Draft Two-Area Harvest Control Rules for OMP-13

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Introduction

Interim OMP-13 v2 (de Moor and Butterworth 2013) allows for the recommendation of a single ≥14cm directed sardine Total Allowable Catch (TAC), regardless of the number of sardine stocks. Candidate Management Procedures that allow for the recommendation of two sardine TACs, a west and south coast TAC, separated by Cape Agulhas, are also being developed. This document details the generalised Harvest Control Rules (HCRs) for Candidate MPs for OMP-13 allowing for one or two-area ≥14cm directed sardine TACs.

Two-area ≥14cm directed sardine TAC

The Appendix details the HCRs for South African sardine and anchovy allowing for the calculation of either one and two-area ≥14cm directed sardine TAC(s). The Appendix text and/or equations that have been added or updated from Interim OMP-13 v2 are highlighted in yellow.

In developing HCRs that calculate two ≥14cm directed sardine TACs, based on observations of sardine November 1+ biomass west and east of Cape Agulhas, the following assumptions have been made:

- In setting the initial <14cm sardine TAB with anchovy, a conservative estimate of the anticipated ratio of juvenile sardine to juvenile anchovy in subsequent catches is used (equation OMP.7). For HCRs that calculate a single ≥14cm directed sardine TAC, this ratio is based on the total observed sardine biomass. For HCRs that calculate two ≥14cm directed sardine TACs, this ratio is still based on the total observed sardine biomass to allow for better comparisons between Candidate MPs. However, given that the sardine TAB with anchovy is mostly taken from sardine west of Cape Agulhas, future Candidate MPs should consider basing this ratio on the observed biomass west of Cape Agulhas only.
- If two area-specific >14cm sardine TACs are allocated, then two area-specific <14cm sardine TABs with ≥14cm directed sardine will also be allocated.
- In simulation testing a two-area ≥14cm directed sardine TAC on a single sardine stock, future November survey observations of sardine 1+ biomass west of Cape Agulhas are generated as a proportion of the total observed 1+ biomass, by drawing proportions from either a) the 1984-1999 observed proportions of 1+ biomass west of Cape Agulhas, or b) the 2000-2011 observed proportions of 1+ biomass west of Cape Agulhas.

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- If sardine Exceptional Circumstances are declared, half the calculated ≥14cm directed sardine TAC is allocated in December, with an increase in the sardine TAC dependent on the observed recruitment from the May recruit survey. This increase is dependent on the observed recruitment up to Cape Infanta, regardless of whether one or two ≥14cm directed sardine TACs are allocated (equation OMP.16).
- The minimum TAC applicable for a single-area ≥14cm directed sardine TAC in the absence of Exceptional Circumstances (90 000t) applies to the sum of the two area-specific ≥14cm directed sardine TACs. The proportion of the minimum TAC allocated west/east of Cape Agulhas will be the same as that allocated prior to the implementation of the constraint (equation OMP.2b).
- The maximum TAC applicable for a single-area ≥14cm directed sardine TAC (500 000t) applies to the sum of the two area-specific ≥14cm directed sardine TACs. The proportion of the maximum TAC allocated west/east of Cape Agulhas will be the same as that allocated prior to the implementation of the constraint (equation OMP.2b).
- If the previous year's sum of the two area-specific ≥14cm directed sardine TACs is below the 2-tier threshold, the two area-specific ≥14cm directed sardine TACs are restricted to decrease at most 20% from the previous year's area-specific TAC.
- If the previous year's sum of the two area-specific ≥14cm directed sardine TACs is above the 2-tier threshold, then the sum of the current year's two area-specific ≥14cm directed sardine TACs is at most 20% below the 2-tier threshold. The proportion of this TAC allocated west/east of Cape Agulhas will be the same as that allocated prior to the implementation of the constraint, unless in the prevailing circumstances that would lead to a seriously inappropriate allocation, in which case the matter would be dealt with under Exceptional Circumstances provisions[1].
- A single threshold, at the same biomass use for the single-area TAC HCR, will be used to determine if Exceptional Circumstances apply for sardine for the area-specific TAC HCR. If the sum of the two survey observations of sardine 1+ biomass west and east of Cape Agulhas is below the threshold, then Exceptional Circumstances are declared. If Exceptional Circumstances are declared then the combined ≥14cm directed sardine TAC is reduced quadratically (in the same manner as for the single-area TAC HCR); this combined TAC is then split by area in the same proportion as existed prior to the application of the Exceptional Circumstances rule (equation OMP.15b).
- Linear smoothing to the total ≥14cm directed sardine TAC(s) is applied when the total survey estimate of 1+ biomass (west and east of Cape Agulhas) is between the Exceptional Circumstances threshold and $\Delta^S = 400\,000\,\mathrm{t}$ above the Exceptional Circumstances threshold.

