agriculture,
forestry & fisheries

Department:
Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

INITIAL RECOMMENDATION OF THE SMALL PELAGIC SCIENTIFIC WORKING GROUP FOR THE SUSTAINABLE MANAGEMENT OF SMALL PELAGIC RESOURCES FOR THE SEASON 2016

December 2015

SUMMARY

Following results from the recent November 2015 pelagic biomass survey, the initial small pelagic Total Allowable Catches and Total Allowable Bycatches (TACs/TABs) for the 2016 pelagic fishing season are recommended in terms of OMP-14 as follows:

Initial directed >14cm sardine TAC:	64 563 t
Initial ≤14cm sardine TAB for directed >14cm sardine fishing:	4 519 t
Initial directed anchovy TAC:	254 483 t
Initial ≤14cm sardine TAB with directed anchovy fishing:	25 866 t
>14cm sardine TAB with directed round herring and anchovy fishing:	7 000 t
≤14cm sardine TAB with directed round herring fishing:	1 000 t
Anchovy TAB for sardine only right holders:	500 t

BACKGROUND

TACs, TABs and catches for 2015 - The document entitled “Final recommendation of the Small Pelagic Scientific Working group for the sustainable management of small pelagic resources for the season 2015, July 2015” (FISHERIES/2015/JUL/SWG-PEL/30) provides a description of the process followed to set the final pelagic TACs and TABs for 2015. The TACs, TABs, Precautionary Upper Catch Limits (PUCLs), and total landed catches (up to 10/12/2015 and subject to verification) for 2015 are shown below (Table 1). Catches are close to the TAC for directed > 14 cm sardine whereas sardine TABs, as expected under the

OMP, are substantially lower than the limits set for these allowances. Anchovy catches are well below the TAC despite the good recruitment measured in May 2015. Information available suggests that the availability of anchovy recruits on the West Coast was sporadic and at times these fish were too close to the bottom to be targeted by purse-seine nets. Redeye round herring, horse mackerel and mesopelagic catches were all far below their respective PUCLs, and achieved total catches for 2015 amounted to around 350 000t. Time-series of annual catches of pelagic fish species are given in Table 2.

Table 1. Pelagic TAC/TAB/PUCLs and landed catches for 2015. All figures are in tonnes.

	Initial TAC / TAB	Final TAC / TAB / PUCL[1]	Total landed catch[2]
Directed >14 cm sardine TAC	75 443	83 470	79 848
≤14cm sardine TAB with directed >14cm sardine fishing	5 281	5 843	48
Initial directed anchovy TAC	305 060	450 000	238 153
≤14cm sardine TAB with directed anchovy fishing	31 118	66 375	13 264
>14cm sardine TAB with directed round herring and anchovy fishing		7 000	1984
≤14cm sardine TAB with directed round herring fishing		1 000	62
Anchovy TAB for sardine only right holders		500	71
Round herring PUCL		100 000	13 928
Horse mackerel PUCL		12 233	1 972
Mesopelagic PUCL		50 000	0

1. TAB and PUCL pools have intentionally been set quite generously so that the chance of them being reached with a resultant premature closure of the fishery is small
2. As at 10/12/2015 and subject to verification

OMP-14 was adopted by the Small Pelagic Scientific Working Group (SPSWG) in November 2014 (see FISHERIES/2014/NOV/SWG-PEL/60) and approved by the Deputy Director-General as the basis for calculating recommended initial and final TAC/TABs for 2015 and 2016. This OMP, which was developed over a period of several years, took into account the most recent resource status of anchovy and sardine, the possible existence of multiple sardine stocks (to some extent), the impact of future recommended catches on the ecosystem, and the need to ensure industry stability over the short and medium term (see Appendix A).

