Hake Projections under a Variety of Candidate OMPs

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Introduction

This paper provides performance statistics for a variety of candidates OMPs applied to the New Reference Set trials. These OMPs include OMP1, OMP2 and OMP3 for which results were previously reported in WG/09/06/D:H:33, together with seven new candidates developed in discussions at the last WG meeting and a following TG meeting. In all but one case, these further candidates reflect different options for limitations on the extent of TAC change from one year to the next, with the specifics detailed in Table 1. The exception is OMP4 (Gaylard's suggestion), which instead modifies the basic TAC setting algorithm slightly.

Previously different candidate OMPs were rendered comparable by tuning each to the same **median** recovery level for *M. paradoxus* after the next 20 years. For this paper, whose primary purpose is to compare the different options, the 20% recovery target was adopted. However, it became evident that tuning to the same **median** recovery level was not appropriate for all the candidates considered, in particular the extreme constant future catch option of OMP10, for which such a tuning results in instances of extinction for *M. paradoxus* (see Fig. B2 of appendix B). Accordingly tuning has been carried out in terms of the **lower 5%-ile** of the *M. paradoxus* 20-year recovery level, which is in any case a more defensible approach from an "equivalent resource risk" perspective. The target chosen was 0.121, which reflects this **lower 5%-ile** for OMP1 (annual TAC variation up or down limited to 10%) when tuned to a 20% **median** recovery target for *M. paradoxus*. Note that consequently **median** recovery statistics for *M. paradoxus* differ between equivalently tuned candidate OMPs.

Results

Fig. 1 provides past estimates of spawning biomass for both hake species and of the exploitable biomass available to the offshore trawlers (a surrogate for their CPUE) from 1970 onwards for the new Reference Set. This is purely to provide a convenient basis for comparison of projections, as subsequent plots commence in 1992.

The OMP performance statistics correct two errors in those reported earlier, which arose from incorrect treatment of the last year of the projections in the coding. Relative comparisons are not affected, but in absolute terms the net effect is that average TACs are higher, and AAV statistics lower, than previously reported for this **median** tuning.

Key comparative results for the variety of OMPs considered may be found in Table 1 and Fig. 2. Medians of projections under the different candidates are compared in Figs 3a-c. Full graphical sets of projections for each of the candidates are reproduced in Appendix A.

Equivalent results for these candidates, but tuned to the same **median** (20%) rather than **lower 5%-ile** recovery target for *M. paradoxus*, are reported in Appendix B. Time, however, did not allow these computations to be completed for all ten candidate OMPs, so that OMPs 7, 8 and 9 are absent from the results reported.

In terms of these **median** tunings, OMP1 involves the lowest resource risk for *M. paradoxus*, achieving also near the best average TAC, and also nearly the lowest AAV.

For the tunings to the same **lower 5%-ile** for *M. paradoxus* recovery (Table 2), OMP1 again achieves the best catches, though at the expense of lesser recovery in median terms. AAV, however, is worse than for most of the other candidates. Note that median off shore trawler CPUE increase over the next 10 years is typically about 50% (range 43% to 70%).

Table 1: Tuning parameters for each candidate OMP presented in this paper. δ_1, δ_2 and δ_3 are the rate parameters of the year-dependent tuning parameter, λ_y .

Case		Fixed phase down	*p*	α_1	α_2	α_3	Yr_join	Target incr para	Target incr cap	Y	Max incr	Max decr1	Max decr2	Limit1	Limit2
OMP1		-	6	0.40	2	1.1	10	0.0240	0	15	10%	10%	-	-	-
OMP2		-	6	0.50	3	1.1	10	0.0340	0	10	5%	5%	20%	0.9	0.7
OMP3		-	6	0.50	4	1.1	10	0.0850	0	10	5%	5%	35%	0.6	0.35
OMP4	Gaylard	-	6	0.40	4	1.1	10	0.0700	0	10	10%	10%	-	-	-
OMP5	Penney	-	6	0.50	3	1.1	10	0.0370	0	10	10%	10%	20%	0.8	0.6
OMP6	Ind1	3x7.5%	6	0.50	4	1.1	10	0.0620	0	10	5%	5%	-	-	-
OMP7	Ind2	3x7.5%	6	0.50	4	1.1	10	0.0380	0	10	5%	5%	15%	0.8	0.6
OMP8	Leslie	-	6	0.50	4	1.1	10	0.0215	0	10	5%	5%	20%	1.2	0.5
OMP9	Redell	1x7.5%[+]	6	0.50	4	1.1	10	0.0445	0	10	5%	5%	20%	0.8	0.6
OMP10	Const catch	constant annual catch of 114.45 thousand tons													

[+] Inadvertently the quantum here was set to 7.5% rather than the intended 10%, with the error discovered too late to repeat the computations. However the qualitative consequences of the correction should be evident from comparison with other results for the other candidates which follow.

Note: “Max decr1”, “Max decr2”, “Limit1” and “Limit2” correspond to D_1, D_2, L_1 and L_2 respectively from equation 4 in document WG/09/06/D:H:33. The shape of the function of the maximum annual decrease in TAC as a function of relative CPUE is shown below

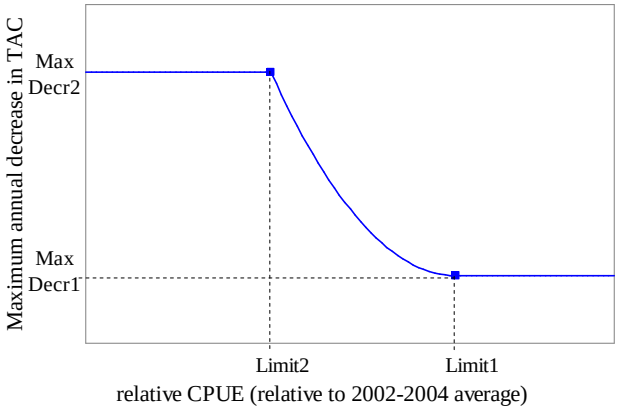

Table 2: Summary of performance statistics for a series of candidate OMPs, tuned to the same lower 5%-ile recovery level (0.121) for *M. paradoxus*, for the RS. For each statistic, the median and 90% PIs are shown.

