Further testing of "top-up" rules for the directed sardine TAC in OMP-14

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Background

The next Operational Management Procedure (OMP) under development for the South African sardine and anchovy fishery, OMP-14, allows for a conservative lower initial directed sardine TAC for the range of November hydroacoustic survey estimates of sardine biomass from 300 000t (below which Exceptional Circumstances would be declared) to 600 000t. The initial directed sardine TAC increases linearly from 50% of the TAC calculated from the Harvest Control Rule (TAC#) at a survey observation of 300 000t to 100% of TAC# at a survey estimate of 600 000t (Figure 1). For a November survey biomass estimate of 600 000t and above, TAC# as recommended by the directed sardine Harvest Control Rule (HCR) of OMP-14 at the start of the year is final and for the full calendar year with no mid-season increase.

The Small Pelagic Scientific Working Group agreed in July 2014 that the rule governing the potential increase in the directed sardine TAC would be of the form (based on Candidate MP-14.2 of de Moor (2014)):

$$TAC^{final} = \begin{cases} TAC_{init} + \dfrac{N_y^{obs}}{R_{crit}} \times \left(1.1 \times TAC^{\#} - TAC_{init}\right) & \text{if } N_y^{obs} \le R_{crit} \\ TAC_{init} + \left(1.1 \times TAC^{\#} - TAC_{init}\right) & \text{if } N_y^{obs} > R_{crit} \end{cases} \tag{1}$$

This allows the final TAC to range from the initial TAC (between 50-100% of TAC#, dependent on the survey estimate of November 1+ biomass) to 110% of TAC#, dependent on the May/June survey estimate of recruitment (Figure 2).

Further testing of R_{crit}

The historical (May 1984 – 2011) average observed May sardine recruitment is 13.74 billion recruits (Figure 3). For Interim OMP-13, and subsequent versions, $R_{crit} = 16.48$ billion, such that the mid-year revision is the same as the original TAC# when observed recruitment from the May survey is average.

The impact of the choice of a value for R_{crit} is explored. Alternative values of observed recruitment at which the mid-year revision is the same as the original TAC# were chosen as follows:

i) Historical (May 1984-2011) median observed May sardine recruitment of 5.63 billion recruits, with $R_{crit} = 6.76$ billion.

ii) Historical (May 1984-1999,2004-2011) average observed May sardine recruitment, excluding the 'peak' years of 2000-2003, of 8.92 billion recruits, with $R_{crit} = 10.71$ billion.

iii) A higher value of 16 billion recruits, than the historic average, with $R_{crit} = 19.2$ billion.

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All results in this document assume a single sardine stock hypothesis.

Results

The initial and final directed sardine TACs that would result from the candidate MP HCRs assuming the different values for R_{crit} are compared to those from HCRs without the conservative initial directed sardine TAC between 300 and 600 000t (i.e. assuming Interim OMP-13v2 HCRs). Results are shown assuming the survey estimates of 1+ biomass and May recruitment from the past eight years and for two sets of control parameters (see following paragraph). Table 1 shows that the initial TAC only differs from the final TAC under Interim OMP-13v2 HCRs if Exceptional Circumstances are declared (in 2008 the survey observation of 1+ biomass was <300 000t). For cases where the survey observation of 1+ biomass is between 300 and 600 000t (2009-2011, 2013), the lower R_{crit} values allow for a greater chance that the maximum of 110% of the original TAC[#] will be awarded mid-year.

Tables 2 and 3 show the key performance statistics for the candidate MP with two different R_{crit} values (the current value of 16.5 and the lowest alternative of 6.76) compared to Interim OMP-13v2 HCRs and a no catch scenario. Each table gives results for a different set of key control parameters. These key control parameter values were chosen from the trade-off curve of the candidate MP with $R_{crit} = 16.48$, constraining $risk_S < 0.21$ and $risk_A < 0.25$ (Figure 4). The points chosen were the 'corner point' ($\beta = 0.085$, $\alpha_{ns} = 0.911$) and the point maintaining the same β value as Interim OMP-13v2 ($\beta = 0.090$, $\alpha_{ns} = 0.726$).

These tables show little difference between the key performance statistics of Interim OMP-13v2 HCRs and the candidate MP with two different R_{crit} values. The greatest difference is in the average proportional average change in directed sardine catches, AAV^S, with a smaller R_{crit} value corresponding to a lower AAV^S likely due to the greater chance of the final TACs being close to the original TAC[#]. The projected median directed sardine catches are about 20% lower than the averages.

One of the reasons for the lack of difference in the key performance statistics is that these statistics are calculated over all years and simulations, while the difference between the rules would only occur in years/simulations where the simulated survey observation of November 1+ biomass is less than 600 000t. The survey observations are simulated to be between 300 and 600 000t in about 14% of simulations (Table 4). The median projected final directed sardine TAC from these simulations only ranges from 96 000t ($R_{crit} = 19.2$ billion) to 106 000t ($R_{crit} = 10.7$ and $R_{crit} = 6.8$ billion), compared to 97 000t under Interim OMP-13v2 HCRs.

