Final Set of Candidate Management Procedures for the South African hake resource

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October 2010

Abstract

This paper presents detailed results for the anticipated performances of six final Candidate Management Procedures (CMPs) for hake, both for the Reference Set of trials and for a wide range of robustness tests. The final choice amongst these six CMPs for the hake OMP to be recommended to provide TAC recommendations for 2011 to 2014 is to be made at the Demersal Working Group (DWG) meeting on 18 October. It is suggested that in making this choice the DWG focus on trade-offs amongst the six CMPs shown in four specific plots related to: i) future TACs compared to the risk of *M. paradoxus* depletion (together with subsequent recovery) for the Reference Set of trials and for the most difficult of the robustness tests (a decrease in carrying capacity *K* in the past), and also ii) the extent of inter-annual TAC variability that each CMP evidences.

Introduction

As agreed at the last DWG meeting, the final set of CMPs for consideration include three tunings to the median average TAC (2011-2020) of 127, 132 and 137 000t and two options for the annual TAC change constraints (+10%,-5% and +10%,-10%), i.e. six candidates in all. For all these CMPs, a penalty term (see equations 1 and 2, Rademeyer and Butterworth, 2010) is included to secure improved performance for certain more severe robustness tests.

The full set of CMPs considered in this document are listed in Table 1a, with their control parameter values given in Table 1b. This paper provides results for their application to the Reference Set (RS) trials and the full set of robustness tests.

Results

Reference Set

Results for the six CMPs are reported in Table 2. Figs 1a-f plot a large number of projection statistics for each of the six CMPs, with Fig. 1g comparing the percentage annual TAC change for the six CMPs. Medians and lower 2.5%iles for the TAC and for B^{sp}/B^{sp}_{2010} for *M. paradoxus* under RSa are compared in Fig. 2, while Fig. 3 is a similar plot of B^{sp}/B^{sp}_{MSY} for *M. paradoxus* under RSa. Worm plots together with 80%iles for the TAC and for B^{sp}/B^{sp}_{2010} for each of the six CMPs under RSa are shown in Fig. 4.

Fig. 5 compares medians and 95%iles for a series of performance statistics under the six CMPs for the RS.

Robustness tests

The full set of robustness tests are listed in Appendix A. Results for the base case CMP (CMPf1a) under the full set of robustness tests are given in Table 3, and medians and 95%iles for a series of performance statistics are plotted in Fig. 6. To save on time (and report length), only the least conservative of the six CMPs (CMPf1a) has been tested against the full set, because the other candidates would show better risk-related performances.

Medians and lower 2.5%iles are plotted for the TAC and for B^{sp}/B^{sp}_{2010} for *M. paradoxus* for the more severe robustness tests based on the RC are shown in Fig. 7. Similarly Fig. 8 plots the medians and lower 2.5%iles for the TAC and for for B^{sp}/B^{sp}_{2010} for *M. capensis* for the robustness tests based on the RS11 (*M. capensis* in need of rebuilding).

Medians and lower 2.5%iles for the TAC and for B^{sp}/B^{sp}_{2010} for *M. paradoxus* under Rob13, the most severe robustness test (decrease in *K* in the past), are compared in Fig. 9 for each of the six CMPs.

Discussion

Broadly speaking the results for the six CMPs for the RS have been seen in the past. The only new aspect here is the presentation of their anticipated performances in rather more detail. However, no new qualitative features seem to have become evident in this process.

Full presentation of robustness test results is what is new here. What stands out from the comparisons in Fig. 6 for RSa-related tests is that the risk in terms of unintended depletion of *M. paradoxus* to a low spawning biomass is much higher for test Rob13 (a decrease in *K* in the past) than for any of the other tests. This is confirmed in the Fig. 7 plots for the seven most difficult of these tests, where only for Rob13 is there any appreciable reduction at the lower 2.5%ile below the 2007 minimum spawning biomass for *M. paradoxus*.

For the RSb-related robustness tests for which results are shown in Fig. 8, median recovery rates for *M. capensis* are slow, but perhaps of most importance is that again there is scarcely any probability at the lower 2.5%ile of dropping below the 2007 spawning biomass minimum.

Summary remarks

The key decision to be made on the basis of the results presented in this paper is a choice amongst the six CMPs considered. It is suggested that in making this choice, the Demersal Working Group should focus on the trade-offs amongst these candidates that are evident from four specific plots.

Trade-offs between higher TACs and higher risk of M. paradoxus depletion

Fig. 2b: which shows the trade-offs at the lower 2.5%ile in relation to the *M. paradoxus* spawning biomass dropping below its current 2010 level; and

Fig. 3: which shows similar plots in terms of recovery to the MSY level for spawning biomass; these and those in Fig. 2c need to be considered also in the context of satisfying MSC-related recovery requirements; and further

Fig. 9: which shows these same trade-offs for the most difficult of the robustness tests, Rob13.

Trade-offs in relation to inter-annual TAC variation

Fig. 1g: which contrasts the levels of this variation to be expected under the six CMPs.

Reference

Rademeyer RA and Butterworth DS. 2010. Further Candidate Management Procedure testing for the South African hake resource. Unpublished report, Marine and Coastal Management, South Africa. FISHERIES/2010/AUGUST/SWG-DEM/37.

Table 1a: Summary of the CMPs tested.

CMP	Description
CMPf1a	**Base Case f**, tuned to average catch of **137 000t** over 2011-2020, with +10%, -5% inter-annual TAC change constraints
CMPf1b	**Base Case f**, tuned to average catch of **132 000t** over 2011-2020, with +10%, -5% inter-annual TAC change constraints
CMPf1c	**Base Case f**, tuned to average catch of **127 000t** over 2011-2020, with +10%, -5% inter-annual TAC change constraints
CMPf1d	**Base Case f**, tuned to average catch of **137 000t** over 2011-2020, with +10%, -10% inter-annual TAC change constraints
CMPf1e	**Base Case f**, tuned to average catch of **132 000t** over 2011-2020, with +10%, -10% inter-annual TAC change constraints
CMPf1f	**Base Case f**, tuned to average catch of **127 000t** over 2011-2020, with +10%, -10% inter-annual TAC change constraints

Table 1b: Tuning parameter values for each CMP presented. T^{para} applies up to the year 2015 and then declines linearly to zero in year 2018.

CMP	λ_{up}	λ_{down}	T^{para}	T^{cap}	w	a^{para}	a^{cap}	b^{para}	b^{cap}	c^{para}	c^{cap}	p^{para}	p^{cap}	Q_{min}	Annual change constraints	
CMPf1a	1.25	1.50	0.50%	0	1-0.5	114.3	40	60	20	180	20	0.75	0.75	0.75	+10%	-5%*
CMPf1b	1.25	1.50	0.75%	0	1-0.5	104.5	40	60	20	180	20	0.75	0.75	0.75	+10%	-5%*
CMPf1c	1.25	1.50	1.00%	0	1-0.5	94.7	40	60	20	180	20	0.75	0.75	0.75	+10%	-5%*
CMPf1d	1.25	1.50	0.50%	0	1-0.5	115.4	40	60	20	180	20	0.75	0.75	0.75	+10%	-10%*
CMPf1e	1.25	1.50	0.75%	0	1-0.5	105.7	40	60	20	180	20	0.75	0.75	0.75	+10%	-10%*
CMPf1f	1.25	1.50	1.00%	0	1-0.5	96.2	40	60	20	180	20	0.75	0.75	0.75	+10%	-10%*

Table 2a: Projections results (either median, lower or upper 2.5%ile) "at a glance" for a series of performance statistics for the final set of CMPs under the RS. Catch units are thousand tons.

			CMPf1a	CMPf1b	CMPf1c	CMPf1d	CMPf1e	CMPf1f
		RSa						
median	BS	avC: 2011-2020	137.0	132.0	127.0	137.0	132.0	127.0
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.71	0.72	0.73	0.71	0.72	0.73
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.75	0.77	0.78	0.77	0.78	0.78
median	para	B^{sp}_{2020}/B_{MSY}	1.11	1.20	1.29	1.10	1.19	1.29
median	cap	B^{sp}_{2020}/B_{MSY}	2.87	2.90	2.93	2.87	2.89	2.93
median	BS	AAV	3.6	3.5	3.5	3.8	3.7	3.7
low	BS	lowest TAC (2011-2030)	94.5	91.9	87.8	99.7	94.9	89.7
	BS	Prob decl >20% (2011-2013)	1.3	1.5	1.5	0.1	0.2	0.2
	BS	Prob decl >20% (2012-2014)	1.4	1.4	1.6	1.0	1.2	1.1
median	BS	Pdecl>20% (2011-2028)	0.0	0.0	0.0	0.0	0.0	0.0
high	BS	Pdecl>20% (2011-2028)	5.6	5.6	5.6	5.6	0.1	0.0
		RSb						
median	BS	avC: 2011-2015	130.5	125.6	120.6	131.6	126.7	121.8
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.93	0.93	0.93	0.93	0.93	0.93
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.80	0.85	0.87	0.80	0.84	0.87
median	para	B^{sp}_{2020}/B_{MSY}	0.89	0.96	1.04	0.88	0.95	1.00
median	cap	B^{sp}_{2020}/B_{MSY}	0.55	0.57	0.60	0.54	0.56	0.58
median	BS	AAV	3.5	3.4	3.6	3.4	3.4	3.6
low	BS	lowest TAC (2011-2030)	86.1	84.5	75.3	99.4	87.7	84.2
	BS	Prob decl >20% (2011-2013)	3.0	3.5	3.5	0.0	0.0	1.0
	BS	Prob decl >20% (2012-2014)	3.0	7.0	9.0	2.0	2.0	2.0
median	BS	Pdecl>20% (2011-2028)	0.0	0.0	0.0	0.0	0.0	0.0
high	BS	Pdecl>20% (2011-2028)	5.6	11.1	11.1	5.6	5.6	5.6

Table 2b: Projections results (medians with, lower and upper 2.5%iles shown in parenthesis below) for the series of performance statistics for which plots are given in Fig. 5 for the final set of CMPs under the RS. Catch units are thousand tons.