[1] These are the Exceptional Circumstances provisions as detailed in Appendix 2 of Rademeyer et al. (2008) which would initiate an OMP review.

In Summary

The method presented in this document is a first attempt at a set of HCRs for two-area ≥14cm directed sardine TACs. Some discussion on the method used to constrain the ≥14cm directed sardine TAC in each area is welcomed. The assumptions made in this document may result in discontinuity in the separate west coast and south coast directed sardine TACs when some constraints are applied. These discontinuities will be addressed as best as is possible, once decisions have been reached on how constraints will be applied given two-area directed sardine TAC HCRs. It is expected discussion on area-specific Exceptional Circumstances provisions may be warranted. In addition, the current rule used for linear smoothing is not satisfactory, and may require area-specific Exceptional Circumstances provisions if different control parameters for the directed sardine TAC west and south of Cape Agulhas will be used.

References

de Moor, C.L., and Butterworth, D.S. 2013. Interim OMP-13 v2. DAFF: Branch Fisheries Document FISHERIES/2013/JUL/SWG-PEL/15. 18pp.

Rademeyer, R.A., Butterworth, D.S., and Plaganyi, E.E. 2008. A history of recent bases for management and the development of a species-combined Operational Management Procedure for the South African hake resource. African Journal of Marine Science 30(2):291-310.

Table 1. Definitions of control parameters and constraints used in OMP-02, OMP-04, OMP-08, Interim OMP-13 and Interim OMP-13v2 together with their values. All mass-related quantities are given in thousands of tons. Values for Interim OMP-13v2 which differ from OMP-08 are given in bold face.

	Key Control Parameters	**OMP-02**	**OMP-04**	**OMP-08**	**Interim OMP-13**	**Interim OMP13v2**
β	≥14cm directed sardine catch control parameter	0.1865	0.14657	0.097	**0.090**	**0.090**
α_{ns}	Directed anchovy catch control parameter for normal season	0.16655	0.73752	0.78	**0.321**	**0.871**
α_{ads}	Directed anchovy catch control parameter for additional season	0.99956	1.47504	1.17	**0.4815**	**N/A**
	Fixed TABs	**OMP-02**	**OMP-04**	**OMP-08**	**Interim OMP-13**	**Interim OMP13v2**
TAB^{S}_{big}	Fixed >14cm sardine bycatch	10[2]	10[1]	3.5[1]	**7**	**7**
TAB^{A}	Fixed anchovy bycatch for sardine only right holders	N/A	N/A	N/A	**0.5**	**0.5**
$TAB^{S}_{y,small,rh}$	Fixed ≤14cm sardine bycatch with round herring	N/A	N/A	N/A	**1.0**	**1.0**
	Fixed Control Parameters	**OMP-02**	**OMP-04**	**OMP-08**	**Interim OMP-13**	**Interim OMP13v2**
δ	Scale-down factor applied to initial anchovy TAC	0.85[3]	0.85	0.85	0.85	0.85
p	Weighting given to recruitment survey in anchovy TAC	0.7[4]	0.7	0.7	0.7	0.7
q	Relates to average TAC under OMP-99 if $\alpha_{ns}=1$	300[5]	300	300	300	300
$\overline{B}^{A}_{Nov}$	Historic average 1984 to 1999 index of anchovy abundance from the November spawner biomass surveys		2 149	1 380	1 380	1380
$\overline{N}^{A}_{rec0}$	Average 1985 to 1999 observed anchovy recruitment in May, back-calculated to November of the previous year	N/A	N/A	198 billion	**180 billion**	**217 billion**
ϖ	Estimate of the percentage of ≤14cm sardine bycatch in the >14cm sardine catch	N/A	N/A	N/A	**0.07**	**0.07**
γ_y	Range within which initial estimate of juvenile sardine : anchovy ratio is set, dependent upon observed sardine biomass	0.1	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2
$\gamma_{\max}$	Maximum of the logistic curve for γ_y	N/A	0.1	0.1	0.1	0.1
B_{50}	Biomass of sardine where the logistic curve for γ_y reaches 50%	N/A	2 000	2 000	2 000	2000

[2] TAB (assumed adult) with round herring only, initially set at 10 000t calculated as 12.5% of the predicted average round herring catch of 80 000t; subsequently decreased to 3 500t when considering historic bycatch had not been greater than 3 500t.

[3] 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.

[4] A value of $p = 0.7$ reflects the greater importance of the incoming recruits in the year's catch relative to the previous year's biomass survey.

