Hake predation model mortality rates

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Summary

The natural mortalities-at-age indicated by an explicit model of hake predation on hake are compared with those assumed for the Rademeyer and Butterworth (2014) Reference Case Operating Model. This RC model is re-run with the 1984-2014 average natural mortality rates at age from the predation model and the results compared. The main difference is in estimates of B_{MSY} and of the status of each species relative to that biomass level.

A brief comparison is provided between the time-independent natural mortality rates used in the Reference Case (RC) Rademeyer and Butterworth (2014) model (no explicit modelling of hake predation effects) and the time-varying natural mortality rates estimated in the Ross-Gillespie (2016) hake predation model for both *M. paradoxus* and *M. capensis*. Figure 1 shows the Ross-Gillespie (2016) natural mortality rates (for pre-exploitation equilibrium and averaged over the 1984-2014 period) compared to the natural mortality rates assumed for the Rademeyer and Butterworth (2014) RC. Figure 2a depicts bubble plots showing the Ross-Gillespie (2016) mortality rates as they vary by age and year, while Figure 2b gives line plots of these mortality rates for a selection of years. Figure 3 shows the population numbers-at-age by year for each species for the predation model.

The predation model natural mortality rate consists of a basal mortality component (fixed at 0.2 yr^{-1}) and a hake-on-hake predation mortality component. An upper bound of 0.92 yr^{-1} has been enforced on the total mortality to prevent unrealistically high mortality rates. Note that the predation model mortality rates presented here are the original ones from Ross-Gillespie (2016) and do not account for recommendations made at the 2016 International Stock Assessment Workshop (IWS), which are still in the process of being implemented. As such, since these results may be subject to change as the predation model is developed further, this document serves primarily to illustrate in broad terms the potential difference in natural mortality rates that could arise when hake-on-hake predation is taken into account.

There is considerable fluctuation in the mortality rates across the years, most likely a result of the lower numbers of *M. capensis* of intermediate ages present around that time, which reduces the extent of predation on youngest hake (see Figure 3). Because of these fluctuations in the predator age structure, the mortality-at-age vectors neither decrease steadily over time, nor are always monotonic with age. Nonetheless the predation model generally estimates higher natural mortality rates for hake of intermediate age of 3-5 years than those assumed for the Rademeyer and Butterworth (2014) RC model. This is particularly true for the pre-exploitation equilibrium, where the mortality rates are higher in the predation model for hake up to age 7. If such high mortality rates do in fact occur in reality, this could help account for the low numbers of older hake found in catches. Furthermore they have the potential to have a sizeable impact on the hake stock assessment results.

For an initial investigation of this potential impact, the Rademeyer and Butterworth (2014) RC model was re-run with the natural mortality rates-at-age fixed at the predation model 1984-2014 average mortality rates-at-age for each species. Table 1 gives the parameter estimates for this run (as well as those for the Rademeyer and Butterworth (2014) RC), and the corresponding negative log-likelihood values are listed in Table 2. This indicates that the worse fit for the predation model based natural mortalities-at-age vectors is primarily a consequence of a poorer match to the sex-aggregated commercial catch-at-length (CAL) data. Figure 4 compares the spawning biomass trajectories for the RC and this "predation model based" re-run, and Figure 5 contrasts the stock-recruitment relationships estimated for the two runs. The survey and commercial selectivity functions for the two runs are shown in Figure 6 and 7 respectively. Further results are not shown here as they did not show any notable qualitative contrast between the two runs. Apart from somewhat important differences in the estimates of spawning biomass relative to B^{sp}_{MSY} (see Table 1 and Figure 4), the results of the two runs did not differ substantially. This is perhaps not entirely unexpected as the 1984-2014 averaged predation mortality vector is not as different from the RC mortality vector as, say, the 1916 predation mortality vector. A re-run with this

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latter mortality vector for each species, or with the full matrix of yearly varying natural mortalities-at-age, would be interesting to explore, but have not been completed at this stage.

Sensitivity to the upper limit of 0.92 yr^{-1} and the basal mortality rate of 0.2 yr^{-1} for the predation mortality was explored by Ross-Gillespie (2016), but are being reinvestigated as the recommendations made at the 2016 IWS are implemented.

Acknowledgements

Tables 1 and 2, and Figures 5 and 6 were generated from an excel spreadsheet set up by R. Rademeyer.

References

Rademeyer, R. A. and Butterworth, D. S. 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/MAR/SWG-DEM/14 and MARAM/IWS/2017/Hake/BG3.

Ross-Gillespie, A. 2016. Modelling cannibalism and inter-species predation for the Cape hake species *Merluccius capensis* and *M. paradoxus*. PhD thesis, University of Cape Town.

