Further Results relating to Appropriate TACs for the South African *Merluccius paradoxus* and *M. capensis* Resources

R.A. Rademeyer and D.S. Butterworth

MARAM (Marine Resource Assessment and Management Group)
Department of Mathematics and Applied Mathematics
University of Cape Town, Rondebosch 7701, South Africa

September 2006

Abstract

A simple species-aggregated population model is applied to combined-species hake CPUE data since 1992 as a "reality check" on the short term substantial reductions in TACs being indicated by candidate OMPs when tested under the operating model. These simple computations suggest similar levels of TAC reduction are necessary to restore resource abundance (and hence CPUE) to 1992 levels over the next 10 years. Retrospective analyses comparing the reliabilities of the SR1 and SR2 options in predicting recent recruitment are pursued, and suggest slight preference for use of the SR2 option. TAC projections under the various OMP candidates for fixed future inputs for resource abundance indices are shown to illustrate how the TACs output by these OMPs depend on the index values input.

Introduction

This document is intended to complement the OMP results in WG/09/06/D:H:33, particularly given that those suggest that substantial TAC reductions over the next few years are likely.

Reservations have been expressed about the manner in which past catches are split between species in the operating models used for OMP testing, and also about the current biomass ratio of *M. paradoxus* vs *M. capensis* implied by these models, with the implicit inference that the resultant OMP and associated TACs from such a process might not be appropriate. To address this, as a reality check, a much simpler population model is applied to offshore trawler CPUE data without separating the species to ascertain whether similar implications concerning future TAC reductions (to those from the OMP testing process) follow.

As robustness tests using the SR1 rather than the SR2 option for estimating recent recruitments suggest that resource recovery predictions (and future TACs in the short term) are much more optimistic under SR1, retrospective analyses are pursued to provide an objective basis to choose which of the two options provides the more reliable predictions.

Finally to indicate how the candidate OMP outputs depend on future data and their trends, future TACs under these OMPs are contrasted for a number of scenarios for future values for CPUE and survey estimates of abundance.

Methods

Species combined Constant Surplus Production Model

The resource (both species and coast combined) is modelled by:

$$B_{y+1} = B_y + P - C_y \tag{1}$$

where

B_y is the total exploitable biomass in year y,

C_y is the total catch in year y, and

P is the surplus production, taken to be constant over time.

The model is fitted to species and coast combined GLM-standardised CPUE. The likelihood is calculated by assuming that the observed CPUE is log-normally distributed about its expected value:

$$I_y = \hat{I}_y e^{\varepsilon_y} \tag{2}$$

where

I_y is the GLM-standardised CPUE for year y,

$\hat{I}_y = qB_y$ is the corresponding model estimate,

q is the constant of proportionality, and

ε_y from $N\left(0, \sigma^2\right)$

The log-likelihood function is then given by:

$$-\ln L^{CPUE} = \sum_{y=1992}^{2005} \left[\ln \sigma + \frac{\varepsilon_y^2}{2\sigma^2} \right] \tag{3}$$

where

σ is the standard deviation of the residuals, which is estimated in the fitting procedure by its maximum likelihood value:

$$\sigma = \sqrt{\frac{1}{n} \sum_y \left(\ln I_y - \ln\left(qB_y\right)\right)^2} \tag{4}$$

where

n is the number of data points used.

The catchability coefficient q is estimated by its maximum likelihood value, which is given by:

$$\ln q = \frac{\sum_y \frac{1}{\sigma^2} \left[\left(\ln I_y - \ln B_y \right) \right]}{\sum_y \frac{1}{\sigma^2}} \tag{5}$$

The constant surplus production P is then estimated for a series of input values for B_1. The GLM-standardised CPUE series is assumed to be comparable from 1992 only (because prior to that time it is conventionally assumed that the use of net-liners was being phased out), so that year 1 is taken to be 1992. The total catch and CPUE series used are given in Table 1.

