Re-Revised OMP-04

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Introduction

The Operational Management Procedure currently used to set South African sardine and anchovy total allowable catches and sardine bycatches, OMP-04, was revised in early 2005 and documented in Cunningham and Butterworth (2005). This was in response to a Supreme Court of Appeal ruling which referred the matter of the distribution of the pelagic TAC for the 2005 season back to the Department for fresh determination. Subsequent to this ruling, the Cape High Court ruled that the revised pelagic allocations for 2005 again be set aside and fresh determinations made. This document details the further modifications made to OMP-04 in response thereto, and provides the science behind this "re-revision". It should be read in conjunction with Cunningham and Butterworth (2004a), which detailed OMP-04 as agreed by the Marine and Coastal Management Pelagic Working Group in June 2004, and Cunningham and Butterworth (2004b) which contains the finalised rules governing exceptional circumstances.

Preferred Ratios

The opportunity accorded to rights holders in the pelagic industry to revise their preferred sardine-anchovy ratios at the beginning of 2002 resulted in an overall shift towards a greater preference for directed sardine quotas at the expense of anchovy quotas (De Oliveira, 2003). Such a request resulted in an overall move towards a greater average directed sardine TAC on the OMP-02 trade-off curve at the expense of a much larger proportional reduction of the average anchovy TAC. Had these revisions been accepted in their entirety, it appeared at that time that the anchovy resource would have been wastefully under-utilised. A cap was consequently imposed on the extent to which the individual rights holders could change their preferred ratio (De Oliveira, 2003). Ultimately, the preferred ratios of the individual rights holders were only allowed to change by a maximum of 20% in favour of sardine (unrestricted changes in favour of anchovy were allowed).

Updated and additional data were used in the construction of OMP-04, resulting in a change in the trade-off curve towards greater average directed sardine and anchovy catches, for the same set of preferred ratios as used in OMP-02 (Figure 1). Following the Supreme Court of Appeal ruling in late 2004, it was decided to retest the effect of the cap on the requested change to the individual rights holders' preferred

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ratios. This shifted the OMP-02 trade-off choice up and leftward on the curve of Figure 1, so that the corresponding change to the projection line yielded a revised trade-off choice on the OMP-04 curve (see Figure 2). From the comparison of the original and revised trade-off choices in Figure 2, it was considered that the revised scientific perceptions of the status of the sardine and anchovy resources now allowed the revised preferred ratios as originally requested to be fully honoured, without undue under-utilisation of anchovy.

The August 2005 ruling by the Cape High Court argued that allocations as revised earlier in 2005 had not changed sufficiently from those prior to the Supreme Court ruling, where concern had been expressed that some of the effective “swops” achieved by certain rights holders from anchovy towards sardine subsequent to their 2001 allocations appeared inappropriately large. To effect a lesser extent of allowed change, the preferred ratios corresponding to each 2001 rights holder’s allocation that year were computed, and a cap of 25% was placed on the extent to which any increase towards sardine would be allowed. New entrants (from 2002) were unaffected by this cap, being accorded whatever ratio they had finally requested. The 25% figure was arrived at following discussions at a senior level within MCM~~with some companies potentially appreciably impacted by such a modification~~. The modification does however mean that, in contrast to the revision earlier in 2005, some individual rights holders are now no longer receiving allocations in exact relation to the revised preferred sardine-anchovy ratios they requested in early 2002.

As before (Cunningham and Butterworth, 2005) the remaining unallocated proportion of percentage rights in the fishery (held for appeals) was allocated pro-rata.

Updated Trade-off Choice on the Trade-off Curve

These changes result in new control parameters for OMP-04 (Table 1) and a new trade-off point on the OMP-04 trade-off curve. The average directed sardine TAC decreases as a result of this change from 375 to 369 thousand tons, while the average anchovy TAC increases from 299 to 309 thousand tons (Figure 2). This increase in the average anchovy TAC is coupled with an increase in sardine bycatch, and thus the decrease in the average directed sardine TAC does not result in a decrease in risk to the sardine resource. (This is because the trade-off curve illustrates the average trade-off between directed sardine and anchovy catches *for the same level of risk*.)