TACs/TABs for 2016 output from OMP-14 at this time are as follows:

Initial directed >14cm sardine TAC [1]	64 563 t
Initial ≤14cm sardine TAB for directed >14cm sardine fishing [1]	4 519 t
Initial directed anchovy TAC[2]	254 483 t
Initial ≤14 cm sardine TAB with directed anchovy fishing[2]	25 866 t
>14cm sardine TAB with directed round herring and anchovy fishing [3]	7 000 t
≤14 cm sardine TAB with directed round herring fishing[3]	1 000 t
Anchovy TAB for sardine only right holders[4]	500 t

1. This TAC and TAB may be revised upwards following the May 2016 recruitment survey and is allocated individually to sardine Right Holders.
2. This TAC and TAB may be revised upwards following the May 2016 recruitment survey and is allocated individually to anchovy Right Holders.
3. These TABs are final for the full year and are not allocated on an individual basis to Right Holders but kept in a pool for all Right Holders.
4. This TAB is final for the full year and not allocated on an individual basis to right holders but kept in a pool for sardine only Right Holders.

This is the second time that an initial directed >14cm sardine TAC has been recommended. In 2013 and 2014 the directed >14cm sardine TAC remained unchanged at 90 000t, the minimum allowed under the previous OMP. The introduction of a "buffer rule" under OMP-14 for the directed sardine TAC in cases where the November survey estimate of sardine biomass is between 300 000t (below which Exceptional Circumstances would be declared) and 600 000t, results in a conservative initial sardine TAC being recommended at the beginning of the year, with a mid-season increase dependent on the survey estimate of sardine recruitment. Because the 2014 November survey estimate of sardine biomass was within this range an initial directed >14cm sardine TAC for 2015 of 75 443t was recommended, this being increased to 83 470t in July 2015 following completion of the May 2015 recruit survey. The final directed >14cm sardine TAC for 2016 will thus depend on the May 2016 survey estimate of sardine recruitment, and will fall somewhere between this initial TAC of 64 563t and a maximum of 95 418t. Note too that because the sardine survey estimate was below the threshold of 600 000t, the associated initial ≤14cm sardine TAB for directed >14cm sardine fishing will also be revised in mid-year, and this revision will depend on any revision to the directed >14cm sardine TAC.

The initial directed anchovy TAC is not constrained by any minimum or maximum TAC levels or maximum allowed interannual change in the TAC. The estimate of redeye round herring abundance from the

November 2015 pelagic biomass survey does not indicate any need for modifying the present precautionary upper catch limit (PUCL) of 100 000t for this species. The >14cm sardine TAB with directed round herring and anchovy fishing, the <14cm sardine TAB with directed round herring fishing and the anchovy TAB for sardine only Right Holders are final for the year.

MANAGEMENT OBJECTIVES

OMPs used to provide TAC recommendations for the sardine-anchovy fishery comprise formulae which calculate these recommendations from resource monitoring data, primarily the estimates of abundance provided by the May pelagic recruitment and November pelagic biomass hydro-acoustic surveys. The results from the November 2015 pelagic biomass survey constitute the primary inputs into OMP-14 leading to the TAC and TAB recommendations for 2016. The OMP-14 formulae have been selected with the objectives of maximising average directed sardine and anchovy catches in the medium term, subject to constraints on the extent to which TACs can vary from year to year in order to enhance industrial stability. The OMP-14 formulae are also conditioned on low probabilities that the abundances of these resources drop below agreed threshold levels below which successful future recruitment might be compromised (see Annexure A for further details).

RESOURCE ASSESSMENT

The biomasses of small pelagic fish species off the coast of South Africa have been monitored since 1984. These time-series of November biomass and May recruitment estimates, derived from hydro-acoustic surveys, form the basis for sustainable management of both the South African sardine and anchovy resources and are central to the setting of annual TACs.

The November 2015 pelagic biomass survey is the most recent in this series, and results from this survey are fully described in FISHERIES/2015/DEC/SWG-PEL/47. Anchovy biomass was estimated at around 1.9 million tonnes, appreciably lower than that estimated between 2012 and 2014, and below the long term (1984-2014) average of 2.28 million tonnes. The sardine biomass of just over 363 thousand tonnes is lower than the 444.5 thousand tonnes estimated in 2014 and also well below the long-term (1984-2014) average of 968.7 thousand tonnes for this species (Figure 1). The redeye round herring biomass estimate of just over 1.3 million tonnes is similar to that measured in 2014 and remains higher than the long-term (1984-2014) average of 967.2 thousand tonnes. Time-series of annual November survey estimates of anchovy, sardine and redeye round herring biomass are given in Table 3.

