Conditioning of some Robustness Tests for the New Reference Case Hake Assessment

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SUMMARY

Results are presented for a number of sensitivity tests to the New Reference Case hake assessment. The broad feature of these results is that while the current depletion of the *M. paradoxus* population is quite robustly determined, that for *M. capensis* is less certain.

INTRODUCTION

The new Reference Case (RC) for the South African *M. paradoxus* and *M. capensis* resources (Rademeyer and Butterworth, 2009a) is preliminarily put forward as the current “best” representation of the actual dynamics for these two resources. There are however some uncertainties (in the data, as well as in some of the assumptions made in the RC) that need to be taken into account when testing the performance of candidate OMPs. A list of these robustness tests is given in Rademeyer and Butterworth (2009b). Some of these tests are conditioned here using the assessment methodology of Rademeyer and Butterworth (2009a), and the results of these alternatives are compared to the RC.

RESULTS

A. Robustness tests relating to uncertainty in the data:

Catch data

A.catches.1: uncertainty in the pre-1978 species split of the offshore trawl fleet

Five robustness tests have been run varying the parameter P_1 of App.I.1 (Rademeyer and Butterworth, 2009a) which controls when the offshore trawl catches became predominantly *M. paradoxus*.
A.catches.1i: P_1 = 1940;
A.catches.1ii: P_1 = 1960;
A.catches.1iii: P_1 = 1965;
A.catches.1iv: P_1 = 1970;
A.catches.1v: P_1 = 1975;

For the RC, P_1=1950. In all cases, P_2 = 1.5.

The total catches for each species assumed for these robustness tests are shown in Fig. 1, together with the resulting proportion of *M. capensis* in the catch.

Table 1 compares the estimates of management quantities for the RC and these five robustness tests, while Fig. 2 plots the corresponding spawning biomass trajectories. The estimated spawning biomass ratios for *M. capensis* compared with *M. paradoxus* are also shown.

As the changeover from a mainly *M. capensis* fishery to a mainly *M. paradoxus* fishery is taken to occur later (i.e. less *M. paradoxus* caught overall), the estimated carrying capacity of *M. paradoxus* decreases, while the current spawning biomass remains relatively stable; the stock therefore is estimated to be in a better state. On the other hand, for *M. capensis*, both the carrying capacity and the current spawning biomass increase as the shift is moved later.

As P_1 moves through 1970, the likelihood of the model fits starts deteriorating substantially, particularly because of difficulties in matching the CPUE series trends. With P_1 = 1975, the current *M.*

capensis to *M. paradoxus* ratio exceeds 5:1, which was deemed implausible by the MCM Demersal Working Group during the development of OMP-2007.

CPUE data

A.CPUE.1: Changes in efficiency in the offshore trawl fleet in 1994/1995.

This test is a surrogate approach to allow for the effect of improved navigational aids introduced in the mid-1990s throughout the fleet, which are hypothesised to have improved the performance of the weaker skippers, at least. In this test, the *M. paradoxus* and *M. capensis* GLM CPUE series are each split into two series in 1994/1995 with a different catchability q and residual CV σ estimated for each, though subject to the constraint that the q value for either series can only increase across the split, consistent with an increase in efficiency.

A.CPUE.2: All offshore vessels are included in CPUE standardisation.

This robustness test uses alternative GLM CPUE series for which all offshore companies (or offshore vessels) are included in the CPUE standardisation rather than only those companies operating since 1994 (Glazer and Butterworth, 2009).

A.CPUE.3: Alternative depth stratification

Results to come in addendum.

A.CPUE.4: Omit days with nominal CPUE=0.

Alternative GLM CPUE series are used in which the days with nominal CPUE of zero for *M. capensis* and the days with nominal CPUE of zero for *M. paradoxus* have been omitted from the standardisation so that the need to add a δ factor to CPUE before taking logarithms falls away (Glazer and Butterworth, 2009).

Table 2 compares the estimates of management quantities for the RC and these three robustness tests relative to the CPUE, while Fig. 3 plots the corresponding spawning biomass trajectories. None of these robustness tests affect perceptions of the status (depletion) of the *M. paradoxus* resource. Omitting the days with nominal CPUE of zero has some impact on the estimated biomass for *M. capensis* in absolute terms, but not on the depletion estimates.

When the model allows for a possible increase in efficiency in the offshore trawl fleet in 1994/1995, the resulting spawning biomass trajectory for *M. capensis* becomes very different from that for the RC, with the current biomass estimated to be below 10% of its pre-exploitation level.

Surveys data

A.survey.1: Calibration factor between old and new *Africana* gear

In the RC, the calibration factor between the *Africana* with the old gear and the *Africana* with the new gear for *M. capensis* has been fixed to 0.8, as the results from a calibration experiment were deemed suspect. In these robustness tests, variants on this value are tested.

A.survey.1i: Calibration factor for *M. capensis* increased from 0.8 to 0.6.

A.survey.1ii: Calibration factor for *M. capensis* decreased from 0.8 to 0.6.

A.survey.1iii: Calibration factors for both *M. capensis* and *M. paradoxus* are estimated in the model fitting procedure.

Results to come in addendum

Age-length data

A.length.1: Ageing out by 1 year for *M. capensis* and *M. paradoxus*

Wilhelm *et al*. (2009) suggest that there is a possible ageing bias for *M. capensis*. In this robustness test, the fish are assumed to be one year younger than they were measured to be (with zero year old fish staying zero). This is assumed to apply to both *M. capensis* and *M. paradoxus*.

Table 3 compares the estimates of management quantities for the RC and this robustness test, while Fig. 4 plots the corresponding spawning biomass trajectories. The estimated male and female growth curves estimated in this robustness test are compared to those estimated in the RC in Fig. 5.

Although the results for M. paradoxus hardly differ from those of the RC, the spawning biomass trajectory for *M. capensis* is very different from that for the RC, with the current biomass estimated to be below 20% of its pre-exploitation level.

B. Robustness tests relating to uncertainty in the model assumptions

Selectivity

<u>B.sel.1</u>: Alternative selectivity slope assumptions.

In this robustness test, the survey and commercial selectivities are fixed to those estimated in the RC except that a factor of 0.1 is added to the exponential decline estimated (or fixed in some cases), with the condition that the slope must be negative. This effectively reflects a greater proportion of older fish to be outside the survey and catching areas.

<u>B.sel.2</u>: Alternative assumption for the *M. capensis* offshore selectivity.

The length information for the offshore trawl fleet is not disaggregated by species. As it is therefore not possible to estimate the selectivity for both species, the *M. capensis* selectivity is assumed to be similar to the inshore trawl fleet selectivity but shifted to the right by 5cm and with a slope of 1/3 of that of the estimated inshore trawl slope. In this sensitivity, the offshore trawl fleet is assumed to be equal to the inshore trawl fleet.

<u>B.sel.3</u>: Alternative assumption re south coast female *M. paradoxus* selectivity scaling factor.

In the RC, the female *M. paradoxus* selectivity on the south coast is scaled down by a factor estimated in the model fitting procedure, because the south coast spring and autumn surveys show a clear male bias. Rather than estimating the commercial scaling factor, it is fixed in this robustness test to that estimated for the spring survey (the lowest between the spring and autumn survey).

Table 4 compares the estimates of management quantities for the RC and these robustness tests. The commercial selectivities-at-length are plotted in Fig. 6 for the RC and robustness test B.sel.1. Fig. 7 plots the spawning biomass trajectories. Absolute estimates of abundance increase, particularly for the B.sel.1 test. However in terms of depletion, estimates show little change from the RC, except for a more depleted status for *M. paradoxus* for B.sel.1,, but that is at the expense of a substantial deterioration of the fit to the catch-at-length data. .

Natural Mortality

<u>B.M.1</u>: Alternative upper bounds on natural mortality (*M*) at age

In this robustness test, upper bounds of 0.5 and 0.3 on ages 2 and 5 respectively are implemented, rather than 1.0 and 0.5 in the RC.

Table 5 compares the estimates of management quantities for the RC and this robustness test, while Fig. 8 plots the corresponding spawning biomass trajectories. Estimates of biomass in absolute terms differ as would be expected given the decreased values of the bounds on *M*. In terms of current depletion, there is little change for *M. paradoxus*, but the status of *M. capensis* is estimated to be slightly worse.