Table 1: Key parameter outputs of the Rademeyer and Butterworth (2014) RC model and the Rademeyer and Butterworth (2014) model re-run with the predation model 1984-2014 natural mortality vectors for each species. Note that the spawning biomass values correspond to the female component of the population.

		Rademeyer RC	Predation mortality
	-lnL total	-5244.1	-5226.52
M. paradoxus	K^{sp}	547	539
	B^{sp}_{MSY}	109	93
	B^{sp}_{2016}	106	110
	B^{sp}_{2017}	112	116.24
	B^{sp}_{2016}/K^{sp}	0.19	0.20
	B^{sp}_{2017}/K^{sp}	0.20	0.22
	$B^{sp}_{2016}/B^{sp}_{MSY}$	0.97	1.18
	$B^{sp}_{2017}/B^{sp}_{MSY}$	1.03	1.25
	MSY	141	142
M. capensis	K^{sp}	187	224
	B^{sp}_{MSY}	33	71
	B^{sp}_{2016}	119	154
	B^{sp}_{2017}	120	159
	B^{sp}_{2016}/K^{sp}	0.64	0.69
	B^{sp}_{2017}/K^{sp}	0.64	0.71
	$B^{sp}_{2016}/B^{sp}_{MSY}$	3.57	2.15
	$B^{sp}_{2017}/B^{sp}_{MSY}$	3.62	2.22
	MSY	79	80

Table 2: Negative log-likelihood components of the Rademeyer and Butterworth (2014) RC model and the Rademeyer and Butterworth (2014) model re-run with the predation model 1984-2014 natural mortality vectors for each species.

		Rademeyer RC				Predation mortality			
		Total	Both	para	cap	Total	Both	para	cap
-lnL total		-5244.09				-5226.52			
ICSEAF CPUE	WC	-40.88	-29.89			-41.03	-30.05		
	SC		-10.99				-10.98		
GLM CPUE	WC	-189.56		-59.86	-46.33	-188.96		-62.04	-40.56
	SC			-51.58	-31.79			-53.30	-33.05
Survey	WC summer	-20.45		*	5.77	-18.08		*	6.19
	WC winter			-14.33	-2.53			-14.16	-2.44
	SC spring			-3.20	-0.70			-3.06	-0.76
	SC autumn			0.42	-5.88			1.58	-5.43
Commercial sex-aggregated CAL	WC offshore	-1328.67	-416.36			-1317.72	-411.82		
	SC offshore		-370.13				-367.29		
	SC inshore				-415.98				-412.08
	WC longline		-66.97				-66.97		
	SC longline				-59.22				-59.56
Commercial sex-disaggregated CAL	WC longline	-1111.73		-369.91	-285.60	-1109.65		-368.17	-285.47
	SC longline			-338.50	-117.73			-337.72	-118.30
Survey sex-aggreagted CAL	WC summer	-709.85		-161.95	-118.71	-706.01		-161.12	-118.61
	WC winter			-86.70	-73.26			-82.98	-73.61
	SC spring			-59.38	-69.04			-60.07	-69.21
	SC autumn			-71.99	-68.82			-71.91	-68.49
Survey sex-disaggreagted CAL	WC summer	-1960.18		-543.76	-438.12	-1965.24		-542.58	-437.67
	SC spring			-89.68	-95.05			-88.35	-95.39
	SC autumn			-341.03	-452.54			-348.16	-453.10
Age-length keys		124.07				126.67			
SR residuals		9.73		4.55	5.18	9.68		4.25	5.43