SR1 vs SR2

To assess the relative abilities of the SR1 and SR2 options to predict recent recruitment, a "retrospective" analysis is conducted. The "true" values for recruitment residuals up to 2002 are taken to be as provided by assessments using data up to 2006. The averages of such estimates under SR1 and SR2 are used for that "truth", though the difference is minimal for all years except 2002.

Since SR1 and SR2 differ in the manner in which they give relative weights to the data for the most recent three years, comparisons with "true" values are carried out for only the first three years for which the cohort concerned enters the assessment. Thus, for example, the recruit residual for the year 1999 as estimated in the 1999, 2000 and 2001 assessments is compared to the "true" value provided by the 2006 assessment, and overall predictive capability assessed by the root mean square error (RMSE) statistic evaluated over those three estimation years.

Note that the computations conducted were not "completely" retrospective because of the burden of the computer time required. Instead, all estimable quantities except the recruitment residuals were set at their values for the 2006 assessment for the particular scenario examined (M4-H1-C3a from the Reference Set). The "retrospective" residuals were then obtained by estimating residuals only using data up to 1999, 2000, 2001, etc.

Results

Simple Constant Surplus Production Model

The model is fitted to the CPUE series for a series of inputs for the starting (1992) B value as there is not enough information in the data to estimate both B_1 and P, as evidenced by the marginal change in $-\ln L$ as the B_{1992} value input is altered (see Table 2). The choice of the range for B_{1992} in this Table is based on estimates for species combined offshore trawler exploitable biomass, which range from 400 to 600 thousand tons for the scenarios which comprise the new Reference Set. The fit of the model to the CPUE series is shown in Fig. 1 for B_{1992} = 500 000t. The resource is then projected forward under a series of constant catches so that the biomass at the end of the projection period is a) back at the 1992 level, b) 10% above the 1992 level and c) 20% above the 1992 level at the end of a 10-year period (i.e. by 2016). The results are given in Table 2.

SR1 vs SR2

Root mean square error measurements of the predictive ability of these two options for recent recruitment are shown for stock-recruitment residuals for the years 1999 to 2002 in Table 3 for each species.

Fig. 2 compares recruitment residuals for each species as evaluated with data to 2004 and to 2006.

OMP TAC projections

This section reports the TACs that would be recommended under the OMPs presented in WG/08/06/D:H:33 if certain series future CPUE and survey results eventuate.

Comparison of catch trajectories for an application of candidate OMP1 for four recovery tunings, and for $OMP1_{20\%}$, $OMP2_{20\%}$ and $OMP3_{20\%}$, assuming all future indices stay constant at the average of the last four years data (2002-2005 for CPUE and 2003-2006 for surveys biomass estimates) are shown in Fig. 3 and Fig. 4 respectively. Appendix 1 details the specific calculation of the TAC for 2007 under $OMP1_{20\%}$ to illustrate how the algorithm works.

Figs 5 and 6 compare the catch trajectories for an application of $OMP1_{20\%}$ and $OMP3_{20\%}$ respectively assuming all future indices a) stay constant at, b) increase by 5% per annum from and c) decrease by 5% per annum from the average of the last four years data (2002-2005 for CPUE and 2003-2006 for surveys biomass estimates).

Discussion

Simple Constant Surplus Production Model

Depending on the absolute value for the 1992 combined species exploitable biomass, and the target recovery level for the resource, estimated future constant catches in Table 2 range between 108 and 138 thousand tons. Such estimates are not dissimilar from those arising of the more complex species-disaggregated and age-structured operating models used for OMP testing.

Thus even if there remain residual reservations about the species-split results from these operating model, the results of the simple calculations here suggest that these operating models nevertheless provide robust advice on appropriate TAC levels.

SR1 vs SR2

Table 3 indicates no difference in the reliability of the recruitment prediction estimates provided by the SR1 and SR2 options for 1999 and 2000, but for 2001 and particularly 2002 SR2 achieve slightly better performance.

Fig. 2 shows that the strong recruitments for *M. paradoxus* in 2002 and 2003 predicted by the operating model under SR1 two years ago with data up to 2004 have not turned out to be reliable. SR2 also “got it wrong”, but the magnitude of the error was not as great.

