Results leading to a Proposal for a Reference Set of Operating Models for Testing the 2014 OMP Revision for the South African hake resource

Rebecca Rademeyer and Doug Butterworth
May 2014

The starting design for this proposed Reference Set (RS) of Operating Models (OMs) is a full cross of factors covering three major axes of uncertainty: 3 center-years for the species preponderance change in the catch x 3 natural mortality vectors x 3 stock-recruitment relationship (see Rademeyer 2014). Specifically these are:

- Centre years for change from *M. capensis* to *M. paradoxus* preponderance in catch: 1950, 1958 and 1965.
- Natural mortality vectors: "Mmed": M_{2-}=0.75 and M_{5+}=0.375, "Mlow": M_{2-}=0.6 and M_{5+}=0.25 and "Mhigh": M_{2-}=0.9 and M_{5+}=0.5.
- Stock-recruitment relations: "Ricker": modified Ricker, "BH": Beverton-Holt, *h* estimated, and "BH08": Beverton-Holt, *h*=0.8.

For the Beverton-Holt with fixed *h* cases, the original suggestion was to use *h*=0.7 (Rademeyer 2014), as was the case in developing the 2010 OMP. However, since virtually all these cases failed the constraint that -ΔlnL <15 (compared to the best-fitting OM) which was applied in the past, it was decided to rerun all of them with *h*=0.8. This yields the ***initial*** set of 27 OMs.

Two concerns arose with this initial set. The first was that even with *h* increased to 0.8, nearly all the associated OMs again failed the -ΔlnL <15 constraint. Omitting all these cases from the RS would result in a lack of balance and of similarity to the RS used in developing OMP-2010. This is because when the BH stock recruitment function is assumed, the value estimated for *h* is often very high (being frequently above 0.9), so that if spawning biomass drops below the lowest levels that occurred in the past under catch limits set unduly high, there is hardly any consequent penalty to future resource prospects as a result of “recruitment overfishing”. To allow for the possibility of such overfishing in these circumstances, rather than force the bad fits that result from a fixed lower value of *h*, a less optimistic relationship of recruitment to spawning biomass is assumed when this biomass falls below its lowest previous level (*B*min). The curve below this level is replaced by the average of that curve and a straight line from the origin to the value of the curve at *B*min, yielding the “BHmod” model (see Figure 1). Thus the overall curve is continuous, though with a derivative discontinuity at *B*min, and recruitment will fall further than in the case of the BH curve should spawning biomass in the future be reduced below *B*min. In terms of the fit of the assessment model, there is no difference, but if for the original fit *B*msy/*K* fell below *B*min, MSY decreases although *B*msy and *F*msy remain unchanged. These BHmod models have replaced the corresponding BH0.8 ones.

The second concern was the large size of the initial RS (27 OMs compared to the “equivalent” 10 OMs used in 2010). To reduce this number without sacrificing the design’s balance, only combinations where both the natural mortality vector and the year of the reversal in species dominance are changed from their central choices, are included. This leads to a ***revised*** set of 15 OMs.

Results for this ***revised*** set of OMs are given in Table 1 and summarized in Table 2. The corresponding spawning biomass trajectories are plotted in Figure 2. Figure 3 plots the median and range (minimum and maximum) spawning biomass trajectories for the full ***initial*** set of 27 OMs, for this ***revised*** set of 15 OMs and for the 9 of the

10 OMs equivalent to the 2010 RSa (RS1, RS4, RS5, RS7, RS8, RS10, RS11, RS13 and RS14), as one of the 10 from 2010 did not progress to the ***revised*** set.

The stock-recruitment curves (for *M. paradoxus* and *M. capensis*) are shown in Figure 4, grouped by type of stock-recruitment relationship (Figure 4a) and grouped by level of natural mortality (Figure 4b). Figure 4a shows that for the BHmod relationship for case RS3 for which the stock-recruitment "data" are plotted that the kink corresponding to the start of poorer recruitment at spawning biomass declines occurs at the left side limit (*B*min) of spawning biomass "data" shown for *M. paradoxus*, as to be expected. It might seem surprising that this is not the case for the corresponding R3 plot for *M. capensis*; the reason is that in this instance *B*min occurs around 1960 before the data required to estimate recruitment become available.

The fits to the CPUE and survey biomass indices for the revised set of 15 OMs are shown in Figure A1 in Appendix A. The fits to the catch-at-length data are shown in Figure A2 for RS1, RS12 (which has the worst overall -lnL) and RS13 (which has the best overall -lnL)

Final proposal

The task team considering this issue agreed that the final RS should drop RS8 and RS9 from the ***revised*** set because of their questionably small B_{MSY}/K = 0.11 value for *M. capensis*, thus leaving 13 OMs for the ***final*** RS.

There were differences of views amongst the task team as to whether RS11 and RS12 should also be dropped:

a) their elimination is supported by their relatively poor fits to the data, with -ΔlnL = 23.6, and would be consistent with the approach adopted when developing OMP-2010; but
b) their continued inclusion maintains a balance in the ***final*** RS amongst the choice of centre year values for the change from *M. capensis* to *M. paradoxus* preponderance in catch.

The final choice between these two options in specifying the ***final*** RS is to be made at the next meeting of the DWG.

Reference

Rademeyer RA. 2014. Proposed Reference Set for the South African hake resource. FISHERIES/2014/APR/SWG-DEM/HASTT/03

Table 1: Results for the **15 OMs** of the ***revised*** set.

