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Performance of Revised CMPs

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Contents

Abstract

The performance of three revised forms of Candidate Management Procedures (CMPs) for SBT were explored. The Gene-Tagging+CPUE(rh11) and Gene+tagging+CPUE+Close-kin (rh12) CMPs are modified forms of the examples considered at the June 2018, OMMP9 meeting in Seattle. The third CMP (D25)uses only the Gene-tagging and Close-kin data. Performance of CMPs was compared across the 0.3SSB by 2035 and 0.35SSB0 by 2040 tuning criterion. For the 0.3SSB0 by 2035, there was a general requirement for CMPs to increase the TAC for both the first two TAC decisions (i.e. 2021-2023 and 2024-2026 TAC blocks) in order to meet the tuning criterion. In the case of rh11 and rh12, as a maxTAC constraint was added. This prevented these CMPs from raising TAC (and total catches) to levels that were unsustainable in the longer-term and would, as a result, require substantial TAC decreases in the future. The D25 CMP was not able to be tuned to the 0.3 by 2035 level, so alternative formulations of this CMP will need to be explored further to this tuning combination. All three CMPs could be tuned to the 0.35SSB by 2040 tuning criterion and achieved the 0.2SSB by 2035 with 70% probability. Preliminary results suggest that similar average catch performance can be achieved by rh11 and rh112 for the 0.3SSB by 2035 (20,000 t/yr) ands for 0.35 by 2040 tuning level(17,000-18,000 t/yr), with D25 having similar performance for average catch(18,500 t/yr) for the 0.35 by 2040 level. Both of the CMPs that include the CKMR data have a very low annual average catch variation and a very low to zero probability for both TAC up/down performance statistics, with no loss of robustness against the four trials with the largest impact (as2016, reclow5, cpueupq and cpuehcv).

1 Background

The CCSBT has agreed to develop a new management procedure for recommending the global TAC for SBT as a central component of the rebuilding plan for the stock and fishery. The current management procedure cannot be used to recommend TACs beyond 2018-2020 TAC block because the aerial survey will not be conducted from 2018 onwards. The aerial survey is used as the recruitment monitoring series in the harvest control rule of the current management procedure. The CCSBT has funded a gene-tagging recruitment monitoring program that will provide an index of juvenile abundance to be used in the new management procedure as a replacement for the aerial survey. The new management procedure is required by 2020 for recommending the TAC for the 2021-2023 TAC block. The process of development through to selection of a management procedure requires substantial consultation between scientists, managers, industry and other stakeholders. The process involves iterations of development and revision of management procedures (coding of computer models), presentation of results, discussion of performance and risks and their potential implications, revision of objectives and performance measures, and clarification of relative importance and trade-offs between conflicting objectives. This paper provides updated evaluation and exploration of candidate management procedures following review of initial candidates MPs at the OMMP technical working group meeting in June 2018.

2 Data and forms of Candidate MPs

The ESC has agreed to consider three data sources for use in development and evaluation of candidate MPs. The candidate MPs explored below use different combinations of these data and alternative forms of MP (i.e. analyses, form of HCR). The agreed data sources are:

1. Japanese long-line CPUE
2. The gene tagging (GT) data (matches and number of comparisons)
3. The close-kin mark-recapture (CKMR) data (matches and number of comparisons)

We present initial results of testing 3 alternative CMPs: revised versions of **rh3** (GT+CPUE) and **rh8** (GT+CPUE+CKMR) [2], which were considered at OMMP9 and have been renamed **rh11** and **rh12**, respectively; and an additional CMP, **D25**, which uses only GT and CKMR.

2.1 Candidate MPs using the CPUE & GT data

The original target/limit form of **rh3** descibed in [2] has been slightly modified for this candidate MP **rh11**. The target/limit formulation is retained for years prior to y_{targ}, albeit with a slight modification to include a reactivity parameter β^{cpue} (interpretation is that values of this parameter greater/less than equal to 1 are more/less reactive). For years after the target year, the MP reverts to a trend-driven structure (with gain parameter k^{cpue}).