All in all, these results provide some support for the SR2 option to be preferred to SR1.

OMP TAC projections

For all the candidate OMPs, maintenance of present CPUE and survey abundance estimates will result in some reduction of the TAC over time. For a 20% depletion *M. paradoxus* recovery target, increases in these indices at rates averaging as much as 5% are required for there to be any appreciable TAC increase in the medium term.

Table 1: Total catch (in thousand tons) and species and coast combined GLM-standardised CPUE (from J. Glazer, pers. commn) used in the constant surplus production model.

Year	Total catch	CPUE
1992	141.600	13.63
1993	141.473	12.02
1994	147.177	12.80
1995	141.040	11.42
1996	159.263	13.83
1997	147.680	12.60
1998	154.222	12.97
1999	137.399	12.54
2000	154.651	13.39
2001	158.567	11.93
2002	147.358	11.54
2003	154.838	11.81
2004	154.403	11.16
2005	143.613	10.19
2006	150.000	

Table 2: Estimated catches to bring the biomass at the end of the 10-year projection period (i.e. by 2016) to a) the 1992 level, b) 10% above the 1992 level and c) 20% above the 1992 level for a series of starting biomass values in 10-years time (i.e. by 2016) for the constant surplus production. The negative log-likelihood is also shown. Catch and biomass values are in thousand tons.

B_{1992}	-lnL	C to bring CPUE back to 1992 level	C to bring CPUE to 10% above 1992 level	C to bring CPUE to 20% above 1992 level
300	-33.4	138.2	134.6	131.0
400	-33.7	134.8	130.0	125.4
500	-33.4	131.4	125.6	119.6
600	-33.2	128.0	121.0	114.0
700	-33.0	124.6	116.4	108.2

Table 3: RMSE values for retrospective stock-recruitment residual estimates for 1999-2002 when compared to “true” values from the 2006 assessment for SR1 vs SR2 scenarios for *M. paradoxus* and *M. capensis* for the M4-H1-C3a scenario from the Reference Set.

Year to which residual applies	*M. paradoxus*		*M. capensis*	
	SR1	SR2	SR1	SR2
1999	0.196	0.196	0.426	0.426
2000	0.199	0.199	0.221	0.221
2001	0.078	0.076	0.128	0.119
2002	0.140	0.135	0.093	0.075

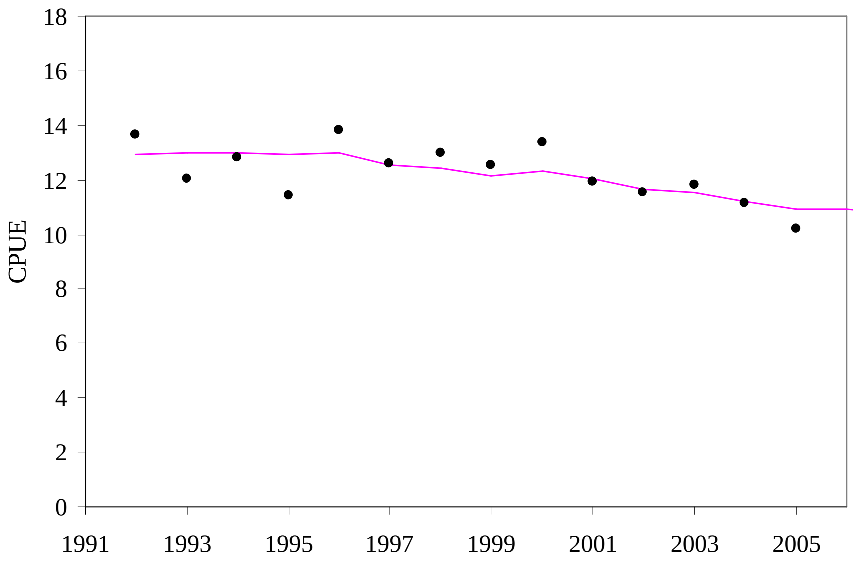


Fig. 1: Fit of the constant surplus production model to the species and coast combined GLM-standardised CPUE series.

