Reference Set results and projections under the current OMP for the South African hake resource

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Summary

The full hake Reference Set (RS) of OMs is updated at the mid-way stage of the four-year implementation of OMP-14, and used to project under continued application of that OMP. Combining across the full RS indicates that in median terms, TACs are expected to decline for a further four years. This raises the question of whether the OMP review scheduled for 2018 should be brought forward a year to 2017, thus admitting the possibility of a larger (than 5%) TAC decrease for 2018, and thereby speeding recovery and reducing the period for which TAC decreases are to be expected.

Introduction

The Updated Reference Set

The 2014 Reference Set of Operating Models is updated to take account of updated and new data as well as changes to the model, as described for the RC in Rademeyer and Butterworth (2016). The RS consists of 11 OMs, covering three major axes of uncertainty, as described in Rademeyer and Butterworth (2014):

- 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 "BHmod": the modified Beverton-Hold.

  For the modified Ricker relationship: $R_y = \alpha B_y^{sp} exp\left(-\beta\left(B_y^{sp}\right)^{\gamma}\right)$ (1)

  For the modified Beverton-Holt, the curve below Bmin (the lowest previous biomass level) is replaced by the average of that curve and a straight line from the origin to the value of the curve at Bmin.

The 11 OMs are:

- RS1: Ricker, 1958, Mmed; this is the Reference Case (RC)
- RS2: BH, 1958, Mmed;
- RS3: BHmod, 1958, Mmed;
- RS4: Ricker, 1950, Mlow;
- RS5: BH, 1950, Mlow;
- RS6: BHmod, 1950, Mlow;
- RS7: Ricker, 1950, Mhigh;
- RS10: Ricker, 1965, Mlow;
- RS13: Ricker, 1965, Mhigh;
- RS14: BH, 1965, Mhigh;
- RS15: BHmod, 1965, Mhigh;

Projections under OMP 2014

The RS is projected forward under OMP-2014, assuming the actual catch for 2015 and the TAC for that in 2016.

Results and Discussion

The Updated Reference Set

Results for the RS are compared in Table 1, with the spawning biomass trajectories plotted in Figures 1 and 2. The stock-recruitment curves are compared in Figure 3.

Projections under OMP 2014

Table 2 give results for the projections under the RS and each of the 11 OMs of the RS separately. Medians, 95, 75 and 50% PI envelopes are plotted for projected TAC, annual TAC changes, *M. paradoxus* female B^{sp} relative to B^{sp}_{MSY} and CPUE relative to 2013 level for the RS and each of the 11 OMs of the RS separately in Figures 4 to 15. Further results are given in Appendix A.

Aside from checking this assessment update across the full RS to assess whether there is evidence for Exceptional Circumstances (which seems not to be the case), a key reason behind this analysis is to obtain an estimate for the number of further years a TAC decrease can be expected under continued application of OMP-14. Table 2 indicates that in median terms this ranges from 2 to 6 years for the different OMs making up the RS, and 4 years for the RS as a whole when combining these results. Figure 1 indicates that in these same terms an increase in (offshore trawl) CPUE can be expected, but also a drop in the fishing effort required to take the catch (Figure A.1).

The next OMP review is scheduled for 2018. A key question to be addressed is whether this review should be brought forward a year to 2017, thus admitting the possibility of a larger (than 5%) TAC decrease for 2018, thereby speeding recovery of the *M. paradoxus* stock and reducing the period for which TAC decreases are to be expected.

REFERENCES

Rademeyer RA and Butterworth DS. 2014. Results leading to a Proposal for a Reference Set of Operating Models for Testing the 2014 OMP Revision for the South African hake resource. FISHERIES/2014/MARCH/SWG-DEM/14.

Rademeyer RA and Butterworth DS. 2016. Corrected Reference Case for the South African hake resource. FISHERIES/2016/NOV/SWG-DEM/83.

Table 1: Estimates of management quantities for the RS.

		RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS10	RS13	RS14	RS15
	-lnL total	-3665.5	-3665.9	-3665.9	-3652.1	-3650.5	-3650.8	-3657.8	-3633.1	-3648.5	-3639.0	-3639.0
M. paradoxus	K^{sp}	554	817	817	874	1733	1715	452	662	404	478	478
	B^{sp}_{MSY}	144	159	159	209	401	396	110	224	156	75	75
	B^{sp}_{2016}	102	119	119	124	222	212	89	179	160	110	110
	B^{sp}_{2016}/K^{sp}	0.18	0.15	0.15	0.14	0.13	0.12	0.20	0.27	0.40	0.23	0.23
	$B^{sp}_{2016}/B^{sp}_{MSY}$	0.71	0.75	0.75	0.60	0.55	0.54	0.81	0.80	1.03	1.47	1.47
	MSY	119	113	113	121	125	124	114	129	119	115	115
M. capensis	K^{sp}	219	309	310	224	377	377	197	509	270	411	411
	B^{sp}_{MSY}	82	52	52	82	113	113	83	168	111	108	108
	B^{sp}_{2016}	160	182	182	147	66	66	139	372	210	296	296
	B^{sp}_{2016}/K^{sp}	0.73	0.59	0.59	0.66	0.18	0.17	0.71	0.73	0.78	0.72	0.72
	$B^{sp}_{2016}/B^{sp}_{MSY}$	1.95	3.50	3.50	1.79	0.59	0.58	1.68	2.22	1.88	2.75	2.75
	MSY	75	68	65	58	40	40	68	96	102	116	108

Table 2: Projection results for the RS (i.e. combination of all OMs equally weighted) and each of the OM in the RS under OMP-2014.

	Number of years median TAC drops (incl. 2016 to 2017 drop)	Year *M. paradoxus* median $B^{sp} > B^{sp}_{MSY}$	*M. paradoxus* Median B^{sp}/B^{sp}_{MSY} in 2026	Median TAC in 2026	Lower 2.5%ile TAC in 2026	Median CPUE relative to 2013 in 2026	Median effort relative to 2010 in 2026
RS	4	2026	1.021	145.60	103.58	1.289	0.917
RS1	5	2035	0.895	144.62	108.80	1.234	0.993
RS2	6	>2036	0.847	138.32	100.17	1.288	0.913
RS3	6	>2036	0.846	138.29	100.17	1.289	0.912
RS4	3	>2036	0.768	148.71	108.80	1.335	0.888
RS5	4	>2036	0.635	150.00	116.74	1.669	0.759
RS6	4	>2036	0.603	150.00	114.03	1.663	0.762
RS7	6	2027	0.982	140.07	104.15	1.217	0.991
RS10	2	2022	1.190	150.00	122.44	1.368	0.910
RS13	4	2016	1.230	139.33	105.31	1.181	1.023
RS14	5	2016	1.774	135.26	98.20	1.202	0.957
RS15	5	2016	1.774	135.26	98.20	1.202	0.957

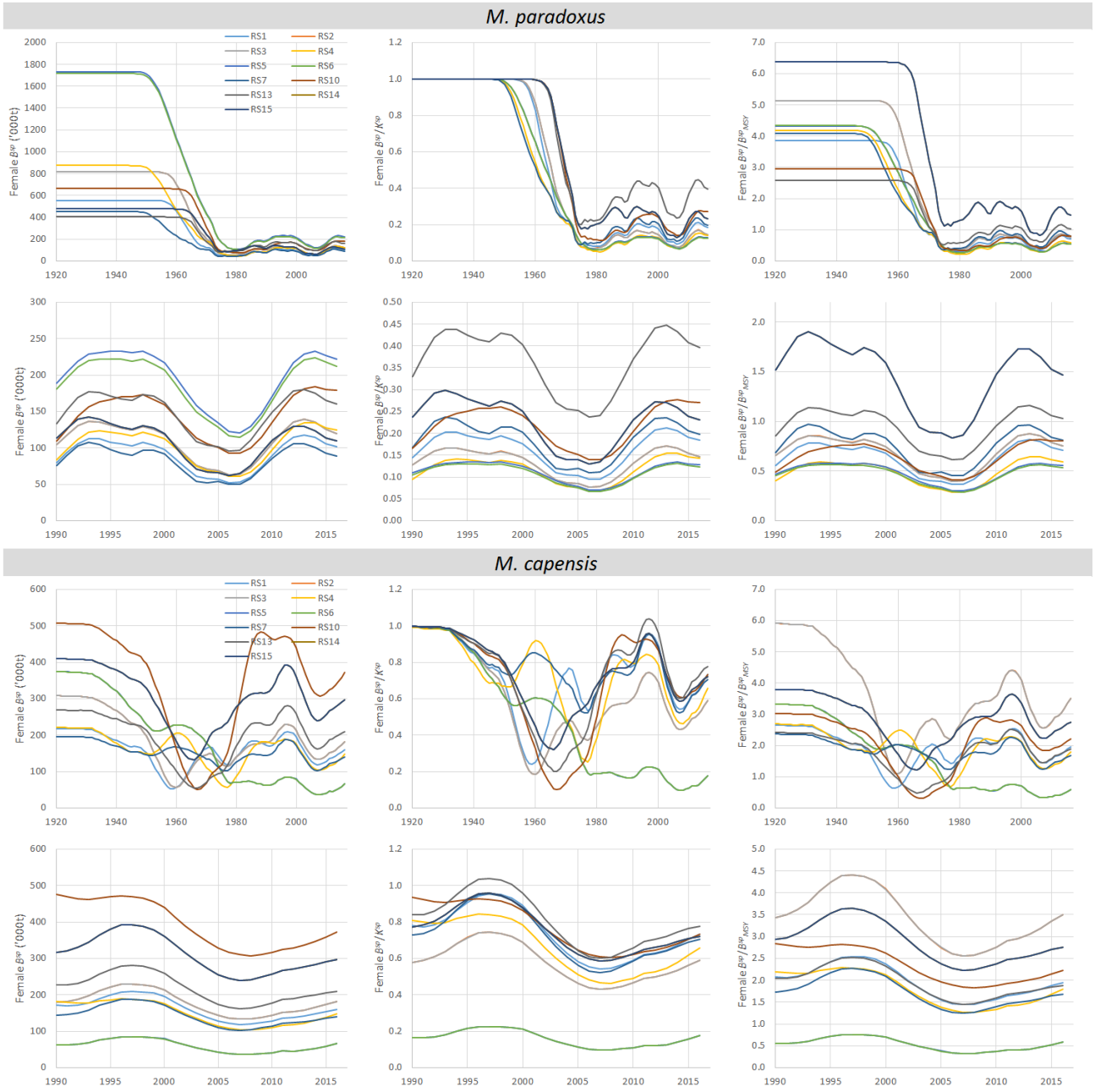

Figure 1: Spawning biomass trajectories (in absolute terms, and relative to pre-exploitation level and to B_{MSY}) for *M. paradoxus* and *M. capensis*, for the 11 OMs of the RS. For each species, the second row repeats the first row but with a different range of years.

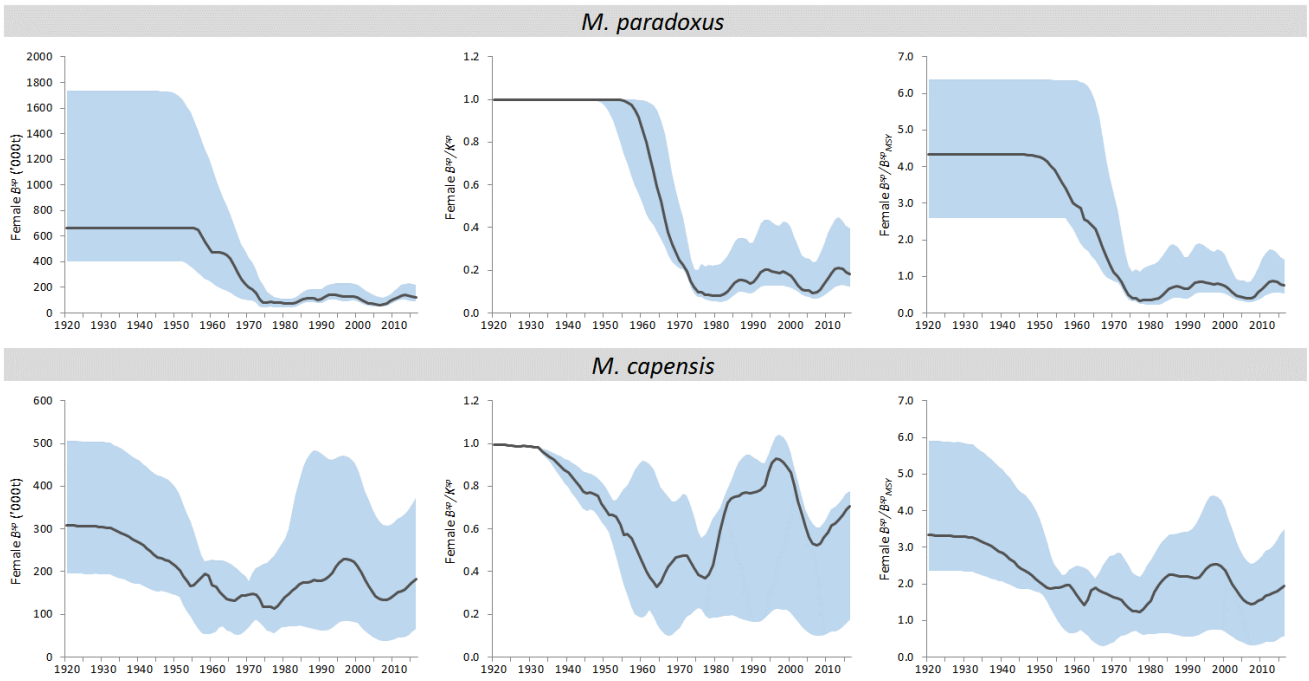

Figure 2: Median (black line) with minimum-maximum range (shading) spawning biomass trajectories (in absolute terms and relative to pre-exploitation level and to B_{MSY}) for *M. paradoxus* and *M. capensis*, for the 11 OMs of the RS.

