Sardine projections based on constant catch scenarios

C.L. de Moor*

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

Short- and long-term projections of the sardine resource are considered under alternative constant catch scenarios. Recruitment to the west component is estimated to be the primary driver of the population as a whole, and thus management considerations focus on the west component. The west component effective spawner biomass is estimated to be of a similar size to that estimated a year ago, but increases to this biomass are projected to be substantially less optimistic than those projected a year ago, while it is possible that the west component total biomass may decrease between November 2019 to November 2020, even under a no catch scenario.

Introduction

In December 2018 the Small Pelagic Scientific Working Group (SWG-PEL) declared that Exceptional Circumstances for the sardine resource as a result of (among other things) the very low survey estimate of sardine abundance in November 2018. Any Total Allowable Catch/Bycatches (TAC/Bs) that would have been recommended under OMP-18 have thus been set aside. To assist Right Holders who typically catch sardine while they are available on the south coast early in the year, an interim directed >14cm sardine TAC of 10 000t was recommended by the SWG-PEL (DFFE 2020a), with no more than 3 000t of this amount to be caught west of Cape Agulhas. An interim >14cm sardine TAB with round herring and anchovy of 2 650t (DFFE 2020b), an interim ≤14cm sardine TAB with directed sardine catches of 200t, an interim ≤14cm sardine TAB with round herring and an initial ≤14cm sardine TAB with anchovy fishing of 5 500t have also been approved (DFFE 2020a).

An updated assessment of the sardine resource has recently been undertaken (de Moor 2020b). This document provides short- and medium-term projections of the sardine resource based on this updated assessment to assess whether increases in the directed sardine TAC and/or sardine TABs could be scientifically justified, and if so, to what extent the catch limits could be increased without likely substantially negatively impacting the resource.

Methods

The model used for projections was based on the most recent updated assessment of the sardine resource (de Moor 2020a,b). Most of the population dynamics were similar to those assumed historically (Appendix A) except that catch was modelled to be taken in a single pulse during the year. Other assumptions made during these projections are detailed in Appendix A.

The assessment provided a single set of model parameters at the joint posterior mode, including numbers-at-length (age) and biomass in November 2019 from which projections were initiated. The AD Model Builder simulated likelihood profile for the model predicted November survey biomass in 2019 was unrealistically narrow when compared to the Hessian-based SE and thus variability in the starting point for projections was not incorporated identically to de Moor (2019b). Rather, initial variability was more realistically incorporated by sampling from normal distributions using the Hessian-based CV of the model predicted November survey biomass in 2019:

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

$N^{S,i}_{j,2019,a} = N^{S}_{j,2019,a} e^{0.524\omega_{j,i} - 0.5*0.524^2}$ for $1 \leq a \leq 5^+$ and $B^{S,i}_{j,2019} = B^{S}_{j,2019} e^{0.524\omega_{j,i} - 0.5*0.524^2}$, for $j = 1$[1], and

$N^{S,i}_{j,2019,a} = N^{S}_{j,2019,a} e^{0.345\omega_{j,i} - 0.5*0.345^2}$ for $1 \leq a \leq 5^+$ and $B^{S,i}_{j,2019} = B^{S}_{j,2019} e^{0.345\omega_{j,i} - 0.5*0.345^2}$, for $j = 2$.

For these analyses, 500 simulations i were run. Sensitivity to the variability in this starting point was also tested (see below).

Variability in the projections (over and above the variability in the starting point) was additionally included by running the 500 simulations with different future recruitment each year (see Appendix A). Baseline future recruitment was assumed to be according to the recent 'regime' (Appendix A) in line with the relatively high autocorrelation in the historical time series of recruitment (Figure 1). Sensitivity to this assumption was tested by assuming that the future expectation for recruitment would be according to the Hockey Stick stock recruitment relationship or the Beverton Holt stock recruitment relationship (both of which show little dependence of recruitment on spawner biomass) (see below).

A single baseline model was considered, based on de Moor (2020b). The 'old' model and 'alternative November 2018 survey length frequency' models considered by de Moor (2019b) when providing short- and medium-term projections to inform the 2019 sardine TAC/TABs are no longer applicable (de Moor and Coetzee 2019, de Moor *et al*. 2019, Die *et al*. 2019).

Sensitivity of results to the following alternative assumptions was examined:

i) $\mathrm{move}_{\mathrm{y},1} = 0.2$: The proportion of 1-year old sardine moving from the west to the south coast in November each year was 0.2 in all future years. Baseline has $\mathrm{move}_{\mathrm{y},1} = 0.4$.

ii) $\mathrm{move}_{\mathrm{y},1} = 0.6$: The proportion of 1-year old sardine moving from the west to the south coast in November each year was 0.6 in all future years. Baseline has $\mathrm{move}_{\mathrm{y},1} = 0.4$.

iii) HS: Future recruitment was generated from a Hockey-Stick stock recruitment relationship fit to the historically estimated effective spawning biomass and recruitment time series (excluding pulse years: Table 2 and Figure 14 of de Moor 2020b).

iv) BH: Future recruitment was generated from a Beverton Holt stock recruitment relationship fit to the historically estimated effective spawning biomass and recruitment time series (excluding pulse years: Table 2 and Figure 14 of de Moor 2020b).

v) No Init Var: No variability in the starting point.

vi) Srec 14-18: Future recruitment to the south component was generated from that estimated for 2014-2018. Baseline future recruitment to the south component is generated from 2012-2016.

Sensitivity tests (i) – (iii) were also considered by de Moor (2019b). Sensitivity test (iv) is considered as the Beverton Holt stock recruitment relationship provided a (slightly) better fit to the estimated west component spawner-recruitment values than the Hockey Stick stock recruitment relationship (de Moor 2020b). Sensitivity test (v) considers the impact of the initial variability on the results, while (vi) considers the impact of using the less precise but more recent years in generating recruitment to the south component. The sensitivity tests of alternative stock weights-at-length and lower starting numbers-at-age considered by de Moor (2019b) are no longer applicable.

[1] The effective spawning biomass in 2019 was similarly adjusted for the purpose of reporting statistics only.

Results and Discussion

The resource was first projected forward assuming no future catch. The starting level of abundance for these projections in November 2019 was similar to the level of west component effective spawner biomass as was estimated a year ago for November 2018 (de Moor 2020b, Figure 2). The updated assessment model conditioned to an updated and extended time series of data resulted in recruitment values from which future recruitments were drawn for these projections that were, on average, lower than those which were used by de Moor (2019b) (Table 1). The projected west component effective spawner biomass under a no catch scenario is therefore more pessimistic than was projected from a similar starting point a year ago (Figure 2, Tables 2 and 3). Figure 3a shows the one year projected additive change ("growth") in the west component effective spawner biomass. The contribution of 8% of the south component spawner biomass to west component effective spawner biomass is substantial (Figure 3a v 4a) given the currently estimated differential in biomasses between the two components. Figure 5a shows the one year projected additive change ("growth") in the west component total biomass. This could be taken to indicate the 'surplus' biomass in the population from which the catch in 2020 would be removed. Die *et al*. (2019) recommended that the proportion of the resource growth assigned to recovery of a depleted population, rather than to the fishery, should be higher the more depleted the population. However, Figure 5a indicates that there is a notable chance of the west component total biomass decreasing even under a no catch scenario. On the other hand, the projections indicate a high probability of an increase in the south component abundance between November 2019 and 2020 under a no catch scenario (Figures 3b, 4b and 5b).

The impact of fishing on the sardine population was considered for the immediate (1-year) future as follows:

i) The multiplicative change in effective spawning biomass from November 2019 to November 2020;
ii) The additive change (increase or decrease) in effective spawning biomass from November 2019 to November 2020;
iii) The additive change (increase or decrease) in total biomass from November 2019 to November 2020;
iv) The multiplicative change under alternative catch options relative to a no catch scenario; and
v) The probability of the west component effective spawning biomass in November 2020 being below that in November 2007 (the sardine risk threshold).

Tables 2 and 4 show the 5%iles, 20%iles and medians of (i)-(iv) above for the west component under alternative catch options and models while Tables 3 and 5 show the same for the south component. Further results are given in Appendix B, including the west component results under $\mathrm{move}_{y,1} = 0.2$ and south component results under $\mathrm{move}_{y,1} = 0.6$. Table 6a gives the 20%ile of the multiplicative 1-year change in west component effective spawner biomass under alternative catch options relative to the 20%ile of the multiplicative 1-year change under a no catch option. This is the statistic that was primarily considered when recommending sardine catch limits for 2019 (DAFF 2019). Table 6b gives the more reliable statistic of the 20%ile of the multiplicative 1-year change in west component effective spawner biomass under alternative catch options relative to a no catch option.

The impact on the resource naturally increases with increasing catch alternatives (Tables 2 to 5). While many of the catch options listed in Tables 2 and 4 have an "impact" on the west component (multiplicative 1-year change in effective spawning biomass under catch relative to no catch) that is less than that considered in 2019 (i.e. less than 12% or greater

than 0.88 at the 20%ile), the increase (additive or multiplicative) in effective spawner biomass is projected to be substantially lower than that projected a year ago and it is likely that the total west component biomass in November 2020 will remain similar to or decrease from that estimated in November 2019. As expected, the west component is projected to become larger under $\mathrm{move}_{y,1} = 0.2$ and lower under $\mathrm{move}_{y,1} = 0.6$ than that projected under the baseline model. The wider range of projected recruitments from the Hockey Stick and Beverton Holt alternatives result in more optimistic results for the west component at the median level and less optimistic results at the 5%ile than under the baseline model (see, also, Figure 8). The alternative south component recruitment model has some positive impact on the west component through its contribution to the effective spawning biomass.

Many of the catch options listed in Tables 3 and 5 have an "impact" on the south component that is greater than that considered in 2019. However, the range of projected 1-year change in effective spawner biomass and total biomass is much narrower than that projected a year ago. In particular, the south component effective spawner biomass is projected to increase under all the catch options considered, even at the 5%ile of the distribution. The south component total biomass is also projected to increase (by 10 000t at the 5%ile) under a no catch scenario, although there is still some small chance of the south component biomass decreasing under the catch alternatives considered. As expected, the south component is projected to become smaller under $\mathrm{move}_{y,1} = 0.2$ and larger under $\mathrm{move}_{y,1} = 0.6$ than that projected under the baseline model. The wider range of projected recruitments from the Hockey Stick and Beverton Holt alternatives result in more optimistic results for the south component at the median level and less optimistic results at the 5%ile than under the baseline model (see, also, Figure 9). As expected, the south component projections are more optimistic under the alternative south component recruitment model.

There is a relatively small probability of the sardine west component effective spawner biomass falling below the risk threshold by November 2020, but this probability increases in the longer-term (Table 7).

Figures 6-11 show both the short- and longer-term impact of alternative catch options. Under these projection assumptions, the resource is expected to remain low compared to historical levels, but with a median increase in the west component effective spawner biomass compared to the 2018-2019 level. While a greater small sardine bycatch does not appear to have a substantial impact on the 1-year statistics considered in (i)-(v) above, and shown in the Tables (as juveniles have little impact on these statistics), the larger impact of a larger bycatch resulting in fewer adults in subsequent years can be seen by comparing the alternatives of 36 050t (with 7 400t bycatch) to 35 050t (with 10 400t bycatch) in Figure 10.

References

DAFF 2019. Final sardine TAC/TAB recommendation of the small pelagic scientific working group for the sustainable management of small pelagic resources for the 2019 season. DAFF: Branch Fisheries Document FISHERIES/2019/APR/SWG-PEL/13.

de Moor CL. 2019a. Revision to the Initial Assessment of the South African sardine resource using data from 1984-2018. DAFF: Branch Fisheries Document FISHERIES/2019/MAR/SWG-PEL/06.

de Moor CL. 2019b. Sardine projections based on constant catch scenarios. DAFF: Branch Fisheries Document FISHERIES/2019/APR/SWG-PEL/07.

de Moor CL. 2020a. Final baseline assessment of the South African sardine resource using data from 1984-2018. DEA: Branch Fisheries Document FISHERIES/2020/MAR/SWG-PEL/28.

de Moor CL. 2020b. Baseline assessment of the South African sardine resource using data from 1984-2019. DEA: Branch Fisheries Document FISHERIES/2020/APR/SWG-PEL/30.

de Moor CL and Coetzee JC. 2019. A summary of the method used to provide 2019 catch limit advice for South African sardine. MARAM International Stock Assessment Workshop Document MARAM/IWS/2019/Sardine/P2.

de Moor CL, Coetzee JC and Butterworth DS. 2019. Uncertainties and associated concerns relating to using short-term projections to advise on the 2020 sardine TAC and TABs. MARAM International Stock Assessment Workshop , 2-5 December 2019, Cape Town, Document MARAM/IWS/2019/Sardine/P3.

DFFE 2020a. Revised interim initial recommendation of the small pelagic scientific working group for the sustainable management of small pelagic resources for the season 2020. DFFE: Branch Fisheries Document FISHERIES/2020/FEB/SWG-PEL/11.

DFFE 2020b. Ad hoc recommendation of the small pelagic scientific working group to increase the >14cm sardine TAB with round herring and anchovy. DFFE: Branch Fisheries Document FISHERIES/2020/APR/SWG-PEL/34.

Die DJ, Punt AE, Tiedemann R, Waples R and Wilberg MJ. 2019. International Review Panel Report for the 2018 International Fisheries Stock Assessment Workshop. MARAM International Stock Assessment Workshop, 2-5 December 2019, Cape Town, Document MARAM/IWS/2019/General/5.

Szuwalski CS, Britten GL, Licandeo R, Amoroso RO, Hilborn R and Walters C. 2019. Global forage fish recruitment dynamics: A comparison of methods, time-variation, and reverse causality. Fisheries Research 214: 56-64.

Table 1. The sardine November recruitment (in billions) estimated at the joint posterior mode in recent years by de Moor (2020) and de Moor (2019a). The values used by the baseline model for short-term projections to advise the 2019 TAC and TABs (de Moor 2019b) are given in *italics* while the values used by this baseline model for short-term projections to advise the 2020 TAC and TABs are given in **bold**.

	West component November recruitment		South component November recruitment	
	de Moor (2019a)	de Moor (2020b)	de Moor (2019a)	de Moor (2020b)
2012	19.9	12.7	1.1	**0.6**
2013	*7.0*	5.8	*3.2*	**5.5**
2014	*13.6*	**11.6**	*7.5*	**2.3**
2015	*7.1*	**7.0**	*2.9*	**1.8**
2016	*15.3*	**8.1**	*14.4*	**8.0**
2017	*32.3*	**3.5**	*23.8*	18.5
2018		**14.1**		24.5