Stock-recruitment relationship

<u>B.SR.1</u>: Ricker stock-recruitment function.

A modified Ricker stock-recruitment function (equation 1) is used in this robustness test rather than the Beverton-Holt relationship.

$$R_y = \alpha B_y^{sp} e^{-\beta \left[B_y^{sp}\right]^{\gamma}} \tag{1}$$

(Ricker form results when fixing γ=1).

B.SR.2: Alternative σ_R values

B.SR.2i: σ_R = 0.35 (instead of 0.25 in the RC)

B.SR.2ii: σ_R = 0.45

B.SR.3: Steepness fixed to 0.7 for both *M. paradoxus* and *M. capensis*.

B.SR.4: Alternative maturity at length combined with fixed lower *h* values.

In this robustness test, the maturity-at-length ogive is shifted to the right by 20 cm so that the age at 50% maturity corresponds to approximately 6 rather than about 4 in the RC. Together with this alternative maturity-at-length, the steepness parameters for both species are fixed to 0.7.

Results for B.SR.4 to come in addendum

Table 6 compares the estimates of management quantities for the RC and these robustness tests, while Fig. 9 plots the corresponding spawning biomass trajectories. The stock-recruitment relationships and the standardized stock-recruitment residuals estimated in the Ricker robustness test are plotted in Fig.10. The standardized stock-recruitment residuals estimated in the robustness tests with alternative σ_R values are shown in Fig. 11, while the estimated stock-recruitment relationships when *h*=0.7 are compared to that of the RC in Fig. 12. Differences in estimated status (current depletion) are small for *M. paradoxus*, but larger for *M. capensis* for which the Ricker form results in a notably improved estimate.

The σ_R input and the actual σ_R output for each of these robustness tests are also listed in Table 6. Even if σ_R input is increased to 0.45, the slightly increased σ_R output values of 0.23 for *M. paradoxus* and 0.31 for *M. capensis* fall below the level of recruitment variability that is usually evident for populations of similar demersal species.

C. Others

C.others.1: Assessment commencing in 1978.

In this robustness test, the assessment starts in 1978 to avoid the need to make any assumption about the split of the catch between *M. capensis* and *M. paradoxus* before that year (1978 is the first year for which data on the depth of catches are available, allowing application of the species-splitting algorithm). The stock is assumed to be at a fraction (θ) of its pre-exploitation biomass, i.e.:

$$B_{y_0}^{sp} = \theta \cdot K^{sp} \tag{2}$$

with the starting age structure:

$$N_{y_0,a} = R_{start} N_{start,a} \qquad \text{for } 1 \le a \le m \tag{2}$$

where

$$N_{start,1} = 1 \tag{3}$$

$$N_{start,a} = N_{start,a-1} e^{-M_{a-1}} (1 - \zeta S_{a-1}) \qquad \text{for } 2 \le a \le m-1 \tag{4}$$

$$N_{start,m} = N_{start,m-1} e^{-M_{m-1}} (1 - \zeta\, S_{m-1}) \big/ (1 - e^{-M_m} (1 - \zeta\, S_m)) \tag{5}$$

where ζ characterises the average fishing proportion over the years immediately preceding y_0.

Both θ and ζ are estimated in the model fitting procedure.

Table 7 compares the estimates of management quantities for the RC and this robustness test, while Fig. 13 plots the corresponding spawning biomass trajectories. In terms of current depletion, the estimate for *M. paradoxus* scarcely differs from that for the RC, but for *M. capensis* is notably lower than the RC estimate..

C.others.2: Changes in past *K* values over time (30% linear decrease over 1980 to 2000)

Results to come in addendum

C.others.3: Forced rather than estimated current depletions.

In the RC, the estimated 2009 depletions (in terms of gender-aggregated spawning biomass) for *M. paradoxus* and *M. capensis* are 0.22 and 0.50 respectively. In these robustness tests, the depletions for both species are forced to fixed values through the use of a penalty function.

C.others.3i: *M. paradoxus*: 0.22, *M. capensis*: 0.3.

C.others.3ii: *M. paradoxus*: 0.22, *M. capensis*: 0.1.

C.others.3iii: *M. paradoxus*: 0.1, *M. capensis*: 0.5.

C.others.3iv: *M. paradoxus*: 0.4, *M. capensis*: 0.5.

C.others.3v: *M. paradoxus*: 0.1, *M. capensis*: 0.1.

C.others.3vi: *M. paradoxus*: 0.4, *M. capensis*: 0.1.

Results to come in addendum

C.others.4: Retrospective (2 yrs back)

These retrospectives are projected to the current year by assuming future catches equal to those actually taken. They cannot be taken back beyond two years because of the paucity of sex-disaggregated data which would then be available. Table 8 compares the estimates of management quantities for the RC and these retrospective assessments, while Fig. 14 plots the corresponding spawning biomass trajectories. There is very little difference in results, except that over the most recent years, the later assessments give somewhat more optimistic results for *M. paradoxus*, and more pessimistic for *M. capensis.I*

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Table 1: Estimates of management quantities for the RC ("Shift in 1950") and the five robustness tests **"A.catches.1"** varying the year when the pre-1978 offshore trawl catch became predominantly *M. paradoxus*. The SS component of the –lnL contribution excludes the –lnσ term, i.e. this component would be zero if the data fitted the model estimates exactly.

	A.catches.1i			RC			A.catches.1ii			A.catches.1iii			A.catches.1iv			A.catches.1v		
	Shift in 1940			Shift in 1950			Shift in 1960			Shift in 1965			Shift in 1970			Shift in 1975		
	Both	SS		Both	SS		Both	SS		Both	SS		Both	SS		Both	SS	
-lnL total	81.7			80.5			82.7			87.3			99.4			341.9		
CPUE historic	-40.3	4.1		-40.7	3.7		-41.5	2.8		-41.0	3.3		-40.9	3.5		196.4	208.9	
CPUE GLM	-163.4	56.3		-164.3	55.6		-161.9	57.1		-157.3	56.7		-147.1	53.3		-140.0	54.1	
Survey	-32.9	56.2		-32.7	56.2		-32.9	56.5		-33.7	56.3		-32.3	56.1		-30.1	55.8	
Commercial CAL	-54.7			-54.9			-54.4			-54.4			-55.5			-56.7		
Survey CAL (sex-aggr.)	-6.3			-6.3			-6.3			-6.2			-6.3			-5.8		
Survey CAL (sex-disaggr.)	24.0	5543.5		23.9	5538.9		24.2	5494.5		24.3	5524.6		24.1	5557.4		24.6	5533.2	
ALK	319.6			319.0			319.8			319.5			320.8			319.6		
Recruitment penalty	20.2			20.7			19.6			20.1			20.4			17.7		
Selectivity smoothing penalty	15.5			15.6			16.1			16.0			16.3			16.1		
	Both	Males	Females	Both	Males	Females	Both	Males	Females	Both	Males	Females	Both	Males	Females	Both	Males	Females
M. paradoxus K^{sp}	1641	696	945	1535	649	886	1439	609	830	1132	478	654	918	387	531	907	383	525
M. paradoxus h	0.75			0.75			0.87			0.98			0.98			0.98		
M. paradoxus B^{sp}_{2009}	361	60	301	353	62	292	335	58	276	301	57	243	313	91	221	274	68	207
M. paradoxus B^{sp}_{2009}/K^{sp}	0.22	0.09	0.32	0.23	0.10	0.33	0.23	0.10	0.33	0.27	0.12	0.37	0.34	0.24	0.42	0.30	0.18	0.39
M. capensis K^{sp}	795	382	413	784	377	407	908	437	471	1336	643	693	1612	776	837	2268	1091	1177
M. capensis h	0.98			0.98			0.98			0.98			0.98			0.98		
M. capensis B^{sp}_{2009}	398	190	208	387	185	202	486	233	253	812	390	422	1010	486	524	1476	711	765
M. capensis B^{sp}_{2009}/K^{sp}	0.50	0.50	0.50	0.49	0.49	0.50	0.54	0.53	0.54	0.61	0.61	0.61	0.63	0.63	0.63	0.65	0.65	0.65
2009 cap:para ratio B^{sp}	1.10	3.17	0.69	1.10	2.98	0.69	1.45	4.02	0.92	2.70	6.84	1.74	3.23	5.34	2.37	5.39	10.46	3.70

Table 2: Estimates of management quantities for the RC and three robustness tests relating to the GLM CPUE series assumptions: "**A.CPUE.1**" (split series in 1994/1995), "**A.CPUE.2**" (include all offshore companies in standardisation) and "**A.CPUE.4**" (omit days with nominal CPUE=0). Note: the GLM CPUE q's for the RC relate to the 1978-2008 period.