ECOSYSTEM CONSIDERATIONS

OMP-14 was simulation tested to ensure an acceptable level of risk regarding the probability that sardine and anchovy abundances would drop below specified thresholds over a variety of harvest strategies. That OMP was also tested using parameters denoting risk to the African penguin population *Spheniscus demersus*. Penguins were chosen as a key predator species for consideration because they feed predominantly on anchovy and sardine and because of their conservation status which has been of recent concern due to appreciable reductions in numbers at the major breeding colonies on Robben and Dassen Islands over the last few years. As part of the implementation of an ecosystems approach to fisheries (EAF) in South Africa's fishery for small pelagic fish, a model of penguin dynamics has been developed for use in conjunction with the small pelagic fish OMP so that the impact on penguins of predicted future pelagic fish trajectories under alternative harvest strategies could be evaluated. These studies have so far indicated that even with large reductions in pelagic catches under an alternative OMP, there would be little benefit for penguins. Further evaluation of these results under a sardine 2-stock operating model will be attempted during the development of the next OMP.

Additionally, penguins may be potentially sensitive to changes in pelagic fish abundance and distribution as a consequence of their land-based breeding sites and their limited foraging range (<20 km) during breeding. Additional measures to possibly restrict fishing in close proximity to penguin breeding colonies are also being investigated. Since 2009 a feasibility study, aimed at collecting data and determining when sufficient data were available to conduct a power analysis in relation to an experiment to determine the effect of fishing on penguins, has been underway. This feasibility study has now been completed. The International Scientific Review Panel recommended in December 2014 that pending further analyses, the current program of closures to pelagic fishing around certain islands which contain penguin breeding colonies be continued (see Recommendation 4 below). Further progress in developing the methods to evaluate the results of this closure program was made in 2015, and the 2015 International Scientific Review Panel put forward recommendations on how to finalise this process. It is anticipated that a decision on the future of this experiment will be taken in December 2016.

ASSOCIATED ADVICE

I. The SPSWG is concerned about the low sardine population size observed over the past few years as a consequence of a prolonged period of poor recruitment. Given that a population recovery depends on survival of as many recruits as possible, and because sardine recruits are caught in anchovy-directed fishing operations, the pelagic industry should take appropriate steps to attempt to keep the sardine bycatch as low as possible by avoiding areas where a relatively high proportion of small sardine is found mixed with anchovy schools.

II. In development of OMP-14, the Small Pelagic Scientific Working Group undertook substantial analyses related to the implications of the sardine resource consisting of two stocks rather than a single stock. The International Scientific Review Panel that met and considered this matter over 2-6 December 2013 reconfirmed that the two stock hypothesis is more plausible than that of a single sardine stock. This in turn lead to the conclusion that spatial management measures may be necessary to safeguard the sardine resource, perhaps in the form of separate directed sardine TACs for the areas to the west and east of Cape Agulhas to match hypothesized stock distributions. In finalisation of OMP-14, however, the SPSWG agreed that due to the unclear understanding of the mixing dynamics of the two stocks, it was premature to move to an OMP developed on the baseline hypothesis of assuming two mixing stocks. This was agreed on condition that some guidelines for spatial management of the directed sardine catches be developed and accepted as part of OMP-14. The agreed target percentage for the directed sardine TAC to be caught West of Cape Agulhas in any one year is the average of the percentages of sardine found west of Cape Agulhas in the November surveys in the preceding two years. A tolerance about this percentage of 10% has been set to allow some flexibility, especially because most of the sardine processing capacity remains on the West Coast and time is needed for industry to adapt to this new measure. Given the low biomass (<100 000t) estimated to the west of Cape Agulhas during the 2015 November survey and the fact that future sardine recruitment appears to be dependent on successful recruitment from this area, it is important that the pelagic industry does not exceed the target percentage for the directed sardine TAC to be caught west of Cape Agulhas.