Table 2. The 5%ile, 20%ile and 50%ile of the multiplicative and additive change in **west component effective spawning biomass** and additive change in **west component total biomass** from November 2019 to 2020 under alternative catch options and the alternative models considered. The 5%ile, 20%ile and 50%ile of the multiplicative change under the catch options relative to the no catch option are also given. Grey cells indicate cases for which the selectivity function needed modification to enable the catch to be taken; the percentage of times this occurred for ages 2 and below (S2) and ages 1 and below (S1) are given. The percentage of times the full bycatch could not be realised (By) or the full catch could still not be realised after selectivity was modified (C) are also given. These statistics (S2, S1, By and C) are given for 2020 only, although such problems in realising the catch are also projected to occur in subsequent years. The top two rows give the comparative statistics under the zero catch and 2019 TAB/B alternatives as estimated by de Moor (2019b).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ						
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	S2	S1	C	By
2019	0	0	0	0	2.20	2.67	3.40	25	35	50										
	23	6.5	7	9.5	1.88	2.36	3.09	19	28	43				0.86	0.88	0.90				
Baseline	0	0	0	0	1.25	1.55	2.14	9	15	21	-35	-8	17				0	0	0	0
	18.35	5.65	7	5.7	1.21	1.49	2.03	7	13	19	-41	-15	11	0.94	0.95	0.96	0.2	0	0	0
	27.05	5.65	14	7.4	1.19	1.47	2.01	7	13	19	-42	-16	10	0.92	0.94	0.95	0.2	0	0	0
	32.05	12.65	12	7.4	1.15	1.43	1.94	6	12	18	-46	-19	6	0.89	0.90	0.92	11.6	1.4	0	0
	36.05	14.65	14	7.4	1.14	1.42	1.92	5	11	17	-47	-21	5	0.87	0.89	0.91	17.6	2.4	0	0
	40.05	16.65	16	7.4	1.13	1.40	1.89	5	11	17	-48	-22	4	0.86	0.88	0.90	29.6	4.4	0	0
	35.05	14.65	10	10.4	1.14	1.41	1.91	5	11	17	-49	-22	3	0.87	0.89	0.91	18.6	2.6	0	0
$move_{y,1}$ =0.6	0	0	0	0	1.01	1.30	1.84	0	8	15	-83	-48	-17				0	0	0	0
	18.35	5.65	7	5.7	0.97	1.26	1.76	-1	7	14	-88	-53	-21	0.95	0.95	0.96	0.2	0	0	0
	27.05	5.65	14	7.4	0.96	1.24	1.74	-2	6	13	-88	-53	-22	0.93	0.94	0.95	0.2	0	0	0
	32.05	12.65	12	7.4	0.94	1.21	1.69	-2	6	13	-91	-56	-24	0.90	0.91	0.93	11.6	1.4	0	0
	36.05	14.65	14	7.4	0.93	1.19	1.67	-3	5	12	-91	-56	-25	0.88	0.90	0.92	17.6	2.4	0	0
	40.05	16.65	16	7.4	0.92	1.17	1.65	-3	5	12	-92	-57	-26	0.87	0.89	0.91	29.6	4.4	0	0
	35.05	14.65	10	10.4	0.93	1.19	1.67	-3	5	12	-93	-58	-26	0.88	0.90	0.92	18.6	2.6	0	0
Hockey Stick	0	0	0	0	1.39	1.81	2.64	12	18	28	-22	15	65				0	0	0	0
	18.35	5.65	7	5.7	1.33	1.74	2.53	10	17	26	-28	9	58	0.94	0.95	0.96	0.6	0	0	0
	27.05	5.65	14	7.4	1.32	1.72	2.50	9	16	26	-29	8	57	0.92	0.94	0.96	0.6	0	0	0
	32.05	12.65	12	7.4	1.29	1.68	2.44	8	15	25	-33	4	53	0.88	0.91	0.93	12.2	2.2	0	0
	36.05	14.65	14	7.4	1.27	1.66	2.41	8	15	24	-34	3	52	0.86	0.90	0.93	16.4	3.6	0	0
	40.05	16.65	16	7.4	1.26	1.64	2.39	7	14	24	-35	2	51	0.85	0.89	0.92	22.4	5.0	0.2	0
	35.05	14.65	10	10.4	1.27	1.66	2.40	7	14	24	-35	1	50	0.86	0.89	0.92	16.4	3.8	0	0

Table 2 (continued).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ						
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	S2	S1	C	By
Beverton Holt	0	0	0	0	1.35	1.73	2.47	11	17	26	-21	10	59				0	0	0	0
	18.35	5.65	7	5.7	1.31	1.66	2.36	9	16	24	-28	3	52	0.93	0.95	0.96	0.6	0	0	0
	27.05	5.65	14	7.4	1.29	1.64	2.35	9	15	24	-29	2	51	0.92	0.94	0.95	0.6	0	0	0
	32.05	12.65	12	7.4	1.25	1.59	2.29	7	14	23	-33	-2	46	0.88	0.90	0.93	12.4	2.2	0	0
	36.05	14.65	14	7.4	1.23	1.57	2.26	7	14	22	-34	-3	45	0.86	0.89	0.92	17.0	3.6	0	0
	40.05	16.65	16	7.4	1.22	1.55	2.23	6	13	22	-35	-4	44	0.84	0.88	0.91	23.8	5.0	0	0
	35.05	14.65	10	10.4	1.23	1.57	2.25	7	13	22	-36	-5	43	0.86	0.89	0.92	17.4	3.8	0	0.2
No Init Var	0	0	0	0	1.76	1.88	1.95	16	19	21	-16	-9	10				0	0	0	0
	18.35	5.65	7	5.7	1.67	1.79	1.87	14	17	19	-22	-16	4	0.95	0.95	0.96	0	0	0	0
	27.05	5.65	14	7.4	1.65	1.77	1.85	14	17	18	-23	-17	3	0.94	0.94	0.95	0	0	0	0
	32.05	12.65	12	7.4	1.59	1.72	1.79	13	15	17	-27	-21	-1	0.91	0.91	0.92	0	0	0	0
	36.05	14.65	14	7.4	1.57	1.70	1.77	12	15	17	-28	-22	-2	0.89	0.90	0.91	0	0	0	0
	40.05	16.65	16	7.4	1.55	1.68	1.75	12	15	16	-29	-23	-3	0.88	0.89	0.90	0	0	0	0
	35.05	14.65	10	10.4	1.57	1.69	1.77	12	15	17	-30	-24	-4	0.89	0.90	0.91	0	0	0	0
14-18 South Rec	0	0	0	0	1.26	1.60	2.20	10	16	22	-35	-8	17				0	0	0	0
	18.35	5.65	7	5.7	1.23	1.53	2.10	8	14	20	-41	-15	11	0.94	0.95	0.96	0.2	0	0	0
	27.05	5.65	14	7.4	1.22	1.51	2.07	7	14	20	-42	-16	10	0.92	0.94	0.95	0.2	0	0	0
	32.05	12.65	12	7.4	1.18	1.47	2.01	6	13	19	-46	-19	6	0.89	0.91	0.92	11.6	1.4	0	0
	36.05	14.65	14	7.4	1.16	1.46	1.99	6	12	18	-47	-21	5	0.87	0.89	0.91	17.6	2.4	0	0
	40.05	16.65	16	7.4	1.14	1.44	1.96	5	12	18	-48	-22	4	0.86	0.88	0.90	29.6	4.4	0	0
	35.05	14.65	10	10.4	1.16	1.46	1.98	6	12	18	-49	-22	3	0.87	0.89	0.91	18.6	2.6	0	0

Table 3. The 5%ile, 20%ile and 50%ile of the multiplicative and additive change in **south component effective spawning biomass** and additive change in **south component total biomass** from November 2019 to November 2020 under alternative catch options and the alternative models considered. The 5%ile, 20%ile and 50%ile of the multiplicative change under the catch options relative to the no catch option are also given. There were no problems in the scenarios tested being able to realise the catch from the south component. The top two rows give the comparative statistics under the zero catch and 2019 TAB/B alternatives as estimated by de Moor (2019b).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ		
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile
2019	0	0	0	0	0.45	1.05	1.55	-70	6	70						
	23	6.5	7	9.5	0.44	1.01	1.51	-72	1	65				0.96	0.97	0.97
Baseline	0	0	0	0	1.27	1.31	1.39	43	53	65	10	42	79			
	18.35	5.65	7	5.7	1.25	1.29	1.36	38	48	60	-1	31	68	0.97	0.97	0.98
	27.05	5.65	14	7.4	1.23	1.27	1.34	35	45	57	-7	25	62	0.94	0.95	0.96
	32.05	12.65	12	7.4	1.23	1.27	1.33	34	44	56	-9	23	61	0.94	0.95	0.96
	36.05	14.65	14	7.4	1.22	1.26	1.32	33	43	55	-11	21	58	0.93	0.94	0.95
	40.05	16.65	16	7.4	1.22	1.25	1.32	31	41	54	-14	18	56	0.92	0.93	0.95
	35.05	14.65	10	10.4	1.23	1.27	1.34	35	45	57	-9	23	60	0.94	0.95	0.96
$\text{move}_{y,1}=0.2$	0	0	0	0	1.24	1.26	1.31	34	42	52	-18	6	35			
	18.35	5.65	7	5.7	1.22	1.24	1.28	30	38	47	-27	-3	27	0.97	0.97	0.98
	27.05	5.65	14	7.4	1.20	1.22	1.26	26	35	44	-33	-9	21	0.94	0.95	0.96
	32.05	12.65	12	7.4	1.20	1.22	1.26	26	35	44	-33	-9	21	0.94	0.95	0.96
	36.05	14.65	14	7.4	1.19	1.22	1.25	25	34	43	-35	-11	19	0.93	0.95	0.96
	40.05	16.65	16	7.4	1.19	1.21	1.25	24	32	42	-37	-13	17	0.93	0.94	0.95
	35.05	14.65	10	10.4	1.20	1.23	1.26	27	36	45	-32	-8	22	0.95	0.96	0.97
Hockey Stick	0	0	0	0	1.27	1.34	1.45	42	55	75	-2	37	109			
	18.35	5.65	7	5.7	1.24	1.31	1.42	37	50	69	-13	26	98	0.97	0.97	0.98
	27.05	5.65	14	7.4	1.22	1.28	1.39	34	46	66	-19	20	91	0.94	0.95	0.97
	32.05	12.65	12	7.4	1.22	1.28	1.39	33	46	65	-21	18	90	0.94	0.95	0.96
	36.05	14.65	14	7.4	1.21	1.27	1.38	32	44	64	-23	16	88	0.93	0.95	0.96
	40.05	16.65	16	7.4	1.21	1.26	1.37	31	43	63	-26	13	85	0.92	0.94	0.95
	35.05	14.65	10	10.4	1.22	1.28	1.39	34	46	66	-21	18	90	0.94	0.95	0.97

Table 3 (continued).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ		
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile
Beverton Holt	0	0	0	0	1.27	1.33	1.42	41	53	72	-5	31	91			
	18.35	5.65	7	5.7	1.24	1.30	1.39	36	48	67	-16	20	80	0.97	0.97	0.98
	27.05	5.65	14	7.4	1.22	1.27	1.36	33	44	63	-22	14	73	0.94	0.95	0.96
	32.05	12.65	12	7.4	1.22	1.27	1.36	32	44	63	-23	12	72	0.94	0.95	0.96
	36.05	14.65	14	7.4	1.21	1.27	1.35	31	42	62	-26	10	69	0.93	0.94	0.96
	40.05	16.65	16	7.4	1.20	1.26	1.34	29	41	60	-29	7	67	0.92	0.94	0.95
	35.05	14.65	10	10.4	1.22	1.27	1.36	33	44	63	-24	12	71	0.94	0.95	0.96
No Init Var	0	0	0	0	1.35	1.36	1.39	59	61	65	32	48	76			
	18.35	5.65	7	5.7	1.32	1.33	1.36	53	56	60	21	37	65	0.98	0.98	0.98
	27.05	5.65	14	7.4	1.29	1.31	1.33	50	52	57	14	31	58	0.96	0.96	0.96
	32.05	12.65	12	7.4	1.29	1.31	1.33	49	52	56	13	30	57	0.96	0.96	0.96
	36.05	14.65	14	7.4	1.28	1.30	1.32	48	51	55	10	27	55	0.95	0.95	0.96
	40.05	16.65	16	7.4	1.27	1.29	1.32	46	49	54	8	24	52	0.95	0.95	0.95
	35.05	14.65	10	10.4	1.29	1.31	1.33	50	52	57	12	29	57	0.96	0.96	0.96
14-18 South Rec	0	0	0	0	1.28	1.36	1.48	47	59	80	22	61	143			
	18.35	5.65	7	5.7	1.26	1.33	1.44	42	54	75	11	50	132	0.97	0.97	0.98
	27.05	5.65	14	7.4	1.24	1.31	1.42	39	51	72	4	44	126	0.94	0.95	0.96
	32.05	12.65	12	7.4	1.24	1.31	1.42	38	50	71	3	43	124	0.94	0.95	0.96
	36.05	14.65	14	7.4	1.24	1.30	1.41	37	49	70	1	40	122	0.93	0.95	0.96
	40.05	16.65	16	7.4	1.23	1.29	1.40	36	48	68	-2	37	119	0.92	0.94	0.95
	35.05	14.65	10	10.4	1.24	1.31	1.42	39	51	71	2	42	124	0.94	0.96	0.96

Table 4. A repeat of Table 2, but for additional catch options.

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ						
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	S2	S1	C	By
2019	0	0	0	0	2.20	2.67	3.40	25	35	50										
	23	6.5	7	9.5	1.88	2.36	3.09	19	28	43				0.86	0.88	0.90				
Baseline	0	0	0	0	1.25	1.55	2.14	9	15	21	-35	-8	17				0	0	0	0
	32.05	11.65	13	7.4	1.16	1.44	1.95	6	12	18	-45	-19	7	0.89	0.91	0.92	0.09	0.01	0	0
	34.05	11.65	13	9.4	1.15	1.43	1.94	6	12	17	-47	-20	6	0.88	0.90	0.92	0.09	0.01	0	0
	34.05	13.65	13	7.4	1.15	1.43	1.93	5	12	17	-46	-20	6	0.88	0.90	0.91	0.14	0.02	0	0
	35.05	11.65	13	10.4	1.15	1.43	1.94	5	12	17	-47	-21	5	0.88	0.90	0.92	0.09	0.01	0	0
	36.05	13.65	13	9.4	1.14	1.42	1.92	5	11	17	-48	-21	5	0.87	0.89	0.91	0.15	0.02	0	0
	40.05	16.65	16	7.4	1.13	1.40	1.89	5	11	17	-48	-22	4	0.86	0.88	0.90	0.30	0.04	0	0
$move_{y,1}$ =0.6	0	0	0	0	1.01	1.30	1.84	0	8	15	-83	-48	-17				0	0	0	0
	32.05	11.65	13	7.4	0.94	1.21	1.70	-2	6	13	-90	-55	-24	0.90	0.92	0.93	0.09	0.01	0	0
	34.05	11.65	13	9.4	0.94	1.21	1.69	-3	6	13	-91	-56	-25	0.89	0.91	0.92	0.09	0.01	0	0
	34.05	13.65	13	7.4	0.94	1.20	1.68	-3	5	12	-91	-56	-24	0.89	0.91	0.92	0.14	0.02	0	0
	35.05	11.65	13	10.4	0.94	1.20	1.69	-3	5	13	-91	-57	-25	0.89	0.91	0.92	0.09	0.01	0	0
	36.05	13.65	13	9.4	0.93	1.19	1.67	-3	5	12	-92	-57	-25	0.88	0.90	0.92	0.15	0.02	0	0
	40.05	16.65	16	7.4	0.92	1.17	1.65	-3	5	12	-92	-57	-26	0.87	0.89	0.91	0.30	0.04	0	0
Hockey Stick	0	0	0	0	1.39	1.81	2.64	12	18	28	-22	15	65				0	0	0	0
	32.05	11.65	13	7.4	1.29	1.68	2.45	8	15	25	-32	5	54	0.88	0.91	0.94	0.10	0.02	0	0
	34.05	11.65	13	9.4	1.29	1.68	2.43	8	15	25	-33	4	52	0.88	0.91	0.93	0.10	0.02	0	0
	34.05	13.65	13	7.4	1.28	1.67	2.42	8	15	25	-33	4	53	0.87	0.90	0.93	0.14	0.03	0	0
	35.05	11.65	13	10.4	1.28	1.67	2.43	8	15	25	-34	3	52	0.88	0.91	0.93	0.10	0.02	0	0
	36.05	13.65	13	9.4	1.27	1.66	2.41	8	15	24	-34	2	51	0.87	0.90	0.93	0.15	0.03	0	0
	40.05	16.65	16	7.4	1.26	1.64	2.39	7	14	24	-35	2	51	0.85	0.89	0.92	0.22	0.05	0.002	0

Table 4 (continued).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ						
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	S2	S1	C	By
Beverton Holt	0	0	0	0	1.35	1.73	2.47	11	17	26	-21	10	59	1.00	1.00	1.00	0	0	0	0
	32.05	11.65	13	7.4	1.26	1.60	2.30	8	14	23	-32	-2	47	0.88	0.91	0.93	0.10	0.01	0	0
	34.05	11.65	13	9.4	1.25	1.59	2.29	7	14	23	-33	-3	46	0.87	0.90	0.93	0.10	0.01	0	0.002
	34.05	13.65	13	7.4	1.24	1.58	2.28	7	14	23	-33	-3	46	0.87	0.90	0.92	0.15	0.03	0	0
	35.05	11.65	13	10.4	1.25	1.58	2.28	7	14	23	-34	-3	45	0.87	0.90	0.93	0.10	0.01	0	0.002
	36.05	13.65	13	9.4	1.23	1.57	2.26	7	14	22	-34	-4	44	0.86	0.89	0.92	0.15	0.03	0	0.002
	40.05	16.65	16	7.4	1.22	1.55	2.23	6	13	22	-35	-4	44	0.84	0.88	0.91	0.24	0.05	0	0
No Init Var	0	0	0	0	1.76	1.88	1.95	16	19	21	-16	-9	10	1.00	1.00	1.00	0	0	0	0
	32.05	11.65	13	7.4	1.60	1.72	1.80	13	16	17	-26	-20	0	0.91	0.92	0.92	0	0	0	0
	34.05	11.65	13	9.4	1.59	1.72	1.79	13	15	17	-27	-21	-1	0.91	0.91	0.92	0	0	0	0
	34.05	13.65	13	7.4	1.58	1.71	1.78	13	15	17	-27	-21	-1	0.90	0.91	0.91	0	0	0	0
	35.05	11.65	13	10.4	1.59	1.71	1.79	13	15	17	-28	-22	-2	0.90	0.91	0.91	0	0	0	0
	36.05	13.65	13	9.4	1.57	1.70	1.78	12	15	17	-29	-22	-2	0.90	0.90	0.91	0	0	0	0
	40.05	16.65	16	7.4	1.55	1.68	1.75	12	15	16	-29	-23	-3	0.88	0.89	0.90	0	0	0	0
14-18 South Rec	0	0	0	0	1.26	1.60	2.20	10	16	22	-35	-8	17	1.00	1.00	1.00	0	0	0	0
	32.05	11.65	13	7.4	1.18	1.48	2.02	6	13	19	-45	-19	7	0.89	0.91	0.92	0.09	0.01	0	0
	34.05	11.65	13	9.4	1.18	1.47	2.01	6	13	19	-47	-20	6	0.89	0.91	0.92	0.09	0.01	0	0
	34.05	13.65	13	7.4	1.17	1.47	2.00	6	13	19	-46	-20	6	0.88	0.90	0.92	0.14	0.02	0	0
	35.05	11.65	13	10.4	1.17	1.47	2.00	6	13	19	-47	-21	5	0.88	0.90	0.92	0.09	0.01	0	0
	36.05	13.65	13	9.4	1.16	1.46	1.99	6	12	19	-48	-21	5	0.87	0.90	0.91	0.15	0.02	0	0
	40.05	16.65	16	7.4	1.14	1.44	1.96	5	12	18	-48	-22	4	0.86	0.88	0.90	0.30	0.04	0	0

Table 5. A repeat of Table 3, but for additional catch options.