	RC			A.CPUE.1 GLM CPUE series split in 1994/1995			A.CPUE.2 Including all offshore companies in CPUE			A.CPUE.4 Omit days with nominal CPUE=0		
	Both	SS		Both	SS		Both	SS		Both	SS	
-lnL total	80.5			73.3			73.0			102.7		
CPUE historic	-40.7	3.7		-40.2	0.0		-40.7	3.7		-40.6	3.7	
CPUE GLM	-164.3	55.6		-168.2	-14.4		-169.8	50.0		-146.1	73.7	
Survey	-32.7	56.2		-28.5	55.3		-32.4	56.4		-30.9	55.9	
Commercial CAL	-54.9			-52.0			-55.1			-54.6		
Survey CAL (sex-aggr.)	-6.3			-5.6			-6.4			-6.1		
Survey CAL (sex-disaggr.)	23.9	5538.9		21.4	5492.1		24.1	5530.1		23.7	5517.9	
ALK	319.0			316.4			319.6			318.0		
Recruitment penalty	20.7			17.3			18.1			23.7		
Selectivity smoothing penalty	15.6			12.8			15.6			15.6		
	Both	Males	Females	Both	Males	Females	Both	Males	Females	Both	Males	Females
M. paradoxus K^{sp}	1535	649	886	1569	661	908	1523	644	880	1494	631	863
h	0.75			0.73			0.74			0.75		
B^{sp}_{2009}	353	62	292	358	55	303	327	52	275	321	57	264
B^{sp}_{2009}/K^{sp}	0.23	0.10	0.33	0.23	0.08	0.33	0.21	0.08	0.31	0.22	0.09	0.31
GLM CPUE q:	WC	SC		WC	SC		WC	SC				
1978-1994	0.011	0.018		0.010	0.016							
1995-2008				0.010	0.016							
M. capensis K^{sp}	784	377	407	705	336	370	768	369	399	908	436	472
h	0.98			0.71			0.98			0.98		
B^{sp}_{2009}	387	185	202	58	26	31	388	185	203	443	212	231
B^{sp}_{2009}/K^{sp}	0.49	0.49	0.50	0.08	0.08	0.09	0.51	0.50	0.51	0.49	0.49	0.49
GLM CPUE q:	WC	SC		WC	SC							
1978-1994	0.003	0.008		0.012	0.031							
1995-2008				0.017	0.037							
2009 cap:para ratio B^{sp}	1.10	2.98	0.69	0.16	0.47	0.10	1.19	3.56	0.74	1.38	3.72	0.88

Table 3: Estimates of management quantities for the RC and the robustness test "**A.length.1**" for which all ages are assumed to be one year too high.

		RC			A.length.1 Ageing out by 1 year		
		Both	SS		Both	SS	
	-lnL total	80.5			93.5		
	CPUE historic	-40.7	3.7		-40.5	3.9	
	CPUE GLM	-164.3	55.6		-166.1	58.5	
	Survey	-32.7	56.2		-32.3	55.8	
	Commercial CAL	-54.9			-46.4		
	Survey CAL (sex-aggr.)	-6.3			-9.4		
	Survey CAL (sex-disaggr.)	23.9	5538.9		20.3	5489.4	
	ALK	319.0			333.2		
	Recruitment penalty	20.7			21.7		
	Selectivity smoothing penalty	15.6			13.1		
		Both	Males	Females	Both	Males	Females
M. paradoxus	K^{sp}	1535	649	886	1531	642	889
	h	0.75			0.70		
	B^{sp}_{2009}	353	62	292	341	61	281
	B^{sp}_{2009}/K^{sp}	0.23	0.10	0.33	0.22	0.09	0.32
M. capensis	K^{sp}	784	377	407	649	309	340
	h	0.98			0.53		
	B^{sp}_{2009}	387	185	202	119	55	64
	B^{sp}_{2009}/K^{sp}	0.49	0.49	0.50	0.18	0.18	0.19
2009 cap:para ratio B^{sp}		1.10	2.98	0.69	0.35	0.90	0.23

Table 4: Estimates of management quantities for the RC and three robustness tests relating to the fishing selectivities: "**B.sel.1**", "**B.sel.2**" and "**B.sel.3**".

		RC			B.sel.1 Alternative slope assumptions			B.sel.2 Offshore trawl *M. capensis* selectivity			B.sel.3 Female *M. paradoxus* south coast sel. scaling		
		Both	SS		Both	SS		Both	SS		Both	SS	
	-lnL total	80.5			136.7			83.5			80.6		
	CPUE historic	-40.7	3.7		-39.6	4.7		-40.5	3.8		-40.6	3.7	
	CPUE GLM	-164.3	55.6		-153.5	62.0		-162.7	57.2		-164.3	55.6	
	Survey	-32.7	56.2		-31.6	55.9		-33.3	56.4		-32.7	56.1	
	Commercial CAL	-54.9			-25.8			-54.4			-54.9		
	Survey CAL (sex-aggr.)	-6.3			-2.6			-5.7			-6.2		
	Survey CAL (sex-disaggr.)	23.9	5538.9		28.7	5272.9		24.6	5523.3		24.0	5537.4	
	ALK	319.0			322.9			320.2			319.0		
	Recruitment penalty	20.7			17.4			19.7			20.7		
	Selectivity smoothing penalty	15.6			15.6			15.8			15.6		
		Both	Males	Females	Both	Males	Females	Both	Males	Females	Both	Males	Females
M. paradoxus	K^{sp}	1535	649	886	5252	2271	2981	1558	659	900	1540	651	889
	h	0.75			0.71			0.75			0.76		
	B^{sp}_{2009}	353	62	292	645	81	564	372	63	309	356	62	295
	B^{sp}_{2009}/K^{sp}	0.23	0.10	0.33	0.12	0.04	0.19	0.24	0.10	0.34	0.23	0.10	0.33
M. capensis	K^{sp}	784	377	407	1224	589	636	1069	513	556	785	377	408
	h	0.98			0.98			0.98			0.98		
	B^{sp}_{2009}	387	185	202	635	304	331	588	282	306	388	185	203
	B^{sp}_{2009}/K^{sp}	0.49	0.49	0.50	0.52	0.52	0.52	0.55	0.55	0.55	0.49	0.49	0.50
2009 cap:para ratio B^{sp}		1.10	2.98	0.69	0.98	3.75	0.59	1.58	4.48	0.99	1.09	2.98	0.69

Table 5: Estimates of management quantities for the RC and the robustness test "**B.M.1**" with lower upper bounds on natural mortality

		RC			B.M.1		
		Upper bounds of 1.0 and 0.5 for *M* on ages 2 and 5 respectively			Upper bounds of 0.5 and 0.3 for *M* on ages 2 and 5 respectively		
		Both	SS		Both	SS	
-lnL total		80.5			96.7		
CPUE historic		-40.7	3.7		-39.4	5.0	
CPUE GLM		-164.3	55.6		-160.9	59.0	
Survey		-32.7	56.2		-33.5	55.7	
Commercial CAL		-54.9			-53.0		
Survey CAL (sex-aggr.)		-6.3			-5.3		
Survey CAL (sex-disaggr.)		23.9	5538.9		25.1	5427.7	
ALK		319.0			323.9		
Recruitment penalty		20.7			21.7		
Selectivity smoothing penalty		15.6			18.1		
		Both	Males	Females	Both	Males	Females
M. paradoxus	K^{sp}	1535	649	886	2858	1220	1638
	h	0.75			0.97		
	B^{sp}_{2009}	353	62	292	641	64	577
	B^{sp}_{2009}/K^{sp}	0.23	0.10	0.33	0.22	0.05	0.35
	M_{2-}	1.00			0.50		
	M_3	0.70			0.40		
	M_4	0.51			0.34		
	M_{5+}	0.39			0.30		
M. capensis	K^{sp}	784	377	407	1202	579	623
	h	0.98			0.98		
	B^{sp}_{2009}	387	185	202	466	221	245
	B^{sp}_{2009}/K^{sp}	0.49	0.49	0.50	0.39	0.38	0.39
	M_{2-}	0.66			0.50		
	M_3	0.58			0.40		
	M_4	0.53			0.34		
	M_{5+}	0.50			0.30		
2009 cap:para ratio B^{sp}		1.10	2.98	0.69	0.73	3.45	0.42

Table 6: Estimates of management quantities for the RC ("Shift in 1950") and the three robustness tests relating to the stock recruitment curve ("**B.SR.1**", "**B.SR.2**" and "**B:SR.3**").

