The Bergh *et al.* (2016) hake cannibalism and inter-species predation model with the predator / prey preference, the daily ration of hake predators and the diet of the predators from the Ross-Gillespie (2016) model

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Outline of this document

It was suggested that the Bergh *et al*. (2016) model use the predator / prey preference, the daily ration of hake predators and the diet of the predators from the Ross-Gillespie (2016) model.

For ease of reference, the original Bergh *et al.* (2016) model will be referred to as the OLRAC1 model, the suggested Bergh *et al*. (2016) model (with the input from the Ross-Gillespie (2016) model) as the OLRAC2 model and the Ross-Gillespie (2016) model as the MARAM model.

This document compares the results for the OLRAC1, OLRAC2 and the MARAM models.

Table 1: Comparison between the negative log-likelihood components for the OLRAC1, OLRAC2 and MARAM models. Rows in grey indicate that the data are identical. Rows in blue indicate that the data are the same apart from the additional years of data included in the OLRAC models. Rows in yellow in either the OLRAC or the MARAM columns indicate that the data are use in that model only. The remaining rows in white indicate that there are more substantial differences in the underlying data.

		Predation on								
		OLRAC1			OLRAC2			MARAM		
	No. of Fitted Parameters		**267**			**267**			**259**	
	Hake	**Par**	**Comb**	**Cap**	**Par**	**Comb**	**Cap**	**Par**	**Comb**	**Cap**
CPUE	ICSEAF WC		-29.4			-27.9			-26.0	
	ICSEAF SC		-8.1			-5.5			-4.9	
	GLM WC	-63.5		-48.8	-61.8		-43.2	-31.1		-36.9
	GLM SC	-56.8		-33.6	-51.3		-34.5	-53.7		-56.8
Survey abundance	Summer	-13.4		-3.6	-13.0		-2.8	-13.4		-3.6
	Winter	-2.9		0.3	-2.9		-0.03	-3.3		0.9
	Spring	1.6		-7.2	0.9		-7.0	1.9		-6.0
	Autumn	5.0		-18.0	5.8		-17.6	6.1		-13.4
Stock-recruitment	SR Residuals		6.5			6.8			8.6	
Commercial CAL, sex-aggregated	Trawl Off WC Both Species		-20.8			-20.5			-16.2	
	Trawl Off SC Both Species		-10.6			-10.8			3.3	
	Trawl Inshore SC			-23.8			-22.0			-19.1
	Longline WC Both Species		-14.0			-13.8			-11.7	
	Longline SC			-6.2			-4.8			-6.4
Commercial CAL, sex-disaggregated	Longline WC	-27.5		-21.7	-25.7		-23.0	-		-
	Longline SC	-0.5		-20.2	-0.2		-18.5	-		-
Survey CAL, sex-aggregated	Summer WC	-0.1		14.6	0.8		13.9	0.8		58.7
	Winter WC	-1.2		8.8	-1.4		8.2	-1.6		9.3
	Spring SC	4.8		-0.9	5.1		-1.3	7.1		-8.1
	Autumn SC	4.9		-5.1	5.0		-3.5	8.9		-26.4
Survey CAL, sex-disaggregated	Summer WC	-4.9		30.2	-7.1		29.1	-		-
	Spring SC	3.5		-3.4	3.9		0.7	-		-
	Autumn SC	19.3		1.1	19.5		4.7	-		-
Age-Length Keys	ALK	49.4		72.9	50.1		73.9	-		-
Predation	Proportion of hake in diet		-			-			68.0	
	Preference		-			-			41.4	
Totals	-lnL (strictly comparable)		-51.2						-40.4	
	-lnL (roughly comparable)		-82.8						-66.2	
	-lnL **(non-comparable)**		-						-	
	-lnL (unique)		52.3						109.4	
	Penalties		5.10			10.7			7.7	
	Total –lnL (excl. penalties)		**-224**			**-192**			**-124**	

Table 2a: Selected parameter estimates and key model outputs for the OLRAC1, OLRAC2 and MARAM predation-on models.

