Why does the current hake assessment indicate the extent of depletion of the *M. paradoxus* population to be high, but that of *M. capensis* to be much less?

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SUMMARY

The relatively high extent of depletion estimated for the *M. paradoxus* population is found to be robustly determined, with all five sources of data contributing to the assessment suggesting that both this extent and current fishing mortality are relatively high. However these fives sources lead to appreciably differently perceptions for the extent of depletion of the *M capensis* population. The GLM-standardised CPUE series commencing in 1978 is found to be the most influential of the five in leading to present estimates of both a relatively low extent of depletion and fishing mortality for this population. However if there is a trend in bias over time in this index as a measure of abundance, irrespective (almost) of the direction of this bias, the extent of depletion of the *M. capensis* population would be estimated to be notably higher. Research priorities indicated by this analysis are a focus on ageing and sex-differentiation for *M. paradoxus*, and on the possibility that factors responsible for an increase in catching efficiency may have been omitted from the *M. capensis* CPUE GLM standardisation.

INTRODUCTION

Since the time that the hake assessments were changed from a species-combined to a species-disaggregated form, surprise has been expressed in a number of quarters at the different status' estimated for *M. paradoxus* (well below its MSYL) and *M capensis* (well above its MSYL). Identification of the underlying determinants of these estimates was identified as a high priority issue at the international stock assessment workshop held in December 2008.

This document investigates the reasons underlying the current estimates of depletion for the two South African hake species reported in the most recent assessment (Rademeyer and Butterworth, 2008) and aims to identify which data source(s) is the primary determinant of these current estimates. This is effected by setting up the assessment model in a form which includes catch data, pre-specifies natural mortality and selectivity (in most cases) at the values estimated for the full assessment, sets the recruitment deviations to zero, and then fits to each data source in turn. These restrictions are necessary as with only single sources of data, it is not possible to estimate as many parameters as for the full assessment.

METHODS

The model used for this analysis is as for the 'New Baseline' assessment described in Rademeyer and Butterworth (2008), except that the model is not fit to the commercial and survey catch-at-length data, as questions have arisen about bias in the growth curves that have been used to incorporate these data. The only two parameters that are estimated for every implementation of these "limited data" assessments are the carrying capacities K^{sp} and the steepness parameters, h, for each species.

Two choices for natural mortality have been used, M1 and M2, in both of which M is age dependent and for which the following values have been set for ages 2 and 5 with the standard assumptions for age-dependence made to provide the values at other ages:

M1: $M_2 = 0.7$, and $M_5 = 0.35$

M2: $M_2 = 0.4$, and $M_5 = 0.2$

Note that these are not identical to the specifications for the standard Reference Set of assessments, where bounds are set on the values of M at these ages, rather than the values being fixed. Here the M1 selection is close to the estimates obtained for the best fit amongst the Reference Set, and the selection made for M2 was primarily intended to provide substantial contrast to M1.

The survey and commercial fishing selectivities have been set to those estimated when all the data sources are used. When the model is fit to catch-at-age data, it is possible to estimate the corresponding selectivities and this has been done in some cases. The deviations about the stock-recruitment curve are set to zero.

The final *M. paradoxus* and *M. capensis* depletions are estimated when each data source is included in turn. Then to investigate the shape of the likelihood profile for these depletions, the model is run including a penalty function that forces the 2008 depletions to specific values chosen across a wide range.

RESULTS AND DISCUSSION

Implications of using only single sources of data

Fig. 1 plots the negative log-likelihood for a series of *M. paradoxus* final depletions and for each data source fitted in turn. In most cases, this is shown for the two choices of natural mortality. The *M. paradoxus* depletions estimated when all data sources are included are shown as arrows. When the model is fit to commercial or survey catch-at-age data, the results are also shown when the corresponding selectivities are estimated as well.

Fig. 2 is similar to the first figure except that the negative log-likelihoods are plotted for a series of *M. capensis* final depletions. Only the first choice for the M vector has been investigated in this case, as the computations are time consuming, and the inter-M-choice change in pertinent results is not large for *M. paradoxus*.

Table 1 summarises the results shown in Figs 1 and 2. It lists the estimated final depletions and the increase in the negative log-likelihood for a specific data source when i) all data sources are included and ii) when the final depletion is forced to 0.4 for *M. paradoxus* and to 0.3 for *M. capensis*.

For *M. paradoxus*, all data sources point towards a high extent of depletion. Although the catch-at-age information (both commercial and survey) seems the most influential in determining the depletion estimate, when the selectivity is estimated, these data are not more influential than the others.

