

OMP-08

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Introduction

OMP-08, the management procedure to be used to recommend total allowable catches for sardine and anchovy and total allowable sardine bycatch in South African waters, was adopted by the Pelagic Working Group in May 2008. This document details the final version of OMP-08 adopted.

Important Changes from OMP-04

Some of the key differences between OMP-08 and OMP-04 include the following:

- i) The sardine Exceptional Circumstances rules have been modified such that, in the event of sardine Exceptional Circumstances being declared, only 50% of the directed sardine TAC is given at the start of the year, and an upward adjustment may be made in mid-season depending on the results of the recruitment survey (Figure 1).
- ii) The initial, revised and final anchovy TAC rules have been modified to ensure continuity by allowing for a downward-adjustment to the TAC up to an amount of $\Delta^A = 100\,000t$ above the Exceptional Circumstances biomass threshold (no such smoothing is required for the directed sardine TAC as this function is already smooth due to the adjustment made below a November survey biomass estimate of 800 000t).
- iii) The rule used to calculate the anchovy additional season TAC has been modified to allow for a more rapid increase from the TAC calculated using the 'standard' formula up to a maximum of 120 000t (Figure 2).
- iv) The sardine Exceptional Circumstances rules decrease the directed sardine TAC to zero should the November survey sardine biomass estimate fall to less than 75 000t (25% of the Exceptional Circumstances threshold). (However, in the case of a zero directed sardine TAC, allowance is still made for sardine bycatch associated with both the anchovy and red-eye fisheries.)

In addition, there have been changes to the OMP constraints of the maximum proportion by which the sardine TAC can be annually reduced (impacting the sardine 2-tier threshold), the minimum anchovy TAC, maximum increase in normal season anchovy TAC, maximum additional season anchovy TAC, and the sardine Exceptional Circumstances threshold (see Table 1).

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Trade-Off Curve

The trade-off curve for OMP-08 is shown in Figure 3. This curve is constructed by limiting $risk_S < 0.18$ and $risk_A < 0.10$, where the definitions of risk have been maintained from OMP-04:

- $risk_S$ - the probability that adult sardine biomass falls below the average adult sardine biomass over November 1991 and November 1994 at least once during the projection period of 20 years.
- $risk_A$ - the probability that adult anchovy biomass falls below 10% of the average adult anchovy biomass between November 1984 and November 1999 at least once during the projection period of 20 years.

The ‘corner point’ of the curve where the directed average sardine catch is maximised while maintaining the maximum average anchovy catch was chosen to specify the directed sardine-anchovy trade-off. The risk thresholds were chosen such that the lower halves of the simulated sardine and anchovy biomass distributions after 20 years of simulation under OMP-08 relative to those under a no-catch scenario were close to those simulated under OMP-04 (Cunningham and Butterworth 2008b,c).

In Summary

The details of all the rules governing OMP-08 are fully described in the Appendix, while Table 1 lists the control parameters of OMP-08, with comparisons to those for previous OMPs. Table 2 lists some key summary statistics for the sardine and anchovy resources under OMP-08, while Table 3 lists the mean and median simulated TACs and TABs under OMP-08.

References

- Cunningham, C.L., and Butterworth, D.S. 2008a. Re-evaluation of Risk Thresholds for Sardine and Anchovy. MCM Document MCM/2008/SWG-PEL/01. 7pp.
- Cunningham, C.L., and Butterworth, D.S. 2008b. Proposed Final OMP-08. MCM Document MCM/2008/SWG-PEL/09. 42pp.
- Cunningham, C.L., and Butterworth, D.S. 2008c. Adjusted Anchovy Assessment with Implications for OMP-08. MCM Document MCM/2008/SWG-PEL/10. 7pp.

Table 1. Parameters and constraints in OMP-02, re-revised OMP-04, and OMP-08. (Note that although all biomass values are given in tons in the table, the equations in the Appendix use biomass in thousands of tons.)

