OMP-18 development: alternative constraints on the sardine Harvest Control Rule

C.L. de Moor*

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

Introduction

A reference case Harvest Control Rule (HCR) for sardine was selected as having the following constraints (de Moor 2018a,b):

- A stable directed sardine TAC of 50 000t.
- A minimum directed sardine TAC of 10 000t.
- A maximum directed sardine TAC of 200 000t.
- The maximum proportion by which the directed sardine TAC can be decreased from one year to the next (in the absence of the Critical Biomass metarule and linear smoothing) of 0.2
- Critical Biomass threshold of 350 000t on total survey estimated sardine biomass.
- Linear smoothing of the HCR applying for 350 000t above the Critical Biomass threshold, i.e. from 350 000t to 700 000t[1].

However, concern was raised regarding the high inter-annual variability that could result from the implementation of this rule. This document considers various changes to the directed sardine HCR to investigate the impact of additional constraints on inter-annual variability in the directed sardine TAC. All projections are undertaken assuming the interim OMP-18 anchovy HCR which has a maximum anchovy TAC of 350 000t and a scale-down factor applied to the initial anchovy TAC of 0.85 (de Moor 2018c).

Method

The following additional constraints to the reference case HCR are considered:

i) If $B_{y-1,N}^{obs,S} \geq B_{crit}^{S}$, a constraint of a maximum increase of 20% ($c_{mxinc}^{S} = 0.2$) from the previous year's TAC applies ("*20%up*").

ii) If $B_{y-1,N}^{obs,S} \geq B_{crit}^{S}$, a constraint of a maximum increase of 20% ($c_{mxinc}^{S} = 0.2$) from the maximum of previous year's TAC or the stable TAC applies ("*20%up>50*").

iii) A constraint of a maximum increase of 20% ($c_{mxinc}^{S} = 0.2$) from the previous year's TAC applies ("*20%upALL*").

iv) If $B_{y-1,N}^{obs,S} < B_{crit}^{S}$, a constraint of a maximum decrease of 30% ($c_{crit}^{S} = 0.3$) from the previous year's TAC applies ("*CB30%dn*").

v) If $B_{y-1,N}^{obs,S} < B_{crit}^{S}$, a constraint of a maximum decrease of 40% ($c_{crit}^{S} = 0.4$) from the previous year's TAC applies ("*CB40%dn*").

---

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

[1] This is to avoid any discontinuities in the rule at the Critical Biomass threshold given the metarule below 350 000t does not allow for any 20% constraint in the decrease in directed sardine TAC from one year to the next.

vi) If $B_{y-1,N}^{obs,S} < B_{crit}^{S}$, a constraint of a maximum decrease of 50% ($c_{crit}^{S} = 0.5$) from the previous year's TAC applies ("*CB50%dn*").

vii) If $B_{y-1,N}^{obs,S} < B_{crit}^{S}$, a constraint of a maximum decrease or increase[2] of 30% ($c_{crit}^{S} = 0.3$) from the previous year's TAC applies ("*CB30%*").

viii) If $B_{y-1,N}^{obs,S} < B_{crit}^{S}$, a constraint of a maximum decrease or increase[2] of 40% ($c_{crit}^{S} = 0.4$) from the previous year's TAC applies ("*CB40%*").

ix) If $B_{y-1,N}^{obs,S} < B_{crit}^{S}$, a constraint of a maximum decrease or increase[2] of 50% ($c_{crit}^{S} = 0.5$) from the previous year's TAC applies ("*CB50%*").

x) As per vi), but with $B_{crit}^{S} = 250$ thousand tons ("*250-350*").

xi) As per vi), but with $B_{crit}^{S} = 300$ thousand tons ("*300-350*").

xii) As per vi), but with $B_{crit}^{S} = 400$ thousand tons ("*400-350*").

xiii) As per vi), but with linear smoothing applying from 350 000t to 450 000t ("*350-100*").

xiv) As per ix), but with linear smoothing applying from 250 000t to 350 000t ("*250-100*").

xv) As per x), but with linear smoothing applying from 300 000t to 400 000t ("*300-100*").

xvi) As per xv), but with linear smoothing applying from 400 000t to 500 000t ("*400-100*").

xvii) As per vi), but the maximum decrease constraint applies to the minimum of TAC_{y-1}^{S} or $c_{min}^{S}/(1 - c_{crit}^{S})$ ("*CBonly30%*").

xviii) As per vii), but the maximum decrease constraint applies to the minimum of TAC_{y-1}^{S} or $c_{min}^{S}/(1 - c_{crit}^{S})$ ("*CBonly40%*").

xix) As per vii), but the maximum decrease constraint applies to the minimum of TAC_{y-1}^{S} or $c_{min}^{S}/(1 - c_{crit}^{S})$ ("*CBonly50%*").