	'Δ-lnL	4.7	6.6	6.6	11.1	13.0	13.0	5.0	5.8	5.8	14.1	23.6	23.6	0.0	10.1	10.1
		RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8*	RS9*	RS10	RS11**	RS12**	RS13	RS14	RS15
		1958	1958	1958	1950	1950	1950	1950	1950	1950	1965	1965	1965	1965	1965	1965
		Mmed	Mmed	Mmed	Mlow	Mlow	Mlow	Mhigh	Mhigh	Mhigh	Mlow	Mlow	Mlow	Mhigh	Mhigh	Mhigh
		Ricker	BH	BHmod	Ricker	BH	BHmod	Ricker	BH	BHmod	Ricker	BH	BHmod	Ricker	BH	BHmod
	-lnL total	-181.3	-179.4	-179.4	-174.9	-173.0	-173.0	-181.1	-180.2	-180.2	-172.0	-162.4	-162.4	-186.0	-175.9	-175.9
	CPUE historic	-40.0	-39.8	-39.8	-39.1	-39.7	-39.7	-38.1	-36.4	-36.4	-39.2	-38.4	-38.4	-39.2	-39.8	-39.8
	CPUE GLM	-180.7	-179.9	-179.9	-178.6	-176.9	-176.9	-183.0	-183.2	-183.2	-177.0	-169.8	-169.8	-183.4	-175.3	-175.3
	Survey	-32.1	-33.1	-33.1	-35.6	-36.5	-36.5	-31.9	-33.0	-33.0	-36.5	-34.0	-34.0	-33.2	-31.9	-31.9
	Comm. CAL (sex-aggr.): trawl	-42.8	-42.2	-42.2	-42.7	-41.5	-41.5	-38.8	-39.0	-39.0	-38.4	-43.7	-43.7	-42.0	-43.5	-43.5
	longline	-17.2	-17.2	-17.2	-16.1	-17.2	-17.2	-17.2	-17.3	-17.3	-17.1	-17.2	-17.2	-17.3	-17.2	-17.2
	Comm. CAL (sex-disaggr.)	-51.9	-51.8	-51.8	-50.3	-50.3	-50.3	-53.3	-53.1	-53.1	-51.2	-49.5	-49.5	-53.0	-53.2	-53.2
	Survey CAL (sex-aggr.)	-1.8	-1.8	-1.8	0.5	0.8	0.8	-3.6	-3.6	-3.6	-0.1	-1.0	-1.0	-3.8	-3.2	-3.2
	Survey CAL (sex-disaggr.)	42.3	42.5	42.5	45.5	45.5	45.5	43.6	44.3	44.3	45.1	45.2	45.2	43.7	43.6	43.6
	ALK	117.8	118.1	118.1	117.9	117.8	117.8	116.9	116.2	116.2	117.3	118.3	118.3	116.7	117.6	117.6
	Recruitment penalty	8.7	9.7	9.7	7.5	8.8	8.8	9.1	9.3	9.3	7.3	9.8	9.8	9.1	10.2	10.2
	Selectivity smoothing penalty	16.1	15.9	15.9	16.1	16.2	16.2	15.2	15.6	15.6	17.4	17.8	17.8	16.4	16.4	16.4
M. paradoxus	K^{sp}	849	826	826	1697	1821	1821	545	525	525	893	1907	1907	366	468	468
	h	0.91	0.95	0.95	1.02	0.95	0.95	0.82	0.88	0.88	1.70	0.98	0.98	1.20	0.96	0.96
	B^{sp}_{2012}	154	150	150	257	266	266	107	116	116	305	388	388	131	119	119
	B^{sp}_{2012}/K^{sp}	0.18	0.18	0.18	0.15	0.15	0.15	0.20	0.22	0.22	0.34	0.20	0.20	0.36	0.25	0.25
	B^{sp}_{2013}	150	147	147	268	277	277	98	108	108	323	403	403	125	109	109
	B^{sp}_{2013}/K^{sp}	0.18	0.18	0.18	0.16	0.15	0.15	0.18	0.21	0.21	0.36	0.21	0.21	0.34	0.23	0.23
	B^{sp}_{MSY}	153	153	153	412	416	416	100	110	110	343	366	366	114	66	66
	B^{sp}_{MSY}/K^{sp}	0.18	0.18	0.18	0.24	0.23	0.23	0.18	0.21	0.21	0.38	0.19	0.19	0.31	0.14	0.14
	$B^{sp}_{2012}/B^{sp}_{MSY}$	1.00	0.98	0.98	0.62	0.64	0.64	1.07	1.06	1.06	0.89	1.06	1.06	1.15	1.80	1.80
	$B^{sp}_{2013}/B^{sp}_{MSY}$	0.98	0.96	0.96	0.65	0.67	0.67	0.98	0.98	0.98	0.94	1.10	1.10	1.10	1.64	1.64
	MSY	111	111	111	121	120	120	106	111	111	122	119	119	116	110	110
M. capensis	K^{sp}	231	311	311	297	456	456	148	182	182	635	879	879	148	349	349
	h	1.15	0.95	0.95	1.07	0.98	0.98	0.86	0.98	0.98	0.99	0.98	0.98	2.20	0.87	0.87
	B^{sp}_{2012}	142	152	152	173	168	168	96	94	94	417	507	507	109	232	232
	B^{sp}_{2012}/K^{sp}	0.61	0.49	0.49	0.58	0.37	0.37	0.65	0.52	0.52	0.66	0.58	0.58	0.73	0.67	0.67
	B^{sp}_{2013}	158	169	169	193	188	188	107	106	106	451	544	544	121	252	252
	B^{sp}_{2013}/K^{sp}	0.69	0.55	0.55	0.65	0.41	0.41	0.72	0.58	0.58	0.71	0.62	0.62	0.82	0.72	0.72
	B^{sp}_{MSY}	81	53	53	140	82	82	61	20	20	267	158	158	36	68	68
	B^{sp}_{MSY}/K^{sp}	0.35	0.17	0.17	0.47	0.18	0.18	0.41	0.11	0.11	0.42	0.18	0.18	0.24	0.20	0.20
	$B^{sp}_{2012}/B^{sp}_{MSY}$	1.75	2.85	2.85	1.23	2.04	2.04	1.57	4.63	4.63	1.56	3.21	3.21	3.04	3.41	3.41
	$B^{sp}_{2013}/B^{sp}_{MSY}$	1.94	3.17	3.17	1.38	2.28	2.28	1.75	5.22	5.22	1.69	3.44	3.44	3.37	3.70	3.70
	MSY	62	59	59	57	50	41	55	63	44	89	92	69	114	99	99

* Dropped for the ***final*** RS

** Possibly to be dropped from the ***final*** RS.

Table 2: Lowest, median and highest results for the **full 27 OMs** of the ***initial*** set**,** the **15 OMs** of the ***revised*** set, and the two candidates for the ***final*** RS: the ***revised*** set excluding RS8 and RS9, and the ***revised*** set excluding RS8, RS9, RS11 and RS12.