[5] Leaving $q = 300$ unchanged facilitated easy comparison between the outputs from OMP-02 and subsequent revised OMP candidates

Table 1 (continued)**.**

	Constraints	OMP-02	OMP-04	OMP-08	Interim OMP-13	Interim OMP13v2
B_{95}	Biomass of sardine where the logistic curve for γ_y reaches 95%	N/A	3 178	3 178	3 178	3178
c^S_{mntac}	Minimum ≥14cm directed sardine TAC	90	90	90	90	90
c^A_{mntac}	Minimum normal season anchovy TAC	150	150	120	120	120
c^S_{mxtac}	Maximum ≥14cm directed sardine TAC	250	500	500	500	500
c^A_{mxtac}	Maximum total anchovy TAC	600	600	600	**450**	**450**
c^S_{tier}	Two-tier threshold for ≥14cm directed sardine TAC	N/A	240	255	255	255
c^A_{tier}	Two-tier threshold for normal season anchovy TAC	N/A	330	330	330	330
c^S_{mxdn}	Maximum proportion by which ≥14cm directed sardine TAC can be reduced annually	0.20	0.15	0.20	0.20	0.20
c^A_{mxdn}	Maximum proportion by which normal season anchovy TAC can be reduced annually	0.30	0.25	0.25	0.25	0.25
$c^{ns,A}_{mxinc}$	Maximum increase in normal season anchovy TAC	150	200	150	150	**N/A**
$c^{ads,A}_{mxinc}$	Maximum additional season anchovy TAC	100	150	120	120	**N/A**
TAB^S_{ads}	Maximum sardine bycatch during the additional season	2	2	2	**1.5**[6]	**N/A**
B^S_{ec}	Threshold at which Exceptional Circumstances are invoked for sardine	150	250	300	300	300
B^A_{ec}	Threshold at which Exceptional Circumstances are invoked for anchovy	400	400	400	400	**600**
Δ^S	threshold above B^S_{ec} at which linear smoothing is introduced before sardine exceptional circumstances are declared (to ensure continuity)	N/A	500	500	**400**	**400**
Δ^A	threshold above B^A_{ec} at which linear smoothing is introduced before anchovy exceptional circumstances are declared (to ensure continuity)	N/A	N/A	100	100	100
B_1	threshold above which the anchovy additional sub-season TAC can increase more rapidly	N/A	N/A	1 000	1 000	**N/A**
B_2	threshold above which the anchovy additional sub-season TAC reaches a maximum	N/A	N/A	1 500	1 500	**N/A**
x^S	the proportion of B^S_{ec} below which sardine TAC is zero.	0	0	0.25	0.25	0.25
x^A	the proportion of B^A_{ec} below which anchovy TAC is zero.	0	0.25	0.25	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	**16.48**	**16.48**

[6] Interim OMP-13 assumed the additional season runs from October to December, rather than September to December as assumed for earlier OMPs.

Table 2. The data required as input to the Candidate MPs for OMP-13 formulae to provide the ≥14cm directed sardine TAC(s) and initial anchovy TAC and sardine TAB recommendations for year y in December of year $y-1$, and to set the revised and final anchovy TAC and sardine TAB recommendations in June of year y.

	Input	Definition
December *y*-1	$B^{S}_{area,y-1,N}$	November survey estimate of sardine 1+ biomass in year $y-1$ (in thousands of tons) by area[7]
	$B^{A}_{y-1,N}$	November survey estimate of anchovy 1+ biomass in year $y-1$ (in thousands of tons)
June *y*	$N^{A}_{y,r}$	May survey estimate of anchovy recruitment in year y (in billions)
	$N^{S}_{west,y,r}$ [8]	May survey estimate of sardine recruitment west of Cape Infanta in year y (in billions)
	t^{A}_{y}	Day of commencement of recruitment survey (time in months after 1 May)
	$C^{A}_{y,1}$	Anchovy catch at age 1[9] from 1 November of year $y-1$ to the day before the commencement of the recruitment survey (in billions)
	$C^{A}_{y,0bs}$	Anchovy catch at age 0[9] from 1 November of year $y-1$ to the day before the commencement of the recruitment survey (in billions)
	$r_{y,sur}$	Ratio of juvenile sardine to anchovy (by mass) indicated by the recruitment survey
	$r_{y,com}$	Ratio of juvenile sardine to anchovy (by mass) in the commercial catches during May, using only the commercial catches comprising at least 50% anchovy
	$\overline{w}^{A}_{1}=10.689$	Average historic anchovy weight-at-age 1 in November
	$\overline{w}^{A}_{2}=13.671$	Average historic anchovy weight-at-age 2 in November
	$\overline{w}^{A}_{0c}=4.847$	Average historic anchovy catch weight-at-age 0
	$\overline{w}^{A}_{1c}=10.983$	Average historic anchovy catch weight-at-age 1

[7] Either a single value for the full surveyed area (single-area directed sardine TAC) or two values, separated at Cape Agulhas (two-area directed sardine TACs)

[8] Needed only if sardine Exceptional Circumstances are declared in December of year $y-1$.