The sardine Operating Model (OM) used to simulation test these alternative rules assumes 8% of the south coast spawner biomass contributes to the west coast 'effective' spawner biomass and a baseline movement hypothesis MoveR (de Moor 2017). However, the variability about the stock recruitment relationships for both the west and south components has been increased from $\sigma_{r,j} = 0.5$ to $\sigma_{r,j} = 0.9$ (Bergh 2018). Projections under the Reference Case HCR given in this document, will therefore not match those given previously (e.g. by de Moor 2018b).

Results and discussion

The greater variability in the OM compared to previously used models results in both higher and lower recruitments being generated more frequently. If all other things remained equal, the lower recruitments (particularly if in succession) would increase the risk to the resource, while the higher recruitments would increase biomass and subsequently any quota calculated as a proportion of this biomass. However, any increase in risk would occur both in the presence and absence of fishing. While the acceptable level of risk could be termed a policy decision (de Moor 2018a,c) SA pelagic OMPs have typically been tuned to a level of risk deemed acceptable when comparing the impact of fishing on the distribution of biomass after 20 years projection to that which would occur in the absence

[2] The maximum of 10 000t or $c_{crit}^{S} TAC_{y-1}^{S}$ is used as the constraint.

of fishing. For this OM, the fixed harvest proportion which results in a comparable 'leftward shift' in the biomass distribution occurs at 17% (Table 1 and Figure 1). Fixing the control parameter $\beta = 0.17$ in the reference case HCR gives a risk of 0.15 (Table 2). All comparisons between alternative directed sardine HCRs are thus tuned to a risk <0.15.

A substantial decrease in the inter-annual variability of the directed sardine TACs can be attained if a restriction on year-on-year increases in the TAC is applied similar to the already included restriction to year-on-year decreases in the TAC (Table 2, Figure 2). *20%up, 20%up>50* and *20%upALL* also result in a slightly lower probability of TAC< 20 000t (Figure 5). While *20%up, 20%up>50* and *20%upALL* have a substantially higher control parameter than the reference case, this is due to the maximum TAC constraint and the additional constraint on inter-annual increases in the TAC. The 'cost' of these benefits is that the median total catch is reduced by 25-50% from that under the reference case HCR (Table 2, Figures 2,5). Figure 6 demonstrates some example comparisons between the reference case, *20%up* and *20%up>50*.

A decrease in inter-annual variability can also be attained by restricting inter-annual changes in the TAC during years when the Critical Biomass metarule is used, i.e. when $B_{y-1,N}^{obs,S} < B_{crit}^{S}$ in cases (iv)-(ix) and (xvii)-(xix) (Table 2, Figure 2). A greater decrease in the MAV is attained for a greater restriction (e.g. 30% compared to 50%), but again the 'cost' is a decrease in median directed catch. Cases (xvii)-(xix) apply the 30-50% constraint only on low TACs, thereby allowing TACs to be more quickly reduced from high levels should the survey estimate of biomass drop substantially from one year to less than the Critical Biomass threshold in another year. Some examples of the differences in *CB30%* to *CBonly30%* can be seen in the individual trajectory plots of Figure 7. In some cases for *CB30%* the TAC remains (substantially) above the stable TAC of 50 000t even when $B_{y-1,N}^{obs,S} < B_{crit}^{S}$ due to the constraint of a maximum decrease to 70% of the previous year's directed sardine TAC. While Figure 2 only compares the medians, Figure 4 demonstrates the range in median total catches and total MAV that could be attained under the reference case compared to HCRs with a 30% constraint on inter-annual variability when $B_{y-1,N}^{obs,S} < B_{crit}^{S}$ (Table 2).

Figure 3 shows that a decrease in the Critical Biomass threshold results in a lower β control parameter and a lower median catch.

Finally, all current results assume CMP calculated catches are taken during 2018. Any final MP will need to be tuned assuming the directed sardine TAC (and subsequently derived catch) is (at least) 59 214t.

Acknowledgements

The SWG-PEL OMP Task Team members are thanked for their input and discussions during the development of this work.

