Simple target-based CMPs for southern bluefin tuna

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SUMMARY

Simple target-type CMPs for SBT, first developed in 2018, and using CPUE, close kin mark recapture (CKMR) and gene tagging (GT) information, are further refined and tuned to median recovery of 30% and 35% of the pristine TRO in 2035 and 2040 respectively for the operating models as finalized for 2019. These tunings are carried out for each information type separately, and then selections are made amongst differently weighted combinations of the resultant three CMPs. Particular stress is placed on attempting to achieve greater values for the lower percentile for SSB depletion in the tuning year, especially for the robustness test involving low recruitment, which is best achieved by the GT index-based CMP. For that reason, the preferred combined CMP gives 60% weight to the GT-based CMP, with 20% to each of the other two.

要旨

2018 年に最初に開発された、ミナミマグロのための単純なターゲットタイプの管理方式（CPUE、近縁遺伝標識再捕親子（CKMR)、遺伝標識（GT）の三つの情報を利用する）をさらに改良し、2019 年に最終化したオペレーティングモデル（OM）に適用し、2035 年および 2040 年の総再生産出力（TRO）の中央値がそれぞれ初期の 30%および 35%となるようチューニングを行った。これらのチューニングは、はじめに個々の情報に対して別々に行い、その後、それら三つの管理方式に対して様々な重みづけを与え、三つの情報を統合した最良の管理方式の選択を行った。我々が特に重視した点は、チューニング年における産卵親魚量（SSB）の下限値がより大きくなる点であり、特に低い加入量を想定した頑健性テストにおいて最もこのことを重視した。このようなパフォーマンスは、GT の情報に基づく管理方式において優れていた。このような理由から、今回選択された三つの情報を統合させた管理方式においては、60%の重みを GT による管理方式に与え、残り 20%ずつの重みを CKMR と CPUE による管理方式に与えた。

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Introduction

This paper extends the target-type Candidate Management Procedures (CMPs) for SBT developed during 2018 and earlier in 2019 (Butterworth et al. 2018a, b; 2019) to the updated RC grid (base18). The extensions involve 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, and further allowing for a possible upward trend in that target value after the tuning year to allow for continued resource growth after that time. These CMPs are tuned to a median recovery to 30% of the pristine TRO in 2035, and to 35% of this value in 2040. (Note that in the rest of this paper the term SSB is often used, rather than TRO, as is often the case in CCSBT meetings, but in all instances it is TRO that is being referenced.)

The approach is applied separately for each of the three types of information available (close kin mark recapture (CKMR), CPUE and gene tagging (GT)). Then the performance of some weighted combinations of each of the three CMPs is investigated.

Results are presented and discussed for these CMPs applied to the RC (base18) and to the robustness tests with the variable squares CPUE (cpuew0) and with five successive years of a reduced expectation for the value of recruitment (reclow5). Preferred CMPs are put forward for each of the two tunings for the case where the maximum TAC change is set at 3000 mt. Finally, the preferred weighted combination for each tuning is applied to the other robustness tests.

Methods

Indices

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

CKMR index

J_y^{CKMR} is a relative CKMR index averaged over 2 years as follows:

$$J_y^{CKMR} = \frac{\left(\mathrm{S}_{y-5} + \mathrm{S}_{y-6}\right)\cdot\frac{1}{2}}{\left(\mathrm{S}_{2013} + \mathrm{S}_{2012}\right)\cdot\frac{1}{2}}$$

CPUE index

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

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

GT index

J_y^{GT} is a relative GT index averaged over 5 years as follows:

$$J_y^{GT} = \frac{\left(J_{y-2}^{GT} + J_{y-3}^{GT} + J_{y-4}^{GT} + J_{y-5}^{GT} + J_{y-6}^{GT}\right)\cdot\frac{1}{5}}{J_{2016}^{GT}}$$

CMPs

The CMPs explored are as follows. Note that catch units are mt.

DMRMCKMR

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

If $(J_y^{CKMR} > J_{targ}^{CKMR})$: $$\mathrm{TAC}_{\mathrm{y+1}}^{\mathrm{CKMR}} = \mathrm{TAC}_{\mathrm{y}}^{\mathrm{CKMR}} \times \left(1 + \kappa_{\mathrm{up}} \cdot \left(J_y^{CKMR} - J_{targ}^{CKMR}\right)\right)$$

If $(J_y^{CKMR} < J_{targ}^{CKMR})$: $$\mathrm{TAC}_{\mathrm{y+1}}^{\mathrm{CKMR}} = \mathrm{TAC}_{\mathrm{y}}^{\mathrm{CKMR}} \times \left(1 + \kappa_{\mathrm{down}} \cdot \left(J_y^{CKMR} - J_{targ}^{CKMR}\right)\right)$$

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

where J_{targ}^{CKMR} and the other control parameters are defined below:

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

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

Furthermore, if $\mathrm{y} > y_t$ (where y_t is the tuning year, i.e. either 2035 or 2040):

$$J_{targ,y}^{CKMR} = \mathrm{T2}\left(1 + \alpha^{CKMR}(y - y_t)\right)$$

DMRMCPUE

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

If $(J_y^{CPUE} > J_{targ}^{CPUE})$: $$\mathrm{TAC}_{\mathrm{y+1}}^{\mathrm{CPUE}} = \mathrm{TAC}_{\mathrm{y}}^{\mathrm{CPUE}} \times \left(1 + \beta_{\mathrm{up}} \cdot \left(J_y^{CPUE} - J_{targ}^{CPUE}\right)\right)$$

If $(J_y^{CPUE} < J_{targ}^{CPUE})$: $$\mathrm{TAC}_{\mathrm{y+1}}^{\mathrm{CPUE}} = \mathrm{TAC}_{\mathrm{y}}^{\mathrm{CPUE}} \times \left(1 + \beta_{\mathrm{down}} \cdot \left(J_y^{CPUE} - J_{targ}^{CPUE}\right)\right)$$