[9] Monthly cut-off lengths are used to split the anchovy catch into juveniles and adults. The monthly cut-off lengths for November to March are given in de Moor *et al.* (2012), while the monthly cut-off lengths for April, May and June (if necessary) are dependent on the recruit cut-off length used for the recruit survey in year y.

Appendix: Interim OMP-13v2 Harvest Control Rules

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 ≥14cm directed sardine TAC(s) and initial directed anchovy TAC and TAB for sardine bycatch are based on the results of the November biomass survey. These limits are announced prior to the start of the pelagic fishery at the beginning of each year.

The ≥14cm directed sardine TAC(s) is set at a proportion of the previous year's November 1+ biomass index of abundance, but subject to the constraints of a minimum and a maximum value. If the previous year's TAC(s) is below the 'two-tier' threshold, then the TAC(s) is subject to a maximum percentage drop from the previous year's TAC(s). If it is above this threshold, any reduction in TAC(s) 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 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.

A fixed anchovy TAB, TAB^A, for sardine only right holders has been introduced in OMP-13 (see Table 1).

A fixed >14cm sardine TAB, TAB^S_{big}, consisting of mainly adult sardine bycatch with round herring and to a lesser extent with anchovy has been introduced in OMP-13 (replacing the "adult sardine bycatch with round herring" TAB in OMP-08) (see Table 1).

A new <14cm sardine TAB has been introduced in OMP-13. This consists of a fixed allocation for bycatch with round herring, $TAB^S_{y,small,rh}$, and an allocation for small sardine bycatch in the >14cm directed sardine landings, set proportional to the directed sardine TAC(s).

The final TAB is a ≤14cm sardine TAB with anchovy, and is set proportional to the anchovy TAC.

Single-area TAC:

≥14cm directed sardine TAC: $$TAC_y^S = \beta\, B_{y-1,Nov}^{obs,S} \qquad \text{(OMP.1a)}$$

Subject to:

$$\begin{array}{ll} \max\left\{\left(1-c_{mxdn}^S\right)TAC_{y-1}^S\ ;c_{mntac}^S\right\} \le TAC_y^S \ \le c_{mxtac}^S & \text{if } TAC_{y-1}^S \le c_{tier}^S \\ \max\left\{\left(1-c_{mxdn}^S\right)c_{tier}^S\ ;c_{mntac}^S\right\} \le TAC_y^S \ \le c_{mxtac}^S & \text{if } TAC_{y-1}^S > c_{tier}^S \end{array} \qquad \text{(OMP.2a)}$$

Two-area TACs:

≥14cm directed sardine TAC: $$TAC_{area,y}^S = \beta_{area} B_{area,y-1,Nov}^{obs,S} \qquad \text{(OMP.1b)}$$

Subject to:

$$TAC_{area,y}^S = \frac{TAC_{area,y}^S}{\sum_{area} TAC_{area,y}^S} c_{mntac}^S \qquad \text{if } \sum_{area} TAC_{area,y}^S < c_{mntac}^S$$

$$TAC_{area,y}^S = \frac{TAC_{area,y}^S}{\sum_{area} TAC_{area,y}^S} c_{mxtac}^S \qquad \text{if } \sum_{area} TAC_{area,y}^S > c_{mxtac}^S$$

$$TAC_{area,y}^S \ge \left(1-c_{mxdn}^S\right)TAC_{area,y-1}^S \qquad \text{if } \sum_{area} TAC_{area,y}^S < \left(1-c_{mxdn}^S\right)c_{tier}^S$$

$$TAC_{area,y}^S \ge \frac{TAC_{area,y}^S}{\sum_{area} TAC_{area,y}^S} \times \left(1-c_{mxdn}^S\right)c_{tier}^S \qquad \text{if } \sum_{area} TAC_{area,y}^S \ge \left(1-c_{mxdn}^S\right)c_{tier}^S \qquad \text{(OMP.2b)}$$

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

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

Single-area TAC:

<14cm sardine TAB with directed ≥14cm sardine:

$$TAB_{y,small}^S = \omega TAC_y^S \qquad \text{(OMP.5a)}$$

Two-area TACs:

<14cm sardine TAB with directed ≥14cm sardine:

$$TAB_{area,y,small}^S = \omega TAC_{area,y}^S \qquad \text{(OMP.5b)}$$

Initial <14cm sardine TAB with anchovy: $$TAB_{y,anch}^{1,S} = \gamma_y TAC_y^{1,A} \qquad \text{(OMP.6)}$$

where: $$\gamma_y = 0.1 + \frac{\gamma_{\max}}{1+\exp\left(-\ln(19)\frac{\left(B_{y-1,N}^{S,obs} - B_{50}\right)}{\left(B_{95}-B_{50}\right)}\right)}. \qquad \text{(OMP.7)}$$

Here γ_y increases according to a logistic curve from 10% in years in which the survey estimated total sardine November 1+ biomass, $B_{y-1,N}^{S,obs}$, is poor to average, towards a maximum when sardine biomass is higher (Figure A.1).