		Initial set			Revised set			Revised set excluding RS8 and RS9			Revised set excluding RS8, RS9, RS11 and RS12		
		Lowest	Median	Highest	Lowest	Median	Highest	Lowest	Median	Highest	Lowest	Median	Highest
	-lnL total	-186.0	-171.4	-154.8	-186.0	-175.9	-162.4	-186.0	-175.9	-162.4	-186.0	-175.9	-172.0
	CPUE historic	-41.0	-38.5	-32.8	-40.0	-39.2	-36.4	-40.0	-39.7	-38.1	-40.0	-39.7	-38.1
	CPUE GLM	-183.4	-175.3	-162.3	-183.4	-178.6	-169.8	-183.4	-177.0	-169.8	-183.4	-178.6	-175.3
	Survey	-36.5	-33.0	-31.8	-36.5	-33.1	-31.9	-36.5	-33.2	-31.9	-36.5	-33.1	-31.9
	Comm. CAL (sex-aggr.): trawl	-47.3	-43.5	-38.7	-43.7	-42.2	-38.4	-43.7	-42.2	-38.4	-43.5	-42.2	-38.4
	longline	-17.4	-17.2	-16.0	-17.3	-17.2	-16.1	-17.3	-17.2	-16.1	-17.3	-17.2	-16.1
	Comm. CAL (sex-disaggr.)	-53.3	-51.7	-49.3	-53.3	-51.8	-49.5	-53.3	-51.8	-49.5	-53.3	-51.8	-50.3
	Survey CAL (sex-aggr.)	-4.1	-2.0	0.8	-3.8	-1.8	0.8	-3.8	-1.8	0.8	-3.8	-1.8	0.8
	Survey CAL (sex-disaggr.)	42.3	44.2	46.4	42.3	44.3	45.5	42.3	43.7	45.5	42.3	43.6	45.5
	ALK	116.2	117.8	119.6	116.2	117.8	118.3	116.7	117.8	118.3	116.7	117.8	118.1
	Recruitment penalty	7.4	9.8	11.9	7.3	9.3	10.2	7.3	9.1	10.2	7.3	9.1	10.2
	Selectivity smoothing penalty	15.2	16.5	18.9	15.2	16.2	17.8	15.2	16.2	17.8	15.2	16.2	17.4
M. paradoxus	K^{sp}	366	849	2510	366	826	1907	366	849	1907	366	826	1821
	h	0.80	0.91	1.43	0.82	0.95	1.70	0.82	0.96	1.70	0.82	0.95	1.70
	B^{sp}_{2012}	107	193	733	107	150	388	107	154	388	107	150	305
	B^{sp}_{2012}/K^{sp}	0.14	0.25	0.38	0.15	0.20	0.36	0.15	0.20	0.36	0.15	0.18	0.36
	B^{sp}_{2013}	98	182	755	98	147	403	98	150	403	98	147	323
	B^{sp}_{2013}/K^{sp}	0.15	0.23	0.40	0.15	0.21	0.36	0.15	0.18	0.36	0.15	0.18	0.36
	B^{sp}_{MSY}	66	162	718	66	153	416	66	153	416	66	153	416
	B^{sp}_{MSY}/K^{sp}	0.12	0.23	0.43	0.14	0.19	0.38	0.14	0.19	0.38	0.14	0.18	0.38
	$B^{sp}_{2012}/B^{sp}_{MSY}$	0.62	1.06	1.97	0.62	1.06	1.80	0.62	1.00	1.80	0.62	0.98	1.80
	$B^{sp}_{2013}/B^{sp}_{MSY}$	0.65	1.01	1.93	0.65	0.98	1.64	0.65	0.98	1.64	0.65	0.96	1.64
	MSY	106	115	124	106	111	122	106	116	122	106	111	122
M. capensis	K^{sp}	148	375	986	148	311	879	148	349	879	148	311	635
	h	0.80	0.95	2.20	0.86	0.98	2.20	0.86	0.98	2.20	0.86	0.98	2.20
	B^{sp}_{2012}	90	232	568	94	168	507	96	168	507	96	168	417
	B^{sp}_{2012}/K^{sp}	0.35	0.61	0.76	0.37	0.58	0.73	0.37	0.58	0.73	0.37	0.61	0.73
	B^{sp}_{2013}	101	252	609	106	188	544	107	188	544	107	188	451
	B^{sp}_{2013}/K^{sp}	0.38	0.68	0.84	0.41	0.62	0.82	0.41	0.65	0.82	0.41	0.69	0.82
	B^{sp}_{MSY}	20	87	278	20	68	267	36	81	267	36	68	267
	B^{sp}_{MSY}/K^{sp}	0.11	0.24	0.43	0.11	0.18	0.47	0.17	0.20	0.47	0.17	0.20	0.47
	$B^{sp}_{2012}/B^{sp}_{MSY}$	1.29	2.54	4.63	1.23	2.85	4.63	1.23	2.85	3.41	1.23	2.04	3.41
	$B^{sp}_{2013}/B^{sp}_{MSY}$	1.42	2.75	5.22	1.38	3.17	5.22	1.38	3.17	3.70	1.38	2.28	3.70
	MSY	44	89	137	41	62	114	41	62	114	41	59	114

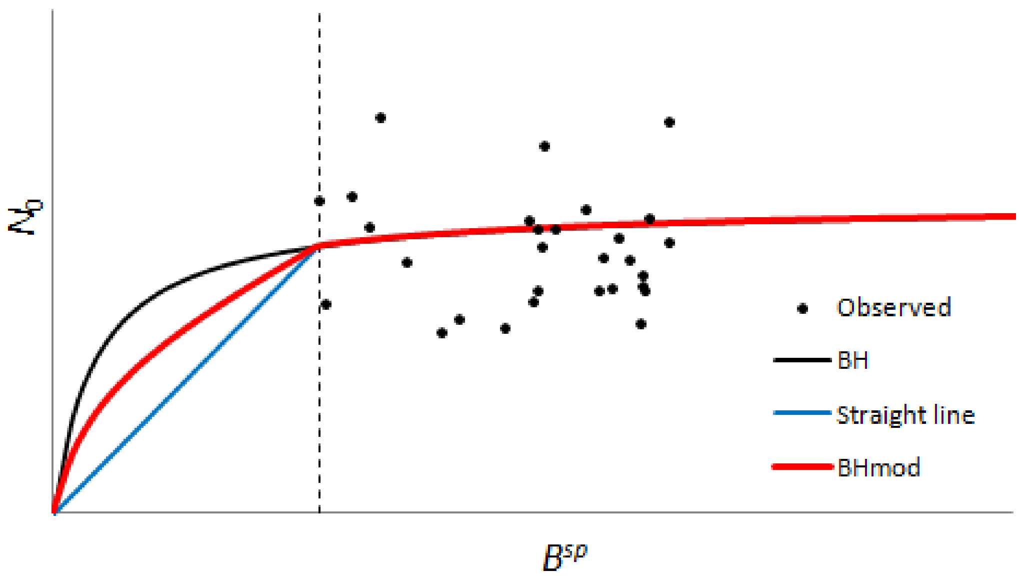

Figure 1: Schematic representation of the "BHmod" stock-recruitment curve.

