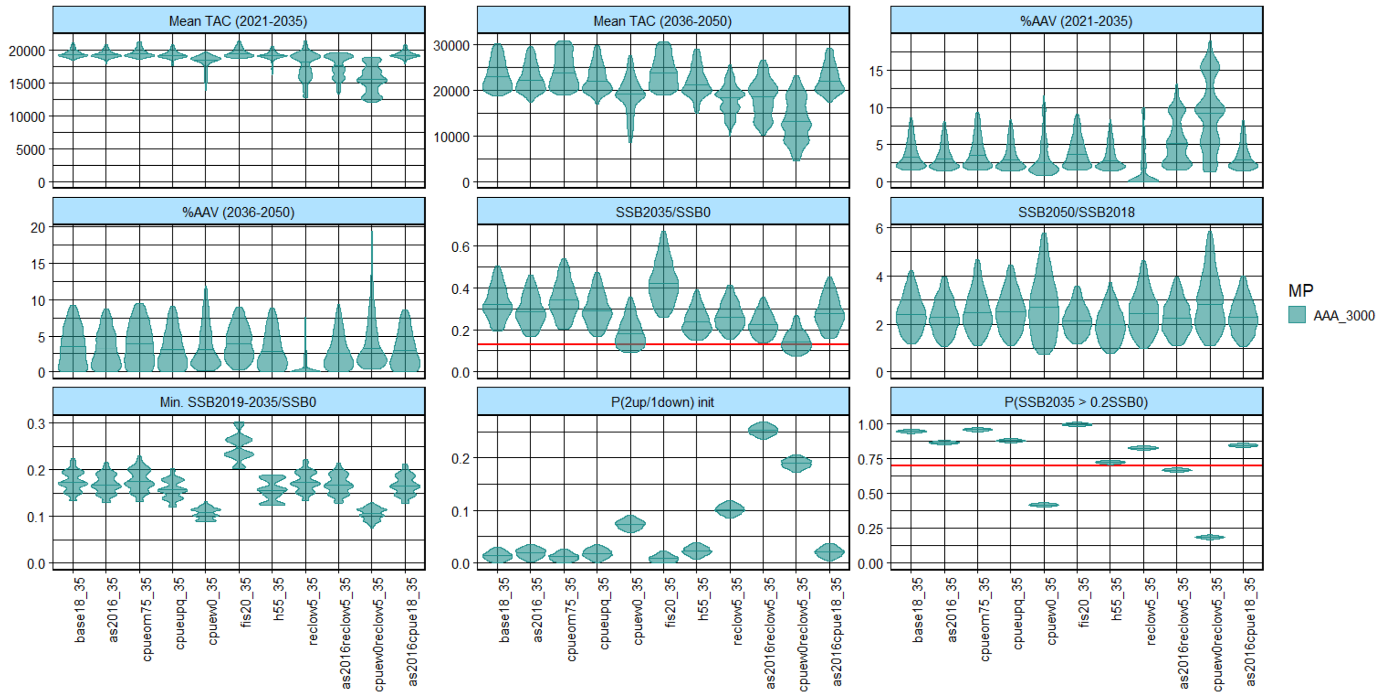

Figure 4. Output statistics for MP tuned to 35% SSB_0 by 2040 for the base set and robustness test. The horizontal line within each violin represents the median. The red horizontal line on the SSB2035 > 0.2SSB0 panel indicates the 70% probability level which was the target for the Bali Procedure MP adopted in 2011: being above this level is a minimum requirement for the new MP.

