Joint Assessment of the South African *Merluccius paradoxus* and *M. capensis* Resources

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Abstract

The assessments of December 2004 are updated in three respects: commercial catch-at-age data which cannot be species-disaggregated directly are taken into account in the fitting process, a new basis to split pre-1978 catches by species is introduced, and a new method is used to fit to pre-1978 CPUE series for the two species combined. The low estimated status of the *M. paradoxus* resource remains unchanged but a better status is estimated for *M. capensis*.

1. Introduction

In previous species-disaggregated assessments of the South African hake resource (e.g. Rademeyer and Butterworth, 2004), the *Merluccius paradoxus* and *M. capensis* resources were assessed independently of each other. In such assessments, data which cannot be disaggregated by species (either directly such as the survey information, or indirectly such as the commercial information) must either be ignored, or strong (and possibly inadequate) assumptions must be made about them. This paper presents a joint assessment of the hake resources off South Africa in which species-combined data can be incorporated in a more defensible way.

In this joint assessment, the two species are treated as two separate stocks but are assessed simultaneously within a single assessment framework, for the south and west coasts combined. Species-disaggregated catch series are external inputs to the model, though a more flexible basis for splitting catches between species in the earlier period of the fishery is introduced (see section 2.1 below for details).

2. Data

The tables of data used are given in Appendix A.

2.1 Total catches

The South African hake stocks are fished by four fleets: the offshore trawl fleet and the longline fleet operate on both the south and west coasts, while the inshore trawl fleet and the handline fleet operate on the south coast only. The annual catches by mass assumed for each fleet and coast are given in Table A.1 for the period 1917 to 2004. A summary of the assumptions made to disaggregate the catches by species and fleet for the Reference Case is given below.

a) Offshore trawl fleet:
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 developed by Gaylard and Bergh (2004). Prior to 1978, there is no depth information recorded for the landings so that the proportion of *M. capensis* caught cannot be estimated using this method. Previously, the proportion over the 1917-1977 period has been assumed to equal the average that pertained over the 1978-1982 in splitting the catches for these years (16% on the west coast and 46% on the south coast for *M. capensis*). In this paper, the catch data for the 1917-1977 period are split by assuming that the proportion of *M. capensis* caught follows a logistic function over this period (see Fig. 1 for the function used in the Reference Case). Indeed, trawling was concentrated in inshore areas around Cape Town when the fishery began (i.e. probably catching *M. capensis* exclusively) and progressively moved offshore, so that this seems a more defensible approach. The proportion of *M. capensis* in the offshore trawl catch in year y on coast c is thus given by:

$$prop_{cy}^{prop} = \frac{1-\Delta_c}{1+\exp\left[\left(y-P_1\right)/P_2\right]} + \Delta_c \qquad (1)$$

where

Δ_c is the average proportion of *M. capensis* in the offshore catch over the 1978-1982 period for coast *c* (16% on the west coast and 46% on the south coast), and

P_1, P_2 are parameters of the logistic function. Parameter P_1 is the year in which the proportion of *M. capensis* in the catch is half-way from 100% to Δ_c; while P_2 defines how rapidly this change in proportion occurs.

For the Reference Case considered here, values of P_1=1960 and P_2=4 were considered, to reflect a large proportion of *M. paradoxus* in the catch by the end of the 1960s when foreign effort in South African waters had become substantial. Alternative values can be chosen to allow tests of sensitivity to such assumptions.

The proportion of *M. capensis* consequently assumed for the offshore trawl catches is shown in Fig. 1 for the west and for the south coasts.

b) Inshore trawl fleet:
The inshore trawl fleet operates on the south coast only. Catches made by this fleet are assumed to consist of *M. capensis* only, as it operates in relatively shallow water.

Because fleet-disaggregated catch data are not available prior to 1974, the assumption has been made that the annual catch of the inshore trawl fleet from 1960 to 1973 increased linearly from 1000t to 5000t, and that the balance of the total catch recorded was taken by the offshore trawl fleet.

c) Longline fleet:
Longline catches on the west coast are assumed to consist of 30% *M. capensis* for the whole period, while on the south coast, catches by this fleet are assumed to consist of *M. capensis* exclusively.

d) Handline fleet:
The handline fleet operates on the south coast only. As for the inshore fleet, catches made by this fleet are assumed to consist of *M. capensis* only.

The catch in 2004 is taken to be the TAC for that year, with the same proportion of each species as caught by each fleet in 2003 assumed.

2.2 Abundance indices

Historic and GLM-standardised CPUE data are given in Table A2. The historic CPUE series cannot be disaggregated by species, as there are no effort-by-depth data available for this pre-1978 period. The GLM standardised CPUE data used are from Glazer (2004); these are species-specific indices (and based also on the new Gaylard and Bergh estimated species-proportion *vs.* depth relationship).

Survey biomass estimates for the west and south coasts are shown in Table A3 for *M. paradoxus* and Table A4 for *M. capensis*.

2.3 Catches-at-age

Survey catch-at-age data are shown in Tables A5-A8 for *M. paradoxus* and in Tables A9-A13 for *M. capensis*.

Commercial catches-at-age for the offshore (both coasts combined) and for the inshore and longline (south coast only) fleets are shown in Table A14-A16. They cannot be split by species on an age-basis, but this is not a problem for the south coast inshore and longline fleets as their catches are assumed to consist of *M. capensis* only.

3. Methods

The model used in this analysis is an Age-Structured Production Model (ASPM) and is described in detail in Appendix B. This includes a new method introduced to model CPUE series based upon species-aggregated catches – see equations B14-20.

A summary of the specifications for each species for the Reference Case assessment is given below.

3.1 *M. paradoxus*

a) Natural mortality:
M_a is taken to be age-dependent (M_a) (with the form of equation as shown in B33).

b) Commercial selectivity-at-age:
The selectivities of the offshore and longline fleet (the two fleets assumed to catch *M. paradoxus*) take the form of a logistic curve (equation B35). As there is no information on the age-structure of the longline catches of *M. paradoxus* alone, the selectivity of the longline fleet for *M. paradoxus* is assumed to be of the same form as the longline selectivity for *M. capensis* (which can be estimated from the south coast longline catches-at-age – assumed to be *M. capensis* only).

This assessment makes use of the offshore species-combined catch-at-age data (ignored in previous species-disaggregated assessments), so that if the selectivity of one of the species is known, the selectivity of the other species can be estimated. In this case, an assumption is made for the offshore selectivity for *M. capensis* (see below), and therefore the offshore selectivity for *M. paradoxus* can be estimated directly. The periods of fixed and changing selectivity used in previous assessments (to take account for the change in the selectivity at low ages over time in the commercial catches, likely due to the phasing out of net liners) have also been assumed for this assessment. The first selectivity period is from 1917 to 1984 and the second from 1993 to the present, with the selectivities in the intervening period assumed to vary linearly between these 1984 and 1993 values. The offshore trawl selectivity is assumed to decrease exponentially from age 3 (equation B36), with a slope parameter estimated in the model fitting procedure.

c) Survey selectivity-at-age
Because there are no catch-at-age data available from the west coast winter survey, the same selectivity is assumed to apply to both the summer and winter west coast surveys (conducted by the *Africana*). A separate selectivity function is estimated for the *Nansen* west coast summer survey. On the south coast, a single selectivity function is estimated for the spring and south coast surveys. The survey selectivities are estimated directly for each age.

d) Stock-recruitment residuals
The variability level σ_R is fixed at 0.25. The residuals are assumed not to be serially correlated, i.e., $\rho = 0$. They are estimated from year 1985 to 2004.

3.2 *M. capensis*

a) Natural mortality:
M_a is taken to be age-dependent (M_a) (with the form of equation B33).

b) Commercial selectivity-at-age:

The selectivity patterns characterising each of the four fleets (offshore, inshore, longline and handline) all take the form of a logistic curve. For the inshore fleet, the selectivity is allowed to decrease exponentially from age 5, as this fleet does not fully select older fish because the distribution of hake extends deeper than its area of operation. The selectivity for the offshore fleet is assumed to be as that for the inshore fleet but shifted one year of age to the right (i.e. $a^c_{cap,off} = a^c_{cap,insh} + 1$ in equation B35) and with a flat selectivity for older ages.

Because the longline fishery targets principally older fish, the selectivity for that fleet is also assumed to be flat for older ages. Furthermore, the selectivity indicated by a logistic curve is multiplied by a factor λ for ages ≤ 4. Indeed, the selectivity for this fleet and these ages is so low that it is not adequately represented by a logistic curve. The parameter λ is treated as another estimable parameter in the likelihood maximisation process.

As is the case for the offshore fleet, there are no catch-at-age data available to estimate a selectivity vector for the handline fleet, so the assumption is made that the selectivity for this fleet is intermediate between the offshore trawl and longline selectivities (i.e. the average of the two a^c_{sf} and δ^c_{sf} - see equation B35 - is assumed to apply).

c) Survey selectivity-at-age
A different survey selectivity is estimated for each of the three survey series on the west coast, while on the south coast a single selectivity is estimated. The survey selectivities are estimated separately for each age.

d) Stock-recruitment residuals
The variability level σ_R is fixed at 0.25. For simplicity, the residuals are assumed not to be serially correlated, i.e., $\rho = 0$. They are estimated from year 1985 to 2004.

3.3 Assessments presented

Different assessments are presented together with the New Reference Case assessment provided for comparison. Results are shown for the following cases:

I. the December 2004 Reference Case; in Rademeyer and Butterworth (2004), a minor error was made in computing the penalty on the calibration factor between the *Africana* with the old gear and the *Africana* with the new gear (equation B26), in this assessment, the error (which has very little effect on the results) has been corrected;

II. the new joint assessment, with the same catch series as used in I), i.e. the proportion of *M. capensis* in the catch is assumed to be constant before 1978;

III. the new joint assessment with the new catch series (shown in Table A1), and with a logistic change with time in the proportion of *M. capensis* in the offshore catches;

IV. the New Reference Case, which is as III) but with the offshore selectivity for *M. capensis* shifted one year to the right;

V. as IV) but with the natural mortalities for both species forced to be ≤ 0.5;

VI. as IV) but with steepness parameters for both *M. paradoxus* and *M. capensis* forced to be ≤ 0.8;

VII. as IV) but including unreported catches from the south coast offshore fleet; indeed, in other assessments, offshore catches on the south coast are assumed to have started in 1967 only, but it is known that some vessels operated in the region right from the beginning of the 20th century; these unreported catches are included in this sensitivity and are assumed to have increased linearly from 100t in 1917 to 5000t in 1967 (with the species-split based on the logistic equation above);

VIII. as IV) but with a different logistic function for the change with time in the proportion of *M. capensis* in the offshore catches (P_1=1950 and P_2=2, i.e. the offshore fleet is assumed to have moved towards deeper water earlier and the shift is assumed to have been faster than in Case IV);

IX. as IV) but the calibration factor between the *Africana* with the old gear and the *Africana* with the new gear for *M. capensis* is decreased: $\Delta \ell n q^{capensis} = -0.250$ instead of –0.494 (the variance on this value has been kept the same);

4. Results

Tables 1 and 2 compare the results of the different assessments for the *M. paradoxus* and *M. capensis* resources respectively. The total likelihood and the contribution of each data source for each of these cases are compared in Table 3.

Fig. 2 plots the population trajectories (in terms of pre-exploitation level) for the New Reference Case assessment for each of the two species (with 90% Hessian-based confidence envelopes), while Fig. 3 compares these population trajectories in absolute terms with those from the December 2004 Reference Case.

The survey and commercial selectivity functions estimated for the New Reference Case are plotted in Fig. 4.

Figs. 5 and 6 show the fits of the New Reference Case to the CPUE and survey indices respectively, while Figs. 7 and 8 show the fits of this model to the commercial and survey catch-at-age data. In these figures, the fits of the December 2004 Reference Case are also shown for comparison.

Fig. 9 plots the time-series of recruitment and the estimated stock-recruitment curve for the New Reference Case.

5. Discussion

In the case of the *M. paradoxus* resource, the estimate of current depletion from the New Reference Case assessment is very similar to that estimated in the December 2004 Reference Case, with the current level estimated to be well below *MSYL* (in fact, <10% of the pre-exploitation level). The estimate of current biomass in absolute terms for this species for the New Reference Case is also very similar to the previous assessment. For the *M. capensis* resource on the other hand, the current biomass level is estimated to be substantially higher for the New Reference Case compared to the 2004 December Reference Case, both in absolute terms (see Fig. 3) and in terms of the pre-exploitation level (about 60% of pristine for the New Reference Case compared to about 40% in the December 2004 Reference Case). However, as expected, the changes in the assumptions about the species-split of the historic offshore catches have an effect on the past population trajectories of the two species (see Fig. 3).

The New Reference Case estimates of natural mortality and steepness for both species are also substantially different from those estimated in the December 2004 Reference Case. Natural mortality for *M. paradoxus* is less than in the previous assessment and now seems biologically realistic (0.21 for 5+). However, steepness is estimated to be unrealistically high (0.98 – the upper bound imposed for this parameter) which is a concern because a low level of current spawning biomass is estimated, for which taking expected recruitment to remain unchanged might be dangerously inappropriate. For *M. capensis* on the other hand, the estimate of steepness decreases from the upper bound of 0.98 to 0.45, but the estimate of natural mortality increases to an age-independent 0.80 which seems unrealistically high biologically. These changes are principally due to the contribution of the species-combined catch-at-age data in the likelihood. From Fig. 7a, it is clear that the December 2004 Reference Case does not fit these data satisfactorily.

The estimates of multiplicative bias for the survey (q) seem more plausible for *M. capensis* (for which they are generally less than 1), but are very high for west coast *M. paradoxus* (>2).

Cases V and VI are assessments in which more credible values are forced for natural mortality and steepness. In Case V, where natural mortality for age 5+ is forced to be equal or smaller than 0.5, the resulting slight deterioration in the model fit is caused principally by the fit to the inshore catch-at-age data for *M. capensis*. Estimates of current depletion, MSY and related quantities remain largely unchanged. In Case VI, the deterioration in the fit is due mainly to a deterioration in the fit to the species-combined catch-at-age data. In this case, the current spawning biomass for the *M. paradoxus* resource is estimated to be at about 15% of its pre-exploitation level, while this level of depletion is hardly changed for *M. capensis*.

Including unreported catches from the south coast offshore fleet (Case VII) and decreasing the estimated difference in the catchability coefficient between the *Africana* with the old gear and the *Africana* with the new gear for *M. capensis* (Case VIII) make no substantial change to the results.

In Case IX, a different logistic function is assumed for the historic species-split of the offshore trawl catches compared to that in the New Reference Case. Although estimates of absolute biomass change (increase for *M. paradoxus* and decrease for *M. capensis*), the current level of depletion for both species remains very similar compared to the results of the New Reference Case.

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Table 1: Estimates of management quantities of the ***M. paradoxus*** coast-combined resource for a series of assessments. Exploitable biomass and associated quantities are estimated for each fleet separately, and also for an 'average-selectivity' which reflects that of the last year (2004) of the assessment, and is shown in the first column.

