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

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

SUMMARY

Simple constant proportion and target-based empirical candidate management procedures are applied to the basic grid operating model and a low recruitment robustness test for SBT. The first two approaches, DMM1 and DMM2, respectively use CPUE index data only, while DMM3 adds gene tagging data to the DMM2 approach. The key results are that the DMM2 target-based approach substantially outperforms the constant proportion DMM1 one in terms of smoothness of the TAC trajectories, and that (at least as far as investigations have been possible to date) the addition of gene tagging data offers little improvement to depletion statistics in instances where low recruitment has occurred. Performance under DMM2 is unusually good, but this approach still needs to be subjected to the other robustness tests, and further attempts need to be made to seek more improvement in performance when gene tagging data are used.

Introduction

This paper reports results of three simple Candidate Management Procedure (CMP) approaches for the management of Southern Bluefin Tuna (SBT), tested using the code developed for this purpose for CCSBT.

The intent is not to propose genuine candidates at this stage, but rather to investigate the properties of some simple approaches to provide guidance for future work. Two are based on the use of the CPUE index only, while the third uses the gene-tagging (GT) index of juvenile abundance. The technical details of these approaches are provided in the Methods section below.

In addition to the application of these CMPs to the baseline ("grid") operating model (OM), applications are also reported for a low recruitment (lowR) variant of the baseline model where this low recruitment (obtained by halving the expected level indicated by the stock-recruitment relationship) continues for a period of 10 years. The purpose is to distinguish what otherwise would be effectively identical performances by some of the different CMPs.

Methods

First we define some aggregate indices, and follow this with CMP specifications.

CPUE index

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

---

[1] Marine Resource Assessment and Management Group (MARAM), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch 7701, South Africa

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

Sensitivities to this average over 3 years and 7 years are also been explored.

GT index

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

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

CMP specifications

DMM1

The first CMP (DMM1) tested sets the TAC very simply as a multiple of the J_y value at the time.

$$TAC_{y+1} = \alpha \times J_y \times \frac{TAC_{2016}}{J_{2016}}$$

DMM2

The second CMP (DMM2) tested incorporates a target J_y value called J_{targ}.

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

DMM3

The third CMP (DMM3) tested adds a target GTJ_y value called GTJ_{targ}

$$TAC_{y+1} = TAC_y \times \left(1 + \beta \cdot \left(J_y - J_{targ}\right) + \gamma\left(GTJ_y - GTJ_{targ}\right)\right)$$

For all three CMPs above, TACs are set every third year as a base case (sensitivities to this frequency being every two years are also explored). Furthermore, any change in the TAC is restricted to a maximum of 3000t (up or down) (sensitivities to this of 2000 and 4000 are also explored). The minimum TAC change limit is 100t. Thus:

$$100 \le \left|TAC_{y+1} - TAC_y\right| \le 3000\text{, 2000 or 4000}$$

Results and Discussion

Results for baseline CMPs for the first and simplest DMM1 approach (effectively intended constant fishing mortality) are tuned in median terms to the four recovery targets for 2035 (25, 30, 35 and 40% of SSB_0, where SSB_0 is the unfished spawning biomass); but variations on the baseline are pursued for the two central tunings only. The same is done for the DMM2 approach, which is a target-based empirical approach. However, for DMM3, which includes a further term which utilizes the gene-tagging data, only tuning to the 30% SSB_0 target is investigated. This exercise includes application to the lowR scenario of the DMM2 and DMM3 baseline CMPs.

Table 1 lists the values of the α control parameter for DMM1 tuned to a 50% probability of achieving 25%, 30%, 35%, and 40% of the SSB_0. α values are also shown for various sensitivity tests that are carried out for the 30% and 35% SSB_0 scenarios. These sensitivities are:

DMM1_3yr – when the CPUE index is averaged over 3 years instead of 5 years,

DMM1_7yr – when the CPUE index is averaged over 7 years instead of 5 years, DMM1_20 – when the TAC change is restricted to maximum 2000 t (up or down),

DMM1_40 – when the TAC change is restricted to maximum 4000 t (up or down), and

DMM1_TAC2 – when the TAC is changed every 2 years.

Table 2 similarly lists the β and J_{targ} control parameter values for DMM2 tuned to a 50% probability of achieving these same targets. β and J_{targ} values are also shown for the same sensitivity tests as in Table 1.

Table 3 lists the key summary statistics of DMM1, DMM2 and DMM3 for two different J_{targ} values ($J_{targ} = 1.0$ and 1.5) when tuned to 30% SSB_0. Performance for the low recruitment scenario is also reported for DMM2 and DMM3 for each case. Key summary statistics shown here are:

TROtrend(2021-2035) – the log-linear trend in TRO from 2021 to 2035,

MaxTACdec(2021-2035) – the maximum TAC decrease from 2021 to 2035,

MeanTAC(2021-2035) – the mean TAC from 2021 to 2035,

Mean_low10%ileTAC(2021-2035) – the mean (averaged over years and from 2021 to 2035) of the lower 10%ile for the TAC, and

AAV(2021-2035) – the average annual variability in the TAC from 2021 to 2035.

Figure 1 shows medians of TAC and TRO for DMM1 for the projection years when tuned to 25%, 30%, 35% and 40% SSB_0 in the year 2035, while Figure 2 shows these for DMM2. The trends are broadly similar for the two approaches, though comparatively the TACs are a little less variable for DMM2. The trends as the tuning percentage changes are in the directions that would be expected, but do also suggest that the two tunings extremes would be unlikely choices because respectively of inadequate recovery and TACs dropping too low.

Figures 3 to 7 focus on comparisons within each CMP approach, specifically DMM1 and DMM2 for various sensitivity tests tuned to 30% and 35% SSB_0 in year 2035.

Figure 3 shows the TRO statistics for DMM1 and DMM2 and their sensitivity scenarios, tuned to 30% and 35% SSB_0 in year 2035. The three TRO statistics shown here are:

Probability ($TRO_{2035} > 0.2\ TRO_0$): the previous MP tuning objective,

Probability ($TRO_{2035} > TRO_{2017}$): the probability that the TRO in the tuning year is greater than the current level, and

Probability ($TRO_{2040} > TRO_{2035}$): the probability that the TRO five years after the tuning year is above that in the tuning year, to identify MPs which increase the TAC too high/fast when attaining the tuning objective and cause a future "undershoot".

There is hardly any difference in the TRO statistics for both the DMM1 and DMM2 approaches for the various sensitivity tests.

Figure 4 shows the log-linear trends in TRO from 2021 to 2035 for both the DMM1 and DMM2 baseline CMPs and their sensitivity scenarios. Again, there is hardly any difference in this trend for both DMM1 and DMM2 approaches for these sensitivity tests.

Figure 5 shows three summary statistics for TACs (meanTAC, MaxTACdec, and Mean_low10%ileTAC) for the baseline DMM1 and DMM2 CMPs and their sensitivity scenarios. For DMM1, the 25% to 75% quantile range increases especially when tuned to 30% SSB_0, and for the cases when the maximum TAC change is 4000t and when the TAC is changed every 2 years. This is not obvious for DMM2 for which the mean TAC is similar amongst the sensitivity scenarios. The 25% to 75% quantile range for the maximum decrease in TAC is quite variable among the scenarios for DMM1, but is almost constant for DMM2. The mean_low 10%ile TAC is higher and more stable amongst the scenarios for DMM2 than for DMM1.

Figure 6 shows the AAV (%) from 2021 to 2035 for DMM1 and DMM2 and their sensitivity scenarios. AAV is much smaller (typically less than half) for DMM2 than DMM1 for all the sensitivity scenarios.

Figure 7 shows Probability ($TAC_{r+3} < TAC_{r+2n}$) if $TAC_{r+2} > TAC_{r+1}$ and $TAC_{r+1} > TAC_r$, for the r^{th} TAC decision (default is currently r=1) for DMM1 and DMM2 and their sensitivity scenarios, tuned to 30%SSB and 35%SSB in the year 2035.

Figures 8 to 12 focus on comparison among the CMPs, specifically DMM1, DMM2 and DMM3 for various sensitivity tests tuned to 30% and 35% SSB_0 in the year 2035. Results are also shown for the low recruitment scenarios.

Figure 8 shows the TRO statistics for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR tuned to 30% and 35% SSB_0 in the year 2035. The probability ($TRO_{2040} > TRO_{2035}$) is slightly higher for DMM1 but all are higher than 50%.

Figure 9 shows the log-linear trends in TRO from 2021 to 2035 for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR tuned to 30% and 35% SSB_0 in the year 2035. There is hardly any difference among the CMPs. The whiskers are slightly shorter for DMM3_lowR than for DMM2_lowR.

Figure 10 shows three summary statistics for TACs (meanTAC, MaxTACdec, and Mean_low10%ileTAC) for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR tuned to 30% and 35% SSB_0 in year 2035. For the mean TAC, although the medians are similar between the CMPs, the 25% to 75% quantile ranges are much larger for DMM1 than for the other CMPs. DMM1 also shows large maximum TAC decrease and the Mean_low10%ileTAC is very low. The Mean_low10%ileTAC is also slightly lower for DMM3_lowR compared to DMM2_lowR which reflects some advantage in incorporating GT data in the CMPs.