		OMP1	OMP2	OMP3	OMP4 Gaylard	OMP5 Penney	OMP6 Ind1	OMP7 Ind2	OMP8 Leslie	OMP9 Redell	OMP10 CC
Species combined	avTAC	125.05	120.50	120.04	122.08	125.12	119.89	122.70	123.05	121.93	114.45
		108.76	92.53	90.15	107.99	103.74	103.25	94.20	96.69	86.00	114.45
		139.27	136.76	132.02	131.74	139.56	132.90	138.96	137.80	138.42	114.45
	AAV	4.99	4.56	4.02	4.95	5.56	4.04	4.13	4.63	4.01	1.19
		3.45	3.26	3.28	3.87	3.87	3.38	3.34	3.45	3.06	1.19
		6.82	6.47	6.67	6.20	7.77	4.97	6.39	6.47	7.05	1.19
	$CPUE_{2016}/CPUE_{2005}$	1.57	1.69	1.43	1.54	1.70	1.59	1.54	1.67	1.53	1.67
		1.27	1.33	1.12	1.24	1.39	1.17	1.26	1.33	1.23	1.19
		1.96	2.21	1.82	1.95	2.18	1.99	1.96	2.12	2.03	2.17
	C_{2007}	135.00	135.86	142.50	135.00	134.97	138.75	138.75	134.83	138.75	114.45
		-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-
	C_{2008}	121.50	125.23	135.37	121.50	121.47	128.34	128.34	122.05	131.81	114.45
		121.50	111.32	135.37	121.50	118.54	128.34	128.34	118.05	127.29	114.45
		130.02	129.05	135.38	121.50	124.26	128.34	128.34	126.36	131.81	114.45
	C_{2009}	111.00	112.55	128.61	109.35	108.98	118.72	118.72	109.63	124.53	114.45
		109.35	94.03	128.61	109.35	101.97	118.72	118.72	102.79	112.39	114.45
		128.16	124.76	134.54	133.65	121.99	118.72	118.72	123.97	129.58	114.45
M. paradoxus	B_{2027}/K	0.200	0.247	0.225	0.229	0.218	0.240	0.219	0.229	0.231	0.326
		0.121	**0.121**	**0.121**	**0.121**	**0.121**	**0.121**	**0.121**	**0.121**	**0.121**	**0.121**
		0.312	0.461	0.402	0.346	0.371	0.365	0.421	0.420	0.481	0.450
	B_{2027}/B_{2007}	2.91	3.72	3.34	3.45	3.20	3.66	3.26	3.38	3.26	4.66
		1.98	1.93	1.60	1.77	2.02	2.05	1.91	2.05	1.84	1.37
		4.91	8.74	8.13	6.58	5.58	6.55	7.56	8.11	8.70	9.38
M. capensis	B_{2027}/K	0.70	0.73	0.72	0.72	0.71	0.71	0.72	0.72	0.73	0.75
		0.59	0.59	0.59	0.58	0.59	0.58	0.59	0.59	0.59	0.56
		0.85	0.89	0.87	0.87	0.86	0.88	0.86	0.88	0.88	0.91
	B_{2027}/B_{2007}	1.49	1.54	1.53	1.52	1.50	1.53	1.52	1.53	1.52	1.59
		1.22	1.26	1.23	1.23	1.22	1.21	1.23	1.23	1.23	1.21
		1.78	1.86	1.90	1.82	1.83	1.83	1.84	1.85	1.89	1.93

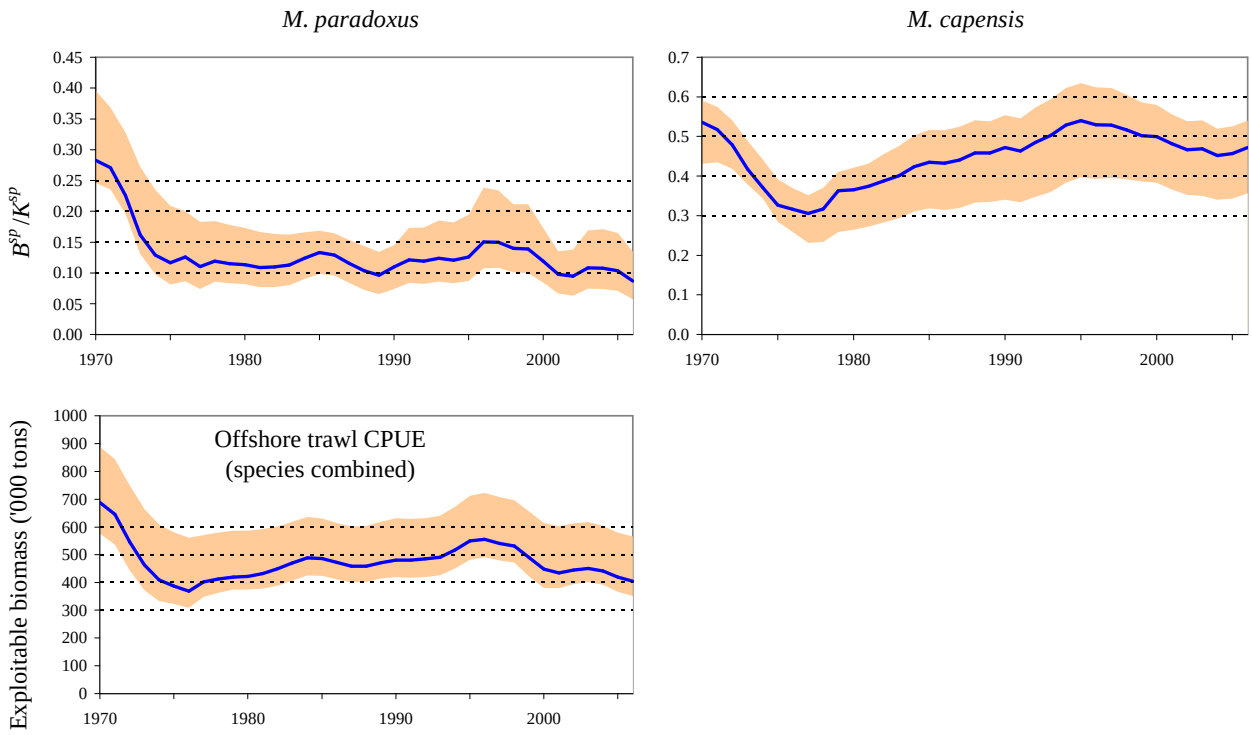

Fig. 1: Trajectories of estimated spawning biomass (as a proportion of its pre-exploitation level) and offshore trawl exploitable biomass (a proxy for CPUE) for both species combined for the updated Reference Set. The median is indicated by a thick line while the shaded area represents the full uncertainty of the updated Reference Set (minimum and maximum for each year). Note that prior to 1992, the exploitable biomass shown is comparable with achieved CPUE rather than biomass after 1992, because of changes in selectivity introduced prior to 1992 to take account of the gradual removal of net liners.

