

Additional sardine projections based on constant catch scenarios assuming alternative November 2019 recruitment levels

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Short-term projections of the South African sardine resource under alternative small sardine bycatch and large sardine west and south coast catch options have been run, assuming five alternative west component recruitment scenarios for November 2019, each corresponding to one of the five most recent years. The previous baseline projections randomly sampled west component recruitment from all of these years. The impact of the alternative catch options on the sardine resource is now considered given the June 2020 survey observation of recruitment west of Cape Infanta.

Introduction

de Moor (2020a) undertook short- and medium-term projections of the South African sardine resource to assist the Small Pelagic Scientific Working Group (SWG-PEL) in assessing whether increases in the 2020 directed sardine TAC and/or sardine TABs could be scientifically justified. Those projections assumed that future recruitment to the west component from November 2019 onwards was randomly drawn from the recruitments estimated from 2014 to 2018 by de Moor (2020b). This document reports on some of the short-term statistics assuming five different recruitment levels for November 2019, and one new recruitment level, and provides a new randomly sampled set of results taking the June 2020 survey observation of recruitment west of Cape Infanta into account. The possible management implications of these updated results are discussed.

Methods

The short-term projections of de Moor (2020a) assumed future recruitment was drawn randomly from the most recent 5 years of estimated recruitment. These short-term projections have been re-run, replacing the single baseline west component recruitment option of randomly drawing recruitment from the most recent 5 years with five alternative options, each assuming west component recruitment in November 2019 corresponded to one of the years 2014 to 2018 only. An additional run assuming a November 2019 recruitment of 17.47 billion (Butterworth and Ross-Gillespie 2020) was also run. There was no change to the modelling of recruitment to the south component.

Four sets of catch options were considered:

- i) Six alternative small sardine bycatch options, from 7 000t (bycatch with anchovy) + 400t (bycatch with round herring and directed sardine) to 12 000t + 400t, in steps of 1 000t of bycatch with anchovy. The large sardine catch west of Cape Agulhas remained fixed at 2 625t (bycatch) + 9 000t (directed) and the large sardine catch east of Cape Agulhas remained fixed at 13 000t.
- ii) Six alternative large sardine west of Cape Agulhas catch options, from 2 625t (bycatch) + 9 000t (directed) to 2 625t (bycatch) + 14 000t (directed), in steps of 1 000t of directed catch. The small sardine bycatch remained fixed at 10 000t (bycatch with anchovy) + 400t (bycatch with round herring and directed sardine) and the large sardine catch east of Cape Agulhas remained fixed at 13 000t.

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- iii) Six alternative large sardine east of Cape Agulhas catch options, from 13 000t to 18 000t (directed), in steps of 1 000t of directed catch. The small sardine bycatch remained fixed at 10 000t (bycatch with anchovy) + 400t (bycatch with round herring and directed sardine) and the large sardine catch west of Cape Agulhas remained fixed at 2 625t (bycatch) + 9 000t (directed).
- iv) Six alternative large sardine catch options, from 2 625t (bycatch) + 9 000t (directed) to 2 625t (bycatch) + 14 000t (directed) west of Cape Agulhas and 13 000t to 18 000t (directed) east of Cape Agulhas, in steps of 1000t of directed catch on each coast. The small sardine bycatch remained fixed at 10 000t (bycatch with anchovy) + 400t (bycatch with round herring and directed sardine).

Note that the directed sardine catch is assumed to consist of fish of all ages, including some recruits and changes to the bycatch levels impacts changes to the directed catches-at-age (Appendix A, de Moor 2020a) as the directed fishing mortality is assumed to apply to the biomass available after bycatch. This subsequently impacts the contribution of 2+ year olds to the November 2020 biomass and spawner biomass.

Recruitment in November 2019

The weight applied to each of these alternative November 2019 recruitment options in making a management decision can be informed to some extent by the June 2020 survey estimate of sardine recruitment west of Cape Infanta which is assumed to represent west component recruitment¹. Firstly, the June 2020 survey estimate of 7.01 billion sardine recruits west of Cape Infanta was close to two of the four most recent observations – 6.26 billion in May 2015 and 7.18 billion in June 2017 (Figure 1).

Secondly, the model predicted recruitment at the time of the survey, $N_{2020,r}^A$, can be back-projected to November as follows (de Moor 2020b):

$$N_{w,2019,0}^S = \left(\left(\left(N_{w,NI,2020,r}^S e^{(0.5t_{2020}/12)M_0^S} + C_{w,2020,obs}^S \right) e^{(1/8+0.5t_{2020}/12)M_0^S} + C_{w,NI,2020,2,0}^S \right) e^{M_0^S/4} + C_{w,NI,2020,1,0}^S \right) e^{M_0^S/8} \quad (1)$$

where

$M_0^S = 1.0 \text{ year}^{-1}$ denotes the rate of natural mortality of age 0 sardine;

$t_{2020} = 1.57 \text{ months}$ denotes the time lapsed between 1 May and the start of the recruit survey on 17th June 2020;

$C_{w,NI,2020,q,0}^S$ denotes the number of west component sardine recruits caught during quarter q of 2020; and

$C_{w,2020,0,bs}^S$ denotes the number of west component sardine recruits caught between 1 May and the day before the start of the recruit survey in 2020.

Equation (1) requires sardine recruit catch from 1 November 2019 to 16 June 2020. Unlike for anchovy, there is no frequently used pre-agreed formula to calculate real-time 0-year-old catch from the available length frequencies using cut-off lengths, and commercial length frequencies are not yet available for April – June 2020. In addition, and again unlike anchovy, the sardine fishery primarily targets larger fish. Recruits are mostly landed as bycatch. The historical sardine

¹ There was no survey estimate of recruitment east of Cape Infanta in June 2020 to inform the south coast recruitment.

recruit catch between 1 November and the day before the survey has ranged from 0.06 to 1.1 billion fish, with a median of 0.39 billion (de Moor 2020c). Equation (1) could thus realistically be used assuming no recruit catch from 1 November 2019 to 16 June 2020, although the impact of alternatively assuming a recruit catch of 0.4 or a maximum of 1 billion fish is also given.

As for anchovy (de Moor 2020d), four alternative values for model predicted recruitment at the time of the survey were used to account for (i) survey bias ($k_{w,r}^S$) and (ii) both survey and additional variance.

- a) No survey or additional uncertainty, $k_{w,r}^S N_{w,NI,2020,r}^S = N_{w,2020,r}^{obs}$
- b) One SE difference using the 2020 survey CV of 0.354: $k_{w,r}^S N_{w,NI,2020,r}^S = (1 - 0.354) N_{w,2020,r}^{obs}$
- c) Multiplicative differences between the survey observation and the bias corrected recruitment based on that estimated in recent years and close to 7 billion recruits (Figure 2): $k_{w,r}^S N_{w,NI,2020,r}^S = 0.34 N_{w,2020,r}^{obs}$ and $k_{w,r}^S N_{w,NI,2020,r}^S = 0.59 N_{w,2020,r}^{obs}$.

This predicts a range of November 2019 recruitment of 8 to 23 billion fish (Table 1), with 8 and 15 billion corresponding to the recent survey estimates of around 7 billion fish in June 2017 and May 2015 as was similarly estimated in June 2020.

In selecting which of the below sets of results might best reflect true recruitment in November 2019, the first option above would suggest focusing on the $N_{w,0,2016,0}^S = 8.11$ and $N_{w,0,2014,0}^S = 11.5$ scenarios, while the second option above would suggest focusing on the $N_{w,0,2016,0}^S = 8.11$ and $N_{w,0,2018,0}^S = 14.14$ scenarios. An additional run where west component recruitment in November 2019 was randomly drawn from these three highest of the most recent 5 years was thus also undertaken.

