OMP-14: Alternative initial directed sardine TAC Rules

C.L. de Moor*

Correspondence email: *carryn.demoor@uct.ac.za*

Background

The latest Candidate Management Procedure (CMP) proposed to be used as the next Operational Management Procedure (OMP) for the South African sardine and anchovy fishery, OMP-14, is detailed in the Appendix. The Small Pelagic Scientific Working Group has previously agreed the form of the rule governing the increase in the directed sardine TAC in cases where the November survey estimate of 1+ biomass is between 300 and 600 000t, and only a portion of the original TAC is recommended at the start of the year. The OMP Task Team agreed in September 2014 that the increase would continue to be dependent on the historical observed 1985-2011 average of 13.74 billion, with a critical value of $R_{crit} = 1.2 \times Avg_{rec} = 16.48$ billion.

This document shows the results of assuming different alternatives to the rule governing the portion of the directed sardine TAC recommended at the start of the year in cases where the November survey estimate of 1+ biomass is between 300 and 600 000t. In addition, the maximum possible increase is now smoothed from 110% of the original TAC at 300 000t, to 100% of the original TAC at 600 000t.

All results in this document are based on a single sardine stock operating model.

Alternative Rules for Initial Sardine TAC

OMP-14 will allow for a conservative initial directed sardine TAC for the range of November survey estimates of sardine biomass between 300 000t (below which Exceptional Circumstances would be declared) and 600 000t, as agreed for Interim OMP-13v3 (de Moor and Butterworth 2013, Figure 1):

CMP: The initial directed sardine TAC increases **linearly** from 50% of the TAC calculated from the Harvest Control Rule (HCR), $TAC^{\#}$, at a survey estimate of 300 000t, to 100% of $TAC^{\#}$ at a survey estimate of 600 000t (equation OMP.10). This results in an initial directed sardine TAC of **~67% of $TAC^{\#}$ at a survey estimate of 400 000t**.

Alt 1: The initial directed sardine TAC increases **non-linearly** from 50% of the $TAC^{\#}$ at a survey estimate of 300 000t, to 100% of $TAC^{\#}$ at a survey estimate of 600 000t, with an initial directed sardine TAC of **~78% of $TAC^{\#}$ at a survey estimate of 400 000t**.

Alt 2: The initial directed sardine TAC increases **non-linearly** from 50% of the $TAC^{\#}$ at a survey estimate of 300 000t, to 100% of $TAC^{\#}$ at a survey estimate of 600 000t, with an initial directed sardine TAC **of ~89% of $TAC^{\#}$ at a survey estimate of 400 000t**.

The general form of equation (OMP.10) thus becomes:

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

If $B_{ec}^{S} \leq B_{y-1,N}^{S} < 2 \times B_{ec}^{S}$,

$$TAC_{y,init}^{S} = \frac{TAC_{y}^{S}}{2} + \frac{TAC_{y}^{S}}{2} \times \left(\frac{B_{y-1,N}^{obs,S} - B_{ec}^{S}}{B_{ec}^{S}} \right)^{p} \tag{1}$$

With $p = 1$ for CMP, $p = 0.535$ for Alt 1, and $p = 0.229$ for Alt 2.

The rule governing the mid-season increase for the CMP has been updated from previous documents such that the maximum possible final TAC decreases from 110% of the original TAC at $B_{y-1,N}^{obs,S} = B_{ec}^{S} = 300$ thousand tons, to 100% of the original TAC at $B_{y-1,N}^{obs,S} = 2B_{ec}^{S} = 600$ thousand tons. This ensures continuity as the survey observation approaches 600 000t. Given the smaller "sacrifice" of initial TAC under the two alternatives, the "bonus" of above 100% of the original TAC decreases quicker (Figure 2).

The general form of the final TAC is still the same as (OMP.11):

$$TAC_{final,y}^{S} = TAC_{y,init}^{S} + \frac{N_{y,r}^{obs,S}}{Avg_{rec}} \times \left(TAC_{y}^{S} - TAC_{y,init}^{S} \right) \tag{2}$$

However, the maximum is now given by:

Subject to:

$$TAC_{final,y}^{S} \leq \left(1.1 + \frac{0.1}{1 - 2^{q}} \left\{ \left(\frac{B_{y-1,N}^{obs,S}}{B_{ec}^{S}} \right)^{q} - 1 \right\} \right) \times TAC_{y}^{S} \tag{3}$$

With $q = 1$ for CMP, $q = -1.66099$ for Alt 1, and $q = -4.82301$ for Alt 2.

Results

Figure 3 shows the trade-off curves for the CMP and the two alternative sardine rules, with $risk^{A} < 0.25$ and $risk^{S} < 0.21$. Table 1 shows the key performance statistics for the CMP and the two alternative sardine rules for the corner points of these trade-off curves, while Table 2 shows the same statistics, but keeping the control parameter β unchanged from Interim OMP-13v2, at 0.09, and adjusting the control parameter α_{ns} accordingly.

By design, the risk statistics and depletion ratios are similar for all the corner points (Table 1). The small decrease in β corresponds with a slight decrease in projected average directed sardine catch (Table 1), while the increase in the initial directed sardine TAC corresponds with a decrease in the average proportional annual change in directed sardine catch (Tables 1 and 2).

The risk to the anchovy resource decreases as a higher β (and thus lower α_{ns} due to the trade-off with sardine bycatch from anchovy directed fishing) is selected (Table 2). The lower α_{ns} values result in a lower median and three year average projected anchovy catch. There is a smaller difference in the twenty year average projected anchovy catch due to the influence of the maximum anchovy TAC constraint and the relatively good status of the projected resource.

