Do Alternative Assumptions for the Baseline Hake Assessment lead to Substantial Changes in Results?

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INTRODUCTION

Results are presented for a series of sensitivities to the new baseline assessment (NBA) for the South African hake resource (Rademeyer and Butterworth, 2008). The selection of these sensitivities follows in part from issues/concerns in the assessment used for the last OMP that need further consideration in specifying Operating Models (OMs) for the next OMP revision. These include the use of catch-at-length (CAL) information for years where age-length keys (ALKs) are not available, perceptions of the relative status of the two species, the appropriateness of the survey-based algorithm to split the offshore trawl catches by species and the values of the survey constant of proportionality (from swept area estimate to total biomass in absoluter terms).

In the development of the 2006 OMP, a series of scenarios was considered including different hypotheses about aspects of the assessment such as the level of discarding, the splitting of the past catches into species, the natural mortality, the shape of the stock-recruitment function and the current level of depletion for both species. Three aspects were found to account for most of the uncertainty regarding key considerations of resource status and productivity: a) natural mortality for each species, b) the species split in the pre-1978 catches, and c) the steepness parameter of the stock-recruitment functions. The Reference Set (RS) used to test the candidate OMPs comprised of 24 scenarios which included variations for these three aspects (see Rademeyer *et al*. 2008, for details). Only one scenario is presented here (options M2 – upper bounds of 1.0 and 0.5 on ages 2 and 5 respectively are implemented; C1 – species catch split; and H1 – the steepness parameters for both species are estimated in the minimisation process). This was chosen because it has the best negative log-likelihood.

RESULTS AND DISCUSSION

Table 1 compares estimates of management quantities for the NBA and a series of sensitivities described below.

A. The use of CAL information for years where ALKs are not available

The previous assessment used CAA information that was, for some years, based on other years' ALKs. The NBA now fits to the CAL information directly for those years for which there is no ageing data.

There remain the concerns that commercial CAA are based on species aggregated ALKs, and that all ALKs currently used are sex aggregated.

B. The species split of the offshore trawl catches

From 1978 onwards, the catches made by the offshore trawl fleet have been split by species by applying the size-based species proportion-by-depth relationships for the west and south coasts; these were developed by Gaylard and Bergh (2004) from research survey data. There have been concerns that these algorithms could produce biased results. Results from the observer programme instituted to sample trawl catch species composition on board vessels have now become

available for 2005 to 2007. These have been used to produce three alternative species split catch and CPUE series for this fleet.

Three different sets of offshore CPUE and catches are available based on these observer data (Glazer, 2008)

B1. Using the year-specific observer-based algorithm for 2005 to 2007 and the survey-based algorithm for the rest of the period;

B2. Using the 2006 observer-based algorithm for the whole 1978-2007 period; and

B3. Using the 2007 observer-based algorithm for the whole 1978-2007 period.

Another sensitivity has been run (B4), assuming that, at the beginning of the fishery in 1917, the percentage of *M. paradoxus* in the offshore trawl catches was 40% rather than 0% as in the NBA.

Fig. 1 compares the spawning biomass trajectories for the NBA and these three sensitivities. Although there is some change in terms of absolute spawning biomass estimated when these alternative CPUE and catch series are used, relative to pre-exploitation level, these three sensitivities do not affect the results substantially.

Fig. 2 plots the spawning biomass trajectories for the NBA and sensitivity B4. Here again, there is some change in terms of absolute spawning biomass but not really relative to pre-exploitation level.

C. Start in 1978

A sensitivity has been run starting the model in 1978 to investigate whether the perception reflected by the NBA of a relatively healthy *M. capensis* resource and a very depleted *M. paradoxus* resource are a direct effect of the pre-1978 data.

In starting the assessment in 1978, the assumption of pre-exploitation equilibrium is not valid and Appendix A describes how the starting populations (and their age-structures) are computed. Essentially, two further parameters (for each species) are estimated, namely θ which is the ratio of the starting spawning biomass B^{sp} to that for the pristine resource K^{sp}, and ϕ which effectively specifies the extent to which the mean total mortality Z reflected by the starting age-structure of the population exceeds M.

θ is estimated at 2.9% (CV=0) for *M. paradoxus* and 52.7% (CV=0.07) for *M. capensis*, while the estimates for ϕ are 0.60 (CV=0) and 0.36 (CV=0.22) for *M. paradoxus* and *M. capensis* respectively (CVs quoted here are Hessian-based, but based on fixing all parameters except and at their estimated values because of convergence difficulties when fitting the full model – this means that these CVs are probably substantial underestimates of the true uncertainty).