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ		
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile
2019	0	0	0	0	0.45	1.05	1.55	-70	6	70						
	23	6.5	7	9.5	0.44	1.01	1.51	-72	1	65				0.96	0.97	0.97
Baseline	0	0	0	0	1.27	1.31	1.39	43	53	65	10	42	79			
	32.05	11.65	13	7.4	1.23	1.27	1.33	34	44	56	-9	23	60	0.94	0.95	0.96
	34.05	11.65	13	9.4	1.23	1.27	1.33	34	44	56	-10	22	59	0.93	0.95	0.96
	34.05	13.65	13	7.4	1.23	1.27	1.33	34	43	56	-10	22	59	0.93	0.95	0.96
	35.05	11.65	13	10.4	1.23	1.27	1.33	34	44	56	-10	22	59	0.93	0.95	0.96
	36.05	13.65	13	9.4	1.23	1.26	1.33	33	43	55	-11	21	58	0.93	0.94	0.96
	40.05	16.65	16	7.4	1.22	1.25	1.32	31	41	54	-14	18	56	0.92	0.93	0.95
$move_{y,1}$ =0.2	0	0	0	0	1.24	1.26	1.31	34	42	52	-18	6	35			
	32.05	11.65	13	7.4	1.20	1.22	1.26	26	34	44	-33	-9	20	0.94	0.95	0.96
	34.05	11.65	13	9.4	1.20	1.22	1.26	26	34	44	-34	-10	20	0.94	0.95	0.96
	34.05	13.65	13	7.4	1.20	1.22	1.26	26	34	43	-34	-10	20	0.94	0.95	0.96
	35.05	11.65	13	10.4	1.20	1.22	1.26	26	34	43	-34	-10	20	0.94	0.95	0.96
	36.05	13.65	13	9.4	1.20	1.22	1.26	26	34	43	-34	-10	20	0.94	0.95	0.96
	40.05	16.65	16	7.4	1.19	1.21	1.25	24	32	42	-37	-13	17	0.93	0.94	0.95
Hockey Stick	0	0	0	0	1.27	1.34	1.45	42	55	75	-2	37	109			
	32.05	11.65	13	7.4	1.22	1.28	1.38	33	45	65	-21	18	90	0.94	0.95	0.96
	34.05	11.65	13	9.4	1.22	1.28	1.38	33	45	65	-22	17	89	0.93	0.95	0.96
	34.05	13.65	13	7.4	1.21	1.28	1.38	33	45	65	-22	17	89	0.93	0.95	0.96
	35.05	11.65	13	10.4	1.22	1.28	1.38	33	45	65	-22	16	88	0.93	0.95	0.96
	36.05	13.65	13	9.4	1.21	1.28	1.38	32	45	65	-23	16	88	0.93	0.95	0.96
	40.05	16.65	16	7.4	1.21	1.26	1.37	31	43	63	-26	13	85	0.92	0.94	0.95

Table 5 (continued).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ		
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile
Beverton Holt	0	0	0	0	1.27	1.33	1.42	41	53	72	-5	31	91			
	32.05	11.65	13	7.4	1.22	1.27	1.36	32	43	63	-24	12	71	0.94	0.95	0.96
	34.05	11.65	13	9.4	1.21	1.27	1.36	32	43	63	-25	11	71	0.93	0.95	0.96
	34.05	13.65	13	7.4	1.21	1.27	1.36	31	43	62	-25	11	71	0.93	0.95	0.96
	35.05	11.65	13	10.4	1.21	1.27	1.36	32	43	62	-25	11	70	0.93	0.95	0.96
	36.05	13.65	13	9.4	1.21	1.27	1.36	31	43	62	-26	10	70	0.93	0.95	0.96
	40.05	16.65	16	7.4	1.20	1.26	1.34	29	41	60	-29	7	67	0.92	0.94	0.95
No Init Var	0	0	0	0	1.35	1.36	1.39	59	61	65	32	48	76			
	32.05	11.65	13	7.4	1.29	1.30	1.33	49	52	56	13	29	57	0.96	0.96	0.96
	34.05	11.65	13	9.4	1.29	1.30	1.33	49	52	56	12	28	56	0.96	0.96	0.96
	34.05	13.65	13	7.4	1.29	1.30	1.33	49	51	56	12	28	56	0.96	0.96	0.96
	35.05	11.65	13	10.4	1.29	1.30	1.33	49	51	56	11	28	55	0.96	0.96	0.96
	36.05	13.65	13	9.4	1.29	1.30	1.33	48	51	55	11	27	55	0.96	0.96	0.96
	40.05	16.65	16	7.4	1.27	1.29	1.32	46	49	54	8	24	52	0.95	0.95	0.95
14-18 South Rec	0	0	0	0	1.28	1.36	1.48	47	59	80	22	61	143			
	32.05	11.65	13	7.4	1.24	1.31	1.42	38	50	71	3	42	124	0.94	0.95	0.96
	34.05	11.65	13	9.4	1.24	1.30	1.42	38	50	71	2	41	123	0.94	0.95	0.96
	34.05	13.65	13	7.4	1.24	1.30	1.41	38	50	70	2	41	123	0.94	0.95	0.96
	35.05	11.65	13	10.4	1.24	1.30	1.42	38	50	71	1	41	123	0.94	0.95	0.96
	36.05	13.65	13	9.4	1.24	1.30	1.41	38	50	70	1	40	122	0.94	0.95	0.96
	40.05	16.65	16	7.4	1.23	1.29	1.40	36	48	68	-2	37	119	0.92	0.94	0.95

Table 6a. The 20%ile of the multiplicative change in **west component effective spawning biomass** from November 2019 to November 2020 under alternative catch options relative to the 20%ile of the multiplicative change under a zero catch option. Results are given for the alternative models considered and the catch options listed in Tables 2 and 3. The equivalent value for the recommended 2019 catch limits under the 2019 projection model was 0.82.

Total Catch	Baseline	$\text{move}_{y,1}$ =0.2	$\text{move}_{y,1}$ =0.6	Hockey Stick	Beverton Holt	No Init Var	South Rec
18.35	0.96	0.96	0.96	0.96	0.96	0.95	0.96
27.05	0.95	0.95	0.95	0.95	0.95	0.94	0.95
32.05	0.92	0.92	0.93	0.93	0.92	0.91	0.92
36.05	0.91	0.90	0.91	0.92	0.91	0.90	0.91
40.05	0.90	0.89	0.90	0.91	0.90	0.89	0.90
35.05	0.91	0.90	0.91	0.92	0.91	0.90	0.91

Table 6b. The 20%ile of the multiplicative change in **west component effective spawning biomass** from November 2019 to November 2020 under alternative catch options relative to the no catch option. Results are given for the alternative models considered and the catch options listed in Tables 2 and 3. The equivalent value for the recommended 2019 catch limits under the 2019 projection model was 0.88.

Total Catch	Baseline	$\text{move}_{y,1}$ =0.2	$\text{move}_{y,1}$ =0.6	Hockey Stick	Beverton Holt	No Init Var	South Rec
18.35	0.95	0.94	0.95	0.95	0.95	0.95	0.95
27.05	0.94	0.93	0.94	0.94	0.94	0.94	0.94
32.05	0.90	0.90	0.91	0.91	0.90	0.91	0.91
36.05	0.89	0.88	0.90	0.90	0.89	0.90	0.89
40.05	0.88	0.87	0.89	0.89	0.88	0.89	0.88
35.05	0.89	0.88	0.90	0.89	0.89	0.90	0.89

Table 7. The probability that the **west component effective spawning biomass** is below the risk threshold of the 2007 level (i) in November 2020 and (ii) over the projection period of 2020-2040. Results are given for the alternative models considered and the catch options listed in Tables 2 and 3.

	Total Catch	Baseline	$\text{move}_{y,1}$ =0.2	$\text{move}_{y,1}$ =0.6	Hockey Stick	Beverton Holt	No Init Var	South Rec
2020	0	0.01	0.01	0.02	0.01	0.01	0.00	0.01
	18.35	0.01	0.01	0.03	0.02	0.02	0.00	0.01
	27.05	0.02	0.01	0.04	0.03	0.03	0.00	0.01
	32.05	0.02	0.01	0.06	0.03	0.04	0.00	0.02
	36.05	0.03	0.01	0.07	0.04	0.04	0.00	0.02
	40.05	0.03	0.02	0.08	0.04	0.05	0.00	0.02
	35.05	0.03	0.02	0.07	0.04	0.05	0.00	0.02
2020-2040	0	0.03	0.03	0.25	0.03	0.03	0.05	0.03
	18.35	0.07	0.03	0.52	0.03	0.03	0.08	0.04
	27.05	0.08	0.03	0.59	0.03	0.03	0.10	0.04
	32.05	0.16	0.04	0.72	0.03	0.0.3	0.18	0.06
	36.05	0.20	0.04	0.76	0.03	0.03	0.21	0.08
	40.05	0.24	0.05	0.79	0.03	0.04	0.25	0.09
	35.05	0.23	0.05	0.78	0.03	0.04	0.24	0.08

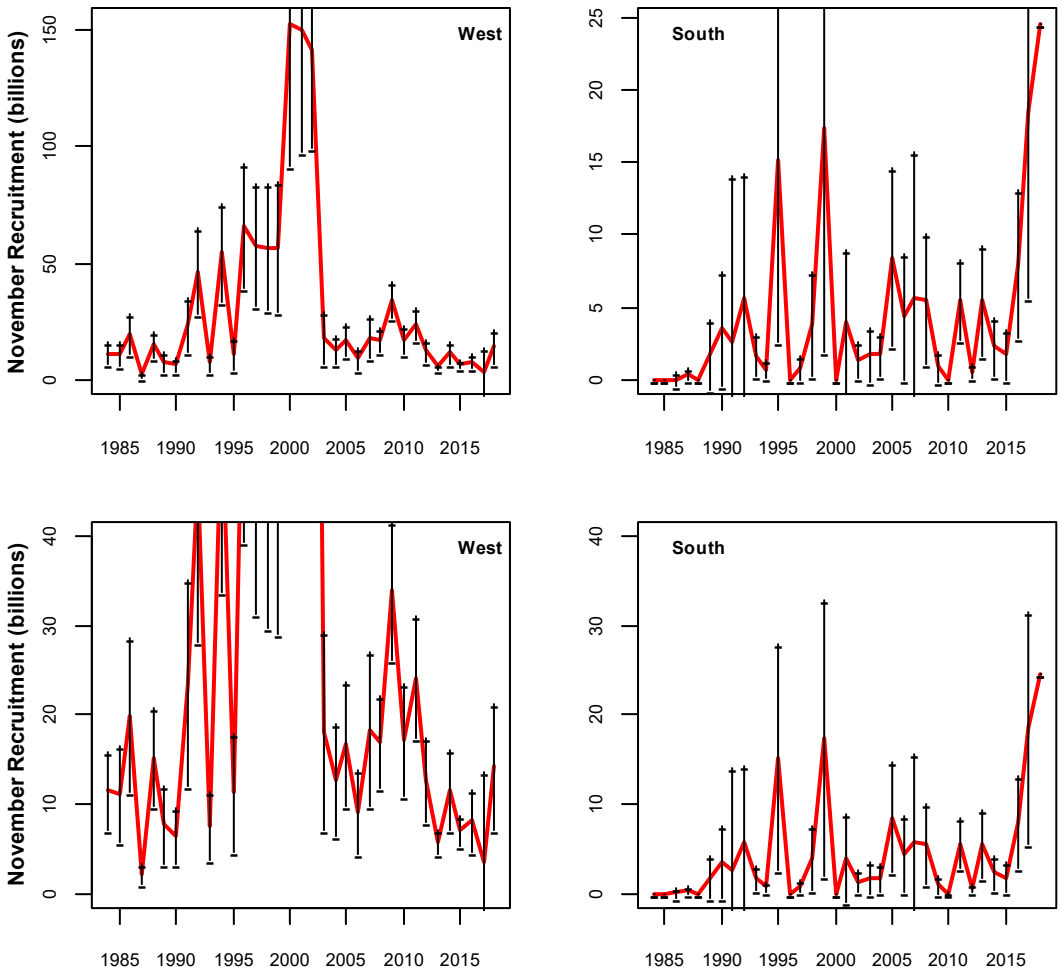

Figure 1. The de Moor (2020b) model estimated November recruitment for the west and south components. The +-1SE (from ADMB Hessian) values are also shown. The lower plots are a repeat of the upper plots, but with the same vertical-axis range for both the west and the south components. The lag-1 autocorrelation in the west recruitment time series is 0.67, while that for the south is 0.25.

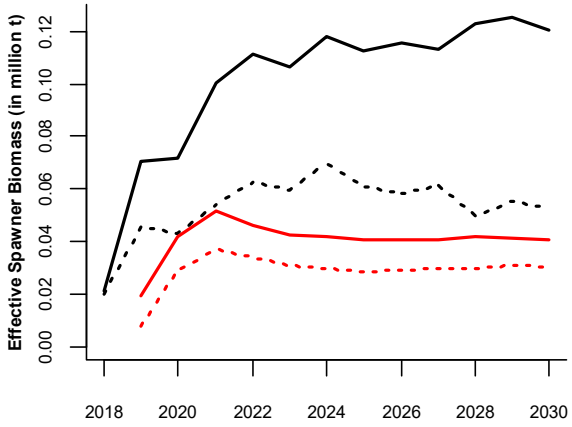

Figure 2. The projected west component effective spawner biomass from de Moor (2019b) and the projections carried out in this document.

