Modelling selectivity as a random walk process for the offshore trawl fleet for *M. paradoxus*

Rebecca A. Rademeyer and Doug S. Butterworth

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Introduction

In the current South African hake Reference Set of assessments, commercial fishing selectivity is assumed to be constant over fixed, pre-defined periods. In the case of the offshore trawl fleet, the three periods of fixed and changing selectivity (pre-1977, 1977-1984, and post-1992) have been selected to take account of the changes in the selectivity likely due to the phasing out of the (illegal) use of net liners to enhance catch rates. For the longline fleet, three periods have also been selected (pre-1999, 2000-2005, and post-2005). These have been chosen by examining the residual patterns of the fit to the catch-at-length data for that fleet.

In this analysis, the selectivity of *M. paradoxus* by the offshore trawl fleet (the largest component of the catches) is modelled instead as a random-walk process (similar to the approach in SAM) to allow it to vary more freely over time (see Appendix A for details). Catch-at-length data for the offshore trawl fleet are currently available for the period 1981-2012 (with a gap over 2000-2004) for the west coast, and over 1975-1996 for the south coast. The random walk process is therefore estimated only for those periods for which data are available; for the remainder of the assessment period, averages are used (see Table A.1). The reason why a random walk process cannot be readily estimated for both *M. paradoxus* and *M. capensis* is that the data available are not disaggregated by species. The exercise here is intended as a simple first cut to examine the potential of such a model for selectivity.

Results and Discussion

Three runs are compared:

a. "RS1": (Rademeyer and Butterworth, 2014 - "traditional" selectivity)

b. "sig=0.05": As RS1 but with offshore trawl selectivity for *M. paradoxus* modelled as a random walk process with σ_{RW} fixed to 0.05 (see Appendix A).

c. "sig=0.1": As "sig=0.05" but with σ_{RW} fixed to 0.1.

Table 1 give the difference in values of components of the negative log-likelihood for the two random walk cases compared to RS1. Unsurprisingly, the biggest improvement for the random walk cases is in the fit to the offshore CAL data. However, these changes have very little effect on the overall estimated trends in abundance (see Figure 1).

Selectivity does not vary much over time on the south coast. Changes are more noticeable on the west coast, where it is pleasing to note that the L parameter (the length at maximum selectivity) in particular behaves essentially as assumed on input for the RS over the liner-change period (see Figure 2).

Reference

Rademeyer RA and Butterworth DS. 2014. Specifications of the South African Hake 2014 Reference Case Assessment. MARAM/IWS/DEC14/Hake/P2.

Table 1: Difference in values of components of the negative log-likelihood for the two random walk cases compared to RS1.

		spp	sig=0.05	sig=0.1
CPUE	ICSEAF WC	combined	0.0	-0.4
	ICSEAF SC	combined	-0.3	-0.4
	GLM WC	paradoxus	1.8	1.1
	GLM SC	paradoxus	-2.1	-2.5
	GLM WC	capensis	0.0	-0.2
	GLM SC	capensis	-0.1	0.1
Survey	WC summer	paradoxus	-0.2	-0.1
	WC winter	paradoxus	0.0	0.0
	SC spring	paradoxus	-0.1	-0.2
	SC autumn	paradoxus	0.1	0.0
	WC summer	capensis	-0.9	-0.9
	WC winter	capensis	0.1	0.1
	SC spring	capensis	-0.1	-0.1
	SC autumn	capensis	-0.2	-0.2
Commercial sex-aggregated CAL	WC offshore trawl	combined	-12.7	-17.1
	SC offshore trawl	combined	-3.4	-7.4
	SC inshore	capensis	0.0	0.1
	WC longline	combined	0.0	0.0
	SC longline	capensis	0.0	0.0
Commercial sex-disaggregated CAL	WC longline	paradoxus	-0.3	-0.5
	WC longline	capensis	0.0	0.0
	SC longline	paradoxus	0.0	0.0
	SC longline	capensis	0.3	0.4
Survey sex-aggregated CAL	WC summer	paradoxus	-0.2	-0.3
	WC winter	paradoxus	-0.1	-0.2
	SC spring	paradoxus	0.2	0.3
	SC autumn	paradoxus	-0.4	-0.3
	WC summer	capensis	0.4	0.4
	WC winter	capensis	0.0	0.0
	SC spring	capensis	0.3	0.3
	SC autumn	capensis	0.0	0.0
Survey sex-disaggregated CAL	WC summer	paradoxus	-0.8	-0.8
	SC spring	paradoxus	-0.2	-0.3
	SC autumn	paradoxus	-1.4	-1.5
	WC summer	capensis	0.1	0.0
	SC spring	capensis	2.2	2.2
	SC autumn	capensis	-0.3	-0.3
Age-length keys			-0.2	0.7
Stock-recruit residuals		paradoxus	-0.9	-0.5
		capensis	0.1	0.1
Survey selectivity smoothing			-0.7	-1.0
Random walk residuals			6.9	6.5
Total			-12.9	-22.5

