

Further sardine projections based on constant catch scenarios

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Short- and medium-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.

Keywords: sardine, short-term projections, total allowable bycatch, total allowable catch

Introduction

Due to Exceptional Circumstances, the directed sardine Total Allowable Catch (TAC) and sardine Total Allowable Bycatches (TABs) for 2019 and 2020 were recommended by 'ad hoc' methods based on updated assessments and short-term projections (e.g. de Moor 2019a,b and de Moor 2020a,b). A similar process is being followed in 2021. Short- and medium-term projections of the sardine resource based on a recent updated assessment (de Moor 2021a) were provided by de Moor (2021b). This document provides further alternative catch options.

Methods

The model used is identical to that used by de Moor (2021b), but additional further alternatives are considered for

- i) large sardine catch on the west coast (to cover both >14cm directed sardine TAC and >14cm sardine TAB with round herring and anchovy fishing),
- ii) large sardine catch on the south coast (to cover >14cm directed sardine TAC) and
- iii) small sardine catch assumed to be taken on the west coast (to cover ≤ 14 cm sardine TAB with directed sardine, with anchovy and with round herring).

Results and Discussion

Figure 1 shows the predicted west component effective spawning biomass under a no catch scenario. This is predicted to increase quickly to a similar level to that which was expected from projections undertaken during 2019, and higher than that expected from projections undertaken during 2020. The current 'starting point' of November 2020 west component effective spawning biomass is lower than that expected during projections undertaken in both 2019 and 2020, but further analysis will be required to determine if that is due to the catch taken during 2019 and 2020 or if the population was less productive than predicted by those models.

As before, 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 2020 to November 2021;
- ii) The additive change (increase or decrease) in effective spawning biomass from November 2020 to November 2021;
- iii) The additive change (increase or decrease) in total biomass from November 2020 to November 2021; and
- iv) The multiplicative change under alternative catch options relative to a no catch scenario.

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Table 1 shows the 5%iles, 20%iles and medians of (i)-(iv) above for the west component under alternative catch options and models while Table 2 shows the same for the south component. The impact on the resource naturally increases with increasing catch alternatives.

The trade-off of small sardine bycatch resulting in lower directed sardine catch in subsequent years is well known in this fishery and is a key element in OMP development and testing. However, it is important to note that these 1-year projection statistics – which, for example, indicate that a ~4000t increase in directed sardine catch on the west coast will have a substantially greater impact than a ~4000t increase in small sardine bycatch - do not account for the full impact that small sardine bycatch has on the population in subsequent years.

Some catch options listed have a greater “impact” on the west component (multiplicative 1-year change in effective spawning biomass under catch relative to no catch) than that considered acceptable in 2019 and 2020. As expected, the west component is projected to become larger under $move_{y,1} = 0.15$ and lower under $move_{y,1} = 0.55$ than that projected under the baseline model. The impact of the catch (compared to a no catch scenario) is greater for the lower movement scenario. In all models, the west component total biomass is expected to increase after 1 year at the 20%ile under a no catch scenario. This changes to a decrease for higher catch options if future movement is $move_{y,1} = 0.55$.

On the other hand, the projections indicate a high probability of a decrease in the south component total biomass between November 2020 and 2021, under a no catch scenario (Table 2), following the lower future recruitment assumed compared to the preceding years. The increase in directed sardine catch on the south coast from 8500t to 18000t increases the “impact” on the south component to a relative multiplicative change in effective spawner biomass of 0.95 at the 20%ile. This is in line with what was deemed acceptable in 2020.

Statistics corresponding to additional catch alternatives are given in Tables A1 and A2.

Figures 2 and 3 (and Figures A1 and A2) show the medium-term impact of alternative catch options. Under these projection assumptions, the short-lived resource is expected to increase on the west coast to the level corresponding to average recent recruitment, while the level corresponding to average recent recruitment on the south coast is lower than that estimated in June 2020 and a decline is thus projected.

References

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

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de Moor CL. 2020c. Additional sardine projections based on constant catch scenarios assuming alternative November 2019 recruitment levels. DEFF: Branch Fisheries Document FISHERIES/2020/AUG/SWG-PEL/70rev.

de Moor CL. 2021a. Updated assessment of the South African sardine resource using data from 1984-2020. DEFF: Branch Fisheries Document FISHERIES/2021/APR/SWG-PEL/23.

de Moor CL. 2021b. Sardine projections based on constant catch scenarios. DEFF: Branch Fisheries Document FISHERIES/2021/APR/SWG-PEL/27.