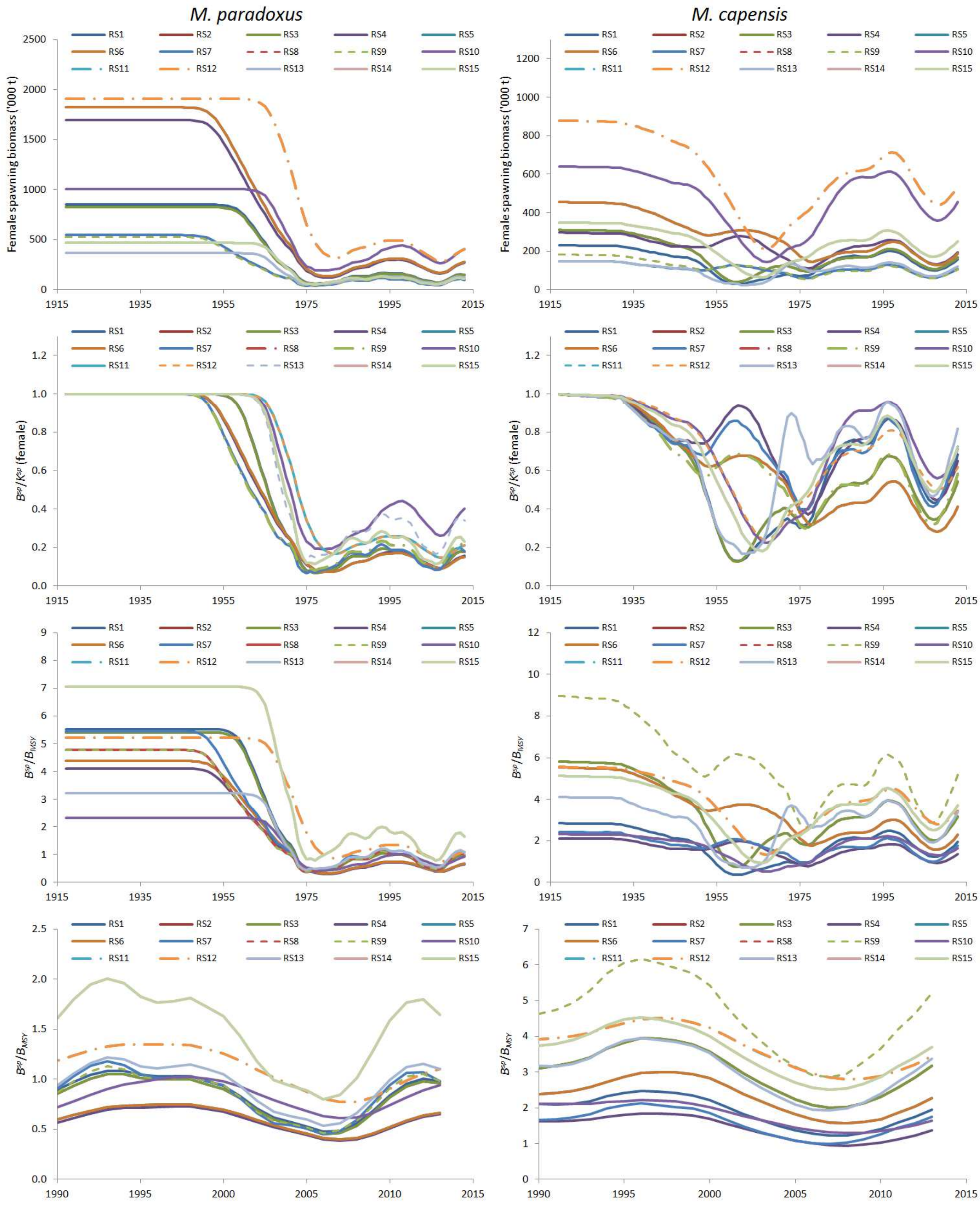

Figure 2: Female spawning biomass trajectories (in absolute terms - first row -, relative to pre-exploitation level - second row - and relative to B_{MSY} - third and fourth rows) for *M. paradoxus* (left hand column) and *M. capensis* (right hand column) for the **15 OMs** of the ***revised*** set. The third and fourth rows are the same except for the horizontal axis. Note trajectories for OMs RS3, RS6, RS9, RS12 and RS15 are the same as those for RS2, RS5, RS8, RS11 and RS14 respectively. RS8 and RS9 which will be dropped for the ***final*** RS are shown as dashed lines, while RS11 and RS12 which will possibly be dropped from the final RS are shown as dashed-dot lines.

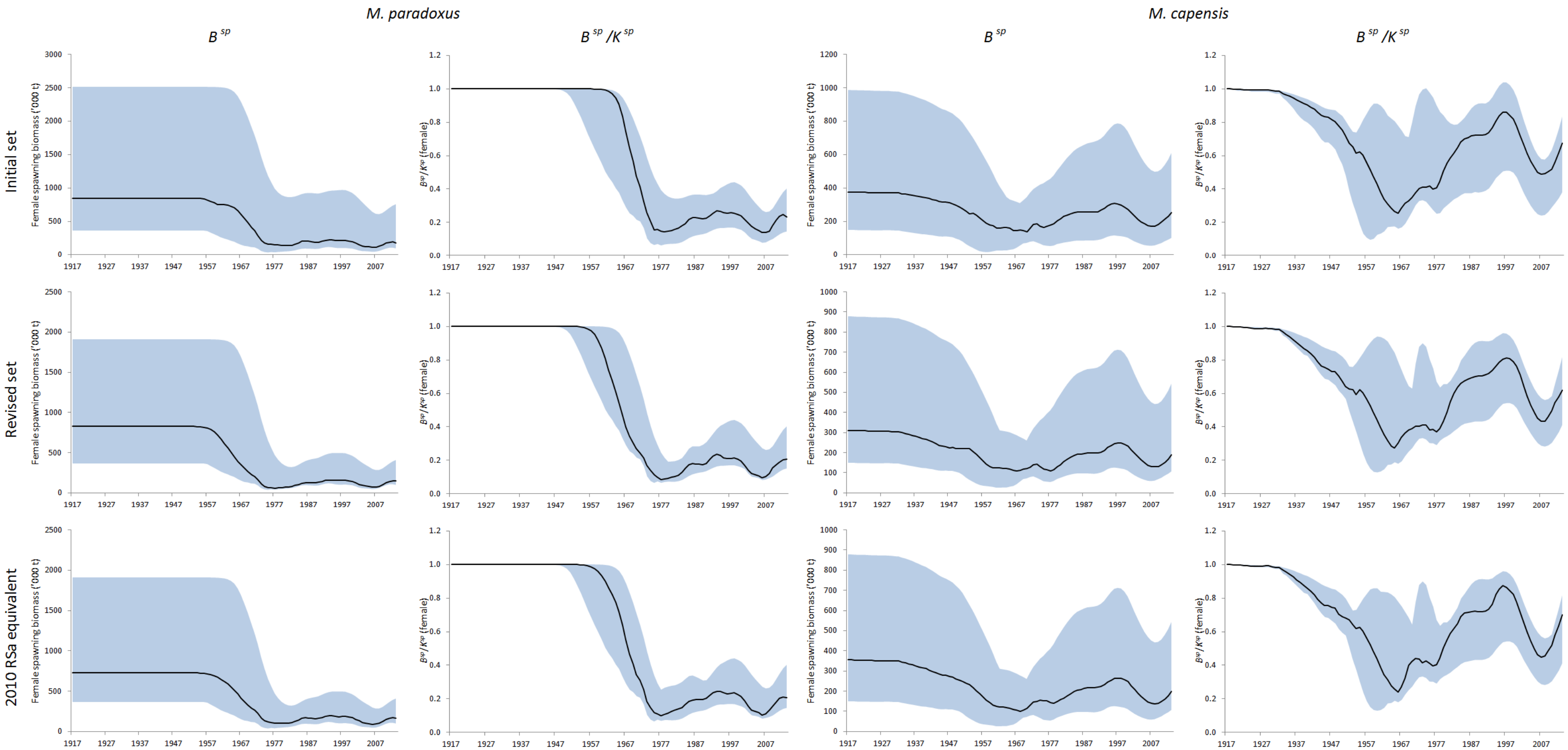

Figure 3: Median (black line) with minimum-maximum range (shading) spawning biomass trajectories (in absolute terms and relative to pre-exploitation level) for *M. paradoxus* and *M. capensis*, for the **27 OMs** of the ***initial*** set (first row), for the **15 OMs** of the ***revised*** set (second row), and for the set of 9 OMs most nearly equivalent to the 10 OMs used in the **2010 RSa** (third row).