Figure 4 shows the lowest percentiles of "worm plots" where the trajectories of simulated future sardine 1+ biomass are shown under the candidate MP and two alternative sardine rules rules, for the same set of random numbers. The trajectories are sorted according to the lowest simulated value under the CMP projection. Figure 5 shows the same percentiles, but for projections excluding any variability about the stock-recruit relationship and excluding all error except the multiplicative bias in the survey estimates of 1+ biomass and May recruitment[1]. Excluding this variability results in less pessimistic projections and thus only the medians of the lower 1st, 2nd and 3rd%iles are shown as all other percentiles are above the 600 000t range.

References

de Moor, C.L. and Butterworth, D.S. 2013. Interim OMP-13v3. Department of Agriculture, Forestry and Fisheries Document FISHERIES/2013/DEC/SWG-PEL/43. 6pp.

de Moor, C.L., Coetzee, J., Durholtz, D., Merkle, D., van der Westhuizen, J.J. and Butterworth, D.S. 2012. A record of the generation of data used in the 2012 sardine and anchovy assessments. DAFF Branch Fisheries document: FISHERIES/2012/AUG/SWG-PEL/41. 29pp.

[1] All other forms of variability and error in the simulated projections remain.

Table 1. Key summary statistics for the sardine and anchovy resources under a no catch scenario, the CMP and two alternative rules for the initial directed sardine TAC when the survey estimate of biomass is between 300 and 600 000t. The control parameters used correspond to the corner point of the trade-off curves (Figure 2).

- 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, $risk^{A}$;
- the ratio of the lower percentiles of the predicted distribution of sardine/anchovy 1+ biomass in the final projection year under the MP to that under a no catch scenario;
- the probability of breaching the sardine/anchovy risk threshold **in any one year, averaged over years,** during the projection period ($risk^{*S/A}$);
- average minimum biomass over the projection period ($B_{\min}^{S/A}$) as a proportion of carrying capacity ($K^{S/A}$) and as a proportion of the risk threshold ($Risk^{S/A}$);
- average biomass at the end of the projection period ($B_{2032}^{S/A}$) 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 ($B_{2011}^{S/A}$);
- average (median in brackets) directed catch (in thousands of tons), $\overline{C}^{S}$ / $\overline{C}^{A}$, and average anchovy catch during the additional season, $\overline{C}_{ad}^{A}$;
- average sardine bycatch comprising juvenile sardine bycatch with anchovy, round herring and large sardine (in thousands of tons), $\overline{C}_{by}^{S}$;
- average proportional annual change in directed catch, AAV^{S} / AAV^{A} .
- proportion of times the directed TAC decreases below the minimum TAC (i.e., Exceptional Circumstances are declared), $p\left(TAC_{y}^{A/S} < c_{mntac}^{A/S}\right)$;
- average number of years for which Exceptional Circumstances, if declared, are declared consecutively, $EC_{ton\ \sec}^{A/S}$;
- proportion of times the anchovy normal season fishery is closed due to the sardine TAB limit[2], $p(Close)$;

---

[2] This is the proportion of times the revised normal season sardine TAB with anchovy is reached and excludes any times the initial normal season sardine TAB with anchovy may be reached.

- average normal season anchovy catch lost in each of those years in which the fishery was closed, $\overline{C}^{A}_{lost}$; and
- average normal season anchovy TAC in years in which the fishery was closed $\overline{TAC}^{A}_{close}$.

		No Catch	CMP	Alt 1	Alt 2
Control parameters	β	-	0.087	0.086	0.084
	α_{ns}	-	0.898	0.895	0.913
Risk statistics	$risk^{S}$	0.047	0.209	0.209	0.209
	$risk^{A}$	0.008	0.239	0.239	0.244
	$risk^{*S}$	0.008	0.066	0.067	0.067
	$risk^{*A}$	0.002	0.041	0.041	0.043
Anchovy depletion ratios	10%ile	1.00	0.14	0.14	0.14
	20%ile	1.00	0.17	0.17	0.17
	30%ile	1.00	0.20	0.20	0.20
	40%ile	1.00	0.24	0.24	0.24
	50%ile	1.00	0.28	0.28	0.27
Anchovy biomass statistics	$\overline{B^{A}_{\min}/K^{A}}$	0.26	0.10	0.10	0.10
	$\overline{B^{A}_{\min}/Risk^{A}}$	9.21	3.60	3.60	3.55
	$\overline{B^{A}_{2032}/K^{A}}$	1.20	0.56	0.56	0.55
	$\overline{B^{A}_{2032}/Risk^{A}}$	49.27	22.59	22.63	22.42
	$\overline{B^{A}_{2032}/B^{A}_{2011}}$	4.55	1.79	1.80	1.78
Anchovy catch statistics	$\overline{C}^{A}$ ('13-'32)	0	290 (322)	290 (322)	290 (324)
	$\overline{C}^{A}$ ('13-'15)	0	342 (377)	341 (376)	343 (381)
	AAV^{A} ('13-'32)		0.21	0.21	0.21
	AAV^{A} ('13-'15)		0.13	0.13	0.13
Sardine depletion ratios	10%ile	1.00	0.59	0.59	0.59
	20%ile	1.00	0.68	0.68	0.69
	30%ile	1.00	0.73	0.73	0.72
	40%ile	1.00	0.76	0.76	0.76
	50%ile	1.00	0.78	0.78	0.78
Sardine biomass statistics	$\overline{B^{S}_{\min}/K^{S}}$	0.50	0.39	0.39	0.39
	$\overline{B^{S}_{\min}/Risk^{S}}$	1.94	1.51	1.51	1.51
	$\overline{B^{S}_{2032}/K^{S}}$	0.99	0.77	0.77	0.77
	$\overline{B^{S}_{2032}/Risk^{S}}$	4.13	3.15	3.16	3.16
	$\overline{B^{S}_{2032}/B^{S}_{2011}}$	2.08	1.57	1.57	1.57
Sardine catch statistics	$\overline{C}^{S}$ ('13-'32)	0	153 (129)	152 (128)	150 (125)
	$\overline{C}^{S}_{by}$	0	33	33	33
	$\overline{C}^{S}$ ('13-'15)	0	121 (96)	120 (95)	119 (93)
	AAV^{S} ('13-'32)		0.39	0.36	0.33
	AAV^{S} ('13-'15)		0.62	0.62	0.61