I) *M. paradoxus* December 2004 Reference Case

		Offshore	Longline					
K^{sp}	888							
K^{ex}	1089	896	761					
$B^{sp}{}_y$	86							
B^{exp}	137	142	25					
h	0.846							
$MSYL^{sp}$	214	208	495					
$MSYL^{ex}$	293	283	286					
MSY	141	137	141					
$B^{sp}{}_y/K^{sp}$	0.097							
$B^{ex}{}_y/K^{ex}$	0.126	0.158	0.033					
$B^{sp}{}_y/MSYL^{sp}$	0.402	0.414	0.174					
$B^{ex}{}_y/MSYL^{ex}$	0.469	0.502	0.087					
$MSYL^{sp}/K^{sp}$	0.241	0.234	0.558					
$MSYL^{ex}/K^{ex}$	0.269	0.315	0.375					
Age	M_a	S^{surv} (WC Africana)	S^{surv} (WC *Nansen*)	S^{surv} (SC spring Africana)	S^{surv} (SC autumn Africana)	S_1^{off}	S_2^{off}	S_{1long}
0	0.64	0.02	0.24	0.00	0.00	0.00	0.00	0.00
1	0.64	0.37	1.00	0.03	0.01	0.00	0.00	0.00
2	0.64	1.00	0.93	0.56	0.25	0.52	0.09	0.00
3	0.48	0.69	0.78	1.00	1.00	1.00	0.98	0.01
4	0.38	0.47	0.61	0.37	0.74	0.82	1.00	0.04
5+	0.32	0.32	0.48	0.14	0.54	0.67	0.82	1.00
Commercial q's:								
SC ICSEAF CPUE	0.003							
WC ICSEAF CPUE	0.028							
GLM CPUE	0.039							
Commercial sigma's:								
SC ICSEAF CPUE	0.250 *							
WC ICSEAF CPUE	0.250 *							
GLM CPUE	0.150 *							
Survey q's:	WC sum	WC wint	WC Nan	SC spr	SC aut			
	1.55	1.39	1.25	0.22	0.57			
new *Africana*	1.45	-	-	0.22	0.53			
Catches-at-age sigma's:	0.15	-	0.07	0.06	0.29			
Addnl sigma (survey)	0.316							

II) *M. paradoxus* from joint assessment with catches as in December 2004 Reference Case

		Offshore	Longline				
K^{sp}	1493						
K^{ex}	1807	1523	1554				
$B^{sp}{}_y$	74						
B^{exp}	131	144	26				
h	0.980						
$MSYL^{sp}$	291	286	326				
$MSYL^{ex}$	364	364	121				
MSY	147	141	212				
$B^{sp}{}_y/K^{sp}$	0.050						
$B^{ex}{}_y/K^{ex}$	0.073	0.094	0.017				
$B^{sp}{}_y/MSYL^{sp}$	0.255	0.260	0.228				
$B^{ex}{}_y/MSYL^{ex}$	0.361	0.394	0.218				
$MSYL^{sp}/K^{sp}$	0.195	0.191	0.219				
$MSYL^{ex}/K^{ex}$	0.201	0.239	0.078				
Age	M_a	S^{surv} (WC Africana)	S^{surv} (WC *Nansen*)	S^{surv} (SC Africana)	S_1^{off}	S_2^{off}	S_{1long}
0	0.31	0.12	0.35	0.00	0.00	0.00	0.00
1	0.31	0.51	1.00	0.04	0.15	0.00	0.00
2	0.31	1.00	0.68	0.45	0.88	0.25	0.00
3	0.23	0.61	0.53	1.00	1.00	1.00	0.01
4	0.18	0.24	0.61	0.37	0.88	0.95	0.04
5+	0.15	0.15	0.13	0.42	0.77	0.90	1.00
Commercial q's:							
SC ICSEAF CPUE	0.030						
WC ICSEAF CPUE	0.003						
GLM CPUE	0.038						
Commercial sigma's:							
SC ICSEAF CPUE	0.250 *						
WC ICSEAF CPUE	0.250 *						
GLM CPUE	0.150 *						
Survey q's:	WC sum	WC wint	WC Nan	SC spr	SC aut		
	2.65	2.16	2.72	0.30	0.67		
new *Africana*	2.45	-	-	0.30	0.63		
Catches-at-age sigma's:	0.12	-	0.07	0.09	0.20		
Addnl sigma (survey)	0.341						

III) *M. paradoxus* from joint assessment with changing species proportion in historic catches

		Offshore	Longline				
K^{sp}	1183						
K^{ex}	1436	1059	1189				
$B^{sp}{}_y$	80						
B^{exp}	140	149	29				
h	0.980						
$MSYL^{sp}$	228	221	305				
$MSYL^{ex}$	296	289	109				
MSY	134	129	192				
$B^{sp}{}_y/K^{sp}$	0.067						
$B^{ex}{}_y/K^{ex}$	0.098	0.140	0.025				
$B^{sp}{}_y/MSYL^{sp}$	0.349	0.361	0.261				
$B^{ex}{}_y/MSYL^{ex}$	0.474	0.514	0.268				
$MSYL^{sp}/K^{sp}$	0.193	0.186	0.258				
$MSYL^{ex}/K^{ex}$	0.206	0.273	0.092				
Age	M_a	S^{surv} (WC Africana)	S^{surv} (WC *Nansen*)	S^{surv} (SC Africana)	S_1^{off}	S_2^{off}	S_{1long}
0	0.37	0.11	0.33	0.00	0.00	0.00	0.00
1	0.37	0.48	1.00	0.04	0.14	0.00	0.00
2	0.37	1.00	0.72	0.44	0.87	0.23	0.00
3	0.28	0.64	0.59	1.00	1.00	1.00	0.01
4	0.22	0.25	0.68	0.36	0.80	0.94	0.03
5+	0.18	0.14	0.14	0.39	0.63	0.88	1.00
Commercial q's:							
SC ICSEAF CPUE	0.016						
WC ICSEAF CPUE	0.002						
GLM CPUE	0.036						
Commercial sigma's:							
SC ICSEAF CPUE	0.250 *						
WC ICSEAF CPUE	0.250 *						
GLM CPUE	0.150 *						
Survey q's:	WC sum	WC wint	WC Nan	SC spr	SC aut		
	2.40	1.99	2.35	0.28	0.64		
new *Africana*	2.23	-	-	0.28	0.60		
Catches-at-age sigma's:	0.12	-	0.07	0.09	0.20		
Addnl sigma (survey)	0.344						

* constraint boundary

Table 1: ***M. paradoxus*** continued

	IV) ***M. paradoxus*** **New Reference Case (as III but offshore selectivity for *M. capensis* shifted one year of age to the right)**							V) ***M. paradoxus*** **as New Reference Case but M_{5+}<=0.5 for both species**							VI) ***M. paradoxus*** **as New Reference Case but *h*=0.8 for both species**						
		Offshore	Longline						Offshore	Longline						Offshore	Longline				
K^{sp}	1069							1041							743						
K^{ex}	1246	1019	1043					1215	1065	1012					845	909	559				
B^{sp}_{y}	72							73							113						
B^{exp}	104	129	18					107	131	20					154	180	34				
h	0.980							0.980							**0.800**						
$MSYL^{sp}$	212	204	309					207	199	303					200	196	358				
$MSYL^{ex}$	239	270	108					236	264	108					237	270	103				
MSY	140	135	190					139	134	188					140	136	180				
B^{sp}_{y}/K^{sp}	0.067							0.070							0.152						
B^{ex}_{y}/K^{ex}	0.084	0.127	0.017					0.088	0.123	0.019					0.182	0.198	0.061				
$B^{sp}_{y}/MSYL^{sp}$	0.339	0.353	0.233					0.354	0.368	0.242					0.564	0.576	0.316				
$B^{ex}_{y}/MSYL^{ex}$	0.436	0.479	0.164					0.454	0.496	0.181					0.647	0.669	0.333				
$MSYL^{sp}/K^{sp}$	0.198	0.191	0.289					0.199	0.191	0.291					0.270	0.264	0.482				
$MSYL^{ex}/K^{ex}$	0.192	0.265	0.104					0.194	0.248	0.107					0.281	0.297	0.184				
Age	M_a	S^{surv} (WC Africana)	S^{surv} (WC *Nansen*)	S^{surv} (SC Africana)	S_1^{off}	S_2^{off}	S_{1long}	M_a	S^{surv} (WC Africana)	S^{surv} (WC *Nansen*)	S^{surv} (SC Africana)	S_1^{off}	S_2^{off}	S_{1long}	M_a	S^{surv} (WC Africana)	S^{surv} (WC *Nansen*)	S^{surv} (SC Africana)	S_1^{off}	S_2^{off}	S_{1long}
0	0.37	0.11	0.33	0.00	0.01	0.00	0.00	0.36	0.11	0.33	0.00	0.01	0.00	0.00	0.44	0.09	0.31	0.00	0.00	0.00	0.00
1	0.37	0.48	1.00	0.04	0.12	0.01	0.00	0.36	0.49	1.00	0.04	0.12	0.01	0.00	0.44	0.45	1.00	0.04	0.12	0.01	0.00
2	0.37	1.00	0.71	0.44	0.77	0.18	0.00	0.36	1.00	0.71	0.44	0.78	0.18	0.00	0.44	1.00	0.76	0.42	0.79	0.16	0.00
3	0.29	0.63	0.56	1.00	1.00	0.82	0.01	0.29	0.62	0.56	1.00	1.00	0.82	0.01	0.44	0.65	0.62	1.00	1.00	0.82	0.01
4	0.24	0.25	0.59	0.40	0.83	0.99	0.03	0.24	0.25	0.58	0.40	0.87	0.99	0.06	0.44	0.25	0.61	0.40	0.90	0.99	0.03
5+	0.21	0.24	0.21	0.74	0.68	1.00	1.00	0.22	0.23	0.20	0.72	0.74	1.00	1.00	0.44	0.20	0.21	0.67	0.81	1.00	1.00
Commercial q's:																					
SC ICSEAF CPUE	0.018							0.017							0.016						
WC ICSEAF CPUE	0.002							0.002							0.002						
GLM CPUE	0.042							0.042							0.032						
Commercial sigma's:																					
SC ICSEAF CPUE	0.250 *							0.250 *							0.250 *						
WC ICSEAF CPUE	0.250 *							0.250 *							0.250 *						
GLM CPUE	0.150 *							0.150 *							0.150 *						
Survey q's:	WC sum	WC wint	WC Nan	SC spr	SC aut			WC sum	WC wint	WC Nan	SC spr	SC aut			WC sum	WC wint	WC Nan	SC spr	SC aut		
	2.37	2.02	2.34	0.28	0.63			2.39	2.03	2.38	0.28	0.63			1.78	1.56	1.64	0.22	0.48		
new *Africana*	2.20	-	-	0.28	0.59			2.22	-	-	0.28	0.58			1.64	-	-	0.22	0.45		
Catches-at-age sigma's:	0.12	-	0.07	0.10	0.19			0.12	-	0.07	0.10	0.19			0.13	-	0.07	0.11	0.20		
Addnl sigma (survey)	0.327							0.327							0.317						

* constraint boundary

Table 1: ***M. paradoxus*** continued

	VII) *M. paradoxus* as New Reference Case but including unreported catches on the south coast						
		Offshore	Longline				
K^{sp}	1073						
K^{ex}	1251	1026	1048				
$B^{sp}{}_y$	72						
$B^{ex}{}_y$	104	129	18				
h	0.980						
$MSYL^{sp}$	213	205	310				
$MSYL^{ex}$	240	271	108				
MSY	141	136	191				
$B^{sp}{}_y/K^{sp}$	0.067						
$B^{ex}{}_y/K^{ex}$	0.083	0.126	0.017				
$B^{sp}{}_y/MSYL^{sp}$	0.338	0.351	0.232				
$B^{ex}{}_y/MSYL^{ex}$	0.434	0.477	0.163				
$MSYL^{sp}/K^{sp}$	0.198	0.191	0.288				
$MSYL^{ex}/K^{ex}$	0.192	0.264	0.103				
Age	M_a	S^{surv} (WC Africana)	S^{surv} (WC *Nansen*)	S^{surv} (SC Africana)	S_1^{off}	S_2^{off}	S_{1long}
0	0.37	0.11	0.33	0.00	0.01	0.00	0.00
1	0.37	0.48	1.00	0.04	0.12	0.01	0.00
2	0.37	1.00	0.71	0.44	0.77	0.18	0.00
3	0.29	0.63	0.56	1.00	1.00	0.82	0.01
4	0.24	0.25	0.59	0.40	0.83	0.99	0.03
5+	0.21	0.24	0.21	0.74	0.68	1.00	1.00
Commercial q's:							
SC ICSEAF CPUE	0.018						
WC ICSEAF CPUE	0.002						
GLM CPUE	0.042						
Commercial sigma's:							
SC ICSEAF CPUE	0.250 *						
WC ICSEAF CPUE	0.250 *						
GLM CPUE	0.150 *						
Survey q's:	WC sum	WC wint	WC Nan	SC spr	SC aut		
	2.38	2.02	2.34	0.28	0.63		
new *Africana*	2.20	-	-	0.28	0.59		
Catches-at-age sigma's:	0.12	-	0.07	0.10	0.19		
Addnl sigma (survey)	0.327						

	VIII) *M. paradoxus* as New Reference Case but different calibration factor between old and new *Africana* for *M. capensis* (see text for details)						
		Offshore	Longline				
K^{sp}	1070						
K^{ex}	1248	1018	1044				
$B^{sp}{}_y$	72						
$B^{ex}{}_y$	104	129	18				
h	0.980						
$MSYL^{sp}$	212	204	309				
$MSYL^{ex}$	239	270	108				
MSY	140	136	190				
$B^{sp}{}_y/K^{sp}$	0.067						
$B^{ex}{}_y/K^{ex}$	0.084	0.127	0.017				
$B^{sp}{}_y/MSYL^{sp}$	0.339	0.352	0.233				
$B^{ex}{}_y/MSYL^{ex}$	0.435	0.479	0.164				
$MSYL^{sp}/K^{sp}$	0.198	0.191	0.289				
$MSYL^{ex}/K^{ex}$	0.192	0.265	0.104				
Age	M_a	S^{surv} (WC Africana)	S^{surv} (WC *Nansen*)	S^{surv} (SC Africana)	S_1^{off}	S_2^{off}	S_{1long}
0	0.37	0.11	0.33	0.00	0.01	0.00	0.00
1	0.37	0.48	1.00	0.04	0.12	0.01	0.00
2	0.37	1.00	0.71	0.44	0.77	0.18	0.00
3	0.29	0.63	0.56	1.00	1.00	0.82	0.01
4	0.24	0.25	0.59	0.40	0.83	0.99	0.03
5+	0.21	0.24	0.21	0.74	0.68	1.00	1.00
Commercial q's:							
SC ICSEAF CPUE	0.018						
WC ICSEAF CPUE	0.002						
GLM CPUE	0.042						
Commercial sigma's:							
SC ICSEAF CPUE	0.250 *						
WC ICSEAF CPUE	0.250 *						
GLM CPUE	0.150 *						
Survey q's:	WC sum	WC wint	WC Nan	SC spr	SC aut		
	2.38	2.02	2.34	0.28	0.63		
new *Africana*	2.20	-	-	0.28	0.59		
Catches-at-age sigma's:	0.12	-	0.07	0.10	0.19		
Addnl sigma (survey)	0.327						

	IX) *M. paradoxus* as New Reference Case but different logistic function for offshore historic species-split						
		Offshore	Longline				
K^{sp}	1357						
K^{ex}	1594	1379	1378				
$B^{sp}{}_y$	69						
$B^{ex}{}_y$	102	128	17				
h	0.980						
$MSYL^{sp}$	269	263	334				
$MSYL^{ex}$	301	340	120				
MSY	154	148	213				
$B^{sp}{}_y/K^{sp}$	0.051						
$B^{ex}{}_y/K^{ex}$	0.064	0.092	0.012				
$B^{sp}{}_y/MSYL^{sp}$	0.257	0.263	0.207				
$B^{ex}{}_y/MSYL^{ex}$	0.339	0.376	0.139				
$MSYL^{sp}/K^{sp}$	0.198	0.194	0.246				
$MSYL^{ex}/K^{ex}$	0.189	0.246	0.087				
Age	M_a	S^{surv} (WC Africana)	S^{surv} (WC *Nansen*)	S^{surv} (SC Africana)	S_1^{off}	S_2^{off}	S_{1long}
0	0.31	0.12	0.35	0.00	0.01	0.00	0.00
1	0.31	0.51	1.00	0.04	0.13	0.01	0.00
2	0.31	1.00	0.68	0.45	0.78	0.19	0.00
3	0.24	0.61	0.52	1.00	1.00	0.84	0.01
4	0.20	0.24	0.54	0.40	0.88	0.99	0.03
5+	0.17	0.24	0.20	0.76	0.76	1.00	1.00
Commercial q's:							
SC ICSEAF CPUE	0.025						
WC ICSEAF CPUE	0.003						
GLM CPUE	0.044						
Commercial sigma's:							
SC ICSEAF CPUE	0.250 *						
WC ICSEAF CPUE	0.250 *						
GLM CPUE	0.150 *						
Survey q's:	WC sum	WC wint	WC Nan	SC spr	SC aut		
	2.59	2.16	2.67	0.29	0.66		
new *Africana*	2.40	-	-	0.29	0.61		
Catches-at-age sigma's:	0.12	0.00	0.07	0.10	0.19		
Addnl sigma (survey)	0.329						

* constraint boundary

Table 2: Estimates of management quantities of the coast-combined ***M. capensis*** resource for a series of assessments. Exploitable biomass and associated quantities are estimated for each fleet separately, and also for an 'average-selectivity' which reflects that of the last year (2004) of the assessment, and is shown in the first column.