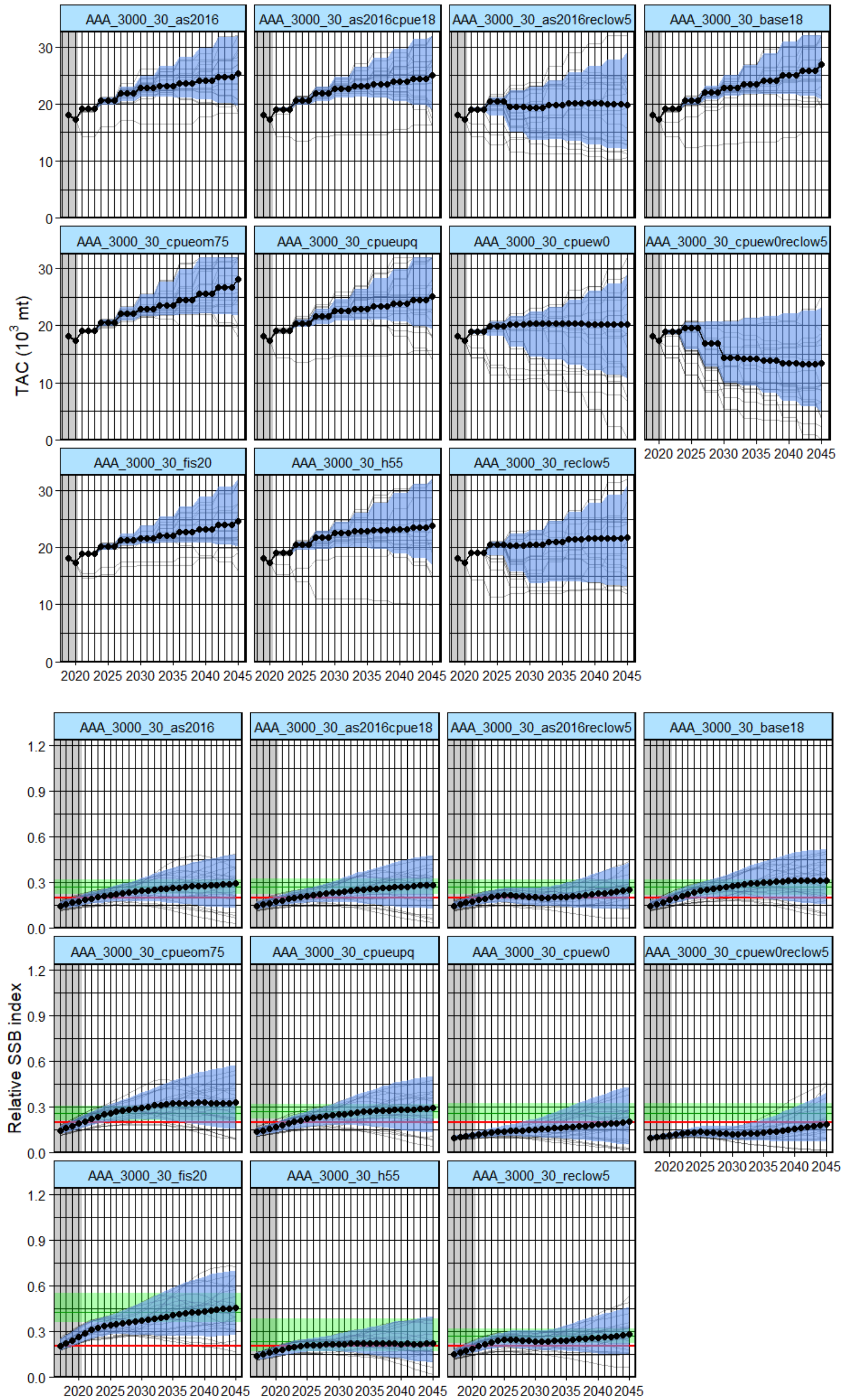

Figure 5. Detailed TAC (upper block) and SSB (lower block) results for the MP tuned to 30% SSB_0 by 2035 for the base set and robustness tests.