Table 1 (continued).

Anchovy Exceptional Circumstances	$p\left(TAC_y^A < c_{mntac}^A\right)$		0.27	0.27	0.27
	$EC_{ton\sec}^A$		3.47	3.46	3.47
Anchovy Fishery Closure	$p(Close)$		0.23	0.23	0.23
	$\bar{C}_{lost}^A$		36	36	36
	$\overline{TAC}_{close}^A$		169	169	168
Sardine Exceptional Circumstances	$p\left(TAC_y^S < c_{mntac}^S\right)$		0.05	0.05	0.06
	$EC_{ton\sec}^S$		1.32	1.33	1.34

Table 2. As for Table 1, except the control parameters were chosen from the trade-off curves (Figure 3) such that the directed sardine control parameter remains unchanged from Interim OMP-13v2.

		No Catch	CMP	Alt 1	Alt 2
Control parameters	β	-	0.090	0.090	0.090
	α_{ns}	-	0.754	0.705	0.664
Risk statistics	$risk^S$	0.047	0.209	0.209	0.209
	$risk^A$	0.008	0.175	0.163	0.149
	$risk^{*S}$	0.008	0.065	0.066	0.067
	$risk^{*A}$	0.002	0.031	0.029	0.026
Anchovy depletion ratios	10%ile	1.00	0.17	0.18	0.19
	20%ile	1.00	0.21	0.23	0.25
	30%ile	1.00	0.25	0.28	0.30
	40%ile	1.00	0.31	0.33	0.35
	50%ile	1.00	0.34	0.36	0.38
Anchovy biomass statistics	$\overline{B_{\min}^A / K^A}$	0.26	0.11	0.11	0.12
	$\overline{B_{\min}^A / Risk^A}$	9.21	4.04	4.21	4.35
	$\overline{B_{2032}^A / K^A}$	1.20	0.60	0.62	0.63
	$\overline{B_{2032}^A / Risk^A}$	49.27	24.47	25.13	26.73
	$\overline{B_{2032}^A / B_{2011}^A}$	4.55	1.94	2.00	2.05
Anchovy catch statistics	$\bar{C}^A$ ('13-'32)	0	287 (301)	285 (290)	283 (282)
	$\bar{C}^A$ ('13-'15)	0	324 (328)	318 (309)	312 (293)
	AAV^A ('13-'32)		0.23	0.24	0.24
	AAV^A ('13-'15)		0.13	0.13	0.13
Sardine depletion ratios	10%ile	1.00	0.58	0.57	0.56
	20%ile	1.00	0.68	0.68	0.68
	30%ile	1.00	0.72	0.72	0.72
	40%ile	1.00	0.75	0.76	0.75
	50%ile	1.00	0.78	0.78	0.78

Table 2 (continued).

Sardine biomass statistics	$\overline{B^S_{\min}/K^S}$	0.50	0.39	0.39	0.39
	$\overline{B^S_{\min}/Risk^S}$	1.94	1.51	1.51	1.51
	$\overline{B^S_{2032}/K^S}$	0.99	0.76	0.76	0.76
	$\overline{B^S_{2032}/Risk^S}$	4.13	3.15	3.14	3.14
	$\overline{B^S_{2032}/B^S_{2011}}$	2.08	1.56	1.56	1.56
Sardine catch statistics	$\overline{C}^S$ ('13-'32)	0	156 (131)	157 (131)	157 (131)
	$\overline{C}^S_{by}$	0	31	30	30
	$\overline{C}^S$ ('13-'15)	0	124 (98)	124 (98)	124 (98)
	AAV^S ('13-'32)		0.40	0.39	0.37
	AAV^S ('13-'15)		0.62	0.62	0.62
Anchovy Exceptional Circumstances	$p\left(TAC^A_y < c^A_{mntac}\right)$		0.23	0.21	0.20
	$EC^A_{ton\sec}$		3.25	3.17	3.12
Anchovy Fishery Closure	$p\left(Close\right)$		0.21	0.21	0.20
	$\overline{C}^A_{lost}$		37	36	36
	$\overline{TAC}^A_{close}$		175	174	175
Sardine Exceptional Circumstances	$p\left(TAC^S_y < c^S_{mntac}\right)$		0.05	0.05	0.06
	$EC^S_{ton\sec}$		1.32	1.32	1.34