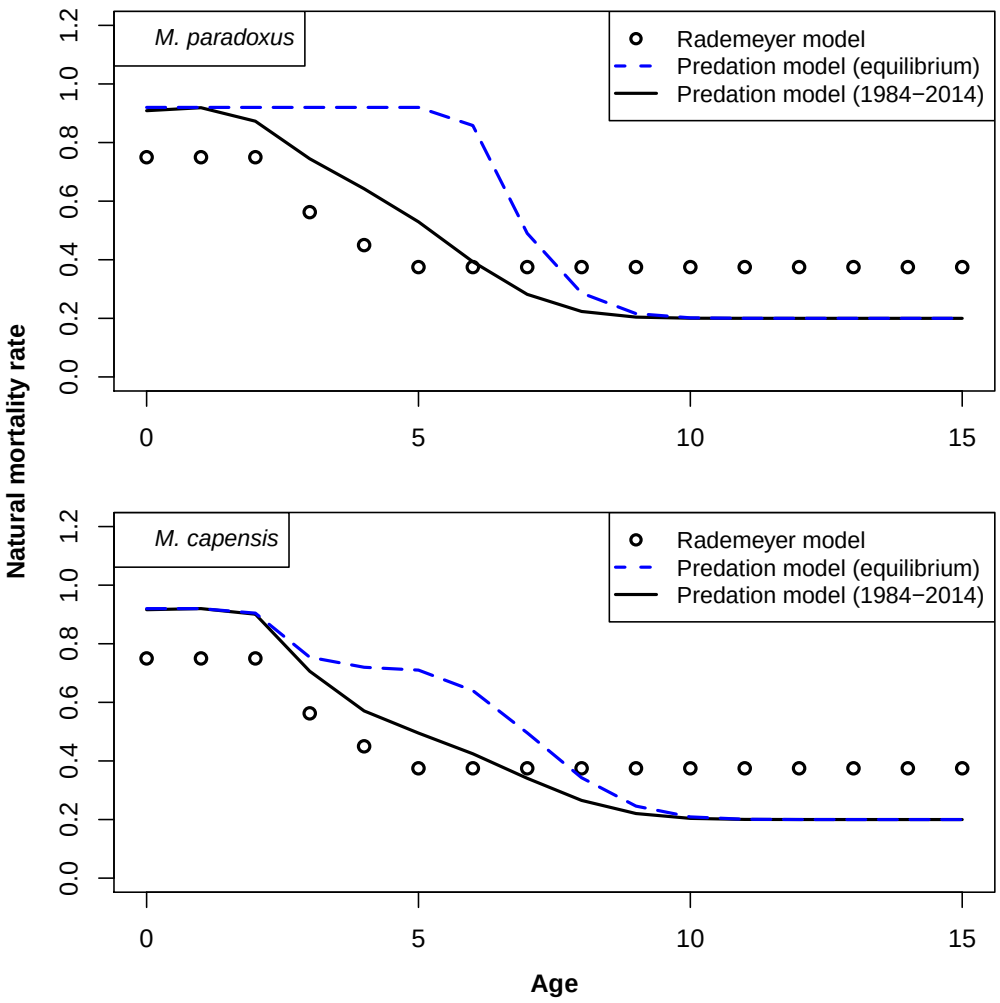

Figure 1: Natural mortality rates are shown for the Rademeyer and Butterworth (2014) model and the Ross-Gillespie (2016) hake predation model. The predation model mortality rates are time-varying and are shown for the pre-exploitation equilibrium (dashed blue line) and averaged over the last three decades (1984-2014) (solid black line).

