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A candidate MP that uses only fishery independent data

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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.

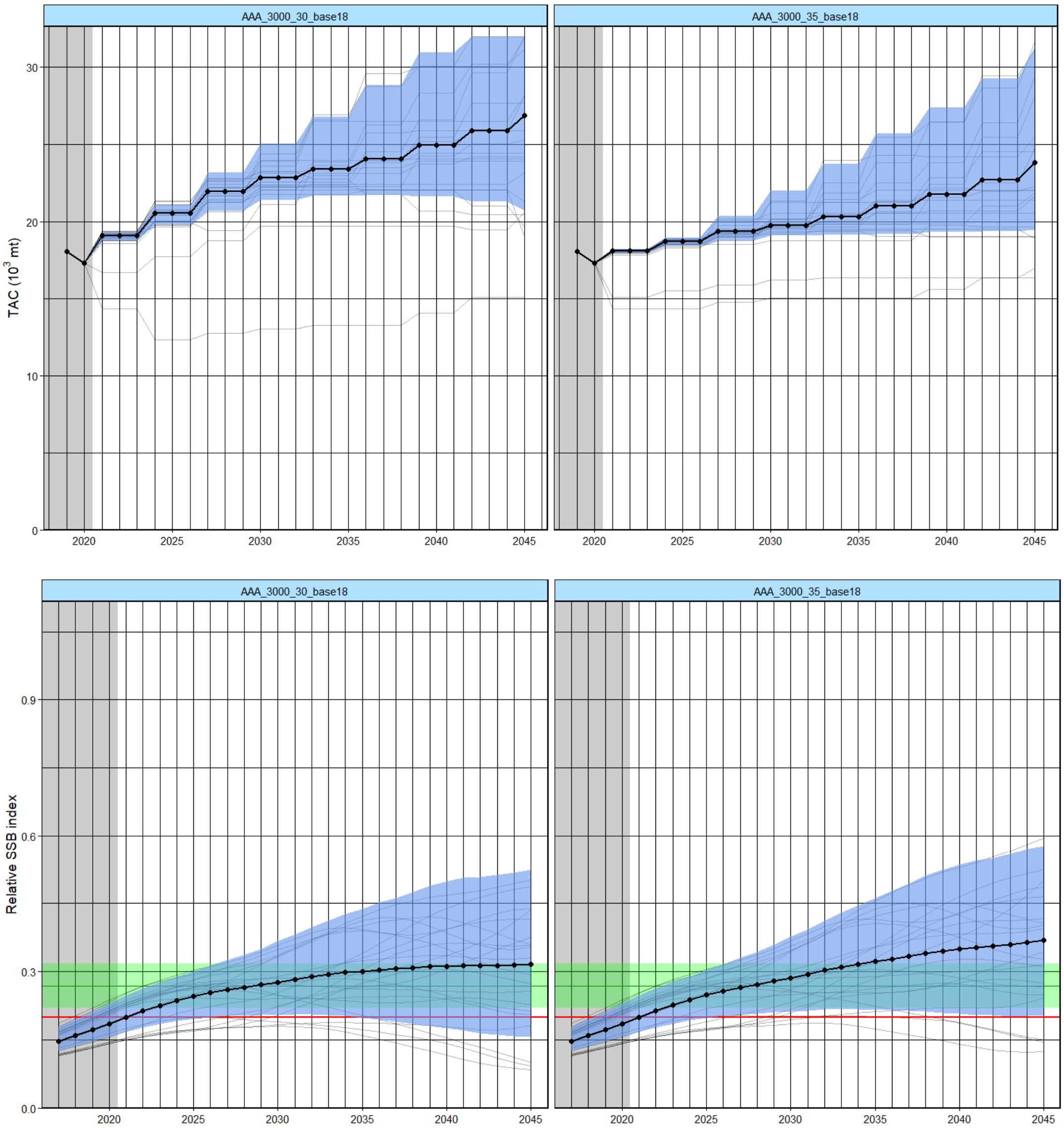

Figure 1. The TAC (top) and relative spawning stock biomass (SSB, bottom) for tuning level 30% SSB_0 by 2035 (left) and 35% SSB_0 by 2040 (right) showing 20 individual iterations, or worms, (thin black lines), the median (bold black line and points), and 80% confidence interval (blue shading). The median 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).