To maintain continuity in the directed sardine and initial anchovy TACs as the Exceptional Circumstances thresholds (see below), B_{ec}^{S} and B_{ec}^{A}, are approached from above and below, the following linear smoothing is applied.

Single-area TAC:

If $B_{ec}^{S} \le B_{y-1,N}^{obs,S} \le B_{ec}^{S} + \Delta^{S}$ we have:

$$TAC_y^S = \left(1 - \frac{B_{y-1,N}^{obs,S} - B_{ec}^S}{\Delta^S}\right) \times TAC_y^{S\_EC} + \left(\frac{B_{y-1,N}^{obs,S} - B_{ec}^S}{\Delta^S}\right) \times TAC_y^S \qquad \text{(OMP.8a)}$$

where $TAC_y^{S\_EC}$ is the value output from equation (OMP.15a) when $B_{y-1,N}^{obs,S} = B_{ec}^S$, while TAC_y^S is the value output from equations (OMP 1.a and OMP.2a) when $B_{y-1,N}^{obs,S} = B_{ec}^S + \Delta^S$.

Two-area TACs:

If $B_{ec}^{S} \le \sum_{area} B_{area,y-1,N}^{obs,S} \le B_{ec}^{S} + \Delta^{S}$ we have:

$$TAC_{area,y}^S = \frac{TAC_{area,y}^{S*}}{\sum_{area} TAC_{area,y}^{S*}} \left\{ \left(1 - \frac{\sum_{area} B_{area,y-1,N}^{obs,S} - B_{ec}^S}{\Delta^S}\right) \times \sum_{area} TAC_{area,y}^{S\_EC} + \left(\frac{\sum_{area} B_{area,y-1,N}^{obs,S} - B_{ec}^S}{\Delta^S}\right) \times \sum_{area} TAC_{area,y}^S \right\} \qquad \text{(OMP.8b)}$$

where $TAC_{area,y}^{S*}$ is the output from equation (OMP.2b), $TAC_{area,y}^{S\_EC}$ is the value output from equation (OMP.15b) when $\sum_{area} B_{area,y-1,N}^{obs,S} = B_{ec}^S$, while TAC_y^S is the value output from equation (OMP.1b and OMP.2b) when $\sum_{area} B_{area,y-1,N}^{obs,S} = B_{ec}^S + \Delta^S$.

If $B_{ec}^{A} \le B_{y-1,N}^{obs,A} \le B_{ec}^{A} + \Delta^{A}$ we have:

$$TAC_y^{1,A} = \left(1 - \frac{B_{y-1,N}^{obs,A} - B_{ec}^A}{\Delta^A}\right) \times TAC_y^{1,A\_EC} + \left(\frac{B_{y-1,N}^{obs,A} - B_{ec}^A}{\Delta^A}\right) \times TAC_y^{1,A} \qquad \text{(OMP.9)}$$

where TAC_y^{1,A_EC} is the value output from equation (OMP.17) when $B_{y-1,N}^{obs,A} = B_{ec}^A$, while $TAC_y^{1,A}$ is the value output from equation (OMP.4) when $B_{y-1,N}^{obs,A} = B_{ec}^A + \Delta^A$.

In the above equations the symbols used are as follows. See Table 1 for fixed values:

$B_{y,N}^{obs,S}$ - the observed estimate of sardine abundance from the hydroacoustic biomass survey in November of year y.

β - a control parameter reflecting the proportion of the previous year's November 1+ biomass index of abundance that is used to set the directed sardine TAC, scaled to meet target risk levels for sardine and anchovy.

$B_{y,N}^{obs,A}$ - the observed estimate of anchovy abundance from the hydroacoustic biomass survey in November of year y.

$\overline{B}_{Nov}^{A}$ - the historic average index of anchovy 1+ biomass from the November surveys from 1984 to 1999.

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 1+ biomass survey component in setting the anchovy TAC.