Fig. 3 compares the spawning biomass trajectories for this sensitivity and the NBA. Again, relative to pre-exploitation level, the trajectories for this sensitivity are similar to that of the NBA, though slightly more pessimistic.

D. The surveys' constants of proportionality, q's:

Although the model is coast-combined, it is fitted to the coast-specific survey data. The q's implicitly include a coast component which accounts for the fact that the resources are distributed with different proportions on the south and west coasts. *A priori*, q estimates <1 would be expected to account for the presence of fish outside the survey area concerned. In this regard, estimates >1 for *M. paradoxus* for the west coast summer surveys may constitute cause to query results from the NBA. The sensitivity of the assessment to these results has been investigated by forcing the q's < 1.0 and <0.5.

Furthermore, the survey biomass estimates currently used assume that the density of hake in the untrawlable areas is the same as in the trawlable areas. Leslie and Fairweather (2008) have estimated the proportion of trawlable grounds on the west and south coasts so that different assumptions about the extrapolation to untrawlable areas could be tested. Three sensitivities have been run to bound the issue, assuming a density in the untrawlable areas of 0, half and twice that in the trawlable areas ($\lambda=0$, $\lambda=0.5$ or $\lambda=2.0$); for these sensitivities, the q's either have no upper bound or are forced <1.0 and <0.5.

The decrease in the negative log-likelihood as λ decreases (Table 1b) is principally due to a better fit to the survey biomass estimates and suggests that the density in the untrawlable areas may be less than in the trawlable areas. Although there is little change in the negative log-likelihood if the survey q's are forced <1.0, there is a substantial increase in the negative log-likelihood if this upper bound is 0.5. The model fit deterioration cannot be attributed to a single data source. Table 2 compares the estimated survey q's for these sensitivities. Note that resource status estimates are hardly affected by changes in λ; though the estimated status of *M. paradoxus* is much better for smaller q values, this is at the expense of a severe deterioration to the fit in likelihood terms.

11 surveys have now been conducted using the new gear on the *Africana*. The calibration factors input $\left(q^{new}/q^{old}\right)$ are 0.95 for *M. paradoxus* and 0.8 for *M. capensis*, while the values output from the NBA are 0.95 (CV=0.03) and 0.79 (CV=0.04) for *M. paradoxus* and *M. capensis* respectively.

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E. Modified Ricker stock-recruitment relationship

Instead of the Beverton-Holt stock-recruitment relationship used in the new baseline assessment, a 'modified Ricker' function is used:

$$R_y = \alpha B_{y-1}^{sp} \exp\left[-\beta\left(B_{y-1}^{sp}\right)^{\gamma}\right] e^{(\varsigma_y - (\sigma_R)^2/2)} \tag{1}$$

where

α, β and γ are spawning biomass-recruitment relationship parameters.

    E1. Ricker: the steepness *h* is estimated (separately for each species) but γ is fixed at 1;

    E2. Both *h* and γ are estimated directly for each species.

Fig. 4 plots the stock-recruitment relationships for these two sensitivities and Fig. 5 compares the spawning biomass trajectories for these and the NBA.

The Ricker stock-recruitment relationship (E1 – γ=1) leads to a fit to the data which is appreciably worse than the Beverton-Holt relationship (loss of about 10 points to the negative log-likelihood). The modified Ricker (E2 – γ estimated) however fits the data better than the Beverton-Holt, with a improvement of about 5 log-likelihood points.

Summary

Few of these sensitivities indicate much change to estimated resource status. If the assessment commences in 1978, *M. paradoxus* is estimated to be even more depleted. If a (modified) Ricker form is used for the stock-recruitment relationship, the status of *M. paradoxus* relative to *K* improves, but there is little difference relative to the estimated MSYL as this also increases relative to *K*.

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Table 1a: Estimates of management quantities for the NBA and a series of sensitivities. Non-comparable –lnL values are shown in parenthesis.