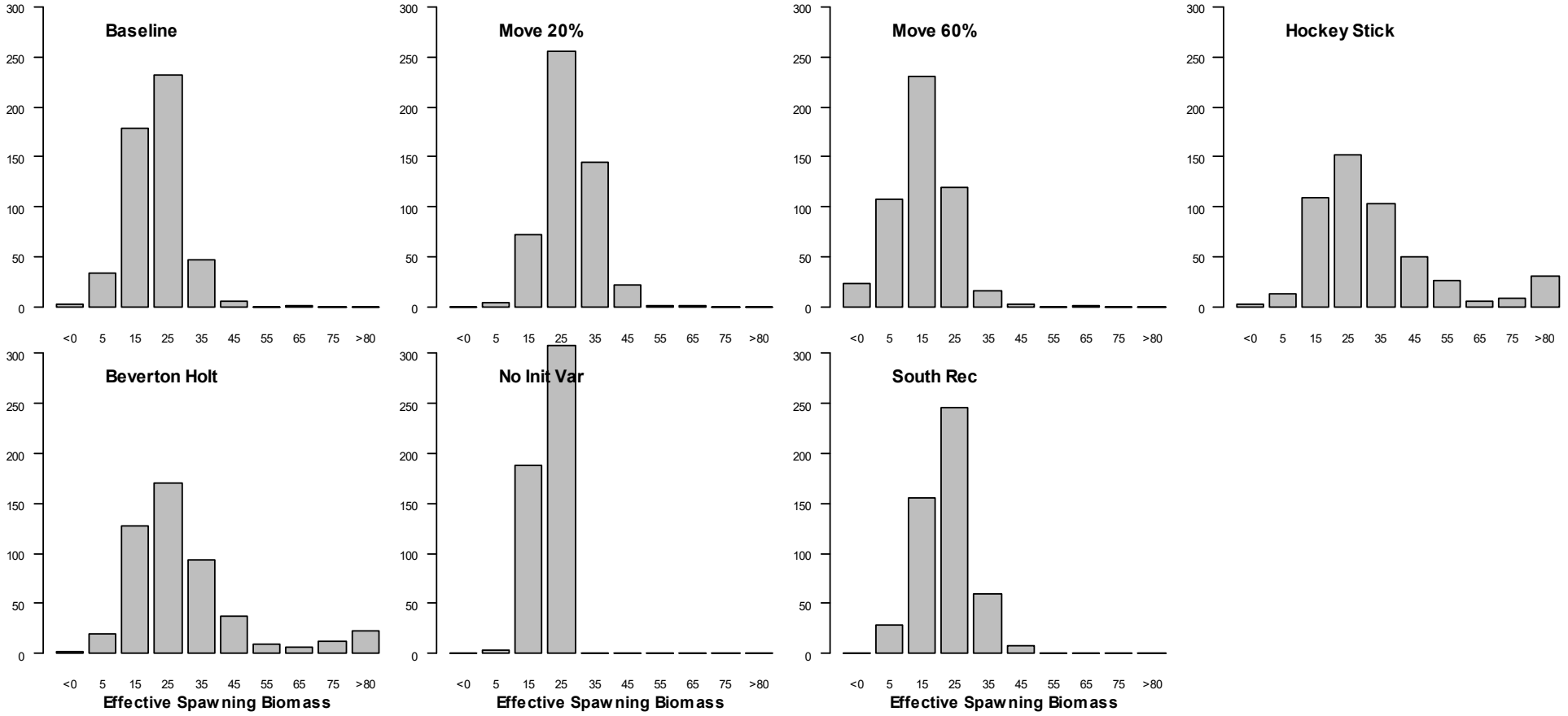

Figure 3a. The histogram of additive change (growth or shrinkage) in the **west component effective spawner biomass** from November 2019 to November 2020 under a zero catch option and the alternative models considered. Note that the bin widths are not equal.

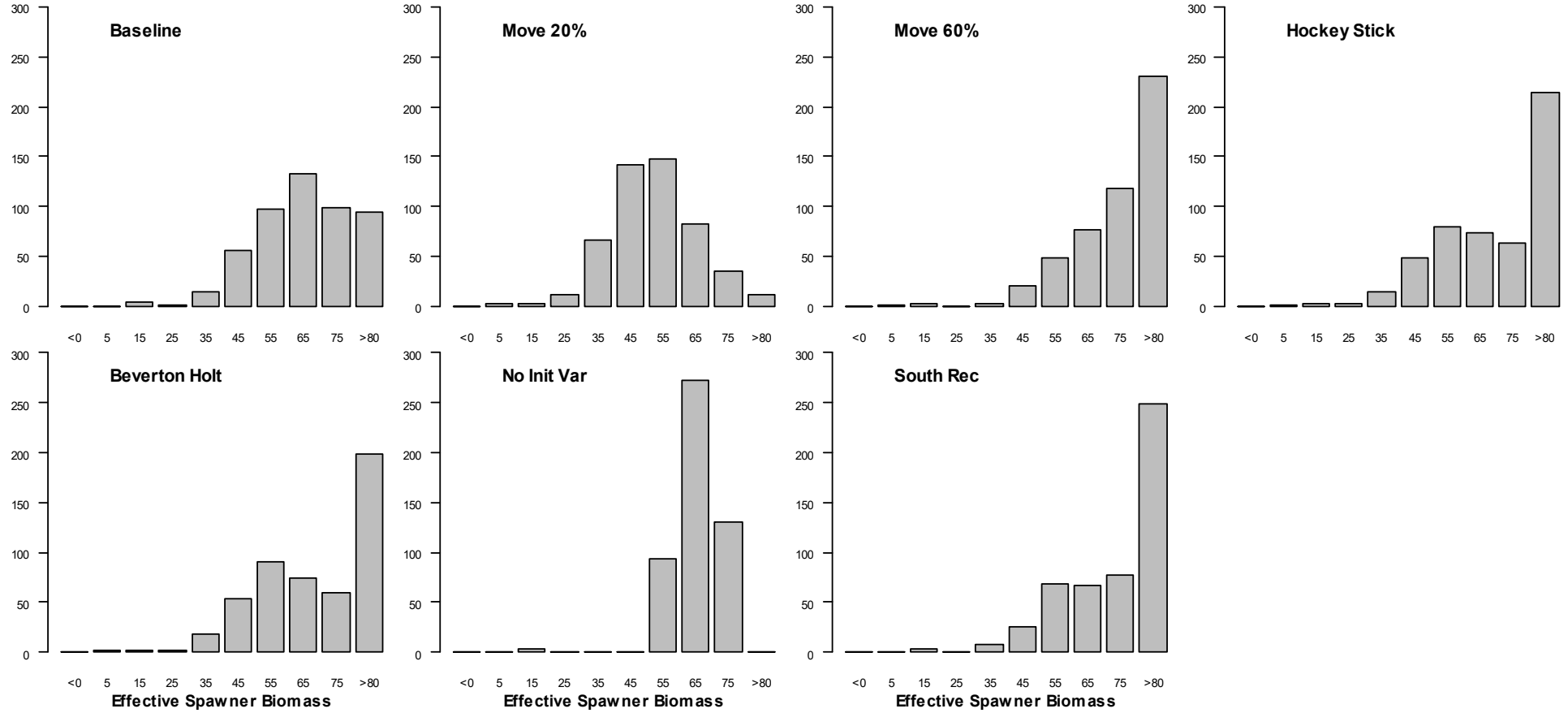

Figure 3b. The histogram of additive change (growth or shrinkage) in the **south component effective spawner biomass** from November 2019 to November 2020 under a zero catch option and the alternative models considered. Note that the bin widths are not equal.

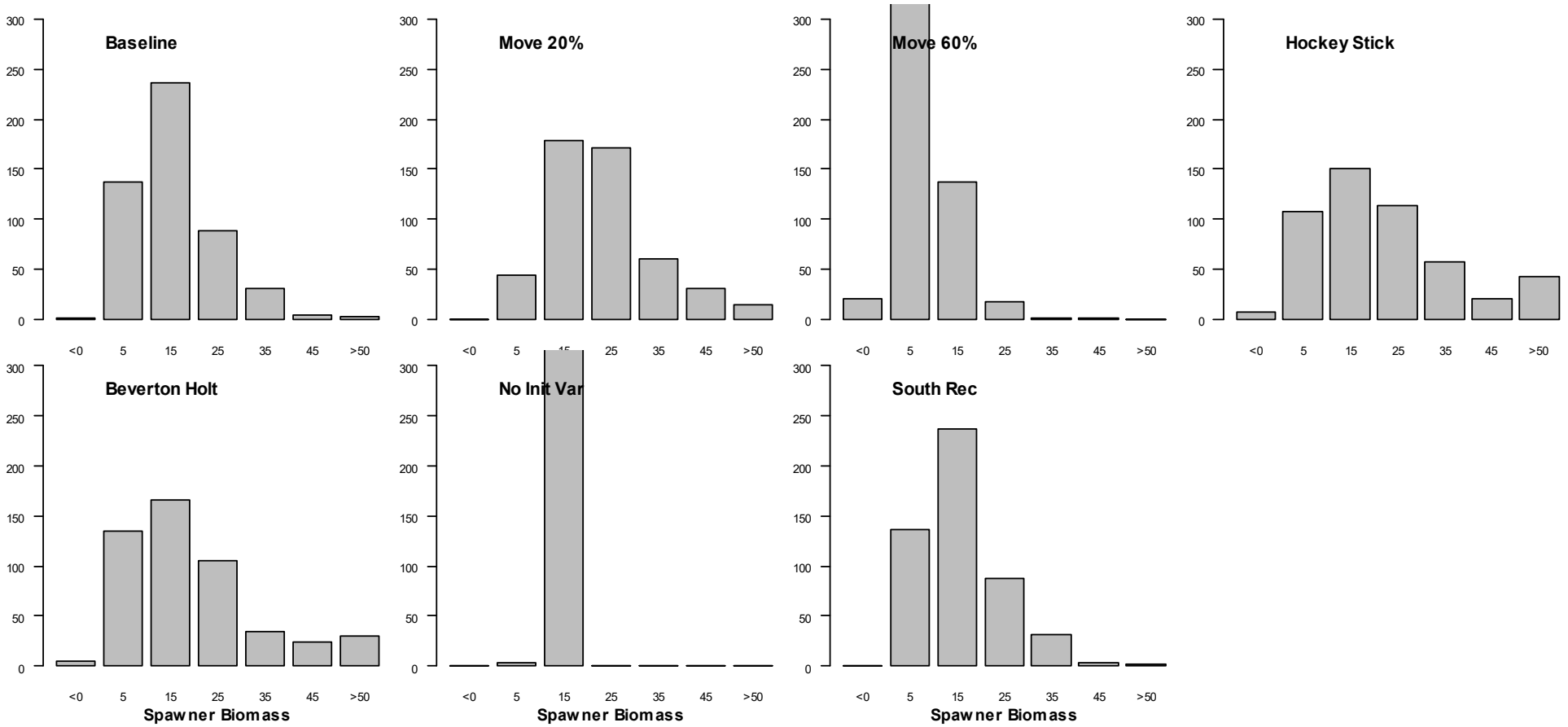

Figure 4a. The histogram of additive change (growth or shrinkage) in the **west component spawner biomass** from November 2019 to November 2020 under a zero catch option and the alternative models considered. Note that the bin widths are not equal.

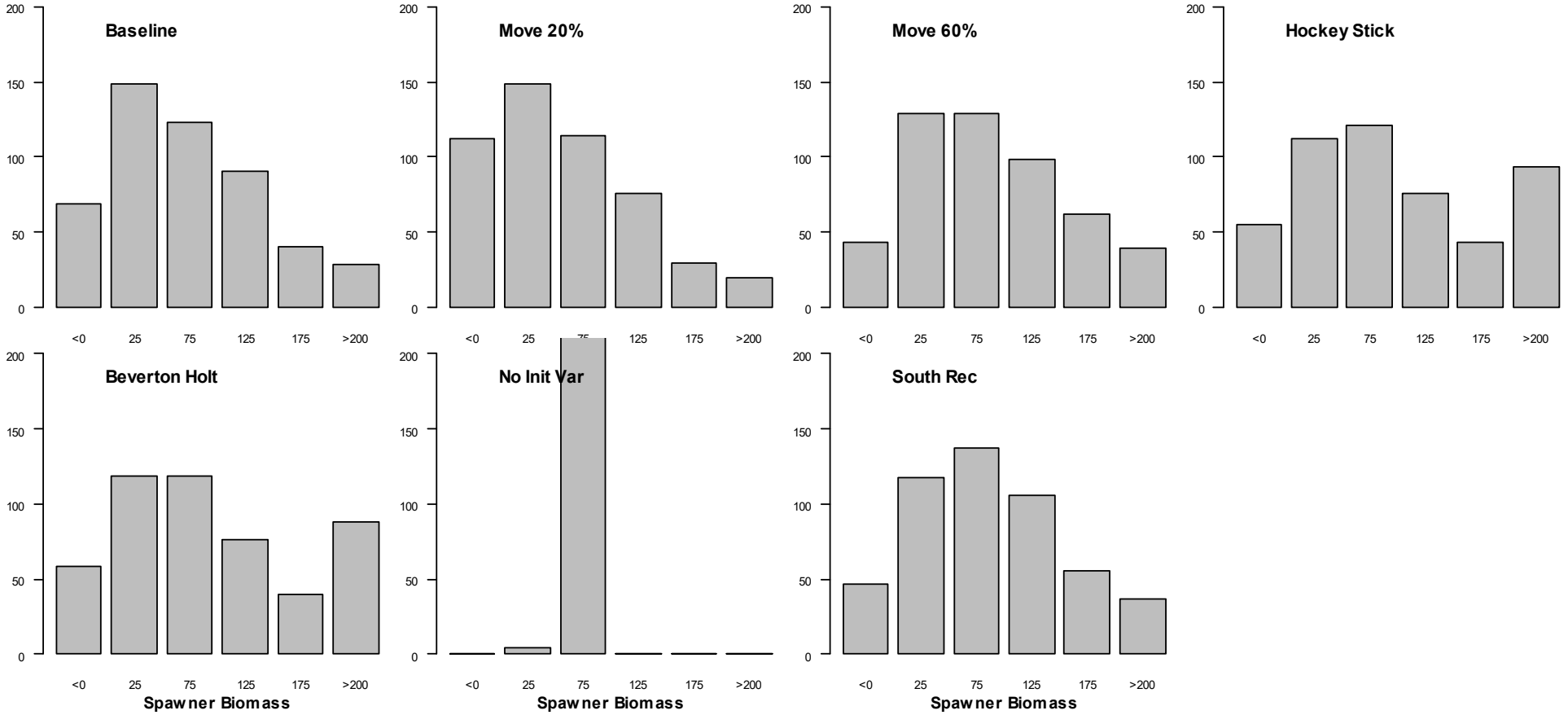

Figure 4b. The histogram of additive change (growth or shrinkage) in the **south component spawner biomass** from November 2019 to November 2020 under a zero catch option and the alternative models considered. Note that the bin widths are not equal.

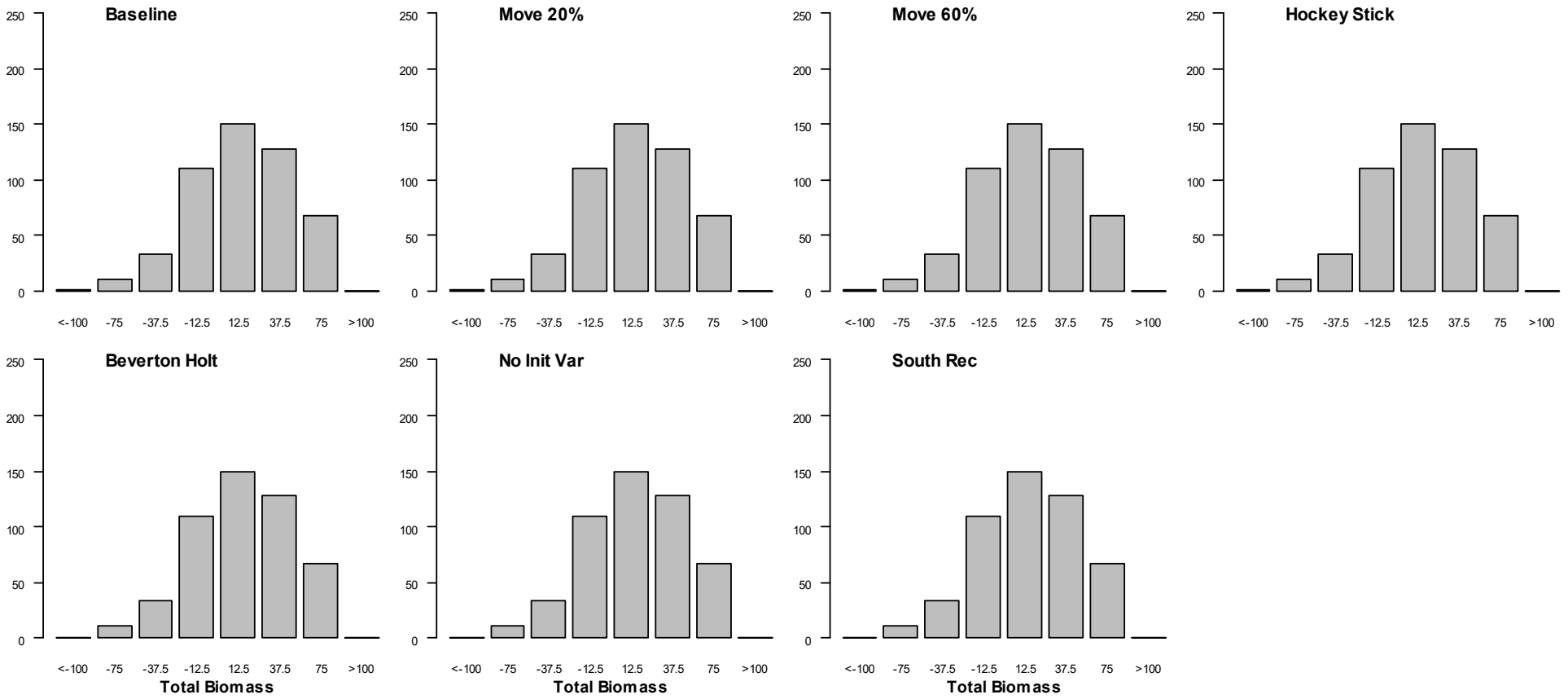

Figure 5a. The histogram of the additive change (growth or shrinkage) in the **west component total biomass** from November 2019 to November 2020 under a zero catch option and the alternative models considered. Note that the bin widths are not equal.