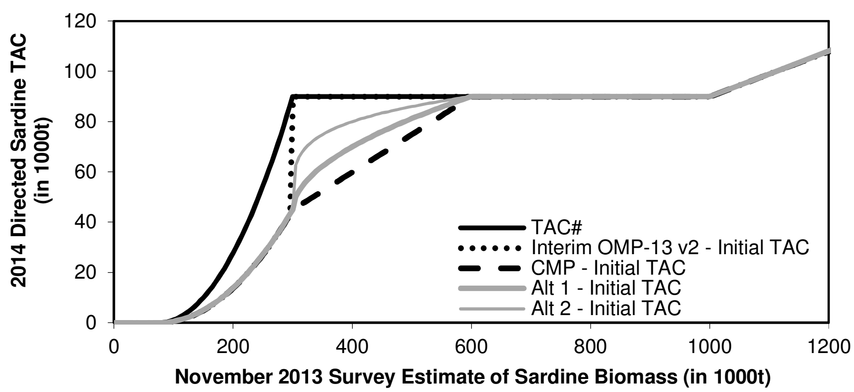

Figure 1. The "original" Harvest Control Rule for directed ≥14cm sardine TAC in 2014, TAC[#], and the initial directed sardine TACs under the candidate MP and two alternative rules considered here.

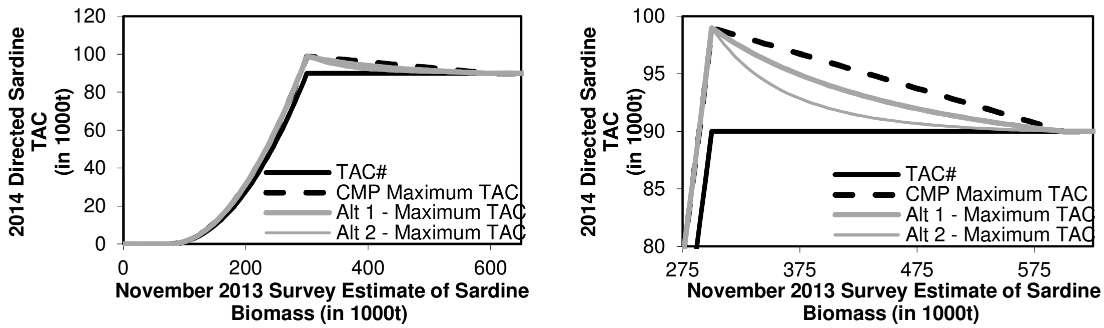

Figure 2. The "original" Harvest Control Rule for directed ≥14cm sardine TAC in 2014, TAC[#], and the maximum possible TACs under the candidate MP and two alternative rules considered here. The original TAC is obtained when the May survey estimate of recruitment equals Avg_{rec} for all alternatives. The maximum possible TAC is obtained when the May survey estimate of recruitment equals or exceeds $R_{crit} = 1.2Avg_{rec}$ for $B_{y-1,N}^{obs,S} \leq B_{ec}^{S}$ and for the CMP for $B_{y-1,N}^{obs,S} < 2B_{ec}^{S}$. The maximum possible TAC is obtained only at a higher recruitment for the two alternative rules considered here. The right hand plot is a repeat of the left hand plot, but over a smaller range.