Control Parameter		OMP-02	Re-Revised OMP-04	OMP-08
β	directed sardine control parameter	0.14657	0.14387	0.097
α_{ns}	directed anchovy control parameter for normal season	0.73752	0.72858	0.78
α_{ads}	directed anchovy control parameter for additional season	1.47504	1.45716	1.17
Constraints		OMP-02	Re-Revised OMP-04	OMP-08
TAB_{rh}^S	fixed annual adult sardine bycatch	10 000t	10 000t	3 500t
C_{mxdn}^S	maximum proportion by which directed sardine TAC can be annually reduced	0.15	0.15	0.20
C_{mxdn}^A	maximum proportion by which normal season anchovy TAC can be annually reduced	0.25	0.25	0.25
C_{mntac}^S	minimum directed sardine TAC	90 000t	90 000t	90 000t
C_{mntac}^A	minimum directed anchovy TAC	150 000t	150 000t	120 000t
C_{mxtac}^S	maximum directed sardine TAC	500 000t	500 000t	500 000t
C_{mxtac}^A	maximum directed normal season anchovy TAC	600 000t	600 000t	600 000t
C_{tier}^S	2-tier break for directed sardine TAC	240 000t	240 000t	255 000t
C_{tier}^A	2-tier break for directed anchovy TAC	330 000t	330 000t	330 000t
$C_{mxinc}^{ns,A}$	maximum increase in normal season anchovy TAC	200 000t	200 000t	150 000t
$C_{mxinc}^{ads,A}$	maximum additional season anchovy TAC	150 000t	150 000t	120 000t
TAB_{ads}^S	maximum sardine bycatch during the additional season	2 000t	2 000t	2 000t
B_{smooth}^S	threshold at which directed sardine TAC is linearly decreased	N/A	800 000t	800 000t
B_{ec}^S	threshold at which Exceptional Circumstances are invoked for sardine	250 000t	250 000t	300 000t
B_{ec}^A	threshold at which Exceptional Circumstances are invoked for anchovy	400 000t	400 000t	400 000t
B_1	threshold above which the anchovy additional sub-season TAC can increase more rapidly	N/A	N/A	1 000 000t
B_2	threshold above which the anchovy additional sub-season TAC reaches a maximum	N/A	N/A	1 500 000t
x^S	the proportion of the Exceptional Circumstances threshold below which sardine TAC is zero.	0	0	0.25
x^A	the proportion of the Exceptional Circumstances threshold below which anchovy TAC is zero.	0	0.25	0.25
R_{crit}	sardine recruitment threshold above which the maximum possible mid-year increase in sardine TAC under Exceptional Circumstances is achieved	N/A	N/A	17.38
Δ^A	threshold above B_{ec}^A at which linear smoothing is introduced before anchovy Exceptional Circumstances are declared (to ensure continuity)	N/A	N/A	100 000t

Table 1 (continued).

Fixed Controls		OMP-02	Re-Revised OMP-04	OMP-08
δ	'scale-down' factor on initial anchovy TAC	0.85	0.85	0.85
p	weighting given to recruit survey in anchovy TAC	0.7	0.7	0.7
q	relates to average TAC under OMP99	300	300	300
γ_y	conservative initial estimate of juvenile sardine : anchovy ratio	0.1-0.2 (eqn. A.5)	0.1-0.2 (eqn. A.5)	0.1-0.2 (eqn. A.5)

Table 2. Key summary statistics for the sardine and anchovy resources: the probability that adult sardine biomass falls below the average adult sardine biomass over November 1991 to November 1994 (the “risk threshold”, $Risk^S$) at least once during the projection period of 20 years, $risk_S$ / the probability that adult anchovy biomass falls below 10% of the average adult anchovy biomass between November 1984 and November 1999 at least once during the projection period of 20 years, $risk_A$; average directed catch (in thousands of tons), \bar{C}^S / \bar{C}^A ; average proportional annual change in directed catch, AAV^S / AAV^A ; average biomass at the end of the projection period as a proportion of carrying capacity, as a proportion of the risk threshold, and as a proportion of biomass at the beginning of the projection period; and average minimum biomass over the projection period as a proportion of carrying capacity (where $K_{non-peak}^S$ denotes the sardine carrying capacity for non-peak years, i.e. excluding 2000-2004, and K^A denotes the carrying capacity for anchovy) and as a proportion of the risk threshold. Statistics are calculated from all simulations and from the 10% of simulations corresponding to the lowest projected biomass under an earlier version of OMP-08 (Cunningham and Butterworth 2008a).

Sardine	All Simulations	Lowest 10%	Anchovy	All Simulations	Lowest 10%
$risk_S$	0.178	0.178	$risk_A$	0.097	0.097
\bar{C}^S (2008-2027)	190	80	\bar{C}^A (2008-2027)	381	293
AAV^S (2008-2027)	0.24	0.37	AAV^A (2008-2027)	0.30	0.38
$B_{2027}^S / K_{non-peak}^S$	0.68	0.19	B_{2027}^A / K^A	0.61	0.40
$\bar{B}_{2027}^S / Risk^S$	10.45	2.02	$\bar{B}_{2027}^A / Risk^A$	1.81	1.09
B_{2027}^S / B_{2007}^S	5.66	1.32	B_{2027}^A / B_{2007}^A	0.84	0.53
$B_{min}^S / K_{non-peak}^S$	0.26	0.06	B_{min}^A / K^A	0.14	0.06
$B_{min}^S / Risk^S$	1.78	0.45	$B_{min}^A / Risk^A$	0.39	0.16

Table 3. Risk and average and median projected TAC/TAB and catch/bycatch (rounded to nearest '000t) for OMP-08.