Another way of considering the impact of the difference in the rules between Interim OMP-13v2 and the CMP with different values for R_{crit} is to consider the impact on the sardine catch and biomass in the year following which the sardine survey 1+ biomass is simulated to be between 300 and 600 000t[1]. The average (median) model predicted sardine 1+ biomass one year after the survey is estimated to be between 300 and 600 000t is 13 000t (6 000t) higher under the CMP with $R_{crit} = 16.48$ compared to Interim OMP-13v2, while the average (median) sardine catch during that year is only 3 000t (1 000t) less. This increase/decrease in average (median) model predicted 1+ biomass is three (two) times higher than the increase/decrease in catch for different R_{crit} values (Table 5). The differences are much larger when the key sources of uncertainty are removed from the projections, i.e. when variability about the stock-recruit relationship and all error except the multiplicative bias in the survey estimates of 1+ biomass and May recruitment are removed (Table 6).

Figure 5 shows the medians of the lowest percentiles of "worm plots" where the trajectories of simulated future sardine 1+ biomass are shown under Interim OMP-13v2 HCRs and the candidate MP with different R_{crit} values, for the same set of random numbers. The trajectories are sorted according to the lowest simulated value under the CMP projection with $R_{crit} = 16.48$. Figure 6 shows the same medians, 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[2]. Excluding this variability results in less pessimistic projections and thus only the medians of the lower 1 and 2%ile are shown as all other medians are above the 600 000t range. Finally, Figure 7 shows some of the individual "worm plots" for the worst 1% of these projections excluding the variability about the stock-recruitment relationship and all variability except the multiplicative bias in the survey estimates of abundance. A low R_{crit} value corresponding to the median historical (1984-2011) observed survey estimates of recruitment is more pessimistic than Interim OMP-13v2. This is likely because the maximum mid-season top-up in the TAC is frequently allowed, resulting in a final directed sardine TAC which is 110% of that recommended under Interim OMP-13v2. There is little difference in the trajectories for $R_{crit} = 16.48$ and $R_{crit} = 19.2$.

References

de Moor, C.L. 2014. Options for OMP-14. Department of Agriculture, Forestry and Fisheries Document FISHERIES/2014/JUN/SWG-PEL/26rev. 18pp.

[1] These cases were chosen from the CMP with $R_{crit} = 16.48$.

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

Table 1. A comparison of the sardine TACs (rounded to the nearest thousand tons) generated under Interim OMP-13v2 HCRs and candidate MPs that allow for a conservative initial directed sardine TAC for November survey estimates of 1+ biomass between 300 000 and 600 000t. The historic observations are as follows:

$B^S_{y,N}$ - November survey estimate of sardine 1+ biomass in year y (in thousands of tons)

$N^S_{y,r}$ - May survey estimate of sardine recruitment in year y (in billions)

Results are shown for two sets of control parameters ($\beta = 0.085$, $\alpha_{ns} = 0.911$ and $\beta = 0.090$, $\alpha_{ns} = 0.726$) from the trade-off curve assuming $R_{crit} = 16.48$ and four sets of R_{crit} values. As the initial TAC does not differ between different R_{crit} values, the initial TAC for candidate MPs that allow for a conservative initial directed sardine TAC are shown together. "Normal" refers to the part of the HCR that is applies for a November survey observation above 600 000t, "EC" refers to the Exceptional Circumstances HCRs that apply for a November survey observation below 300 000t and "New Rule" refers to the change in the HCR that applies for a November survey observation between 300 and 600 000t, the effect of which is being tested in this document.

				2006	2007	2008	2009	2010	2011	2012	2013
$B^S_{y-1,N}$				1048.991	712.557	252.201	384.080	501.575	508.392	1037.060	345.054
$N^S_{y,r}$				9.564	2.937	3.852	9.207	35.569	5.469	8.10	12.124
HCR				Normal	Normal	EC	New rule	New rule	New rule	Normal	New rule
$\beta = 0.085$ $\alpha_{ns} = 0.911$	Initial TAC	Interim OMP-13v2		90	90	28	90	90	90	90	90
		Candidate MPs		90	90	28	58	75	76	90	52
	Final TAC	Interim OMP-13v2		90	90	36	90	90	90	90	90
		Candidate MPs	R_{crit}=6.8	90	90	47	99	99	95	90	99
			R_{crit}=10.7	90	90	40	93	99	88	90	99
			R_{crit}=16.5	90	90	36	81	99	84	90	87
			R_{crit}=19.2	90	90	35	77	99	83	90	82
$\beta = 0.090$ $\alpha_{ns} = 0.726$	Initial TAC	Interim OMP-13v2		94	90	28	90	90	90	93	90
		Candidate MPs		94	90	28	58	75	76	93	52
	Final TAC	Interim OMP-13v2		94	90	36	90	90	90	93	90
		Candidate MPs	R_{crit}=6.8	94	90	47	99	99	95	93	99
			R_{crit}=10.7	94	90	40	93	99	88	93	99
			R_{crit}=16.5	94	90	36	81	99	84	93	87
			R_{crit}=19.2	94	90	35	77	99	83	93	82