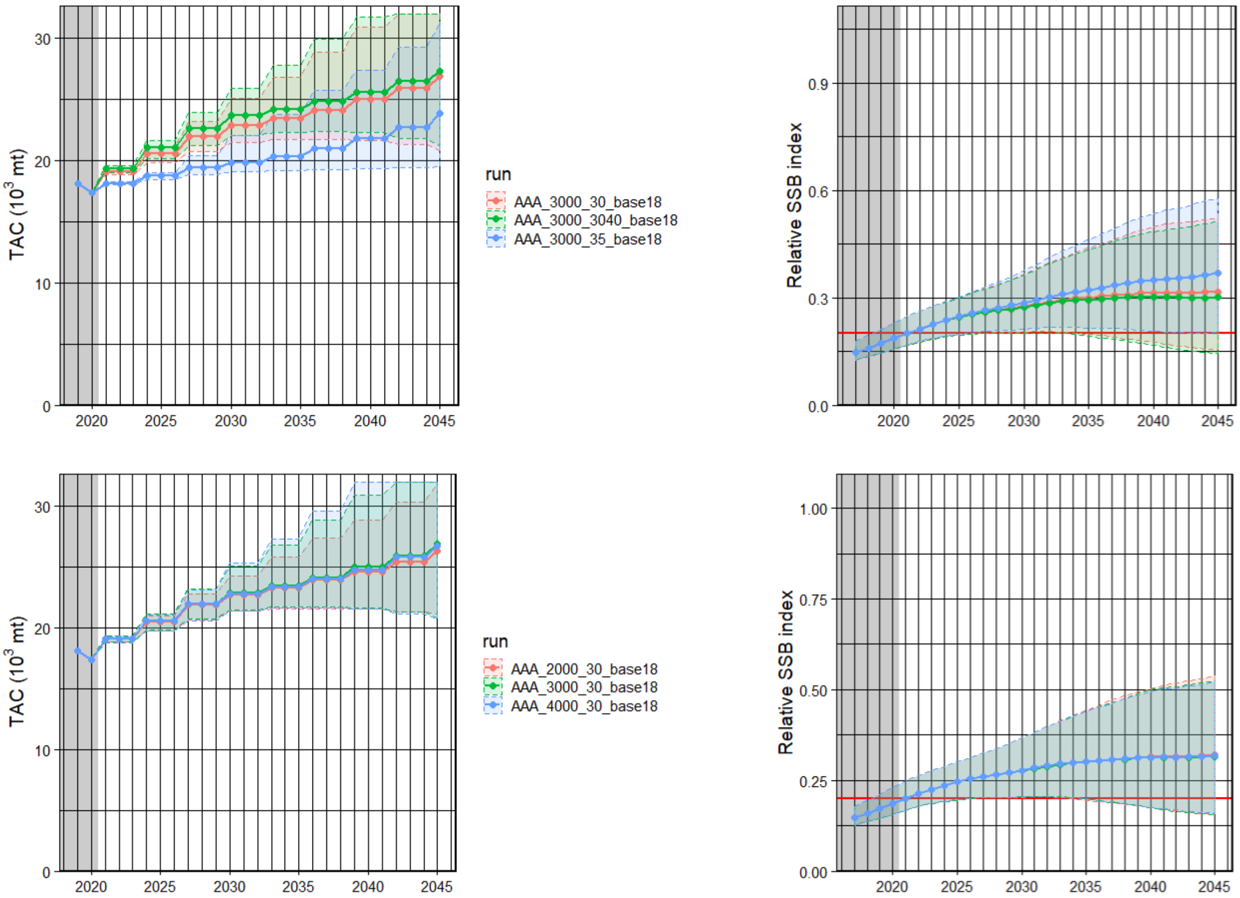

Figure 2. Comparison of MP performance for TAC (left) SSB (right) for three tuning combinations and different levels of maximum TAC change: a) (top) TAC and SSB performance for the MP tuned to 30% SSB_0 by 2040 MP (green), 30% SSB_0 by 2035 (red) and 35% SSB_0 by 2040 (blue); b) (bottom) maximum TAC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