Unlike for *M. paradoxus*, the different data sources do not all point in the same direction in terms of final depletion estimates for *M. capensis,* with the surveys in particular pointing to current biomass well below MSYL while the GLM CPUE (the most influential in terms of the likelihood) pointing towards the opposite direction.

Estimates of F

Table 2 lists the current fishing proportions for the two species (reported as averages over the 2004 to 2008 period), while Fig. 3 plots the annual fishing proportions. These fishing proportions (summed over all fleets) are for the assessment with all data included and for the two choices of M; they are also shown for two historical catch series (C1 and C3). The C3 series assumes that the centre point of the historic change from a primarily *M. capensis* to primarily *M. paradoxus* fishery occurred in 1957 rather than 1950 for C1, and hence reflects a greater cumulative catch of *M. capensis*. With the C3 catch option, the fishing proportion is increased slightly in the 1950's and 1960's but this does not have a substantial effect on the overall fishing proportion.

The current fishing proportion is approximately 10 fold larger for *M. paradoxus* than for *M. capensis*.

Fig. 4 shows the average catch-at-age proportions for the two species on the west and south coasts. These plots clearly evidence a larger total mortality rate *Z* for *M. paradoxus* than for *M. capensis*. This

is not an unambiguous reflection of greater fishing mortality on *M. paradoxus* than on *M. capensis*. It arises in part this from the declining selectivity of *M. paradoxus* at older ages, one likely reason for which being that some larger *M. paradoxus* are located in waters deeper than those in which the fishery operates. However the assessment admits unrestricted estimation of the parameter accounting for this declining selectivity effect, and hence indicates that that effect alone is insufficient to account for the higher *Z* for *M. paradoxus* for which higher fishing mortality than for *M. capensis* must therefore be a contributory factor.

Fig. 5 shows the average fishing proportion-at-age over the 2004-2008 period for both species, again illustrating the higher present fishing intensity on *M. paradoxus* compared to *M. capensis*. .

Fig. 6 plots the spawning biomass per recruit as a function of fishing proportion *F* for the two species. Given that the assessments generally estimate stock-recruitment steepness *h* to be very high, these plots closely reflect the population depletion to be expected as *F* is increased. It is therefore very clear that the existing estimates of depletion are closely related to these estimated fishing proportions.

What would lead to a greater extent of depletion for M. capensis

It is clear from Table 1 that all data sources point to a low current extent of depletion for *M. paradoxus*. The estimate for *M. capensis* is however heavily influenced by the GLM CPUE series. It is possible that the GLM series trend could be biased as an index of abundance as a consequence of undetected changes in fleet efficiency. To investigate the effect of such possible biases in the GLM CPUE series, the assessment has been run including biases in trends for these series for a number of different values for this bias for each species in turn. Fig. 7 shows the actual GLM CPUE series and as they would appear if adjusted for certain potential positive and negative biases in their overall trend. Fig. 8 shows how the depletion estimates are affected by these possible biases. The estimated steepness parameters are also shown as the sudden important large change in depletion for *M. capensis* is caused by a switch from an estimated high steepness to a low steepness. Depletions estimates for *M. paradoxus* are not as affected as those for *M. capensis* by trends in bias in the GLM CPUE series. The current series for *M. capensis* correspond (almost) to the lowest of the range of possible extents of depletion of the *M. capensis* population; in particular if the bias trend is negative (as would correspond to an undetected increase in efficiency in the catching power of the fleet, the extent of depletion would be estimated to be appreciably higher (e.g. for an undetected increase in efficiency of 2% per year, the depletion estimate for *M. capensis* drops from 0.75 to 0.23).

Fig. 9 plots the spawning biomass trends for *M. capensis* for a series of trends in bias in the GLM CPUE series, while Fig. 10 shows how these trends affect estimates of the current ratio of the spawning biomasses of *M. capensis* to *M. paradoxus*. With an undetected increase in efficiency in the *M. capensis* fishery, this ratio drops from 4 towards parity, which some have suggested would be a more realistic appraisal.

CONCLUSIONS

All five data sources point to a high extent of depletion for *M. paradoxus*. The value itself is driven by the combination of recent catch levels (note that these have on average been some fourfold larger than for those for *M. capensis* over the last five years) and of the high fishing mortality indicated by the rapid fall off in *M. paradoxus* catches with age. In contrast, the different data sources point in different directions with respect to the estimated depletion of the *M. capensis* population, with the GLM-standardised CPUE series commencing in 1978 playing the most influential role in the current low fishing mortality and extent of depletion estimated for this population.