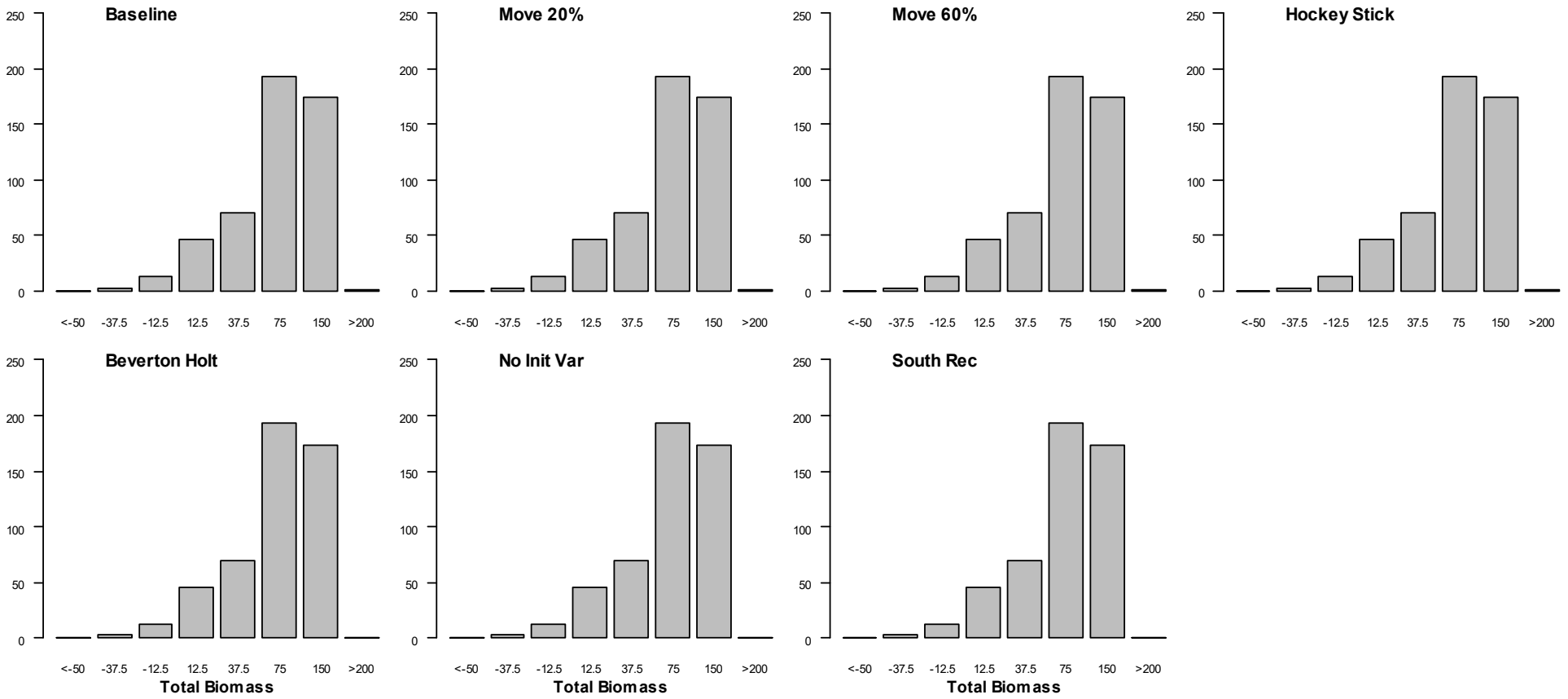

Figure 5b. The histogram of additive change (growth or shrinkage) in the **south component total biomass** from November 2019 to November 2020 under a zero catch option and the alternative models considered. Note that the bin widths are not equal.

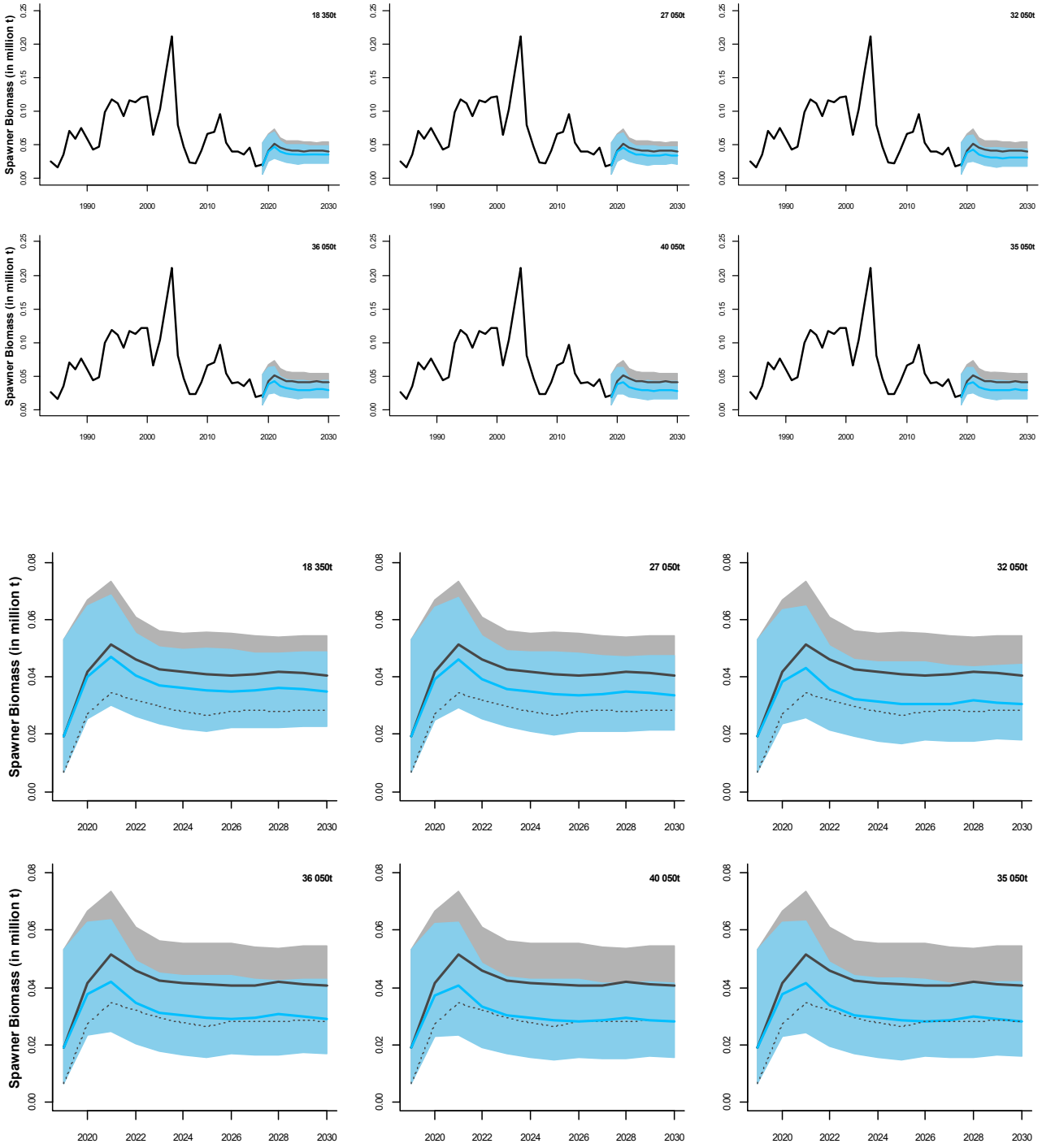

Figure 6. The historical best estimate from 1984 to 2019 and projected median and 95%ile confidence intervals of sardine **west component effective spawner biomass** from 2019 to 2030 under a no catch (grey) and six alternative catch (blue) scenarios corresponding to Table 2 for the **baseline model**. The lower set of panels are a repeat of the above set, but over a smaller range. The black dotted line indicates the lower 2.5%ile for the no catch scenario.

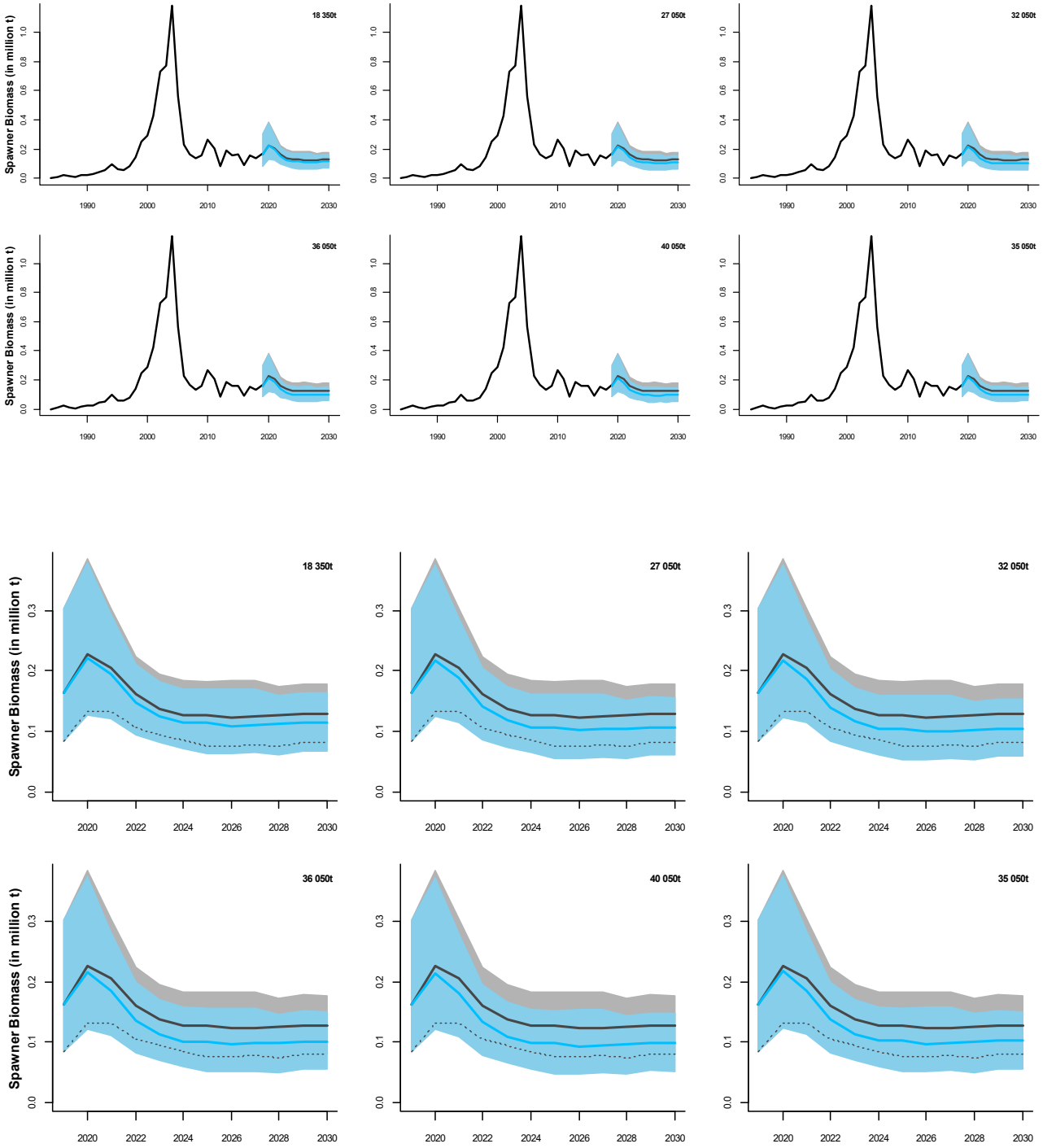

Figure 7. The historical best estimate from 1984 to 2019 and projected median and 95%ile confidence intervals of sardine **south component effective spawner biomass** from 2019 to 2030 under a no catch (grey) and six alternative catch (blue) scenarios corresponding to Table 3 for the **baseline model**. The lower set of panels are a repeat of the above set, but over a smaller range. The black dotted line indicates the lower 2.5%ile for the no catch scenario.

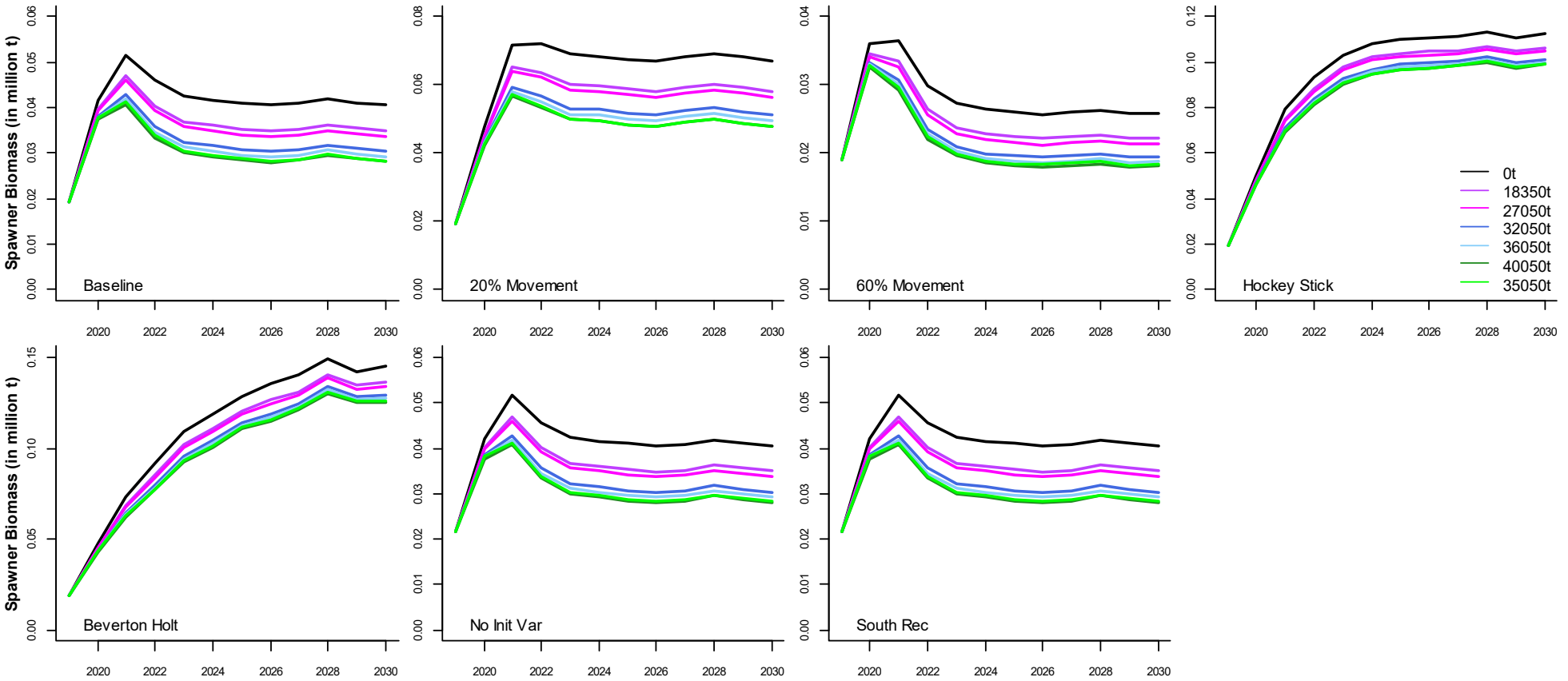

Figure 8a. The projected medians of sardine **west component effective spawner biomass** from 2019 to 2030 under a no catch and six alternative catch scenarios corresponding to Table 2, for the alternative models considered.