III. Given that not all sardine Rights Holders are affiliated to industry associations, the Department will need to assist in managing the distribution of sardine catches. Efficient reporting of catches will be required to enable near-real time monitoring of the catch distribution.

RECOMMENDATIONS

1. The TAC/Bs for 2016 should be set as follows:

Initial directed >14cm sardine TAC:	64 563 t
Initial ≤14cm sardine TAB for directed >14cm sardine fishing:	4 519 t
Initial directed anchovy TAC:	254 483 t
Initial ≤14cm sardine TAB with directed anchovy fishing:	25 866 t
>14cm sardine TAB with directed round herring and anchovy fishing:	7 000 t
≤14cm sardine TAB with directed round herring fishing:	1 000 t
Anchovy TAB for sardine only right holders:	500 t

2. No exchange between directed sardine TACs and bycatch allowances should be permitted. Note that the evaluations underlying OMP-14 assume that ≤14cm sardine bycatch allowances, set for fishing directed at anchovy and >14 cm sardine, may be reached on occasion, but are anticipated to be under-caught on average through time, which is one reason that such change is not allowed.

3. Industry associations should request their members to spread their combined effort such that the overall directed >14cm sardine catch is in proportion to the average of the percentage of observed biomass in the area to the west of Cape Agulhas in November 2014 and November 2015. For 2016 the proportion of the directed >14 cm sardine TAC taken to the West of Cape Agulhas (west of 20° E) should lie between 25.6% and 45.6% (this range allows for +-10% tolerance about the target proportion). Failure to limit catches taken to the west of Cape Agulhas could jeopardise the recovery of the sardine population.

4. An area around the St Croix Island penguin breeding colony in the Eastern Cape should be closed to purse-seine fishing until the 31st December 2016. The extent of the closed area should be a circle of 20 km radius seaward from the mid-point of St Croix Island, and an additional circle of 5 km radius seaward from the midpoint of Riy Bank. Additionally, a circle of 20 km radius seaward from the mid-point of Dassen Island on the West Coast should be closed to purse-seine fishing until the 31st December 2016. These closures are components of a program of pelagic fishing exclusions around islands with penguin breeding colonies to inform whether or not restriction of pelagic fishing in the vicinity of these colonies enhances penguin reproductive success.

5. The catch of juvenile horse mackerel in the purse-seine fishery should not exceed 7 268 t. Adaptive management measures by the industry such as those implemented previously (i.e. local area closures) should be put in place if necessary to avoid areas of high bycatch but care should be taken not to unduly compromise catches of anchovy. It should also be borne in mind that under the current PUCL rule catches of horse mackerel in 2016 will impact the PUCL available for 2017 and 2018.

6. A precautionary upper catch limit (PUCL) of 100 000 t should apply to round herring, as in immediately previous years.

7. A precautionary upper catch limit (PUCL) of 50 000 t should apply to catches of mesopelagic fish (lanternfish and lightfish combined).

8. The bycatch of both juvenile and adult sardine resulting from directed round herring fishing should be closely monitored. The difficulty experienced by the fishery in targeting “clean” round herring shoals results in unavoidable catches of sardine. Adaptive management measures should, however, be put in place by the industry to try to avoid areas of high sardine bycatch.

Janet Coetzee
Chair of the Small Pelagic Scientific Working Group

Table 2. Time-series of annual catches of pelagic fish species (in thousands of tonnes).