Figure 11 shows AAV (%) from 2021 to 2035 for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR tuned to 30% and 35% SSB_0 in year 2035. AAV is large for DMM1.

Figure 12 shows Probability ($TAC_{r+3} < TAC_{r+2n}$) if $TAC_{r+2} > TAC_{r+1}$ and $TAC_{r+1} > TAC_r$, for the r^{th} TAC decision (the default is currently r=1) for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR tuned to 30% and 35% SSB_0

in year 2035.

Figure 13 shows worm plots for TAC and TRO for DMM1, DMM2 and DMM3 for the projection years when tuned to 30% SSB_0 in the year 2035, while Figure 14 shows these plots for DMM3 when applied for low R case. These plots make very clearer how much smoother the trajectories are under DMM2 and DMM3 compared to DMM1.

Figure 15 shows worm plots for TAC and TRO for DMM1 and DMM2 when tuned to 35% SSB_0 in year 2035.

Figure 16 shows plots of median TAC and TRO for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR for the projection years when tuned to 30% SSB_0 in the year 2035. Again, TAC plots are smoother for DMM2 and DMM3 than for DMM1. Although small, one can see a slight increase in TRO for DMM3_lowR compared to DMM2_lowR, reflecting some improvement in performance when taking the gene tagging data into account.

Conclusions

There would seem to be four important conclusions to be drawn from this work to date.

1) Performances of the variants of DMM1 and DMM2 considered (different TAC-setting frequency, etc.) were generally little changed from the respective baselines.
2) DMM2 (a target-based rule) outperforms DMM1 (a constant proportion rule) in terms of AAV and in particular smoother TAC trends.
3) The DMM2 performance appears unrealistically good in terms of the results shown here; the key test of this approach will come when further robustness tests are applied.
4) Addition of the gene tagging data in DMM3 led to some but relatively little improvement in performance (less depletion) under the low recruitment scenario.

Further analyses

Only the lowR robustness test has been considered for this initial study, having been specifically chosen to allow some test of the value of the gene tagging data for improving performance. Further robustness tests are listed in Table 3 of Agenda item 12 of the Report of the 22nd Meeting of the Extended Scientific Committee. DMM2 will need, in the first instance, to be tested (and resultantly perhaps improved) against these trials.

Only limited time has been available to explore the use of the gene tagging data. Hopefully further attempts will show these to be able to provide more improvement in depletion performance in instances where poor recruitment has occurred.

Acknowledgments

We thank Richard Hillary and Ana Parma for advice on the coding package used to obtain the results reported, and Norio Takahashi for providing codes to output the worm plots.

Table1. Alpha (α) values for DMM1 for various sensitivity tests. Details of these sensitivities are: DMM1_3yr – when the CPUE index is averaged over 3 years, DMM1_7yr – when the CPUE index is averaged over 7 years, DMM1_20 – when the TAC change is restricted to maximum 2000 (up or down), DMM1_40 – when the TAC change is restricted to maximum 4000 (up or down), DMM1_TAC2 – when the TAC is changed every 2 years. The proportion 25% (or 30%, 35%, 40%) of the SSB denotes that CMP is tuned to a 50% probability of achieving 25% (or 30%, 35%, 40%) of the unfished spawning stock biomass (SSB_0) in the year 2035.

alpha	25%SSB	30%SSB	35%SSB	40%SSB
DMM1	1.1	0.73	0.54	0.325
DMM1_3yr	-	0.76	0.54	-
DMM1_7yr	-	0.69	0.52	-
DMM1_20	-	0.75	0.535	-
DMM1_40	-	0.715	0.54	-
DMM1_TAC2	-	0.715	0.54	-

Table2. Beta (β) and J_{targ} values for DMM2 for various sensitivity tests. Details of the sensitivities are same as described in Table1.

	J_{targ}=1.0		J_{targ}=2.5	
beta	25%SSB	30%SSB	35%SSB	40%SSB
DMM2	0.28	0.07	0.06	0.26
DMM2_3yr	-	0.07	0.055	-
DMM2_7yr	-	0.07	0.055	-
DMM2_20	-	0.07	0.06	-
DMM2_40	-	0.07	0.06	-
DMM2_TAC2	-	0.05	0.04	-

Table 3. Summary statistics of DMM1, DMM2 and DMM3 when tuned to 30%SSB. Performance for the low recruitment (n=10) scenario is also reported for DMM2 and DMM3. **(a)** shows results for J_{targ}=1.0 for DMM2 and DMM3. **(b)** shows these results when J_{targ}=1.5. The numbers in the brackets show 25% and 75% quantiles.

(a) Tuning parameters are α =0.73 for DMM1, J_{targ}=1.0, β=0.07 for DMM2 and J_{targ}=1.0, β=0.07, GTJ_{targ}=1.0, γ=0.015 for DMM3.

	$TRO_{trend(2021\text{-}2035)}$	TRO_{2035} ('000)	TRO_{2046} ('000)	$MaxTACdec_{(2021\text{-}2035)}$	$MeanTAC_{(2021\text{-}2035)}$	Mean_low10%ileTAC$_{(2021\text{-}2035)}$	$AAV_{(2021\text{-}2035)}$
DMM1	0.028 (0.013, 0.044)	2518 (2046, 3058)	2900 (2257, 3546)	3000 (1447, 3000)	20014 (17795, 22251)	15172	12.24 (10.56, 13.75)
DMM2	0.029 (0.012, 0.045)	2561 (1995, 3153)	2610 (1828, 3452)	0	20235 (19457, 21158)	18742	4.87 (3.09, 6.89)
DMM3	0.029 (0.013, 0.045)	2579 (2019, 3164)	2652 (1894, 3466)	0	20058 (19209, 21069)	18447	4.67 (2.80, 6.85)
DMM2_lowR	-0.022 (-0.04, -0.01)	1326 (962, 1708)	1411 (747, 2124)	623.5 (289.8, 856.9)	19396 (18761, 20182)	18195	3.53 (2.90, 4.34)
DMM3_lowR	-0.021 (-0.04, 0)	1359 (9969, 1737)	1507 (859, 2210)	691.5 (352.8, 944.6)	19008 (18334, 19827)	17764	3.41 (2.78, 4.13)

(b) Tuning parameters are J_{targ}=1.5, β=0.5 for DMM2 and J_{targ}=1.5, β=0.5, GTJ_{targ}=1.0, γ=0.025 for DMM3.

	$TRO_{trend(2021\text{-}2035)}$	TRO_{2035} ('000)	TRO_{2046} ('000)	$MaxTACdec_{(2021\text{-}2035)}$	$MeanTAC_{(2021\text{-}2035)}$	Mean_low10%ileTAC$_{(2021\text{-}2035)}$	$AAV_{(2021\text{-}2035)}$
DMM2	0.029 (0.014, 0.045)	2579 (2019, 3164)	2652 (1894, 3466)	1232 (0, 3000)	20816 (17151, 23505)	13535	12.15 (10.08, 13.28)
DMM3	0.030 (0.015, 0.045)	2540 (2104, 3068)	2784 (2032, 3691)	1223 (0, 3000)	20639 (16852, 23439)	13197	12.15 (10.07, 13.35)
DMM2_lowR	-0.018(-0.036, 0)	1413 (1112, 1753)	2212 (1549, 2962)	3000	18245 (14699, 20906)	12218	13.19 (12.10, 14.78)
DMM3_lowR	-0.016 (-0.03, 0)	1442 (1142, 1785)	2291 (1627, 3037)	3000	17759 (14251, 20701)	11784	13.29 (12.14, 15.16)

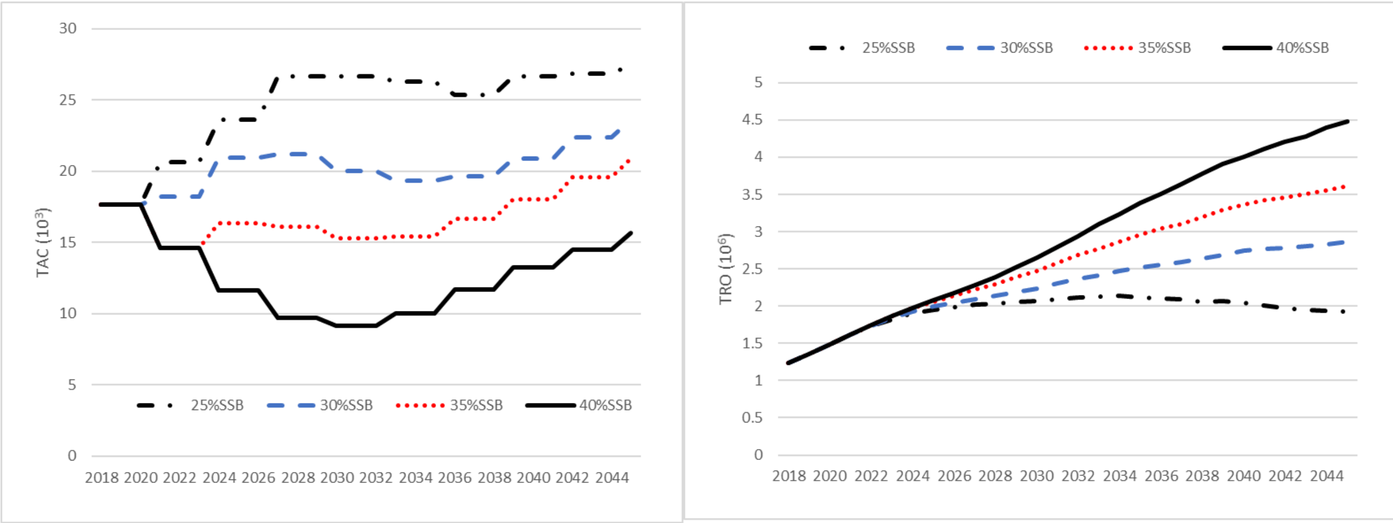


Figure 1. Median of TAC and TRO for **DMM1** for the projection years when tuned to 25%, 30%, 35% and 40% SSB_0 in the year 2035.