		CMPf1a	CMPf1b	CMPf1c	CMPf1d	CMPf1e	CMPf1f
	RSa						
BS	C_{2011}	126.1 (120.3; 131.5)	125.8 (120.0; 131.2)	125.5 (119.7; 130.9)	126.1 (120.3; 131.5)	125.8 (120.0; 131.2)	125.5 (119.7; 130.9)
BS	C_{2012}	129.6 (114.8; 140.1)	129.0 (112.7; 139.5)	128.3 (112.1; 138.9)	129.6 (115.5; 140.1)	129.0 (114.8; 139.5)	128.3 (114.1; 138.9)
BS	C_{2013}	131.0 (105.5; 151.0)	129.9 (101.0; 150.0)	128.9 (100.4; 148.9)	131.0 (109.1; 151.0)	129.9 (108.2; 150.0)	128.8 (107.2; 148.9)
BS	AAV	3.6 (1.3; 6.2)	3.5 (1.3; 6.0)	3.5 (1.3; 6.0)	3.8 (1.3; 6.3)	3.7 (1.3; 6.2)	3.7 (1.3; 6.2)
BS	avC: 2011-2015	130.6 (110.2; 150.1)	128.7 (107.1; 148.1)	127.0 (105.6; 146.2)	130.5 (112.9; 150.2)	128.5 (111.0; 148.2)	126.6 (109.1; 146.4)
BS	avC: 2011-2020	137.0 (116.5; 157.9)	132.0 (111.7; 153.1)	127.0 (107.1; 147.9)	137.0 (118.0; 157.7)	132.0 (113.3; 152.5)	127.0 (108.8; 147.5)
BS	avC: 2011-2030	139.9 (126.0; 153.9)	134.7 (120.8; 148.7)	129.0 (114.7; 143.4)	140.1 (126.4; 153.9)	134.7 (120.9; 148.5)	129.2 (115.2; 143.6)
BS	Pdecl>20% (2011-2028)	0.0 (0.0; 5.6)	0.0 (0.0; 5.6)	0.0 (0.0; 5.6)	0.0 (0.0; 5.6)	0.0 (0.0; 0.1)	0.0 (0.0; 0.0)
	RSa						
para	$B^{sp}_{low}/B^{sp}_{2010}$	1.00 (0.71; 1.10)	1.00 (0.72; 1.10)	1.00 (0.73; 1.10)	1.00 (0.71; 1.10)	1.00 (0.72; 1.10)	1.00 (0.73; 1.10)
para	B^{sp}_{2020}/B_{MSY}	1.11 (0.66; 3.79)	1.20 (0.72; 4.00)	1.29 (0.77; 4.19)	1.10 (0.66; 3.75)	1.19 (0.72; 3.95)	1.29 (0.79; 4.16)
para	B^{sp}_{2030}/K^{sp}	0.32 (0.16; 0.54)	0.36 (0.19; 0.59)	0.39 (0.23; 0.63)	0.32 (0.16; 0.54)	0.35 (0.19; 0.58)	0.39 (0.23; 0.62)
para	$B^{sp}_{2030}/B^{sp}_{2010}$	1.74 (1.12; 2.56)	1.98 (1.27; 2.88)	2.18 (1.40; 3.20)	1.74 (1.16; 2.56)	1.96 (1.29; 2.87)	2.16 (1.40; 3.16)
	RSb						
cap	$B^{sp}_{low}/B^{sp}_{2010}$	1.07 (0.80; 1.18)	1.08 (0.85; 1.18)	1.08 (0.87; 1.18)	1.07 (0.80; 1.18)	1.08 (0.84; 1.18)	1.08 (0.87; 1.18)
cap	B^{sp}_{2020}/B_{MSY}	0.55 (0.38; 0.71)	0.57 (0.40; 0.73)	0.60 (0.42; 0.75)	0.54 (0.38; 0.70)	0.56 (0.40; 0.73)	0.58 (0.42; 0.75)
cap	B^{sp}_{2030}/K^{sp}	0.25 (0.16; 0.35)	0.27 (0.18; 0.38)	0.30 (0.21; 0.40)	0.25 (0.16; 0.35)	0.27 (0.18; 0.37)	0.29 (0.20; 0.40)
cap	$B^{sp}_{2030}/B^{sp}_{2010}$	1.38 (0.89; 1.86)	1.51 (1.00; 2.01)	1.63 (1.13; 2.13)	1.36 (0.87; 1.83)	1.49 (0.98; 1.97)	1.61 (1.10; 2.10)

Table 3a: Projections results (either median, lower or upper 2.5%ile) for a series of performance statistics for CMPf1a under the full set of robustness tests based on the RC. The "low para $B^{sp}_{low}/B^{sp}_{2010}$" cells are shaded if values are less than 0.7 (the 2007 level); the "lowest TAC (2011-2030)" cells are shaded if less than 95 (thousand tons).

			RS1	Rob1	Rob2	Rob3	Rob4	Rob5	Rob6	Rob7	Rob8	Rob9
median	BS	avC: 2011-2020	138.2	131.0	131.4	133.3	141.1	130.9	138.2	141.1	146.2	159.3
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.83	0.92	0.59	0.85	1.01	0.69	0.95	0.86	0.89	0.84
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.98	1.02	1.01	1.00	1.03	0.96	0.93	0.99	0.80	0.82
median	para	B^{sp}_{2020}/B_{MSY}	1.05	1.58	1.00	2.21	0.82	0.80	1.06	1.10	0.75	0.70
median	cap	B^{sp}_{2020}/B_{MSY}	2.41	5.32	4.13	4.41	2.43	2.00	2.32	2.36	2.34	1.95
median	BS	AAV	3.5	3.7	3.6	3.6	3.4	3.5	3.3	3.6	4.2	4.6
low	BS	lowest TAC (2011-2030)	105.6	92.1	97.4	100.4	116.3	97.1	111.3	112.6	107.4	117.2
	BS	Prob decl >20% (2011-2013)	0.0	4.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	BS	Prob decl >20% (2012-2014)	0.0	3.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
median	BS	Pdecl>20% (2011-2028)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
high	BS	Pdecl>20% (2011-2028)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

			RS1	Rob10	Rob11	Rob12a	Rob12b	Rob12c	Rob12d	Rob13	Rob14	Rob15
median	BS	avC: 2011-2020	138.2	142.3	139.8	135.9	137.6	139.6	137.8	87.9	150.7	131.0
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.83	0.75	0.88	0.87	0.85	0.76	0.80	0.26	0.80	0.69
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.98	0.59	1.03	0.94	0.92	0.80	0.93	1.02	0.83	0.88
median	para	B^{sp}_{2020}/B_{MSY}	1.05	1.12	1.04	1.06	1.12	1.01	0.99	0.72	1.15	1.07
median	cap	B^{sp}_{2020}/B_{MSY}	2.41	1.11	2.64	1.82	1.90	2.13	2.38	2.11	1.92	2.03
median	BS	AAV	3.5	3.9	3.5	3.6	3.6	3.5	3.5	7.6	4.0	3.5
low	BS	lowest TAC (2011-2030)	105.6	93.9	109.0	99.7	102.6	109.1	106.3	31.4	113.0	96.3
	BS	Prob decl >20% (2011-2013)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.0	0.0	0.0
	BS	Prob decl >20% (2012-2014)	0.0	0.0	0.0	1.0	0.0	0.0	0.0	66.0	0.0	0.0
median	BS	Pdecl>20% (2011-2028)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
high	BS	Pdecl>20% (2011-2028)	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.3	0.1	0.0

			RS1	Rob16	Rob17	Rob18	Rob19a	Rob19b	Rob19c	Rob20a	Rob20b	Rob20c
median	BS	avC: 2011-2020	138.2	142.7	155.2	145.1	145.2	145.6	133.5	138.6	137.4	138.7
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.83	1.00	0.80	0.79	0.83	0.78	0.87	0.83	0.83	0.79
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.98	1.05	0.82	0.94	1.00	0.88	1.02	0.98	0.97	0.98
median	para	B^{sp}_{2020}/B_{MSY}	1.05	0.85	1.06	1.33	1.03	0.97	1.27	1.05	1.06	0.96
median	cap	B^{sp}_{2020}/B_{MSY}	2.41	3.76	1.90	2.12	1.99	1.84	2.52	2.42	2.38	2.41
median	BS	AAV	3.5	3.4	4.3	3.7	3.6	3.8	3.5	3.5	3.6	3.6
low	BS	lowest TAC (2011-2030)	105.6	117.2	119.3	113.3	118.9	115.8	90.8	106.4	103.9	105.5
	BS	Prob decl >20% (2011-2013)	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0
	BS	Prob decl >20% (2012-2014)	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1.0	0.0
median	BS	Pdecl>20% (2011-2028)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
high	BS	Pdecl>20% (2011-2028)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0

			RS1	Rob21	Rob22	Rob23	Rob24a	Rob24b	Rob25	Rob26	Rob27	Rob28
median	BS	avC: 2011-2020	138.2	141.4	152.6	136.6	138.0	138.3	115.2	153.5	140.2	146.1
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.83	0.78	0.62	0.86	0.84	0.82	0.53	0.74	0.84	0.87
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.98	0.89	0.79	1.00	0.98	0.98	1.07	1.00	0.97	0.94
median	para	B^{sp}_{2020}/B_{MSY}	1.05	1.06	0.83	1.10	1.05	1.05	0.58	1.23	1.14	1.14
median	cap	B^{sp}_{2020}/B_{MSY}	2.41	1.60	1.15	1.92	2.35	2.48	2.11	2.47	2.55	1.85
median	BS	AAV	3.5	3.8	4.3	3.5	3.5	3.6	4.5	4.0	3.6	3.9
low	BS	lowest TAC (2011-2030)	105.6	101.5	114.8	103.1	105.3	105.8	69.4	122.1	110.0	117.9
	BS	Prob decl >20% (2011-2013)	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0
	BS	Prob decl >20% (2012-2014)	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0
median	BS	Pdecl>20% (2011-2028)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
high	BS	Pdecl>20% (2011-2028)	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0

			RS1	Rob29	Rob34a	Rob34b	Rob35	Rob36a	Rob36b	Rob36c	Rob37	Rob38
median	BS	avC: 2011-2020	138.2	139.4	138.0	138.6	142.5	142.4	139.3	140.8	137.3	138.2
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.83	0.80	0.82	0.84	0.74	0.93	0.85	0.88	0.52	0.83
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.98	1.04	1.00	0.96	0.95	1.06	1.01	1.03	0.49	0.98
median	para	B^{sp}_{2020}/B_{MSY}	1.05	0.98	1.02	1.09	0.97	1.25	1.11	1.18	1.31	1.05
median	cap	B^{sp}_{2020}/B_{MSY}	2.41	2.53	2.46	2.34	2.37	2.75	2.60	2.67	3.12	2.41
median	BS	AAV	3.5	3.6	3.6	3.5	3.6	3.6	3.6	3.6	6.0	3.5
low	BS	lowest TAC (2011-2030)	105.6	106.0	105.4	105.9	115.0	113.1	107.2	109.8	45.2	105.6
	BS	Prob decl >20% (2011-2013)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	BS	Prob decl >20% (2012-2014)	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
median	BS	Pdecl>20% (2011-2028)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
high	BS	Pdecl>20% (2011-2028)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0

Table 3b: Projections results (either median, lower or upper 2.5%ile) for a series of performance statistics for CMPf1a under the full set of robustness tests based on RS11 (*M. capensis* in need of rebuilding). The "low para $B^{sp}_{low}/B^{sp}_{2010}$" cells are shaded if values are less than 0.7 (the 2007 level); the "lowest TAC (2011-2030)" cells are shaded if less than 95 (thousand tons).