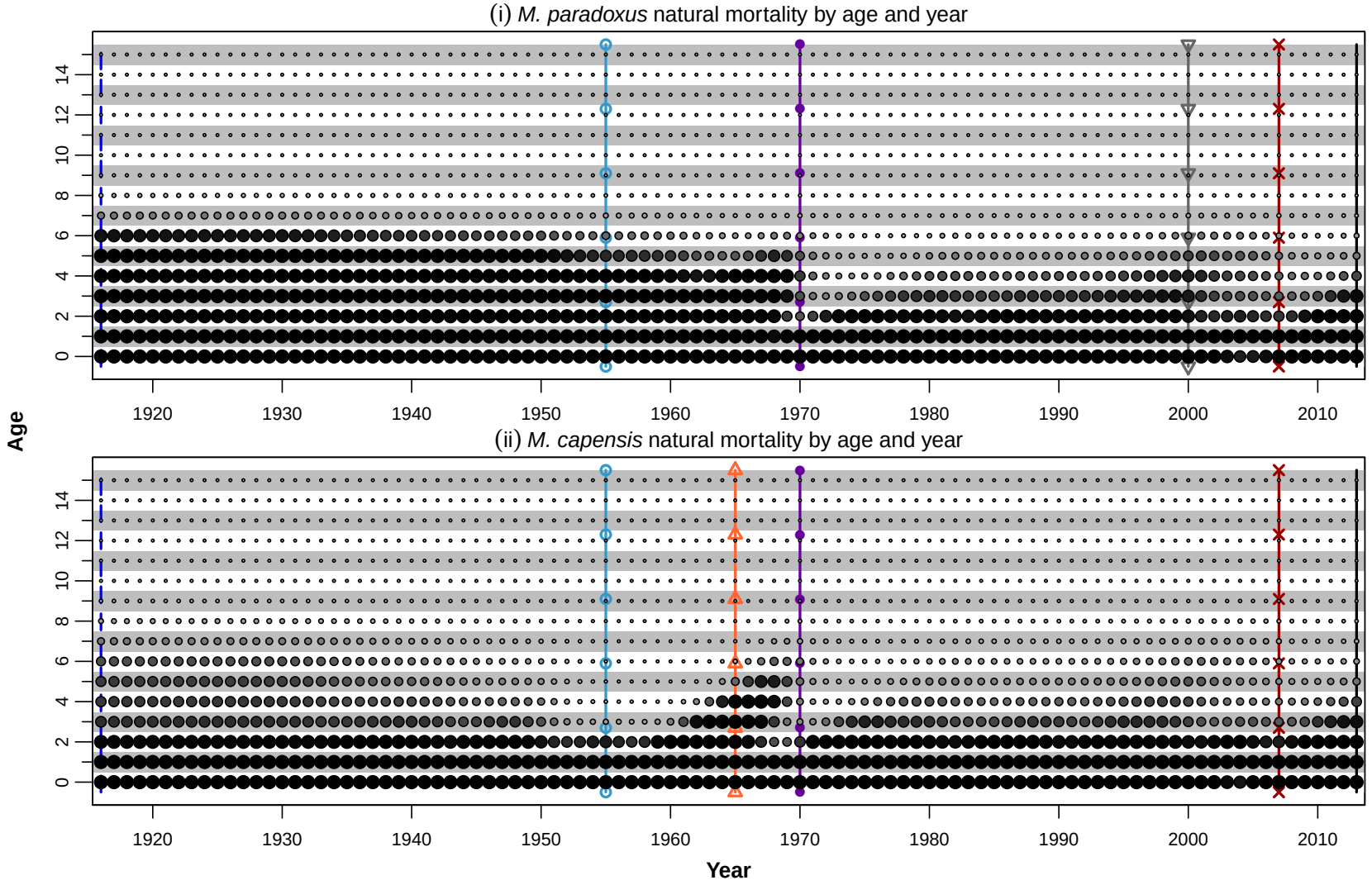

Figure 2a: Annual natural mortality rates for the Ross-Gillespie (2016) predation model. The size and shading of the each circle is relative to the magnitude of the mortality rate for that given year and age group, with large black circles corresponding to the largest mortality rate. The vertical lines of different colours show the years for which the mortality rate curves are shown in Figure 2b.

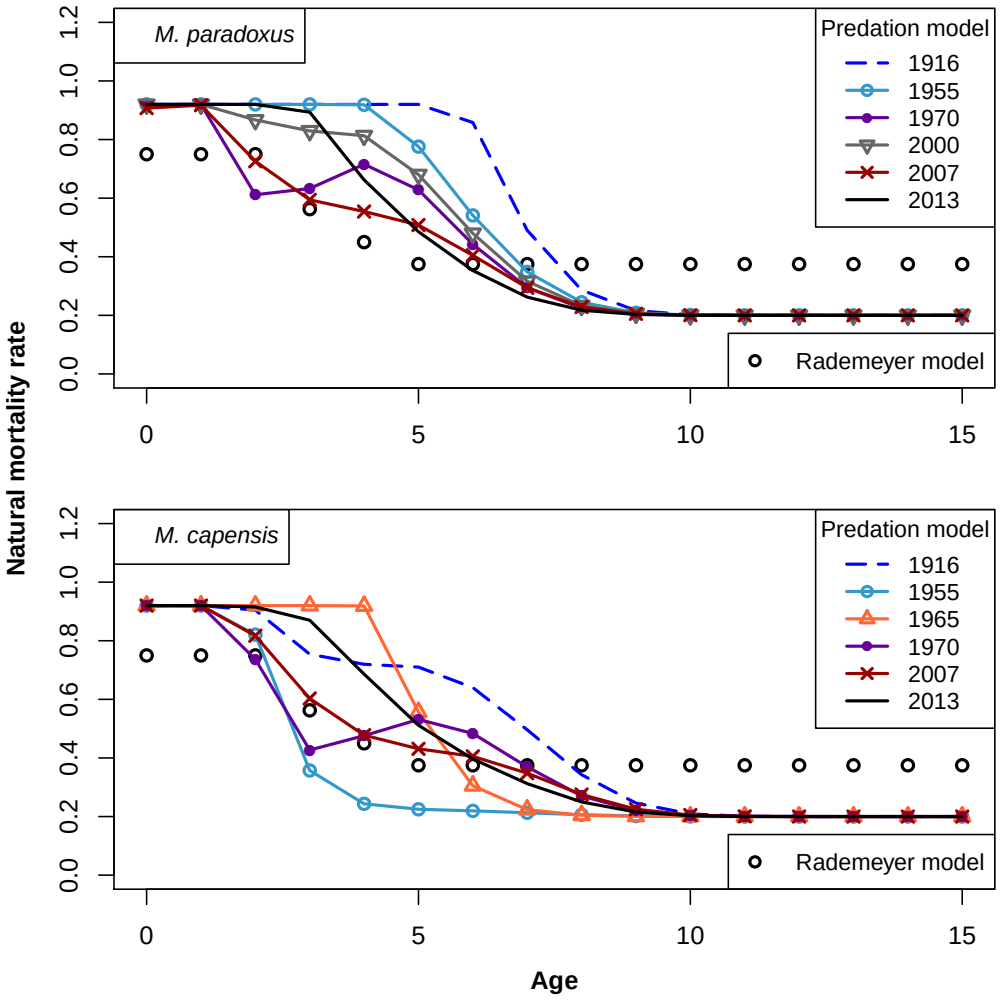

Figure 2b: Natural mortality rates are shown for the Ross-Gillespie (2016) hake predation model for a selection of years, as well as for the the Rademeyer and Butterworth (2014) single-stock model.