References

Bergh M. 2018. The performance of different simulation schemas for forward simulations of sardine recruitment. DAFF: Branch Fisheries Document FISHERIES/2018/MAY/SWG-PEL/11.

de Moor CL. 2017. A summary of the operating models being used to simulation test OMP-18 for South African sardine and anchovy. MARAM International Stock Assessment Workshop, 27 November – 1 December 2017, Cape Town. Document MARAM/IWS/2017/Sardine/P6

de Moor CL. 2018a. Some comparisons against a reference sardine Harvest Control Rule for OMP-18. DAFF: Branch Fisheries Document FISHERIES/2018/MAR/SWG-PEL/03.

de Moor CL. 2018b. Considering the variability in directed sardine catches for the current OMP-18 reference case HCR. DAFF: Branch Fisheries Document FISHERIES/2018/MAR/SWG-PEL/04.

de Moor CL. 2018bc Considering alternative constraints to the anchovy Harvest Control Rule. DAFF: Branch Fisheries Document FISHERIES/2018/APR/SWG-PEL/06.

Table 1. The ratio of the lower percentiles of the distribution of sardine biomass at the end of the projection period under a constant harvest proportion catch : no catch scenario. In the catch scenarios directed sardine TACs are set at 0%, 16%, 17% or 18% of survey estimated biomass, and all catch options additionally model sardine bycatch with anchovy.

			Total Biomass				West Component				South Component			
	OMP-08	OMP-14	U=0	U=0.16	U=0.17	U=0.18	U=0	U=0.16	U=0.17	U=0.18	U=0	U=0.16	U=0.17	U=0.18
10%ile	0.50	0.59	0.90	0.63	0.62	0.61	0.94	0.69	0.68	0.68	0.89	0.57	0.55	0.53
20%ile	**0.68**	**0.68**	0.92	0.69	0.68	0.67	0.92	0.73	0.73	0.72	0.93	0.61	0.59	0.57
30%ile	0.72	0.73	0.94	0.71	0.70	0.69	0.95	0.76	0.76	0.75	0.92	0.61	0.59	0.58
40%ile	0.73	0.76	0.94	0.74	0.72	0.71	0.93	0.77	0.77	0.76	0.94	0.65	0.63	0.62
50%ile	0.72	0.78	0.95	0.72	0.71	0.70	0.94	0.78	0.77	0.77	0.94	0.66	0.65	0.63

Table 2. Sardine performance statistics for some of the alternative sardine Harvest Control Rules. The reference case HCR is shown with $\beta = 0.17$, while all other cases are shown tuned to a risk of <0.15. Where appropriate, medians [90% probability intervals] are provided. All biomasses are given in thousands of tons.