	RC (BH, σ_R=0.25)			B.SR.1 - Ricker			B.SR.2i - σ_R=0.35			B.SR.2ii - σ_R=0.45			B.SR.3 - h=0.7		
	Both	SS		Both	SS		Both	SS		Both	SS		Both	SS	
-lnL total	80.5			77.9			69.1			63.1			81.8		
CPUE historic	-40.7	3.7		-40.8	3.6		-40.7	3.7		-40.7	3.7		-40.7	3.7	
CPUE GLM	-164.3	55.6		-167.1	52.8		-169.2	50.7		-171.0	48.8		-163.0	56.9	
Survey	-32.7	56.2		-33.0	56.2		-33.5	56.1		-33.4	56.0		-32.6	56.1	
Commercial CAL	-54.9			-53.6			-54.7			-54.7			-55.6		
Survey CAL (sex-aggr.)	-6.3			-4.6			-5.5			-5.3			-5.2		
Survey CAL (sex-disaggr.)	23.9	5538.9		24.6	5560.2		25.4	5383.6		25.3	5387.3		23.9	5518.0	
ALK	319.0			319.1			318.3			318.0			319.1		
Recruitment penalty	20.7			18.3			14.2			10.0			21.0		
Selectivity smoothing penalty	15.6			15.0			14.8			14.9			15.0		
	Both	Males	Females	Both	Males	Females	Both	Males	Females	Both	Males	Females	Both	Males	Females
M. paradoxus K^{sp}	1535	649	886	1360	580	780	1534	649	886	1534	649	886	1411	612	799
h	0.75			0.67			0.75			0.75			0.70		
$B^{sp}{}_{2009}$	353	62	292	302	60	242	361	66	296	364	67	297	313	60	254
$B^{sp}{}_{2009}/K^{sp}$	0.23	0.10	0.33	0.22	0.10	0.31	0.24	0.10	0.33	0.24	0.10	0.34	0.22	0.10	0.32
σ_R input	0.25			0.25			0.35			0.45			0.25		
σ_R output	0.17			0.17			0.21			0.23			0.17		
M. capensis K^{sp}	784	377	407	684	329	355	733	352	381	721	346	375	966	463	503
h	0.98			0.79			0.98			0.98			0.70		
$B^{sp}{}_{2009}$	387	185	202	393	187	206	319	152	167	292	139	153	465	222	243
$B^{sp}{}_{2009}/K^{sp}$	0.49	0.49	0.50	0.57	0.57	0.58	0.44	0.43	0.44	0.41	0.40	0.41	0.48	0.48	0.48
σ_R input	0.25			0.25			0.35			0.45			0.25		
σ_R output	0.26			0.26			0.30			0.31			0.26		
2009 cap:para ratio B^{sp}	1.10	2.98	0.69	1.30	3.12	0.85	0.88	2.30	0.56	0.80	2.07	0.52	1.49	3.70	0.96

Table 7: Estimates of management quantities for the RC and the robustness test starting in 1978, "**C.others.1**".

		RC			start in 1978		
		Both	SS		Both	SS	
	-lnL total	80.5			126.7		
	CPUE historic	-40.7	3.7		-	-	
	CPUE GLM	-164.3	55.6		-146.4	44.6	
	Survey	-32.7	56.2		-39.1	57.5	
	Commercial CAL	-54.9			-60.6		
	Survey CAL (sex-aggr.)	-6.3			-7.1		
	Survey CAL (sex-disaggr.)	23.9	5538.9		25.5	5461.1	
	ALK	319.0			318.9		
	Recruitment penalty	20.7			20.7		
	Selectivity smoothing penalty	15.6			14.8		
		Both	Males	Females	Both	Males	Females
M. paradoxus	K^{sp}	1535	649	886	2673	1150	1521
	θ	-			0.16		
	ζ	-			0.08		
	h	0.75			0.92		
	B^{sp}_{2009}	353	62	292	552	68	484
	B^{sp}_{2009}/K^{sp}	0.23	0.10	0.33	0.21	0.06	0.32
M. capensis	K^{sp}	784	377	407	498	240	259
	θ	-			0.27		
	ζ	-			0.44		
	h	0.98			0.98		
	B^{sp}_{2009}	387	185	202	157	73	85
	B^{sp}_{2009}/K^{sp}	0.49	0.49	0.50	0.32	0.30	0.33
2009 cap:para ratio B^{sp}		1.10	2.98	0.69	0.28	1.07	0.18

Table 8: Estimates of management quantities for the RC and two retrospective assessments, "**C.others.4**".

		RC			C.others.4i 1-year retrospective			C.others.4ii 2-year retrospective		
		Both	SS		Both	SS		Both	SS	
	-lnL total	80.5			79.9			57.4		
	CPUE historic	-40.7	3.7		-40.7	3.7		-40.6	3.7	
	CPUE GLM	-164.3	55.6		-158.0	53.0		-154.4	51.7	
	Survey	-32.7	56.2		-30.9	53.9		-27.5	50.7	
	Commercial CAL	-54.9			-55.2			-55.8		
	Survey CAL (sex-aggr.)	-6.3			-5.8			-4.8		
	Survey CAL (sex-disaggr.)	23.9	5538.9		17.9	5488.4		16.0	4118.5	
	ALK	319.0			320.0			297.1		
	Recruitment penalty	20.7			17.3			13.0		
	Selectivity smoothing penalty	15.6			15.4			14.5		
		Both	Males	Females	Both	Males	Females	Both	Males	Females
M. paradoxus	K^{sp}	1535	649	886	1520	642	878	1534	649	886
	h	0.75			0.73			0.73		
	B^{sp}_{2009}	353	62	292	303	46	258	299	42	257
	B^{sp}_{2009}/K^{sp}	0.23	0.10	0.33	0.20	0.07	0.29	0.20	0.06	0.29
M. capensis	K^{sp}	784	377	407	797	383	414	806	387	419
	h	0.98			0.98			0.98		
	B^{sp}_{2009}	387	185	202	415	198	217	467	223	244
	B^{sp}_{2009}/K^{sp}	0.49	0.49	0.50	0.52	0.52	0.52	0.58	0.58	0.58
2009 cap:para ratio B^{sp}		1.10	2.98	0.69	1.37	4.30	0.84	1.56	5.31	0.95