Table 2. Key summary statistics for the sardine and anchovy resources under a no catch scenario, Interim OMP-13 v2 HCRs (but different control parameters), and candidate MPs including a rule for the mid-year increase in the directed sardine TAC when the survey estimate of biomass is between 300 and 600 000t, assuming R_{crit} =6.8 and R_{crit}=16.5. The control parameters used ($\beta = 0.085$ and $\alpha_{ns} = 0.911$) correspond to the corner point of the trade-off curve for the candidate MP with R_{crit}=16.5 constraining $risk^S$<0.21 and $risk^A$<0.25.

- 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 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 ($B^{S/A}_{\min}$) 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 ($B^{S/A}_{2032}$) 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 ($B^{S/A}_{2011}$);
- average (median in brackets) directed catch (in thousands of tons), $\overline{C}^S / \overline{C}^A$, and average anchovy catch during the additional season, $\overline{C}^A_{ad}$;
- average sardine bycatch comprising juvenile sardine bycatch with anchovy, round herring and large sardine (in thousands of tons), $\overline{C}^S_{by}$;
- 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), $p\left(TAC^{A/S}_y < c^{A/S}_{mntac}\right)$;
- average number of years for which Exceptional Circumstances, if declared, are declared consecutively, $EC^{A/S}_{consec}$;
- proportion of times the anchovy normal season fishery is closed due to the sardine TAB limit[3], $p(Close)$;

[3] 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, $\bar{C}^{A}_{lost}$; and
- average normal season anchovy TAC in years in which the fishery was closed $\overline{TAC}^{A}_{close}$.

		No Catch	Interim OMP-13 v2	R_{crit}=6.8	R_{crit}=16.5
Risk statistics	$risk^{S} < 0.21$	0.047	0.213	0.218	0.208
	$risk^{A}$	0.008	0.244	0.244	0.244
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	3.56	3.56	3.56
	$\overline{B^{A}_{2032}/K^{A}}$	1.20	0.55	0.55	0.55
	$\overline{B^{A}_{2032}/Risk^{A}}$	49.27	22.44	22.43	22.44
	$\overline{B^{A}_{2032}/B^{A}_{2011}}$	4.55	1.78	1.78	1.78
Anchovy catch statistics	$\bar{C}^{A}$ ('13-'32)	0	290 (324)	290 (324)	290 (323)
	$\bar{C}^{A}$ ('13-'15)	0	343 (381)	343 (381)	343 (381)
	AAV^{A} ('13-'32)		0.21	0.21	0.21
	AAV^{A} ('13-'15)		0.13	0.13	0.13
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	1.50	1.40	1.51
	$\overline{B^{S}_{2032}/K^{S}}$	0.99	0.76	0.76	0.77
	$\overline{B^{S}_{2032}/Risk^{S}}$	4.13	3.15	3.14	3.16
	$\overline{B^{S}_{2032}/B^{S}_{2011}}$	2.08	1.56	1.56	1.57
Sardine catch statistics	$\bar{C}^{S}$ ('13-'32)	0	151 (126)	152 (127)	151 (127)
	$\bar{C}^{S}_{by}$	0	33	33	33
	$\bar{C}^{S}$ ('13-'15)	0	120 (94)	122 (99)	120 (98)
	AAV^{S} ('13-'32)		0.30	0.30	0.37
	AAV^{S} ('13-'15)		0.63	0.46	0.62
Anchovy Exceptional Circumstances	$p\left(TAC^{A}_{y} < c^{A}_{mntac}\right)$		0.27	0.27	0.27
	EC^{A}_{consec}		3.47	3.46	3.46
Anchovy Fishery Closure	$p(Close)$		0.23	0.23	0.23
	$\bar{C}^{A}_{lost}$		36	36	36
	$\overline{TAC}^{A}_{close}$		168	168	168
Sardine Exceptional Circumstances	$p\left(TAC^{S}_{y} < c^{S}_{mntac}\right)$		0.06	0.06	0.05
	EC^{S}_{consec}		1.37	1.36	1.32

Table 3. As for Table 2, except the control parameters used ($\beta = 0.090$ and $\alpha_{ns} = 0.726$) were chosen from the trade-off curve for the candidate MP with R_{crit}=16.5 constraining $risk^S$<0.21 and $risk^A$<0.25 such that the directed sardine control parameter remains unchanged from Interim OMP-13v2.