Performance Statistic	No Catch	Ref Case	Ref Case	20%up	20%up>50	CB30%	CB50%	CBonly30%	300-350
β		0.17	0.179	0.5[3]	0.5[3]	0.080	0.113	0.099	0.073
$Risk^S$	0.07	0.15	0.15	0.13[3]	0.14[3]	0.15	0.15	0.15	0.15
p(TAC^S<20)	-	0.20	0.21	0.17	0.19	0.05	0.08	0.05	0.03
$B^S_{tot,2036}$	320 [141,807]	212 [73,594]	210 [72,589]	240 [89,667]	222 [77,631]	227 [68,630]	219 [71,618]	222 [68,620]	230 [69,633]
$B^S_{west,2036}$	138 [29,506]	89 [16,371]	89 [16,370]	99 [17,407]	93 [16,377]	93 [13,393]	92 [15,385]	92 [14,390]	93 [13,396]
$B^S_{south,2036}$	165 [69,424]	105 [33,309]	104 [32,308]	123 [43,360]	112 [35,335]	117 [34,337]	112 [35,322]	115 [35,331]	119 [35,340]
$\frac{B^S_{tot,2036}}{B^S_{tot,2015}}$	4.2 [1.3,21.3]	2.7 [0.7,15.2]	2.7 [0.7,15.1]	3.1 [0.8,17.3]	2.8 [0.7,16.2]	2.9 [0.7,16.4]	2.8 [0.7,15.8]	2.8 [0.7,16.0]	2.9 [0.7,16.6]
$\frac{B^S_{west,2036}}{B^S_{west,2015}}$	3.1 [0.6,20.2]	2.0 [0.3,14.5]	2.0 [0.3,14.4]	2.2 [0.3,16.6]	2.0 [0.3,15.5]	2.0 [0.2,15.5]	2.0 [0.3,15.1]	2.0 [0.3,15.3]	2.1 [0.2,15.4]
$\frac{B^S_{south,2036}}{B^S_{south,2015}}$	0.9 [0.4,2.4]	0.6 [0.2,1.7]	0.6 [0.2,1.6]	0.7 [0.2,1.9]	0.6 [0.2,1.8]	0.7 [0.2,1.8]	0.6 [0.2,1.7]	0.6 [0.2,1.8]	0.7 [0.2,1.8]
$B^S_{tot,min}$	159 [92,234]	96 [39,168]	95 [38,166]	109 [49,180]	99 [41,170]	103 [37,183]	100 [42,175]	102 [42,183]	103 [38,185]
$B^S_{west,min}$	31 [8,72]	20 [4,54]	20 [4,56]	21 [4,56]	20 [4,54]	20 [3,54]	20 [3,54]	20 [3,54]	20 [3,54]
$B^S_{south,min}$	78 [38,135]	41 [10,89]	40 [9,88]	51 [20,100]	44 [14,91]	49 [15,98]	46 [15,95]	48 [16,99]	49 [16,99]
C^S_{tot}	0 [0,28]	77 [10,200]	80 [10,200]	40 [10,145]	60 [10,186]	51 [22,151]	61 [14,192]	53 [22,170]	50 [24,141]
Med C^S_{tot}[4]	0 [0,0]	78 [27,140]	82 [27,145]	40 [24,74]	60 [30,104]	53 [36,88]	62 [34,108]	53 [36,95]	50 [43,83]
C^S_{west}	0 [0,24]	51 [9,154]	52 [9,155]	33 [9,98]	48 [9,119]	44 [16,114]	47 [12,135]	44 [16,126]	44 [17,108]
C^S_{south}	0 [0,4]	14 [0,95]	15 [0,98]	5 [0,52]	9 [0,77]	9 [0,50]	11 [0,67]	10 [0,57]	9 [0,45]
$\frac{C^S_{west}}{C^S_{tot}}$	-	0.80 [0.35,1.0]	0.80 [0.35,1.0]	0.87 [0.51,1.0]	0.83 [0.41,1.0]	0.83 [0.44,1.0]	0.82 [0.42,1.0]	0.82 [0.44,1.0]	0.83 [0.45,1.0]
ByC^S_{tot}	0 [0,5.2]	10.6 [1.4,58.2]	10.6 [1.4,58.2]	10.2 [1.3,57.6]	10.4 [1.4,57.8]	10.3 [1.4,57.9]	10.5 [1.4,57.9]	10.4 [1.4,57.9]	10.3 [1.4,57.8]
ByC^S_{west}	0 [0,5.2]	10.6 [1.4,58.1]	10.6 [1.4,58.1]	10.2 [1.3,57.6]	10.4 [1.4,57.8]	10.3 [1.4,57.9]	10.5 [1.4,57.9]	10.4 [1.4,57.9]	10.3 [1.4,57.8]
ByC^S_{south}	0 [0,0]	0 [0,0.0]	0 [0,0.0]	0 [0,0.0]	0 [0,0.0]	0 [0,0.0]	0 [0,0.0]	0 [0,0.0]	0 [0,0.0]
AAV^S_{tot}[5]	-	0.64 [0.3,0.89]	0.65 [0.29,0.9]	0.26 [0.20,0.5]	0.2 [0.2,0.76]	0.3 [0.20,0.3]	0.47 [0.25,0.5]	0.3 [0.22,0.43]	0.26 [0.13,0.3]
AAV^S_{west}	-	0.57 [0.31,0.83]	0.58 [0.31,0.84]	0.34 [0.22,0.53]	0.42 [0.22,0.71]	0.28 [0.18,0.4]	0.4 [0.24,0.51]	0.32 [0.2,0.47]	0.27 [0.16,0.39]
AAV^S_{south}	-	0.96 [0.72,1.0]	0.96 [0.71,1.0]	0.88 [0.52,1.0]	0.94 [0.59,1.0]	0.72 [0.45,1.0]	0.8 [0.55,1.0]	0.77 [0.49,1.0]	0.71 [0.44,1.0]

[3] The same risk is achieved for control parameters β>0.5.
[4] This gives the median and 90%ile of the 1000 median catches.
[5] Median and 90%ile of $AAV^b_y = \left(C^{S,b}_{tot,y} - C^{S,b}_{tot,y-1}\right)/C^{S,b}_{tot,y-1}$