			RS11	Rob5	Rob13	Rob25	Rob37
median	BS	avC: 2011-2020	130.6	132.0	90.0	128.9	128.9
low	para	$B^{sp}_{low}/B^{sp}_{2010}$	0.93	1.00	0.38	0.78	0.78
low	cap	$B^{sp}_{low}/B^{sp}_{2010}$	0.84	0.75	0.92	0.69	0.69
median	para	B^{sp}_{2020}/B_{MSY}	0.89	0.78	0.99	1.10	1.10
median	cap	B^{sp}_{2020}/B_{MSY}	0.58	0.52	2.85	0.74	0.74
median	BS	AAV	3.5	3.4	8.2	4.4	4.4
low	BS	lowest TAC (2011-2030)	87.2	96.0	36.5	61.5	61.5

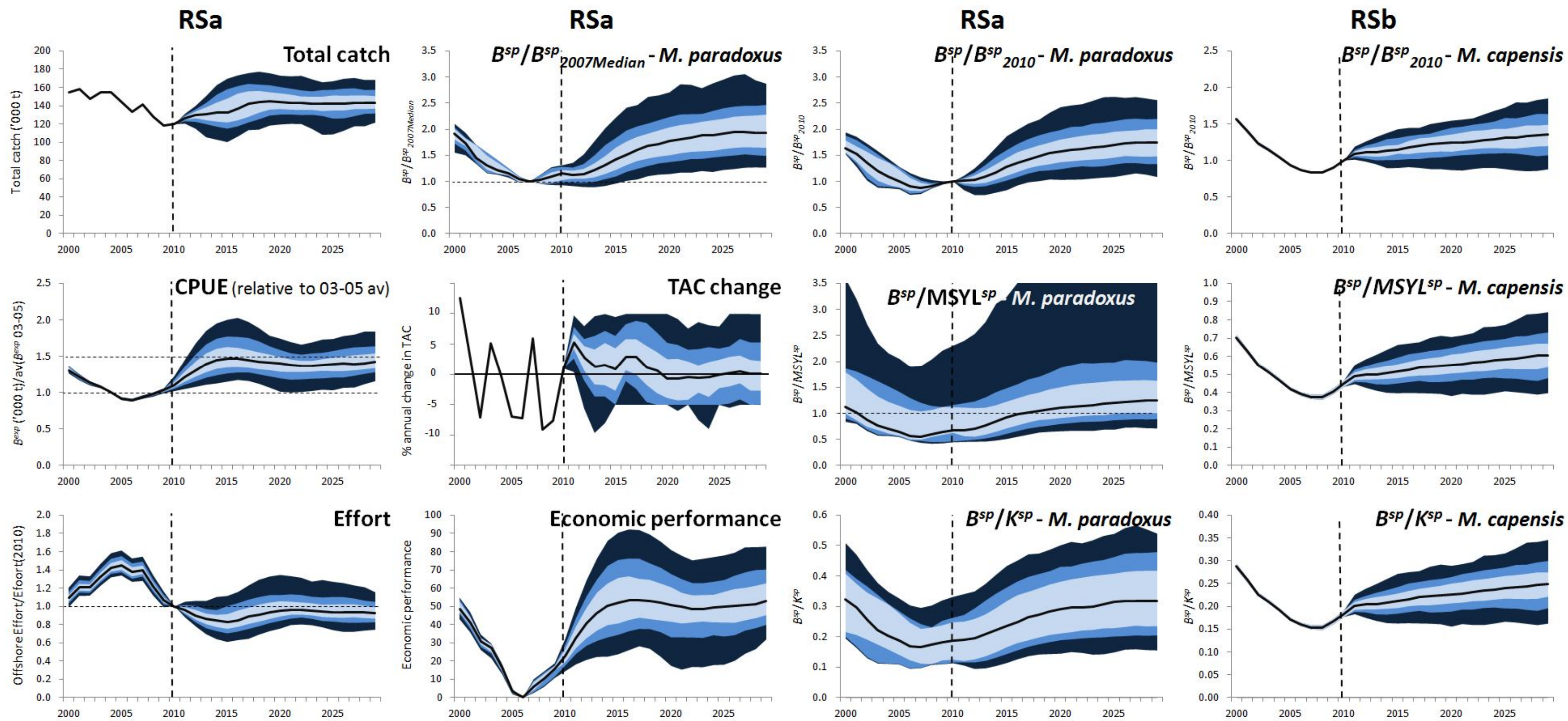

Fig. 1a: 95, 75, 50% PI and median for a series of performance statistics for **CMPf1a**.

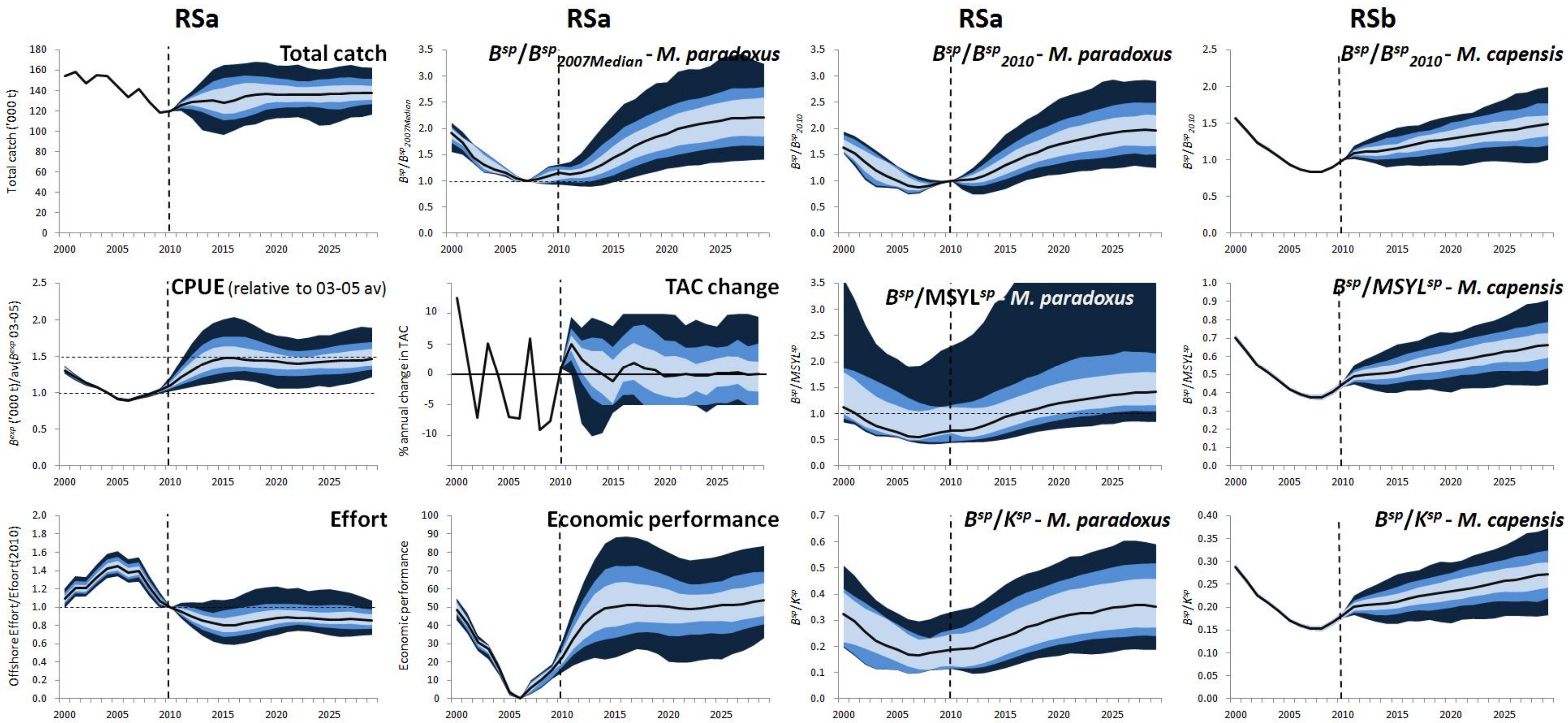

Fig. 1b: 95, 75, 50% PI and median for a series of performance statistics for **CMPf1b**.

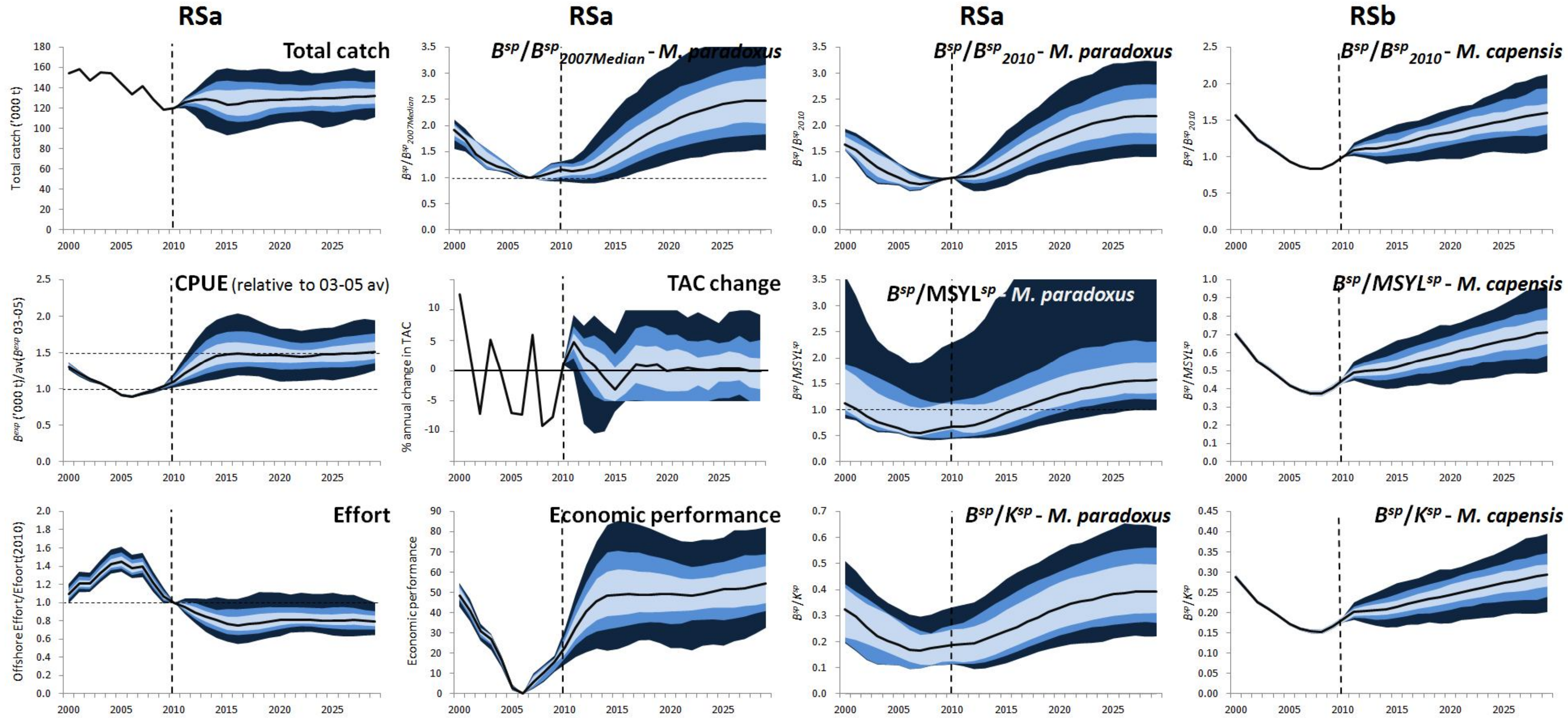

Fig. 1c: 95, 75, 50% PI and median for a series of performance statistics for **CMPf1c**.