$$\Delta_y^{\text{cpue}} = \left(0.5 \times \left(1 + \frac{\bar{I} - I_{\text{lim}}}{I_{\text{targ}} - I_{\text{lim}}}\right)\right)^{\beta^{\text{cpue}}} \quad \text{if} \quad \bar{I} \geq I_{\text{lim}} \quad \& \quad y < y_{\text{targ}}$$
$$\Delta_y^{\text{cpue}} = 2^{-\beta^{\text{cpue}}} \left(\frac{\bar{I}}{I_{\text{lim}}}\right)^2 \quad \text{if} \quad \bar{I} < I_{\text{lim}} \quad \& \quad y < y_{\text{targ}}$$
$$\Delta_y^{\text{cpue}} = 1 + k^{\text{cpue}}\lambda^{\text{cpue}} \quad \text{if} \quad y \geq y_{\text{targ}}$$

The target/limit formulation is retained for years prior to y_{targ}, albeit with a slight modification to include a reactivity parameter β^{cpue} (interpretation is that values of this parameter greater/less than equal to 1 are more/less reactive). For years after the target year, the MP reverts to a trend-driven structure (with gain parameter k^{cpue}). The actual HCR works as follows:

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

where ω^{cpue} is the CPUE intertia term and Δ_y^{gt} is the same limit-style GT functional form as used previously. It is referred to as **rh11**. In both this MP and the one using CKMR data the limit form of the gene tagging part of the HCR is unchanged from that explored in the OMMP work and presented at the meeting in Seattle.

2.2 Candidate MPs using the CKMR data

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

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

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 2.1: Settings for CKMR MP population model

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 [4]. 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 2.1.

The general structure of the revised MP is as follows:

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

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 subtley but 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:

- 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:

$$k^{\text{cpue}}(\eta) = k_1^{\text{cpue}}\left(1 - \left(1 + e^{-2\kappa\eta}\right)^{-1}\right) + k_2^{\text{cpue}}\left(1 + e^{-2\kappa\eta}\right)^{-1}$$

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:

$$\Delta_y^{\text{cpue}} = k^{\text{cpue}}(\eta)(1+\nu)\lambda^{\text{cpue}} \quad \text{if} \quad \lambda^{\text{cpue}} \leq 0,$$
$$\Delta_y^{\text{cpue}} = k^{\text{cpue}}(\eta)(1-\nu)\lambda^{\text{cpue}} \quad \text{if} \quad \lambda^{\text{cpue}} > 0$$

For the CKMR part of the HCR we try to preserve the main elements of the previous candidate MP (**rh8**): 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:

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

The threshold level at which a trend goes from a TAC decrease to an increase essentially begins at $\lambda_{\text{min}} > 0$ 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.

2.3 Introduction of a maximum TAC

Along with embedding a kind of switching mechanism in both **rh11** and **rh12**, in terms of behaviour once the target is met, we also introduce 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.

2.4 GT and CK Candidate MPs

Candidate MPs that use only the gene-tagging and close-kin data were also explored, using code described earlier [2], for GT and section 2.1 above for CKMR). Various changes to parameters were made to turn off the CPUE component and for tuning the new CMP. This form of CMP is of interest because it is fishery independent and avoids known issues with CPUE and uncertainty in the relationship between CPUE and abundance. This CMP is different because it does not use the recent positive trend in CPUE that drives some of the behaviour seen in other forms of CMP.

3 Candidate MP performance on the reference set

3.1 CMPs tuned to median of 30% of unfished level by 2035

Regardless of the CMP examined, there appears to be a general requirement for *any* CMP to be able to increase the TAC in the first two decisions by around 1,000t each time to be able to tune to this level. In