Table 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 2020 to 2021 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 2021 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 TAC/B alternatives as estimated by de Moor (2019b). The next three rows give the comparative statistics under the zero catch and April 2020 TAC/B as estimated by de Moor (2020b) and August 2020 TAC/B under a more optimistic recruitment model (de Moor 2020c).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ			S2	S1	C	By
	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	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				
2020	0	0	0	0	1.25	1.55	2.14	9	15	21	-35	-8	17				0	0	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
	45.05	16.65	18	10.4	1.27	1.59	2.14	10	16	21	-44	-19	5	0.88	0.89	0.9	0.20	0.01		
Baseline	0	0	0	0	1.81	2.29	3.61	27	36	48	22	41	104				0	0	0	0
	27.00	12.25	8.5	6.25	1.72	2.15	3.34	22	31	43	10	29	92	0.88	0.90	0.93	7.6	6.2	0.6	0
	40.65	12.25	18.0	10.4	1.71	2.13	3.29	22	30	43	7	26	88	0.85	0.89	0.92	7.6	6.4	0.6	0
	42.05	13.65	18.0	10.4	1.70	2.11	3.26	21	30	42	6	25	87	0.84	0.88	0.91	10.6	7.4	1.2	0
move _{y,1} =0.55	0	0	0	0	1.68	2.09	3.21	20	29	41	4	23	86	0.82	0.86	0.90	16.4	12.0	1.6	0
	27.00	12.25	8.5	6.25	1.35	1.80	3.01	18	25	35	-34	11	51				0	0	0	0
	40.65	12.25	18.0	10.4	1.29	1.69	2.77	15	22	31	-42	2	42	0.89	0.91	0.94	7.6	6.2	0.6	0
	42.05	13.65	18.0	10.4	1.28	1.67	2.73	14	21	31	-45	0	40	0.87	0.90	0.93	7.6	6.4	0.6	0
move _{y,1} =0.15	0	0	0	0	1.28	1.65	2.71	14	21	30	-45	-1	39	0.86	0.89	0.92	10.6	7.4	1.2	0
	27.00	12.25	8.5	6.25	1.27	1.63	2.67	13	20	30	-46	-2	38	0.84	0.88	0.91	16.4	12.0	1.6	0
	40.65	12.25	18.0	10.4	2.25	2.80	4.24	34	44	60	61	73	156				0	0	0	0
	42.05	13.65	18.0	10.4	2.16	2.60	3.91	29	38	54	45	57	140	0.86	0.89	0.93	7.6	6.2	0.6	0
No Init Var	0	0	0	0	2.14	2.58	3.85	28	37	53	41	52	136	0.84	0.88	0.91	7.6	6.4	0.6	0
	27.00	12.25	8.5	6.25	2.14	2.57	3.82	27	36	53	40	51	135	0.83	0.87	0.91	10.6	7.4	1.2	0
	40.65	12.25	18.0	10.4	2.14	2.57	3.82	27	36	53	40	51	135	0.83	0.87	0.91	10.6	7.4	1.2	0
	42.05	13.65	18.0	10.4	2.11	2.54	3.73	26	35	52	38	49	132	0.80	0.84	0.89	16.4	12.0	1.6	0
No Init Var	0	0	0	0	2.52	2.57	2.80	40	42	48	30	31	103				0	0	0	0
	27.00	12.25	8.5	6.25	2.33	2.37	2.61	35	36	43	18	18	91	0.92	0.92	0.93	0	0	0	0
	40.65	12.25	18.0	10.4	2.30	2.34	2.58	35	36	42	15	15	87	0.91	0.91	0.92	0	0	0	0
	42.05	13.65	18.0	10.4	2.28	2.33	2.57	34	35	42	14	14	86	0.90	0.91	0.92	0	0	0	0
	45.05	16.65	18.0	10.4	2.24	2.29	2.53	33	34	41	12	12	85	0.89	0.89	0.90	0	0	0	0

Table 2. 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 2020 to 2021 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 TAC/B alternatives as estimated by de Moor (2019b). The next three rows give the comparative statistics under the zero catch and April 2020 TAC/B as estimated by de Moor (2020b) and August 2020 TAC/B under a more optimistic recruitment model (de Moor 2020c).