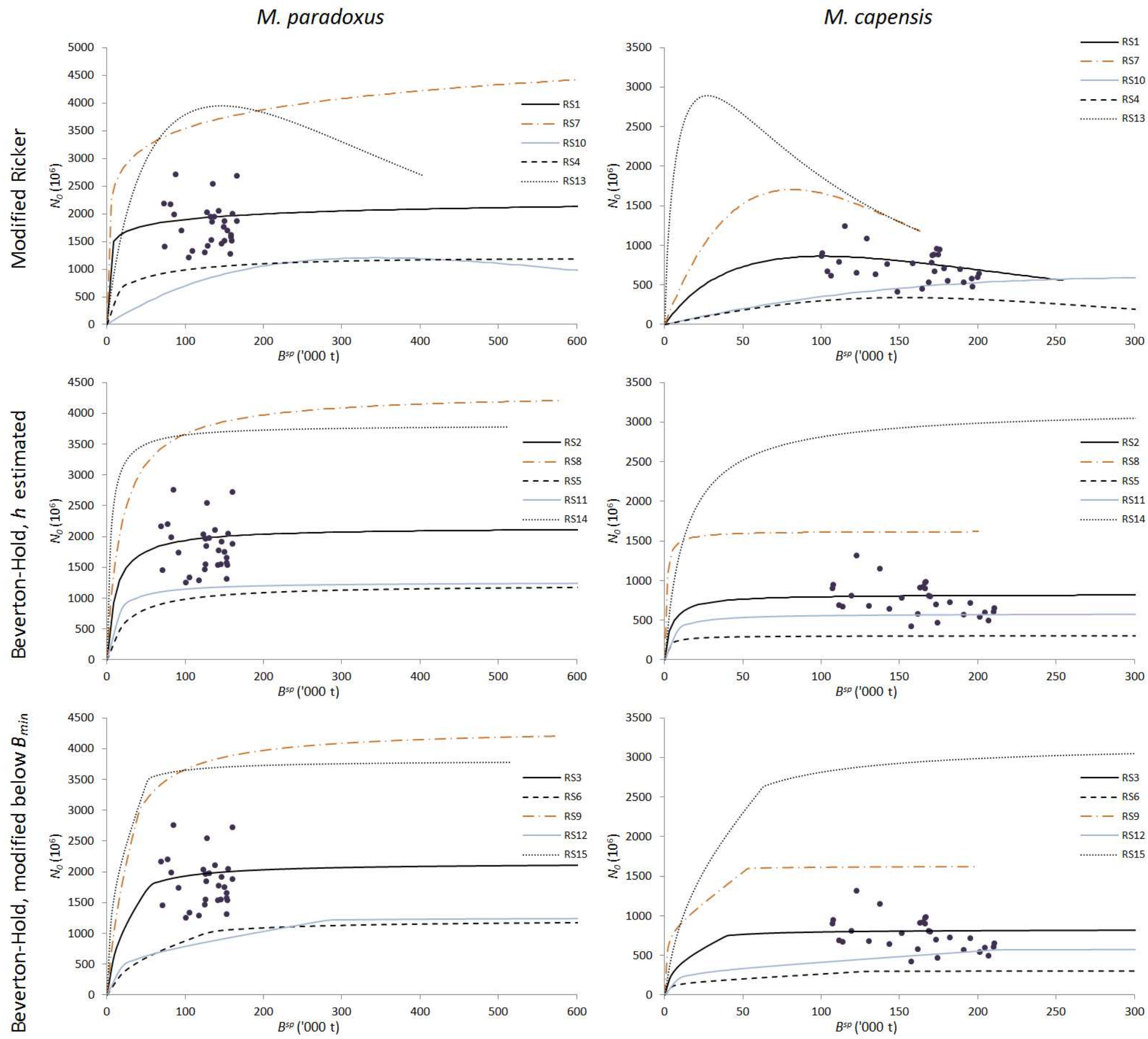

Figure 4a: Estimated stock-recruitment curves for each of the 15 OMs of the ***revised*** set for *M. paradoxus* and *M. capensis*, grouped by stock-recruitment curve type. In each plot, the "data" are plotted for a single OM, corresponding to the medium natural mortality and 1958 center-year.