	I) *M. capensis* December 2004 Reference Case					II) *M. capensis* from joint assessment with catches as in December 2004 Reference Case					III) *M. capensis* from joint assessment with changing species proportion in historic catches				
		Offshore	Inshore	Longline	Handline		Offshore	Inshore	Longline	Handline		Offshore	Inshore	Longline	Handline
K^{sp}	250					304					484				
K^{ex}	181	256	176	122	176	235	309	208	138	207	281	465	375	133	239
B^{sp}_y	103					178					308				
B^{ex}_y	53	101	91	17	45	120	177	146	47	96	164	296	258	58	131
h	0.980					0.885					0.472				
$MSYL^{sp}$	81	29	29	162	105	88	65	58	200	132	191	182	177	360	228
$MSYL^{ex}$	37	31	31	30	35	48	64	56	35	43	85	169	149	43	57
MSY	46	45	44	41	46	60	60	60	47	57	70	67	65	58	74
B^{sp}_y/K^{sp}	0.410					0.586					0.637				
B^{ex}_y/K^{ex}	0.294	0.394	0.519	0.139	0.255	0.512	0.574	0.701	0.338	0.462	0.583	0.636	0.688	0.438	0.549
$B^{sp}_y/MSYL^{sp}$	1.266	3.530	3.578	0.635	0.975	2.028	2.757	3.052	0.891	1.354	1.616	1.689	1.741	0.856	1.354
$B^{ex}_y/MSYL^{ex}$	1.438	3.221	2.918	0.573	1.303	2.505	2.779	2.590	1.328	2.236	1.941	1.755	1.730	1.350	2.292
$MSYL^{sp}/K^{sp}$	0.324	0.116	0.115	0.645	0.420	0.289	0.213	0.192	0.658	0.433	0.394	0.377	0.366	0.744	0.471
$MSYL^{ex}/K^{ex}$	0.204	0.122	0.178	0.243	0.196	0.205	0.206	0.271	0.254	0.207	0.301	0.363	0.398	0.325	0.239

I) *M. capensis* December 2004 Reference Case

Age	M_a	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	0.497	0.22	0.04	0.61	0.03	0.00	0.00	0.00	0.00
1	0.497	0.40	0.73	0.55	0.05	0.01	0.01	0.00	0.00
2	0.497	1.00	0.87	0.58	0.12	0.06	0.06	0.00	0.00
3	0.497	0.80	0.85	1.00	0.21	0.44	0.44	0.00	0.03
4	0.497	0.44	0.52	0.56	0.51	0.90	0.91	0.00	0.16
5	0.497	0.51	1.00	0.38	0.75	0.99	1.00	0.11	0.58
6	0.497	0.92	0.93	0.56	0.90	1.00	0.59	0.42	0.92
7+	0.497	0.64	0.85	0.39	1.00	1.00	0.35	1.00	1.00

II) *M. capensis* from joint assessment with catches as in December 2004 Reference Case

Age	M_a	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	0.85	0.08	0.02	0.21	0.01	0.00	0.00	0.00	0.00
1	0.85	0.21	0.40	0.27	0.03	0.00	0.00	0.00	0.00
2	0.85	0.75	0.69	0.40	0.11	0.04	0.04	0.00	0.00
3	0.72	0.84	0.87	1.00	0.24	0.39	0.39	0.00	0.03
4	0.65	0.53	0.57	0.67	0.64	0.91	0.91	0.01	0.20
5	0.60	0.61	1.00	0.48	0.93	1.00	1.00	0.15	0.67
6	0.56	1.00	0.80	0.62	1.00	1.00	0.51	0.54	0.95
7+	0.53	0.52	0.53	0.29	0.76	1.00	0.25	1.00	1.00

III) *M. capensis* from joint assessment with changing species proportion in historic catches

Age	M_a	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	0.76	0.09	0.02	0.27	0.01	0.00	0.00	0.00	0.00
1	0.76	0.22	0.43	0.31	0.03	0.00	0.00	0.00	0.00
2	0.76	0.73	0.69	0.44	0.09	0.04	0.04	0.00	0.00
3	0.76	0.74	0.81	1.00	0.20	0.36	0.36	0.00	0.02
4	0.76	0.47	0.54	0.68	0.55	0.89	0.89	0.00	0.13
5	0.76	0.56	1.00	0.50	0.84	1.00	1.00	0.10	0.53
6	0.76	1.00	0.87	0.68	1.00	1.00	0.59	0.40	0.90
7+	0.76	0.65	0.76	0.43	0.97	1.00	0.35	1.00	1.00

Commercial:	I) Sigmas:	I) *q*'s:	II) Sigmas:	II) *q*'s: *cap* only	II) *q*'s: mixed	III) Sigmas:	III) *q*'s: *cap* only	III) *q*'s: mixed
South coast hist.CPUE	0.250 *	0.007	0.250 *	0.033	9.032×10^{-6}	0.250 *	0.156	9.032×10^{-6}
West coast hist.CPUE	0.250 *	0.071	0.250 *	0.004	1.025×10^{-6}	0.250 *	0.018	1.025×10^{-6}
GLM CPUE	0.150 *	0.042	0.150 *	0.023		0.150 *	0.014	

Survey *q*'s:	WC sum	WC wint	WC Nan	SC spr	SC aut
I)	1.097	0.949	2.363	2.260	2.476
I) new *Africana*	0.731	-	-	1.374	1.501
II)	0.548	0.540	1.247	1.074	1.200
II) new *Africana*	0.365	-	-	0.653	0.728
III)	0.325	0.303	0.656	0.671	0.760
III) new *Africana*	0.216	-	-	0.408	0.461

Catches-at-age sigma's:	WC sum	WC wint	WC Nan	SC spr	SC aut	inshore	longline
I)	0.246	0.148	0.082	0.104	0.131	0.119	0.108
II)	0.243	0.142	0.079	0.108	0.128	0.121	0.108
III)	0.242	0.140	0.079	0.106	0.127	0.121	0.107

	I)	II)	III)
Additional sigma (survey)	0.391	0.399	0.401

* constraint boundary

Table 2: ***M. capensis*** continued

IV) *M. capensis* New Reference Case (as III but offshore selectivity for *M. cap* shifted one year of age to the right)

		Offshore	Inshore	Longline	Handline
K^{sp}	447				
K^{ex}	208	288	365	108	198
$B^{sp}{}_y$	277				
$B^{ex}{}_y$	108	161	241	39	98
h	0.445				
$MSYL^{sp}$	189	181	169	346	230
$MSYL^{ex}$	55	77	146	36	51
MSY	65	66	59	49	66
$B^{sp}{}_y/K^{sp}$	0.619				
$B^{ex}{}_y/K^{ex}$	0.518	0.559	0.661	0.361	0.494
$B^{sp}{}_y/MSYL^{sp}$	1.464	1.524	1.637	0.800	1.204
$B^{ex}{}_y/MSYL^{ex}$	1.974	2.102	1.654	1.074	1.914
$MSYL^{sp}/K^{sp}$	0.423	0.406	0.378	0.773	0.514
$MSYL^{ex}/K^{ex}$	0.262	0.266	0.399	0.336	0.258

Age	M_a	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	0.80	0.07	0.01	0.24	0.01	0.00	0.00	0.00	0.00
1	0.80	0.19	0.36	0.29	0.02	0.00	0.00	0.00	0.00
2	0.80	0.62	0.59	0.42	0.06	0.00	0.04	0.00	0.00
3	0.80	0.65	0.70	1.00	0.14	0.04	0.36	0.00	0.01
4	0.80	0.41	0.46	0.68	0.39	0.36	0.89	0.00	0.10
5	0.80	0.51	0.89	0.50	0.63	0.89	1.00	0.08	0.46
6	0.80	1.00	0.89	0.77	0.82	1.00	0.68	0.33	0.88
7+	0.80	0.82	1.00	0.62	1.00	1.00	0.46	1.00	1.00

Commercial:	Sigmas:	*q* 's:	*cap* only	mixed	
South coast hist.CPUE	0.250 *		0.348	9.032×10^{-6}	
West coast hist.CPUE	0.250 *		0.040	1.025×10^{-6}	
GLM CPUE	0.150 *		0.028		
Survey *q* 's:	WC sum	WC wint	WC Nan	SC spr	SC aut
	0.384	0.367	0.681	1.004	1.157
new *Africana*	0.255	-	-	0.611	0.700
Catches-at-age sigma's:	WC sum	WC wint	WC Nan	SC spr	SC aut
	0.242	0.142	0.079	0.106	0.127
	inshore	longline			
	0.119	0.107			
Additional sigma (survey)	0.402				

V) *M. capensis* as New Reference Case but M_{5+}<=0.5 for both species

		Offshore	Inshore	Longline	Handline
K^{sp}	511				
K^{ex}	455	449	318	282	406
$B^{sp}{}_y$	315				
$B^{ex}{}_y$	266	260	238	132	227
h	0.615				
$MSYL^{sp}$	181	183	159	258	189
$MSYL^{ex}$	134	123	128	57	100
MSY	66	68	53	77	71
$B^{sp}{}_y/K^{sp}$	0.616				
$B^{ex}{}_y/K^{ex}$	0.586	0.578	0.748	0.469	0.560
$B^{sp}{}_y/MSYL^{sp}$	1.735	1.719	1.974	1.218	1.661
$B^{ex}{}_y/MSYL^{ex}$	1.987	2.102	1.858	2.339	2.262
$MSYL^{sp}/K^{sp}$	0.355	0.358	0.312	0.506	0.371
$MSYL^{ex}/K^{ex}$	0.295	0.275	0.403	0.201	0.248

Age	M_a	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	**0.50**	0.21	0.04	0.59	0.05	0.00	0.00	0.00	0.00
1	**0.50**	0.40	0.82	0.51	0.11	0.00	0.01	0.00	0.00
2	**0.50**	1.00	1.00	0.56	0.25	0.01	0.08	0.00	0.01
3	**0.50**	0.78	0.88	1.00	0.40	0.08	0.57	0.00	0.05
4	**0.50**	0.37	0.43	0.52	0.85	0.57	0.95	0.01	0.33
5	**0.50**	0.34	0.61	0.29	1.00	0.95	1.00	0.22	0.81
6	**0.50**	0.47	0.41	0.31	0.92	1.00	0.39	0.67	0.98
7+	**0.50**	0.18	0.22	0.11	0.51	1.00	0.15	1.00	1.00

Commercial:	Sigmas:	*q* 's:	*cap* only	mixed	
South coast hist.CPUE	0.250 *		0.224	9.032×10^{-6}	
West coast hist.CPUE	0.250 *		0.025	1.025×10^{-6}	
GLM CPUE	0.150 *		0.017		
Survey *q* 's:	WC sum	WC wint	WC Nan	SC spr	SC aut
	0.613	0.478	1.293	0.556	0.653
new *Africana*	0.406	-	-	0.338	0.394
Catches-at-age sigma's:	WC sum	WC wint	WC Nan	SC spr	SC aut
	0.240	0.139	0.077	0.112	0.126
	inshore	longline			
	0.127	0.108			
Additional sigma (survey)	0.405				

VI) *M. capensis* as New Reference Case but *h* =0.8 for both species

		Offshore	Inshore	Longline	Handline
K^{sp}	354				
K^{ex}	240	258	249	150	226
$B^{sp}{}_y$	230				
$B^{ex}{}_y$	130	143	189	57	116
h	**0.800**				
$MSYL^{sp}$	141	138	76	238	164
$MSYL^{ex}$	53	48	69	37	47
MSY	67	67	73	50	63
$B^{sp}{}_y/K^{sp}$	0.650				
$B^{ex}{}_y/K^{ex}$	0.541	0.554	0.758	0.378	0.515
$B^{sp}{}_y/MSYL^{sp}$	1.639	1.670	3.039	0.969	1.404
$B^{ex}{}_y/MSYL^{ex}$	2.434	3.001	2.722	1.539	2.463
$MSYL^{sp}/K^{sp}$	0.397	0.389	0.214	0.671	0.463
$MSYL^{ex}/K^{ex}$	0.222	0.185	0.278	0.246	0.209

Age	M_a	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	1.34	0.01	0.00	0.05	0.00	0.00	0.00	0.00	0.00
1	1.34	0.05	0.15	0.10	0.01	0.00	0.00	0.00	0.00
2	1.34	0.32	0.42	0.24	0.06	0.00	0.02	0.00	0.00
3	1.01	0.57	0.73	1.00	0.18	0.02	0.33	0.00	0.02
4	0.81	0.45	0.54	0.85	0.56	0.33	0.91	0.00	0.17
5	0.67	0.56	1.00	0.64	0.88	0.91	1.00	0.14	0.66
6	0.58	1.00	0.85	0.91	1.00	1.00	0.53	0.52	0.95
7+	0.50	0.55	0.61	0.45	0.76	1.00	0.28	1.00	1.00

Commercial:	Sigmas:	*q* 's:	*cap* only	mixed	
South coast hist.CPUE	0.250 *		0.708	9.032×10^{-6}	
West coast hist.CPUE	0.250 *		0.081	1.025×10^{-6}	
GLM CPUE	0.150 *		0.030		
Survey *q* 's:	WC sum	WC wint	WC Nan	SC spr	SC aut
	0.456	0.406	0.706	0.889	1.035
new *Africana*	0.303	-	-	0.541	0.626
Catches-at-age sigma's:	WC sum	WC wint	WC Nan	SC spr	SC aut
	0.242	0.142	0.078	0.109	0.127
	inshore	longline			
	0.120	0.108			
Additional sigma (survey)	0.403				

* constraint boundary

Table 2: ***M. capensis*** continued

VII) *M. capensis* as New Reference Case but including unreported catches on the south coast

		Offshore	Inshore	Longline	Handline				
K^{sp}	456								
K^{ex}	210	290	373	107	198				
B^{sp}_y	287								
B^{ex}_y	111	166	250	40	101				
h	0.444								
$MSYL^{sp}$	197	185	173	356	239				
$MSYL^{ex}$	56	77	149	36	52				
MSY	67	68	61	49	67				
B^{sp}_y/K^{sp}	0.630								
B^{ex}_y/K^{ex}	0.531	0.572	0.670	0.373	0.507				
$B^{sp}_y/MSYL^{sp}$	1.458	1.550	1.665	0.808	1.205				
$B^{ex}_y/MSYL^{ex}$	1.975	2.169	1.682	1.097	1.925				
$MSYL^{sp}/K^{sp}$	0.432	0.406	0.378	0.779	0.523				
$MSYL^{ex}/K^{ex}$	0.269	0.264	0.399	0.340	0.263				
Age	M_a	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	0.81	0.07	0.01	0.24	0.01	0.00	0.00	0.00	0.00
1	0.81	0.18	0.35	0.28	0.02	0.00	0.00	0.00	0.00
2	0.81	0.60	0.57	0.42	0.06	0.00	0.04	0.00	0.00
3	0.81	0.64	0.69	1.00	0.13	0.04	0.36	0.00	0.01
4	0.81	0.41	0.45	0.69	0.38	0.36	0.89	0.00	0.10
5	0.81	0.51	0.89	0.51	0.62	0.89	1.00	0.08	0.46
6	0.81	1.00	0.89	0.78	0.82	1.00	0.68	0.33	0.88
7+	0.81	0.82	1.00	0.63	1.00	1.00	0.46	1.00	1.00
Commercial:	Sigmas:		*q*'s:	*cap* only	mixed				
South coast hist.CPUE	0.250 *			0.362	9.032×10^{-6}				
West coast hist.CPUE	0.250 *			0.041	1.025×10^{-6}				
GLM CPUE	0.150 *			0.027					
Survey *q*'s:	WC sum	WC wint	WC Nan	SC spr	SC aut				
	0.370	0.355	0.646	0.973	1.121				
new *Africana*	0.246	-	-	0.592	0.678				
Catches-at-age sigma's:	WC sum	WC wint	WC Nan	SC spr	SC aut				
	0.242	0.142	0.079	0.106	0.127				
	inshore	longline							
	0.119	0.107							
Additional sigma (survey)	0.402								

VIII) *M. capensis* as New Reference Case but different calibration factor btw old and new *Africana* for *M. cap*

		Offshore	Inshore	Longline	Handline				
K^{sp}	444								
K^{ex}	207	285	363	106	196				
B^{sp}_y	273								
B^{ex}_y	106	158	238	38	96				
h	0.448								
$MSYL^{sp}$	190	180	167	345	231				
$MSYL^{ex}$	55	75	145	36	51				
MSY	65	66	59	48	66				
B^{sp}_y/K^{sp}	0.614								
B^{ex}_y/K^{ex}	0.514	0.555	0.654	0.359	0.490				
$B^{sp}_y/MSYL^{sp}$	1.435	1.517	1.630	0.792	1.184				
$B^{ex}_y/MSYL^{ex}$	1.933	2.103	1.643	1.063	1.879				
$MSYL^{sp}/K^{sp}$	0.428	0.405	0.377	0.776	0.519				
$MSYL^{ex}/K^{ex}$	0.266	0.264	0.398	0.337	0.261				
Age	M_a	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	0.80	0.07	0.01	0.25	0.01	0.00	0.00	0.00	0.00
1	0.80	0.18	0.36	0.29	0.02	0.00	0.00	0.00	0.00
2	0.80	0.62	0.58	0.43	0.06	0.00	0.04	0.00	0.00
3	0.80	0.65	0.69	1.00	0.14	0.04	0.36	0.00	0.01
4	0.80	0.41	0.45	0.68	0.38	0.36	0.89	0.00	0.10
5	0.80	0.51	0.89	0.50	0.62	0.89	1.00	0.08	0.46
6	0.80	1.00	0.89	0.77	0.82	1.00	0.68	0.33	0.88
7+	0.80	0.83	1.00	0.62	1.00	1.00	0.46	1.00	1.00
Commercial:	Sigmas:		*q*'s:	*cap* only	mixed				
South coast hist.CPUE	0.250 *			0.355	9.032×10^{-6}				
West coast hist.CPUE	0.250 *			0.041	1.025×10^{-6}				
GLM CPUE	0.150 *			0.028					
Survey *q*'s:	WC sum	WC wint	WC Nan	SC spr	SC aut				
	0.379	0.369	0.682	0.992	1.140				
new *Africana*	0.315	-	-	0.767	0.861				
Catches-at-age sigma's:	WC sum	WC wint	WC Nan	SC spr	SC aut				
	0.242	0.142	0.080	0.105	0.127				
	inshore	longline							
	0.119	0.107							
Additional sigma (survey)	0.393								

IX) *M. capensis* as New Reference Case but different logistic function for offshore historic species-split

		Offshore	Inshore	Longline	Handline				
K^{sp}	295								
K^{ex}	187	215	219	118	180				
B^{sp}_y	187								
B^{ex}_y	91	112	160	36	83				
h	0.893								
$MSYL^{sp}$	132	120	52	208	149				
$MSYL^{ex}$	47	43	51	31	41				
MSY	58	59	70	42	54				
B^{sp}_y/K^{sp}	0.633								
B^{ex}_y/K^{ex}	0.489	0.520	0.729	0.310	0.462				
$B^{sp}_y/MSYL^{sp}$	1.411	1.552	3.580	0.897	1.253				
$B^{ex}_y/MSYL^{ex}$	1.963	2.621	3.143	1.191	2.037				
$MSYL^{sp}/K^{sp}$	0.449	0.408	0.177	0.706	0.505				
$MSYL^{ex}/K^{ex}$	0.249	0.198	0.232	0.260	0.227				
Age	M_a	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	1.26	0.02	0.00	0.06	0.00	0.00	0.00	0.00	0.00
1	1.26	0.06	0.17	0.12	0.01	0.00	0.00	0.00	0.00
2	1.26	0.33	0.43	0.27	0.06	0.00	0.03	0.00	0.00
3	0.96	0.56	0.71	1.00	0.17	0.03	0.34	0.00	0.02
4	0.79	0.43	0.52	0.80	0.52	0.34	0.91	0.00	0.15
5	0.67	0.53	1.00	0.61	0.82	0.91	1.00	0.11	0.60
6	0.59	1.00	0.95	0.92	1.00	1.00	0.60	0.45	0.93
7+	0.52	0.67	0.81	0.56	0.94	1.00	0.35	1.00	1.00
Commercial:	Sigmas:		*q*'s:	*cap* only	mixed				
South coast hist.CPUE	0.250 *			0.083	9.032×10^{-6}				
West coast hist.CPUE	0.250 *			0.010	1.025×10^{-6}				
GLM CPUE	0.150 *			0.038					
Survey *q*'s:	WC sum	WC wint	WC Nan	SC spr	SC aut				
	0.566	0.496	0.853	1.153	1.317				
new *Africana*	0.376	-	-	0.701	0.798				
Catches-at-age sigma's:	WC sum	WC wint	WC Nan	SC spr	SC aut				
	0.244	0.145	0.079	0.106	0.128				
	inshore	longline							
	0.118	0.107							
Additional sigma (survey)	0.399								

* constraint boundary

Table 3: Likelihood contributions for cases I to IX. The differences in the likelihood contribution for cases V to IX compared to the New Reference Case are shown in parenthesis.