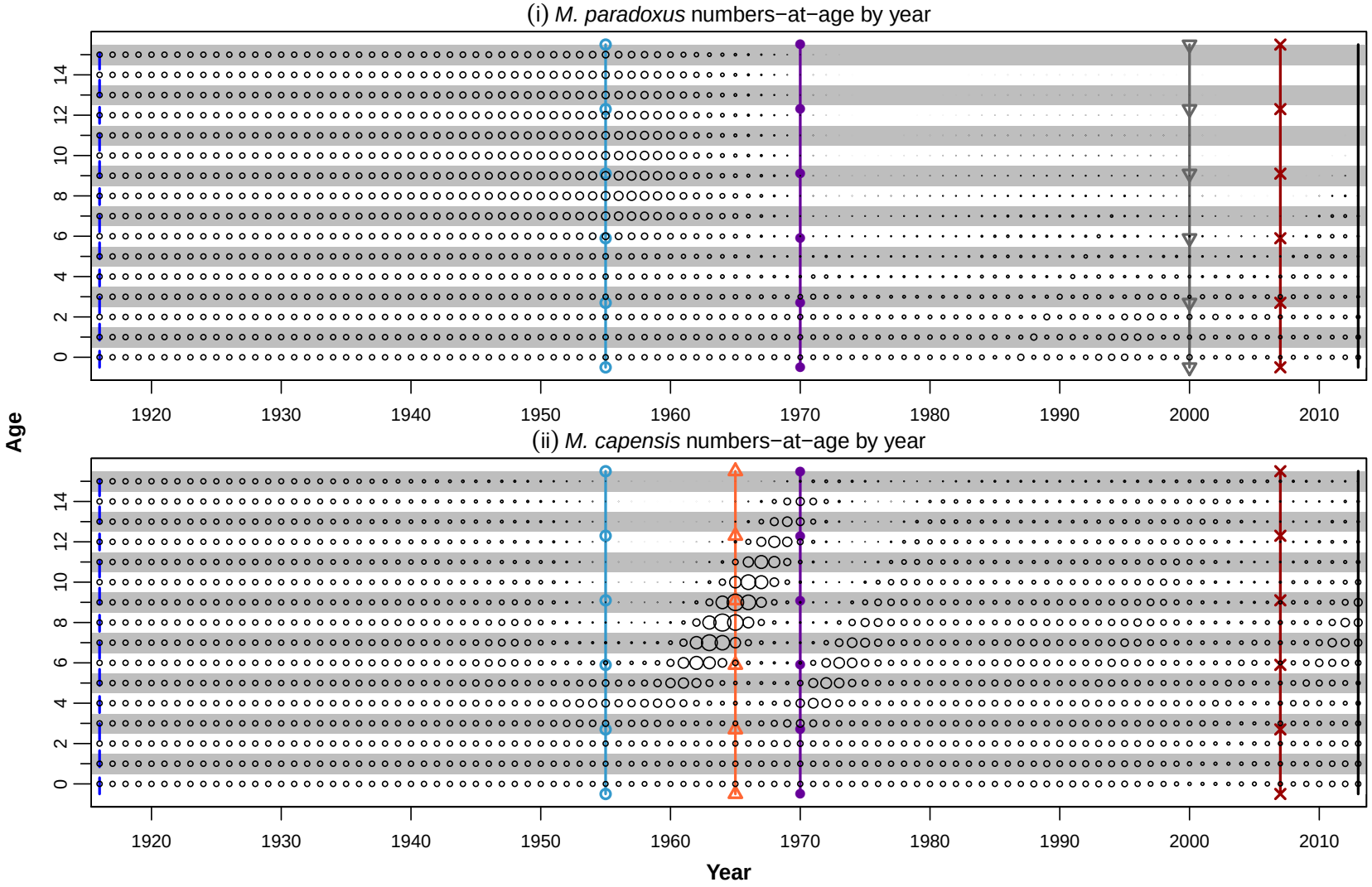

Figure 3: Annual numbers-at-age for the Ross-Gillespie (2016) predation model. The size each circle is relative to the numbers for that age group at equilibrium, i.e. the circles in 1916 correspond to a radius of one for all the age groups. The vertical lines of different colours show the years for which the mortality rate curves are shown in Figure 2b.