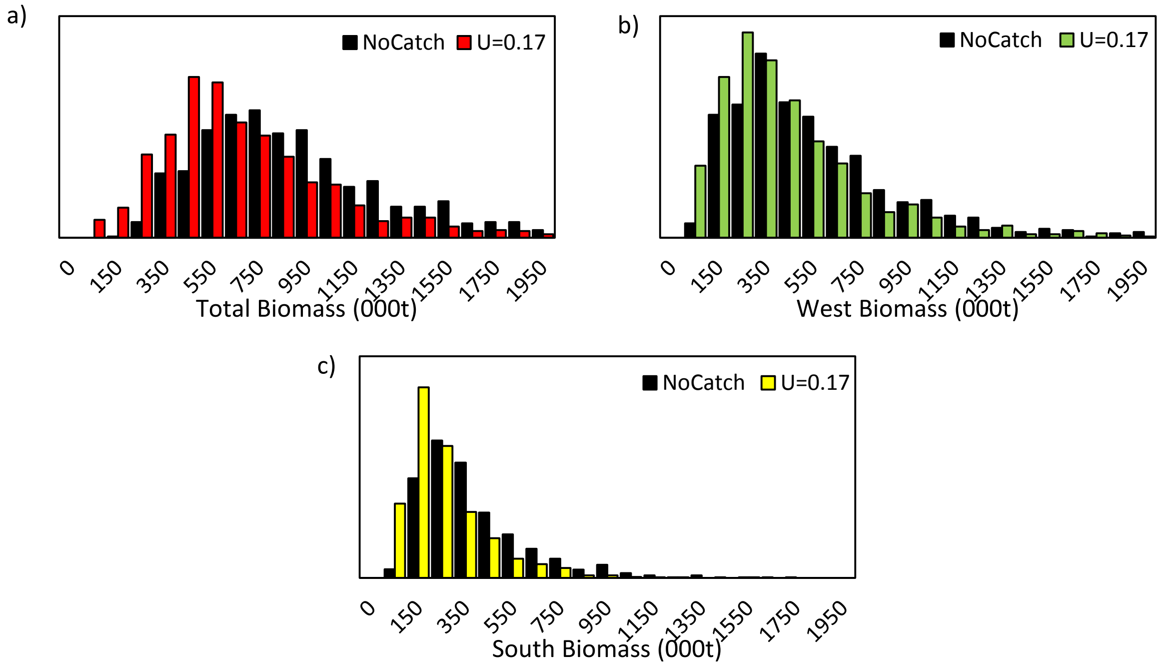

Figure 1. Histograms of a) total, b) west and c) south sardine November biomass under a no-catch scenario and a scenario with a constant harvest proportion of 17% of the survey estimated biomass.

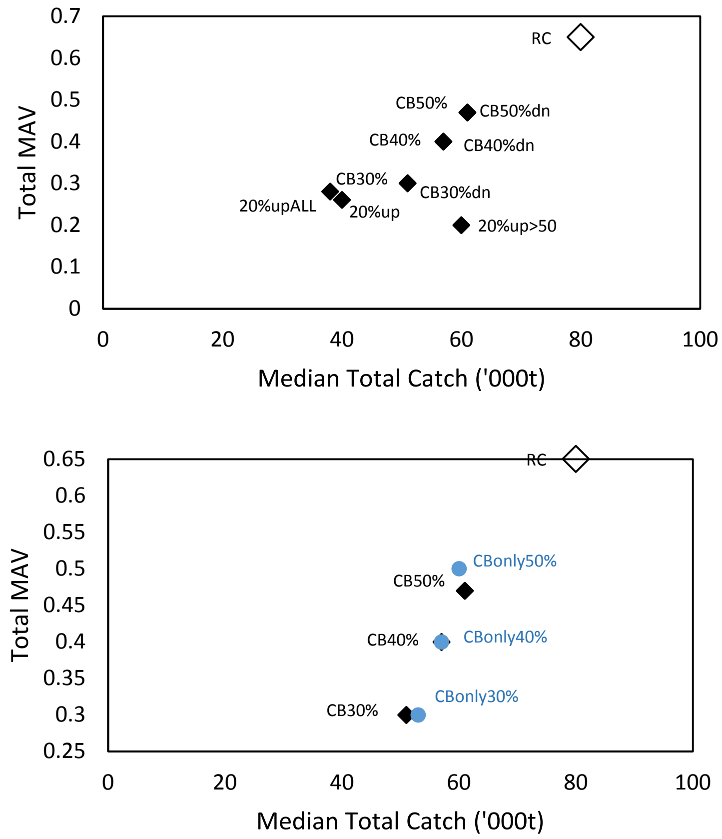

Figure 2. The MAV in the total directed sardine catch plotted against median total directed sardine catch, tuned to risk of <0.15 for all HCRs. The data labels correspond with those given on pages 1-2. The lower panel compares two alternative methods of restricting the increase or decrease in the TAC when survey estimated biomass is below the Critical Biomass threshold.