		No Catch	Interim OMP-13 v2	R_{crit}=6.8	R_{crit}=16.5
Risk statistics	$risk^S < 0.21$	0.047	0.215	0.217	0.209
	$risk^A$	0.008	0.168	0.168	0.168
Anchovy biomass statistics	$\overline{B^A_{\min}/K^A}$	0.26	0.11	0.11	0.11
	$\overline{B^A_{\min}/Risk^A}$	9.21	4.14	4.14	4.14
	$\overline{B^A_{2032}/K^A}$	1.20	0.61	0.61	0.61
	$\overline{B^A_{2032}/Risk^A}$	49.27	24.84	24.84	24.85
	$\overline{B^A_{2032}/B^A_{2011}}$	4.55	1.97	1.97	1.97
Anchovy catch statistics	$\overline{C}^A$ ('13-'32)	0	286 (295)	286 (295)	286 (294)
	$\overline{C}^A$ ('13-'15)	0	321 (318)	321 (318)	321 (318)
	AAV^A ('13-'32)		0.23	0.23	0.23
	AAV^A ('13-'15)		0.13	0.13	0.13
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	1.50	1.49	1.51
	$\overline{B^S_{2032}/K^S}$	0.99	0.76	0.76	0.76
	$\overline{B^S_{2032}/Risk^S}$	4.13	3.13	3.12	3.15
	$\overline{B^S_{2032}/B^S_{2011}}$	2.08	1.55	1.55	1.56
Sardine catch statistics	$\overline{C}^S$ ('13-'32)	0	157 (131)	157 (131)	157 (132)
	$\overline{C}^S_{by}$	0	31	31	31
	$\overline{C}^S$ ('13-'15)	0	125 (98)	126 (100)	124 (99)
	AAV^S ('13-'32)		0.33	0.30	0.40
	AAV^S ('13-'15)		0.63	0.46	0.62
Anchovy Exceptional Circumstances	$p(TAC^A_y < c^A_{mntac})$		0.22	0.22	0.22
	EC^A_{consec}		3.20	3.20	3.20
Anchovy Fishery Closure	$p(Close)$		0.21	0.21	0.21
	$\overline{C}^A_{lost}$		37	36	36
	$\overline{TAC}^A_{close}$		175	174	175
Sardine Exceptional Circumstances	$p(TAC^S_y < c^S_{mntac})$		0.06	0.05	0.05
	EC^S_{consec}		1.36	1.35	1.31

Table 4. The average and median November survey estimates of 1+ biomass and final directed sardine TAC for simulations in which the survey estimate is between 300 000t and 600 000t, i.e. for simulations in which the candidate MPs give a conservative initial directed sardine TAC of between 50% and 100% of the original TAC[#] calculated by the HCR, and then increase this TAC mid-year, dependent on the May/June survey estimate of sardine recruitment. The proportion of simulations for which the November survey estimate of 1+ biomass is within this range, $p\left(300 < B_{y,i}^{obs} < 600\right)$, is also given.

		$p\left(300 < B_{y,i}^{obs} < 600\right)$	Survey estimate ('000t)		Final TAC ('000t)	
			Average	Median	Average	Median
$\beta = 0.085$ $\alpha_{ns} = 0.911$	Interim OMP-13v2	0.14	463	470	104	97
	R_{crit}=6.8	0.14	462	467	108	106
	R_{crit}=10.7	0.14	462	468	104	106
	R_{crit}=16.5	0.14	462	467	100	98
	R_{crit}=19.2	0.14	463	470	98	96
$\beta = 0.090$ $\alpha_{ns} = 0.726$	Interim OMP-13v2	0.14	462	468	104	97
	R_{crit}=6.8	0.14	463	467	109	106
	R_{crit}=10.7	0.14	462	467	105	106
	R_{crit}=16.5	0.14	463	469	101	98
	R_{crit}=19.2	0.14	463	468	99	96

Table 5. The difference between the model predicted sardine 1+ biomass and directed sardine catch (rounded to the nearest thousand tons) one year after the survey is estimated to be between 300 and 600 000t[4] for the CMP with $R_{crit} = 16.48$ and alternative values of R_{crit} as well as under Interim OMP-13v2.

		1+ biomass		catch		1+ biomass/(-catch)	
		Average	Median	Average	Median	Average	Median
$\beta = 0.085$ $\alpha_{ns} = 0.911$	Interim OMP-13v2	-13 000	-5 000	+3 000	+1 000	4.6	5.3
	R_{crit}=6.8	-22 000	-12 000	+7 000	+6 000	3.1	2.0
	R_{crit}=10.7	-11 000	-7 000	+4 000	+3 000	2.8	2.1
	R_{crit}=19.2	+4 000	+2 000	-1 000	-1 000	2.6	2.1
$\beta = 0.090$ $\alpha_{ns} = 0.726$	Interim OMP-13v2	-13 000	-6 000	+3 000	+ 1 000	4.6	5.4
	R_{crit}=6.8	-22 000	-12 000	+7 000	+ 6 000	3.1	2.0
	R_{crit}=10.7	-11 000	-7 000	+4 000	+3 000	2.8	2.1
	R_{crit}=19.2	+4 000	+2 000	-1 000	-1 000	2.6	2.1

[4] These cases were chosen from the CMP with $R_{crit} = 16.48$.

Table 6. As for Table 5, but excluding any variability about the stock-recruit relationship and all error except the multiplicative bias in the survey estimates of abundance.