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

If $\mathrm{y} > y_t$:

$$J_{targ,y}^{CPUE} = J_{targ}^{CPUE}\left(1 + \alpha^{CPUE}(y - y_t)\right)$$

DMRMGT

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

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

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

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

If $y > y_t$:

$$J^{GT}_{targ,y} = J^{GT}_{targ}\left(1 + \alpha^{GT}(y - y_t)\right)$$

DMRCOMB

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

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

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) – time did not allow for tuning to alternative values for this constraint
- The minimum change limit is 100t, hence: $100 \leq \left|\mathrm{TAC}_{\mathrm{y+1}} - \mathrm{TAC}_{\mathrm{y}}\right| \leq 3\,000$ 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 various CMPs considered are listed in Table 1 for the each of the two tunings (to a median TRO in 2035 which is 30% and one in 2040 which is 35% of its pristine value). Tables 2a and 2b list performance statistics for these two tunings respectively for the RC (base18) and the cpuew0 and reclow5 robustness tests. The tunings were conducted for 2000 draws from the respective OM grids; this was achieved to within 0.004 of the tuning target for the CMPs based on each separate data type. The weighted combination CMPs were not re-tuned, as they proved not to need further tuning to achieve the tuning target concerned within the same tolerance.

These CMPs were developed by first tuning a CMP using one source of information only (DMRMCKMR, DMRMCPUE and DMRMGT). This involved the choice of minimally two control parameter values: a target value (more complex for DMRMCKMR) 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 be able to cut the TAC sufficiently so as to react appropriately to low values of the index. To enhance such reactivity, this approach was extended to allow for greater values of the gain parameter when the index was below rather than to above its associated target value. After the tuning year (2035 or 2040), the target control parameter was allowed to increase linearly where considered desirable, so as to try to better allow for some continued increase in SSB.

A key consideration in selecting control parameter values was to increase the value of the gain parameter when the index was below its target value to try to improve the lower percentile values for the SSB2035/SSB0 or SSB2040/SSB0 distributions, particularly for the reclow5 robustness test. The greatest success in that respect was achieved for the GT index (unsurprisingly as it is the first to directly detect a change in recruitment). The combination CMPs are shown first with equal weighting for each data type (comb1), and then also for the preferred option which weights the GT component by 60% with each of the other two reduced to 20% (comb2); this has the key consideration above in mind. The α parameters, for situations where a greater increase in SSB after the tuning year was considered desirable, were set as high as possible without causing the median TAC to begin a marked decreasing trend in the 2040s. More care (given that more time was available) was taken in adjusting the control parameter values for the case of tuning to a median TRO in 2035 which is 30% of its pristine value, in an attempt to achieve what were considered to be optimal trade-offs amongst the performance statistics. For the alternative tuning, most of the control parameter values were left unchanged from those for this first tuning, but the target-related control parameter value or values were increased to reduce the rate in increase in the TAC for the RC (base18) in an attempt to increase the SSB further. In some cases, the α parameter value was set to zero as the median SSB already continued to increase through to 2040s without adding this further feature to the control law.

Figure 1 shows plots of results for the tuning to a median TRO in 2035 which is 30% of its pristine value. Figure 1a compares these results for the five CMPs considered using the standard "guitar plot" approach. Figure 1b reports TAC and SSB projections for these five CMPs with both medians and 90% probability envelopes shown. Finally, Figure 1c compares results for the preferred DMRcomb2 for RC (base18) and all the robustness tests, again using the standard "Guitar plot".

Figure 2 repeats Figure 1 for the other tuning to a median TRO in 2040 which is 35% of its pristine value. In the guitar plots, the SSB2035/SSB0 statistic panel is replaced by one for SSB2040/SSB0 to correspond to the tuning year to which the 35% pertains.

Comments

For the tuning to a median TRO in 2035 which is 30% of its pristine value, these CMPs have difficulty in securing much SSB increase after 2035 without decreasing the TAC allocated in consequence. This could be avoided by having the TAC increase further in the early projection years, and then more slowly later so that it is lower when 2035 is reached, but this would require moving to a more complex formulation than the intentionally simple approach used here of uncomplicated control rules which approximate a constant fishing mortality strategy.

Broadly speaking, the CKMR based CMPs are best for achieving lower AAV and worst for the lower percentile on SSB depletion in the tuning year, the GT based CMPs show the opposite trade-off, and the CPUE based ones are intermediate. Median TAC trends with time also differ notably amongst the three, with those using the CKMR index increasing the fastest initially and then steadying, whereas medians for the others increase more smoothly throughout the period with the GT based ones rising somewhat faster than those based on CPUE.

The worst SSB depletion performance under the robustness tests is evident for the OMs based on the variable squares CPUE hypothesis (cpuew0). This is the one instance in which the CPUE-based CMPs show better depletion performance than the others. While performance of the combination CMPs might be improved a little in that respect by giving greater weight to the CPUE-based component, preference was accorded to giving greater weight for the GT-based component in the CMPs advocated because this gives the best performance for the low recruitment (reclow5) scenario, which it seen by the authors as the more plausible of these two robustness test scenarios.

Conclusions

The CMPs which combine the individual ones for each data type, but with 60% weight to the GT index and 20% weight to CKMR and CPUE information, are put forward as final candidates for each of the two tunings.