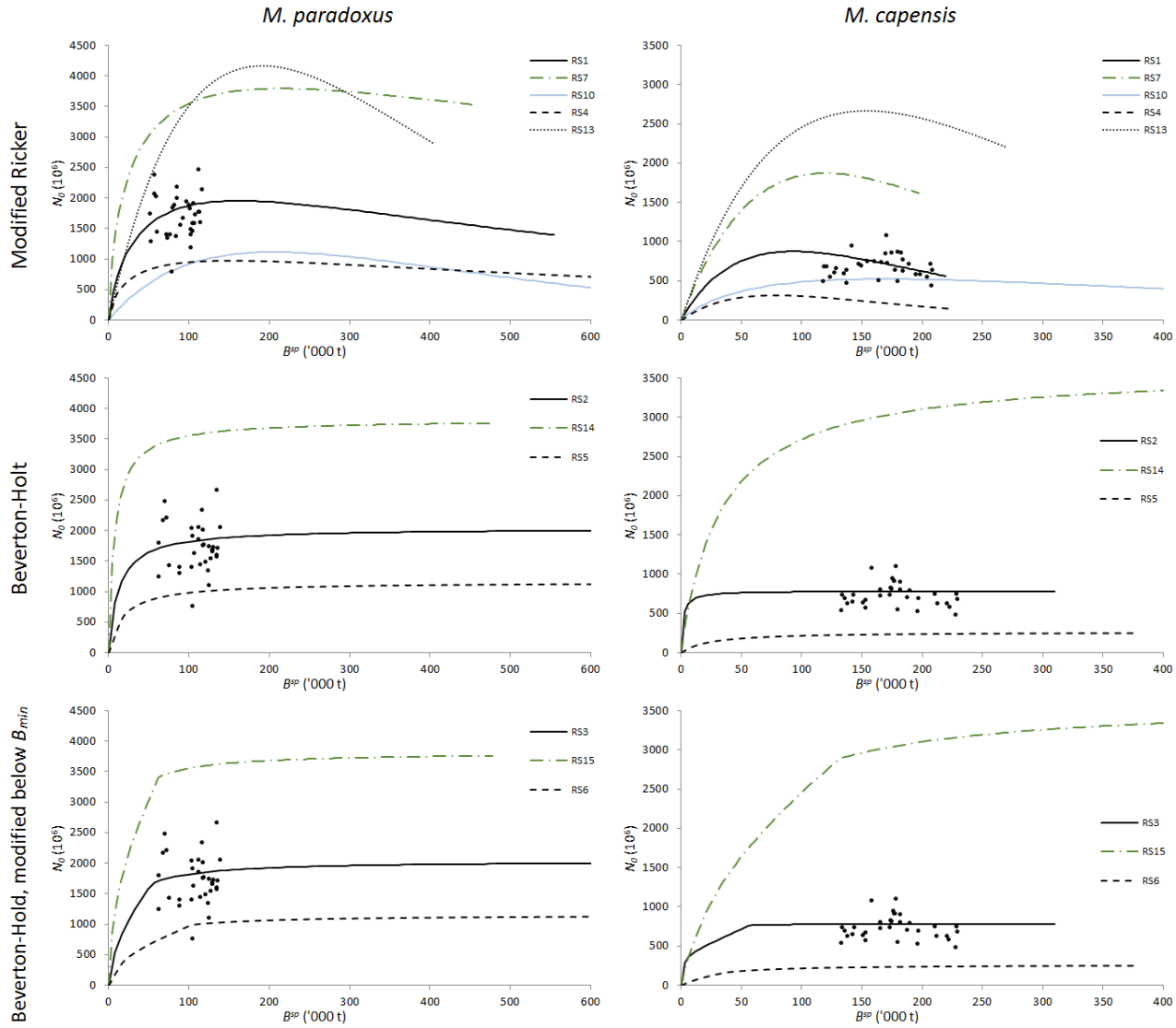

Figure 3a: Estimated stock-recruitment curves for each of the 11 OMs of the RS for *M. paradoxus* and *M. capensis*, grouped by stock-recruitment curve type. In each plot, the "data" are plotted for a single OM, corresponding to the medium natural mortality and 1958 centre-year, i.e. RS1, RS2 and RS3 for the top, middle and bottom rows respectively.

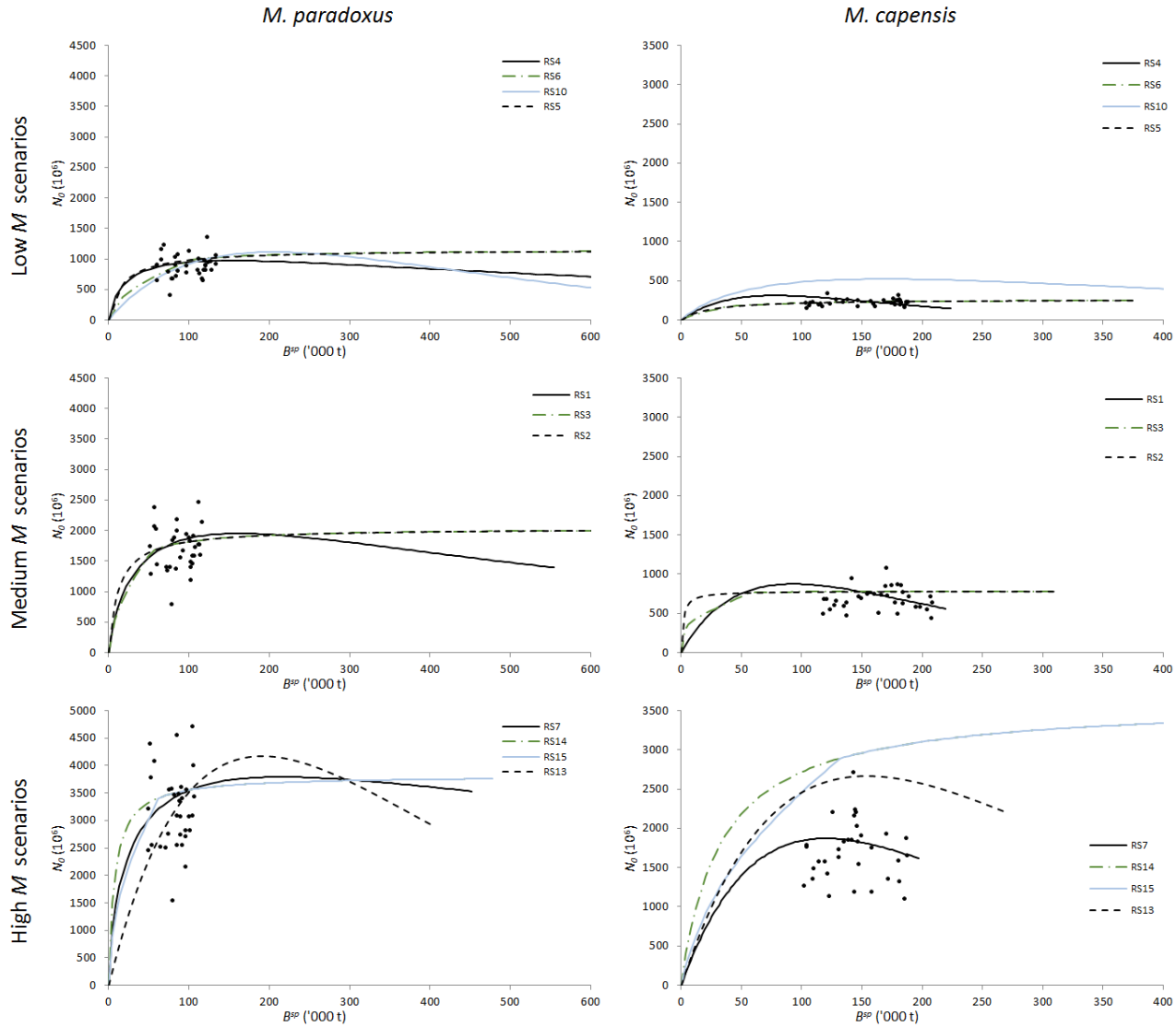

Figure 3b: Estimated stock-recruitment curves for each of the 11 OMs of the RS for *M. paradoxus* and *M. capensis*, grouped by level of natural mortality. In each plot, the "data" are plotted for a single OM, RS4, RS1 and RS7 for the top, middle and bottom rows respectively.

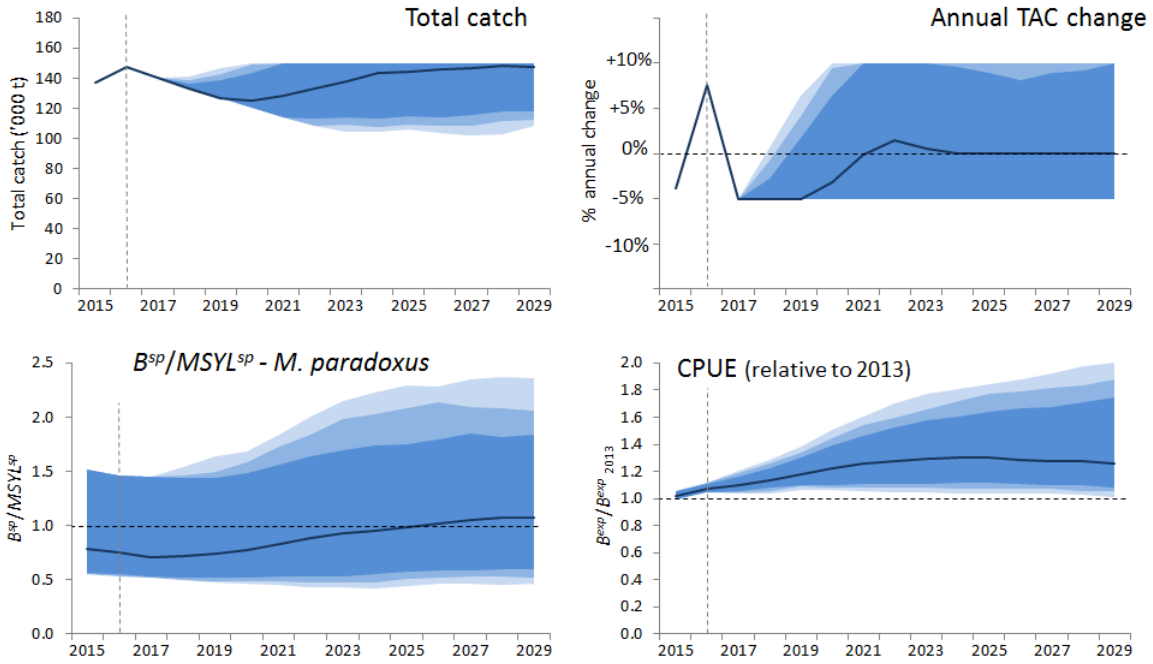

Figure 4: Projection results for the **RS** under OMP-2014.