		I') December 2004 Reference Case	I) December 2004 Reference Case - error corrected	II) Joint assessment with catches as in December 2004 Reference Case	III) Joint assessment with changing species proportion in historic catches	IV) New Reference Case (as III but offshore selectivity for *M. capensis* shifted one year to the right)	V) as New Reference Case but M_{5+}<=0.5 for both species	VI) as New Reference Case but *h* =0.8 for both species	VII) as New Reference Case but including unreported catches on the south coast	VIII) as New Reference Case but different calibration factor between old and new *Africana* for *M. capensis* (see text for details)	IX) as New Reference Case but different logistic function for offshore historic species-split
-lnL: Total				-178.5	-180.8	-183.8	-180.3 (3.6)	-173.9 (9.9)	-183.9 -(0.1)	-184.4 -(0.6)	-180.8 (3.1)
-lnL: CPUE	WC historic (spp combined)	(-10.1) + (-10.3)	(-10.1) + (-10.3)	-10.3	-10.4	-10.7	-10.7 (0.0)	-10.2 (0.5)	-10.7 (0.0)	-10.7 (0.0)	-11.1 -(0.4)
	SC historic (spp combined)	(-29.0) + (-25.8)	(-29.0) + (-25.8)	-28.2	-27.0	-25.7	-25.4 (0.3)	-28.7 -(3.0)	-25.7 (0.1)	-25.7 (0.0)	-26.4 -(0.6)
	M. paradoxus GLM	-44.3	-44.2	-41.7	-41.3	-42.8	-42.8 -(0.1)	-42.9 -(0.2)	-42.8 (0.0)	-42.8 (0.0)	-42.8 -(0.1)
	M. capensis GLM	-40.9	-40.8	-40.5	-42.5	-42.1	-42.4 -(0.4)	-41.7 (0.4)	-42.1 (0.0)	-42.1 (0.0)	-39.6 (2.5)
-lnL: Survey	*M. paradoxus*, WC summer	-8.9	-9.4	-8.5	-8.4	-8.8	-8.8 (0.0)	-9.4 -(0.5)	-8.8 (0.0)	-8.8 (0.0)	-8.7 (0.1)
	M. paradoxus, WC winter	-4.0	-4.0	-4.1	-4.0	-4.1	-4.2 (0.0)	-4.2 -(0.1)	-4.1 (0.0)	-4.1 (0.0)	-4.1 (0.0)
	M. paradoxus, WC *Nansen*	-2.1	-2.1	-1.9	-1.9	-2.0	-2.0 (0.0)	-2.1 -(0.1)	-2.0 (0.0)	-2.0 (0.0)	-2.0 (0.0)
	M. paradoxus, SC spring	-0.6	-0.6	-0.6	-0.5	-0.6	-0.6 (0.0)	-0.8 -(0.2)	-0.6 (0.0)	-0.6 (0.0)	-0.6 (0.0)
	M. paradoxus, SC autumn	6.8	6.2	6.3	6.4	6.0	6.0 (0.0)	6.4 (0.4)	6.0 (0.0)	6.0 (0.0)	5.9 (0.0)
	M. capensis, WC summer	18.9	-1.1	-0.8	-0.7	-0.8	-0.7 (0.1)	-0.7 (0.1)	-0.7 (0.0)	-1.5 -(0.8)	-0.8 (0.0)
	M. capensis, WC winter	1.6	0.5	0.4	0.3	0.4	0.3 -(0.1)	0.4 (0.0)	0.4 (0.0)	0.5 (0.1)	0.5 (0.0)
	M. capensis, WC *Nansen*	-1.7	-1.4	-1.4	-1.3	-1.4	-1.3 (0.0)	-1.3 (0.0)	-1.4 (0.0)	-1.4 (0.0)	-1.4 (0.0)
	M. capensis, SC spring	22.7	-1.6	-1.6	-1.6	-1.6	-1.6 (0.0)	-1.6 (0.0)	-1.6 (0.0)	-1.6 (0.0)	-1.6 (0.0)
	M. capensis, SC autumn	14.6	-8.1	-7.8	-7.7	-7.7	-7.5 (0.2)	-7.7 (0.0)	-7.7 (0.0)	-7.6 (0.1)	-7.8 -(0.1)
-lnL: commercial CAA	species combined, offshore	-	-	-38.9	-39.2	-41.3	-41.3 (0.0)	-33.4 (8.0)	-41.3 (0.0)	-41.3 (0.0)	-40.9 (0.4)
	M. capensis, inshore	-30.5	-30.6	-29.6	-29.6	-30.5	-25.9 (4.6)	-29.9 (0.6)	-30.5 (0.0)	-30.5 (0.0)	-31.0 -(0.5)
	M. capensis, longline	-14.9	-14.7	-14.9	-15.0	-15.0	-14.8 (0.2)	-14.9 (0.1)	-15.0 (0.0)	-15.0 (0.0)	-15.0 (0.0)
-lnL: survey CAA	*M. paradoxus*, WC summer	-5.7	-5.8	-15.6	-15.5	-15.5	-15.5 (0.0)	-15.0 (0.5)	-15.5 (0.0)	-15.5 (0.0)	-15.7 -(0.2)
	M. paradoxus, WC *Nansen*	-10.7	-10.6	-10.5	-10.5	-10.2	-10.2 (0.0)	-10.3 -(0.1)	-10.2 (0.0)	-10.2 (0.0)	-10.2 (0.0)
	M. paradoxus, SC spring	-10.1	-10.1	-4.3	-4.2	-3.4	-3.4 (0.0)	-2.3 (1.0)	-3.4 (0.0)	-3.4 (0.0)	-3.5 -(0.1)
	M. paradoxus, SC autumn	33.3	33.4	29.0	29.1	28.2	28.2 (0.0)	29.5 (1.3)	28.2 (0.0)	28.2 (0.0)	28.2 (0.0)
	M. capensis, WC summer	87.5	86.5	85.1	84.4	84.4	83.6 -(0.8)	84.5 (0.1)	84.4 (0.0)	84.6 (0.2)	85.4 (1.0)
	M. capensis, WC winter	9.7	9.7	8.2	7.5	8.0	7.2 -(0.8)	8.1 (0.0)	8.0 (0.0)	8.0 (0.0)	8.9 (0.9)
	M. capensis, WC *Nansen*	-4.5	-4.9	-5.6	-5.6	-5.5	-5.9 -(0.4)	-5.7 -(0.2)	-5.5 (0.0)	-5.4 (0.1)	-5.5 (0.0)
	M. capensis, SC spring	-11.3	-10.2	-9.5	-9.9	-9.9	-9.0 (0.8)	-9.5 (0.4)	-9.8 (0.0)	-10.0 -(0.2)	-9.9 (0.0)
	M. capensis, SC autumn	-26.5	-27.6	-29.4	-30.0	-30.0	-30.5 -(0.6)	-29.9 (0.1)	-30.0 (0.0)	-29.8 (0.1)	-29.2 (0.8)
Recruit residual penalty		(3.5) + (3.3)	(3.5) + (3.6)	13.8	14.0	14.1	14.5 (0.3)	14.3 (0.2)	14.1 (0.0)	14.0 -(0.1)	13.7 -(0.4)

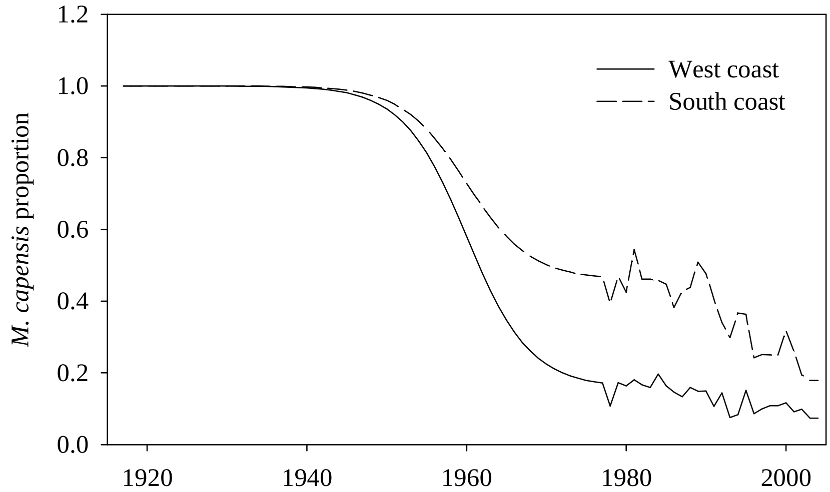

Fig. 1: Assumed proportion of *M. capensis* in the offshore catches for the west and south coasts for the Reference Case.

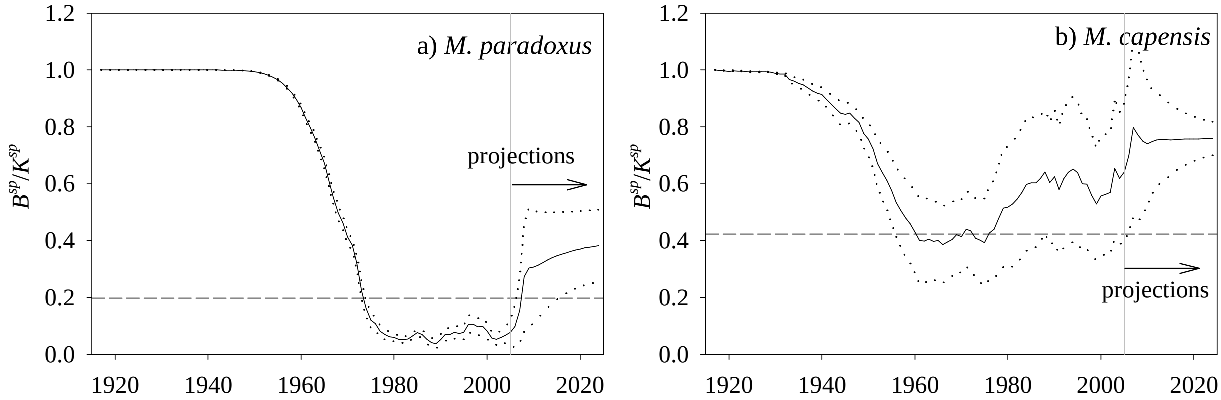

Fig. 2: Resource abundance trajectories (expressed in terms of spawning biomass as a proportion of its pre-exploitation equilibrium level) for the New Reference Case assessment (Case IV) of the *M. paradoxus* (a) and *M. capensis* (b) resources for the south and west coasts combined. The 90% CIs shown (dotted lines) are Hessian-based. Projections assume future catches of 120 and 40 thousand tons for *M. paradoxus* and *M. capensis* respectively.

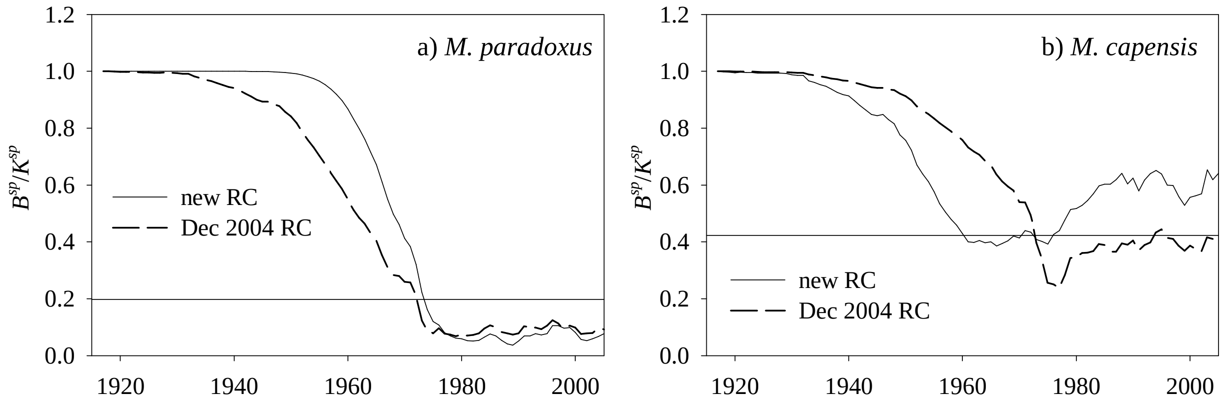

Fig. 3: Resource abundance trajectories for the New Reference Case assessment (Case IV) of the coast-combined *M. paradoxus* (a) and *M. capensis* (b) resources, and for the corresponding December 2004 Reference Case (Case I) (Rademeyer and Butterworth, 2004).

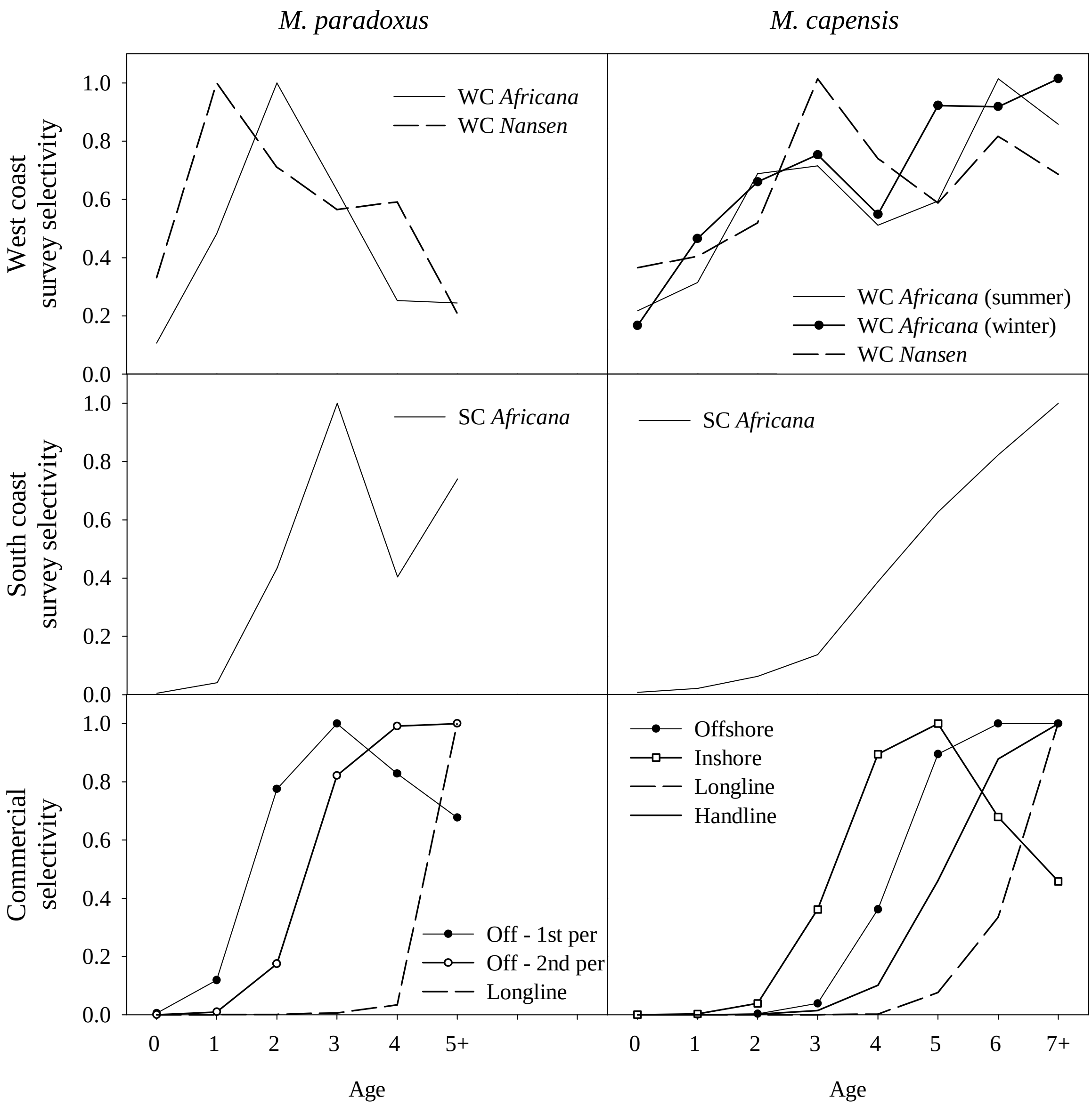

Fig. 4: Survey and commercial selectivity functions estimated for the *M. paradoxus* and *M. capensis* resource for both coasts combined, for the New Reference Case assessment (Case IV).