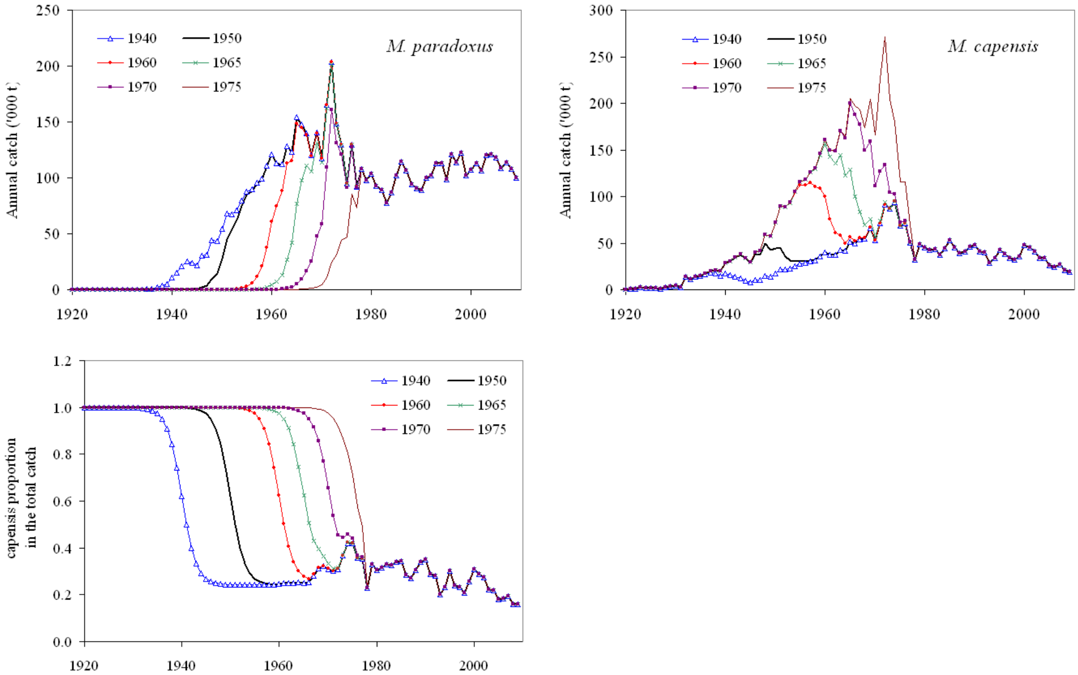

Fig. 1: Annual catch (total across fleets) assumed for *M. paradoxus* and *M. capensis* for the RC ("1950") and the five associated robustness tests "**A.catches.1**" on the pre-1978 offshore trawl catch species split.

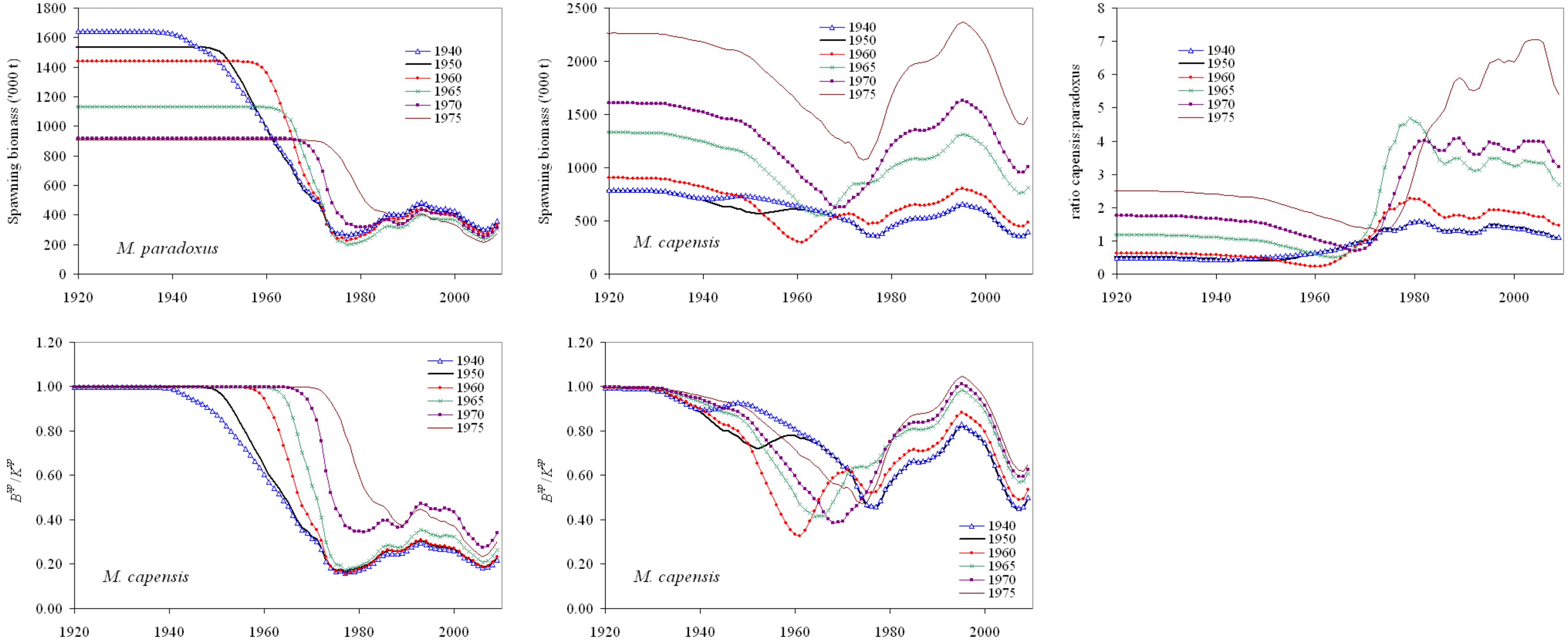

Fig. 2: Estimated gender-aggregated spawning biomass trajectories for *M. paradoxus* and *M. capensis*, both in absolute terms and relative to pre-exploitation levels, for the RC and the five associated robustness tests "**A.catches.1**" for the pre-1978 offshore trawl catch species split.

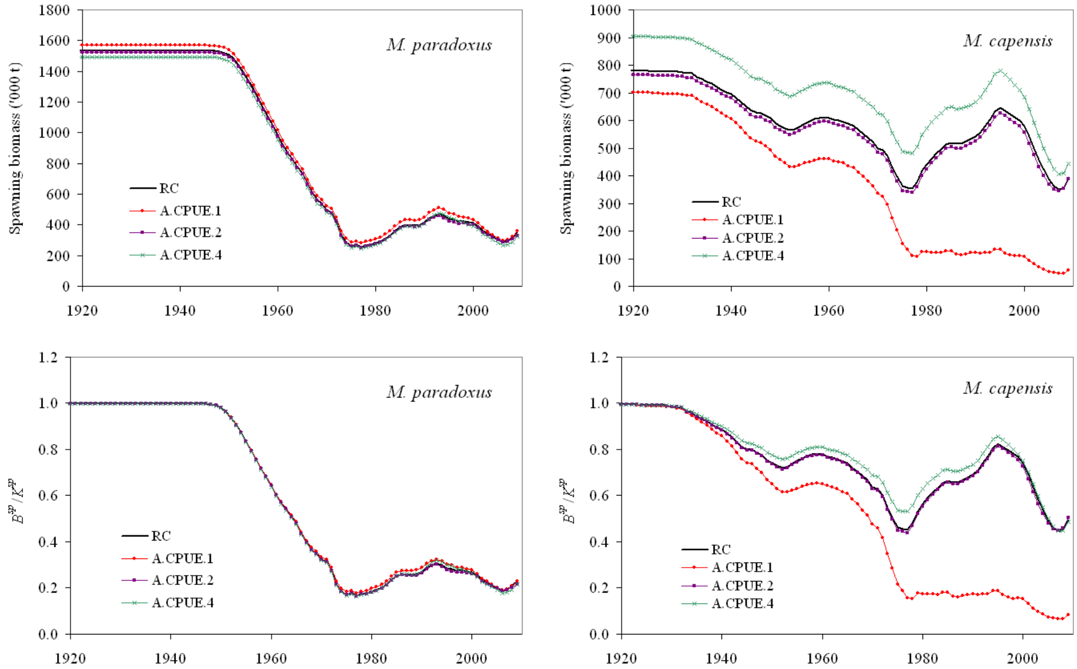

Fig. 3: Estimated gender-aggregated spawning biomass trajectories for *M. paradoxus* and *M. capensis*, both in absolute terms and relative to pre-exploitation level, for the RC and three robustness tests relating to the GLM CPUE assumptions "**A.CPUE.1**" (split series in 1994/1995), "**A.CPUE.2**" (include all offshore companies in standardisation) and "**A.CPUE.4**" (omit days with nominal CPUE=0).