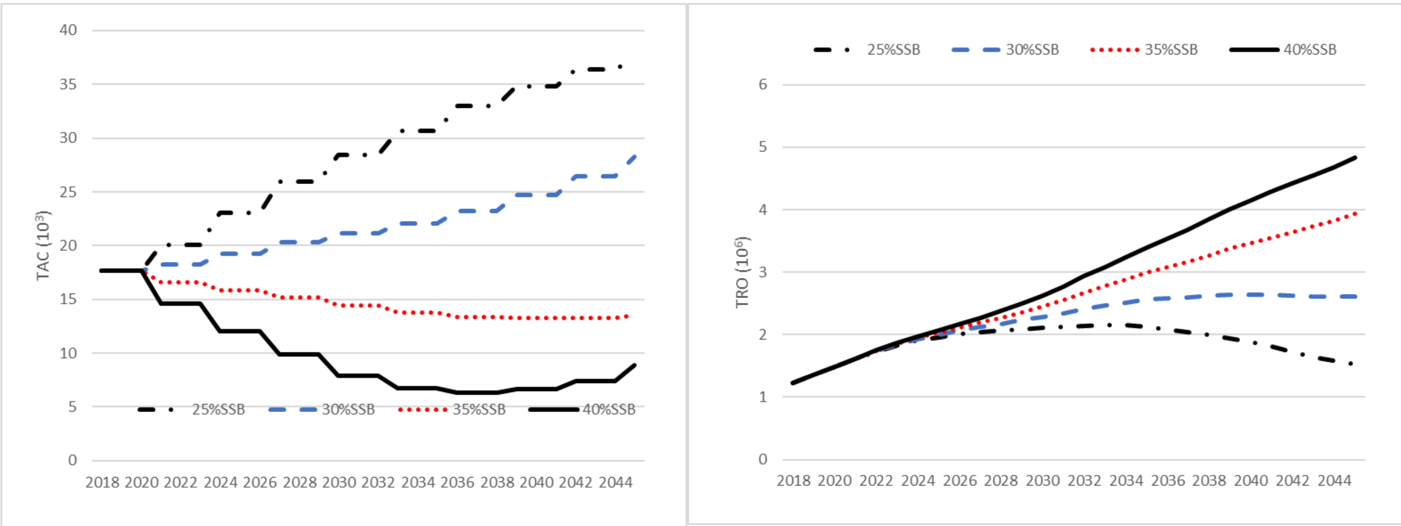


Figure 2. Median of TAC and TRO for **DMM2** for the projection years when tuned to 25%, 30%, 35% and 40% SSB_0 in the year 2035.

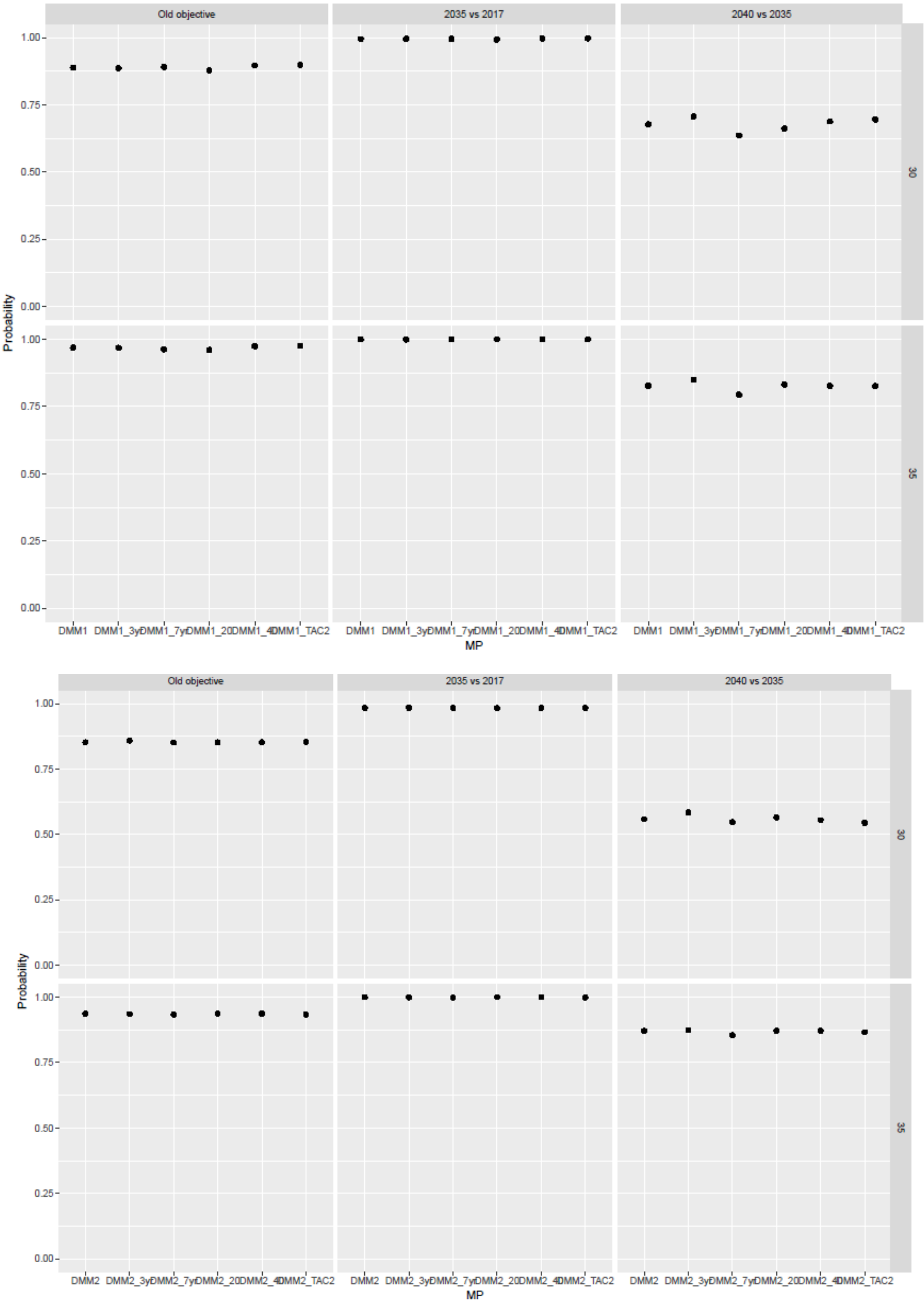


Figure 3. Plots showing the TRO statistics for DMM1 and DMM2 and their sensitivity scenarios, tuned to 30% SSB_0 and 35% SSB_0 in year 2035. Details of the sensitivity scenarios are the same as described in Table 1. The leftmost panel plots Probability ($TRO_{2035} > 0.2\ TRO_0$): the previous MP tuning objective; the middle panel plots Probability ($TRO_{2035} > TRO_{2017}$): the probability that the TRO in the tuning year is greater than the current level; and the rightmost panel plots Probability ($TRO_{2040} > TRO_{2035}$): the probability that the TRO five years after the tuning year is above that in the tuning year, to identify MPs which increase the TAC too high/fast when attaining the tuning objective and cause a future “undershoot”.