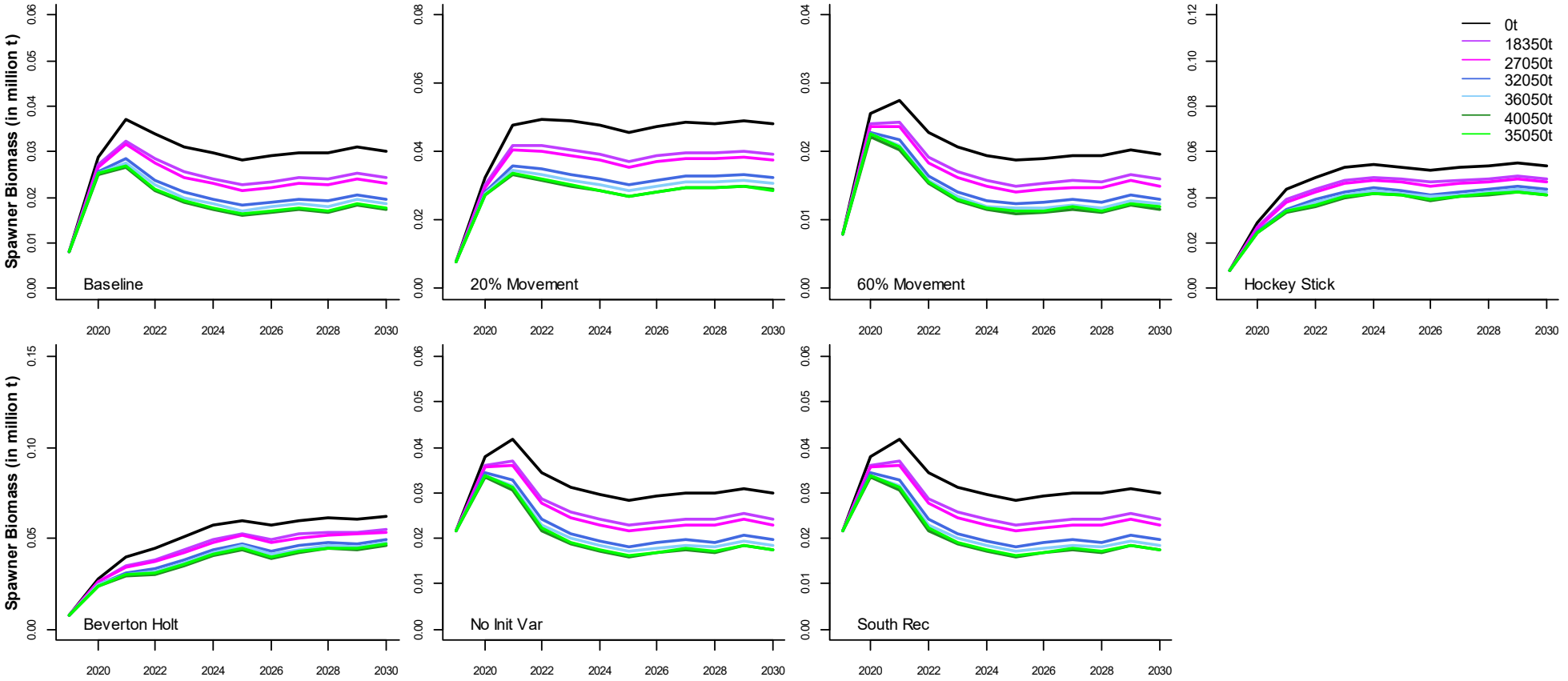

Figure 8b. The projected lower 5%iles of sardine **west component effective spawner biomass** from 2019 to 2030 under a no catch and six alternative catch scenarios corresponding to Table 2, for the alternative models considered.

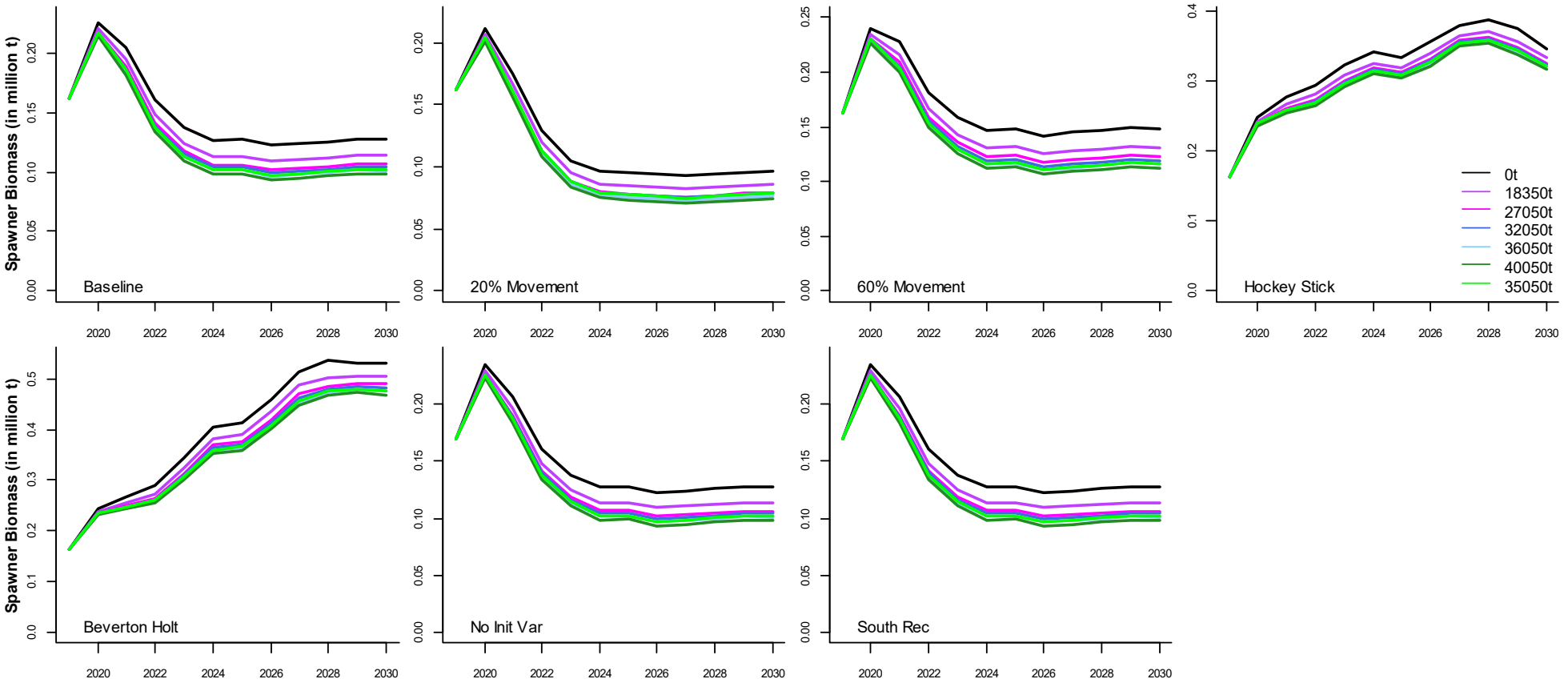

Figure 9a. The projected medians of sardine **south component effective spawner biomass** from 2019 to 2030 under a no catch and six alternative catch scenarios corresponding to Table 3, for the alternative models considered.

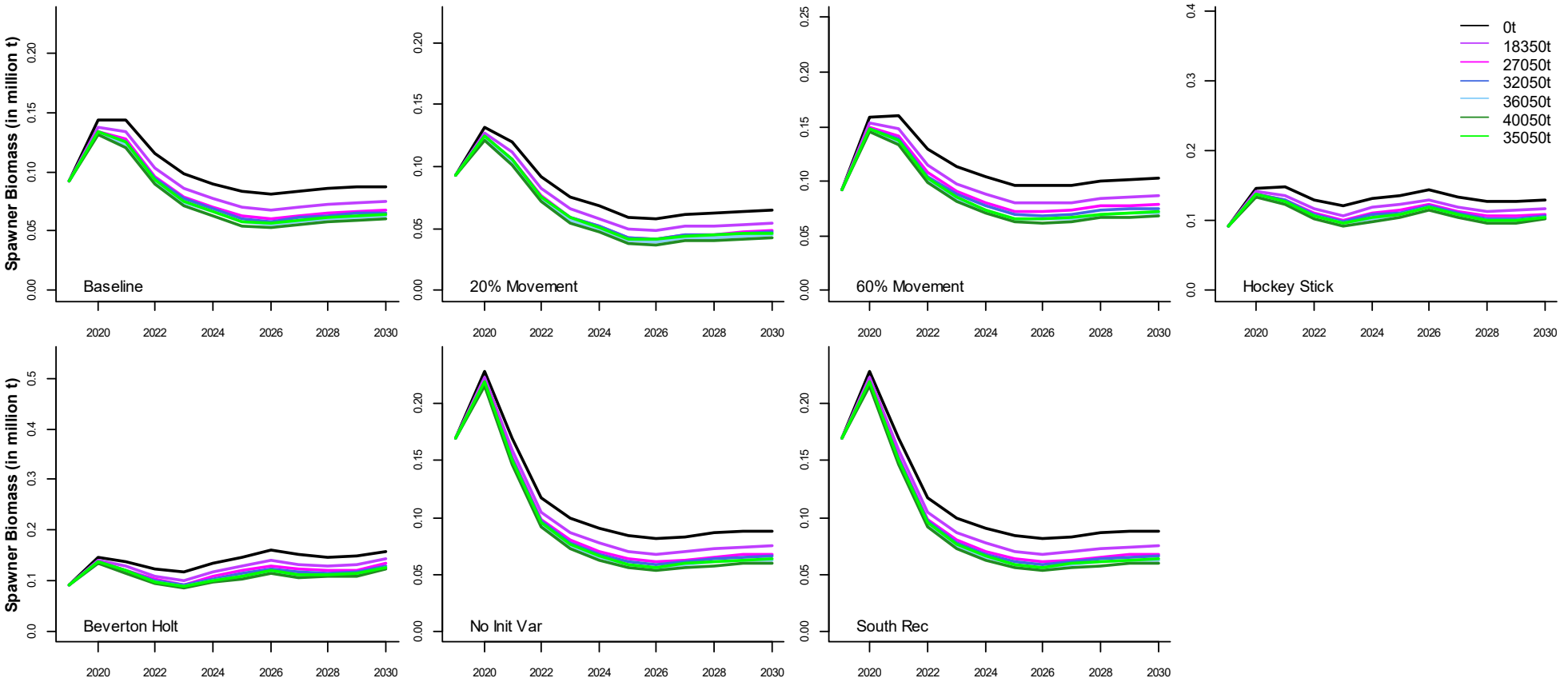

Figure 9b. The projected lower 5%iles of sardine **south component effective spawner biomass** from 2019 to 2030 under a no catch and six alternative catch scenarios corresponding to Table 3, for the alternative models considered.

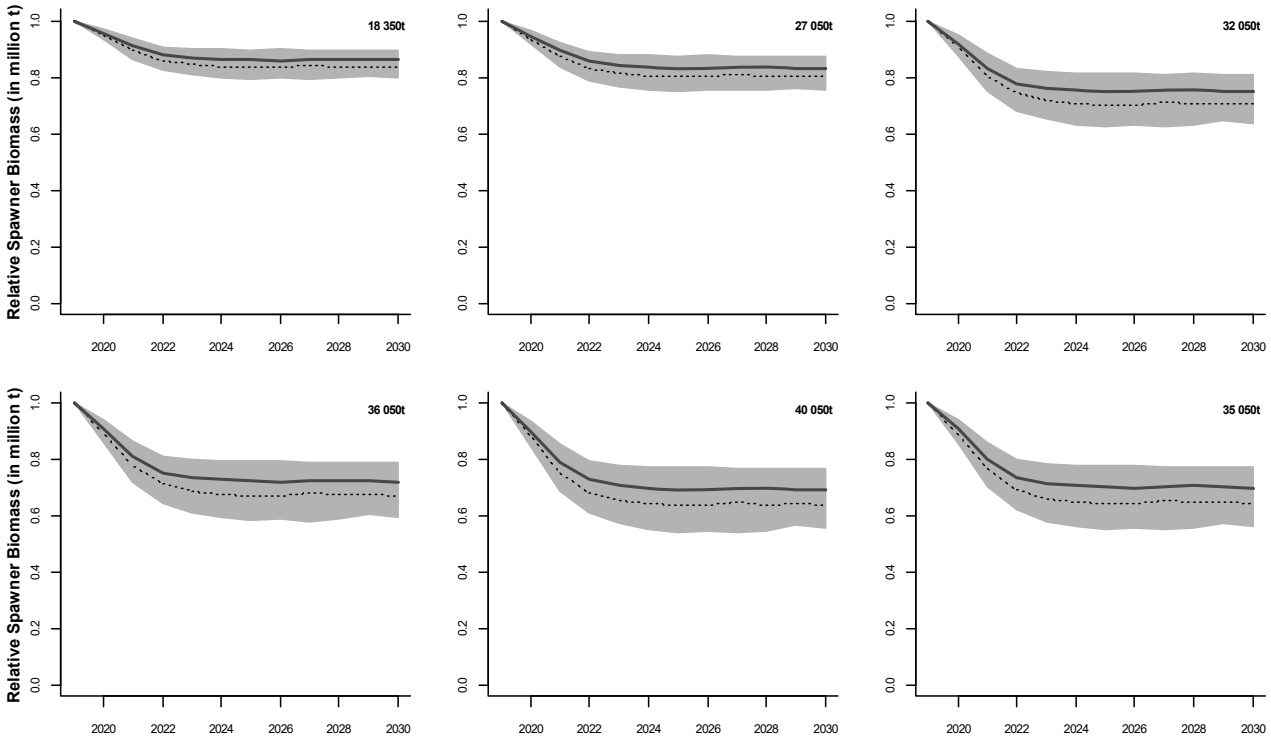

Figure 10. The median and 95%ile confidence intervals of sardine **west component effective spawner biomass** from 2019 to 2030 under six alternative catch scenarios corresponding to Table 2, relative to the no catch scenario for the baseline model.

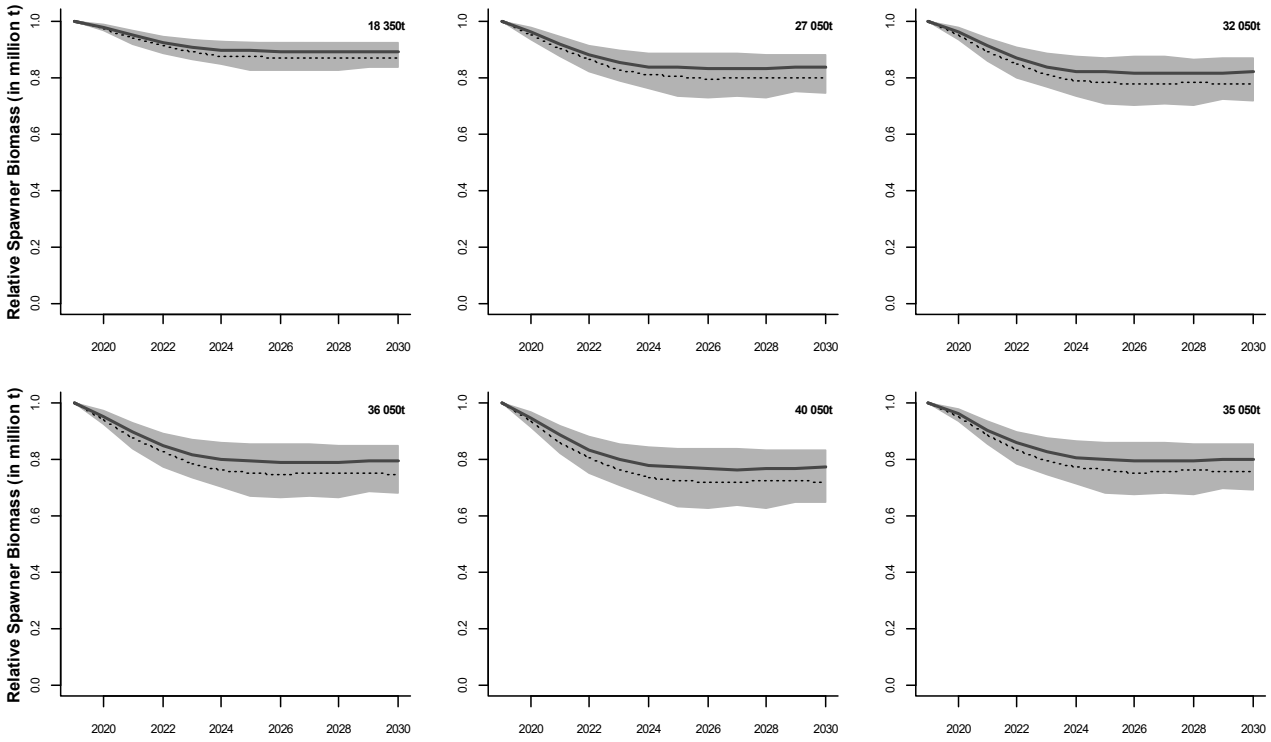

Figure 11. The median and 95%ile confidence intervals of sardine **south component effective spawner biomass** from 2019 to 2030 under six alternative catch scenarios corresponding to Table 3, relative to the no catch scenario for the baseline model.