	$risk_S$	$risk_A$	Directed sardine TAC	Total anchovy TAC	Sardine TAB	Directed sardine catch	Anchovy catch	Sardine bycatch
Average	0.178	0.097	190	420	100	190	381	79
Median	0.178	0.097	152	448	49	152	400	33

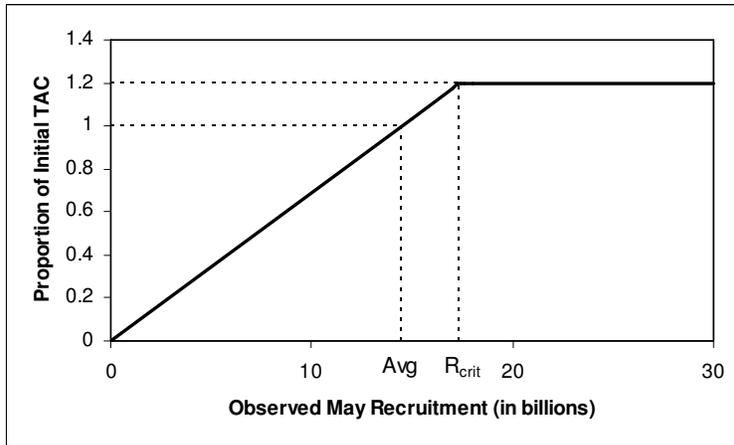


Figure 1. The proportion of the initial directed sardine TAC that is awarded in the mid-year revision to the directed sardine TAC if Exceptional Circumstances are declared. The historic (May 1984 – 2006, i.e. including the peak years) average observed May sardine recruitment is 14.48 billion recruits. For the proposed final OMP-08, $R_{crit} = 17.38$, such that the mid-year revision is the same as the initial TAC when observed recruitment from the May survey is average.

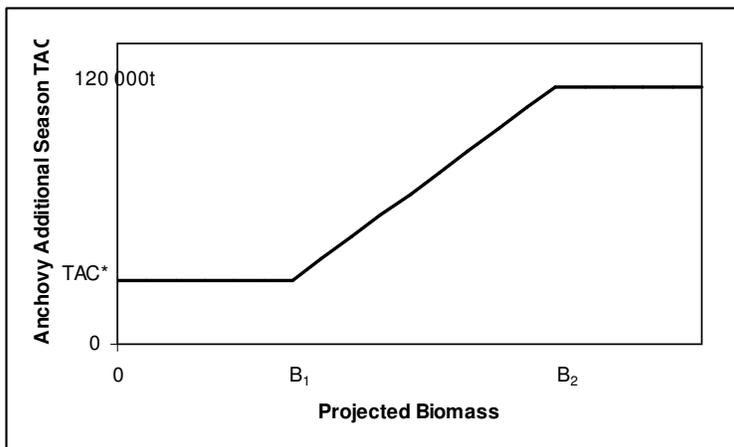


Figure 2. The rule used for anchovy additional season TAC in OMP-08, which increases linearly from $TAC^* = TAC_y^{3,A*} - TAC_y^{2,A}$, where $TAC_y^{3,A*}$ is that output from equations (A.12), (A.13) and (A.14), at $B_{proj} = B_1 = 1\,000\,000t$ to the maximum of $120\,000t$ for $B_{proj} \geq B_2 = 1\,500\,000t$.

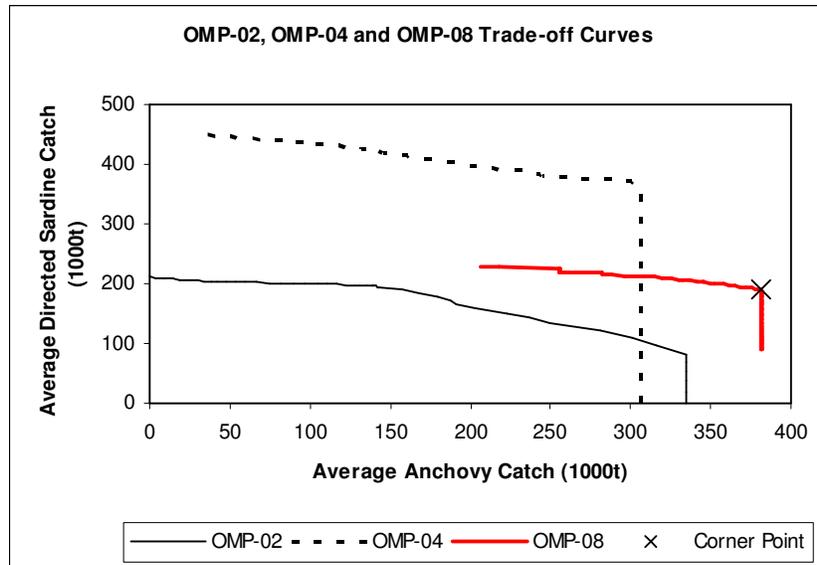


Figure 3. Trade-off curves for OMP-02, OMP-04 and OMP-08. The trade-off curve for OMP-08 is determined by points satisfying $risk_S < 0.18$ and $risk_A < 0.10$.

Appendix: OMP-08

In this Appendix, catches-at-age are given in numbers of fish (in billions), whereas the TACs and TABs are given in thousands of tons. Sardine and anchovy total allowable catches (TACs) and sardine total allowable bycatches (TABs) are set at the start of the year and the latter two are revised during the year (or all three if Exceptional Circumstances apply for sardine).

Initial TACs / TAB (January)

The directed sardine TAC and initial directed anchovy TAC and TAB for sardine bycatch are based on the results of the November spawner biomass survey. These limits are announced prior to the start of the pelagic fishery at the beginning of each year.