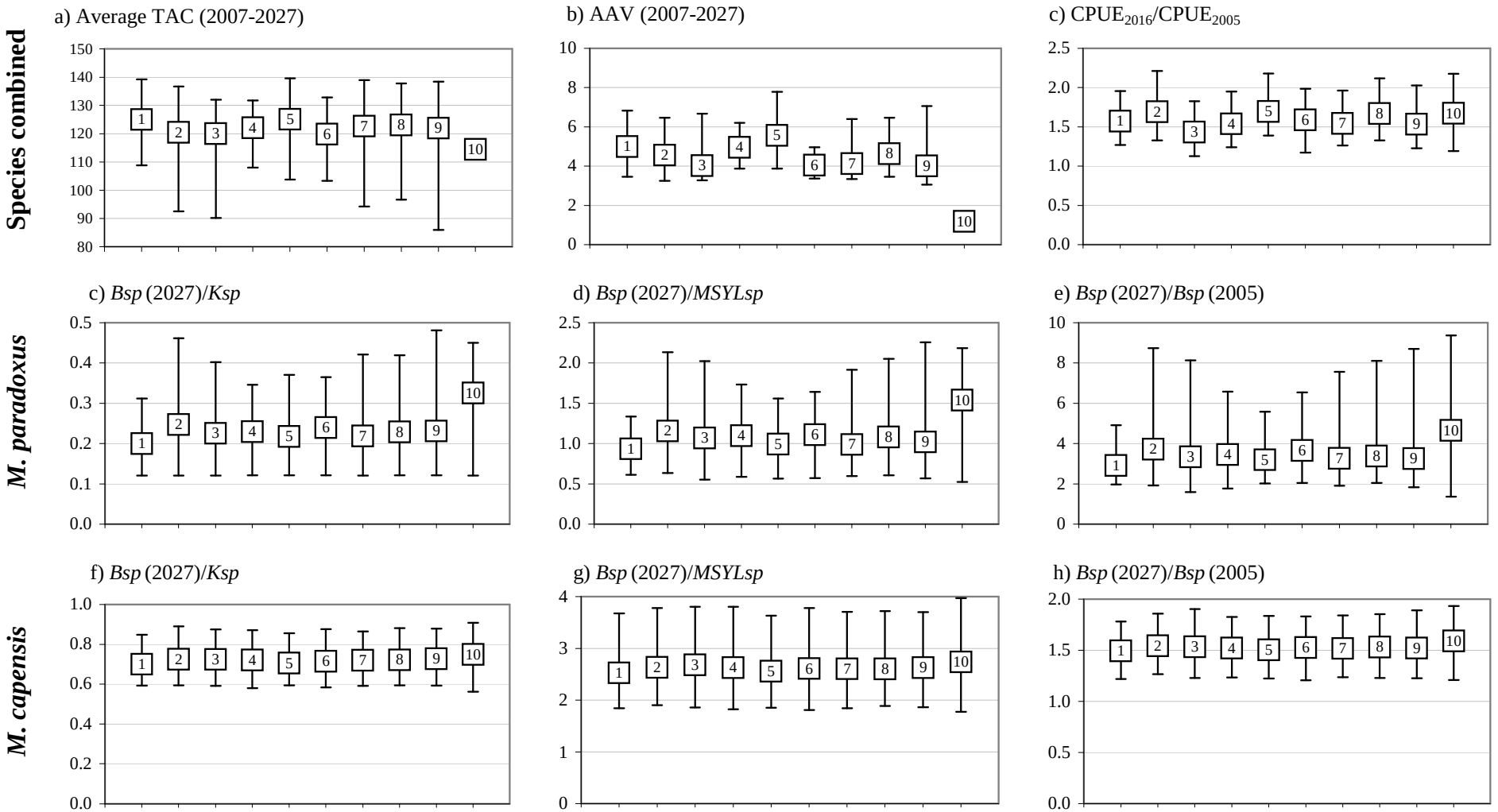

Fig. 2: Graphical summary of performance statistics for a series of candidate OMPs, tuned to the same lower 5%-ile recovery level (of 0.121) for *M. paradoxus* for the RS. Each panel shows medians together with 90% PIs.

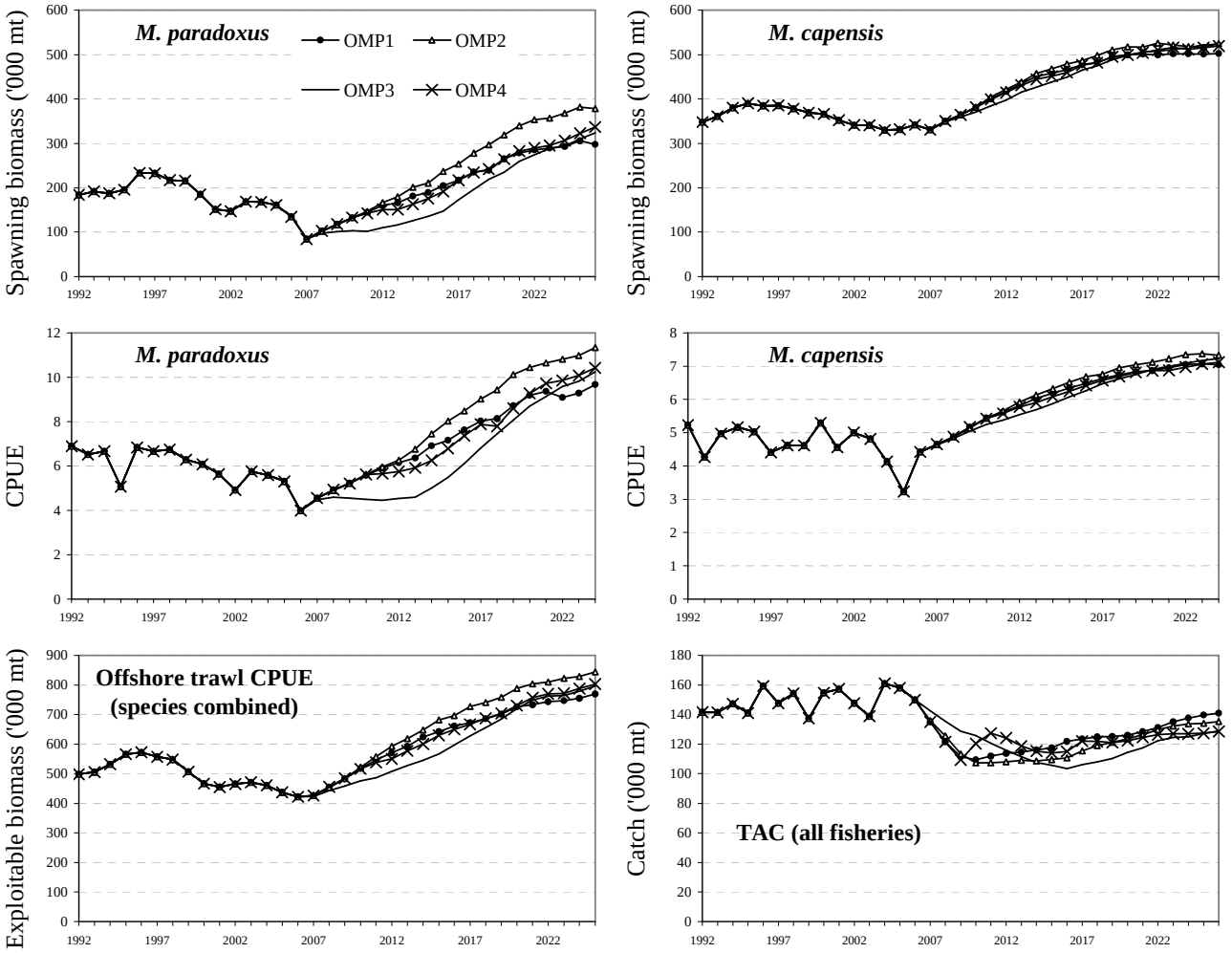

Fig. 3a: Median trajectories of resource abundance and catch for an application of **OMP1**, **OMP2**, **OMP3** and **OMP4** for a comparable **lower 5%-ile** recovery tuning of 0.121 for *M. paradoxus* for the **Reference Set**. Note units for species combined CPUE are those of the exploitable biomass to which it corresponds. Pre-2007, the average spawning biomass and species combined CPUE trajectories of the Reference Set and the actual species disaggregated CPUE and total catch are also shown.