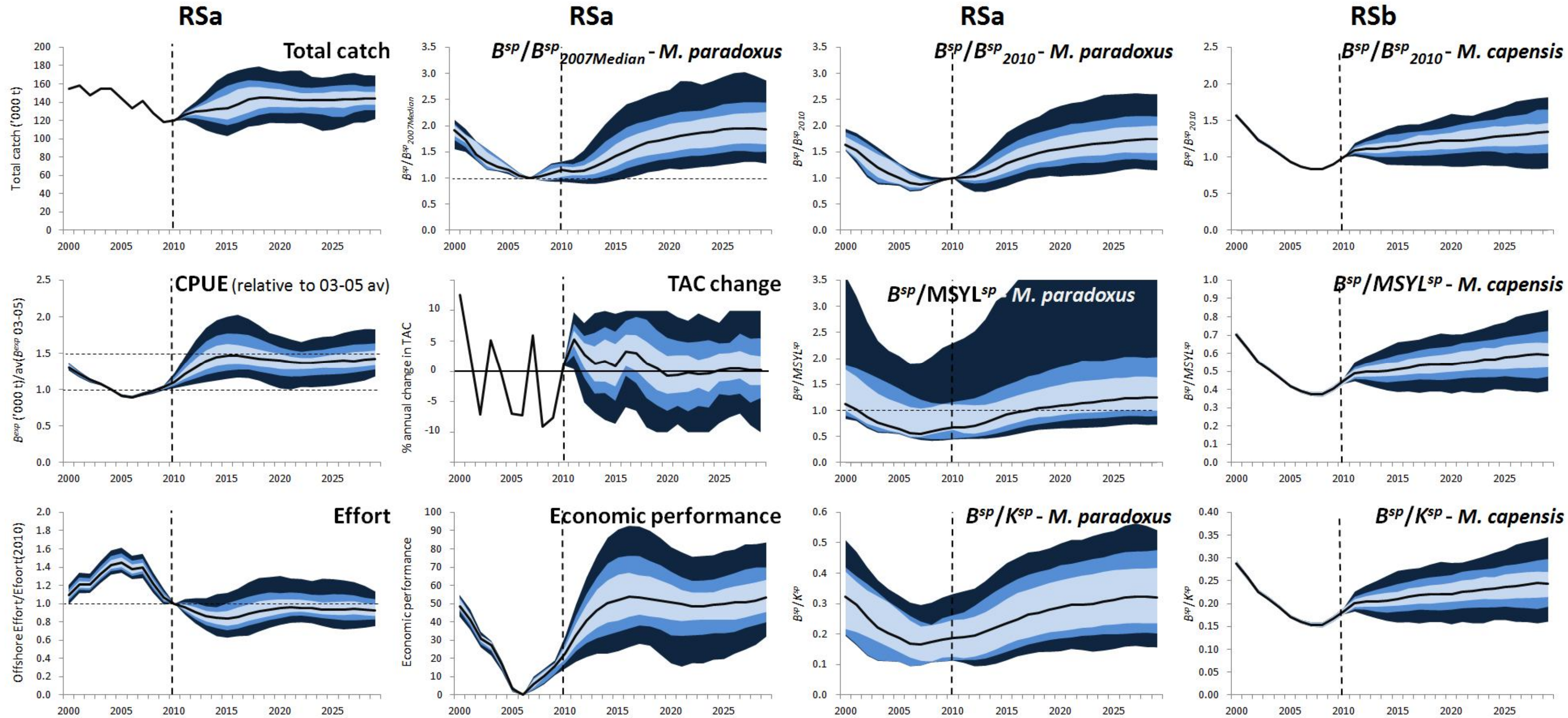

Fig. 1d: 95, 75, 50% PI and median for a series of performance statistics for **CMPf1d**.

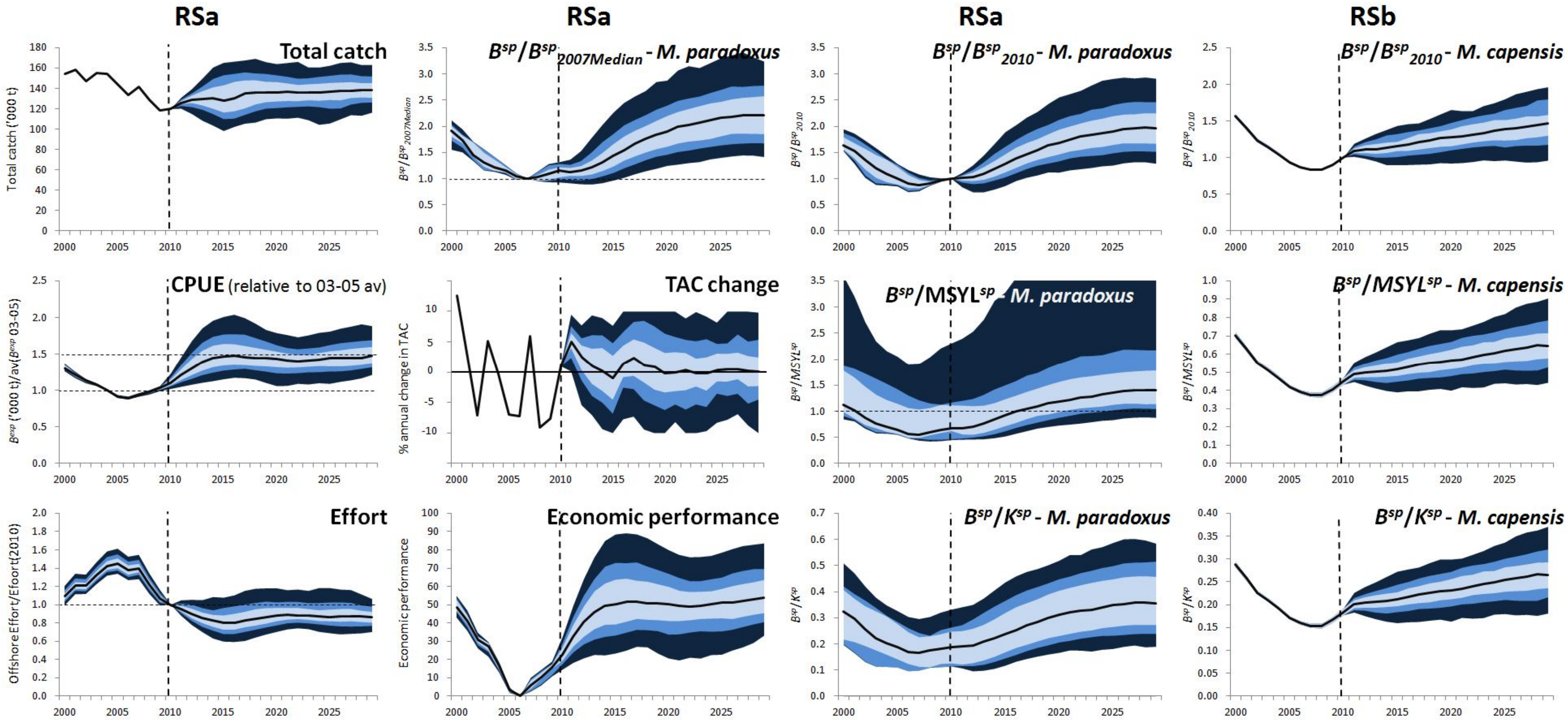

Fig. 1e: 95, 75, 50% PI and median for a series of performance statistics for **CMPf1e**.

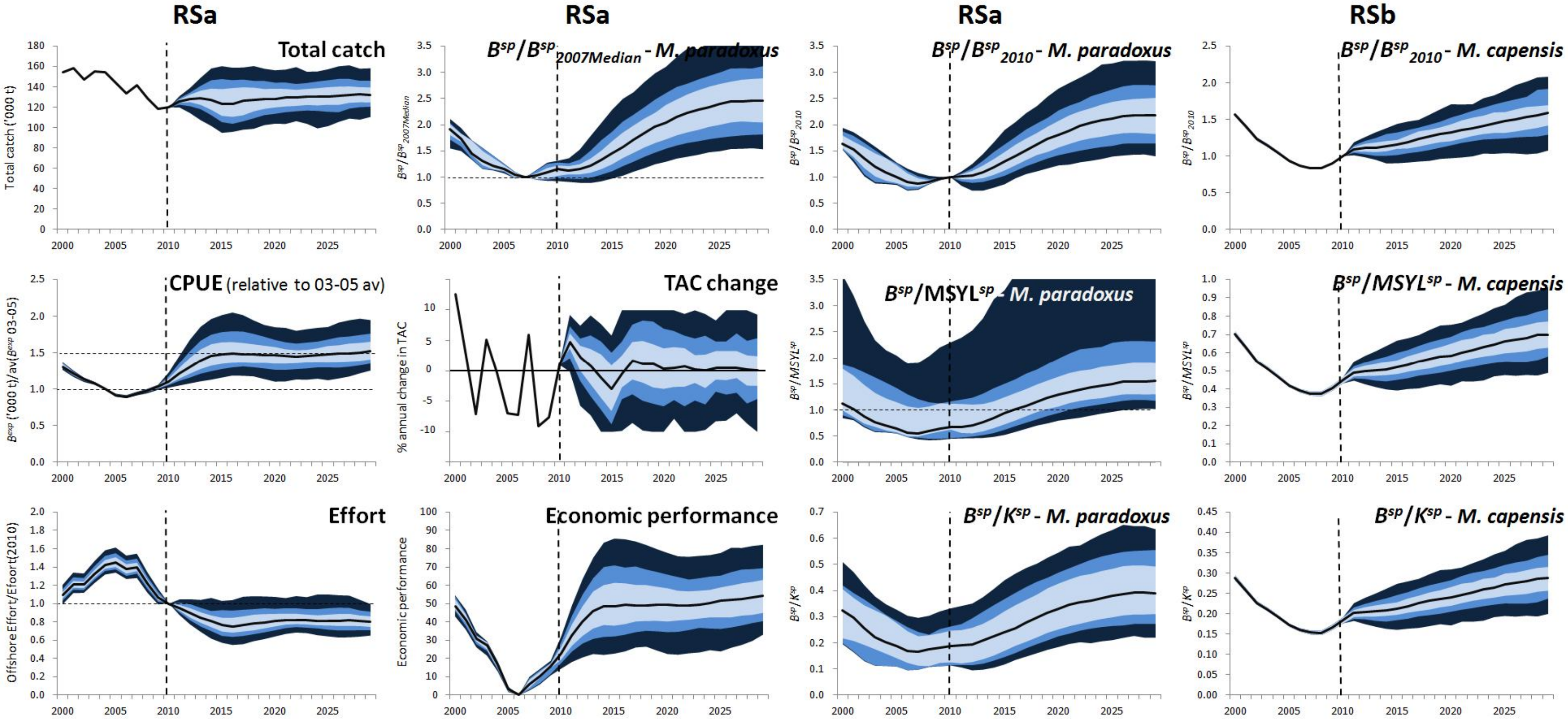

Fig.1f: 95, 75, 50% PI and median for a series of performance statistics for **CMPf1f**.