Acknowledgments

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References

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Table 1. Values of the control parameters for the CMPs considered.

	a) Tuned to achieve a median TRO in 2035 which is 30% of its pristine value for the RC (base18) OM grid.					b) Tuned to achieve a median TRO in 2040 which is 35% of its pristine value for the RC (base18) OM grid.				
	DMRMCKMR	**DMRMCPUE**	**DMRMGT**	**DMRcomb1**	**DMRcomb2**	**DMRMCKMR**	**DMRMCPUE**	**DMRMGT**	**DMRcomb1**	**DMRcomb2**
CKMR:										
κ_{up}	0.17			0.17	0.17	0.17			0.17	0.17
κ_{down}	0.17			0.17	0.17	0.17			0.17	0.17
T1	0.4			0.4	0.4	0.595			0.595	0.595
T2	1.5			1.5	1.5	1.695			1.695	1.695
y1	2021			2021	2021	2021			2021	2021
y2	2030			2030	2030	2030			2030	2030
α^{CKMR}	0.03			0.03	0.03	0.03			0.03	0.03
CPUE:										
β_{up}		0.13		0.13	0.13		0.13		0.13	0.13
β_{down}		0.7		0.7	0.7		0.7		0.7	0.7
J_{targ}^{CPUE}		0.9		0.9	0.9		1.152		1.152	1.152
α^{CPUE}		0.03		0.03	0.03		0		0	0
GT:										
γ_{up}			0.25	0.25	0.25			0.25	0.25	0.25
γ_{down}			1.25	1.25	1.25			1.25	1.25	1.25
J_{targ}^{GT}			0.47	0.47	0.47			0.65	0.65	0.65
α^{GT}			0.08	0.08	0.08			0	0	0
Comb										
w_{CKMR}				1/3	0.2				1/3	0.2
w_{CPUE}				1/3	0.2				1/3	0.2
w_{GT}				1/3	0.6				1/3	0.6

Table 2a. Some performance statistics for the six CMPs considered for the RC (base18) and two robustness tests (cpuew0 and reclow5). Median values are shown for the distributions for each statistic together with 90% PIs for most of these. Each CMP is tuned to achieve a median TRO **in 2035 which is 30%** of its pristine value for the RC (base18) OM.

MP	run	Mean TAC (2021-2035)	Mean TAC (2036-2050)	%AAV (2021-2035)	%AAV (2036-2050)	SSB2035/SSB0	SSB2040/SSB0	P(2up/1down)
1 DMRMCKMR	base18	21276 (20701, 21828)	24670 (19554, 27453)	3.9 (2.9, 5.5)	3.5 (1.2, 7.5)	0.301 (0.173, 0.494)	0.316 (0.140, 0.588)	0
2 DMRMCPUE	base18	21286 (18978, 23344)	26878 (14160, 28000)	7.6 (4.2, 11.1)	3.3 (0.000, 13.1)	0.303 (0.184, 0.488)	0.315 (0.166, 0.566)	0
3 DMRMGT	base18	22056 (19164, 24398)	27679 (21921, 28000)	9.4 (3.9, 11.2)	1.5 (0.000, 9.1)	0.301 (0.191, 0.479)	0.301 (0.158, 0.548)	0.012
4 DMRcomb1	base18	21743 (19823, 23561)	27130 (17636, 28000)	7.3 (3.3, 10.1)	2.4 (0.000, 10.4)	0.301 (0.184, 0.483)	0.305 (0.156, 0.553)	0.005
5 DMRcomb2	base18	21997 (19625, 24043)	27400 (19375, 28000)	8.6 (3.2, 10.6)	1.9 (0.000, 9.2)	0.300 (0.187, 0.477)	0.301 (0.157, 0.547)	0.013
1 DMRMCKMR	cpuew0	20311 (19654, 20930)	15701 (11537, 21809)	4.4 (3.0, 6.0)	9.3 (1.8, 22.3)	0.154 (0.050, 0.339)	0.169 (0.014, 0.453)	0.048
2 DMRMCPUE	cpuew0	17087 (14825, 19487)	12439 (3929, 26171)	7.4 (1.9, 14.8)	10.0 (2.7, 35.6)	0.186 (0.086, 0.364)	0.226 (0.084, 0.487)	0.01
3 DMRMGT	cpuew0	20180 (15737, 23563)	24762 (9521, 28000)	6.8 (2.3, 11.0)	6.3 (0.000, 25.8)	0.165 (0.083, 0.328)	0.168 (0.062, 0.409)	0.058
4 DMRcomb1	cpuew0	19019 (16544, 21379)	16199 (5845, 27079)	4.7 (2.2, 9.9)	7.6 (1.6, 34.6)	0.170 (0.077, 0.342)	0.194 (0.065, 0.445)	0.31
5 DMRcomb2	cpuew0	19474 (16219, 22594)	19341 (6936, 27733)	4.6 (1.7, 10.0)	7.0 (0.719, 34.2)	0.168 (0.080, 0.334)	0.183 (0.067, 0.424)	0.152
1 DMRMCKMR	reclow5	21259 (20698, 21832)	22148 (17631, 27052)	3.9 (2.9, 5.5)	4.3 (1.3, 12.4)	0.224 (0.125, 0.368)	0.229 (0.086, 0.456)	0
2 DMRMCPUE	reclow5	20130 (17827, 22555)	20685 (9456, 27840)	8.0 (4.3, 11.2)	6.9 (0.674, 17.3)	0.234 (0.142, 0.371)	0.249 (0.124, 0.459)	0.001
3 DMRMGT	reclow5	20001 (16006, 23311)	26435 (15419, 28000)	7.5 (3.4, 10.8)	4.7 (0.000, 12.3)	0.242 (0.157, 0.372)	0.247 (0.136, 0.459)	0.254
4 DMRcomb1	reclow5	20480 (18001, 22431)	23794 (12176, 27867)	4.9 (2.6, 8.5)	4.2 (0.540, 14.5)	0.234 (0.143, 0.369)	0.240 (0.123, 0.448)	0.188
5 DMRcomb2	reclow5	20338 (17158, 22847)	25407 (13496, 27960)	5.5 (2.4, 9.4)	4.2 (0.117, 13.4)	0.237 (0.150, 0.367)	0.243 (0.128, 0.454)	0.275

Table 2b. Some performance statistics for the six CMPs considered for the RC (base18) and two robustness tests (cpuew0 and reclow5). Median values are shown for the distributions for each statistic together with 90% PIs for most of these. Each CMP is tuned to achieve a median TRO **in 2040 which is 35%** of its pristine value for the RC (base18) OM.