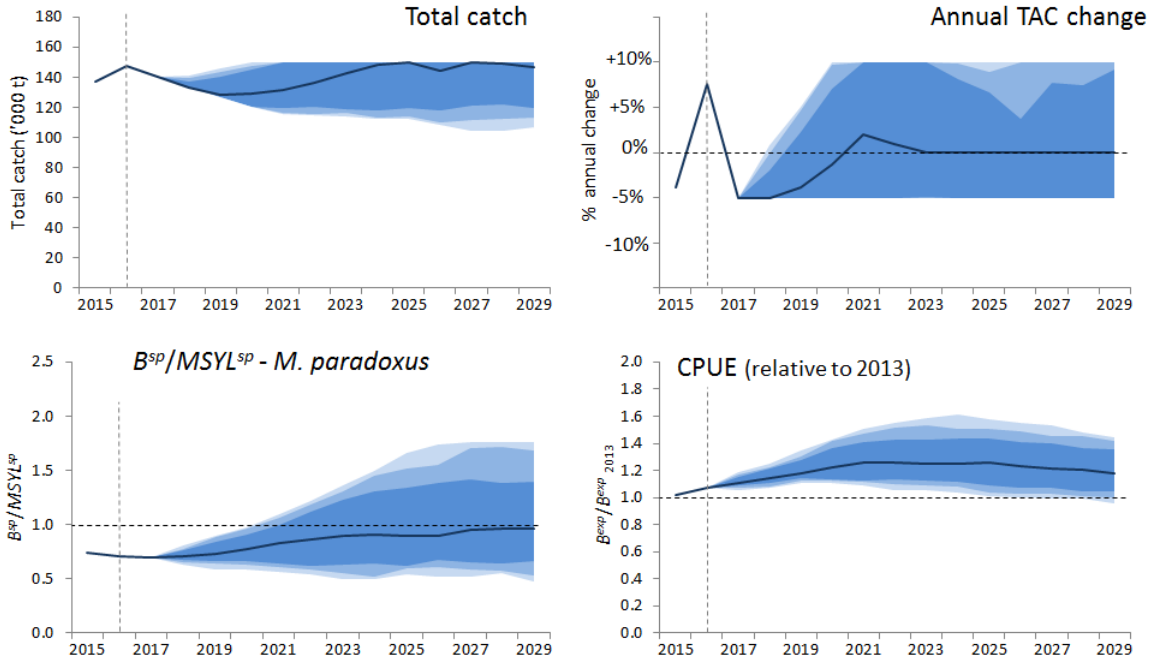

Figure 5: Projection results for the **RS1** under OMP-2014.

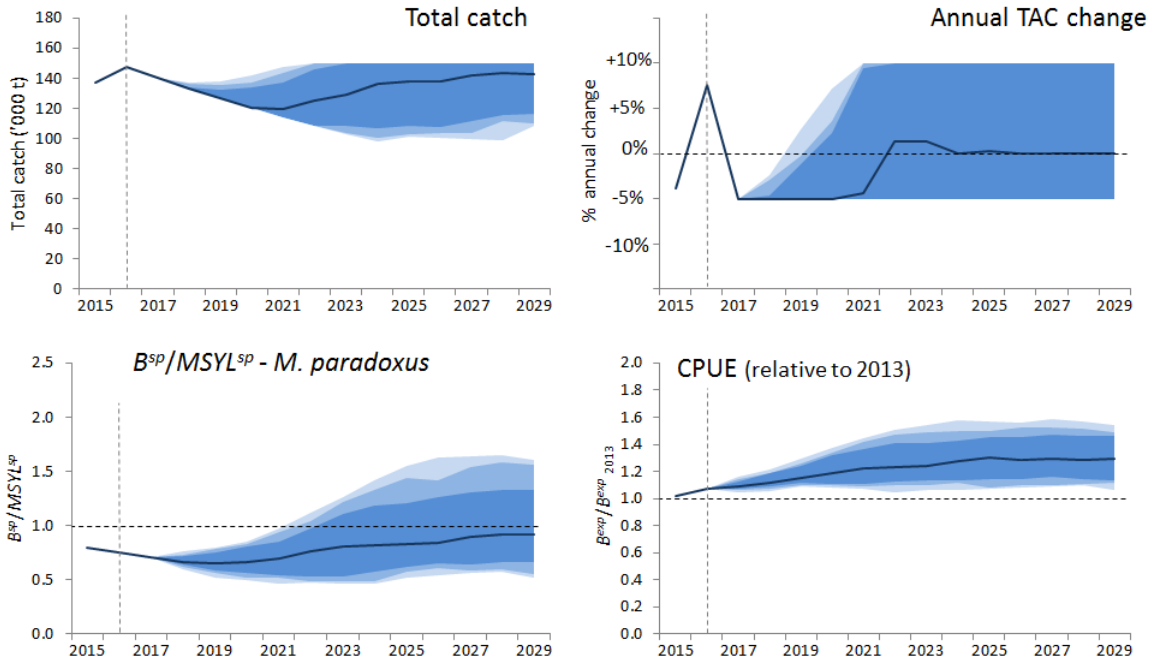

Figure 6: Projection results for the **RS2** under OMP-2014.

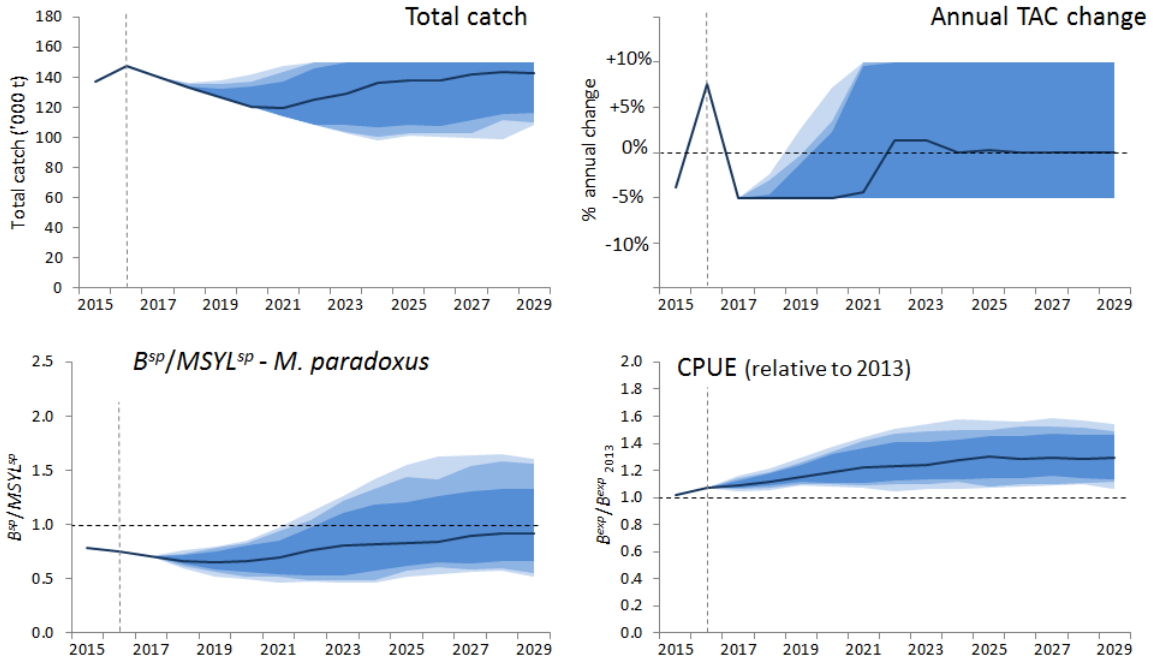

Figure 7: Projection results for the **RS3** under OMP-2014.

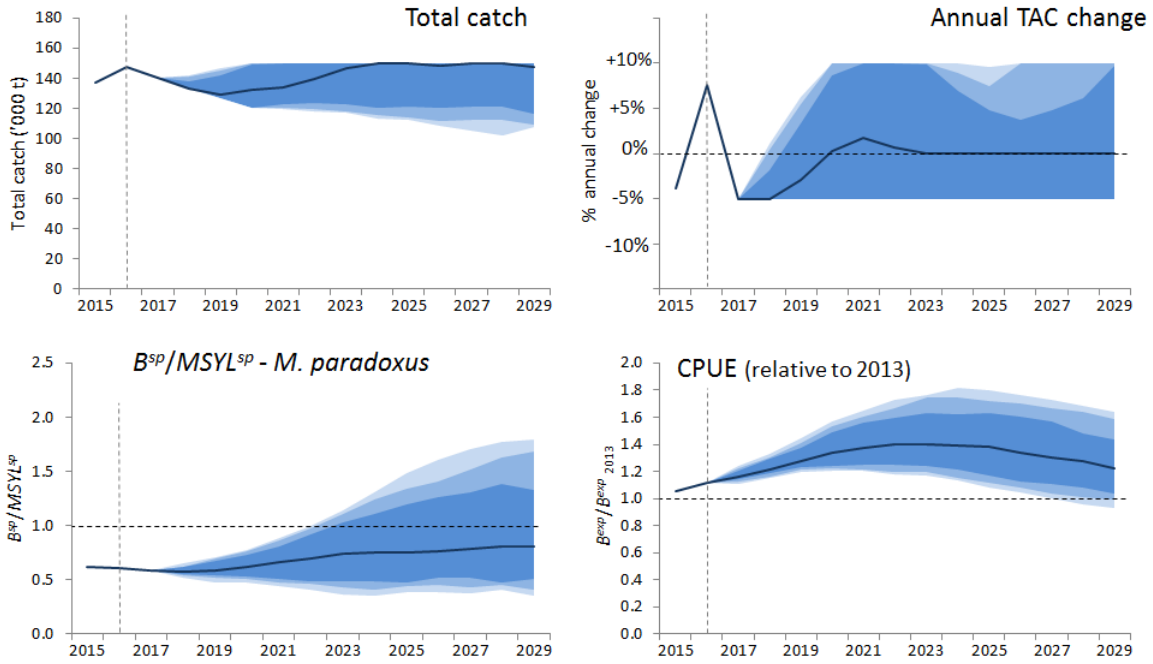

Figure 8: Projection results for the **RS4** under OMP-2014.

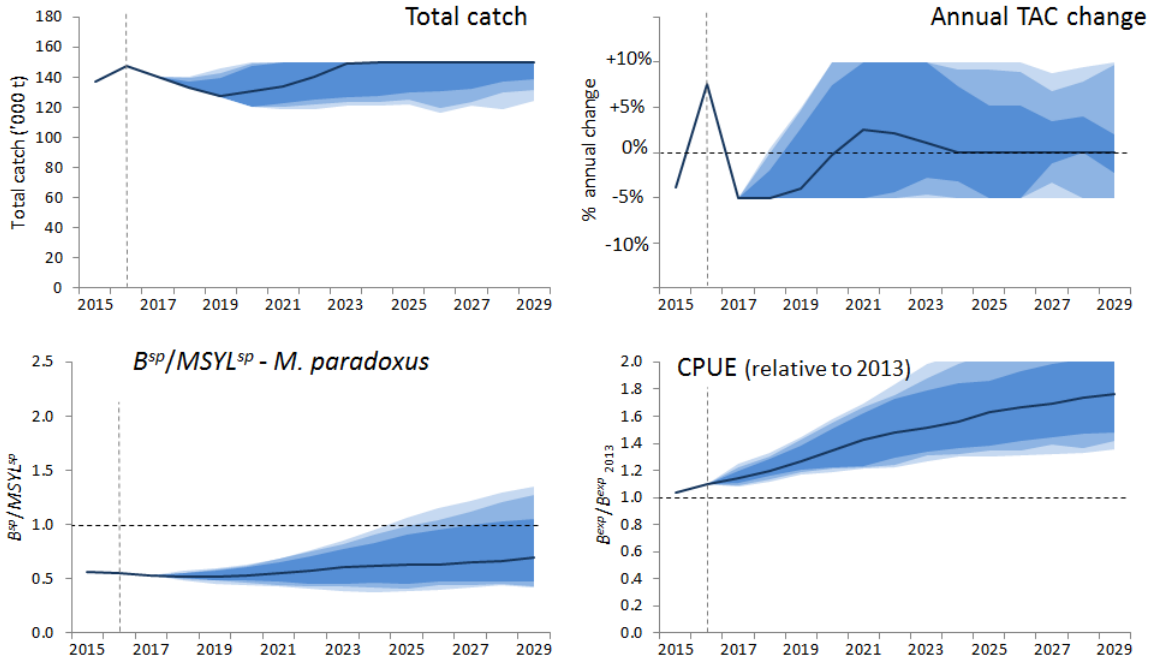

Figure 9: Projection results for the **RS5** under OMP-2014.