		1+ biomass		catch		1+ biomass/(-catch)	
		Average	Median	Average	Median	Average	Median
$\beta = 0.085$	Interim OMP-13v2	-40 000	-21 000	+1 000	+3 000	38.1	8.4
$\alpha_{ns} = 0.911$	R_{crit}=6.8	-77 000	-62 000	+3 000	+6 000	26.1	9.8
	R_{crit}=10.7	-32 000	-23 000	+2 000	+2 000	18.1	9.7
	R_{crit}=19.2	+9 000	+6 000	-1 000	-1 000	13.3	9.5
$\beta = 0.090$	Interim OMP-13v2	-38 000	-18 000	+1 000	+2 000	26.2	8.3
$\alpha_{ns} = 0.726$	R_{crit}=6.8	-79 000	-58 000	+4 000	+6 000	26.6	9.2
	R_{crit}=10.7	-33 000	-22 000	+2 000	+3 000	19.0	9.3
	R_{crit}=19.2	+8 000	+5 000	-1 000	-1 000	12.0	8.5

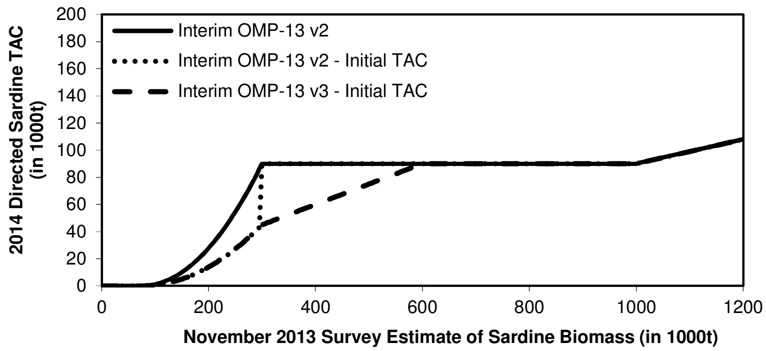

Figure 1. The Harvest Control Rule for directed ≥14cm sardine TAC in 2014 under Interim OMP-13 v2 and Interim OMP-13 v3. The initial sardine TAC awarded at the beginning of the year under Interim OMP-13 v2 and Interim OMP-13 v3 are also plotted.

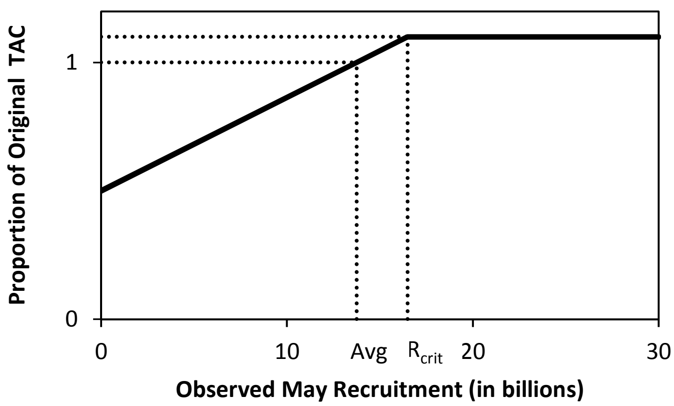

Figure 2. The proportion of the original directed sardine TAC ($TAC^{\#}$) that is awarded as a final directed sardine TAC in the mid-year revision under the Candidate MPs in this paper, when the November survey estimate of sardine 1+ biomass is between 300 and 600 000t. The final TAC can be a maximum of 110% of $TAC^{\#}$.

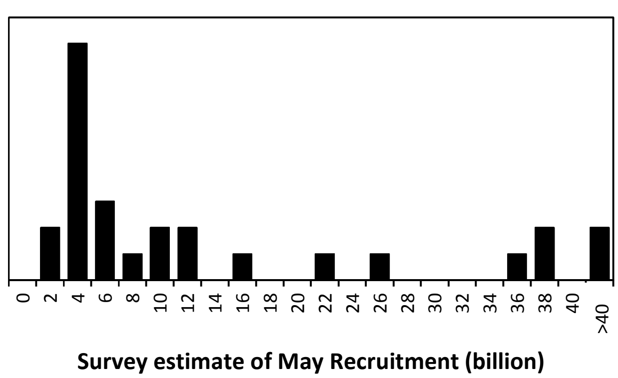

Figure 3. Histogram of the survey estimates of recruits from May 1985 to 2011.