MP	run	Mean TAC (2021-2035)	Mean TAC (2036-2050)	%AAV (2021-2035)	%AAV (2036-2050)	SSB2035/SSB0	SSB2040/SSB0	P(2up/1down)
1 DMRMCKMR	base18	19336 (18789, 19847)	20948 (16511, 25217)	2.4 (1.6, 3.8)	4.7 (1.3, 9.4)	0.318 (0.189, 0.513)	0.350 (0.170, 0.620)	0.19
2 DMRMCPUE	base18	19301 (16487, 21732)	24458 (10606, 28000)	6.4 (2.6, 11.1)	5.8 (0.000, 14.6)	0.322 (0.202, 0.507)	0.349 (0.200, 0.601)	0
3 DMRMGT	base18	19429 (14051, 23162)	26835 (14644, 28000)	8.5 (3.3, 13.1)	3.9 (0.000, 12.3)	0.329 (0.219, 0.497)	0.347 (0.215, 0.586)	0.018
4 DMRcomb1	base18	19456 (16388, 21782)	25132 (13545, 27920)	4.6 (1.8, 9.7)	4.4 (0.304, 9.8)	0.322 (0.207, 0.502)	0.347 (0.201, 0.591)	0.032
5 DMRcomb2	base18	19508 (15262, 22661)	26137 (14126, 28000)	6.1 (2.3, 10.9)	4.0 (0.000, 10.7)	0.325 (0.213, 0.498)	0.346 (0.208, 0.586)	0.022
1 DMRMCKMR	cpuew0	18488 (17909, 19040)	13389 (9789, 18439)	5.0 (3.1, 6.9)	8.1 (1.6, 20.9)	0.172 (0.066, 0.359)	0.202 (0.041, 0.491)	0.746
2 DMRMCPUE	cpuew0	13890 (12340, 17195)	8122 (2438, 21751)	14.4 (3.5, 20.4)	10.9 (3.3, 27.0)	0.214 (0.106, 0.393)	0.280 (0.120, 0.546)	0
3 DMRMGT	cpuew0	16131 (11540, 21582)	18914 (4865, 28000)	9.1 (3.1, 20.8)	7.2 (0.000, 16.5)	0.202 (0.119, 0.351)	0.240 (0.133, 0.457)	0.011
4 DMRcomb1	cpuew0	15699 (12905, 18922)	11864 (3931, 25042)	8.3 (1.9, 18.8)	6.6 (1.8, 18.4)	0.200 (0.106, 0.367)	0.251 (0.119, 0.496)	0.026
5 DMRcomb2	cpuew0	15859 (11972, 19940)	14271 (4307, 27042)	7.3 (1.8, 20.4)	6.4 (1.5, 16.5)	0.202 (0.114, 0.357)	0.247 (0.130, 0.482)	0.029
1 DMRMCKMR	reclow5	19325 (18799, 19808)	18787 (15025, 23539)	2.4 (1.7, 3.8)	4.3 (1.2, 11.0)	0.241 (0.140, 0.387)	0.262 (0.113, 0.498)	0.172
2 DMRMCPUE	reclow5	17759 (15836, 20512)	15983 (7462, 26786)	9.5 (4.0, 11.9)	9.4 (2.9, 17.2)	0.254 (0.157, 0.392)	0.288 (0.155, 0.502)	0.001
3 DMRMGT	reclow5	15827 (12214, 20814)	20830 (9494, 27848)	10.3 (4.3, 17.7)	8.2 (0.701, 15.6)	0.276 (0.189, 0.403)	0.315 (0.195, 0.516)	0.104
4 DMRcomb1	reclow5	17208 (14393, 20192)	18051 (8563, 27118)	5.6 (2.1, 13.3)	5.9 (1.5, 12.8)	0.261 (0.171, 0.395)	0.295 (0.174, 0.507)	0.239
5 DMRcomb2	reclow5	16484 (13033, 20516)	19251 (8762, 27551)	7.1 (2.6, 15.4)	6.7 (1.4, 14.4)	0.270 (0.182, 0.400)	0.307 (0.188, 0.508)	0.16