What aspects of the data merit checking to confirm the correctness or otherwise of these results? For *M. paradoxus*, attention should most likely be focussed on the combination of ageing and sex-differentiation, as changes there could impact the conclusion concerning high fishing mortality that is being drawn from the recent catch-at-age distributions shown in Fig. 4. For *M. capensis* re-examination of factors that might influence catching efficiency in the GLM-standardisation needs emphasis, particularly as undetected efficiency increases there could markedly change current perceptions of a relatively low extent of depletion of this population. The sensitivity (see Fig. 8) of the estimate of steepness *h* for *M. capensis* to possible undetected trends in catching efficiency of the fleet suggests investigating cases where h is fixed at intermediate values in the [0.30; 0.98] range.

REFERENCE

Rademeyer RA and Butterworth DS. 2008. Development of a new Baseline Assessment for the South African hake resource, incorporating catch-at-length information. Unpublished document, MCM, South Africa. MCM/2008/SEPT/SWG-DEM/60. 21pp.

Table 1: For each source of data being fitted and each M vector choice, the first column gives the estimated *M. paradoxus* depletion value (note that depletion is B_{sp}/K_{sp}, as distinct from extent of depletion which is $[1 - B_{sp}/K_{sp}]$), and the next two columns give the –lnL increase when all five data sources are included and when the *M. paradoxus* depletion is forced to 0.4. *M. capensis* results are shown similarly, except that the last column compares the –lnL to that when the *M. capensis* depletion is forced to 0.3.

	Fitted to:	*M. paradoxus*			*M. capensis*		
		a) Estimated *M. paradoxus* depletion	b) Increase in -lnL from a) when all data sources are included	c) Increase in -lnL from a) when 2008 *M. paradoxus* depletion is forced to 0.4	d) Estimated *M. capensis* depletion	e) Increase in -lnL from d) when all data sources are included	f) Increase in -lnL from a) when 2008 *M. capensis* depletion is forced to 0.3
$M_2=0.7$, $M_5=0.35$	survey	0.17	1.2	4.6	0.10	2.0	0.5
	historic CPUE	0.28	1.6	3.2	0.54	1.6	0.0
	GLM-CPUE	0.11	1.4	3.4	0.80	1.4	23.8
	survey CAA	0.08	1.2	20.5	0.39	1.4	0.0
	survey CAA (sel est)	0.09	1.6	2.5			
	commercial CAA	0.10	2.2	56.0	0.66	2.2	1.1
	commercial CAA (sel est)	0.10	7.7	3.4			
	all data	0.14	0.0	92.7	0.75	0.0	11.4
$M_2=0.4$, $M_5=0.2$	survey	0.14	1.2	6.0			
	historic CPUE	0.26	0.6	16.0			
	GLM-CPUE	0.10	2.7	1.4			
	survey CAA	0.10	0.2	16.0			
	commercial CAA	0.10	5.7	52.9			
	all data	0.11	0.0	86.6			

Table 2: Average fishing proportion (summed over all fleets) for the period 2004 to 2008 for the ages at maximum selectivity for *M. paradoxus* and *M. capensis*. This is shown for both choices of M vectors and two historical catch series (C1 and C3). Note that the C3 series assumes that centre point of the historic change from a primarily *M. capensis* to primarily *M. paradoxus* fishery took place in 1957 rather than 1950 for C1, and hence reflects a greater cumulative catch of *M. capensis*.

