Further Progress on the Development of Candidate Management Procedures for the Canadian Pollock in the in the Western Component (4Xopqrs+5Zc)

Rebecca A Rademeyer and Doug S Butterworth

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Abstract

Results are presented for a few simple Candidate Management Procedures for Canadian Pollock applied to the trials developed during the December 2010 St Andrews meeting. The Procedures are tuned to yield performances in the range sought by that meeting. The intent is to facilitate discussions in a coming conference call about how to advance the process further, and some suggestions are made for topics for discussion during that call.

Introduction

The intent of this progress paper is to provide an initial impression of the sorts of results to be expected from the Canadian Pollock Management Procedure development process (MSE) agreed at the December 2010 meeting in St Andrews. A number of Candidate Management Procedures (CMPs) are developed which yield anticipated performances broadly within the range for objectives set out at that St Andrews meeting.

The aims are to enhance the familiarity of stakeholders with the types of outputs which the MSE process provides, and to obtain feedback to facilitate refinements as the process is then taken further forwards.

Methodology

The CMPs considered have been applied to the Reference Set (RS) of Operating Models (OMs) agreed at the December 2010 meeting at St Andrews, for which the details are given in Appendix A. Appendix B provides detailed technical specifications of the CMPs. The CMPs explored are either:

a) based on the slope over recent years of the trend in the available index of abundance (here the survey aggregated weight/tow), such that positive slopes lead to TAC increases and negative slopes to TAC decreases, or

b) based on a target value for the abundance index, such that values above this target will lead to TAC increases, and *vice versa.*

Furthermore, all CMPs presented here incorporate a 20% constraint on the maximum TAC change between years, and place an upper bound (“cap”) on the TAC. In the target-based CMPs, the target level has been chosen as the average value of the index over the 1984 to 1994 period (see Appendix B), though other choices could be explored in due course.

For ease of comparison of different forms of CMPs, the CMPs have been tuned to correspond to a common achieved median catch in 2016 for the RS. The resultant tuning parameter values are reported in Table 1.

Results

Projections results for four CMPs under the RS are given in Table 2. The CMPs have been tuned (i.e. had their control parameters adjusted) to achieve a median catch in 2016 of either 10000 or 15000t. Examples of some actual catch trajectory realisations ("worm plots") are shown in Fig. 1 for each of the four CMPs under the RS. Shade plots, showing medians, 50%, 75% and 95% PI of a series of performance statistics, are shown in Fig. 2a-d for each CMP under the RS. For comparison, medians and lower 2.5%iles catch and biomass trajectories are compared in Fig. 3.

Robustness test

To check that the performance of the CMPs is reasonably robust to plausible variations of the OMs that constitute the RS, at this stage one robustness test has been run for each of the CMPs. The chosen test (probably the most pessimistic) is "Rob3" (Rademeyer and Butterworth, 2010), in which the recruitment over the first eight years of projections is assumed to be at the level of the lowest recruitment over the period from which the recruitment relationship is calculated (1999-2008 for OM1, OM2, OM3, OM8 and OM14 and 2004-2008 for OM13).

Results for this robustness test are given in Table 3 and plotted in Fig. 2e-f and Fig. 3.

Summary

Fig. 4 summarises performance statistics and compares them under the different CMPs for the RS and Rob3, while Fig. 5 compares the results under CMPa1 for each of the six OMs of the RS.

Discussion

At this stage we draw attention only to a few key features of the results, leaving others to peruse them to develop their questions and suggestions for the coming conference call. Individuals will likely differ in terms of which tables and/or plots they find the most helpful in assimilating projected performance and comparing the different CMPs, though we would mention that the form of plots shown in Fig. 4 often provide the most useful consolidated summary, particularly in the final step of comparing amongst the anticipated performances of the various CMPs to select the MP to be implemented from them.

- Under the RS, even for the more aggressive of the CMPs considered, there is a very low probability of the population dropping below its previous lowest abundance (P_{2000}) – see Table 2 and Figs 2a-d and 4.
- For similar levels of median anticipated catch, the target-based CMPs show much less variability from year to year in catch levels (see Figs 1 and 2a-d), as well as less variability in the average catch over a period of years, and achieve this without any real additional risk of undue depletion of resource abundance (see Fig. 4).
- Even under the very pessimistic scenario of eight successive years of poor recruitment (robustness test Rob3), risk to the resource is reasonably controlled with catches being brought down timeously under the CMPs in line with the future lower survey results forthcoming (see Table 1 and Figs 3c-f).
- Some care must be taken in interpreting the results from the RS, as that in integrating over future outcomes for six rather different OMs. Fig. 5 is useful in that respect in showing for one of the CMP's how different anticipated performance is amongst them. Broadly speaking these differences do not seem that large, with OM3 (excluding the 2010 survey result) resulting in somewhat larger catches, whereas OM8 (higher M at older ages) manifesting slightly more recovery.
- The plots in Fig. 2 now also include projections for the average age of future catches. The wideness of these distributions as time progresses cautions against relying on this information to be able to discriminate in the future amongst different resource scenarios.

Next steps

Broadly speaking, further work in this process will involve refining the CMPs to better address the agreed objectives for the fishery, and testing them against the complete set of OMs agreed at the December 2010 meeting in St Andrews. The coming conference call should provide some pointers for that process. As a subset of some of the issues which might merit discussion during that call, we offer the following.

- We suggest that refinement of the structure of the CMPs focus on the target-based approach because of the lesser variability in the annual TACs to which it leads without compromising other objectives.
- Would it be important to explore further the trade-offs involved in reducing the maximum inter-annual TAC change permitted below 20%?
- Do any of the objectives set out during the December meeting merit revision in the light of the results presented here?

- Given that the possible first implementation of the MP formula to yield a TAC recommendation would be for 2012, should future calculations involve fixing a likely catch for 2011?
- How large a difference between the 2012 TAC and a likely 2011 catch should be allowed.

References

Stone, H.H. 2011. Pollock Assessment Update for the Western Component (4Xopqrs5). *In* Porter, J.M., and Docherty, V., Chairpersons. 2011. Proceedings of 4X5 Pollock Management Strategy Evaluation Workshop – 2010. Can. Manuscr. Rep. Fish. Aquat. Sci. 2945. pp. 21-96.

Rademeyer, R.A., and Butterworth, D.S. 2011. Progress on the Development of Candidate Management Procedures for the Canadian Pollock in the Western Component (4Xopqrs+5Zc). *In* Porter, J.M., and Docherty, V., Chairpersons. 2011. Proceedings of 4X5 Pollock Management Strategy Evaluation Workshop – 2010. Can. Manuscr. Rep. Fish. Aquat. Sci. 2945. pp. 115-134.

Table 1: Tuning parameter values for each CMP presented (see Appendix A for definitions of the symbols used).

	Comment	Initial TAC	λ_{up}	λ_{down}	P	a	b	Interannual change constraints	Cap
CMPa1	Slope-based tuned to 2016 median catch of 10000t	6550	2.0	2.0	10	-	-	+20%; -20%	20000t
CMPa2	Slope-based tuned to 2016 median catch of 15000t	9000	3.0	3.0	10	-	-	+20%; -20%	20000t
CMPb1	Target-based tuned to 2016 median catch of 10000t	6550	-	-	-	17120	9500	+20%; -20%	20000t
CMPb2	Target-based tuned to 2016 median catch of 15000t	6550	-	-	-	20440	7000	+20%; -20%	20000t

Table 2: Projections results (median and 95% PI in parenthesis) for a series of performance statistics for different CMPs under the RS. The symbol "a" in the name indicates "slope-based" CMPs, while the symbol "b" indicates "target-based" CMP. For each CMP tuning parameters were adjusted to meet the performance criterion shown in bold.