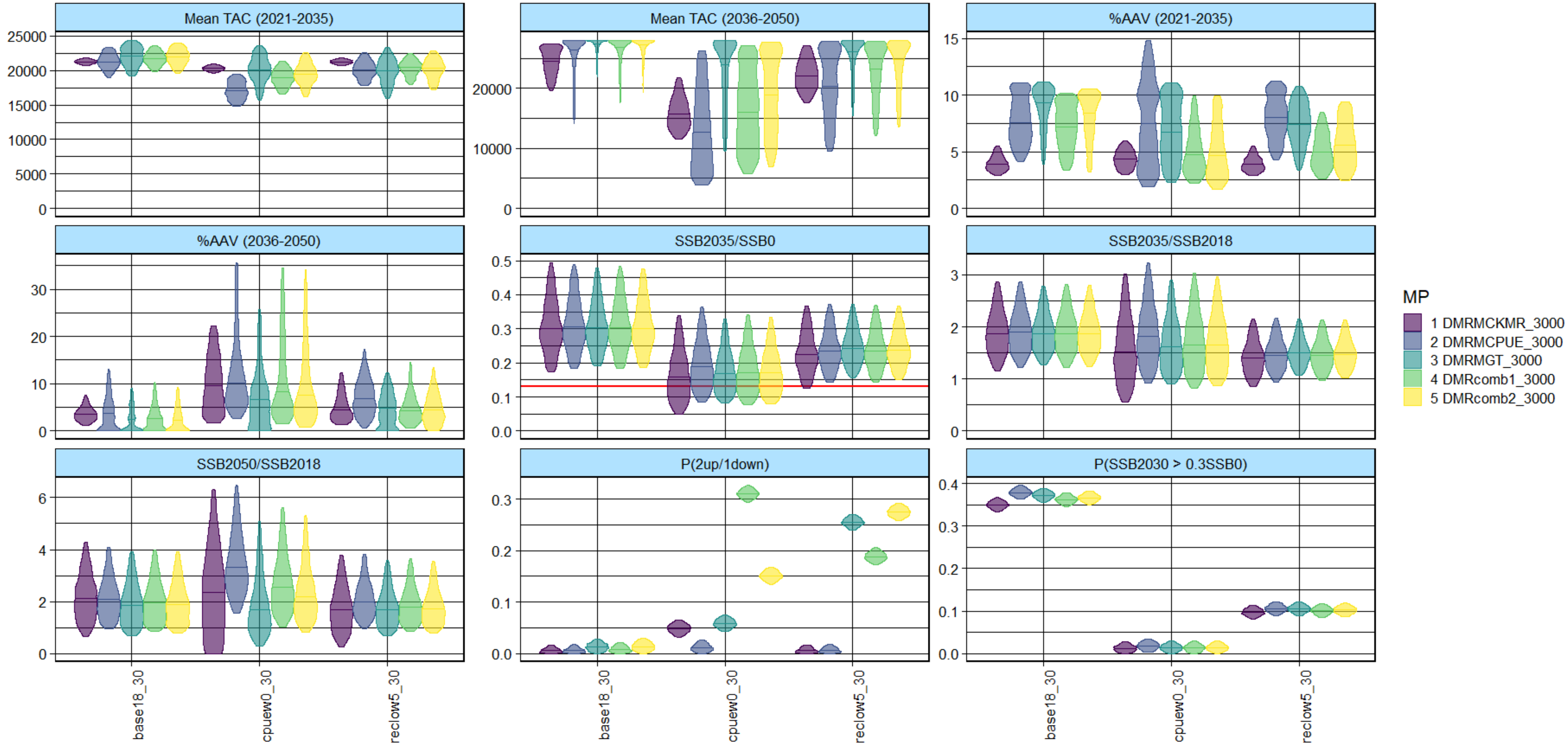

Figure 1a. "Guitar plots" of performance statistics for the five CMPs investigated tuned to achieve a median TRO **in 2035 which is 30%** of its pristine value for the RC (base18) OM.