		NBA	B. The species split of the offshore trawl catches				C. Start in 1978
			B1	B2	B3	B4	C
	-lnL total	-57.8	-60.2	-56.4	-56.8	-58.2	(-27.0)
M. paradoxus	K^{sp}	1407	1279	1182	1199	1413	3148
	h	0.89	0.86	0.89	0.87	0.89	0.95
	MSY	108	108	110	108	108	147
	B^{sp}_{2008}	228	217	223	222	224	180
	B^{sp}_{2008}/K^{sp}	**0.16**	**0.17**	**0.19**	**0.19**	**0.16**	**0.06**
	$B^{sp}_{2008}/MSYL^{sp}$	0.80	0.76	0.86	0.80	0.78	0.23
	$MSYL^{sp}$	0.20	0.22	0.22	0.23	0.20	0.24
	M 0	0.94	0.99	0.98	0.97	0.94	1.00
	1	0.94	0.99	0.98	0.97	0.94	1.00
	2	0.94	0.99	0.98	0.97	0.94	1.00
	3	0.64	0.68	0.68	0.68	0.64	0.60
	4	0.46	0.49	0.50	0.50	0.46	0.37
	5+	0.34	0.37	0.38	0.38	0.34	0.21
M. capensis	K^{sp}	684	664	670	857	684	540
	h	0.95	0.95	0.95	0.95	0.95	0.95
	MSY	87	85	85	109	87	69
	B^{sp}_{2008}	418	449	431	559	418	292
	B^{sp}_{2008}/K^{sp}	**0.61**	**0.68**	**0.64**	**0.65**	**0.61**	**0.54**
	$B^{sp}_{2008}/MSYL^{sp}$	1.75	1.93	1.83	1.86	1.75	1.54
	$MSYL^{sp}$	0.35	0.35	0.35	0.35	0.35	0.35
	M 0	1.00	1.00	1.00	1.00	1.00	1.00
	1	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	1.00	1.00	1.00	1.00
	3	0.75	0.75	0.75	0.75	0.75	0.75
	4	0.60	0.60	0.60	0.60	0.60	0.60
	5	0.50	0.50	0.50	0.50	0.50	0.50
	6	0.50	0.50	0.50	0.50	0.50	0.50
	7+	0.50	0.50	0.50	0.50	0.50	0.50
2008 species ratio	B^{sp}	1.84	2.07	1.93	2.51	1.87	1.62
(*paradoxus/capensis*)	B^{2+}	1.54	1.64	1.54	2.01	1.55	1.29

Table 1b: continued

			$\lambda = 0.0$			$\lambda = 0.5$			$\lambda = 1.0$			$\lambda = 2.0$		
			no upper bound on q s	q s<1	q s<0.5	no upper bound on q s	q s<1	q s<0.5	no upper bound on q s	q s<1	q s<0.5	no upper bound on q s	q s<1	q s<0.5
			D1a	D1b	D1c	D2a	D2b	D2c	**NBA**	D3a	D3b	D4a	D4b	D4c
	-lnL total		-65.2	-64.8	-52.0	-61.3	-60.7	-44.8	-57.8	-56.9	-37.4	-53.2	-51.6	-29.4
M. paradoxus	K^{sp}		1413	1442	1033	1413	1476	1046	1407	1393	1087	1432	1273	1113
	h		0.89	0.89	0.71	0.89	0.90	0.71	0.89	0.88	0.68	0.90	0.85	0.67
	MSY		107	107	110	108	107	111	108	107	111	108	108	112
	B^{sp}_{2008}		230	247	426	229	248	444	228	254	506	227	267	531
	B^{sp}_{2008}/K^{sp}		**0.16**	**0.17**	**0.41**	**0.16**	**0.17**	**0.42**	**0.16**	**0.18**	**0.47**	**0.16**	**0.21**	**0.48**
	$B^{sp}_{2008}/MSYL^{sp}$		0.81	0.87	1.57	0.81	0.87	1.60	0.80	0.90	1.71	0.79	0.98	1.73
	$MSYL^{sp}$		0.20	0.20	0.26	0.20	0.19	0.26	0.20	0.20	0.27	0.20	0.21	0.28
	M	0	0.93	0.94	1.00	0.93	0.93	1.00	0.94	0.96	1.00	0.93	1.00	1.00
		1	0.93	0.94	1.00	0.93	0.93	1.00	0.94	0.96	1.00	0.93	1.00	1.00
		2	0.93	0.94	1.00	0.93	0.93	1.00	0.94	0.96	1.00	0.93	1.00	1.00
		3	0.64	0.64	0.75	0.64	0.63	0.75	0.64	0.65	0.75	0.63	0.69	0.75
		4	0.46	0.46	0.60	0.46	0.45	0.60	0.46	0.47	0.60	0.46	0.50	0.60
		5+	0.34	0.34	0.50	0.34	0.33	0.50	0.34	0.35	0.50	0.34	0.38	0.50
M. capensis	K^{sp}		683	683	779	683	683	840	684	686	914	684	690	1065
	h		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	MSY		87	87	99	87	87	107	87	87	117	87	88	136
	B^{sp}_{2008}		415	416	507	417	417	565	418	421	635	420	425	772
	B^{sp}_{2008}/K^{sp}		**0.61**	**0.61**	**0.65**	**0.61**	**0.61**	**0.67**	**0.61**	**0.61**	**0.69**	**0.61**	**0.62**	**0.72**
	$B^{sp}_{2008}/MSYL^{sp}$		1.74	1.74	1.87	1.74	1.75	1.93	1.75	1.76	2.00	1.76	1.77	2.09
	$MSYL^{sp}$		0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	M	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		3	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		4	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
		5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
		6	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
		7+	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
2008 species ratio	B^{sp}		1.81	1.68	1.19	1.82	1.68	1.27	1.84	1.66	1.25	1.85	1.59	1.45
(paradoxus/capensis)	B^{2+}		1.52	1.44	1.05	1.53	1.45	1.12	1.54	1.41	1.12	1.55	1.34	1.30