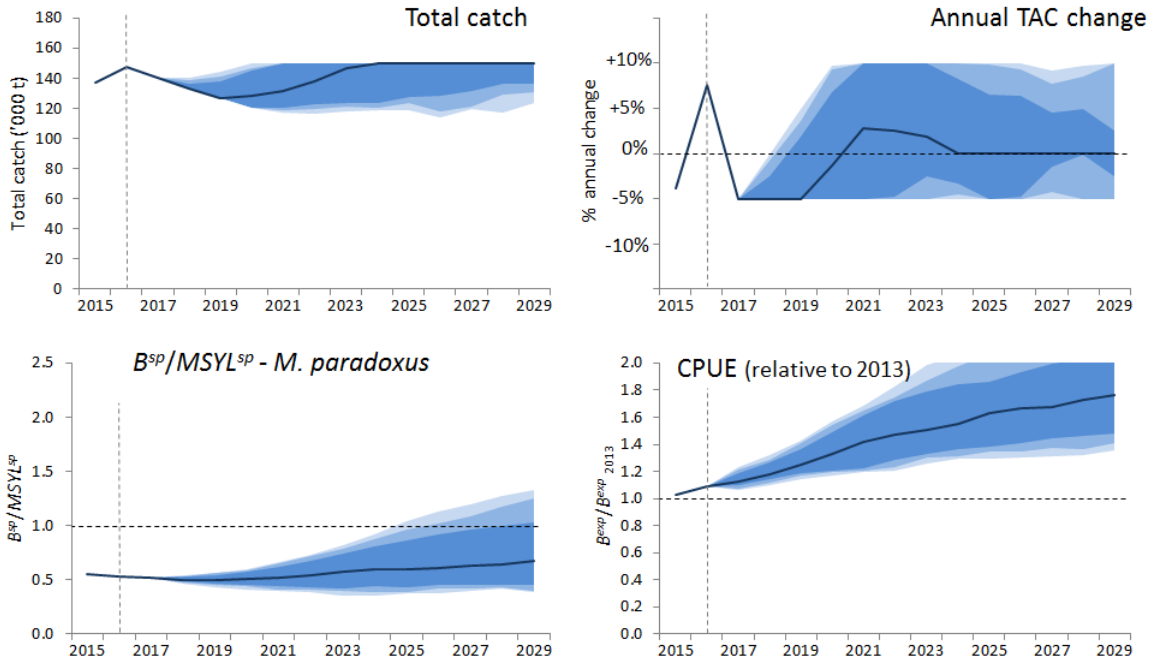

Figure 10: Projection results for the **RS6** under OMP-2014.

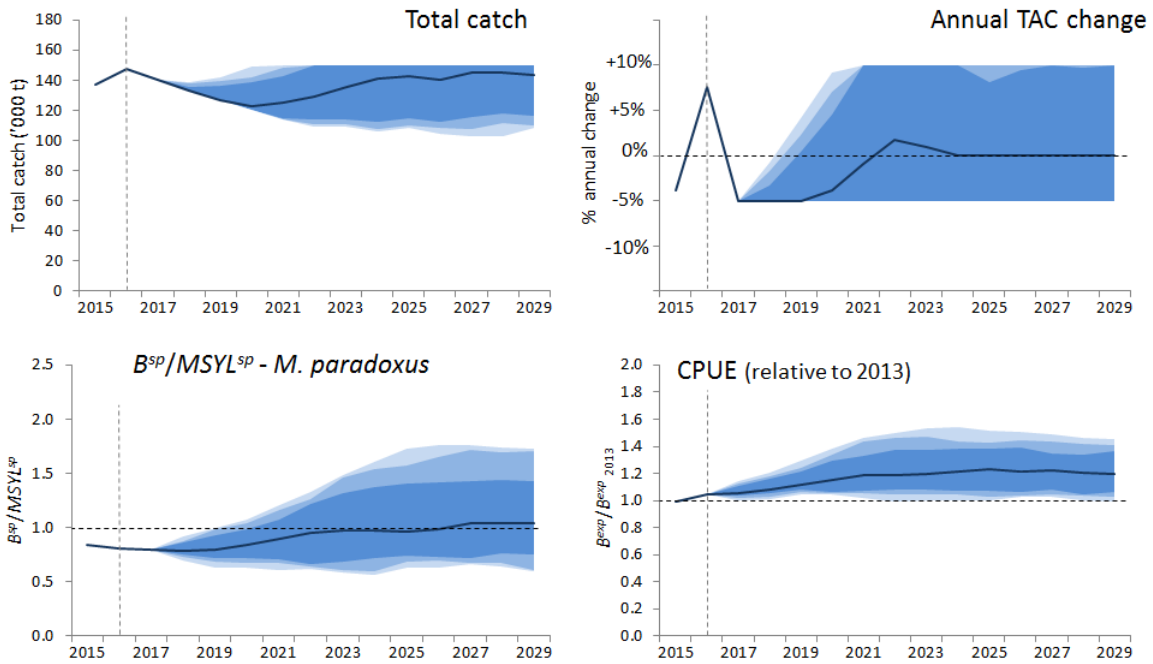

Figure 11: Projection results for the **RS7** under OMP-2014.

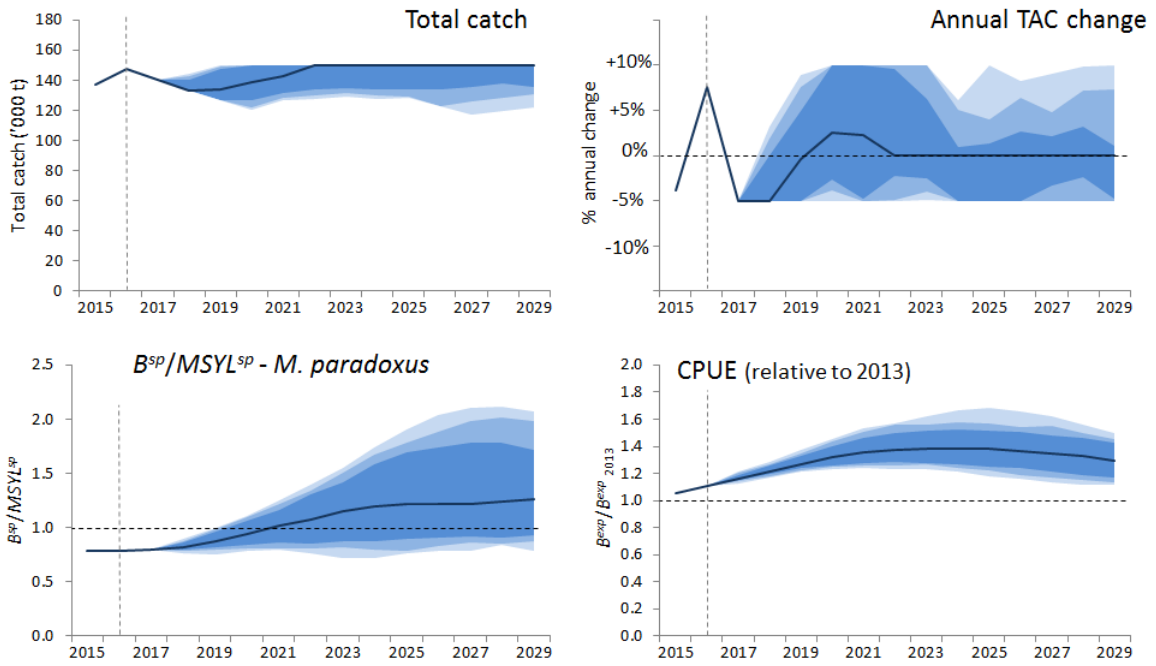

Figure 12: Projection results for the **RS10** under OMP-2014.

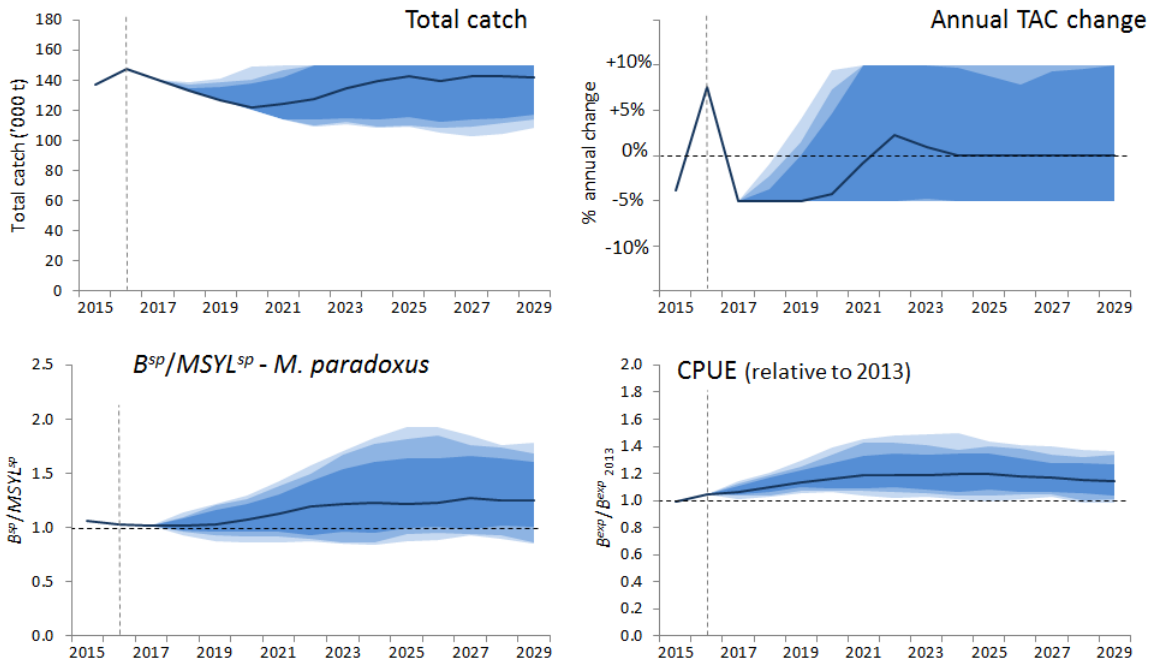

Figure 13: Projection results for the **RS13** under OMP-2014.

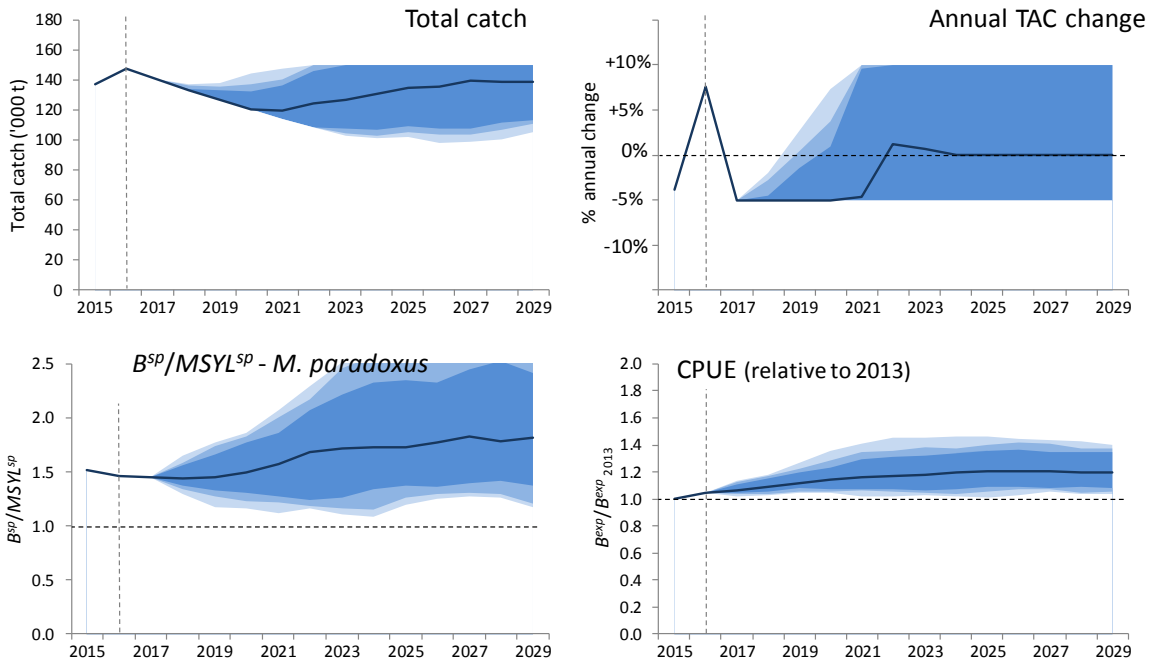

Figure 14: Projection results for the **RS14** under OMP-2014.