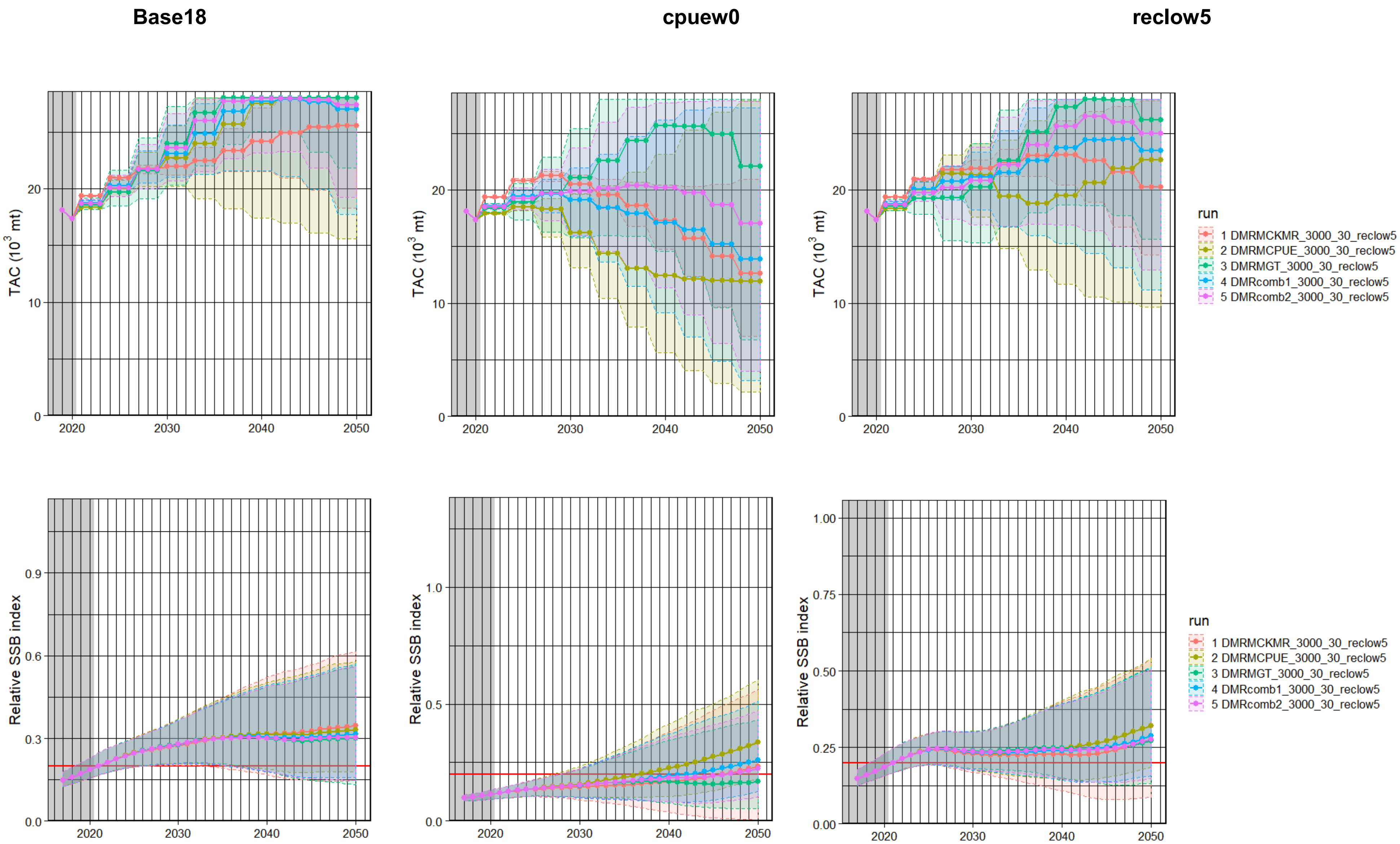

Figure 1b. TAC and SSB trajectory plots for the five CMPs investigated tuned to achieve a median TRO **in 2035 which is 30%** of its pristine value for the RC (base18) OM.

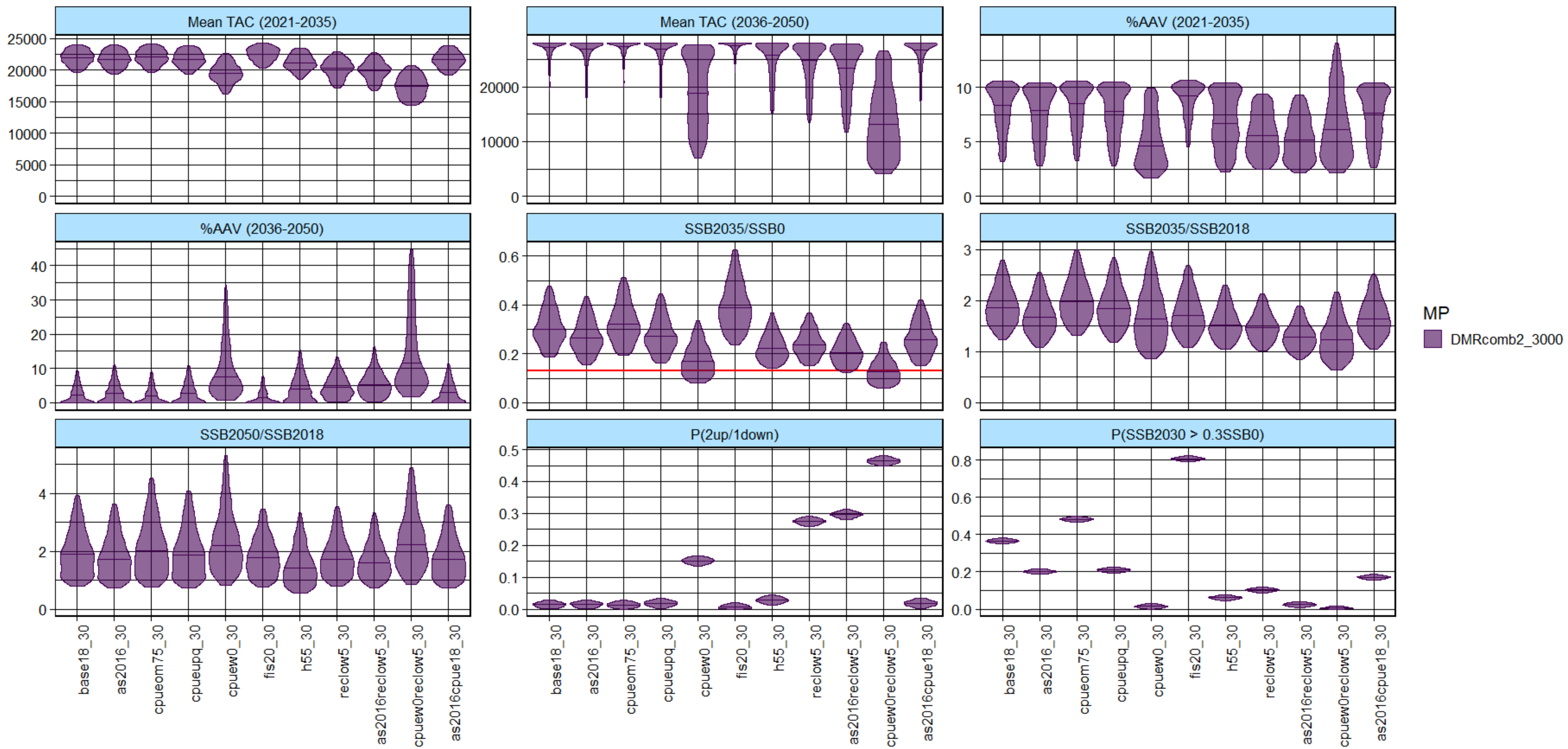

Figure 1c. “Guitar plots” of performance statistics for the DMRcomb2 tuned to achieve a median TRO **in 2035 which is 30%** of its pristine value for the RC (base18) OM for base18 and all the robustness tests.