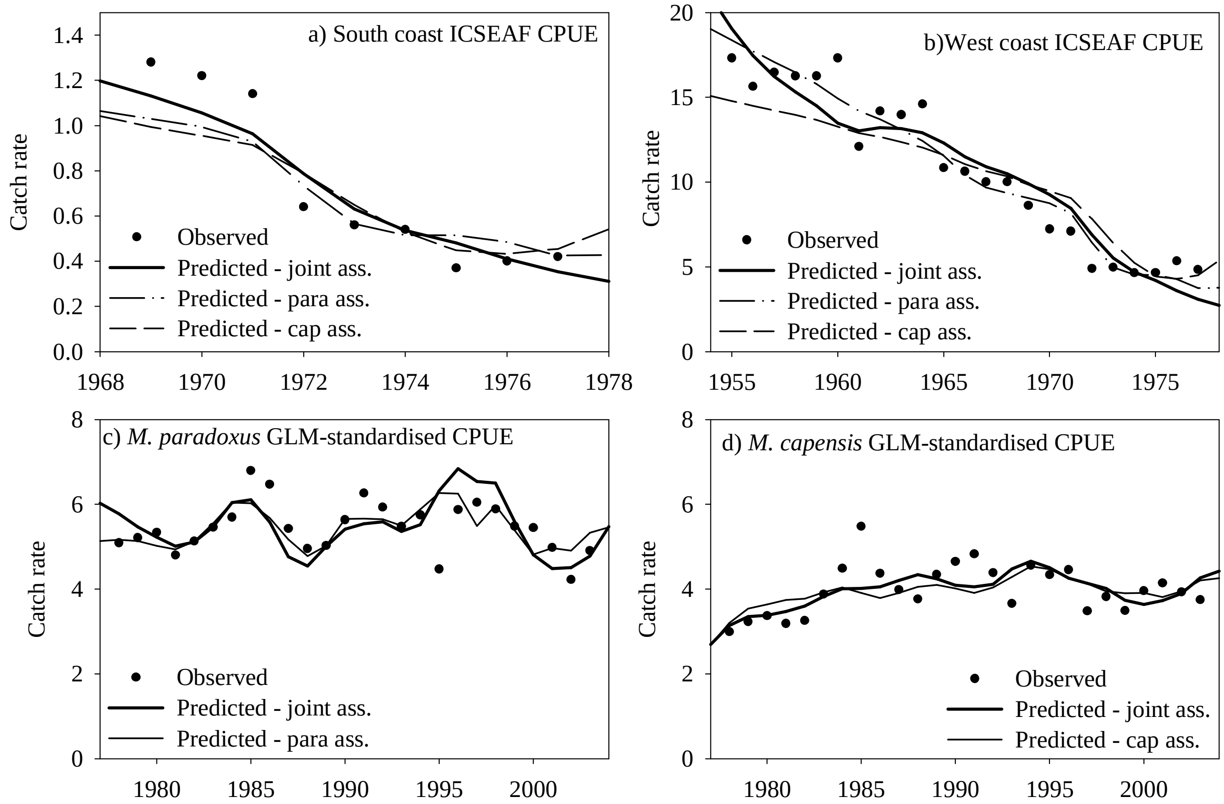

Fig. 5: New Reference Case fits to the CPUE abundance indices. The fits of the December 2004 Reference Case are also shown for comparison. The historic (pre-1978) CPUE data are for both *M. capensis* and *M. paradoxus* combined.

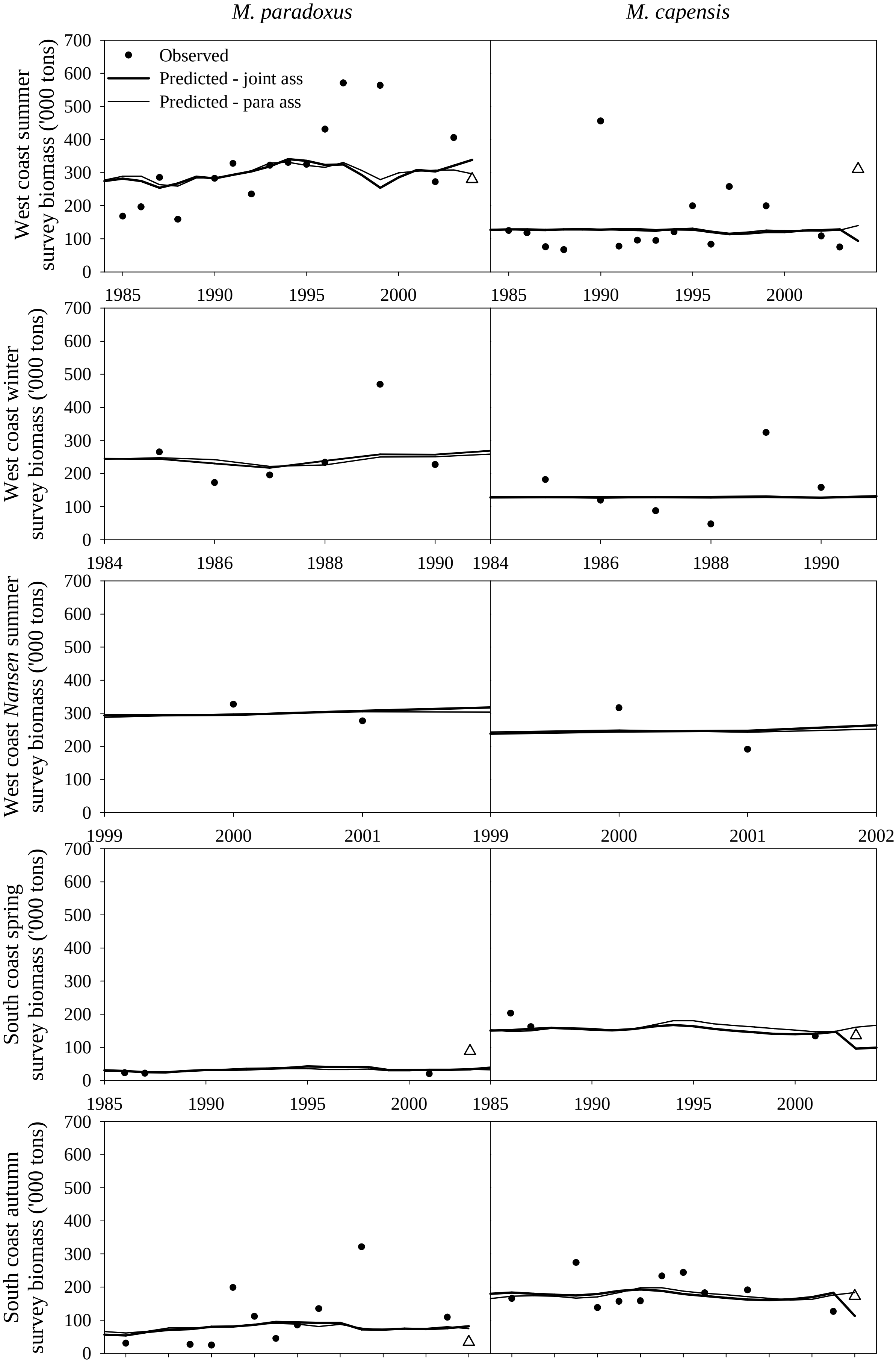

Fig. 6: New Reference Case fits to the survey abundance indices. The fits of the December 2004 Reference Case are also shown for comparison. Biomass estimates from surveys conducted with the new *Africana* gear have been rescaled by the ratio of the *q*'s estimated and are marked by Δ.

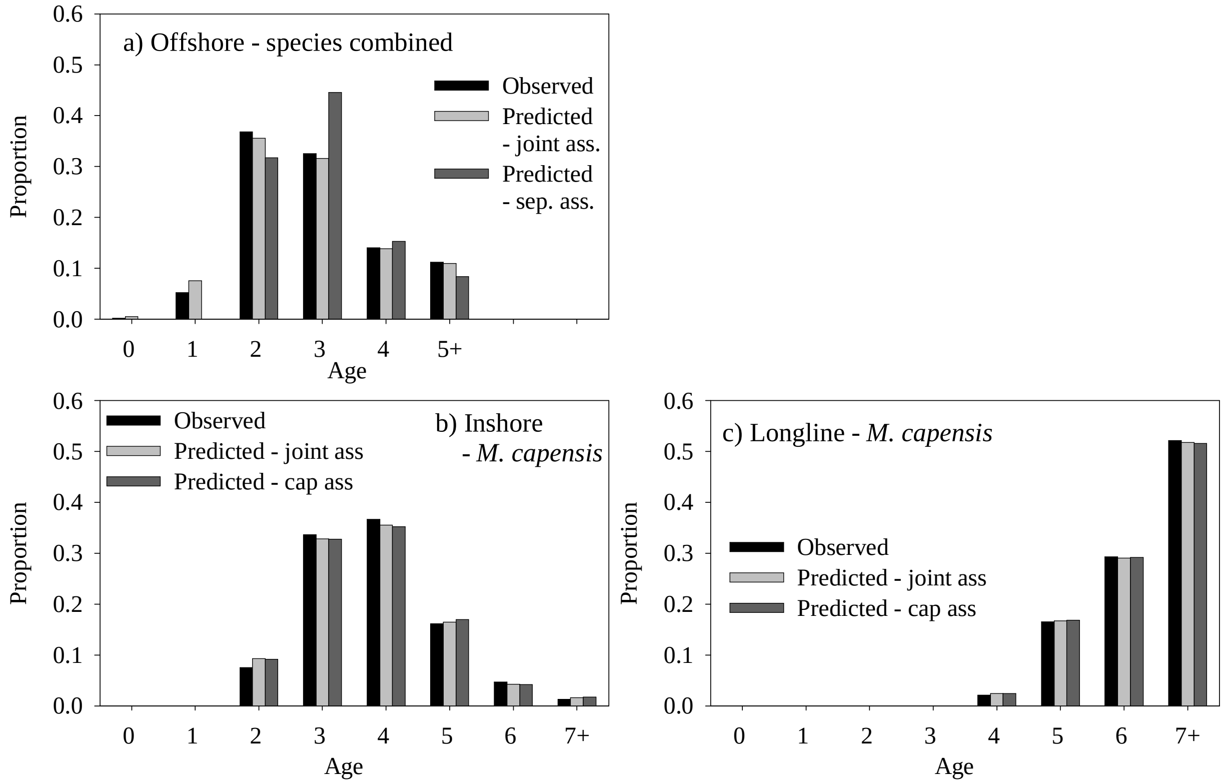

Fig. 7: New Reference Case assessment model fits to commercial catch-at-age data. The fits of the December 2004 Reference Case are also shown for comparison; note however that that assessment was not fit to the species-combined offshore catch-at-age data.

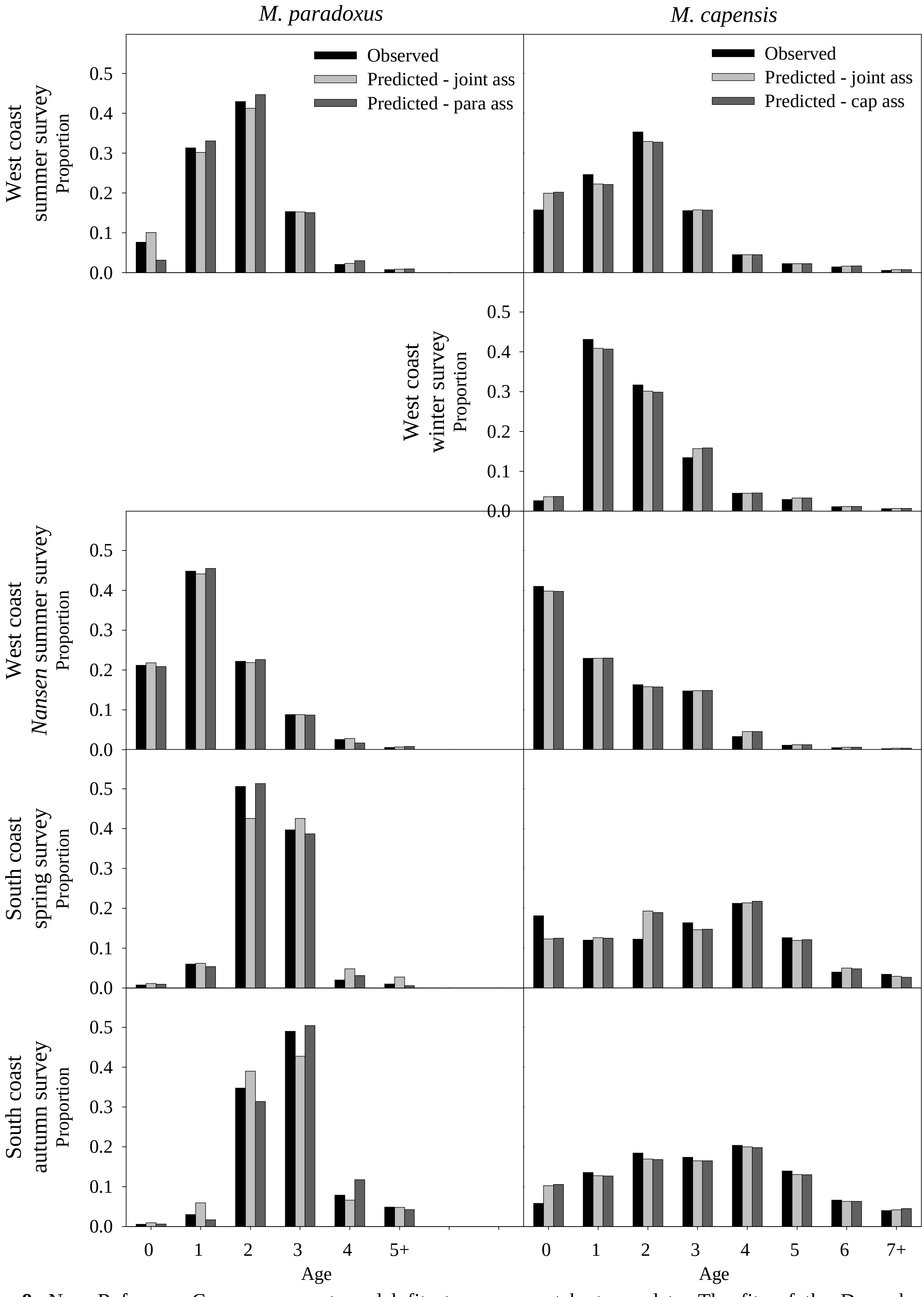

Fig. 8: New Reference Case assessment model fits to survey catch-at-age data. The fits of the December 2004 Reference Case are also shown for comparison.