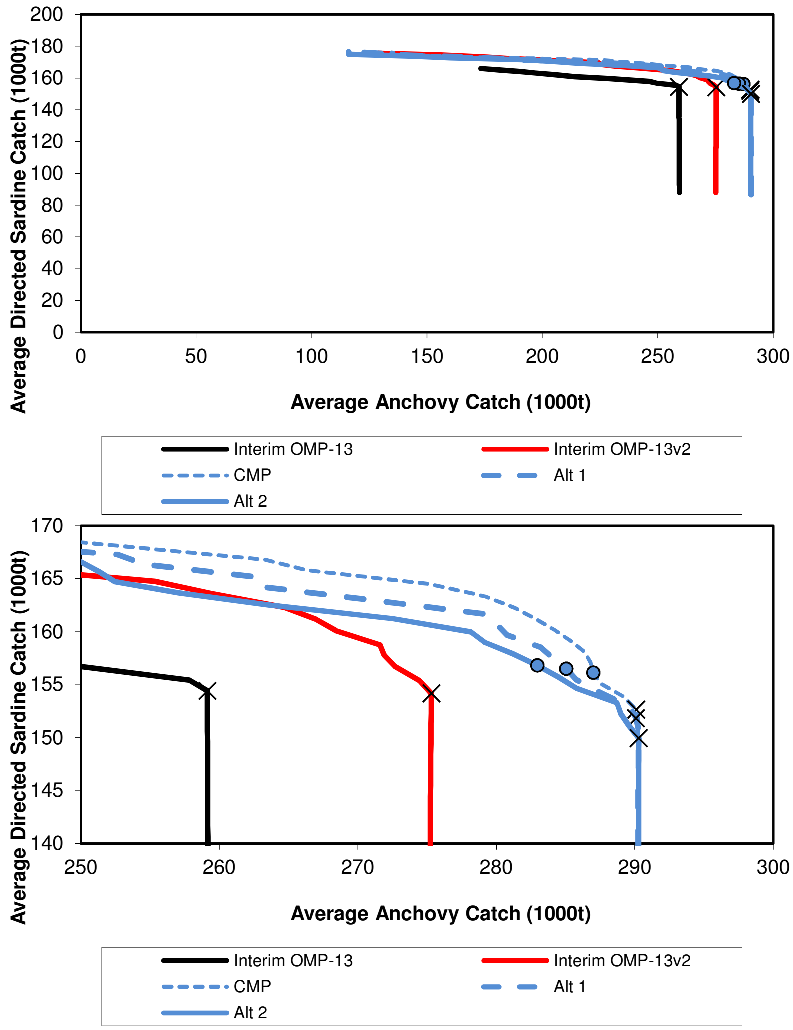

Figure 3. Trade-off curves for Interim OMP-13 ($risk_S < 0.21$, $risk_A < 0.20$), Interim OMP-13v2 ($risk_s < 0.21$, $risk_A < 0.25$) and the candidate MP and two alternative directed sardine TAC rules considered here ($risk_s < 0.21$, $risk_A < 0.25$). The lower figure covers a smaller range on both axes to allow easier comparison. The marked crosses on the curves are those corresponding to the corner point and the circles correspond to $\beta = 0.09$.

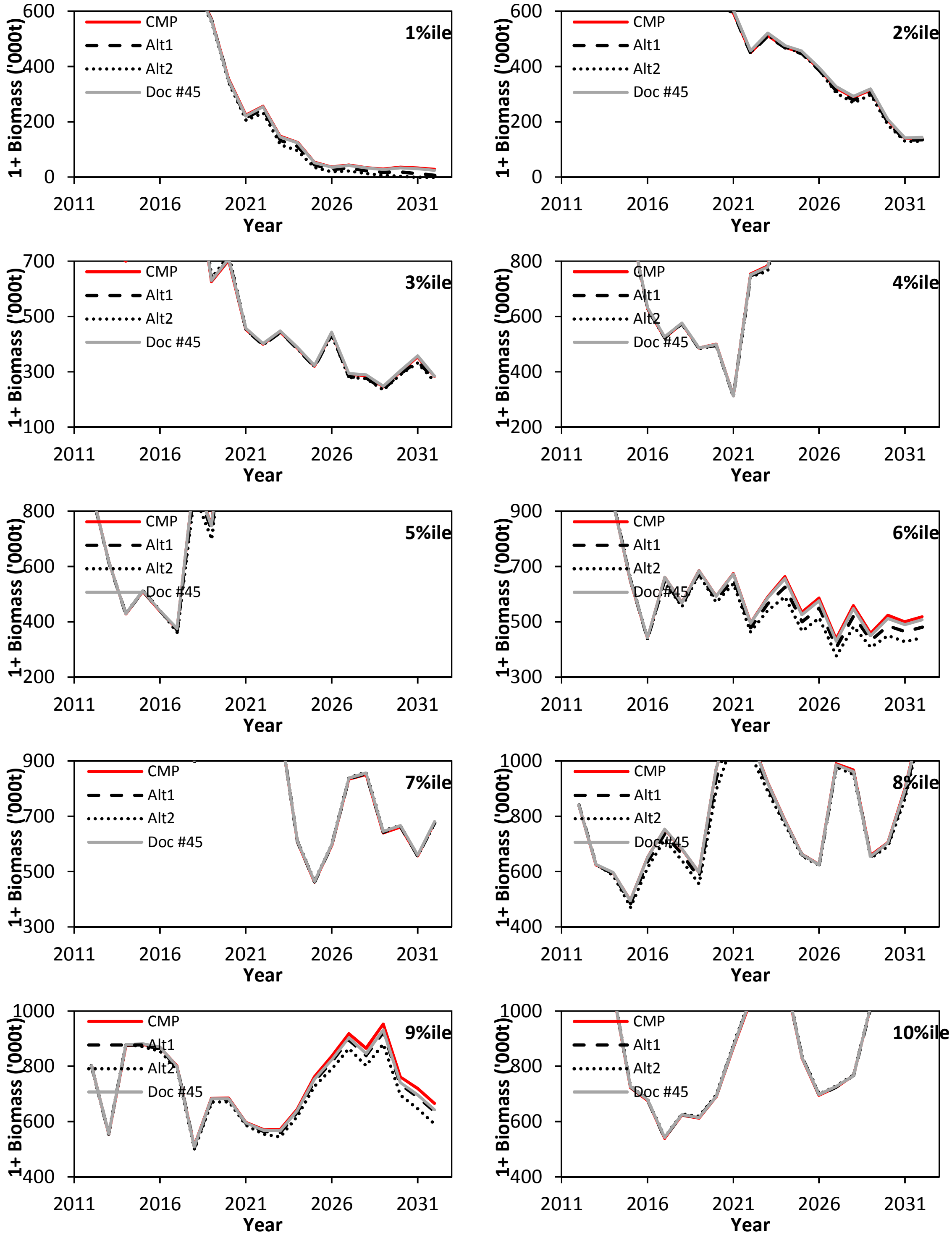

Figure 4. Trajectories of the 10 projections corresponding to the 1-10%iles of simulations which project the lowest future sardine biomass under the candidate MP ($\beta = 0.087$, $\alpha_{ns} = 0.898$), together with the corresponding simulations (with identical random numbers) for the two alternative directed sardine TAC rules ($\beta = 0.086$, $\alpha_{ns} = 0.895$ for Alt1 and $\beta = 0.084$, $\alpha_{ns} = 0.913$ for Alt2) and the CMP from de Moor (2014) ($\beta = 0.085$, $\alpha_{ns} = 0.911$). Note that although the vertical scale of all the plots is the same, the range differs.