Table 1c: continued

			NBA	E. Modified Ricker stock-recruitment relationship	
				E1	E2
	-lnL total		-57.8	-58.5	-62.1
M. paradoxus	K^{sp}		1407	710	963
	h		0.89	1.25	1.39
	MSY		108	124	119
	B^{sp}_{2008}		228	237	211
	B^{sp}_{2008}/K^{sp}		**0.16**	**0.33**	**0.22**
	$B^{sp}_{2008}/MSYL^{sp}$		0.80	0.88	0.74
	$MSYL^{sp}$		0.20	0.38	0.29
	γ		1.00	1.00	0.52
	M	0	0.94	0.99	1.00
		1	0.94	0.99	1.00
		2	0.94	0.99	1.00
		3	0.64	0.70	0.66
		4	0.46	0.52	0.46
		5+	0.34	0.40	0.33
M. capensis	K^{sp}		684	613	607
	h		0.95	0.71	0.68
	MSY		87	81	80
	B^{sp}_{2008}		418	417	416
	B^{sp}_{2008}/K^{sp}		**0.61**	**0.68**	**0.68**
	$B^{sp}_{2008}/MSYL^{sp}$		1.75	1.52	1.48
	$MSYL^{sp}$		0.35	0.45	0.46
	γ		1.00	1.00	1.12
	M	0	1.00	1.00	1.00
		1	1.00	1.00	1.00
		2	1.00	1.00	1.00
		3	0.75	0.75	0.75
		4	0.60	0.60	0.60
		5	0.50	0.50	0.50
		6	0.50	0.50	0.50
		7+	0.50	0.50	0.50
2008 species ratio		B^{sp}	1.84	1.76	1.97
(*paradoxus/capensis*)		B^{2+}	1.54	1.41	1.56

Table 2: Comparison of estimated survey coefficients of proportionality (q) for the NBA and a series of sensitivities involving different assumptions about densities on untrawlable grounds and upper bounds on q. Values in parenthesis are the estimated q's for the *Africana* with new gear*.