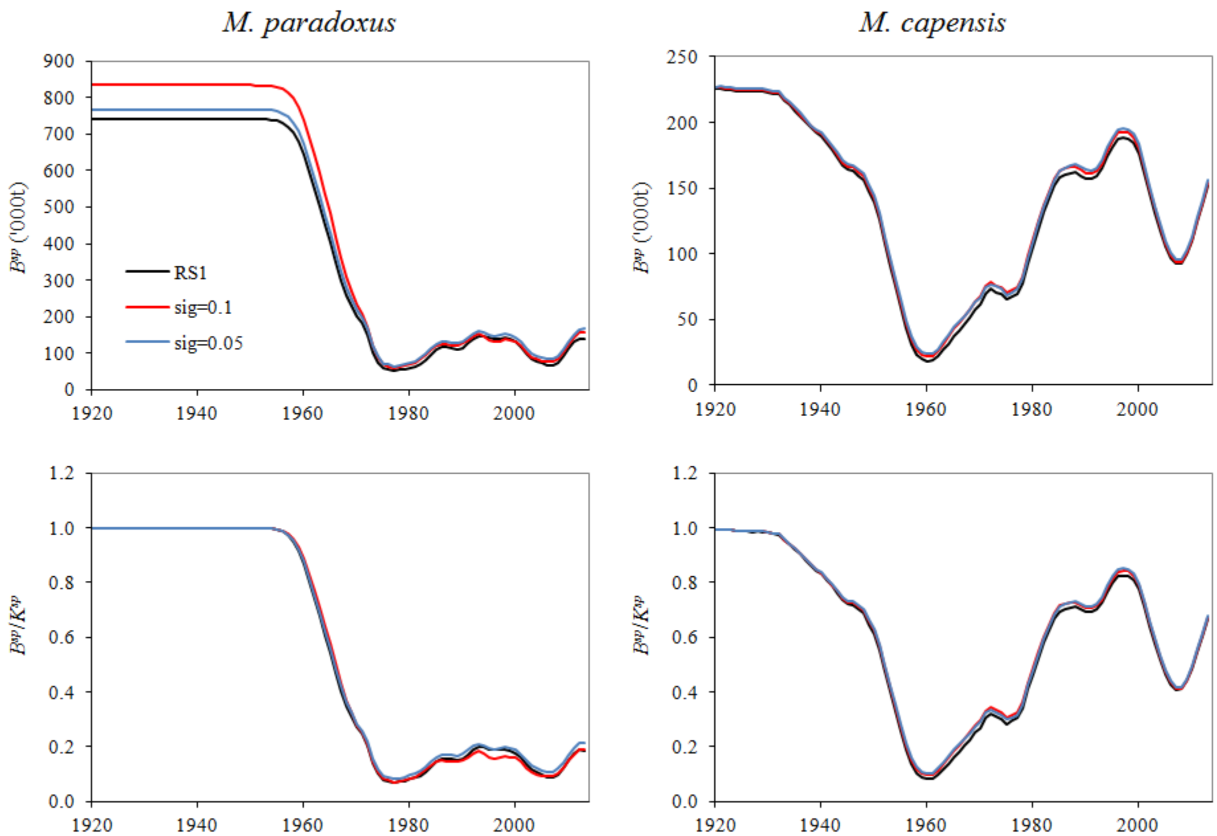

Figure 1: Spawning biomass trajectories (in absolute terms, top row, and relative to pre-exploitation level, bottom row) for the three cases for *M. paradoxus* (LHS) and *M. capensis* (RHS). The "sig" indicated within the plots refers to the selectivity random walk parameter σ_{RW} (see equation A.2).