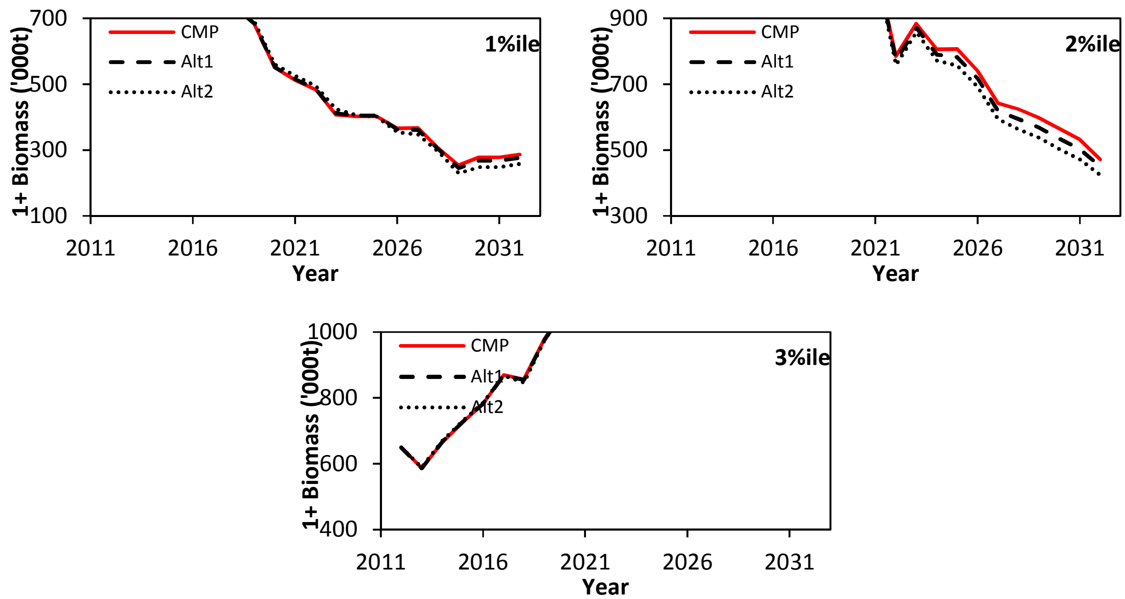

Figure 5. Trajectories of the projections corresponding to the 1st %ile, 2nd %ile and 3rd %ile of simulations which project the lowest future sardine biomass under the candidate MP ($\beta = 0.087$, $\alpha_{ns} = 0.898$), together with the corresponding simulations (with identical random numbers) for the two alternative directed sardine TAC rules ($\beta = 0.086$, $\alpha_{ns} = 0.895$ for Alt1 and $\beta = 0.084$, $\alpha_{ns} = 0.913$ for Alt2). These projections exclude any variability about the stock-recruit relationship and exclude all error except the multiplicative bias in the survey estimates of abundance. Note that although the vertical scale of all the plots is the same, the range differs.

Appendix: Candidate OMP-14 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 the November survey estimates of sardine 1+ biomass are below 600 000t).

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 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 1+ 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 in TAC is limited only by a lower bound of the corresponding threshold less the maximum percentage drop. If the previous year's November 1+ biomass index of abundance is below a "buffer" threshold, only a portion of the TAC is given as an initial TAC.

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 A.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 A.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.

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

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

Subject to:

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

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

Subject to:

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

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

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

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

where:

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

Here γ_y increases according to a logistic curve from 10% in years in which the survey estimated 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.

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

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

where $TAC_y^{S\_EC}$ is the value output from equation (OMP.18) when $B_{y-1,N}^{obs,S} = B_{ec}^S$, while TAC_y^S is the value output from equation (OMP.2) when $B_{y-1,N}^{obs,S} = B_{ec}^S + \Delta^S$.

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

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

where TAC_y^{1,A_EC} is the value output from equation (OMP.19) when $B_{y-1,N}^{obs,A} = B_{ec}^A$, while $TAC_y^{1,A}$ is the value output from equation (OMP.4) when $B_{y-1,N}^{obs,A} = B_{ec}^A + \Delta^A$.

If $B_{ec}^S \le B_{y-1,N}^S < 2\times B_{ec}^S$, only a portion of the TAC calculated above is given at the start of the year:

$$TAC_{y,init}^S = \frac{TAC_y^S}{2B_{ec}^S}\times B_{y-1,N}^{obs,S} \qquad \text{(OMP.10)}$$

Where TAC_y^S is the value output from equations (OMP.2) and (OMP.8).

In the above equations the symbols used are as follows. See Table A.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^A_{mxdn} - 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^S_{ec} - the biomass threshold below which Exceptional Circumstances apply for sardine.

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

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

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

Revised TACs / TAB (June)

If only a portion of the directed sardine TAC was given as an initial TAC, the midyear increase is dependent on the survey estimate of recruitment, compared to a historical average.