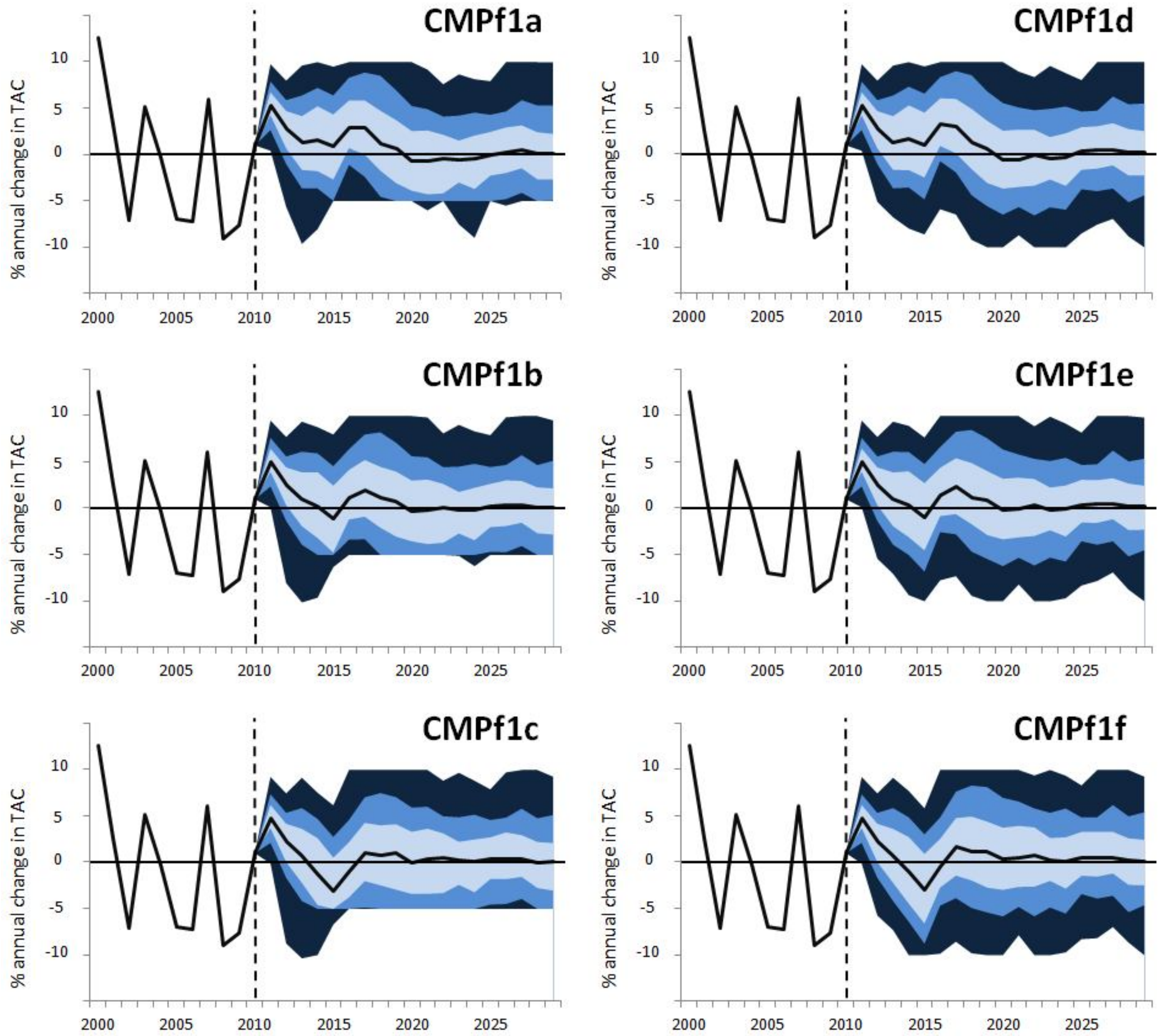

Fig. 1g: 95, 75, 50% PI and median for the percentage annual change in TAC for each of the six CMPs.

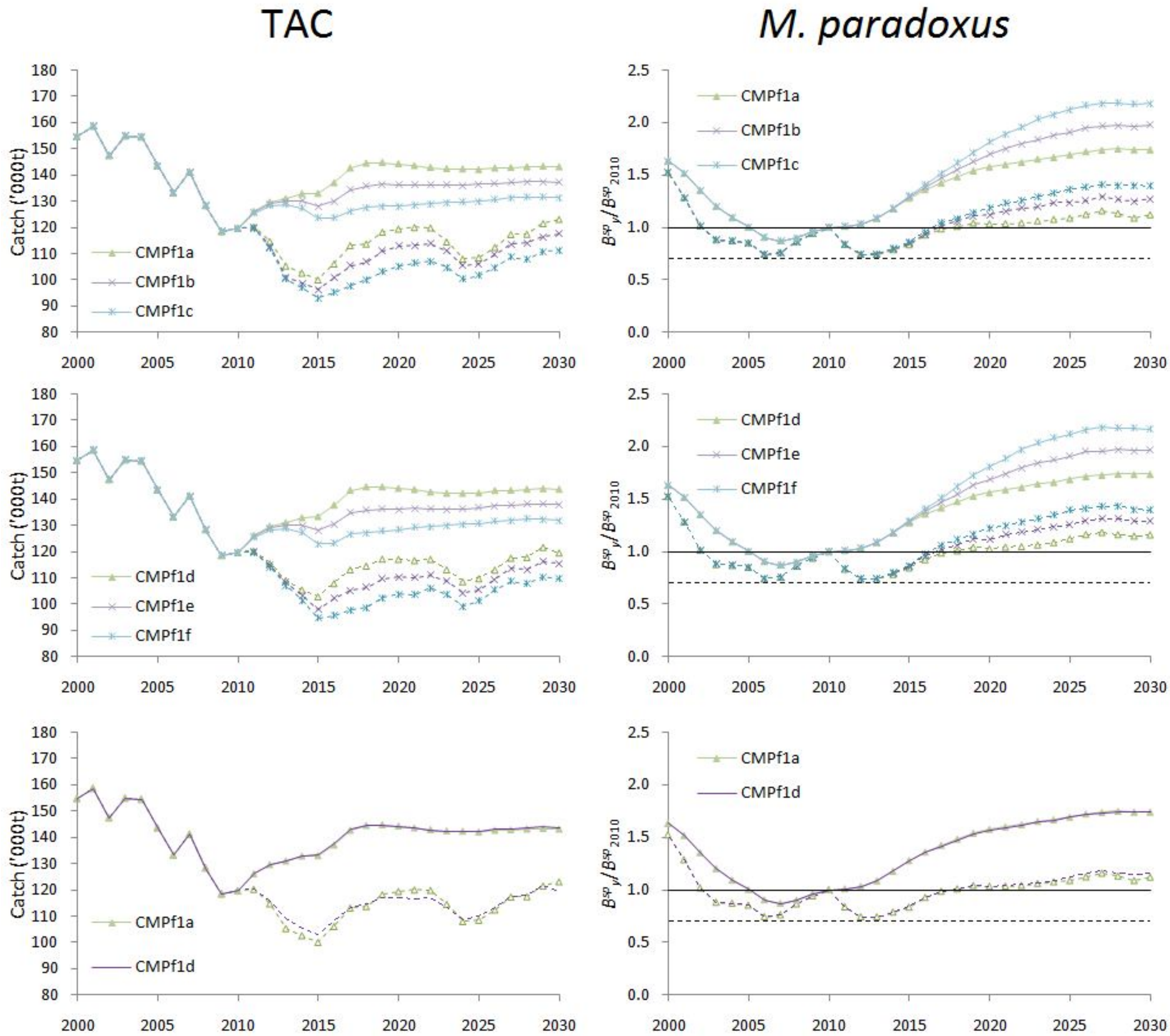

Fig. 2a: Median (full lines) and lower 2.5%iles (dashed lines) TAC and spawning biomass (in terms of 2010 level) for *M. paradoxus* for the final set of CMPs based on RSa. The horizontal dashed line shows the 2007 level.

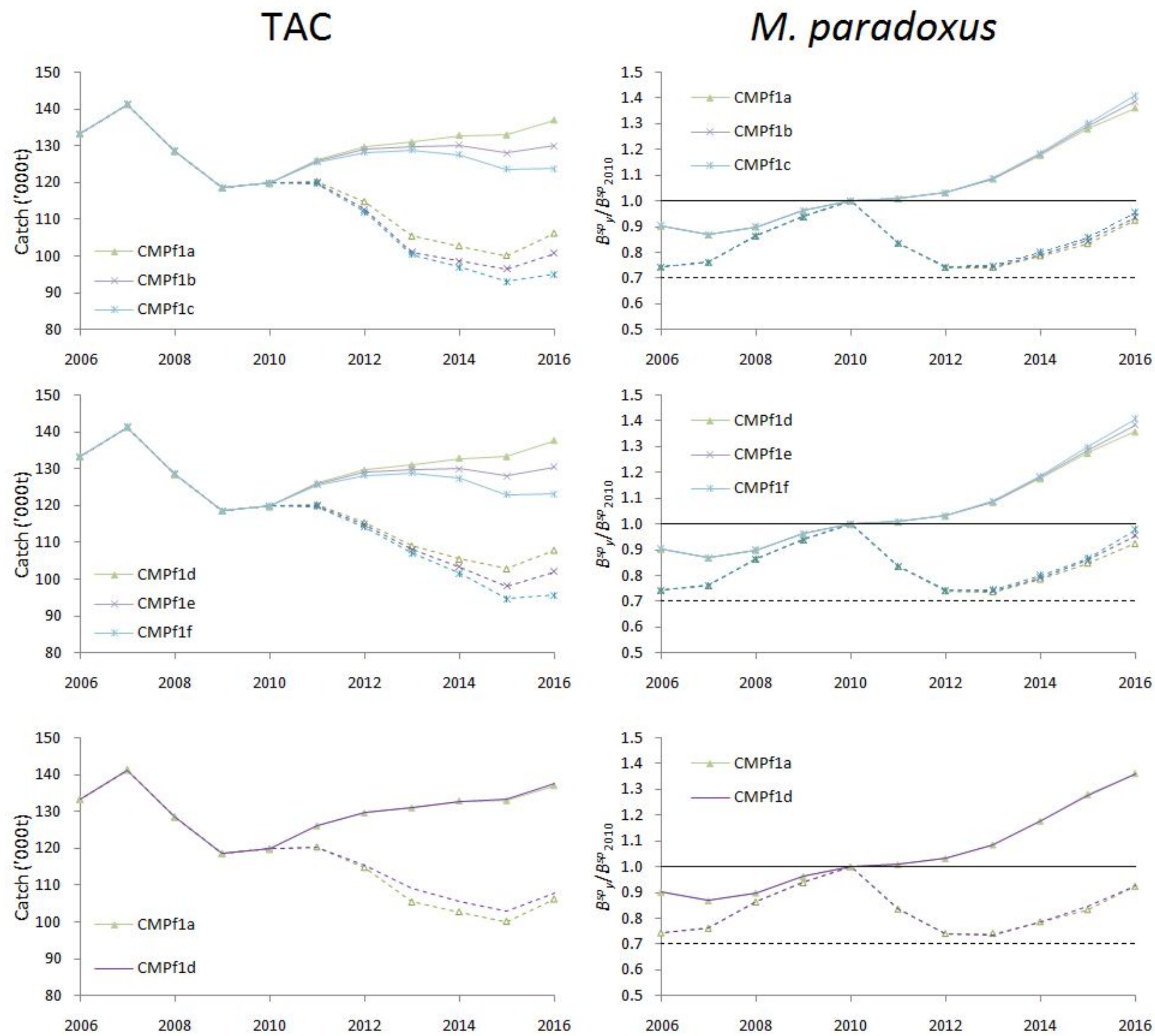

Fig. 2b: As Fig. 2a but with different scales to show projections for the short term more clearly.

