FURTHER EXPLORATORY INVESTIGATIONS OF SOME SIMPLE CANDIDATE MANAGEMENT PROCEDURES FOR SOUTHERN BLUEFIN TUNA

D.S Butterworth, M.R.A Jacobs, R.A. Rademeyer[1] and M. Miyagawa[1,2]

SUMMARY

Target-type CMPs for SBT developed in 2018, and using CPUE, close kin mark recapture (CKMR) and gene tagging information, are somewhat refined and re-tuned to median recovery to 30% of the pristine TRO in 2035 for the 2018 update of the operating models. The tuning is carried out for each information type separately, and then the performance of weighted combinations of the resultant three CMPs is explored further for the base grid and the low recruitment (reclow5) robustness test. For the limited exploration of options possible thus far, broad indications are that the GT data provide the best basis to secure against unintended resource depletion (conceivably because they are the first to detect poor recruitment), whereas use of the CKMR information leads to greater predictability and stability for the fishery.

要旨

CPUE,遺伝標識（GT)、近親遺伝標識再捕親子（CKMR）を用いた 2018 年に開発されたターゲットタイプの管理方式を、OM の 2018 年のアップデートのために改良し、資源水準目標（2035 年の TRO が初期のそれの 30%まで回復する）に合わせてチューニングをし直した。CPUE,GT,CKMR の個々の情報に対して別々にまずはチューニングを行い、その後三つの CMP を重みづけして統合させたものについて、ベースケースと、頑健性テストの一つである低加入シナリオ（reclow5）についてパフォーマンスを評価した。限られた時間の中での解析結果から分かった大まかなことは、意図的でない資源の減少に対しての反応が最もよい指標は GT データであり、おそらく、加入量が低いということを一番最初にみつけるためであろう。一方、CKMR による情報は、漁業の予測性と安定性に貢献する。

Introduction

This paper applies the target-type Candidate Management Procedures (CMPs) for SBT developed during 2018 (Butterworth et al. 2018a, b) to the updated RC grid (base18), re-tuning these to a median recovery of 30% of the pristine TRO in 2035. A further refinement considered is allowing the “gain” control parameter value for these CMPs to differ depending on whether the current value of the index concerned is above or below its target value.

The approach is applied separately for each of the three types of information available (CPUE, close kin mark recapture (CKMR) and gene tagging (GT)). Then the performance of a weighted combination of each of the three CMPs is investigated. In these combinations, the GT component is refined as described above with

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[1] Marine Resource Assessment and Management Group (MARAM), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch 7701, South Africa
[2] current- National Research Institute of Fisheries Science, Japanese Fisheries Research and Education Agency, Yokohama, Japan

different values for its “gain” parameter. This is done for the GT component only, as it was found unable to improve performance for the approaches when based on CPUE or CKMR information.

Results are presented and discussed for six CMPs applied to base18 and to the robustness test with five successive years of a reduced expectation for the value of recruitment (reclow5). Conclusions are summarised and future work is suggested in the context that the specific choices made for the control parameter values of these CMPs are very preliminary, given the short time for which the updated grid OMs have been available.

Methods

Indices

Aggregate indices for the data inputs are defined below, followed by the specifications of the CMPs considered.

CPUE index

J_y is a relative CPUE index averaged over 5 years as follows:

$$J_y = \frac{\left(CPUE_{y-2} + CPUE_{y-3} + CPUE_{y-4} + CPUE_{y-5} + CPUE_{y-6}\right)\cdot\frac{1}{5}}{\left(CPUE_{2016} + CPUE_{2015} + CPUE_{2014} + CPUE_{2013} + CPUE_{2012}\right)\cdot\frac{1}{5}}$$

CKMR index

$CKMR_y$ is a relative CKMR index averaged over 2 years as follows:

$$CKMR_y = \frac{\left(S_{y-5} + S_{y-6}\right)\cdot\frac{1}{2}}{\left(S_{2013} + S_{2012}\right)\cdot\frac{1}{2}}$$

GT index

GTJ_y is a relative GT index averaged over 5 years as follows:

$$GTJ_y = \frac{\left(GTJ_{y-2} + GTJ_{y-3} + GTJ_{y-4} + GTJ_{y-5} + GTJ_{y-6}\right)\cdot\frac{1}{5}}{GTJ_{2016}}$$

CMPs

The CMPs explored are as follows.

