Revised Assessments of the *Merluccius paradoxus* and *M. capensis* Resources for the South and West Coasts Combined

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Abstract

Coast-wide assessments for the *M. capensis* and *M. paradoxus* resources are conducted, taking into account the recommendations of the January 2004 BENEFIT/NRF/BCLME workshop and newly available data. This revised approach allows more data to be taken into account, but these assessments remain separate for the two species at this stage, with past catches split by species external to the model. Projections under a number of future constant catch series are presented.

1. Introduction

Revised assessments of the *Merluccius paradoxus* and *M. capensis* resources off South Africa are presented. The two species are assessed independently, each for the south and west coasts combined.

The methodology for coast-combined assessments has been slightly modified compared to previous assessments. The changes to the formulation used for the *M. paradoxus* coast-combined 2003 Reference Case assessment (Butterworth and Rademeyer, 2003) include:

1) Lower bounds on the standard deviations of the residuals for the logarithm of the CPUE abundance indices used in the likelihood function 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 $\sigma^{GLM} \geq 0.15$.
2) In previous assessments, the south coast autumn and the west coast summer survey biomass estimates were combined to form a single survey time-series (similarly for the survey catches-at-age data). This was unsatisfactory as considerable data were left unused and possible differences in survey selectivities on the south and west coasts were ignored. In this analysis, the model is fitted to the coast-specific survey data. The constants of proportionality, or multiplicative biases, q^i, implicitly include a coast-component which accounts for the fact that the resources are distributed with different proportions on the south and west coasts. A survey selectivity function is estimated for each survey series.

These changes are in line with the recommendations of the January 2004 BENEFIT/NRF/BCLME Stock Assessment Workshop. In particular, coast-specific selectivities for the surveys are used as a basis to reflecting differing proportions by age of each species on each coast. However, for the moment the species are still assessed separately with the catches by species input, rather than jointly with the species-split of the catch estimated in the model fit (as is the eventual plan in terms of the BENEFIT/NRF/BCLME Workshop recommendations).

2. Data

The tables of data used are given in the Appendix.

M. paradoxus

The south coast *M. paradoxus* hake stock is assumed to be fished by an offshore trawl fleet only (i.e. the south coast inshore trawl, longline and handline fleets are assumed to catch *M. capensis* only). On the west coast, both the offshore trawl and longline fleets catch *M. paradoxus*. The annual catches by mass of *M. paradoxus* assumed for each fleet and coast in this analysis are shown in Table A1. The offshore catches 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. paradoxus* cannot be estimated by this method. Consequently, the catch data for the 1917-1977 period have been split by species by assuming that the average proportion of *M. paradoxus* in the offshore fleet catch over the 1978-1982 period applies to these earlier data. These proportions are 54% and 84% for the south and west coasts respectively. The longline catches have been split by species to reflect that 70% of the landings on the west coast consist of *M. paradoxus*, while on the south coast, *M. capensis* only is caught by the longline fleet. The catch in 2004 is taken to be the TAC for that year, assuming the same proportion of each species as caught by each fleet in 2003.

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. However, since information on the CPUE trend over this period is important for the assessment, the assumption is made that these combined-species data are also reflective of trends in the separate *M. paradoxus* stock alone. The GLM standardised CPUE data used are from Glazer (2004); these are for *M. paradoxus* only (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. Survey catch-at-age data are shown in Tables A4-A7. The survey data used are for *M. paradoxus* alone. Commercial catches cannot be split by species on an age-basis and therefore catch-at-age information for *M. paradoxus* only is not available for the commercial catches.

M. capensis

The south coast *M. capensis* hake stock is fished by four fleets: the offshore and inshore trawl fleets and the longline and handline fleets. The west coast *M. capensis* stock is taken to be fished by the offshore trawl and the longline fleets only. The annual catches by mass assumed for each fleet are given in Table A8. The method used to disaggregate the offshore and longline catches by species is described above. The inshore trawl fleet and the handline fleet on the south coast are assumed to catch *M. capensis* only.

Historic and GLM-standardised CPUE data are given in Table A2. As for the *M. paradoxus* assessment, the pre-1978 historic species-combined CPUE series are assumed to reflect the trend in the *M. capensis* stock alone. The GLM-standardised CPUE data used are from Glazer (2004) and are for *M. capensis* only. Survey biomass estimates for the west and south coasts are shown in Table A9. Catch-at-age information are available from the inshore and longline fleet on the south coast and are shown in Tables A10 and A11 respectively. Survey catch-at-age data are shown in Tables A12-A16.

3. Methods

The model used in this analysis is an Age-Structured Production Model (ASPM) and is described in detail in Rademeyer (2003).

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:

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

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

where

$$\ell n q^i_{new} = \ell n q^i_{old} + \Delta \ell n q^i \quad \text{with } i = capensis \text{ or } paradoxus \tag{1}$$

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

$$-\ell n L^{q-ch} = \left(\ell n q_{new} - \ell n q_{old} - \Delta \ell n q\right)^2 \Big/ 2\sigma^2_{\Delta \ell n q} \tag{2}$$

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 remaines unchanged.

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

M. paradoxus

Natural mortality is assumed to be age-dependent according to the functional form adopted previously for the Reference Case assessment.

Because there are no catch-at-age data available from the west coast winter survey, the same selectivity is assumed to apply for 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 different selectivity is estimated for the spring and south coast surveys. The survey selectivities are estimated directly for ages 0, 1 and 2. For ages above those, the selectivity is set to 1 modified by an exponential decrease estimated from age 2 on the west coast and from age 3 on the south coast.

As there is no information on the age-structure of the commercial catches of *M. paradoxus* alone, commercial selectivity-at-age cannot be estimated directly. Commercial offshore trawl selectivity is therefore estimated assuming that the ratios of survey to commercial selectivities-at-age from the combined-species west coast assessment (Rademeyer, 2003) apply here too. Similarly, the periods of fixed and changing selectivity used in the combined species west coast assessment (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 used in 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 (see Rademeyer, 2003, for details). The offshore trawl selectivity is assumed to decrease exponentially from age 3, with a slope parameter $s = 0.2$ yr^{-1}. In the Reference Case assessment, the longline selectivity for *M. paradoxus* is taken to be the same as that estimated for *M. capensis* on the south coast.

The stock-recruitment residuals are estimated over years 1985 to 2004, corresponding to the period for which age information is available.

Results for this Reference Case assessment and three sensitivities are presented:

a) Reference Case;

b) the proportion of *M. paradoxus* in the longline catches on the west coast is taken to be 80% instead of 70%;

c) the longline selectivity is fixed to 0 for ages 0 to 3, 0.5 for age 4 and 1 for ages 5 and above, instead of assuming the same selectivity as the south coast longline fleet for *M. capensis*;

d) the Reference Case shows strong recruitment of *M. paradoxus* for the last two years. This signal is partly based on the catch-at-age information from the more recent surveys, but because of the change in gear on the *Africana*, and consequently a possible change in selectivity of the surveys, one cannot be entirely confident that this signal is quantitatively reliable. For this reason, this last sensitivity sets a limit on the recent recruitment fluctuations by having the σ_R decreasing linearly from 0.25 in 2000 to 0.1 in 2004, effectively forcing the last three years of recruitment closer towards the stock-recruitment relationship curve.

e) the west coast summer survey biomass estimates in 1997 and 1999 were substantially higher than estimates in the rest of the series, while the proportion of 0 and 1-year old in the catch-at-age data was particularly high as well (1999 especially). It was suggested that the information from these two surveys might be suspect and that a run be conducted ignoring these data.

f) in the latest assessment, the selectivity of the *Africana* with the new gear is taken to be the same as that of the *Africana* with the old gear. In this sensitivity assessment, a separate multiplicative factor for ages 0 and 1 is estimated for the new *Africana* selectivity

M. capensis

The Reference Case assumes that the natural mortality *M* is independent of age, as in the past for assessment of this species on the south coast.

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.

The selectivity patterns characterising each of the three fleets (offshore, inshore, longline and handline) all take on 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 of the depth distribution of hake. As there are no catch-at-age data available to estimate a selectivity vector for the offshore fleet, the selectivity for this fleet is assumed to be the same as for the inshore fleet but 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. There is no age-structured information for the handline fleet, so the assumption is made that the selectivity for this fleet is intermediate between the offshore trawl and longline selectivities.

The stock-recruitment residuals are estimated from year 1984 to 2004, corresponding to the period for which age information is available.

Results for this Reference Case assessment and two sensitivities are presented:

a) Reference Case;

b) the proportion of *M. capensis* in the longline catches on the west coast is taken to be 20% instead of 30%;

c) with limits on recent recruitment variability as described above.

4. Results

M. paradoxus

Table 1 gives the results of the model for the Reference Case assessment and a series of sensitivities to this. Fig. 1 plots the population trajectory for the Reference Case assessment (with 90% MCMC-based probability envelope).

The survey and commercial selectivity functions are plotted in Fig. 2.

Fig. 3 shows the fit of the CPUE and survey indices to the Reference Case assessment, while Fig. 4 shows the fit of the model to the survey catch-at-age data. Fig. 5 plots the standardised catch-at-age residuals for the survey data.

Fig. 6 plots the time-series of recruitment and the estimated stock-recruitment curve.

Projections under a series of constant catches (assuming the same proportion caught by each fleet as in 2003) are shown in Fig. 7.

M. capensis

Management quantities estimates for the Reference Case assessment and a series of sensitivities are shown in Table 2. Fig. 8 plots the population trajectory (with 90% MCMC-based probability envelope) for the Reference Case assessment.

The survey and commercial selectivity functions are plotted in Fig. 9. The estimates presented suggest that young (to age 2) *M. capensis* are primarily restricted to the west coast. At intermediate ages, a large proportion of these fish move to the south coast. However for the oldest fish (ages 7+) there is some movement back to the west coast.

Fig. 10 shows the fit of the CPUE and survey indices to the Reference Case assessment, while Fig. 11 shows the fit of the model to the survey and commercial catch-at-age data respectively. Fig. 12 plots the standardised catch-at-age residuals for the commercial and survey data.

Fig. 13 plots the time-series of recruitment and the estimated stock-recruitment curve.

Projections under a series of constant catches (assuming the same proportion caught by each fleet as in 2003) are shown in Fig. 14.

The age-dependent multiplicative biases ($q_a^{surv} = q^{surv} S_a^{surv}$) for each surveys for the *M. paradoxus* and *M. capensis* Reference Case assessments are shown in Fig. 15.

5. Discussion

TAC advice for 2005

The default recommendation is to decrease the TAC from 161 000 t to 158 000 t unless these assessments show strong evidence that alternative action is needed. To bound possibilities, constant catch projections have considered the 3000 t decrease to be taken either all from the current *M. capensis*, or all from the *M. paradoxus* catch.

For *M. capensis*, Fig. 14 suggests that maintaining the estimated current catch level of 41 000 t is not a problem. The resource is above MSYL, and though maintenance of the catch at this level would reduce the current spawning biomass slightly, this seems unlikely to reduce catch rates below 1990’s levels, and hence impact the economics of south coast operations in particular.

Fig. 7, which shows the *M. paradoxus* resource to be well below MSYL, indicates a decrease in spawning biomass under a steady continuation of the estimated current catch level of 120 000 t, suggesting that it is here that catch reduction is desirable. The default reduction to 117 000 t is not suggestive of short-term problems in terms of best estimate projections, even if more conservative estimates of recent recruitment are used. However lower probability interval envelopes for these projections, even for constant TACs below 117 000 t, are of concern and suggest that consideration needs to be given to whether a reduction of more then 3000 t is needed for next year, or rather such consideration of action can be postponed until 2006.