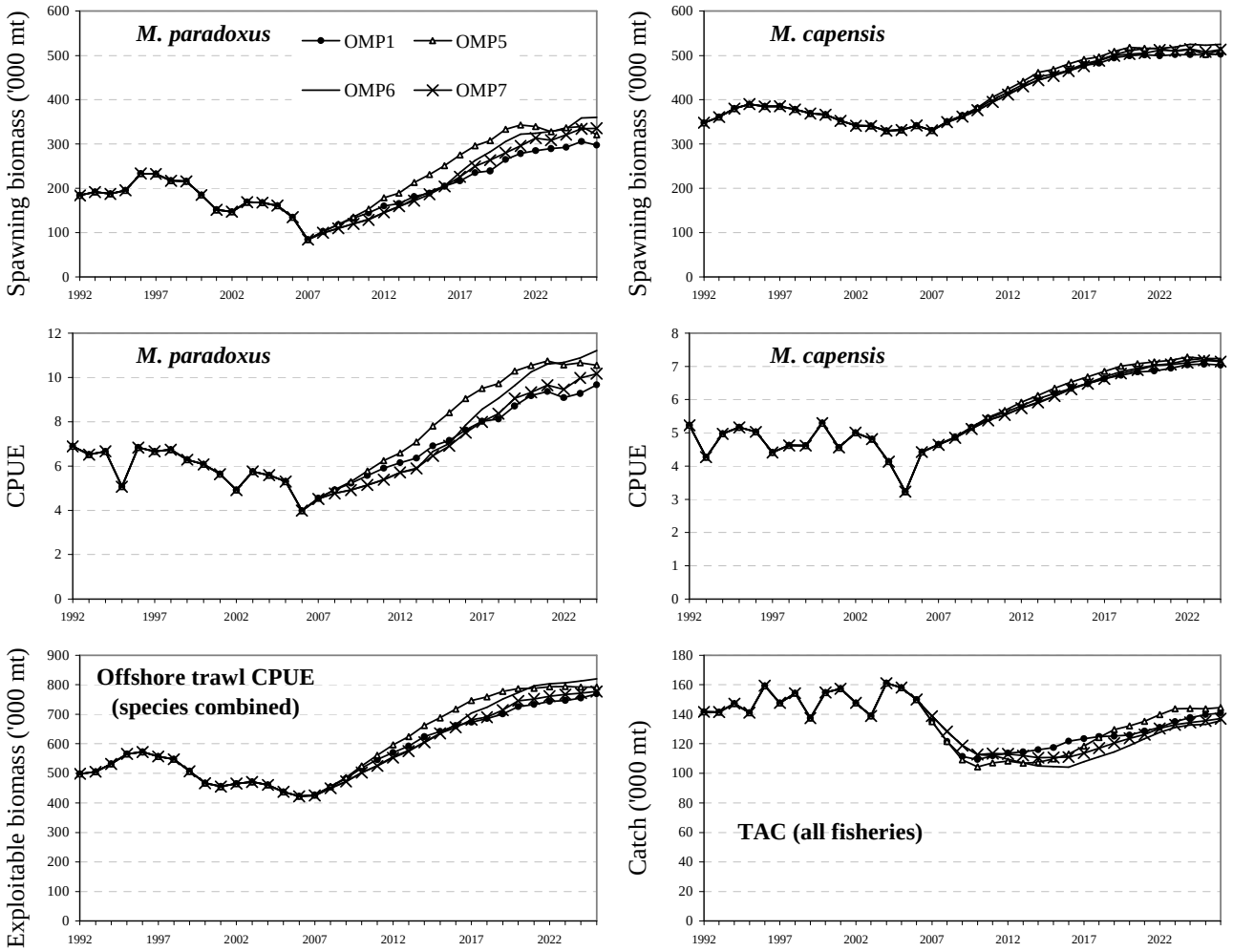

Fig. 3b: Median trajectories of resource abundance and catch for an application of **OMP1**, **OMP5**, **OMP6** and **OMP7** for a comparable **lower 5%-ile** recovery tuning of 0.121 for *M. paradoxus* for the **Reference Set**. Note units for species combined CPUE are those of the exploitable biomass to which it corresponds. Pre-2007, the average spawning biomass and species combined CPUE trajectories of the Reference Set and the actual species disaggregated CPUE and total catch are also shown.

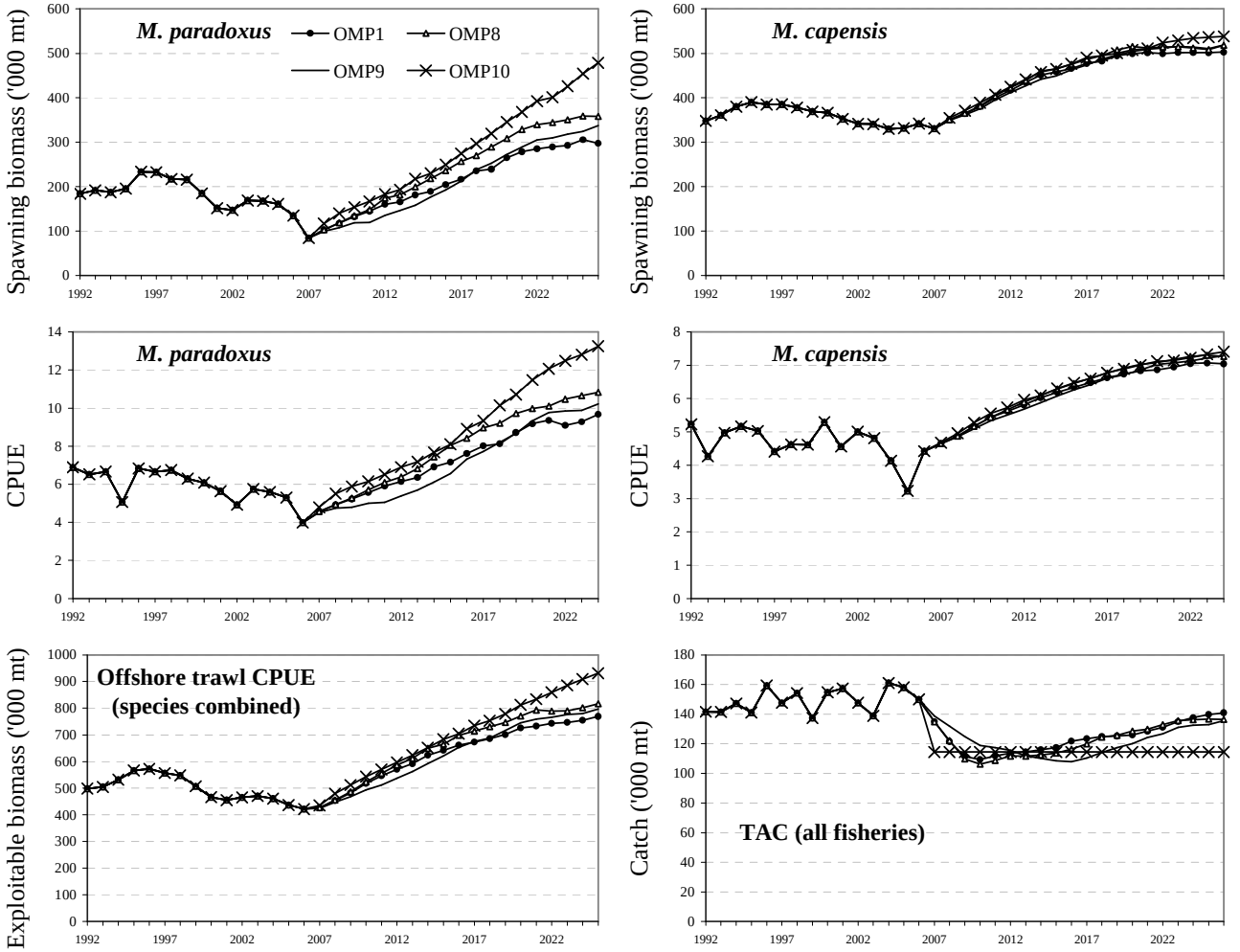

Fig. 3c: Median trajectories of resource abundance and catch for an application of **OMP1, OMP8**, **OMP9** and **OMP10** for a comparable **lower 5%-ile** recovery tuning of 0.121 for *M. paradoxus* for the **Reference Set**. Note units for species combined CPUE are those of the exploitable biomass to which it corresponds. Pre-2007, the average spawning biomass and species combined CPUE trajectories of the Reference Set and the actual species disaggregated CPUE and total catch are also shown.

