Performance of the final candidate management procedures selected at the 4th Management Procedure Workshop

Trevor A. Branch
Ana M. Parma
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Introduction

Four candidate management procedures (CMP_1, CMP_2, CMP_3 and CMP_4) were selected for further analysis at the 4th Management Procedure Workshop and Special Management Procedure Management Consultation in Canberra, 16-23 May 2005. At that meeting the following decisions were made:

1. A new reference set would be produced that would exclude scenarios which predicted abundance at ages three and four in 2004 that were below the actual catches in 2004.
2. TAC reductions of 0, 2500 and 5000 t in 2006 would be run for the “b” catch schedule (TAC changes in 2008 and every three years thereafter).
3. A new catch schedule “d” would be implemented (TAC changes in 2007, 2009, 2011 and every three years thereafter).
4. The basic runs for the CMPs would comprise the following axes:
    a. Tuning parameters for each CMP corresponding to two tuning levels (1.1 and 1.3) for the old Cfull2 reference set.
    b. Four catch schedules (“b” with 0, 2500, 5000 TAC reduction in 2006, and “d”).
    c. Five scenarios (new reference set, lowR2, lowR4, tripleR, expl). LowR2 and LowR4 refer to the number of years of low recruitment modeled after the 2000 and 2001 years of low recruitment, tripleR triples the recruitments in 2000 and 2001, and expl constrains the catch-to-abundance ratio, H, by applying a heavy penalty when $H(3,2003:2004) > H_{high}$ where $H_{high} = 0.8 \cdot \mathrm{mean}(H(2:3,84:88))$.
    d. Four CMPs.
5. In total, there would be 160 combinations of runs.

Intersessional discussions based on analyses conducted after MPW4 lead to changes in the approach used to conduct the final CMP testing. First, the process used to amend the reference set was modified. Instead of excluding scenarios for which abundance was less than the catches in 2004, abundances at ages 3 and 4 in 2003 and 2004 were forced to exceed the actual catches by penalizing the likelihood whenever the ratio of actual catch to abundance at age exceeded 0.60. Also, the expl scenario was modified by using the actual catches in the computation of the (penalized) harvest rates, instead of the predicted catches as was done before. Details are provided in Appendix I.

Second, a new schedule of TAC changes (schedule “e”) was proposed to replace schedule “d”. The rationale behind the evaluation of catch reductions in 2006 and the new catch schedule “d” was that the pessimistic status of the stock resulting from estimated low recruitments in 2000 and 2001, and possibly more years after 2001, may require TAC reductions sooner than 2008, when the first change in TAC would occur under schedule “b”. Catch schedule “d” allowed more TAC changes than schedule “b” and should therefore allow for earlier TAC reductions. However, initial examination revealed that under schedule “d” the CMPs generally recommended that the 2007 TACs remained constant (CMP_1, CMP_2, CMP_4) or increased (CMP_3), depending on in-built restrictions on allowing increases in that year (Figure 1). The reason for this unexpected result was that CPUE had generally increased in the preceding years, and the additional year (2004) of simulated CPUE used for catch schedule "d" did not provide strong enough evidence for TAC decreases (Figure 2).

An intersessional email discussion came to the conclusion that the runs for schedule "d" be replaced by three additional runs under a new schedule "e". Schedule "e" is the same as schedule "d", except that in the first TAC decision period (2007) there would be direct TAC reductions of either 0, 2500 or 5000 t. The CMPs would then set TACs in 2009, 2011 and every three years thereafter, as before. Replacing schedule "d" with new schedules "e", "e2500" and "e5000" increased the total number of runs from 160 to 240.

In addition, some of the procedures that included constraints to prevent quota increases in the initial period did not achieve the intended effect in those cases where the TAC was initially cut by 2500 or 5000 t. This is the case for CMP_1 and CMP_4. The reason is that in those procedures the no-increase constraint was implemented as not allowing the TAC in the initial period to exceed the current TAC. This became ineffective when the quota cuts were added because in those cases the TACs could increase back to the current level in the next change period, as they did in many cases. This problem was corrected in this paper. Except for these modifications to the constraints, the original MP codes provided by the developers were used for these evaluations. Details about the four CMP formulations are provided in Appendix II.

This paper aims to provide a full set of figures describing the performance of the four CMPs combined with alternative initial catch reductions in either 2006 or 2007 under the various scenarios outlined above.

Terminology
Each of the 200 runs is denoted by CMP_*i*_*jk*_*l*
i is the number of the CMP (1, 2, 3, or 4)
j is the tuning level parameters used (2 for 1.1 and 3 for 1.3)
k is the catch schedule (b, b2500, b5000, e2500, e5000)
l is the scenario (refset, lowR2, lowR4, tripleR, expl).
CMP_1_2e5000_refset refers to CMP_1, tuning level 1.1, catch schedule "e" with catch reduction of 5000 t in 2007, applied to the reference set.
CMP_4_3b_lowR4 refers to CMP_4, tuning level 1.3, catch schedule "b" with no TAC reduction in 2006, under the lowR4 scenario.

Brief discussion

It must first be noted that it is difficult to directly compare the performance of the CMPs based on these plots because of the differences in tuning under the new reference set. It was decided in Canberra that the CMPs would *not* be retuned based on the new reference set, but that the tuning parameters obtained from the old reference set (Cfull2) would be used. In addition, the tuning parameters for the "b" schedule have also been used for the new "e" catch schedule. The implications are that the ratio of B2022:B2004 is no longer 1.1 for the "1.1 tuning parameters", and is no longer 1.3 for the "1.3 tuning parameters), as can be seen in Figure 7 through Figure 16. The ratios for schedule 2b (no quota cut in 2006) went from 1.1 in the old reference set to 1.23, 1.23, 1.29 and 1.17 respectively for CMPs 1 to 4 in the new reference set (Table 3). This difference reflects the higher recruitment estimates obtained by constraining the catch-to-abundance ratio in conditioning so that it could not exceed 0.60.

Substantially higher rebuilding ratios were obtained with the addition of quota cuts for CMP_2, CMP_3 and CMP_4, but much less so for CMP_1 (Table 3). The ratios for CMP_1 were generally lower than for the other CMPs, with a maximum of 1.46 for the 1.1 tuning parameters compared to 1.81-1.99 for the other CMPs (Table 3). When early TAC reductions were implemented in 2006 or 2007, CMP_1, CMP_2 and CMP_4 were constrained to not allow catch increases for the next 2-3 decision periods, and the decision rule CMP_3 rarely allowed catch increases above the 2006/2007 catch level. However, CMP_1 was more likely to increase later catches as soon as catch increases were allowed (after 2015), resulting in a B2022:B2004 ratio closer to the one attained with no TAC cuts and maintaining the 20-yr average catches at similar levels (Figure 23, Figure 24). For CMP_2, CMP_3 and CMP_4, the TAC reductions in 2006 or 2007 generally resulted in lower average catches over 20 years, reduced short-term risks and higher biomasses in 2022 (Figure 23).

Of all the procedures, CMP_3 tended to have the smallest AAV values, smallest maximum TAC decreases and lowest 20-yr average catches. Even though it was the only procedure that would allow the TAC to increase in the start period if indicated by the data (the other three CMPs did not allow any TAC increases in the start period), it was the least likely to propose TAC increases if the TACs were reduced in 2006 or 2007 (Figure 17 to Figure 22). A possible reason for this difference is that CMP_3 uses the minimum of a recruitment-based and a CPUE-trend-based components (see Appendix II), and thus was more reactive to recent recruitment failure. The other procedures were slower to respond, even those procedures that had built in recruitment effects (CMP_1 and CMP_2). When initial quotas were reduced, a sizeable proportion of the TACs in 2011 were set at the bound imposed by the no-increase constraints (Figures 3 and 4). CMP_3, on the other hand, was less responsive to possible stock increases after 2015.

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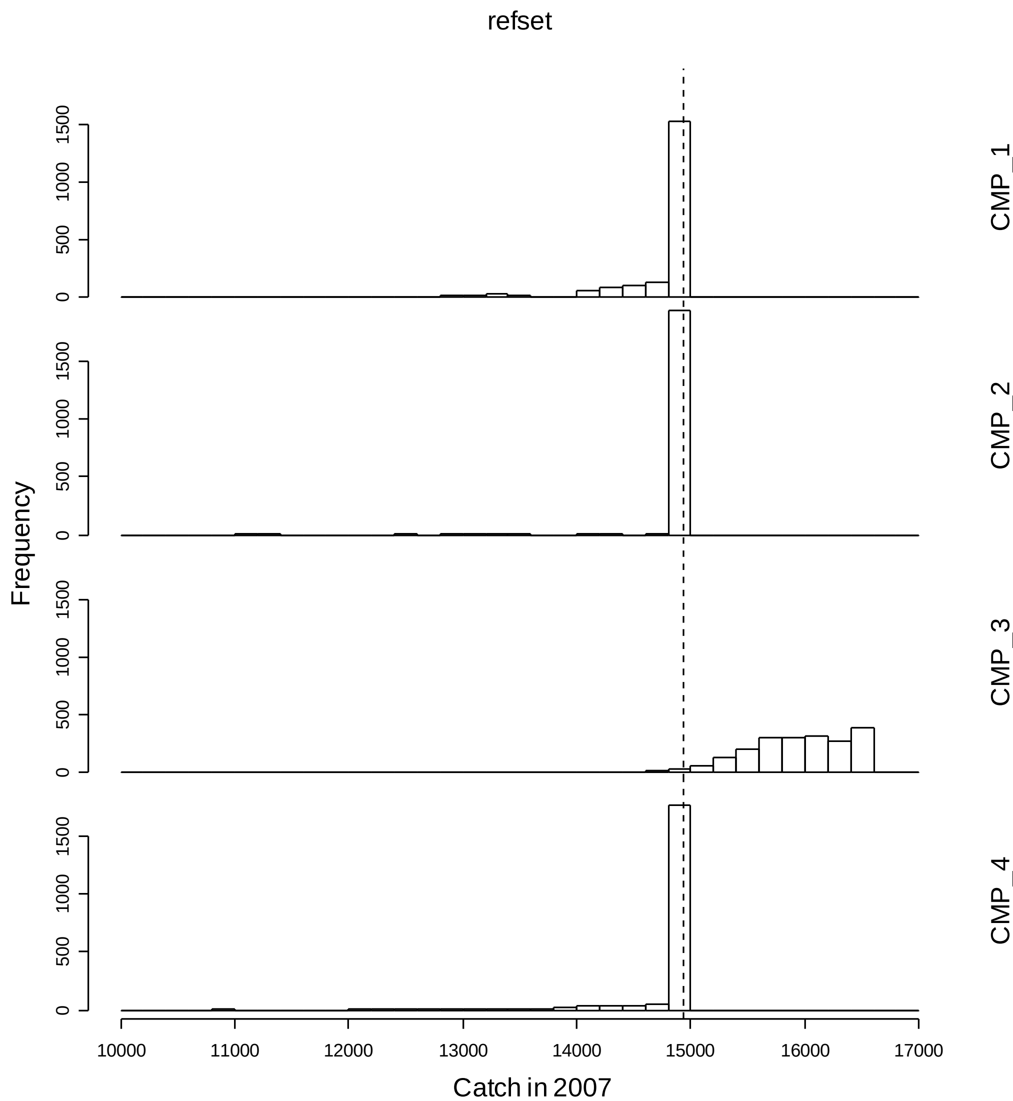


Figure 1 Catches in 2007 under the “d” catch schedule for each of the four management procedures under the new reference set.

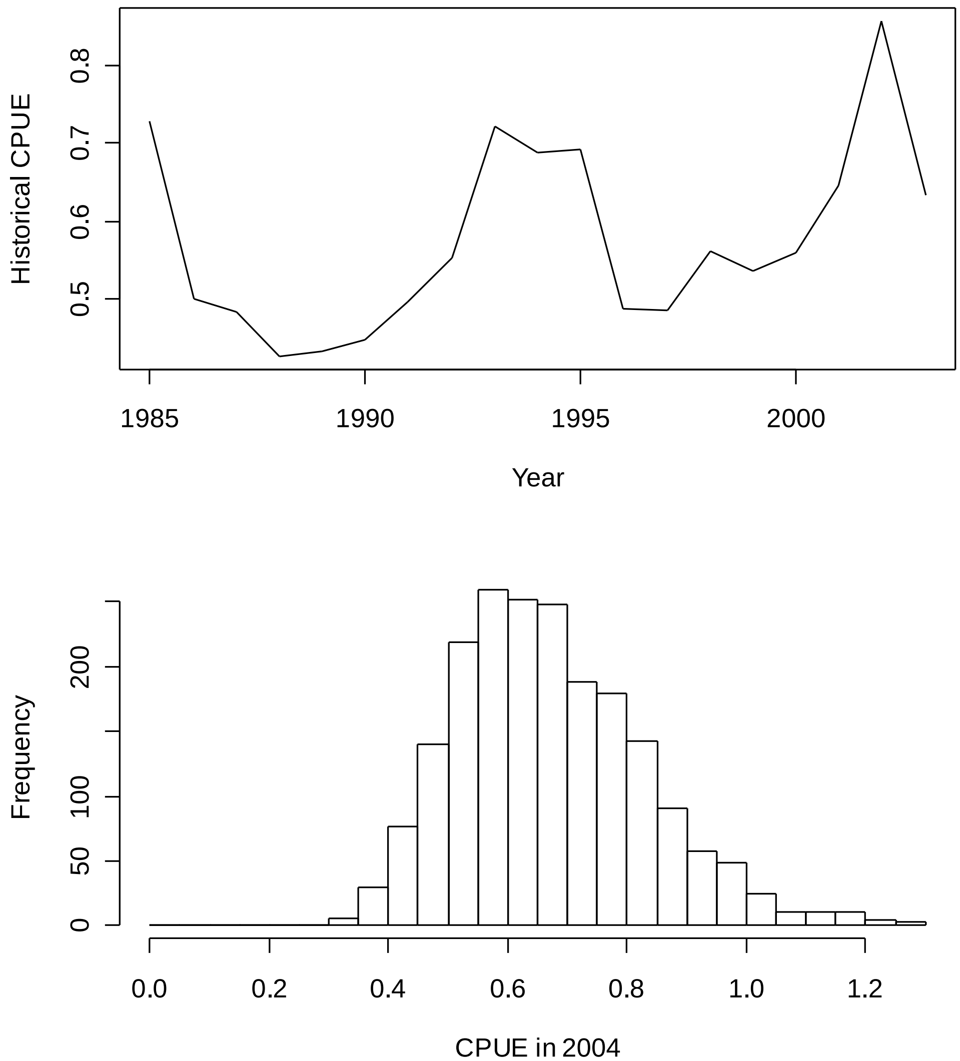


Figure 2 Historical CPUE (top) and projected CPUE in 2004 (bottom) under the new reference set.

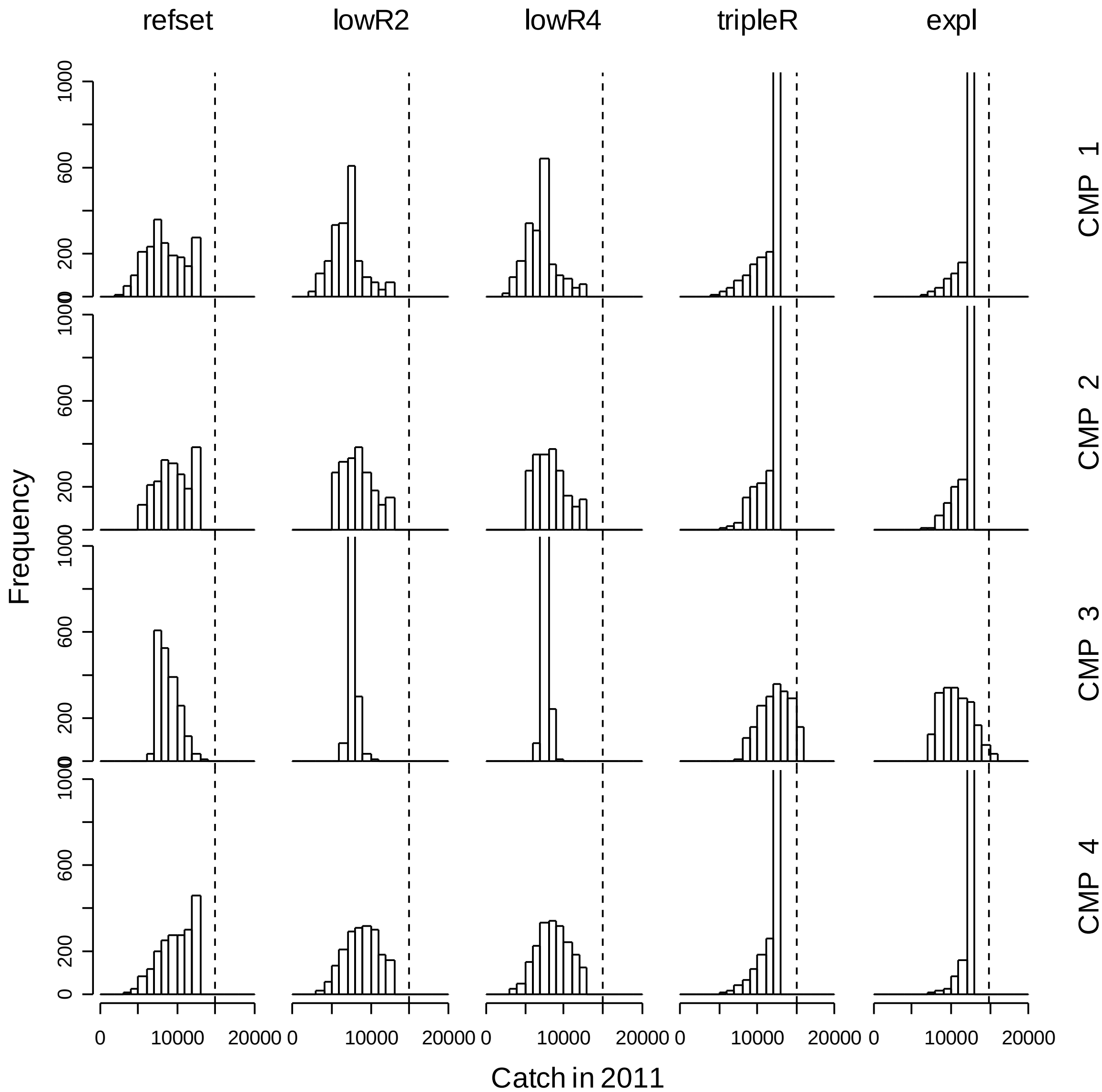


Figure 3 Distributions of catch in 2011 under catch schedule “2b” with 2500 t TAC reduction in 2006 for the four CMPs and the five scenarios.

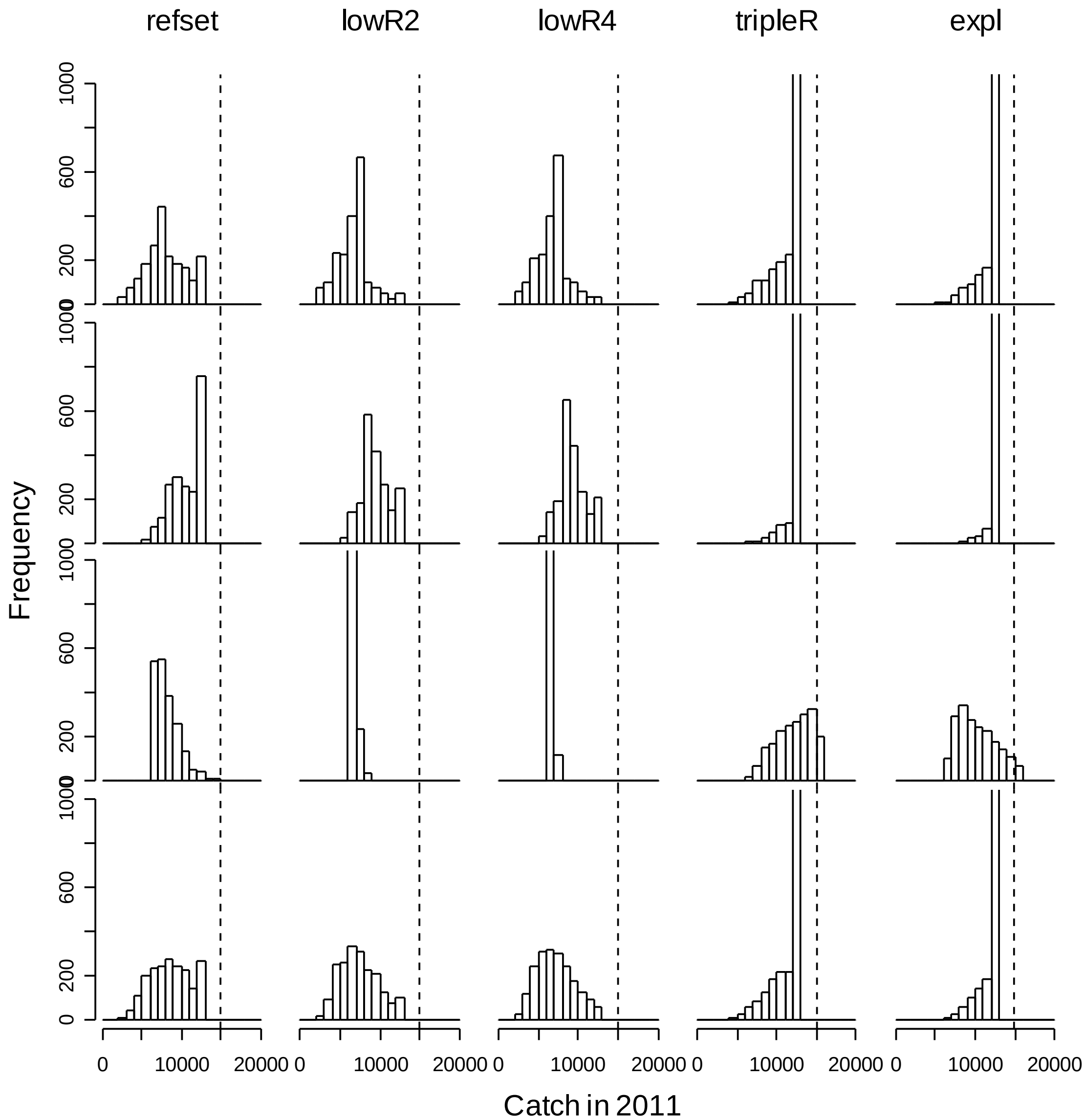


Figure 4 Distributions of catch in 2011 under catch schedule “2e” with 2500 t TAC reduction in 2007 for the four CMPs and five scenarios.