Other features of the results

- Overall assessment results are hardly affected by the changes considered concerning assumptions about the selectivity or species-split of the longline catches.
- Steepness *h* is estimated to be unrealistically high (0.98) for *M. capensis*, but this is not a major concern because the projections considered do not reduce the spawning biomass to a level where taking expected recruitment to remain unchanged might be dangerously inappropriate.
- Natural mortality estimates (0.32 for 5+ *M. paradoxus*, and an age-independent 0.50 for *M. capensis*) are less than for previous assessments, but still seem unrealistically high biologically.
- Estimates of current biomass are low – indeed lower than swept-area based absolute estimates for the research surveys. Note that some estimates of survey q_a's exceed 1 (see Fig. 15), even though they pertain only to the fraction of the resource to be found on the coast concerned. For the south coast *M. capensis* surveys, these estimates are particularly high; this is difficult to reconcile with the survey results unless there is considerable herding by the net and/or a large fraction of that area is untrawlable and contains hake at much lower density than on trawlable ground.
- Although the *q* calibration factor for new vs. old *Africana* is close to 1 for *M. paradoxus*, it is markedly different (higher) for *M. capensis*. Discussion is desirable as to why the new *Africana* net configuration should be so much more efficient at catching *M. capensis*, but not *M. paradoxus*. This may also reflect different selectivity-at-age patterns for the two gears (the current assessment assumes this pattern to be the same for the two, with an age-independent *q* being the only scaling factor).
- As in previous assessments, the low level of recruitment variability indicated in these assessments (σ_R – outputs of less than 0.15 for both *M. paradoxus* and *M. capensis*) scarcely seems credible. It could be that recruitment fluctuations are moderated by the heavy degree of cannibalism and inter-species predation on younger hake, *M. paradoxus* in particular. However, it might also be that there are errors in hake ageing, which could confound the detection of stronger and weaker cohorts.
- Comparison of Fig. 3d and Fig. 6a suggests that the present need to reduce *M. paradoxus* catch levels is a consequence of poor recruitment in 1996 and 1997 combined with misleadingly high survey estimates of abundance from the 1997 and 1999 west coast summer surveys.
- There remains potential to improve the parameterisations of the selectivity functions.

References

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Rademeyer RA. 2003. Assessment of and Management Procedures for the Hake Stocks off Southern Africa. MSc thesis, University of Cape Town. South Africa.

Table 1: Estimates of management quantities for Reference Case and a series of sensitivities for this assessment of the ***M. paradoxus*** resource for the south and west coasts combined. The first figure shown is the best estimate, followed by the Hessian-based CV in parenthesis.

	a) *M. paradoxus* Reference Case							
Total -lnL	-87.6							
-lnL : CPUE	-83.4							
-lnL: Survey	-8.8							
-lnL: CAA com.	0.0							
-lnL: CAA surv	1.1							
-lnL: SR Residuals	3.5							
			Offshore		Longline			
K^{sp}	891	(0.23)						
K^{ex}	1093	(0.24)	898	(0.16)	765	(0.34)		
B^{sp}_{y}	85	(0.23)						
B^{exy}	136	(0.23)	140	(0.19)	24	(0.48)		
h	0.845	(0.05)						
$MSYL^{sp}$	215	(0.07)	209	(0.07)	497	(0.07)		
$MSYL^{ex}$	294	(0.02)	284	(0.02)	287	(0.17)		
MSY	141	(0.02)	137	(0.02)	141	(0.17)		
B^{sp}_{y}/K^{sp}	0.096	(0.24)						
B^{ex}_{y}/K^{ex}	0.124	(0.25)	0.155	(0.22)	0.032	(0.36)		
$B^{sp}_{y}/MSYL^{sp}$	0.396	(0.29)	0.408	(0.22)	0.172	(0.20)		
$B^{ex}_{y}/MSYL^{ex}$	0.460	(0.25)	0.492	(0.19)	0.085	(0.39)		
$MSYL^{sp}/K^{sp}$	0.241	(0.26)	0.234	(0.17)	0.557	(0.16)		
$MSYL^{ex}/K^{ex}$	0.269	(0.25)	0.316	(0.15)	0.375	(0.17)		
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	0.63	0.02	0.24	0.00	0.00	0.00	0.00	0.00
1	0.63	0.38	1.00	0.03	0.01	0.00	0.00	0.00
2	0.63	1.00	0.92	0.57	0.25	0.52	0.09	0.00
3	0.48	0.68	0.78	1.00	1.00	1.00	0.98	0.01
4	0.38	0.47	0.61	0.37	0.73	0.82	1.00	0.04
5+	0.32	0.32	0.47	0.14	0.54	0.67	0.82	1.00
σ_R - output	0.15							
Commercial q's:								
SC ICSEAF CPUE	0.003	(0.12)						
WC ICSEAF CPUE	0.028	(0.14)						
GLM CPUE	0.038	(0.11)						
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			
	1.56	1.39	1.26	0.22	0.57			
	(0.31)	(0.21)	(0.48)	(0.09)	(0.11)			
new *Africana*	1.46	-	-	0.22	0.53			
	(0.31)			(0.09)	(0.11)			
Catches-at-age sigma's:	0.15	-	0.07	0.06	0.29			
	(0.04)		(0.11)	(0.24)	(0.07)			
Addnl sigma (survey)	0.316	(0.07)						

* constraint boundary

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

	b) Assuming 80% *M. paradoxus* in west coast longline catch instead of 70%							
Total -lnL	-87.4							
-lnL : CPUE	-83.4							
-lnL: Survey	-8.7							
-lnL: CAA com.	-							
-lnL: CAA surv	1.2							
-lnL: SR Residuals	3.5							
		Offshore		Longline				
K^{sp}	898							
K^{ex}	1102	903		774				
B^{sp}_{y}	86							
B^{exy}	136	140		25				
h	0.845							
$MSYL^{sp}$	217	211		499				
$MSYL^{ex}$	297	285		290				
MSY	141	137		141				
B^{sp}_{y}/K^{sp}	0.096							
B^{ex}_{y}/K^{ex}	0.124	0.155		0.032				
$B^{sp}_{y}/MSYL^{sp}$	0.396	0.407		0.172				
$B^{ex}_{y}/MSYL^{ex}$	0.460	0.492		0.085				
$MSYL^{sp}/K^{sp}$	0.242	0.235		0.555				
$MSYL^{ex}/K^{ex}$	0.269	0.316		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	0.63	0.02	0.24	0.00	0.00	0.00	0.00	0.00
1	0.63	0.38	1.00	0.03	0.01	0.00	0.00	0.00
2	0.63	1.00	0.92	0.57	0.25	0.52	0.09	0.00
3	0.47	0.68	0.77	1.00	1.00	1.00	0.98	0.01
4	0.38	0.46	0.59	0.37	0.73	0.82	1.00	0.04
5+	0.31	0.31	0.46	0.14	0.53	0.67	0.82	1.00
σ_R - output	0.15							
Commercial *q* 's:								
SC ICSEAF CPUE	0.003							
WC ICSEAF CPUE	0.028							
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			
	1.57	1.40	1.28	0.22	0.57			
new *Africana*	1.47	-	-	0.22	0.53			
Catches-at-age sigma's:	0.15	-	0.07	0.06	0.29			
Addnl sigma (survey)	0.316							

* constraint boundary

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

	c) Longline selectivity fixed to 0 for ages 0-3, 0.5 for age 4 and 1 for age 5 and above		
Total -lnL	-87.7		
-lnL : CPUE	-83.4		
-lnL: Survey	-8.8		
-lnL: CAA com.	0.0		
-lnL: CAA surv	1.0		
-lnL: SR Residuals	3.5		
		Offshore	Longline
K^{sp}	891		
K^{ex}	1030	898	849
$B^{sp}{}_{y}$	85		
B^{exy}	135	139	43
h	0.845		
$MSYL^{sp}$	212	209	251
$MSYL^{ex}$	287	284	116
MSY	139	137	175
$B^{sp}{}_{y}/K^{sp}$	0.095		
$B^{ex}{}_{y}/K^{ex}$	0.131	0.155	0.050
$B^{sp}{}_{y}/MSYL^{sp}$	0.401	0.406	0.338
$B^{ex}{}_{y}/MSYL^{ex}$	0.473	0.491	0.367
$MSYL^{sp}/K^{sp}$	0.238	0.234	0.282
$MSYL^{ex}/K^{ex}$	0.278	0.316	0.137

Age	*Ma*	Ssurv (WC Africana)	Ssurv (WC Nansen)	Ssurv (SC spring Africana)	Ssurv (SC autumn Africana)	S1off	S2off	S1long
0	0.63	0.02	0.24	0.00	0.00	0.00	0.00	0.00
1	0.63	0.38	1.00	0.03	0.01	0.00	0.00	0.00
2	0.63	1.00	0.93	0.57	0.25	0.52	0.09	0.00
3	0.48	0.68	0.78	1.00	1.00	1.00	0.98	0.00
4	0.38	0.47	0.61	0.37	0.73	0.82	1.00	0.50
5+	0.32	0.32	0.48	0.14	0.54	0.67	0.82	1.00

σ_R - output	0.15				
Commercial *q*'s:					
SC ICSEAF CPUE	0.003				
WC ICSEAF CPUE	0.028				
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 spring	SC aut
	1.55	1.39	1.25	0.22	0.57
new *Africana*	1.46	-	-	0.22	0.53
Catches-at-age sigma's:	0.15	-	0.07	0.06	0.29
Addnl sigma (survey)	0.316				

* constraint boundary

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

	d) With limit on recent recruitment variability (see text)							
Total -lnL	-86.8							
-lnL : CPUE	-83.4							
-lnL: Survey	-8.8							
-lnL: CAA com.	0.0							
-lnL: CAA surv	2.3							
-lnL: SR Residuals	3.1							
			Offshore		Longline			
K^{sp}	879							
K^{ex}	1079		890		750			
$B^{sp}{}_{y}$	84							
B^{exy}	132		136		24			
h	0.845							
$MSYL^{sp}$	212		206		493			
$MSYL^{ex}$	291		281		283			
MSY	141		137		140			
$B^{sp}{}_{y}/K^{sp}$	0.096							
$B^{ex}{}_{y}/K^{ex}$	0.123		0.153		0.032			
$B^{sp}{}_{y}/MSYL^{sp}$	0.397		0.409		0.171			
$B^{ex}{}_{y}/MSYL^{ex}$	0.454		0.485		0.084			
$MSYL^{sp}/K^{sp}$	0.241		0.234		0.561			
$MSYL^{ex}/K^{ex}$	0.270		0.316		0.377			
Age	*Ma*	Ssurv (WC Africana)	Ssurv (WC Nansen)	Ssurv (SC spring Africana)	Ssurv (SC autumn Africana)	S1off	S2off	S1long
0	0.64	0.02	0.24	0.00	0.00	0.00	0.00	0.00
1	0.64	0.38	1.00	0.03	0.01	0.00	0.00	0.00
2	0.64	1.00	0.93	0.57	0.24	0.52	0.09	0.00
3	0.48	0.69	0.79	1.00	1.00	1.00	0.98	0.01
4	0.39	0.48	0.62	0.37	0.74	0.82	1.00	0.04
5+	0.32	0.33	0.49	0.14	0.55	0.67	0.82	1.00
σ_R - output	0.13							
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 spring	SC aut			
	1.53	1.37	1.23	0.22	0.57			
new *Africana*	1.44	-	-	0.22	0.53			
Catches-at-age sigma's:	0.16	-	0.07	0.06	0.29			
Addnl sigma (survey)	0.315							

* constraint boundary

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

	b) Ignoring 1997 and 1999 west coast summer survey estimates and catch-at-age information							
Total -lnL	-98.3							
-lnL : CPUE	-82.3							
-lnL: Survey	-11.8							
-lnL: CAA com.	0.0							
-lnL: CAA surv	-8.3							
-lnL: SR Residuals	4.1							
			Offshore		Longline			
K^{sp}	782							
K^{ex}	946		824		633			
B^{sp}_{y}	79							
B^{exy}	134		147		20			
h	0.838							
$MSYL^{sp}$	188		181		462			
$MSYL^{ex}$	256		260		247			
MSY	140		136		131			
B^{sp}_{y}/K^{sp}	0.101							
B^{ex}_{y}/K^{ex}	0.142		0.179		0.031			
$B^{sp}_{y}/MSYL^{sp}$	0.422		0.437		0.171			
$B^{ex}_{y}/MSYL^{ex}$	0.524		0.566		0.080			
$MSYL^{sp}/K^{sp}$	0.240		0.231		0.591			
$MSYL^{ex}/K^{ex}$	0.271		0.315		0.390			
Age	*Ma*	Ssurv (WC Africana)	Ssurv (WC Nansen)	Ssurv (SC spring Africana)	Ssurv (SC autumn Africana)	S1off	S2off	S1long
0	0.73	0.02	0.19	0.00	0.00	0.00	0.00	0.00
1	0.73	0.35	0.91	0.02	0.01	0.00	0.00	0.00
2	0.73	1.00	1.00	0.48	0.24	0.52	0.09	0.00
3	0.55	0.80	0.82	1.00	1.00	1.00	0.98	0.01
4	0.44	0.64	0.68	0.37	0.84	0.82	1.00	0.04
5+	0.37	0.51	0.56	0.14	0.71	0.67	0.82	1.00
Commercial *q*'s:								
SC ICSEAF CPUE	0.003							
WC ICSEAF CPUE	0.030							
GLM CPUE	0.040							
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			
	1.15	1.21	1.08	0.23	0.54			
new *Africana*	1.08	-	-	0.23	0.50			
Catches-at-age sigma's:	0.14	-	0.07	0.06	0.29			
Addnl sigma (survey)	0.235							