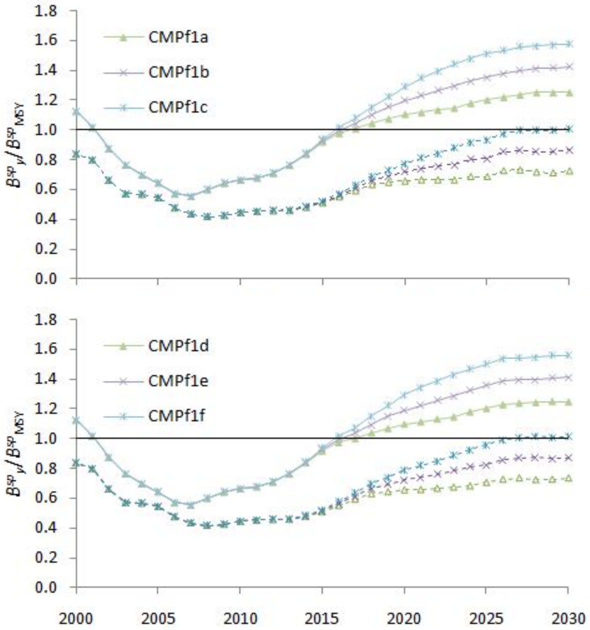

Fig. 3: Median (full lines) and lower 2.5%iles (dashed lines) for spawning biomass (in terms of B^{sp}_{MSY}) for *M. paradoxus* for the final set of CMPs based on RSa.

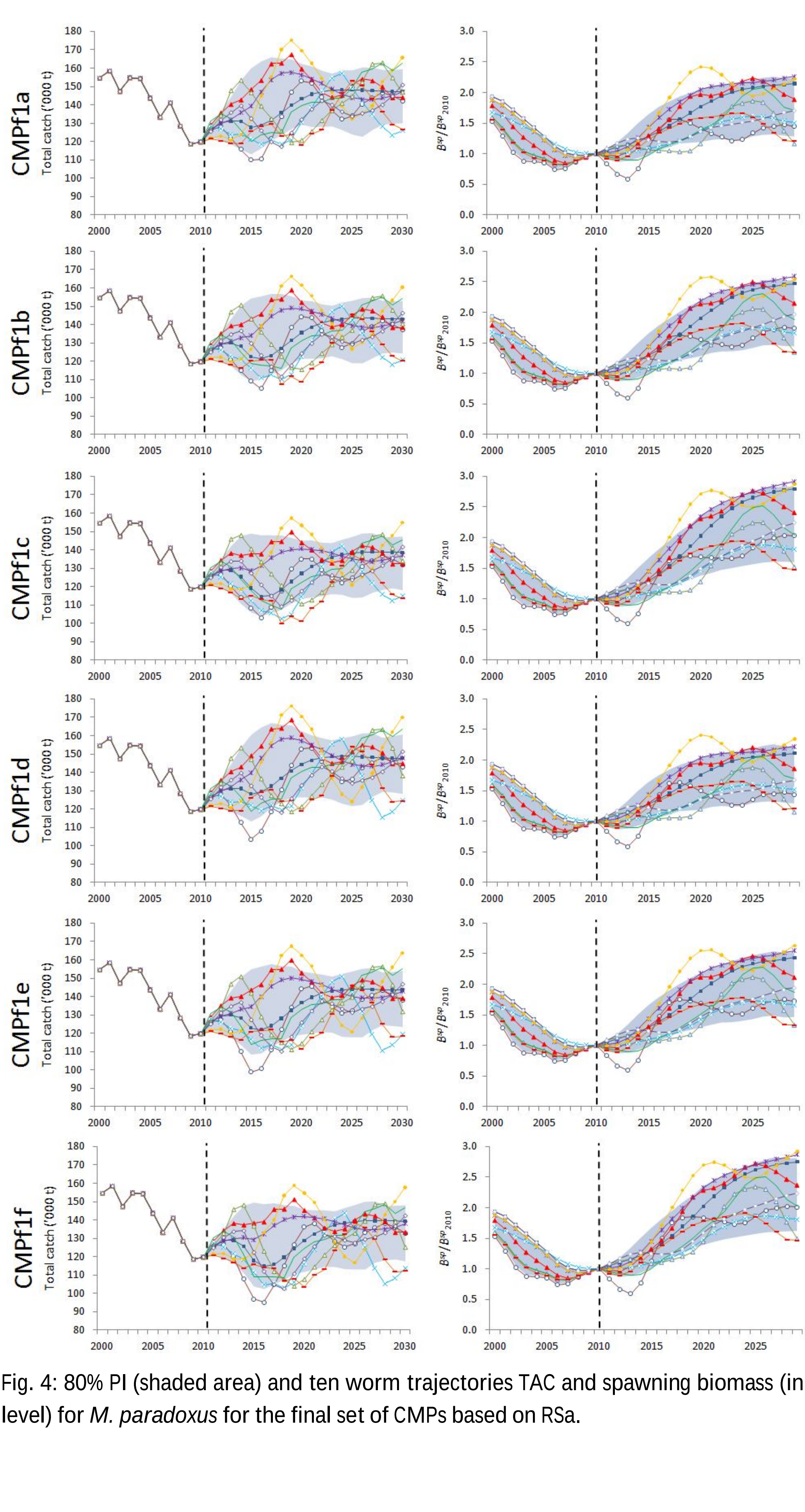

Fig. 4: 80% PI (shaded area) and ten worm trajectories TAC and spawning biomass (in terms of 2010 level) for *M. paradoxus* for the final set of CMPs based on RSa.

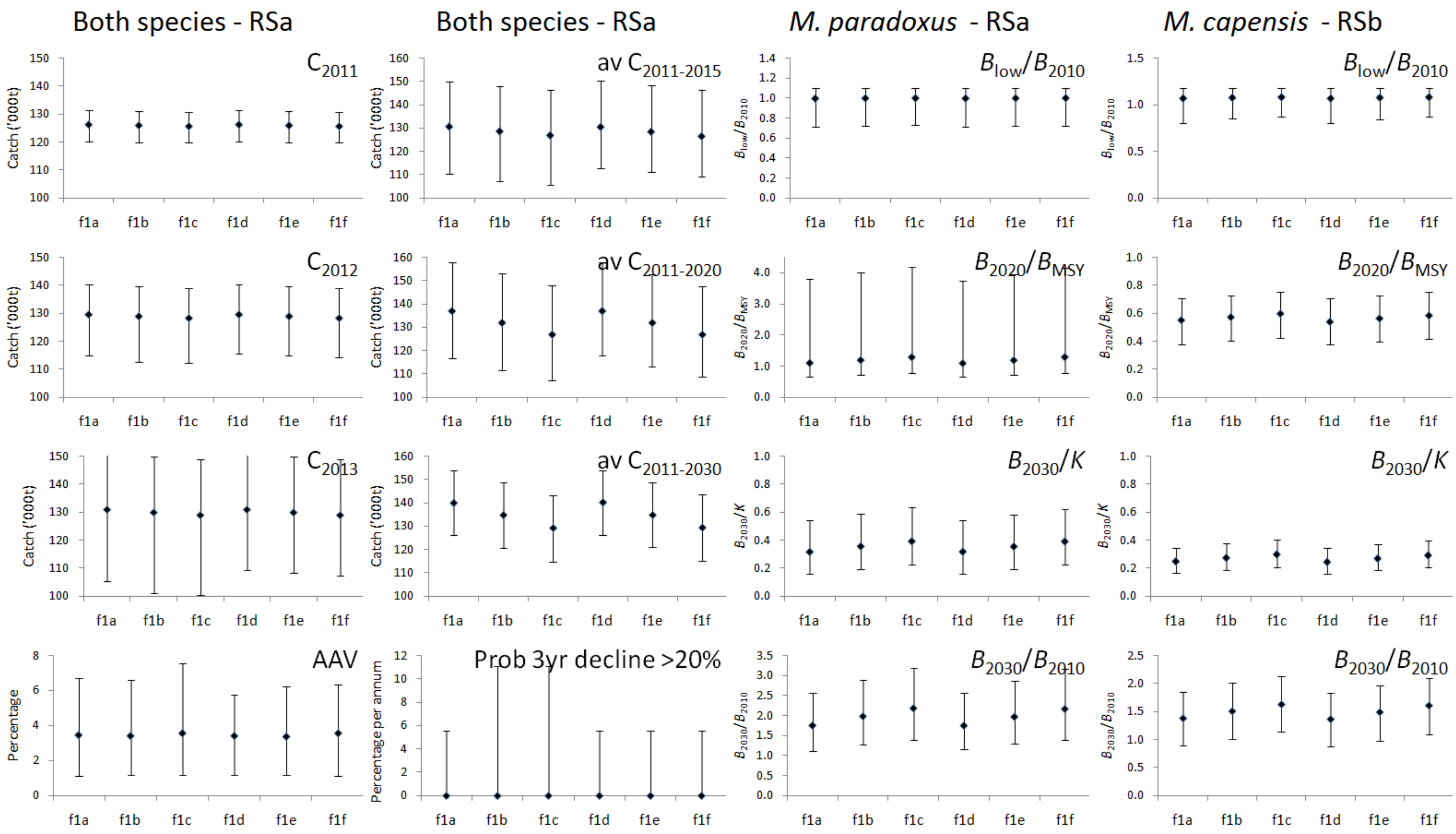

Fig. 5: Performance statistics (medians) under the final set of CMPs for the RS. The error bars show the 95% PI.