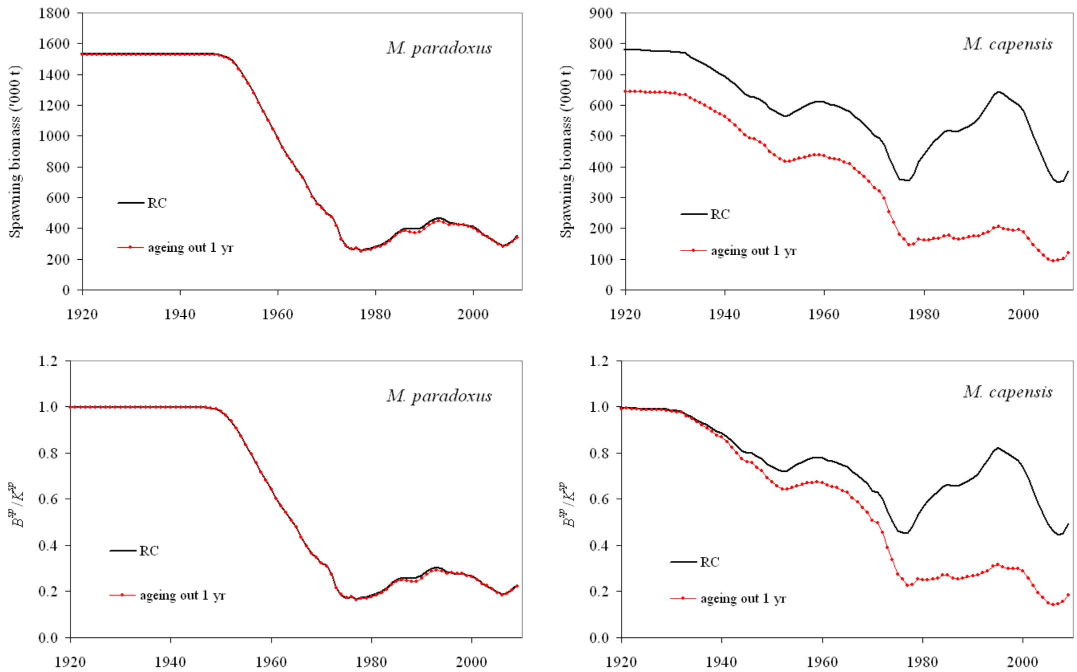

Fig. 4: Estimated gender-aggregated spawning biomass trajectories for *M. paradoxus* and *M. capensis*, both in absolute terms and relative to pre-exploitation level, for the RC and robustness test "**A.length.1**" for which all ages are assumed to be one year too high.

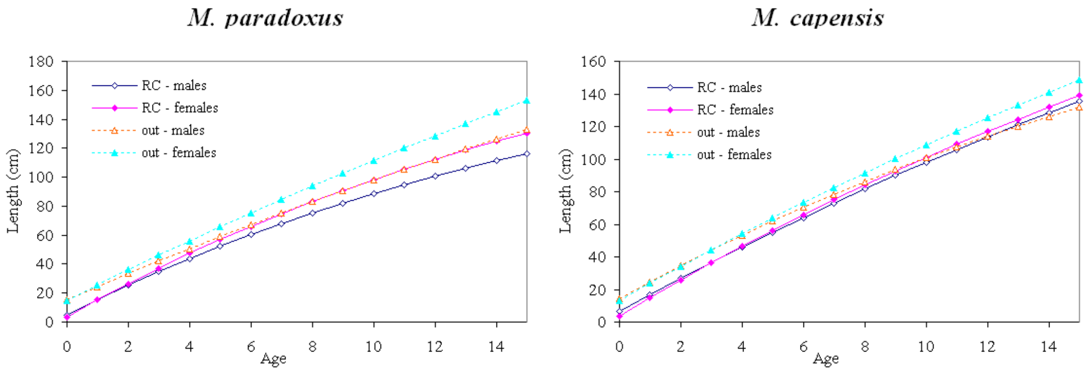

Fig. 5: Estimated male and female growth curves for the RC and the robustness test "**A.length.1**" in which the ageing is assumed to be out by 1 year.

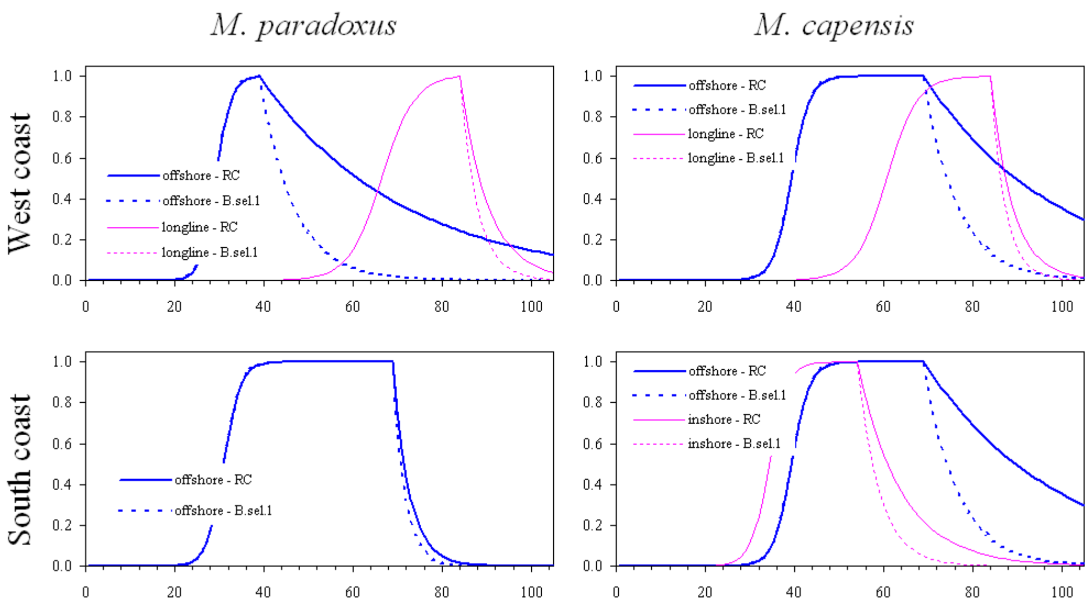

Fig. 6: Commercial selectivities-at-length for the RC and the robustness test "B.sel.1" with alternative slope assumption. Note: on the South Coast, the longline (which is assumed to catch only *M. capensis*) selectivity is taken to be the same as on the West Coast.

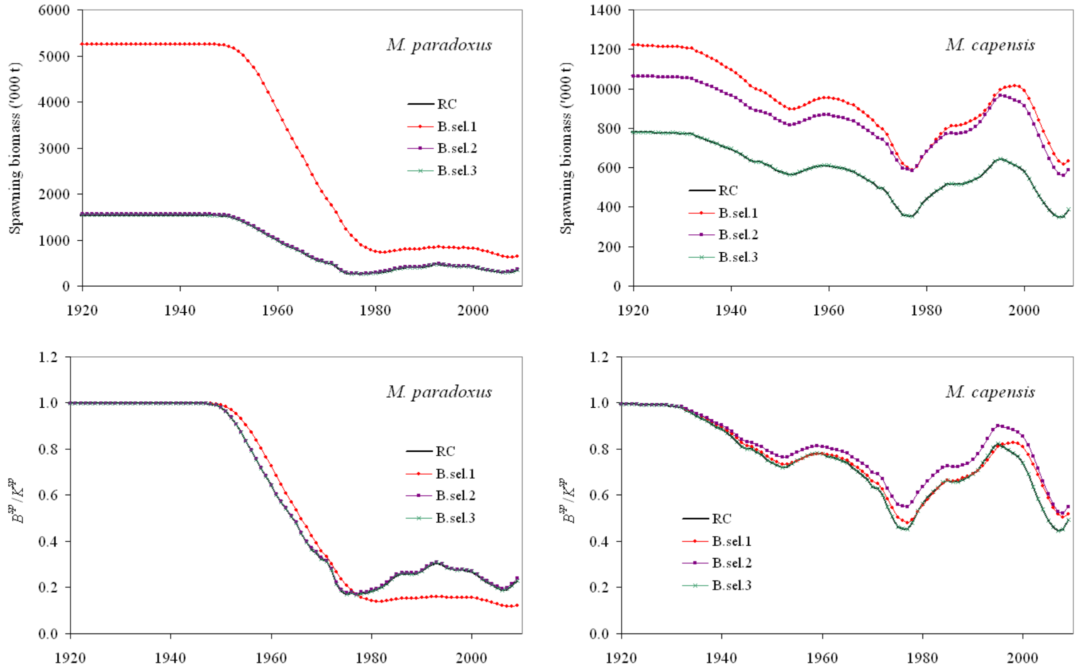

Fig. 7: Estimated gender-aggregated spawning biomass trajectories for *M. paradoxus* and *M. capensis*, both in absolute terms and relative to pre-exploitation level, for the RC and three robustness tests relating to fishing selectivities "**B.sel.1**" (alternative selectivity slope assumptions), "**B.sel.2**" (alternative offshore *M. capensis* selectivity assumption) and "**B.sel.3**" (fixed scaling factor for the offshore trawl female *M. paradoxus* selectivity).