		M. paradoxus (age = 3)	*M. capensis* (age = 5)
Catch series C1	$M_2=0.7$, $M_5=0.35$	0.523	0.054
	$M_2=0.4$, $M_5=0.2$	0.540	0.075
Catch series C3	$M_2=0.7$, $M_5=0.35$	0.540	0.062
	$M_2=0.4$, $M_5=0.2$	0.541	0.067
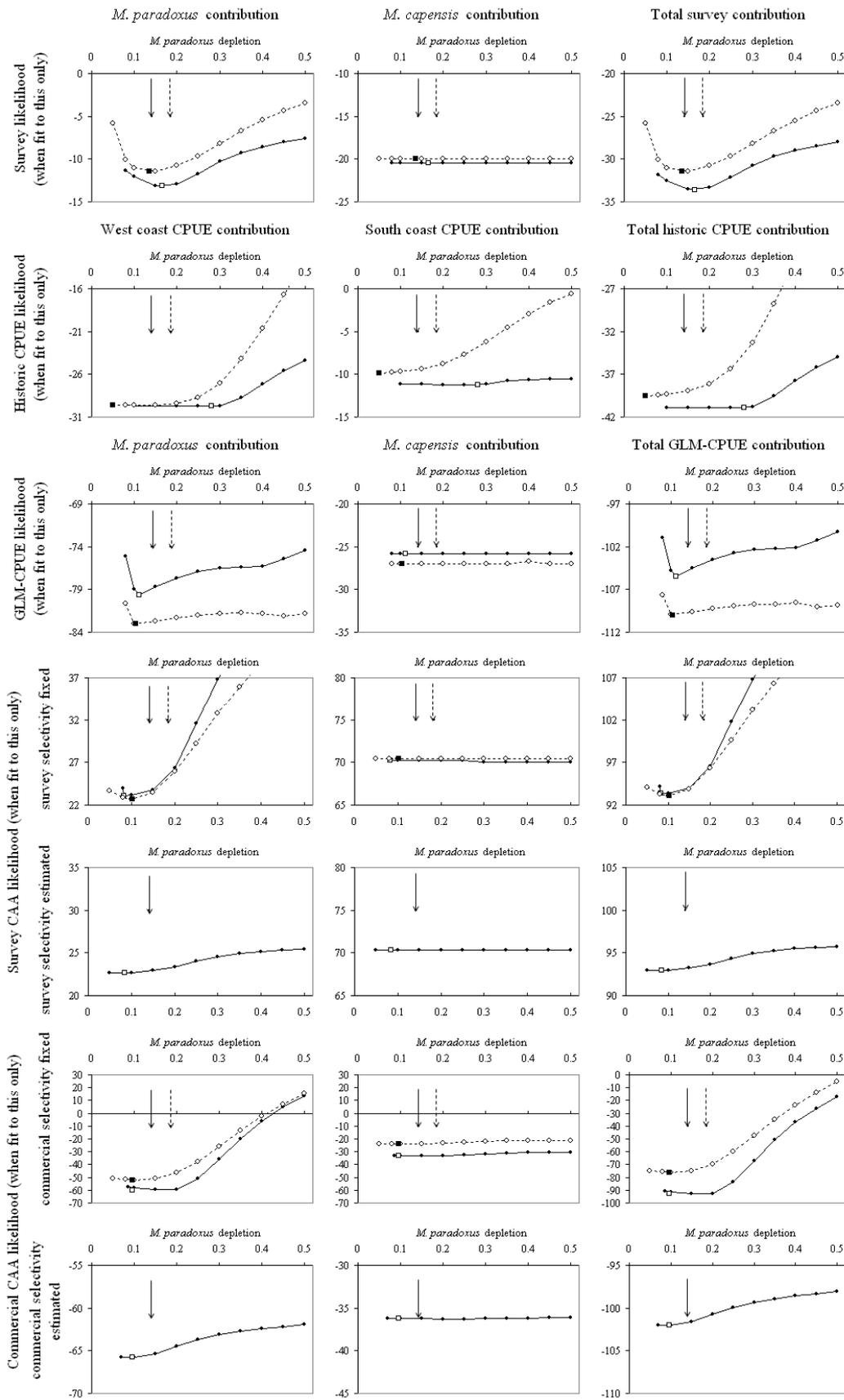
Fig. 1: -lnL contribution of each data source when fitted on their own for a series of *M. paradoxus* depletions. The full lines represent the first *M* vector choice (M1: "M_2=0.7 and M_{5+}=0.35") while the dashed lines represent the second choice (M2: "M_2=0.4 and M_{5+}=0.2"). The downward arrows show the *M. paradoxus* depletion estimated for the