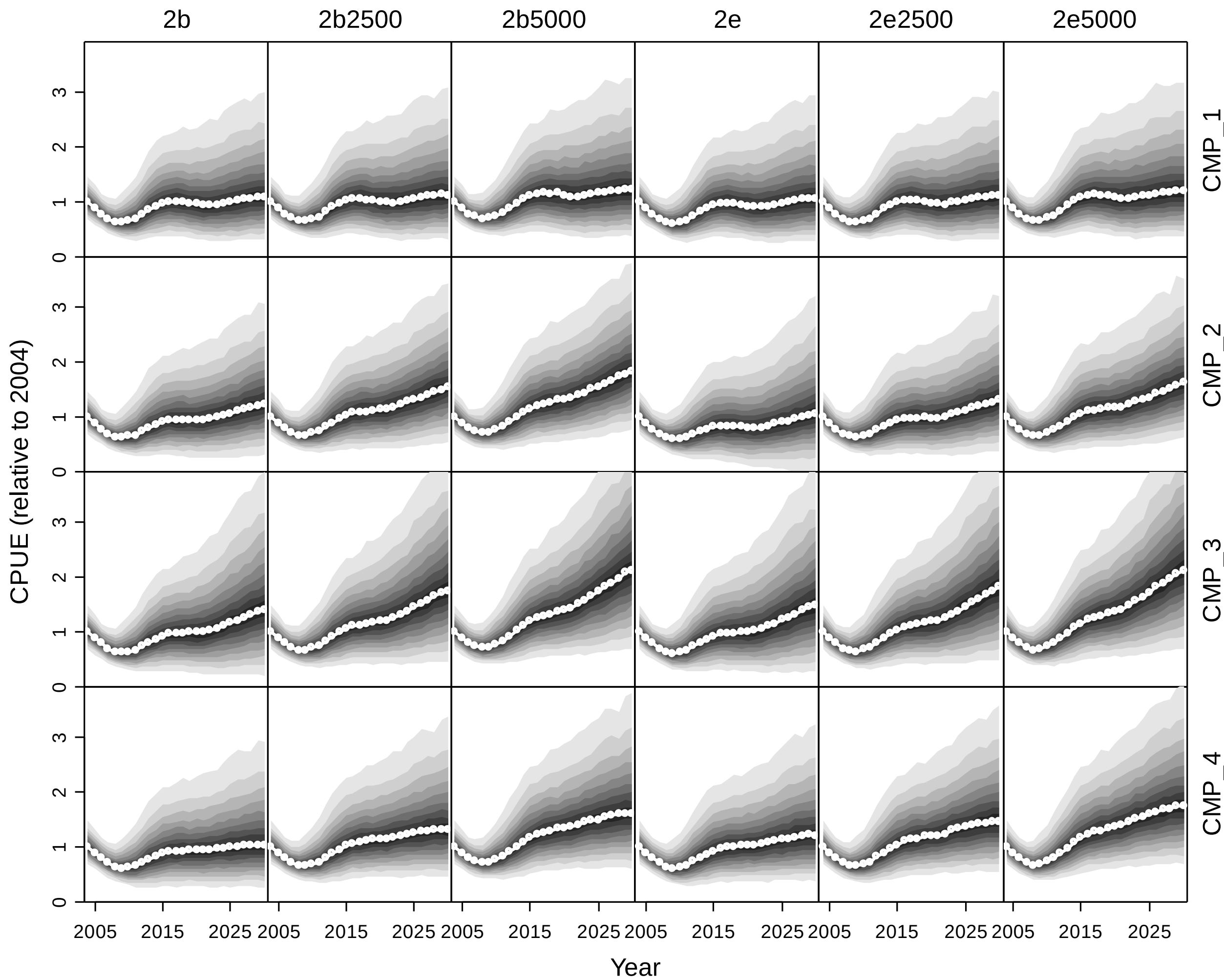


Figure 5 Projected CPUE under the six catch schedules and four candidate management procedures for the new reference set and 1.1 tuning parameters.

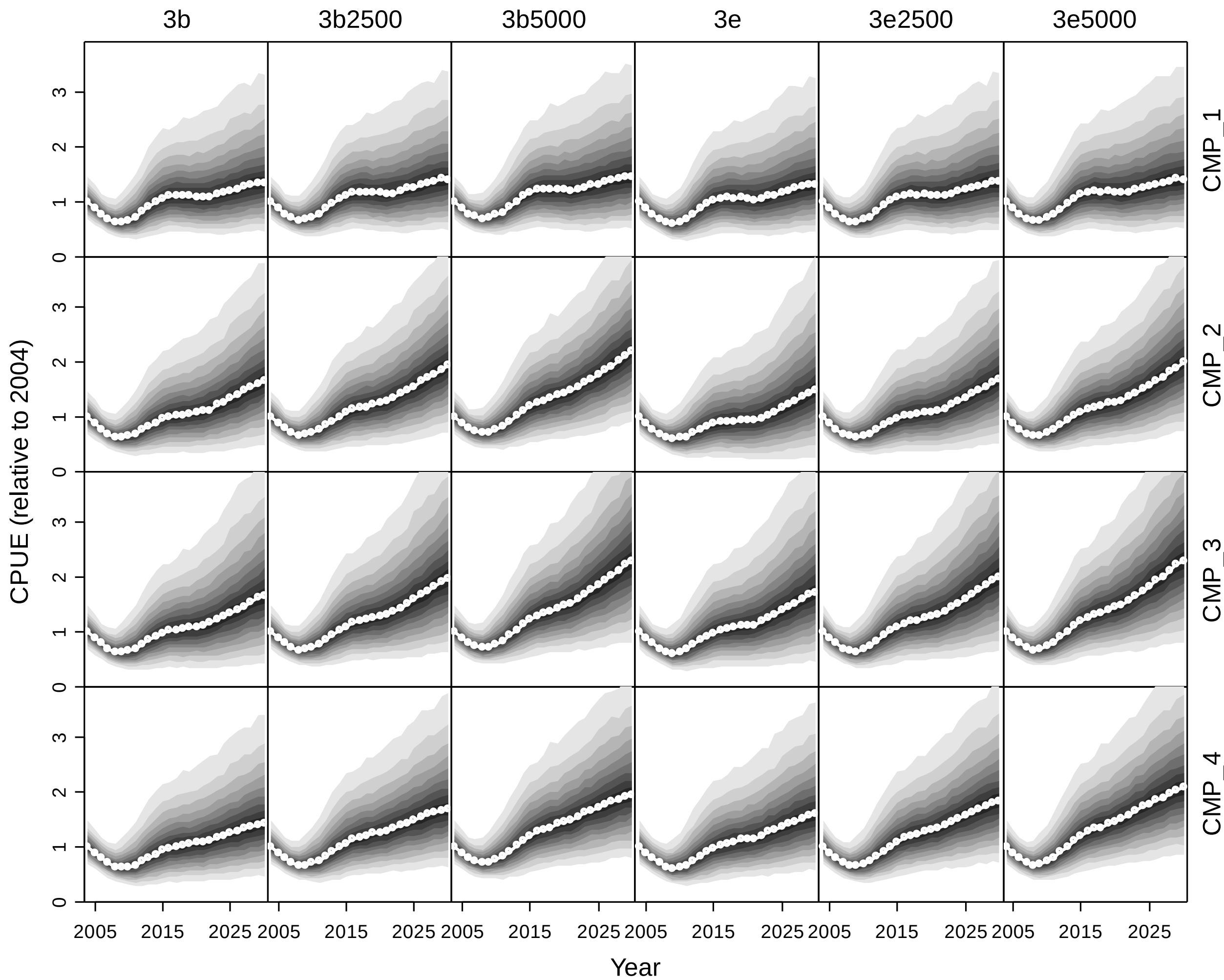


Figure 6 CPUE trajectories, as for Figure 5 but using the 1.3 tuning parameters.

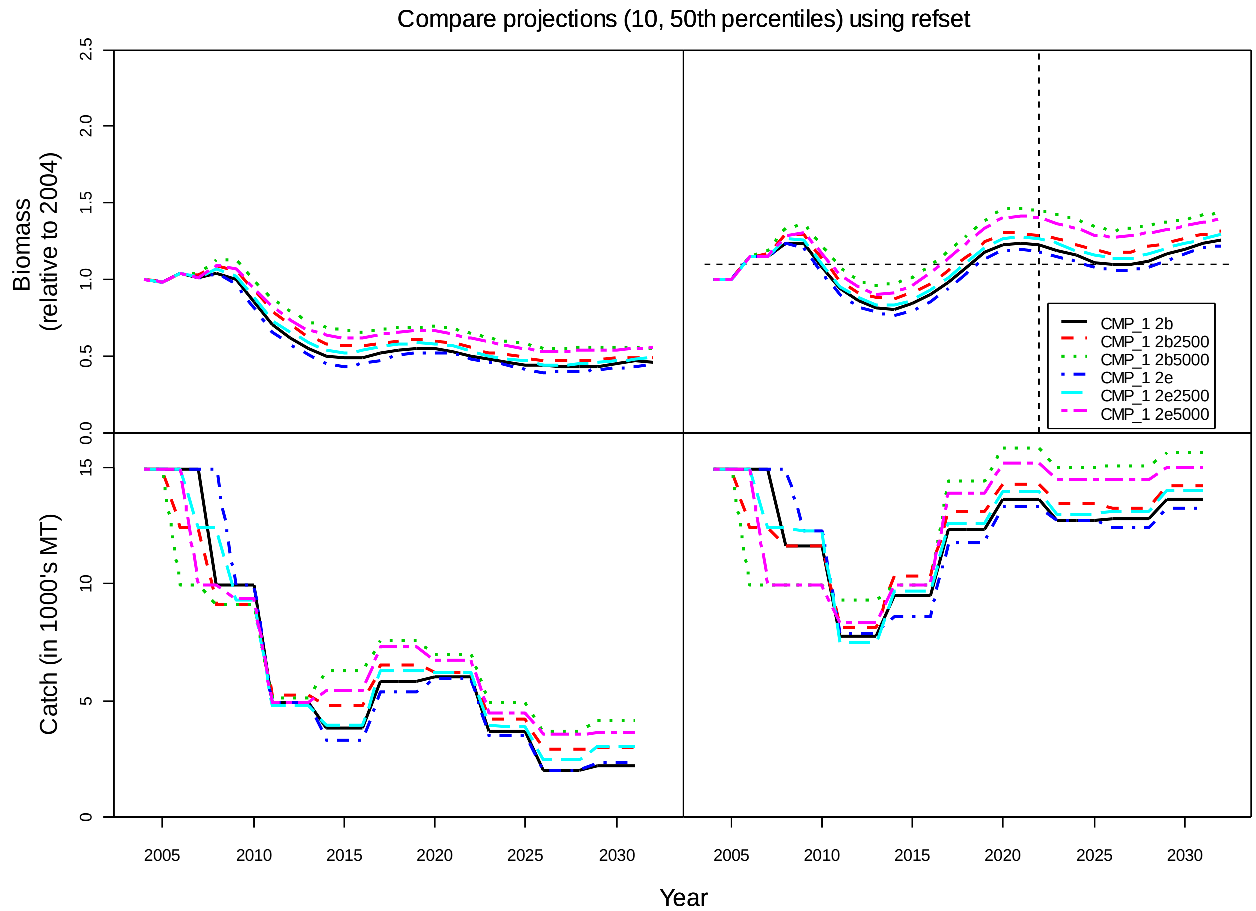


Figure 7 10th and 50th percentiles of biomass and catch for CMP_1 under the five different catch schedules for the reference set and 1.1 tuning level.

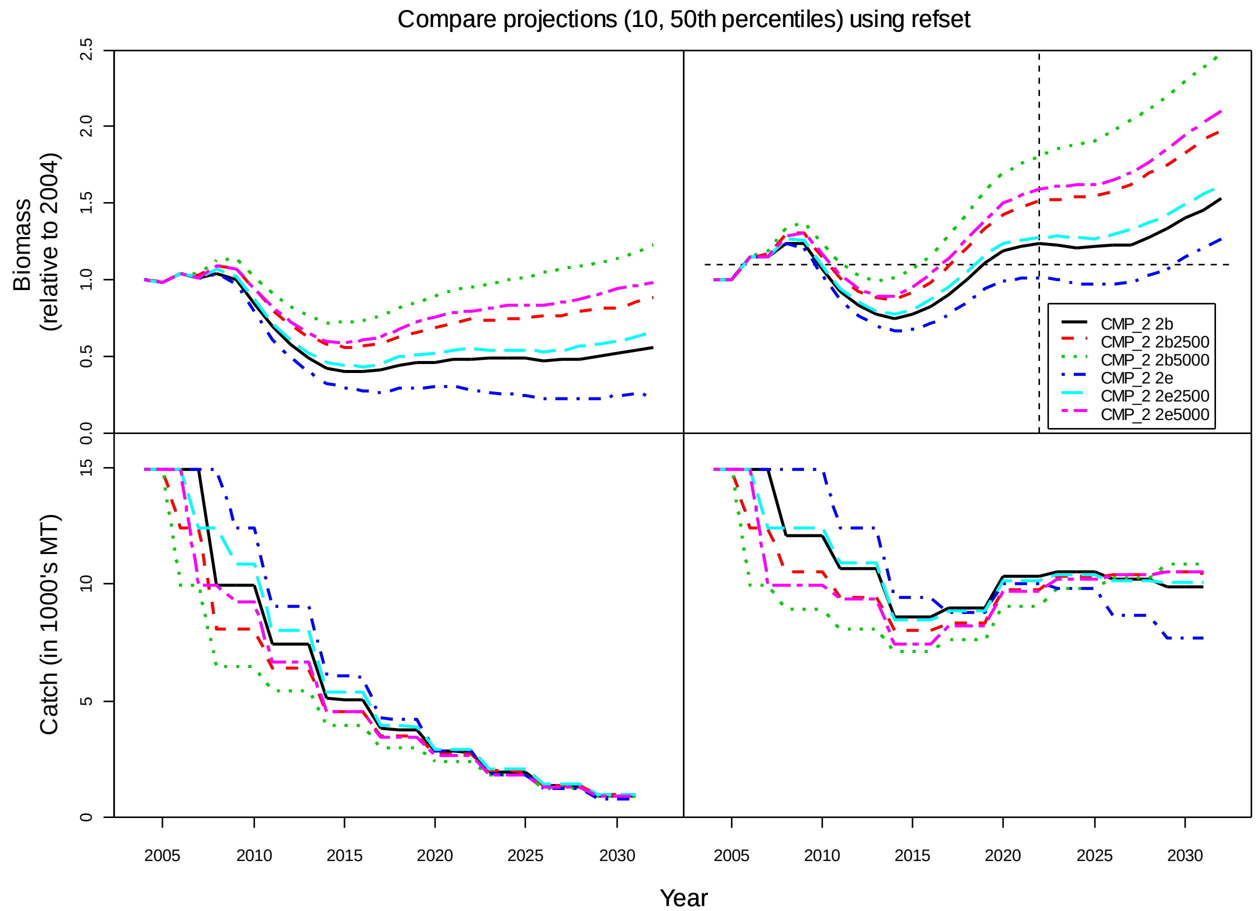
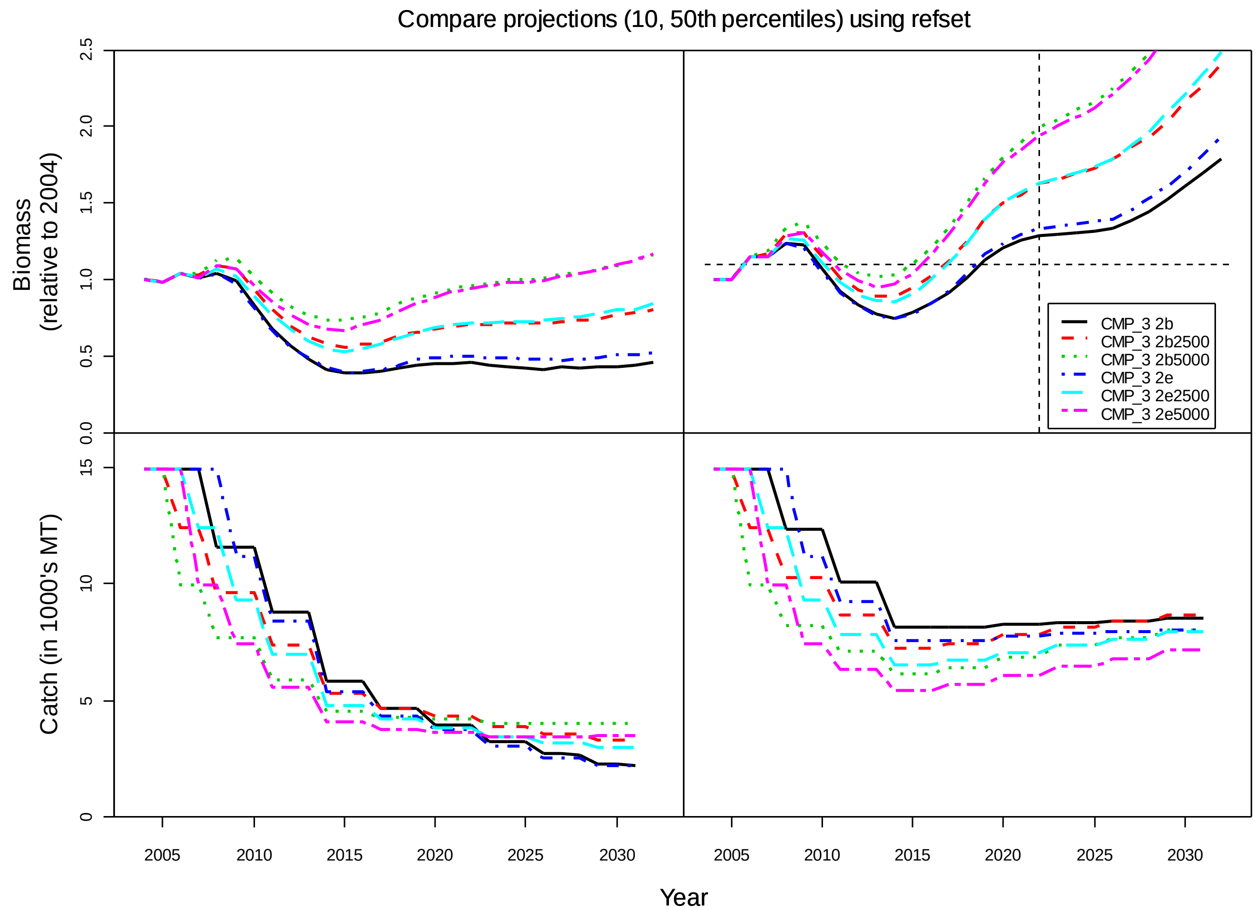


Figure 8 As for Figure 7 but for CMP_2.