Year	Anchovy	Total Sardine	Directed Sardine	Bycatch Sardine	Horse Mackerel	Chub Mackerel	Round Herring	Lantern fish	Total
1949	0	20	0	0	3	0	0	0	23
1950	0	85	0	0	50	0	0	0	135
1951	0	102	0	0	99	0	0	0	200
1952	0	170	0	0	103	0	0	0	273
1953	0	133	0	0	85	0	0	0	218
1954	0	88	0	0	118	4	0	0	211
1955	0	122	0	0	79	20	0	0	221
1956	0	77	0	0	46	33	0	0	155
1957	0	110	0	0	85	7	0	0	202
1958	0	194	0	0	56	22	1	0	273
1959	1	260	0	0	18	33	3	0	315
1960	0	318	0	0	63	31	0	0	412
1961	0	402	0	0	39	50	0	0	490
1962	0	410	0	0	67	20	0	0	497
1963	0	390	0	0	23	13	0	0	427
1964	92	256	0	0	24	50	3	0	426
1965	171	205	0	0	55	41	8	0	480
1966	144	118	0	0	26	53	15	0	357
1967	271	70	0	0	9	128	32	0	509
1968	138	108	0	0	1	91	30	0	369
1969	149	56	0	0	27	92	23	5	352
1970	169	62	0	0	8	78	24	18	358
1971	157	88	0	0	2	54	22	2	325
1972	236	104	0	0	1	57	21	15	434
1973	251	69	0	0	2	59	29	42	451
1974	350	16	0	0	3	31	1	0	401
1975	224	89	0	0	2	69	24	0	407
1976	218	176	0	0	0	1	12	0	408
1977	236	58	0	0	2	21	35	6	357
1978	210	97	0	0	4	2	67	1	380
1979	291	53	0	0	4	3	21	9	381
1980	316	51	0	0	0	0	14	0	381
1981	292	46	0	0	6	0	24	10	379
1982	306	35	0	0	1	3	31	1	377
1983	235	65	0	0	2	4	69	1	378
1984	269	30	0	0	3	1	27	18	349
1985	277	30	0	0	1	0	38	32	382
1986	304	31	0	0	1	0	52	1	393
1987	600	34	23	11	3	1	34	0	672
1988	573	36	26	10	6	0	64	0	680
1989	294	35	19	15	26	0	45	5	405
1990	152	57	42	15	8	0	46	1	263
1991	151	53	40	13	1	10	34	1	249
1992	349	55	34	21	2	0	48	1	455
1993	236	51	30	21	12	0	57	1	357
1994	156	95	50	44	8	2	54	1	316
1995	178	121	77	44	2	3	77	1	382
1996	41	108	79	29	19	1	47	0	216
1997	60	119	92	27	13	4	92	0	289
1998	108	133	109	24	27	0	53	7	327
1999	180	132	118	14	2	0	59	0	373
2000	267	135	124	12	5	0	37	0	445
2001	288	192	173	19	1	0	55	0	535
2002	213	261	245	16	8	0	55	0	537
2003	259	290	274	16	1	0	43	0	593
2004	190	374	366	8	2	0	47	0	614
2005	283	247	240	6	6	0	28	0	564
2006	134	217	206	11	5	0	42	0	398
2007	253	140	135	5	2	0	48	0	443
2008	266	91	86	5	2	1	64	0	424
2009	174	94	89	5	2	1	40	0	312
2010	217	112	88	25	4	1	88	0	423
2011	120	112	89	23	11	0	65	7	315
2012	307	109	98	12	2	0	68	0	487
2013	79	92	88	4	1	0	31	0	203
2014	240	98	89	9	3	1	34	0	376
2015	238	93	80	13	2	1	14	0	348

Table 3. Estimated anchovy, sardine and redeye round herring biomass (in thousands of tonnes) and their coefficients of survey sampling variation (CV) from the November acoustic surveys.