assessment using all five data sources. Note: the vertical axis has been kept within a 15 points range for all cases except for the second last row.
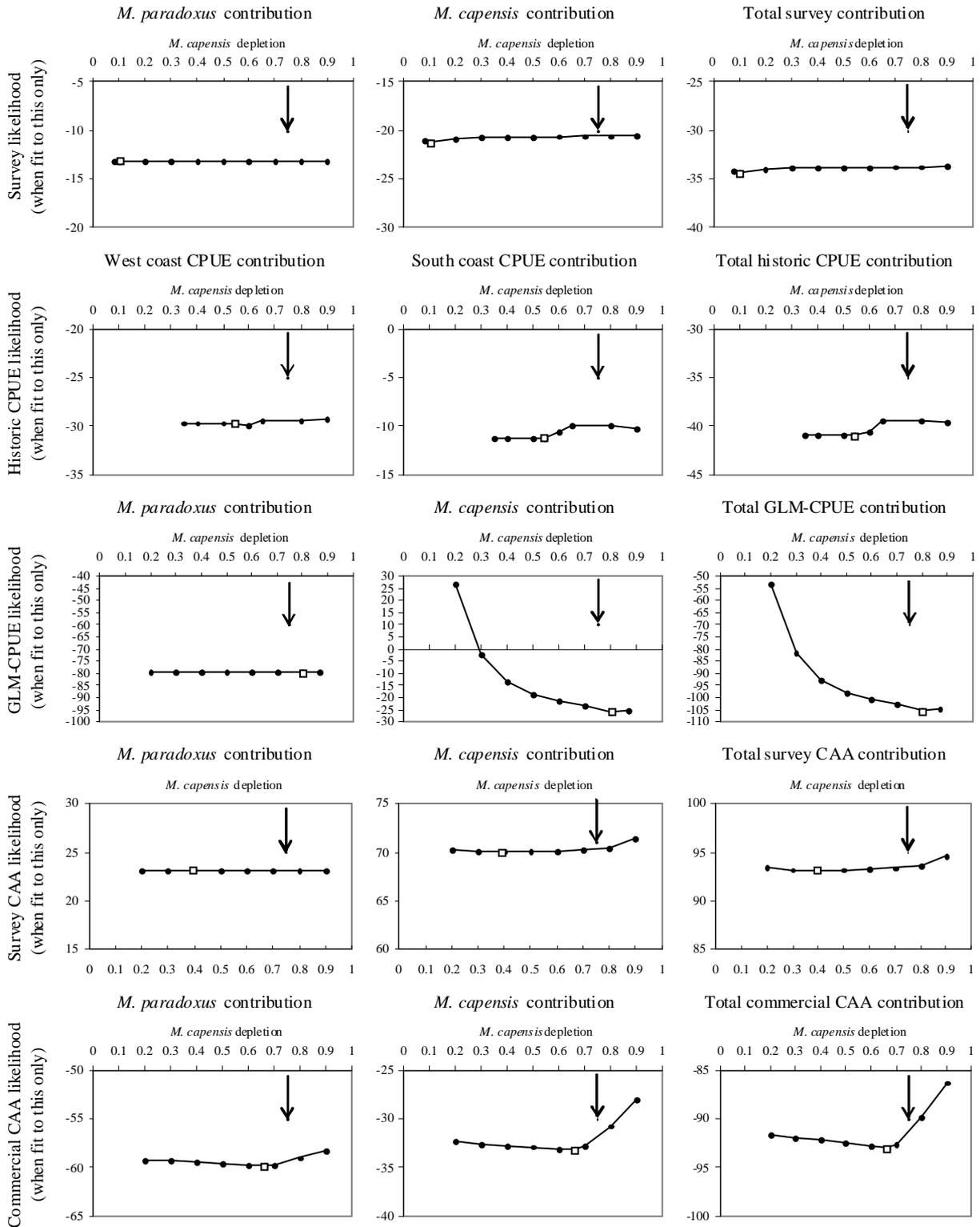
Fig. 2: -lnL contribution of each data source when fitted on their own for a series of *M. capensis* depletions for the choice of *M* vector M1: "M_2=0.7 and M_{5+}=0.35". The downward arrows show the *M. capensis* depletion estimated for the assessment using all five data sources. Note: the vertical axis has been kept within a 15 points range for all cases except for the middle row.
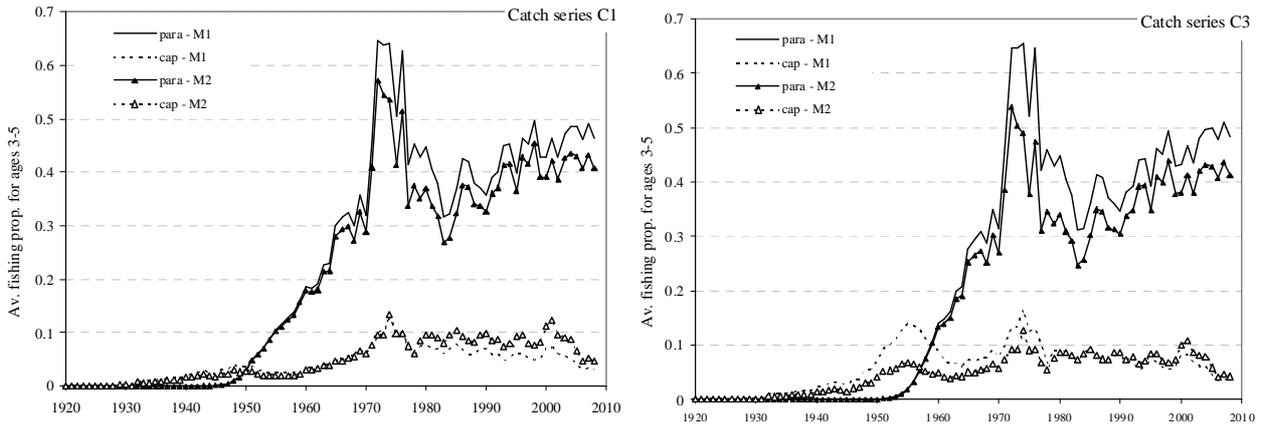