Short-term projection results

Tables 2 to 5 shows the summary statistics reflecting the impact of alternative small bycatch and large catch levels on the population after a single year assuming 2019 west component recruitment corresponds to one of the years 2014 to 2018. The “Baseline” results correspond to the random sampling of November 2019 recruitment from 2014 to 2018 (de Moor 2020a), while the “Three highest” results correspond to the random sampling of November 2019 recruitment from 2014, 2016 and 2018.

Discussion and Management Implications

One of the key considerations in managing the sardine population is the size of the “effective” west component spawning biomass, as it is assumed that recruitment to the west component (a primary driver of growth for the whole population) is dependent on this effective spawning biomass. This biomass is assumed to consist of all the west component spawning biomass as well as 8% of the south component spawning biomass. A combination of growth in the south component at the turn of the century and a subsequent decrease in the west component has resulted in a substantial proportion of the effective west component spawning biomass consisting of south component spawning biomass in some years (68% in 2019, Figure 3, de Moor (2020c)). Under a no catch scenario the effective west component spawning biomass is predicted to consist of 45%² of south component spawning biomass in 2020.

² Median

In April 2020, the SWG-PEL recommended a directed >14cm sardine TAC (by coast) and sardine TABs based primarily on the short-term projections of de Moor (2020a). The recommendation was made considering not only the baseline model (as repeated here), but alternative key sensitivity tests too – some producing more optimistic and some more pessimistic projections. There were two key considerations underlying the earlier recommendation:

- i) That the 20%ile of the multiplicative change in effective spawning biomass from November 2019 to 2020 relative to that under a no catch scenario be similar to that used to recommend the 2019 sardine TAC/Bs; and
- ii) What proportion of resource growth should be assigned to fishing compared to resource recovery, with the proportion being assigned to recovery being higher for a more depleted resource (Die *et al.* 2019).

Unfortunately, the results in de Moor (2020a) indicated there was a non-negligible probability of a *decrease* in the west component biomass from November 2019 to November 2020, even under a no catch scenario (Figure 4 shows the baseline change in biomass, see de Moor (2020a) for projections under alternative models). The projections for resource recovery at the time of making the 2019 TAC/B recommendations were more optimistic than those available in April 2020. This meant that the SWG-PEL could no longer effectively discuss what proportion of resource growth should be assigned to resource recovery v fishing. Instead, the SWG-PEL selected a lower 20% “impact factor” (consideration (i) above, where “lower impact” equates to a higher proportion) to go some way to alleviate the concern raised from the less optimistic projections and possible decrease in west component biomass.

The following bullet points revisits the earlier sardine TAC/B recommendation process given the results in this document in a similar manner as was used for anchovy (de Moor 2020d):

- One can focus on the three higher recent November recruitments (2014, 2016, 2018), in preference to the lower two of Novembers 2015 and 2017.
- One then locates which catch/bycatch alternatives have a 20%ile of the multiplicative change in effective spawning biomass from November 2019 to 2020 relative to that under a no catch scenario of at least 0.90 for the west component and 0.95 for the south component (termed ‘impact factor’ below).
- When considering only the three highest recent recruitments, there is still a non-negligible probability of a decrease in the west component biomass from November 2019 to 2020, albeit slightly less than when randomly sampling from the five most recent years (Figure 4, Table 6).
- The below bullet points assume the SWG-PEL would aim to provide revised advice for this 2020 fishing season (if any) under the same projected level of west component biomass change. The SWG-PEL may, however prefer to allow any *relatively* positive indication of incoming recruitment to rather reduce/increase the possibility of a decrease/increase in west component biomass with a subsequent positive impact on both the ecosystem and the fishery.
- The selections of ‘acceptable’ TAC/B combinations sometimes differ between the three higher recent recruitment alternatives (see Tables 2 to 5 for details), but for convenience, comment here is only made on the statistics resulting from randomly sampling from these three years.

- Considering an increase to the west coast small bycatch (Table 2), the small bycatch options of 11 400t and 12 400t have a west component impact factor of 0.90 and the small bycatch option of 11 400t corresponds closest to the additive change in west component biomass selected in April 2020³.
- Considering an increase to the west coast large catch only (Table 3), the west large catch options of 12 650t and 13 650t have a west component impact factor of 0.90 and these two options and 14 650t have a south component impact factor of 0.95. The west large catch option of 12 650t corresponds closest to the additive change in west component biomass selected in April 2020.
- Considering an increase to the south coast large catch only (Table 4), the south large catch options of 15 000t to 18 000t have a west component impact factor of 0.90 and the option of 13 000t has a south component impact factor of 0.95. The south large catch options from 13 000t to 18 000t all result in the same additive change in west component biomass.
- Considering increases to both the west and south coast large catches (Table 5), the total catch options of 37 050t and 39 050t have a west component impact factor of 0.90 and the total catch option of 35 050t has a south component impact factor of 0.95. The total catch options of 35 050t and 37 050t correspond closest to the additive change in west component biomass selected in April 2020, with 35 050t having the same probability of an increase in west component biomass from November 2019 to 2020 as that 'accepted' in April 2020 (Table 6, Figure 4).

An addendum has been added to update this discussion following a revision to the June 2020 survey estimate of sardine recruitment.

References

- Butterworth DS and Ross-Gillespie A. 2020. Continuous approach applied to sardine recruitment survey estimate to advise on juvenile sardine TAB estimates for 2020 and the corresponding recruitment strength. DEFF: Branch Fisheries Document FISHERIES/2020/JUL/SWG-PEL/60.
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- de Moor CL. 2020c. Baseline assessment of the South African sardine resource using data from 1984-2019. DEFF: Branch Fisheries Document FISHERIES/2020/APR/SWG-PEL/30.

³ The statistics reported in Table 2, reflecting a change in the population after just one year, will not give an accurate reflection of the impact of small sardine bycatch on the population. Small sardine bycatch is assumed to consist of only recruits in the model. The 2019 recruits will contribute relatively less to the November 2020 biomass due to the lower weight of 1-year olds than 2+ year olds, and few 1-year-olds will form part of the November 2020 spawner biomass. The impact of small sardine bycatch during 2019 will be better reflected in changes in the population after a few years.

de Moor CL. 2020d. A method to recommend the final anchovy Total Allowable Catch for 2020 based on short-term projections of the anchovy resource. DEFF: Branch Fisheries Document FISHERIES/2020/JUL/SWG-PEL/54.

de Moor CL. 2020e. Sardine projections based on constant catch scenarios separated by recruitment scenarios. DEFF: Branch Fisheries Document FISHERIES/2020/JUL/SWG-PEL/63.

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.

Table 1. The November 2019 back-projected recruitment based on alternative levels of recruit catch and recruitment at the time of the June 2020 survey.