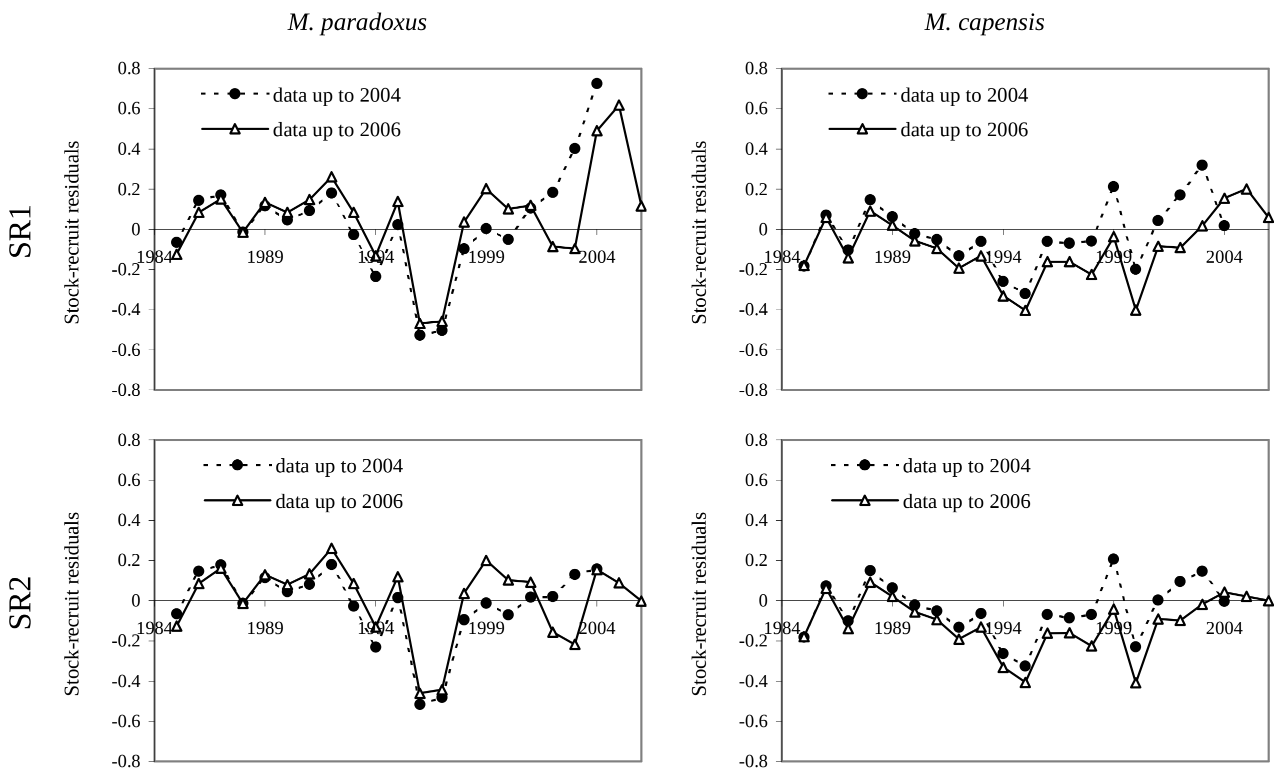


Fig. 2: Time series of stock-recruitment residuals for two scenarios of the Reference Set (M1-H1-C3a-SR1/SR2) with data up to 2006 compared with those with data up to 2004.