Fig. 3: Annual fishing proportion (summed over all fleets) averaged over ages 3 to 5 for the assessment with all data, for the two choices of *M* and catch series C1 (left plot) and C3 (right plot).
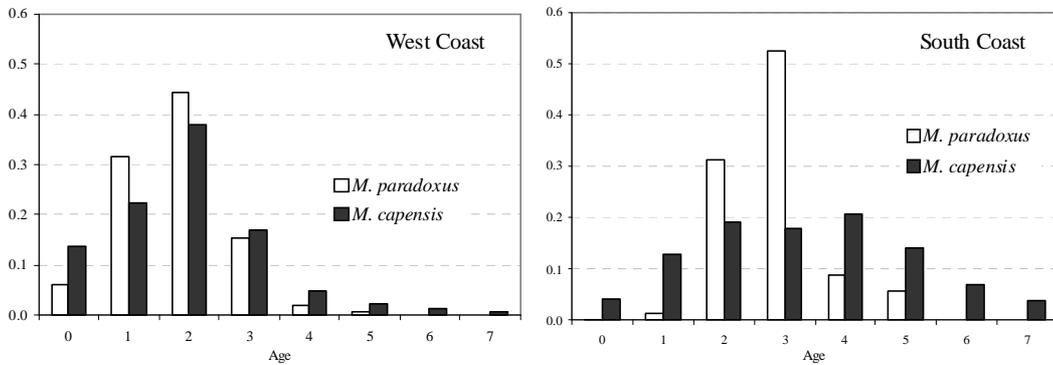
Fig. 4: Survey catch-at-age proportions (averaged over all the years available).
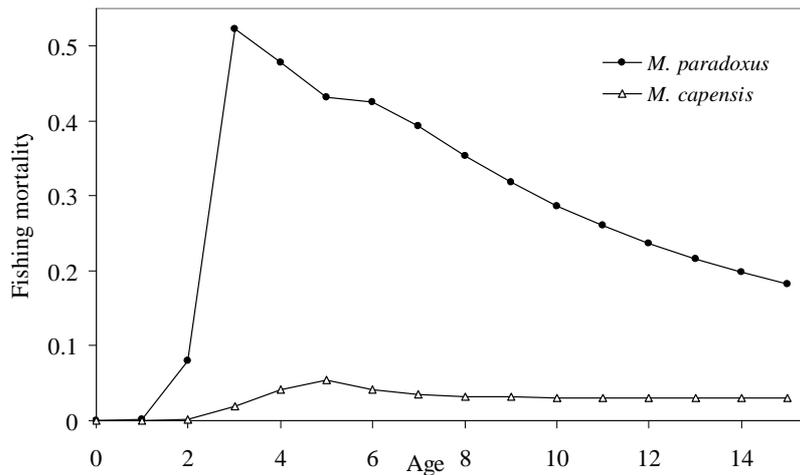
Fig. 5: Average fishing proportion-at-age (summed over all fleet) for the period 2004 to 2008 for *M. paradoxus* and *M. capensis*, for the assessment with all data sources included, the M1 vector choice for natural mortality and historical catch series C1.