The directed sardine TAC is set at a proportion of the previous year's November spawner biomass index of abundance, but subject to the constraints of a minimum and a maximum value. If the previous year's TAC is below the 'two-tier' threshold, then the TAC is subject to a maximum percentage drop from the previous year's TAC. If it is above this threshold, any reduction is limited only by a lower bound of the corresponding threshold less the maximum percentage drop.

The directed anchovy initial TAC is based on how the most recent November spawner biomass survey estimate of abundance relates to the historic (non-peak) average between 1984 and 1999. In the absence of further information, which will become available after the May recruitment survey, this initial TAC assumes the forthcoming recruitment (which will form the bulk of the catch) will be average. A 'scale-down' factor, δ , is therefore introduced to provide a buffer against possible poor recruitment. The anchovy TAC is subject to similar constraints as apply for sardine.

The initial sardine TAB consists of two components. The first component, consisting of mainly juvenile sardine, is proportional to the anchovy TAC. The second, consisting of mainly adult sardine, is a fixed tonnage to make allowance for bycatch with round herring.

$$\text{Directed sardine TAC:} \quad TAC_y^S = \beta B_{y-1,Nov}^{obs,S} \quad (A.1)$$

Subject to:

if $TAC_{y-1}^S \leq c_{tier}^S$:

$$\max \left\{ \left(1 - c_{mxdn}^S \right) TAC_{y-1}^S \times \frac{B_{y-1,N}^{obs,S} - B_{ec}^S}{B^* - B_{ec}^S} + TAC_y^{S*} \frac{B_{smooth}^S - B_{y-1,N}^{obs,S}}{B_{smooth}^S - B_{ec}^S}; c_{mntac}^S \right\} \leq TAC_y^S \leq c_{mxtac}^S \quad \text{if } B_{y-1,N}^{obs,S} \leq B_{smooth}^S$$

$$\max \left\{ \left(1 - c_{mxdn}^S \right) TAC_{y-1}^S; c_{mntac}^S \right\} \leq TAC_y^S \leq c_{mxtac}^S \quad \text{if } B_{y-1,N}^{obs,S} > B_{smooth}^S$$

where $TAC_y^{S*} = \max\{\beta B_{y-1,N}^{obs,S}; c_{mntac}^S\}$

$$\text{if } TAC_{y-1}^S > c_{tier}^S : \quad (1 - c_{mxdn}^S) c_{tier}^S \leq TAC_y^S \leq c_{mxtac}^S \quad (\text{A.2})$$

$$\text{Initial directed anchovy TAC:} \quad TAC_y^{1,A} = \alpha_{ns} \delta q \left(p + (1-p) \frac{B_{y-1}^{obs,A}}{\bar{B}_{Nov}^A} \right) \quad (\text{A.3})$$

$$\text{Subject to:} \quad \max\left\{ (1 - c_{mxdn}^A) TAC_{y-1}^{2,A}; c_{mntac}^A \right\} \leq TAC_y^{1,A} \leq c_{mxtac}^A \quad TAC_{y-1}^{2,A} \leq c_{tier}^A \\ (1 - c_{mxdn}^A) c_{tier}^A \leq TAC_y^{1,A} \leq c_{mxtac}^A \quad TAC_{y-1}^{2,A} > c_{tier}^A \quad (\text{A.4})$$

$$\text{Initial sardine TAB:} \quad TAB_y^{1,S} = \gamma_y TAC_y^{1,A} + TAB_{rh}^S \quad (\text{A.5})$$

$$\text{where:} \quad \gamma_y = 0.1 + \frac{0.1}{1 + \exp\left(-\frac{1}{0.1} 0.00025 (B_{y-1}^{obs,S} - 2000)\right)}$$

To maintain continuity in the initial anchovy TAC as the Exceptional Circumstances threshold (see below), B_{ec}^A , is approached from above and below, if $B_{ec}^A \leq B_{y-1,N}^{obs,A} \leq B_{ec}^A + \Delta^A$ we have:

$$TAC_y^{1,A} = \left(1 - \frac{B_{y-1,N}^{obs,A} - B_{ec}^A}{\Delta^A} \right) \times TAC_y^{1,A-before} + \left(\frac{B_{y-1,N}^{obs,A} - B_{ec}^A}{\Delta^A} \right) \times TAC_y^{1,A*} \quad (\text{A.6})$$

where $TAC_y^{1,A*}$ is the value output from equations (A.3) and (A.4).

In the above equations the symbols used are:

- β - a control parameter reflecting the proportion of the previous year's November spawner biomass index of abundance that is used to set the directed sardine TAC (see Table 1)
- $B_{y,N}^{obs,S}$ - the observed estimate of sardine abundance from the hydroacoustic spawner biomass survey in November of year y .
- $B_{y,N}^{obs,A}$ - the observed estimate of anchovy abundance from the hydroacoustic spawner biomass survey in November of year y .
- \bar{B}_{Nov}^A - the historic average index of anchovy abundance from the spawner biomass surveys from November 1984 to November 1999, of 1380.28 thousand tonnes.
- B_{smooth}^S - the threshold below which the directed sardine TAC is decreased linearly until the Exceptional Circumstances threshold, B_{ec}^S , is reached.
- B_{ec}^S - the biomass threshold below which Exceptional Circumstances apply for sardine (see Table 1).