Discussion

This document has described the reasons for and process followed to re-revise the Operational Management Procedure for South African sardine and anchovy, OMP-04, in August 2005. This “re-revision” is a consequence of a 25% cap on changes towards sardine being placed on individual rights holders’ revised preferred ratios from that which their implicit holdings in 2001 (clearly though new entrants (rights holders) in 2002 were unaffected by this change). The rules governing OMP-04 and the data required for implementing the OMP are detailed in the appendix.

References

Butterworth, D.S., De Oliveira, J.A.A., and Cochrane, K.L. 1993. Current Initiatives in Refining the Management Procedure for the South African Anchovy Resource. In Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations. Alaska Sea Grant College Program, 1993. pp 439-473.

Cunningham, C.L., and Butterworth, D.S. 2004a. OMP-04 Description. MCM document WG/JUN2004/PEL/01.

Cunningham, C.L., and Butterworth, D.S. 2004b. Exceptional Circumstances in OMP-04. MCM document WG/AUG2004/PEL/03.

Cunningham, C.L., and Butterworth, D.S. 2005. Revised OMP-04. MCM document SWG/AUG2005/PEL/10.

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.

Table 1. Parameters and constraints in OMP-02 and OMP-04, showing the change in the control parameters in OMP-04 given the update to the "re-revised" version recorded in this paper.

Control Parameter		**OMP-02**	**OMP-04**	**Revised OMP-04, Feb '05**	**Re-Revised OMP-04, Aug '05**
β	directed sardine control parameter	0.1865	0.14387	0.15148	0.14657
α_{ns}	directed anchovy control parameter for normal season	0.16655	0.72858	0.69382	0.73752
α_{ads}	directed anchovy control parameter for additional season	0.99956	1.45716	1.38764	1.47504
Constraints		**OMP-02**	**OMP-04**	**Revised OMP-04, Feb '05**	**Re-Revised OMP-04, Aug '05**
TAB^S_{rh}	fixed annual adult sardine bycatch	10 000t	10 000t	10 000t	10 000t
c^S_{mxdn}	maximum proportion by which directed sardine TAC can be annually reduced	0.2	0.15	0.15	0.15
c^A_{mxdn}	maximum proportion by which normal season anchovy TAC can be annually reduced	0.3	0.25	0.25	0.25
c^S_{mntac}	minimum directed sardine TAC	90 000t	90 000t	90 000t	90 000t
c^A_{mntac}	minimum directed anchovy TAC	150 000t	150 000t	150 000t	150 000t
c^S_{mxtac}	maximum directed sardine TAC	250 000t	500 000t	500 000t	500 000t
c^A_{mxtac}	maximum directed anchovy TAC	600 000t	600 000t	600 000t	600 000t
c^S_{tier}	2-tier break for directed sardine TAC	N/A	240 000t	240 000t	240 000t
c^A_{tier}	2-tier break for directed anchovy TAC	N/A	330 000t	330 000t	330 000t
$c^{ns,A}_{mxinc}$	maximum increase in normal season anchovy TAC	150 000t	200 000t	200 000t	200 000t
$c^{ads,A}_{mxinc}$	maximum additional season anchovy TAC	100 000t	150 000t	150 000t	150 000t
TAB^S_{ads}	maximum sardine bycatch during the additional season	2 000t	2 000t	2 000t	2 000t
B^S_{ec}	threshold at which exceptional circumstances are invoked for sardine	150 000t	250 000t	250 000t	250 000t
B^A_{ec}	threshold at which exceptional circumstances are invoked for anchovy	400 000t	400 000t	400 000t	400 000t
Fixed Controls		**OMP-02**	**OMP-04**	**Revised OMP-04, Feb '05**	**Re-Revised OMP-04, Aug '05**
δ	'scale-down' factor on initial anchovy TAC	0.85	0.85	0.85	0.85
p	weighting given to recruit survey in anchovy TAC	0.7	0.7	0.7	0.7
q	relates to average TAC under OMP99	300	300	300	300
γ_y	conservative initial estimate of juvenile sardine : anchovy ratio	0.1	0.1-0.2 (eqn. A.5)	0.1-0.2 (eqn. A.5)	0.1-0.2 (eqn. A.5)