	Predation-on					
	OLRAC1		OLRAC2		MARAM	
	M. par	M. cap	M. par	M. cap	M. par	M. cap
Ksp	290	96	380	187	481	285
h	1.0	0.5	0.9	0.5	0.9*	0.9*
gamma	0.3	2.4	0.1	1.6		
Max(Bsp(y)/Ksp)	1.4	1.0	1.1	1.0	1.3	1.0
Bsp(2013)	146	68	169	129	70	213
Bsp(2013)/Ksp	0.50	0.71	0.44	0.69	0.15	0.75

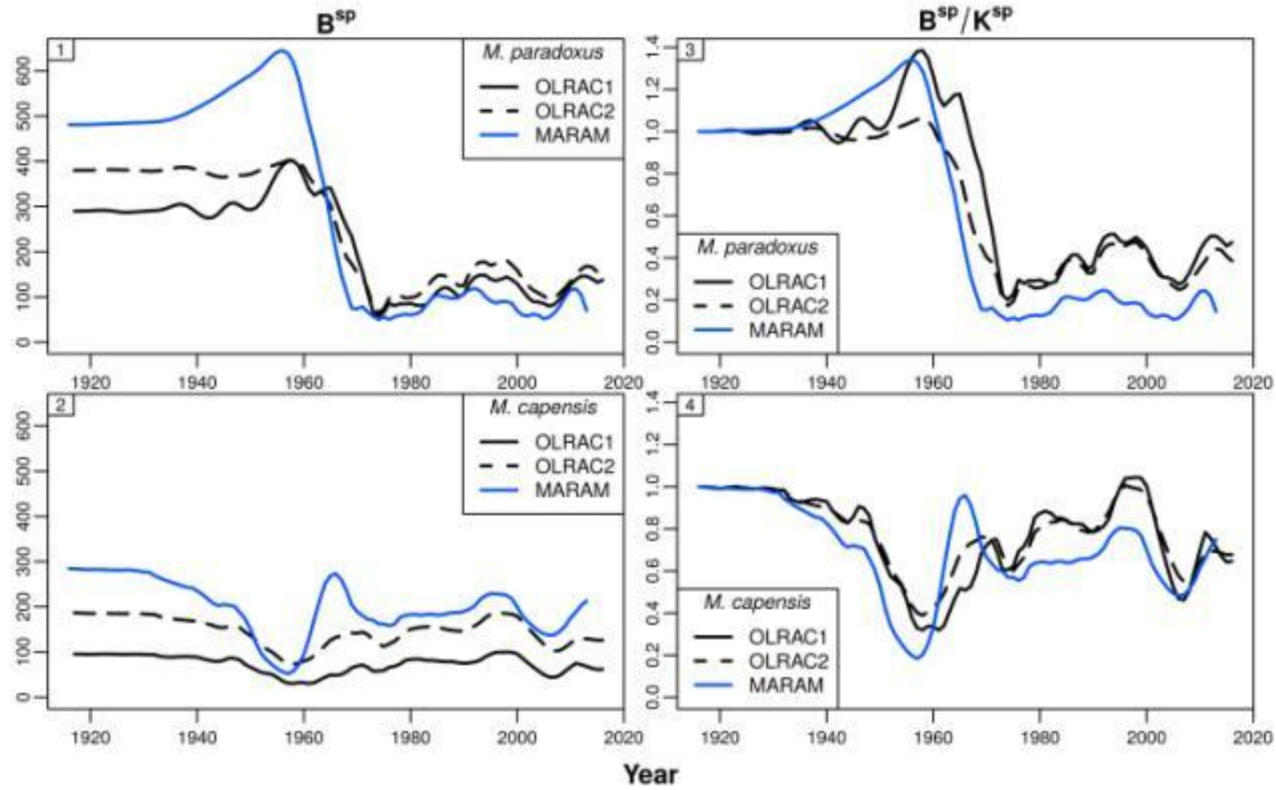

Figure 1. Spawning biomass trajectories are shown for the predation-on variants for each of the OLRAC1, OLRAC2 and MARAM models. The plots show the spawning biomass trajectory in 1000 tons and the biomass relative to pre-exploitation equilibrium.