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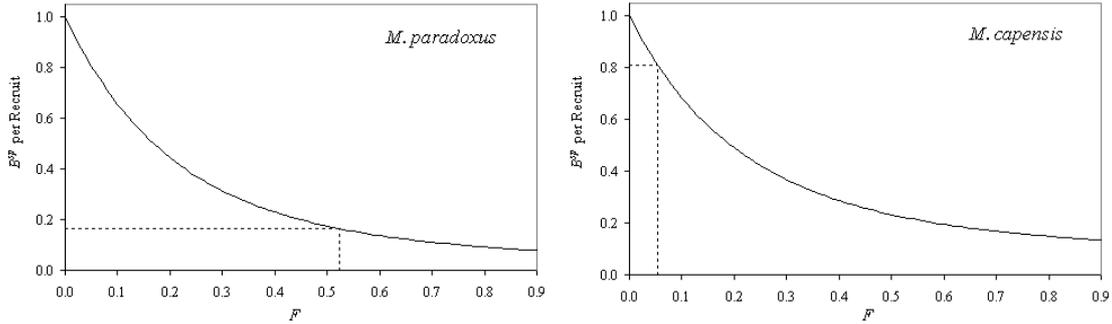
Fig. 6: Spawning biomass-per-recruit (relative to that for the unexploited population) as a function of the fully selected fishing proportion *F*, for the assessment with all data sources included, the first choice (M1) for the *M* vector, and historical catch series C1. The selectivity used to compute these is the average over all fleets, assuming the same proportion of the catch as was made by each fleet in 2008. The dashed lines show the recent *F* levels (average of 2004 to 2008).
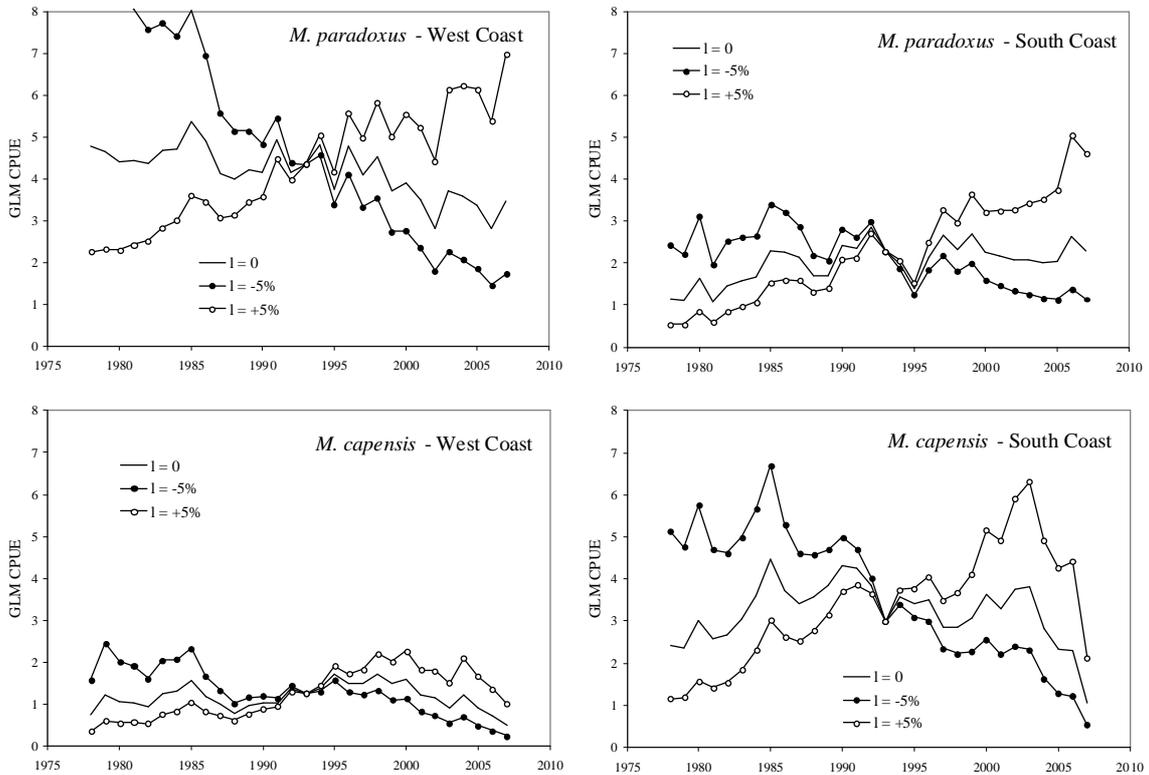