					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
2020	0	0	0	0	1.27	1.31	1.39	43	53	65	10	42	79			
	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
	45.05	16.65	18	10.4	1.23	1.27	1.33	34	44	56	17	42	75	0.91	0.93	0.94
Baseline	0	0	0	0	1.45	1.48	1.52	55	74	98	-280	-143	-52			
	27.00	12.25	8.5	6.25	1.42	1.45	1.49	49	69	92	-293	-156	-65	0.96	0.97	0.98
	40.65	12.25	18.0	10.4	1.40	1.43	1.47	45	64	88	-302	-165	-74	0.93	0.95	0.97
	42.05	13.65	18.0	10.4	1.40	1.42	1.47	45	64	88	-303	-165	-75	0.93	0.95	0.96
	45.05	16.65	18.0	10.4	1.40	1.42	1.47	45	64	87	-304	-166	-76	0.93	0.95	0.96
move _{y,1} = 0.55	0	0	0	0	1.46	1.51	1.58	61	84	108	-237	-95	-3			
	27.00	12.25	8.5	6.25	1.44	1.48	1.54	54	77	102	-253	-112	-19	0.96	0.97	0.98
	40.65	12.25	18.0	10.4	1.42	1.45	1.52	50	72	98	-263	-122	-30	0.93	0.95	0.96
	42.05	13.65	18.0	10.4	1.42	1.45	1.51	50	72	97	-264	-123	-30	0.93	0.95	0.96
	45.05	16.65	18.0	10.4	1.42	1.45	1.51	49	72	97	-265	-124	-32	0.92	0.94	0.96
move _{y,1} = 0.15	0	0	0	0	1.43	1.44	1.47	46	64	86	-345	-189	-113			
	27.00	12.25	8.5	6.25	1.41	1.42	1.44	41	59	82	-355	-199	-122	0.97	0.98	0.98
	40.65	12.25	18.0	10.4	1.38	1.40	1.42	37	55	77	-363	-207	-130	0.93	0.95	0.97
	42.05	13.65	18.0	10.4	1.38	1.40	1.42	37	55	77	-363	-207	-131	0.93	0.95	0.97
	45.05	16.65	18.0	10.4	1.38	1.40	1.42	36	55	77	-363	-207	-131	0.93	0.95	0.97
No Init Var	0	0	0	0	1.50	1.51	1.53	98	99	104	-129	-108	-69			
	27.00	12.25	8.5	6.25	1.47	1.48	1.50	92	94	98	-142	-121	-82	0.98	0.98	0.98
	40.65	12.25	18.0	10.4	1.44	1.46	1.48	87	89	94	-151	-130	-91	0.97	0.97	0.97
	42.05	13.65	18.0	10.4	1.44	1.45	1.48	87	89	94	-151	-131	-91	0.97	0.97	0.97
	45.05	16.65	18.0	10.4	1.44	1.45	1.48	87	89	93	-152	-132	-92	0.96	0.96	0.97

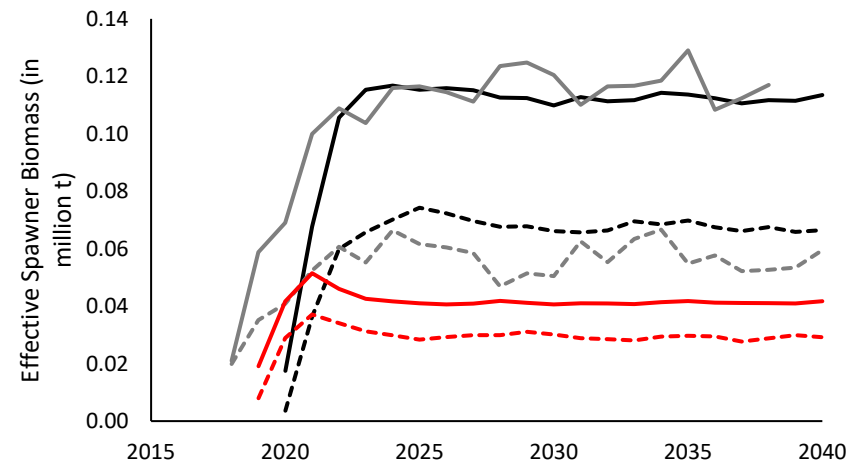


Figure 1a. The projected median and lower 5%ile west component effective spawner biomass from de Moor (2019b) (grey), de Moor (2020b) (red) and the baseline projections carried out in this document (black).