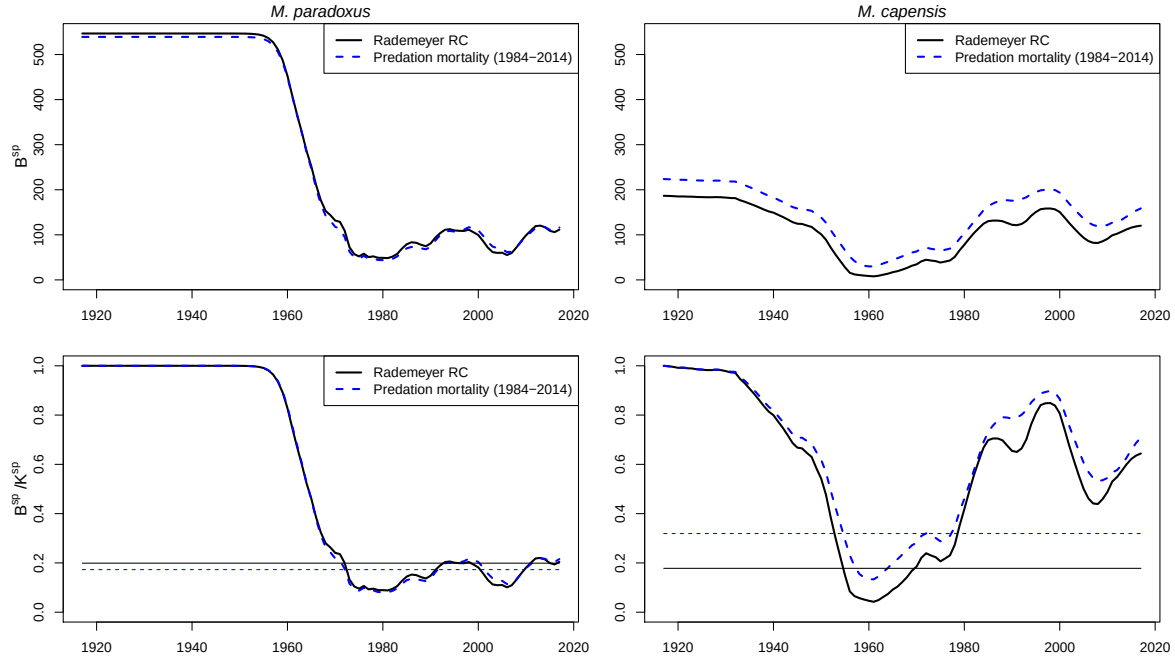

Figure 4: Female spawning biomass trajectories for the Rademeyer and Butterworth (2014) RC model and for the Rademeyer and Butterworth (2014) model re-run with the predation model 1984-2014 natural mortality vectors for each species. The horizontal lines in the second row show the maximum sustainable yield levels relative to pristine female biomass.