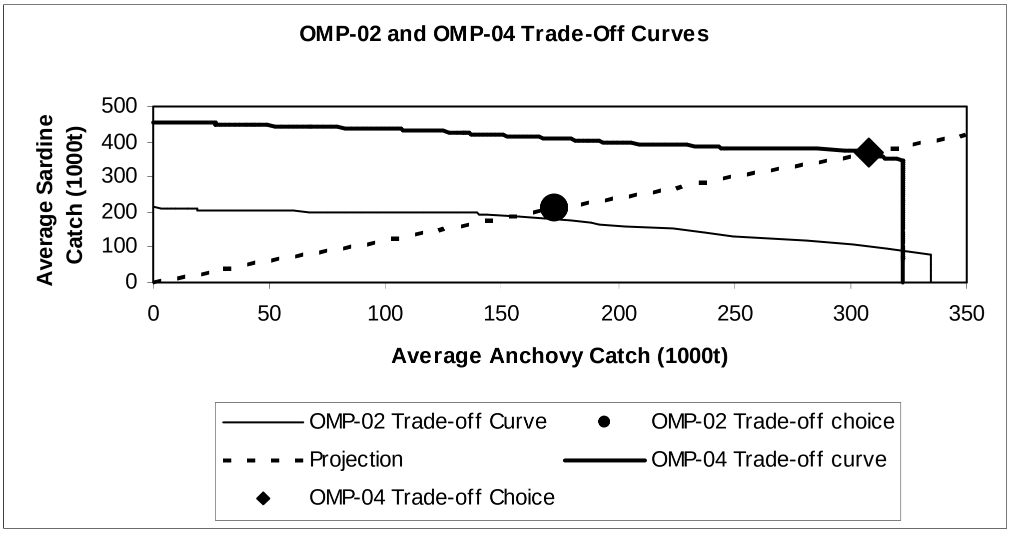
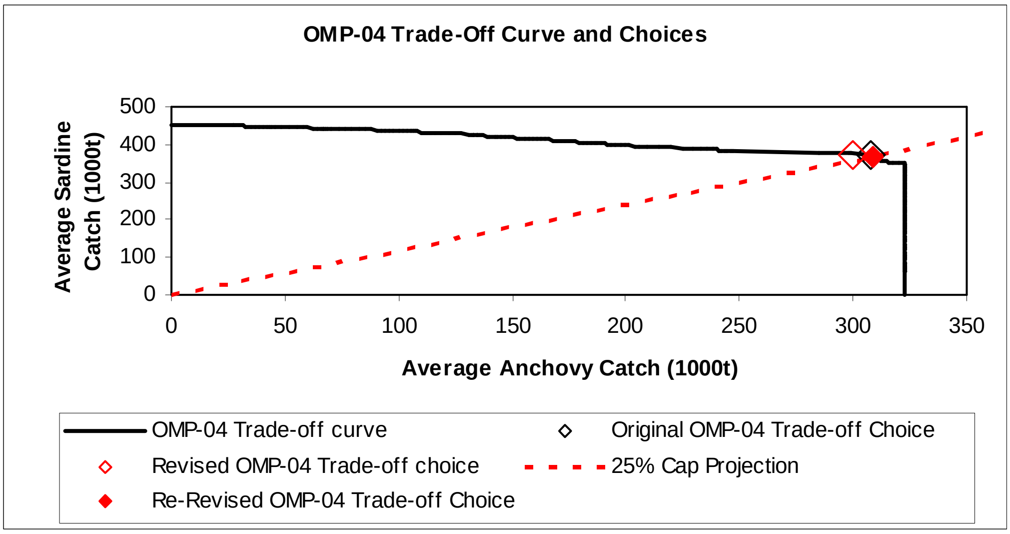


Figure 1. The trade-off curves used for OMP-02 and OMP-04. The projection line, obtained using the control values in OMP-02, was used to indicate where the new trade-off selection of OMP-04 lay. (Note that the OMP-04 trade-off curve is updated from that in Cunningham and Butterworth (2004a) to allow for a greater maximum in average anchovy catch due to the exceptional circumstances rules finalised in Cunningham and Butterworth (2004b).)