- B_{ec}^A - the biomass threshold below which Exceptional Circumstances apply for anchovy (see Table 1).
- Δ^A - the threshold below which the anchovy TAC is smoothed until the Exceptional Circumstances threshold, B_{ec}^A , is reached (see Table 1).
- α_{ns} - a control parameter which scales the anchovy TAC to meet target risk levels for sardine and anchovy (see Table 1).
- δ - a ‘scale-down’ factor used to lower the initial anchovy TAC to provide a buffer against possible poor recruitment (see Table 1 – a value of $\delta = 0.85$, used since OMP-02, reflects the industry’s desire for greater ‘up-front’ TAC allocation for planning purposes, even if this means some sacrifice in expected average TAC to meet the same risk criterion).
- p - the weight given to the recruit survey component compared to the spawner biomass survey component in setting the anchovy TAC (see Table 1 – the input value of $p = 0.7$ reflects the greater importance of the incoming recruits in the year’s catch relative to the previous year’s spawner biomass survey).
- q - a constant value reflecting the average annual TAC expected under OMP99 under average conditions if $\alpha_{ns} = 1$ (see Table 1 – unchanged since OMP-02 to facilitate easy comparison between the outputs from consecutive OMPs).
- TAB_{rh}^S - the fixed tonnage of adult sardine bycatch set aside for the round herring fishery each year (see Table 1 – a value of $TAB_{rh}^S = 3\,500t$ is now set since that occurring historically has been about 3 000t; OMP-02 and OMP-04 set $TAB_{rh}^S = 10\,000t$, 12.5% of 80 000t, the predicted average round herring catch (De Oliveira 2003)).
- γ_y - a conservative estimate of the anticipated ratio of juvenile sardine to juvenile anchovy in subsequent catches.
- c_{mxdn}^S - the maximum proportional amount by which the directed sardine TAC can be reduced from one year to the next (see Table 1).
- c_{mxdn}^A - the maximum proportional amount by which the normal season directed anchovy TAC can be reduced from one year to the next, (note that the additional season anchovy TAC is not taken into consideration in this constraint, which consequently depends on $TAC_{y-1}^{2,A}$, not $TAC_{y-1}^{3,A}$ - see below for formulae for these quantities) (see Table 1).
- c_{mntac}^S - the minimum directed TAC to be set for sardine (see Table 1).
- c_{mntac}^A - the minimum directed TAC to be set for anchovy (see Table 1).
- c_{mxtac}^S - the maximum directed TAC to be set for sardine (see Table 1).
- c_{mxtac}^A - the maximum directed TAC to be set for anchovy during the normal season (see Table 1).

Revised TACs / TAB (June)

The anchovy TAC and sardine TAB midyear revisions are based on the most recent November and now also recruit surveys. As the estimate of recruitment is now available, the ‘scale-down’ factor, δ , is no longer needed to set the directed anchovy TAC. The additional constraints include restricting the amount to which the revised anchovy TAC may exceed the initial anchovy TAC (because of limitations in industry processing capacity) and ensuring that the revised anchovy TAC is not less than the initial anchovy TAC.

The revised sardine TAB is calculated using an estimate of the ratio, r_y , of juvenile sardine to anchovy, provided this ratio is larger than γ_y , which was used to set the initial TAB.

$$\text{Revised anchovy TAC:} \quad TAC_y^{2,A} = \alpha_{ns} q \left(p \frac{N_{y-1,rec0}^A}{\bar{N}_{rec0}^A} + (1-p) \frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^A} \right) \quad (A.7)$$

Subject to:

$$\begin{aligned} \max \left\{ (1 - c_{mxdn}^A) TAC_{y-1}^{2,A}; TAC_y^{1,A}; c_{mtac}^A \right\} \leq TAC_y^{2,A} \leq \min \left\{ c_{mtac}^A; TAC_y^{1,A} + c_{mxinc}^{ns,A} \right\} \quad TAC_{y-1}^{2,A} \leq c_{tier}^A \\ \max \left\{ TAC_y^{1,A}; (1 - c_{mxdn}^A) c_{tier}^A \right\} \leq TAC_y^{2,A} \leq \min \left\{ c_{mtac}^A; TAC_y^{1,A} + c_{mxinc}^{ns,A} \right\} \quad TAC_{y-1}^{2,A} > c_{tier}^A \end{aligned} \quad (A.8)$$

$$\text{Revised sardine TAB:} \quad TAB_y^{2,S} = \lambda TAC_y^{1,A} + r_y (TAC_y^{2,A} - TAC_y^{1,A}) + TAB_{rh}^S \quad (A.9)$$

$$\text{Where:} \quad \lambda = \max\{\gamma_y, r_y\}$$

To maintain continuity in the revised anchovy TAC as B_{ec}^A is approached from above and below, if $B_{ec}^A \leq B_{y,proj}^A \leq B_{ec}^A + \Delta^A$ we have:

$$TAC_y^{2,A} = \left(1 - \frac{B_{y,proj}^A - B_{ec}^A}{\Delta^A} \right) \times TAC_y^{2,A_before} + \left(\frac{B_{y,proj}^A - B_{ec}^A}{\Delta^A} \right) \times TAC_y^{2,A*} \quad (A.10)$$

where $TAC_y^{2,A*}$ is the value output from equations (A.7) and (A.8) and $B_{y,proj}^A$ is determined by equation (A.21).