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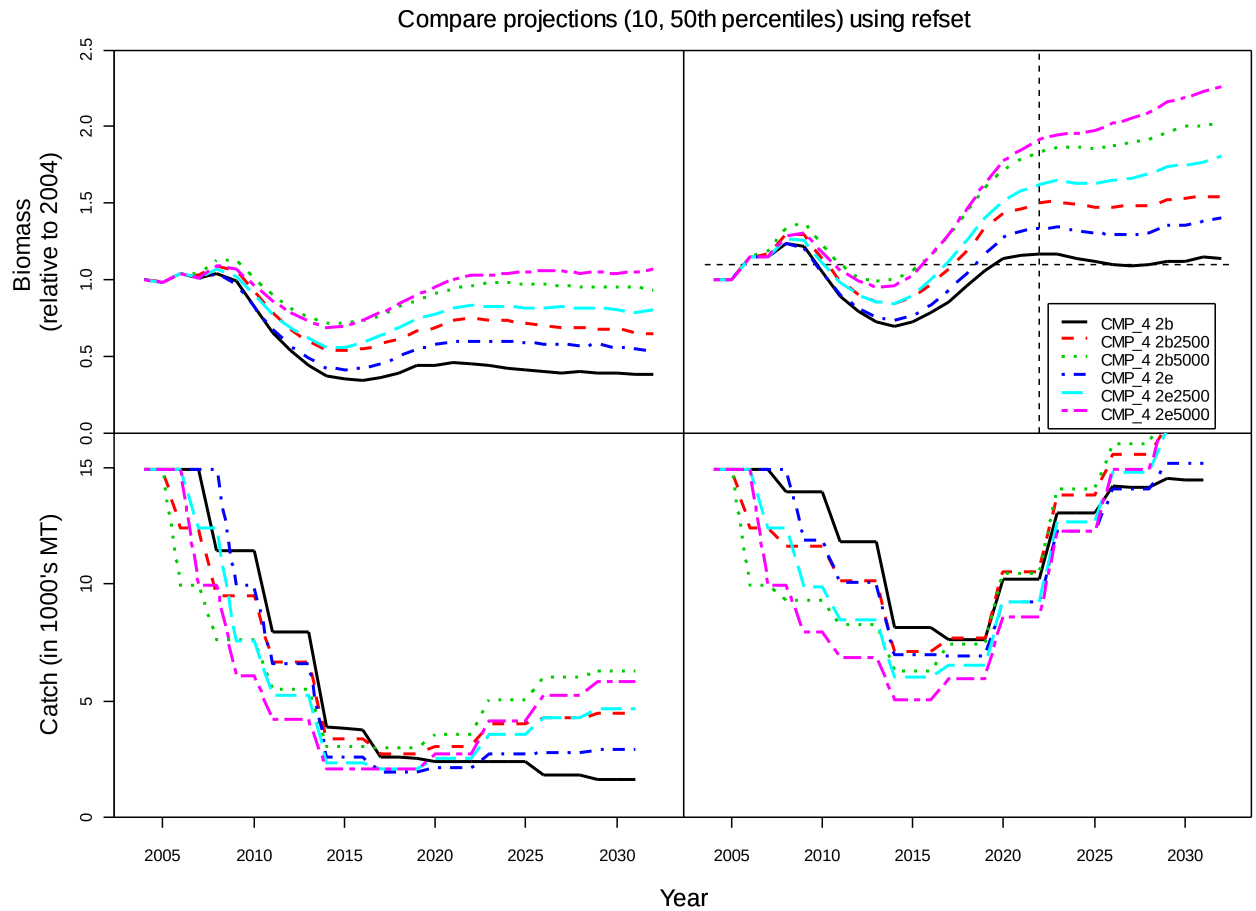

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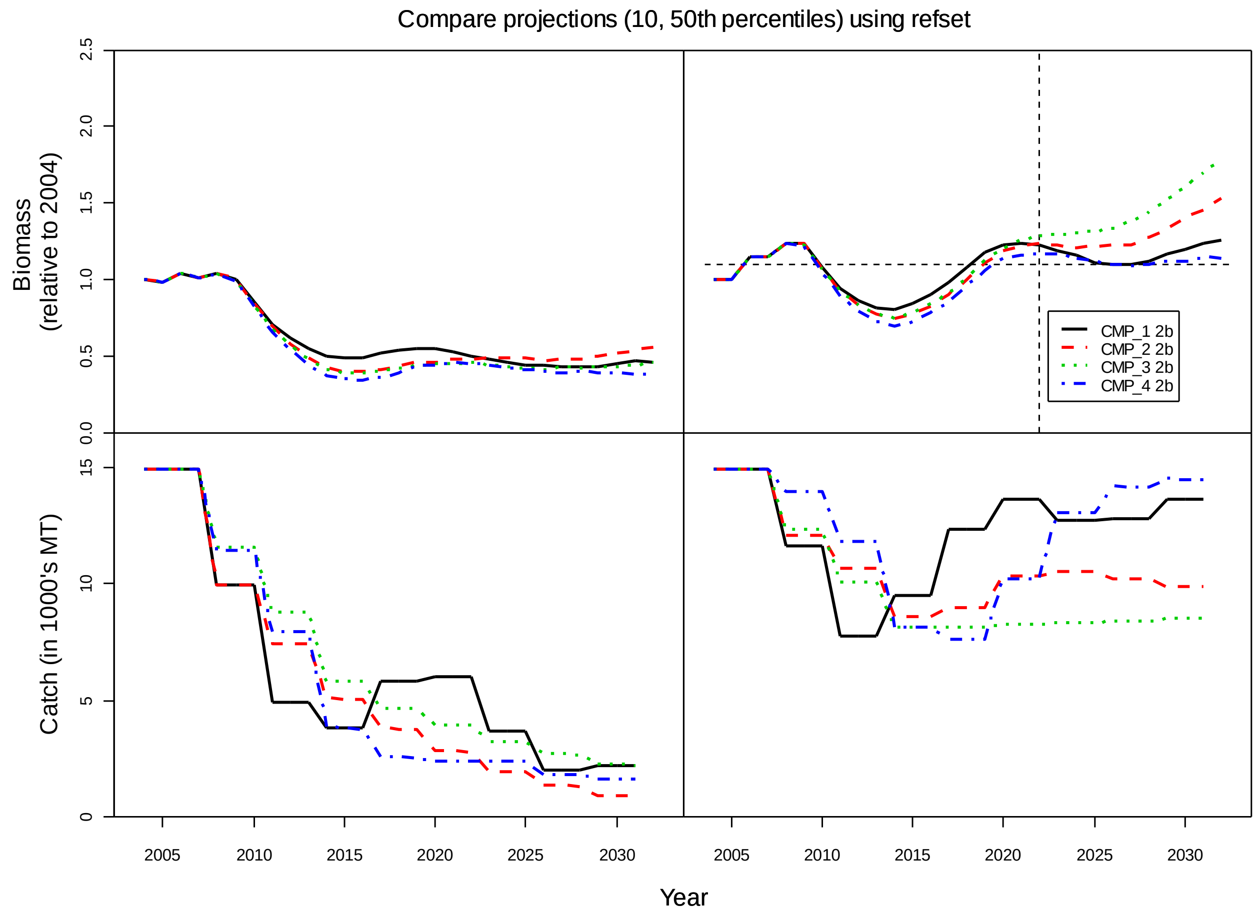

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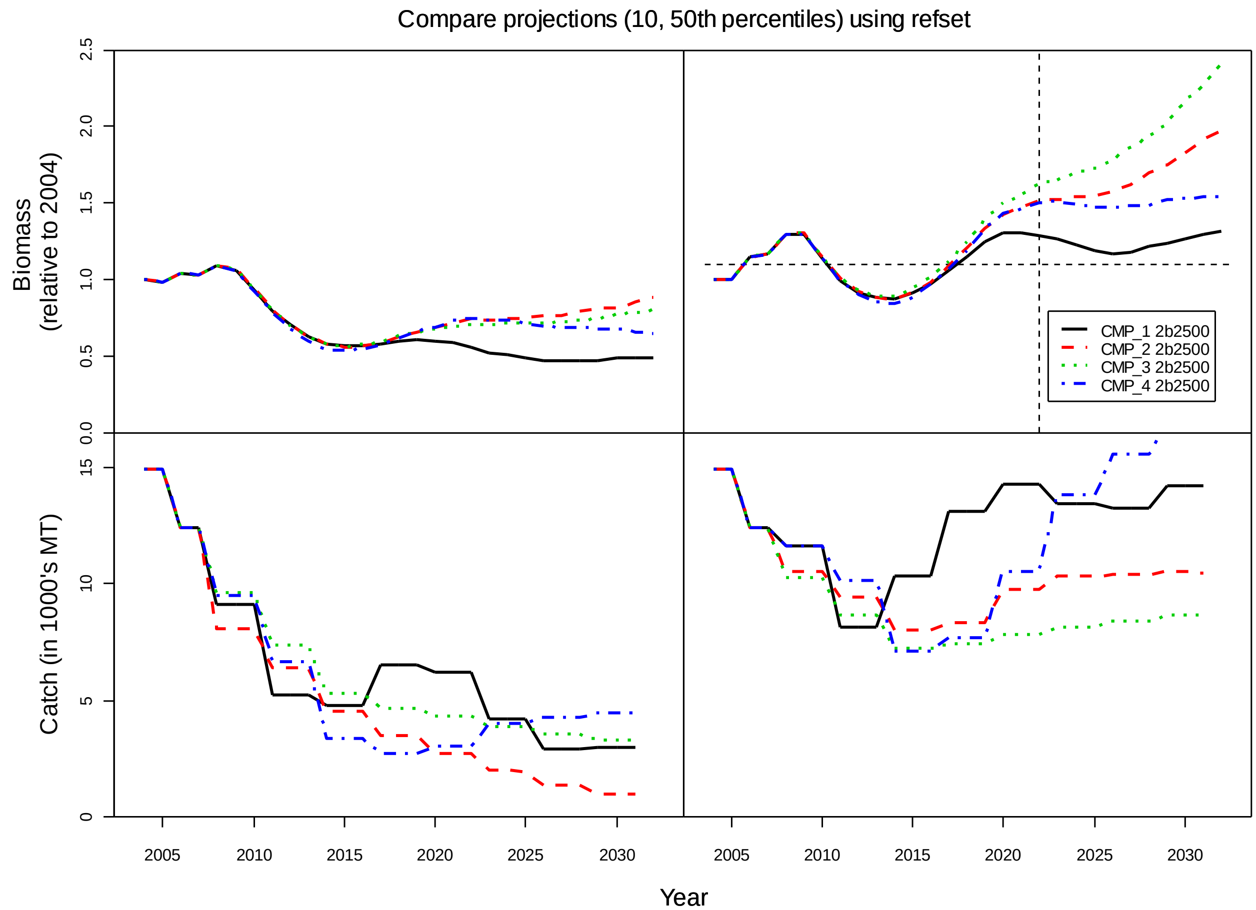


Figure 12 As for Figure 11 but with a 2500 t catch reduction in 2006.

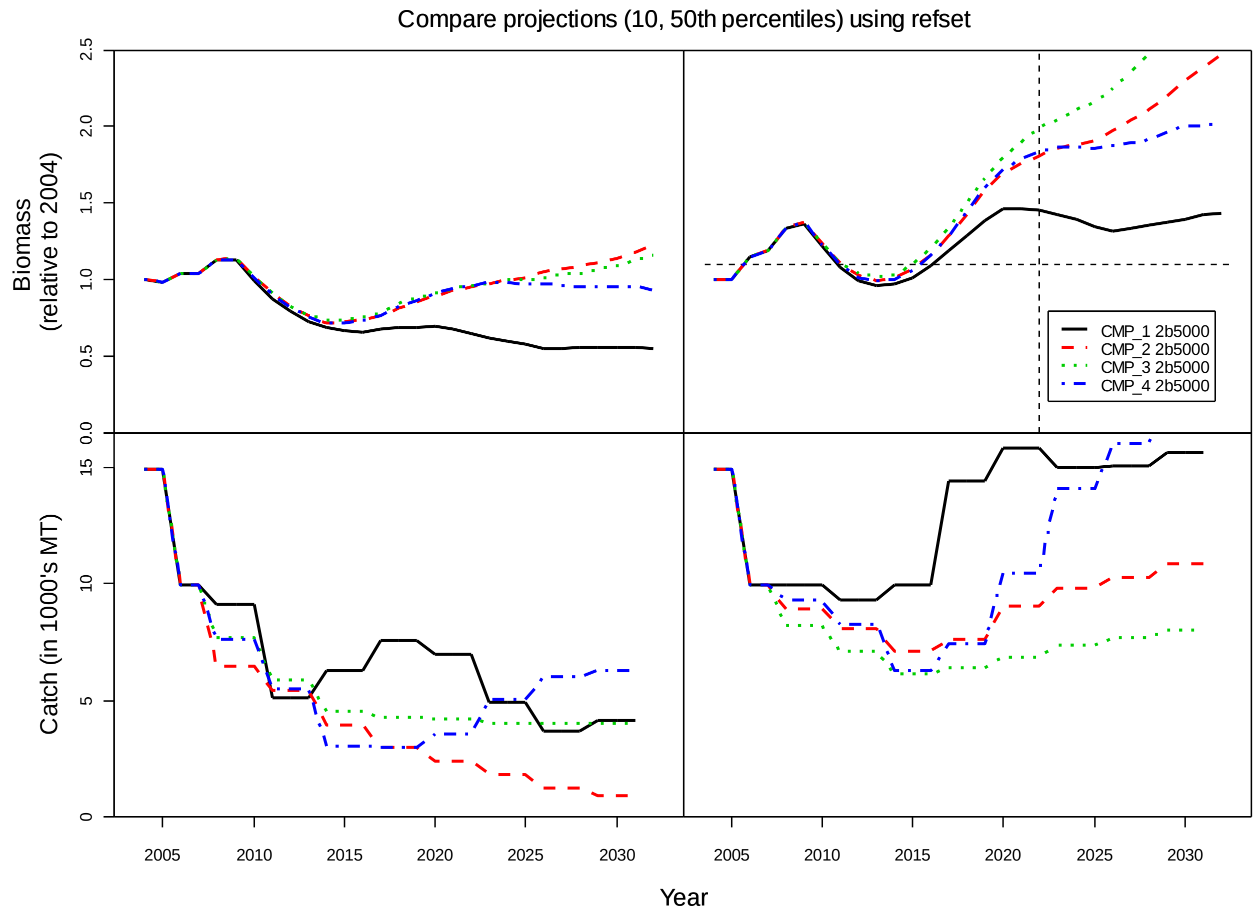
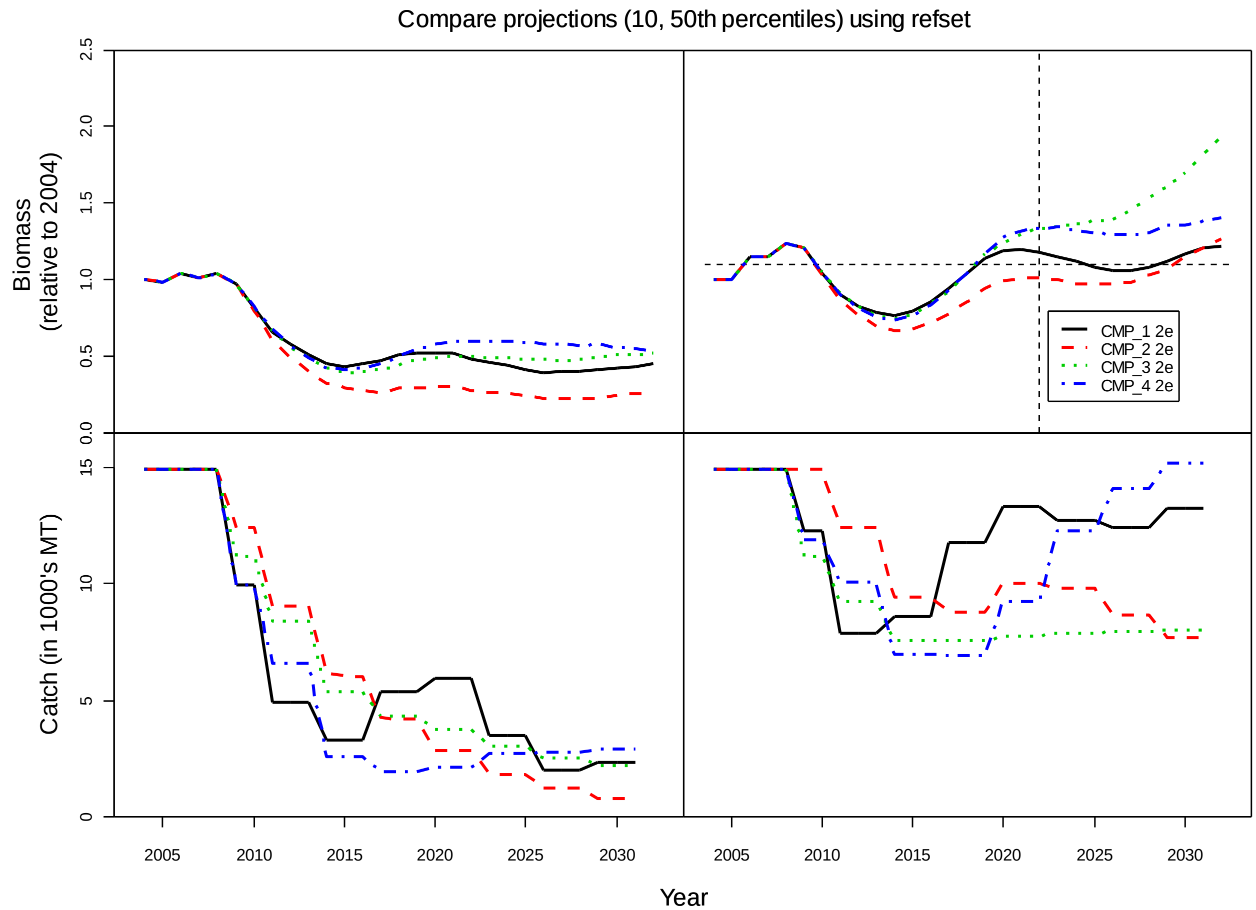


Figure 13 As for Figure 11 but with a 5000 t catch reduction in 2006.