DMRCPUE

DMRCPUE is a CMP that uses CPUE data only, based on the following formulae:

$$TAC_{y+1}^{CPUE} = TAC_y^{COMB} \times \left(1 + \beta\cdot\left(J_y - J_{targ}\right)\right)$$

$$\text{If } TAC_{y+1}^{CPUE} > 28\,000, \text{then } TAC_{y+1}^{CPUE} = 28\,000$$

DMRCKMR

DMRCKMR is a CMP that uses CKMR summary data only, based on the following formulae:

$$\mathrm{TAC}_{y+1}^{\mathrm{CKMR}} = \mathrm{TAC}_{y}^{\mathrm{COMB}} \times \left(1 + \kappa \cdot \left(\mathrm{CKMR}_{y} - \mathrm{CKMR}_{\mathrm{targ}}\right)\right)$$

$$\text{If } \mathrm{TAC}_{y+1}^{\mathrm{CKMR}} > 28\,000, \text{then } \mathrm{TAC}_{y+1}^{\mathrm{CKMR}} = 28\,000$$

where $\mathrm{CKMR}_{\mathrm{targ}}$ and the other control parameters are defined below:

$$\mathrm{CKMR}_{\mathrm{targ}} = \left(\frac{T2-T1}{y2-y1}\right) \cdot (y - y1) + T1 \qquad y1 \le y \le y2$$

$$\mathrm{CKMR}_{\mathrm{targ}} = T2 \qquad y2 < y$$

DMRGT

DMRGT is a CMP that uses GT data only, based on the following formulae:

$$\mathrm{TAC}_{y+1}^{\mathrm{GT}} = \mathrm{TAC}_{y}^{\mathrm{COMB}} \times \left(1 + \gamma \cdot \left(\mathrm{GTJ}_{y} - \mathrm{GTJ}_{\mathrm{targ}}\right)\right)$$

$$\text{If } \mathrm{TAC}_{y+1}^{\mathrm{GT}} > 28\,000, \text{then } \mathrm{TAC}_{y+1}^{\mathrm{GT}} = 28\,000$$

DMRGTD

DMRGTD is a variant of DMRGT that again uses GT data only, based on the following formulae, which differ depending on whether the index is above or below the target level:

If $(\mathrm{GTJ}_{y} > \mathrm{GTJ}_{\mathrm{targ}})$: $$\mathrm{TAC}_{y+1}^{\mathrm{GTD}} = \mathrm{TAC}_{y}^{\mathrm{GTD}} \times \left(1 + \gamma_{\mathrm{up}} \cdot \left(\mathrm{GTJ}_{y} - \mathrm{GTJ}_{\mathrm{targ}}\right)\right)$$

If $(\mathrm{GTJ}_{y} < \mathrm{GTJ}_{\mathrm{targ}})$: $$\mathrm{TAC}_{y+1}^{\mathrm{GTD}} = \mathrm{TAC}_{y}^{\mathrm{GTD}} \times \left(1 + \gamma_{\mathrm{down}} \cdot \left(\mathrm{GTJ}_{y} - \mathrm{GTJ}_{\mathrm{targ}}\right)\right)$$

$$\text{If } \mathrm{TAC}_{y+1}^{\mathrm{GTD}} > 28\,000, \text{then } \mathrm{TAC}_{y+1}^{\mathrm{GT}} = 28\,000$$

DMRCOMB

DMRCOMB is a CMP that uses a combination of CPUE, CKMR and GTD information, based on the following formulae:

$$\mathrm{TAC}_{y+1}^{\mathrm{COMB}} = w_{\mathrm{CPUE}} \cdot \mathrm{TAC}_{y+1}^{\mathrm{CPUE}} + w_{\mathrm{CKMR}} \cdot \mathrm{TAC}_{y+1}^{\mathrm{CKMR}} + w_{\mathrm{GTD}} \cdot \mathrm{TAC}_{y+1}^{\mathrm{GTD}}$$
$$\text{where } w_{\mathrm{CPUE}} + w_{\mathrm{CKMR}} + w_{\mathrm{GTD}} = 1$$

The various CMPs are tested with the following common additional specifications:

- TACs are set in 3-year blocks
- TAC is restricted to a maximum change of 3 000t (up or down)
- The minimum change limit is 100t, hence: $100 \le \left|\mathrm{TAC}_{y+1} - \mathrm{TAC}_{y}\right| \le 3\,000$ in years when there is a TAC change
- The maximum TAC for all the CMPs considered is 28 000t

Results and Discussion

The control parameter values chosen for the six CMPs considered are listed in Table 1, with values (medians where distributions are concerned) of the summary performance statistics for the Reference Case (RC) grid (base18) and the reclow5 (five successive years of low recruitment) robustness test provided in Table 2. To date, only tunings to achieve a median TRO in 2035 which is 30% of its pristine value for the RC grid have been developed. The results are compared graphically in a "guitar" plot in Figure 1, with worm plots for the TAC and for the TRO for the RC grid shown in Figures 2a to 2f for each of the CMPs in turn.