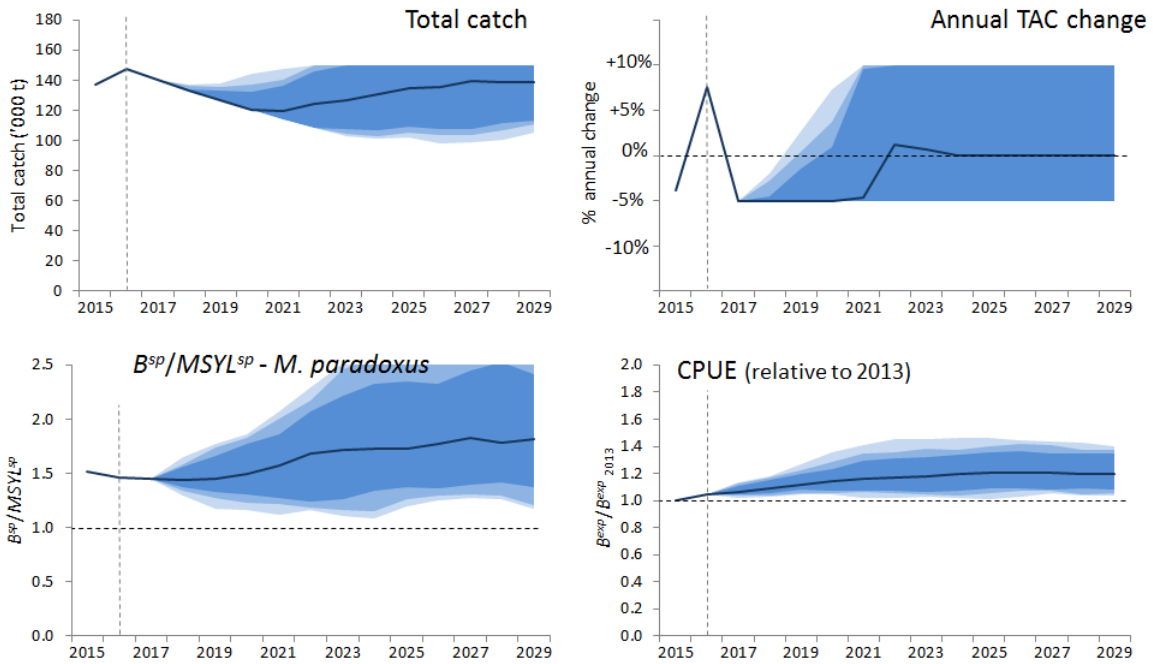

Figure 15: Projection results for the **RS15** under OMP-2014.

Appendix A – More detailed projection results

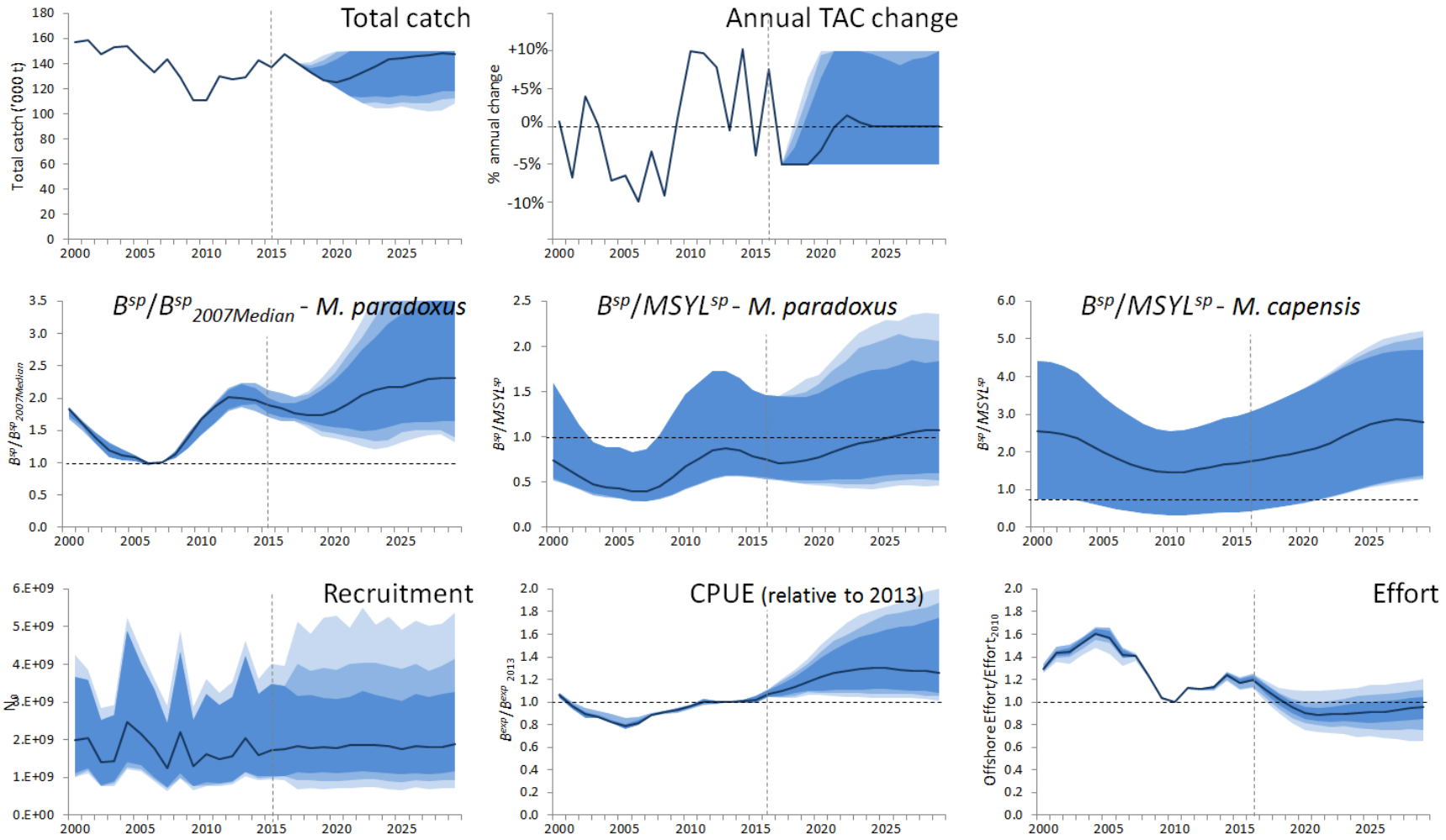

Figure A1: Projection results for the **RS** under OMP-2014.

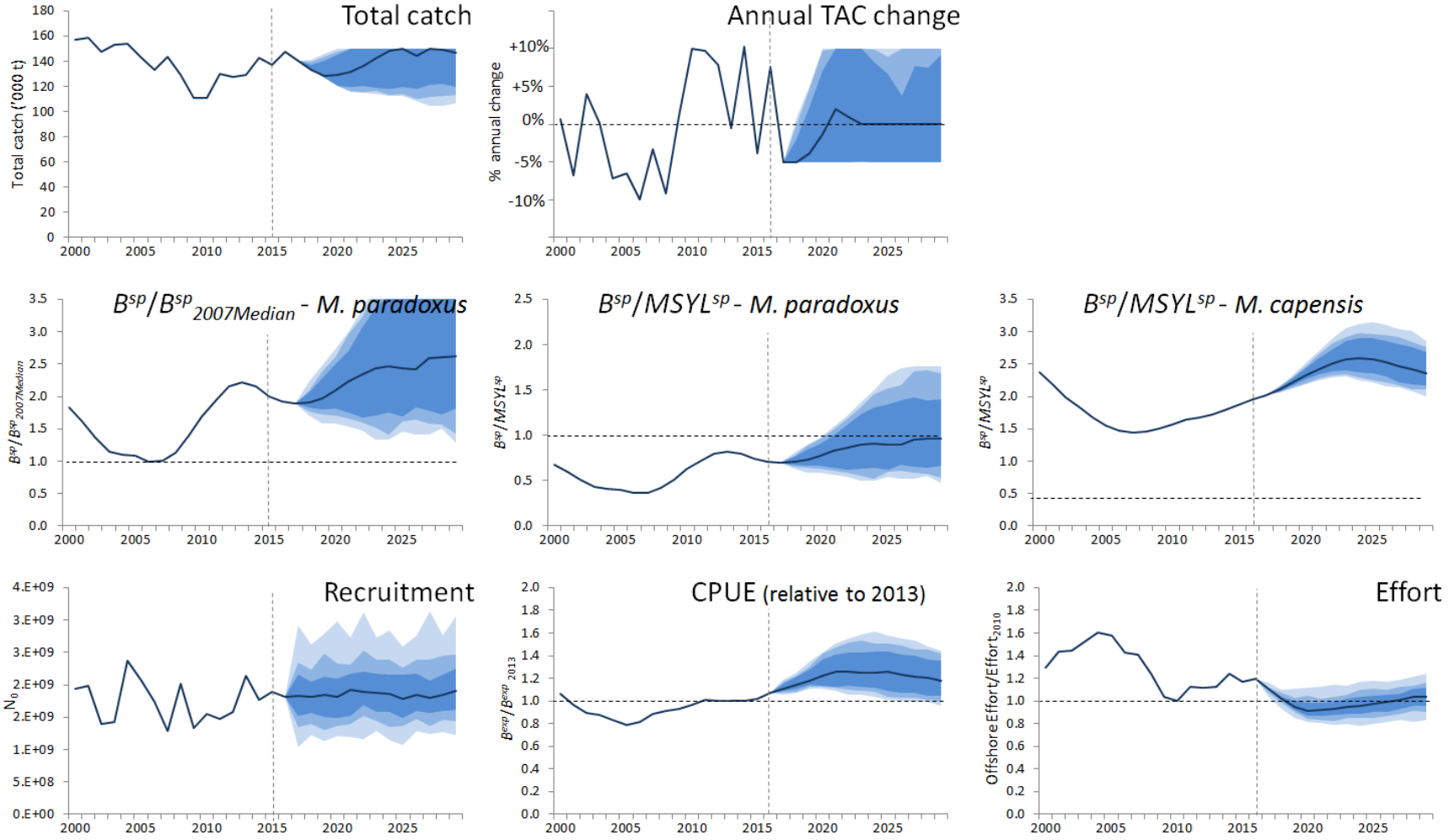

Figure A2: Projection results for the **RS1** under OMP-2014.