Note that by construction $TAB_y^{2,S} \geq TAB_y^{1,S}$ as $\lambda \geq \gamma_y$ and $TAC_y^{2,A} \geq TAC_y^{1,A}$. In addition to the previous definitions, we have:

$N_{y-1,rec0}^A$ - the simulated estimate of anchovy recruitment from the recruitment survey in year y , $N_{y,r}^{obs,A}$ ¹, back-calculated to 1 November $y-1$ by taking natural and fishing mortality into account (equation (A.11)).

\bar{N}_{rec0}^A - the average 1985 to 1999 observed anchovy recruitment in May, back-calculated (using equation (A.11)) to November of the previous year of 197.96 billion recruits.

$C_{maxinc}^{ns,A}$ - the maximum amount by which the anchovy TAC is allowed to be increased within the normal season (see Table 1).

$$r_y = \frac{1}{2}(r_{y,sur} + r_{y,com})$$

- the ratio of juvenile sardine to anchovy “in the sea” during May in year y , calculated from the recruit survey and the sardine bycatch to anchovy ratio in the commercial catches² during May.

The anchovy TAC equations require that $N_{y,r}^{obs,A}$, the recruitment numbers estimated in the survey, be back-calculated to November of the previous year, assuming a fixed value of 0.9 year^{-1} for M_j^A . The back-calculated recruitment numbers are calculated as follows:

$$N_{y-1,rec0}^A = (N_{y,r}^{obs,A} e^{0.5(6+t_y^A)0.9/12} + C_{y,obs}^A) e^{[0.5(6+t_y^A)]0.9/12} \quad (\text{A.11})$$

In the above equation we have

$C_{y,obs}^A$ - the observed anchovy landed by number (in billions) from the 1st of November year $y-1$ to the day before the recruit survey commences in year y .

t_y^A - the timing of the anchovy recruit survey in year y (number of months) relative to the 1st of May that year.

Final TACs / TABs (the anchovy additional sub-season from September)

The final anchovy TAC is adjusted from the revised June TAC to achieve better utilisation of the anchovy resource later in the year when the anchovy and juvenile sardine no longer shoal together in large quantities. Two thresholds, $B_1 \geq B_{ec}^A + \Delta^A$ and $B_2 \geq B_1$ allow for a possible rapid increase to the maximum in the additional season anchovy TAC dependent on the projected November spawner biomass (based on the observed May recruitment). This rapid increase starts once the projected biomass exceeds B_1 , and reaches the maximum when the projected biomass reaches B_2 (see Figure 2). The sardine TAB is increased by a

¹ This estimate of recruitment is calculated using a cut-off length determined from modal progression analysis. In the event of this modal progression analysis being unable to detect a clear mode, a recruit cut-off (caudal) length of 10.5cm for anchovy and 15.5cm for sardine will be used. These are the cut-off lengths used historically and from which there has not been substantial deviation over a 10 year period (Coetzee pers. comm.).

² Only commercial catches comprising at least 50% anchovy with sardine bycatch are considered.

small tonnage. This increase is the minimum of a fixed tonnage or γ_y of the difference between the anchovy revised and final TACs.

Because the anchovy additional sub-season is treated as completely separate from the anchovy normal season, the anchovy TAC and sardine TAB actually applied during the sub-season are $TAC_y^{3,A} - TAC_y^{2,A}$ and $TAB_y^{3,S} - TAB_y^{2,S}$ respectively.

$$\text{Final anchovy TAC: } TAC_y^{3,A} = \alpha_{ads} q \left(p \frac{N_{y-1,rec0}^A}{\bar{N}_{rec0}^A} + (1-p) \frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^A} \right) \quad (\text{A.12})$$

$$\text{Subject to: } \max\{ TAC_y^{2,A} ; c_{mmtac}^A \} \leq TAC_y^{3,A} \leq \min\{ c_{mxtac}^A ; TAC_y^{2,A} + c_{mxinc}^{ads,A} \} \quad (\text{A.13})$$