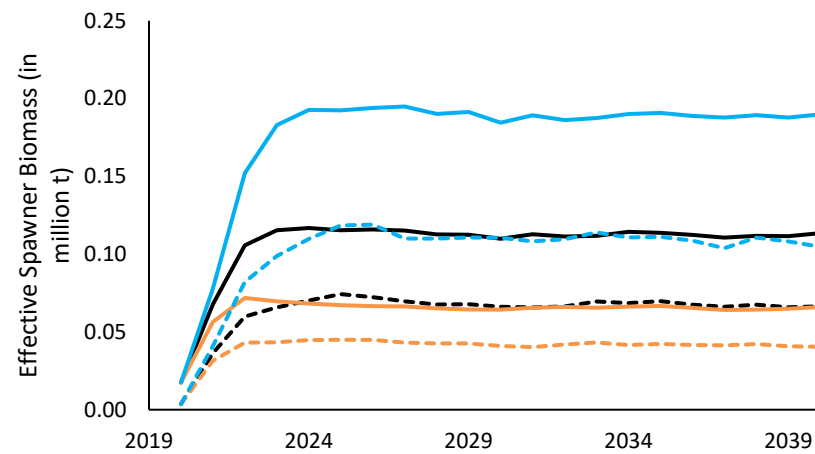


Figure 1a. The projected median and lower 5%ile west component effective spawner biomass from the baseline projections carried out in this document (black) together with those for higher (orange) and lower (blue) future proportions of west component fish moving to the south component.

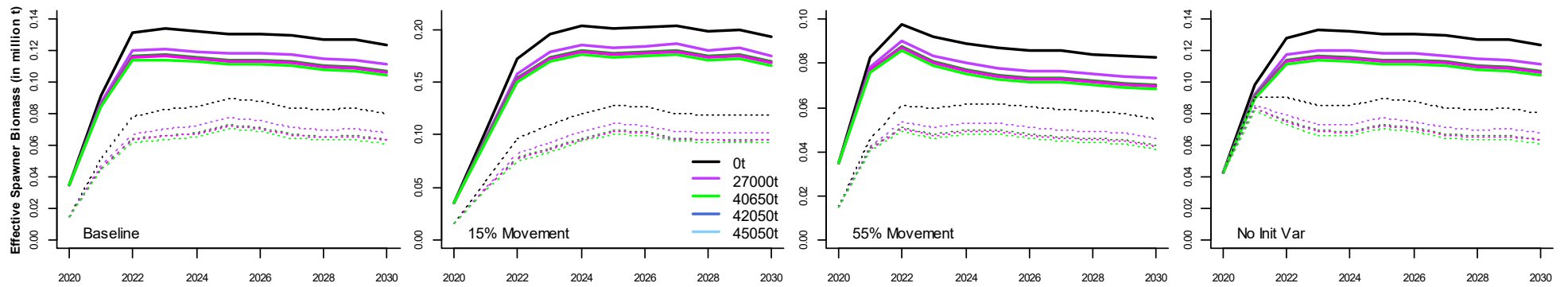


Figure 2. The projected medians (upper) and 5%iles (lower) of sardine **west component effective spawner biomass** from 2020 to 2030 under a no catch and four alternative catch scenarios corresponding to Table 1, for the alternative models considered. Note that the vertical axis differs between alternative models.