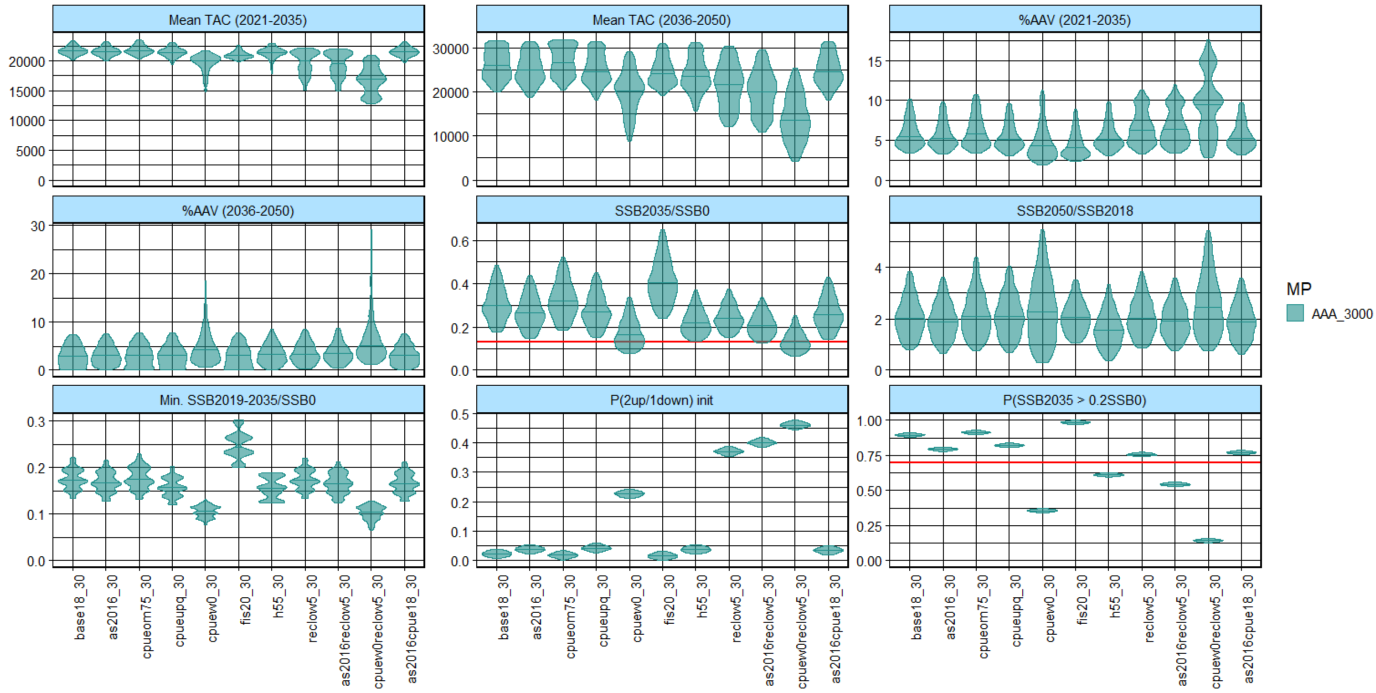

Figure 3. Output statistics for the MP tuned to 30% SSB_0 by 2035 for the base set and robustness tests. The horizontal line within each violin represents the median. The red horizontal line on the SSB2035 > 0.2SSB0 panel indicates the 70% probability level which was the interim rebuilding target for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