In addition:

$$TAC_y^{3,A} = TAC_y^{2,A} + \frac{c_{mxinc}^{ads,A} - (TAC_y^{3,A*} - TAC_y^{2,A})}{B_2 - B_1} (B_{y,proj}^A - B_1) + (TAC_y^{3,A*} - TAC_y^{2,A}) \quad \text{if } B_1 \leq B_{y,proj}^A < B_2$$

$$TAC_y^{3,A} = TAC_y^{3,A*} \quad \text{if } B_{y,proj}^A < B_1$$

$$TAC_y^{3,A} = TAC_y^{2,A} + c_{mxinc}^{ads,A} \quad \text{if } B_{y,proj}^A \geq B_2$$

$$(\text{A.14})$$

where $TAC_y^{3,A*}$ is the value output from equations (A.12) and (A.13) and $B_{y,proj}^A$ is calculated using the equivalent of equation (A.21) for the final TAC.

$$\text{Sardine 3rd TAB: } TAB_y^{3,S} = TAB_y^{2,S} + \min\{ TAB_{ads}^S ; \gamma_y (TAC_y^{3,A} - TAC_y^{2,A}) \} \quad (\text{A.15})$$

To maintain continuity in the revised anchovy TAC as B_{ec}^A is approached from above and below, if $B_{ec}^A \leq B_{y,proj}^A \leq B_{ec}^A + \Delta^A$ we have:

$$TAC_y^{3,A} = \left(1 - \frac{B_{y,proj}^A - B_{ec}^A}{\Delta^A} \right) \times TAC_y^{3,A_before} + \left(\frac{B_{y,proj}^A - B_{ec}^A}{\Delta^A} \right) \times TAC_y^{3,A**} \quad (\text{A.16})$$

where $TAC_y^{3,A**}$ is the value output from equations (A.12), (A.13) and (A.14). We also specify the following:

α_{ads} - a control parameter which scales the anchovy TAC to meet target risk levels for sardine and anchovy (see Table 1).

$c_{mxinc}^{ads,A}$ - the maximum amount by which the anchovy TAC is allowed to be increased within the additional sub-season (see Table 1).

B_1 - a biomass-related control parameter determining the point at which the anchovy additional sub-season TAC can increase more rapidly (see Figure 2 and Table 1).

B_2 - a biomass-related control parameter determining the point at which the anchovy additional sub-season TAC reaches a maximum (see Figure 2 and Table 1).

TAB_{ads}^S - the maximum fixed tonnage of juvenile sardine bycatch set aside for the anchovy additional sub-season each year (see Table 1).

Exceptional Circumstances

Sardine directed TAC

Exceptional Circumstances for the sardine directed TAC apply if:

$$B_{y-1,N}^{obs,S} < B_{ec}^S$$

in which case the TAC under Exceptional Circumstances is calculated as follows. Only a portion (half) of the directed sardine TAC is awarded with the initial TACs, with a revised TAC in June dependent on the observed May sardine recruitment (see Figure 1):

$$\text{Initial TAC: } TAC_{y,init}^S = 0.5 \times \begin{cases} 0 & \text{if } \frac{B_{y-1,N}^{obs,S}}{B_{ec}^S} < x^S \\ TAC_y^{S_before} \left(\frac{\frac{B_{y-1,N}^{obs,S}}{B_{ec}^S} - x^S}{1 - x^S} \right)^2 & \text{if } x^S < \frac{B_{y-1,N}^{obs,S}}{B_{ec}^S} < 1 \end{cases} \quad (\text{A.17})$$

$$\text{Revised TAC: } TAC_y^S = \begin{cases} TAC_{y,init}^S + 1.2 \times \frac{N_{y,r}^{obs,S}}{R_{crit}} TAC_{y,init}^S & \text{if } N_{y,r}^{obs,S} \leq R_{crit} \\ TAC_{y,init}^S + 1.2 \times TAC_{y,init}^S & \text{if } N_{y,r}^{obs,S} > R_{crit} \end{cases} \quad (\text{A.18})$$

where $TAC_y^{S_before} = \beta B_{y-1,N}^{obs,S}$, subject to $c_{mntac}^S \leq TAC_y^{S_before} \leq c_{mxtac}^S$. The rule allows for the TAC to be set to zero if the survey estimated sardine biomass falls below x^S of the threshold (see Table 1). Further we have:

R_{crit} - the level of sardine recruitment required in order to achieve the maximum possible mid-year increase in sardine TAC under Exceptional Circumstances (see Figure 1 and Table 1).

Initial Anchovy TAC

Exceptional Circumstances for the initial anchovy TAC apply if

$$B_{y-1,N}^{obs,A} < B_{ec}^A$$

in which case the TAC under Exceptional Circumstances is calculated as follows:

$$TAC_y^{1,A} = \begin{cases} 0 & \text{if } \frac{B_{y-1,N}^{obs,A}}{B_{ec}^A} < x^A \\ TAC_y^{1,A_before} \left(\frac{\frac{B_{y-1,N}^{obs,A}}{B_{ec}^A} - x^A}{1 - x^A} \right)^2 & \text{if } x^A < \frac{B_{y-1,N}^{obs,A}}{B_{ec}^A} < 1 \end{cases} \quad (\text{A.19})$$

where $TAC_y^{1,A_before} = \alpha_{ns} \delta q \left(p + (1-p) \frac{B_{y-1,N}^{obs,A}}{B_{Nov}^A} \right)$, subject to $c_{mntac}^A \leq TAC_y^{1,A_before} \leq c_{mxtac}^A$. The rule allows

for the TAC to be set to zero if the survey estimated anchovy biomass falls below x^A of the threshold (see Table 1).