* constraint boundary

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

	c) With multiplicator factor for new *Africana* selectivity ages 0 and 1										
Total -lnL	-107.1										
-lnL : CPUE	-82.2										
-lnL: Survey	-9.7										
-lnL: CAA com.	0.0										
-lnL: CAA surv	-19.3										
-lnL: SR Residuals	4.2										
			Offshore		Longline						
K^{sp}	866										
K^{ex}	1053		882		734						
$B^{sp}{}_{y}$	78										
B^{exy}	145		155		23						
h	0.843										
$MSYL^{sp}$	209		203		490						
$MSYL^{ex}$	282		279		278						
MSY	141		137		139						
$B^{sp}{}_{y}/K^{sp}$	0.090										
$B^{ex}{}_{y}/K^{ex}$	0.137		0.175		0.032		Multiplicative factor for				
$B^{sp}{}_{y}/MSYL^{sp}$	0.374		0.386		0.160		new Africana selectivity:				
$B^{ex}{}_{y}/MSYL^{ex}$	0.513		0.555		0.083			Age 0:	12.5		
$MSYL^{sp}/K^{sp}$	0.242		0.234		0.565			Age 1:	1.3		
$MSYL^{ex}/K^{ex}$	0.268		0.316		0.379						
Age	*Ma*	Ssurv (WC **old** Africana)	Ssurv (WC Nansen)	Ssurv (SC spr **old** Africana)	Ssurv (SC aut **old** Africana)	Ssurv (WC **new** Africana)	Ssurv (SC spr **new** Africana)	Ssurv (SC aut **new** Africana)	S1off	S2off	S1long
0	0.66	0.02	0.20	0.00	0.00	0.21	0.00	0.01	0.00	0.00	0.00
1	0.66	0.36	1.00	0.02	0.01	0.47	0.02	0.01	0.00	0.00	0.00
2	0.66	1.00	1.00	0.50	0.25	1.00	0.50	0.25	0.53	0.09	0.00
3	0.49	0.72	0.74	1.00	1.00	0.72	1.00	1.00	1.00	0.98	0.01
4	0.39	0.51	0.55	0.37	0.78	0.51	0.37	0.78	0.82	1.00	0.04
5+	0.33	0.37	0.41	0.14	0.62	0.37	0.14	0.62	0.67	0.82	1.00
Commercial *q*'s:											
SC ICSEAF CPUE	0.003	(0.03)	(0.04)								
WC ICSEAF CPUE	0.028										
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						
	1.45	1.35	1.26	0.23	0.55						
new *Africana*	1.34	-	-	0.23	0.51						
Catches-at-age sigma's:	0.15	-	0.07	0.06	0.29						
Addnl sigma (survey)	0.316										

* constraint boundary

Table 2: Estimates of management quantities for Reference Case assessment and a series of sensitivities for this assessment of the ***M. capensis*** resource for the south and west coasts combined. The first figure shown is the best estimate, followed by the Hessian-based CV in parenthesis (note that the Hessian-based CV for *h* is unreliable, as this parameter is estimated at a bound and hence shown as ***). Exploitable biomass and associated quantities are estimated for each fleet separately and also for an 'average-selectivity', reflecting that of the last year (2003) of the assessment, which is shown in the first column.

a) *M. capensis* Reference Case

			Offshore		Inshore		Longline		Handline	
Total -lnL	-8.2									
-lnL : CPUE	-77.0									
-lnL: Survey	56.1									
-lnL: CAA com.	-45.4									
-lnL: CAA surv	54.8									
-lnL: SR Residuals	3.3									
K^{sp}	246	(0.08)								
K^{ex}	174	(0.20)	251	(0.10)	175	(0.07)	116	(0.22)	170	(0.19)
B^{sp}_{y}	94	(0.12)								
B^{ex}_{y}	46	(0.29)	90	(0.14)	82	(0.12)	14	(0.40)	39	(0.28)
h	0.980	(0.00)								
$MSYL^{sp}$	83	(0.16)	30	(0.15)	29	(0.15)	161	(0.02)	106	(0.09)
$MSYL^{ex}$	37	(0.02)	32	(0.07)	32	(0.07)	29	(0.13)	34	(0.04)
MSY	45	(0.04)	45	(0.06)	45	(0.07)	40	(0.12)	46	(0.05)
B^{sp}_{y}/K^{sp}	0.381	(0.14)								
B^{ex}_{y}/K^{ex}	0.265	(0.18)	0.361	(0.14)	0.471	(0.13)	0.122	(0.28)	0.228	(0.19)
$B^{sp}_{y}/MSYL^{sp}$	1.122	(0.22)	3.144	(0.19)	3.189	(0.18)	0.580	(0.12)	0.880	(0.15)
$B^{ex}_{y}/MSYL^{ex}$	1.243	(0.27)	2.843	(0.15)	2.600	(0.13)	0.491	(0.31)	1.132	(0.24)
$MSYL^{sp}/K^{sp}$	0.340	(0.24)	0.121	(0.22)	0.119	(0.22)	0.657	(0.09)	0.433	(0.16)
$MSYL^{ex}/K^{ex}$	0.213	(0.20)	0.127	(0.17)	0.181	(0.11)	0.249	(0.10)	0.202	(0.15)
M	0.509									

Age	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	0.22	0.04	0.61	0.02	0.00	0.00	0.00	0.00
1	0.40	0.68	0.56	0.05	0.01	0.01	0.00	0.00
2	1.00	0.83	0.60	0.11	0.06	0.06	0.00	0.00
3	0.81	0.83	1.00	0.19	0.43	0.44	0.00	0.03
4	0.45	0.51	0.55	0.46	0.90	0.91	0.00	0.16
5	0.51	1.00	0.38	0.70	0.99	1.00	0.10	0.58
6	0.99	0.95	0.56	0.84	1.00	0.60	0.41	0.92
7+	0.80	0.90	0.40	1.00	1.00	0.36	1.00	1.00

σ_R - output			
Commercial:	Sigmas:	*q*'s:	
South coast hist.CPUE	0.250 *	0.007	(0.13)
West coast hist.CPUE	0.250 *	0.072	(0.11)
GLM CPUE	0.150 *	0.043	(0.10)

Survey *q*'s:	old *Africana*/*Nansen*	new *Africana*
West coast summer	1.043	0.725
West coast winter	0.957	-
West coast *Nansen*	2.380	-
South coast spring	2.470	1.503
South coast autumn	2.682	1.647

Catches-at-age sigma's:	Commercial:			Survey:		
	inshore	0.119	(0.04)	WC sum	0.248	(0.02)
	longline	0.108	(0.08)	WC wint	0.148	(0.05)
				WC *Nan*	0.084	(0.12)
				SC spring	0.097	(0.32)
				SC aut	0.133	(0.04)
Additional sigma (survey)	0.320	(0.16)				

* constraint boundary

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

	b) Assuming 20% *M. capensis* in west coast longline catch instead of 30%				
Total -lnL	-8.6				
-lnL : CPUE	-77.2				
-lnL: Survey	56.1				
-lnL: CAA com.	-45.5				
-lnL: CAA surv	54.6				
-lnL: SR Residuals	3.3				
		Offshore	Inshore	Longline	Handline
K^{sp}	242				
K^{ex}	172	246	175	112	165
B^{sp}_{y}	92				
B^{ex}_{y}	46	89	82	14	38
h	0.980				
$MSYL^{sp}$	82	30	30	161	107
$MSYL^{ex}$	37	32	32	28	34
MSY	45	45	45	39	46
B^{sp}_{y}/K^{sp}	0.382				
B^{ex}_{y}/K^{ex}	0.270	0.362	0.467	0.122	0.228
$B^{sp}_{y}/MSYL^{sp}$	1.132	3.061	3.105	0.574	0.865
$B^{ex}_{y}/MSYL^{ex}$	1.257	2.793	2.563	0.485	1.109
$MSYL^{sp}/K^{sp}$	0.337	0.125	0.123	0.665	0.442
$MSYL^{ex}/K^{ex}$	0.214	0.130	0.182	0.252	0.205
M	0.516				

Age	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	0.21	0.04	0.60	0.02	0.00	0.00	0.00	0.00
1	0.39	0.66	0.55	0.04	0.01	0.01	0.00	0.00
2	0.98	0.81	0.59	0.10	0.06	0.06	0.00	0.00
3	0.79	0.81	1.00	0.18	0.43	0.43	0.00	0.03
4	0.45	0.50	0.55	0.45	0.89	0.90	0.00	0.15
5	0.51	1.00	0.39	0.68	0.99	1.00	0.10	0.57
6	1.00	0.96	0.57	0.83	1.00	0.61	0.41	0.91
7+	0.83	0.92	0.42	1.00	1.00	0.37	1.00	1.00

σ_R - output	0.14	
Commercial:	Sigmas:	q's:
South coast hist.CPUE	0.250 *	0.007
West coast hist.CPUE	0.250 *	0.074
GLM CPUE	0.150 *	0.043

Survey q's:	old *Africana*/*Nansen*	new *Africana*
West coast summer	1.053	0.732
West coast winter	0.971	-
West coast *Nansen*	2.370	-
South coast spring	2.577	1.569
South coast autumn	2.795	1.715

Catches-at-age sigma's:	Commercial:		Survey:	
	inshore	0.119	WC sum	0.248
	longline	0.107	WC wint	0.148
			WC *Nan*	0.084
			SC spring	0.097
			SC aut	0.132
Additional sigma (survey)	0.320			

* constraint boundary

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

	c) With limit on recent recruitment variability (see text)				
Total -lnL	-7.5				
-lnL : CPUE	-77.0				
-lnL: Survey	55.9				
-lnL: CAA com.	-45.3				
-lnL: CAA surv	55.6				
-lnL: SR Residuals	3.2				
		Offshore	Inshore	Longline	Handline
K^{sp}	246				
K^{ex}	174	251	175	116	170
B^{sp}_{y}	93				
B^{ex}_{y}	45	89	81	14	38
h	0.980				
$MSYL^{sp}$	83	30	29	161	106
$MSYL^{ex}$	37	32	32	29	34
MSY	45	45	45	40	46
B^{sp}_{y}/K^{sp}	0.378				
B^{ex}_{y}/K^{ex}	0.261	0.355	0.464	0.120	0.226
$B^{sp}_{y}/MSYL^{sp}$	1.114	3.124	3.168	0.575	0.874
$B^{ex}_{y}/MSYL^{ex}$	1.226	2.802	2.563	0.483	1.123
$MSYL^{sp}/K^{sp}$	0.339	0.121	0.119	0.656	0.432
$MSYL^{ex}/K^{ex}$	0.213	0.127	0.181	0.248	0.201
M	0.509				

Age	S_{surv} (WC summer)	S_{surv} (WC winter)	S_{surv} (WC *Nansen*)	S_{surv} (SC)	S_{off}	S_{in}	S_{ll}	S_{hl}
0	0.22	0.04	0.63	0.02	0.00	0.00	0.00	0.00
1	0.40	0.68	0.56	0.05	0.01	0.01	0.00	0.00
2	1.00	0.83	0.59	0.11	0.06	0.06	0.00	0.00
3	0.81	0.83	1.00	0.19	0.43	0.44	0.00	0.03
4	0.45	0.51	0.55	0.47	0.90	0.91	0.00	0.16
5	0.51	1.00	0.38	0.70	0.99	1.00	0.10	0.58
6	0.98	0.95	0.56	0.86	1.00	0.60	0.41	0.92
7+	0.80	0.90	0.40	1.00	1.00	0.36	1.00	1.00