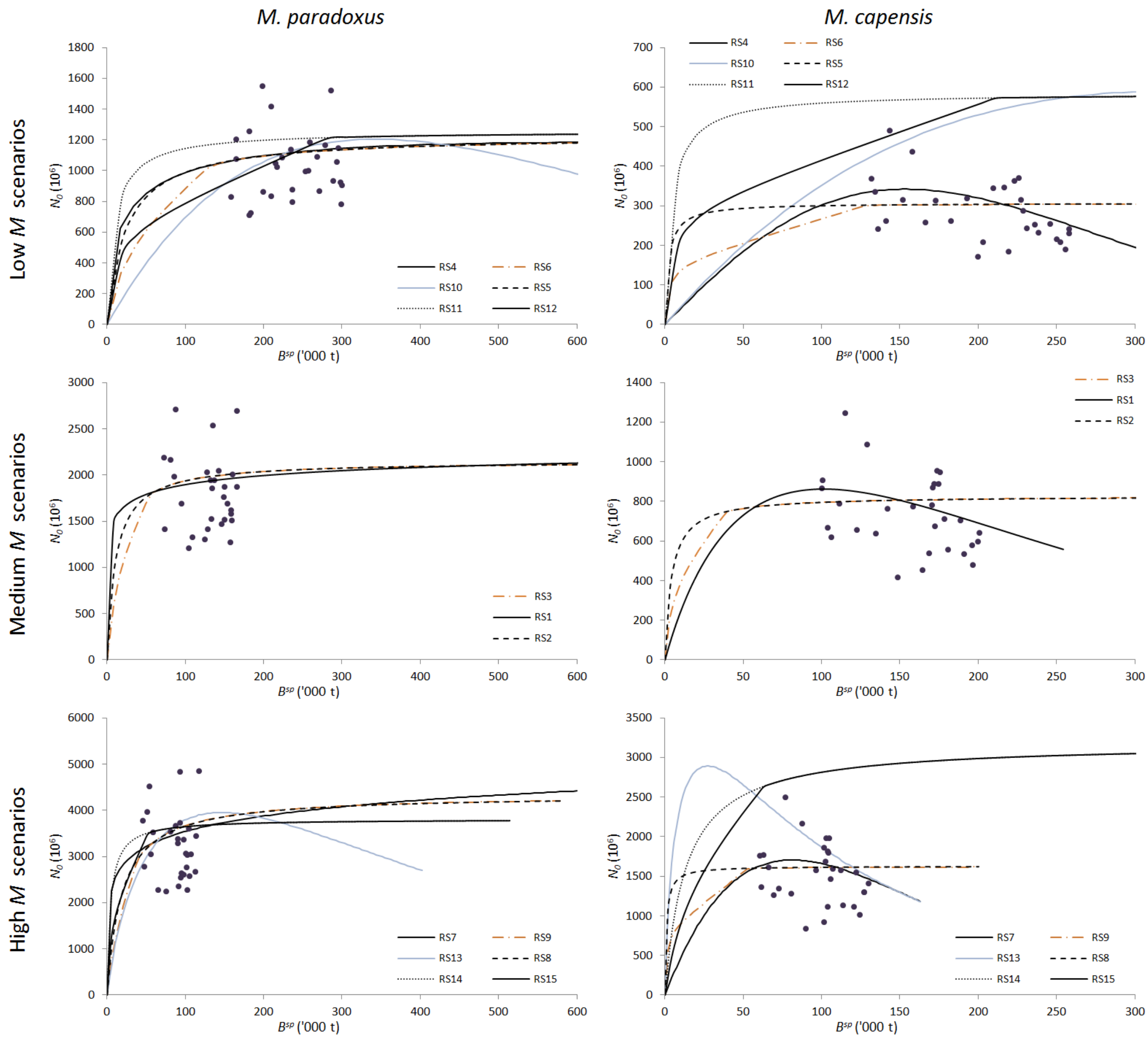

Figure 4b: Estimated stock-recruitment curves for each of the 15 OMs of the ***revised*** set for *M. paradoxus* and *M. capensis*, grouped by level of natural mortality. In each plot, the "data" are plotted for a single OM, corresponding to the modified Ricker stock-recruitment curve and 1958 center-year.

Appendix A

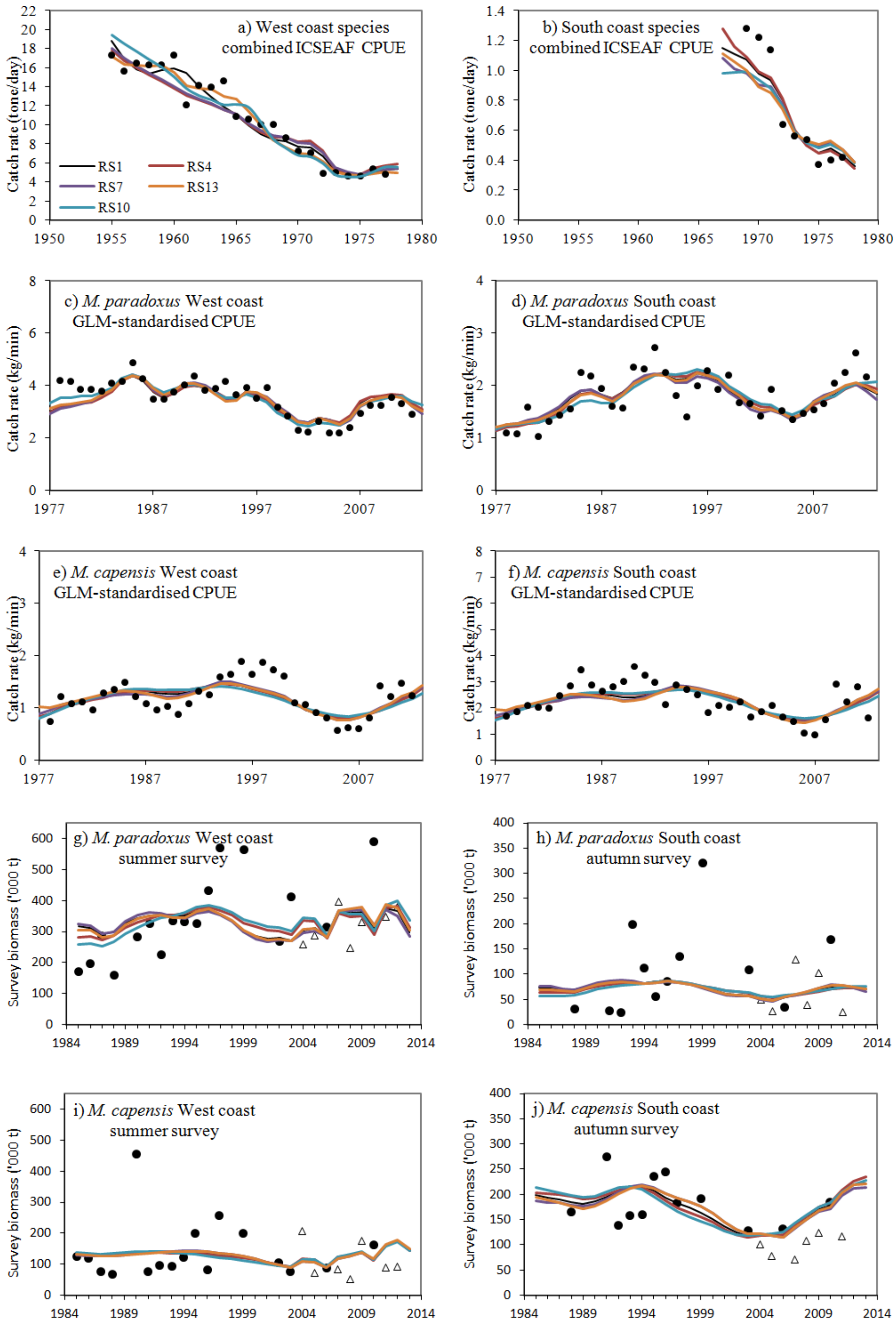

Figure A1a: Fits of RS1, RS4, RS7, RS10 and RS13 (Ricker) to the CPUE and survey indices.