| | $\lambda = 0.0$ | | | $\lambda = 0.5$ | | | $\lambda = 1.0$ | | | $\lambda = 2.0$ | | |
| | no upper bound on q s | q s<1 | q s<0.5 | no upper bound on q s | q s<1 | q s<0.5 | no upper bound on q s | q s<1 | q s<0.5 | no upper bound on q s | q s<1 | q s<0.5 |
	D1a	D1b	D1c	D2a	D2b	D2c	NBA	D3b	D3c	D4a	D4b	D4c
M. paradoxus												
west coast summer	0.9 (0.9)	0.9 (0.9)	0.5 (0.5)	1.0 (0.9)	1.0 (0.9)	0.5 (0.5)	1.1 (1.0)	1.0 (0.9)	0.5 (0.5)	1.1 (1.1)	1.0 (0.9)	0.5 (0.5)
west coast winter	1.3 -	1.0 -	0.5 -	1.4 -	1.0 -	0.5 -	1.5 -	1.0 -	0.5 -	1.6 -	1.0 -	0.5 -
west coast *Nansen*	0.9 -	0.9 -	0.5 -	0.9 -	0.9 -	0.5 -	1.0 -	0.9 -	0.5 -	1.1 -	1.0 -	0.5 -
south coast spring	0.2 (0.2)	0.2 (0.2)	0.1 (0.1)	0.2 (0.2)	0.2 (0.2)	0.1 (0.1)	0.3 (0.3)	0.3 (0.3)	0.1 (0.1)	0.3 (0.3)	0.3 (0.3)	0.2 (0.2)
south coast autumn	0.3 (0.3)	0.3 (0.3)	0.2 (0.2)	0.3 (0.3)	0.3 (0.3)	0.2 (0.2)	0.4 (0.4)	0.4 (0.3)	0.2 (0.2)	0.5 (0.4)	0.4 (0.4)	0.2 (0.2)
M. capensis												
west coast summer	0.2 (0.2)	0.2 (0.2)	0.2 (0.2)	0.3 (0.2)	0.3 (0.2)	0.2 (0.2)	0.3 (0.2)	0.3 (0.2)	0.2 (0.2)	0.4 (0.3)	0.4 (0.3)	0.2 (0.2)
west coast winter	0.2 -	0.2 -	0.2 -	0.3 -	0.3 -	0.2 -	0.3 -	0.3 -	0.2 -	0.3 -	0.3 -	0.2 -
west coast *Nansen*	0.6 -	0.6 -	0.5 -	0.7 -	0.7 -	0.5 -	0.8 -	0.8 -	0.5 -	0.9 -	0.9 -	0.5 -
south coast spring	0.4 (0.3)	0.4 (0.3)	0.3 (0.3)	0.4 (0.3)	0.4 (0.3)	0.3 (0.3)	0.5 (0.4)	0.5 (0.4)	0.3 (0.3)	0.6 (0.5)	0.6 (0.4)	0.3 (0.3)
south coast autumn	0.4 (0.3)	0.4 (0.3)	0.4 (0.3)	0.5 (0.4)	0.5 (0.4)	0.4 (0.3)	0.5 (0.4)	0.5 (0.4)	0.4 (0.3)	0.6 (0.5)	0.6 (0.5)	0.3 (0.3)

* Since 2003, new fishing gear has occasionally been used on the *Africana*, for which a calibration factor is available: $\left(q^{new}/q^{old}\right)^{paradoxus} = 0.948$ and $\left(q^{new}/q^{old}\right)^{capensis} = 0.610$.
No plausible explanation has yet been found for the particularly large extent to which catch efficiency for *M. capensis* is estimated to have decreased for the new research survey trawl net. It was therefore recommended (BENEFIT, 2004) that the ratio of the catchability of the new to the previous *Africana* net be 0.8.
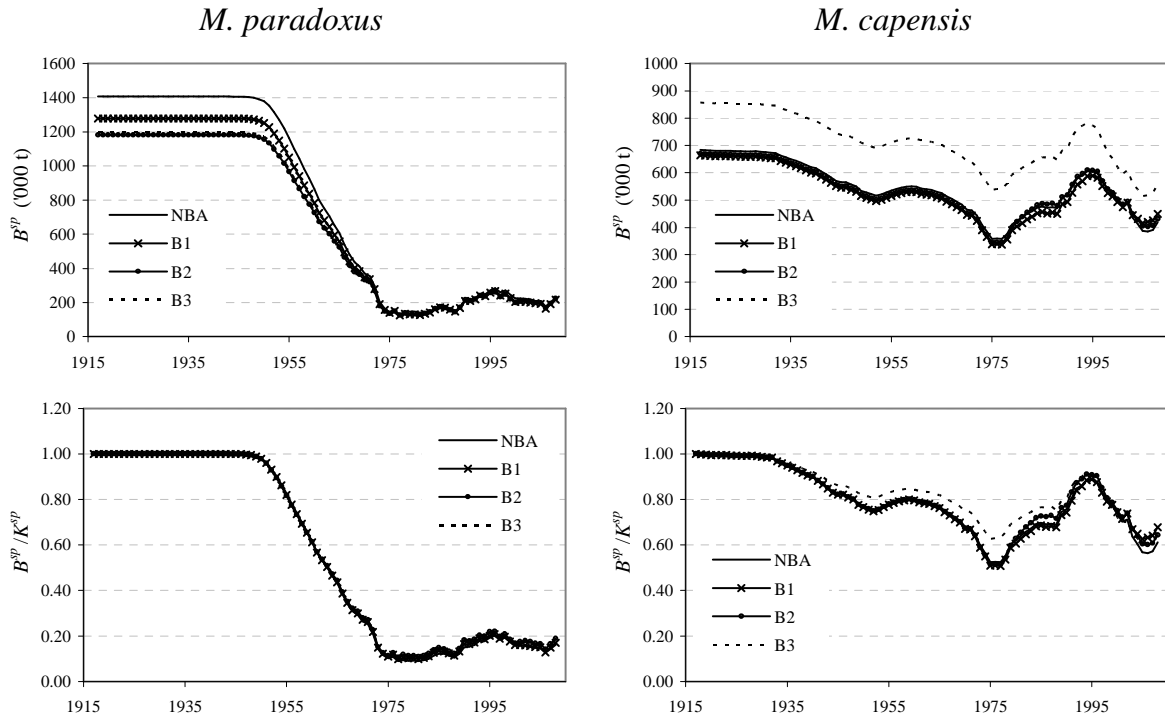
M. paradoxus   *M. capensis*