		CMPa1 - RS		CMPa2 - RS		CMPb1 - RS		CMPb2 - RS	
P_{2021}/P_{target}	$B^{4\text{-}8}$	1.49	(0.36; 4.02)	1.32	(0.25; 3.79)	1.67	(0.28; 3.95)	1.35	(0.20; 3.57)
	B^{sp}	2.93	(0.62; 9.50)	1.93	(0.34; 7.63)	3.34	(0.29; 9.15)	1.94	(0.22; 7.71)
P_{2016}/P_{2000}	$B^{4\text{-}8}$	5.04	(1.60; 10.00)	3.95	(1.24; 8.79)	5.21	(1.59; 10.38)	4.36	(1.29; 9.00)
	B^{sp}	6.32	(2.02; 12.70)	4.63	(1.50; 10.58)	6.68	(1.87; 13.21)	5.48	(1.54; 11.63)
P_{2021}/P_{2000}	$B^{4\text{-}8}$	6.05	(1.56; 14.57)	5.40	(1.07; 13.64)	6.62	(1.21; 14.73)	5.44	(0.86; 12.43)
	B^{sp}	15.00	(3.32; 38.57)	9.87	(1.75; 29.09)	17.04	(1.55; 38.42)	10.06	(1.15; 29.94)
P_{2031}/P_{2000}	$B^{4\text{-}8}$	5.86	(0.72; 15.28)	5.52	(0.72; 15.01)	6.11	(0.66; 15.41)	5.53	(0.44; 14.85)
	B^{sp}	15.65	(0.91; 52.09)	14.09	(0.85; 49.67)	17.58	(0.80; 52.61)	13.99	(0.57; 50.56)
Prob<P_{2000}	$B^{4\text{-}8}$	0.00	(0.00; 0.29)	0.05	(0.00; 0.38)	0.00	(0.00; 0.38)	0.05	(0.00; 0.43)
	B^{sp}	0.00	(0.00; 0.14)	0.00	(0.00; 0.24)	0.00	(0.00; 0.19)	0.00	(0.00; 0.33)
C_{2011}		7860	(7860; 7860)	12600	(12600; 12600)	7860	(7860; 7860)	7860	(7860; 7860)
C_{2012}		9432	(8023; 9432)	16646	(12993; 17640)	8680	(8503; 9432)	9432	(9432; 9432)
C_{2013}		9518	(6566; 11318)	16795	(10559; 20000)	8245	(7800; 9756)	11318	(11318; 11318)
C_{2014}		9660	(5291; 13582)	16387	(8447; 20000)	8775	(7990; 11010)	13582	(13582; 13582)
C_{2015}		9846	(4259; 16298)	15639	(6825; 20000)	9280	(8070; 12340)	14591	(13765; 16298)
C_{2016}		**10008**	(3635; 19459)	**14948**	(5529; 20000)	**10009**	(8144; 13722)	**15002**	(13788; 17980)
C_{2021}		17995	(4152; 20000)	20000	(4837; 20000)	14322	(8362; 20000)	16651	(13786; 20000)
$C_{2011\text{-}2015}$		9273	(6455; 11698)	15821	(10314; 18048)	8590	(8088; 9977)	11357	(11191; 11698)
$C_{2016\text{-}2020}$		12890	(3570; 19815)	15206	(5194; 20000)	11697	(8413; 16158)	15694	(13889; 18992)
$C_{2011\text{-}2020}$		10801	(5263; 15683)	15237	(8301; 19024)	10203	(8362; 12632)	13545	(12557; 15320)
$C_{2021\text{-}2030}$		18072	(7839; 20000)	18916	(8221; 20000)	17492	(8478; 20000)	18091	(13872; 20000)
$AAV_{2011\text{-}2020}$		19.5	(16.7; 24.4)	33.0	(25.0; 41.5)	16.5	(11.9; 20.9)	17.4	(15.3; 20.1)
$AAV_{2012\text{-}2020}$		12.0	(8.8; 17.5)	14.4	(5.6; 23.9)	8.7	(3.5; 13.6)	9.7	(7.3; 12.7)
$AAV_{2021\text{-}2030}$		7.0	(0.0; 18.4)	6.0	(0.0; 22.4)	7.3	(0.1; 13.5)	2.9	(0.0; 6.8)

Table 3: Projections results (median and 95% PI in parenthesis) for a series of performance statistics for different CMPs under the **Rob3** robustness test (8 years of poor recruitment).

		CMPa1 - Rob3		CMPa2 - Rob3		CMPb1 - Rob3		CMPb2 - Rob3	
P_{2021}/P_{target}	$B^{4\text{-}8}$	0.71	(0.34; 1.48)	0.63	(0.23; 1.36)	0.59	(0.20; 1.33)	0.53	(0.15; 1.20)
	B^{sp}	0.84	(0.35; 2.01)	0.66	(0.22; 1.68)	0.62	(0.20; 1.55)	0.51	(0.14; 1.25)
P_{2016}/P_{2000}	$B^{4\text{-}8}$	1.31	(0.58; 2.41)	1.18	(0.56; 2.07)	1.29	(0.59; 2.59)	1.18	(0.53; 2.12)
	B^{sp}	1.71	(0.76; 4.07)	1.44	(0.69; 2.97)	1.67	(0.76; 4.90)	1.49	(0.69; 3.73)
P_{2021}/P_{2000}	$B^{4\text{-}8}$	2.88	(1.47; 4.91)	2.58	(1.00; 4.41)	2.41	(0.85; 4.19)	2.19	(0.65; 3.91)
	B^{sp}	4.30	(1.85; 7.70)	3.34	(1.16; 6.02)	3.18	(1.03; 5.87)	2.56	(0.75; 4.54)
P_{2031}/P_{2000}	$B^{4\text{-}8}$	6.46	(1.02; 15.20)	5.46	(0.60; 14.02)	6.17	(0.49; 14.78)	5.07	(0.42; 13.66)
	B^{sp}	22.04	(1.69; 56.61)	13.56	(0.87; 44.29)	17.68	(0.57; 46.70)	9.45	(0.55; 34.05)
Prob<P_{2000}	$B^{4\text{-}8}$	0.10	(0.00; 0.43)	0.14	(0.00; 0.57)	0.14	(0.00; 0.71)	0.19	(0.00; 0.71)
	B^{sp}	0.00	(0.00; 0.33)	0.05	(0.00; 0.43)	0.00	(0.00; 0.53)	0.05	(0.00; 0.53)
C_{2011}		7860	(7860; 7860)	12600	(12600; 12600)	7860	(7860; 7860)	7860	(7860; 7860)
C_{2012}		9432	(7933; 9432)	16559	(12776; 17640)	8674	(8499; 9432)	9432	(9432; 9432)
C_{2013}		9274	(6450; 11318)	16233	(10220; 20000)	8185	(7774; 9661)	11318	(11318; 11318)
C_{2014}		8744	(5160; 13582)	14769	(8176; 20000)	8532	(7864; 10673)	13582	(13582; 13582)
C_{2015}		7677	(4128; 16248)	12100	(6541; 20000)	8574	(7835; 11212)	14114	(13596; 16032)
C_{2016}		6400	(3302; 17851)	9965	(5233; 20000)	8584	(7854; 11159)	14090	(13612; 15785)
C_{2021}		4358	(2039; 14141)	5906	(2784; 18379)	8634	(7878; 11107)	14000	(13624; 15481)
$C_{2011\text{-}2015}$		8617	(6329; 11685)	14431	(10063; 18048)	8409	(7986; 9674)	11261	(11158; 11645)
$C_{2016\text{-}2020}$		4822	(2537; 15804)	6997	(3979; 15639)	8607	(7905; 10450)	14072	(13641; 15017)
$C_{2011\text{-}2020}$		6784	(4452; 13493)	10854	(7161; 16626)	8512	(7979; 9836)	12672	(12409; 13284)
$C_{2021\text{-}2030}$		9062	(4060; 17964)	14388	(5818; 19475)	11324	(8040; 15673)	15059	(13748; 17930)
$AAV_{2011\text{-}2020}$		22.4	(15.2; 25.9)	36.5	(28.3; 40.1)	12.5	(11.0; 16.4)	15.7	(14.9; 18.0)
$AAV_{2012\text{-}2020}$		15.2	(7.2; 19.1)	18.4	(9.2; 22.3)	4.3	(2.5; 8.6)	7.8	(6.9; 10.4)
$AAV_{2021\text{-}2030}$		17.7	(7.0; 20.0)	18.1	(5.5; 27.9)	8.1	(1.3; 12.9)	2.8	(0.5; 6.0)

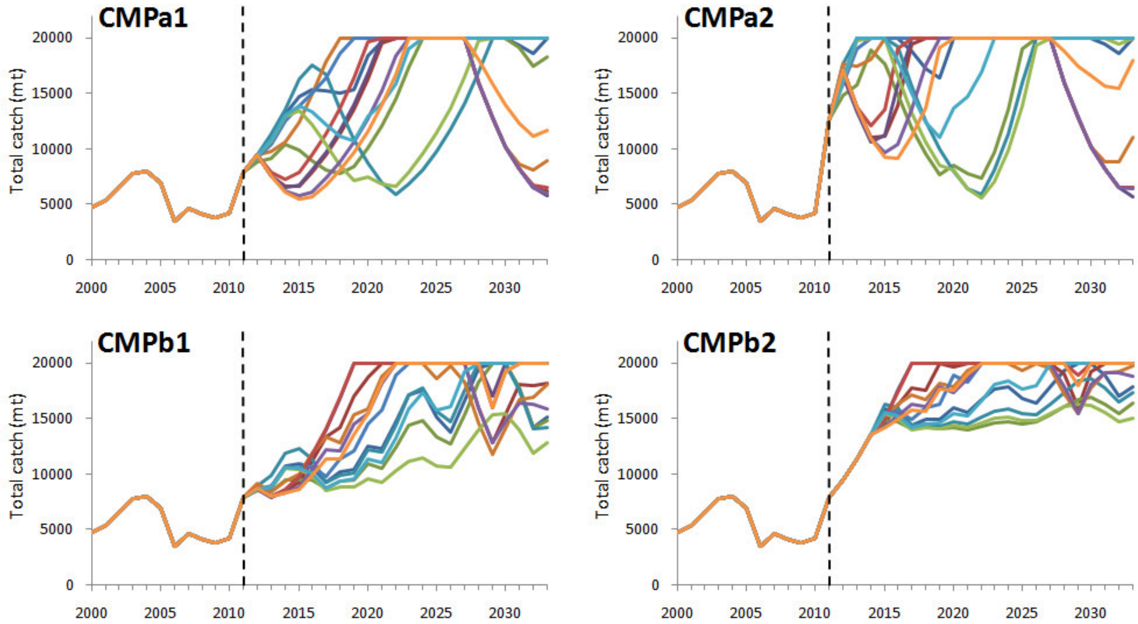

Fig. 1: "Worm plots" of catches for each CMP under the RS.