Year	Anchovy Biomass	CV	Sardine Biomass	CV	Round Herring Biomass	CV
1984	1 554	0.254	48	0.972	82	0.336
1985	1 366	0.183	45	0.449	257	0.224
1986	2 569	0.148	300	0.696	344	0.297
1987	2 109	0.132	111	0.402	545	0.197
1988	1 607	0.204	134	0.715	377	0.318
1989	752	0.143	257	0.225	836	0.254
1990	652	0.167	290	0.276	441	0.171
1991	2 328	0.140	598	0.308	625	0.242
1992	2 088	0.140	494	0.488	715	0.160
1993	916	0.190	560	0.316	521	0.216
1994	617	0.136	518	0.280	283	0.208
1995	601	0.192	844	0.515	571	0.132
1996	162	0.391	529	0.359	576	0.145
1997	1 483	0.267	1 225	0.244	591	0.280
1998	1 229	0.217	1 607	0.251	1 248	0.149
1999	2 052	0.156	1 635	0.212	1 398	0.171
2000	4 654	0.125	2 292	0.500	1 420	0.169
2001	6 720	0.107	2 310	0.142	1 046	0.131
2002	3 868	0.154	4 206	0.227	918	0.189
2003	3 563	0.236	3 564	0.197	1 762	0.108
2004	2 045	0.131	2 616	0.334	1 475	0.100
2005	3 077	0.144	1 049	0.300	1 616	0.130
2006	2 106	0.136	713	0.346	1 228	0.106
2007	2 508	0.157	257	0.345	1 721	0.153
2008	3 706	0.120	384	0.422	1 260	0.118
2009	3 793	0.136	502	0.271	1 991	0.108
2010	2 077	0.144	508	0.235	1 115	0.134
2011	754	0.204	1 037	0.235	1 961	0.101
2012	3 187	0.116	345	0.344	795	0.145
2013	3 820	0.102	612	0.346	959	0.129
2014	2 971	0.137	445	0.291	1 429	0.178
2015	1 944	0.157	363	0.297	1 315	0.136