These CMPs were developed by first tuning a CMP using one source of information only (DMRCPUE, DMRCKMR and DMRGT). This involved the choice of minimally two control parameter values: a target value (more complex for DMRCKMR) and a "gain" value. The approach used in each case was to balance the choice between these two to keep AAV low for the period to 2035, while at the same time allowing for reasonable reactivity to cut the TAC sufficiently to be able to react appropriately to low values of the index. To enhance such reactivity, a variant was explored which allowed for greater values of the gain parameter when the index was below compared to above its associated target value, but this was found to be effective only in the case of the GT data (DMRGTD). Interestingly, this differed from experience for the base16 grid, for which improvements in lowest depletion (and to a greater extent) were found for all three information types. Possibly these differences arise from base18 reflecting improved current resource status compared to base16.

Figure 1 provides perhaps the easiest way to compare the performances of these four CMPs. Considering primarily the period to 2035, the essential trade off is that the CMP based on GT provides the best protection against unintended resource depletion (better still for DMRGTD, especially for reclow5) and the lowest values for P(2up/1down); but this CMP performs the worst in terms of anticipated mean TAC variance (i.e. resource production predictability) and AAV. DMRCKMR shows the opposite behavior in all these respects, with DMRCPUE generally intermediate in performance between these two.

The first combination CMP, DMRCOMB1, accorded a one third weighting to each of the CMPs above (with the DMRCKD variant being used), with these values being chosen purely to provide a baseline. Unsurprisingly performance is intermediate between the DMPGTD and DMRCKMR extremes, though AAV is lower than for the former also because of a reduction of the influence of noise in the data given three rather than a single source of information being input. The second combination CMP, DMRCOMB2, gave relatively more weight to DMRCKMR to reduce AAV, though this came at the expense of less protection against unintended resource depletion.

Conclusions and Future Work Planned

The control parameter choices and relative weightings for the CMPs reported here should be regarded as very provisional, given that very little time was available to explore options after the base18 grid became available. Furthermore, most of the robustness tests have still to be run for the CMPs developed here.

It will be of interest whether further work on exploring alternatives to the current selections confirms the general pattern suggested by the results to date. This is one of the GT data providing the best basis to secure against unintended depletion (conceivably because they are the first to detect poor recruitment), whereas use of the CKMR information leads to greater predictability and stability for the fishery.

Additional work will first need to develop selections of control parameter values for the alternative recovery tuning specified by the Extended Commission (0.35SSB0 by 2040). Then more attention will need to be paid to performance for the 2035-2050 period. For the present control parameter value choices, the broad pattern (in median terms) is for TRO to remain fairly close to its 2035 value with the TAC continuing to increase. Alternative trade-offs in that regard could be obtained by allowing for a change in 2035 in the values of control parameters.

Acknowledgments

We thank those who developed the trials code, especially those who provided assistance in implementing it.

References

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Butterworth, D.S., Miyagawa, M. and Jacobs, M.R.A. 2018b. Further exploratory investigations of some simple candidate management procedures for southern Bluefin tuna. Paper presented to the CCSBT ESC meeting, San Sebastian, 3-8 September 2018. CCSBT-OMMP/1809/43: 11pp.

Table 1. Values of the control parameters for the six CMPs considered. All are tuned to achieve a median TRO in 2035 which is 30% of its pristine value for the RC (base18) OM. Note that the DMRCOMB CMPs both used the GTD variant of the gene tagging CMP.

	DMRCPUE	DMRCKMR	DMRGT	DMRGTD	DMRCOMB1	DMRCOMB2
CPUE:						
β	0.130				0.130	0.130
J_{targ}	0.9				0.9	0.9
CKMR:						
κ		0.163			0.163	0.163
T1		0.4			0.4	0.4
T2		1.5			1.5	1.5
y1		2021			2021	2021
y2		2030			2030	2030
GT:						
γ			0.25			
γ_{up}				0.25	0.25	0.25
γ_{down}				0.75	0.75	0.75
GTJ_{targ}			0.5	0.5	0.5	0.5
COMB:						
w_{CPUE}					1/3	0.25
w_{CKMR}					1/3	0.5
w_{GTD}					1/3	0.25

Table 2. Some performance statistics for the six CMPs considered for the RC (base18) and one robustness test (reclow5). Median values are shown for the distributions for each statistic. Recall that each CMP is tuned to achieve a median TRO in 2035 which is 30% of its pristine value for the RC (base18) OM.