$k_{w,r}^S N_{w,NI,2020,r}^S$		$C_{w,2020,1,0}^S$		
		0.0	0.4	1.0
	$N_{w,2020,r}^{obs}$	22	22	23
	$(1 - 0.354)N_{w,2020,r}^{obs}$	16	17	17
	$0.34N_{w,2020,r}^{obs}$	8	9	10
	$0.59N_{w,2020,r}^{obs}$	15	15	16

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 **small sardine bycatch** options and alternative November 2019 recruitment scenarios. 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) in 2020 only are given. The top two rows give the comparative statistics under the zero catch and 2019 TAC/B as estimated by de Moor (2019) and the next three rows give the statistics considered in setting the 2020 TAC/Bs (de Moor 2020a).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B ⁴			Relative Multiplicative Δ			S2	S1
	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	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
	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
	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
Baseline	0	0	0	0	1.25	1.55	2.14	9	15	21	-35	-8	17					
	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
	33.05	11.65	13	8.4	1.15	1.43	1.94	6	12	18	-46	-20	6	0.89	0.9	0.92	0.09	0.01
	34.05	11.65	13	9.4	1.15	1.43	1.94	6	12	17	-47	-20	6	0.88	0.9	0.92	0.09	0.01
	35.05	11.65	13	10.4	1.15	1.43	1.94	5	12	17	-47	-21	5	0.88	0.9	0.92	0.09	0.01
	36.05	11.65	13	11.4	1.15	1.43	1.93	5	12	17	-48	-21	4	0.88	0.9	0.91	0.09	0.01
	37.05	11.65	13	12.4	1.14	1.42	1.93	5	12	17	-49	-22	4	0.87	0.89	0.91	0.09	0.01
$N_{W,0,2017,0}^S = 3.47$	0	0	0	0	1.16	1.4	1.87	5	11	16	-38	-13	11					
	32.05	11.65	13	7.4	1.06	1.27	1.68	2	7	13	-49	-24	1	0.87	0.89	0.91	0.14	0.02
	33.05	11.65	13	8.4	1.06	1.27	1.67	2	7	12	-49	-24	0	0.86	0.88	0.91	0.14	0.02
	34.05	11.65	13	9.4	1.05	1.26	1.67	1	7	12	-50	-25	0	0.86	0.88	0.9	0.15	0.02
	35.05	11.65	13	10.4	1.05	1.26	1.66	1	7	12	-50	-26	-1	0.86	0.88	0.9	0.15	0.02
	36.05	11.65	13	11.4	1.05	1.26	1.66	1	7	12	-51	-26	-2	0.85	0.88	0.9	0.15	0.02
	37.05	11.65	13	12.4	1.05	1.26	1.65	1	7	12	-52	-27	-2	0.85	0.87	0.9	0.15	0.02
$N_{W,0,2015,0}^S = 6.99$	0	0	0	0	1.23	1.51	2.03	8	14	19	-35	-10	14					
	32.05	11.65	13	7.4	1.15	1.4	1.86	5	11	16	-46	-21	4	0.88	0.9	0.92	0.10	0.00
	33.05	11.65	13	8.4	1.15	1.39	1.86	5	11	16	-46	-21	3	0.88	0.9	0.91	0.10	0.01
	34.05	11.65	13	9.4	1.15	1.39	1.85	5	10	16	-47	-22	3	0.88	0.9	0.91	0.10	0.01
	35.05	11.65	13	10.4	1.14	1.39	1.85	5	10	16	-47	-23	2	0.88	0.89	0.91	0.10	0.01
	36.05	11.65	13	11.4	1.14	1.38	1.84	5	10	15	-48	-23	1	0.87	0.89	0.91	0.10	0.01
	37.05	11.65	13	12.4	1.14	1.38	1.84	4	10	15	-49	-24	1	0.87	0.89	0.91	0.10	0.01

⁴ Note that these results differ from de Moor (2020e) which considered fixed recruitment from 2019 onwards and should not be used to inform 2020 management decisions.

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		
$N_{w,0,2016,0}^S = 8.11$	0	0	0	0	1.25	1.55	2.09	9	15	20	-34	-9	15					
	32.05	11.65	13	7.4	1.18	1.43	1.92	6	12	17	-45	-20	5	0.89	0.91	0.92	0.08	0.00
	33.05	11.65	13	8.4	1.18	1.43	1.91	6	12	17	-45	-21	4	0.89	0.9	0.92	0.09	0.00
	34.05	11.65	13	9.4	1.18	1.43	1.91	6	12	17	-46	-21	4	0.88	0.9	0.92	0.09	0.00
	35.05	11.65	13	10.4	1.17	1.42	1.9	6	11	17	-47	-22	3	0.88	0.9	0.91	0.09	0.00
	36.05	11.65	13	11.4	1.17	1.42	1.9	6	11	17	-47	-22	2	0.88	0.89	0.91	0.09	0.00
	37.05	11.65	13	12.4	1.17	1.42	1.89	5	11	16	-48	-23	2	0.87	0.89	0.91	0.09	0.00
$N_{w,0,2014,0}^S = 11.5$	0	0	0	0	1.32	1.67	2.26	12	18	23	-31	-6	18					
	32.05	11.65	13	7.4	1.24	1.55	2.09	9	15	20	-42	-17	8	0.9	0.91	0.93	0.06	0.00
	33.05	11.65	13	8.4	1.24	1.54	2.08	9	15	20	-42	-18	7	0.9	0.91	0.92	0.06	0.00
	34.05	11.65	13	9.4	1.24	1.54	2.08	9	15	20	-43	-18	7	0.9	0.91	0.92	0.06	0.00
	35.05	11.65	13	10.4	1.24	1.54	2.07	9	15	20	-44	-19	6	0.9	0.91	0.92	0.06	0.00
	36.05	11.65	13	11.4	1.23	1.53	2.07	9	15	20	-44	-19	5	0.89	0.91	0.92	0.06	0.00
	37.05	11.65	13	12.4	1.23	1.53	2.06	9	15	20	-45	-20	5	0.89	0.9	0.92	0.06	0.00
$N_{w,0,2018,0}^S = 14.14$	0	0	0	0	1.37	1.76	2.38	15	21	26	-29	-4	21					
	32.05	11.65	13	7.4	1.3	1.64	2.2	11	17	22	-39	-15	10	0.91	0.92	0.93	0.04	0.00
	33.05	11.65	13	8.4	1.3	1.63	2.2	11	17	22	-40	-15	9	0.91	0.92	0.93	0.04	0.00
	34.05	11.65	13	9.4	1.3	1.63	2.19	11	17	22	-41	-16	9	0.91	0.92	0.93	0.04	0.00
	35.05	11.65	13	10.4	1.3	1.63	2.19	11	17	22	-41	-17	8	0.9	0.91	0.93	0.04	0.00
	36.05	11.65	13	11.4	1.3	1.62	2.19	11	17	22	-42	-17	7	0.9	0.91	0.92	0.04	0.00
	37.05	11.65	13	12.4	1.29	1.62	2.18	11	17	22	-43	-18	7	0.9	0.91	0.92	0.04	0.00
Three highest	0	0	0	0	1.29	1.64	2.24	11	18	23	-33	-6	19					
	32.05	11.65	13	7.4	1.21	1.52	2.06	8	14	20	-44	-17	8	0.9	0.91	0.93	0.06	0.00
	33.05	11.65	13	8.4	1.21	1.51	2.05	8	14	19	-45	-18	8	0.9	0.91	0.92	0.06	0.00
	34.05	11.65	13	9.4	1.21	1.51	2.05	8	14	19	-45	-18	7	0.9	0.91	0.92	0.06	0.00
	35.05	11.65	13	10.4	1.2	1.51	2.04	8	14	19	-46	-19	7	0.89	0.91	0.92	0.06	0.00
	36.05	11.65	13	11.4	1.2	1.5	2.04	8	14	19	-46	-19	6	0.89	0.9	0.92	0.07	0.00
	37.05	11.65	13	12.4	1.2	1.5	2.04	8	14	19	-47	-20	5	0.89	0.9	0.92	0.07	0.00