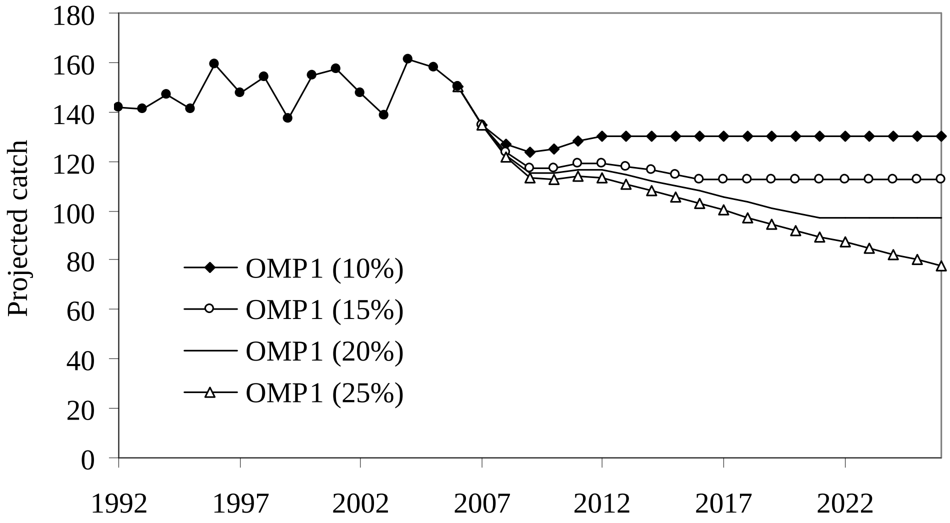


Fig. 3: Comparison of catch trajectories for an application of candidate **OMP1** for four recovery tunings assuming all future indices stay constant at the average of the last four years data (2002-2005 for CPUE and 2003-2006 for surveys biomass estimates).

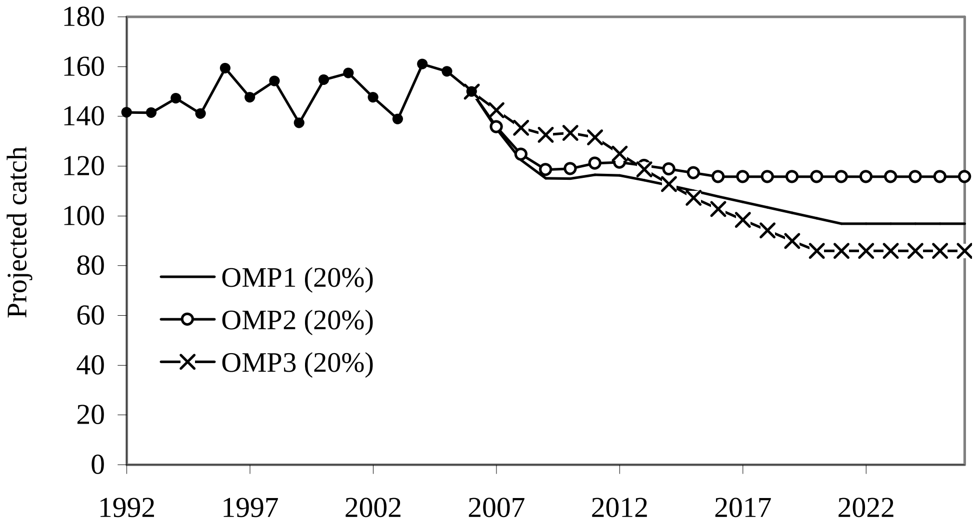


Fig. 4: Comparison of catch trajectories for an application of candidates $\mathbf{OMP1}_{\mathbf{20\%}}$, $\mathbf{OMP2}_{\mathbf{20\%}}$ and $\mathbf{OMP3}_{\mathbf{20\%}}$ assuming all future indices stay constant at the average of the last four years data (2002-2005 for CPUE and 2003-2006 for surveys biomass estimates).