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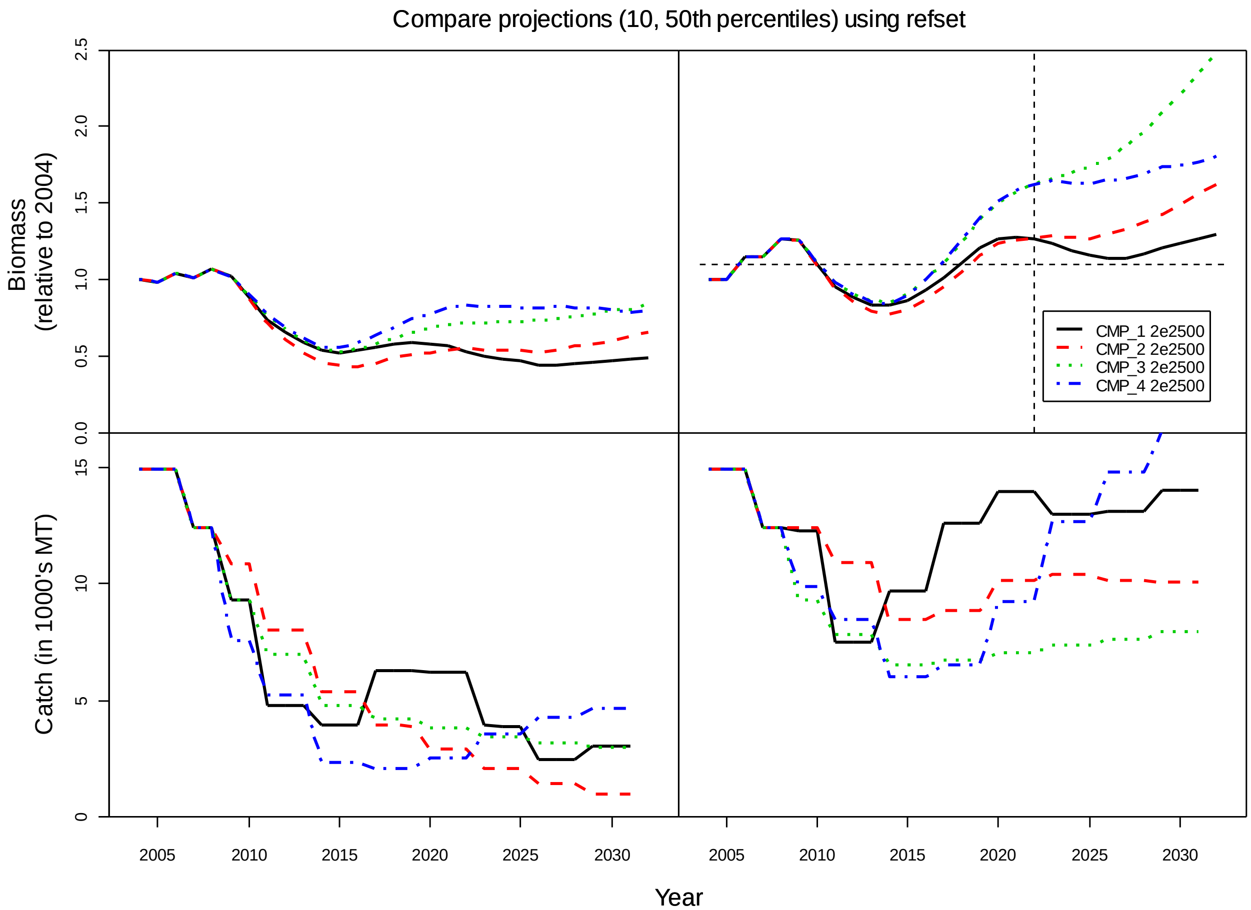

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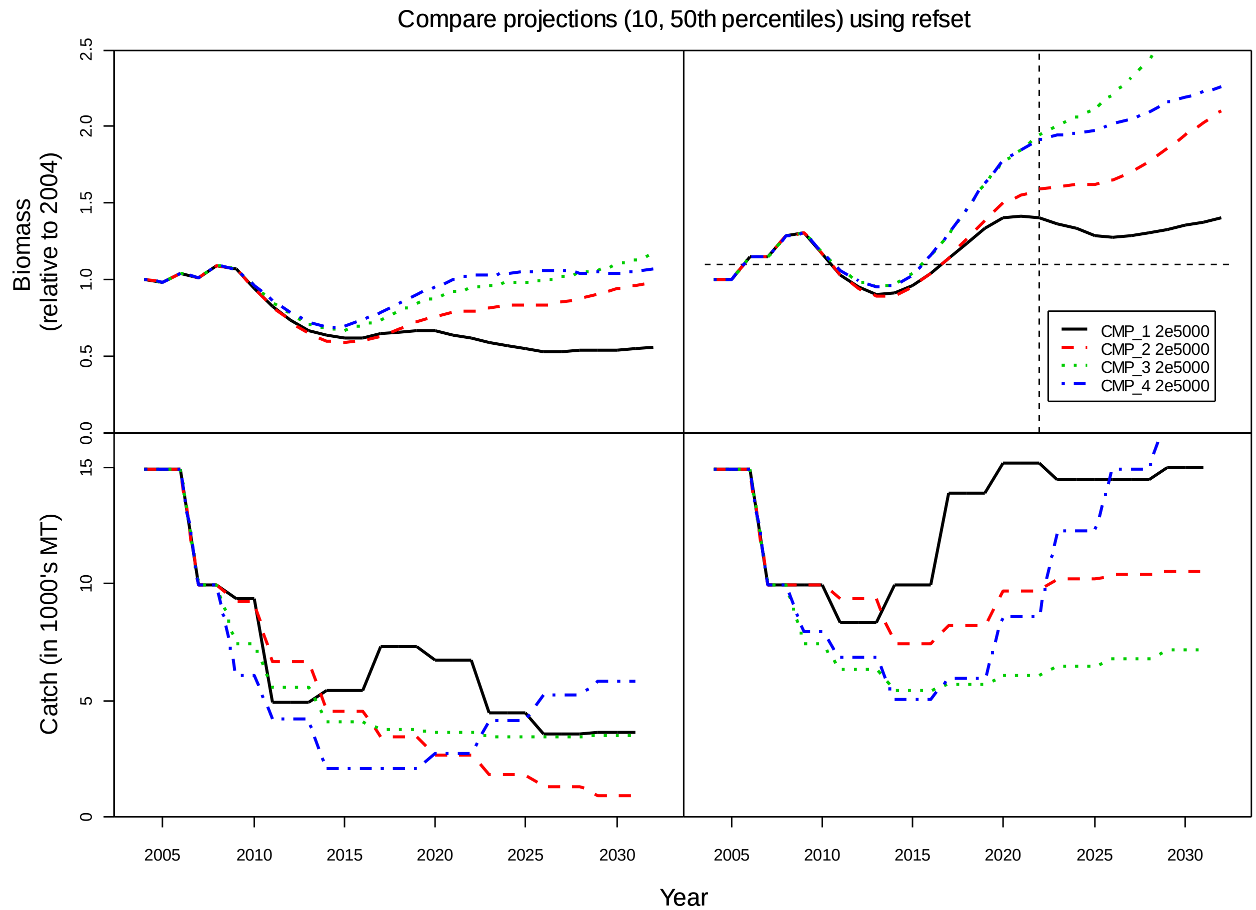


Figure 16 As for Figure 11 but using catch schedule “e” with a 5000 t catch reduction in 2007.

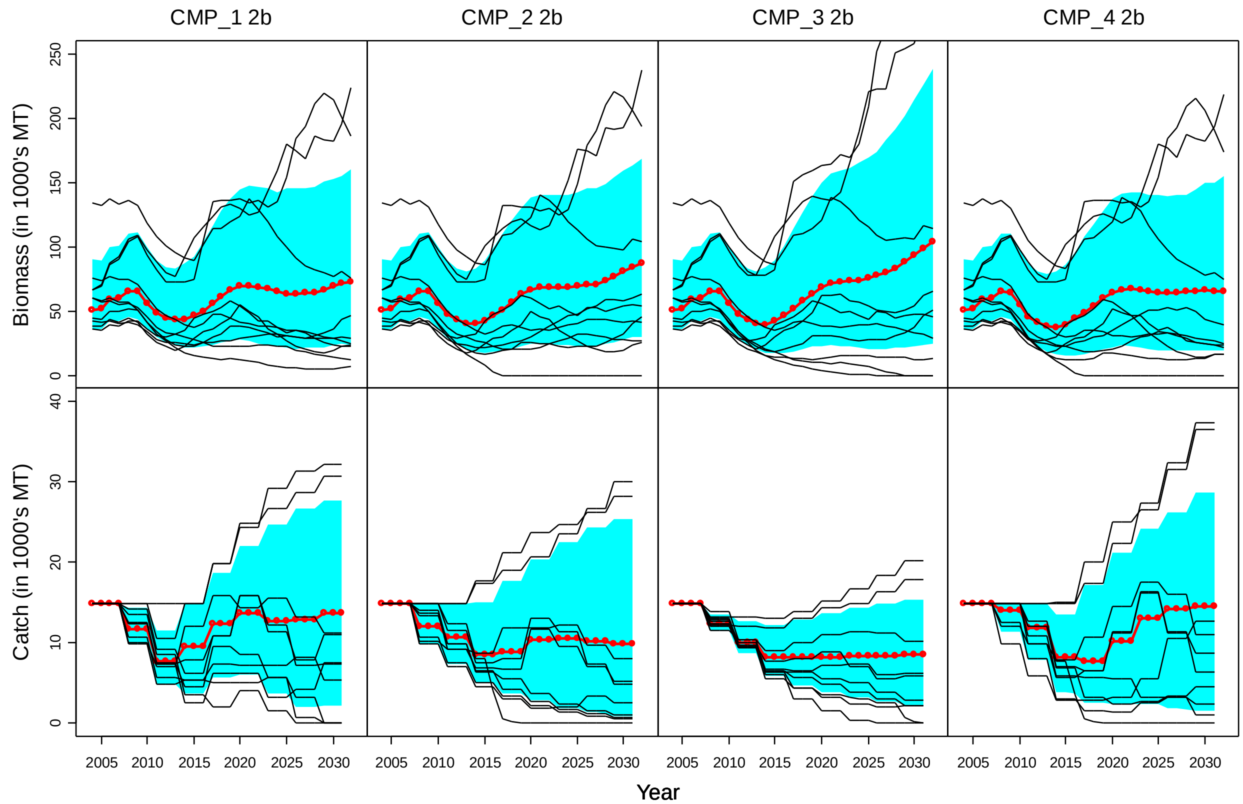
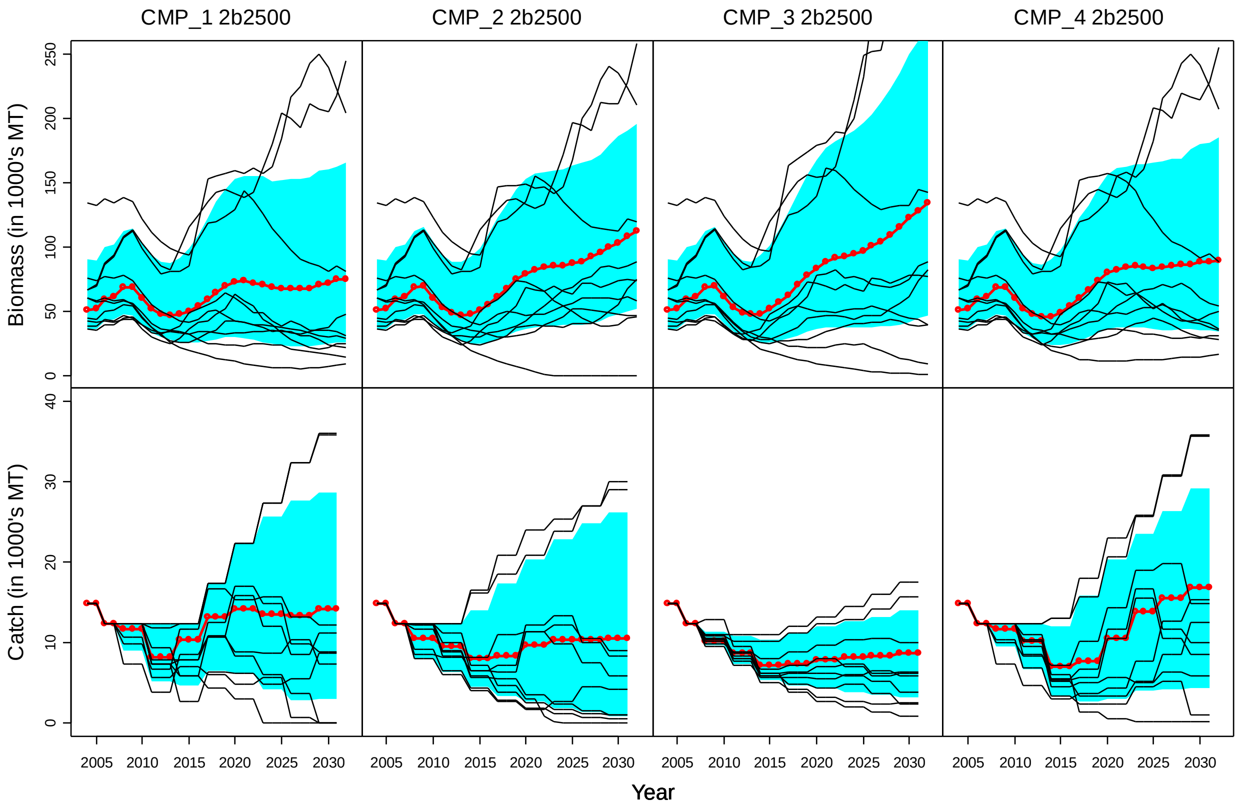


Figure 17 Trajectories of biomass and catch for each of the candidate management procedures under catch schedule "b" and the 1.1 tuning parameters. For each plot, the median is indicated by a red dotted line, the 90th percentiles are shaded, and ten individual biomass and catch realization are plotted. Note: for comparison, the individual worms correspond to the same replicates across the four CMPs.



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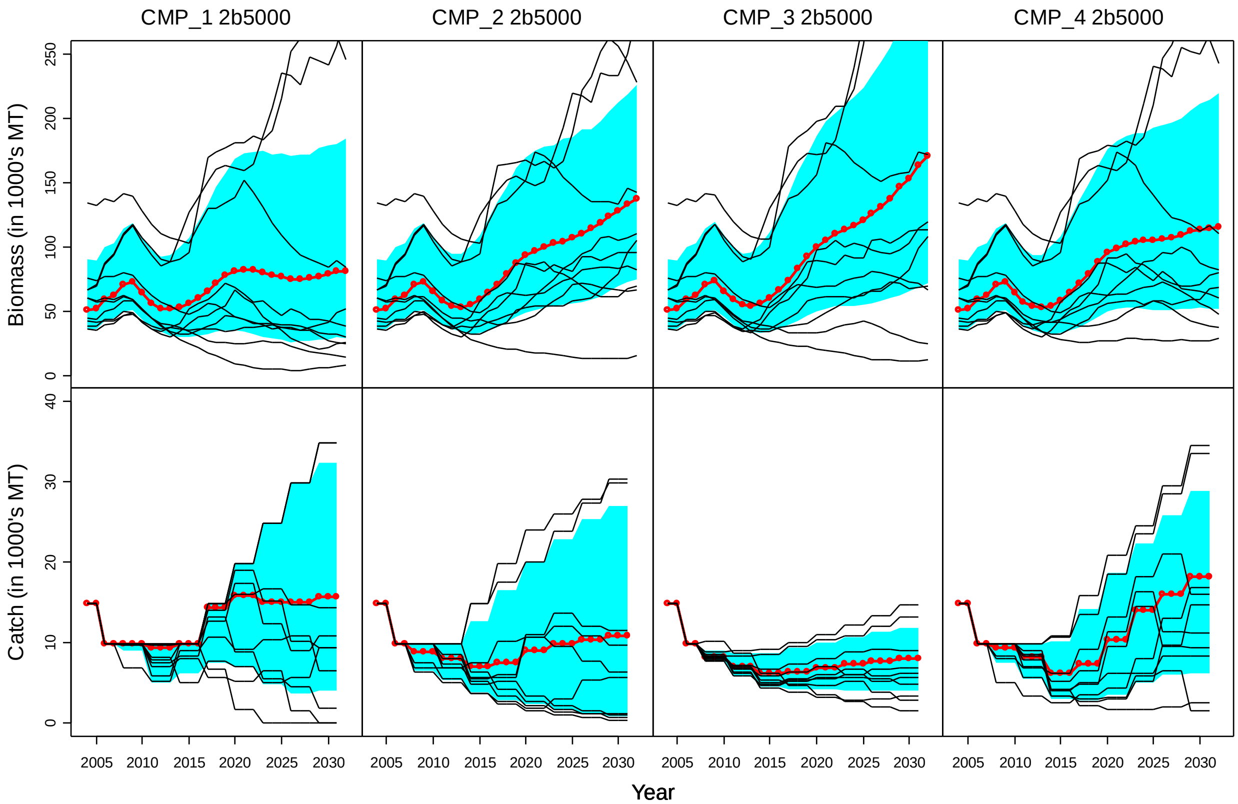

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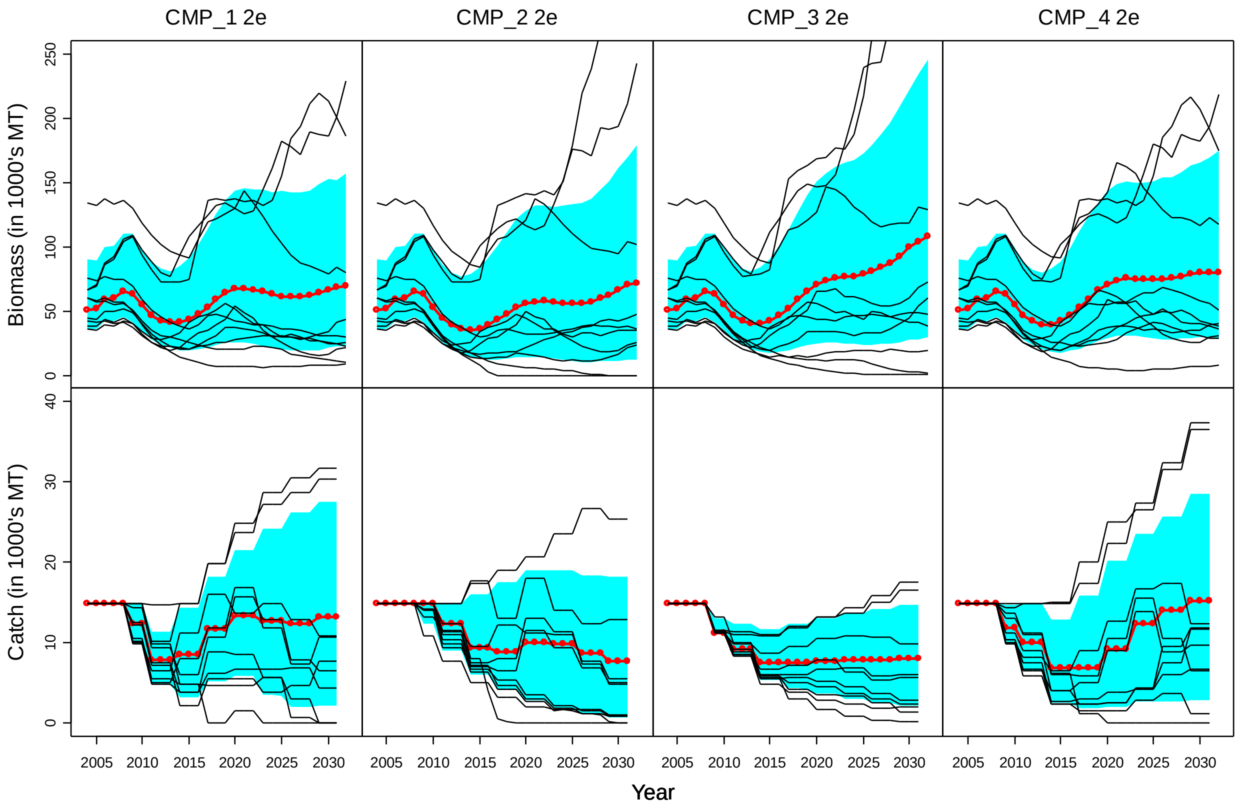

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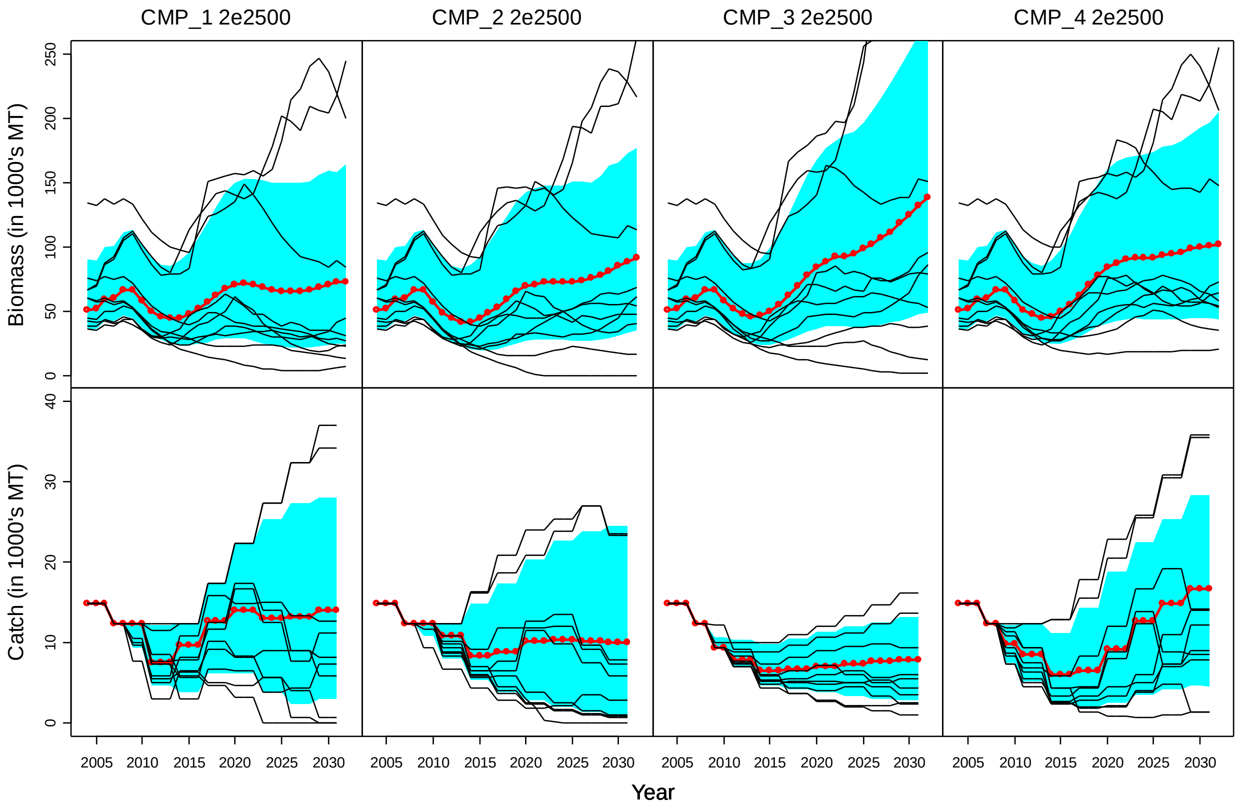