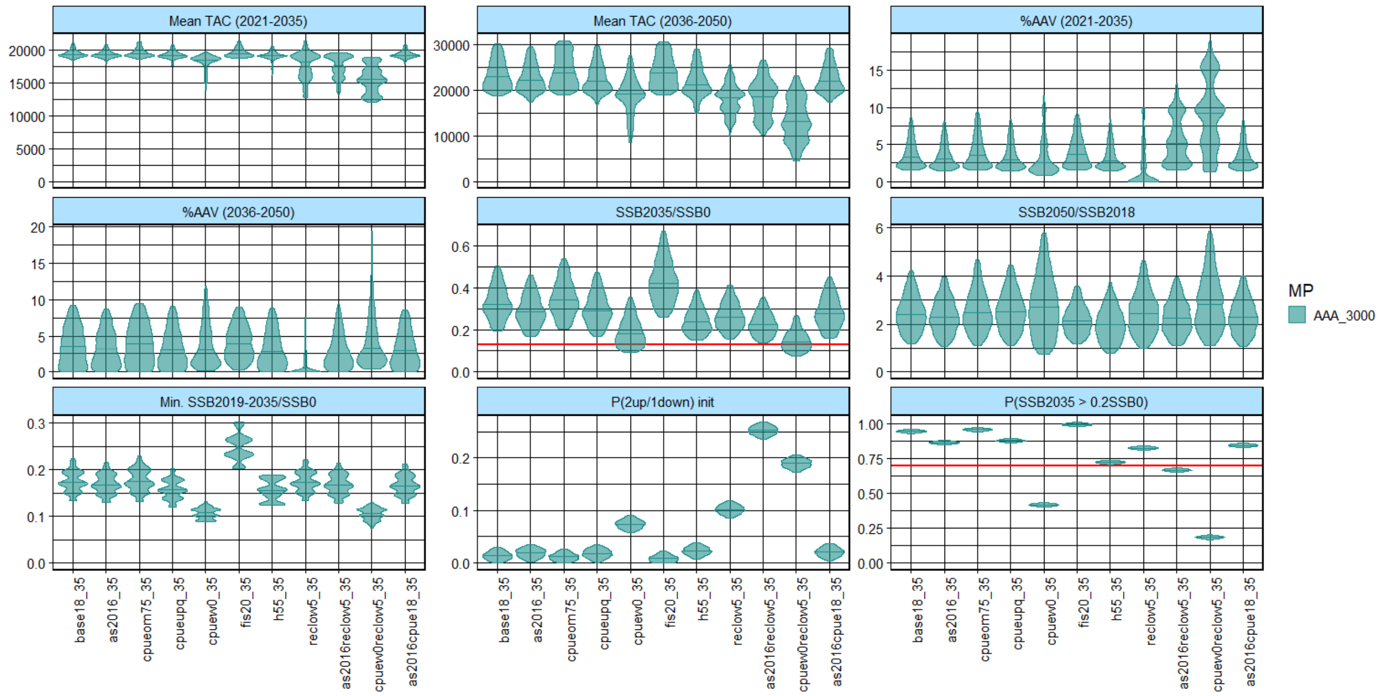

Figure 4. Output statistics for MP tuned to 35% SSB_0 by 2040 for the base set and robustness test. The horizontal line within each violin represents the median. The red horizontal line on the SSB2035 > 0.2SSB0 panel indicates the 70% probability level which was the target for the Bali Procedure MP adopted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