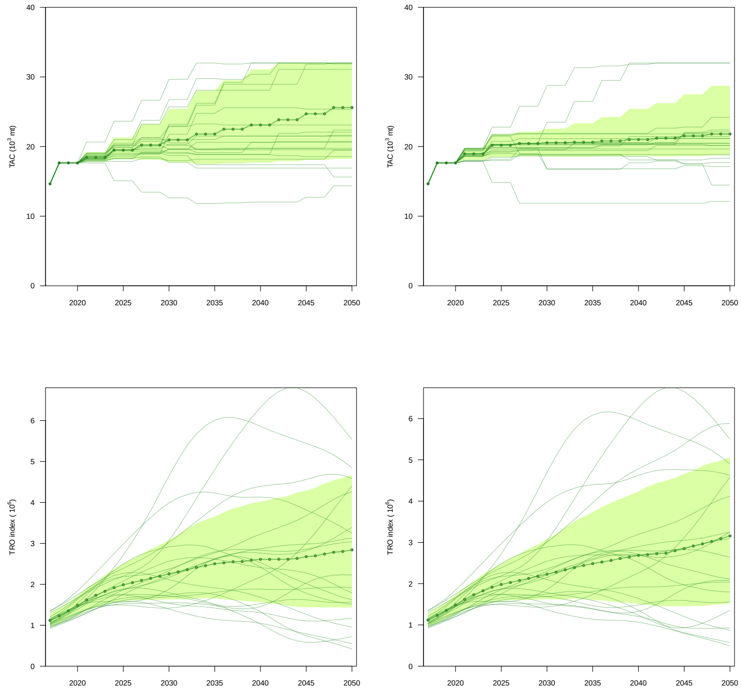

Figure 3.1: *TAC (top) and TRO (bottom) median, 80%CI and 20 random worms for **rh11** (left) and **rh12** (right).*

the case of (**rh11** and **rh12**) this could only really be achieved by making the CMP reasonably responsive to the strong positive signal in the CPUE of the very large 2013 year-class moving through the long-line fishery. In the first 5–7 years of the projections the signals in both the GT and the CKMR data do not make it possible to sensibly construct an HCR that would achieve the required increases in the first two TAC changes and, hence, meet this tuning level.

Figure 3.1 details the TAC and TRO projection summaries (median, 80% CI and 20 worms) for the two MPs (**rh11** and **rh12**). The differences between the two MPs are fairly clear:

- TAC performance: **rh11** shows more variability and a steadily increasing median TAC; **rh12** is far less variable and a slower but still generally increasing median TAC trend after the first two TAC changes
- SSB (TRO) performance: very similar for both, with a slower rate of increase post-2035 for **rh11** than for **rh12** and more variance in SSB (TRO) above the median (given lower levels of catch)

3.2 tuned to median of 35% of unfished level by 2040

Figure 3.2 summarises the TAC and SSB (TRO index) projections for the 35% of unfished level by 2040 tuning level (median, 80% CI and 20 worms) for **rh11** and **rh12**. For this tuning level:

- TAC performance: **rh11** shows more variability and a steadily increasing TAC after 2040 but fairly constant until then; **rh12** is far less variable with minimal chance of consistent TAC increases or decreases before 2040
- SSB (TRO) performance: very similar for both, with a slower rate of increase post-2040 for **rh11** than for **rh12** and more variance in SSB (TRO) above and below the median (given lower levels of catch variability).

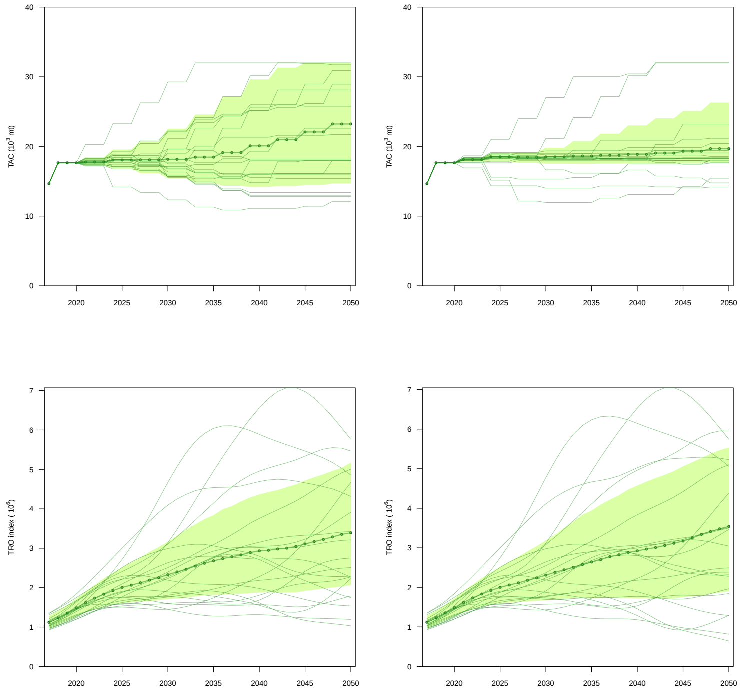

Figure 3.2: *TAC (top) and TRO (bottom) median, 80%CI and 20 random worms for* ***rh11*** *(left) and* ***rh12*** *(right).*

- TAC performance: **rh11** shows more variability and a steadily increasing TAC after 2040 but fairly constant until then; **rh12** is far less variable with minimal chance of consistent TAC increases or decreases before 2040
- TRO performance: very similar for both, with a slower rate of increase post-2040 for **rh11** than for **rh12** and more variance in TRO above and below the median (given lower levels of catch variability).