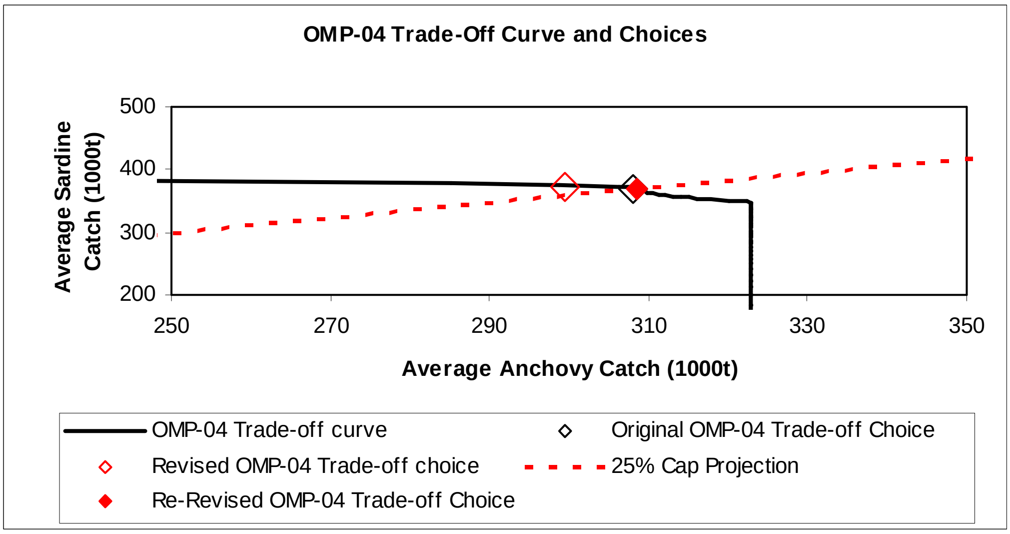


Figure 2. The trade-off curve for OMP-04, showing the projection line used after the inclusion of a 25% cap on the change of preferred sardine-anchovy ratios towards sardine from that implicit in 2001, and the subsequent "re-revised" trade-off selection under OMP-04. The original OMP-04 trade-off choice is also shown, together with the trade-off choice from the revision made to OMP-04 (removing the cap on the preferred ratios) in February 2005. The lower panel shows a magnified area of the upper panel.

Appendix: OMP-04 Rules and Required Data

The convention in this appendix is to index the recruits corresponding to the month in which the recruitment estimate applies. Thus the predicted recruits in May in year y, $N^i_{y,r}$, $i = S, A$, relate to the model-predicted recruitment in November of year $y-1$, $N^i_{y-1,0}$. In addition catches-at-age are given in this appendix in numbers of fish (in billions), whereas the TACs, TABs and observed biomass are given in thousands of tons.

OMP-04 (Harvest Control Model)

Sardine and anchovy total allowable catches (TACs) and sardine total allowable bycatches (TABs) are set at the start of the year and the last two are revised during the year.

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 catch 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 this 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 (pre-2004) average. 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.

Directed sardine TAC: $$TAC^S_y = \beta \, B^S_{y-1,Nov} \qquad \text{(A.1)}$$

Subject to:
$$\begin{array}{ll} \max\left\{\left(1-c^S_{mxdn}\right)TAC^S_{y-1}\, ;\, c^S_{mntac}\right\} \le TAC^S_y \le c^S_{mxtac} & TAC^S_{y-1} \le c^S_{tier} \\ \left(1-c^S_{mxdn}\right)c^S_{tier} \le TAC^S_y \le c^S_{mxtac} & TAC^S_{y-1} > c^S_{tier} \end{array} \qquad \text{(A.2)}$$

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

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

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

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

In the above equations we have (see Table 1 for fixed control parameters and constraint values):

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.

$B_{y,Nov}^S$ - the observed estimate of sardine abundance (in thousands of tons) from the hydroacoustic spawner biomass survey in November of year y.

$B_{y,Nov}^A$ - the observed estimate of anchovy abundance (in thousands of tons) from the hydroacoustic spawner biomass survey in November of year y.

$\overline{B}_{Nov}^A$ - the historic average index of anchovy abundance from the spawner biomass surveys from November 1984 to November 2003, of 2149.15 thousand tons.

α_{ns} - a control parameter which scales the anchovy TAC to meet target risk levels for sardine and anchovy.

δ - a 'scale-down' factor used to lower the initial anchovy TAC to provide a buffer against possible poor recruitment.

p - the weight given to the recruit survey component compared to the spawner biomass survey component in setting the anchovy TAC.

q - reflects the average annual TAC expected under OMP99 under average conditions if $\alpha_{ns} = 1$.

TAB_{rh}^S - the fixed tonnage of adult sardine bycatch set aside for the round herring fishery each year.