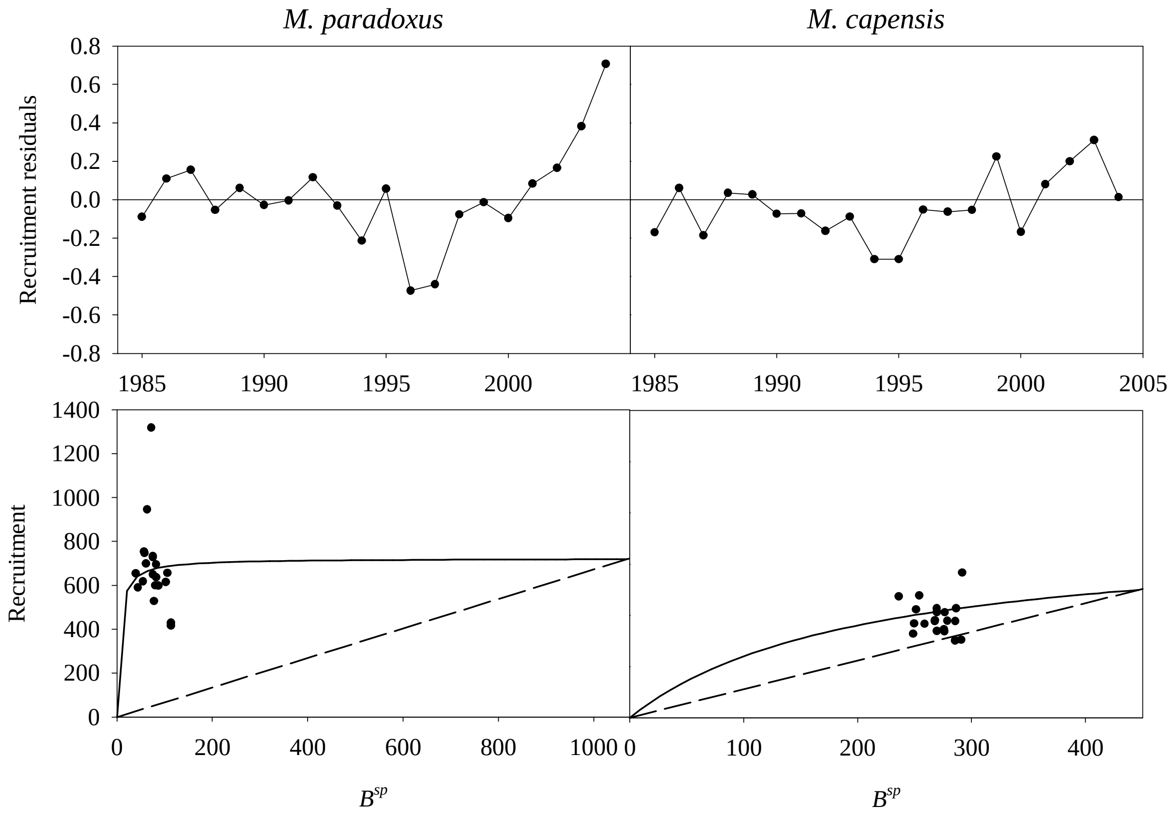

Fig. 9: Recruitment residuals for the New Reference Case assessment and the estimated stock-recruitment relationships. The straight dashed line through the origin is the replacement line which intersects the stock-recruit curve at a spawning biomass of K^{sp}.

Appendix A - Data Tables

Table A1: Assumed total annual catches by species, coast and fleet for the period 1917 to 2004 (see Data section of text for details) for the South African hake resource. Catches are given in thousand tons.

Year	Offshore Fleet				Inshore Fleet		Longline Fleet				Handline Fleet	
	West coast		South coast		South coast		West coast		South coast		South coast	
	M. cap	*M. para*	*M. cap*	*M. para*	*M. cap*	*M. para*	*M. cap*	*M. para*	*M. cap*	*M. para*	*M. cap*	*M. para*
1917	1.000	0.000	0.000	0.000								
1918	1.100	0.000	0.000	0.000								
1919	1.900	0.000	0.000	0.000								
1920	0.000	0.000	0.000	0.000								
1921	1.300	0.000	0.000	0.000								
1922	1.000	0.000	0.000	0.000								
1923	2.500	0.000	0.000	0.000								
1924	1.500	0.000	0.000	0.000								
1925	1.900	0.000	0.000	0.000								
1926	1.400	0.000	0.000	0.000								
1927	0.800	0.000	0.000	0.000								
1928	2.599	0.001	0.000	0.000								
1929	3.799	0.001	0.000	0.000								
1930	4.398	0.002	0.000	0.000								
1931	2.798	0.002	0.000	0.000								
1932	14.289	0.011	0.000	0.000								
1933	11.089	0.011	0.000	0.000								
1934	13.783	0.017	0.000	0.000								
1935	14.976	0.024	0.000	0.000								
1936	17.663	0.037	0.000	0.000								
1937	20.146	0.054	0.000	0.000								
1938	21.028	0.072	0.000	0.000								
1939	19.912	0.088	0.000	0.000								
1940	28.439	0.161	0.000	0.000								
1941	30.380	0.220	0.000	0.000								
1942	34.182	0.318	0.000	0.000								
1943	37.452	0.448	0.000	0.000								
1944	33.585	0.515	0.000	0.000								
1945	28.636	0.564	0.000	0.000								
1946	39.405	0.995	0.000	0.000								
1947	40.102	1.298	0.000	0.000								
1948	56.458	2.342	0.000	0.000								
1949	54.503	2.897	0.000	0.000								
1950	67.412	4.588	0.000	0.000								
1951	82.332	7.168	0.000	0.000								
1952	79.908	8.892	0.000	0.000								
1953	81.872	11.628	0.000	0.000								
1954	89.249	16.151	0.000	0.000								
1955	93.812	21.588	0.000	0.000								
1956	91.497	26.703	0.000	0.000								
1957	92.336	34.064	0.000	0.000								
1958	89.251	41.449	0.000	0.000								
1959	92.305	53.695	0.000	0.000								

Table A1: continued

Year	Offshore Fleet				Inshore Fleet		Longline Fleet				Handline Fleet	
	West coast		South coast		South coast		West coast		South coast		South coast	
	M. cap	*M. para*	*M. cap*	*M. para*	*M. cap*	*M. para*	*M. cap*	*M. para*	*M. cap*	*M. para*	*M. cap*	*M. para*
1960	92.742	67.158	0.000	0.000	1.000							
1961	78.480	70.220	0.000	0.000	1.308							
1962	70.425	77.175	0.000	0.000	1.615							
1963	72.799	96.701	0.000	0.000	1.923							
1964	62.633	99.667	0.000	0.000	2.231							
1965	70.455	132.545	0.000	0.000	2.538							
1966	61.081	133.919	0.000	0.000	2.846							
1967	50.246	126.454	7.660	6.526	3.154							
1968	37.355	106.245	14.634	13.274	3.462							
1969	39.639	125.461	19.401	18.530	3.769							
1970	31.880	110.620	11.884	11.839	4.077							
1971	42.516	159.484	14.830	15.285	4.385							
1972	48.747	195.186	22.676	24.020	4.692							
1973	30.192	127.590	34.742	37.614	5.000							
1974	22.709	100.291	43.230	47.623	10.056							
1975	16.068	73.549	31.870	35.593	6.372							
1976	25.197	118.697	24.392	27.538	5.740							
1977	17.581	84.747	17.288	19.684	3.500							
1978	10.885	90.255	13.386	20.572	4.931							
1979	15.993	76.711	22.381	25.357	4.931							
1980	16.635	84.903	16.333	22.117	4.931							
1981	18.201	82.477	13.983	11.755	9.400							
1982	14.324	71.646	17.881	20.856	8.089							
1983	11.712	61.735	15.427	18.075	7.672		0.069	0.161				
1984	17.350	70.695	15.606	18.539	9.035		0.110	0.256	0.016			
1985	16.065	82.358	20.837	25.826	9.203		0.350	0.817	0.292		0.065	
1986	15.757	91.956	16.066	25.991	8.724		0.413	0.965	0.302		0.084	
1987	13.365	87.074	14.004	18.766	8.607		1.071	2.500	0.353		0.096	
1988	13.484	71.464	15.831	20.319	8.417		1.555	3.628	0.331		0.071	
1989	12.568	72.038	21.133	20.432	10.038		0.087	0.203	0.032		0.137	
1990	11.760	66.772	22.842	25.054	10.012		0.116	0.270	0.000		0.348	
1991	9.111	76.410	17.417	25.586	8.206		0.000	0.000	3.000		1.270	
1992	12.369	73.911	14.775	28.694	9.252		0.000	0.000	1.500		1.099	
1993	7.423	90.687	10.196	24.019	8.870		0.000	0.000	0.000		0.278	
1994	8.402	92.801	12.351	21.365	9.569		0.484	1.130	0.626		0.449	
1995	14.166	79.634	12.433	21.814	10.630		0.287	0.670	0.650		0.756	
1996	7.637	81.264	12.972	40.591	11.062		0.718	1.676	1.828		1.515	
1997	8.991	81.501	10.660	31.838	8.834		0.774	1.806	1.872		1.404	
1998	11.723	96.615	8.333	25.135	8.283		0.277	0.647	1.471		1.738	
1999	8.853	73.097	9.289	27.868	8.595		0.841	1.963	4.144		2.749	
2000	10.656	80.619	12.691	27.266	10.906		1.481	3.456	2.077		5.500	
2001	8.484	83.835	10.550	29.809	11.692		1.197	2.793	1.688		7.300	
2002	7.913	71.994	8.352	34.613	9.448		2.045	4.772	3.945		4.500	
2003	5.034	63.616	7.668	35.280	9.787		2.000	4.668	4.878		5.941	
2004	5.836	73.752	8.890	40.902	11.346		2.319	5.411	5.655		6.888	

Table A2: South and west coast historic and coast-combined GLM standardised (1978 to 2003) CPUE data (J. Glazer, 2004) for *M. paradoxus* and *M. capensis*. The historic CPUE series are for *M. capensis* and *M. paradoxus* combined.

Year	South coast Species combined ICSEAF CPUE tons/hr	West coast Species combined ICSEAF CPUE tons/day	Coasts combined *M. capensis* GLM CPUE kg/min	Coasts combined *M. paradoxus* GLM CPUE kg/min
1955		17.31		
1956		15.64		
1957		16.47		
1958		16.26		
1959		16.26		
1960		17.31		
1961		12.09		
1962		14.18		
1963		13.97		
1964		14.60		
1965		10.84		
1966		10.63		
1967		10.01		
1968		10.01		
1969	1.28	8.62		
1970	1.22	7.23		
1971	1.14	7.09		
1972	0.64	4.90		
1973	0.56	4.97		
1974	0.54	4.65		
1975	0.37	4.66		
1976	0.40	5.35		
1977	0.42	4.84		
1978			2.994	5.089
1979			3.230	5.209
1980			3.371	5.335
1981			3.189	4.801
1982			3.258	5.128
1983			3.880	5.458
1984			4.487	5.693
1985			5.478	6.794
1986			4.370	6.471
1987			3.983	5.425
1988			3.766	4.956
1989			4.341	5.027
1990			4.652	5.633
1991			4.829	6.262
1992			4.385	5.930
1993			3.659	5.477
1994			4.560	5.746
1995			4.336	4.471
1996			4.457	5.875
1997			3.486	6.044
1998			3.821	5.887
1999			3.493	5.482
2000			3.958	5.445
2001			4.143	4.980
2002			3.932	4.223
2003			3.747	4.906

Table A3: Survey abundance estimates and associated standard errors in thousand tons for ***M. paradoxus*** for the depth range 0-500m for the south coast and for the west coast.

Year	South coast				West coast					
	Spring (Sept)		Autumn (Apr/May)		Summer		Winter		*Nansen* summer	
	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)
1985	-	-	-	-	168.139	(36.607)	264.916	(52.968)	-	-
1986	23.049	(5.946)	-	-	196.151	(36.366)	172.522	(24.129)	-	-
1987	21.545	(4.601)	-	-	284.859	(53.108)	195.530	(44.425)	-	-
1988	-	-	30.236	(11.084)	158.796	(27.390)	233.103	(64.016)	-	-
1989	-	-	-	-	-	-	468.928	(124.878)	-	-
1990	-	-	-	-	282.225	(78.956)	226.910	(46.016)	-	-
1991	-	-	26.604	(10.431)	327.105	(82.209)	-	-	-	-
1992	-	-	24.305	(15.197)	234.699	(33.963)	-	-	-	-
1993	-	-	198.403	(98.423)	321.782	(48.799)	-	-	-	-
1994	-	-	111.354	(34.622)	329.927	(58.332)	-	-	-	-
1995	-	-	44.618	(19.823)	324.626	(80.370)	-	-	-	-
1996	-	-	85.530	(25.485)	430.971	(80.614)	-	-	-	-
1997	-	-	134.656	(50.922)	570.091	(108.230)	-	-	-	-
1998	-	-	-	-	-	-	-	-	-	-
1999	-	-	321.328	(113.520)	562.988	(116.322)	-	-	-	-
2000	-	-	-	-	-	-	-	-	326.994	(36.816)
2001	19.930	(9.957)	-	-	-	-	-	-	276.604	(34.833)
2002	-	-	-	-	272.177	(35.586)	-	-	-	-
2003	88.431	(36.054)	108.756	(37.529)	405.457	(68.882)	-	-	-	-
2004			31.653	(25.906)	259.566	(56.034)	-	-	-	-

Table A4: Survey abundance estimates and associated standard errors in thousand tons for ***M. capensis*** for the depth range 0-500m for the south coast and for the west coast.

Year	South coast				West coast					
	Spring (Sept)		Autumn (Apr/May)		Summer		Winter		*Nansen* summer	
	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)
1985	-	-	-	-	124.652	(22.709)	181.517	(27.480)	-	-
1986	202.871	(27.845)	-	-	117.829	(23.639)	119.609	(18.492)	-	-
1987	162.282	(17.512)	-	-	75.705	(10.242)	87.407	(11.201)	-	-
1988	-	-	165.184	(21.358)	66.737	(10.767)	47.129	(9.570)	-	-
1989	-	-	-	-	-	-	323.879	(67.303)	-	-
1990	-	-	-	-	455.861	(135.253)	157.826	(23.565)	-	-
1991	-	-	273.897	(44.363)	77.369	(14.997)	-	-	-	-
1992	-	-	137.798	(15.317)	95.568	(11.753)	-	-	-	-
1993	-	-	156.533	(13.628)	94.564	(17.346)	-	-	-	-
1994	-	-	158.243	(23.607)	120.206	(35.885)	-	-	-	-
1995	-	-	233.359	(31.862)	199.173	(26.816)	-	-	-	-
1996	-	-	243.934	(25.035)	83.347	(9.287)	-	-	-	-
1997	-	-	182.157	(18.601)	257.332	(46.062)	-	-	-	-
1998	-	-	-	-	-	-	-	-	-	-
1999	-	-	190.864	(14.929)	198.748	(32.471)	-	-	-	-
2000	-	-	-	-	-	-	-	-	316.105	(42.077)
2001	133.533	(20.845)	-	-	-	-	-	-	191.068	(25.780)
2002	-	-	-	-	108.025	(16.086)	-	-	-	-
2003	82.726	(89.940)	126.313	(19.986)	74.771	(12.989)	-	-	-	-
2004			104.763	(12.867)	205.976	(33.221)	-	-	-	-

Table A5: Summer survey catches-at-age (proportions) of ***M. paradoxus*** on the west coast for the 0-500m depth range.

	Proportions caught at age: *Merluccius paradoxus*					
Age	0	1	2	3	4	5+
1990	0.0285	0.3098	0.4918	0.1583	0.0088	0.0017
1991	0.0182	0.2777	0.5608	0.1069	0.0240	0.0079
1992	0.0098	0.3834	0.4847	0.0824	0.0231	0.0118
1993	0.0089	0.1995	0.5469	0.1866	0.0439	0.0097
1994	0.0107	0.2441	0.5508	0.1656	0.0174	0.0078
1995	0.0651	0.1905	0.4435	0.2583	0.0282	0.0096
1996	0.0572	0.3939	0.3018	0.2096	0.0298	0.0050
1997	0.0055	0.1708	0.5459	0.2564	0.0164	0.0032
1998	-	-	-	-	-	-
1999	0.1613	0.4099	0.3358	0.0808	0.0084	0.0026
2000	-	-	-	-	-	-
2001	-	-	-	-	-	-
2002	0.1828	0.4572	0.2551	0.0837	0.0132	0.0080
2003	0.1514	0.3704	0.3394	0.1184	0.0107	0.0098
2004	0.2144	0.3438	0.2842	0.1240	0.0262	0.0073

Table A6: *Nansen* summer survey catches-at-age (proportions) of ***M. paradoxus*** on the west coast for the 0-500m depth range.

	Proportions caught at age: *Merluccius paradoxus*					
Age	0	1	2	3	4	5+
2000	0.2612	0.4600	0.2041	0.0561	0.0151	0.0035
2001	0.1627	0.4360	0.2396	0.1191	0.0354	0.0072

Table A7: Spring survey catches-at-age (proportions) of ***M. paradoxus*** on the south coast for the 0-500m depth range.

	Proportions caught at age: *Merluccius paradoxus*					
Age	0	1	2	3	4	5+
2001	0.0066	0.0852	0.5182	0.3689	0.0154	0.0057
2002	-	-	-	-	-	-
2003	0.0083	0.0342	0.4936	0.4250	0.0244	0.0145

Table A8: Autumn survey catches-at-age (proportions) of ***M. paradoxus*** on the south coast for the 0-500m depth range.

	Proportions caught at age: *Merluccius paradoxus*					
Age	0	1	2	3	4	5+
1991	0.0038	0.0099	0.5219	0.2920	0.1162	0.0563
1992	0.0000	0.0006	0.3698	0.5407	0.0653	0.0236
1993	0.0000	0.0047	0.4157	0.5439	0.0260	0.0097
1994	0.0054	0.0898	0.6558	0.1857	0.0170	0.0463
1995	0.0002	0.0002	0.1241	0.7729	0.0886	0.0139
1996	0.0000	0.0000	0.0968	0.7494	0.0999	0.0539
1997	0.0002	0.0012	0.1108	0.5806	0.1055	0.2016
1998	-	-	-	-	-	-
1999	0.0001	0.0140	0.2155	0.5266	0.1898	0.0540
2000	-	-	-	-	-	-
2001	-	-	-	-	-	-
2002	-	-	-	-	-	-
2003	0.0003	0.0409	0.5624	0.3427	0.0333	0.0204
2004	0.0439	0.1365	0.4040	0.3684	0.0411	0.0060

Table A19: Summer survey catches-at-age (proportions) of ***M. capensis*** on the west coast for the 0-500m depth range.