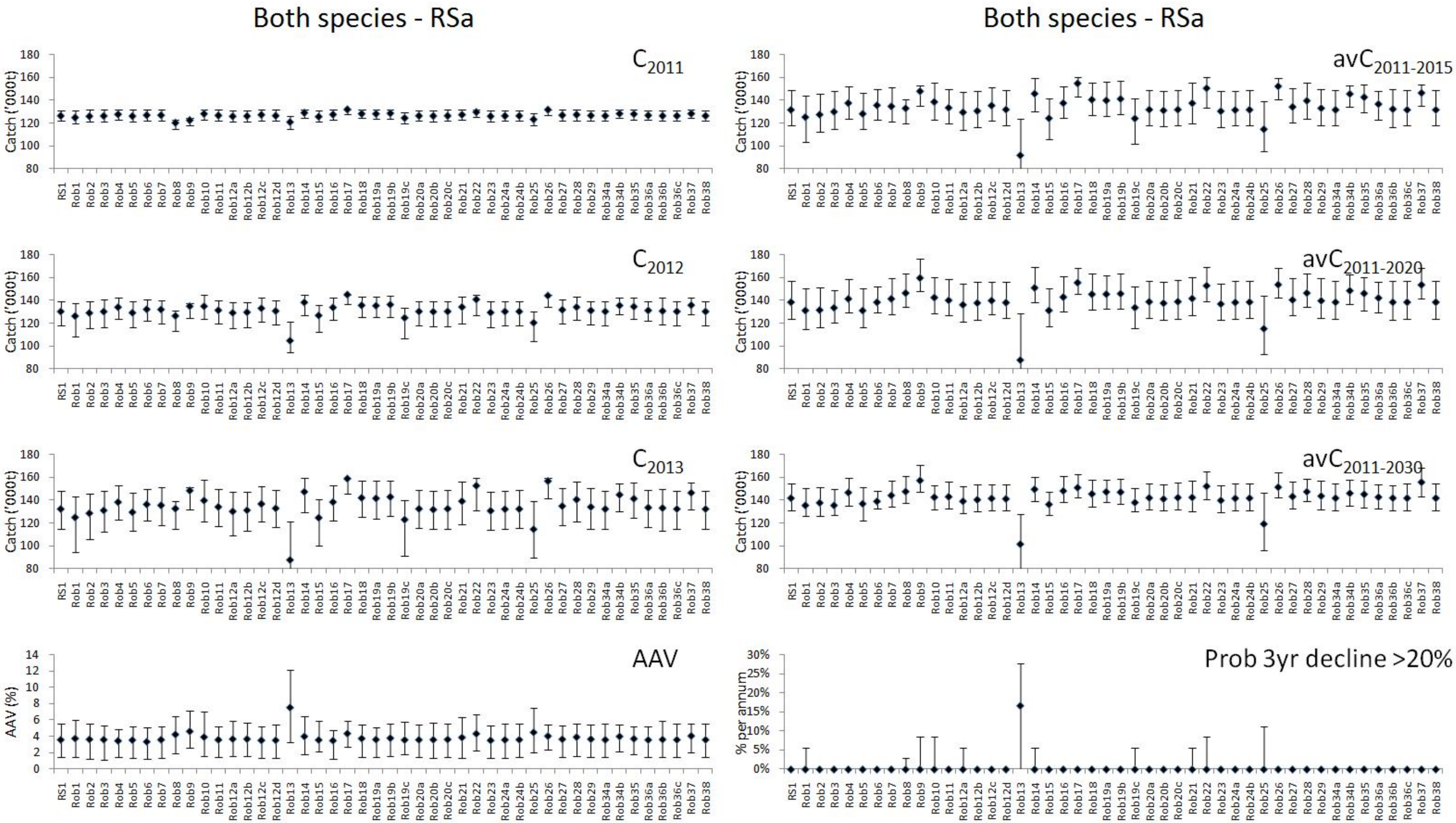

Fig. 6: Performance statistics (medians) under CMPf1a for the full set of robustness tests. The error bars show the 95% PI.

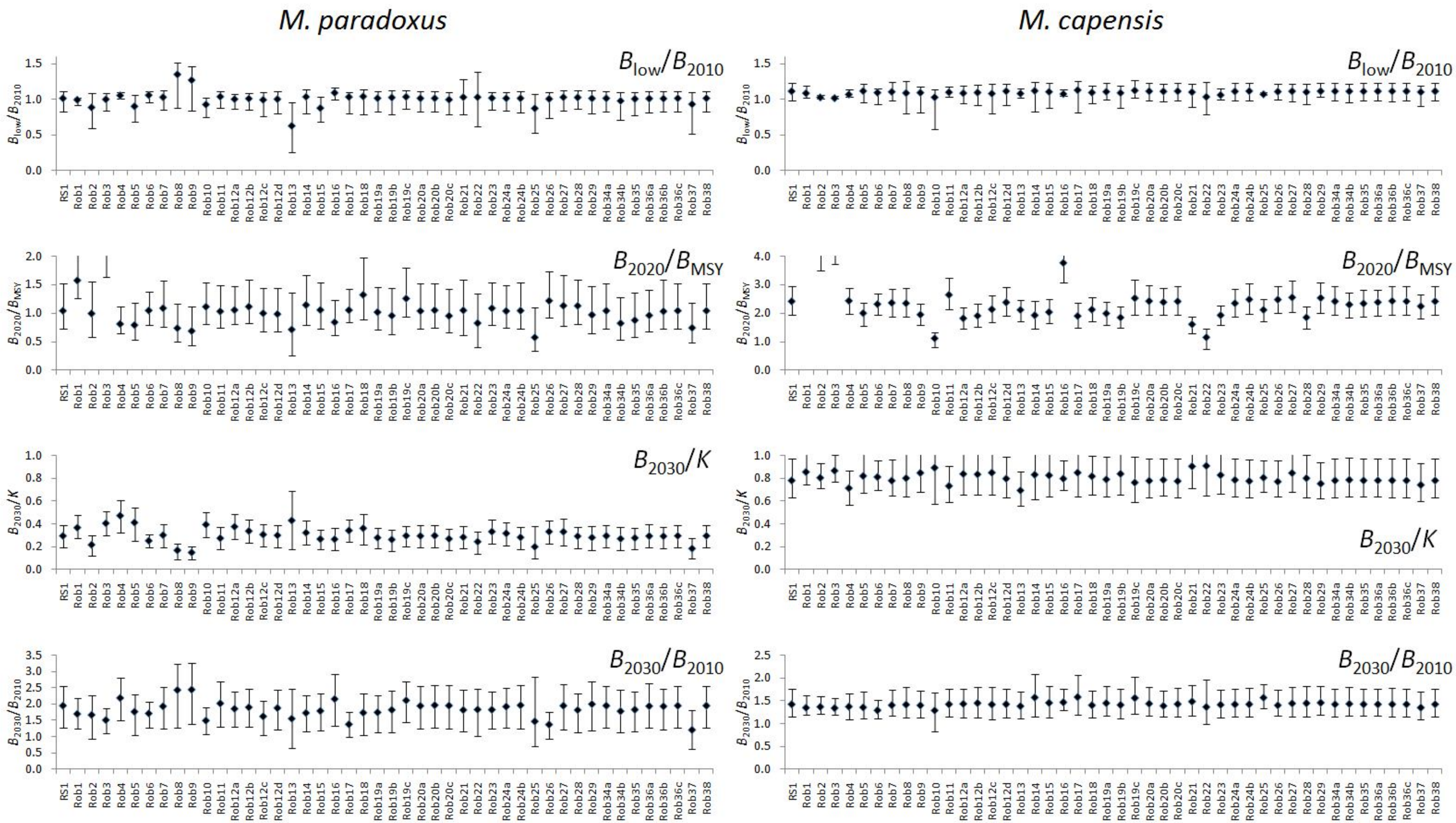

Fig. 6: continued

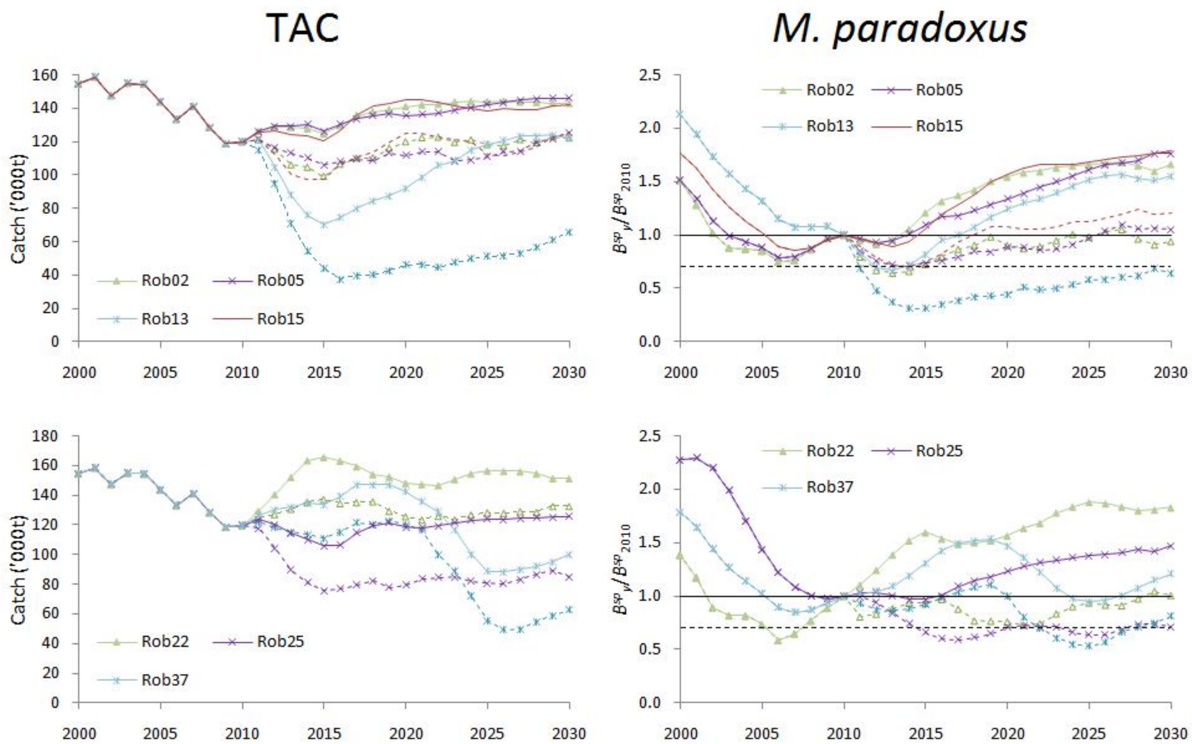

Fig. 7: Median (full lines) and lower 2.5%iles (dashed lines) TAC and spawning biomass (in terms of 2010 level) for *M. paradoxus* for the more difficult robustness tests based on the RC, under CMPf1a. The horizontal dashed line shows the 2007 level. The robustness tests are:

Rob02: BH est., shift center in 1950, paradoxus: M_{2-}=0.9, M_{5+}=0.5, capensis: M_{2-}=0.6, M_{5+}=0.5;
Rob05: True Ricker, shift center in 1950, both species: M_{2-}=0.9, M_{5+}=0.5;
Rob13: Decrease in *K* in the past;
Rob15: No shrinking of recent recruitment towards the stock-recruitment relationship predicted;
Rob22: Ageing of both species to be halved;
Rob25: Alternative maturity-at-length with fixed lower *h* value;
Rob37: Decrease in *K* in the future.