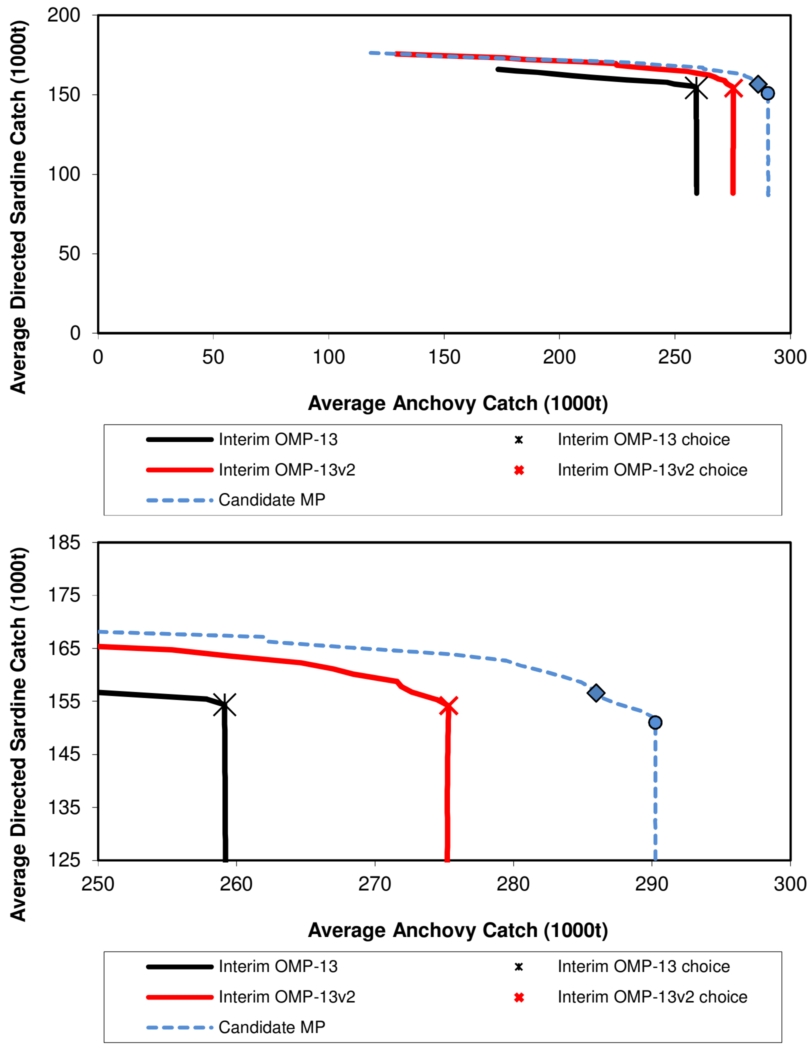

Figure 4. Trade-off curves for Interim OMP-13 ($risk_S < 0.21$, $risk_A < 0.20$), Interim OMP-13v2 ($risk_s < 0.21$, $risk_A < 0.25$) and the candidate MP considered here, with $R_{crit} = 16.48$ ($risk_s < 0.21$, $risk_A < 0.25$). The lower figure covers a smaller range on both axes to allow easier comparison of the corner points. The marked points on the candidate MP trade-off curve are those corresponding to the corner point and that for which β is unchanged from Interim OMP-13v2.