Table 3a. 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 **large sardine west coast catch** options and alternative November 2019 recruitment scenarios. 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) in 2020 only are given. The top two rows give the comparative statistics under the zero catch and 2019 TAC/B as estimated by de Moor (2019) and the next three rows give the statistics considered in setting the 2020 TAC/Bs (de Moor 2020a).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ			S2	S1
	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	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
	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
	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
Baseline	0	0	0	0	1.25	1.55	2.14	9	15	21	-35	-8	17	1	1	1	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
	36.05	12.65	13	10.4	1.14	1.42	1.93	5	12	17	-48	-21	4	0.87	0.89	0.91	0.12	0.01
	37.05	13.65	13	10.4	1.14	1.42	1.92	5	11	17	-48	-22	4	0.87	0.89	0.91	0.15	0.02
	38.05	14.65	13	10.4	1.13	1.41	1.91	5	11	17	-49	-22	3	0.86	0.88	0.90	0.19	0.03
	39.05	15.65	13	10.4	1.13	1.40	1.89	5	11	17	-49	-23	3	0.86	0.88	0.90	0.23	0.04
	40.05	16.65	13	10.4	1.13	1.40	1.88	5	11	16	-50	-23	2	0.85	0.87	0.89	0.30	0.05
$N_{W,0,2017,0}^S = 3.47$	0	0	0	0	1.16	1.40	1.87	5	11	16	-38	-13	11	1	1	1	0	0
	35.05	11.65	13	10.4	1.05	1.26	1.66	1	7	12	-50	-26	-1	0.86	0.88	0.90	0.15	0.02
	36.05	12.65	13	10.4	1.05	1.26	1.65	1	7	12	-51	-26	-2	0.85	0.87	0.90	0.20	0.03
	37.05	13.65	13	10.4	1.04	1.25	1.64	1	7	12	-52	-27	-2	0.84	0.87	0.89	0.24	0.04
	38.05	14.65	13	10.4	1.03	1.24	1.63	1	7	12	-52	-27	-3	0.83	0.86	0.89	0.29	0.05
	39.05	15.65	13	10.4	1.03	1.24	1.61	1	6	12	-53	-28	-3	0.83	0.86	0.88	0.33	0.07
$N_{W,0,2015,0}^S = 6.99$	0	0	0	0	1.23	1.51	2.03	8	14	19	-35	-10	14	1	1	1	0	0
	35.05	11.65	13	10.4	1.14	1.39	1.85	5	10	16	-47	-23	2	0.88	0.89	0.91	0.10	0.01
	36.05	12.65	13	10.4	1.14	1.38	1.84	4	10	15	-48	-23	1	0.87	0.89	0.91	0.14	0.01
	37.05	13.65	13	10.4	1.13	1.37	1.83	4	10	15	-48	-24	1	0.86	0.88	0.90	0.19	0.02
	38.05	14.65	13	10.4	1.12	1.36	1.82	4	10	15	-49	-24	0	0.86	0.88	0.90	0.23	0.03
	39.05	15.65	13	10.4	1.12	1.35	1.81	4	10	15	-50	-25	0	0.85	0.87	0.89	0.28	0.04
40.05	16.65	13	10.4	1.11	1.35	1.80	4	10	15	-50	-25	-1	0.85	0.87	0.89	0.32	0.05	

Table 3a (continued).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ			S2	S1
	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		
$N_{w,0,2016,0}^S = 8.11$	0	0	0	0	1.25	1.55	2.09	9	15	20	-34	-9	15	1	1	1	0	0
	35.05	11.65	13	10.4	1.17	1.42	1.90	6	11	17	-47	-22	3	0.88	0.9	0.91	0.09	0.00
	36.05	12.65	13	10.4	1.17	1.42	1.89	5	11	16	-47	-22	2	0.87	0.89	0.91	0.13	0.01
	37.05	13.65	13	10.4	1.17	1.41	1.88	5	11	16	-48	-23	2	0.87	0.89	0.90	0.16	0.01
	38.05	14.65	13	10.4	1.16	1.40	1.87	5	11	16	-48	-23	1	0.86	0.88	0.90	0.21	0.02
	39.05	15.65	13	10.4	1.16	1.40	1.86	5	11	16	-49	-24	1	0.86	0.88	0.90	0.25	0.03
40.05	16.65	13	10.4	1.15	1.39	1.85	5	11	16	-49	-24	0	0.85	0.87	0.89	0.31	0.04	
$N_{w,0,2014,0}^S = 11.5$	0	0	0	0	1.32	1.67	2.26	12	18	23	-31	-6	18	1	1	1	0	0
	35.05	11.65	13	10.4	1.24	1.54	2.07	9	15	20	-44	-19	6	0.90	0.91	0.92	0.06	0.00
	36.05	12.65	13	10.4	1.23	1.53	2.06	9	15	20	-44	-19	5	0.89	0.90	0.92	0.08	0.00
	37.05	13.65	13	10.4	1.23	1.53	2.05	9	14	19	-45	-20	5	0.89	0.90	0.91	0.11	0.00
	38.05	14.65	13	10.4	1.23	1.52	2.04	8	14	19	-45	-20	4	0.88	0.89	0.91	0.15	0.01
	39.05	15.65	13	10.4	1.22	1.51	2.03	8	14	19	-46	-21	4	0.88	0.89	0.91	0.20	0.01
40.05	16.65	13	10.4	1.22	1.51	2.02	8	14	19	-46	-21	3	0.87	0.88	0.90	0.24	0.02	
$N_{w,0,2018,0}^S = 14.14$	0	0	0	0	1.37	1.76	2.38	15	21	26	-29	-4	21	1	1	1	0	0
	35.05	11.65	13	10.4	1.30	1.63	2.19	11	17	22	-41	-17	8	0.90	0.91	0.93	0.04	0.00
	36.05	12.65	13	10.4	1.29	1.62	2.18	11	17	22	-42	-17	8	0.90	0.91	0.92	0.06	0.00
	37.05	13.65	13	10.4	1.29	1.62	2.17	11	17	22	-42	-18	7	0.89	0.91	0.92	0.08	0.00
	38.05	14.65	13	10.4	1.29	1.61	2.17	11	17	22	-43	-18	7	0.89	0.90	0.92	0.11	0.00
	39.05	15.65	13	10.4	1.28	1.60	2.16	11	16	22	-43	-19	6	0.89	0.90	0.91	0.16	0.00
40.05	16.65	13	10.4	1.28	1.59	2.15	10	16	21	-44	-19	5	0.88	0.89	0.91	0.20	0.01	
Three highest	0	0	0	0	1.29	1.64	2.24	11	18	23	-33	-6	19	1	1	1	0	0
	35.05	11.65	13	10.4	1.20	1.51	2.04	8	14	19	-46	-19	7	0.89	0.91	0.92	0.06	0.00
	36.05	12.65	13	10.4	1.20	1.50	2.04	8	14	19	-46	-19	6	0.89	0.90	0.92	0.09	0.01
	37.05	13.65	13	10.4	1.19	1.50	2.03	8	14	19	-47	-20	5	0.88	0.90	0.91	0.11	0.01
	38.05	14.65	13	10.4	1.19	1.49	2.02	7	14	19	-47	-20	5	0.88	0.89	0.91	0.15	0.01
	39.05	15.65	13	10.4	1.18	1.48	2.01	7	13	19	-48	-21	4	0.87	0.89	0.90	0.20	0.02
40.05	16.65	13	10.4	1.18	1.48	2.00	7	13	18	-48	-21	4	0.87	0.88	0.90	0.26	0.02	

Table 3b. 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 2020 under alternative **large sardine west coast catch** options and alternative November 2019 recruitment scenarios. 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. The top two rows give the comparative statistics under the zero catch and 2019 TAC/B as estimated by de Moor (2019) and the next three rows give the statistics considered in setting the 2020 TAC/Bs (de Moor 2020a).