γ_y - a conservative allowance for the 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.

c^{A}_{mxdn} - 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 $TAC^{2,A}_{y-1}$, not $TAC^{3,A}_{y-1}$ - see below for formulae for these quantities).

c^{S}_{mntac} - the minimum directed TAC that may be set for sardine.

c^{A}_{mntac} - the minimum directed TAC that may be set for anchovy.

c^{S}_{mxtac} - the maximum directed TAC that may be set for sardine.

c^{A}_{mxtac} - the maximum directed TAC that may be set for anchovy.

The fixed 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. Earlier OMPs used a fixed value of $\delta = 0.7$ to reflect the assumption that 70% of the final TAC to be expected in the case of average recruitment would be caught by the time the revised TAC is announced (Butterworth et al., 1993). For OMP-02 this control parameter was increased to 0.85 to reflect the industry's desire for greater 'up-front' TAC allocation for planning purposes, even if this meant some sacrifice in expected average TAC to meet the same risk criterion (De Oliveira, 2003). Although $q = 300$ is based on an old OMP, the value is not adjusted here. This was to facilitate easy comparison between the outputs from OMP-04 and OMP-02 by stakeholders.

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 an 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 by 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.

Revised anchovy TAC:
$$TAC^{2,A}_{y} = \alpha_{ns}\ q \left(p \frac{N^{A}_{y-1,rec0}}{\overline{N}^{A}_{y-1,rec0}} + (1-p) \frac{B^{A}_{y-1,Nov}}{\overline{B}^{A}_{Nov}} \right) \tag{A.6}$$

Subject to:

$$\max\left\{\left(1-c^{A}_{mxdn}\right)TAC^{2,A}_{y-1}\,;TAC^{1,A}_{y};c^{A}_{mntac}\right\} \le TAC^{2,A}_{y} \le \min\left\{c^{A}_{mxtac};TAC^{1,A}_{y}+c^{ns,A}_{mxinc}\right\} \quad TAC^{2,A}_{y-1} \le c^{A}_{tier}$$
$$\max\left\{TAC^{1,A}_{y};\left(1-c^{A}_{mxdn}\right)c^{A}_{tier}\right\} \le TAC^{2,A}_{y} \le \min\left\{c^{A}_{mxtac};TAC^{1,A}_{y}+c^{ns,A}_{mxinc}\right\} \quad TAC^{2,A}_{y-1} > c^{A}_{tier}$$

(A.7)

Revised sardine TAB: $TAB^{2,S}_{y} = \lambda\, TAC^{1,A}_{y} + r_y\ (TAC^{2,A}_{y} - TAC^{1,A}_{y}) + TAB^{S}_{rh}$ (A.8)

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

Note that by construction $TAB^{2,S}_{y} \ge TAB^{1,S}_{y}$ as $\lambda \ge \gamma_y$ and $TAC^{2,A}_{y} \ge TAC^{1,A}_{y}$. In addition to the previous definitions, we have:

$N^{A}_{y-1,rec0}$ - the simulated estimate of anchovy recruitment from the recruitment survey in year y, back-calculated to 1 November $y-1$ by taking natural and fishing mortality into account, calculated using equation (A.9).

$\overline{N}^{A}_{y-1,rec0}$ - the average simulated estimate of anchovy recruitment at the beginning of November from 1984 to $y-2$, calculated using equation (A.10).

$c^{ns,A}_{mxinc}$ - the maximum amount by which the anchovy TAC is allowed to be increased within the normal season.

r_y - the average of the juvenile sardine to anchovy ratio in the commercial catches in May and in the recruit survey, in year y, calculated using equation (A.11).

The observed $N^{A}_{y,rec}$ is back-calculated to November of the previous year, assuming a fixed value of 0.9 *year*$^{-1}$ for M^{A}_{ju}:

$$N^{A}_{y-1,rec0} = (N^{A}_{y,rec}\, e^{0.5(1+t^{A}_{y})0.9/12} + C^{A}_{y,0bs})\, e^{[5+0.5(1+t^{A}_{y})]0.9/12}\,. \qquad \text{(A.9)}$$

The average recruitment excludes the most recent year in order that the most recent year is compared to the 'independent' historic average:

$$\overline{N}^{A}_{y-1,rec0} = \frac{1}{y-1-1984}\sum_{y'=1984}^{y-2} N^{A}_{y',rec0} \qquad \text{(A.10)}$$

In the above equations we have

$C^{A}_{y,0bs}$ - the observed anchovy landed by number (in billions) from the 1st of April to the day before the recruit survey commences in year *y*, all assumed to be 0-year-old fish.

t^{A}_{y} - the timing of the anchovy recruit survey in year *y* (number of months) relative to the 1st of May that year.