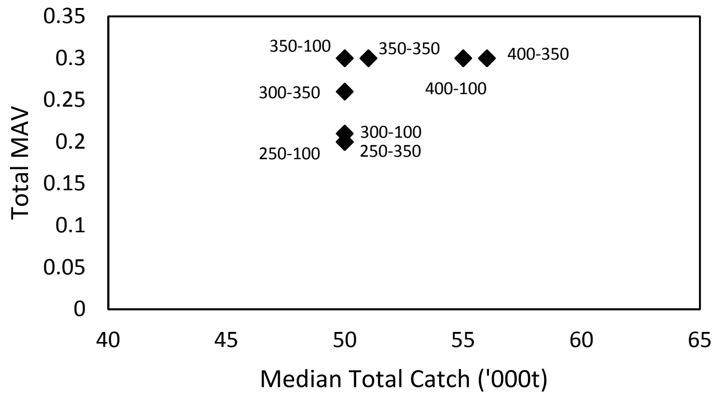

Figure 3. The MAV in the total directed sardine catch plotted against median total directed sardine catch, tuned to risk of <0.15 for all HCRs. Results are shown comparing alternative Critical Biomass thresholds (first number in label) and alternative linear smoothing ranges (second number in label). For example, 300-100 denotes a Critical Biomass threshold of 300 000t and linear smoothing from 300 000t to 400 000t. All cases (vi and ix - xv from pages 1-2) have the restriction of no more than 30% increase/decrease in TACs when the survey estimate of biomass is less than the critical biomass threshold.

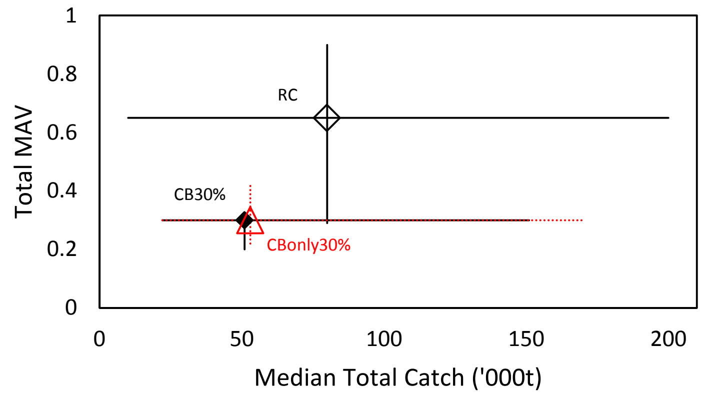

Figure 4. The median and 90% probability intervals of MAV in the total directed sardine catch and median total directed sardine catch, tuned to risk of <0.15. The data labels correspond with those given on pages 1-2.

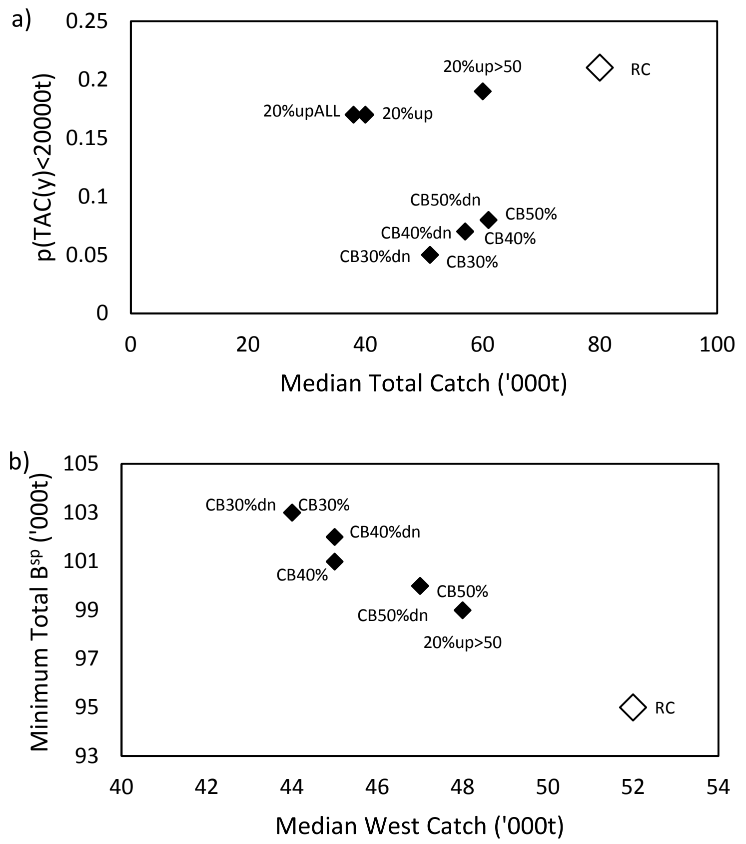

Figure 5. The proportion of times a) the total directed sardine TAC is < 20 000t plotted against median total directed sardine catch, and b) the minimum total spawner biomass plotted against median west coast directed sardine catch, tuned to risk of <0.15 for all HCRs. The data labels correspond with those given on pages 1-2.