CMP	Run	Mean TAC (2021-2035)	Mean TAC (2036-2050)	% AAV (2021-2035)	% AAV (2036-2050)	SSB2035/ SSB0	SSB2050/ SSB0	Min. SSB (2019-2035) / SSB0	P(2up/1down)	P(SSB2035 > 0.2SSB0)
DMRCPUE	base18	21 698	27 542	7.0	1.7	0.30	0.32	0.17	0.08	0.90
	reclow5	20 868	24 631	5.5	4.2	0.23	0.27	0.17	0.36	0.69
DMRCKMR	base18	21 638	26 536	3.9	3.6	0.30	0.33	0.17	0.21	0.87
	reclow5	21 481	24 842	3.8	3.5	0.22	0.25	0.16	0.19	0.64
DMRGT	base18	22 126	28 000	9.0	0.0	0.30	0.30	0.17	0.01	0.92
	reclow5	20 121	27 412	5.9	2.5	0.24	0.25	0.17	0.02	0.75
DMRGTD	base18	22 115	28 000	9.0	0.0	0.30	0.30	0.17	0.01	0.92
	reclow5	19 976	27 216	6.9	3.0	0.24	0.26	0.17	0.03	0.77
DMRCOMB1	base18	21 877	27 732	6.9	1.0	0.30	0.31	0.17	0.01	0.90
	reclow5	20 807	26 496	4.3	3.0	0.23	0.26	0.17	0.06	0.70
DMRCOMB2	base18	21 788	27 546	6.2	1.6	0.30	0.31	0.17	0.02	0.89
	reclow5	20 971	26 190	4.1	3.0	0.23	0.25	0.16	0.08	0.69

Figure 1. “Guitar plots” of performance statistics for the six CMPs investigated.