In calculating the ratio of juvenile sardine to anchovy "in the sea" during May, r_y, only the commercial catches comprising at least 50% anchovy with sardine bycatch were considered. The ratio r_y is calculated as follows:

$$r_y = \tfrac{1}{2}(r_{y,sur} + r_{y,com}), \tag{A.11}$$

where $r_{y,sur}$ denotes the observed ratio in the May recruit survey and $r_{y,com}$ denotes the observed ratio from the commercial catches in May.

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. The sardine TAB is increased by a 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.

Final anchovy TAC:

$$TAC_y^{3,A} = \alpha_{ads}\, q \left(p \frac{N_{y-1,rec0}^{A}}{\overline{N}_{y-2,rec0}^{A}} + (1-p) \frac{B_{y-1,Nov}^{A}}{\overline{B}_{Nov}^{A}} \right) \tag{A.12}$$

Subject to:

$$\max\{TAC_y^{2,A}\,;\, c_{mntac}^{A}\} \le TAC_y^{3,A} \le \min\{c_{mxtac}^{A}\,;\, TAC_y^{2,A} + c_{mxinc}^{ads,A}\} \tag{A.13}$$

Sardine 3rd TAB:

$$TAB_y^{3,S} = TAB_y^{2,S} + \min\left\{TAB_{ads}^{S}\,;\, \gamma_y\,(TAC_y^{3,A} - TAC_y^{2,A})\right\} \tag{A.14}$$

We also define the following (see Table 1):

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

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

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

<u>Exceptional Circumstances</u>

Sardine directed TAC

Exceptional Circumstances for the sardine directed TAC apply if:

$B^S_{y-1,Nov} \; < \; 250\,000 \text{ tons}$

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

$$TAC^S_y = TAC^{S*}_y \left(\frac{B^S_{y-1,Nov}}{250} \right)^2 \tag{A.15}$$

where TAC^{S*}_y is calculated using equation (A.1).

Initial Anchovy TAC

Exceptional Circumstances for the initial anchovy TAC apply if

$B^A_{y-1,Nov} \; < \; 400\,000 \text{ tons}$

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

$$TAC^{1,A}_y = \begin{cases} 0 & \text{if} \quad \dfrac{B^A_{y-1,Nov}}{400} < 0.25 \\ TAC^{1,A*}_y \left(\dfrac{B^A_{y-1,Nov}}{T^A} - x \right)^2 & \text{if} \quad 0.25 < \dfrac{B^A_{y-1,Nov}}{400} < 1 \end{cases} \tag{A.16}$$

where $TAC^{1,A*}_y$ is calculated using equation (A.3).

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 ($B^A_{y,proj}$) for the forthcoming November survey, and hence have a basis for invoking Exceptional Circumstances, if necessary. Given $TAC^{2,A*}_y$ from equation (A.6), a projected anchovy biomass, $B^A_{y,proj0}$, is calculated as follows:

$$B^A_{y,proj0} = \text{max of} \left\{ 0; \left(N^A_{y,rec} - \frac{TAC^{2,A*}_y}{\overline{w}^A_{0c}} - C^A_{y,1} - C^A_{y,0bs} \right) e^{-0.9/2} \overline{w}^A_1 \right\}. \tag{A. 17}$$

Calculate $B^A_{y,proj}$ as follows:

$$B^A_{y,proj} = \left(\frac{B^A_{y-1,Nov} e^{-0.9/4}}{w^A_{y,1}} - C^A_{y,1} \right) e^{-3\times 0.9/4} \overline{w}^A_2 \quad + \quad B^A_{y,proj0} \tag{A. 18}$$

If $B^A_{y,proj} < 400\,000 \text{ tons}$, then Exceptional Circumstances apply. The recruit survey result in year y (in numbers) that would be sufficient to yield a $B^A_{y,proj}$ value of exactly 400 000 tons is calculated as follows:

$$\theta \; = \; \frac{[400 - (B^A_{y,proj} - B^A_{y,proj0})]\, e^{0.9/2}}{\overline{w}^A_1} \quad + \quad \frac{TAC^{2,A*}_y}{\overline{w}^A_{0c}} - C^A_{y,1} - C^A_{y,0bs} \tag{A. 19}$$