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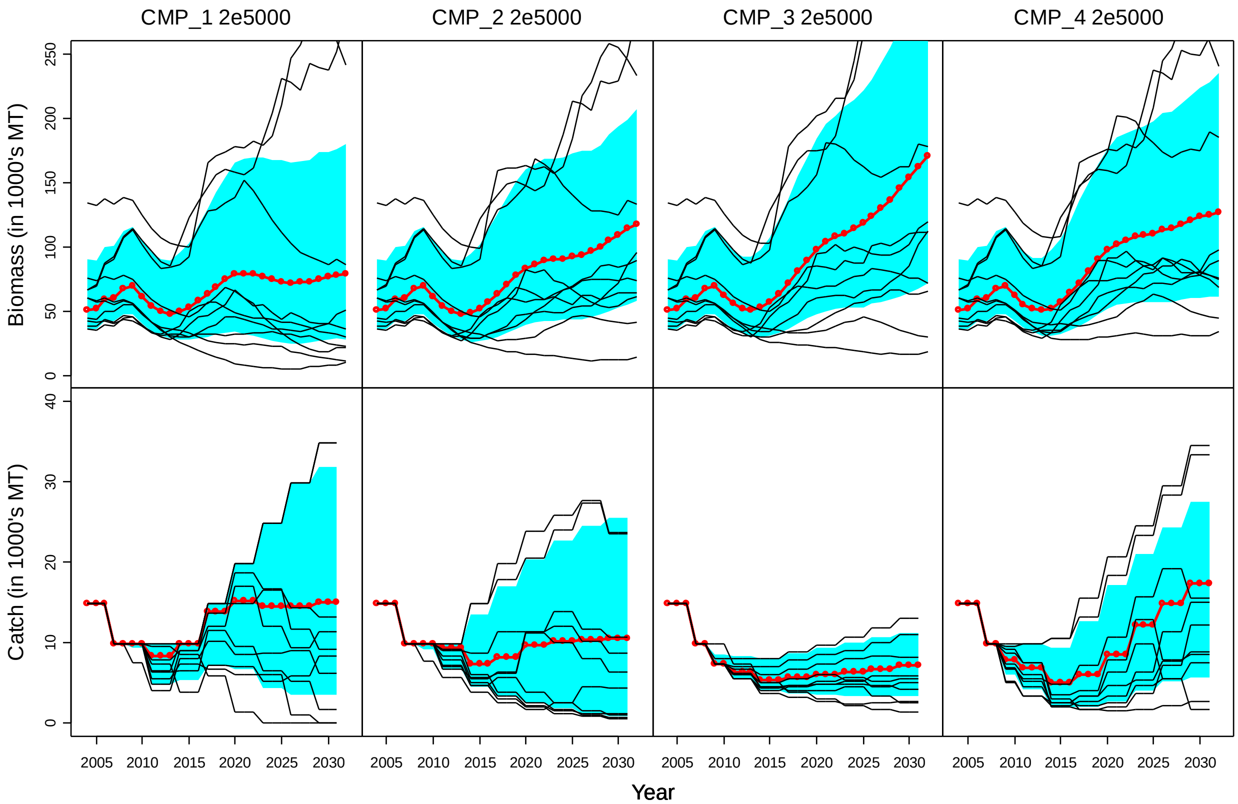

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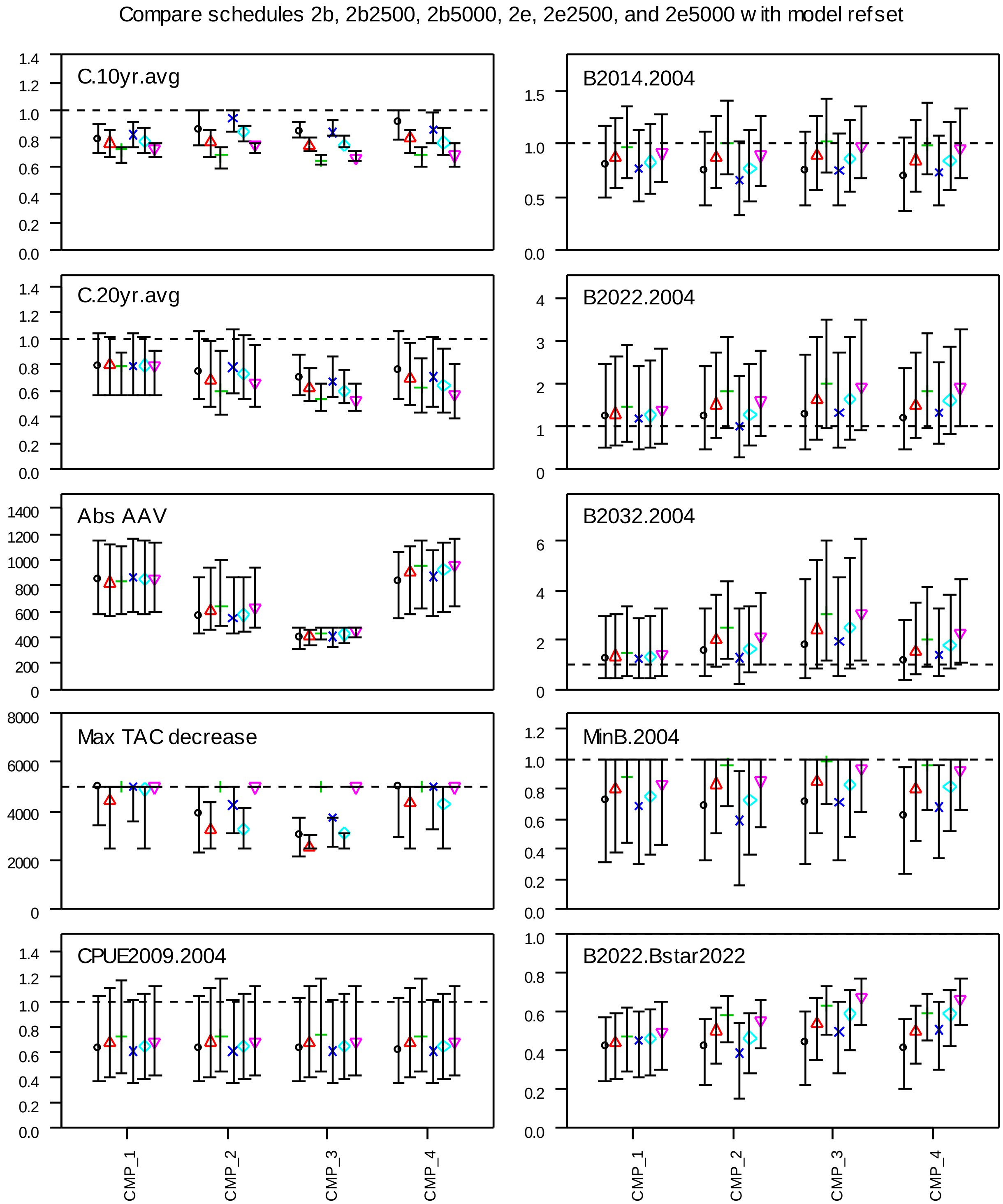

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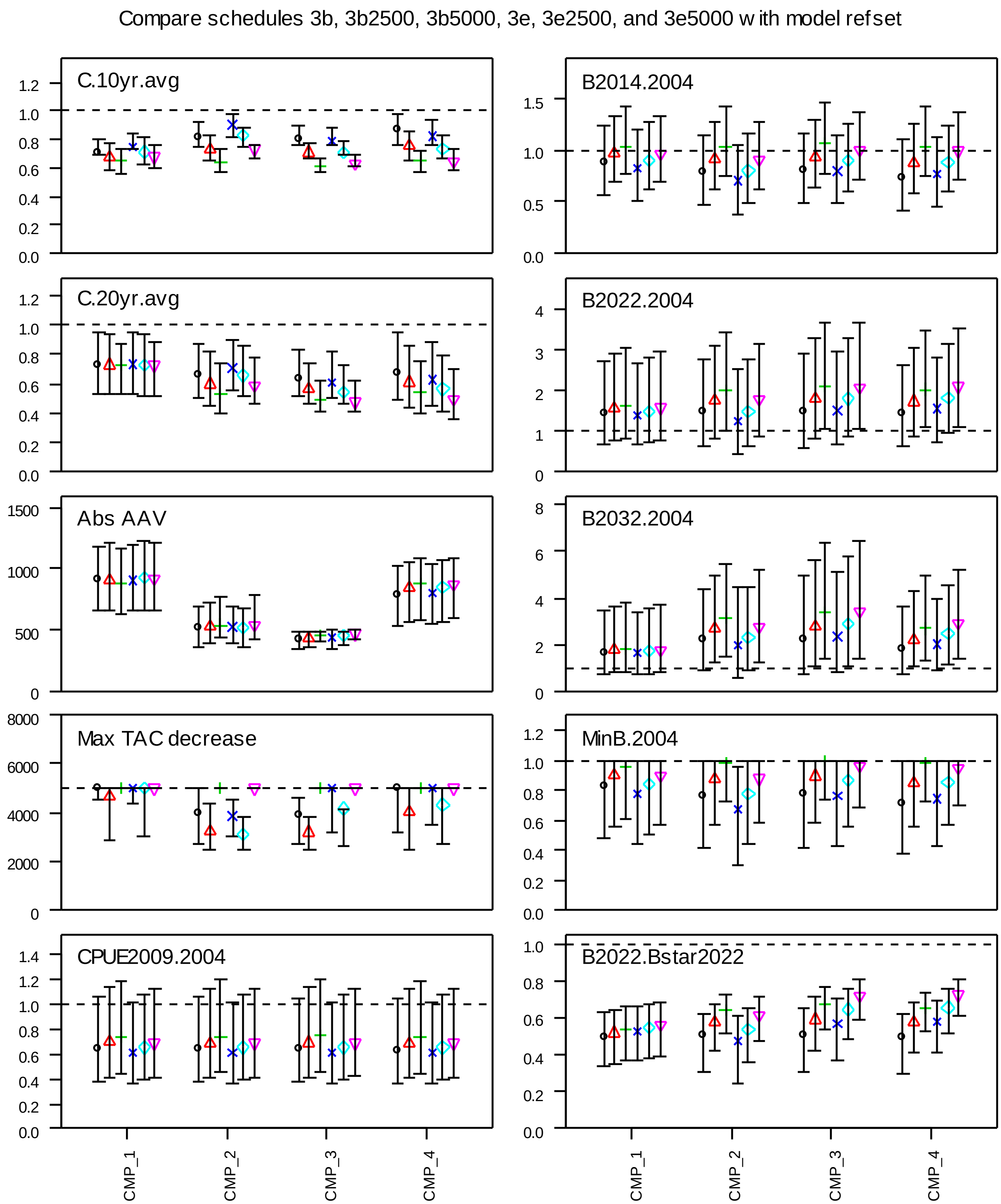


Figure 24 As for Figure 23 but using the 1.3 tuning level parameters.

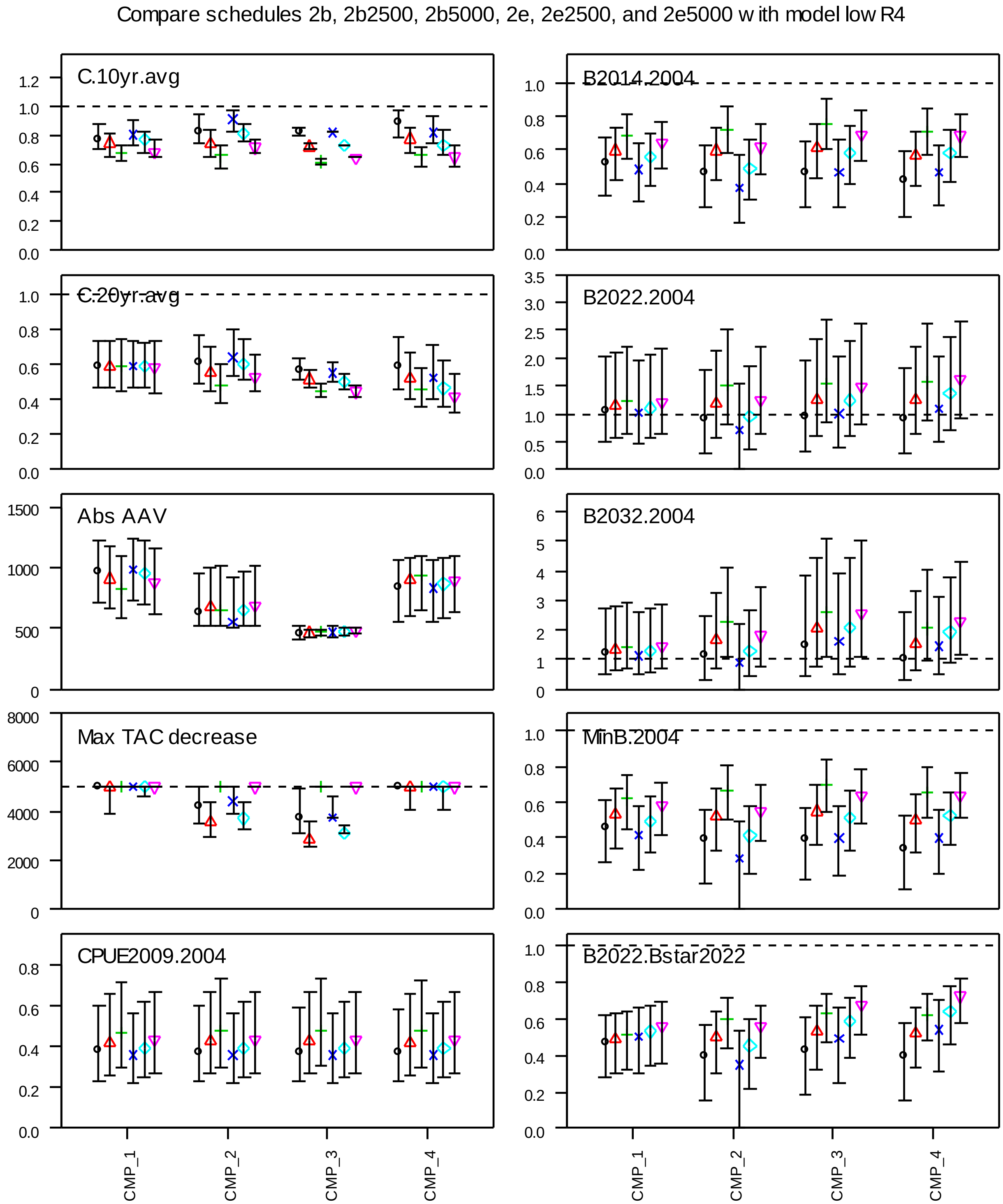


Figure 25 As for Figure 23 but using the lowR4 case instead of the new reference set.

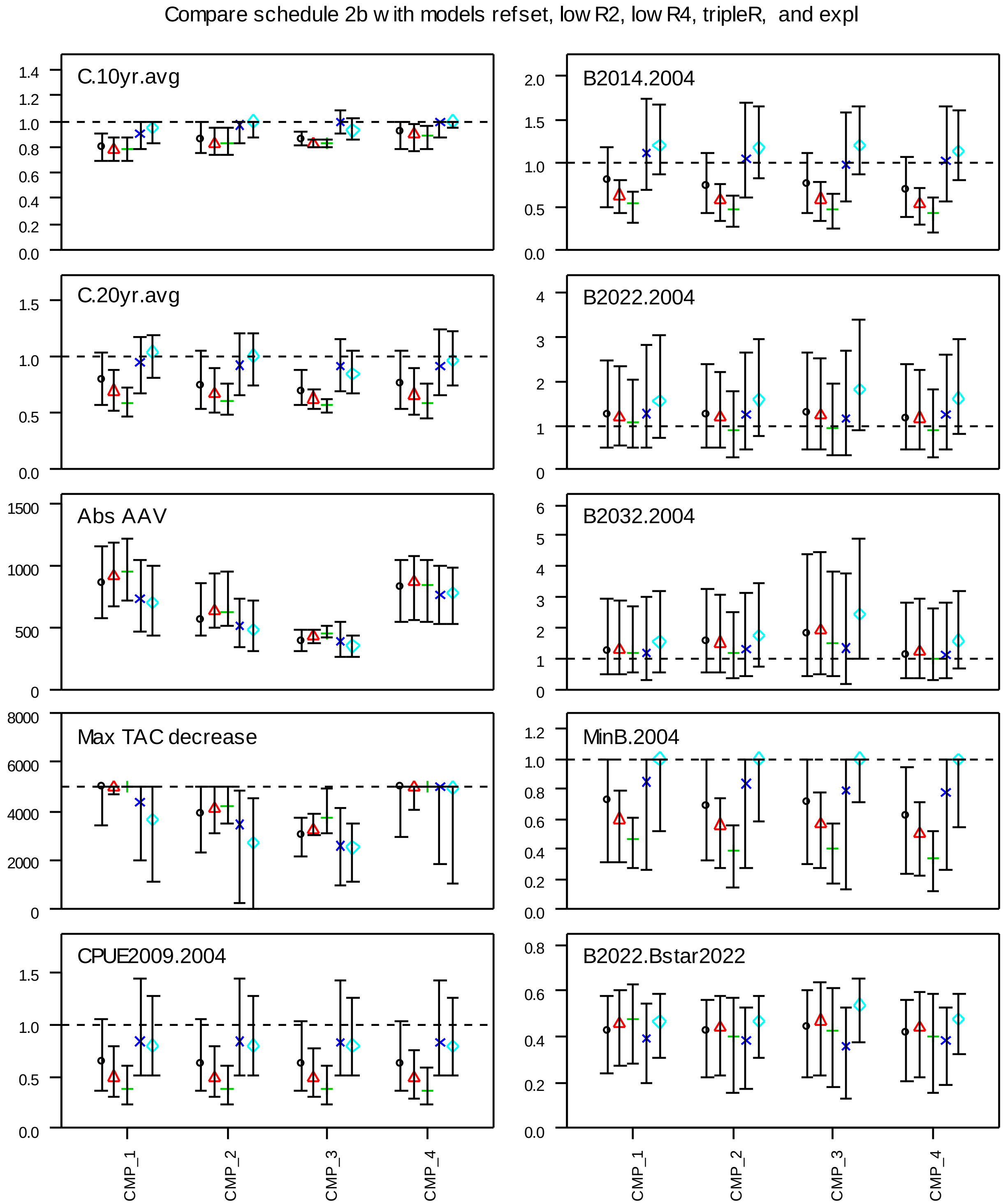
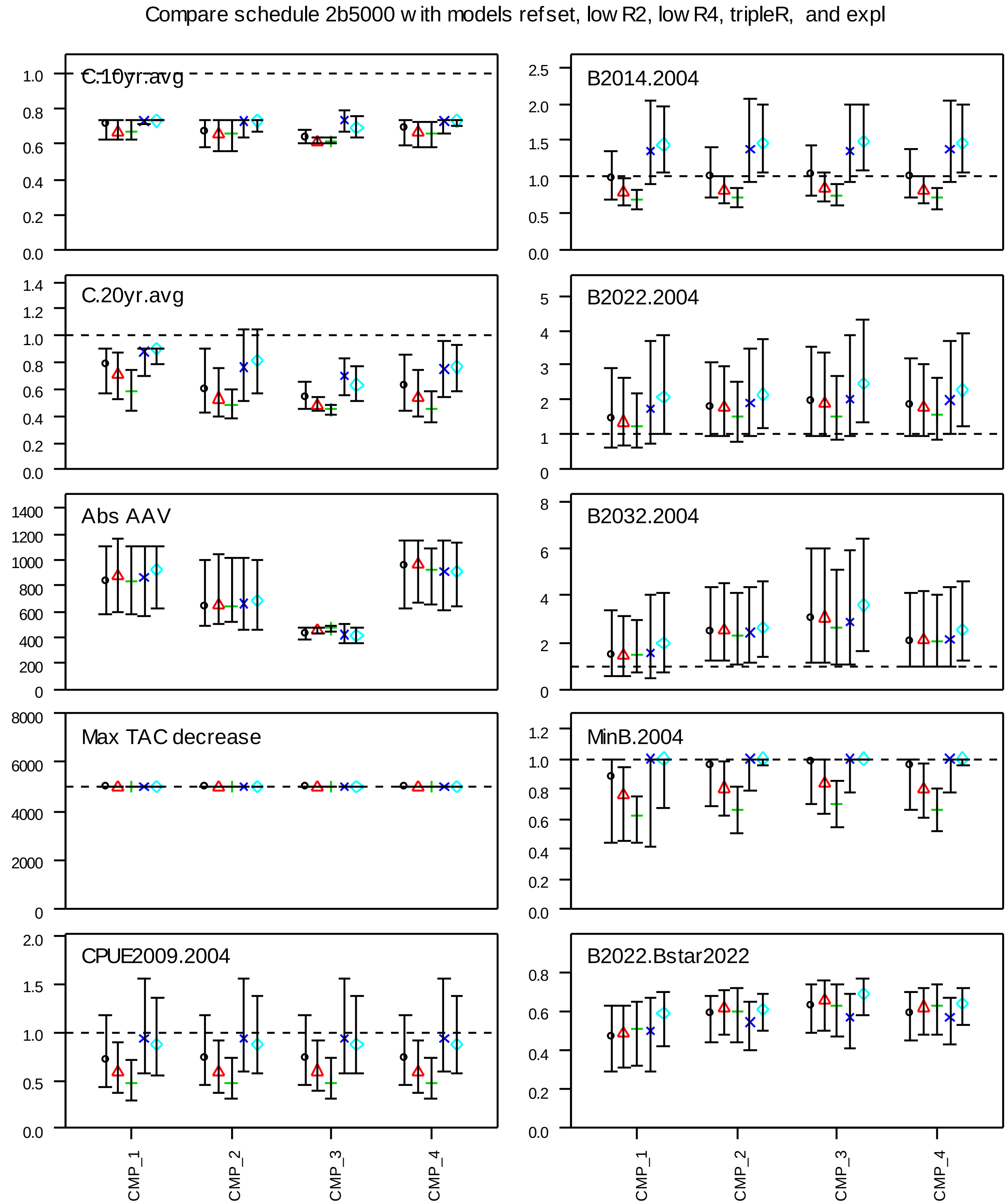


Figure 26 Compare the performance of the CMPs under the reference set and different robustness trials for catch schedule “2b”. For each CMP, the models are (from left to right): the reference set, lowR2, lowR4, tripleR and expl.