σ_R - output	0.13	
Commercial:	Sigmas:	*q*'s:
South coast hist.CPUE	0.250 *	0.007
West coast hist.CPUE	0.250 *	0.072
GLM CPUE	0.150 *	0.043
Survey *q*'s:	old *Africana*/*Nansen*	new *Africana*
West coast summer	1.050	0.733
West coast winter	0.958	-
West coast *Nansen*	2.394	-
South coast spring	2.458	1.496
South coast autumn	2.663	1.639

Catches-at-age sigma's:	Commercial:		Survey:	
	inshore	0.119	WC sum	0.248
	longline	0.107	WC wint	0.148
			WC *Nan*	0.082
			SC spring	0.107
			SC aut	0.132
Additional sigma (survey)	0.318			

* constraint boundary

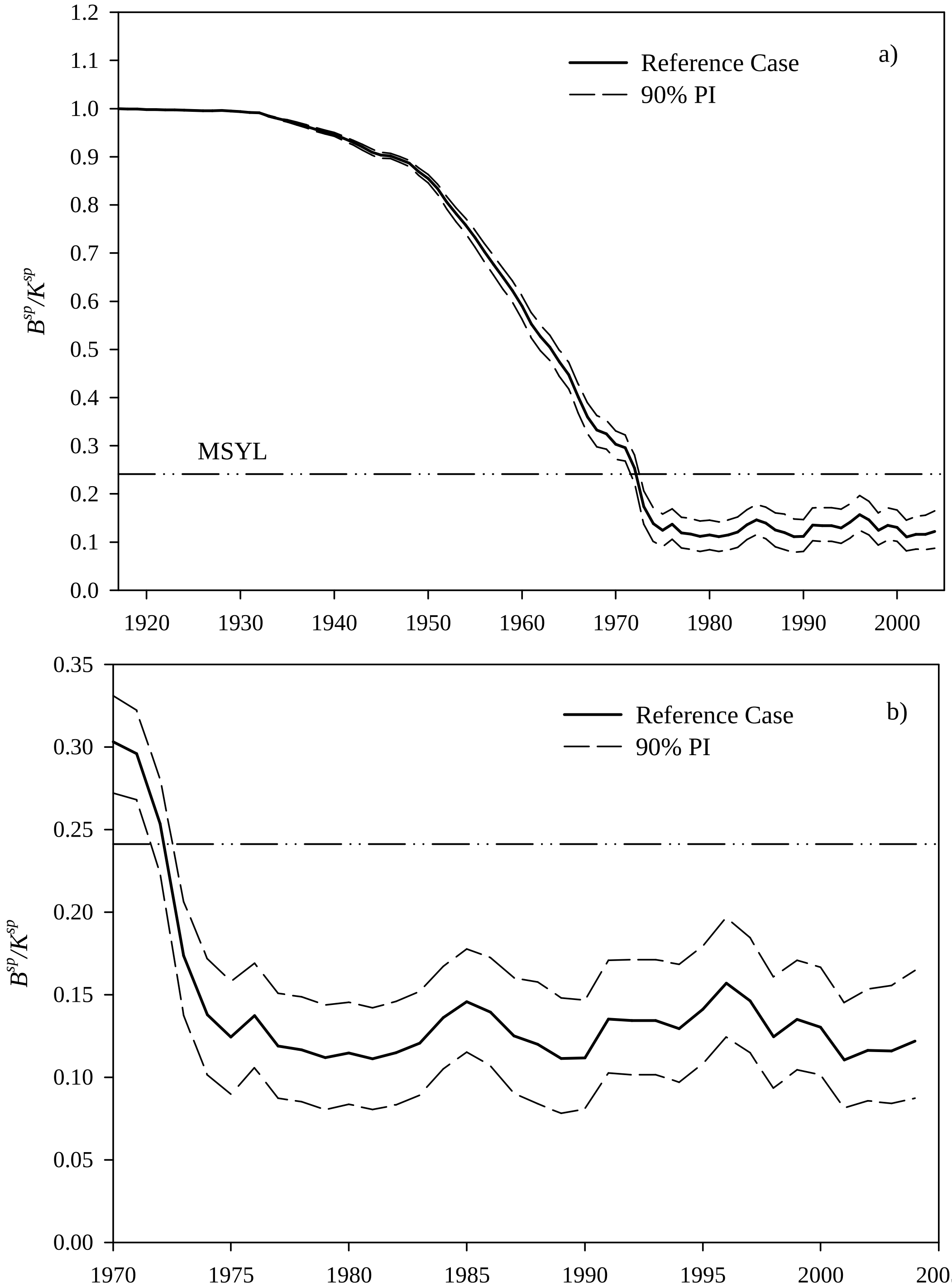

Fig. 1: Resource abundance trajectories (expressed in terms of spawning biomass as a proportion of its pre-exploitation equilibrium level) for the Reference Case assessment of the ***M. paradoxus*** resource for the south and west coasts combined. The 90% PI show is MCMC-based.

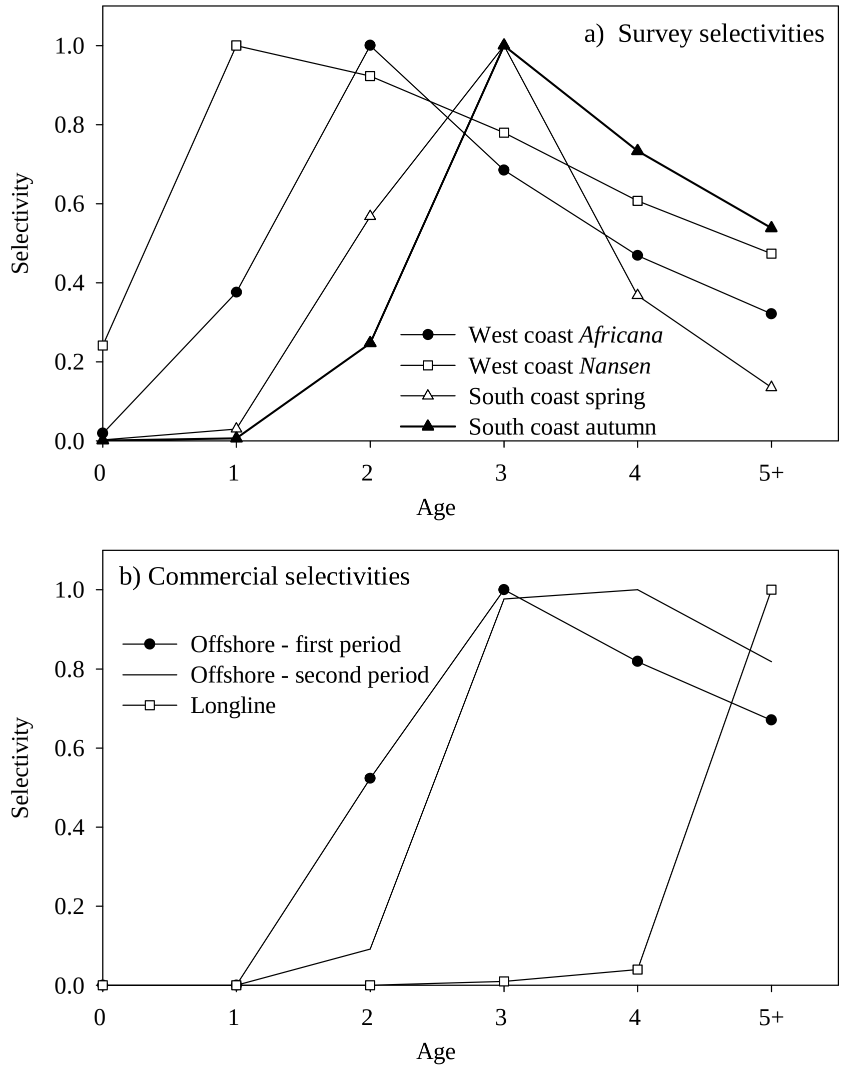

Fig. 2: a) Survey and b) commercial selectivity function estimated for the ***M. paradoxus*** resource for both coasts combined, for the Reference Case assessment.

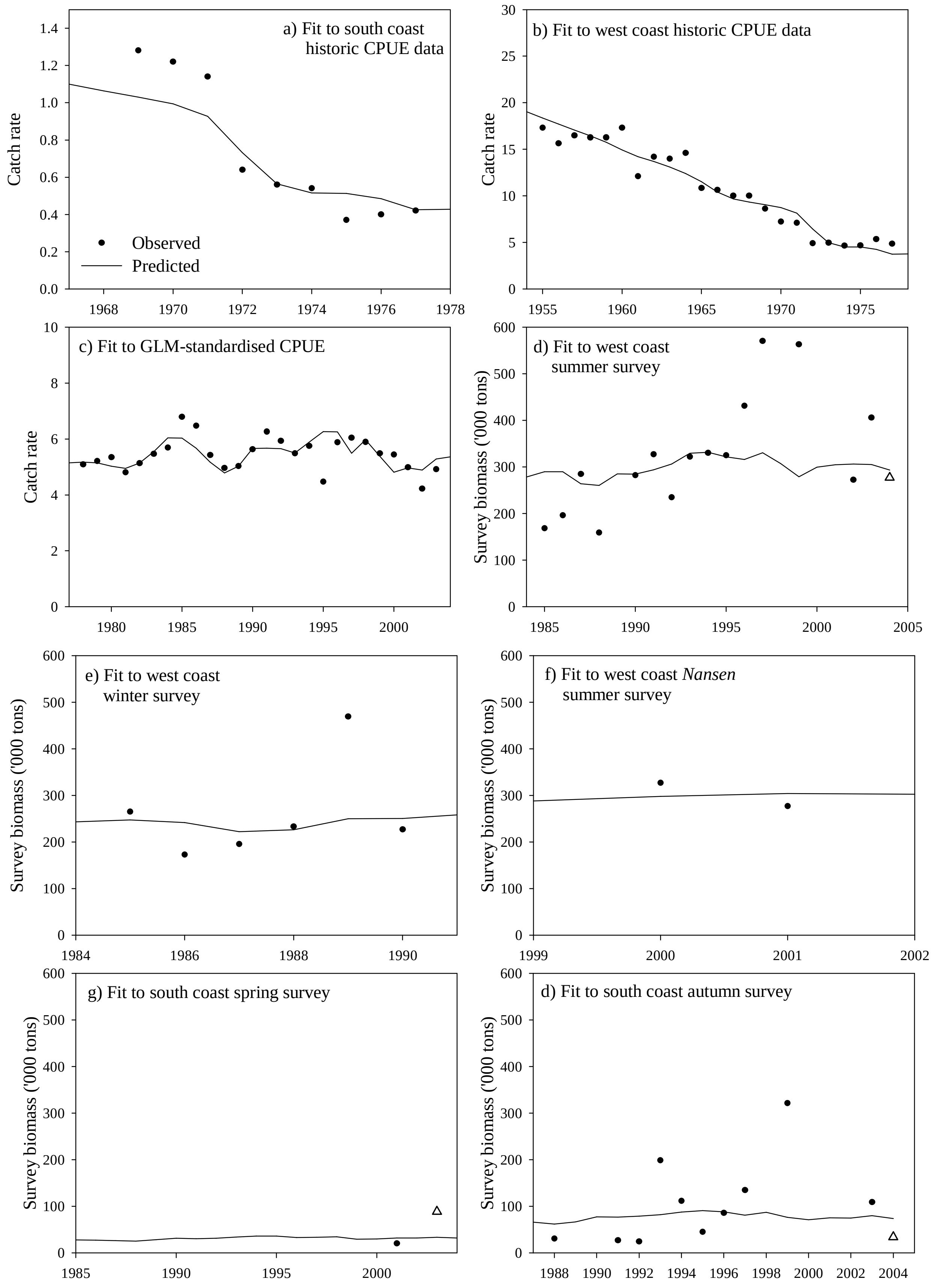

Fig. 3: Reference Case fits for the ***M. paradoxus*** resource, coasts combined, to the abundance indices. The historic (pre-1978) CPUE data are for both *M. capensis* and *M. paradoxus* combined. Biomass estimates from surveys conducted with the new *Africana* gear have been rescaled by the ratio of the q's and are marked by Δ.