Appendix A

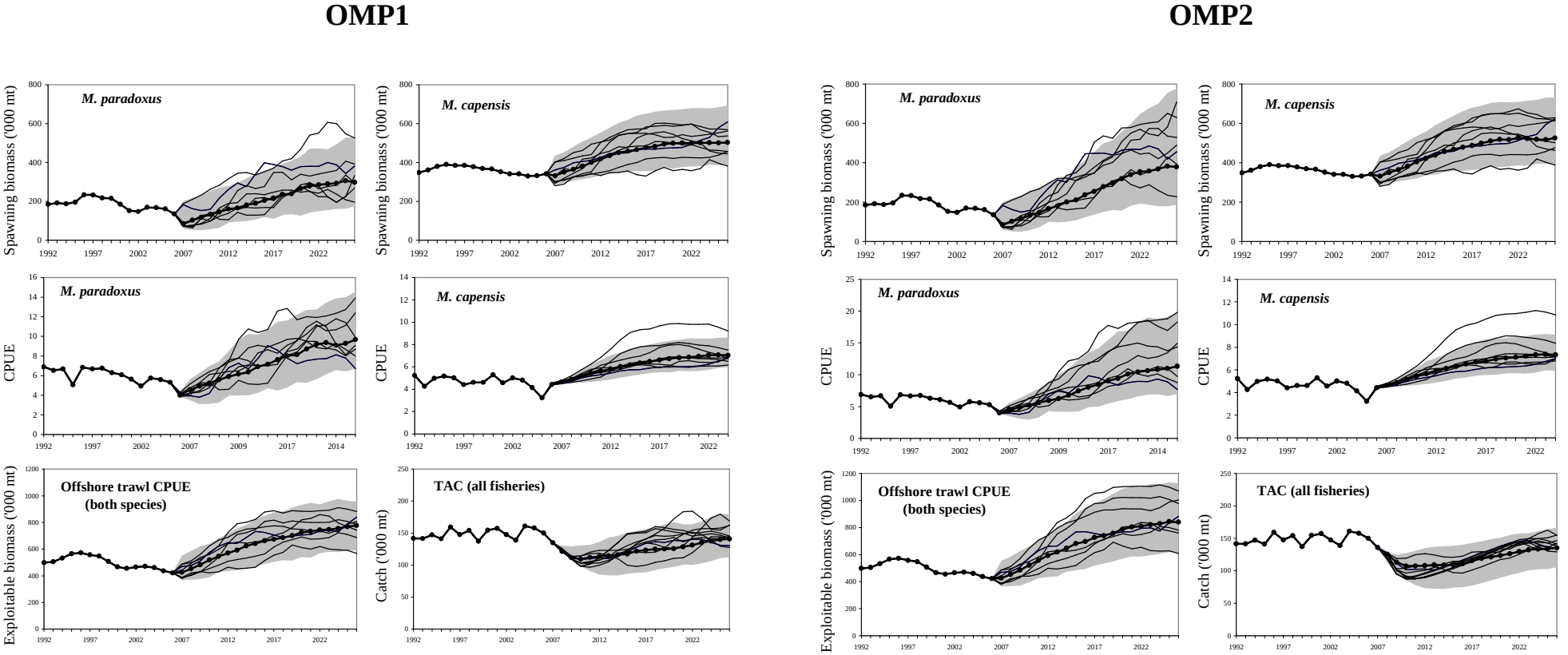

Fig. A1a: Trajectories of resource abundance and catch for an application of **OMP1** and **OMP2** to the updated Reference Set. Ten individual trajectories are shown, with the median a dark dotted line; the shaded areas show 90% PIs. Note units for species-combined CPUE are those of the exploitable biomass to which it corresponds. Pre-2007, the average spawning biomass and species combined CPUE trajectories of the Reference Set and the actual species disaggregated CPUE and total catch are also shown. Tuning is to a **lower 5%-ile** recovery level of 0.121 for *M. paradoxus*.

OMP3 **OMP4**

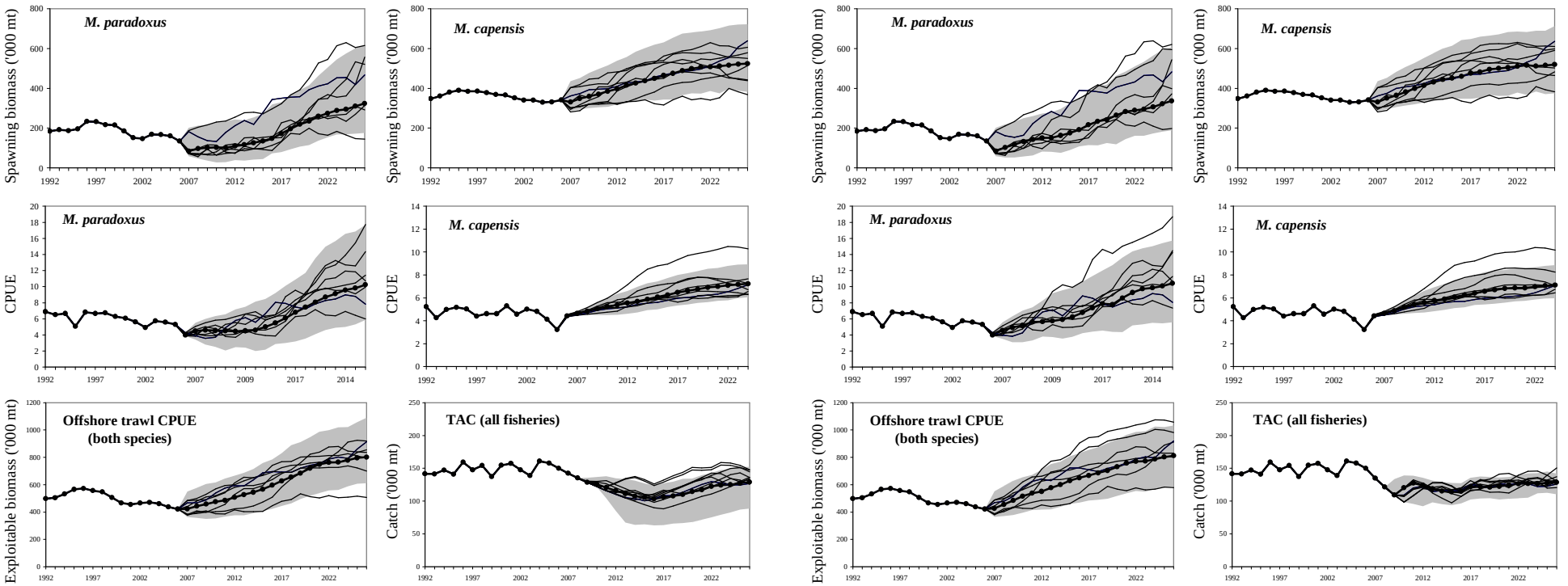

Fig. A1b: Trajectories of resource abundance and catch for an application of **OMP3** and **OMP4** to the updated Reference Set. Ten individual trajectories are shown, with the median a dark dotted line; the shaded areas show 90% PIs. Note units for species-combined CPUE are those of the exploitable biomass to which it corresponds. Pre-2007, the average spawning biomass and species combined CPUE trajectories of the Reference Set and the actual species disaggregated CPUE and total catch are also shown. Tuning is to a **lower 5%-ile** recovery level of 0.121 for *M. paradoxus*.