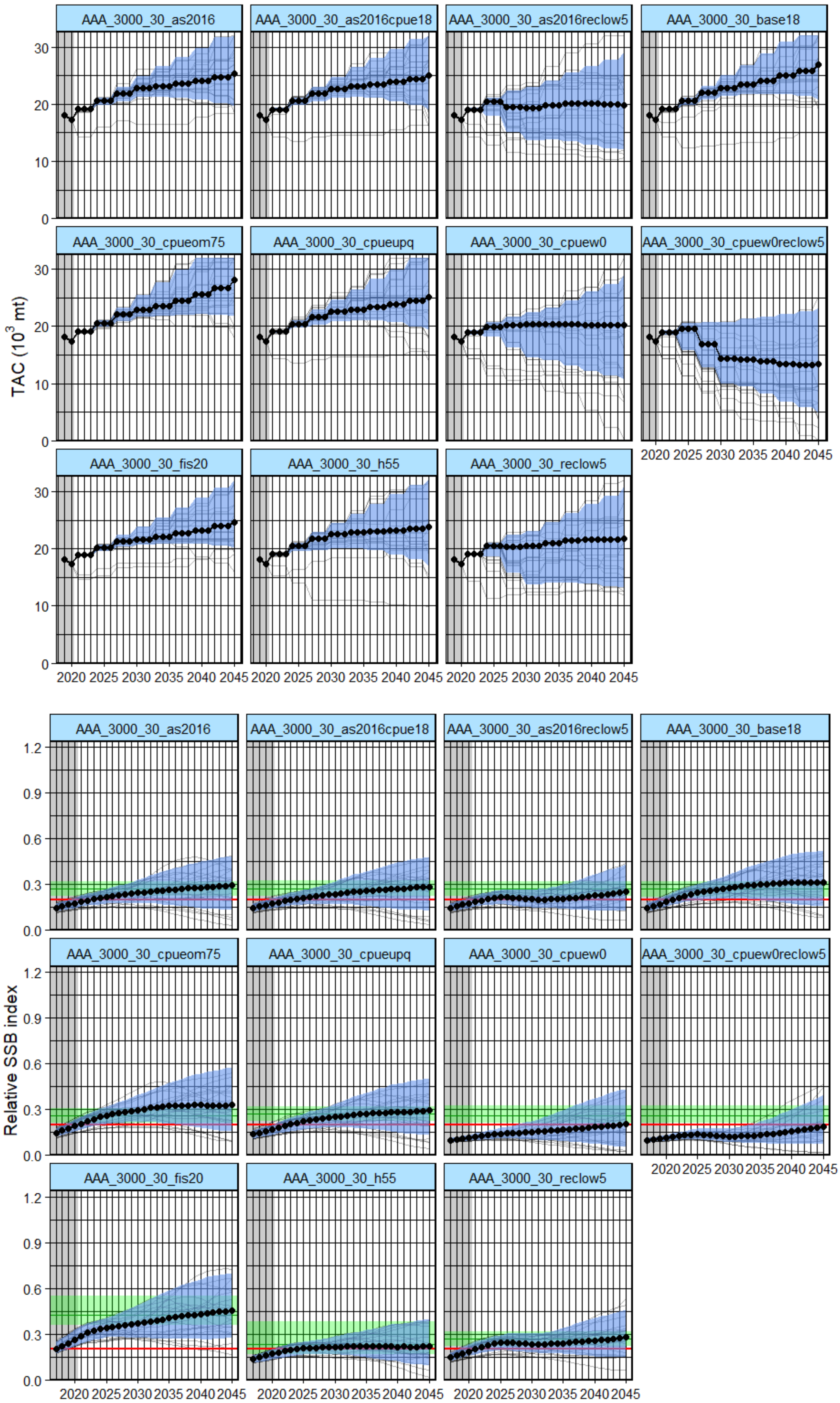

Figure 5. Detailed TAC (upper block) and SSB (lower block) results for the MP tuned to 30% SSB_0 by 2035 for the base set and robustness tests.