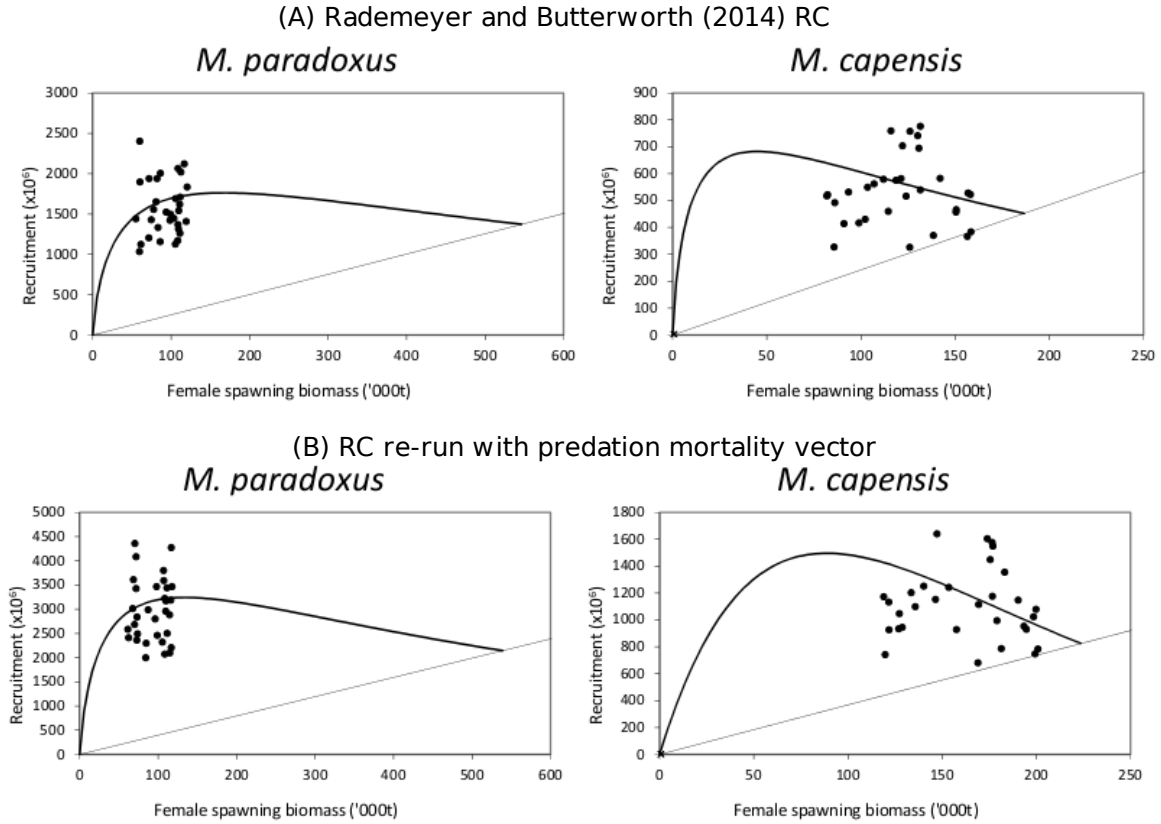

Figure 5: Recruitment is plotted against female spawning biomass for the Rademeyer and Butterworth (2014) RC model and for the Rademeyer and Butterworth (2014) model re-run with the predation model 1984-2014 natural mortality vectors for each species.

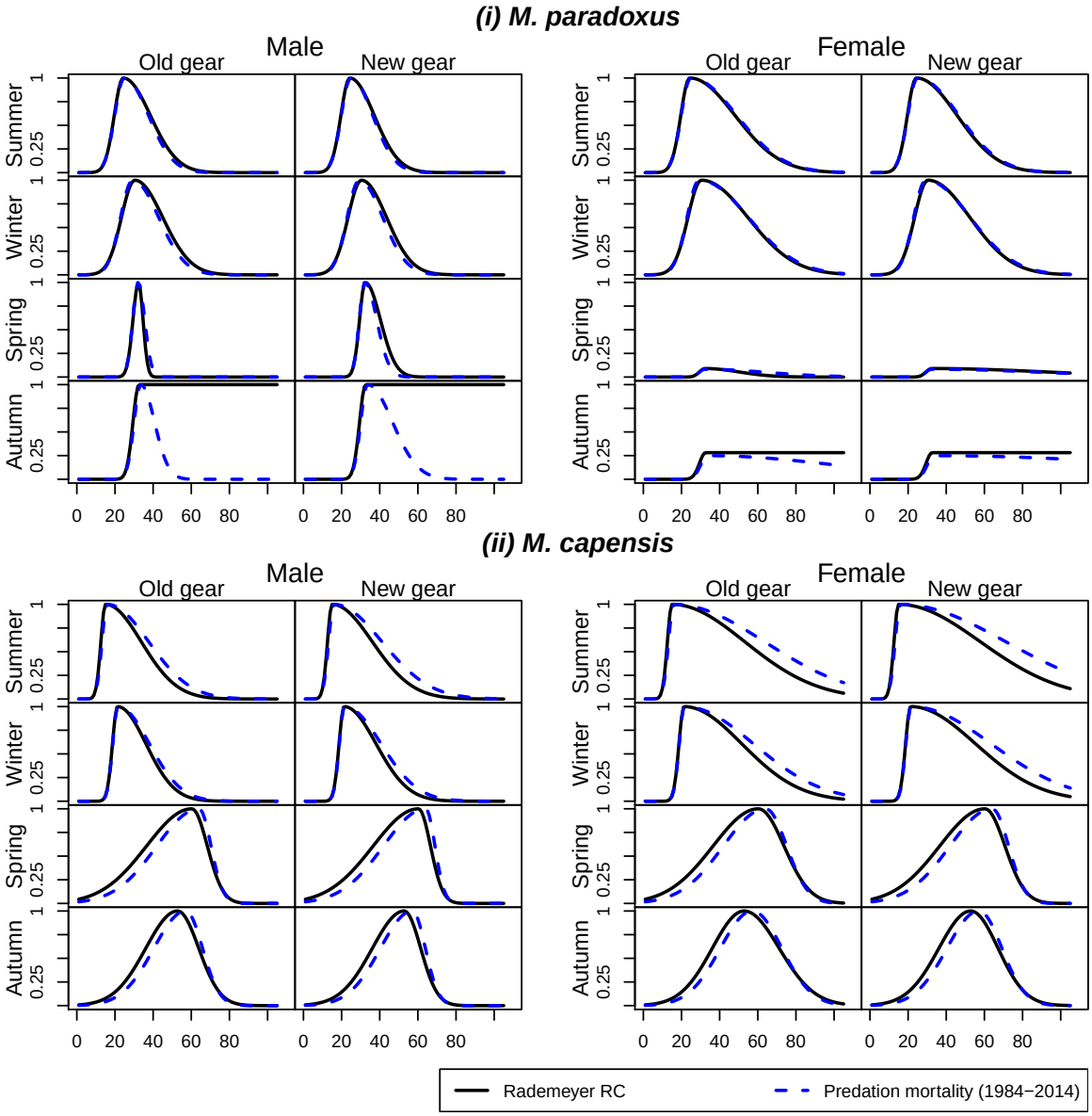

Figure 6: Survey selectivities for the Rademeyer and Butterworth (2014) RC model and for the Rademeyer and Butterworth (2014) model re-run with the predation model 1984-2014 natural mortality vectors for each species.