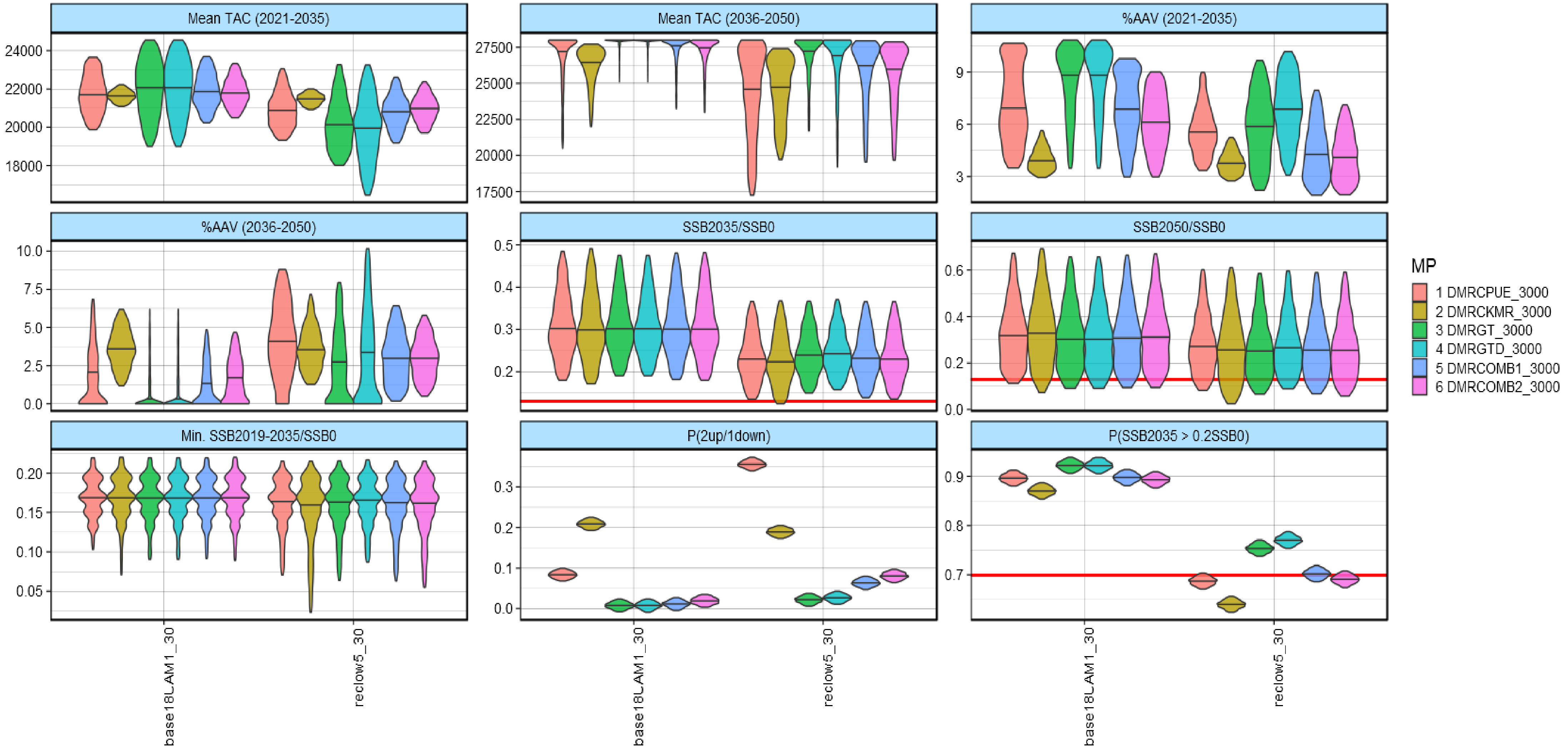


Figure 2a. Worm plots for TAC and TRO (reported as “Relative SSB index”) for **DMRCPUE**, when tuned to 30% of TRO_0 in the year 2035, for the RC (base18). The blue shadings represent 95% probability envelopes, and the bold line with dots shows the medians. In the TRO plots, the red line is the SSB level corresponding to the interim rebuilding target (0.20 SSB0) of the Extended Commission, and the green band represents the 80% confidence interval for the maximum sustainable yield (MSY), with the median as the horizontal green line. The TAC axis upper bound is at the maximum TAC of 28 000 mt which the CMP allows.

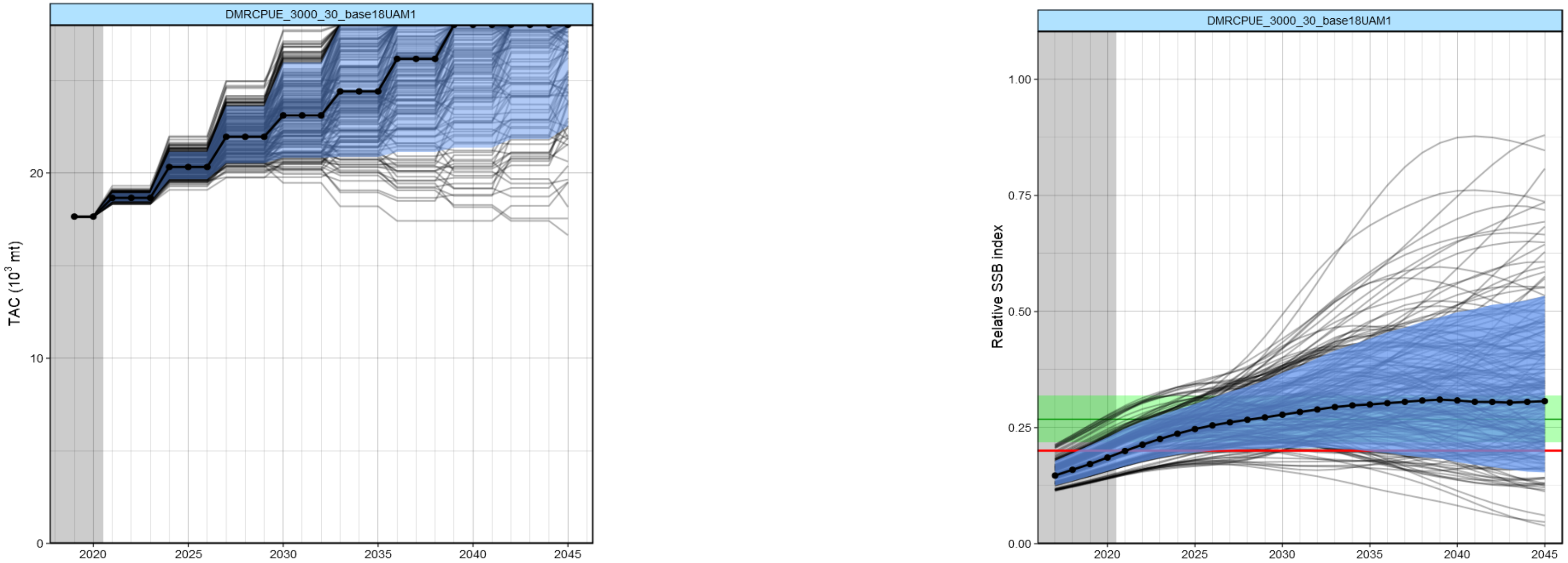
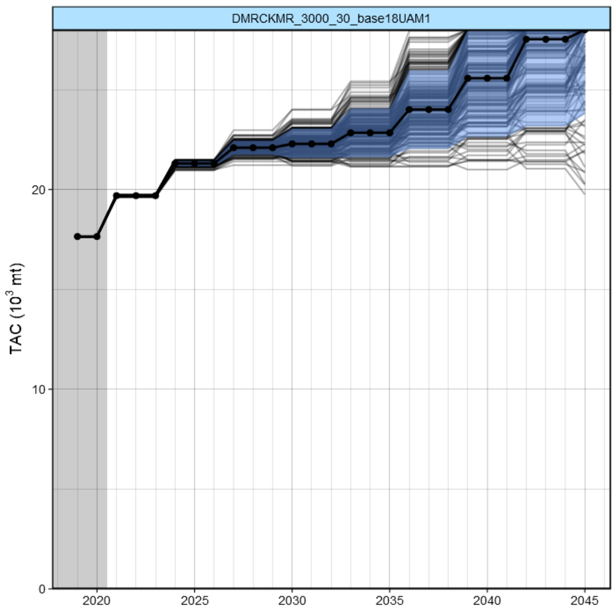