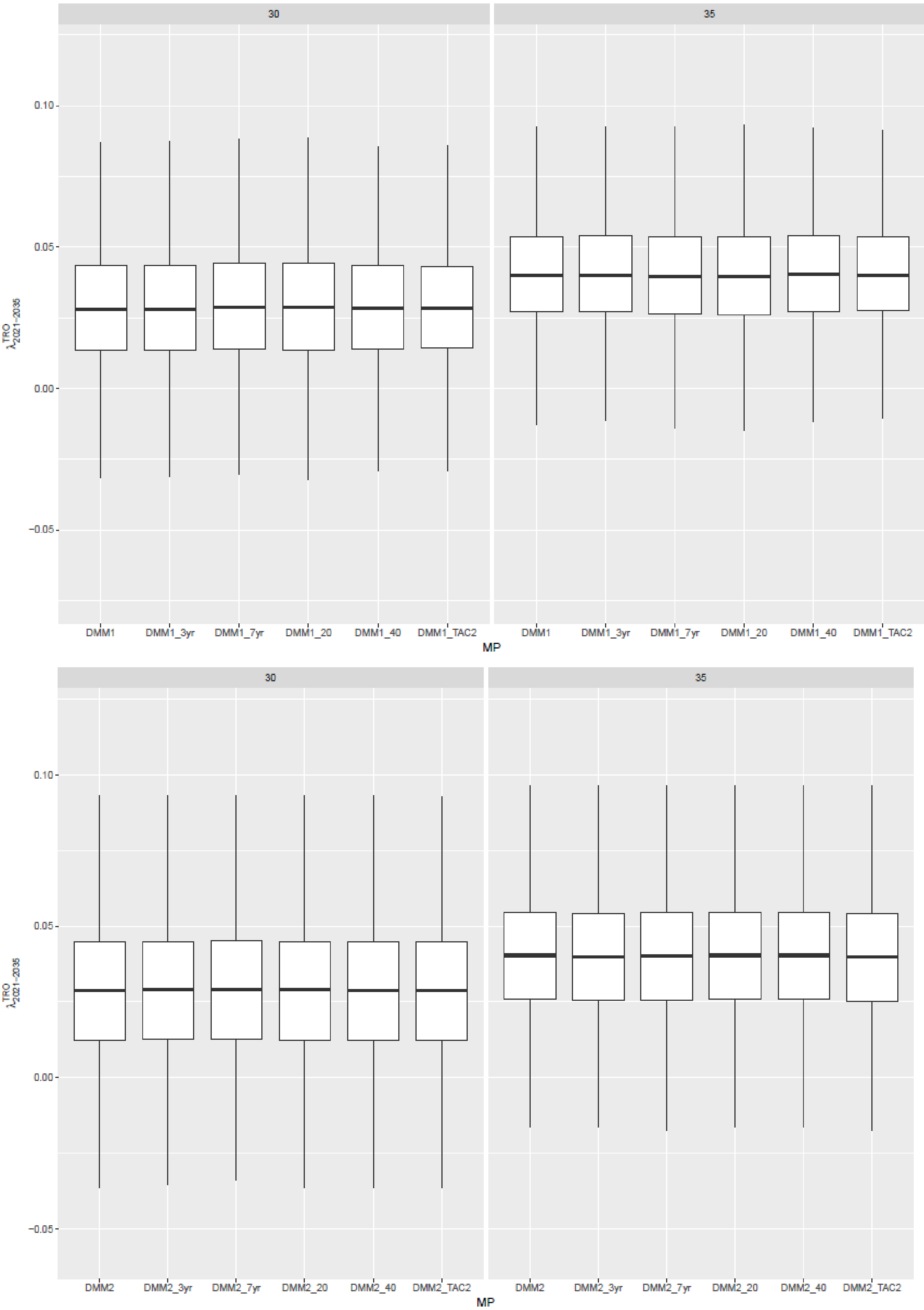


Figure 4. Log-linear trends in TRO from 2021 to 2035 for DMM1 and DMM2 and their sensitivity scenarios, tuned to 30% SSB_0 and 35% SSB_0 in the year 2035. Details of the sensitivity scenarios are the same as described in Table 1.

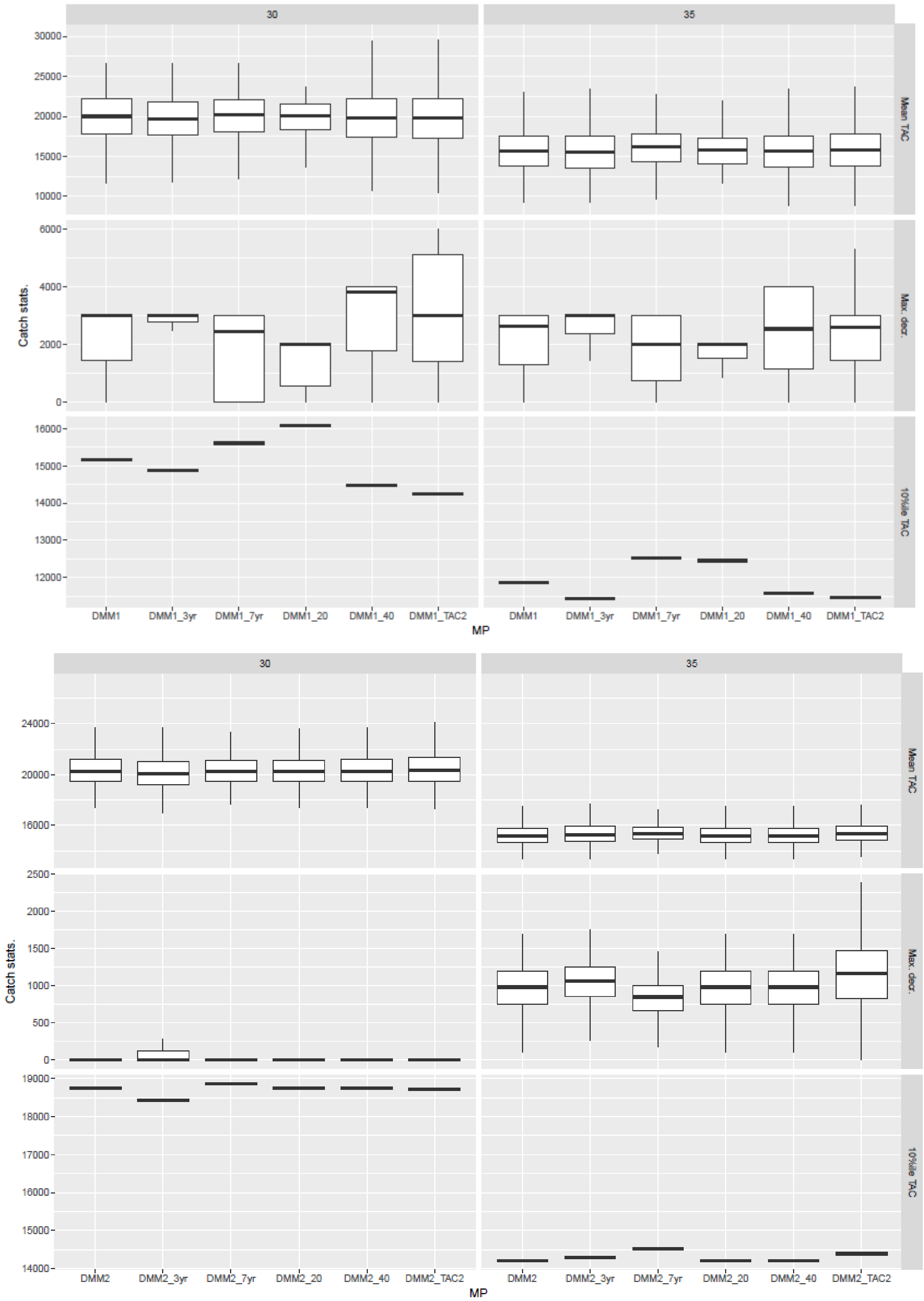


Figure 5. Plots of the summary statistics for TACs for DMM1 and DMM2 and their sensitivity scenarios, tuned to 30% SSB_0 and 35% SSB_0 in the 2035. Details of the sensitivity scenarios are the same as described in Table 1. “Mean TAC “ is calculated for the years from 2021 to 2035. “Max. decr.” is the maximum TAC decrease from 2021 to 2035. “10%ile TAC” is mean (averaged over years and from 2021 to 2035) of the lower 10%ile in the TAC.