Appendix A: Baseline projections using constant catch assumptions

The projections will be run from November $y_1 = 2019$ to November $y_n = 2040$. The notation is the same as that of Appendix A and Tables A1 and A2 of de Moor (2020a). The following assumptions were made:

- The numbers-at-age are calculated as follows:

$$N^{S*}_{j,p,y,a} = \left(N^{S}_{j,p,y-1,a-1} e^{-M^{S}_{y,a-1}/2} - C^{S}_{j,p,y,a-1}\right) e^{-M^{S}_{y,a-1}/2} \qquad p = I, NI, y_1 \le y \le y_n,\ 1 \le a \le 5^{+} \quad \text{(A1)}$$

$$N^{S*}_{j,p,y,5^{+}} = \left(N^{S}_{j,p,y-1,4} e^{-M^{S}_{y,4}/2} - C^{S}_{j,p,y,4}\right) e^{-M^{S}_{y,4}/2} + \left(N^{S}_{j,p,y-1,5^{+}} e^{-M^{S}_{y,5^{+}}/2} - C^{S}_{j,p,y,5^{+}}\right) e^{-M^{S}_{y,5^{+}}/2}$$

$$p = I, NI,\ y_1 \le y \le y_n \quad \text{(A2)}$$

and

$$\mathrm{N}^{\mathrm{S}}_{\mathrm{W,p,y,a}} = \left(1 - \mathrm{move}_{\mathrm{y,a}}\right)\mathrm{N}^{\mathrm{S**}}_{\mathrm{W,p,y,a}} \qquad p = I, NI, y_1 \le y \le y_n,\ 1 \le a \le 5^{+}$$

$$\mathrm{N}^{\mathrm{S}}_{\mathrm{S,p,y,a}} = \mathrm{N}^{\mathrm{S**}}_{\mathrm{S,p,y,a}} + \mathrm{move}_{\mathrm{y,a}}\mathrm{N}^{\mathrm{S**}}_{\mathrm{W,p,y,a}} \qquad p = I, NI, y_1 \le y \le y_n,\ 1 \le a \le 5^{+} \quad \text{(A3)}$$

- Future infection is assumed to be zero (this is inconsequential to projections).
- Future movement of 1-year olds from the west to the south component is assumed to be time-invariant and $\mathrm{move}_{\mathrm{y,1}} = 0.4$[2].
- Future recruitment is generated from the past 5[3] years of recruitment under the assumption that future recruitment, particularly in the immediate short-term future, may be from a similar 'regime' to that of the more recent years. For example, recruitment may depend more on environmental conditions rather than on spawning stock biomass (Szuwalski *et al*. 2019). Autocorrelation in the historical recruitment time series is non-negligible, lending further weight to this being a preferred baseline choice for these analyses (Figure 1). As there was no May recruitment survey on the south coast in 2018 or 2019, the model estimates of recruitment in November 2017 and 2018 are imprecise, and future recruitment to the south component is therefore generated from the 5 years preceding these (Novembers 2012-2016, Die *et al.* 2019).
- Natural mortality is assumed to be time-invariant: $M^{S}_{y,a=0} = \bar{M}^{S}_{ju}$ and $M^{S}_{y,a=1+} = \bar{M}^{S}_{ad}$.
- No allowance is made for early/late recruitment in future years, i.e. $\varepsilon^{t}_{y} = 0$ in de Moor (2020a) equation (A8).
- Growth curves at the mid-point of each quarter (de Moor (2020a) equation A16) and therefore the quarterly commercial selectivity-at-age functions (de Moor (2020a) equation A15) are the same[4] for all future years.
- Growth curves in November (de Moor (2020a) equation A7) are thus also the same for all future years.
- Only the logistic part of the selectivity-at-length curve is used for future projections of alternative directed catches. Small sardine bycatch with directed >14cm sardine is assumed to consist of recruits-of-the-year.
- Future annual selectivity-at-age is assumed to be year-invariant (because selectivity-at-length becomes year-invariant) and averaged over all quarters:

$$S^{S}_{j,a} = 0.25 \sum_{q=1}^{4} \sum_{l=2.5^{-}}^{24^{+}} A^{com}_{j,2020,q,a,l} S_{j,q,l} = 0.25 \quad 0 \le a \le 5^{+} \quad \text{(A4)}$$

- The numbers-at-length are calculated according to de Moor (2020a) equations (A5) and (A6).

[2] The average over the past 5 years is 0.41 for the base case model, and 0.38 over 2013-2017 and 2014-2018. The average over the past 10 years is 0.36.

[3] The most recent 5 or 10 years are frequent choices for the "recent past" in projection analyses internationally.

[4] Except in cases where the selectivity is modified to allow catch to be spread to lower ages (described below).

- The same maturity-at-length relationship, based on that corresponding to the period 1965-1975, is assumed from 2004 onwards, for all projected years.
- The November biomass, spawner biomass and effective spawner biomass are calculated according to de Moor (2020a) equations (A11) to (A13).
- Catch weight-at-age is taken to be the average of the weight-at-age in November immediately before and after the pulse fishery is assumed, i.e.,

$$w_{j,y,a}^{catch} = 0.5\left(w_{j,,a}^{S} + w_{j,a+1}^{S}\right) \quad 0 \le a \le 4$$

$$w_{j,y,5^+}^{catch} = w_{j,,5^+}^{S} \qquad \text{(A5)}$$

where

$$w_{j,y,a}^{S} = \sum_{l=2.5^-}^{l=24^+} A_{j,y,a,l}^{sur} w_{j,y,l}^{S} \qquad \text{(A6)}$$

- Catch is assumed to be taken in a single pulse, mid-way through the year. Small sardine bycatch (assumed to consist of 0-year-olds only[5]) is calculated as:

$$C_{j,p,y,a}^{bycatch} = \frac{Bycatch}{\sum_{p=I,NI} N_{j,p,y-1,a}^{S} e^{-M_{y,0}^{S}/2} w_{j,0}^{catch}} \times N_{j,p,y-1,0}^{S} e^{-M_{y,0}^{S}/2} \le N_{j,p,y-1,0}^{S} e^{-M_{y,0}^{S}/2}$$

and large sardine catch (taken to include directed catch and large sardine bycatch) is calculated as:

$$C_{j,p,y,a}^{dir} = \frac{Directed+Large\ Bycatch}{\sum_{a=0}^{5^+}\sum_{p=I,NI}\left(N_{j,p,y-1,a}^{S} e^{-M_{y,a}^{S}/2} - C_{j,p,y,a}^{bycatch}\right) S_{j,a}^{S} w_{j,a}^{catch}} \times \left(N_{j,p,y-1,a}^{S} e^{-M_{y,a}^{S}/2} - C_{j,p,y,a}^{bycatch}\right) S_{j,a}^{S}$$, with

$$\frac{Directed+Large\ Bycatch}{\sum_{a=0}^{5^+}\sum_{p=I,NI}\left(N_{j,p,y-1,a}^{S} e^{-M_{y,a}^{S}/2} - C_{j,p,y,a}^{bycatch}\right) S_{j,a}^{S} w_{j,a}^{catch}} \times S_{j,5}^{S} \le 0.95$$

$$C_{j,p,y,a}^{S} = C_{j,p,y,a}^{bycatch} + C_{j,p,y,a}^{dir} \qquad p = I, NI, y > y_n, 1 \le q \le 4, 0 \le a \le 5^+ \text{(F7)}$$

- In cases where the above constraints would otherwise result in the realised catch being less than the scenario being tested, the selectivity is increased, with the catch being progressively taken from the older ages first:

  i) Selectivity at age 5 is increased, such that a maximum of 95% of the available biomass of 5+ year olds is removed:

  $$C_{j,p,y,5+}^{dir} = 0.95\left(N_{j,p,y-1,5+}^{S} e^{-M_{y,5+}^{S}/2} - C_{j,p,y,5+}^{bycatch}\right) < Directed + LargeBycatch$$

  ii) If $\frac{Directed+Large\ Bycatch-C_{j,p,y,5+}^{dir} w_{j,5+}^{catch}}{\sum_{a=0}^{4}\sum_{p=I,NI}\left(N_{j,p,y-1,a}^{S} e^{-M_{y,a}^{S}/2} - C_{j,p,y,a}^{bycatch}\right) S_{j,a}^{S} w_{j,a}^{catch}} \times S_{j,4}^{S} \le 0.95$, then

  $$C_{j,p,y,a}^{dir} = \frac{Directed+Large\ Bycatch-C_{j,p,y,5+}^{dir} w_{j,5+}^{catch}}{\sum_{a=0}^{4^+}\sum_{p=I,NI}\left(N_{j,p,y-1,a}^{S} e^{-M_{y,a}^{S}/2} - C_{j,p,y,a}^{bycatch}\right) S_{j,a}^{S} w_{j,a}^{catch}} \times \left(N_{j,p,y-1,a}^{S} e^{-M_{y,a}^{S}/2} - C_{j,p,y,a}^{bycatch}\right) S_{j,a}^{S}$$ for $0 \le a \le 4$, else selectivity at age 4 is increased, such that a maximum of 95% of the available biomass of 4 year olds is removed:

  $$C_{j,p,y,4}^{dir} = 0.95\left(N_{j,p,y-1,4}^{S} e^{-M_{y,4}^{S}/2} - C_{j,p,y,4}^{bycatch}\right) < Directed + LargeBycatch - C_{j,p,y,5+}^{dir} w_{j,5+}^{catch}$$

  and catches for ages 0 to 3 are calculated as follows:

  iii) If $\frac{Directed+Large\ Bycatch-\sum_{a=4}^{5+} C_{j,p,y,a}^{dir} w_{j,a}^{catch}}{\sum_{a=0}^{3}\sum_{p=I,NI}\left(N_{j,p,y-1,a}^{S} e^{-M_{y,a}^{S}/2} - C_{j,p,y,a}^{bycatch}\right) S_{j,a}^{S} w_{j,a}^{catch}} \times S_{j,3}^{S} \le 0.95$, then

[5] The minimum, average and maximum proportion of 0-year olds in the bycatch is 0.84, 0.94 and 1 over 2010-2019 and 0.84, 0.96 and 1 over 1984-2019.

$C^{dir}_{j,p,y,a} = \frac{Directed+Large\ Bycatch-\sum_{a=4}^{5+} C^{dir}_{j,p,y,a} w^{catch}_{j,a}}{\sum_{a=0}^{3}\sum_{p=I,NI}\left(N^{S}_{j,p,y-1,a} e^{-M^{S}_{y,a}/2} - C^{bycatch}_{j,p,y,a}\right) S^{S}_{j,a} w^{catch}_{j,a}} \times \left(N^{S}_{j,p,y-1,a} e^{-M^{S}_{y,a}/2} - C^{bycatch}_{j,p,y,a}\right) S^{S}_{j,a}$ for $0 \leq a \leq 3$, else selectivity at age 3 is increased, such that a maximum of 95% of the available biomass of 3 year olds is removed:

$C^{dir}_{j,p,y,3} = 0.95\left(N^{S}_{j,p,y-1,3} e^{-M^{S}_{y,3}/2} - C^{bycatch}_{j,p,y,3}\right) < Directed + LargeBycatch - \sum_{a=4}^{5+} C^{dir}_{j,p,y,a} w^{catch}_{j,a}$

and catches for ages 0 to 2 are calculated as follows:

iv) If $\frac{Directed+Large\ Bycatch-\sum_{a=3}^{5+} C^{dir}_{j,p,y,a} w^{catch}_{j,a}}{\sum_{a=0}^{2}\sum_{p=I,NI}\left(N^{S}_{j,p,y-1,a} e^{-M^{S}_{y,a}/2} - C^{bycatch}_{j,p,y,a}\right) S^{S}_{j,a} w^{catch}_{j,a}} \times S^{S}_{j,2} \leq 0.95$, then

$C^{dir}_{j,p,y,a} = \frac{Directed+Large\ Bycatch-\sum_{a=3}^{5+} C^{dir}_{j,p,y,a} w^{catch}_{j,a}}{\sum_{a=0}^{2}\sum_{p=I,NI}\left(N^{S}_{j,p,y-1,a} e^{-M^{S}_{y,a}/2} - C^{bycatch}_{j,p,y,a}\right) S^{S}_{j,a} w^{catch}_{j,a}} \times \left(N^{S}_{j,p,y-1,a} e^{-M^{S}_{y,a}/2} - C^{bycatch}_{j,p,y,a}\right) S^{S}_{j,a}$ for $0 \leq a \leq 2$, else selectivity at age 2 is increased, such that a maximum of 95% of the available biomass of 2 year olds is removed:

$C^{dir}_{j,p,y,2} = 0.95\left(N^{S}_{j,p,y-1,2} e^{-M^{S}_{y,2}/2} - C^{bycatch}_{j,p,y,2}\right) < Directed + LargeBycatch - \sum_{a=3}^{5+} C^{dir}_{j,p,y,a} w^{catch}_{j,a}$

and catches for ages 0 to 1 are calculated as follows:

v) If $\frac{Directed+Large\ Bycatch-\sum_{a=2}^{5+} C^{dir}_{j,p,y,a} w^{catch}_{j,a}}{\sum_{a=0}^{1}\sum_{p=I,NI}\left(N^{S}_{j,p,y-1,a} e^{-M^{S}_{y,a}/2} - C^{bycatch}_{j,p,y,a}\right) S^{S}_{j,a} w^{catch}_{j,a}} \times S^{S}_{j,max} \leq 0.95$, where $S^{S}_{j,max} = max\left(S^{S}_{j,0}, S^{S}_{j,1}\right)$, then

$C^{dir}_{j,p,y,a} = \frac{Directed+Large\ Bycatch-\sum_{a=3}^{5+} C^{dir}_{j,p,y,a} w^{catch}_{j,a}}{\sum_{a=0}^{1}\sum_{p=I,NI}\left(N^{S}_{j,p,y-1,a} e^{-M^{S}_{y,a}/2} - C^{bycatch}_{j,p,y,a}\right) S^{S}_{j,a} w^{catch}_{j,a}} \times \left(N^{S}_{j,p,y-1,a} e^{-M^{S}_{y,a}/2} - C^{bycatch}_{j,p,y,a}\right) S^{S}_{j,a}$ for $0 \leq a \leq 1$, else $C^{dir}_{j,p,y,a} = 0.95\left(N^{S}_{j,p,y-1,a} e^{-M^{S}_{y,2}/2} - C^{bycatch}_{j,p,y,a}\right)$ for $0 \leq a \leq 1$[6]

[6] There are still a few cases where the full catch is not realised because this equation reaches the constraint, even after the modifications to the selectivity are made. This is indicated by dark grey shading in the results tables.

Appendix B: Further results

Table B.1. The 5%ile, 20%ile and 50%ile of the multiplicative and additive change in **west component effective spawning biomass** and additive change in **west component total biomass** from November 2019 to 2020 under further alternative catch options and alternative models to those given in Tables 1 and 3. The 5%ile, 20%ile and 50%ile of the multiplicative change under the catch options relative to the no catch option are also given. Grey cells indicate cases for which the selectivity function needed modification to enable the catch to be taken (* denotes where this only occurred in one simulation). Dark grey cells indicate cases for which the full catch could still not be realised after selectivity was modified ("C" in Table 1). Cases for which the full bycatch could not be realised are indicated by ** ("By" in Table 1).