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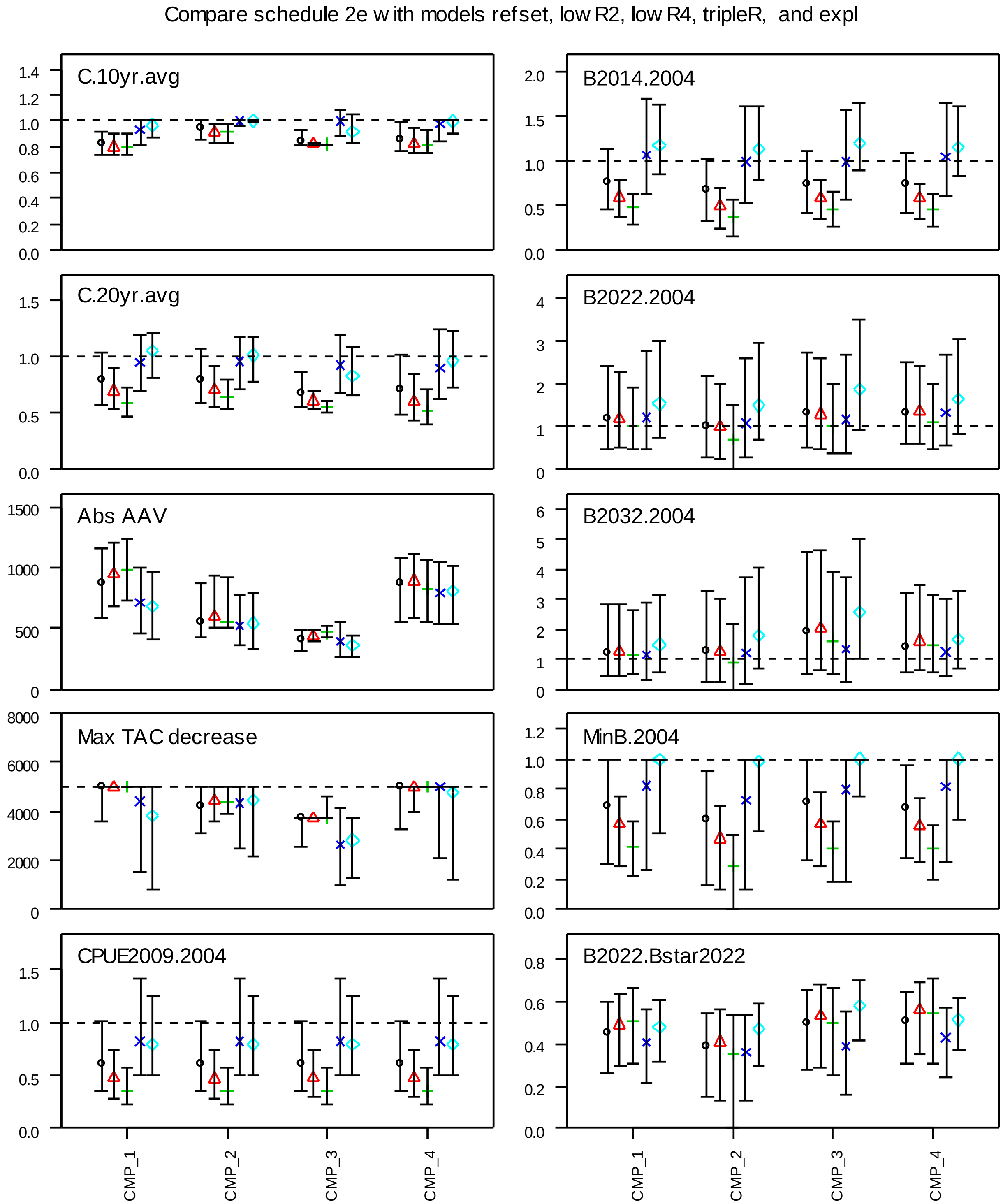

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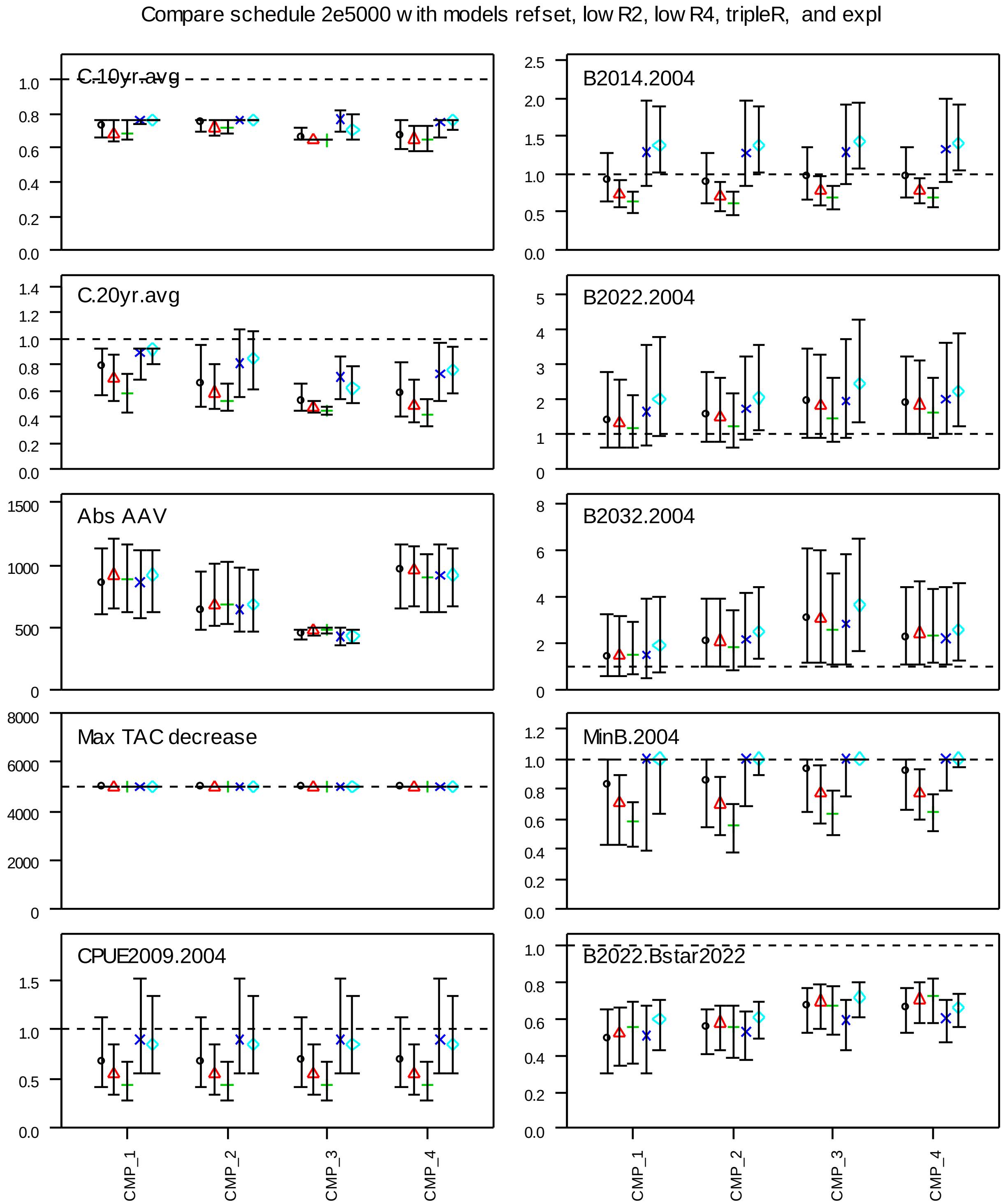


Figure 29 As for Figure 26 but for catch schedule “2e5000”.

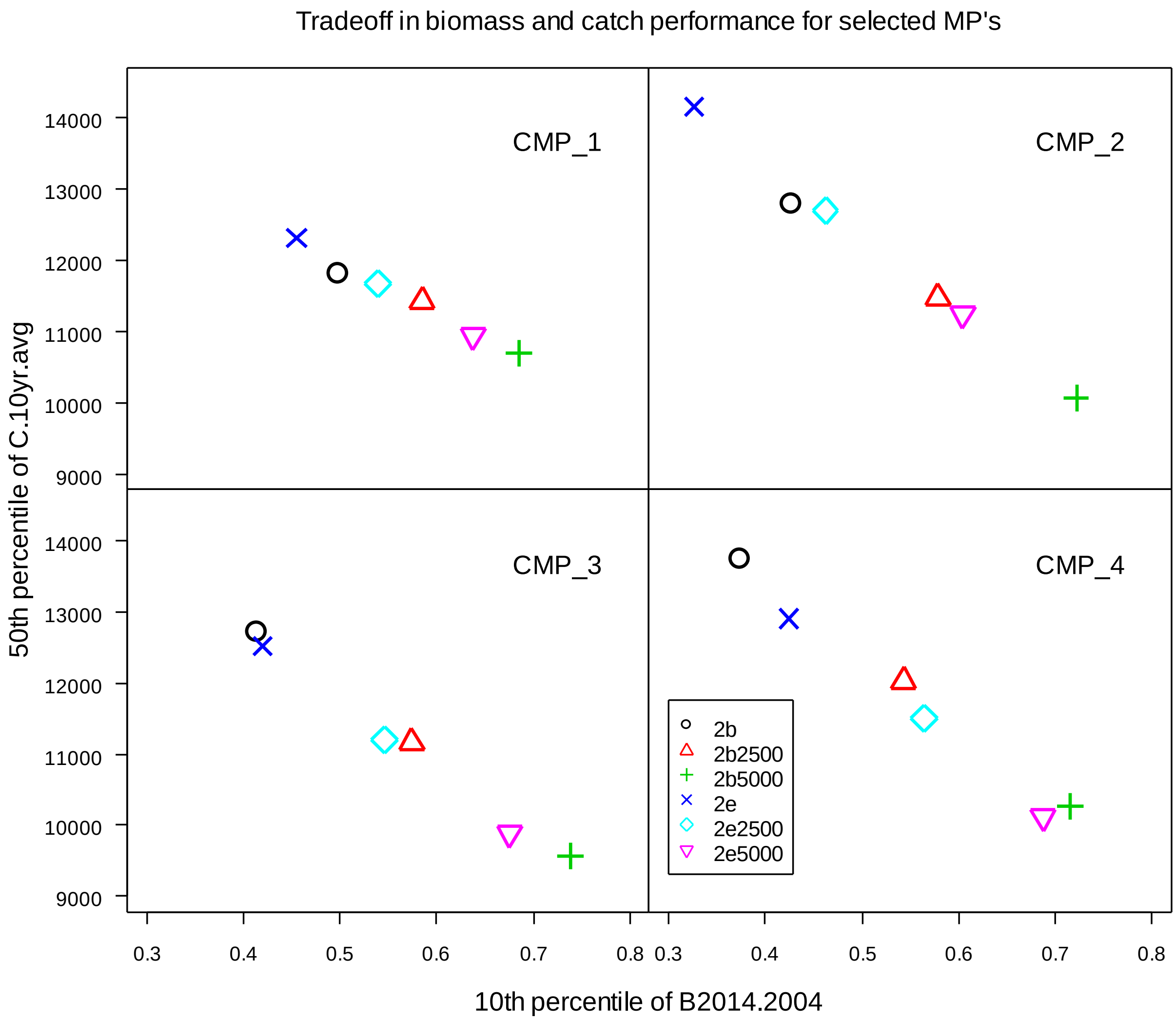


Figure 30 Tradeoff between the median 10-year-average catch and the 10th percentile of the abundance in 2014 (relative to 2004) for the four MPs and six catch schedules using the 1.1 tuning parameters.

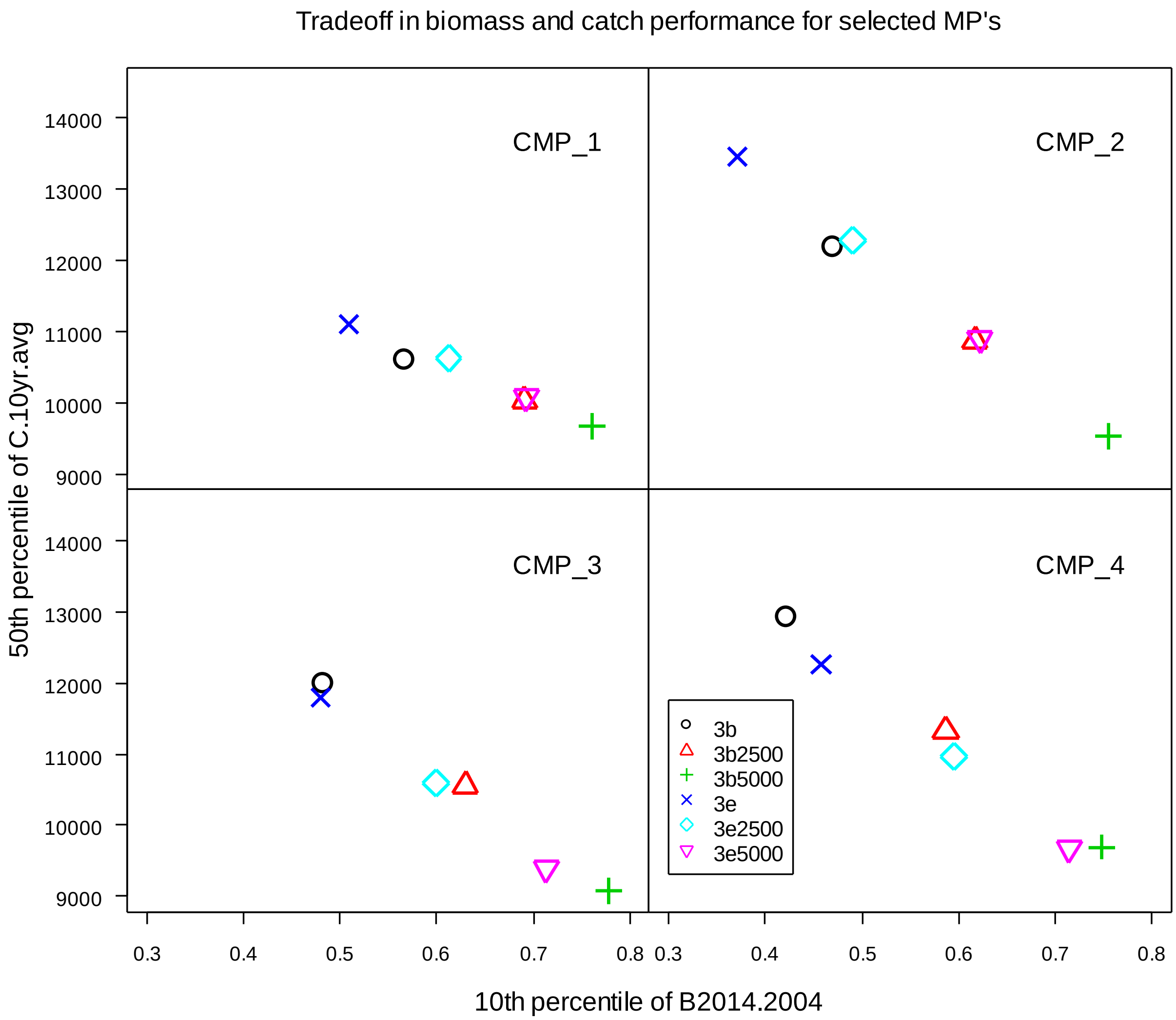


Figure 31 As for Figure 30 but using the 1.3 tuning parameters.

Tradeoff in biomass and catch performance for selected MP's

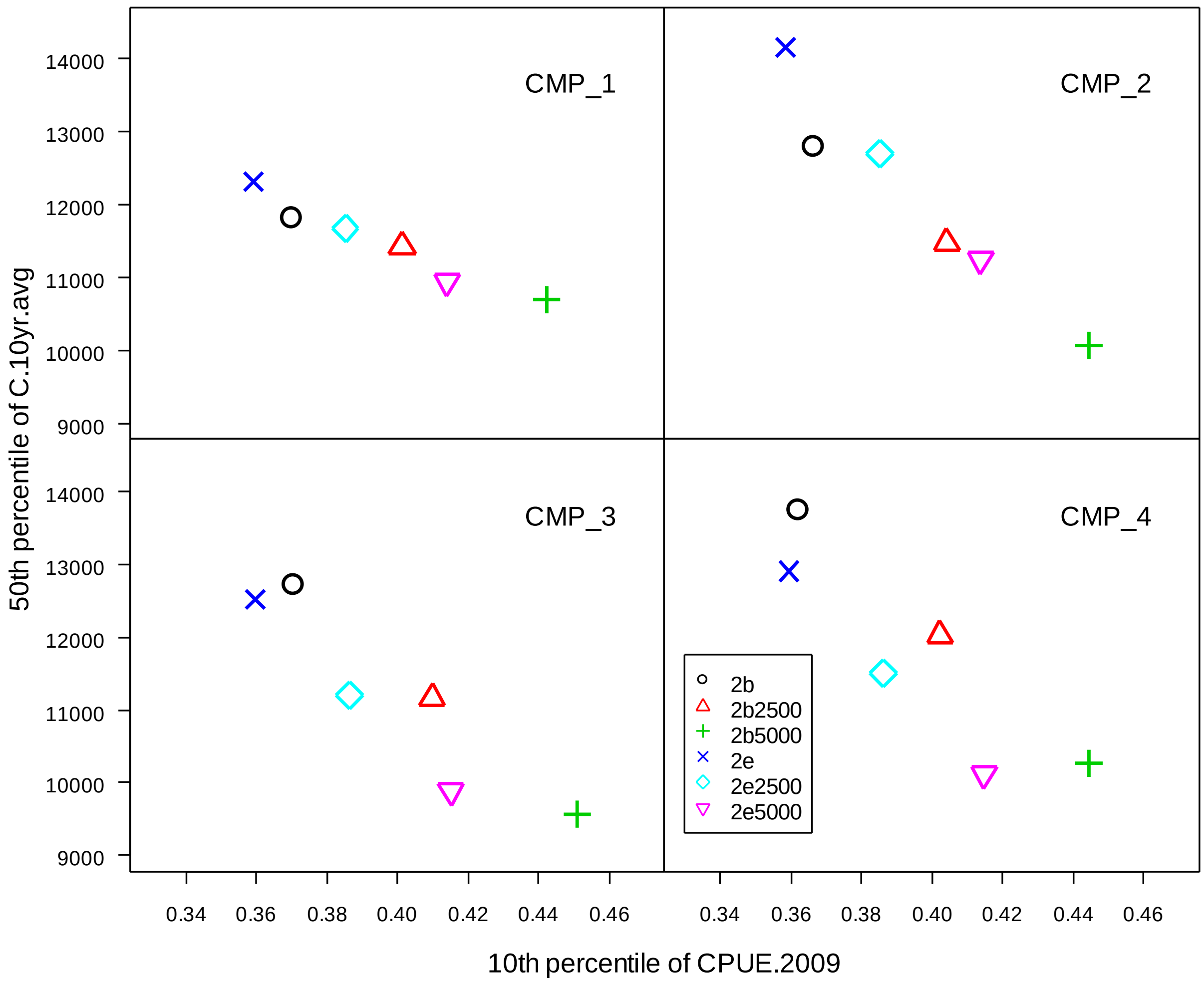


Figure 32 Tradeoff between median 10-year-average catch and the 10th percentile of CPUE in 2009 (relative to 2004) for each of the four CPUEs over the catch schedules using 1.1 tuning parameters.