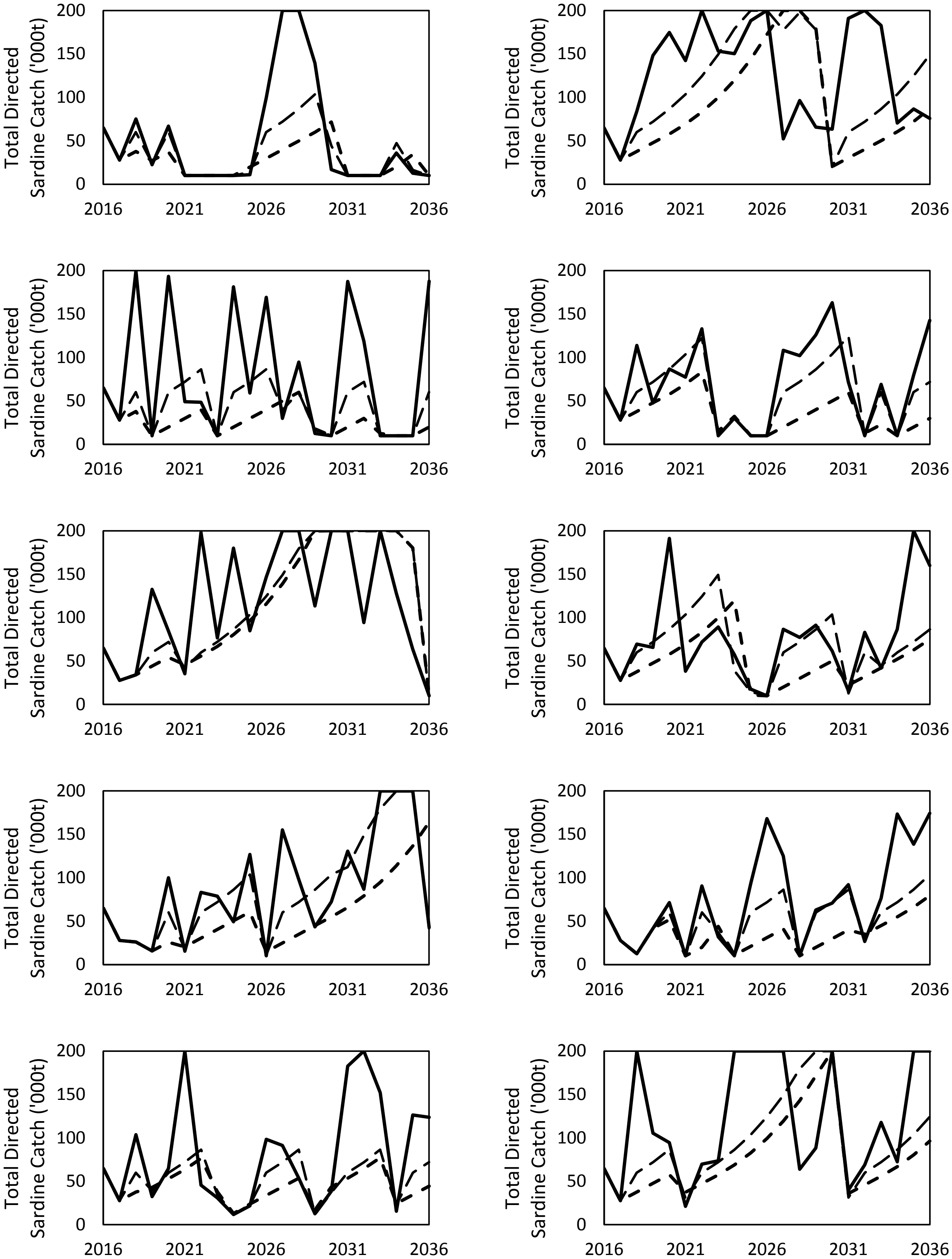

Figure 6. Trajectories of total directed sardine catch from 10 simulations. Trajectories are shown for the Reference Case sardine HCR (solid), with $\beta = 0.179$, and the HCR with a 20%[6] constraint on inter-annual increases in TACs when $B^{obs,S}_{y-1,N} \geq B^{S}_{crit}$ (*20%up*, dashed line), with $\beta = 0.5$, and with this latter restriction only applying to the maximum of the previous year's TAC and the stable TAC of 50 000t (20%up>50, long dashed line), with $\beta = 0.5$.

[6] The constraint on increasing TAC is the maximum of 20% of TAC_{y-1} and 10 000t, applied in the absence of the Critical Biomass metarule.