OMP5 **OMP6**

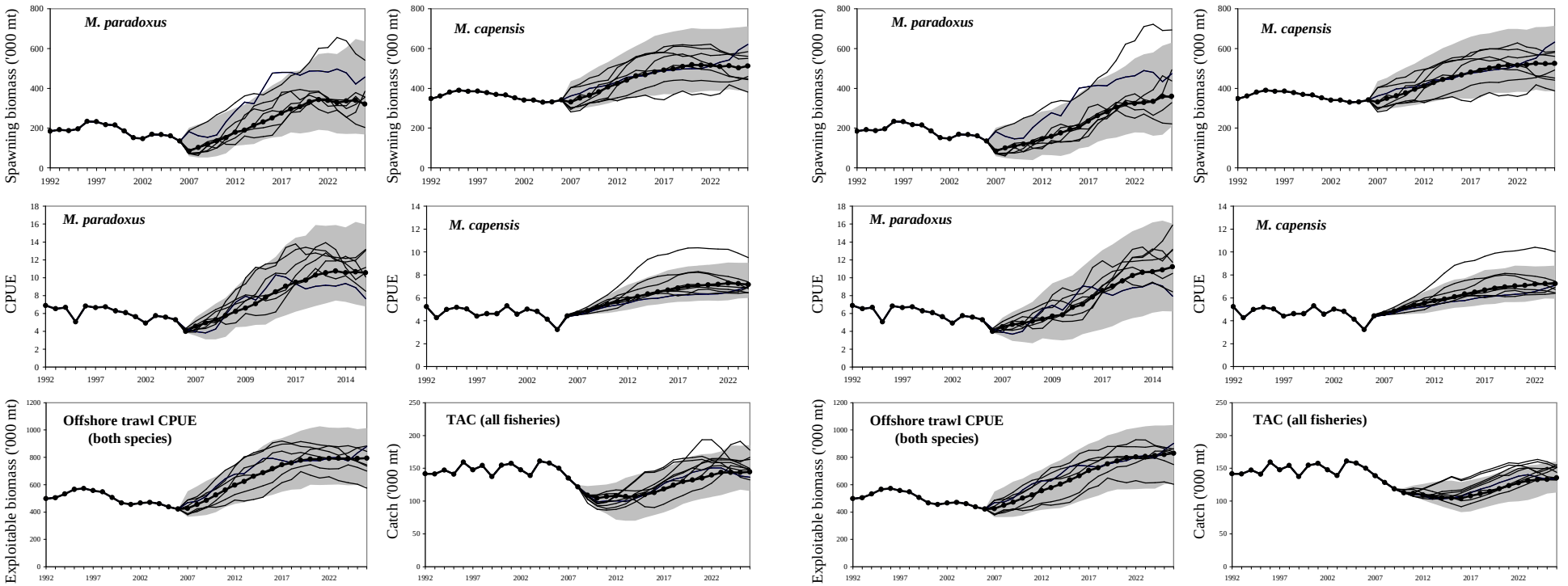

Fig. A1c: Trajectories of resource abundance and catch for an application of **OMP5** and **OMP6** to the updated Reference Set. Ten individual trajectories are shown, with the median a dark dotted line; the shaded areas show 90% PIs. Note units for species-combined CPUE are those of the exploitable biomass to which it corresponds. Pre-2007, the average spawning biomass and species combined CPUE trajectories of the Reference Set and the actual species disaggregated CPUE and total catch are also shown. Tuning is to a **lower 5%-ile** recovery level of 0.121 for *M. paradoxus*.

OMP7 **OMP8**

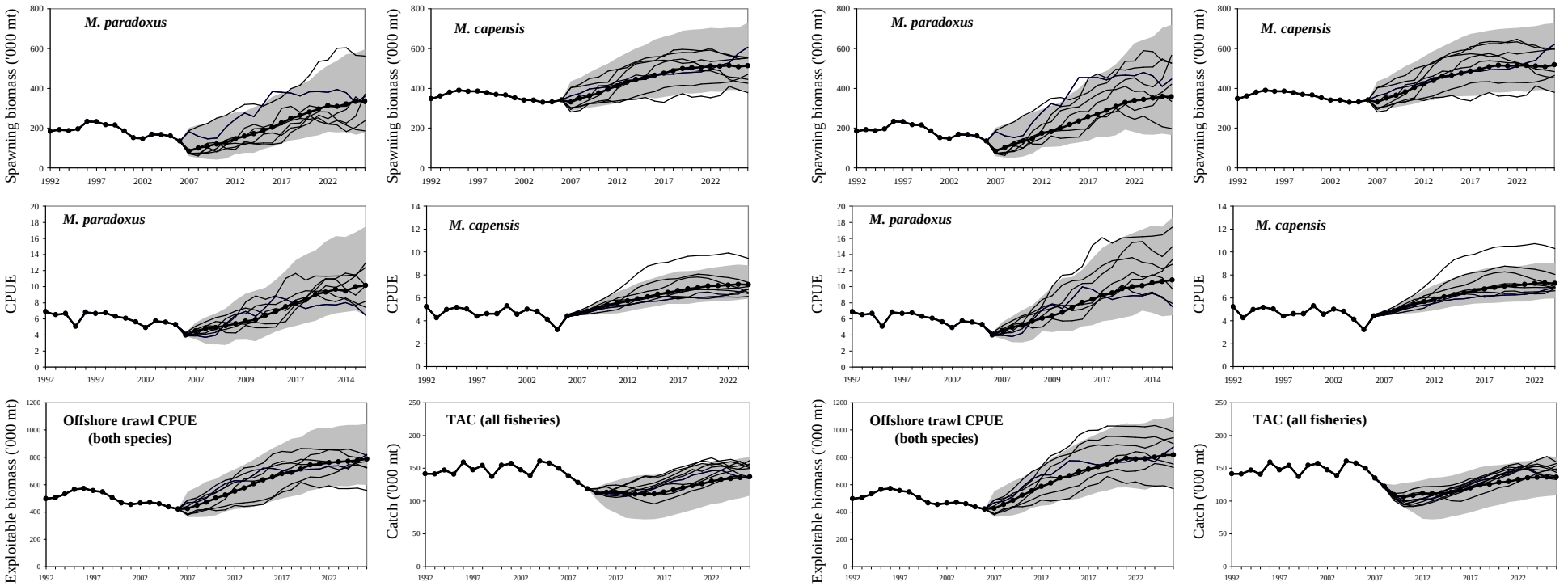

Fig. A1d: Trajectories of resource abundance and catch for an application of **OMP7** and **OMP8** to the updated Reference Set. Ten individual trajectories are shown, with the median a dark dotted line; the shaded areas show 90% PIs. Note units for species-combined CPUE are those of the exploitable biomass to which it corresponds. Pre-2007, the average spawning biomass and species combined CPUE trajectories of the Reference Set and the actual species disaggregated CPUE and total catch are also shown. Tuning is to a **lower 5%-ile** recovery level of 0.121 for *M. paradoxus*.