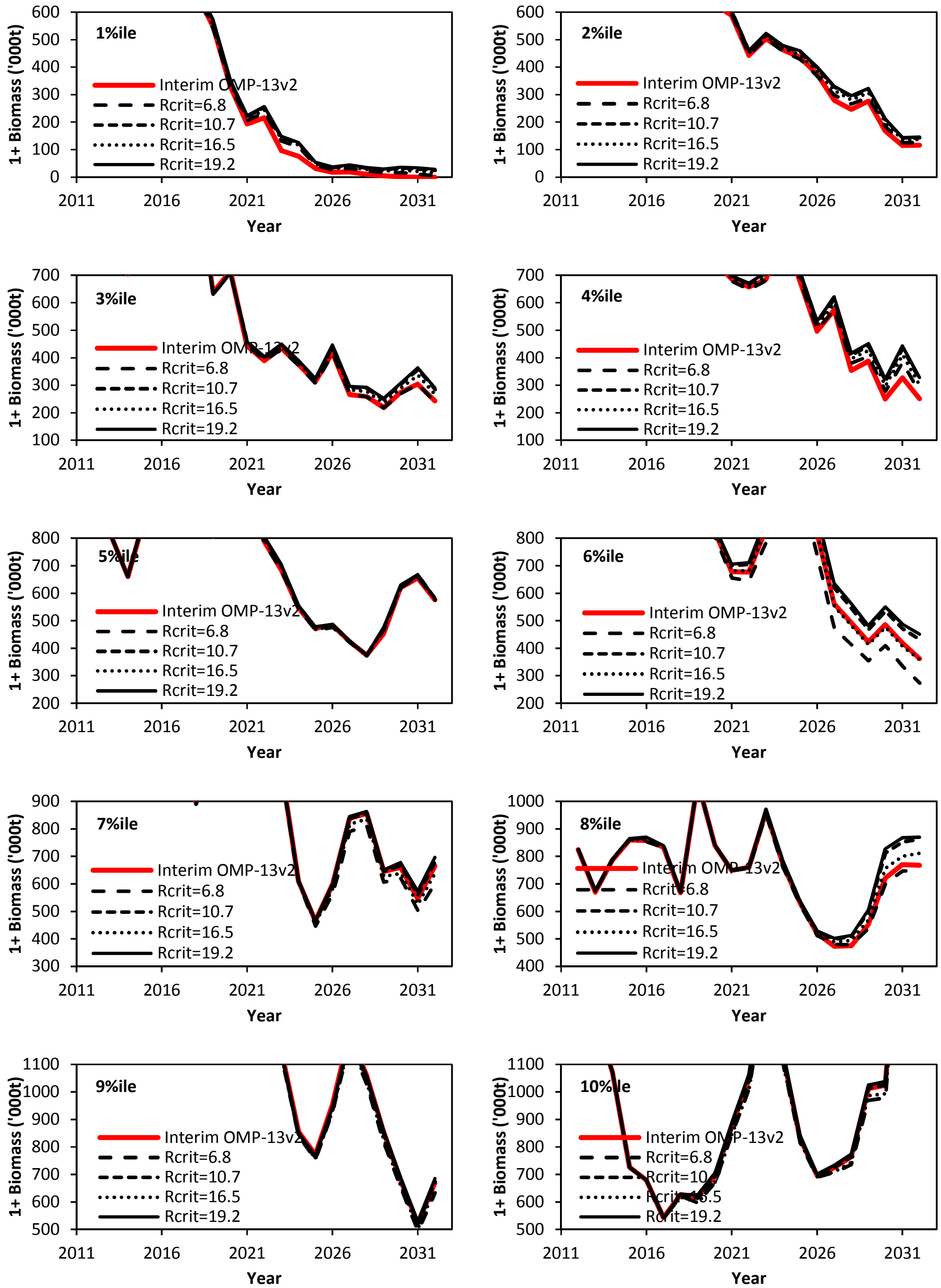

Figure 5. Trajectories of the 10 projections corresponding to the 1-10%iles of simulations which project the lowest future sardine biomass under the candidate MP with $R_{crit} = 16.48$, together with the corresponding simulations (with identical random numbers) assuming Interim OMP13v2 HCRs and the candidate MP with alternative R_{crit} values. All projections assume $\beta = 0.085$ and $\alpha_{ns} = 0.911$. Note that although the vertical scale of all the plots is the same, the range differs.

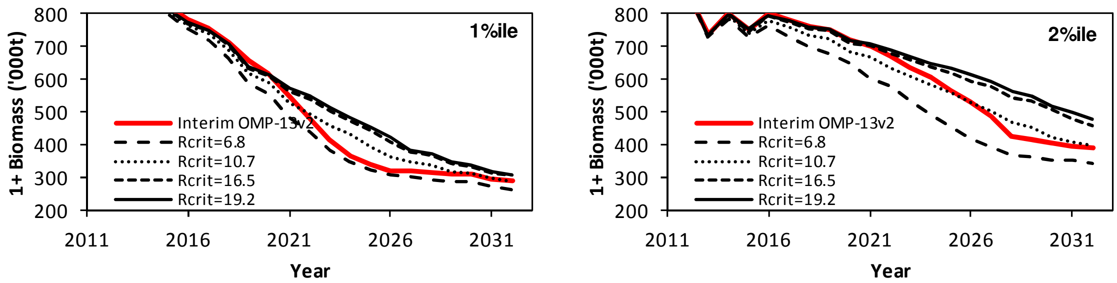

Figure 6. Trajectories of the projections corresponding to the 1st %ile and 2nd %ile of simulations which project the lowest future sardine biomass under the candidate MP with $R_{crit} = 16.48$, together with the corresponding simulations (with identical random numbers) assuming Interim OMP13v2 HCRs and the candidate MP with alternative R_{crit} values. These projections exclude any variability about the stock-recruit relationship and exclude all error except the multiplicative bias in the survey estimates of abundance. All projections assume $\beta = 0.085$ and $\alpha_{ns} = 0.911$.