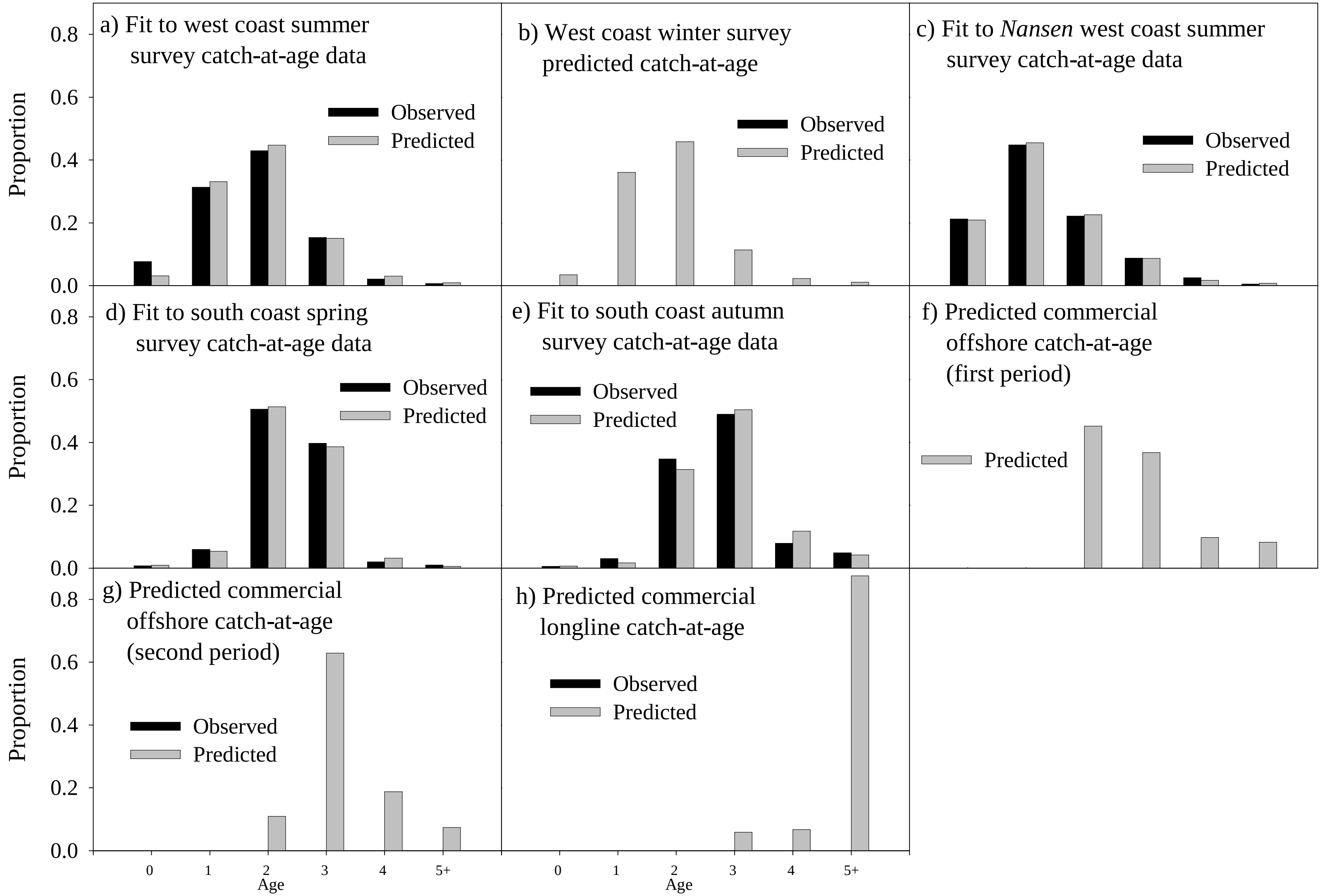

Fig. 4: Reference Case assessment model fits to catch-at-age data for ***M. paradoxus***, coasts combined. Catch-at-age information for *M. paradoxus* is not available for the west coast winter survey, as well as the commercial fleets, but the predicted values are shown for comparison purposes.

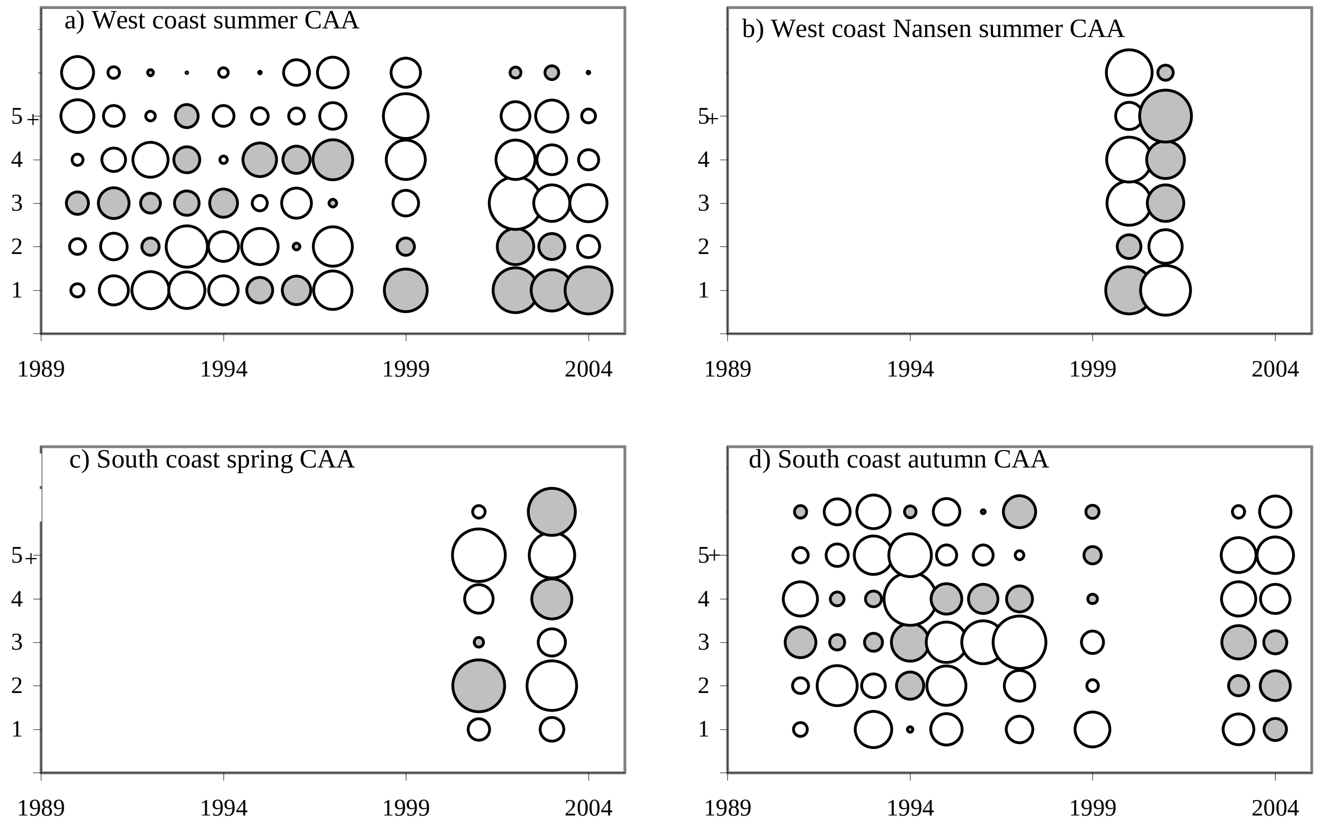

Fig. 5: “Bubble plots” of the catch-at-age residuals for the survey data for the ***M. paradoxus***, coasts combined, Reference Case assessment. The size (area) of the bubble is proportional to the corresponding standardised residual. For positive residuals, the bubbles are grey and for negative residuals, the bubbles are white.

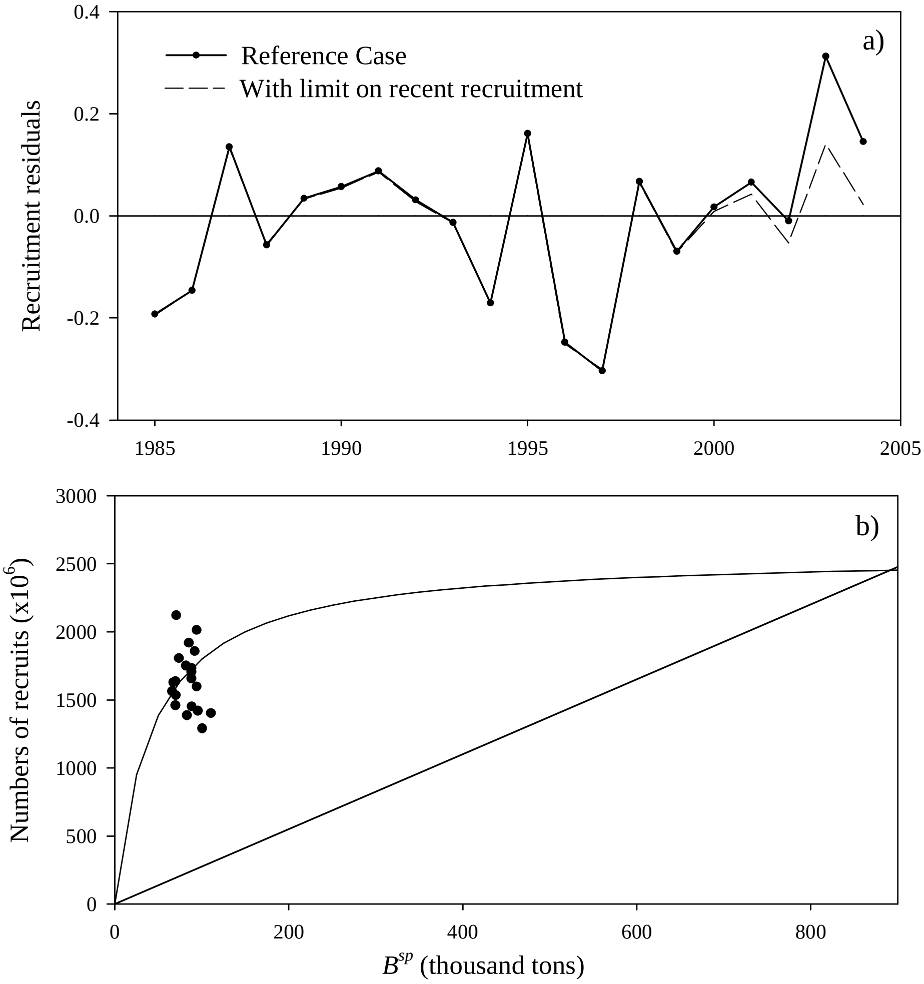

Fig. 6: a) Recruitment residuals for the Reference Case assessment and the sensitivity assessment with limit on recent recruitment of ***M. paradoxus***, coasts combined, resource; b) shows the estimated stock-recruitment relationship and replacement line.