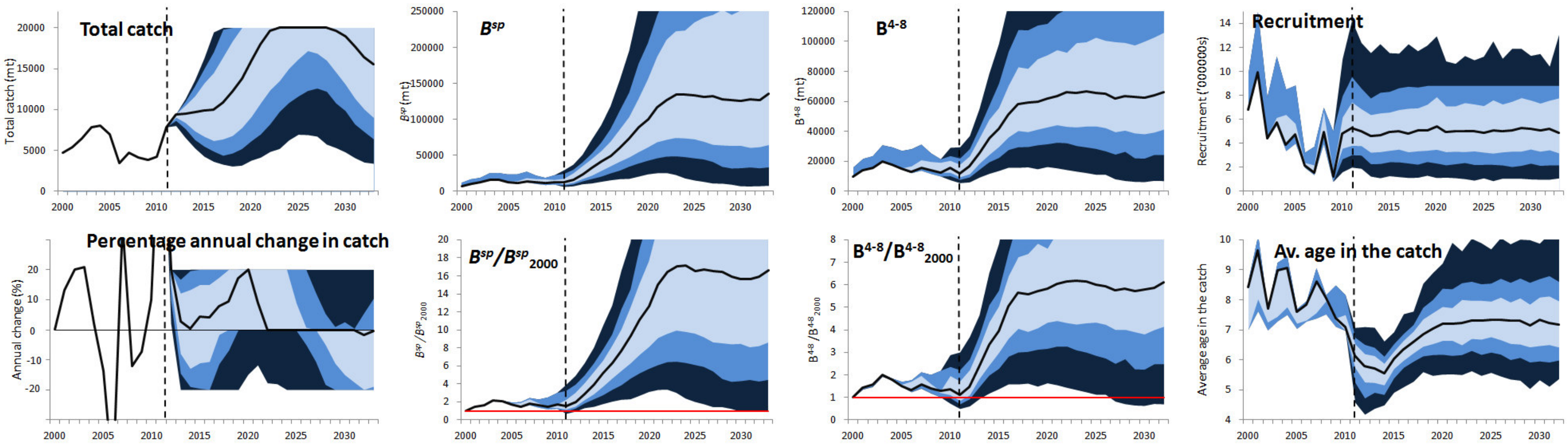

Fig. 2a: 95, 75, 50% PI and median for a series of performance statistics for **CMPa1** (slope-based, tuned to a median catch of 10000t in 2016) under the **RS**.

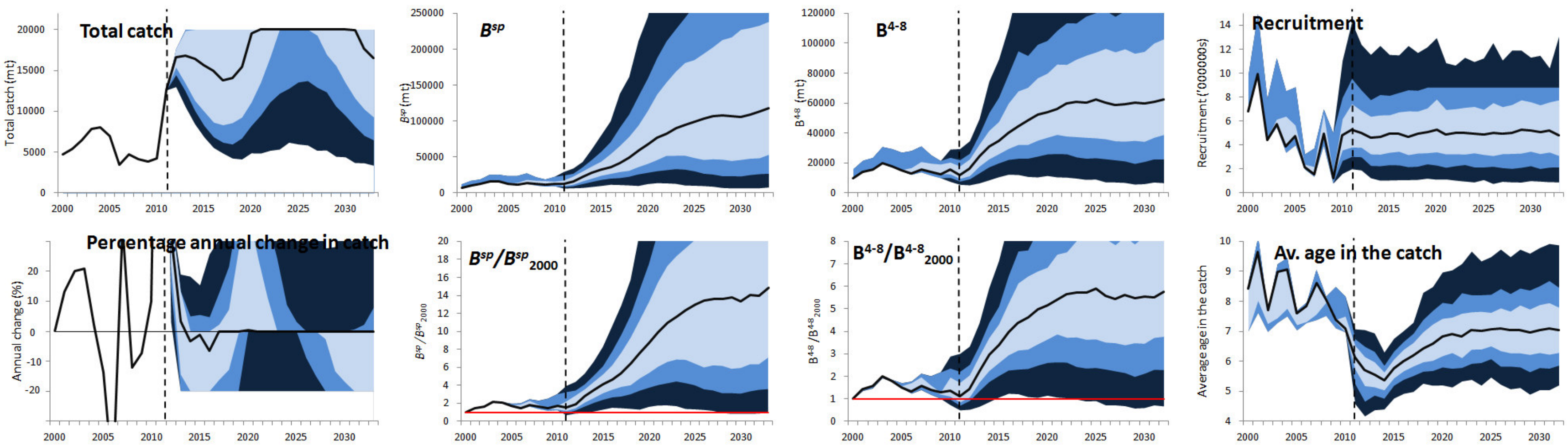

Fig. 2b: 95, 75, 50% PI and median for a series of performance statistics for **CMPa2** (slope-based, tuned to a median catch of 15000t in 2016) under the **RS**.

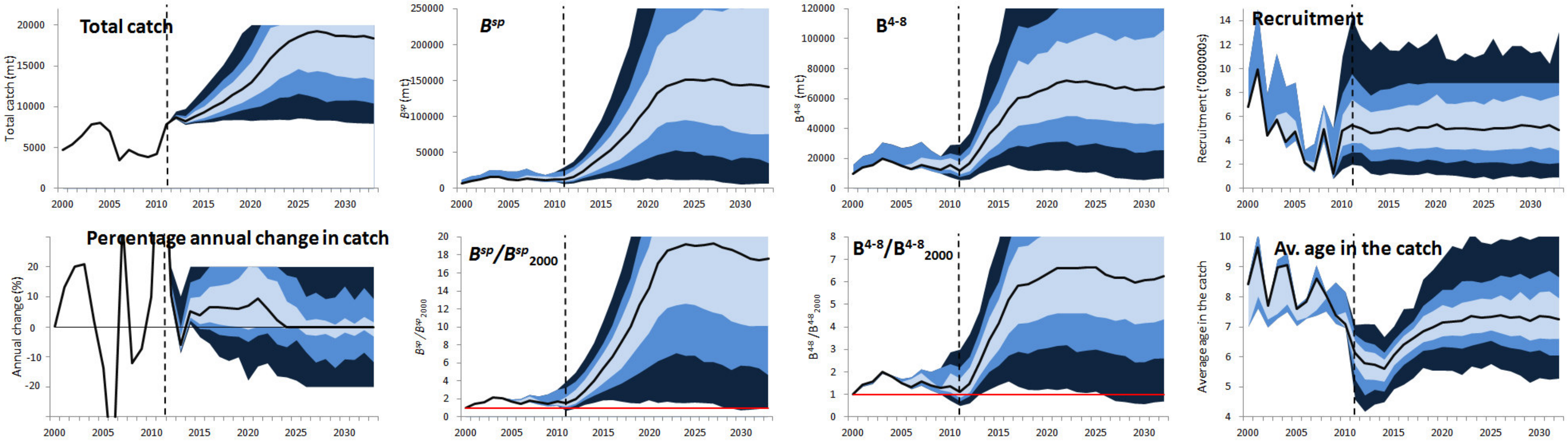

Fig. 2c: 95, 75, 50% PI and median for a series of performance statistics for **CMPb1** (target-based, tuned to a median catch of 10000t in 2016) under the **RS**.

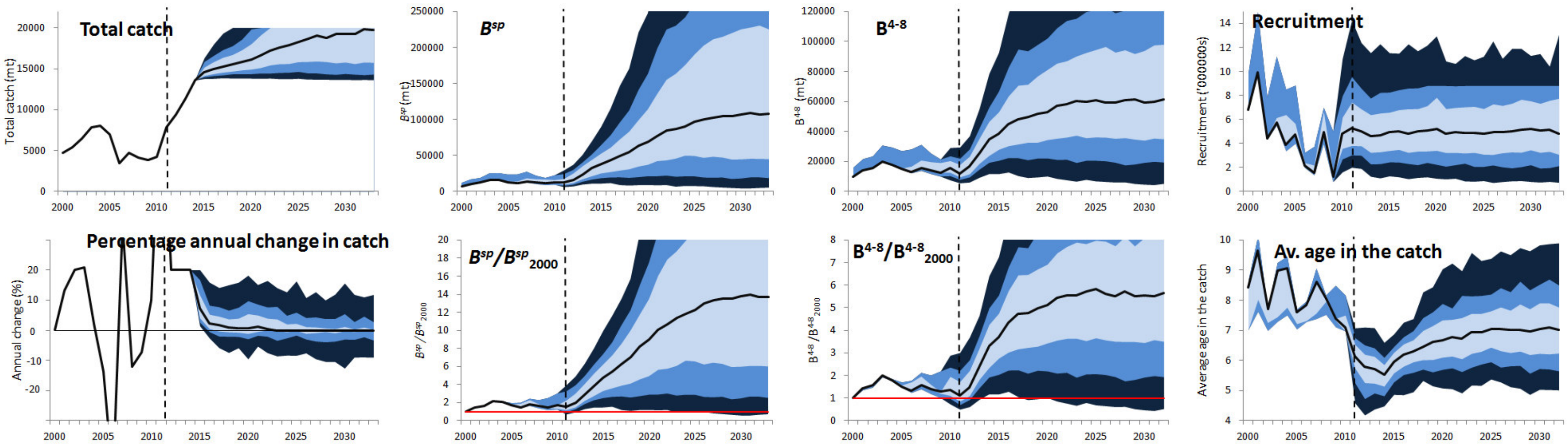

Fig. 2d: 95, 75, 50% PI and median for a series of performance statistics for **CMPb2** (target-based, tuned to a median catch of 15000t in 2016) under the **RS**.