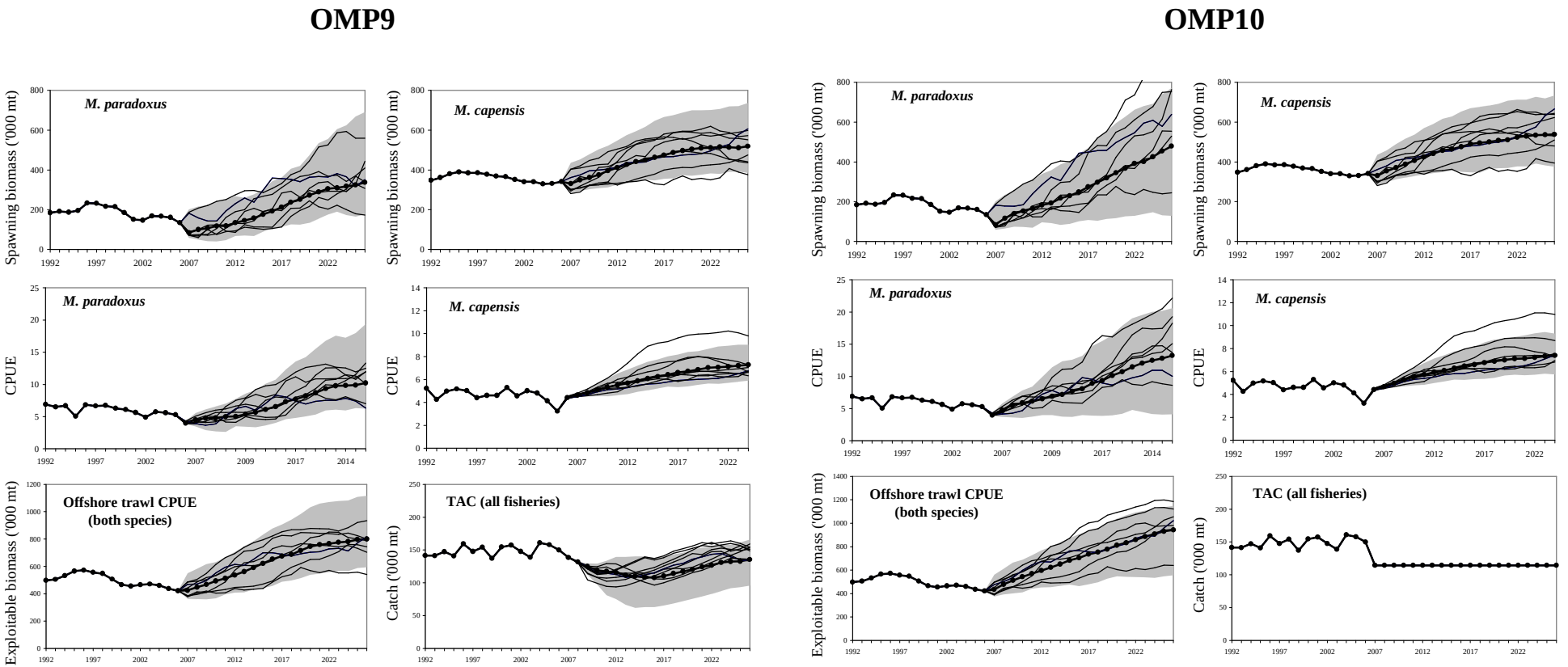

Fig. A1e: Trajectories of resource abundance and catch for an application of **OMP9** and **OMP10** to the updated Reference Set. Ten individual trajectories are shown, with the median a dark dotted line; the shaded areas show 90% PIs. Note units for species-combined CPUE are those of the exploitable biomass to which it corresponds. Pre-2007, the average spawning biomass and species combined CPUE trajectories of the Reference Set and the actual species disaggregated CPUE and total catch are also shown. Tuning is to a **lower 5%-ile** recovery level of 0.121 for *M. paradoxus*.

Appendix B

Table B1: Summary of performance statistics for a series of candidate OMPs, tuned to a 20% median recovery level for *M. paradoxus*, for the Reference Set. For each parameter, the median and 90% PIs are shown.

		OMP1	OMP2	OMP3	OMP4	OMP5	OMP6	OMP10
					Gaylard	Penney	Ind1	CC
Species combined	avTAC	125.05	124.32	118.56	122.09	125.70	122.08	124.50
		108.76	99.47	87.49	107.60	106.03	103.61	124.50
		139.27	140.14	133.44	131.05	139.70	136.36	124.50
	AAV	4.99	5.32	4.72	5.12	6.30	4.88	1.87
		3.45	4.09	4.04	4.05	4.66	4.24	1.87
		6.82	6.88	6.86	6.25	8.30	5.76	1.87
	C_{2007}	135.00	135.86	142.50	135.00	134.97	138.75	124.50
		-	-	-	-	-	-	-
		-	-	-	-	-	-	-
	C_{2008}	121.50	125.67	135.37	121.50	121.47	128.34	124.50
		121.50	112.08	135.37	121.50	118.54	128.34	124.50
		130.02	130.02	135.38	133.94	126.32	128.34	124.50
	C_{2009}	111.00	114.20	128.61	117.69	109.07	118.72	124.50
		109.35	95.70	128.60	109.35	102.20	118.72	124.50
		128.16	128.22	138.27	141.62	124.47	118.72	124.50
M. paradoxus	B_{2027}/K	**0.200**	**0.200**	**0.200**	**0.200**	**0.200**	**0.200**	**0.200**
		0.121	0.085	0.106	0.058	0.105	0.092	0.000
		0.312	0.406	0.355	0.314	0.346	0.325	0.351
	B_{2027}/B_{2007}	2.91	2.85	3.41	3.00	2.92	3.03	2.99
		1.98	1.53	1.38	0.97	1.84	1.74	0.00
		4.91	7.65	6.87	5.92	5.20	5.39	6.97
M. capensis	B_{2027}/K	0.70	0.71	0.71	0.71	0.70	0.70	0.69
		0.59	0.57	0.58	0.54	0.58	0.56	0.04
		0.85	0.87	0.86	0.86	0.85	0.86	0.87
	B_{2027}/B_{2007}	1.49	1.50	1.60	1.50	1.48	1.49	1.45
		1.22	1.23	1.31	1.18	1.21	1.17	0.11
		1.78	1.79	1.97	1.82	1.81	1.78	1.82