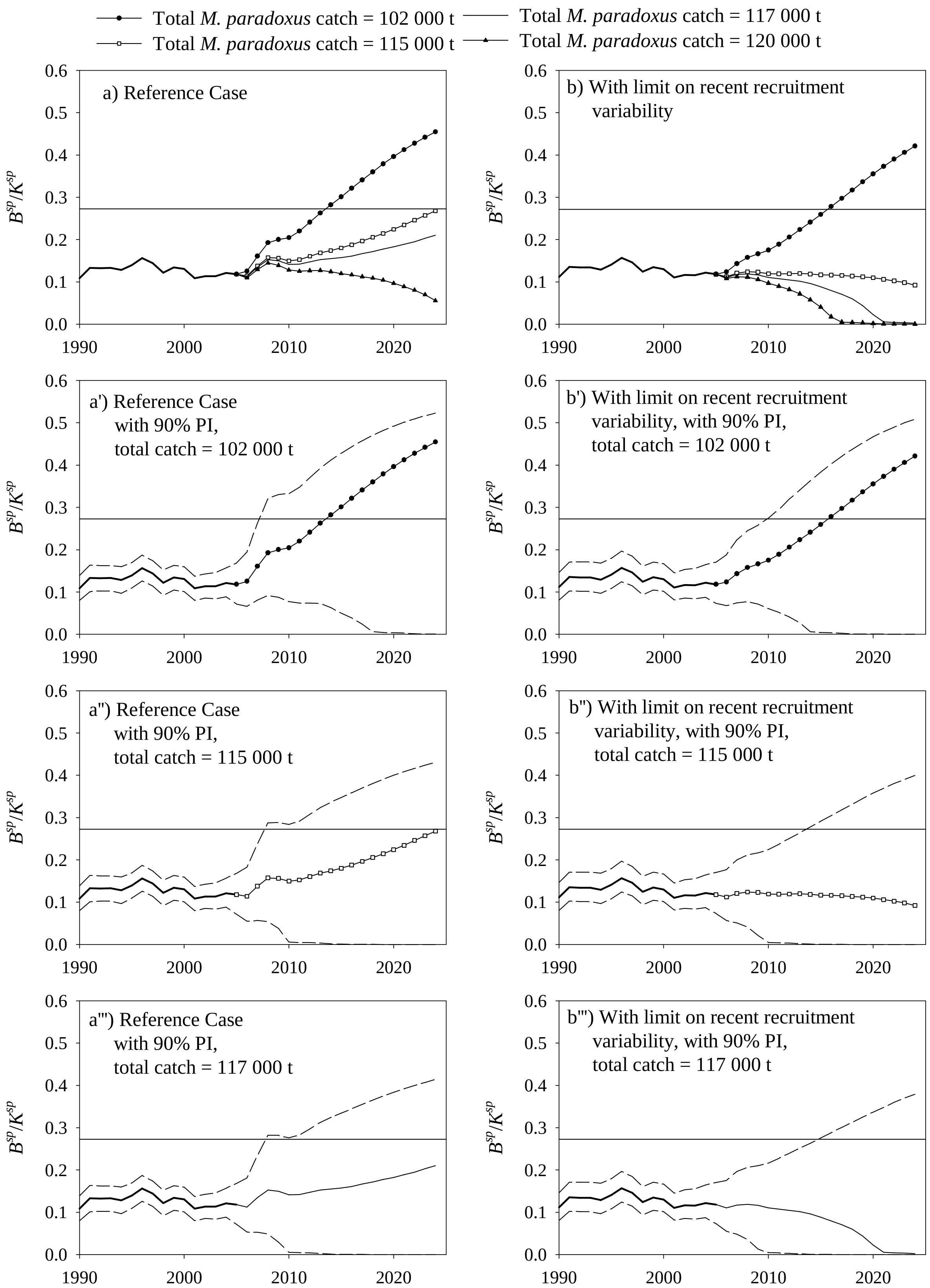

Fig. 7: 20-year spawning biomass projections under four different constant catch strategies for the a) the Reference Case assessment, and b) the sensitivity to this assessment with limits on recent recruitment variability **for *M. paradoxus***, coasts combined. 90% MCMC-based probability envelopes are shown for the 102 000t, 115 000t and 117 000t constant catch.

Fig. 8: Resource abundance trajectories (expressed in terms of spawning biomass as a proportion of its pre-exploitation equilibrium level) for the Reference Case assessment (with 90% MCMC-based PI envelope) for the ***M. capensis*** resource for the south and west coasts combined.

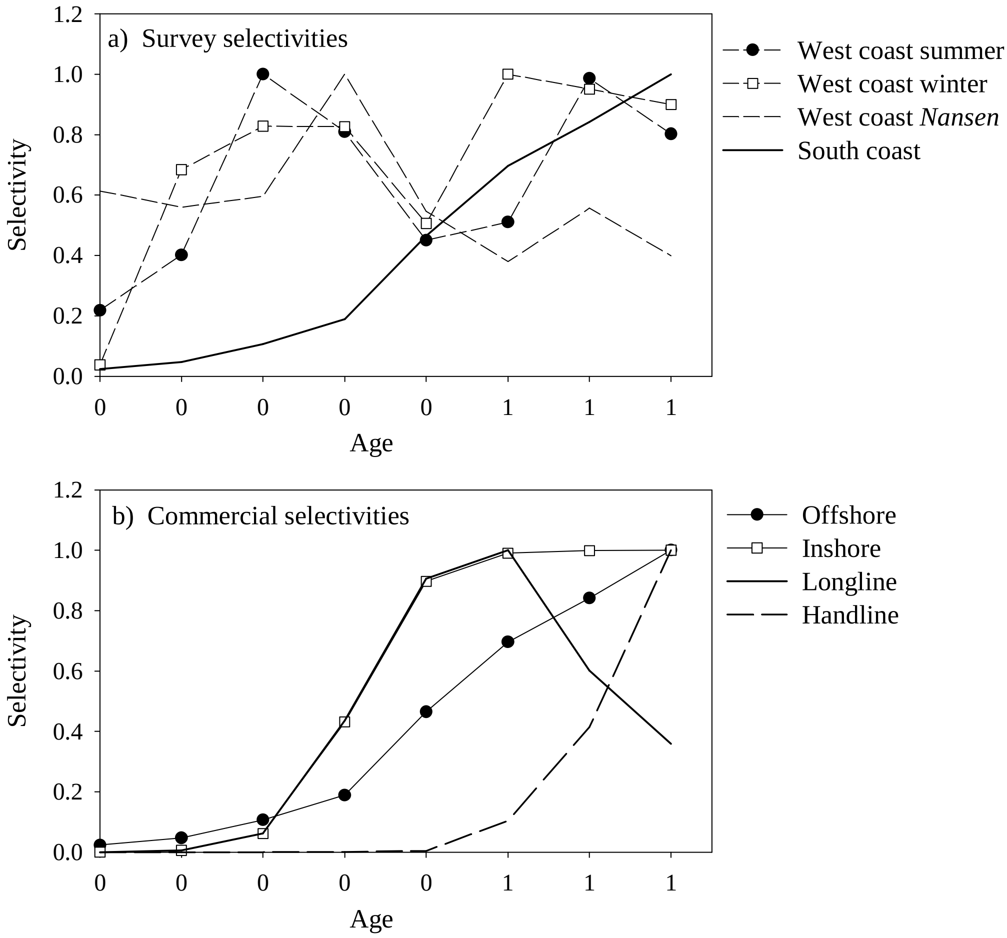

Fig. 9: a) Survey and b) commercial selectivity functions estimated for the ***M. capensis*** resource for both coasts combined for the Reference Case assessment.

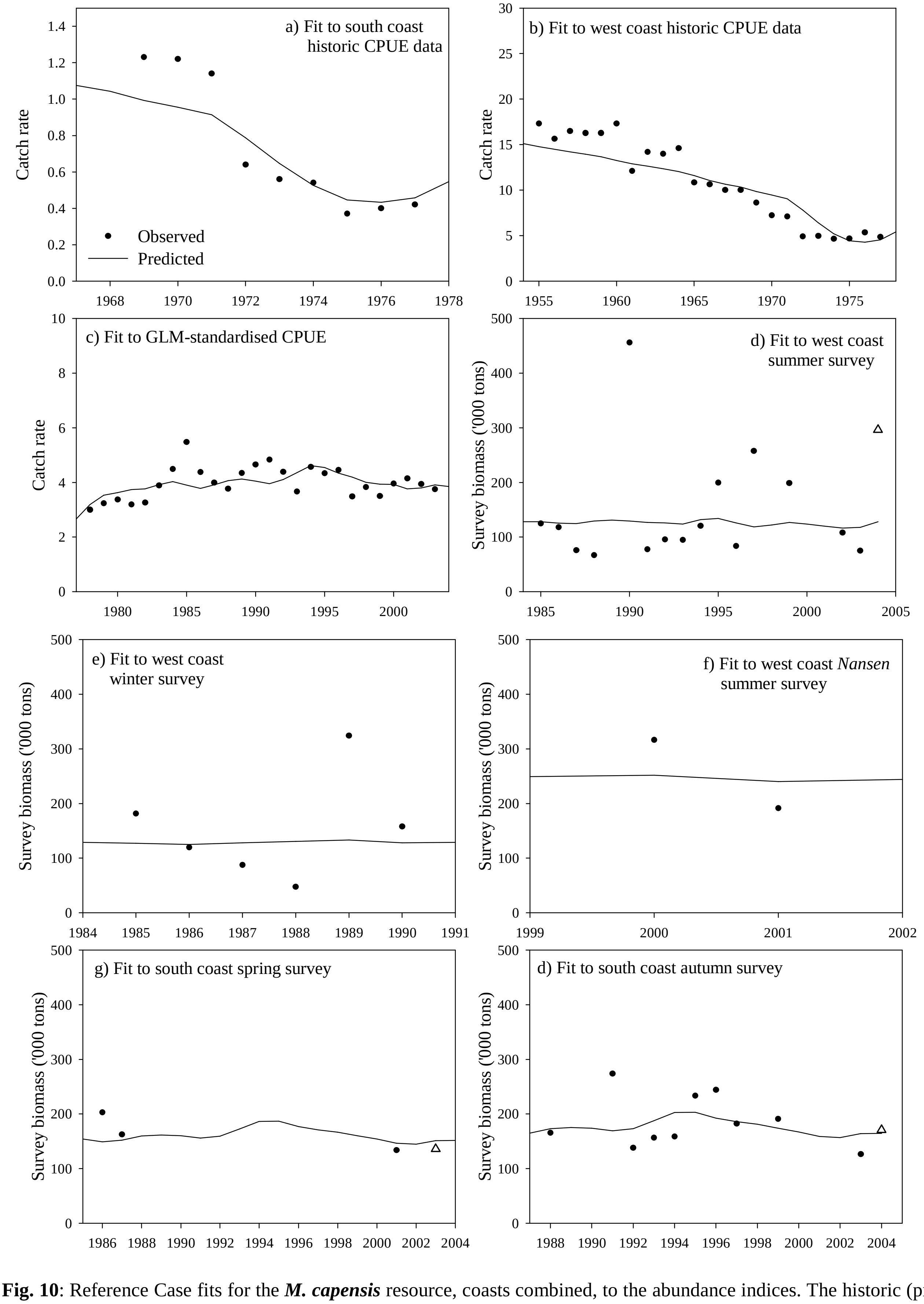

Fig. 10: Reference Case fits for the ***M. capensis*** resource, coasts combined, to the abundance indices. The historic (pre-1978) CPUE data are for both *M. capensis* and *M. paradoxus* combined. Biomass estimates from surveys conducted with the new *Africana* gear have been rescaled by the ratio of the *q*'s and are marked by Δ.