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 sardine TAC:

If $B^S_{ec} \le B^S_{y-1,N} < 2\times B^S_{ec}$:

$$TAC^S_{final,y} = TAC^S_{y,init} + \frac{N^{obs,S}_{y,r}}{Avg_{rec}} \times \left(TAC^S_y - TAC^S_{y,init}\right) \qquad \text{(OMP.11)}$$

Subject to: $$TAC^S_{final,y} \le \left(1.2 - 0.1\frac{B^{obs,S}_{y-1,N}}{B^S_{ec}}\right) \times TAC^S_y$$

Revised anchovy TAC: $TAC_y^{2,A} = \alpha_{ns}\ q\left(p\dfrac{N_{y-1,rec0}^{A}}{\overline{N}_{rec0}^{A}} + (1-p)\dfrac{B_{y-1,N}^{obs,A}}{\overline{B}_{Nov}^{A}} \right)$ (OMP.12)

Subject to:

$$\begin{aligned} \max\{TAC_y^{1,A}; (1-c_{mxdn}^{A})TAC_{y-1}^{2,A}\} \le TAC_y^{2,A} \le c_{mxtac}^{A} \quad & TAC_{y-1}^{2,A} \le c_{tier}^{A} \\ \max\{TAC_y^{1,A}; (1-c_{mxdn}^{A})c_{tier}^{A}\} \le TAC_y^{2,A} \le c_{mxtac}^{A} \quad & TAC_{y-1}^{2,A} > c_{tier}^{A} \end{aligned} \quad \text{(OMP.13)}$$

Revised <14cm sardine TAB with anchovy:

$$TAB_{y,anch}^{2,S} = \lambda_y\ TAC_y^{1,A} + r_y\ (TAC_y^{2,A} - TAC_y^{1,A}) \quad \text{(OMP.14)}$$

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:

$$TAC_y^{2,A} = \left(1 - \frac{B_{y,proj}^{A} - B_{ec}^{A}}{\Delta^{A}}\right) \times TAC_y^{2,A\_EC} + \left(\frac{B_{y,proj}^{A} - B_{ec}^{A}}{\Delta^{A}}\right) \times TAC_y^{2,A} \quad \text{(OMP.15)}$$

where TAC_y^{2,A_EC} is the value output from equation (OMP.24) when $B_{y,proj}^{A} = B_{ec}^{A}$, while $TAC_y^{2,A}$ is the value output from equation (OMP.13) when $B_{y,proj}^{A} = B_{ec}^{A} + \Delta^{A}$, and $B_{y,proj}^{A}$ is determined by equation (OMP.21).

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

$N_{y,r}^{obs.i}$ - the observed estimate of recruitment of sardine ($i = S$) or anchovy ($i = A$) from the hydroacoustic recruit survey in May of year y.

Avg_{rec} - the level of sardine recruitment required in order to achieve the original HCR calculated sardine TAC, such that the maximum possible TAC is achieved at $R_{crit} = 1.2 Avg_{rec}$ for this Candidate MP.

$N_{y-1,rec0}^{A}$ - the simulated estimate of anchovy recruitment from the recruitment survey in year y, $N_{y,r}^{obs,A}$ [3], back-calculated to 1 November $y-1$ by taking natural and fishing mortality into account (equation (OMP.16) 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.

[3] 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.).

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

- 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[4] during May.

The anchovy TAC equations require that $N^{obs,A}_{y,r}$, 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^A_j. The back-calculated recruitment numbers are calculated as follows:

$$N^A_{y-1,rec0} = (N^{obs,A}_{y,r} e^{t^A_y \times 1.2/12} + C^A_{y,0bs})\, e^{0.5\times 1.2} \qquad \text{(OMP.16)}$$

In the above equation we have

$C^A_{y,0bs}$ - 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^A_y - the timing of the anchovy recruit survey in year y (number of months) after the 1st of May year y.

Exceptional Circumstances

Sardine directed TAC

Exceptional Circumstances for the sardine directed TAC apply if:

$B^{obs,S}_{y-1,N} < B^S_{ec}$

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):

Initial TAC:
$$TAC^S_{y,init} = 0.5\times\begin{cases} 0 & \text{if } \dfrac{B^{obs,S}_{y-1,N}}{B^S_{ec}} < x^S \\ TAC^{S\_before}_y \left(\dfrac{\dfrac{B^{obs,S}_{y-1,N}}{B^S_{ec}} - x^S}{1-x^S}\right)^2 & \text{if } x^S < \dfrac{B^{obs,S}_{y-1,N}}{B^S_{ec}} < 1 \end{cases} \qquad \text{(OMP.17)}$$

Revised TAC:
$$TAC^S_y = \begin{cases} TAC^S_{y,init} + 1.2\times\dfrac{N^{obs,S}_{y,r}}{R_{crit}} TAC^S_{y,init} & \text{if } N^{obs,S}_{y,r} \le R_{crit} \\ TAC^S_{y,init} + 1.2\times TAC^S_{y,init} & \text{if } N^{obs,S}_{y,r} > R_{crit} \end{cases} \qquad \text{(OMP.18)}$$

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).

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

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:

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

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 $\max\left\{TAC_y^{1,A}; c_{mntac}^{A}\right\} \leq TAC_y^{2,A\_before} \leq c_{mxtac}^{A}$, a projected anchovy biomass, $B_{y,proj0}^{A}$, is calculated as follows:

$$B_{y,proj0}^{A} = \max \text{ of}\left\{0; \left(N_{y,r}^{obs,A} - \left[\frac{TAC_y^{2,A\_before} + TAB^A - \overline{w}_{1c}^{A}C_{y,1}^{A}}{\overline{w}_{0c}^{A}} - C_{y,0bs}^{A}\right]\right)e^{-(6-t_y)*1.2/12}\,\overline{w}_1^{A}\right\}. \qquad \text{(OMP.20)}$$