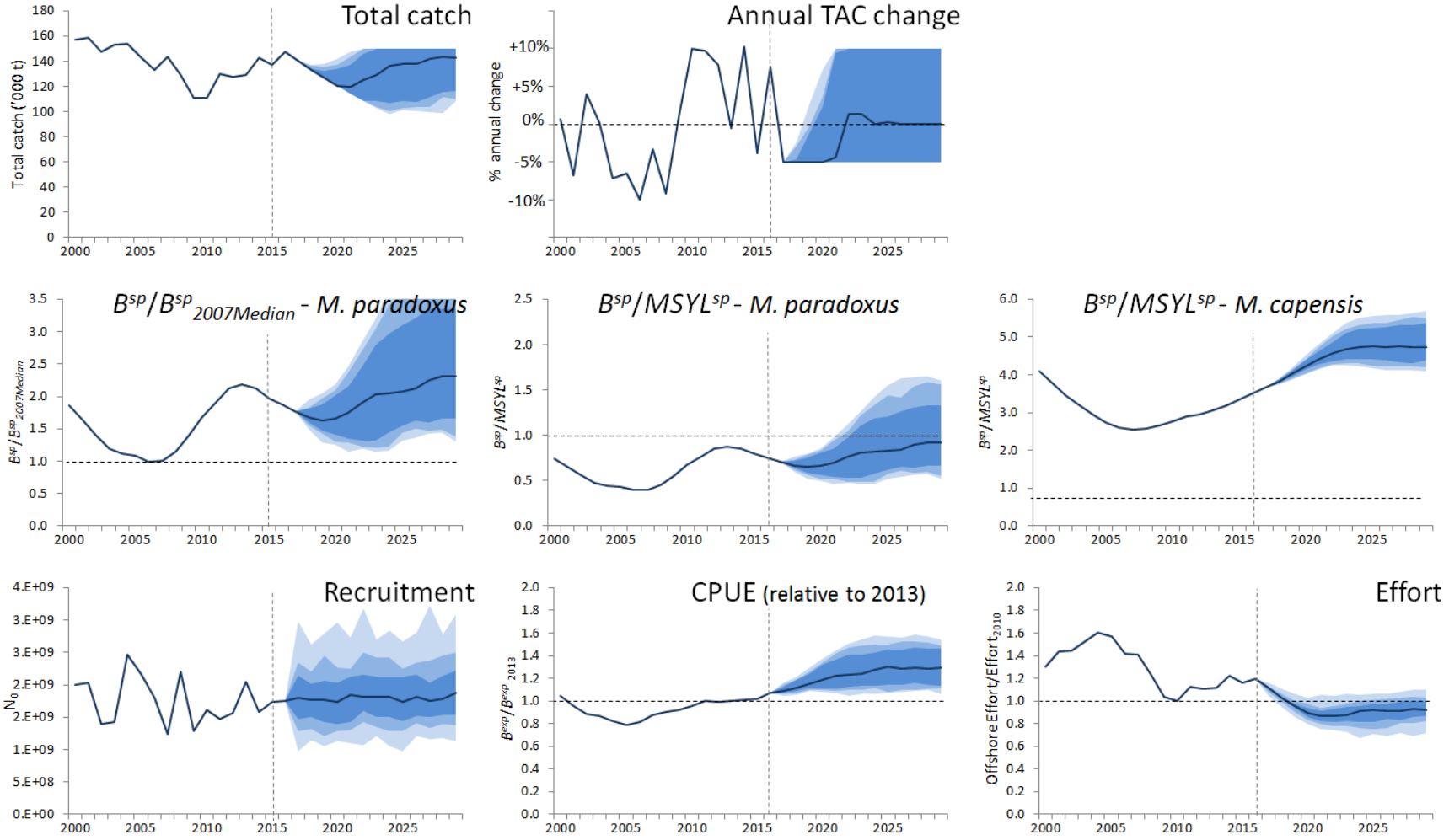

Figure A3: Projection results for the **RS2** under OMP-2014.

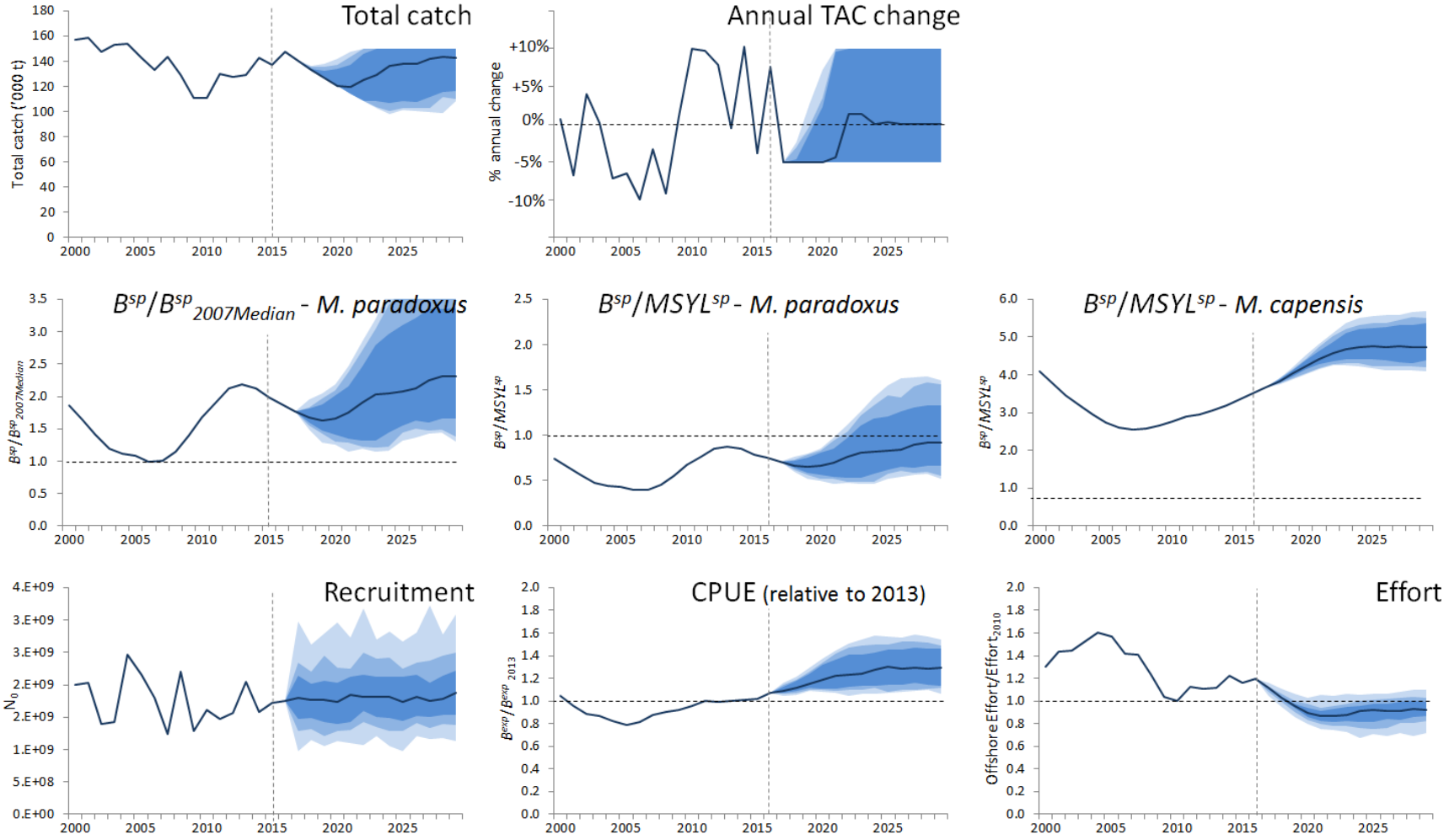

Figure A3: Projection results for the **RS3** under OMP-2014.

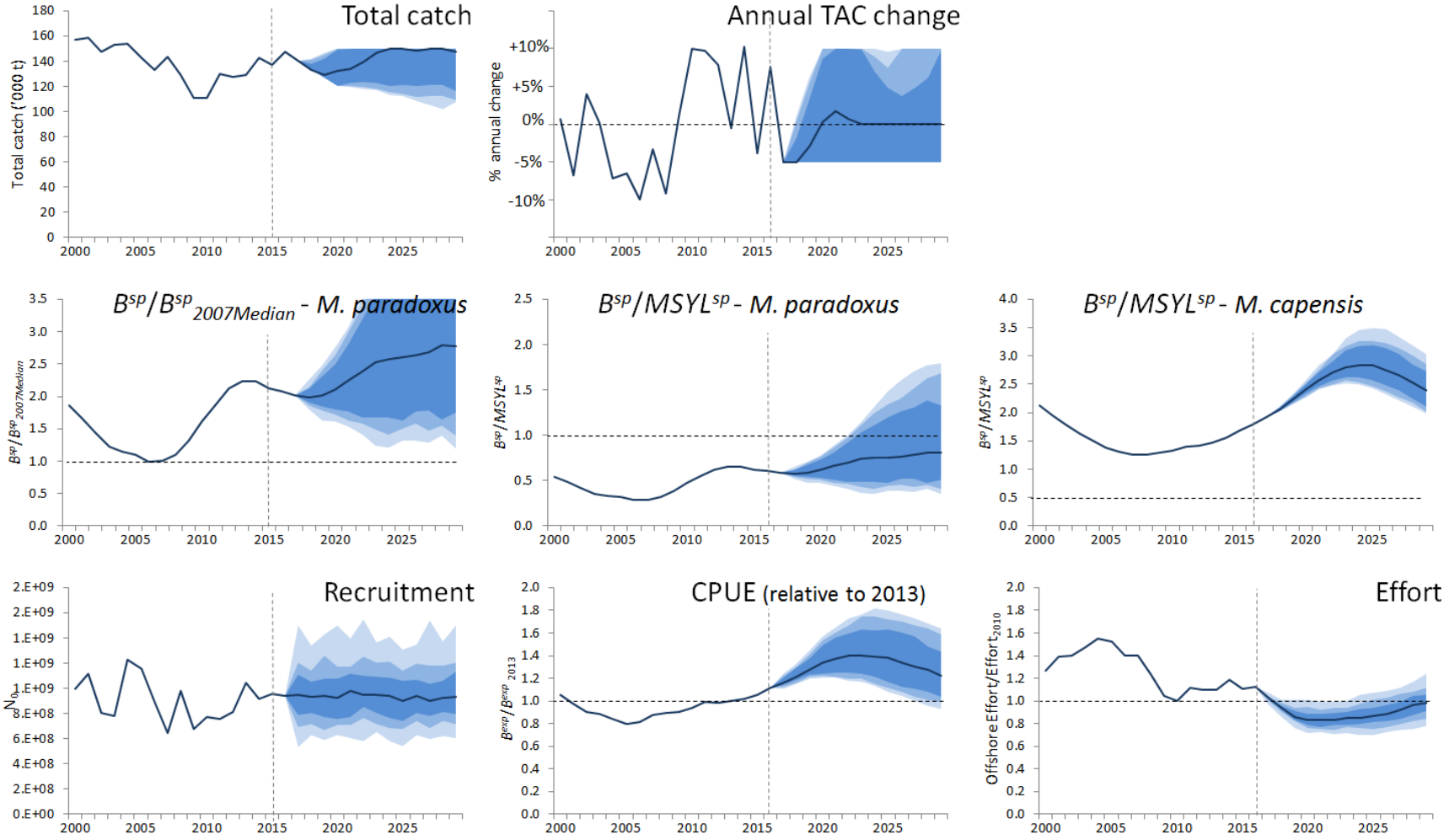

Figure A5: Projection results for the **RS4** under OMP-2014.

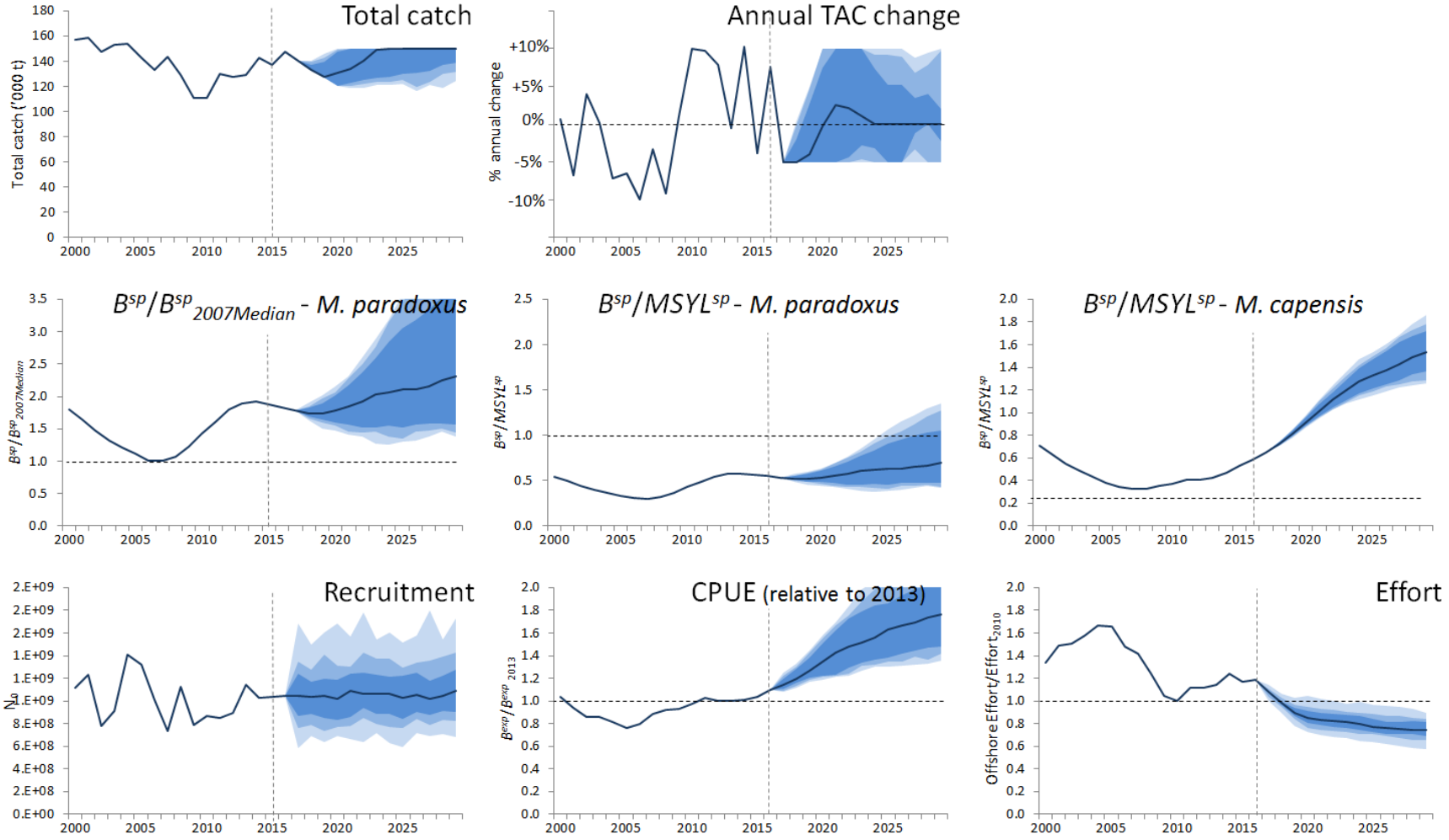

Figure A6: Projection results for the **RS5** under OMP-2014.