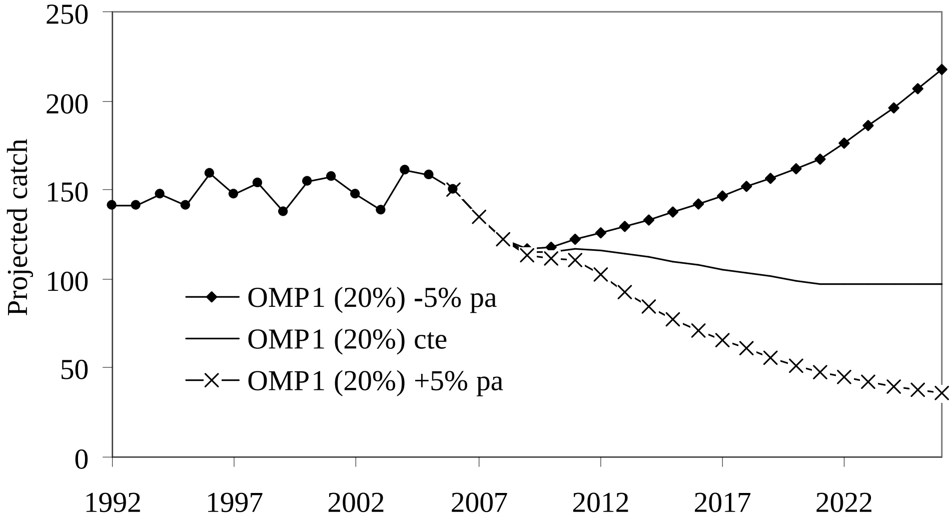


Fig. 5: Comparison of catch trajectories for an application of candidate **OMP1$_{20\%}$**, assuming all future indices a) stay constant at, b) increase by 5% per annum from and c) decrease by 5% per annum from the average of the last four years data (2002-2005 for CPUE and 2003-2006 for surveys biomass estimates).

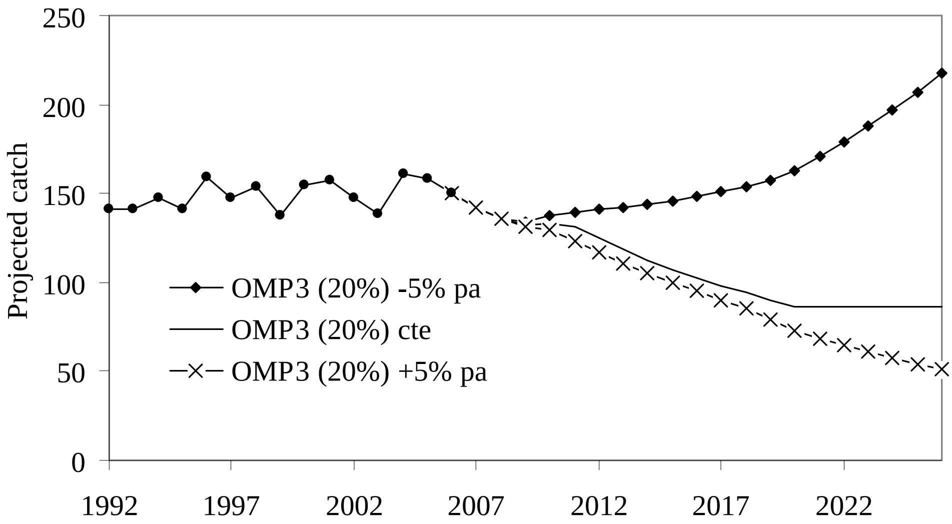


Fig. 6: Comparison of catch trajectories for an application of candidates **OMP3$_{20\%}$**, assuming all future indices a) stay constant at, b) increase by 5% per annum from, and c) decrease by 5% per annum from the average of the last four years data (2002-2005 for CPUE and 2003-2006 for surveys biomass estimates).

Appendix 1

Example of the application of OMP1$_{20\%}$ to calculate the 2007 TAC

See equations 1-3 of WG/08/06/D:H:33.