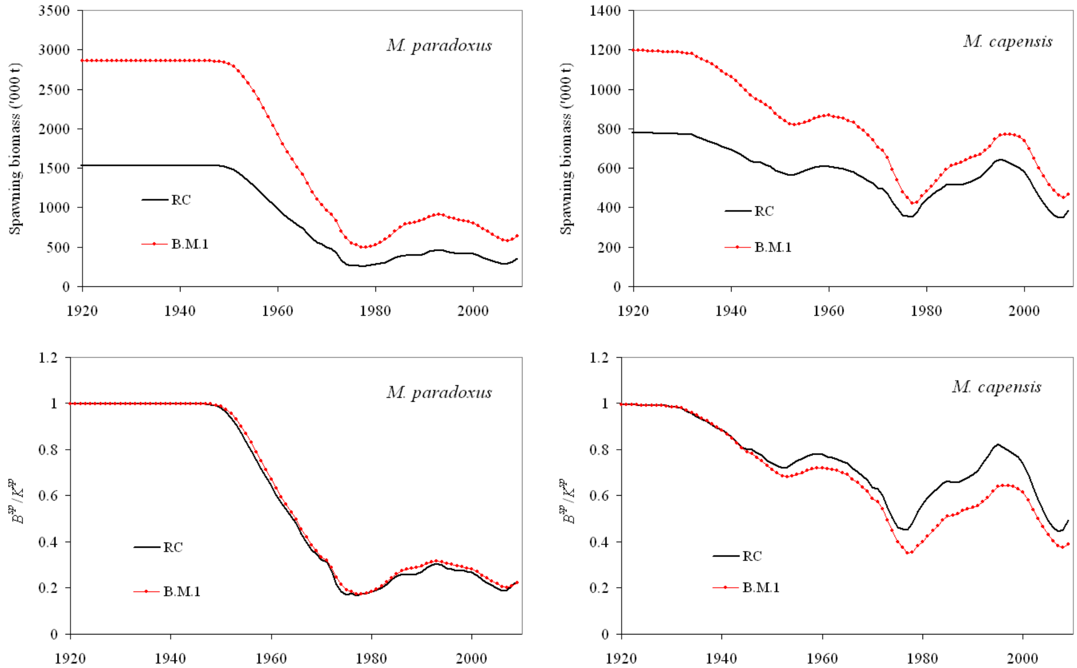

Fig.8: Estimated gender-aggregated spawning biomass trajectories for *M. paradoxus* and *M. capensis*, both in absolute terms and relative to pre-exploitation level, for the RC and the robustness test "**B.M.1**" with lower upper bounds on natural mortality.

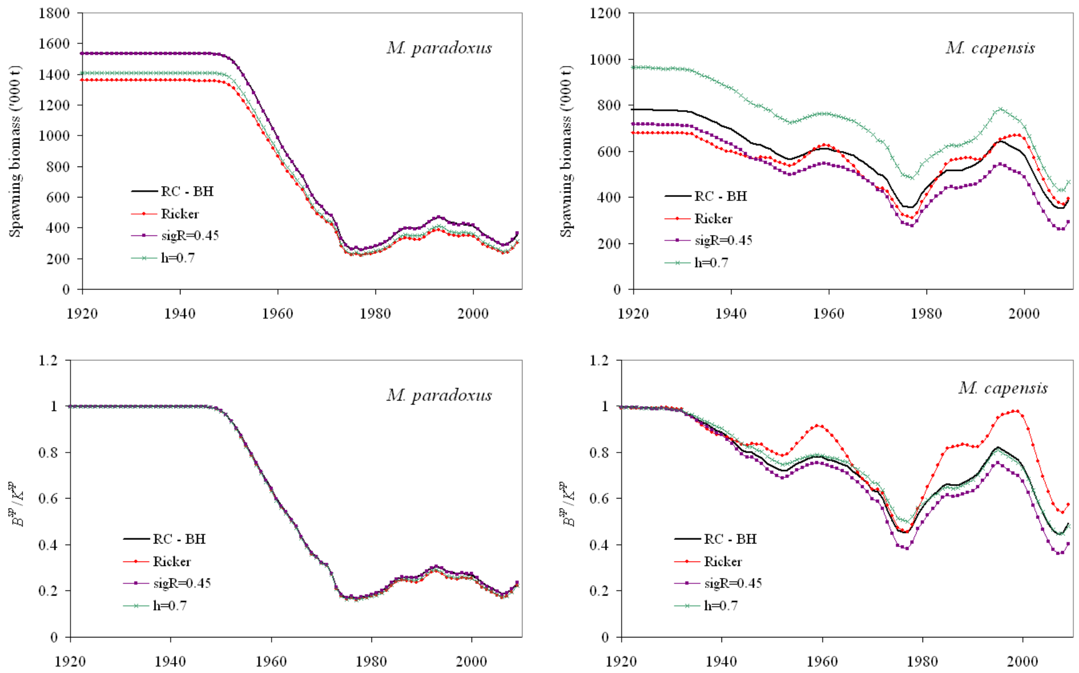

Fig. 9: Estimated gender-aggregated spawning biomass trajectories for *M. paradoxus* and *M. capensis*, both in absolute terms and relative to pre-exploitation level for the RC and robustness tests relating to the stock-recruitment curve: "**B.SR.1**" with Ricker instead of Beverton-Holt stock-recruitment relationship, "**B.SR.2**" with σ_R.=0.45 and "**B.SR.3**" with fixed h values..

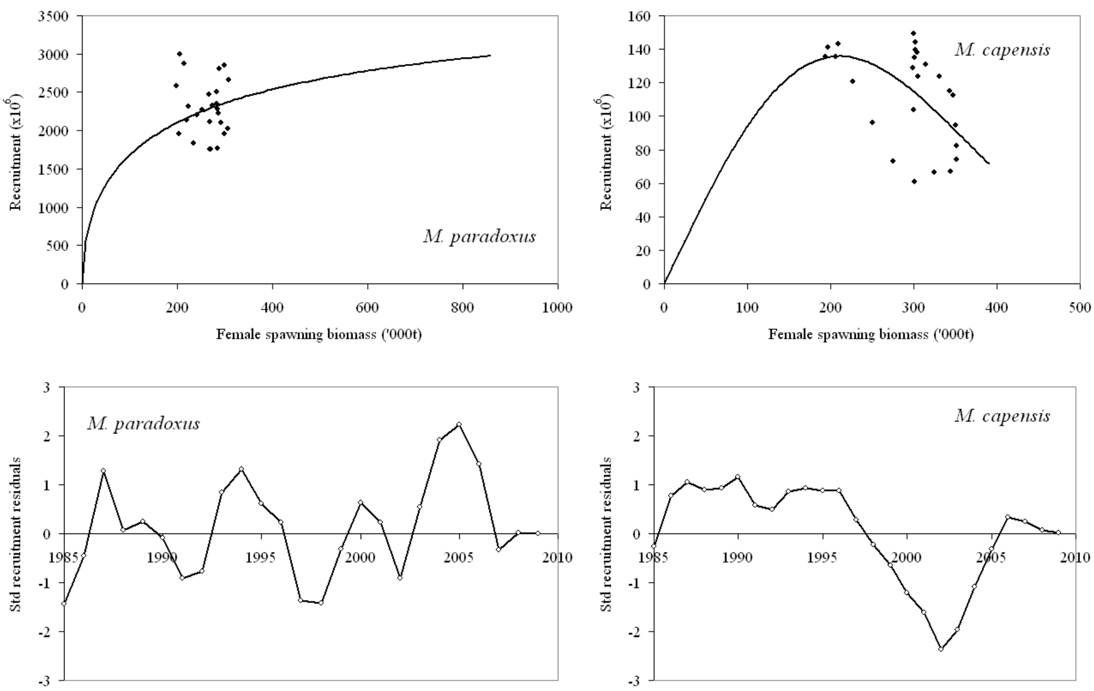

Fig.10: Estimated stock-recruitment relationship and time series of standardised stock-recruitment residuals for the robustness test "**B.SR.1**" with a Ricker instead of Beverton-Holt stock-recruitment relationship.