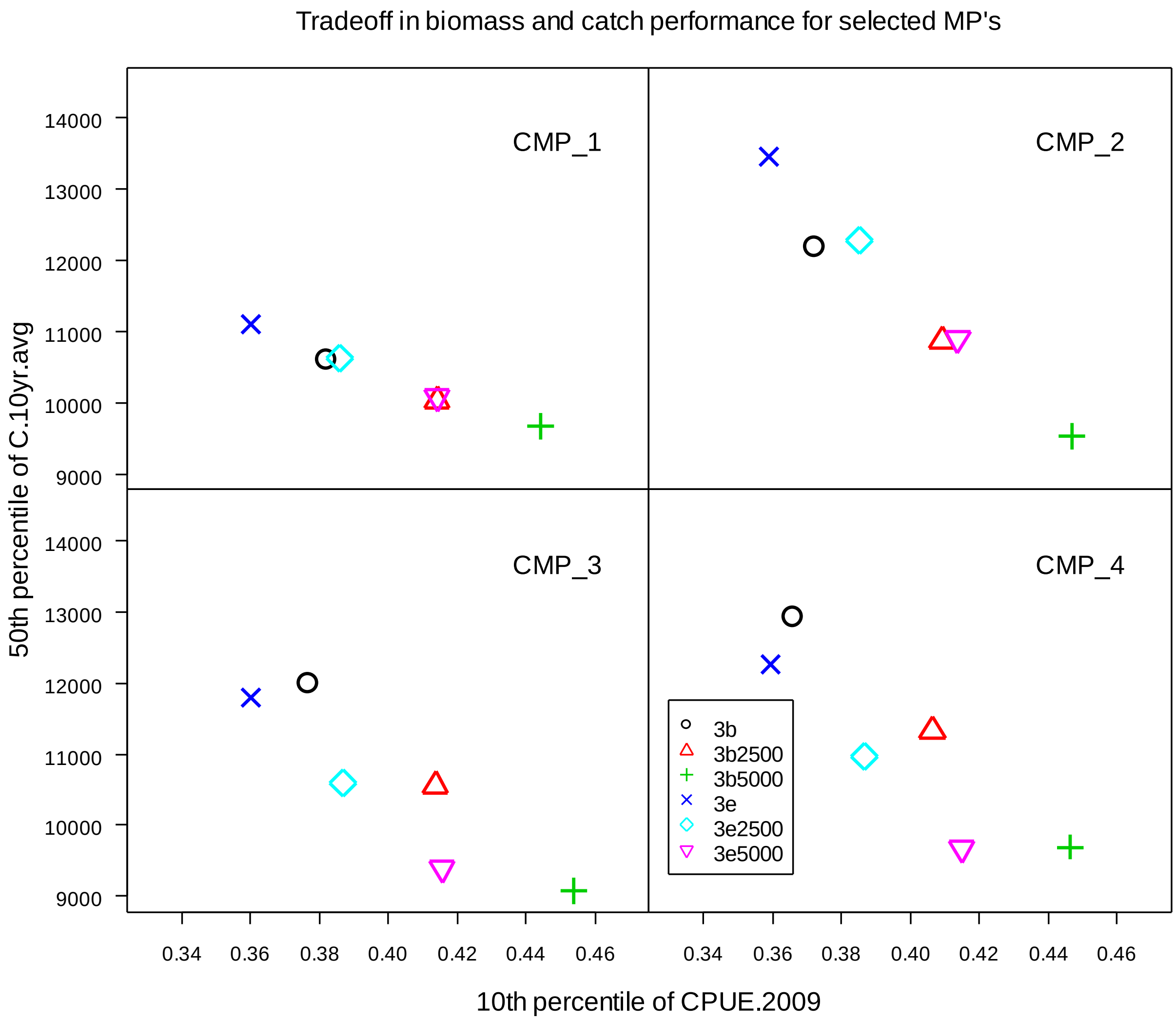


Figure 33 As for Figure 32 but using the 1.3 tuning parameters.

Table 1 10th percentile of B2014 (relative to 2004).

Schedules	ZERO	MAXDEC	CONST	CMP_1	CMP_2	CMP_3	CMP_4
2b	0.92	0.58	0.22	0.50	0.43	0.41	0.38
2b2500	0.98	0.77	0.22	0.58	0.58	0.58	0.54
2b5000	1.04	0.94	0.22	0.69	0.72	0.74	0.72
2e	0.80	0.53	0.22	0.46	0.33	0.42	0.42
2e2500	0.85	0.69	0.22	0.54	0.46	0.55	0.56
2e5000	0.91	0.83	0.22	0.64	0.60	0.68	0.69

Table 2 50th percentile of B2014 (relative to 2004).

Schedules	ZERO	MAXDEC	CONST	CMP_1	CMP_2	CMP_3	CMP_4
2b	1.24	0.90	0.61	0.81	0.74	0.75	0.70
2b2500	1.32	1.08	0.61	0.88	0.87	0.89	0.85
2b5000	1.39	1.26	0.61	0.97	1.01	1.04	1.00
2e	1.11	0.86	0.61	0.77	0.66	0.75	0.74
2e2500	1.17	1.00	0.61	0.83	0.77	0.86	0.85
2e5000	1.22	1.15	0.61	0.92	0.90	0.97	0.97

Table 3 50th percentile of B2022 (relative to 2004) using the 1.1 tuning parameters (for the old Cfull2 reference set). Note that if the CMPs were tuned to 1.1 for the new reference set then all of their values would be 1.1 here.

Schedules	ZERO	MAXDEC	CONST	CMP_1	CMP_2	CMP_3	CMP_4
2b	3.03	2.34	0.49	1.23	1.23	1.29	1.17
2b2500	3.11	2.67	0.49	1.29	1.51	1.63	1.50
2b5000	3.20	2.98	0.49	1.46	1.81	1.99	1.83
2e	2.77	2.24	0.49	1.18	1.01	1.33	1.34
2e2500	2.86	2.53	0.49	1.26	1.28	1.63	1.62
2e5000	2.95	2.80	0.49	1.40	1.60	1.94	1.91

Table 4 50th percentile of B2022 (relative to 2004) using the 1.3 tuning parameters (for the old Cfull2 reference set). Note that if the CMPs were tuned to 1.3 for the new reference set then all of their values would be 1.3 here.

Schedules	ZERO	MAXDEC	CONST	CMP_1	CMP_2	CMP_3	CMP_4
2b	3.03	2.34	0.49	1.44	1.48	1.48	1.42
2b2500	3.11	2.67	0.49	1.55	1.75	1.79	1.73
2b5000	3.20	2.98	0.49	1.64	2.02	2.11	2.03
2e	2.77	2.24	0.49	1.40	1.24	1.51	1.56
2e2500	2.86	2.53	0.49	1.49	1.48	1.80	1.83
2e5000	2.95	2.80	0.49	1.58	1.78	2.07	2.09

Table 5 10th percentile of CPUE in 2009 (relative to that in 2004) using the 1.1 tuning parameters.

Schedules	ZERO	MAXDEC	CONST	CMP_1	CMP_2	CMP_3	CMP_4
2b	0.44	0.39	0.36	0.37	0.37	0.37	0.36
2b2500	0.47	0.43	0.36	0.40	0.40	0.41	0.40
2b5000	0.50	0.47	0.36	0.44	0.44	0.45	0.44
2e	0.37	0.36	0.36	0.36	0.36	0.36	0.36
2e2500	0.39	0.39	0.36	0.39	0.39	0.39	0.39
2e5000	0.42	0.42	0.36	0.41	0.41	0.42	0.42

Table 6 50th percentile of CPUE in 2009 (relative to that in 2004) using the 1.1 tuning parameters.

Schedules	ZERO	MAXDEC	CONST	CMP_1	CMP_2	CMP_3	CMP_4
2b	0.72	0.65	0.61	0.63	0.63	0.63	0.62
2b2500	0.76	0.70	0.61	0.68	0.68	0.68	0.67
2b5000	0.80	0.76	0.61	0.72	0.73	0.73	0.73
2e	0.62	0.61	0.61	0.61	0.61	0.61	0.61
2e2500	0.66	0.65	0.61	0.65	0.65	0.65	0.65
2e5000	0.69	0.68	0.61	0.68	0.68	0.68	0.68

Appendix I. Incorporation of 2004 harvest rate constraints into the OM.

This appendix summarizes intersessional discussions relative to the incorporation of harvest rate constraints into the operating models.

Background

In discussions at the meeting MPW4, it was noted that abundances simulated for the weak cohorts 2000 and 2001 could be lower than the actual catches in a fraction of the scenarios, or could imply unrealistically high harvest rates in 2003 and 2004. One of the robustness trials proposed in Seattle, the Cfull2_expl, was designed to impose a constraint in the harvest rates of the surface fishery, so that harvest rates would not exceed 80% of the high harvest rates estimated for the period 1984-1988. As noted in paper MP/0505/09, this robustness test did not achieve the desired increase in abundance of year classes 2000 and 2001.

The decision at MPW4 was to amend the reference set (Cfull2) by dropping the scenarios for which abundance at ages 3 and 4 in 2004 were lower than the actual catches.

The following models were chosen to test the final MPs under the different TAC-changing schedules:

1) an amended Cfull2, dropping scenarios where

$$N_{3,2004}\, e^{-0.5M(3)} \le C_{3,2004} \quad \text{and} \quad N_{4,2004}\, e^{-0.5M(4)} \le C_{4,2004}$$

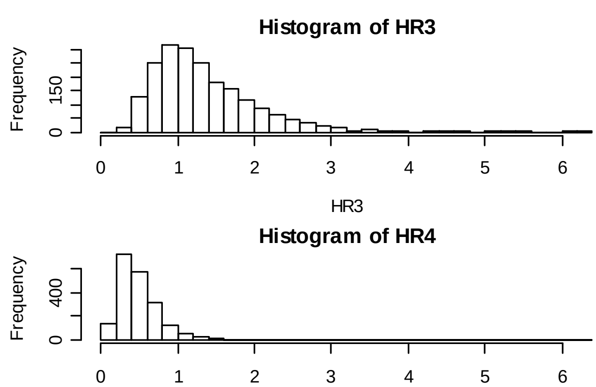
2) lowR2, lowR4, noAC_tripleR, all based on the amended Cfull2
3) Cfull2_expl.

New Results

The 2004 catches at ages 1-5 for all fisheries combined circulated by the Secretariat are

Age	Catch
1	102.18
2	96,089.86
3	207,039.59
4	29,347.37
5	20,894.42

Below are histograms showing the ratios of Catch/N for ages 3 and 4 in 2004 for the 2000 scenarios in Cfull2.



While age 4 is not a big problem (only in 5% of the scenarios HR4>1), in a large fraction of scenarios (~65%) the observed catch $C_{3,2004}$ exceeds the projected abundance. In most cases the exploitation rate for age 3 is very high (in 97% of the scenarios the ratio exceeds 0.5).

Further examination of the robustness test Cfull2_expl indicated that the reason why the penalties applied to the harvest rates had not resulted in substantial increases in recruitment for 2000 and 2001 was that the penalized harvest rates were computed using predicted catches. The constraints in the harvest rates were achieved by reducing the predicted catches in addition to increasing recruitment. The problem was cured when the actual catches in 2003 and 2004 were used to calculate the penalized harvest fractions instead of the predicted catches. A substantial increase in recruitment was achieved.

New procedure for introducing harvest rate constraints

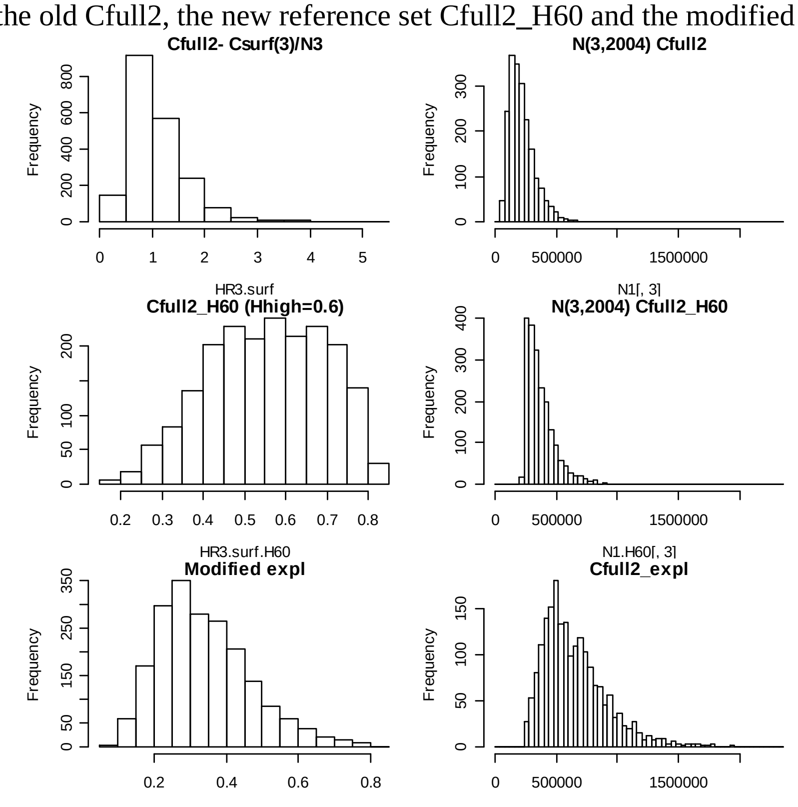
After discussion of preliminary results produced after MPW4, it was decided that dropping a large fraction of the scenarios from the Cfull2 was undesirable and that a better approach would be to impose the harvest rates constraints in the conditioning. The following approach was accepted:

1) To produce a new reference set (**Cfull2_H60)**: Amend the reference set Cfull2 by imposing a penalty in the conditioning to force the C/N ratios for age 3 in the surface fishery in 2003 and 2004 to be less than $H_{high} = 0.60$. The penalized C/N ratios are computed using the actual catches. The models lowR2, lowR4 and noAC_tripleR are based on Cfull2_H60.

2) Modify the **Cfull2_expl** using the actual catches in the computation of the (penalized) harvest rates. The new Cfull2_expl run is done just as before with a penalty applied when $H(3,2003:2004) > H_{high} = 0.8 \text{ mean}(H(2:3,84:88))$.

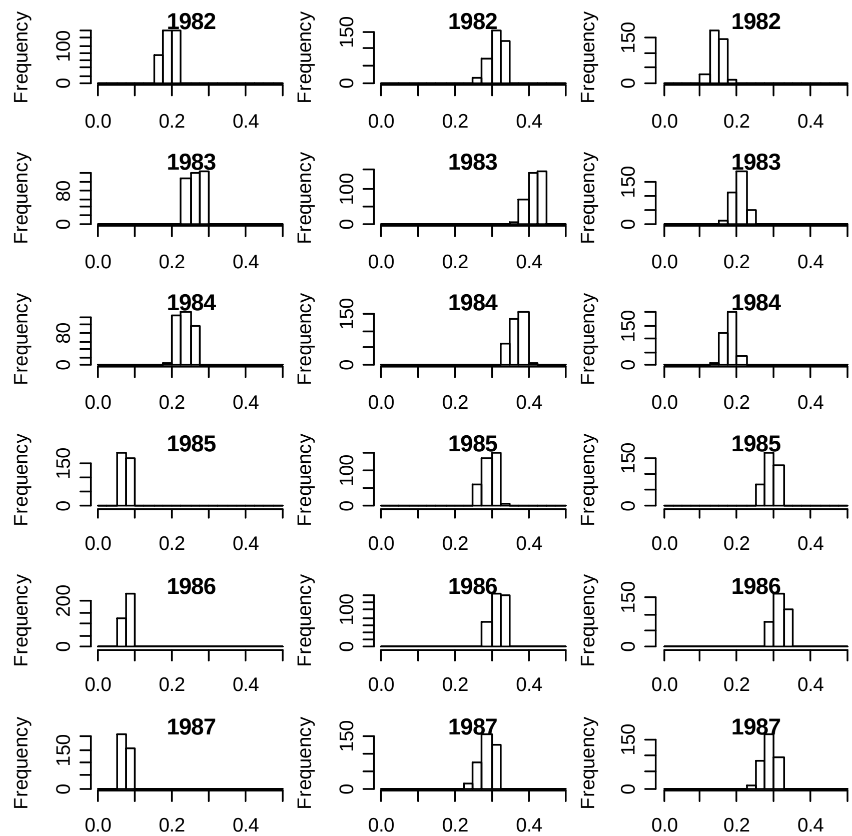
We expect to have a better idea about the actual harvest rates of the surface fishery when the new tagging data have been analysed. The two cases above cover a range of possibilities.

Lognormal error is added to the abundances at ages 3 and 4 in 2004 so that there is variability around the constrained point estimates. The resulting distributions of $N_{3,2004}$ and *C/N* ratios in projections are shown below for the old Cfull2, the new reference set Cfull2_H60 and the modified Cfull2_expl:



For the cases Cfull2_H60 and Cfull2_expl, the projection code has been modified so that when lognormal error is added, random numbers that result in $N_{3,2004}$ exp(-0.5 M) < $C_{3,2004}$ are rejected.

For reference, below is the distribution across grid cells of exploitation rates estimated for the surface fishery, ages 2 to 4 by columns (only for sqrt sample sizes). The highest estimates were for age 3 in 1983, where the median was above 0.40 and the highest value was close to 0.45).



Appendix II. Specification of the four candidate management procedures.

CMP_1

This decision rule, developed by Basson et al. (2005), is based on the Fox production model fitted to the longline (LL1) CPUE biomass and total catch biomass. A ‘preliminary’ TAC (called pTAC) is calculated as the estimated maximum sustainable yield, *MSY*, times the ratio (B_y / B_{MSY}) times δ:

$$pTAC_{y+1} = \delta.MSY\left(\frac{B_y}{B_{MSY}}\right) \qquad (1)$$

where δ is a pre-multiplier, or tuning parameter. Subsequently to that calculation, the TAC is adjusted for the constraints on the maximum change in TAC from year to year (as determined at the MP Technical meeting (Seattle, February 2005)):

If $pTAC_{y+1} - TAC_y < -\text{maxChange}$ then $TAC_{y+1} = TAC_y - \text{maxChange}$

If $pTAC_{y+1}-TAC_y >$ maxChange then $TAC_{y+1} = TAC_y$+maxChange

In addition, the rule has constraints to prevent TAC increases during the initial period as:.

- **Ceiling on TAC until 2015**: if(y<2015) TAC_y=min($pTAC_y$, TAC_{2007})

where y is the year in which the MP calculation is conducted using data up to y-2 and the TAC is applied in y+1. (Note: Since the intention of this constraint was to avoid increases in the early years, the ceiling was set to TAC_{2007} which allows for the cuts in 2006 or 2007 to be taken into account in the relevant scenarios. This means that the different schedules either have a ceiling at: current catch, or (current catch – 2500t), or (current catch – 5000t)).

Recruitment Feedback
Additional modifications to pTAC are introduced based on the mean proportion of age 4 in the LL1 CPUE, which is used as a 'recruitment index'. Based on the range of values of this index under the default Fox rule and the old reference set (Cfull2), the recruitment feedback was implemented as a linear drop in TAC as the recruitment index drops below a threshold:

If (recIndex(y-4:y-2) < 0.125) TAC = pTAC – 10 (0.125- recIndex(y-4:y-2)) maxChange;

If (y > 2009 & recIndex(y-5:y-7)<0.125) TAC = pTAC – 10 (0.125 - recIndex(y-7:y-5))*maxChange

The original constraints on TAC changes are always applied last so that the actual TAC decrease can never exceed the maximum allowed change.

Table II.1. Control parameter values for CMP_1.

	2b (1.1 tuning)	**3b (1.3 tuning)**
Max Change	5000	5000
Δ	1.643	1.3912

Fox Minimization Reliability
Basson et al. (2005) encountered convergence problems when trying to estimate the two Fox model parameters (*r* and *K*) simultaneously in ADMB. They modified their implementation to a grid search over *r*, with *K* estimated for each *r* on the grid. The final phase of the minimization was initiated with both parameters free, starting from the best *r* value. Often this did not result in improved minimization over the grid estimates. For the purpose of testing (i.e. to allow for a manageable run time), the grid resolution was coarse (*r* values of 0.05-0.95 at an interval of 0.05), with a corresponding pTAC resolution of around 2000 *t*). If adopted, the grid resolution can, of course, be increased.

According to the authors, this implementation seemed to eliminate the majority of dubious results but, occasionally, the model converged to biomass estimates arbitrarily close to 0. This presumably relates to a fundamental limitation of the Fox model to describe SBT dynamics in some circumstances. The value of *pTAC* approaches 0 in these cases. Fluctuations in estimated *r* between years were not found to be too wide.