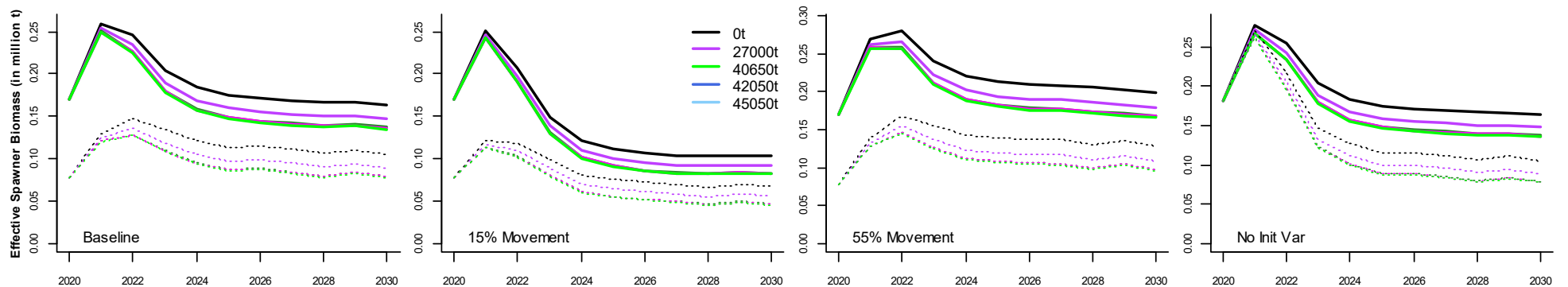


Figure 3. The projected medians (upper) and 5%iles (lower) of sardine **south component effective spawner biomass** from 2020 to 2030 under a no catch and four alternative catch scenarios corresponding to Table 2, for the alternative models considered. Note that the vertical axis differs between alternative models.

APPENDIX: Alternative catch options

Table A1. 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 2020 to 2021 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 2021 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 TAC/B alternatives as estimated by de Moor (2019b). The next three rows give the comparative statistics under the zero catch and April 2020 TAC/B as estimated by de Moor (2020b) and August 2020 TAC/B under a more optimistic recruitment model (de Moor 2020c).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ			S2	S1	C	By
	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	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				
2020	0	0	0	0	1.25	1.55	2.14	9	15	21	-35	-8	17				0	0	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
	45.05	16.65	18	10.4	1.27	1.59	2.14	10	16	21	-44	-19	5	0.88	0.89	0.9	0.20	0.01		
Baseline	0	0	0	0	1.81	2.29	3.61	27	36	48	22	41	104				0	0	0	0
	27.00	12.25	8.5	6.25	1.72	2.15	3.34	22	31	43	10	29	92	0.88	0.90	0.93	7.6	6.2	0.6	0
	31.15	12.25	8.5	10.4	1.71	2.14	3.32	22	31	43	7	26	88	0.87	0.89	0.92	7.6	6.4	0.6	0
	31.40	16.65	8.5	6.25	1.69	2.11	3.24	21	30	42	7	26	89	0.85	0.87	0.91	15.6	11.6	1.6	0
	36.50	12.25	18.0	6.25	1.71	2.14	3.32	22	31	43	10	29	92	0.87	0.89	0.92	7.6	6.2	0.6	0
	43.05	14.65	18.0	10.4	1.69	2.11	3.24	21	30	42	5	24	87	0.84	0.87	0.91	12.8	8.2	1.4	0
	44.05	15.65	18.0	10.4	1.69	2.10	3.22	21	30	42	5	24	86	0.83	0.86	0.90	14.6	10.4	1.6	0
	45.05	16.65	18.0	10.4	1.68	2.09	3.21	20	29	41	4	23	86	0.82	0.86	0.90	16.4	12.0	1.6	0
	48.05	16.65	21.0	10.4	1.68	2.09	3.20	20	29	41	4	23	86	0.82	0.85	0.90	16.4	12.0	1.6	0
	54.06	19.98	21.6	12.48	1.66	2.05	3.15	19	28	40	1	19	82	0.78	0.83	0.88	23.8	19.0	5.0	0