The following tuning parameter values apply to OMP1$_{20\%}$:

Candidate	p	δ_1	δ_2	δ_3	Yr_join	Target incr para	Target incr cap	Y
OMP1$_{20\%}$	6	0.40	2	1.1	10	0.0240	0	15

1) Compute the measure of trend:

The OMP requires a measure of the immediate past trend in the abundance indices, s_y^{spp}. This trend measure is computed from the species-disaggregated GLM-CPUE ($I_y^{CPUE,spp}$), west coast summer survey ($I_y^{surv1,spp}$) and south coast autumn survey ($I_y^{surv2,spp}$) indices:

- linearly regress $\ln I_y^{CPUE,spp}$ vs year y' for $y' = y - p - 1$ to $y' = y - 2$, to yield a regression slope value $s_y^{CPUE,spp}$,
- linearly regress $\ln I_y^{surv1,spp}$ and $\ln I_y^{surv2,spp}$ vs year y' for $y' = y - p$ to $y' = y - 1$, to yield two regression slope values $s_y^{surv1,spp}$ and $s_y^{surv2,spp}$.

Table A1 gives the $\ln I_y^i$ used to compute the slopes for each species and index for the 2007 TAC recommendation. The measure of trend used is then:

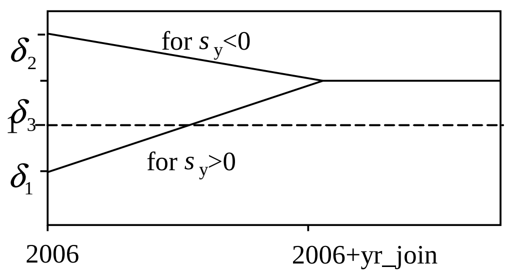
$$s_y^{spp} = \left(\frac{s_y^{CPUE,spp}}{2} + \frac{s_y^{surv1,spp}}{4} + \frac{s_y^{surv2,spp}}{4} \right)$$

so that

$$s_y^{para} = \left(\frac{-0.16}{2} + \frac{0.008}{4} + \frac{-0.396}{4} \right) = -0.105 \text{ and}$$

$$s_y^{cap} = \left(\frac{-0.080}{2} + \frac{0.022}{4} + \frac{0.072}{4} \right) = -0.017 .$$

The function for the year-dependent tuning parameter, λ_y, which is a measure of how responsive the candidate OMP is to change in trend, is shown below:



Thus, in 2007 $\lambda_{2007} = 1.91$, as the measure of trend for both species is negative.

The catch by species is computed as:

$$C_y^{spp} = C_{y-1}^{*spp}\left[1+\lambda_y\left(s_y^{spp} - target^{spp}\right)\right]$$

C_{2006}^{*spp} is computed by applying the species ratio of the catch in 2005 to the TAC for 2006, so that:

$C_{2007}^{para} = 120.38[1+1.91(-0.105-0.024)] = 90.74$ and

$C_{2007}^{cap} = 29.62[1+1.91(-0.017)] = 28.68$

For OMP1, the maximum allowable change in TAC from one year to the next is ±10%. As 90.74+28.68=119.42 leads to a greater TAC decrease than allowed, the TAC for 2007 would be set to 135 000 t, this being 10% less than the 2006 TAC.

A few points to note about this TAC formula:

- As time progresses the current 1.91 λ_y factor drops, so that TAC changes will tend to be less.
- Under invariant indices (slope *s*=0), the formula for *M. capensis* will yield an unchanged contribution to the TAC. However, for *M. paradoxus* catch contributions increase only if the averaged slope is above 2.4% per annum. This reflects the deliberate intent of the formula to provide recovery for *M. paradoxus*. For OMP1$_{20\%}$, this target increase rate applies only to the first Y=15 years of application, dropping to zero thereafter.

Table A1: Indices and slopes used to compute the 2007 TAC under an application of OMP1$_{20\%}$.

	M. paradoxus			*M. capensis*		
	ln(CPUE)	ln(Surv1)	ln(Surv2)	ln(CPUE)	ln(Surv1)	ln(Surv2)
2000	1.81			1.67		
2001	1.73			1.52		
2002	1.59	5.55		1.61	4.46	
2003	1.75	5.95	4.64	1.57	4.09	4.62
2004	1.72	5.51	3.97	1.42	5.10	4.42
2005	1.67	5.64	3.25	1.17	4.27	4.34
2006		5.75	3.56		4.48	4.88
Slope	-0.016	0.008	-0.396	-0.080	0.022	0.072