CMP_2

The CMP_2 is based on fitting a discrete age-aggregated Fox dynamic production model to past catch and CPUE data, as detailed in Butterworth and Mori (2004a). Estimates of the parameter values from this model fit are used to compute future TACs as follows.

$$TAC_{y+1} = \left(w\ TAC_y + \alpha(1-w)\cdot M\hat{S}YR_y \cdot \hat{B}_{MSY,y} \cdot \left(\frac{\hat{B}_y}{\hat{B}_{MSY,y}} \right)^{\gamma} \cdot g(\hat{r}_y)\cdot h\left(CPUE_y^{rat}\right) \right) \cdot f\left(LL_y\right) \qquad (1)$$

where

$\hat{B}_{MSY,y}$ is the maximum sustainable yield level (*MSYL*) as estimated in year *y*,

γ is a control parameter (here fixed to be 0.6),

w is a control parameter,

$M\hat{S}YR_y$ is the year *y* estimated maximum sustainable yield rate, calculated as $M\hat{S}Y_y \big/ MSYL_y$ ($\hat{r}_y / \ln \hat{K}_y$ for the Fox model),

$\hat{B}_y$ is the estimated biomass for year *y*, which (together with $\hat{r}_y$ and $\hat{K}_y$) is re-estimated each time the TAC is calculated,

$g(\hat{r}_y)$ is a function which reduces the TAC further if $\hat{r}_y$ is low,

$f(LL_y)$ is a function which adjusts the TAC depending on the proportion of lower ages in the longline catch,

α is a tuning parameter and

$h\left(CPUE_y^{rat}\right)$ is a function which adjusts the TAC depending on the ratio of the immediate CPUE compared to that over the period immediately preceding application of the MP.

The TAC reduction factor $g(\hat{r}_y)$ is set to:

$$g(\hat{r}_y) = \begin{cases} 0 & \text{for } 0 \le \hat{r}_y \le r_1 \\ \dfrac{1}{r_2 - r_1}(\hat{r}_y - r_1) & \text{for } r_1 < \hat{r}_y < r_2 \\ 1 & \text{for } r_2 \le \hat{r}_y \end{cases} . \qquad (2)$$

with parameter values fixed at r_1=0.4, r_2=1.0 as in Butterworth and Mori (2003).

The *w* parameter is introduced to moderate the extent to which the TAC is adjusted from year to year in the interests of industrial stability. The γ parameter's role is to stabilize the TAC trend and avoid instances where the TAC outputs show a decrease for the first few years followed by a subsequent increase. Setting γ to a value <1 tends to smooth out this undesirable behaviour.

The function $f(LL_y)$ modifies the TAC depending on the proportion of lower ages in longline catch as follows:

1) For the first TAC change year (i.e. 2008)

[Note: For schedule e, this applied to 2009 which is the first year that the CMP is applied.]

$$LL_{2008} = \left(\frac{\sum_{a=4}^{5} LLC_{2004}}{\sum_{a=4}^{30} LLC_{2004}} + \frac{\sum_{a=4}^{5} LLC_{2005}}{\sum_{a=4}^{30} LLC_{2005}} \right) \Big/ 2 \qquad (3)$$

where

$f(LL_{2008}) = 1$ if $LL_{2008} \le 0.13$

$f(LL_{2008}) = (1 + (LL_{2008} - 0.13)\cdot \phi_1)$ if $0.13 < LL_{2008} < 0.20$

$$f\left(LL_{2008}\right) = \left(1 + 0.07 \cdot \phi_1\right) = \theta_1 \qquad \text{if } LL_{2008} \geq 0.20$$

2) For the second TAC change year

For option b):

$$LL_{2011} = \left(\frac{\sum_{a=4}^{6} LLC_{2006}}{\sum_{a=4}^{30} LLC_{2006}} + \frac{\sum_{a=5}^{7} LLC_{2007}}{\sum_{a=4}^{30} LLC_{2007}} + \frac{\sum_{a=6}^{8} LLC_{2008}}{\sum_{a=4}^{30} LLC_{2008}} \right) \Big/ 3 \qquad (4)$$

where

$$f\left(LL_{2011}\right) = 1 \qquad \text{if } LL_{2011} \leq 0.16$$

$$f\left(LL_{2011}\right) = \left(1 + \left(LL_{2011} - 0.16\right) \cdot \phi_2\right) \qquad \text{if } 0.16 < LL_{2011} < 0.30$$

$$f\left(LL_{2011}\right) = \left(1 + 0.14 \cdot \phi_2\right) = \theta_2 \qquad \text{if } LL_{2011} \geq 0.30$$

Parameter values in the equations above were chosen based on the distributions of LL_{2008} and LL_{2011} in the old reference set Cfull2, and in trials Cfull2_noAC and Cfull2_noAC_tripleR (see Butterworth and Mori 2005). This function allows the TAC to vary depending on good or poor recruitment in recent years as reflected by the proportion of lower ages in the longline catch.

The function $h\left(CPUE_y^{rat}\right)$ controls the TAC depending on the ratio of immediate CPUE value compared to that when the MP was first put into effect:

$$CPUE_y^{rat} = \left(\frac{\frac{1}{3} \sum_{y'=y-4}^{y-2} CPUE_{y'}}{\frac{1}{5} \sum_{y=1998}^{2002} CPUE_y} \right) \qquad (5)$$

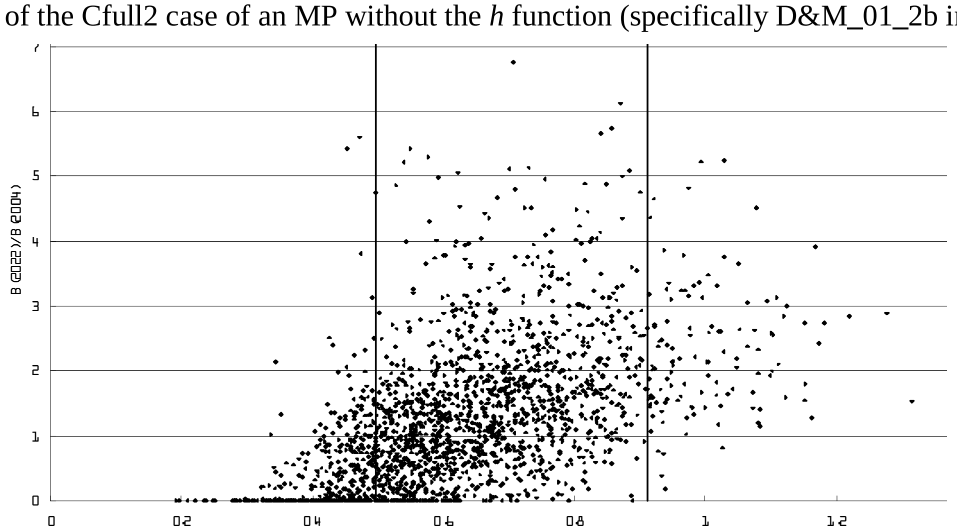
where

$$h\left(CPUE_y^{rat}\right) = 0 \qquad \text{if } 0 < CPUE_y^{rat} \leq 0.5$$

$$h\left(CPUE_y^{rat}\right) = \frac{1}{0.9 - 0.5}\left(CPUE_y^{rat} - 0.5\right) \qquad \text{if } 0.5 < CPUE_y^{rat} < 0.9$$

$$h\left(CPUE_y^{rat}\right) = 1 \qquad \text{if } CPUE_y^{rat} \leq 0.9$$

Figure II1. shows the distribution of $CPUE_{2011}^{rat}$ and the corresponding value of *B*(2022)/*B*(2004) for the 2000 samples of the Cfull2 case of an MP without the *h* function (specifically D&M_01_2b in



Butterworth and Mori 2005). This Figure shows that at this early stage, the CPUE ratio provides a reasonable indicator of the extent of recovery likely; so that the *h* factor was introduced with a view to make use of this information to reduce the TAC at such an early stage in the event of low CPUE. The choices of the values of 0.5 and 0.9 in equation (5) were made on the basis of this Figure. The $CPUE_y^{rat}$ is defined in terms of averages over a number of years to improve the signal:noise ratio in the information input to the *h* function.

Figure II.1. Distribution of $CPUE_{2011}^{rat}$ and the corresponding value of *B*(2004)/*B*(2022) for the 2000 samples of the Cfull2 case under the D&M_01_2b MP. The vertical lines show the range over which the *h* function increases from 0 to 1.

Further constraints added were that for the first two years in which the TAC can change, it is not permitted to exceed its immediately previous value. These were added to counter the consequences of an inaccurate initial determination of *r* leading to an increase in the TAC before more information indicated that the reverse action was required.

The control parameter values for tuning under the Cfull2 trial are listed in Table II.2

.

Table II.2. Control parameter values for CMP_2.

1.1 tuning for a TAC change interval of three years starting with year 2008

Mp name	$\theta_1(\phi_1)$	$\theta_2(\phi_2)$	w	$h(CPUE_y^{rat})$	α
D&M_03_2b	1.2 (2.86)	1.2 (1.43)	0.65	Yes	1.402

1.3 tuning for a TAC change interval of three years starting with year 2008

MP name	$\theta_1(\phi_1)$	$\theta_2(\phi_2)$	w	$h(CPUE_y^{rat})$	α
D&M_03_3b	1.2 (2.86)	1.2 (1.43)	0.65	Yes	0.878

CMP_3

This procedure corresponds to procedure HK5 discussed by Kurota (2005), a hybrid of the "HK1-dfl v2" and the "HK4-ag4 v1" in Tsuji et al. (2003). It has an empirical decision rule that depends on the index of CPUE for the longline fisheries. The TAC is set as a minimum of those determined by the CPUE trend (age 4+) and the value of the age-4 CPUE of the Japanese longline in numbers ($CPUE_{age4}$). The latter is used as the index of recruitment before 2003 (Figure II.2).

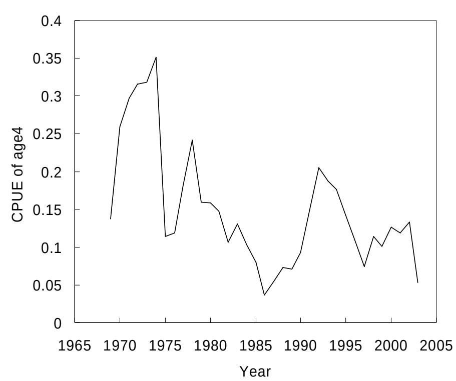


Fig. II.2. CPUE of age 4 fish used as recruitment information.

It is calculated from median CPUE of age 4+ among five series (nominal, ST window, Laslett, w0.8 and w0.5) and age-composition data of Japanese longline. In the projections, $CPUE_{age4}$ is also calculated from CPUE of age 4+ and the age composition of the LL1 fishery provided in the file "sbtOMdata":

$$CPUE_{age4} = \frac{catch_{age4}}{catch_{age4+}} \times CPUE_{age4+} \tag{1}$$

The TACs are determined by:

$$TAC_{y+1} = \begin{cases} TAC_y + max_{up} & if \quad TAC_{y+1} - TAC_y > max_{up} \\ \min\left(TAC_{y+1}^{trend\,4+},\ TAC_{y+1}^{level\,4}\right) & if \quad max_{down} < TAC_{y+1} - TAC_y < max_{up} \\ TAC_y - max_{down} & if \quad TAC_{y+1} - TAC_y < max_{down} \end{cases} \tag{2}$$

$$TAC_{y+1}^{trend\,4+} = TAC_y \times (1 + k\lambda) \tag{3}$$

where

λ: slope of regression of ln($CPUE_{age4+}$) over years (from y - yrs_{cpue4+} to y - 1),
k: control parameter

$$TAC_{y+1}^{level\,4} = TAC_y \times f(CPUE_{age4,\,y-1}) \tag{4}$$

$$f(CPUE_{age4,\,y-1}) = \begin{cases} m_{\max} & if \quad CPUE_{age4,\,y-1} > l_{\max} \\ a \times CPUE_{age4,\,y-1} + b & if \quad l_{\min} \le CPUE_{age4,\,y-1} \le l_{\max} \\ m_{\min} & if \quad CPUE_{age4,\,y-1} < l_{\min} \end{cases} \tag{5}$$

where

$CPUE_{age4,y-1}$: average CPUE of age 4 over years (from y - yrs_{cpue4} to y -1),
m_{max}, m_{min}, l_{max}, l_{min}, a, b: control parameters.

Fig. II.3 shows an example of a relationship between $CPUE_{age4}$ and TAC change for a 1.1 tuning. Table 1 also indicates parameter values used at the tuning level of 1.1 and 1.3.

Table II.3. Parameter values for the tuning levels of 1.1 and 1.3.

tuning level	k	l_{max}	l_{min}	m_{max}	m_{min}	max_{up}	max_{down}	yrs_{cpue4+}	yrs_{cpue4}
1.1	2.5	0.065	0.025	1.10	0.750	5000	5000	10	3
1.3	2.5	0.065	0.025	1.10	0.665	5000	5000	10	3

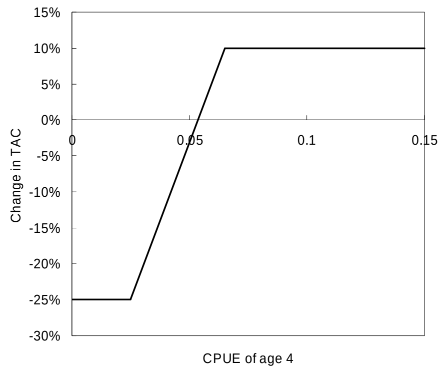


Fig. II.3. Example of relationship between average CPUE of age 4 and change in TAC at a tuning level of 1.1.

CMP_4:

CMP_4, modified from the TAI_05 decision rule presented in Sun (2005), is a CPUE-based rational expectation of next period's TAC, with a build in inverse demand elasticity self-adjustment to soften TAC changes in order to reduce the expected economic deadweight loss to the industry in the short run.

Predicted TAC:

A predicted TAC is first calculated based n the change of the CPUE for the Japanese longline fisheries for the most recent n years, as follows:

$$TAC_{t+1}^{p} = w \cdot TAC_t + (1-w) \cdot TAC_t \cdot (1 + k_1 \lambda_{n,t-2}) \qquad (1)$$

where TAC_{t+1}^{p} is the predicted TAC in the next year;

TAC_t is the current actual TAC in year t.

w is the carryover percentage which represents the grandfathered-in fishing rights in various periods. During the adjustment years before 2010, w is set to 0.7 to account for the grandfathered-in fishing rights in the short-run while allowing the industry to adjust their investment planning. Since the sunk cost of decommission fishing vessels immediately is high, this rule considers the economic burden placed on the fishing industry in the first adjustment period. The carryover weight w is set to zero after 2010 so that the TAC is fully adjusted based on the relative changes in CPUE.

n is the number of years included in the CPUE index.

$\lambda_{n,\ t-2}$ measures the change of CPUE as the slope of the regression of log($CPUE_t$), I_t, with respect to the time for the most recently available n years: $\lambda_{n,t-2} = \dfrac{\sum_{y=t-n-1}^{t-2}(I_y - \bar{I}_{t-2})(y - \bar{y}_{t-2})}{\sum_{y=t-2}^{t-n-1}(y - \bar{y}_{t-2})^2}$, where

$\bar{y}_{t-2} = \dfrac{\sum_{y=t-n-1}^{t-2} y}{n}$ is the average of years and $\bar{I}_{t-2} = \dfrac{\sum_{y=t-n-1}^{t-2} I_y}{n}$ is the average of log(CPUE) for year t = 1969, 1970, …, 2003. The time-window is set to five years to reflect the situation in the short-run before 2010, i.e., $\lambda_{5,\ t-2}$ when t <2010; a ten year time-window is set to reflect the long-run CPUE trend after 2010, i.e., $\lambda_{10,\ t-2}$ when t >= 2010.

k_1 is the weight by which changes in recent CPUE affect future TAC. k_1 is set to 10, following Polacheck, Eveson, Hartog, Basson, and Kolody (2004). Hence, if there is a 1% change of log (CPUE), k1 inflates the change to 10% and increases the second term of equation (1).

The predicted percentage change of next period's TAC with respect to the current TAC is defined as follows,

$$
\begin{aligned}
\%\Delta TAC^{p}_{t+1} &= \frac{TAC^{p}_{t+1} - TAC_t}{TAC_t} \\
&= \frac{[w \cdot TAC_t + (1-w) \cdot TAC_t \cdot (1 + k_1 \lambda_{n,t-2})] - TAC_t}{TAC_t} \qquad (2) \\
&= (1-w) k_1 \lambda_{n,t-2}
\end{aligned}
$$

Adding Economic Considerations to determine TAC:

The CMP_4 rule incorporates the idea of rational expectations that utilizes the inverse demand elasticities to minimize the economic losses to fishermen resulting from an abrupt change of TAC in the short run. Parameter values were based on the following analysis and rational provided by Sun, updated from Sun (2005):

Total imports of SBT into Japan have increased dramatically since 1999. At the same time there has been a downward trend in the import price of frozen and chilled SBT and NBT, i.e., the direction of change in the price of SBT is negatively related to the change of TAC. For example, in 2004, the import quantity of frozen SBT was 8,174.30 MT, or 2.67 times the import quantity of chilled SBT, 3,057.45 MT. In 2004, during the major import season (Aug. to Oct.) of frozen SBT imported into Japan, import quantity increased 34.2% while prices decreased 30.1% relative to the previous year during Sept. to Nov. The inverse demand elasticity is defined as -0.9, which indicates a 1% increase of TAC results in a 0.9% reduction in price to represent the penalty of changing TAC in the short run. In addition, the quantity of chilled SBT imported into Japan was increased 1.0% while import prices decreased 4.4% by comparing Jun.-Aug. 2004 to July.-Sep. 2003, i.e., the inverse demand elasticity for chilled SBT is about -4.4. The inverse demand elasticity (range from -0.9 to -4.4) represents the economic deadweight loss that an abrupt change in the supply would result in a drop in price in the short run. In 2003, SBT imports into Japan dropped 40% relative to 2002, but the price of SBT also declined by 24%, a strong indication that there are plenty of substitutes for consumers to choose from in the short-run.

Because of the negative relationship between SBT prices and changes in TAC, the CMP_4 adjusts the next period's TAC with a penalty weight k_2, as:

$$TAC_{t+1} = \alpha \cdot [w \cdot TAC_t + (1-w) \cdot TAC_t \cdot (1 + k_1 \lambda_{n,t-2} - k_2 \%\Delta TAC^{p}_{t+1})] \qquad (3)$$

where α is the tuning parameter set to meet a given target biomass ratio B2022/B2004 under the old reference set Cfull2.

$-k_2$ is the negative weight given to the predicted percentage change of next period's TAC, defined as $\frac{\%\Delta P}{\%\Delta TAC} < 0$.

The parameter "$-k_2$" represent how the total revenue and average import prices will be affected by the predicted TAC^{p}_{t+1}. Since the inverse demand elasticity is negative, the percentage change of market price will be negatively correlated to the percentage change of TAC^{p}_{t+1}. For instance, if $\%\Delta TAC^{p}_{t+1}$ is positive, the market price will drop and the revenue will not increases as much as the supply. So there is a penalty to increase quantity and k2 will soften the change of TAC in the next period.

To reflect the range of inverse demand elasticities over the various time periods, the short-run penalty "-k2" is set at -0.9 until 2010, -0.5 for years 2010 to 2022, and zero after year 2022. In addition, a restriction is set to prevent quota increases before 2012.

In summary, CMP_4 will adjust TAC_{t+1} in three stages to ensure recovery of the biomass in the long run while preventing a dramatic reduction of the common wealth of the industry in the short run:

(i). In the short-run, when t < 2010,

$$TAC_{t+1} = \alpha \cdot [w + (1-w)((1+k_1\lambda_{5,t-2}) - (1-w)\cdot k_1 k_2 \lambda_{5,t-2})] \cdot TAC_t \qquad (4)$$

where w = 0.7, k_1 = 10, k_2 = 0.9. The percentage change of TAC is positively related to the change of CPUE index, i.e., $\frac{\partial TAC_{t+1}}{\partial \lambda_{5,t-2}} = \alpha(1-w)[k_1 - (1-w)\cdot k_1 k_2]\cdot TAC_t \geq 0$

(ii). In the inter-median run, between 2010 and 2020,

$$TAC_{t+1} = \alpha \cdot (1 + k_1\lambda_{10,t-2})(1-k_2)\cdot TAC_t \qquad (5)$$

where w = 0, k_1 = 10, k_2 = 0.5, and the percentage change of TAC is positively related to the change of CPUE index, i.e., $\frac{\partial TAC_{t+1}}{\partial \lambda_{10,t-2}} = \alpha \cdot k_1 \cdot TAC_t \geq 0$

(iii). In the long run after 2020, the TAC_{t+1} is adjusted as follows:

$$TAC_{t+1} = \alpha \cdot (1 + k_1\lambda_{10,t-2})\cdot TAC_t \qquad (6)$$

where w = 0, k_1 = 10, and the percentage change of TAC is positively related to the change of CPUE index, i.e., $\frac{\partial TAC_{t+1}}{\partial \lambda_{10,t-2}} = \alpha \cdot k_1 \cdot TAC_t \geq 0$.

When the TAC is adjusted every three years, starting in 2008, α is set to 1.0538 to ensure the median biomass ratio B2022/B2004 equals 1.1 under schedule 2b with the old reference set Cfull2, and to 0.97105 for a biomass ratio of 1.3 under schedule 3b.