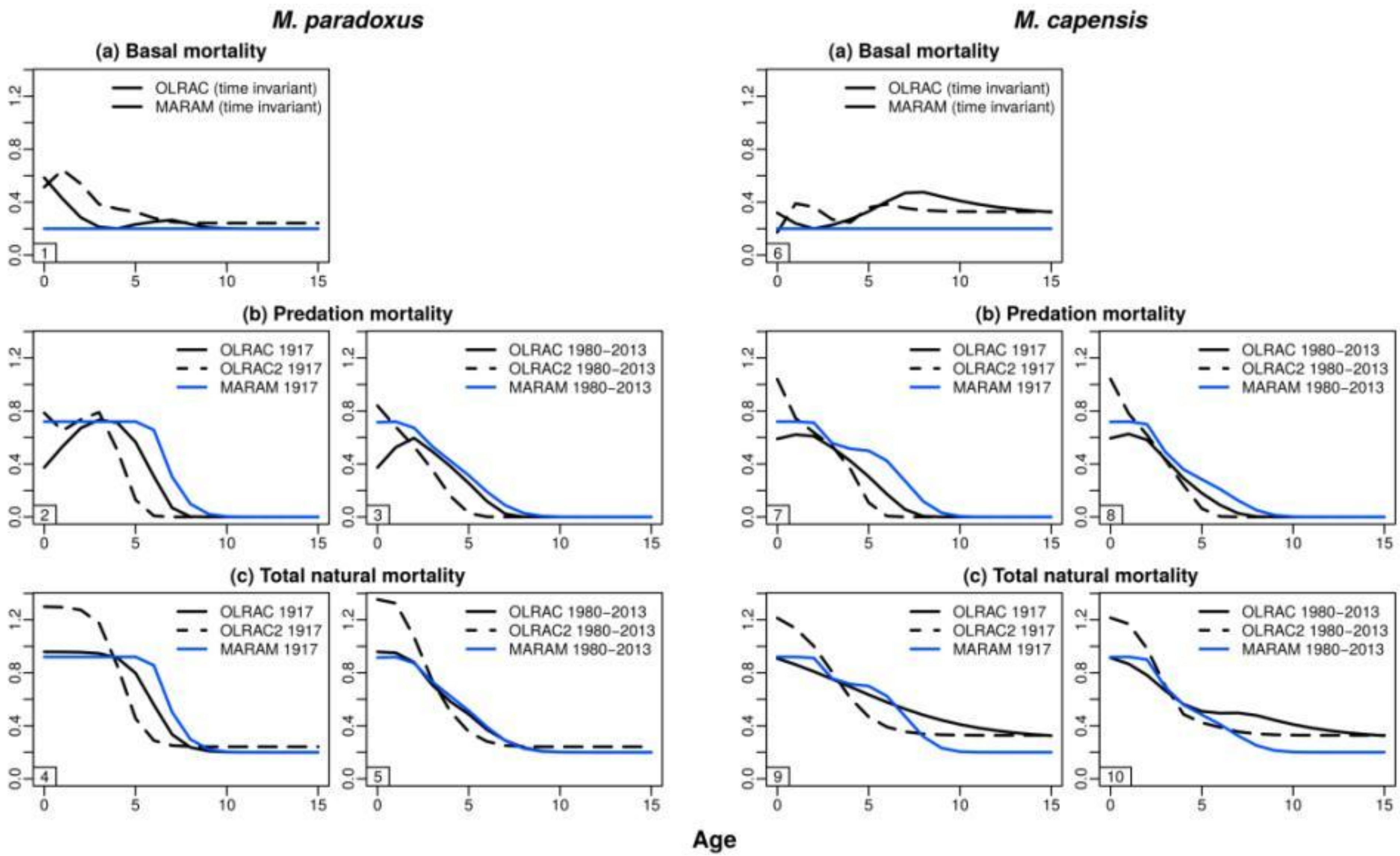

Figure 2: The natural mortality components for the three models. Mbase = Basal mortality, Mpred = Predation mortality and Mtot = Total natural mortality. Mortality rates are reported for the 1917 pre-exploitation equilibrium and as an average over 1980-2013. Mbase is the same for all years.