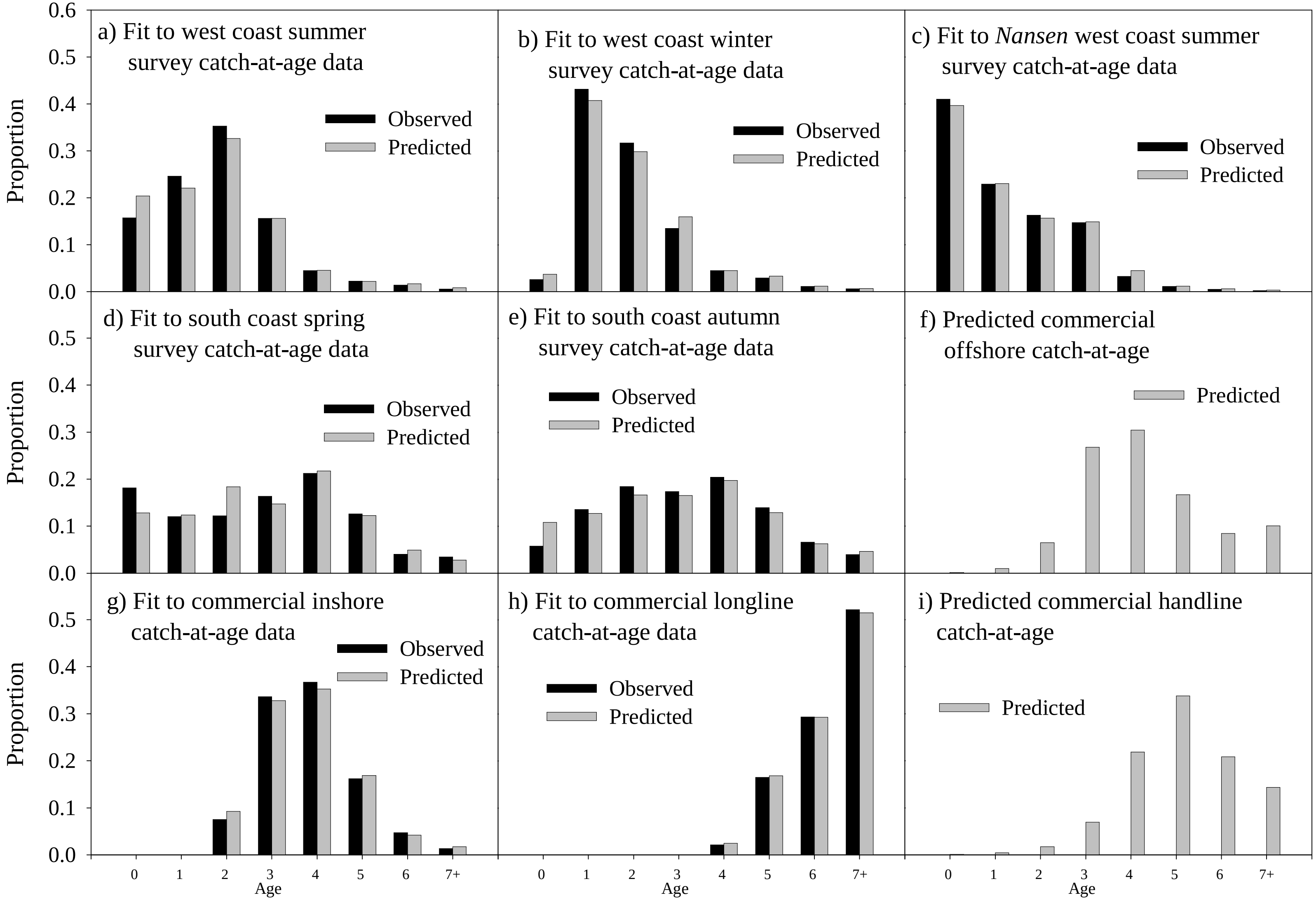

Fig. 11: Reference Case assessment model fits to catch-at-age data for ***M. capensis***, coasts combined. Catch-at-age information for *M. capensis* is not available for the offshore and handline commercial fleets, but the predicted values are shown for comparison purposes.

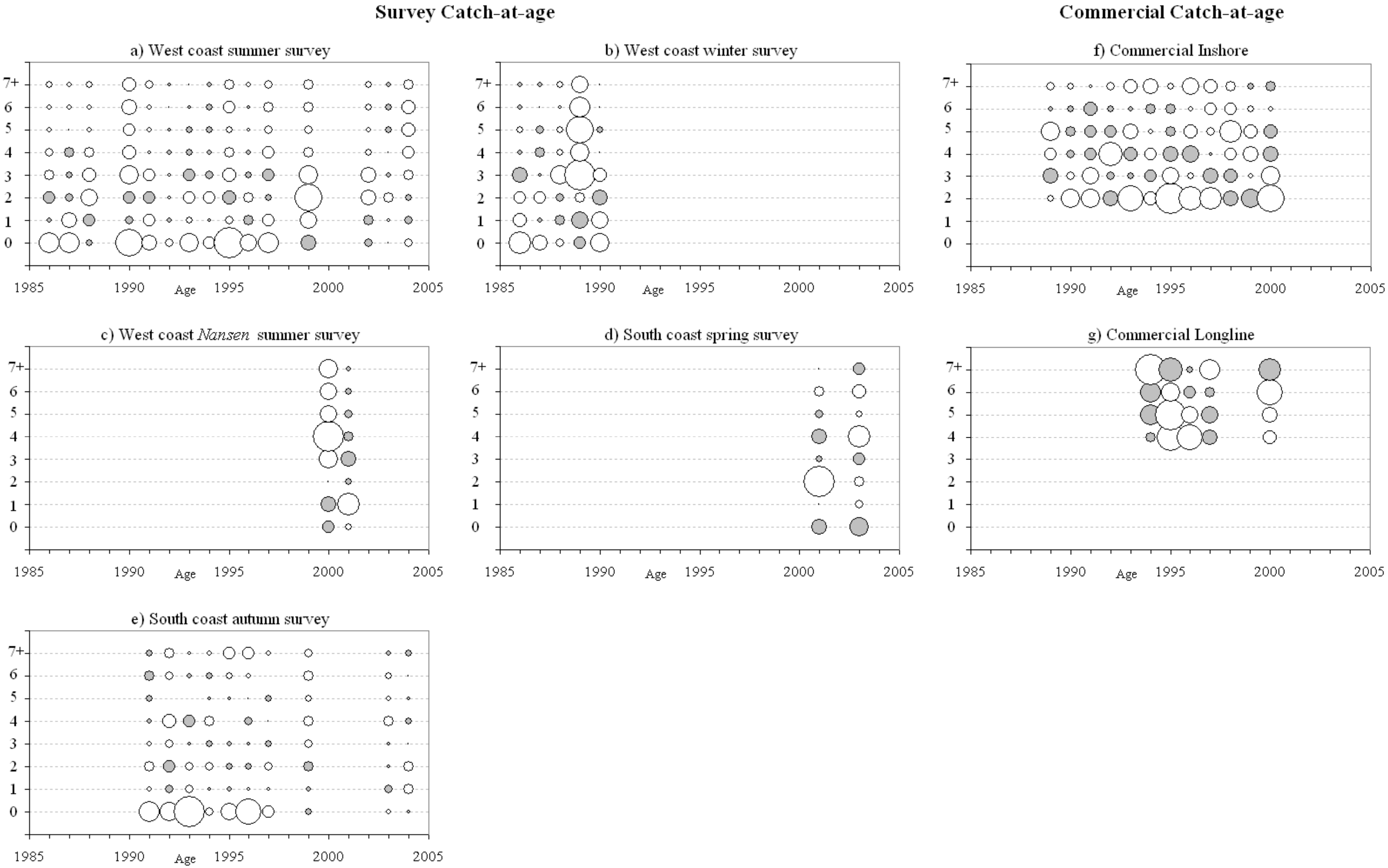

Fig. 12: “Bubble plots” of the catch-at-age residuals for the survey data for the ***M. capensis***, coasts combined, Reference Case assessment. The size (area) of the bubble is proportional to the corresponding standardised residual. For positive residuals, the bubbles are grey and for negative residuals, the bubbles are white.

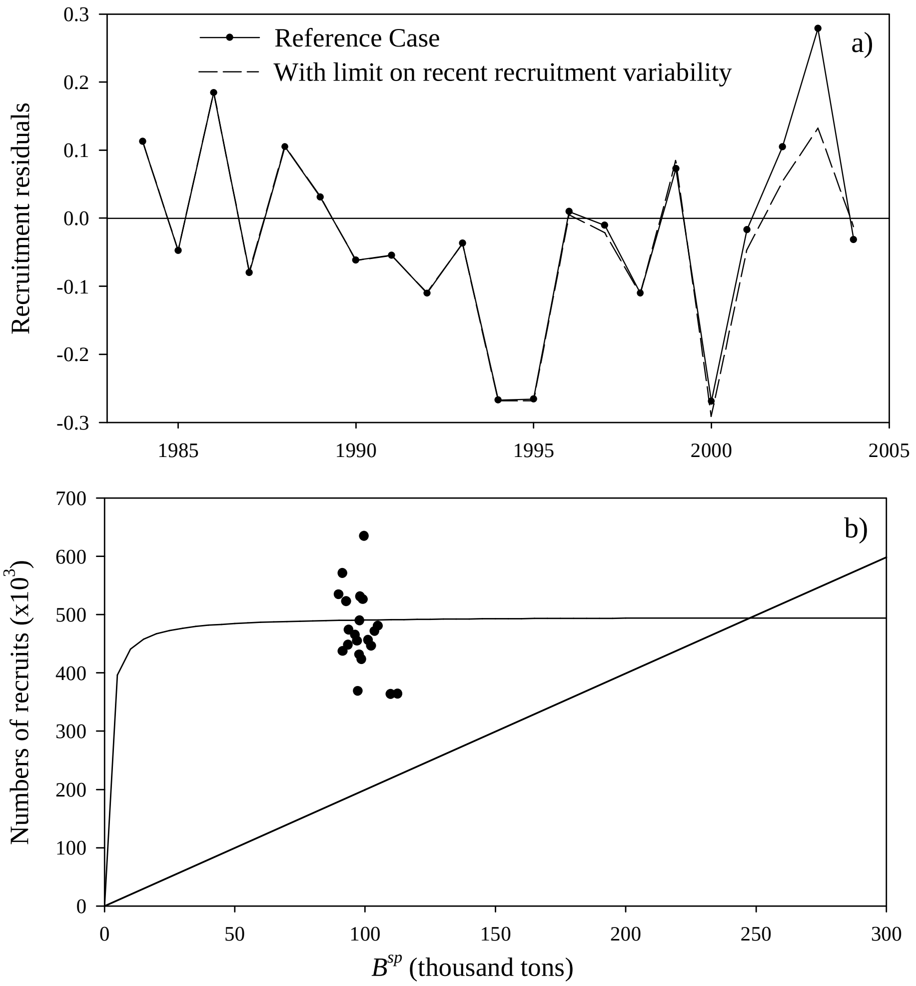

Fig. 13: a) Recruitment residuals for the Reference Case assessment and the sensitivity assessment with limit on recent recruitment of ***M. capensis***, coasts combined, resource; b) shows the estimated stock-recruitment relationship and replacement line.

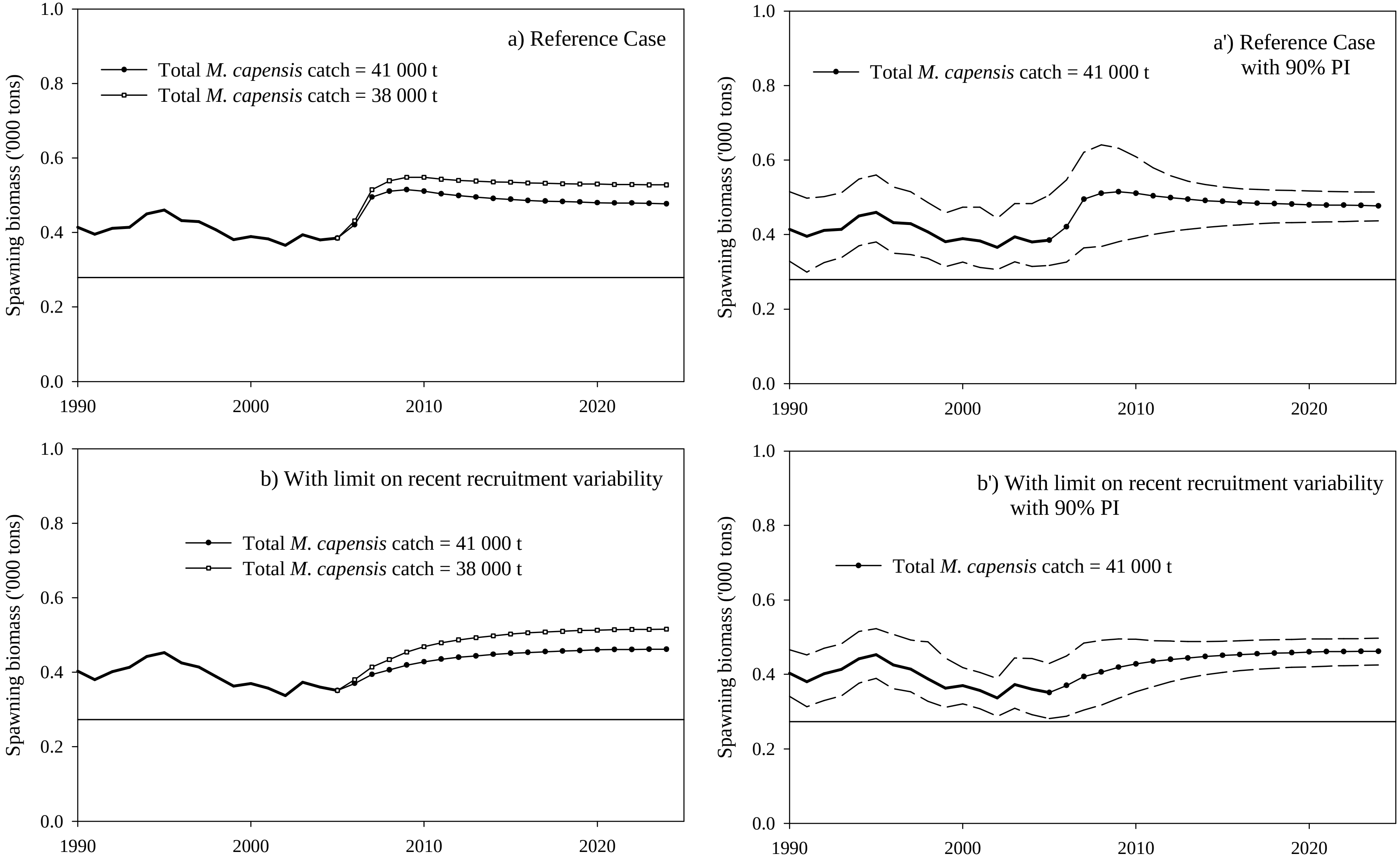

Fig. 14: 20-year spawning biomass projections under two different constant catch strategies for the a) the Reference Case assessment, and b) the sensitivity to this assessment with limits on recent recruitment variability for ***M. capensis***, coasts combined. 90% MCMC-based probability envelopes are shown for the 41 000t constant catch.