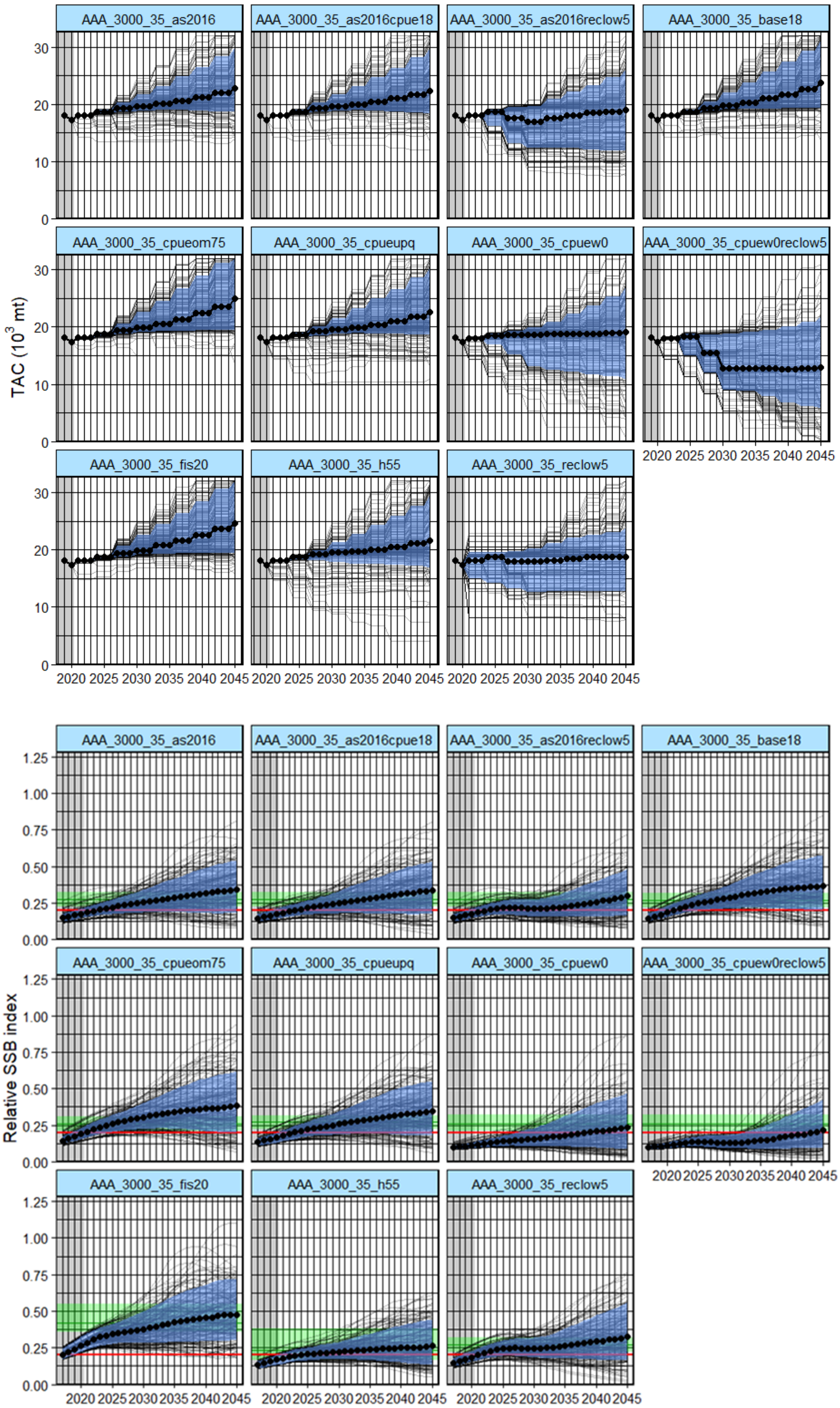

Figure 6. Detailed TAC (upper block) and SSB (lower block) results for the MP tuned to 35% SSB_0 by 2040 for the base set and robustness tests.

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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