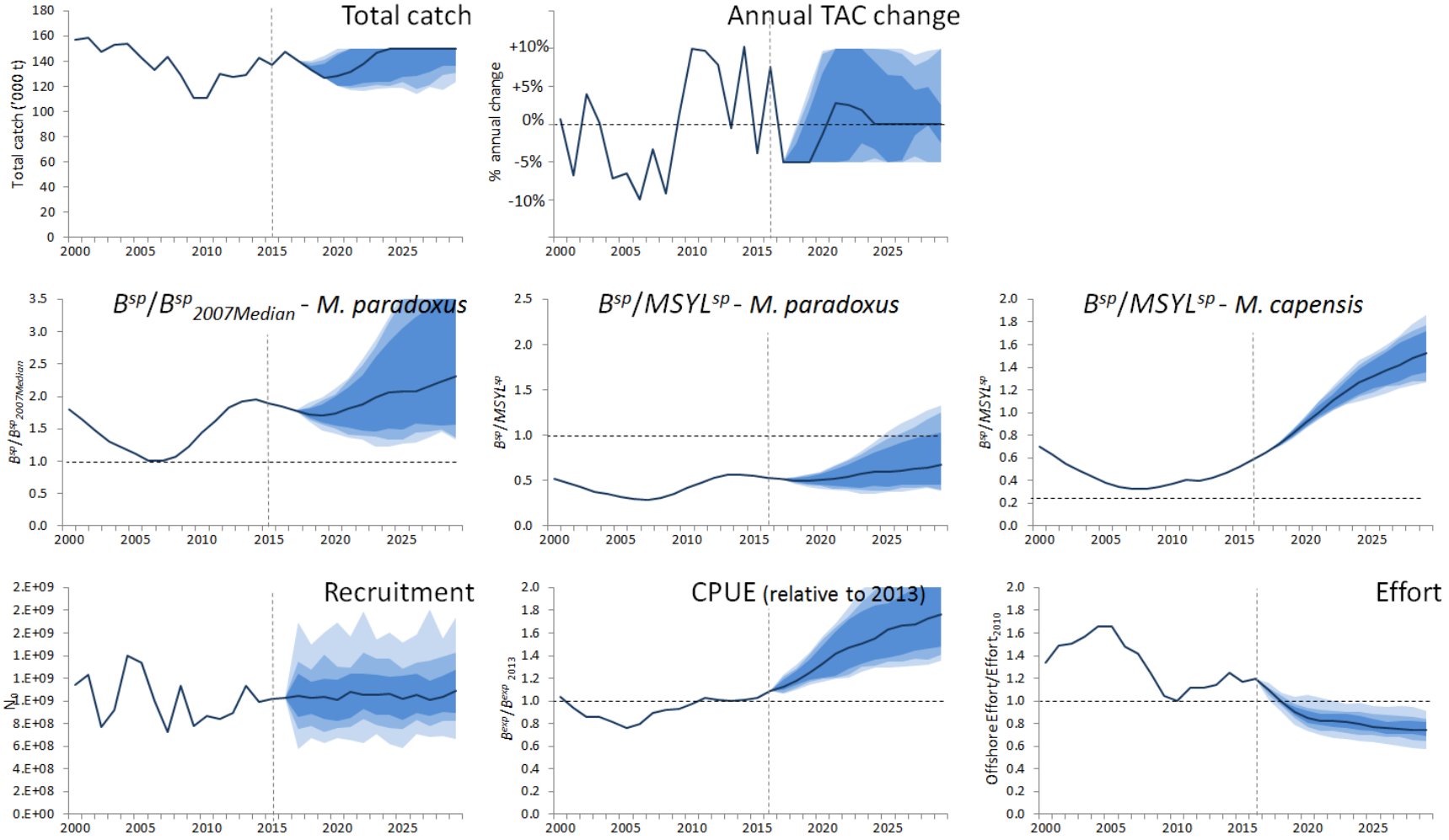

Figure A7: Projection results for the **RS6** under OMP-2014.

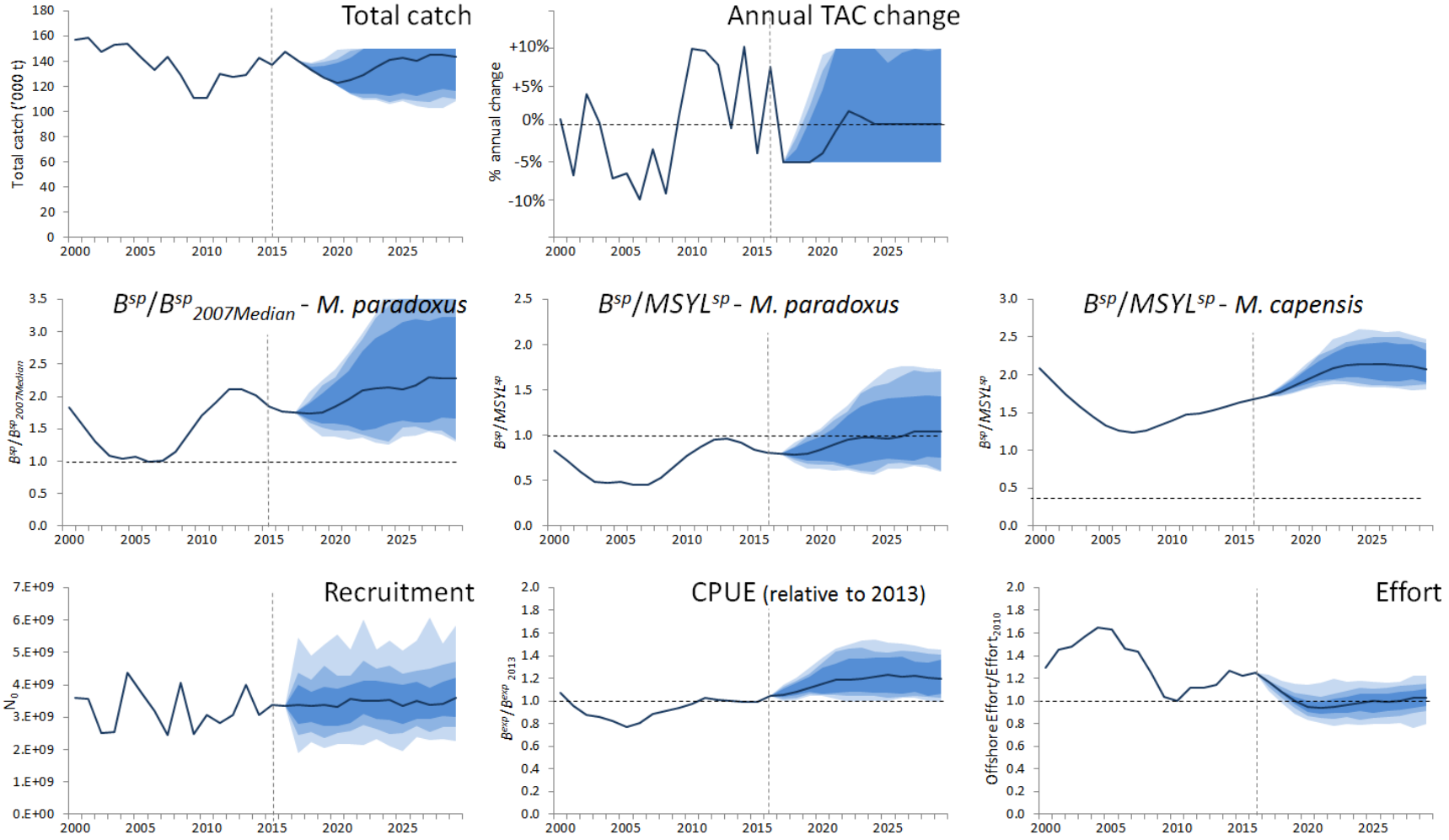

Figure A8: Projection results for the **RS7** under OMP-2014.

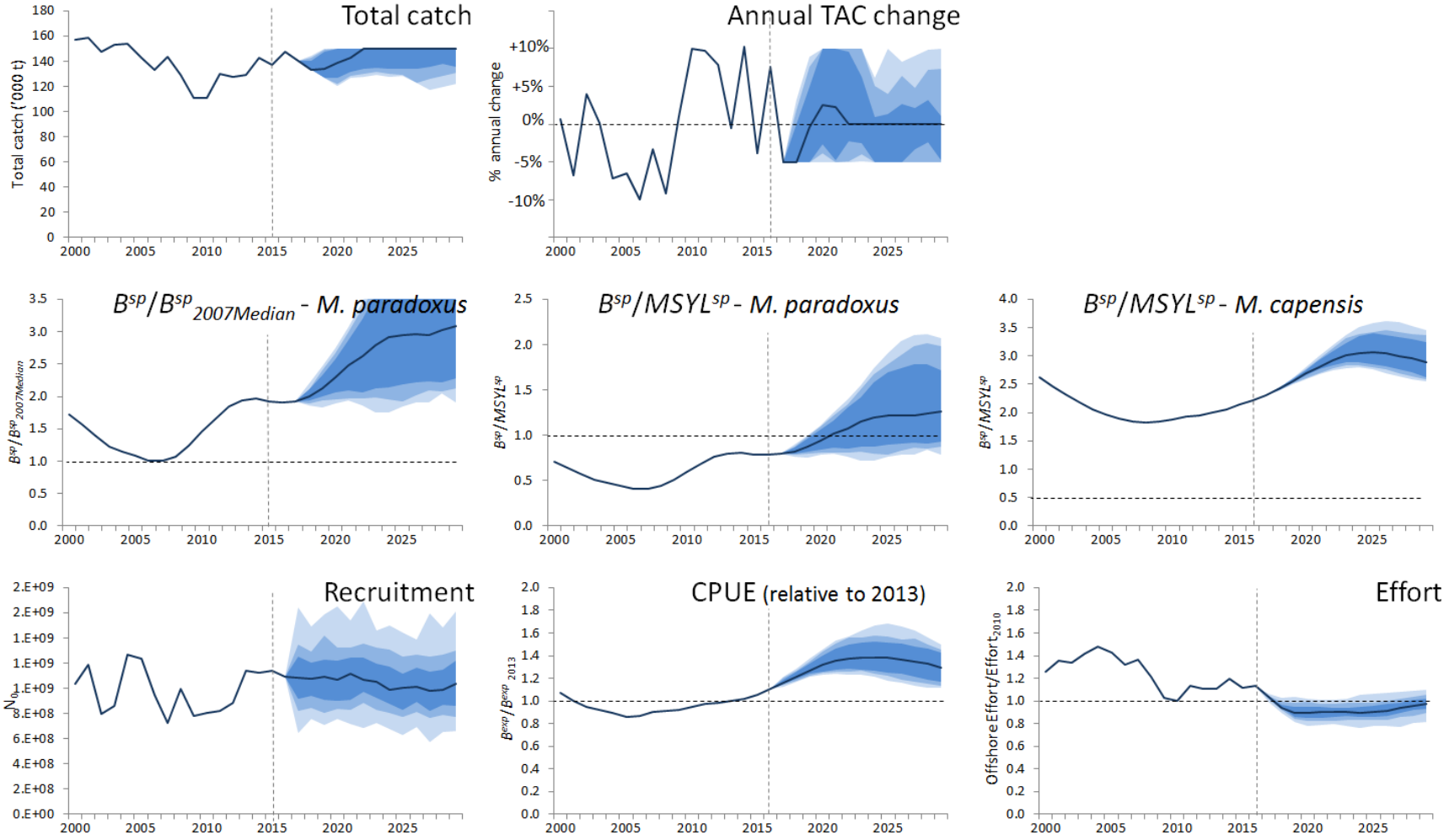

Figure A9: Projection results for the **RS10** under OMP-2014.