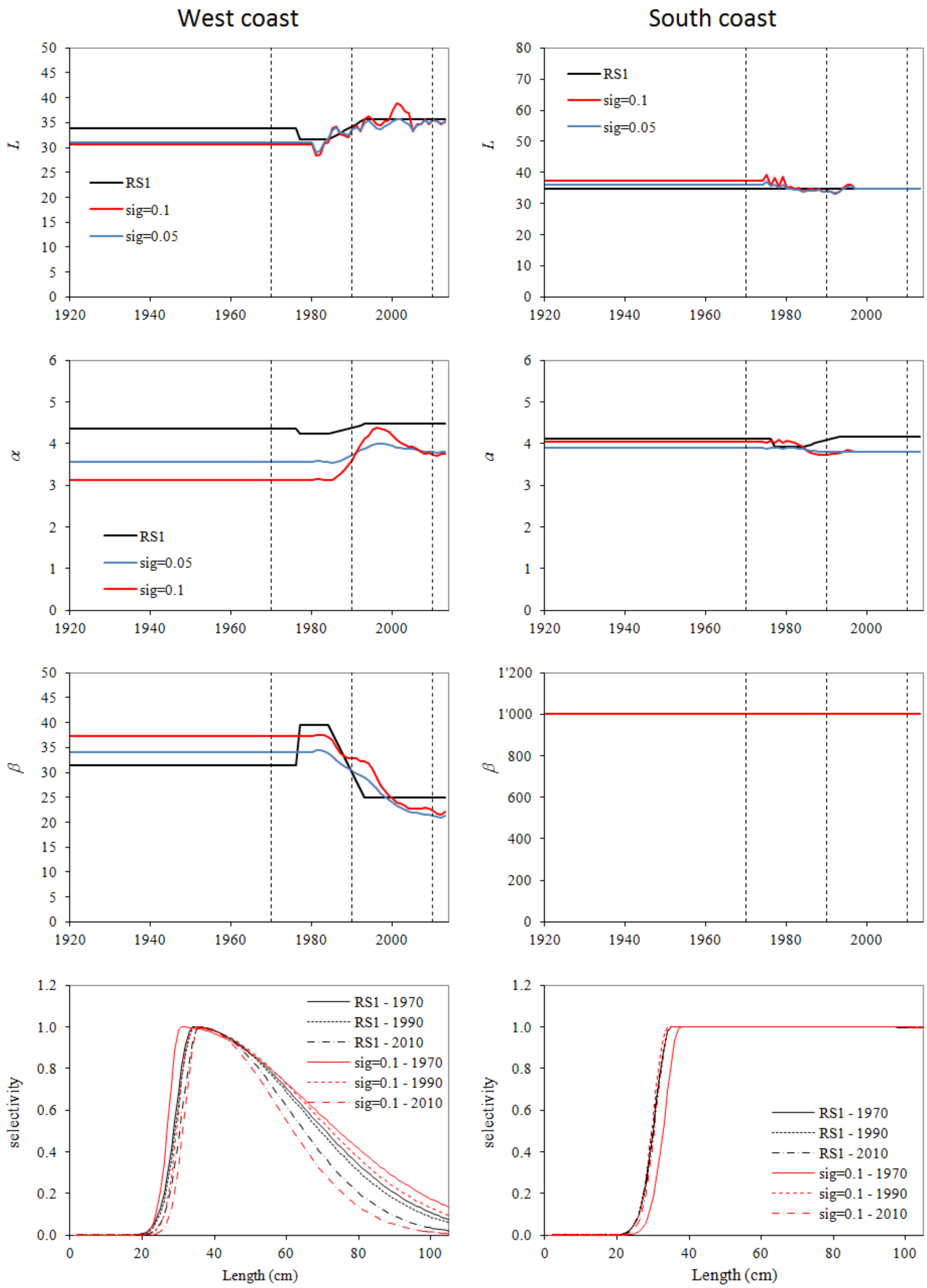

Figure 2: Time trajectories of the double normal selectivity parameter for the west coast (LHS) and south coast (RHS) offshore trawl fleet for *M. paradoxus* for the three cases. The resulting selectivities are shown for the years 1970, 1990 and 2010 for RS1 and sig=0.2 only. Note that the b parameter for RS1 on the south coast is outside the range plotted (i.e. corresponding to a flat selectivity at large lengths).

Appendix A: Changes made to the commercial selectivity

In Rademeyer and Butterworth (2014) three periods of fixed and changing selectivity have been assumed for the offshore trawl fleet to take account of the change in the selectivity at low ages over time in the commercial catches, likely due to the phasing out of the (illegal) use of net liners to enhance catch rates, with the times when the change started and ended specified on input. Here, the offshore trawl selectivity for *M. paradoxus* S_{sfl} is modelled instead as a random-walk process (and without any such input specifications on times of change):

$$S_{sfl} = \exp\left(-\frac{\left(l - L_y\right)^2}{2\alpha_y^2}\right) \qquad \text{for } l \le L_y$$

$$S_{sfl} = \exp\left(-\frac{\left(l - L_y\right)^2}{2\beta_y^2}\right) \qquad \text{for } l > L_y \tag{A.1}$$

where

$$L_y = L_{y-1} e^{\varepsilon_y^L} \qquad \text{with} \qquad \varepsilon_y^L \text{ from } N(0, \sigma_L^2)$$

$$\alpha_y = \alpha_{y-1} e^{\varepsilon_y^\alpha} \qquad \text{with} \qquad \varepsilon_y^\alpha \text{ from } N(0, \sigma_\alpha^2)$$

$$\beta_y = \beta_{y-1} e^{\varepsilon_y^\beta} \qquad \text{with} \qquad \varepsilon_y^\beta \text{ from } N(0, \sigma_\beta^2)$$