Fig. 1: *M. paradoxus* and *M. capensis s*pawning biomass trajectories for the NBA and sensitivities B1, B2 and B3 in which the post-1977 offshore CPUE and catches have been modified using the observer-based species splitting algorithm (see text for detail).
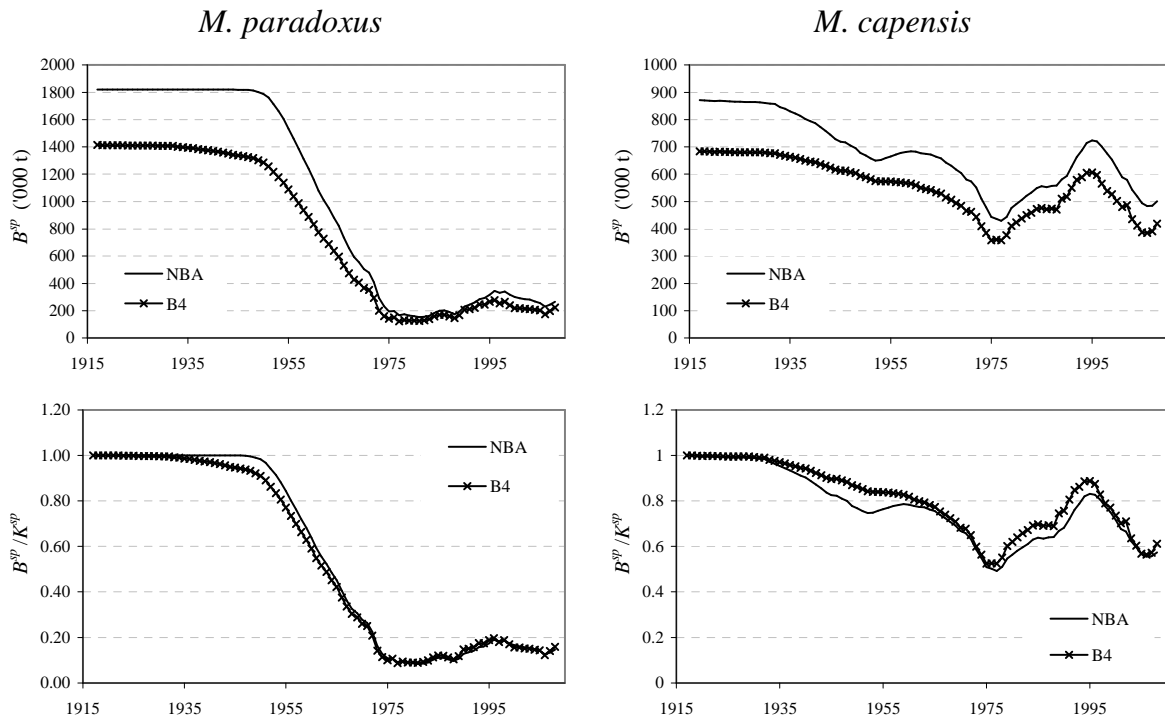
M. paradoxus   *M. capensis*

Fig. 2: *M. paradoxus* and *M. capensis s*pawning biomass trajectories for the NBA and sensitivity B4 in which the offshore trawl catches are assumed to comprise 40% of *M. paradoxus* at the beginning of the fishery