3.2.1 GT and CKMR Candidate MP

The Candidate MP that uses only the gene-tagging and close-kin data has only been tuned to reach 35% SSB0 by 2040, and it has a greater than 70% probability of being at least 20% SSB0 by 2035 (the interim rebuilding target). Under this MP, median recruitment trends are positive, median SSB increases through to 2050, there is a low probability of falling below 20% SSB after 2035, and there are TAC increases on average throughout the period of the projections, with low probability of TACs below current levels.

It was difficult to find parameters that would allow this CMP to be tuned to the 30% SSB0 by 2035 target, as higher initial catches are needed to reach this target. When tuned to 35% by 2040, the 30% target is over-shot with more than 58% of the trajectories above this target. We plan to keep investigating alternative parameterisation of this CMP to reach this or other targets that are preferred or requested by the Commission.

4 Candidate MP performance across key robustness tests

For both tuning scenarios the key robustness tests that seemed to make the most difference (specifcially more pessimistic than the reference case) were:

1. **as2016**: remove the 2016 aerial survey point

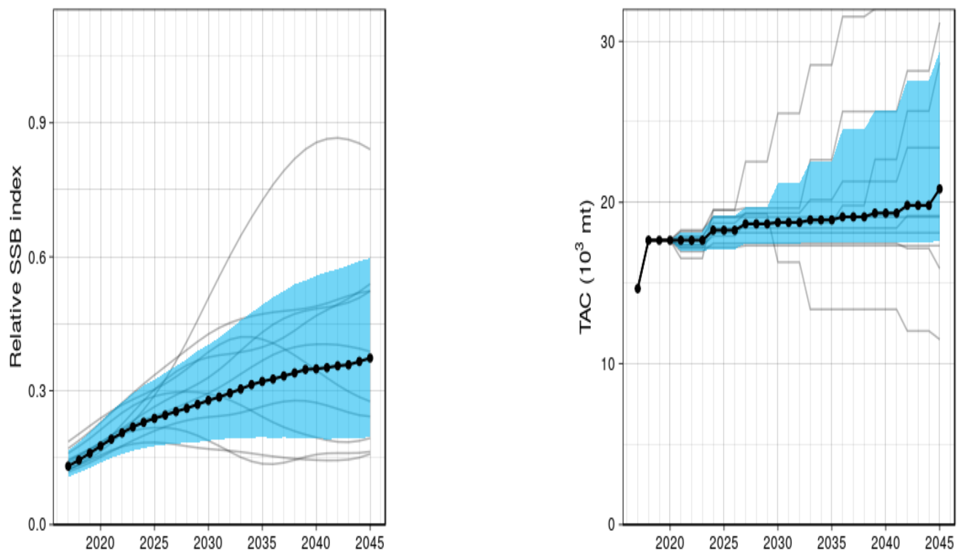

Figure 3.3: *TRO status (left) and TAC (right) for D25 tuned to 35% by 2040.*

2. **reclow5**: mean recruitment reduced by 50% for the first 5 years of the projections
3. **cpueupq**: from 2008 onwards LL catchability is permanently increased by 25%
4. **cpuehcv**: minimum CPUE CV (past and future) is 0.3 instead of the reference case of 0.2

4.1 tuned to median of 30% of unfished level by 2035

Figure 4.1 Summarises stock status (SSB (TRO)) and mean TAC statistics across the important robustness tests for CMPs tuned to median of 30% of unfished level by 2035. Notable results include:

- For the previous rebuilding objective *all* MPs across *all* the displayed robustness trials attained at least the 70% probability of being above 20% of the unfished level by 2035
- Average reference case catches between 2021 and 2035 were around 20,000t for both MPs
- For the maximum TAC decrease, outside of the **reclow5** robustness trial it is less than 1,000t for **rh11** and very close to zero for **rh12**. For the **reclow5** test it is higher and for **rh12** the median is 3,000t so this MP reacts strongly to this test even with the same GT limit term in both MPs
- In terms of AAV, median levels for **rh11** were between 5 and 10%; for **rh12** between 3 and 5%
- In terms of the 2-up-then-down probability for the first 3 TAC changes for **rh11** it was 0.18 for the **reclow5** trial and at or less than 0.12 for the rest. For **rh12** the probability is effectively zero for all trials

4.2 CMPs tuned to median of 35% of unfished level by 2040

Figure 4.2 summarises the SSB (TRO) stock status and mean TAC statistics across the important robustness tests for CMPs tuned to median of 35% of unfished level by 2040.