Figure 2b. Worm plots for TAC and TRO (reported as "Relative SSB index") for **DMRCKMR**, when tuned to 30% of TRO_0 in the year 2035, for the RC (base18). The blue shadings represent 95% probability envelopes, and the bold line with dots shows the medians. In the TRO plots, the red line is the SSB level corresponding to the interim rebuilding target (0.20 SSB0) of the Extended Commission, and the green band represents the 80% confidence interval for the maximum sustainable yield (MSY), with the median as the horizontal green line. The TAC axis upper bound is at the maximum TAC of 28 000 mt which the CMP allows.



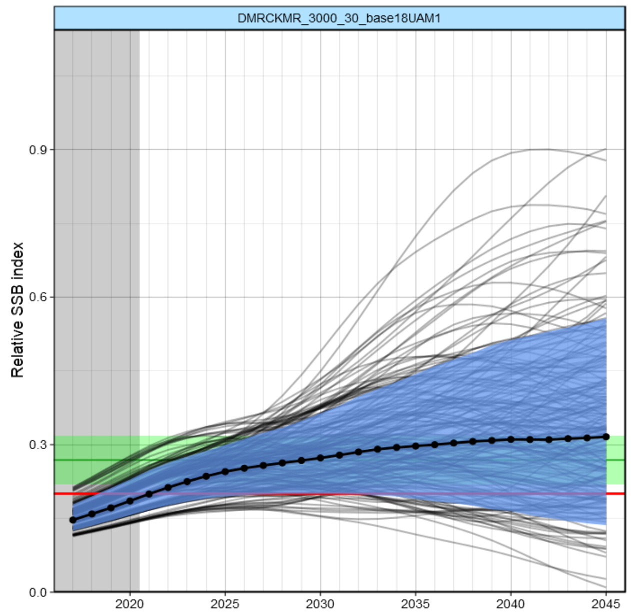


Figure 2c. Worm plots for TAC and TRO (reported as "Relative SSB index") for **DMRGT**, when tuned to 30% of TRO_0 in the year 2035, for the RC (base18). The blue shadings represent 95% probability envelopes, and the bold line with dots shows the medians. In the TRO plots, the red line is the SSB level corresponding to the interim rebuilding target (0.20 SSB0) of the Extended Commission, and the green band represents the 80% confidence interval for the maximum sustainable yield (MSY), with the median as the horizontal green line. The TAC axis upper bound is at the maximum TAC of 28 000 mt which the CMP allows.