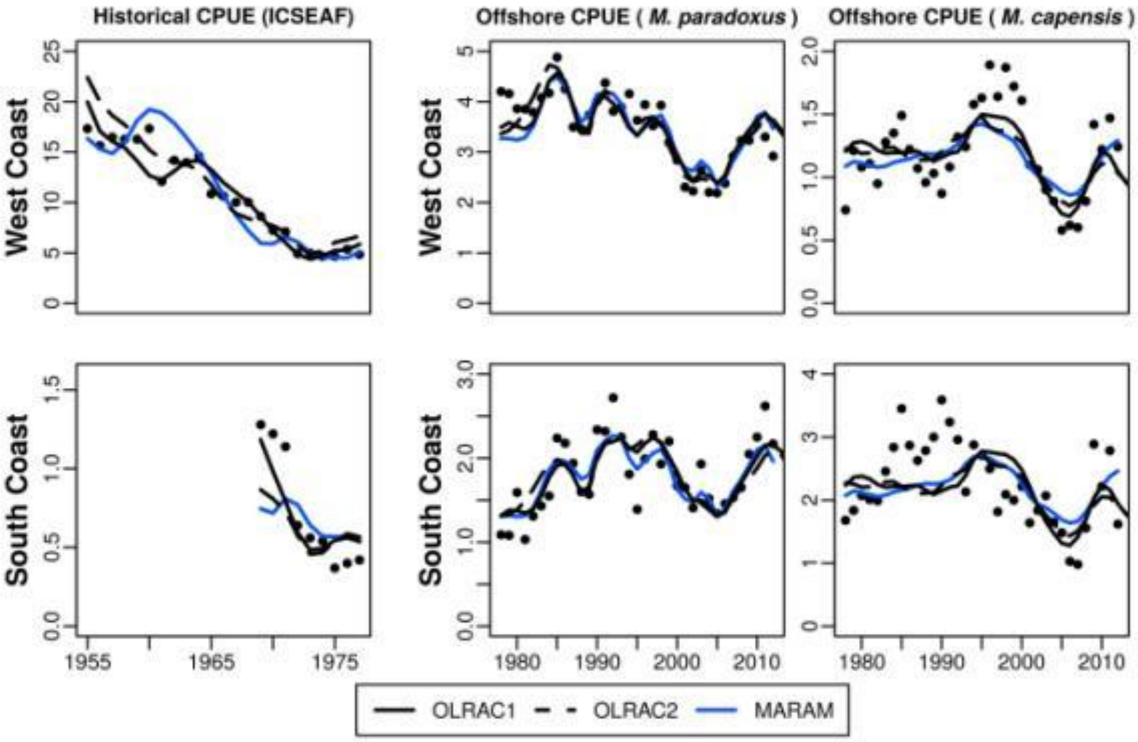

Figure 3. ICSEAF and GLM CPUE plots (observed and modelled) for M. paradoxus and M. capensis are shown for the predation-on variant. OLRAC1 = black solid lines, OLRAC2 = black dashed lines, MARAM = blue solid lines.