- For the previous rebuilding objective *all* CMPs across *all* the robustness trials were clearly above the 70% probability of being above 20% of the unfished level by 2035
- Average reference case catches between 2021 and 2035 were around 17,000–18,000t for both CMPs
- For the maximum TAC decrease, outside of the **reclow5** robustness trial it is less than 1,000t for

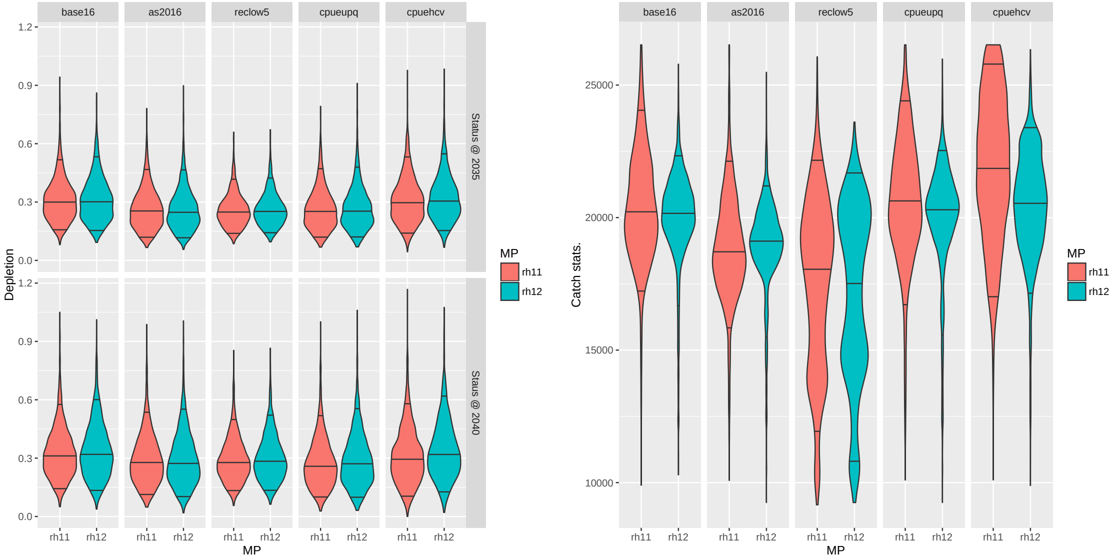

Figure 4.1: *TRO status (left) and mean TAC statistics (right) across the key robustness trials.*