Revised Anchovy TAC

The results of the most recent November and recruit surveys are projected forward, taking natural and anticipated fishing mortality into account, in order to provide a proxy ($B_{y,proj}^A$) for the forthcoming November survey, and hence have a basis for invoking Exceptional Circumstances, if necessary. Define

$$TAC_y^{2,A_before} = \alpha_{ns} q \left(p \frac{N_{y-1,rec0}^A}{\bar{N}_{rec0}^A} + (1-p) \frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^A} \right), \text{ subject to } \max\{TAC_y^{1,A}; c_{mntac}^A\} \leq TAC_y^{2,A_before} \leq c_{mxtac}^A, \text{ a}$$

projected anchovy biomass, $B_{y,proj0}^A$, is calculated as follows:

$$B_{y,proj0}^A = \max \left\{ 0; \left(N_{y,rec}^A - \left[\frac{TAC_y^{2,A_before}}{\bar{W}_{0c}^A} - C_{y,1}^A - C_{y,0bs}^A \right] \right) e^{-5.5*0.9/12 \bar{W}_1^A} \right\}. \quad (\text{A.20})$$

Calculate $B_{y,proj}^A$ as follows:

$$B_{y,proj}^A = \left(\frac{B_{y-1,N}^{obs,A}}{\bar{W}_1^A} e^{-5*0.9/12} - C_{y,1}^A \right) e^{-7*0.9/12 \bar{W}_2^A} + B_{y,proj0}^A \quad (\text{A.21})$$

If $B_{y,proj}^A < B_{ec}^A$, then Exceptional Circumstances apply. The recruit survey result in year y (in numbers) that would be sufficient to yield a $B_{y,proj}^A$ value of exactly B_{ec}^A is calculated as follows:

$$\theta = \frac{[B_{ec}^A - (B_{y,proj}^A - B_{y,proj0}^A)]}{\bar{W}_1^A} e^{5.5*0.9/12} + \frac{TAC_y^{2,A_before}}{\bar{W}_{0c}^A} - C_{y,1}^A - C_{y,0bs}^A \quad (\text{A.22})$$

This is back-calculated to November of the previous year in the same way as equation (A.11) during OMP implementation:

$$N_{y-1,rec0}^{A*} = (\theta e^{0.5(6+t_y^A)0.9/12} + C_{y,0bs}^A) e^{[0.5(6+t_y^A)]0.9/12} \quad (\text{A.23})$$

The revised anchovy TAC is calculated by reducing TAC_y^{2,A_before} by the ratio (squared) of $TAC_y^{2,A}$ calculated with the annual recruitment for year y to $TAC_y^{2,A}$ calculated with θ , thus providing a means to reduce the TAC fairly rapidly when the Exceptional Circumstances threshold is surpassed. The rule allows for the TAC to be set to zero (or to the initial anchovy TAC, if greater than zero) if the survey estimated anchovy recruitment and biomass falls below a quarter of the threshold:

$$TAC_y^{2,A} = \max \left\{ \begin{array}{l} TAC_y^{1,A}; TAC_y^{2,A_before} \left(\frac{\left(p \frac{N_{y-1,rec0}^A}{\bar{N}_{rec0}^A} + (1-p) \frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^A} \right) - x^A}{(1-x^A)^2} \right)^2 \\ TAC_y^{1,A}; 0 \end{array} \right. \quad \begin{array}{l} \text{if } x^A < \frac{p \frac{N_{y-1,rec0}^A}{\bar{N}_{rec0}^A} + (1-p) \frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^A}}{p \frac{N_{y-1,rec0}^{A*}}{\bar{N}_{rec0}^A} + (1-p) \frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^A}} < 1 \\ \text{if } \frac{p \frac{N_{y-1,rec0}^A}{\bar{N}_{rec0}^A} + (1-p) \frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^A}}{p \frac{N_{y-1,rec0}^{A*}}{\bar{N}_{rec0}^A} + (1-p) \frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^A}} < x^A \end{array} \quad (A.24)$$

Final Anchovy TAC

The same procedure as for the revised anchovy TAC is followed, except that

$$TAC_y^{3,A_before} = \alpha_{ads} q \left(p \frac{N_{y-1,rec0}^A}{\bar{N}_{rec0}^A} + (1-p) \frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^A} \right), \text{ subject to } \max\{TAC_y^{2,A}; c_{mntac}^A\} \leq TAC_y^{3,A_before} \leq c_{mxtac}^A$$

replaces TAC_y^{2,A_before} in equations (A.20), (A.22) and (A.24) above. Furthermore, $TAC_y^{2,A}$ replaces $TAC_y^{1,A}$ in equation (A.24) above.

References

De Oliveira, J.A.A. 2003. The Development and Implementation of a Joint Management Procedure for the South African Pilchard and Anchovy Resources. PhD Thesis, University of Cape Town, South Africa.