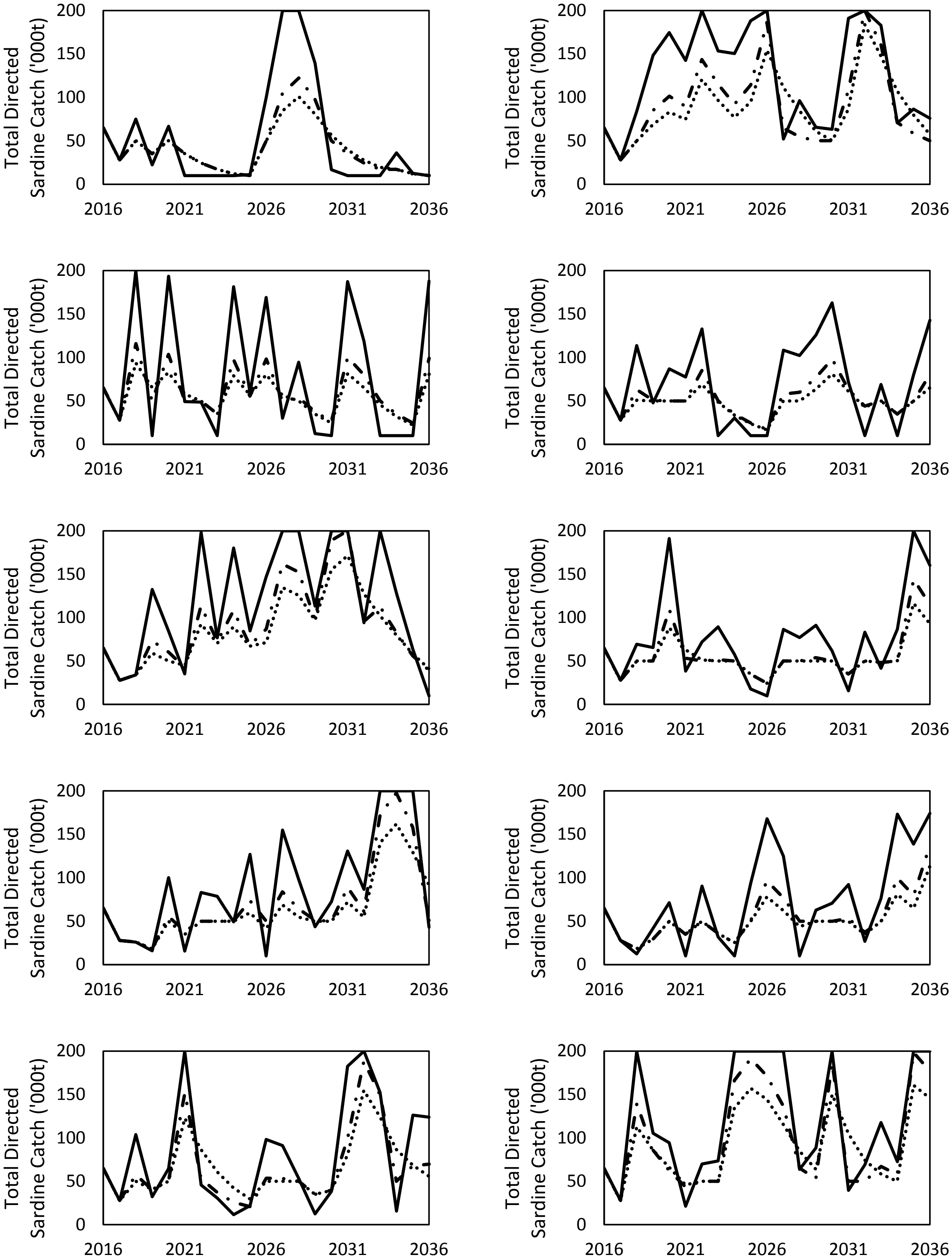

Figure 7. Trajectories of total directed sardine catch from 10 simulations. Trajectories are shown for the Reference Case sardine HCR (solid), with $\beta = 0.179$, the HCR with a 30% constraint on changes in the TAC if $B_{y-1,N}^{obs,S} < B_{crit}^{S}$ (*CB30%*, dotted line), with $\beta = 0.08$, and the HCR with a 30% constraint on changes in the TAC if $B_{y-1,N}^{obs,S} < B_{crit}^{S}$, but the maximum decrease constraint applies to the minimum of TAC_{y-1}^{S} or $c_{min}^{S}/(1 - c_{crit}^{S})$ (*CBonly30%*, dashed line), with $\beta = 0.099$.