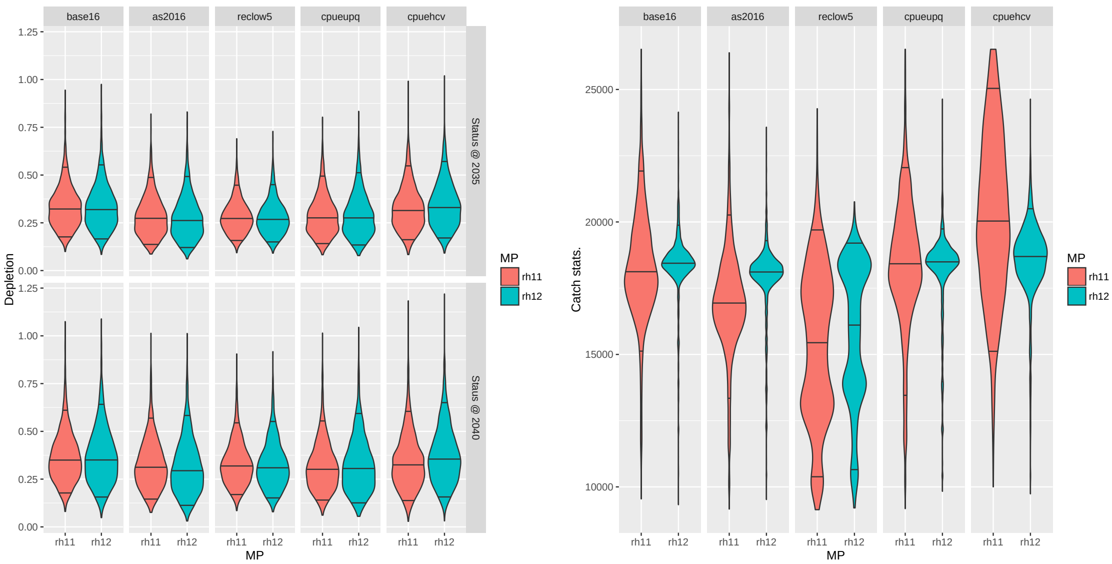

Figure 4.2: *TRO status (left) and mean TAC statistics (right) across the key robustness trials.*

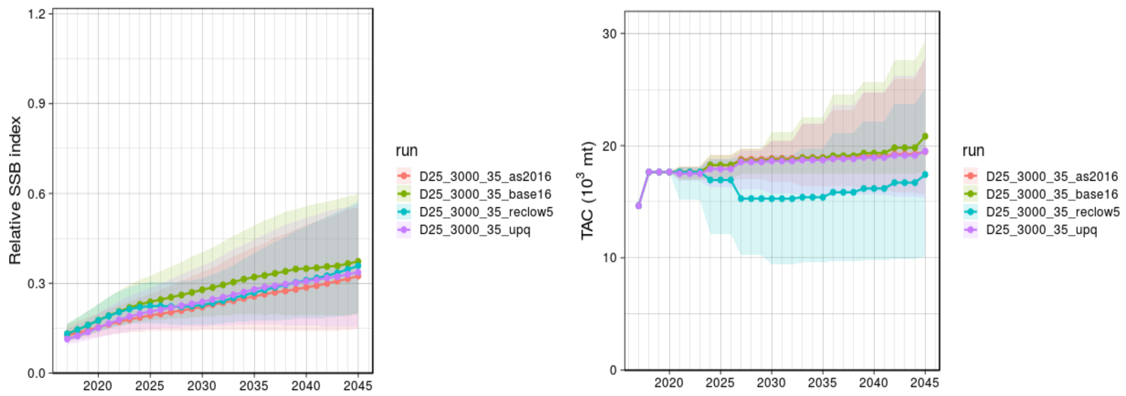

Figure 4.3: *Comparison of SSB and TAC for the base set and 3 robustness tests (noAS, reclow5 and upq)*

Run	base2016	as2016	reclow5	upq
Mean $TAC_{2021\text{-}2035}$	18,533	18,528	16,092	19,407
Mean $TAC_{2036\text{-}2050}$	20,223	19,448	16,829	19,407
AAV (%)	1.9	2.1	5.6	2.1
Status (2035)	0.32	0.26	0.27	0.28
Status (2050)	0.41	0.37	0.44	0.38
Status (2035/2018)	2.17	1.83	1.82	2.15
Status (2050/2018)	2.75	2.62	2.96	2.91
Min. status (2019-2035)	0.16	0.14	0.16	0.14
70% above 20% SSB0	2022	2026	2022	2024
SSB (MSY) year	2027	2031	2033	2030
$\mathbb{P}(SSB_{2041-2050} > SSB_{msy})$	0.74	0.62	0.74	0.66
Max. TAC decr.	0	0	3,000	0
P(2up/1down)	0.003	0.01	0.002	0.01
P(2up/1down) beta	0.007	0.02	0.01	0.015
10%ile TAC	17,303	16,803	11,315	16,114
$\mathbb{P}(SSB_{2035} < 0.2SSB_0$	0.12	0.28	0.19	0.21
$\mathbb{E}(CPUE_{2021-2030}/CPUE_{2019})$	0.9	1.02	0.67	0.9

Table 4.1: *TRO summary for D25.*

rh11 and mostly less than 500t for **rh12**. For the **reclow5** test the median is 3,000t for both MPs so both react strongly for this robustness trial