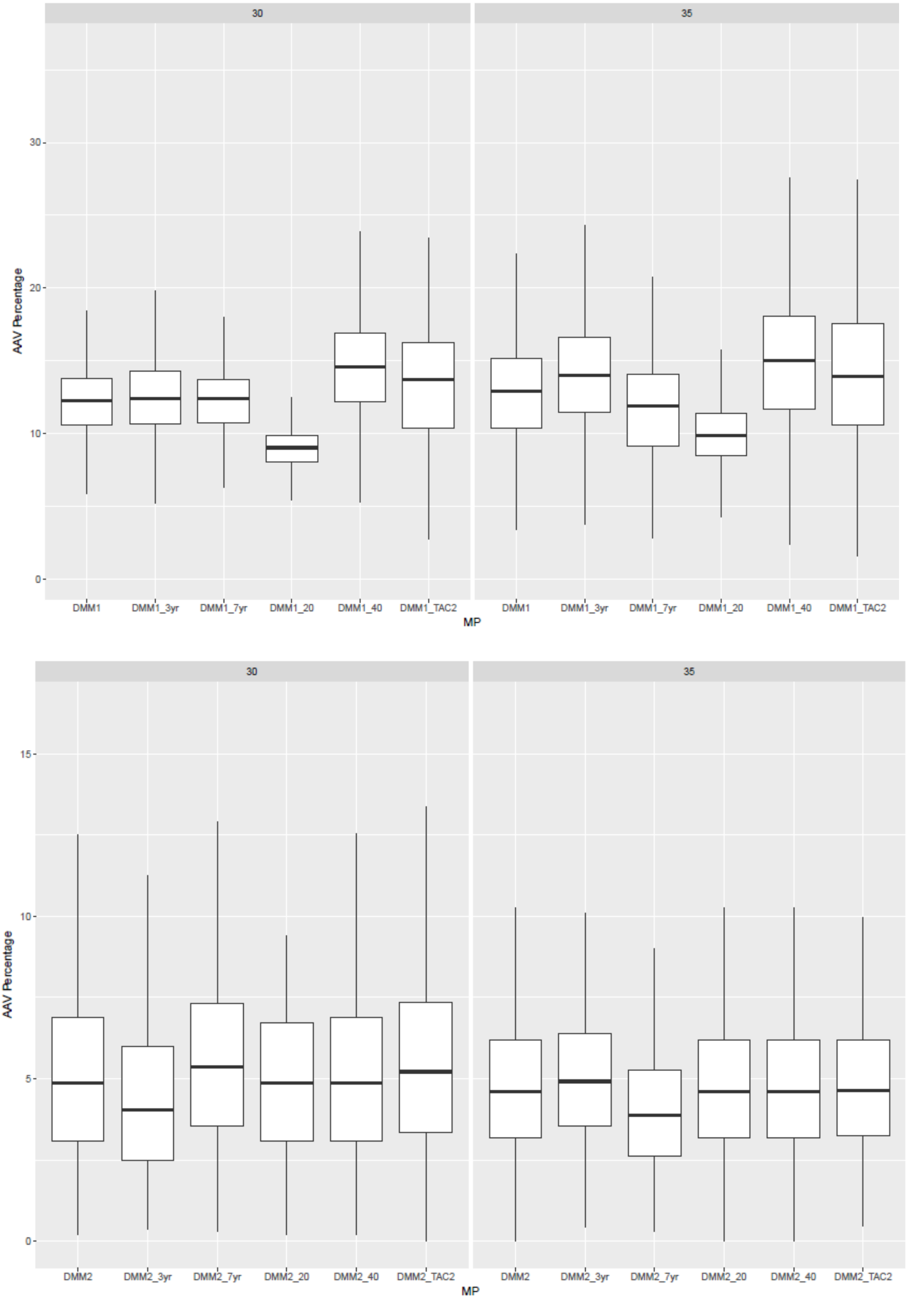


Figure 6. Plots of AAV (%) from 2021 to 2035 for DMM1 and DMM2 and their sensitivity scenarios, tuned to 30% SSB_0 and 35% SSB_0 in year 2035. Details of the sensitivity scenarios are the same as described in Table 1.

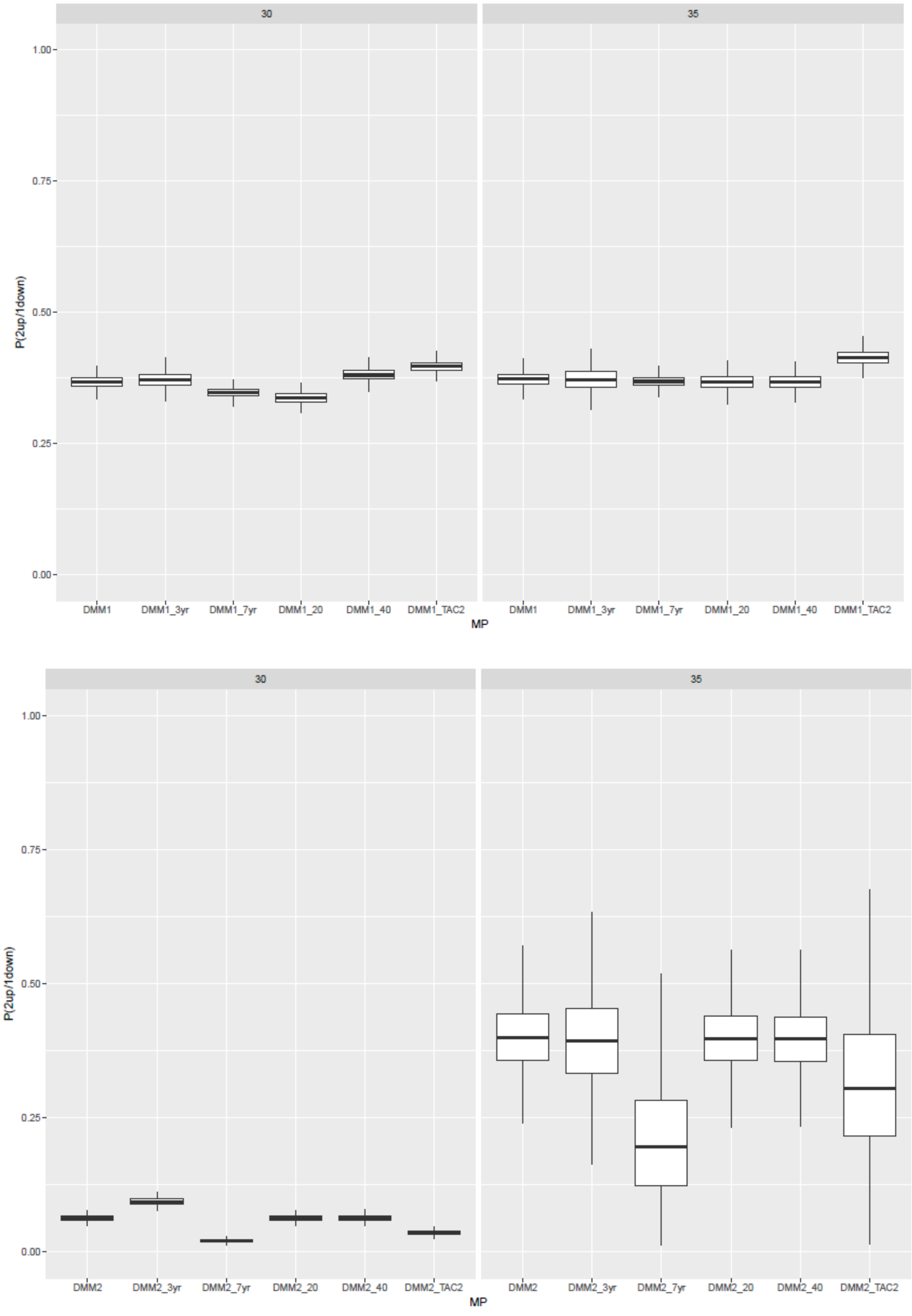


Figure 7. Probability ($TAC_{r+3} < TAC_{r+2n}$) if $TAC_{r+2} > TAC_{r+1}$ and $TAC_{r+1} > TAC_r$, for the r^{th} TAC decision (default is currently r=1) for DMM1 and DMM2 and their sensitivity scenarios, tuned to 30% SSB_0 and 35% SSB_0 in the year 2035. Details of the sensitivity scenarios are the same as described in Table 1.

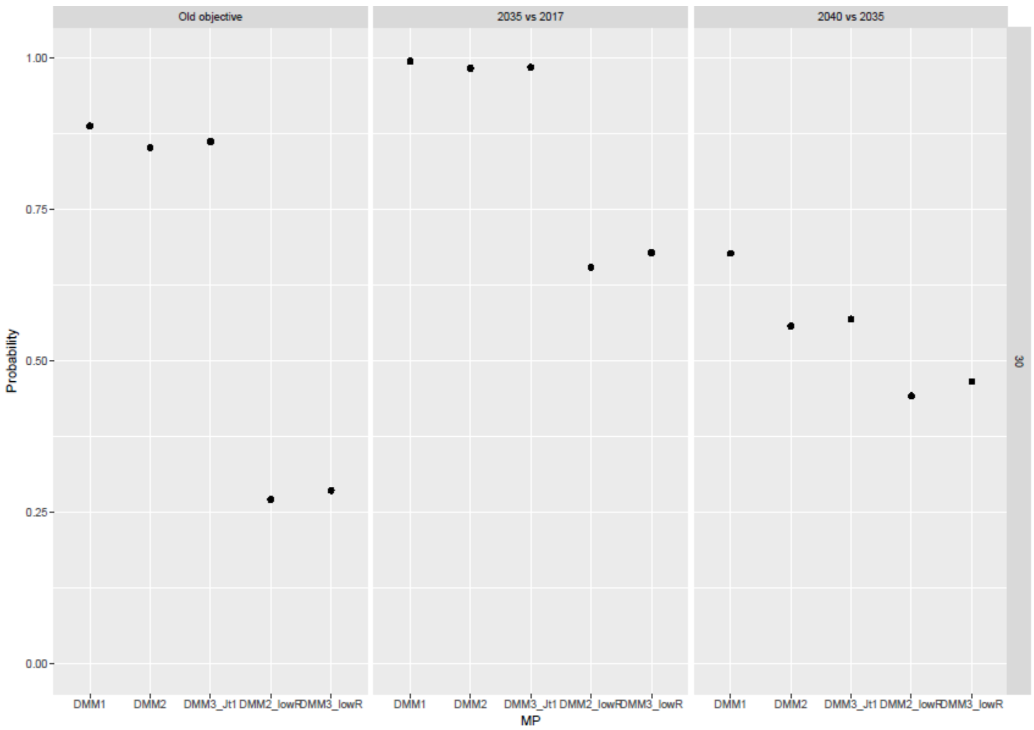


Figure 8. Plots showing the TRO statistics for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR tuned to 30% SSB_0 in year 2035. The leftmost panel plots Probability (TRO_{2035} > 0.2 TRO_0): the previous MP tuning objective; the middle panel plots Probability (TRO_{2035} > TRO_{2017}): the probability that the TRO in the tuning year is greater than the current level; and the rightmost panel plots Probability (TRO_{2040} > TRO_{2035}): the probability that the TRO five years after the tuning year is above that in the tuning year, to identify MPs which increase the TAC too high/fast when attaining the tuning objective and cause a future "undershoot".