M. paradoxus
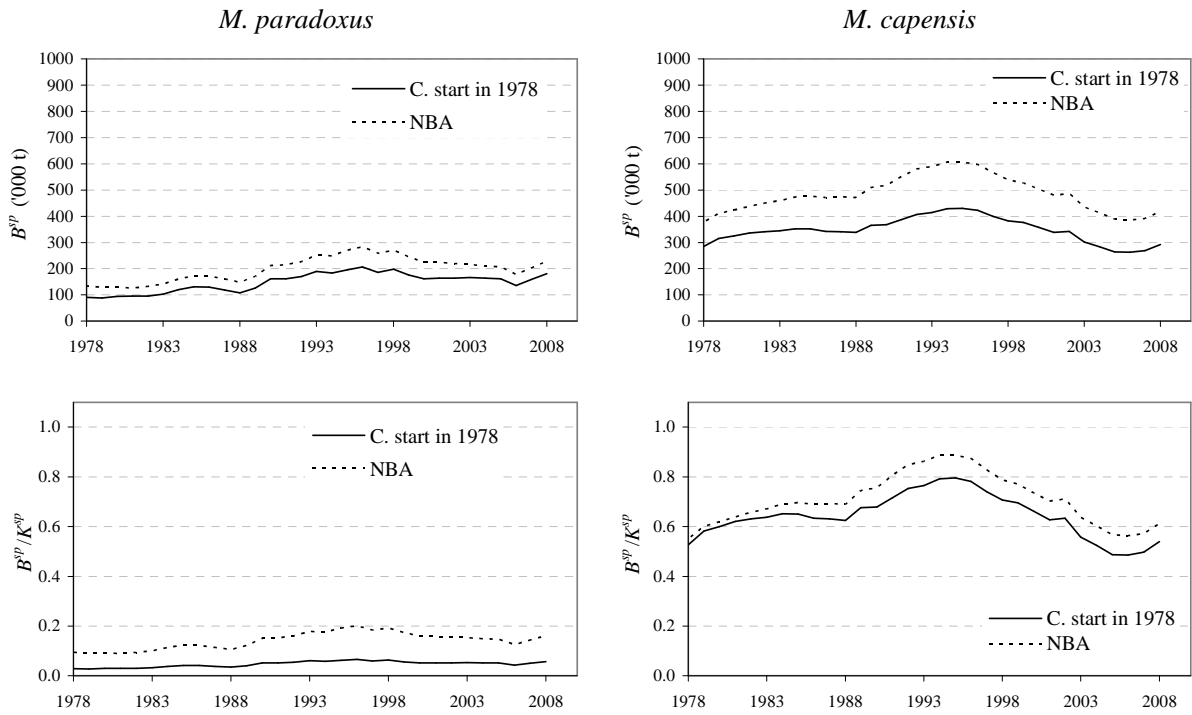
M. capensis

Fig. 3: *M. paradoxus* and *M. capensis s*pawning biomass trajectories for the new baseline and sensitivity C, which starts the assessment in 1978.
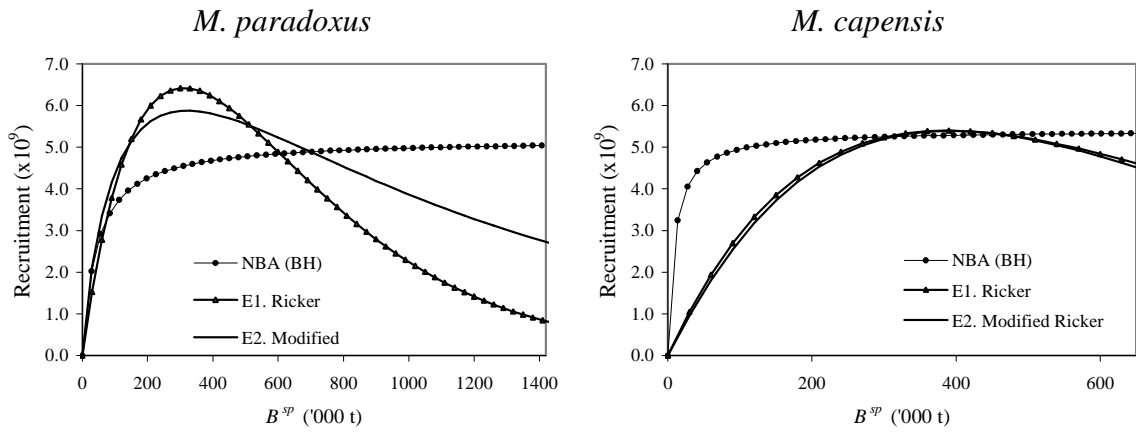
M. paradoxus