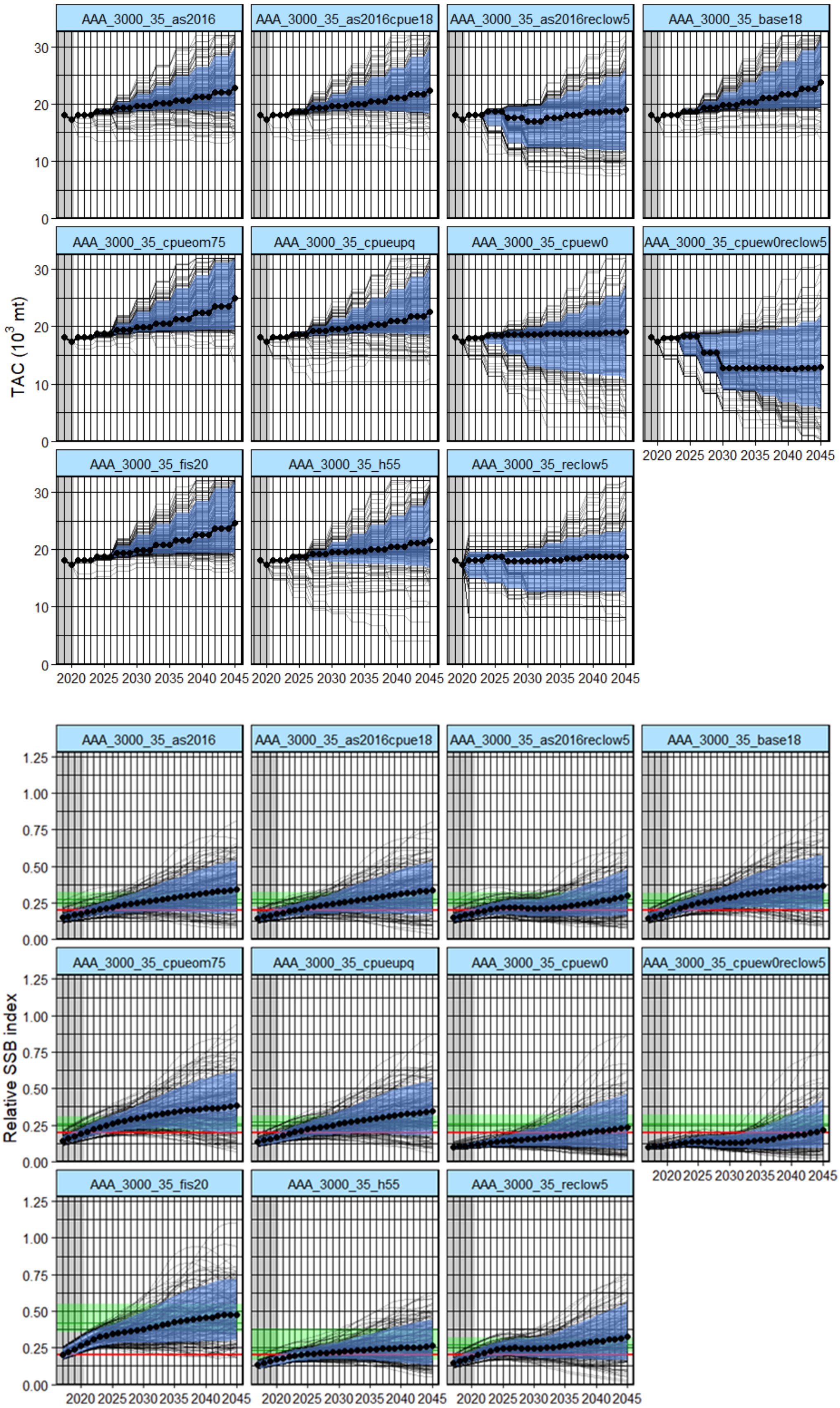

Figure 6. Detailed TAC (upper block) and SSB (lower block) results for the MP tuned to 35% SSB_0 by 2040 for the base set and robustness tests.

5 Conclusion

The advantage of the fishery-independent MP is that it only uses data from scientifically designed monitoring programs, and avoids the use of CPUE data and related uncertainties in data collection and its relationship with abundance. The candidate MP presented here will provide robust advice for rebuilding the SBT stock towards a new target level to be decided by the Commission and for maintaining the SSB above the interim rebuilding objective of 20% SSB_0 with a high probability. TACs are likely to increase steadily as the stock continues to rebuild, with low variability and low likelihood of TACs below the current level for the base set of operating models and many of the robustness tests.

The performance of the fishery-independent MP will be evaluated relative to the other candidate MPs at the 2019 ESC. We have highlighted some of the performance characteristics under the base set of operating models and the robustness tests for this form of MP tuned to both 30% SSB by 2035 and 35% SSB by 2040. In addition, an MP tuned to 30% SSB by 2040 has been included to fill out the combination of tuning level (SSB) and year, and the effect of the maximum TAC change has been explored in MPs tuned to 30% SSB by 2035 with maximum TAC changes of 2000t and 4000t in addition to the default 3000t. All other tuning combinations originally requested by the Commission have been examined and rejected based on performance.

The MP tuned to 35% SSB by 2040 is slightly more conservative, increasing TAC slower than in the MP tuned to 30% SSB by 2035. Performance of the MP tuned to 30% SSB by 2040 is very similar to the MP tuned to 30% SSB by 2035. The MPs with maximum TAC changes of 2000t and 4000t do not show any substantial difference or advantage in terms of rebuilding or catch performance compared to the existing 3000t limit. Full robustness testing would be required if an alteration of the maximum TAC change limit was to be considered further.

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