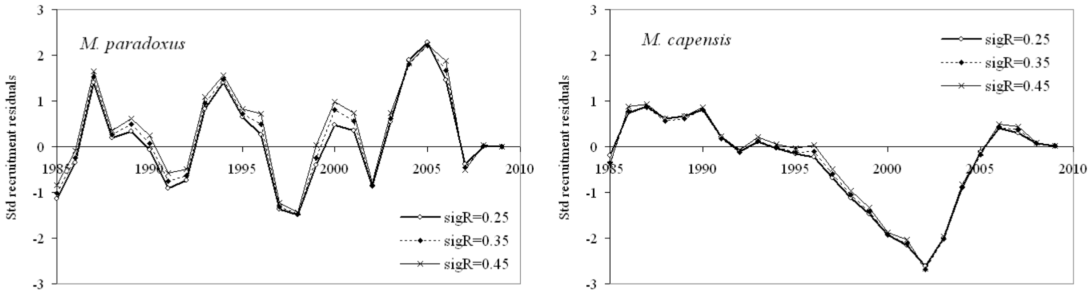

Fig. 11: Time series of standardised stock-recruitment residuals for the RC (σ_R=0.25) and robustness tests "**B.SR.2**", with different σ_R.

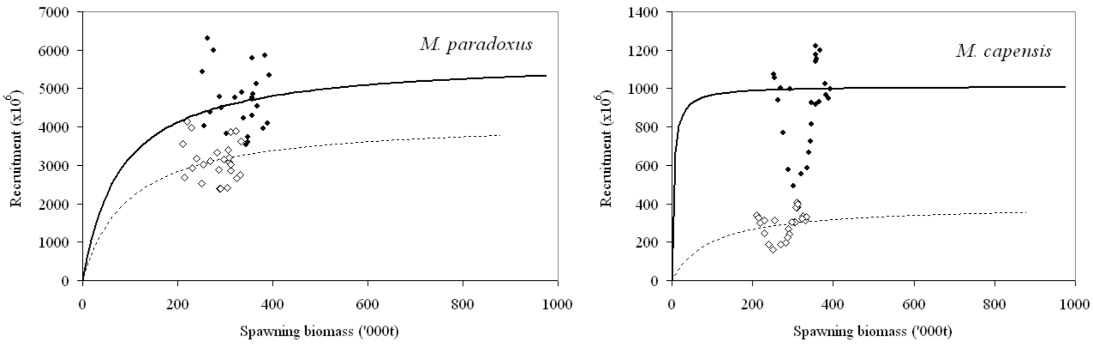

Fig.12: Stock-recruitment relationship for the RC (thick line and full circles) and robustness test "**B.SR.3**", with *h* fixed at 0.7 for both species (dashed line and open circles).

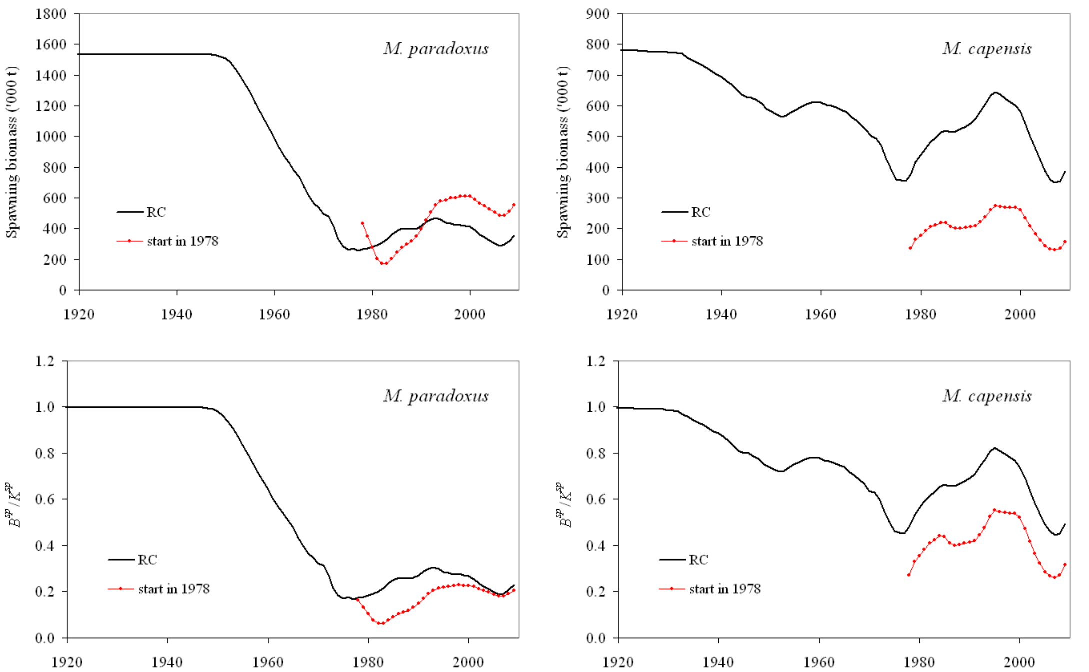

Fig. 13: Estimated gender-aggregated spawning biomass trajectories for *M. paradoxus* and *M. capensis*, both in absolute terms and relative to pre-exploitation level for the RC and robustness test "**C.others.1**" for which the assessments starting in 1978.

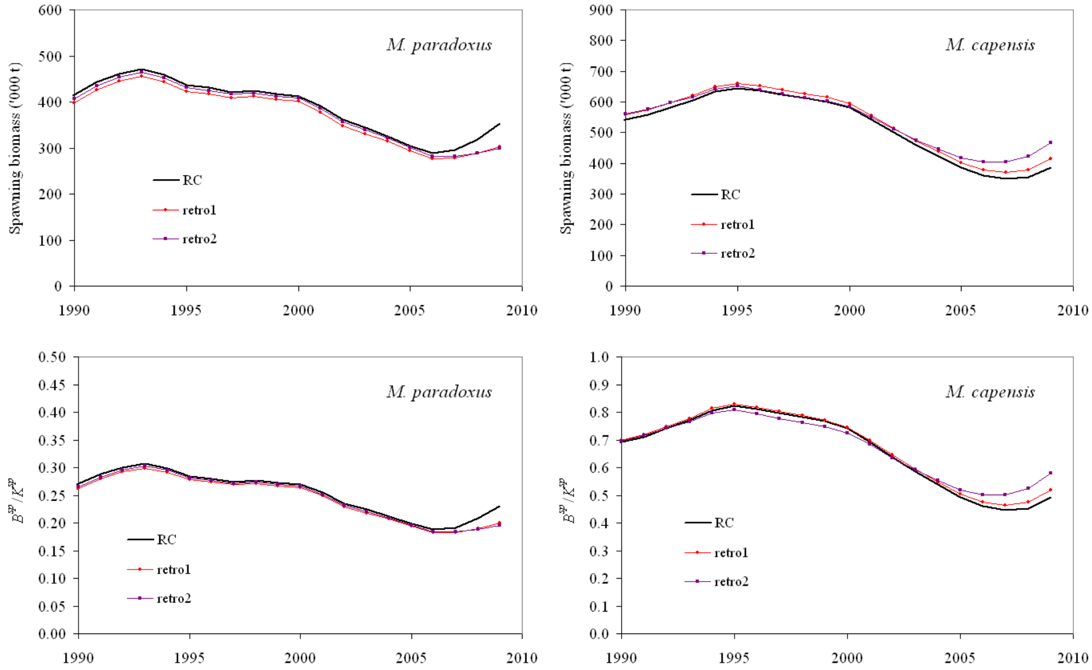

Fig. 14: Estimated gender-aggregated spawning biomass trajectories for *M. paradoxus* and *M. capensis*, both in absolute terms and relative to pre-exploitation level for the RC and the two retrospective assessments “C.others.4”.