- In terms of AAV, median levels for **rh11** were between 3 and 8%; for **rh12** between 2 and 5%
- In terms of the 2-up-then-down probability for the first 3 TAC changes for **rh11** it was mostly below 0.12 for all tests. For **rh12** the probability is less than 0.05 except for the **hcpuecv** case where it was 0.1

4.2.1 GT and CKMR CMP

The GT & CK MP was also tested against the key robustness tests **as2016**, **reclow5** and **upq**. The interim rebuilding objective (70% probability of reaching 20% SSB0 by 2035) is still met under these robustness tests, however, and as with the other CMPs,the probability of reaching the new target is reduced. The CMP continues to work effectively under conditions it was not tuned to and median trends in SSB, recruitment and TAC are similar to the base set. The **upq** and **as2016** robustness tests showed similar median trajecories in SSB and TAC. The D25 MP acted strongly in the low recruitment robustness test to cut TAC and maintain rebuilding of the SSB. Performance statistics are provided in Figures 4.3 and 4.4 and Table 4.1.

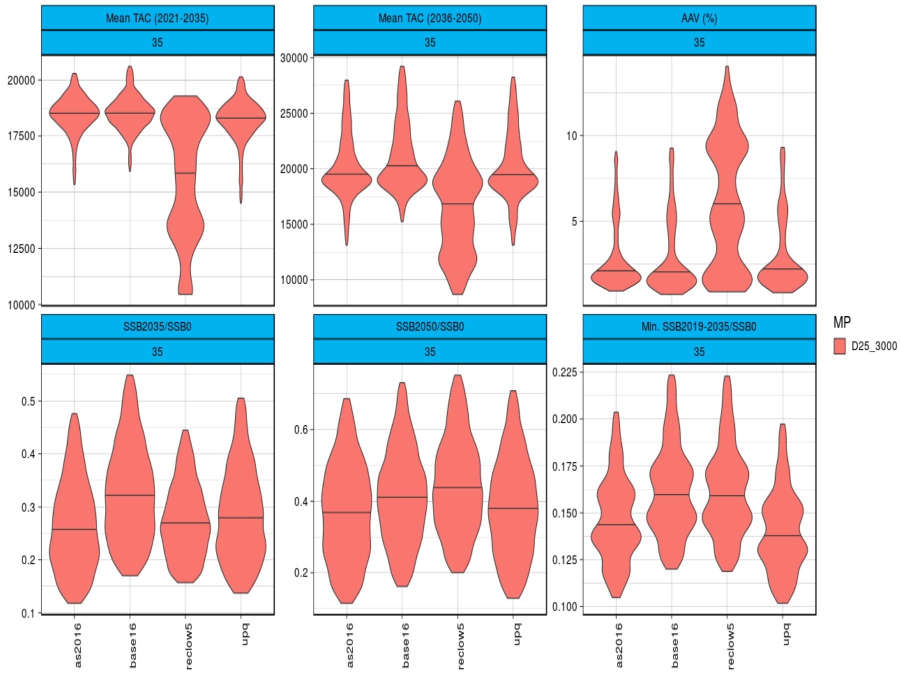

Figure 4.4: *Comparison figures of the main performance meaures for the D25 MP for the base set and three robustness tests.*

5 Conclusions

General conclusions:

- For the 30% by 2035 tuning level, average catches are around 20,000t. A consistent result was that any MP needs to nudge up the TAC by around 1,000t for the first and second decisions to be able to tune to the 30% level. The GT & CKMR CMP was unable to tune to this level as these input data series do not reflect the strong 2013 year class early in the simulation period. This sort-of-necessitates the use of the CPUE data as it “sees” the big 2013 year-class at the right time to give the MPs the signal they need to be able to tune to the 35% by 2035 combination.
- For the 35% by 2035 tuning average catches are around the 17,000–18,000t.
- For same level of relative TRO risk we can reduce the reactivity of the MP using all three data sets (**rh12**) versus the one using only CPUE and GT data (**rh11**). This achieves better performance in terms of AAV and catch variability without any loss of performance in terms of the pessimistic robustness trials. It also makes the chance of a TAC decrease after two initial increases very low across all trials.
- The two clear robustness trials that produce quite different dynamics are the removal of the 2016 aerial survey and the 5-year low recruitment trials. These both result in clearly lower average TACs, but all CMPs appear to still attain the original tuning target of the Bali Procedure even for these robustness trials.

6 Acknowledgements

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