The following parameters are therefore estimated for the west and south coasts separately:

L_{y_0}, α_{y_0}, β_{y_0} and ε_y^L, ε_y^α, ε_y^β from year y_0+1.

Table A.1 summarises the changes made for the offshore trawl fleet selectivity.

The contribution of the random walk parameters to the negative of the log-likelihood function is given by:

$$-\ell n L^{RW} = \sum_{y=y1}^{y2} \frac{\left(\varepsilon_y^L\right)^2 + \left(\varepsilon_y^\alpha\right)^2 + \left(\varepsilon_y^\beta\right)^2}{2\sigma_{RW}^2} \tag{A.2}$$

σ_{RW} is fixed (here 0.05 or 0.1).

Table A.1: Details for the offshore trawl commercial selectivity-at-length, as well as indications of the nature of the data which are available. (The changes are highlighted.)

		Periods of fixed selectivity			**Selectivity modelled as random walk process**			
		Periods	No of est. para.	Comments	Periods	No of est. para.	Comments	Data available
M. paradoxus	West coast offshore trawl	1917-1976	0	average between 77-84 and 93-2013 period	1917-1980	0	average 1981-1985	species combined, 1981-1999, 2005-2012
		1977-1984	3	double normal (σ_{Left}, σ_{Right} and l_{max})	1981-2012	3 + 31*3	double normal with random walk	
		1985-1992	0	linear change between 1984 and 1993 selectivity	2013	0	average 2008-2012	
		1993-2013	3	double logistic (σ_{Left}, σ_{Right} and l_{max})				
	South coast offshore trawl	1917-1976	0	double normal (σ_{Left}, σ_{Right} and l_{max})	1917-1974	0	average 1975-1979	species combined, 1975-1996
		1977-1984	3	double normal (σ_{Left}, σ_{Right} and l_{max})	1975-1996	3 + 21*3	double normal with random walk	
		1985-1992	0	linear change between 1984 and 1993 selectivity	1997-2013	0	average 1992-1996	
		1993-2013	3	double normal (σ_{Left}, σ_{Right} and l_{max})				
			0	female downscaling factor (av. of SC spring and autumn surveys's factors)		0	female downscaling factor (av. of SC spring and autumn surveys's factors)	
M.capensis	West coast offshore trawl	1917-1976	0	average between 77-84 and 93-2013 period		0	average between 77-84 and 93-2013 period	species combined, 1981-1999, 2005-2012
		1977-1984	3	as 93-13 but σ_{Left} same difference as for paradoxus between 77-84 and 93-13		0	as 93-13 but σ_{Left} same difference as for paradoxus between 1984 and 1993	
		1985-1992	0	linear change between 1984 and 1993 selectivity		0	linear change between 1984 and 1993 selectivity	
		1993-2013	3	Based on inshore selectivity: $l_{max}=l_{max}$(inshore)+5, $\sigma_{Left}=\sigma_{Left}$(inshore) and $\sigma_{Right}=3*\sigma_{Right}$(inshore)		0	Based on inshore selectivity: $l_{max}=l_{max}$(inshore)+5, $\sigma_{Left}=\sigma_{Left}$(inshore) and $\sigma_{Right}=3*\sigma_{Right}$(inshore)	
	South coast offshore trawl	1917-1976	0	average between 77-84 and 93-2013 period		0	average between 77-84 and 93-2013 period	species combined, 1975-1996
		1977-1984	3	as 93-13 but σ_{Left} same difference as for paradoxus btw 77-84 and 93-13 periods		0	as 93-13 but σ_{Left} same difference as for paradoxus between 1984 and 1993	
		1985-1992	0	linear change between 1984 and 1993 selectivity		0	linear change between 1984 and 1993 selectivity	
		1993-2013	3	Based on inshore selectivity: $l_{max}=l_{max}$(inshore)+5, $\sigma_{Left}=\sigma_{Left}$(inshore)		0	Based on inshore selectivity: $l_{max}=l_{max}$(inshore)+5, $\sigma_{Left}=\sigma_{Left}$(inshore)	