Table A1 (continued).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ			S2	S1	C	By
	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	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				
2020	0	0	0	0	1.25	1.55	2.14	9	15	21	-35	-8	17				0	0	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
	45.05	16.65	18	10.4	1.27	1.59	2.14	10	16	21	-44	-19	5	0.88	0.89	0.90	0.20	0.01		
move _{y,1} = 0.55	0	0	0	0	1.35	1.80	3.01	18	25	35	-34	11	51				0	0	0	0
	27.00	12.25	8.5	6.25	1.29	1.69	2.77	15	22	31	-42	2	42	0.89	0.91	0.94	7.6	6.2	0.6	0
	31.15	12.25	8.5	10.4	1.29	1.68	2.75	14	21	31	-45	0	40	0.88	0.91	0.93	7.6	6.4	0.6	0
	31.40	16.65	8.5	6.25	1.28	1.65	2.71	14	21	30	-44	1	40	0.86	0.89	0.92	15.6	11.6	1.6	0
	36.50	12.25	18.0	6.25	1.29	1.68	2.75	14	21	31	-42	2	42	0.88	0.91	0.93	7.6	6.2	0.6	0
	43.05	14.65	18.0	10.4	1.27	1.65	2.70	13	20	30	-46	-1	39	0.85	0.89	0.92	12.8	8.2	1.4	0
	44.05	15.65	18.0	10.4	1.27	1.64	2.68	13	20	30	-46	-1	38	0.85	0.88	0.91	14.6	10.4	1.6	0
	48.05	16.65	21.0	10.4	1.26	1.63	2.67	13	20	29	-46	-2	38	0.84	0.87	0.91	16.4	12.0	1.6	0
	54.06	19.98	21.6	12.48	1.25	1.61	2.60	12	19	28	-49	-4	35	0.81	0.85	0.89	23.8	19.0	5.0	0
move _{y,1} = 0.15	0	0	0	0	2.25	2.80	4.24	34	44	60	61	73	156				0	0	0	0
	27.00	12.25	8.5	6.25	2.16	2.60	3.91	29	38	54	45	57	140	0.86	0.89	0.93	7.6	6.2	0.6	0
	31.15	12.25	8.5	10.4	2.15	2.59	3.88	28	37	54	41	52	136	0.85	0.88	0.92	7.6	6.4	0.6	0
	31.40	16.65	8.5	6.25	2.13	2.56	3.80	27	36	52	42	53	137	0.82	0.86	0.90	15.6	11.6	1.6	0
	36.50	12.25	18.0	6.25	2.15	2.59	3.88	28	37	54	45	57	140	0.85	0.88	0.92	7.6	6.2	0.6	0
	43.05	14.65	18.0	10.4	2.13	2.56	3.80	27	36	52	39	51	134	0.82	0.86	0.90	12.8	8.2	1.4	0
	44.05	15.65	18.0	10.4	2.12	2.55	3.76	26	35	52	38	50	133	0.81	0.85	0.90	14.6	10.4	1.6	0
	48.05	16.65	21.0	10.4	2.11	2.54	3.73	26	35	51	38	49	132	0.80	0.84	0.89	16.4	12.0	1.6	0
	54.06	19.98	21.6	12.48	2.06	2.49	3.62	24	33	50	33	44	127	0.76	0.81	0.87	23.8	19.0	5.0	0
No Init Var	0	0	0	0	2.52	2.57	2.80	40	42	48	30	31	103				0	0	0	0
	27.00	12.25	8.5	6.25	2.33	2.37	2.61	35	36	43	18	18	91	0.92	0.92	0.93	0	0	0	0
	31.15	12.25	8.5	10.4	2.31	2.36	2.60	35	36	42	15	15	87	0.92	0.92	0.93	0	0	0	0
	31.40	16.65	8.5	6.25	2.27	2.31	2.56	34	35	41	16	16	88	0.90	0.90	0.91	0	0	0	0
	36.50	12.25	18.0	6.25	2.31	2.36	2.60	35	36	42	18	18	91	0.92	0.92	0.93	0	0	0	0
	43.05	14.65	18.0	10.4	2.27	2.31	2.55	34	35	41	13	14	86	0.90	0.90	0.91	0	0	0	0
	44.05	15.65	18.0	10.4	2.26	2.30	2.54	33	34	41	13	13	85	0.89	0.90	0.91	0	0	0	0
	48.05	16.65	21.0	10.4	2.24	2.28	2.52	33	34	40	12	12	85	0.89	0.89	0.90	0	0	0	0
	54.06	19.98	21.6	12.48	2.19	2.23	2.47	31	33	39	9	9	81	0.87	0.87	0.88	0	0	0	0

Table A2. 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 2020 to 2021 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 TAC/B alternatives as estimated by de Moor (2019b). The next three rows give the comparative statistics under the zero catch and April 2020 TAC/B as estimated by de Moor (2020b) and August 2020 TAC/B under a more optimistic recruitment model (de Moor 2020c).