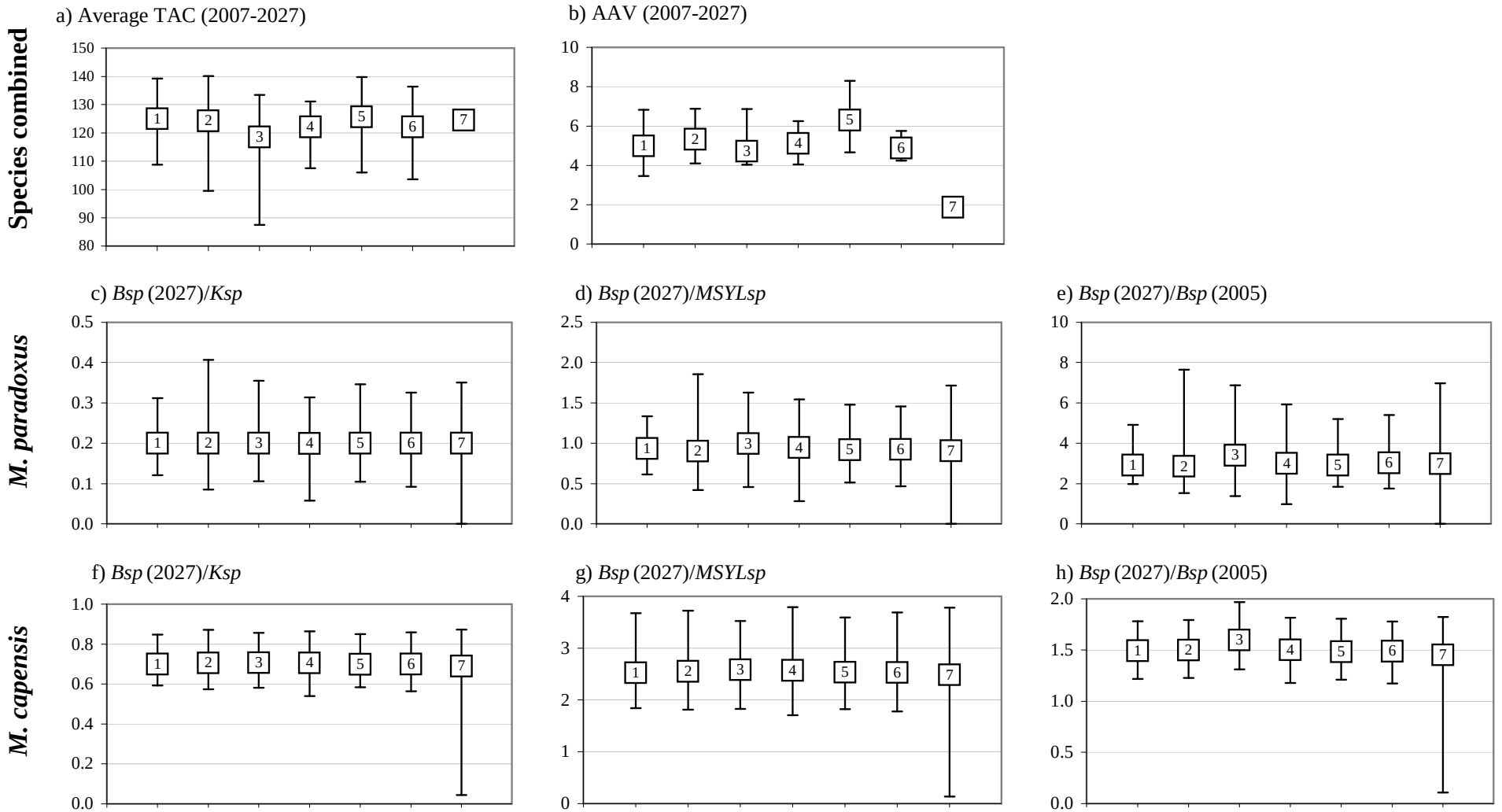

Fig. B1: Graphical summary of performance statistics for a series of candidate OMPs, tuned to a 20% **median** recovery level for *M. paradoxus*, for the Reference Set. Each panel shows medians together with 90% PIs. The labels correspond to the earlier OMP numbers, except for label 7 which correspond to the constant catch strategy of OMP10.

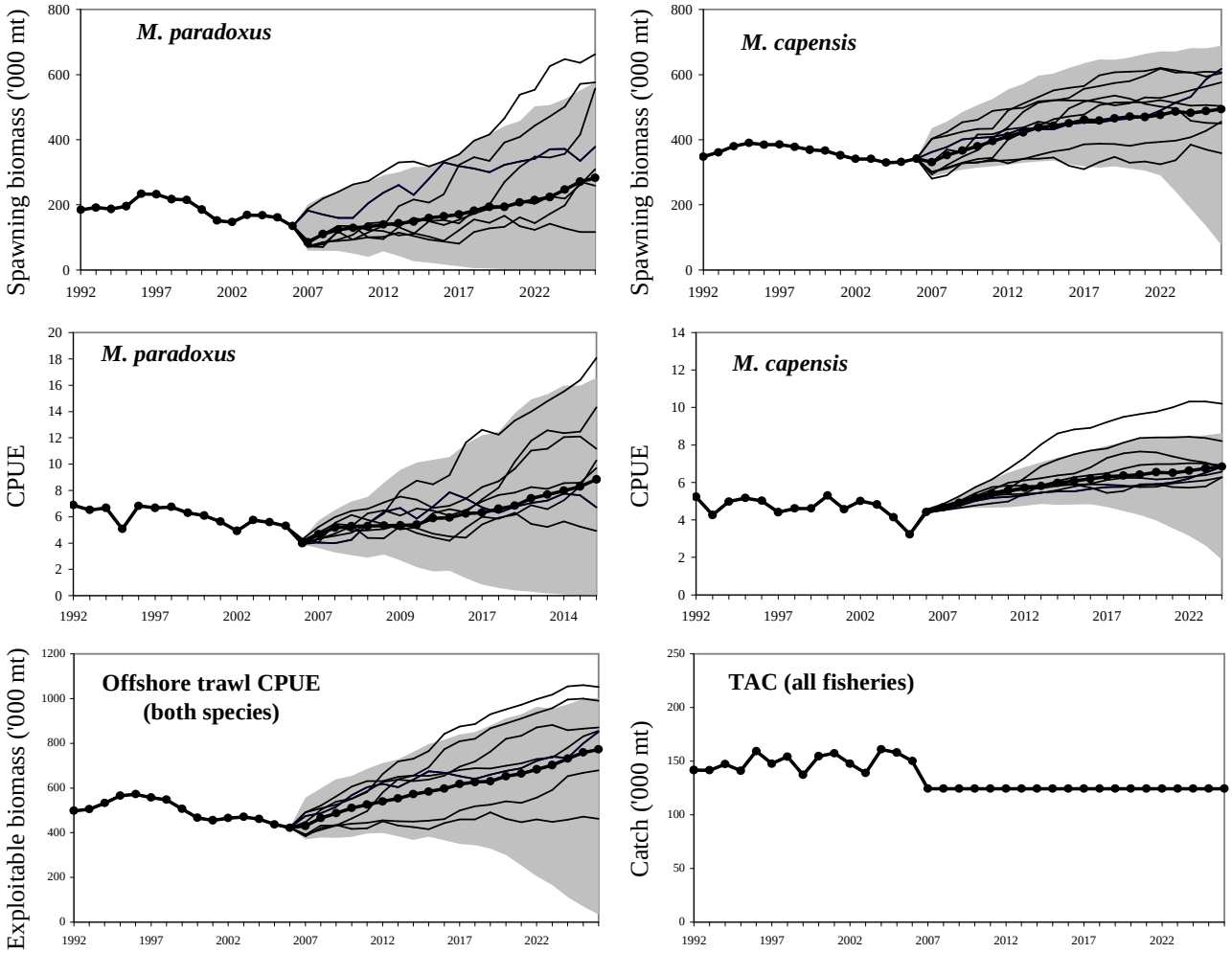

Fig. B2: Trajectories of resource abundance and catch for an application of OMP10 tuned to a 20% median recovery level for *M. paradoxus*, for the Reference Set. Ten individual trajectories are shown, with the median a dark dotted line; the shaded areas show 90% PIs. Note units for species-combined CPUE are those of the exploitable biomass to which it corresponds. Pre-2007, the average spawning biomass and species combined CPUE trajectories of the Reference Set and the actual species disaggregated CPUE and total catch are also shown.