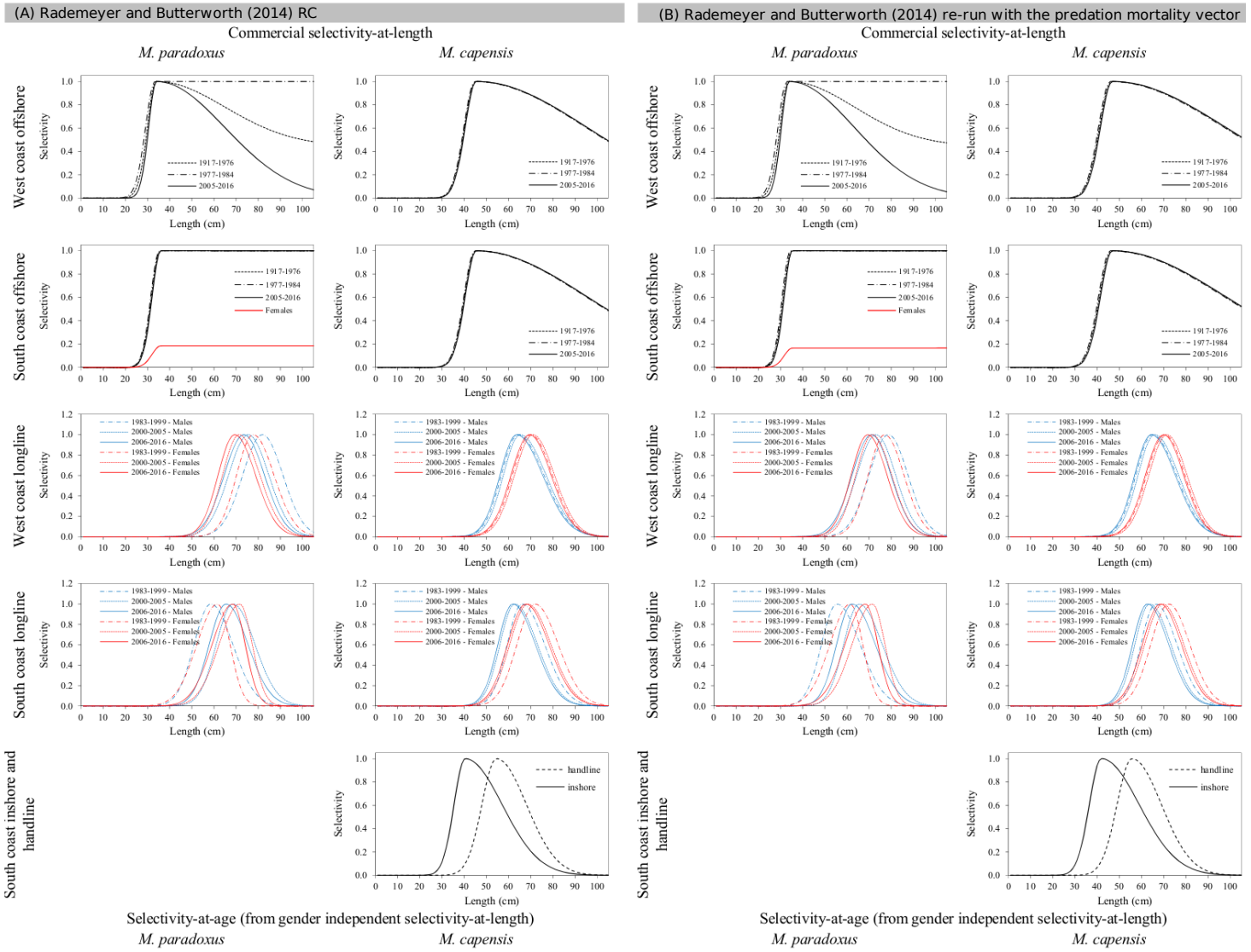

Figure 7: Commercial selectivities for the Rademeyer and Butterworth (2014) RC model and for the Rademeyer and Butterworth (2014) model re-run with the predation model 1984-2014 natural mortality vectors for each species.