	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
2020	0	0	0	0	1.27	1.31	1.39	43	53	65	10	42	79			
	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
	45.05	16.65	18	10.4	1.23	1.27	1.33	34	44	56	17	42	75	0.91	0.93	0.94
Baseline	0	0	0	0	1.45	1.48	1.52	55	74	98	-280	-143	-52			
	27.00	12.25	8.5	6.25	1.42	1.45	1.49	49	69	92	-293	-156	-65	0.96	0.97	0.98
	31.15	12.25	8.5	10.4	1.42	1.45	1.49	49	69	92	-295	-157	-67	0.96	0.97	0.98
	31.40	16.65	8.5	6.25	1.42	1.45	1.49	49	68	92	-294	-157	-67	0.96	0.97	0.98
	36.50	12.25	18.0	6.25	1.40	1.43	1.47	45	65	88	-300	-163	-73	0.93	0.95	0.97
	43.05	14.65	18.0	10.4	1.40	1.42	1.47	45	64	88	-303	-165	-75	0.93	0.95	0.96
	44.05	15.65	18.0	10.4	1.40	1.42	1.47	45	64	87	-303	-166	-75	0.93	0.95	0.96
	48.05	16.65	21.0	10.4	1.39	1.42	1.46	43	63	86	-306	-168	-78	0.92	0.94	0.96
	54.06	19.98	21.6	12.48	1.39	1.41	1.45	43	62	85	-308	-171	-81	0.91	0.94	0.96
move _{y,1} = 0.55	0	0	0	0	1.46	1.51	1.58	61	84	108	-237	-95	-3			
	27.00	12.25	8.5	6.25	1.44	1.48	1.54	54	77	102	-253	-112	-19	0.96	0.97	0.98
	31.15	12.25	8.5	10.4	1.44	1.47	1.54	54	77	102	-256	-115	-22	0.96	0.97	0.98
	31.40	16.65	8.5	6.25	1.43	1.47	1.54	54	76	101	-255	-114	-21	0.95	0.97	0.98
	36.50	12.25	18.0	6.25	1.42	1.45	1.52	50	73	98	-261	-119	-27	0.93	0.95	0.96
	43.05	14.65	18.0	10.4	1.42	1.45	1.51	49	72	97	-265	-123	-31	0.92	0.95	0.96
	44.05	15.65	18.0	10.4	1.42	1.45	1.51	49	72	97	-265	-124	-31	0.92	0.95	0.96
	48.05	16.65	21.0	10.4	1.41	1.44	1.51	48	70	95	-268	-126	-34	0.91	0.94	0.96
	54.06	19.98	21.6	12.48	1.40	1.44	1.50	47	69	94	-271	-130	-37	0.91	0.93	0.95

Table A2 (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
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
2020	0	0	0	0	1.27	1.31	1.39	43	53	65	10	42	79			
	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
	45.05	16.65	18	10.4	1.23	1.27	1.33	34	44	56	17	42	75	0.91	0.93	0.94
move _{y1} = 0.15	0	0	0	0	1.43	1.44	1.47	46	64	86	-345	-189	-113			
	27.00	12.25	8.5	6.25	1.41	1.42	1.44	41	59	82	-355	-199	-122	0.97	0.98	0.98
	31.15	12.25	8.5	10.4	1.41	1.42	1.44	41	59	82	-355	-200	-123	0.97	0.98	0.98
	31.40	16.65	8.5	6.25	1.41	1.42	1.44	41	59	81	-355	-199	-123	0.96	0.98	0.98
	36.50	12.25	18.0	6.25	1.38	1.40	1.42	37	55	77	-362	-206	-130	0.93	0.95	0.97
	43.05	14.65	18.0	10.4	1.38	1.40	1.42	37	55	77	-363	-207	-131	0.93	0.95	0.97
	44.05	15.65	18.0	10.4	1.38	1.40	1.42	37	55	77	-363	-207	-131	0.93	0.95	0.97
	48.05	16.65	21.0	10.4	1.37	1.39	1.41	35	53	76	-366	-210	-133	0.92	0.94	0.96
	54.06	19.98	21.6	12.48	1.37	1.39	1.41	35	53	75	-367	-211	-135	0.92	0.94	0.94
No Init Var	0	0	0	0	1.50	1.51	1.53	98	99	104	-129	-108	-69			
	27.00	12.25	8.5	6.25	1.47	1.48	1.50	92	94	98	-142	-121	-82	0.98	0.98	0.98
	31.15	12.25	8.5	10.4	1.47	1.48	1.50	92	94	98	-144	-123	-84	0.98	0.98	0.98
	31.40	16.65	8.5	6.25	1.46	1.47	1.50	91	93	98	-143	-123	-83	0.98	0.98	0.98
	36.50	12.25	18.0	6.25	1.45	1.46	1.48	88	90	94	-149	-129	-89	0.97	0.97	0.97
	43.05	14.65	18.0	10.4	1.44	1.45	1.48	87	89	94	-152	-131	-92	0.97	0.97	0.97
	44.05	15.65	18.0	10.4	1.44	1.45	1.48	87	89	93	-152	-131	-92	0.96	0.96	0.97
	48.05	16.65	21.0	10.4	1.44	1.45	1.47	85	87	92	-155	-134	-95	0.96	0.96	0.96
	54.06	19.98	21.6	12.48	1.43	1.44	1.46	85	87	91	-157	-136	-97	0.96	0.96	0.96