M. capensis

Fig. 4: Stock-recruitment relationship for the new baseline assessment and sensitivities E1 (Ricker) and E2 (modified Ricker, γ estimated).
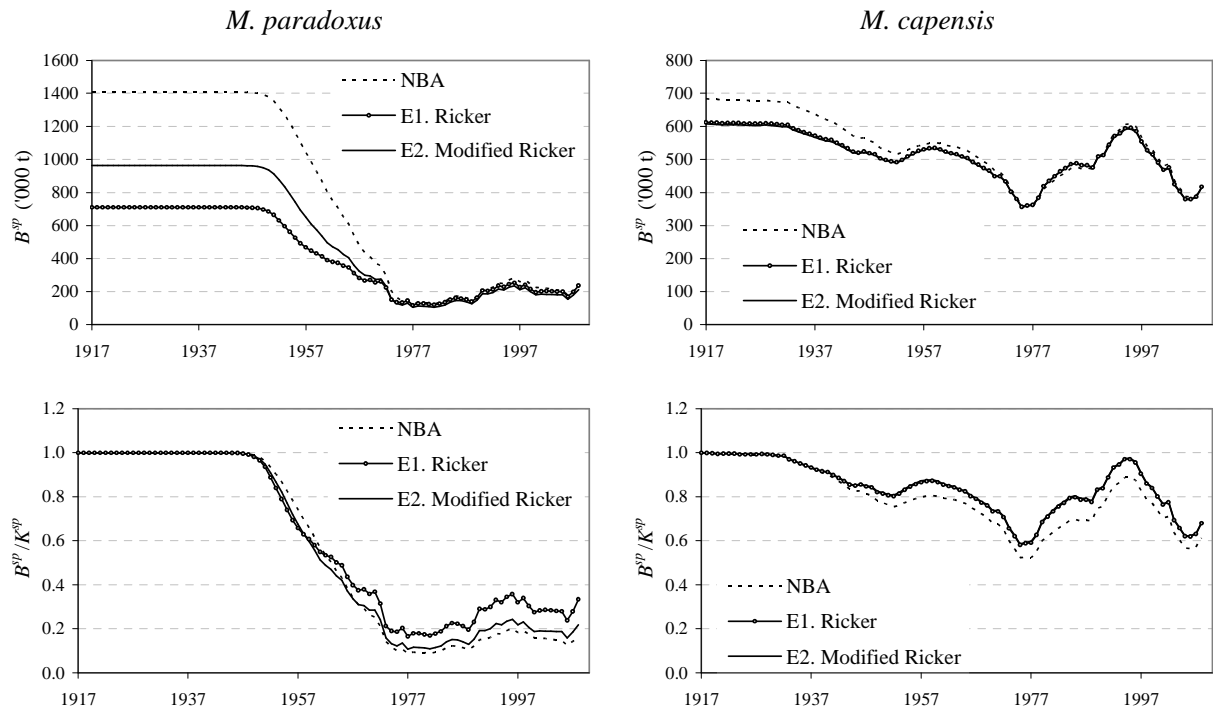
M. paradoxus

M. capensis

Fig. 5: *M. paradoxus* and *M. capensis* spawning biomass trajectories for the new baseline and sensitivities E1 (Ricker) and E2 (modified Ricker).

Appendix A – Initial conditions for 'start in 1978' sensitivity

In the 'start in 1978' sensitivity, one cannot make the conventional assumption in the application of ASPM's that the initial year (1978) reflects a population (and its age-structure) at pre-exploitation equilibrium. For the first year (y_0) considered in the model therefore, the stock is assumed to be at a fraction (θ) of its pre-exploitation biomass, i.e.:

$$B_{y_0}^{sp} = \theta \cdot K^{sp} \tag{A1}$$

with the starting age structure:

$$N_{y_0,a} = R_{start} N_{start,a} \qquad \text{for } 0 \leq a \leq m \tag{A2}$$

where

$$N_{start,0} = 1 \tag{A3}$$

$$N_{start,a} = N_{start,a-1} e^{-M_{a-1}} (1 - \phi S_{a-1}) \qquad \text{for } 1 \leq a \leq m-1 \tag{A4}$$

$$N_{start,m} = N_{start,m-1} e^{-M_{m-1}} (1 - \phi S_{m-1}) \big/ (1 - e^{-M_m} (1 - \phi S_m)) \tag{A5}$$

where

ϕ characterises the average fishing proportion over the years immediately preceding y_0.

For simplicity, S_a, the fishing selectivity-at-age, as been taken as that of the west coast offshore fleet in 1978.