	Proportions caught-at-age: *Merluccius capensis*							
Age	0	1	2	3	4	5	6	7+
1986	0.034	0.230	0.603	0.085	0.023	0.014	0.008	0.003
1987	0.024	0.113	0.465	0.223	0.139	0.022	0.010	0.004
1988	0.280	0.483	0.135	0.059	0.018	0.015	0.009	0.002
1989	-	-	-	-	-	-	-	-
1990	0.004	0.325	0.635	0.023	0.009	0.003	0.001	0.000
1991	0.072	0.122	0.644	0.097	0.038	0.017	0.009	0.002
1992	0.131	0.260	0.313	0.162	0.078	0.025	0.019	0.010
1993	0.038	0.176	0.207	0.399	0.088	0.057	0.024	0.011
1994	0.081	0.253	0.208	0.262	0.075	0.054	0.048	0.020
1995	0.001	0.147	0.739	0.066	0.021	0.018	0.005	0.003
1996	0.065	0.368	0.205	0.237	0.066	0.023	0.025	0.011
1997	0.036	0.141	0.384	0.407	0.014	0.010	0.004	0.003
1998	-	-	-	-	-	-	-	-
1999	0.867	0.059	0.024	0.026	0.011	0.008	0.005	0.001
2000	-	-	-	-	-	-	-	-
2001	-	-	-	-	-	-	-	-
2002	0.351	0.425	0.100	0.062	0.032	0.019	0.009	0.002
2003	0.250	0.225	0.223	0.142	0.053	0.054	0.039	0.014
2004	0.125	0.367	0.411	0.086	0.007	0.002	0.001	0.001

Table A10: Winter survey catches-at-age (proportions) of ***M. capensis*** on the west coast for the 0-500m depth range.

	Proportions caught-at-age: *Merluccius capensis*							
Age	0	1	2	3	4	5	6	7+
1985	-	-	-	-	-	-	-	-
1986	0.005	0.305	0.267	0.318	0.051	0.027	0.017	0.010
1987	0.010	0.477	0.202	0.171	0.072	0.048	0.011	0.009
1988	0.031	0.432	0.388	0.063	0.042	0.029	0.012	0.004
1989	0.079	0.676	0.213	0.022	0.008	0.001	0.001	0.000
1990	0.006	0.267	0.514	0.098	0.052	0.042	0.013	0.008

Table A11: *Nansen* summer survey catches-at-age (proportions) of ***M. capensis*** on the west coast for the 0-500m depth range.

	Proportions caught-at-age: *Merluccius capensis*							
Age	0	1	2	3	4	5	6	7+
2000	0.393	0.336	0.147	0.111	0.007	0.004	0.002	0.001
2001	0.427	0.123	0.179	0.184	0.058	0.018	0.008	0.004

Table A12: Spring survey catches-at-age (proportions) of ***M. capensis*** on the south coast for the 0-500m depth range.

	Proportions caught at age: *Merluccius capensis*							
Age	0	1	2	3	4	5	6	7+
2001	0.158	0.106	0.091	0.171	0.264	0.139	0.039	0.033
2002	-	-	-	-	-	-	-	-
2003	0.205	0.134	0.154	0.157	0.161	0.113	0.041	0.036

Table A13: Autumn survey catches-at-age (proportions) of ***M. capensis*** on the south coast for the 0-500m depth range.

	Proportions caught at age: *Merluccius capensis*							
Age	0	1	2	3	4	5	6	7+
1991	0.011	0.111	0.126	0.173	0.215	0.181	0.112	0.073
1992	0.015	0.203	0.358	0.145	0.118	0.110	0.038	0.014
1993	0.001	0.083	0.120	0.171	0.373	0.143	0.068	0.042
1994	0.061	0.140	0.123	0.219	0.137	0.159	0.116	0.045
1995	0.019	0.121	0.225	0.189	0.202	0.149	0.066	0.029
1996	0.005	0.104	0.188	0.192	0.288	0.131	0.061	0.031
1997	0.064	0.134	0.105	0.187	0.216	0.175	0.067	0.052
1998	-	-	-	-	-	-	-	-
1999	0.159	0.140	0.281	0.145	0.117	0.087	0.040	0.030
2000	-	-	-	-	-	-	-	-
2001	-	-	-	-	-	-	-	-
2002	-	-	-	-	-	-	-	-
2003	0.127	0.212	0.188	0.140	0.153	0.109	0.038	0.033
2004	0.115	0.109	0.131	0.174	0.218	0.152	0.054	0.047

Table A14: Offshore fleet catches-at-age (*M. capensis* and *M. paradoxus* **combined***)* for both coasts combined

	Proportions caught at age: species combined							
Age	0	1	2	3	4	5	6	7+
1975	0.000	0.038	0.151	0.242	0.249	0.189	0.058	0.073
1976	0.000	0.076	0.435	0.302	0.120	0.035	0.022	0.010
1977	0.000	0.119	0.499	0.223	0.081	0.051	0.023	0.005
1978	0.000	0.069	0.683	0.174	0.046	0.018	0.007	0.003
1979	0.000	0.095	0.468	0.218	0.095	0.078	0.029	0.016
1980	0.000	0.048	0.458	0.284	0.120	0.053	0.023	0.014
1981	0.004	0.204	0.459	0.184	0.092	0.034	0.015	0.008
1982	0.030	0.248	0.469	0.130	0.056	0.038	0.020	0.009
1983	0.001	0.097	0.457	0.256	0.099	0.056	0.025	0.010
1984	0.002	0.068	0.460	0.265	0.111	0.052	0.028	0.014
1985	0.000	0.007	0.347	0.380	0.135	0.077	0.036	0.019
1986	0.000	0.011	0.315	0.446	0.119	0.055	0.033	0.019
1987	0.000	0.019	0.502	0.273	0.109	0.059	0.025	0.013
1988	0.000	0.018	0.551	0.265	0.075	0.050	0.028	0.011
1989	0.000	0.011	0.411	0.399	0.097	0.049	0.026	0.008
1990	0.000	0.002	0.282	0.470	0.167	0.050	0.020	0.008
1991	0.000	0.003	0.264	0.379	0.213	0.079	0.045	0.018
1992	0.000	0.010	0.380	0.328	0.149	0.084	0.035	0.014
1993	0.000	0.002	0.152	0.407	0.286	0.112	0.031	0.011
1994	0.000	0.001	0.158	0.468	0.191	0.140	0.032	0.011
1995	0.000	0.001	0.107	0.533	0.218	0.074	0.049	0.018
1996	0.000	0.001	0.096	0.533	0.260	0.066	0.032	0.013

Table A15: Inshore fleet catches-at-age (assumed to consist of ***M. capensis*** only) on the south coast.

	Proportions caught at age: *Merluccius capensis*						
Age	1	2	3	4	5	6	7+
1989	0.000	0.081	0.478	0.285	0.109	0.039	0.008
1990	0.000	0.055	0.279	0.439	0.171	0.045	0.011
1991	0.000	0.053	0.281	0.367	0.219	0.067	0.014
1992	0.001	0.151	0.371	0.237	0.184	0.048	0.009
1993	0.000	0.026	0.332	0.457	0.139	0.039	0.006
1994	0.000	0.060	0.380	0.304	0.183	0.067	0.007
1995	0.000	0.015	0.232	0.455	0.209	0.072	0.018
1996	0.000	0.024	0.327	0.457	0.140	0.043	0.008
1997	0.000	0.034	0.369	0.394	0.159	0.034	0.011
1998	0.008	0.166	0.377	0.284	0.116	0.034	0.015
1999	0.012	0.190	0.365	0.248	0.116	0.044	0.024
2000	0.000	0.022	0.244	0.476	0.196	0.034	0.028

Table A16: Longline fleet catches-at-age (assumed to consist of ***M. capensis*** only) on the south coast.

	Proportions caught at age: *Merluccius capensis*						
Age	1	2	3	4	5	6	7+
1994	0.000	0.000	0.001	0.030	0.248	0.404	0.318
1995	0.000	0.000	0.000	0.006	0.093	0.262	0.638
1996	0.000	0.000	0.000	0.007	0.134	0.297	0.561
1997	0.000	0.000	0.002	0.036	0.201	0.298	0.464
2000	0.000	0.001	0.003	0.020	0.148	0.203	0.626

Appendix B - The Age-Structured Production Model

The model used in the assessment of the coast-wide South African *M. paradoxus* and *M. capensis* hake stocks is an ASPM similar to those used for "standard" assessments (Rademeyer and Butterworth, 2004, for example). It involves assessing the two species as two independent stocks. The model is fitted to species-disaggregated data as well as species-combined data. The model equations and the general specifications of the model are described below, followed by details of the contributions to the log-likelihood function from the different data considered. Quasi-Newton minimisation is used to minimise the total negative log-likelihood function (implemented using AD Model Builder™, Otter Research, Ltd.).

B.1 Population Dynamics

B.1.1 Numbers-at-age

The resource dynamics of the South African hake stocks are modelled by the following set of population dynamics equations:

$$N_{s,y+1,0} = R_{s,y+1} \qquad \text{(B1)}$$

$$N_{s,y+1,a+1} = \left(N_{sya}\, e^{-M_{sa}/2} - \sum_f C_{sfya} \right) e^{-M_{sa}/2} \qquad \text{for } 0 \le a \le m_s - 2 \qquad \text{(B2)}$$

$$N_{s,y+1,m} = \left(N_{sy,m-1}\, e^{-M_{s,m-1}/2} - \sum_f C_{sfy,m-1} \right) e^{-M_{s,m-1}/2} + \left(N_{sym} e^{-M_{sm}/2} - \sum_f C_{sfym} \right) e^{-M_{sm}/2} \qquad \text{(B3)}$$

where

N_{sya} is the number of fish of species *s* and age *a* at the start of year *y*,

R_{sy} is the recruitment (number of 0-year-old fish) of species *s* at the start of year *y*,

M_{sa} denotes the natural mortality rate on fish of species *s* and age *a*,

C_{sfya} is the number of fish of species *s* and age *a* caught in year *y* by fleet *f*, and

m_s is the maximum age considered (taken to be a plus-group) for species *s*.

These equations simply state that for a closed population, i.e. with no immigration or emigration, the only sources of loss are natural mortality (predation, disease, etc.) and fishing mortality (catch). They reflect Pope's approximation (Pope, 1972) (the catches are assumed to be taken as a pulse in the middle of the year) rather than the more customary Baranov catch equations (Baranov, 1918) (where catches are incorporated in the form of a continuous fishing mortality). As long as mortality rates are not too high, the differences between the Baranov and Pope formulation will be minimal. Tests showed this approximation to be adequate for the hake stocks (Punt, University of Washington, pers. commn).

B.1.2 Recruitment

Next year's recruitment depends upon the reproductive output of this year's fish. The number of recruits of each species (i.e. new zero-year old fish) at the start of year *y* is assumed to be related to the spawning stock size (i.e., the biomass of mature fish) by a stock-recruitment relationship. Traditionally, the Beverton-Holt function (Beverton and Holt, 1957) has been used for southern African hake assessments.

The Beverton-Holt stock-recruitment relationship, allowing for annual fluctuations, is written as:

$$R_{sy} = \frac{\alpha_s B_{sy}^{sp}}{\beta_s + B_{sy}^{sp}} e^{(\varsigma_{sy} - \sigma_R^2/2)} \qquad \text{(B4)}$$

where

α_s and β_s are spawning biomass-recruitment relationship parameters for species *s*, α being the maximum number of recruits produced, and β the spawning stock needed to produce a recruitment equal to $\alpha/2$, in the deterministic case;

ς_{sy} reflects fluctuation about the expected recruitment for species *s* in year *y*, which is assumed to be normally distributed with standard deviation σ_R (whose value is input in the applications considered here); these residuals are treated as estimable parameters in the model fitting process. Estimating the stock-recruitment residuals is made possible by the availability of catch-at-age data, which give some indication of the age-structure of the population. The $-\sigma_R^2/2$ term is to correct for bias given the skewness of the log-normal distribution; it ensures that, on average, recruitments will be as indicated by the deterministic component of the stock-recruitment relationship;

B_{sy}^{sp} is the spawning biomass of fish of species *s* at the start of year *y*, computed as:

$$B_{sy}^{sp} = \sum_{a=1}^{m} f_{sa} w_{sa} N_{sya} \qquad \text{(B5)}$$

where

w_{sa} is the begin-year mass of fish of species *s* and age *a*, and

f_{sa} is the proportion of fish of species *s* and age *a* that are mature.

In order to work with estimable parameters that are more biologically meaningful, the stock-recruitment relationship is re-parameterised in terms of the pre-exploitation equilibrium spawning ("virgin") biomass, K_s^{sp}, and the "steepness", h_s, of the stock-recruitment relationship, which is the proportion of the virgin recruitment (R_{1s}) that is realised at a spawning biomass level of 20% of the virgin spawning biomass:

$$\alpha_s = \frac{4h_s R_{s1}}{5h_s - 1} \qquad \text{(B6)}$$

and

$$\beta_s = \frac{K_s^{sp}(1-h_s)}{5h_s - 1} \qquad \text{(B7)}$$

where

$$R_{s1} = K_s^{sp} \Bigg/ \left[\sum_{a=1}^{m-1} f_{sa} w_{sa} \exp\left(-\sum_{a'=0}^{a-1} M_{sa'}\right) + f_{sm} w_{sm} \frac{\exp\left(-\sum_{a'=0}^{m-1} M_{sa'}\right)}{1-\exp(-M_{sm})} \right] \qquad \text{(B8)}$$

In the fitting procedure, both h_s and K_s^{sp} are estimated. The steepness parameter is important, as the overall potential yield of a resource estimated by an ASPM depends primarily on the steepness of the stock-recruitment curve and on the natural mortality rate.

B.1.3 Total catch and catches-at-age

The fleet-disaggregated catch by mass for species *s*, in year is given by:

$$C_{sfy} = \sum_{a=0}^{m} w_{s,a+1/2}\, C_{sfya} = \sum_{a=0}^{m} w_{s,a+1/2}\, N_{sya}\, e^{-M_{sa}/2}\, S_{sfya}\, F_{sfy} \qquad \text{(B9)}$$

where

$w_{s,a+1/2}$ denotes the mid-year mass of fish of species *s* and age *a*, which is assumed to be the same for each fleet (as there are no data available to discriminate between fleets),

C_{sfya} is the catch-at-age, i.e. the number of fish of species *s* and age *a*, caught in year *y* by fleet *f*,

S_{sfya} is the commercial selectivity (i.e. vulnerability to fishing gear, which may depend not only on the gear itself, but also on distribution patterns of the fish by age compared to the areal distribution of fishing effort) of species *s* at age *a* for year *y*, and fleet *f*; when $S_{sfya} = 1$, the age-class *a* is said to be fully selected, and

F_{sfy} is the fished proportion of a fully selected age class of species *s*, for fleet *f*.

The model estimate of the mid-year exploitable ("available") component of biomass for each species and fleet is calculated by converting the numbers-at-age into mid-year mass-at-age (using the mid-year individual weights) and applying natural and fishing mortality for half the year:

$$B_{sfy}^{ex} = \sum_{a=0}^{m_s} w_{s,a+1/2} S_{sfya} N_{sya} e^{-M_{sa}/2} (1 - \sum_f S_{sfya} F_{sfy} / 2) \qquad \text{(B10)}$$

The model estimate of the survey biomass at the start of the year (summer) for each species is given by:

$$B_{sy}^{surv} = \sum_{a=0}^{m_s} w_{sa} S_{sa}^{surv} N_{sya} \qquad \text{(B11)}$$

and in mid-year (winter):

$$B_{sy}^{surv} = \sum_{a-0}^{m_s} w_{s,a+1/2} S_{sa}^{surv} N_{sya}\ e^{-M_{sa}/2} (1 - \sum_f S_{sfya} F_{sfy} / 2) \qquad \text{(B12)}$$

where

S_{sa}^{surv} is the survey selectivity for age *a* for species *s*, and

$w_{s,a+1/2}$ is the mid-year weight of fish of species *s* and age *a* at the start of the year.

It is assumed that the resource is at the deterministic equilibrium that corresponds to an absence of harvesting at the start of the initial year considered, i.e., $B_{sy0}^{sp} = K_s^{sp}$.

B.2 The likelihood function

The model is fitted to CPUE and survey abundance indices, catch information and commercial and survey catch-at-age data, as well as to the stock-recruitment curve to estimate model parameters. Contributions by each of these to the negative of the log-likelihood (- ℓnL) are as follows.

B.2.1 CPUE relative abundance data

The likelihood is calculated assuming that the observed abundance index is log-normally distributed about its expected value:

$$I_y^i = \hat{I}_y^i \exp\left(\varepsilon_y^i\right) \quad \text{or} \quad \varepsilon_y^i = \ell n\left(I_y^i\right) - \ell n\left(\hat{I}_y^i\right) \qquad \text{(B13)}$$

where

I_y^i is the abundance index for year *y* and series *i* (which corresponds to a combination of species and fleet)

$\hat{I}_y^i = \hat{q}^i \hat{B}_{sfy}^{ex}$ is the corresponding model estimate, where $\widehat{B}_{sfy}^{ex}$ is the model estimate of exploitable resource biomass, given by equation B10,

$\hat{q}^i$ is the constant of proportionality for abundance series *i*, and

ε_y^i from $N\left(0, \left(\sigma_y^i\right)^2\right)$.