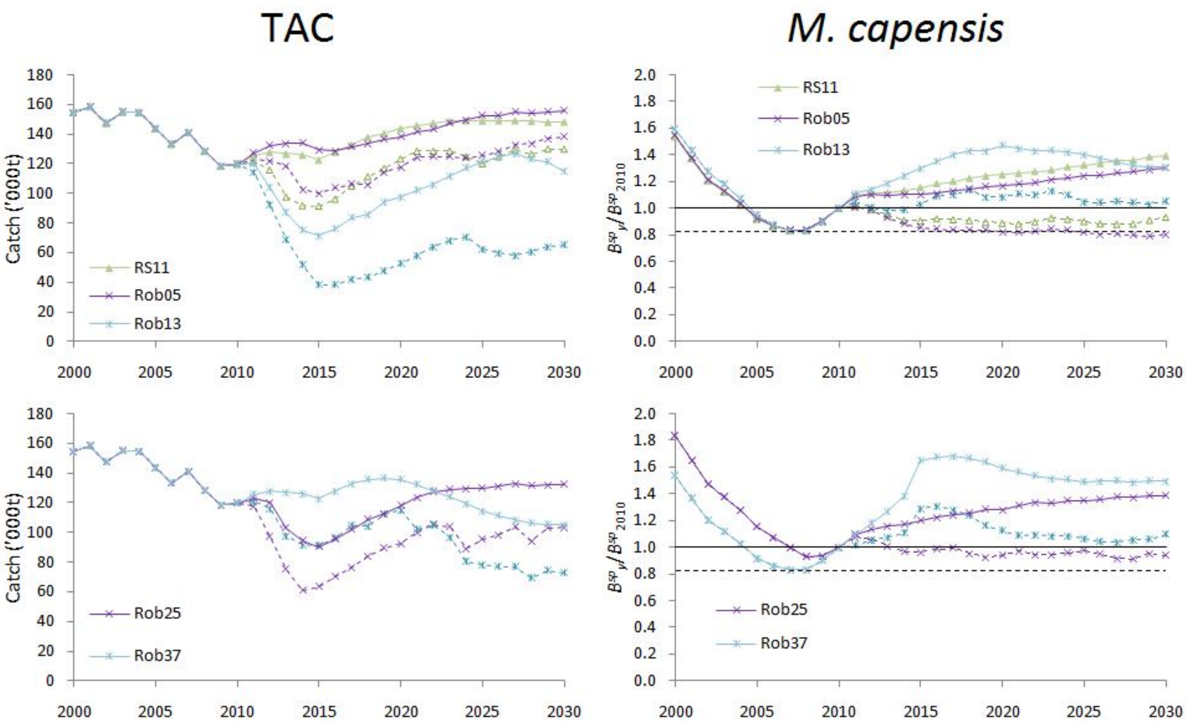

Fig. 8: Median (full lines) and lower 2.5%iles (dashed lines) TAC and spawning biomass (in terms of 2010 level) for *M. paradoxus* for the robustness tests based on RS11 (*M. capensis* in need of rebuilding), under CMPf1a. The horizontal dashed line shows the 2007 level. The robustness tests are:

Rob05: True Ricker, shift center in 1950, both species: M_{2-}=0.9, M_{5+}=0.5;
Rob13: Decrease in *K* in the past;
Rob25: Alternative maturity-at-length with fixed lower *h* value;
Rob37: Decrease in *K* in the future.

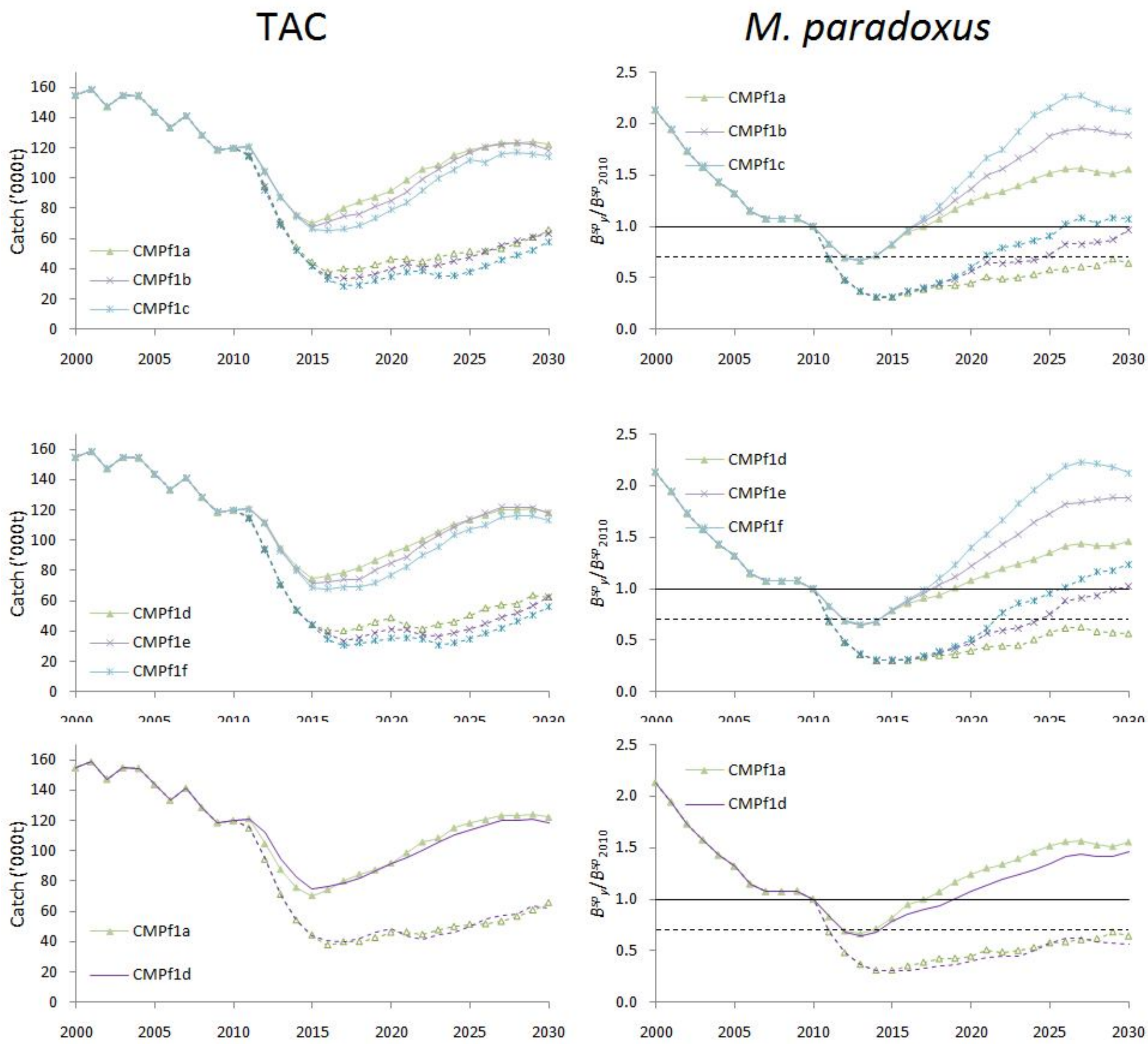

Fig. 9: Median (full lines) and lower 2.5%iles (dashed lines) TAC and spawning biomass (in terms of 2010 level) for *M. paradoxus* for the final set of CMPs based on Rob13 (decrease in *K* in the past). The horizontal dashed line shows the 2007 level.

Appendix A: List of robustness tests

Table A1: Summary of the robustness/sensitivity tests including changes in the past dynamics and based on the Reference Case (RC).

	Shift center	SR relationship	Natural mortality		Other
			M. paradoxus	*M. capensis*	
Changes in the past					
Rob1	1965	BH, *h* estimated	M_{2-}=0.6; M_{5+}=0.25	M_{2-}=0.9; M_{5+}=0.5	
Rob2	1950	BH, *h* estimated	M_{2-}=0.9; M_{5+}=0.5	M_{2-}=0.6; M_{5+}=0.25	
Rob3	1965	BH, *h* estimated	M_{2-}=0.9; M_{5+}=0.5	M_{2-}=0.6; M_{5+}=0.25	
Rob4	1950	True Ricker	M_{2-}=0.6; M_{5+}=0.25	M_{2-}=0.6; M_{5+}=0.25	
Rob5	1950	True Ricker	M_{2-}=0.9; M_{5+}=0.5	M_{2-}=0.9; M_{5+}=0.5	
Rob6			as RC		σ_R = 0.25
Rob7			as RC		W_{ALK} = 0.001
Rob8			as RC		W_{ALK} = 0.1
Rob9			as RC		W_{CAL} = 0.01
Rob10			as RC		W_{CAL} = 1.0
Rob11			as RC		*M* gender dependent (+0.05 for males, -0.05 for females)
Rob12			as RC		All commercial and survey selectivity slopes (in cm^{-1}): a)+0.04, b) +0.02, c) -0.04 and d) -0.02
Rob13			as RC		Decrease in *K* (30% linear decrease between 1980 and 2000 for both spp)
Rob14			as RC		Added weighting (5x) to last 5 year's CPUE and survey data to fit recent abundance indices more closely
Rob15			as RC		No shrinkage of recent recruitments towards the stock-recruitment relationship prediction
Rob 16			as RS2		Increasing *M* at large ages (linear from 0.25 at age 8 to 1 at age 15)
Rob17			as RC		Start in 1978, estimating θ and ζ
Rob 18			as RC		Change in efficiency in the offshore trawl fleet 1994/1995
Rob 19			as RC		Different CPUE series: a. all offshore vessels incl.; b. alt. depth stratifications; c. omit days with nominal CPUE=0; (d. updated after database check)
Rob 20			as RC		Survey calibration factor: a. incr. cap. factor to 0.9; b. decr. cap. factor to 0.6; c. both cap. and para. factors estimated
Rob 21			as RC		Ageing of both species out by one year
Rob 22			as RC		Ageing of both species to be halved
Rob 23			as RC		Alternative assumption for the cap. offshore selectivity
Rob 24			as RC		Alternative assumption re SC female paradoxus selectivity scaling factor: a. as lower; b. as higher
Rob 25			as RC		Alternative maturity-at-length with fixed lower *h* values
Rob 26			as RC		Include discards in the past
Rob 27			as RC		40/60 male/female ratio at birth instead of 50/50
Rob 28			as RC		Alternative species split algorithm (post-1978 catches and CPUE series)
Rob 29			as RC		From 1997 to 2002 q for CPUE dropped by 20% as a result of shorter tows

Table A2: Summary of the robustness/sensitivity tests including changes in the future dynamics and based on the Reference Case (RC).

	Shift center	SR relationship	Natural mortality		Other
			M. paradoxus	*M. capensis*	
Changes in the future					
Rob 30			as RC		Maximum proportion of cohort catchable in one year decrease from 90% to 70%
Rob 31			as RC		Missing/reduced surveys in the future: a. no surveys; b. only WC surveys; c. only SC surveys; d. both surveys missing every 3 years; e. increase all future surveys CVs by multiplicative factor of sqrt(2); f. no surveys plus undetected increase catchability related to CPUE
Rob 32			as RC		Decrease all future survey CVs by a multiplicative factor of 1/sqrt(2)
Rob 33			as RC		MPA possible effects on future CPUE: a. no CPUE; b. new CPUE series with prior on q; c. new CPUE series with lower q; d. new CPUE series with higher q; and e. new CPUE series with no prior on q
Rob 34			as RC		Trend in F_{ratio} over time in the future: a) 2% p.a. and b) -2% p.a., for 10 years then constant
Rob 35			as RC		Undectected 2% p.a. increase in catchability related to CPUE in the future
Rob 36			as Rob26		Change in discard pattern in the future: a) past, but no future discards; b) past and future discards; c) past discards are halved in the future.
Rob 37			as RC		Decrease in K in the future (30% linear decrease between 2011 and 2016 for both spp)
Rob 38			as RC		Allow for serial correlation in recruitment residuals (estimate from RC fit)

Table A3: Summary of the robustness/sensitivity tests based on the RS11, i.e. where *M. capensis* is in need of rebuilding as well as *M. paradoxus*.

	Shift center	SR relationship	Natural mortality		Other
			M. paradoxus	*M. capensis*	
Changes in the past					
Rob5	1950	True Ricker	M_{2-}=0.9; M_{5+}=0.5	M_{2-}=0.9; M_{5+}=0.5	
Rob6			as RS11		σ_R = 0.25
Rob13			as RS11		Decrease in K (30% linear decrease between 1980 and 2000 for both spp)
Rob17			as RS11		Start in 1978, estimating θ and ζ
Rob 25			as RS11		Alternative maturity-at-length with fixed lower h values
Changes in the future					
Rob 37			as RS11		Decrease in K in the future (30% linear decrease between 2011 and 2016 for both spp)