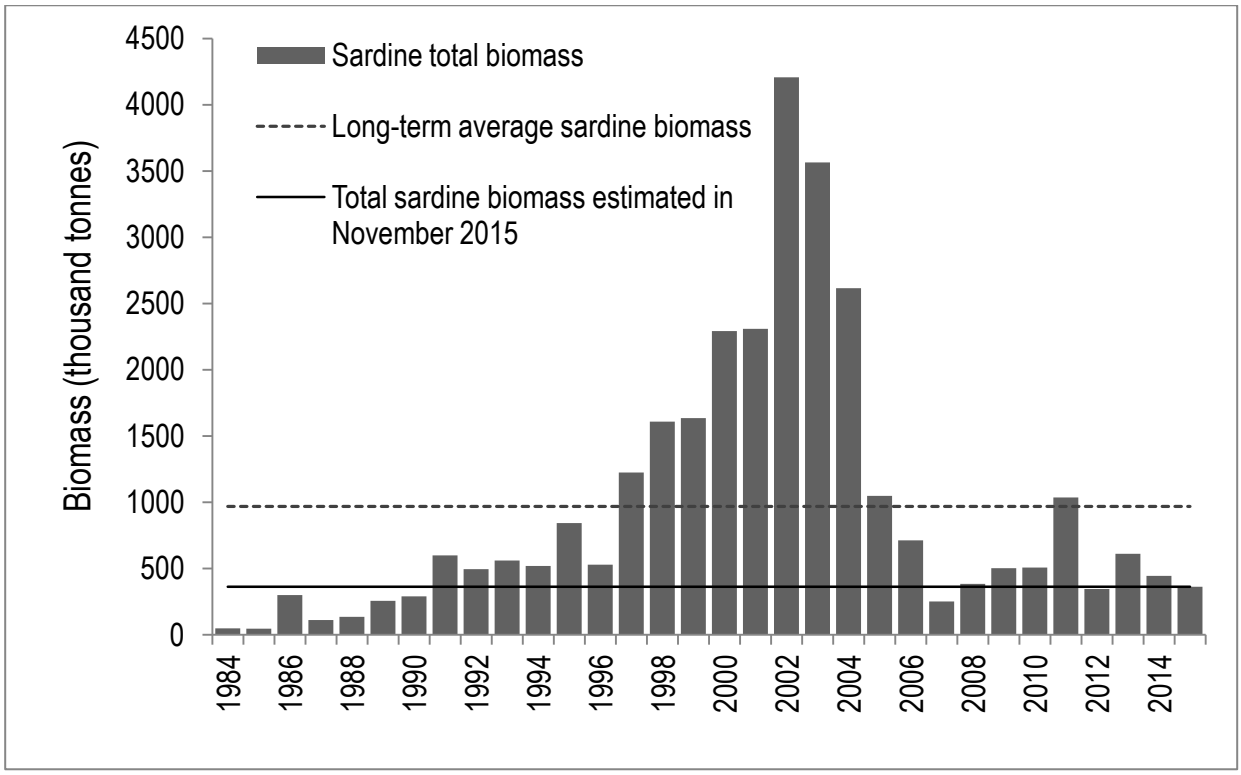

Figure 1. Time-series of sardine biomass estimates derived from November hydro-acoustic surveys. Also shown are the long-term (1984-2014) average sardine biomass (dashed line) and the low level of sardine biomass (solid line) estimated in November 2015, compared to most years since 1991.

Appendix A: 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 estimate of sardine 1+ biomass is below 600 000t).

Initial TACs / TAB (January)

The directed >14cm sardine TAC and initial directed anchovy TAC and TAB for ≤14cm sardine bycatch with anchovy directed fishing 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 decrease 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 decrease. 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 historical (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-14 (see Table A.1).

A fixed >14cm sardine TAB, TAB^{S}_{big}, consisting mainly of adult sardine bycatch with round herring and to a lesser extent with anchovy has been introduced in OMP-14 (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-14. 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 >14cm 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 catch:

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

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.

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

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

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

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

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

Buffer rule:

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:

$$TAC_{y,init}^{S} = \frac{TAC_y^{S}}{2} + \frac{TAC_y^{S}}{2} \times \left(\frac{B_{y-1,N}^{obs,S} - B_{ec}^{S}}{B_{ec}^{S}}\right)^{0.535} \qquad \text{(OMP.10)}$$

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 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, which is tuned to meet target risk levels for sardine and anchovy.

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

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

α_{ns} - a control parameter which tunes 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^A_{tier} - the two-tier threshold for directed anchovy TAC.

c^S_{mxdn} - 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.

Spatial management of the directed ≥14cm sardine TAC

The proportion of the directed >14cm sardine TAC to be caught west of Cape Agulhas in year y, $p_{west}(y)$, is restricted by a 10% error about the average of that observed from the most recent two November surveys:

$$0.5\left(p^{obs}_{west}(y-1)+p^{obs}_{west}(y-2)\right)-0.1\le p_{west}(y)\le 0.5\left(p^{obs}_{west}(y-1)+p^{obs}_{west}(y-2)\right)+0.1$$

where $p^{obs}_{west}(y)$ denotes the proportion of sardine abundance surveyed west of Cape Agulhas in November y.

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 Buffer Rule applied:

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

$$TAC^S_{final,y} = TAC^S_{y,init} + \left(\frac{N^{obs,S}_{y,r}}{R_{avg}} \right)^{1.5} \times \left(TAC^S_y - TAC^S_{y,init} \right) \qquad \text{(OMP.11)}$$

subject to: $$TAC^S_{final,y} \le \left(1.1 + \frac{0.1}{1 - 2^{-1.66099}} \left\{ \left(\frac{B^{obs,S}_{y-1,N}}{B^S_{ec}} \right)^{-1.66099} - 1 \right\} \right) \times TAC^S_y$$