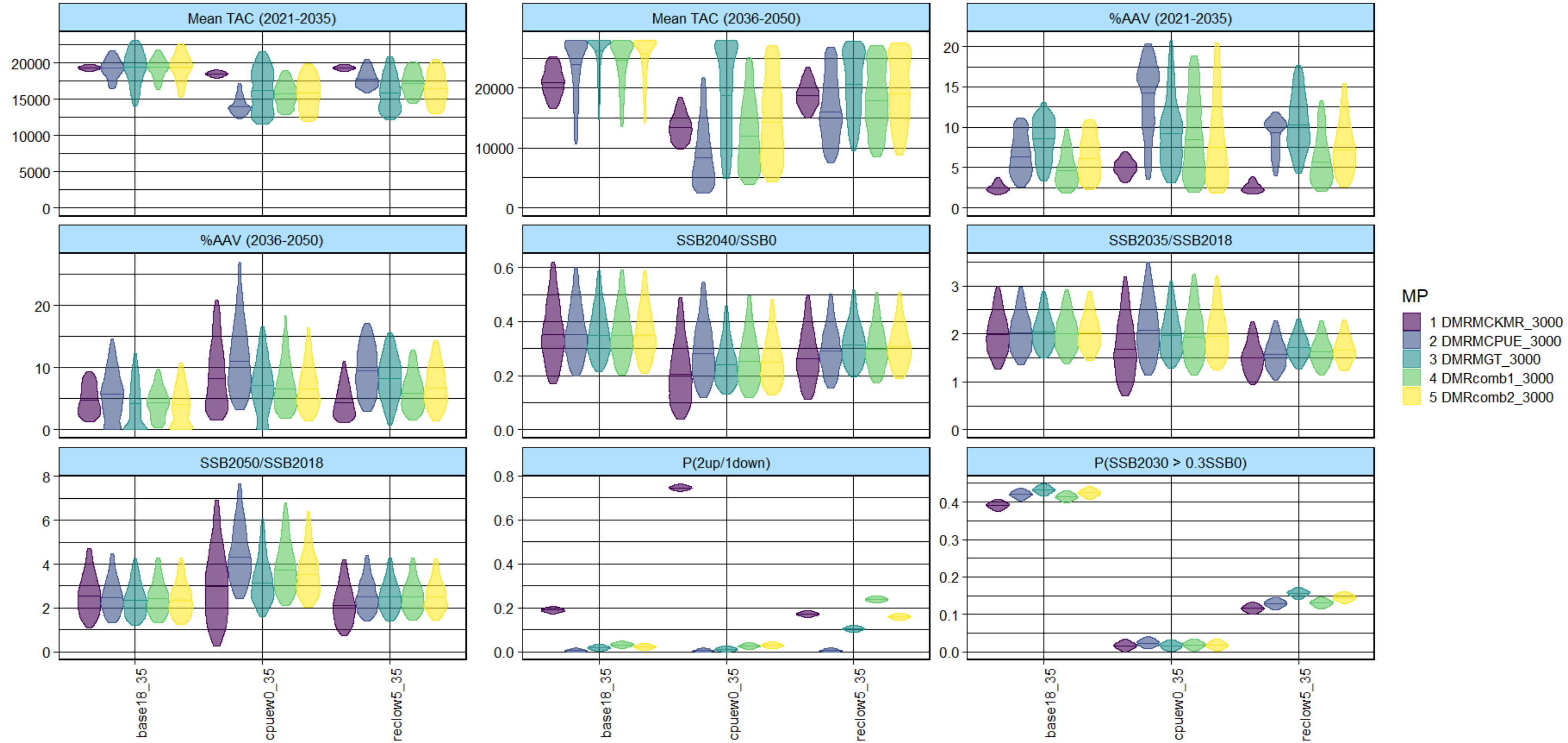

Figure 2a. “Guitar plots” of performance statistics for the five CMPs investigated tuned to achieve a median TRO **in 2040 which is 35%** of its pristine value for the RC (base18) OM. Note that the central block is changed from Figure 1a to give depletion results for the tuning year here of 2040 rather than 2035.