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

c_{mntac}^{S} - the minimum directed TAC to be set for sardine.

c_{mntac}^{A} - the minimum directed TAC to be set for anchovy.

c_{mxtac}^{S} - the maximum directed TAC to be set for sardine.

c_{mxtac}^{A} - the maximum directed TAC to be set for anchovy.

c_{tier}^{S} - the two-tier threshold for directed sardine TAC.

c_{tier}^{A} - the two-tier threshold for directed anchovy TAC.

c_{mxdn}^{S} - the maximum proportional amount by which the directed sardine TAC can be reduced from one year to the next.

c_{mxdn}^{A} - the maximum proportional amount by which the directed anchovy TAC can be reduced from one year to the next.

ϖ - an estimate of the maximum percentage of ≤14cm sardine bycatch in the >14cm sardine catch.

γ_y - a conservative estimate of the anticipated ratio of juvenile sardine to juvenile anchovy in subsequent catches.

$\gamma_{\max}$ - maximum of the logistic curve for γ_y.

B_{50} - biomass where the logistic curve for γ_y reaches 50%.

B_{95} - biomass where the logistic curve for γ_y reaches 95%.

B_{ec}^{S} - the biomass threshold below which Exceptional Circumstances apply for sardine.

B_{ec}^{A} - the biomass threshold below which Exceptional Circumstances apply for anchovy.

Δ^{S} - the threshold above the Exceptional Circumstances threshold, B_{ec}^{S}, below which the sardine TAC is smoothed until B_{ec}^{S} is reached.

Δ^{A} - the threshold above the Exceptional Circumstances threshold, B_{ec}^{A}, below which the anchovy TAC is smoothed until B_{ec}^{A} is reached.

<u>Revised TACs / TAB (June)</u>

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 required to set the anchovy TAC. The additional constraints include ensuring that the revised anchovy TAC is not less than the initial anchovy TAC.

The revised <14cm sardine TAB with anchovy 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:

$$TAC_y^{2,A} = \alpha_{ns}\ q\left(p\frac{N_{y-1,rec0}^{A}}{\bar{N}_{rec0}^{A}} + (1-p)\frac{B_{y-1,N}^{obs,A}}{\bar{B}_{Nov}^{A}}\right) \quad \text{(OMP.10)}$$

Subject to:

$$\begin{array}{ll} \max\left\{TAC_y^{1,A};\left(1-c_{mxdn}^{A}\right)TAC_{y-1}^{2,A}\right\} \le TAC_y^{2,A} \le c_{mxtac}^{A} & TAC_{y-1}^{2,A} \le c_{tier}^{A} \\ \max\left\{TAC_y^{1,A};\left(1-c_{mxdn}^{A}\right)c_{tier}^{A}\right\} \le TAC_y^{2,A} \le c_{mxtac}^{A} & TAC_{y-1}^{2,A} > c_{tier}^{A} \end{array} \quad \text{(OMP.11)}$$

Revised <14cm sardine TAB with anchovy:

$$TAB_{y,anch}^{2,S} = \lambda_y\ TAC_y^{1,A} + r_y\ (TAC_y^{2,A} - TAC_y^{1,A}) \quad \text{(OMP.12)}$$

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

As for the initial TAC, continuity in the revised anchovy TAC as the Exceptional Circumstances thresholds are approached from above and below, is maintained by applying the following linear smoothing.

If $B_{ec}^{A} \le B_{y,proj}^{A} \le B_{ec}^{A} + \Delta^{A}$ we have:

$$TAC_y^{2,A} = \left(1 - \frac{B_{y,proj}^{A} - B_{ec}^{A}}{\Delta^{A}}\right) \times TAC_y^{2,A\_EC} + \left(\frac{B_{y,proj}^{A} - B_{ec}^{A}}{\Delta^{A}}\right) \times TAC_y^{2,A} \quad \text{(OMP.13)}$$

where TAC_y^{2,A_EC} is the value output from equation (OMP.22) when $B_{y,proj}^A = B_{ec}^A$, while $TAC_y^{2,A}$ is the value output from equation (OMP.11) when $B_{y,proj}^A = B_{ec}^A + \Delta^A$, and $B_{y,proj}^A$ is determined by equation (OMP.19).

Note that by construction $TAB_y^{2,S} \geq TAB_y^{1,S}$ as $\lambda_y \geq \gamma_y$ 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, $N_{y,r}^{obs,A}$ [10], back-calculated to 1 November $y-1$ by taking natural and fishing mortality into account (equation (OMP.14) below).

$\overline{N}_{rec0}^A$ - the average 1985 to 1999 observed anchovy recruitment in May, back-calculated (using equation (A.14)) to November of the previous year.