(a) OLRAC1 model (original) (b) OLRAC2 model (MARAM input) (c) MARAM model

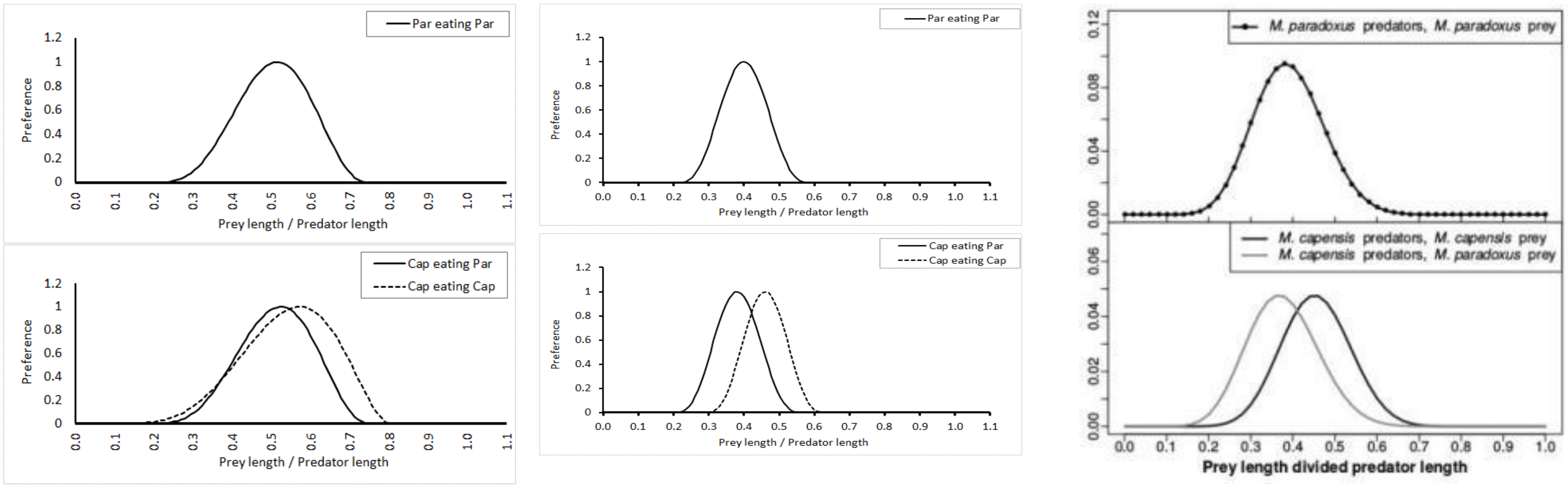

Figure 4. Predator-prey preference. The plots show the preference function evaluated in terms of the ratio of prey length to predator length.