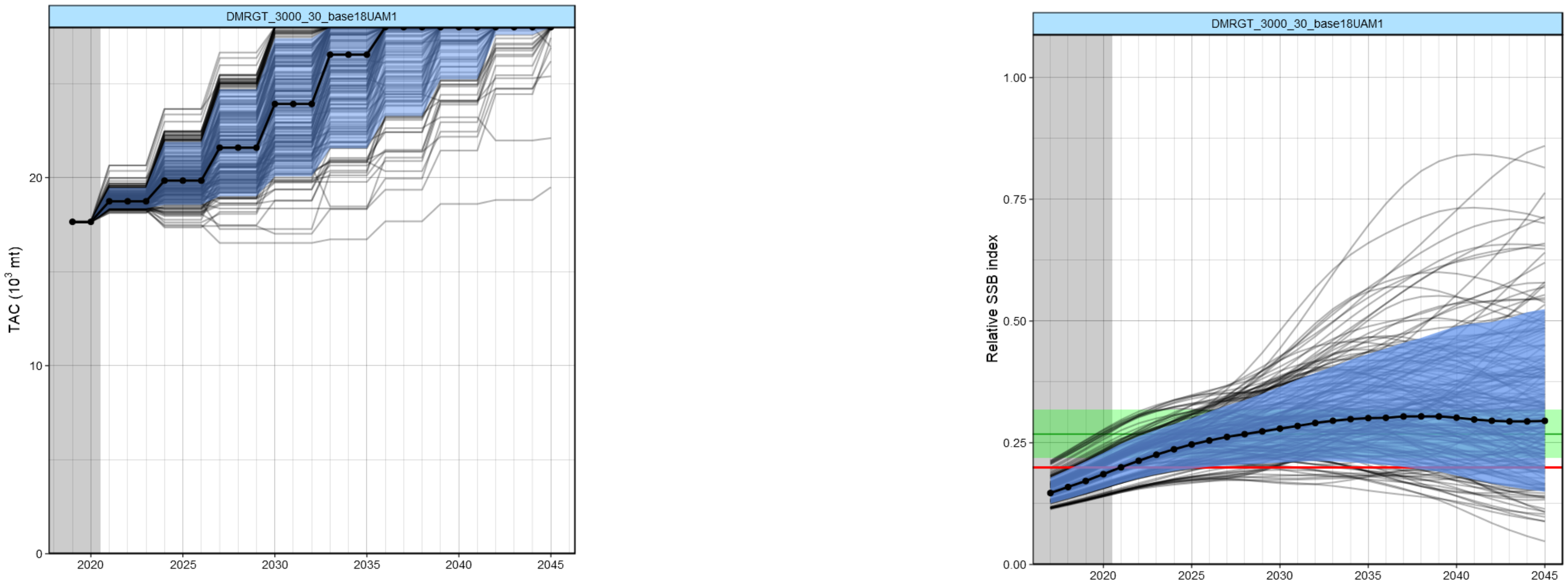


Figure 2d. Worm plots for TAC and TRO (reported as "Relative SSB index") for **DMRGTD**, when tuned to 30% of TRO_0 in the year 2035, for the RC (base18). The blue shadings represent 95% probability envelopes, and the bold line with dots shows the medians. In the TRO plots, the red line is the SSB level corresponding to the interim rebuilding target (0.20 SSB0) of the Extended Commission, and the green band represents the 80% confidence interval for the maximum sustainable yield (MSY), with the median as the horizontal green line. The TAC axis upper bound is at the maximum TAC of 28 000 mt which the CMP allows.