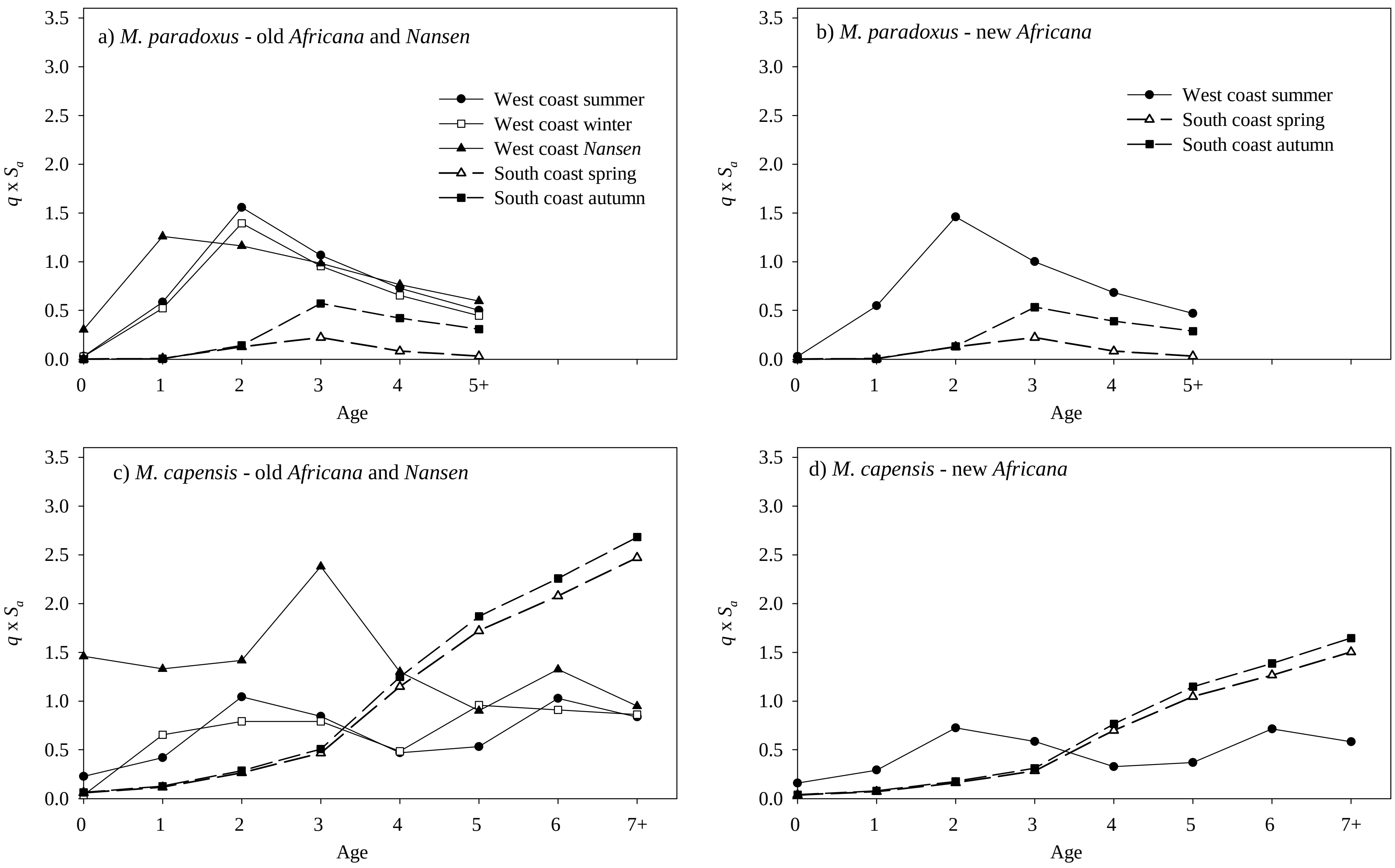

Fig. 15: Age-dependent survey catchability ($q^{surv}S_a^{surv}$) for a) *M. paradoxus* and b) *M. capensis* Reference Case assessments.

Appendix: Data Tables

Table A1: Assumed total annual catches by coast for ***M. paradoxus*** for the period 1917 to 2004 (see Data section of text for details). Catches are given in thousand tons.

Year	West coast Offshore	Year	West coast Offshore	West coast Longline	South coast Offshore	South coast Longline
1917	0.842	1960	134.636	-	-	-
1918	0.926	1961	125.205	-	-	-
1919	1.600	1962	124.279	-	-	-
1920	0.000	1963	142.719	-	-	-
1921	1.095	1964	136.657	-	-	-
1922	0.842	1965	170.926	-	-	-
1923	2.105	1966	164.190	-	-	-
1924	1.263	1967	148.781	-	3.224	-
1925	1.600	1968	120.911	-	9.386	-
1926	1.179	1969	139.014	-	13.891	-
1927	0.674	1970	119.985	-	7.819	-
1928	2.189	1971	170.084	-	10.762	-
1929	3.200	1972	205.392	-	22.259	-
1930	3.705	1973	132.852	-	29.585	-
1931	2.358	1974	103.566	-	39.906	-
1932	12.041	1975	75.458	-	29.632	-
1933	9.346	1976	121.159	-	22.809	-
1934	11.620	1977	86.160	-	16.239	-
1935	12.630	1978	90.255	-	20.572	-
1936	14.903	1979	76.711	-	25.357	-
1937	17.008	1980	84.903	-	22.117	-
1938	17.766	1981	82.477	-	11.755	-
1939	16.840	1982	71.646	-	20.856	-
1940	24.081	1983	61.735	0.161	18.075	-
1941	25.765	1984	70.695	0.256	18.539	-
1942	29.049	1985	82.358	0.817	25.826	-
1943	31.912	1986	91.956	0.965	25.991	-
1944	28.712	1987	87.074	2.500	18.766	-
1945	24.586	1988	71.464	3.628	20.319	-
1946	34.017	1989	72.038	0.203	20.432	-
1947	34.859	1990	66.772	0.270	25.054	-
1948	49.510	1991	76.410	0.000	25.586	-
1949	48.331	1992	73.911	0.000	28.694	-
1950	60.624	1993	90.687	0.000	24.019	-
1951	75.359	1994	92.801	1.130	21.365	-
1952	74.770	1995	79.634	0.670	21.814	-
1953	78.727	1996	81.264	1.676	40.591	-
1954	88.747	1997	81.501	1.806	31.838	-
1955	97.167	1998	96.615	0.647	25.135	-
1956	99.524	1999	73.097	1.963	27.868	-
1957	106.429	2000	80.619	3.456	27.266	-
1958	110.049	2001	83.835	2.793	29.809	-
1959	122.932	2002	71.994	4.772	34.613	-
		2003	63.616	4.668	35.280	-
		2004	73.752	5.411	40.902	-

Table A2: South and west coast historic (1969 to 1977) 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 ICSEAF CPUE tons/hr Spp combined	West coast ICSEAF CPUE tons/day Spp combined	Combined GLM CPUE kg/min *M. capensis*	Combined GLM CPUE kg/min *M. paradoxus*
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: 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 A5: *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 A6: 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 A7: 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 A8: Assumed total annual catches by fleet for the south and west coasts of ***M. capensis*** for the period 1917 to 2004 (see Data section of text for details). Catches are given in thousand tons.

Year	West coast	Year	West coast		South coast			
	Offshore		Offshore	Longline	Offshore	Inshore	Longline	Handline
1917	0.158	1960	25.264	-	-	1.000	-	-
1918	0.174	1961	23.495	-	-	1.308	-	-
1919	0.300	1962	23.321	-	-	1.615	-	-
1920	0.000	1963	26.781	-	-	1.923	-	-
1921	0.205	1964	25.643	-	-	2.231	-	-
1922	0.158	1965	32.074	-	-	2.539	-	-
1923	0.395	1966	30.810	-	-	2.846	-	-
1924	0.237	1967	27.919	-	2.735	3.154	-	-
1925	0.300	1968	22.689	-	7.963	3.462	-	-
1926	0.221	1969	26.086	-	11.786	3.769	-	-
1927	0.126	1970	22.515	-	6.633	4.077	-	-
1928	0.411	1971	31.916	-	9.130	4.385	-	-
1929	0.600	1972	38.541	-	18.885	4.692	-	-
1930	0.695	1973	24.930	-	25.100	5.000	-	-
1931	0.442	1974	19.434	-	33.857	10.056	-	-
1932	2.259	1975	14.159	-	25.141	6.372	-	-
1933	1.754	1976	22.735	-	19.352	5.740	-	-
1934	2.180	1977	16.168	-	13.778	3.500	-	-
1935	2.370	1978	10.885	-	13.386	4.931	-	-
1936	2.797	1979	15.993	-	22.381	4.931	-	-
1937	3.192	1980	16.635	-	16.333	4.931	-	-
1938	3.334	1981	18.201	-	13.983	9.400	-	-
1939	3.160	1982	14.324	-	17.881	8.089	-	-
1940	4.519	1983	11.712	0.069	15.427	7.672	-	-
1941	4.835	1984	17.350	0.110	15.606	9.035	0.016	-
1942	5.451	1985	16.065	0.350	20.837	9.203	0.292	0.065
1943	5.988	1986	15.757	0.413	16.066	8.724	0.302	0.084
1944	5.388	1987	13.365	1.071	14.004	8.607	0.353	0.096
1945	4.614	1988	13.484	1.555	15.831	8.417	0.331	0.071
1946	6.383	1989	12.568	0.087	21.133	10.038	0.032	0.137
1947	6.541	1990	11.760	0.116	22.842	10.012	0.000	0.348
1948	9.290	1991	9.111	0.000	17.417	8.206	3.000	1.270
1949	9.069	1992	12.369	0.000	14.775	9.252	1.500	1.099
1950	11.376	1993	7.423	0.000	10.196	8.870	0.000	0.278
1951	14.141	1994	8.402	0.484	12.351	9.569	0.626	0.449
1952	14.030	1995	14.166	0.287	12.433	10.630	0.650	0.756
1953	14.773	1996	7.637	0.718	12.972	11.062	1.828	1.515
1954	16.653	1997	8.991	0.774	10.660	8.834	1.872	1.404
1955	18.233	1998	11.723	0.277	8.333	8.283	1.471	1.738
1956	18.676	1999	8.853	0.841	9.289	8.595	4.144	2.749
1957	19.971	2000	10.656	1.481	12.691	10.906	2.077	5.500
1958	20.651	2001	8.484	1.197	10.550	11.692	1.688	7.300
1959	23.068	2002	7.913	2.045	8.352	9.448	3.945	4.500
		2003	5.034	2.000	7.668	9.7865	4.878	5.941
		2004	5.836	2.319	8.890	11.3459	5.655	6.888

Table A9: 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 A10: Inshore fleet catches-at-age (proportions) for ***M. capensis*** 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 A11: Longline fleet catches-at-age (proportions) for ***M. capensis*** 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

Table A12: 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 A13: 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 A14: *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 A15: 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 A16: 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