Fig. 7: West Coast and South Coast *M. paradoxus* and *M. capensis* GLM CPUE series, and with two alternative bias trends added.
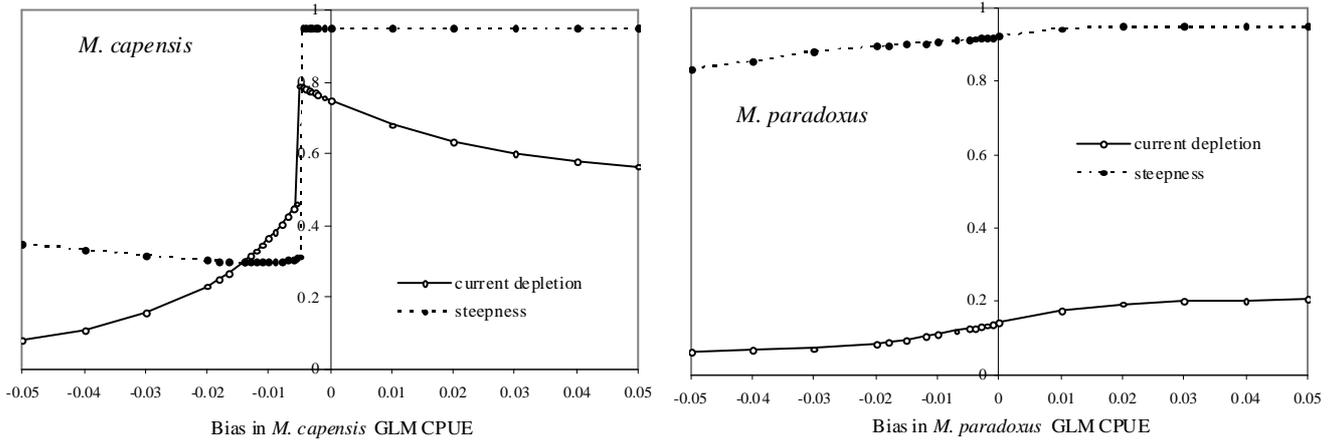
Fig. 8: Estimated depletion and steepness parameters for *M. capensis* and *M. paradoxus* as a function of a bias trend in the respective GLM CPUE series.
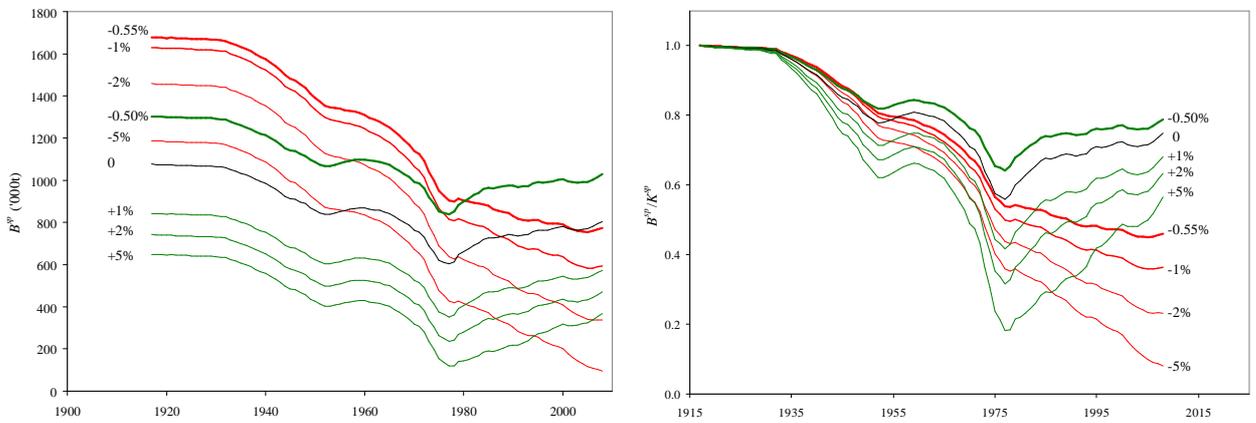
Fig. 9: *M. capensis* spawning biomass trends for a series of values of a trend in bias in the GLM CPUE series.
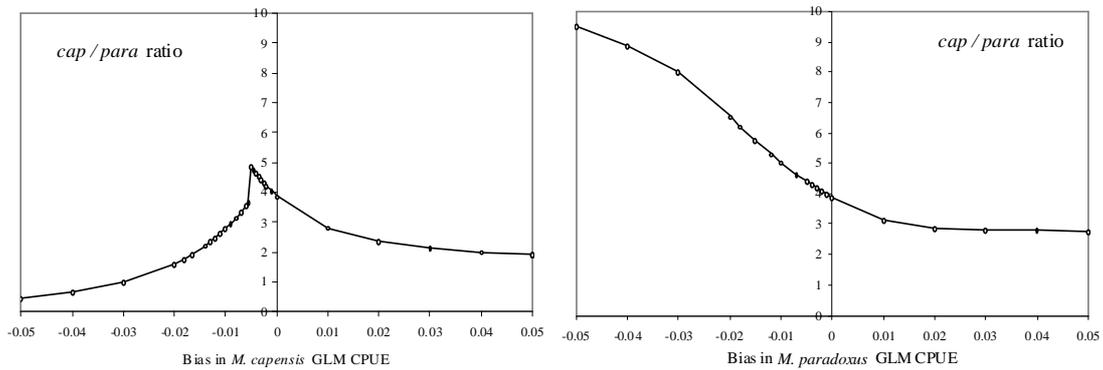
Fig. 10: Estimated current *M. capensis*/ *M. paradoxus* spawning biomass ratio for a series of values of a trend in bias in the GLM CPUE series.