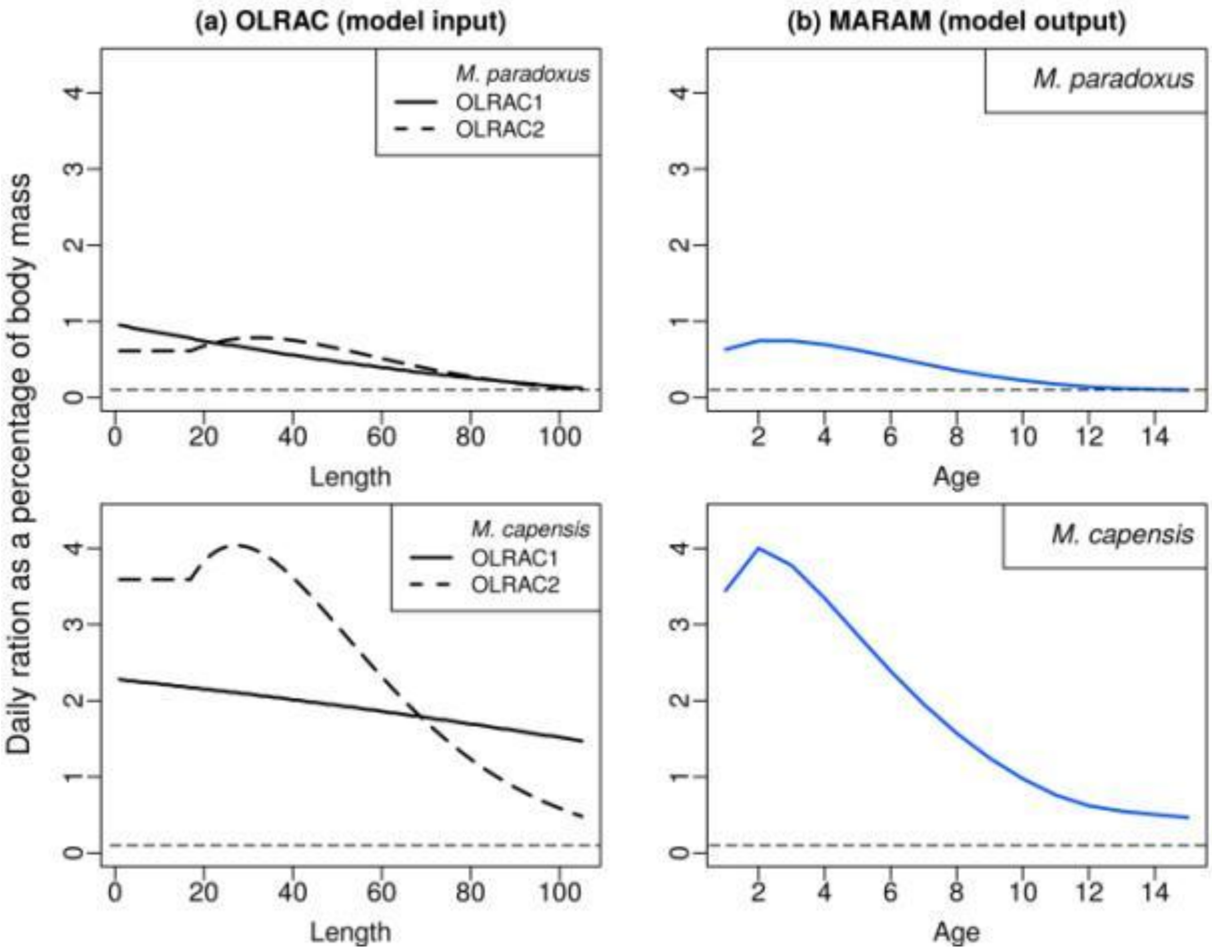

Figure 5: Plots of daily ration of hake predators as a percentage of body mass. The two left panels show the OLRAC1 and OLRAC2 daily rations as a function of predator length. The two right panels show the MARAM daily rations as a function of predator age, which are estimated in the model. The MARAM model enforces a lower bound of 0.1% on the daily ration; the dashed horizontal lines indicate this 0.1% mark. Furthermore, the MARAM model enforces a penalty so that the slope of daily ration with predator age is relatively close to -1/3.