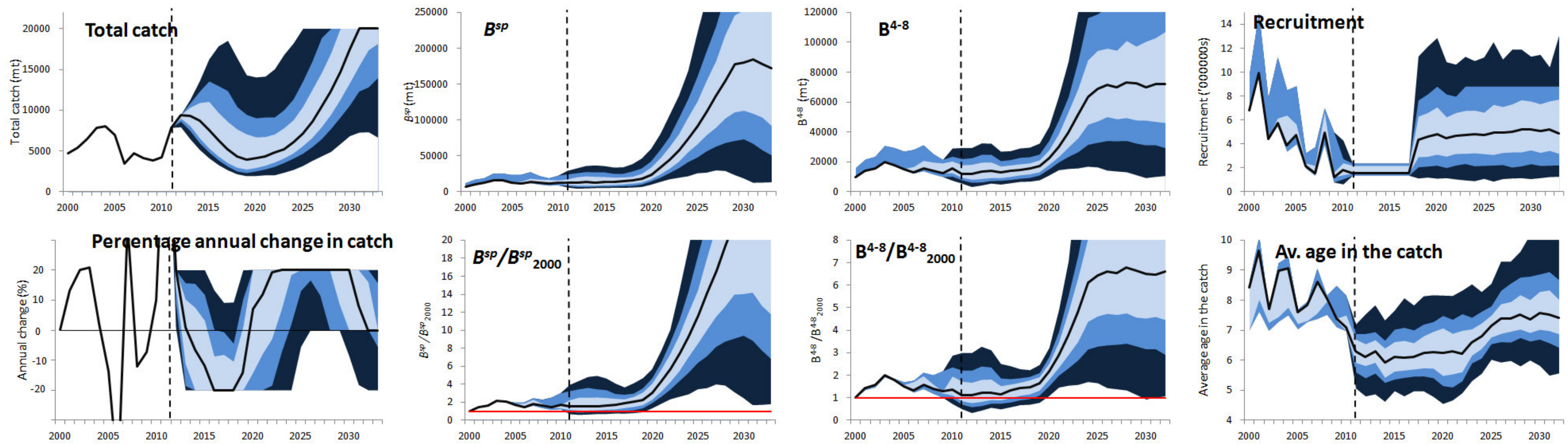

Fig. 2e: 95, 75, 50% PI and median for a series of performance statistics for **CMPa1** (slope-based, tuned to a median catch of 10000t in 2016) under the **Rob3** robustness test.

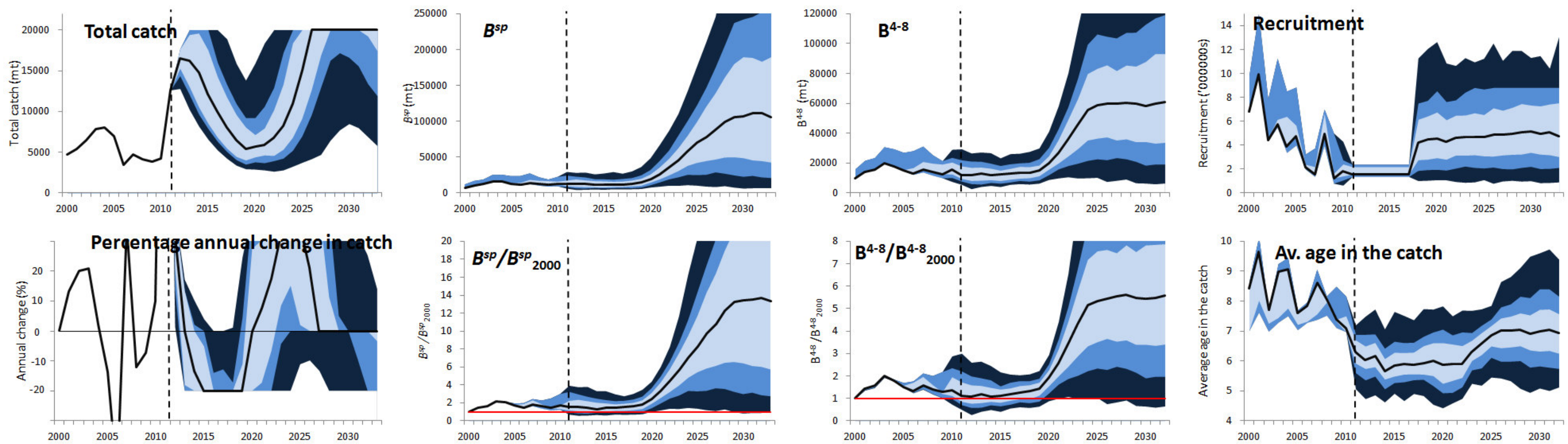

Fig. 2f: 95, 75, 50% PI and median for a series of performance statistics for **CMPa2** (slope-based, tuned to a median catch of 10000t in 2016) under the **Rob3** robustness test.

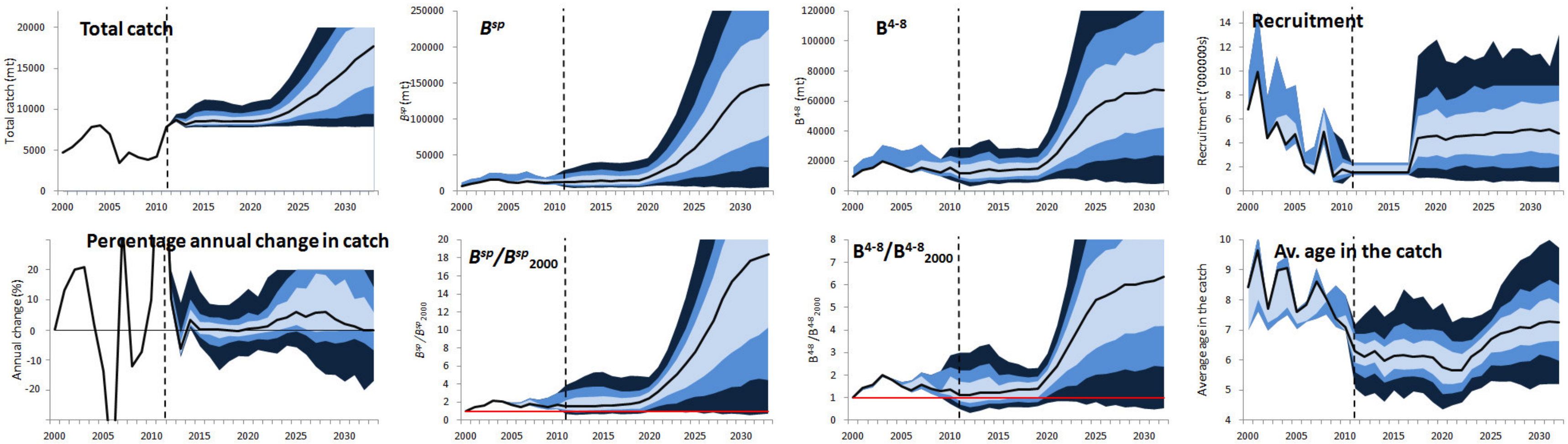

Fig. 2g: 95, 75, 50% PI and median for a series of performance statistics for **CMPb1** (slope-based, tuned to a median catch of 10000t in 2016) under the **Rob3** robustness test.

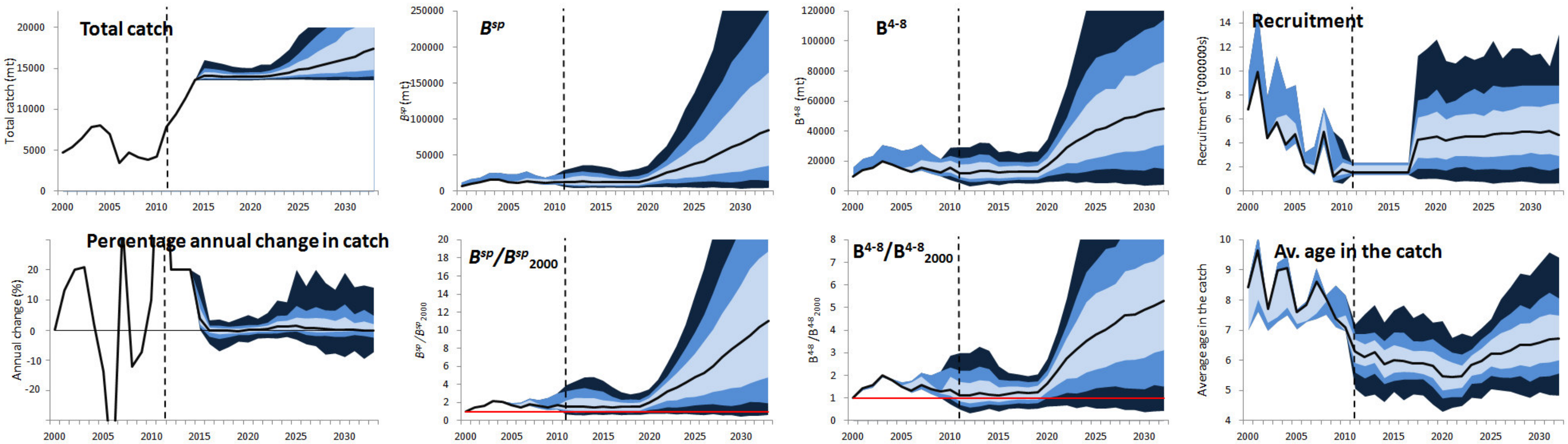

Fig. 2h: 95, 75, 50% PI and median for a series of performance statistics for **CMPb2** (slope-based, tuned to a median catch of 10000t in 2016) under the **Rob3** robustness test.