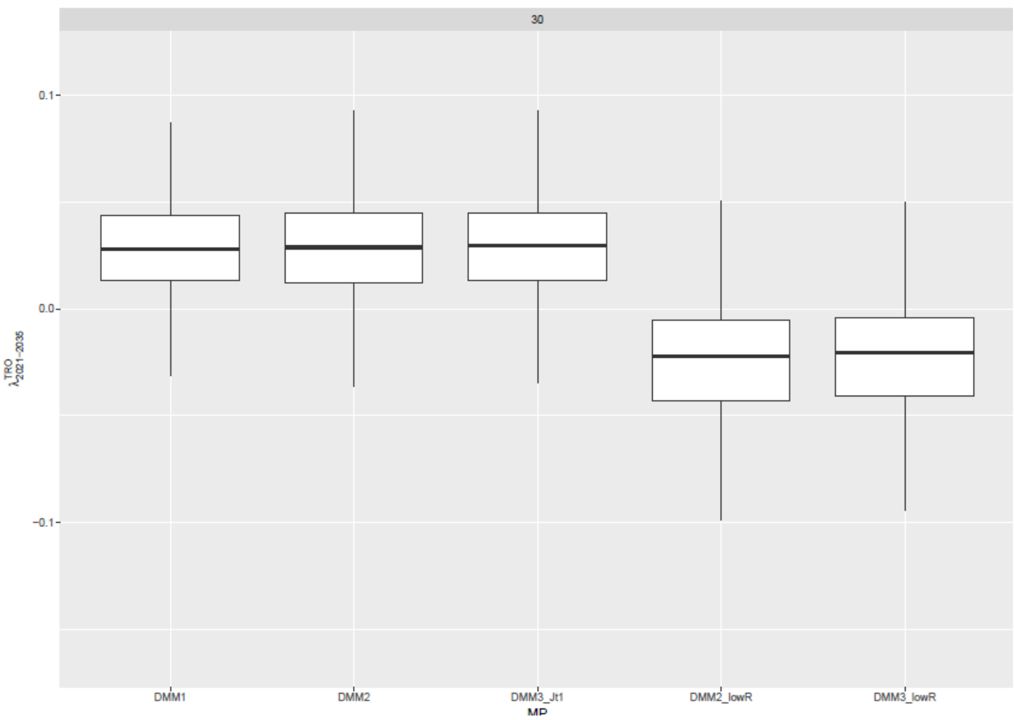


Figure 9. Log-linear trends in TRO from 2021 to 2035 for DMM1, DMM2,DMM3, DMM2_lowR and DMM3_lowR tuned to 30% SSB_0.

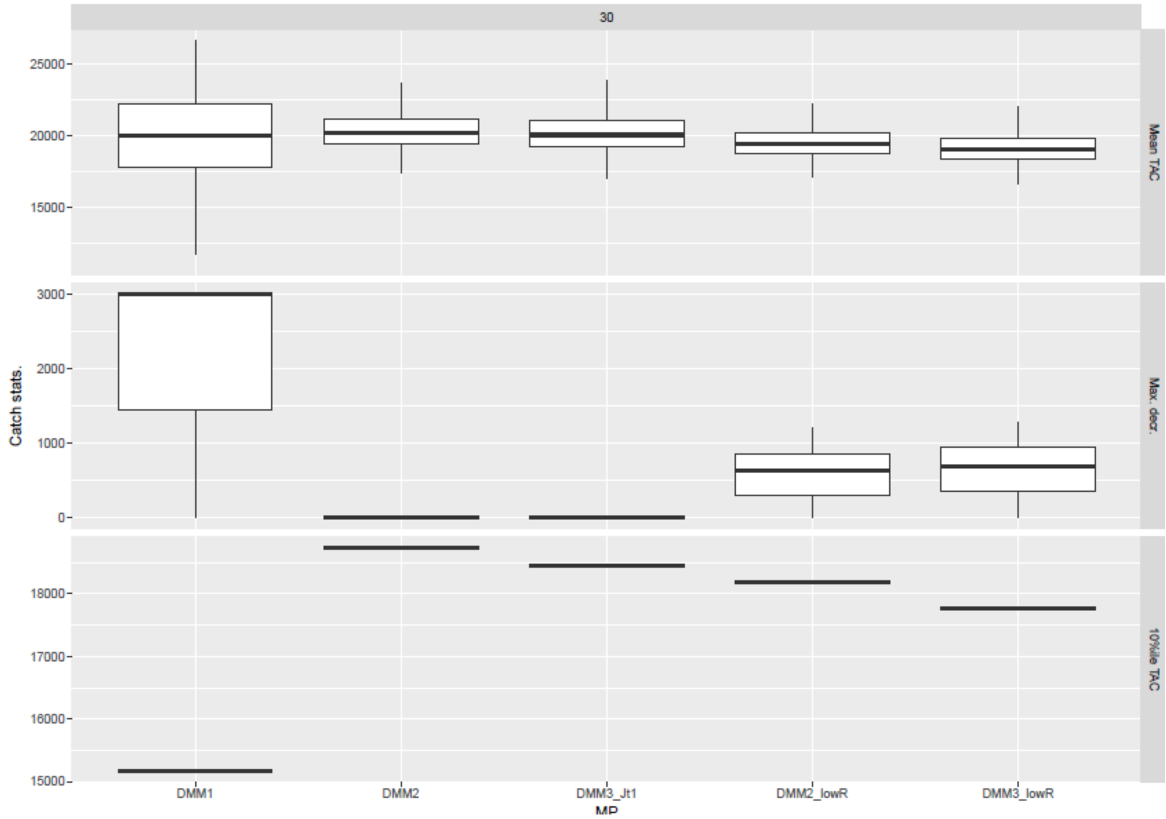


Figure 10. Plots of the summary statistics for TACs for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR tuned to 30% SSB_0. "Mean TAC " is calculated for the years from 2021 to 2035. "Max. decr." is the maximum TAC decrease from 2021 to 2035. "10%ile TAC" is mean (averaged over years and from 2021 to 2035) of the lower 10%ile in the TAC.

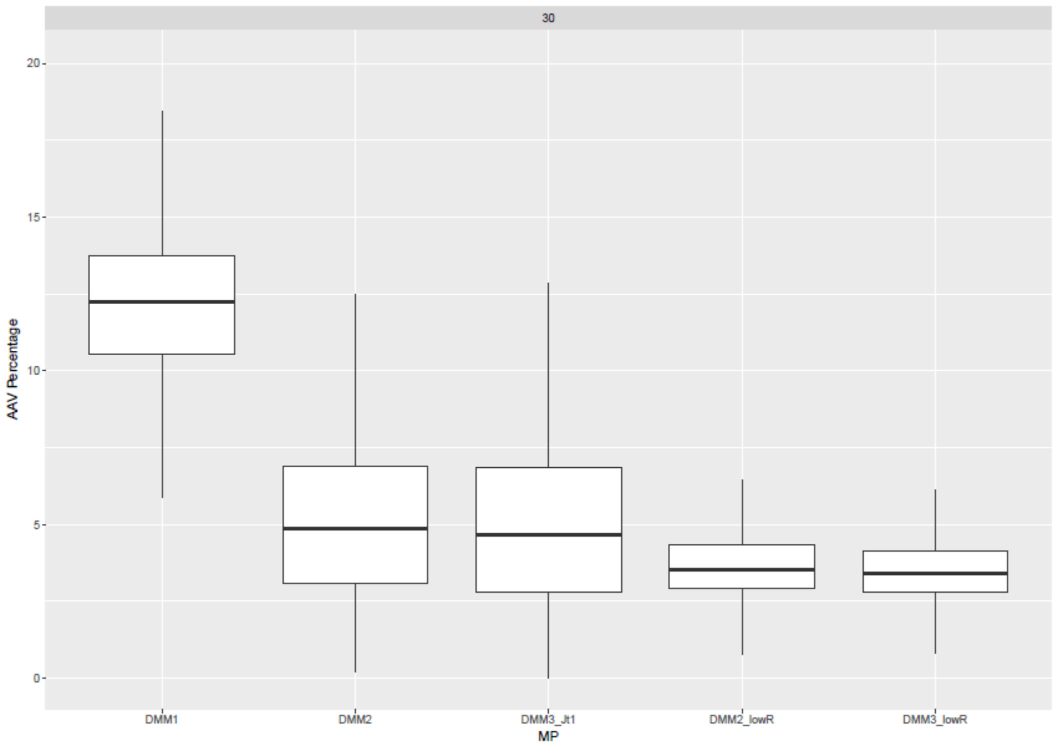


Figure 11. Plots of AAV (%) from 2021 to 2035 for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR tuned to 30% SSB_0.