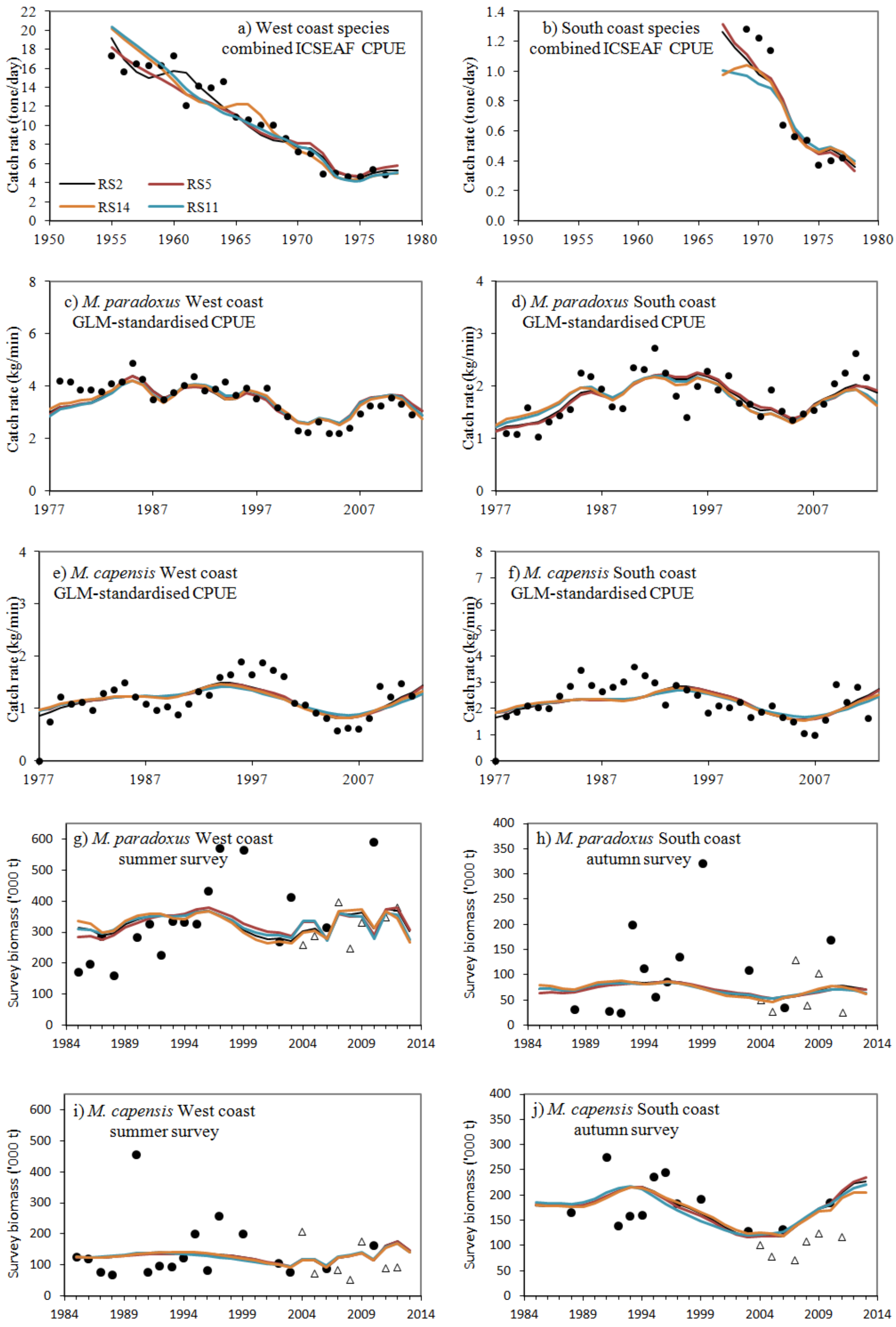

Figure A1b: Fits of RS1, RS5, RS11 and RS14 (Beverton-Holt) to the CPUE and survey indices.

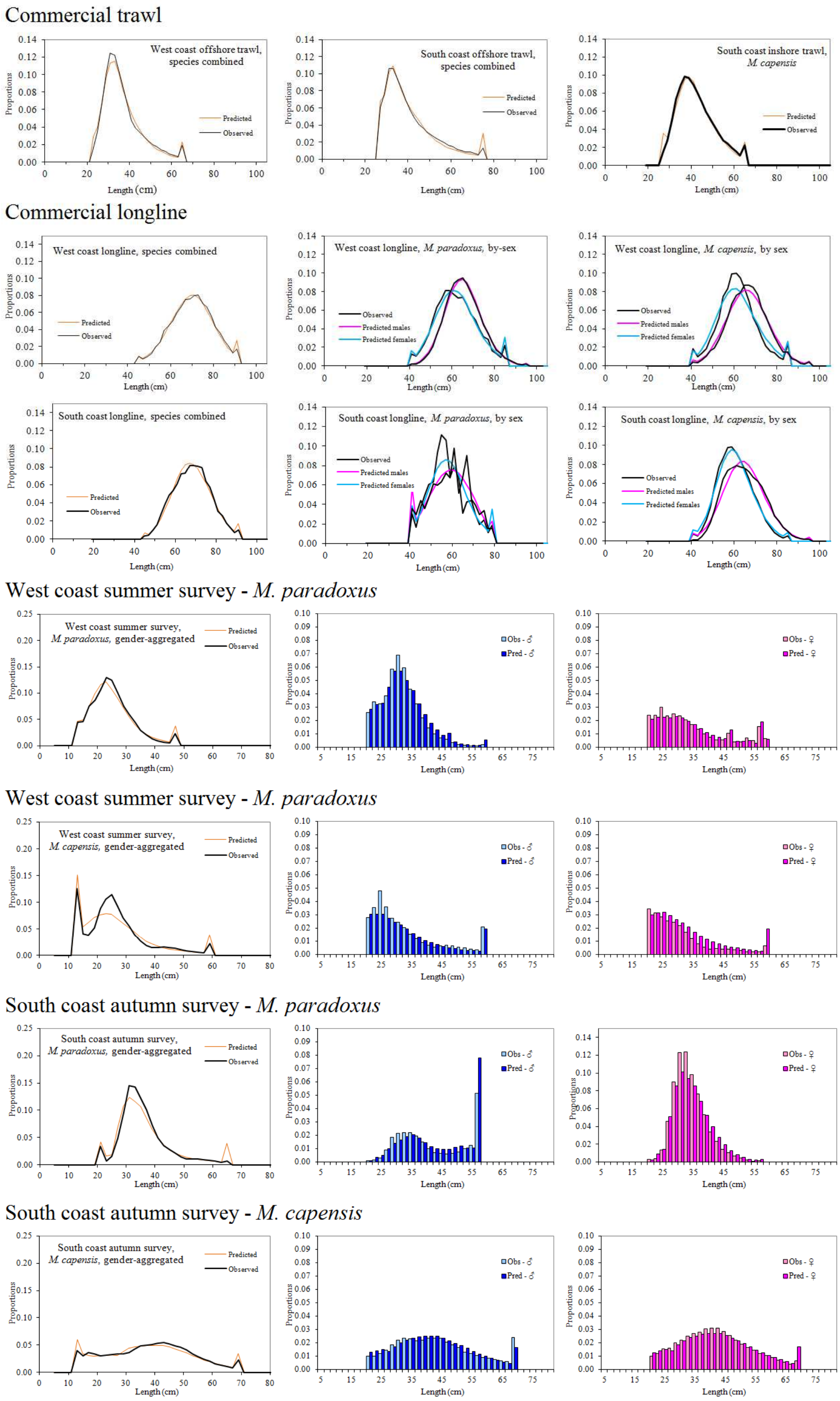

Figure A2a: Fits of RS1 to the commercial and survey catch-at-length data, aggregated over all the years for which data are available.