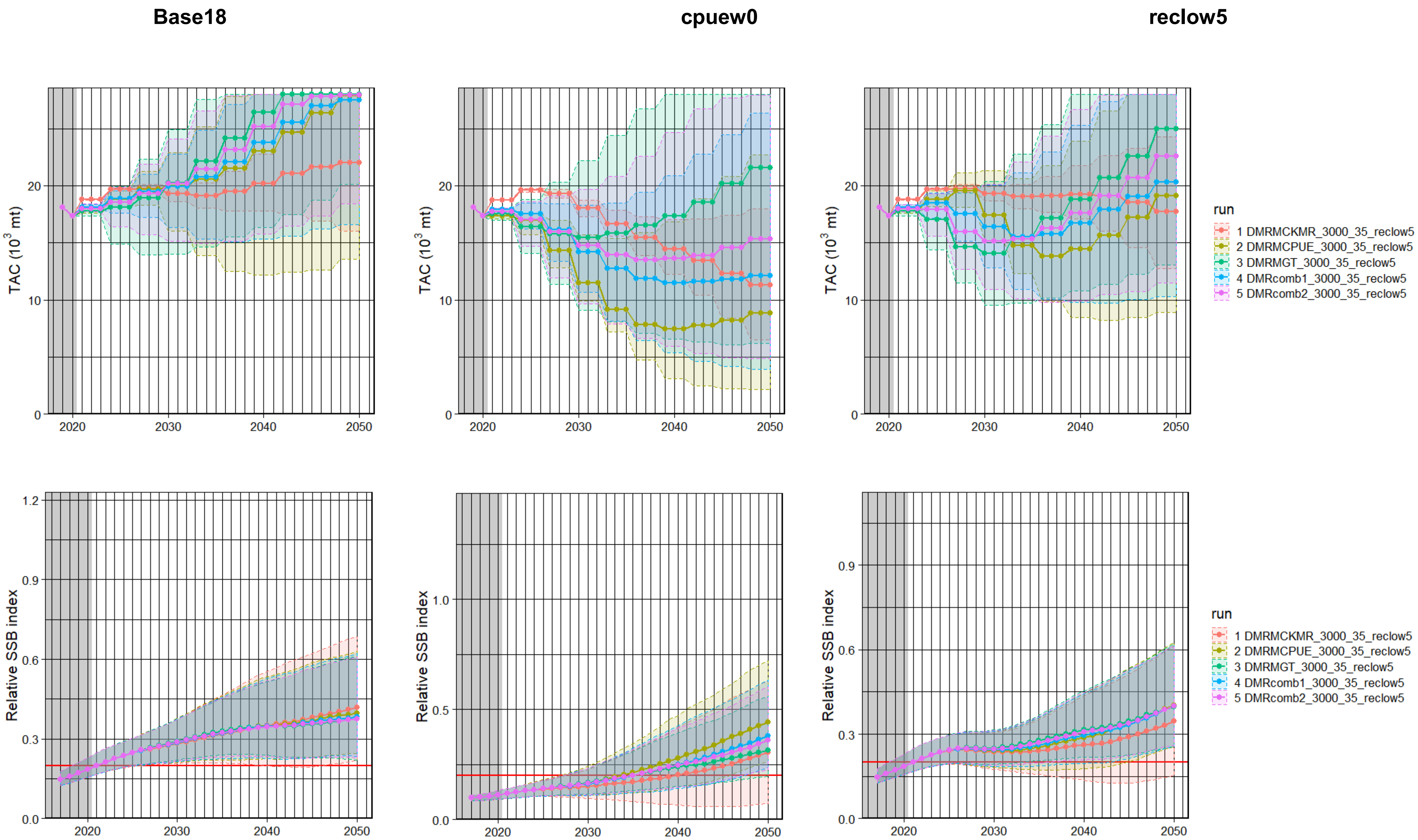

Figure 2b. TAC and SSB trajectory plots for the five CMPs investigated tuned to achieve a median TRO **in 2040 which is 35%** of its pristine value for the RC (base18) OM.

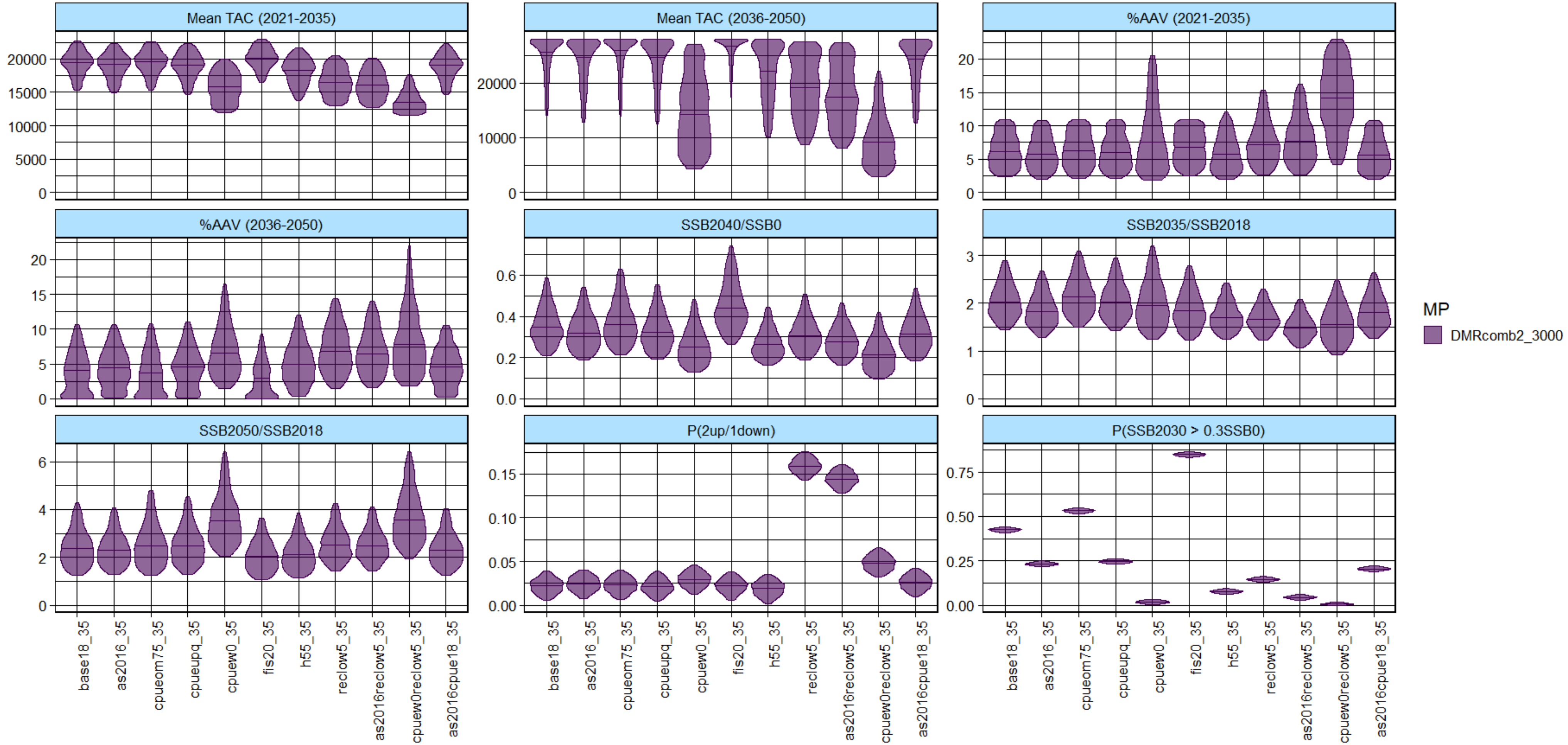

Figure 2c. “Guitar plots” of performance statistics for the DMRcomb2 tuned to achieve a median TRO **in 2040 which is 35%** of its pristine value for the RC (base18) OM for base18 and all the robustness tests. Note that the central block gives depletion results for the tuning year here of 2040 rather than 2035, as for Figure 2a.