					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	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
Baseline	0	0	0	0	1.27	1.31	1.39	43	53	65	10	42	79	1	1	1
	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	12.65	13	10.4	1.23	1.27	1.33	34	43	56	-11	21	58	0.93	0.95	0.96
	37.05	13.65	13	10.4	1.23	1.26	1.33	33	43	55	-11	21	58	0.93	0.94	0.96
	38.05	14.65	13	10.4	1.23	1.26	1.32	33	43	55	-12	20	58	0.93	0.94	0.95
	39.05	15.65	13	10.4	1.22	1.26	1.32	33	43	55	-12	20	57	0.93	0.94	0.95
$N_{w,0,2017,0}^S = 3.47$	0	0	0	0	1.26	1.30	1.37	39	49	61	-6	19	52	1	1	1
	35.05	11.65	13	10.4	1.21	1.25	1.3	30	40	52	-27	-2	31	0.93	0.94	0.96
	36.05	12.65	13	10.4	1.21	1.25	1.3	29	39	51	-27	-2	31	0.93	0.94	0.95
	37.05	13.65	13	10.4	1.21	1.24	1.3	29	39	51	-28	-2	31	0.93	0.94	0.95
	38.05	14.65	13	10.4	1.21	1.24	1.3	29	39	51	-28	-3	30	0.93	0.94	0.95
	39.05	15.65	13	10.4	1.21	1.24	1.3	29	39	51	-28	-3	30	0.93	0.94	0.95
$N_{w,0,2015,0}^S = 6.99$	0	0	0	0	1.27	1.31	1.38	42	52	64	10	35	68	1	1	1
	35.05	11.65	13	10.4	1.23	1.26	1.32	32	42	54	-10	15	48	0.93	0.95	0.96
	36.05	12.65	13	10.4	1.23	1.26	1.32	32	42	54	-11	15	48	0.93	0.94	0.96
	37.05	13.65	13	10.4	1.22	1.26	1.32	32	42	54	-11	14	47	0.93	0.94	0.95
	38.05	14.65	13	10.4	1.22	1.26	1.32	32	42	54	-11	14	47	0.93	0.94	0.95
	39.05	15.65	13	10.4	1.22	1.26	1.32	32	42	54	-12	13	46	0.93	0.94	0.95
40.05	16.65	13	10.4	1.22	1.26	1.31	31	41	53	-12	13	46	0.93	0.94	0.95	

Table 3b (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
$N_{w,0,2016,0}^S = 8.11$	0	0	0	0	1.28	1.32	1.39	43	53	65	16	41	74	1	1	1
	35.05	11.65	13	10.4	1.23	1.27	1.33	33	43	55	-5	20	53	0.93	0.95	0.96
	36.05	12.65	13	10.4	1.23	1.26	1.33	33	43	55	-5	20	53	0.93	0.94	0.96
	37.05	13.65	13	10.4	1.23	1.26	1.32	33	43	55	-6	19	52	0.93	0.94	0.96
	38.05	14.65	13	10.4	1.23	1.26	1.32	33	43	55	-6	19	52	0.93	0.94	0.95
	39.05	15.65	13	10.4	1.23	1.26	1.32	32	42	54	-7	19	52	0.93	0.94	0.95
	40.05	16.65	13	10.4	1.23	1.26	1.32	32	42	54	-7	18	51	0.93	0.94	0.95
$N_{w,0,2014,0}^S = 11.5$	0	0	0	0	1.29	1.33	1.40	45	55	67	32	57	90	1	1	1
	35.05	11.65	13	10.4	1.24	1.28	1.34	36	46	58	12	37	70	0.94	0.95	0.96
	36.05	12.65	13	10.4	1.24	1.28	1.34	36	46	58	11	36	69	0.93	0.95	0.96
	37.05	13.65	13	10.4	1.24	1.28	1.34	36	45	57	11	36	69	0.93	0.95	0.96
	38.05	14.65	13	10.4	1.24	1.28	1.34	35	45	57	10	35	68	0.93	0.94	0.96
	39.05	15.65	13	10.4	1.24	1.28	1.34	35	45	57	10	35	68	0.93	0.94	0.95
	40.05	16.65	13	10.4	1.24	1.27	1.34	35	45	57	9	34	67	0.93	0.94	0.95
$N_{w,0,2018,0}^S = 14.14$	0	0	0	0	1.29	1.34	1.42	47	57	69	44	69	102	1	1	1
	35.05	11.65	13	10.4	1.25	1.29	1.36	38	48	60	24	49	82	0.94	0.95	0.96
	36.05	12.65	13	10.4	1.25	1.29	1.36	38	48	60	23	48	81	0.94	0.95	0.96
	37.05	13.65	13	10.4	1.25	1.29	1.35	38	47	59	23	48	81	0.93	0.95	0.96
	38.05	14.65	13	10.4	1.25	1.29	1.35	37	47	59	22	47	80	0.93	0.95	0.96
	39.05	15.65	13	10.4	1.25	1.29	1.35	37	47	59	22	47	80	0.93	0.94	0.95
	40.05	16.65	13	10.4	1.25	1.29	1.35	37	47	59	21	46	79	0.93	0.94	0.95
Three highest	0	0	0	0	1.28	1.33	1.40	46	55	67	25	55	89	1	1	1
	35.05	11.65	13	10.4	1.24	1.28	1.34	36	46	58	4	34	69	0.94	0.95	0.96
	36.05	12.65	13	10.4	1.24	1.28	1.34	36	46	58	4	34	68	0.93	0.95	0.96
	37.05	13.65	13	10.4	1.24	1.28	1.34	36	46	57	3	33	68	0.93	0.95	0.96
	38.05	14.65	13	10.4	1.24	1.28	1.34	36	45	57	3	33	68	0.93	0.94	0.96
	39.05	15.65	13	10.4	1.23	1.28	1.34	36	45	57	3	32	67	0.93	0.94	0.95
	40.05	16.65	13	10.4	1.23	1.28	1.33	35	45	57	2	32	67	0.93	0.94	0.95

Table 4a. 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 **large sardine south coast catch** options and alternative November 2019 recruitment scenarios. 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) in 2020 only are given. The top two rows give the comparative statistics under the zero catch and 2019 TAC/B as estimated by de Moor (2019) and the next three rows give the statistics considered in setting the 2020 TAC/Bs (de Moor 2020a).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ			S2	S1
	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	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
	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
	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
Baseline	0	0	0	0	1.25	1.55	2.14	9	15	21	-35	-8	17	1	1	1	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
	36.05	11.65	14	10.4	1.15	1.43	1.93	5	12	17	-47	-21	5	0.88	0.90	0.91	0.09	0.01
	37.05	11.65	15	10.4	1.15	1.43	1.93	5	12	17	-47	-21	5	0.88	0.90	0.91	0.09	0.01
	38.05	11.65	16	10.4	1.15	1.42	1.93	5	12	17	-47	-21	5	0.88	0.90	0.91	0.09	0.01
	39.05	11.65	17	10.4	1.14	1.42	1.93	5	12	17	-47	-21	5	0.87	0.89	0.91	0.09	0.01
	40.05	11.65	18	10.4	1.14	1.42	1.92	5	11	17	-47	-21	5	0.87	0.89	0.91	0.09	0.01
$N_{W,0,2017,0}^S = 3.47$	0	0	0	0	1.16	1.40	1.87	5	11	16	-38	-13	11	1	1	1	0	0
	35.05	11.65	13	10.4	1.05	1.26	1.66	1	7	12	-50	-26	-1	0.86	0.88	0.90	0.15	0.02
	36.05	11.65	14	10.4	1.05	1.26	1.66	1	7	12	-50	-26	-1	0.85	0.88	0.90	0.15	0.02
	37.05	11.65	15	10.4	1.05	1.26	1.66	1	7	12	-50	-26	-1	0.85	0.88	0.90	0.15	0.02
	38.05	11.65	16	10.4	1.05	1.26	1.65	1	7	12	-50	-26	-1	0.85	0.87	0.90	0.15	0.02
	39.05	11.65	17	10.4	1.05	1.26	1.65	1	7	12	-50	-26	-1	0.85	0.87	0.90	0.15	0.02
$N_{W,0,2015,0}^S = 6.99$	0	0	0	0	1.23	1.51	2.03	8	14	19	-35	-10	14	1	1	1	0	0
	35.05	11.65	13	10.4	1.14	1.39	1.85	5	10	16	-47	-23	2	0.88	0.89	0.91	0.10	0.01
	36.05	11.65	14	10.4	1.14	1.38	1.84	5	10	16	-47	-23	2	0.87	0.89	0.91	0.10	0.01
	37.05	11.65	15	10.4	1.14	1.38	1.84	5	10	15	-47	-23	2	0.87	0.89	0.91	0.10	0.01
	38.05	11.65	16	10.4	1.14	1.38	1.84	4	10	15	-47	-23	2	0.87	0.89	0.91	0.10	0.01
	39.05	11.65	17	10.4	1.14	1.38	1.84	4	10	15	-47	-23	2	0.87	0.89	0.91	0.10	0.01
40.05	11.65	18	10.4	1.14	1.38	1.83	4	10	15	-47	-23	2	0.87	0.89	0.91	0.10	0.01	

Table 4a (continued).