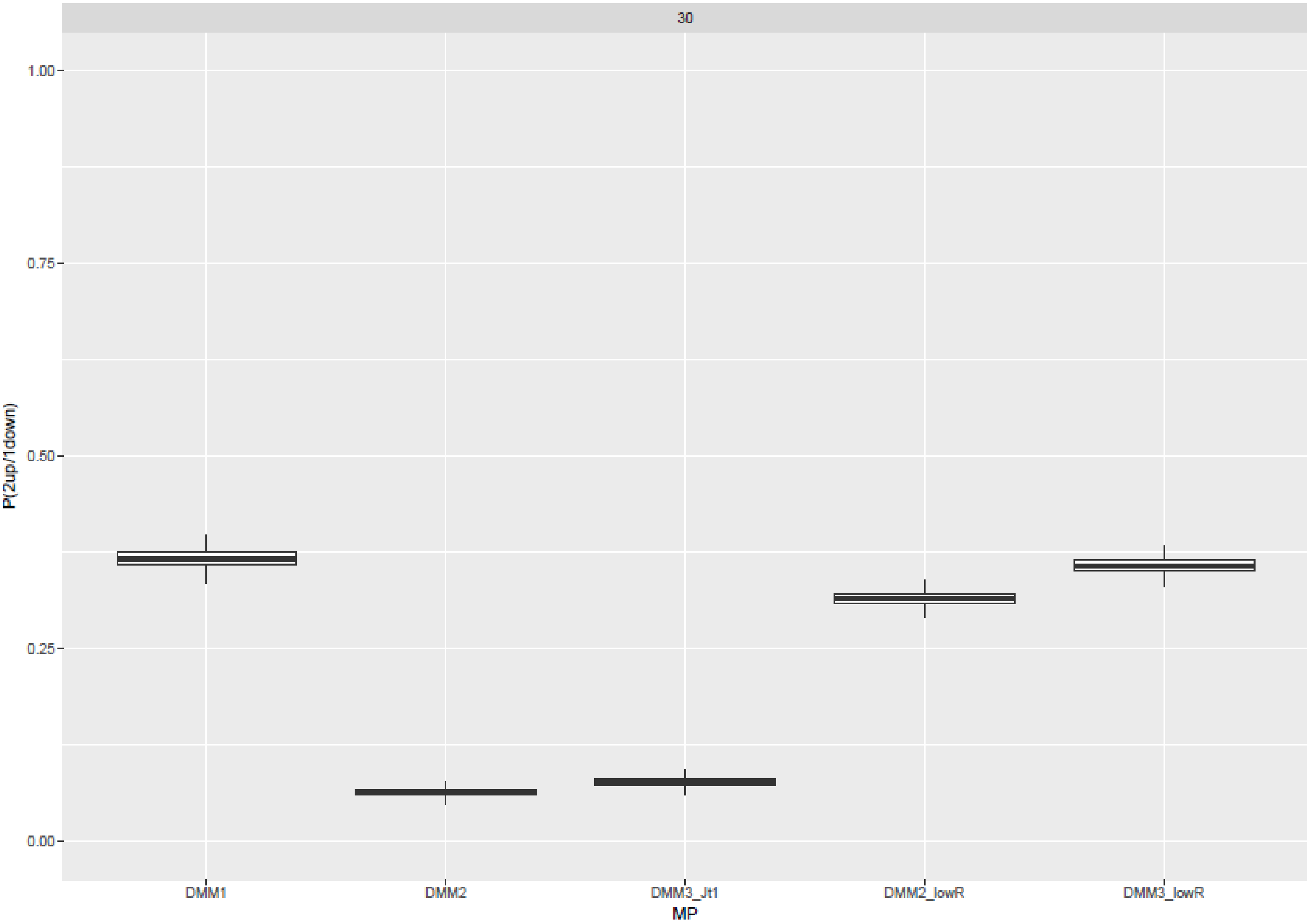
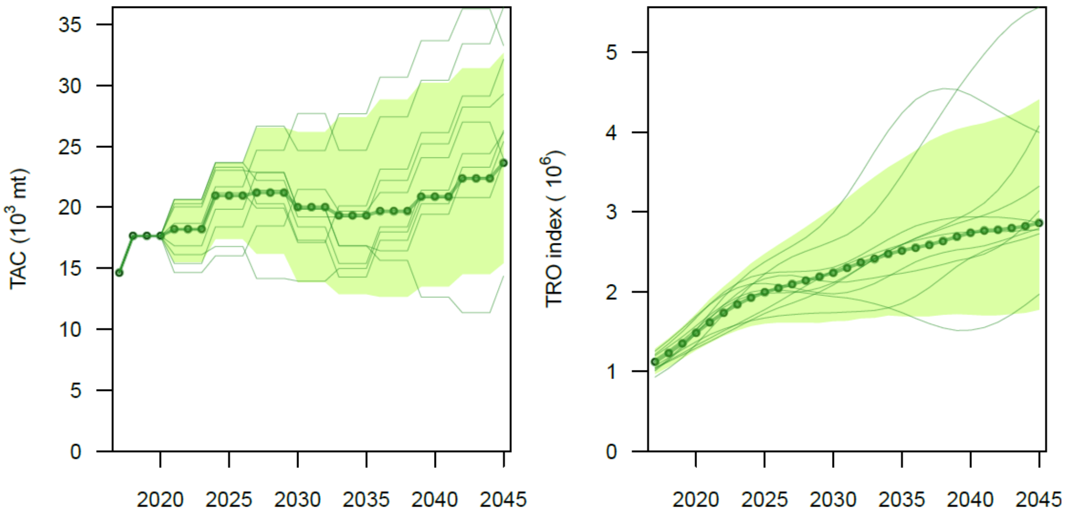
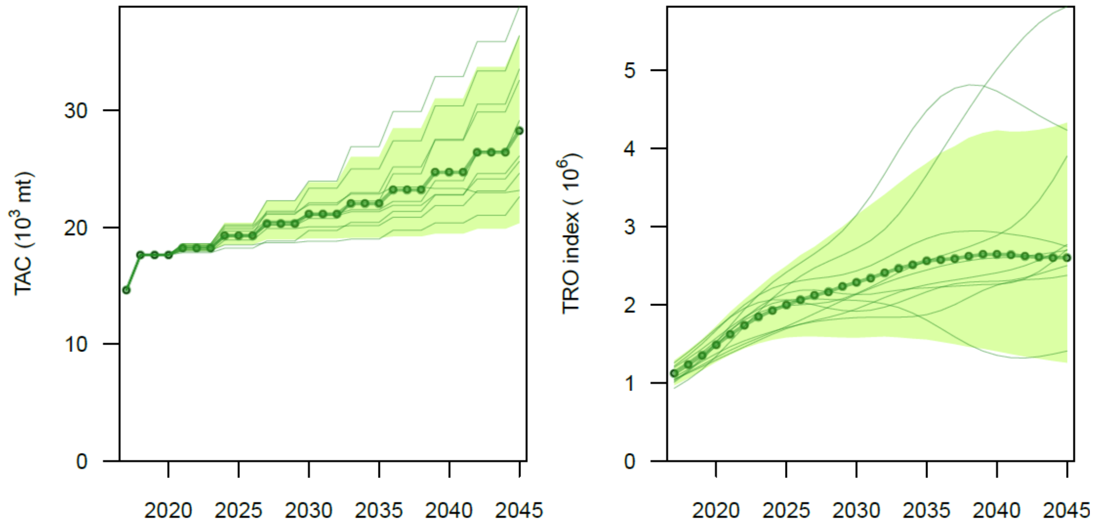


Figure 12. Probability ($TAC_{r+3} < TAC_{r+2n}$) if $TAC_{r+2} > TAC_{r+1}$ and $TAC_{r+1} > TAC_r$, for the r^{th} TAC decision (default is currently r=1) for DMM1, DMM2,DMM3,DMM2_lowR and DMM3_lowR tuned to 30% SSB_0 in the year 2035.

a) DMM1



b) DMM2



c) DMM3

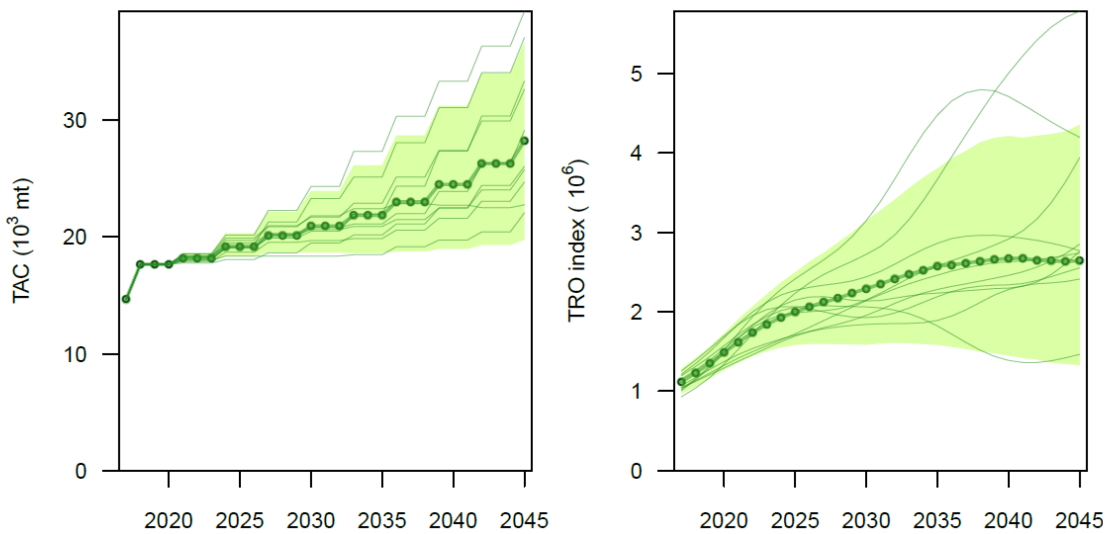


Figure 13. Worm plots for TAC and TRO for DMM1, DMM2 and DMM3 for the projection years when tuned to **30% SSB_0** in the year 2035.