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

- 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 catches[11] 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 1.2 *year*$^{-1}$ for M_j^A. The back-calculated recruitment numbers are calculated as follows:

$$N_{y-1,rec0}^A = (N_{y,r}^{obs,A} e^{t_y^A \times 1.2/12} + C_{y,0bs}^A)\, e^{0.5\times 1.2} \qquad \text{(OMP.14)}$$

In the above equation we have

$C_{y,0bs}^A$ - the observed juvenile 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) after the 1st of May year y.

<u>Exceptional Circumstances</u>

Sardine directed TAC

Exceptional Circumstances for the sardine directed TAC apply if:

[10] 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.).

[11] Only commercial catches comprising at least 50% anchovy with sardine bycatch are considered.

$B^{obs,S}_{y-1,N} < B^S_{ec}$ if a single sardine TAC is allocated, or

$\sum_{area} B^{obs,S}_{area,y-1,N} < B^S_{ec}$ if two area-specific sardine TACs are allocated,

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 A.2):

Single area TAC:

Initial TAC:
$$TAC^S_{y,init} = 0.5 \times \begin{cases} 0 & \text{if } \dfrac{B^{obs,S}_{y-1,N}}{B^S_{ec}} < x^S \\ TAC^{S\_before}_y \left(\dfrac{\dfrac{B^{obs,S}_{y-1,N}}{B^S_{ec}} - x^S}{1 - x^S} \right)^2 & \text{if } x^S < \dfrac{B^{obs,S}_{y-1,N}}{B^S_{ec}} < 1 \end{cases} \quad \text{(OMP.15a)}$$

Revised TAC:
$$TAC^S_y = \begin{cases} TAC^S_{y,init} + 1.2 \times \dfrac{N^{obs,S}_{y,r}}{R_{crit}} TAC^S_{y,init} & \text{if } N^{obs,S}_{y,r} \le R_{crit} \\ TAC^S_{y,init} + 1.2 \times TAC^S_{y,init} & \text{if } N^{obs,S}_{y,r} > R_{crit} \end{cases} \quad \text{(OMP.16a)}$$

where $TAC^{S\_before}_y = \beta\, B^{obs,S}_{y-1,N}$, subject to $c^S_{mntac} \le TAC^{S\_before}_y \le c^S_{mxtac}$. 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 A.2 and Table 1).

Two-area TACs:

Initial TAC:

$$TAC^S_{area,y,init} = \frac{TAC^S_{area,y}}{\sum_{area} TAC^S_{area,y}} \times 0.5 \times \begin{cases} 0 & \text{if } \dfrac{\sum_{area} B^{obs,S}_{area,y-1,N}}{B^S_{ec}} < x^S \\ TAC^{S\_before}_y \left(\dfrac{\dfrac{\sum_{area} B^{obs,S}_{area,y-1,N}}{B^S_{ec}} - x^S}{1 - x^S} \right)^2 & \text{if } x^S < \dfrac{\sum_{area} B^{obs,S}_{area,y-1,N}}{B^S_{ec}} < 1 \end{cases}$$

(OMP.15b)

Revised TAC:
$$TAC^S_{area,y} = \begin{cases} TAC^S_{area,y,init} + 1.2 \times \dfrac{N^{obs,S}_{y,r}}{R_{crit}} TAC^S_{area,y,init} & \text{if } N^{obs,S}_{y,r} \le R_{crit} \\ TAC^S_{area,y,init} + 1.2 \times TAC^S_{area,y,init} & \text{if } N^{obs,S}_{y,r} > R_{crit} \end{cases} \quad \text{(OMP.16b)}$$

where $TAC_y^{S\_before} = \sum_{area} \beta_{area}\ B_{area,y-1,Nov}^{obs,S}$, subject to $c_{mntac}^S \leq TAC_y^{S\_before} \leq c_{mxtac}^S$.

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:

$$TAC_y^{1,A} = \begin{cases} 0 & \text{if} \quad \dfrac{B_{y-1,N}^{obs,A}}{B_{ec}^A} < x^A \\ TAC_y^{1,A\_before}\left(\dfrac{\dfrac{B_{y-1,N}^{obs,A}}{B_{ec}^A} - x^A}{1-x^A}\right)^2 & \text{if} \quad x^A < \dfrac{B_{y-1,N}^{obs,A}}{B_{ec}^A} < 1 \end{cases} \qquad \text{(OMP.17)}$$

where $TAC_y^{1,A\_before} = \alpha_{ns}\delta\, q\left(p + (1-p)\dfrac{B_{y-1,N}^{obs,A}}{\overline{B}_{Nov}^A}\right)$, 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 $TAC_y^{2,A\_before} = \alpha_{ns} q\left(p\dfrac{N_{y-1,rec0}^A}{\overline{N}_{rec0}^A} + (1-p)\dfrac{B_{y-1,N}^{obs,A}}{\overline{B}_{Nov}^A}\right)$, subject to $\max\{TAC_y^{1,A}; c_{mntac}^A\} \leq TAC_y^{2,A\_before} \leq c_{mxtac}^A$, a projected anchovy biomass, $B_{y,proj0}^A$, is calculated as follows:

$$B_{y,proj0}^A = \max \text{ of}\left\{0; \left(N_{y,r}^{obs,A} - \left[\frac{TAC_y^{2,A\_before} + TAB^A - \overline{w}_{1c}^A C_{y,1}^A}{\overline{w}_{0c}^A} - C_{y,0bs}^A\right]\right)e^{-(6-t_y)*1.2/12}\,\overline{w}_1^A\right\}. \qquad \text{(OMP.18)}$$

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

$$B_{y,proj}^A = \left(\frac{B_{y-1,N}^{obs,A}}{\overline{w}_1^A}e^{-5*1.2/12} - C_{y,1}^A\right)e^{-7\times1.2/12}\,\overline{w}_2^A + B_{y,proj0}^A \qquad \text{(OMP.19)}$$

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:

$$\theta = \frac{[B_{ec}^A - (B_{y,proj}^A - B_{y,proj0}^A)]}{\overline{w}_1^A} e^{(6-t_y)*1.2/12} + \frac{TAC_y^{2,A\_before} + TAB^A - \overline{w}_{1c}^A C_{y,1}^A}{\overline{w}_{0c}^A} - C_{y,0bs}^A \qquad \text{(OMP.20)}$$

This is back-calculated to November of the previous year in the same way as equation (A.14) during OMP implementation:

$$N_{y-1,rec0}^{A*} = (\theta\, e^{t_y^A \times 1.2/12} + C_{y,0bs}^A)\, e^{6\times 1.2/12} \qquad \text{(OMP.21)}$$

In the above equations we have:

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

$\overline{w}_a^A$ - average historic anchovy weight-at-age a in November.

$\overline{w}_{ac}^A$ - average historic anchovy catch weight-at-age a.

The revised anchovy TAC is calculated by reducing TAC_y^{2,A_before} by the ratio (squared) of TAC_y^{2,A_before} 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:

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

(OMP.22)

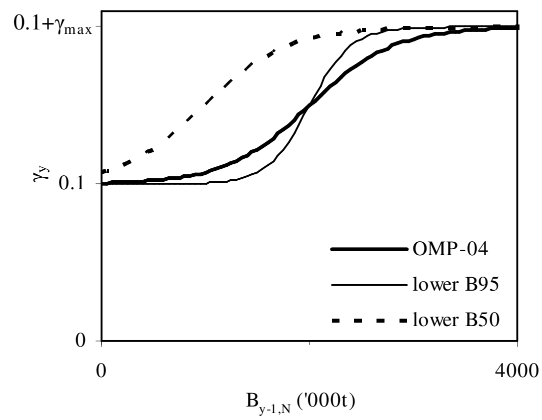

Figure A.1. The logistic curve used to calculate the proportion of initial anchovy TAC that provides the initial sardine TAB (γ_y, Equation OMP.7). Curves for a lower value of B_{95} and centred on a lower value of B_{50} are also shown.

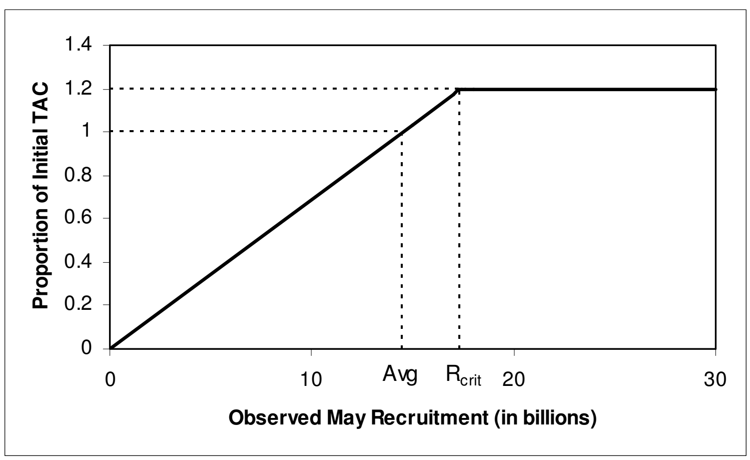

Figure A.2. The proportion of the initial directed sardine TAC that is awarded in the mid-year revision to the directed sardine TAC if Exceptional Circumstances are declared. The historic (May 1984 – 2011) average observed May sardine recruitment is 13.74 billion recruits. For OMP-13, $R_{crit} = 16.48$ billion, such that the mid-year revision is the same as the initial TAC when observed recruitment from the May survey is average.