	Multiplicative Δ in effSSB				Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ			S2	S1			
	Total	West	South	ByC	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile					
$N_{w,0,2016,0}^S = 8.11$	0	0	0	0	1.25	1.55	2.09	9	15	20	-34	-9	15	1	1	1	0	0
	35.05	11.65	13	10.4	1.17	1.42	1.90	6	11	17	-47	-22	3	0.88	0.90	0.91	0.09	0.00
	36.05	11.65	14	10.4	1.17	1.42	1.90	6	11	17	-47	-22	3	0.88	0.90	0.91	0.09	0.00
	37.05	11.65	15	10.4	1.17	1.42	1.90	6	11	17	-47	-22	3	0.88	0.89	0.91	0.09	0.00
	38.05	11.65	16	10.4	1.17	1.42	1.89	6	11	16	-47	-22	3	0.88	0.89	0.91	0.09	0.00
	39.05	11.65	17	10.4	1.17	1.42	1.89	5	11	16	-47	-22	3	0.87	0.89	0.91	0.09	0.00
40.05	11.65	18	10.4	1.17	1.42	1.89	5	11	16	-47	-22	3	0.87	0.89	0.91	0.09	0.00	
$N_{w,0,2014,0}^S = 11.5$	0	0	0	0	1.32	1.67	2.26	12	18	23	-31	-6	18	1	1	1	0	0
	35.05	11.65	13	10.4	1.24	1.54	2.07	9	15	20	-44	-19	6	0.90	0.91	0.92	0.06	0.00
	36.05	11.65	14	10.4	1.23	1.54	2.07	9	15	20	-44	-19	6	0.89	0.91	0.92	0.06	0.00
	37.05	11.65	15	10.4	1.23	1.53	2.07	9	15	20	-44	-19	6	0.89	0.91	0.92	0.06	0.00
	38.05	11.65	16	10.4	1.23	1.53	2.06	9	15	20	-44	-19	6	0.89	0.90	0.92	0.06	0.00
	39.05	11.65	17	10.4	1.23	1.53	2.06	9	15	20	-44	-19	6	0.89	0.90	0.92	0.06	0.00
40.05	11.65	18	10.4	1.23	1.53	2.06	9	14	20	-44	-19	6	0.89	0.90	0.92	0.06	0.00	
$N_{w,0,2018,0}^S = 14.14$	0	0	0	0	1.37	1.76	2.38	15	21	26	-29	-4	21	1	1	1	0	0
	35.05	11.65	13	10.4	1.30	1.63	2.19	11	17	22	-41	-17	8	0.90	0.91	0.93	0.04	0.00
	36.05	11.65	14	10.4	1.30	1.63	2.19	11	17	22	-41	-17	8	0.90	0.91	0.92	0.04	0.00
	37.05	11.65	15	10.4	1.30	1.62	2.19	11	17	22	-41	-17	8	0.90	0.91	0.92	0.04	0.00
	38.05	11.65	16	10.4	1.29	1.62	2.18	11	17	22	-41	-17	8	0.90	0.91	0.92	0.04	0.00
	39.05	11.65	17	10.4	1.29	1.62	2.18	11	17	22	-41	-17	8	0.90	0.91	0.92	0.04	0.00
40.05	11.65	18	10.4	1.29	1.62	2.18	11	17	22	-41	-17	8	0.90	0.91	0.92	0.04	0.00	
Three highest	0	0	0	0	1.29	1.64	2.24	11	18	23	-33	-6	19	1	1	1	0	0
	35.05	11.65	13	10.4	1.20	1.51	2.04	8	14	19	-46	-19	7	0.89	0.91	0.92	0.06	0.00
	36.05	11.65	14	10.4	1.20	1.51	2.04	8	14	19	-46	-19	7	0.89	0.91	0.92	0.06	0.00
	37.05	11.65	15	10.4	1.20	1.50	2.04	8	14	19	-46	-19	7	0.89	0.90	0.92	0.06	0.00
	38.05	11.65	16	10.4	1.20	1.50	2.04	8	14	19	-46	-19	7	0.89	0.90	0.92	0.06	0.00
	39.05	11.65	17	10.4	1.20	1.50	2.04	8	14	19	-46	-19	7	0.89	0.90	0.92	0.06	0.00
40.05	11.65	18	10.4	1.20	1.50	2.03	8	14	19	-46	-19	7	0.89	0.90	0.92	0.06	0.00	

Table 4b. 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 2020 under alternative **large sardine south coast catch** options and alternative November 2019 recruitment scenarios. 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. The top two rows give the comparative statistics under the zero catch and 2019 TAC/B as estimated by de Moor (2019) and the next three rows give the statistics considered in setting the 2020 TAC/Bs (de Moor 2020a).

					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	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
Baseline	0	0	0	0	1.27	1.31	1.39	43	53	65	10	42	79	1	1	1
	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	11.65	14	10.4	1.23	1.26	1.33	33	43	55	-11	21	58	0.93	0.94	0.96
	37.05	11.65	15	10.4	1.22	1.26	1.32	33	43	55	-12	20	57	0.93	0.94	0.95
	38.05	11.65	16	10.4	1.22	1.26	1.32	32	42	54	-13	19	56	0.92	0.94	0.95
	39.05	11.65	17	10.4	1.22	1.26	1.32	32	42	54	-14	18	56	0.92	0.93	0.95
$N_{W,0,2017,0}^S = 3.47$	40.05	11.65	18	10.4	1.22	1.25	1.31	31	41	53	-14	17	55	0.92	0.93	0.95
	0	0	0	0	1.26	1.3	1.37	39	49	61	-6	19	52	1	1	1
	35.05	11.65	13	10.4	1.21	1.25	1.30	30	40	52	-27	-2	31	0.93	0.94	0.96
	36.05	11.65	14	10.4	1.21	1.24	1.30	29	39	51	-27	-2	31	0.93	0.94	0.95
	37.05	11.65	15	10.4	1.21	1.24	1.30	29	39	51	-28	-3	30	0.92	0.94	0.95
	38.05	11.65	16	10.4	1.20	1.24	1.29	28	38	50	-29	-4	29	0.92	0.94	0.95
$N_{W,0,2015,0}^S = 6.99$	39.05	11.65	17	10.4	1.20	1.24	1.29	28	38	50	-30	-5	28	0.92	0.93	0.95
	40.05	11.65	18	10.4	1.20	1.24	1.29	27	37	49	-31	-6	27	0.91	0.93	0.94
	0	0	0	0	1.27	1.31	1.38	42	52	64	10	35	68	1	1	1
	35.05	11.65	13	10.4	1.23	1.26	1.32	32	42	54	-10	15	48	0.93	0.95	0.96
	36.05	11.65	14	10.4	1.22	1.26	1.32	32	42	54	-11	14	47	0.93	0.94	0.95
	37.05	11.65	15	10.4	1.22	1.26	1.31	31	41	53	-12	13	46	0.93	0.94	0.95
$N_{W,0,2015,0}^S = 6.99$	38.05	11.65	16	10.4	1.22	1.25	1.31	31	41	53	-13	12	45	0.92	0.94	0.95
	39.05	11.65	17	10.4	1.22	1.25	1.31	30	40	52	-13	12	45	0.92	0.93	0.95
	40.05	11.65	18	10.4	1.21	1.25	1.31	30	40	52	-14	11	44	0.92	0.93	0.95