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

$$B_{y,proj}^{A} = \left(\frac{B_{y-1,N}^{obs,A}}{\overline{w}_1^{A}}e^{-5*1.2/12} - C_{y,1}^{A}\right)e^{-7\times1.2/12}\,\overline{w}_2^{A} \quad + \quad B_{y,proj0}^{A} \qquad \text{(OMP.21)}$$

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:

$$\theta = \frac{[B_{ec}^{A} - (B_{y,proj}^{A} - B_{y,proj0}^{A})]}{\overline{w}_1^{A}}e^{(6-t_y)*1.2/12} \quad + \quad \frac{TAC_y^{2,A\_before} + TAB^A - \overline{w}_{1c}^{A}C_{y,1}^{A}}{\overline{w}_{0c}^{A}} - C_{y,0bs}^{A} \qquad \text{(OMP.22)}$$

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

$$N^{A*}_{y-1,rec0} = (\theta\, e^{t^A_y \times 1.2/12} + C^A_{y,0bs})\, e^{6\times 1.2/12} \qquad \text{(OMP.23)}$$

In the above equations we have:

$C^A_{y,1}$ - 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.

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

The revised anchovy TAC is calculated by reducing TAC^{2,A_before}_y by the ratio (squared) of TAC^{2,A_before}_y calculated with the annual recruitment for year y to $TAC^{2,A}_y$ 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:

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

(OMP.24)

Table A.1. Definitions of control parameters and constraints used in OMP-02, OMP-04, OMP-08, Interim OMP-13v2 and the Candidate OMP-14[5], together with their values. All mass-related quantities are given in thousands of tons. Values for Interim OMP-13v2 and CMP which differ from OMP-08 are given in bold face.

	Key Control Parameters	**OMP-02**	**OMP-04**	**OMP-08**	**Int OMP-13v2**	**Candidate OMP-14**
β	Directed sardine catch control parameter	0.1865	0.14657	0.097	**0.090**	**0.087**
α_{ns}	Directed anchovy catch control parameter for normal season	0.16655	0.73752	0.78	**0.871**	**0.898**
α_{ads}	Directed anchovy catch control parameter for additional season	0.99956	1.47504	1.17	**N/A**	**N/A**
	Fixed TABs	**OMP-02**	**OMP-04**	**OMP-08**	**OMP-08**	**Candidate OMP-14**
TAB^S_{big}	Fixed >14cm sardine bycatch	10[6]	10[5]	3.5[5]	**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**	**OMP-08**	**Candidate OMP-14**
δ	Scale-down factor applied to initial anchovy TAC	0.85[7]	0.85	0.85	0.85	0.85
p	Weighting given to recruitment survey in anchovy TAC	0.7[8]	0.7	0.7	0.7	0.7
q	Relates to average TAC under OMP-99 if $\alpha_{ns}=1$	300[9]	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	1380	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	**217 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	2000	2000

[5] The control parameters correspond to the corner point of the trade-off curve.
[6] 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.
[7] 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.
[8] 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.
[9] Leaving $q = 300$ unchanged facilitated easy comparison between the outputs from OMP-02 and subsequent revised OMP candidates.

Table A.1 (continued)**.**

	Constraints	OMP-02	OMP-04	OMP-08	Int OMP-13v2	Candidate OMP-14
B_{95}	Biomass of sardine where the logistic curve for γ_y reaches 95%	N/A	3 178	3 178	3178	3178
c^S_{mntac}	Minimum 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 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 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 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	**N/A**	**N/A**
$c^{ads,A}_{mxinc}$	Maximum additional season anchovy TAC	100	150	120	**N/A**	**N/A**
TAB^S_{ads}	Maximum sardine bycatch during the additional season	2	2	2	**N/A**	**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	**600**	**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	**N/A**	**N/A**
B_2	threshold above which the anchovy additional sub-season TAC reaches a maximum	N/A	N/A	1 500	**N/A**	**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**

Table A.2. The data required as input to the Candidate OMP-14 formulae to provide the directed sardine TAC 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	$B^S_{y-1,N}$	November survey estimate of sardine 1+ biomass in year $y-1$ (in thousands of tons)
	$B^A_{y-1,N}$	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)
	$N^S_{y,r}$ [10]	May survey estimate of sardine recruitment 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[11] 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 catch weight-at-age 0
	$\overline{w}^A_{1c} = 10.983$	Average historic catch weight-at-age 1

[10] Only needed if sardine Exceptional Circumstances are declared in December $y-1$, or if the "buffer" rule is applied such that the initial directed sardine TAC is less than that originally calculated by the Harvest Control Rules.
[11] 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.

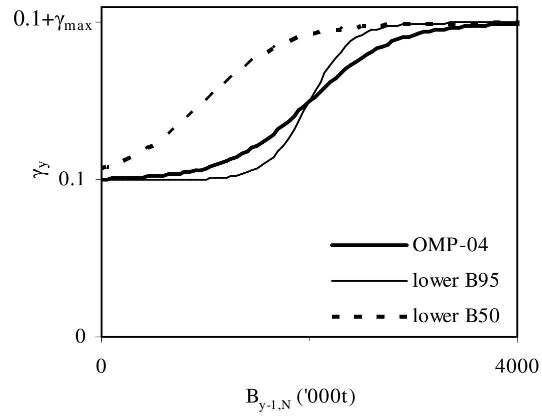

Figure A.1. The logistic curve used to calculate the proportion of initial anchovy TAC that provides the initial sardine TAB (γ_y , Equation OMP.7). Curves for a lower value of B_{95} and centred on a lower value of B_{50} are also shown.