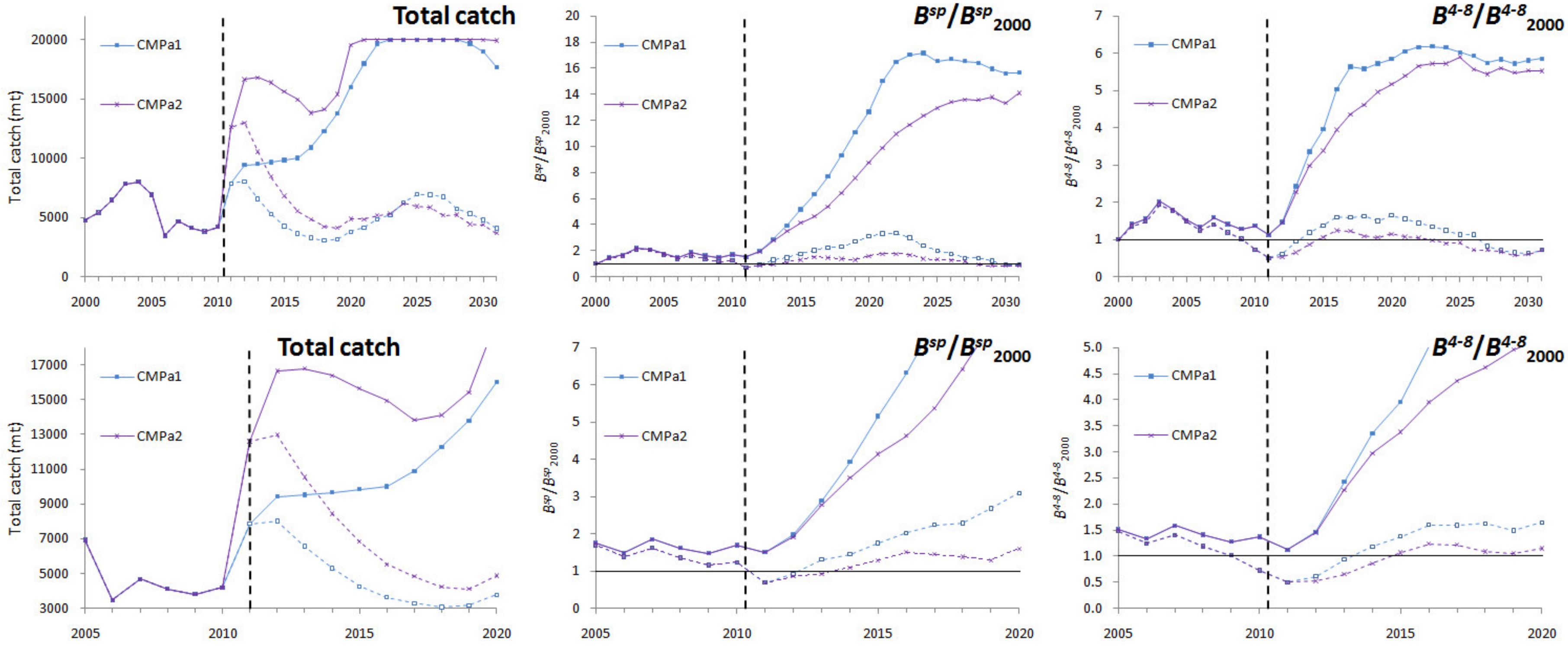

Fig. 3a: Median (full lines) and lower 2.5%iles (dashed lines) TAC, spawning biomass and exploitable (ages 4 to 8) biomass (both in terms of 2000 level) for **CMPa1** and **CMPa2** under the **RS**. The bottom row repeats the top row, but with different scales for improved discrimination.

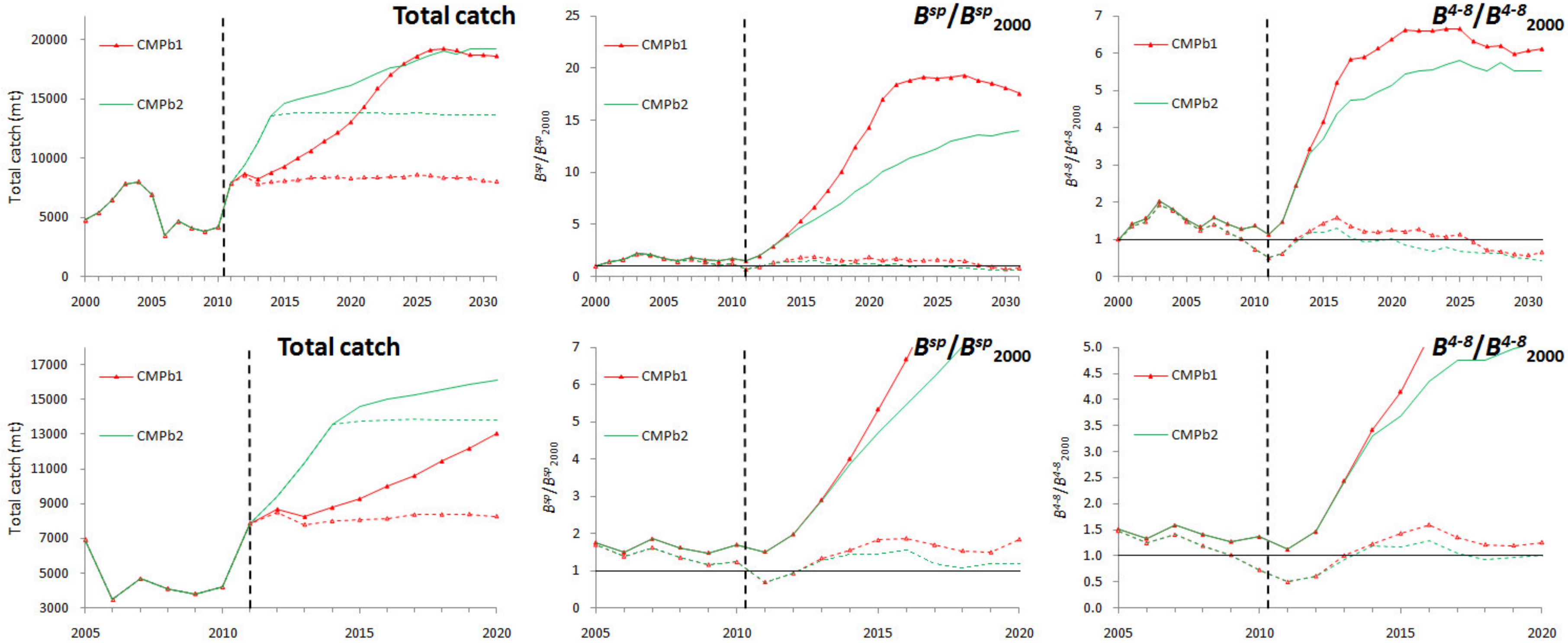

Fig. 3b: Median (full lines) and lower 2.5%iles (dashed lines) TAC, spawning biomass and exploitable (ages 4 to 8) biomass (both in terms of 2000 level) for **CMPb1** and **CMPb2** under the **RS**. The bottom row repeats the top row, but with different scales for improved discrimination.

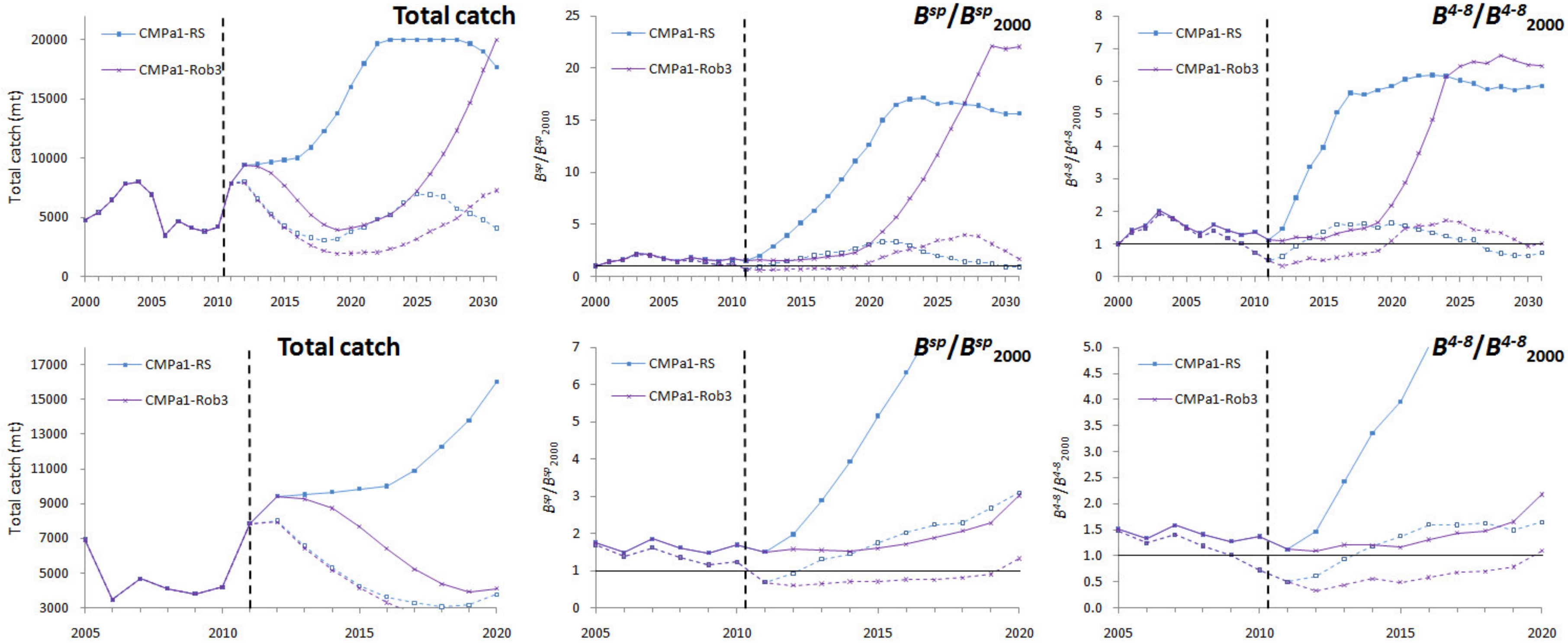

Fig. 3c: Median (full lines) and lower 2.5%iles (dashed lines) TAC, spawning biomass and exploitable (ages 4 to 8) biomass (both in terms of 2000 level) for **CMPa1** under the **RS** and under **Rob3**. The bottom row repeats the top row, but with different scales for improved discrimination.