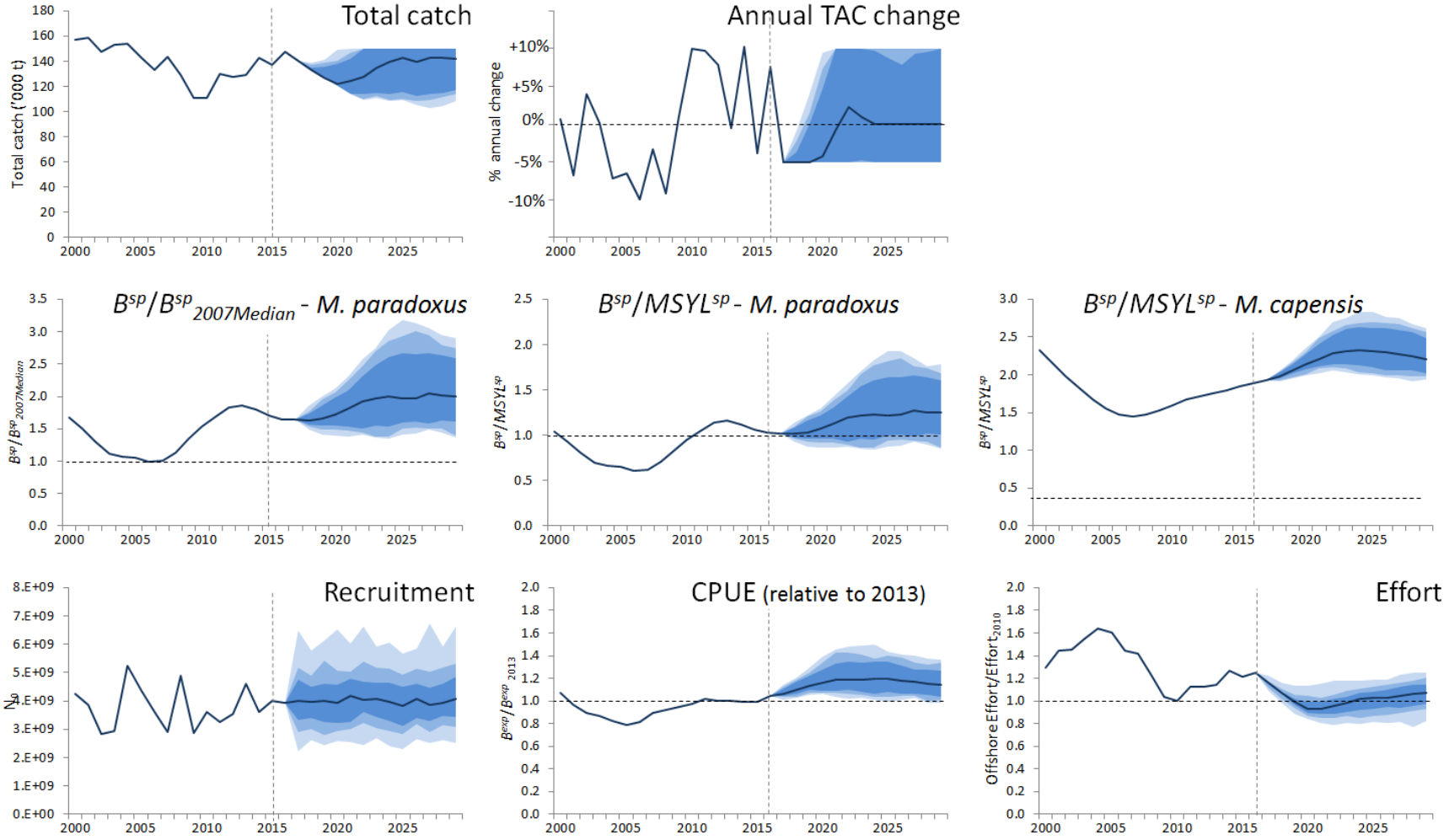

Figure A10: Projection results for the **RS13** under OMP-2014.

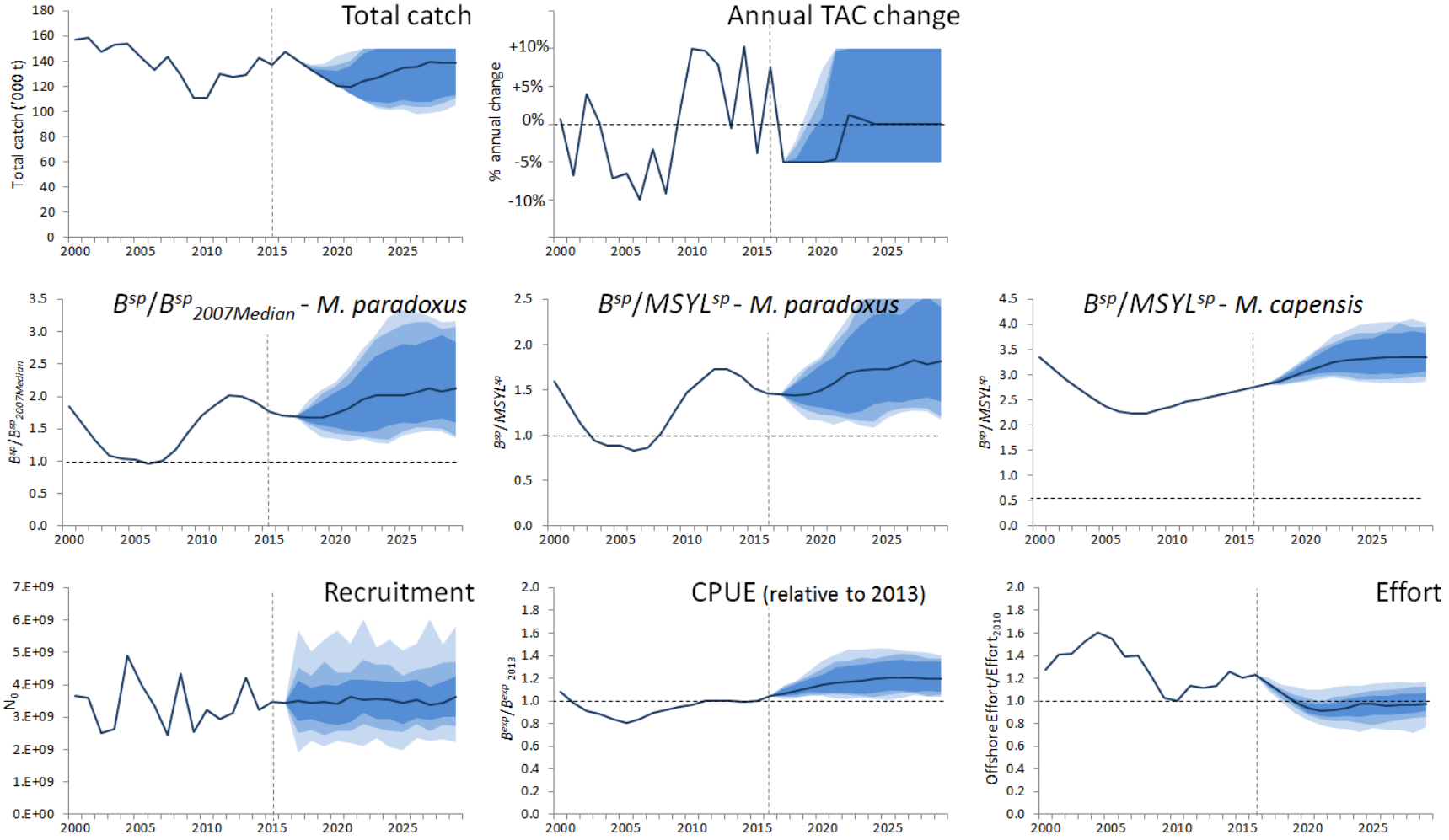

Figure A11: Projection results for the **RS14** under OMP-2014.

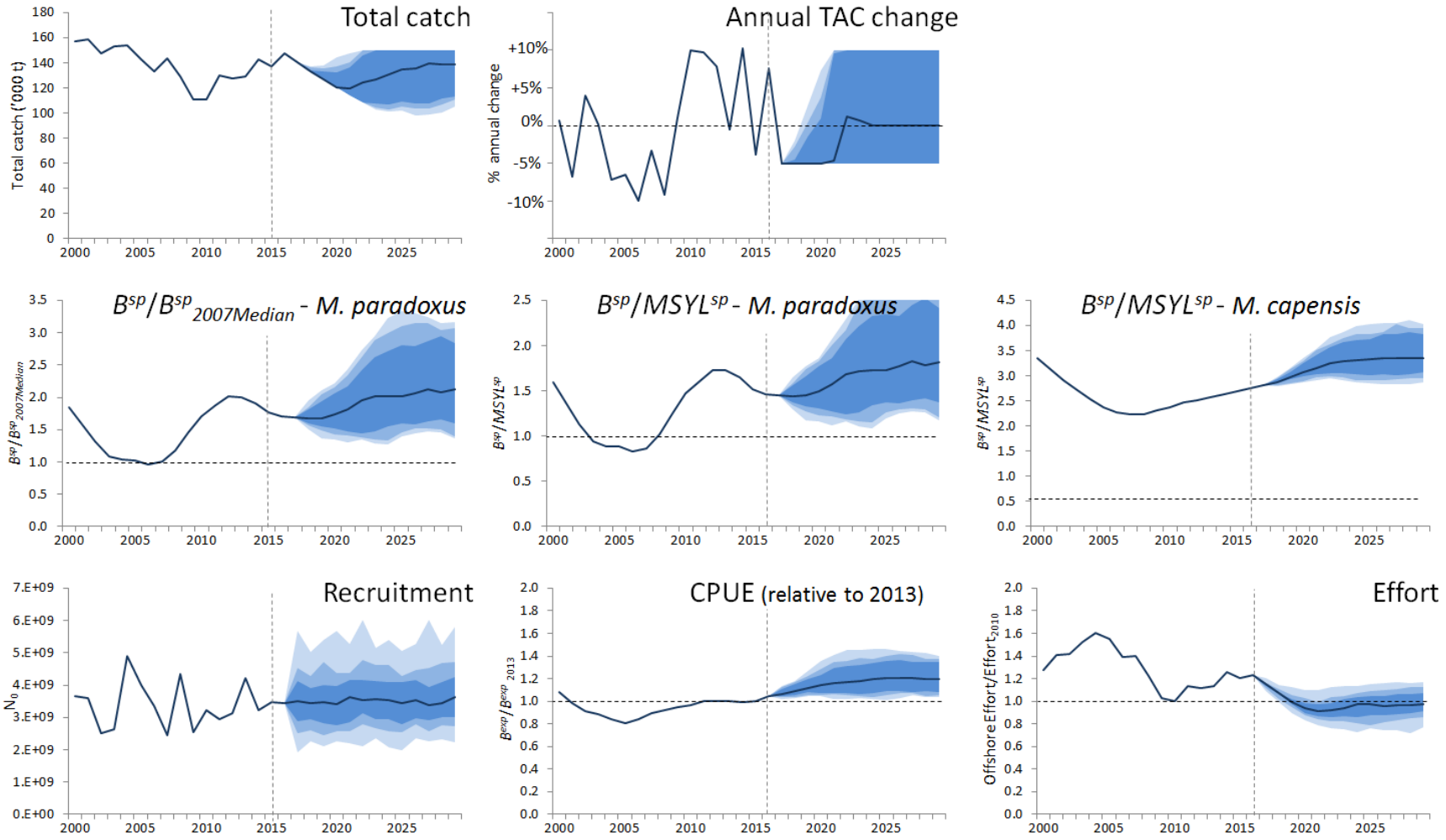

Figure A12: Projection results for the **RS15** under OMP-2014.