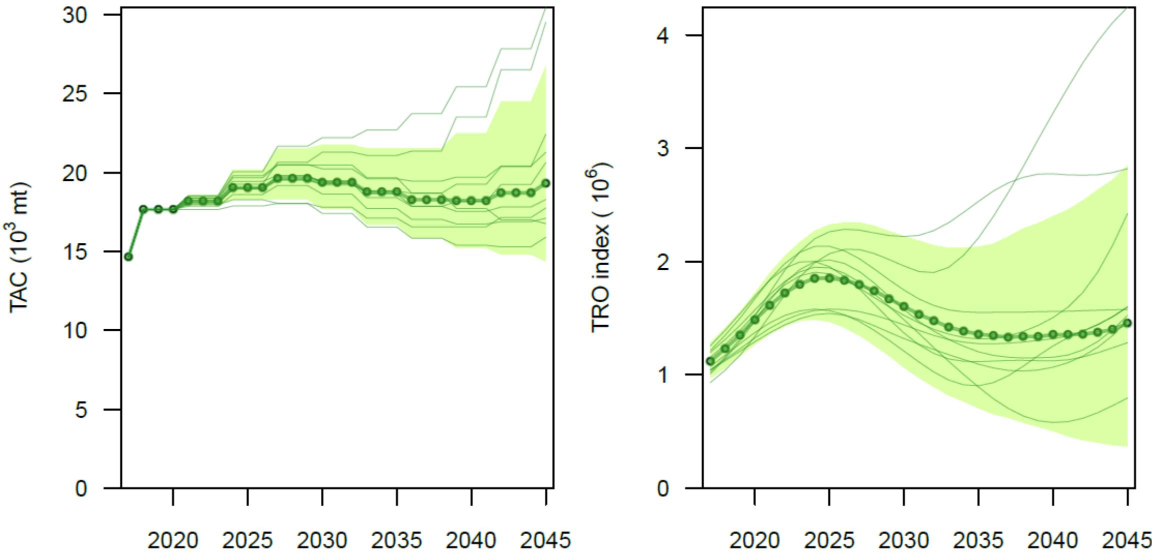
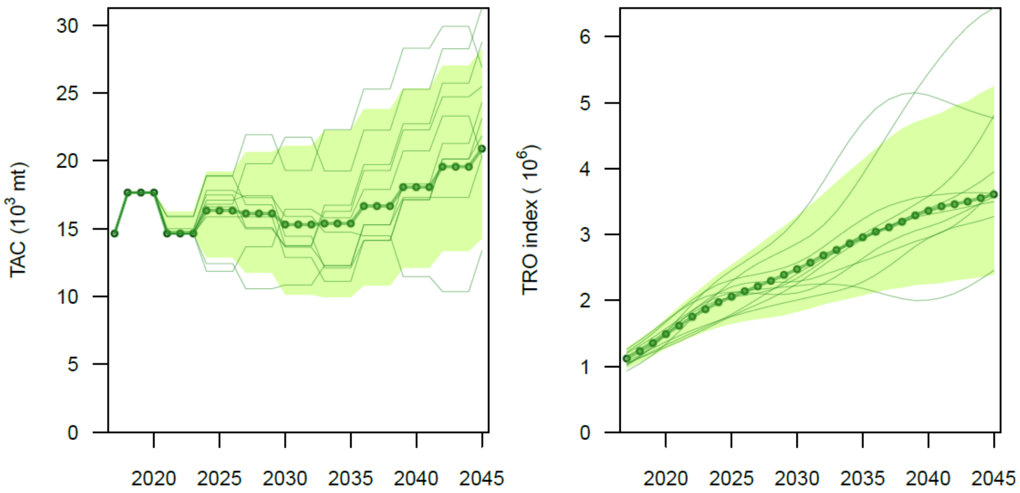


Figure 14. Worm plots for TAC and TRO for DMM3 (30% SSB_0) when applied for lowR (n=10) case.

a) DMM1



b) DMM2

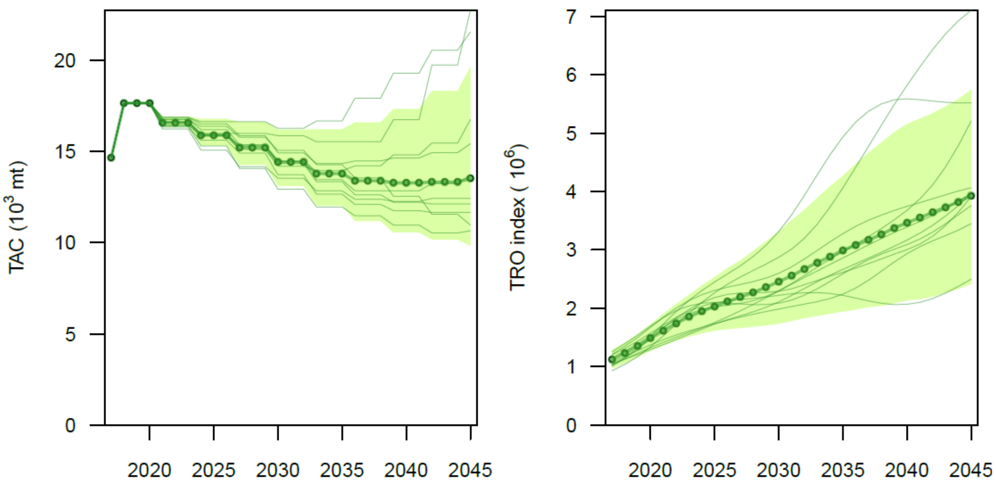


Figure 15. Worm plots for TAC and TRO for DMM1 and DMM2 for the projection years when tuned to **35% SSB_0** in the year 2035.

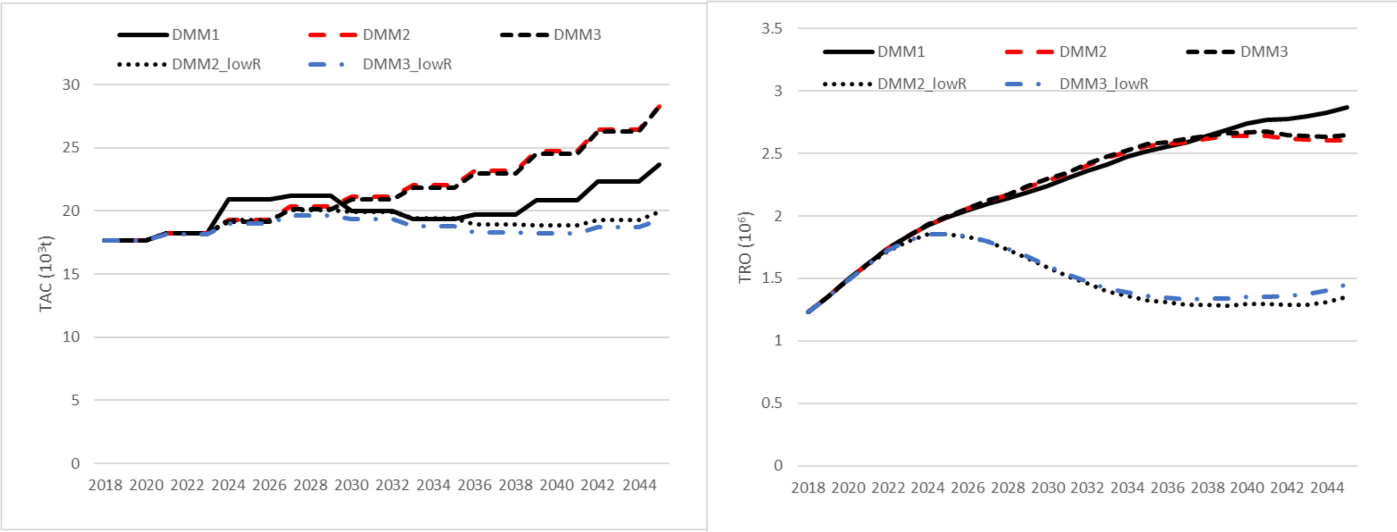


Figure 16. Plots of the medians for TAC and TRO for DMM1, DMM2, DMM3, DMM2_lowR and DMM3_lowR for the projection years when tuned to **30% SSB$_0$** in the year 2035.