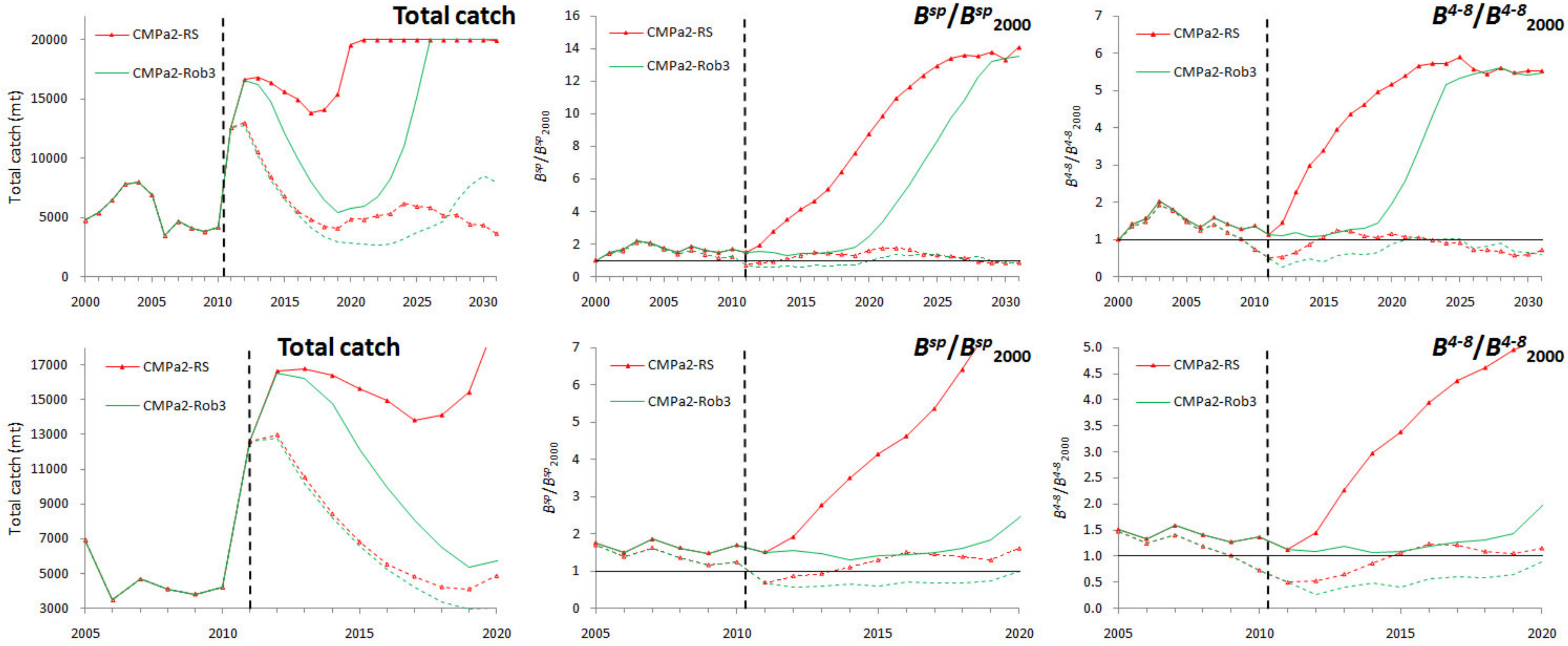

Fig. 3d: Median (full lines) and lower 2.5%iles (dashed lines) TAC, spawning biomass and exploitable (ages 4 to 8) biomass (both in terms of 2000 level) for **CMPa2** under the **RS** and under **Rob3**. The bottom row repeats the top row, but with different scales for improved discrimination.

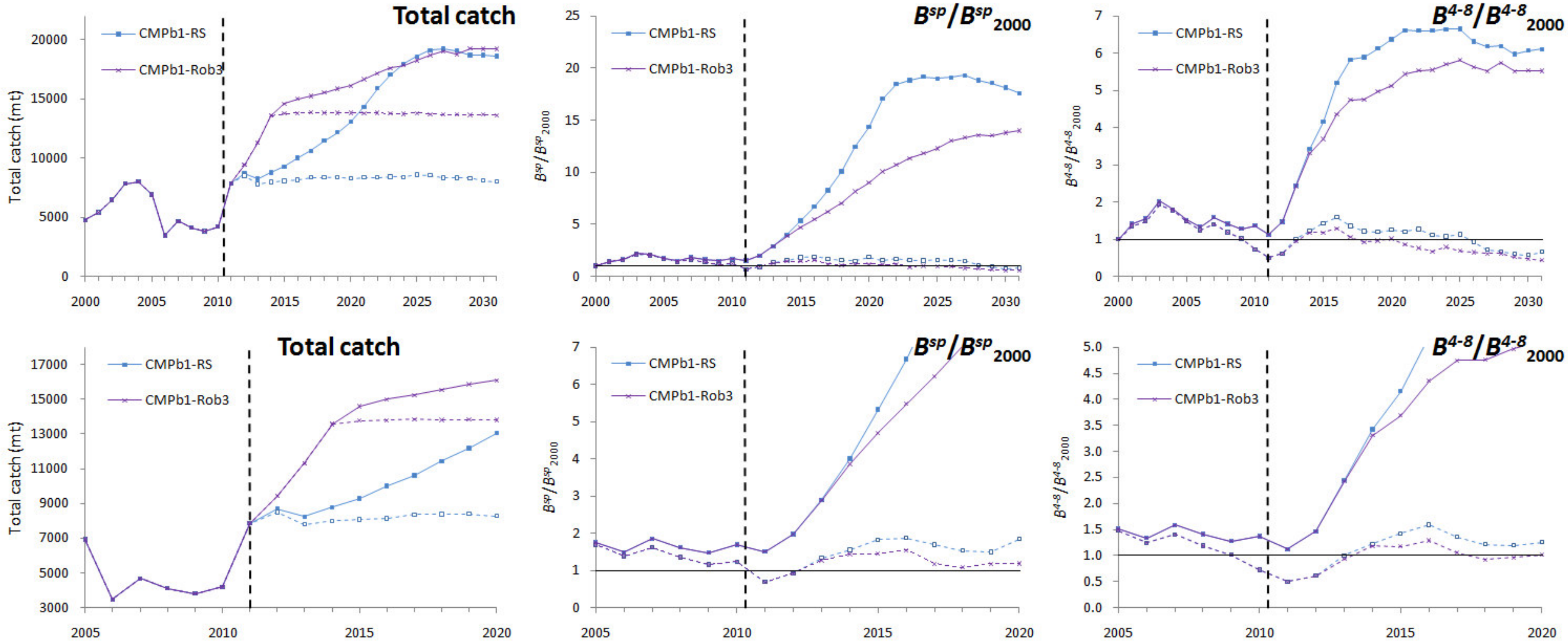

Fig. 3e: Median (full lines) and lower 2.5%iles (dashed lines) TAC, spawning biomass and exploitable (ages 4 to 8) biomass (both in terms of 2000 level) for **CMPb1** under the **RS** and under **Rob3**. The bottom row repeats the top row, but with different scales for improved discrimination.