In cases where the CPUE series are based upon species-aggregated catches (as available pre-1978), the corresponding model estimate is derived by assuming two types of fishing zones: z1) an "*M. capensis* only zone", corresponding to the shallow water and z2) a "mixed zone" (see Fig. B1).

The total catch of hake of both species (*BS*) by fleet *f* in year *y* ($C_{BS,fy}$) can be written as $C_{BS,fy} = C_{Cz1,fy} + C_{Cz2,fy} + C_{P,fy}$, where

$C_{Cz1,fy}$ is the *M. capensis* catch by fleet *f* in year *y* in the *M. capensis* only zone,

$C_{Cz2,fy}$ is the *M. capensis* catch by fleet *f* in year *y* in the mixed zone, and

$C_{P,fy}$ is the *M. paradoxus* catch by fleet *f* in year *y* in the mixed zone.

Catch rate is assumed to be proportional to exploitable biomass. Furthermore, let γ be the proportion of the *M. capensis* exploitable biomass in the mixed zone ($\gamma = B^{ex}_{Cz2,fy} / B^{ex}_{C,fy}$) (assumed to be constant throughout the period) and s_{fy} be the proportion of the effort of fleet *f* in the mixed zone in year *y* ($s_{fy} = E^{z2}_{fy} / E_{fy}$), so that:

$$C_{Cz1,fy} = q^i_{Cz1} B^{ex}_{Cz1,fy} E^1_{fy} = q^i_{Cz1}(1-\gamma) B^{ex}_{C,fy}(1-s_{fy}) E_{fy} \tag{B14}$$

$$C^{Cz2}_{fy} = q^i_{Cz2} B^{ex}_{Cz2,fy} E^{z2}_{fy} = q^i_{Cz2}\gamma B^{ex}_{C,fy} s_{fy} E_{fy} \quad \text{and} \tag{B15}$$

$$C^P_{fy} = q^i_P B^{ex}_{P,fy} E^{z2}_{fy} = q^i_P B^{ex}_{P,fy} s_{fy} E_{fy} \tag{B16}$$

where

$E_{fy} = E^{z1}_{fy} + E^{z2}_{fy}$ is the total effort of fleet *f*, corresponding to combined-species CPUE series *i* which consists of the effort in the *M. capensis* only zone (E^{z1}_{fy}) and the effort in the mixed zone (E^{z2}_{fy}).

It follows that:

$$C_{Cfy} = B^{ex}_{Cfy} E_{fy}\left[q^i_{C1}(1-\gamma)(1-s_y) + q^i_{C2}\gamma s_{fy}\right] \tag{B17}$$

$$C_{Pfy} = B^{ex}_{Cfy} E_{fy} q^i_P s_{fy} \tag{B18}$$

By solving equations B17 and B18, we get:

$$s_{fy} = \frac{q^i_{Cz1}(1-\gamma)}{\left\{\dfrac{C_{Cfy} B^{ex}_{Pfy} q^i_P}{B^{ex}_{Cfy} C_{Pfy}} - q^i_{Cz2}\gamma + q^i_{Cz1}(1-\gamma)\right\}} \tag{B19}$$

so that:

$$\hat{I}^i_y = \frac{C_{fy}}{E_{fy}} = \frac{C_{fy} B^{ex}_{Pfy} q^i_P s_{fy}}{C_{Pfy}} \tag{B20}$$

Zone 1 (z1): *M. capensis* only	Zone 2 (z2): Mixed zone
M. capensis: biomass (B_{Cz1}), catch (C_{Cz1})	*M. capensis*: biomass (B_{Cz2}), catch (C_{Cz2}) *M. paradoxus*: biomass (B_P), catch (C_P)
Effort in zone 1 (E_{z1})	Effort in zone 1 (E_{z2})

Fig. B1: Diagramatic representation of the two theoretical fishing zones.

To correct for possible negative bias in estimates of variance (σ^i_y) and to avoid according unrealistically high precision (and so giving inappropriately high weight) to the CPUE data, lower bounds ($(\sigma^i_A)^2$) on the standard deviations of the residuals for the logarithm of the CPUE series have been enforced; for the historic ICSEAF CPUE series (separate west coast and south coast series) the lower bound is set to 0.25 and for the recent GLM-standardised CPUE series the lower bound is 0.15, i.e.: $\sigma^{ICSEAF} \geq 0.25$ and $\sigma^{GLM} \geq 0.15$.

The contribution of the CPUE data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ell n L^{CPUE} = \sum_i \sum_y \left\{ \ell n \sqrt{(\sigma^i_y)^2 + (\sigma^i_A)^2} + (\varepsilon^i_y)^2 / \left[2\left((\sigma^i_y)^2 + (\sigma^i_A)^2\right)\right]\right\} \tag{B21}$$

where

σ_y^i is the (minimum, when $\sigma_A^i = 0$) standard deviation of the residuals for the logarithms of index *i* in year *y*,

σ_A^i is the square root of the additional variance for abundance series *i*, which is an input value; alternatively, this can be used to as a means of specifying an effective lower bound for σ_y^i.

Homoscedasticity of residuals is usually assumed, so that $\sigma_y^i = \sigma^i$ is estimated in the fitting procedure by its maximum likelihood value:

$$\hat{\sigma}^i = \sqrt{1/n_i \sum_y \left(\ell n(I_y^i) - \ell n(\hat{I}_y^i)\right)^2 - \left(\sigma_A^i\right)^2} \tag{B22}$$

where n_i is the number of data points for abundance index *i*.

In the case of the species-disaggregated CPUE series, the catchability coefficient q^i for abundance index *i* is estimated by its maximum likelihood value, which in the more general case of heteroscedastic residuals, is given by:

$$\ln \hat{q}^i = \frac{\sum_y \left[1 \big/ \left\{\left(\sigma_y^i\right)^2 + \left(\sigma_A^i\right)^2\right\}\right]\left(\ln I_y^i - \ln \hat{B}_{srfy}^{ex}\right)}{\sum_y \left[1 \big/ \left\{\left(\sigma_y^i\right)^2 + \left(\sigma_A^i\right)^2\right\}\right]} \tag{B23}$$

While in the case of the species-combined CPUE, q_{Cz1}^i, q_{Cz2}^i, q_P^i and γ are directly estimated in the fitting procedure.

In the case of the South African hake, two species-aggregated CPUE indices are available: the ICSEAF west coast and the ICSEAF south coast series. For consistency, *q*'s for each species (and zone) are forced to be in the same proportion:

$$q_s^{SC} = r q_s^{WC} \tag{B24}$$

B.2.2 Survey abundance data

Data from the research surveys are treated as relative abundance indices in a similar manner to the species-disaggregated CPUE series above, with survey selectivity function S_{sa}^{surv} replacing the commercial selectivity S_{sfya} (see equations B11 and B12 above). Account is also taken of the begin- or mid-year nature of the survey.

An estimate of sampling variance is available for most surveys and the associated σ_y^i is generally taken to be given by the corresponding survey CV. However, these estimates likely fail to include all sources of variability, and unrealistically high precision (low variance and hence high weight) could hence be accorded to these indices. The contribution of the survey data to the negative log-likelihood is of the same form as that of the CPUE abundance data (see equation B21). The procedure adopted takes into account an additional variance in the same manner as for the CPUE abundance indices, but instead of being input, the additional variance $\left(\sigma_A\right)^2$ is treated as another estimable parameter in the minimisation process. This procedure is carried out enforcing the constraint that $\left(\sigma_A\right)^2$ >0, i.e. the overall variance cannot be less than its externally input component.

In June 2003, the trawl gear on the *Africana* was changed and a different value for the multiplicative bias factor *q* is taken to apply to the surveys conducted with the new gear. Calibration experiments have been conducted between the *Africana* with the old gear (hereafter referred to as the "old *Africana*") and the *Nansen*, and between the *Africana* with the new gear ("new *Africana*") and the *Nansen*, in order to provide a basis to relate the multiplicative biases of the *Africana* with the two types of gear (q_{old} and q_{new}). A GLM analysis assuming negative binomial distributions for the catches made (Brandão *et al*., 2004) provides the following estimates:

$\Delta \ell n q^{capensis} = -0.494$ with $\sigma_{\Delta \ell n q^{capensis}} = 0.141$ and

$\Delta \ell n q^{paradoxus} = -0.053$ with $\sigma_{\Delta \ell n q^{paradoxus}} = 0.117$

where

$$\ell n q_{new}^i = \ell n q_{old}^i + \Delta \ell n q^i \quad \text{with } i = \textit{capensis} \text{ or } \textit{paradoxus} \tag{B25}$$

The following contribution is therefore added as a penalty (or a prior in a Bayesian context) to the negative log-likelihood in the assessment:

$$-\ell nL^{q-ch} = \left(\ell nq_{new} - \ell nq_{old} - \Delta\ell nq\right)^2 \Big/ 2\sigma^2_{\Delta\ell nq} \qquad \text{(B26)}$$

This assessment assumes that the change from "old *Africana*" to "new *Africana*" involves a change in q alone, i.e. the pattern of age-specific selectivity remains unchanged.

B.2.3 Commercial catches-at-age

Catches-at-age cannot be disaggregated by species, the model is therefore fitted to the catches-at-age for both species. The contribution of the catch-at-age data to the negative of the log-likelihood function when assuming an "adjusted" lognormal error distribution is given by:

$$-\ell\text{n}\, L^{age} = \sum_i \sum_y \sum_a \left[\ell n\left(\sigma^i_{com} / \sqrt{p_{iya}}\right) + p_{iya}\left(\ell n\, p_{iya} - \ell n\, \hat{p}_{iya}\right)^2 / 2\left(\sigma^i_{com}\right)^2\right] \qquad \text{(B27)}$$

where

the subscript 'i' refers to a particular series of catch-at-age data which reflect a specific combination of fleet and coast.

$p_{iya} = \dfrac{C_{BS,\,fya}}{\sum_{a'} C_{BS,\,fya'}}$ is the observed proportion of fish (*M. capensis* and *M. paradoxus* combined) caught by fleet f in year y that are of age a,

$\hat{p}_{iya} = \dfrac{\hat{C}_{BS,\,fya}}{\sum_{a'} \hat{C}_{BS,\,fya'}} = \dfrac{\sum_s \hat{C}_{s,\,fya}}{\sum_{a'}\sum_s \hat{C}_{s,\,fya'}}$ is the model-predicted proportion of fish caught by fleet f in year y that are of age a, where:

$$\hat{C}_{sfya} = N_{sya}\; e^{-M_{sa}/2}\; S_{sfya}\; F_{sfya} \qquad \text{(B28)}$$

and

σ^i_{com} is the standard deviation associated with the catch-at-age data, which is estimated in the fitting procedure by:

$$\hat{\sigma}^i_{com} = \sqrt{\sum_y \sum_a p^i_{y,a}\left(\ln p^i_{y,a} - \ln \hat{p}^i_{y,a}\right)^2 / \sum_y \sum_a 1} \qquad \text{(B29)}$$

The log-normal error distribution underlying equation B27 is chosen on the grounds that (assuming no ageing error) variability is likely dominated by a combination of interannual variation in the distribution of fishing effort, and fluctuations (partly as a consequence of such variations) in selectivity-at-age, which suggests that the assumption of a constant coefficient of variation is appropriate. However, for ages poorly represented in the sample, sampling variability considerations must at some stage start to dominate the variance. To take this into account in a simple manner, motivated by multinomial distribution properties, Punt (pers. commn) advocates weighting by the observed proportions (as in equation B27) so that undue importance is not attached to data based upon a few samples only.

Commercial catches-at-age are incorporated in the likelihood function using equation B27, for which the summation over age a is taken from age a_{minus} (considered as a minus group) to a_{plus} (a plus group). The ages for the minus- and plus-groups are chosen so that typically a few percent, but no more, of the fish sampled fall into these two groups.

B.2.4 Survey catches-at-age

The survey catches-at-age are incorporated into the negative of the log-likelihood in an analogous manner to the commercial catches-at-age, assuming an adjusted log-normal error distribution (equation B27). In this case however, the data is available disaggregated by species.

$p^{surv}_{sya} = C^{surv}_{sya} / \sum_{a'} C^{surv}_{sya'}$ is the observed proportion of fish of species s and age a from survey *surv* in year,

$\hat{p}^{surv}_{sya}$ is the expected proportion of fish of species s and age a in year y in the survey *surv*, given by:

$$\hat{p}^{surv}_{sya} = \frac{S^{surv}_{sa} N_{sya}}{\sum_{a'=0}^{m_s} S^{surv}_{sa'} N_{sya'}} \qquad \text{(B30)}$$

for begin-year (summer) surveys, or

$$\hat{p}^{surv}_{sya} = \frac{S^{surv}_{sa} N_{sya} \exp(-M_{sa}/2)\left(1-\sum_f S_{sfya} F_{sfy}/2\right)}{\sum_{a'=0}^{m_s} S^{surv}_{sa'} N_{sya'} \exp(-M_{sa'}/2)\left(1-\sum_f S_{sfya} F_{sfy}/2\right)} \qquad \text{(B31)}$$

for mid-year (winter) surveys.

B2.5 Stock-recruitment function residuals

The stock-recruitment residuals are assumed to be log-normally distributed and serially correlated. Thus, the contribution of the recruitment residuals to the negative of the log-likelihood function is given by:

$$-\ell nL^{SR} = \sum_s \sum_{y=y1+1}^{y2} \left[\ell n\sigma_R + \left(\frac{\varsigma_{sy} - \rho\varsigma_{s,y-1}}{\sqrt{1-\rho^2}} \right)^2 \Big/ 2\sigma_R^2 \right] \qquad \text{(B32)}$$

where

$\varsigma_{sy} = \rho\varsigma_{s,y-1} + \sqrt{1-\rho^2}\,\varepsilon_{sy}$ is the recruitment residual for species *s*, and year *y*, which is estimated for year *y1* to *y2* (see equation B4),

ε_{sy} from $N\left(0,(\sigma_R)^2\right)$

σ_R is the standard deviation of the log-residuals, which is input, and

ρ is the serial correlation coefficient, which is input.

In the interest of simplicity, equation B30 omits a term in $\varsigma_{s,y1}$ for the case when serial correlation is assumed ($\rho \neq 0$), which is generally of little quantitative consequence to values estimated (Cryer, 1986).

B.3 Model parameters

B3.1 Estimable parameters

While in the case of the species-combined CPUE, q^i_{C1}, q^i_{C2}, q^i_P and γ are directly estimated in the fitting procedure.

In addition to the species-specific virgin spawning biomass $\left(K^{sp}_s\right)$ and "steepness" of the stock-recruitment relationship (h_s), the following parameters are also estimated in some of the model fits undertaken.

B3.1.1 Natural mortality:

Natural mortality (M_{sa}) is assumed either to be independent of age or age-specific, and input (fixed) or estimated using the following functional form in the latter case:

$$M_{sa} = \begin{cases} M_{s2} & \text{for} \quad a \le 1 \\ \alpha^M_s + \dfrac{\beta^M_s}{a+1} & \text{for} \quad a \ge 2 \end{cases} \qquad \text{(B33)}$$

M_{s0} and M_{s1} are set equal to M_{s2} ($= \alpha^M_s + \beta^M_s/3$) as there are no data (hake of ages younger than 2 are rare in catch and survey data) which would allow independent estimation of M_{s0} and M_{s1}.

B3.1.2 Fishing selectivity-at-age:

The fishing selectivity-at-age for each species and fleet, S_{sfa}, is either estimated directly:

$$S_{sfa} = \begin{cases} \text{estimated separately} & \text{for } a \le a_{est} \\ =1 & \text{for } a > a_{est} \end{cases} \qquad \text{(B34)}$$

or in terms of a logistic curve given by:

$$S_{sfa} = \begin{cases} 0 & \text{for } a = 0 \\ \left[1+\exp\left(-\left(a-a^{c}_{sf}\right)/\,\delta^{c}_{sf}\right)\right]^{-1} & \text{for } a \ge 1 \end{cases} \qquad \text{(B35)}$$

where

a^{c}_{sf} years is the age-at-50% selectivity,

δ^{c}_{sf} year^{-1} defines the steepness of the ascending limb of the selectivity curve.

The selectivity is sometimes modified to include a decrease in selectivity at older ages, as follows:

$$S_{sfa} \to S_{sfa}\exp\left(-s_{sfa}\left(a-a_{slope}\right)\right) \quad \text{for } a > a_{slope}, \qquad \text{(B36)}$$

where

s_{sfa} measures the rate of decrease in selectivity with age for fish older than a_{slope} for the fleet concerned, and is referred to as the "selectivity slope".

Time dependence may be incorporated into these specification, so that $S_{sfa} \to S_{sfya}$.

B3.2 Input parameters

B3.2.1 Age-at-maturity:

The proportion of fish of species *s* age *a* that are mature is approximated by

$$f_{sa} = \begin{cases} 0 & \text{for } a < a^{mat}_{s} \\ 1 & \text{for } a \ge a^{mat}_{s} \end{cases} \qquad \text{(B37)}$$

where $a^{mat}_{s} = 4$ for the *M. capensis* and *M. paradoxus* stocks (Punt and Leslie, 1991).

B3.2.2 Weight-at-age:

The weight-at-age (begin and mid-year) for each species is calculated from the combination of the von Bertalanffy growth equation and the mass-at-length function.