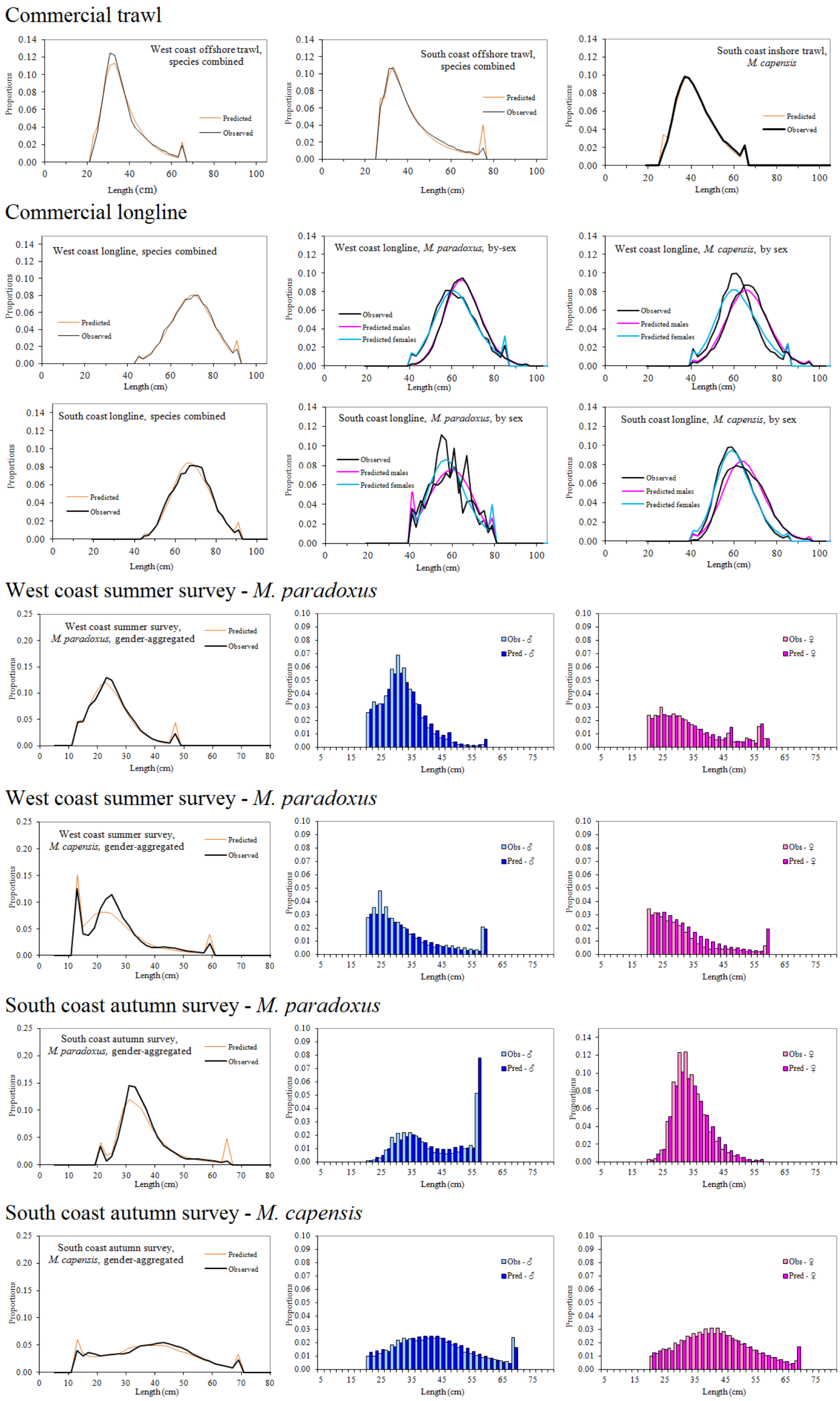

Figure A2b: Fits of RS11 to the commercial and survey catch-at-length data, aggregated over all the years for which data are available.

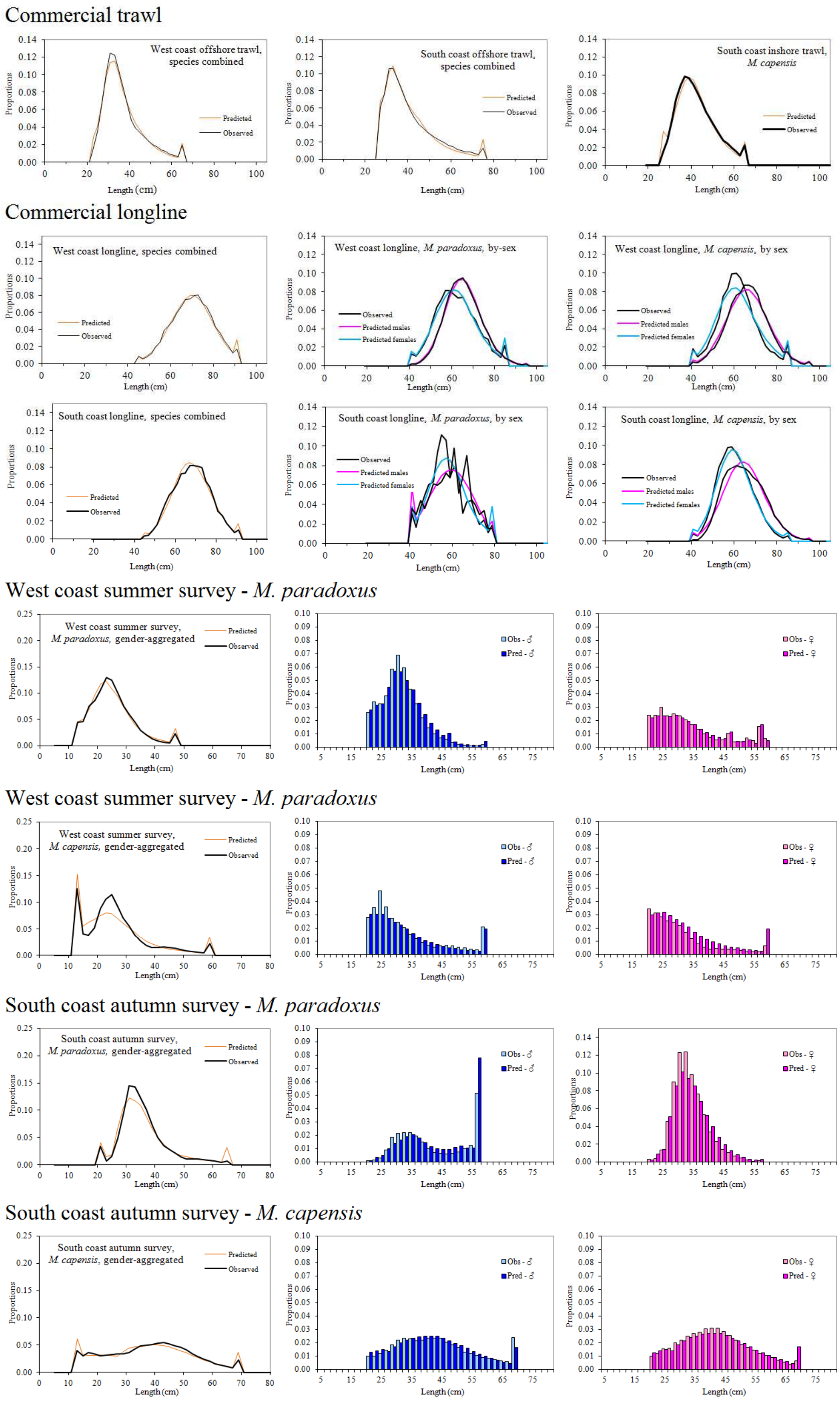

Figure A2c: Fits of RS13 to the commercial and survey catch-at-length data, aggregated over all the years for which data are available.