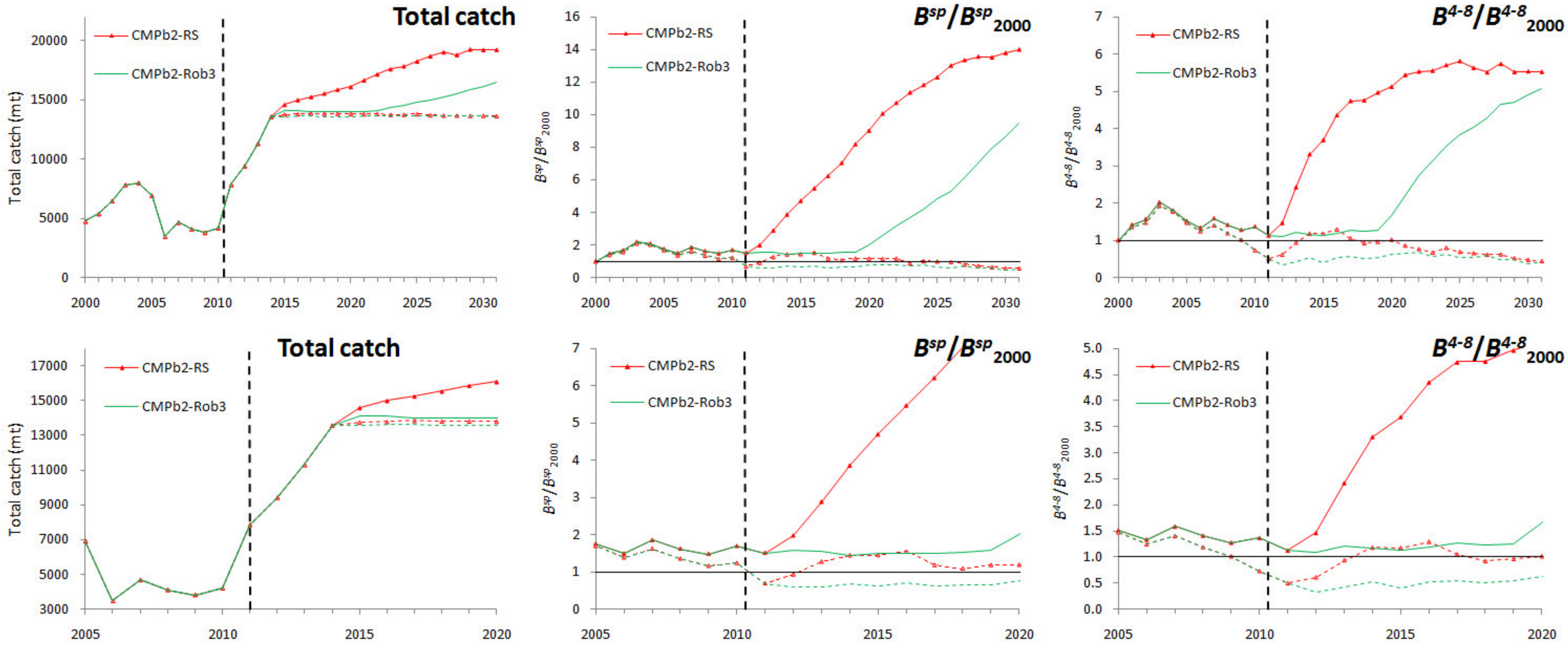

Fig. 3f: Median (full lines) and lower 2.5%iles (dashed lines) TAC, spawning biomass and exploitable (ages 4 to 8) biomass (both in terms of 2000 level) for **CMPb2** under the **RS** and under **Rob3**. The bottom row repeats the top row, but with different scales for improved discrimination.

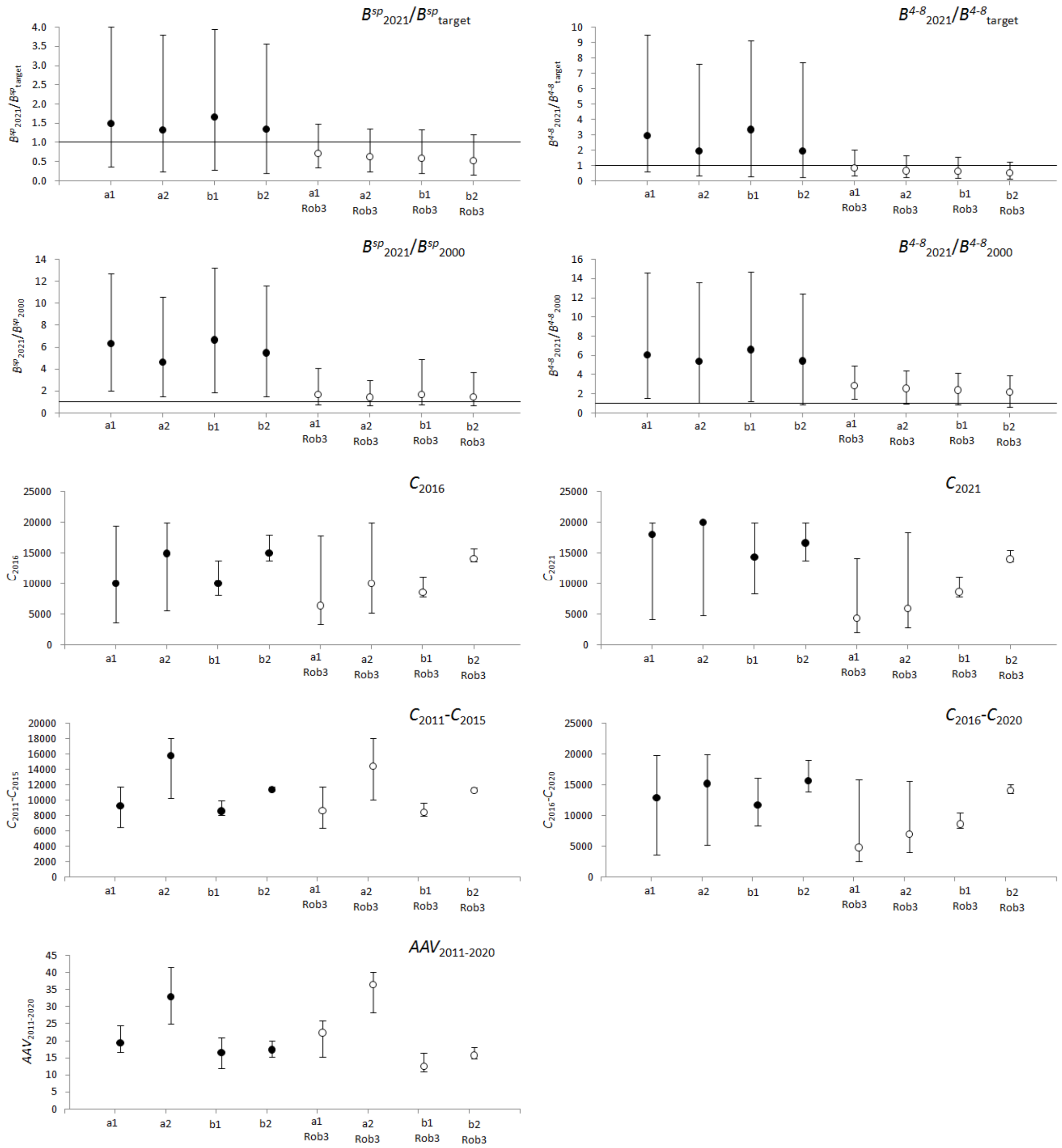

Fig. 4: Medians and 95% PI (error bars) for a series of performance statistic for different CMPs applied to the **RS** (full circles) and **Rob3** robustness test (open circles).

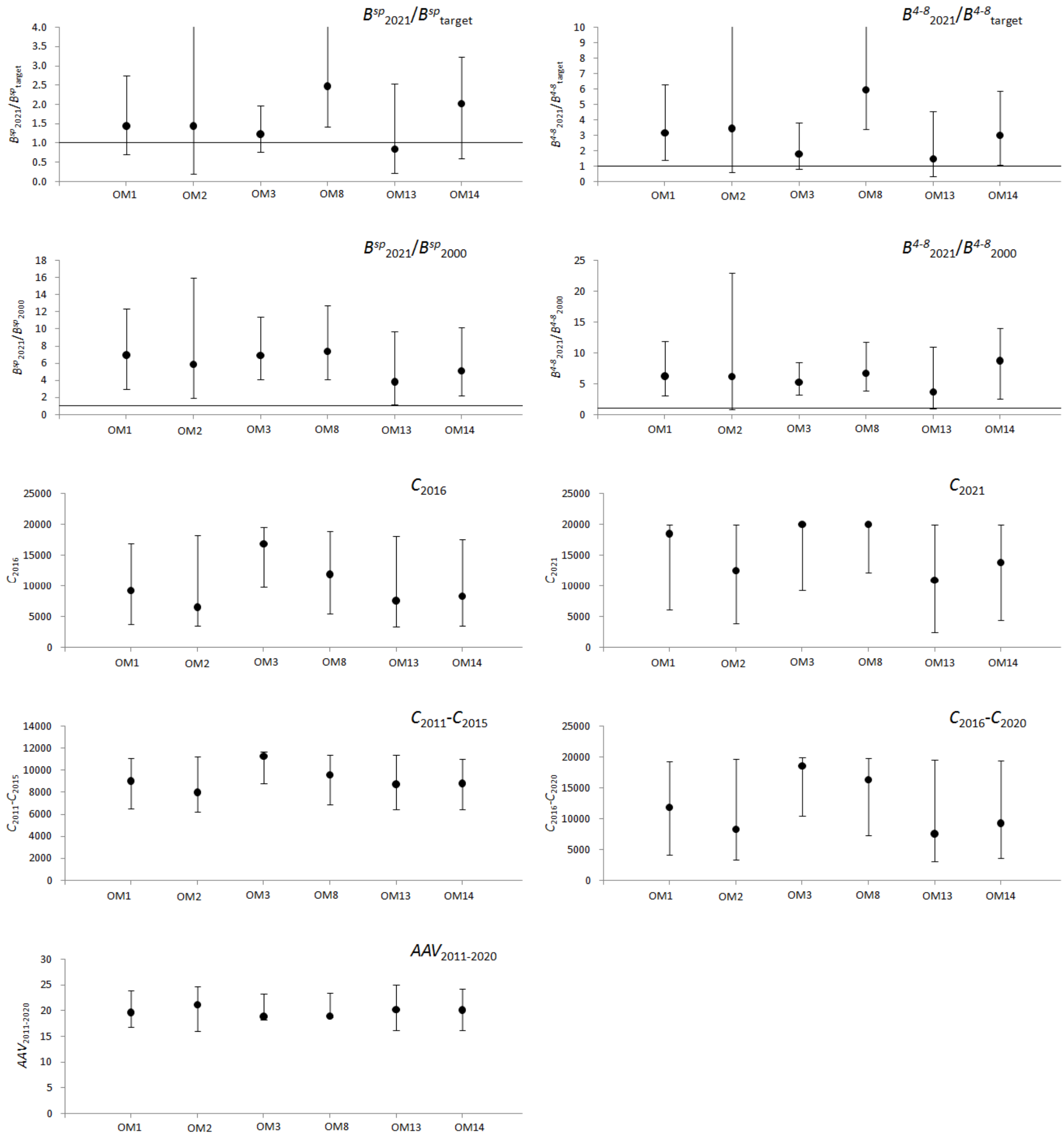

Fig. 5: Medians and 95% PI (error bars) for a series of performance statistic for CMPa1 applied to each OM constituting the RS (OM1=Rademeyer Base Case, OM2=Stone Base Case including 2010 survey, OM3=Stone Base Case excluding 2010 survey, OM8=higher *M* at older ages, OM13=OM1 with future recruitment based on last 5 years data, OM14=OM1 with future recruitment based on modified BH).