This is back-calculated to November of the previous year in the same way as equation (A.9):

$$N_{y-1,rec0}^{A*} = (\theta\, e^{0.5(1+t_y^A)0.9/12} + C_{y,0bs}^A)\, e^{[5+0.5(1+t_y^A)]0.9/12} \quad \text{(A. 20)}$$

The revised anchovy TAC is calculated by reducing $TAC_y^{2,A*}$ 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:

$$TAC_y^{2,A} = \max \text{ of} \begin{cases} TAC_y^{1,A}; TAC_y^{2,A*}\left(\dfrac{0.7\dfrac{N_{y-1,rec0}^A}{\overline{N}_{y-1,rec0}^A}+0.3\dfrac{B_{y-1,Nov}^A}{\overline{B}_{Nov}^A}}{0.7\dfrac{N_{y-1,rec0}^{A*}}{\overline{N}_{y-1,rec0}^A}+0.3\dfrac{B_{y-1,Nov}^A}{\overline{B}_{Nov}^A}}-0.25\right)^2 & \text{if } 0.25 < \dfrac{0.7\dfrac{N_{y-1,rec0}^A}{\overline{N}_{y-1,rec0}^A}+0.3\dfrac{B_{y-1,Nov}^A}{\overline{B}_{Nov}^A}}{0.7\dfrac{N_{y-1,rec0}^{A*}}{\overline{N}_{y-1,rec0}^A}+0.3\dfrac{B_{y-1,Nov}^A}{\overline{B}_{Nov}^A}} < 1 \\ TAC_y^{1,A}; 0 & \text{if } \dfrac{0.7\dfrac{N_{y-1,rec0}^A}{\overline{N}_{y-1,rec0}^A}+0.3\dfrac{B_{y-1,Nov}^A}{\overline{B}_{Nov}^A}}{0.7\dfrac{N_{y-1,rec0}^{A*}}{\overline{N}_{y-1,rec0}^A}+0.3\dfrac{B_{y-1,Nov}^A}{\overline{B}_{Nov}^A}} < 0.25 \end{cases}$$

(A. 21)

In the above equations we have:

$\overline{w}_1^A$ - historical average weight-at-age 1 in the anchovy November survey, 9.412g.

$\overline{w}_2^A$ - historical average weight-at-age 2 in the anchovy November survey, 14.054g.

$\overline{w}_{0c}^A$ - historical average weight of anchovy fish caught from 1 April to 1 November (assumed to be recruits), 5.649g.

$C_{y,1}^A$ - observed anchovy catch-at-age 1 in year y

$w_{y,1}^A$ - mean weight of fish corresponding to $C_{y,1}^A$

Final Anchovy TAC

The same procedure as for the revised anchovy TAC is followed, except that equation (A.12) is used to calculate $TAC_y^{3,A*}$, which then replaces $TAC_y^{2,A*}$ in equations (A.17), (A.19) and (A.20) above. Furthermore, $TAC_y^{3,A}$ replaces $TAC_y^{2,A}$ and $TAC_y^{2,A}$ replaces $TAC_y^{1,A}$ in equation (A.21) above.

<u>Required Data</u>

The data annually required at the end of a year in order to set the directed sardine and initial anchovy TACs and initial sardine TAB for the following year are as follows:

1) November survey sardine spawner biomass ($B_{y-1,Nov}^S$) in thousands of tons.

2) November survey anchovy spawner biomass ($B_{y-1,Nov}^A$) in thousands of tons.

The data annually required in order to set the revised (normal season) and final (normal plus additional season) anchovy TAC and sardine TAB in June are as follows:

1) Day of commencement of recruit survey (to calculate t_y^A).
2) Anchovy catch from 1 November of previous year until 31 March ($C_{y,1}^A$).
3) Mean weight of fish corresponding to $C_{y,1}^A$.
4) Anchovy catch from 1 April to day before the commencement of the survey ($C_{y,0bs}^A$) in billions.
5) Anchovy recruits in numbers from the May recruit survey ($N_{y,rec}^A$).
6) Ratio of juvenile sardine to anchovy (by mass) as observed during the May survey ($r_{y,sur}$).
7) Ratio of juvenile sardine to anchovy (by mass) as observed in the commercial catches during May ($r_{y,com}$), using only the commercial catches comprising of at least 50% anchovy with sardine bycatch.