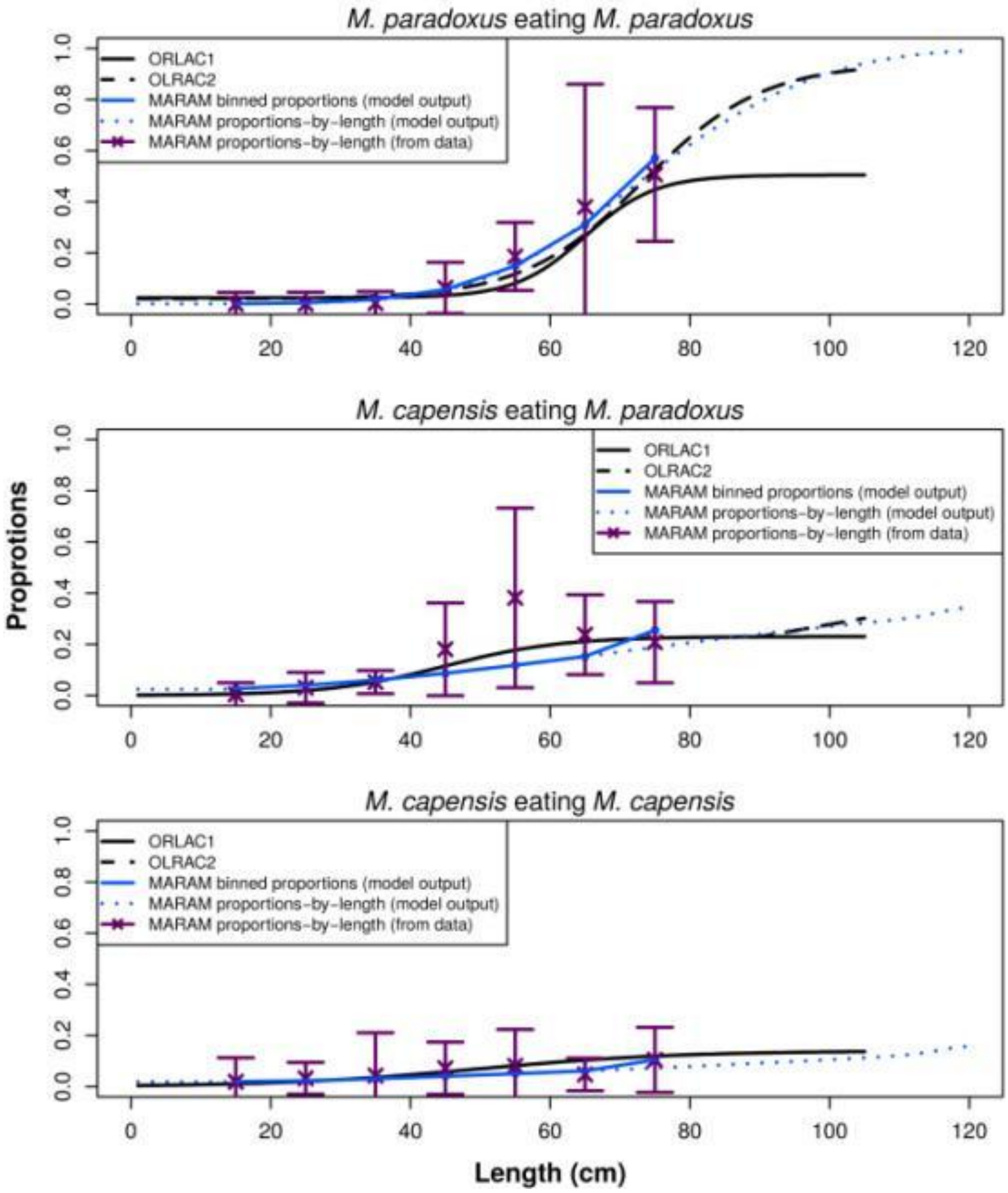

Figure 6: Plots of the proportion of hake in the diet of hake predators. The three panels show the proportions of hake in the diet of hake predators for the OLRAC models (black solid and black dashed lines) and the MARAM model (blue solid lines). The OLRAC1 proportions are taken from Punt and Leslie (1995) and are fixed on input. The MARAM proportions are model outputs, fit to estimates from the 1999-2013 DAFF stomach content data – these estimates from the data are shown with purple crosses along with their 95% confidence intervals. The MARAM proportions are averaged over the years 1999-2013, the years for which stomach content data are available.

Note that for the MARAM model, the model and observed proportions were binned before calculating the likelihood. The binning was done by calculating the total amount of hake consumed in a given length class and dividing by the total ration. Since the daily ration decreases with predator age, the proportions at greater predator lengths will contribute less to the binned proportions. This is why, for example, the proportion of *M. paradoxus* eating *M. paradoxus* can go up to 1 at length 120, but the 70cm plus group proportion is at 0.6.