APPENDIX A: The Reference Set of Operating Models

Fig. A1 plots the trajectories for the proposed VPA Reference Set for use in CMP testing. This proposed Reference Set includes the following cases, which are VPA variants selected to attempt to span the range of uncertainties encompassed by key choices for different features of the VPA:

OM1) RAD 1 (Rademeyer and Butterworth, 2010): no bias correction, *M*=0.2, stock-recruitment relationship based on last 10 reliable years (1999-2008), including 2010 survey estimate;

OM2) Stone (Stone, 2010): with bias correction, *M*=0.2 and including 2010 survey estimate;

OM3) Stone (Stone, 2010): with bias correction, *M*=0.2 and excluding 2010 survey estimate;

OM8) High *M*: *M*=0.2 for ages 4 or less, high *M* (Stone estimates) for ages 5-13;

OM13) as OM1 but with stock-recruitment relationship based on last five reliable years (2004-2008); and

OM14) as OM1 but with Beverton-Holt stock-recruitment relationship fit up to a maximum value corresponding to the average values for spawning biomass above 20 000t.

Fig. A2 compares the stock-recruitment relationships for each of the six OMs.

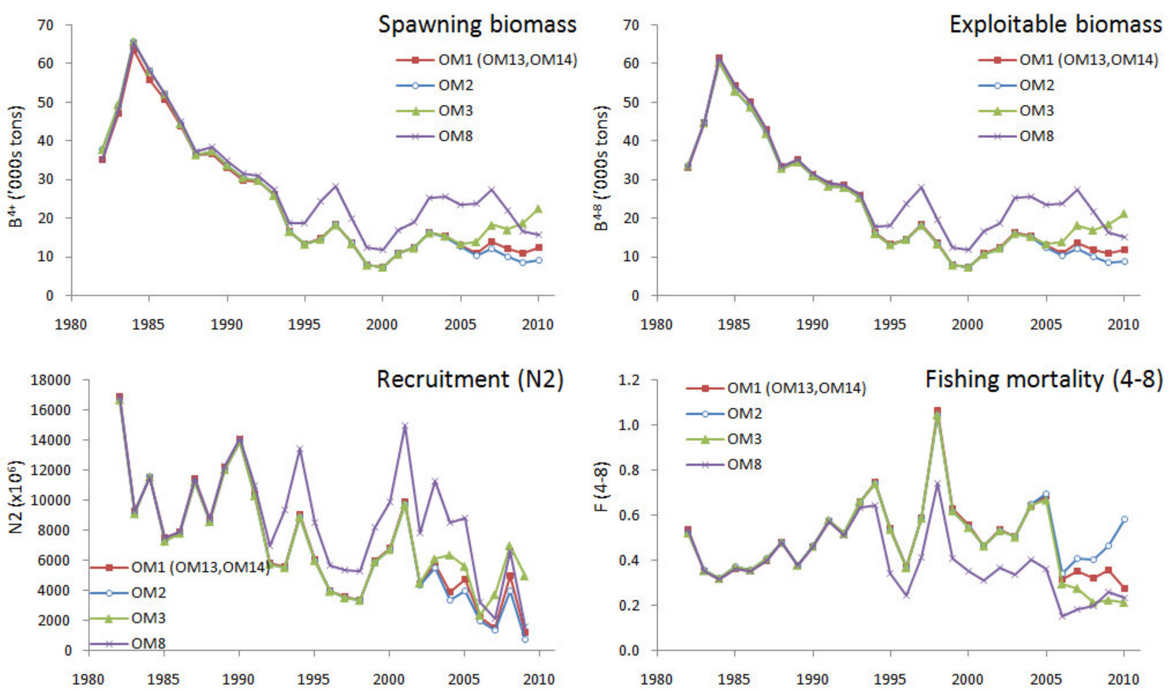

Fig. A1: Time-trajectories of spawning biomass (B4+), exploitable biomass (B4-8), recruitment (N2) and fishing mortality (ages 4-8) for the new RS of OMs.

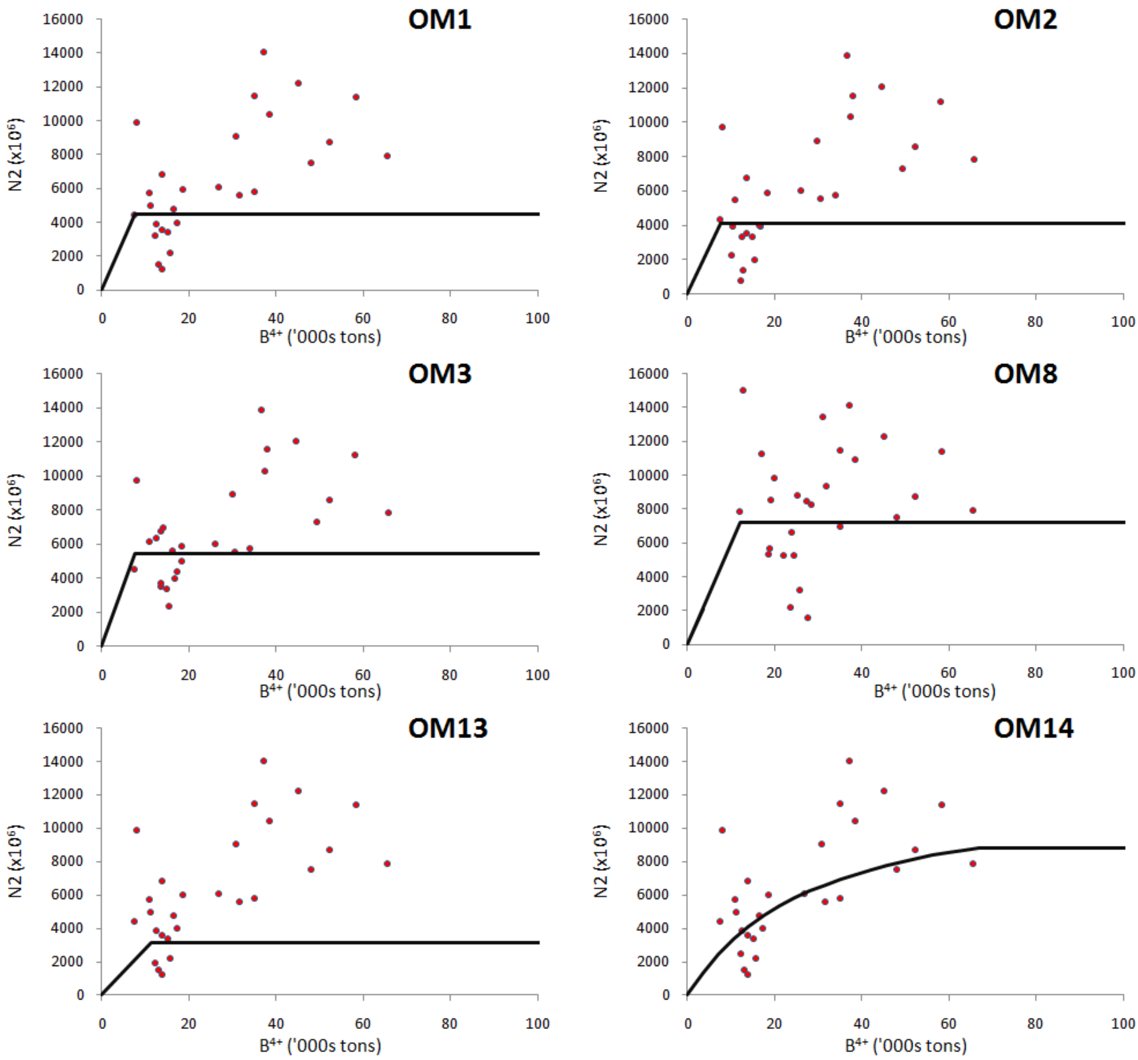

Fig. A2: Stock-recruitment relationships for each of the six OMs in the RS. The past "data" are also shown.

APPENDIX B: Technical Specifications of Candidate Management Procedures

The Candidate Management Procedures (CMPs) formulae for computing the TAC each year are as follows:

$$C_{y+1} = C_y \left[1 + \lambda_{up/down} s_y\right] \quad \text{(B1)}$$

for slope-based CMPs and

$$C_{y+1} = \left[a + b\left(J_y - 1\right)\right] \quad \text{(B2)}$$

for target-based CMPs

where

C_y is the total TAC recommended for year *y*,

$\lambda_{up/down}$ are tuning parameters; λ_{up} is used if $s_y \geq 0$ and λ_{down} is used if $s_y < 0$,

s_y is a measure of the immediate past trend in the survey abundance index (see details below) as available to use for calculations for year *y*,

a and b are tuning parameters, and

J_y is a measure of the immediate past level in the survey abundance index relative to a target level as available to use for calculations for year *y*:

$$J_y = \frac{\sum_{y-2}^{y} I_y \Big/ 3}{\sum_{1984}^{1994} I_y \Big/ 11}$$

where I_y is the survey abundance index in year *y*.

The trend measure s_y is computed by linearly regressing $\ln I_y$ *vs* year *y′* for $y' = y - p$ to $y' = y$.

where *p* is a tuning parameter.

Constraints on the interannual TAC change have also been introduced and a cap (upper bound) on the TAC has been imposed.