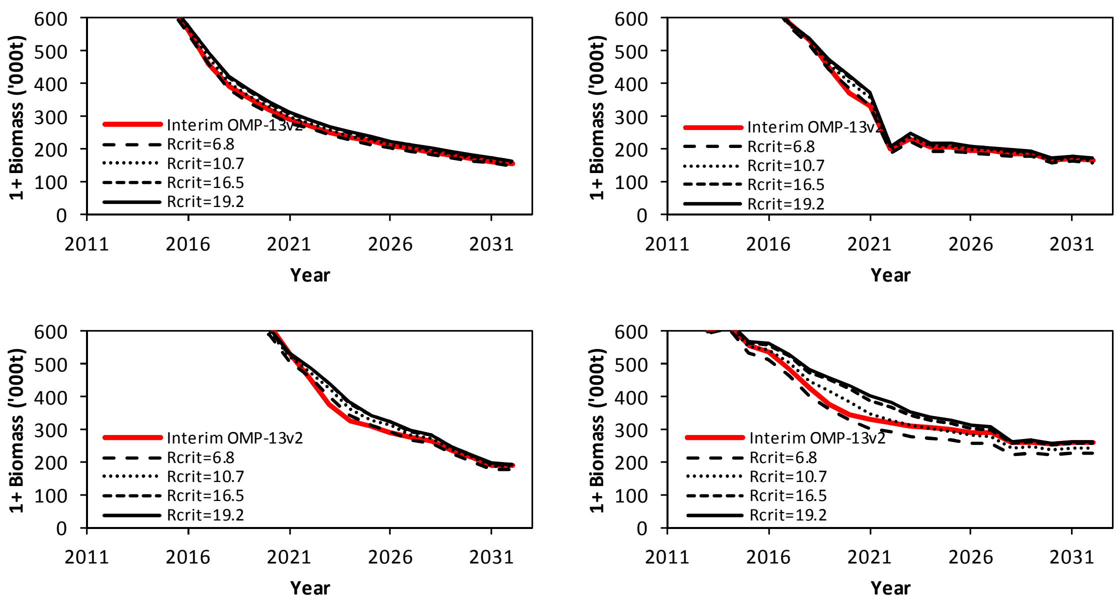

Figure 7. Trajectories of the individual projections corresponding to the lowest 1%ile of simulations which project the lowest future sardine biomass under the candidate MP with $R_{crit} = 16.48$, together with the corresponding simulations (with identical random numbers) assuming Interim OMP13v2 HCRs and the candidate MP with alternative R_{crit} values. These projections exclude any variability about the stock-recruit relationship and exclude all error except the multiplicative bias in the survey estimates of abundance. All projections assume $\beta = 0.085$ and $\alpha_{ns} = 0.911$.

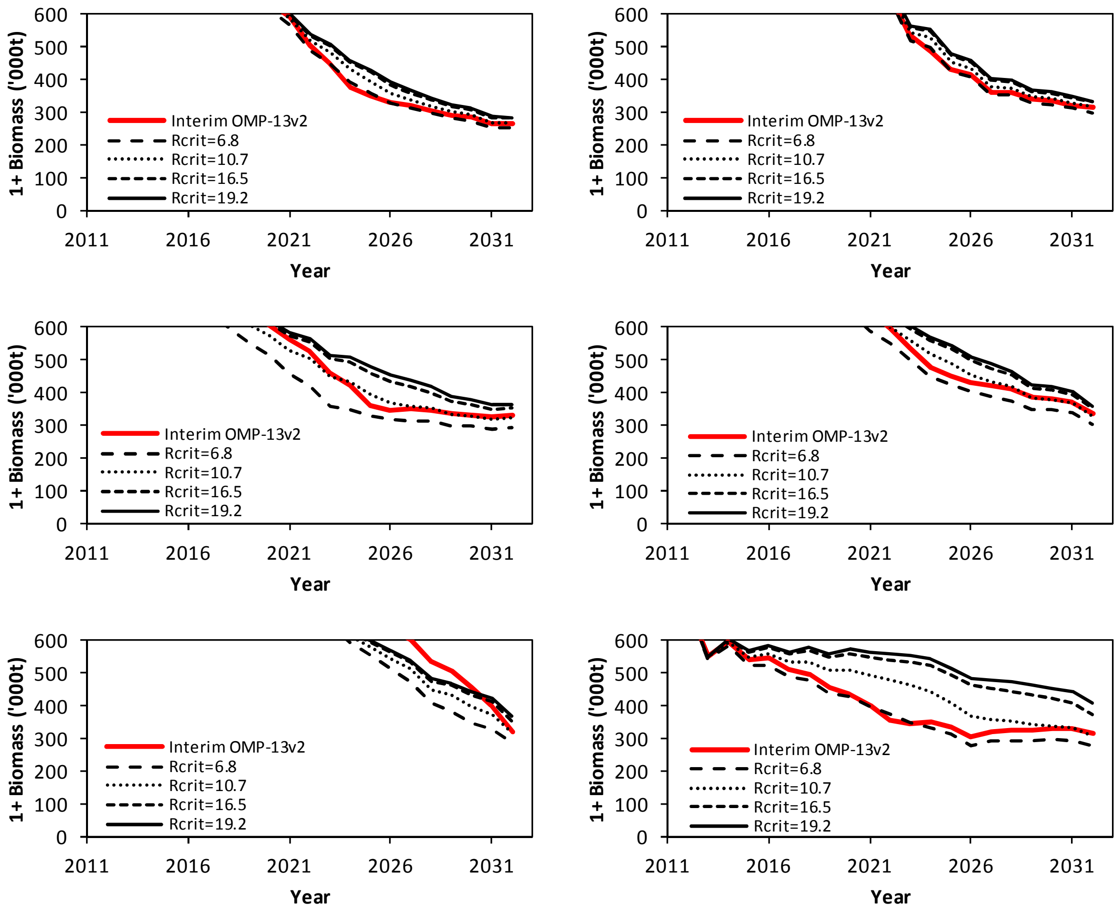

Figure 7 (continued).