					Multiplicative Δ in effSSB			Relative Multiplicative Δ			Additive Δ in effSSB		
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile
Baseline	0	0	0	0	1.25	1.55	2.13				9	15	21
	18.55*	5.65	7	5.9	1.21	1.49	2.03	0.94	0.95	0.96	7	13	19
	20.05*	5.65	7	7.4	1.21	1.48	2.02	0.93	0.94	0.95	7	13	19
	29.3	7.9	14	7.4	1.17	1.46	1.98	0.91	0.92	0.94	6	13	18
	25.05	10.65	7	7.4	1.17	1.45	1.97	0.90	0.92	0.93	6	12	18
	32.05	14.65	10	7.4	1.15	1.42	1.92	0.88	0.90	0.91	5	12	17
	36.05	18.65	10	7.4	1.13	1.4	1.89	0.85	0.88	0.90	5	11	17
	31.05	10.65	10	10.4	1.16	1.44	1.95	0.89	0.91	0.92	6	12	18
	35.05	10.65	10	14.4	1.15	1.43	1.93	0.88	0.90	0.91	5	12	17
	38.05	10.65	20	7.4	1.15	1.43	1.94	0.88	0.90	0.92	6	12	18
$move_{y,1}$ =0.2	0	0	0	0	1.48	1.82	2.41				16	21	27
	18.35*	5.65	7	5.7	1.43	1.75	2.30	0.93	0.94	0.95	14	19	25
	18.55*	5.65	7	5.9	1.42	1.74	2.29	0.93	0.94	0.95	14	19	25
	20.05*	5.65	7	7.4	1.42	1.74	2.28	0.93	0.94	0.95	14	19	25
	27.05	5.65	14	7.4	1.42	1.73	2.27	0.92	0.93	0.94	13	19	24
	29.3	7.9	14	7.4	1.40	1.71	2.24	0.90	0.92	0.93	13	18	24
	25.05	10.65	7	7.4	1.39	1.70	2.22	0.89	0.91	0.93	13	18	24
	32.05	12.65	12	7.4	1.39	1.67	2.18	0.87	0.90	0.91	12	17	23
	32.05	14.65	10	7.4	1.36	1.66	2.16	0.86	0.89	0.91	12	17	23
	35.05	14.65	10	10.4	1.35	1.65	2.15	0.85	0.88	0.90	11	16	22
	36.05	14.65	14	7.4	1.36	1.65	2.15	0.86	0.88	0.90	11	17	22
	36.05	18.65	10	7.4	1.34	1.63	2.11	0.84	0.86	0.89	11	16	22
	31.05	10.65	10	10.4	1.38	1.68	2.19	0.88	0.90	0.92	12	17	23
	35.05	10.65	10	14.4	1.37	1.66	2.17	0.86	0.89	0.91	12	17	23
	38.05	10.65	20	7.4	1.38	1.68	2.19	0.88	0.90	0.92	12	17	23
	40.05	16.65	16	7.4	1.34	1.63	2.13	0.84	0.87	0.89	11	16	22
$move_{y,1}$ =0.6	0	0	0	0	1.01	1.30	1.84				0	8	15
	18.55	5.65	7	5.9	0.97	1.26	1.76	0.94	0.95	0.96	-1	7	14
	20.05	5.65	7	7.4	0.97	1.25	1.76	0.94	0.95	0.96	-1	7	14
	29.3	7.9	14	7.4	0.95	1.23	1.72	0.92	0.93	0.94	-2	6	13
	25.05	10.65	7	7.4	0.95	1.23	1.72	0.91	0.93	0.94	-2	6	13
	32.05	14.65	10	7.4	0.93	1.20	1.68	0.89	0.91	0.92	-3	5	12
	36.05	18.65	10	7.4	0.92	1.17	1.65	0.87	0.89	0.91	-3	5	12
	31.05	10.65	10	10.4	0.94	1.22	1.70	0.90	0.92	0.93	-2	6	13
	35.05	10.65	10	14.4	0.94	1.20	1.69	0.89	0.91	0.92	-3	5	13
	38.05	10.65	20	7.4	0.94	1.20	1.69	0.89	0.91	0.92	-3	5	13

Table B.1 (continued).

					Multiplicative Δ in effSSB			Relative Multiplicative Δ			Additive Δ in effSSB		
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile
Hockey Stick	0	0	0	0	1.39	1.80	2.63				12	18	28
	18.55	5.65	7	5.9	1.32	1.73	2.53	0.94	0.95	0.96	10	17	26
	20.05	5.65	7	7.4	1.32	1.73	2.52	0.93	0.95	0.96	10	16	26
	29.3	7.9	14	7.4	1.30	1.70	2.48	0.91	0.93	0.95	9	16	26
	25.05	10.65	7	7.4	1.30	1.69	2.47	0.90	0.92	0.95	9	16	25
	32.05	14.65	10	7.4	1.28	1.66	2.42	0.87	0.90	0.93	8	15	25
	36.05	18.65	10	7.4	1.25	1.63	2.38	0.85	0.88	0.92	7	14	24
	31.05**	10.65	10	10.4	1.29	1.68	2.45	0.89	0.91	0.94	8	15	25
	35.05**	10.65	10	14.4	1.28	1.67	2.43	0.87	0.90	0.93	8	15	25
	38.05	10.65	20	7.4	1.29	1.67	2.44	0.88	0.91	0.93	8	15	25
Beverton Holt	0	0	0	0	1.35	1.73	2.46				11	17	26
	18.55	5.65	7	5.9	1.30	1.66	2.36	0.93	0.95	0.96	9	16	24
	20.05	5.65	7	7.4	1.29	1.65	2.35	0.93	0.95	0.96	9	15	24
	29.3	7.9	14	7.4	1.27	1.62	2.32	0.90	0.93	0.94	8	15	24
	25.05	10.65	7	7.4	1.26	1.61	2.31	0.90	0.92	0.94	8	15	23
	32.05	14.65	10	7.4	1.24	1.58	2.26	0.87	0.90	0.92	7	14	23
	36.05	18.65	10	7.4	1.21	1.55	2.22	0.84	0.88	0.91	6	13	22
	31.05**	10.65	10	10.4	1.25	1.60	2.29	0.88	0.91	0.93	8	14	23
	35.05**	10.65	10	14.4	1.24	1.58	2.27	0.87	0.90	0.92	7	14	23
	38.05	10.65	20	7.4	1.24	1.59	2.28	0.88	0.90	0.93	7	14	23
No Init Var	0	0	0	0	1.76	1.88	1.95				16	19	21
	18.55	5.65	7	5.9	1.67	1.79	1.87	0.95	0.95	0.96	14	17	19
	20.05	5.65	7	7.4	1.66	1.79	1.86	0.95	0.95	0.95	14	17	19
	29.3	7.9	14	7.4	1.63	1.75	1.83	0.93	0.93	0.94	14	16	18
	25.05	10.65	7	7.4	1.62	1.74	1.82	0.92	0.93	0.93	13	16	18
	32.05	14.65	10	7.4	1.58	1.70	1.78	0.90	0.91	0.91	13	15	17
	36.05	18.65	10	7.4	1.55	1.67	1.75	0.88	0.89	0.89	12	14	16
	31.05	10.65	10	10.4	1.60	1.73	1.80	0.91	0.92	0.92	13	16	17
	35.05	10.65	10	14.4	1.59	1.71	1.78	0.90	0.91	0.91	13	15	17
	38.05	10.65	20	7.4	1.59	1.72	1.79	0.91	0.91	0.92	13	15	17
14-18 South Rec	0	0	0	0	1.26	1.60	2.20				10	16	22
	18.55*	5.65	7	5.9	1.23	1.53	2.09	0.94	0.95	0.96	8	14	20
	20.05*	5.65	7	7.4	1.23	1.52	2.09	0.93	0.95	0.95	8	14	20
	29.3	7.9	14	7.4	1.21	1.50	2.05	0.91	0.93	0.94	7	14	20
	25.05	10.65	7	7.4	1.21	1.49	2.04	0.91	0.92	0.93	7	13	19
	32.05	14.65	10	7.4	1.16	1.47	2.00	0.88	0.90	0.91	6	13	19
	36.05	18.65	10	7.4	1.13	1.44	1.96	0.85	0.88	0.90	5	12	18
	31.05	10.65	10	10.4	1.19	1.48	2.02	0.89	0.91	0.92	6	13	19
	35.05	10.65	10	14.4	1.17	1.47	2.00	0.88	0.90	0.92	6	13	19
	38.05	10.65	20	7.4	1.18	1.48	2.01	0.89	0.91	0.92	6	13	19

Table B.2. The 5%ile, 20%ile and 50%ile of the multiplicative and additive change in **south component effective spawning biomass** from November 2019 to November 2020 under further alternative catch options and the alternative models to those given in Tables 2 and 4. The 5%ile, 20%ile and 50%ile of the multiplicative change under the catch options relative to the no catch option are also given. Grey cells indicate cases for which the selectivity function needed modification to enable the catch to be taken (* denotes where this only occurred in one simulation). Dark grey cells indicate cases for which the full catch could still not be realised after selectivity was modified. Cases for which the full bycatch could not be realised are indicated by **.

					Multiplicative Δ in effSSB			Relative Multiplicative Δ			Additive Δ in effSSB		
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile
Baseline	0	0	0	0	1.27	1.31	1.39				43	53	65
	18.55*	5.65	7	5.9	1.25	1.29	1.36	0.96	0.97	0.98	38	48	60
	20.05*	5.65	7	7.4	1.25	1.29	1.36	0.96	0.97	0.98	38	48	60
	29.3	7.9	14	7.4	1.23	1.27	1.33	0.94	0.95	0.96	34	44	56
	25.05	10.65	7	7.4	1.24	1.29	1.35	0.96	0.97	0.97	37	47	59
	32.05	14.65	10	7.4	1.23	1.27	1.34	0.94	0.95	0.96	35	45	57
	36.05	18.65	10	7.4	1.23	1.27	1.33	0.94	0.95	0.96	34	44	56
	31.05	10.65	10	10.4	1.24	1.28	1.34	0.95	0.96	0.97	35	45	58
	35.05	10.65	10	14.4	1.23	1.28	1.34	0.94	0.95	0.96	35	45	57
	38.05	10.65	20	7.4	1.21	1.25	1.31	0.91	0.93	0.94	30	41	53
$move_{y,1}$ =0.2	0	0	0	0	1.24	1.26	1.31				34	42	52
	18.55*	5.65	7	5.9	1.22	1.24	1.28	0.97	0.97	0.98	29	38	47
	20.05*	5.65	7	7.4	1.22	1.24	1.28	0.97	0.97	0.98	29	38	47
	29.3	7.9	14	7.4	1.20	1.22	1.26	0.94	0.95	0.96	26	34	43
	25.05	10.65	7	7.4	1.21	1.24	1.28	0.96	0.97	0.98	29	37	47
	32.05	14.65	10	7.4	1.20	1.23	1.27	0.95	0.96	0.97	27	36	45
	36.05	18.65	10	7.4	1.20	1.22	1.26	0.95	0.96	0.97	27	35	44
	31.05	10.65	10	10.4	1.20	1.23	1.27	0.95	0.96	0.97	27	36	45
	35.05	10.65	10	14.4	1.20	1.23	1.27	0.95	0.96	0.97	27	36	45
	38.05	10.65	20	7.4	1.18	1.20	1.24	0.91	0.93	0.95	22	31	40
$move_{y,1}$ =0.6	0	0	0	0	1.31	1.37	1.47				51	64	78
	18.35	5.65	7	5.7	1.28	1.34	1.44	0.96	0.97	0.98	46	58	73
	18.55	5.65	7	5.9	1.28	1.34	1.44	0.96	0.97	0.98	45	58	73
	20.05	5.65	7	7.4	1.28	1.34	1.44	0.96	0.97	0.98	45	58	72
	27.05	5.65	14	7.4	1.27	1.32	1.42	0.94	0.95	0.96	43	54	69
	29.3	7.9	14	7.4	1.26	1.32	1.41	0.94	0.95	0.96	41	54	68
	25.05	10.65	7	7.4	1.27	1.33	1.43	0.95	0.96	0.97	44	56	71
	32.05	12.65	12	7.4	1.26	1.31	1.41	0.93	0.95	0.96	42	53	68
	32.05	14.65	10	7.4	1.26	1.32	1.41	0.94	0.95	0.96	41	54	68
	35.05	14.65	10	10.4	1.26	1.31	1.41	0.93	0.95	0.96	42	53	68
	36.05	14.65	14	7.4	1.25	1.31	1.40	0.92	0.94	0.95	40	52	66
	36.05	18.65	10	7.4	1.26	1.31	1.40	0.93	0.94	0.95	40	52	67
	31.05	10.65	10	10.4	1.27	1.32	1.42	0.94	0.95	0.96	42	54	69
	35.05	10.65	10	14.4	1.26	1.32	1.41	0.94	0.95	0.96	41	54	69
	38.05	10.65	20	7.4	1.24	1.30	1.39	0.91	0.93	0.94	37	50	64
	40.05	16.65	16	7.4	1.24	1.30	1.39	0.91	0.93	0.94	38	50	65

Table B.2 (continued).

					Multiplicative Δ in effSSB			Relative Multiplicative Δ			Additive Δ in effSSB		
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile
Hockey Stick	0	0	0	0	1.27	1.34	1.45				42	55	75
	18.55	5.65	7	5.9	1.24	1.31	1.42	0.97	0.97	0.98	37	50	69
	20.05	5.65	7	7.4	1.24	1.31	1.41	0.96	0.97	0.98	37	50	69
	29.3	7.9	14	7.4	1.22	1.28	1.38	0.94	0.95	0.96	33	46	65
	25.05	10.65	7	7.4	1.24	1.30	1.41	0.96	0.97	0.98	36	49	68
	32.05	14.65	10	7.4	1.22	1.29	1.39	0.94	0.96	0.97	34	46	66
	36.05	18.65	10	7.4	1.22	1.28	1.39	0.94	0.95	0.96	33	45	65
	31.05**	10.65	10	10.4	1.23	1.29	1.40	0.95	0.96	0.97	34	47	67
	35.05**	10.65	10	14.4	1.23	1.29	1.39	0.94	0.96	0.97	34	47	66
	38.05	10.65	20	7.4	1.20	1.26	1.36	0.91	0.93	0.95	30	42	62
Beverton Holt	0	0	0	0	1.27	1.33	1.42				41	53	72
	18.55	5.65	7	5.9	1.24	1.30	1.39	0.97	0.97	0.98	36	48	67
	20.05	5.65	7	7.4	1.24	1.30	1.39	0.96	0.97	0.98	36	48	67
	29.3	7.9	14	7.4	1.22	1.27	1.36	0.94	0.95	0.96	32	44	63
	25.05	10.65	7	7.4	1.24	1.29	1.39	0.96	0.97	0.97	35	47	66
	32.05	14.65	10	7.4	1.22	1.28	1.37	0.94	0.96	0.97	33	44	64
	36.05	18.65	10	7.4	1.22	1.27	1.36	0.94	0.95	0.96	32	43	63
	31.05**	10.65	10	10.4	1.22	1.28	1.37	0.95	0.96	0.97	33	45	64
	35.05**	10.65	10	14.4	1.22	1.28	1.37	0.94	0.96	0.97	33	45	64
	38.05	10.65	20	7.4	1.20	1.25	1.34	0.91	0.93	0.95	29	40	59
No Init Var	0	0	0	0	1.35	1.36	1.39				59	61	65
	18.55	5.65	7	5.9	1.32	1.33	1.36	0.98	0.98	0.98	53	56	60
	20.05	5.65	7	7.4	1.31	1.33	1.36	0.98	0.98	0.98	53	56	60
	29.3	7.9	14	7.4	1.29	1.31	1.33	0.96	0.96	0.96	49	52	56
	25.05	10.65	7	7.4	1.31	1.32	1.35	0.97	0.97	0.97	52	55	59
	32.05	14.65	10	7.4	1.29	1.31	1.34	0.96	0.96	0.96	50	53	57
	36.05	18.65	10	7.4	1.29	1.31	1.33	0.96	0.96	0.96	49	52	56
	31.05	10.65	10	10.4	1.30	1.31	1.34	0.96	0.97	0.97	51	53	58
	35.05	10.65	10	14.4	1.30	1.31	1.34	0.96	0.96	0.97	50	53	57
	38.05	10.65	20	7.4	1.27	1.29	1.31	0.94	0.94	0.95	46	48	53
14-18 South Rec	0	0	0	0	1.28	1.36	1.48				47	59	80
	18.55*	5.65	7	5.9	1.26	1.33	1.44	0.97	0.97	0.98	42	54	75
	20.05*	5.65	7	7.4	1.26	1.33	1.44	0.97	0.97	0.98	42	54	75
	29.3	7.9	14	7.4	1.24	1.31	1.42	0.94	0.95	0.96	38	50	71
	25.05	10.65	7	7.4	1.25	1.32	1.44	0.96	0.97	0.97	41	53	74
	32.05	14.65	10	7.4	1.24	1.31	1.42	0.95	0.96	0.97	39	51	72
	36.05	18.65	10	7.4	1.24	1.31	1.42	0.94	0.95	0.96	38	50	71
	31.05	10.65	10	10.4	1.25	1.31	1.43	0.95	0.96	0.97	39	51	72
	35.05	10.65	10	14.4	1.24	1.31	1.43	0.95	0.96	0.97	39	51	72
	38.05	10.65	20	7.4	1.22	1.29	1.40	0.92	0.93	0.95	35	47	67