Revised anchovy TAC: $$TAC^{2,A}_y = \alpha_{ns}\, q \left(p \frac{N^A_{y-1,rec0}}{\overline{N}^A_{rec0}} + (1-p) \frac{B^{obs,A}_{y-1,N}}{\overline{B}^A_{Nov}} \right) \qquad \text{(OMP.12)}$$

subject to:
$$\begin{array}{ll} \max\left\{ TAC^{1,A}_y ; \left(1 - c^A_{mxdn}\right) TAC^{2,A}_{y-1} \right\} \le TAC^{2,A}_y \le c^A_{mxtac} & TAC^{2,A}_{y-1} \le c^A_{tier} \\ \max\left\{ TAC^{1,A}_y ; \left(1 - c^A_{mxdn}\right) c^A_{tier} \right\} \le TAC^{2,A}_y \le c^A_{mxtac} & TAC^{2,A}_{y-1} > c^A_{tier} \end{array} \qquad \text{(OMP.13)}$$

Revised <14cm sardine TAB with anchovy:

$$TAB^{2,S}_{y,anch} = \lambda_y\, TAC^{1,A}_y + r_y\, (TAC^{2,A}_y - TAC^{1,A}_y) \qquad \text{(OMP.14)}$$

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

$$TAC^{2,A}_y = \left(1 - \frac{B^A_{y,proj} - B^A_{ec}}{\Delta^A} \right) \times TAC^{2,A\_EC}_y + \left(\frac{B^A_{y,proj} - B^A_{ec}}{\Delta^A} \right) \times TAC^{2,A}_y \qquad \text{(OMP.15)}$$

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

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

$N^{obs.i}_{y,r}$ - the estimate of recruitment of sardine ($i = S$) or anchovy ($i = A$) from the hydroacoustic recruit survey

in May of year y.

R_{avg} - the level of sardine recruitment required in order to achieve the original HCR calculated sardine TAC.

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

$\overline{N}^{A}_{rec0}$ - the average 1985 to 1999 anchovy recruitment surveyed in May, back-calculated (using equation (OMP.16)) 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[2] 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 evaluated 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 equation above:

$C^{A}_{y,0bs}$ - 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*; and

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 May survey estimate of sardine recruitment (Figure 1):

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

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

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

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 B^{S}_{ec} (see Table 1).

Initial Anchovy TAC

Exceptional Circumstances for the initial anchovy TAC apply if

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

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

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

where $TAC^{1,A\_before}_{y} = \alpha_{ns}\, \delta\, q \left(p + (1-p) \dfrac{B^{obs,A}_{y-1,N}}{\overline{B}^{A}_{Nov}} \right)$, subject to $c^{A}_{mntac} \le TAC^{1,A\_before}_{y} \le c^{A}_{mxtac}$. The rule allows for the TAC to be set to zero if the survey estimated anchovy biomass falls below x^{A} of the threshold B^{A}_{ec} (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 ($B^{A}_{y,proj}$) for the forthcoming November survey, and hence have a basis for invoking Exceptional Circumstances, if necessary. Defining

$$TAC_y^{2,A\_before} = \alpha_{ns} q \left(p \frac{N^A_{y-1,rec0}}{\overline{N}^A_{rec0}} + (1-p) \frac{B^{obs,A}_{y-1,N}}{\overline{B}^A_{Nov}} \right), \text{ subject to } \max\left\{TAC_y^{1,A}; c^A_{mntac}\right\} \le TAC_y^{2,A\_before} \le c^A_{mxtac},$$

a projected anchovy biomass, $B^A_{y,proj0}$, is calculated as follows:

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

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

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

If $B^A_{y,proj} < B^A_{ec}$, 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 B^A_{ec} is calculated as follows:

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

This is back-calculated to November of the previous year in the same way as equation (OMP.16) during OMP implementation:

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

In the equations above:

$C^A_{y,1}$ - 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 historical anchovy weight-at-age a in November (in gm).

$\overline{w}^A_{ac}$ - average historical anchovy catch weight-at-age a (in gm).

The revised anchovy TAC is calculated by reducing TAC_y^{2,A_before} by the ratio (squared) of TAC_y^{2,A_before} evaluated with the annual recruitment for year y to $TAC_y^{2,A}$ calculated using θ, thus providing a means to reduce the TAC fairly rapidly when the Exceptional Circumstances threshold is breached. 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 or biomass falls below a quarter of the corresponding threshold:

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

(OMP.24)