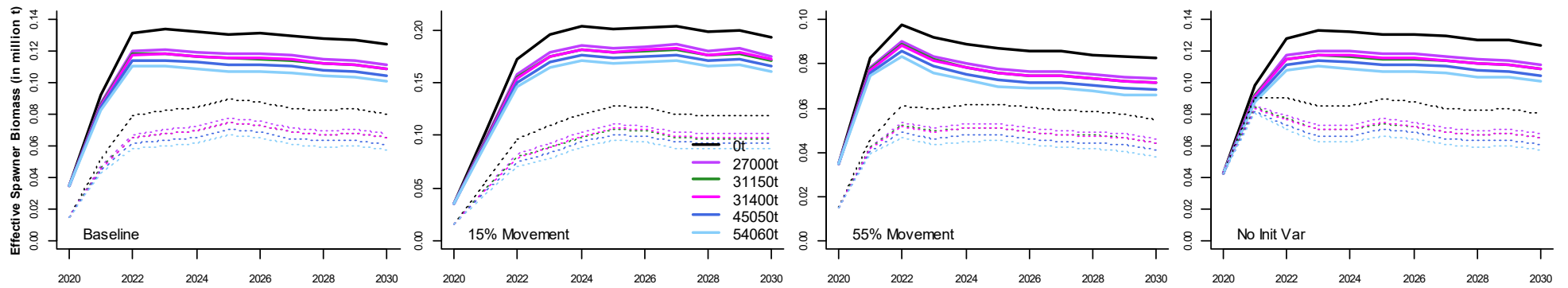


Figure A1. The projected medians (upper) and 5%iles (lower) of sardine **west component effective spawner biomass** from 2020 to 2030 under a no catch and four alternative catch scenarios, for the alternative models considered. Note that the vertical axis differs between alternative models.

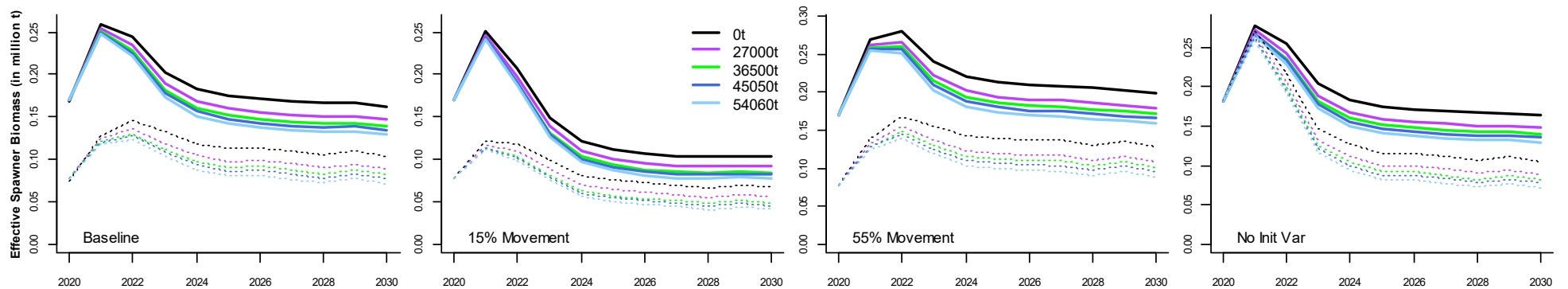


Figure A2. The projected medians (upper) and 5%iles (lower) of sardine **south component effective spawner biomass** from 2020 to 2030 under a no catch and six alternative catch scenarios, for the alternative models considered. Note that the vertical axis differs between alternative models.