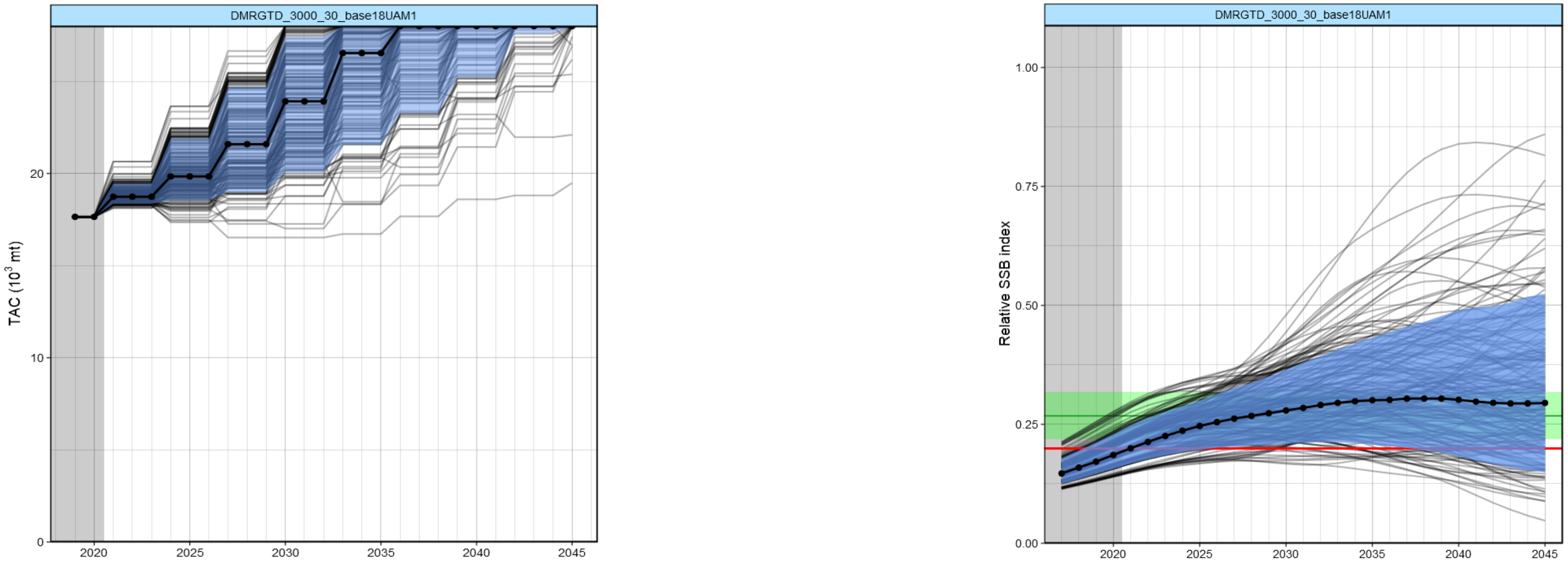
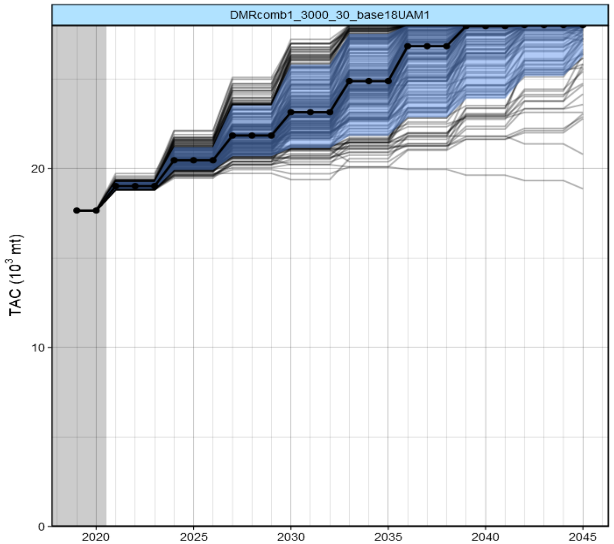


Figure 2e. Worm plots for TAC and TRO (reported as "Relative SSB index") for **DMRCOMB1**, when tuned to 30% of TRO_0 in the year 2035, for the RC (base18). The blue shadings represent 95% probability envelopes, and the bold line with dots shows the medians. In the TRO plots, the red line is the SSB level corresponding to the interim rebuilding target (0.20 SSB0) of the Extended Commission, and the green band represents the 80% confidence interval for the maximum sustainable yield (MSY), with the median as the horizontal green line. The TAC axis upper bound is at the maximum TAC of 28 000 mt which the CMP allows.



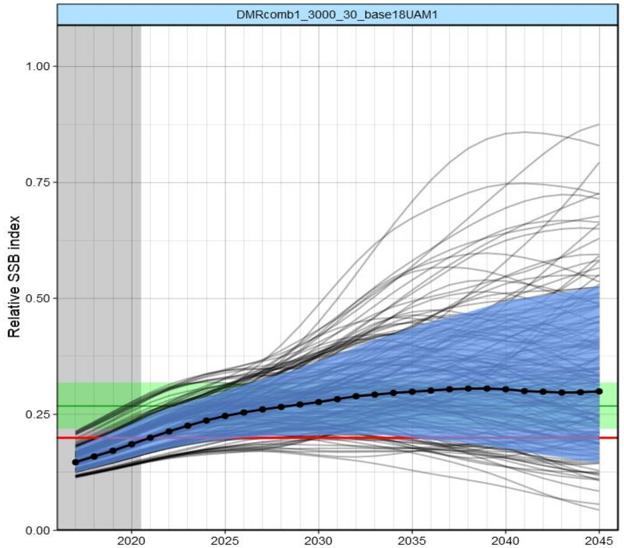


Figure 2f. Worm plots for TAC and TRO (reported as “Relative SSB index”) for **DMRCOMB2**, when tuned to 30% of TRO_0 in the year 2035, for the RC (base18). The blue shadings represent 95% probability envelopes, and the bold line with dots shows the medians. In the TRO plots, the red line is the SSB level corresponding to the interim rebuilding target (0.20 SSB0) of the Extended Commission, and the green band represents the 80% confidence interval for the maximum sustainable yield (MSY), with the median as the horizontal green line. The TAC axis upper bound is at the maximum TAC t of 28 000 mt which he CMP allows.