Table 4b (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
$N_{w,0,2016,0}^S = 8.11$	0	0	0	0	1.28	1.32	1.39	43	53	65	16	41	74	1	1	1
	35.05	11.65	13	10.4	1.23	1.27	1.33	33	43	55	-5	20	53	0.93	0.95	0.96
	36.05	11.65	14	10.4	1.23	1.26	1.32	33	43	55	-6	19	52	0.93	0.94	0.95
	37.05	11.65	15	10.4	1.23	1.26	1.32	32	42	54	-7	19	52	0.93	0.94	0.95
	38.05	11.65	16	10.4	1.22	1.26	1.32	32	42	54	-7	18	51	0.92	0.94	0.95
	39.05	11.65	17	10.4	1.22	1.25	1.31	31	41	53	-8	17	50	0.92	0.93	0.95
	40.05	11.65	18	10.4	1.22	1.25	1.31	31	41	53	-9	16	49	0.92	0.93	0.95
$N_{w,0,2014,0}^S = 11.5$	0	0	0	0	1.29	1.33	1.40	45	55	67	32	57	90	1	1	1
	35.05	11.65	13	10.4	1.24	1.28	1.34	36	46	58	12	37	70	0.94	0.95	0.96
	36.05	11.65	14	10.4	1.24	1.28	1.34	35	45	57	11	36	69	0.93	0.94	0.96
	37.05	11.65	15	10.4	1.24	1.27	1.34	35	45	57	10	35	68	0.93	0.94	0.95
	38.05	11.65	16	10.4	1.23	1.27	1.33	34	44	56	9	34	67	0.93	0.94	0.95
	39.05	11.65	17	10.4	1.23	1.27	1.33	34	44	56	8	33	66	0.92	0.94	0.95
	40.05	11.65	18	10.4	1.23	1.27	1.33	33	43	55	7	32	65	0.92	0.93	0.95
$N_{w,0,2018,0}^S = 14.14$	0	0	0	0	1.29	1.34	1.42	47	57	69	44	69	102	1	1	1
	35.05	11.65	13	10.4	1.25	1.29	1.36	38	48	60	24	49	82	0.94	0.95	0.96
	36.05	11.65	14	10.4	1.25	1.29	1.35	37	47	59	23	48	81	0.93	0.95	0.96
	37.05	11.65	15	10.4	1.25	1.29	1.35	37	47	59	22	47	80	0.93	0.94	0.95
	38.05	11.65	16	10.4	1.25	1.28	1.35	36	46	58	21	46	79	0.93	0.94	0.95
	39.05	11.65	17	10.4	1.24	1.28	1.34	36	46	58	20	45	78	0.92	0.94	0.95
	40.05	11.65	18	10.4	1.24	1.28	1.34	35	45	57	19	44	77	0.92	0.93	0.95
Three highest	0	0	0	0	1.28	1.33	1.40	46	55	67	25	55	89	1	1	1
	35.05	11.65	13	10.4	1.24	1.28	1.34	36	46	58	4	34	69	0.94	0.95	0.96
	36.05	11.65	14	10.4	1.24	1.28	1.34	36	45	57	3	33	68	0.93	0.94	0.96
	37.05	11.65	15	10.4	1.23	1.27	1.33	35	45	57	3	32	67	0.93	0.94	0.95
	38.05	11.65	16	10.4	1.23	1.27	1.33	35	44	56	2	32	66	0.93	0.94	0.95
	39.05	11.65	17	10.4	1.23	1.27	1.33	34	44	56	1	31	65	0.92	0.94	0.95
	40.05	11.65	18	10.4	1.23	1.27	1.32	34	43	55	0	30	65	0.92	0.93	0.95

Table 5a. 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 **large sardine west and south coast catch** options and alternative November 2019 recruitment scenarios. 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) in 2020 only are given. The top two rows give the comparative statistics under the zero catch and 2019 TAC/B as estimated by de Moor (2019) and the next three rows give the statistics considered in setting the 2020 TAC/Bs (de Moor 2020a).

					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
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	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	
	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	
	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	
Baseline	0	0	0	0	1.25	1.55	2.14	9	15	21	-35	-8	17	1	1	1	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	
	37.05	12.65	14	10.4	1.14	1.42	1.92	5	11	17	-48	-21	4	0.87	0.89	0.91	0.12	0.01	
	39.05	13.65	15	10.4	1.14	1.41	1.91	5	11	17	-48	-22	4	0.87	0.89	0.90	0.15	0.02	
	41.05	14.65	16	10.4	1.13	1.4	1.9	5	11	17	-49	-22	3	0.86	0.88	0.90	0.19	0.03	
	43.05	15.65	17	10.4	1.13	1.4	1.88	5	11	16	-49	-23	3	0.85	0.87	0.89	0.23	0.04	
	45.05	16.65	18	10.4	1.12	1.39	1.87	4	11	16	-50	-23	2	0.84	0.87	0.89	0.30	0.05	
$N_{W,0,2017,0}^S = 3.47$	0	0	0	0	1.16	1.40	1.87	5	11	16	-38	-13	11	1	1	1	0	0	
	35.05	11.65	13	10.4	1.05	1.26	1.66	1	7	12	-50	-26	-1	0.86	0.88	0.90	0.15	0.02	
	37.05	12.65	14	10.4	1.04	1.25	1.65	1	7	12	-51	-26	-2	0.85	0.87	0.89	0.20	0.03	
	39.05	13.65	15	10.4	1.04	1.25	1.63	1	7	12	-52	-27	-2	0.84	0.86	0.89	0.24	0.04	
	41.05	14.65	16	10.4	1.03	1.24	1.62	1	6	12	-52	-27	-3	0.83	0.86	0.88	0.29	0.05	
	43.05	15.65	17	10.4	1.02	1.23	1.61	0	6	11	-53	-28	-3	0.82	0.85	0.88	0.33	0.07	
$N_{W,0,2015,0}^S = 6.99$	0	0	0	0	1.23	1.51	2.03	8	14	19	-35	-10	14	1	1	1	0	0	
	35.05	11.65	13	10.4	1.14	1.39	1.85	5	10	16	-47	-23	2	0.88	0.89	0.91	0.10	0.01	
	37.05	12.65	14	10.4	1.14	1.38	1.83	4	10	15	-48	-23	1	0.87	0.89	0.90	0.14	0.01	
	39.05	13.65	15	10.4	1.13	1.37	1.82	4	10	15	-48	-24	1	0.86	0.88	0.90	0.19	0.02	
	41.05	14.65	16	10.4	1.12	1.36	1.81	4	10	15	-49	-24	0	0.85	0.87	0.89	0.23	0.03	
	43.05	15.65	17	10.4	1.11	1.35	1.80	4	10	15	-50	-25	0	0.85	0.87	0.89	0.28	0.04	
45.05	16.65	18	10.4	1.10	1.34	1.79	3	9	14	-50	-25	-1	0.84	0.86	0.88	0.32	0.05		

Table 5a (continued).

					Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ			S2	S1
	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		
$N_{W,0,2016,0}^S = 8.11$	0	0	0	0	1.25	1.55	2.09	9	15	20	-34	-9	15	1	1	1	0	0
	35.05	11.65	13	10.4	1.17	1.42	1.90	6	11	17	-47	-22	3	0.88	0.90	0.91	0.09	0.00
	37.05	12.65	14	10.4	1.17	1.42	1.89	5	11	16	-47	-22	2	0.87	0.89	0.91	0.13	0.01
	39.05	13.65	15	10.4	1.17	1.41	1.88	5	11	16	-48	-23	2	0.87	0.88	0.90	0.16	0.01
	41.05	14.65	16	10.4	1.16	1.40	1.87	5	11	16	-48	-23	1	0.86	0.88	0.90	0.21	0.02
	43.05	15.65	17	10.4	1.15	1.39	1.85	5	11	16	-49	-24	1	0.85	0.87	0.89	0.25	0.03
	45.05	16.65	18	10.4	1.14	1.38	1.84	5	10	16	-49	-24	0	0.85	0.87	0.89	0.31	0.04
$N_{W,0,2014,0}^S = 11.5$	0	0	0	0	1.32	1.67	2.26	12	18	23	-31	-6	18	1	1	1	0	0
	35.05	11.65	13	10.4	1.24	1.54	2.07	9	15	20	-44	-19	6	0.9	0.91	0.92	0.06	0.00
	37.05	12.65	14	10.4	1.23	1.53	2.06	9	14	20	-44	-19	5	0.89	0.90	0.92	0.08	0.00
	39.05	13.65	15	10.4	1.23	1.52	2.05	8	14	19	-45	-20	5	0.88	0.90	0.91	0.11	0.00
	41.05	14.65	16	10.4	1.22	1.51	2.03	8	14	19	-45	-20	4	0.88	0.89	0.91	0.15	0.01
	43.05	15.65	17	10.4	1.22	1.51	2.02	8	14	19	-46	-21	4	0.87	0.88	0.9	0.20	0.01
	45.05	16.65	18	10.4	1.21	1.5	2.01	8	14	19	-46	-21	3	0.86	0.88	0.9	0.24	0.02
$N_{W,0,2018,0}^S = 14.14$	0	0	0	0	1.37	1.76	2.38	15	21	26	-29	-4	21	1	1	1	0	0
	35.05	11.65	13	10.4	1.3	1.63	2.19	11	17	22	-41	-17	8	0.9	0.91	0.93	0.04	0.00
	37.05	12.65	14	10.4	1.29	1.62	2.18	11	17	22	-42	-17	8	0.9	0.91	0.92	0.06	0.00
	39.05	13.65	15	10.4	1.29	1.61	2.17	11	17	22	-42	-18	7	0.89	0.90	0.92	0.08	0.00
	41.05	14.65	16	10.4	1.28	1.6	2.16	11	16	22	-43	-18	7	0.89	0.90	0.91	0.11	0.00
	43.05	15.65	17	10.4	1.28	1.59	2.15	10	16	21	-43	-19	6	0.88	0.89	0.91	0.16	0.00
	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
Three highest	0	0	0	0	1.29	1.64	2.24	11	18	23	-33	-6	19	1	1	1	0	0
	35.05	11.65	13	10.4	1.20	1.51	2.04	8	14	19	-46	-19	7	0.89	0.91	0.92	0.06	0.00
	37.05	12.65	14	10.4	1.20	1.50	2.03	8	14	19	-46	-19	6	0.89	0.90	0.92	0.09	0.01
	39.05	13.65	15	10.4	1.19	1.49	2.02	7	14	19	-47	-20	5	0.88	0.90	0.91	0.11	0.01
	41.05	14.65	16	10.4	1.19	1.49	2.01	7	13	19	-47	-20	5	0.87	0.89	0.90	0.15	0.01
	43.05	15.65	17	10.4	1.18	1.48	2.00	7	13	18	-48	-21	4	0.87	0.88	0.90	0.20	0.02
	45.05	16.65	18	10.4	1.17	1.47	1.99	7	13	18	-48	-21	4	0.86	0.88	0.90	0.26	0.02

Table 5a (continued).

	Total	West	South	ByC	Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ			S2	S1
					5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile		
	0	0	0	0	1.43	1.86	2.55	18	24	29	-26	-1	24	1	1	1	0	0
17.47	35.05	11.65	13	10.4	1.36	1.74	2.36	14	20	25	-38	-14	11	0.91	0.92	0.93	0.02	0.00
	37.05	12.65	14	10.4	1.36	1.73	2.35	14	20	25	-39	-14	10	0.91	0.92	0.93	0.04	0.00
	39.05	13.65	15	10.4	1.35	1.72	2.34	14	20	25	-40	-15	10	0.90	0.91	0.92	0.06	0.00
	41.05	14.65	16	10.4	1.35	1.72	2.33	14	20	25	-40	-15	9	0.90	0.91	0.92	0.08	0.00
	43.05	15.65	17	10.4	1.34	1.71	2.32	13	19	24	-41	-16	9	0.89	0.90	0.92	0.11	0.00
	45.05	16.65	18	10.4	1.34	1.70	2.31	13	19	24	-41	-16	8	0.89	0.90	0.91	0.14	0.00

Table 5b. 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 2020 under alternative **large sardine west and south coast catch** options and alternative November 2019 recruitment scenarios. 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. The top two rows give the comparative statistics under the zero catch and 2019 TAC/B as estimated by de Moor (2019) and the next three rows give the statistics considered in setting the 2020 TAC/Bs (de Moor 2020a).

					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	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
Baseline	0	0	0	0	1.27	1.31	1.39	43	53	65	10	42	79	1	1	1
	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
	37.05	12.65	14	10.4	1.23	1.26	1.32	33	43	55	-12	20	58	0.93	0.94	0.95
	39.05	13.65	15	10.4	1.22	1.26	1.32	32	42	54	-13	19	56	0.92	0.94	0.95
	41.05	14.65	16	10.4	1.22	1.26	1.32	32	42	54	-14	18	55	0.92	0.93	0.95
	43.05	15.65	17	10.4	1.22	1.25	1.31	31	41	53	-15	17	54	0.91	0.93	0.94
$N_{w,0,2017,0}^S = 3.47$	0	0	0	0	1.26	1.3	1.37	39	49	61	-6	19	52	1	1	1
	35.05	11.65	13	10.4	1.21	1.25	1.3	30	40	52	-27	-2	31	0.93	0.94	0.96
	37.05	12.65	14	10.4	1.21	1.24	1.3	29	39	51	-28	-3	30	0.93	0.94	0.95
	39.05	13.65	15	10.4	1.2	1.24	1.3	28	38	50	-29	-4	29	0.92	0.94	0.95
	41.05	14.65	16	10.4	1.2	1.24	1.29	28	37	50	-30	-5	28	0.92	0.93	0.95
	43.05	15.65	17	10.4	1.2	1.23	1.29	27	37	49	-32	-7	26	0.91	0.93	0.94
$N_{w,0,2015,0}^S = 6.99$	0	0	0	0	1.27	1.31	1.38	42	52	64	10	35	68	1	1	1
	35.05	11.65	13	10.4	1.23	1.26	1.32	32	42	54	-10	15	48	0.93	0.95	0.96
	37.05	12.65	14	10.4	1.22	1.26	1.32	32	42	54	-11	14	47	0.93	0.94	0.95
	39.05	13.65	15	10.4	1.22	1.25	1.31	31	41	53	-13	12	45	0.92	0.94	0.95
	41.05	14.65	16	10.4	1.22	1.25	1.31	30	40	52	-14	11	44	0.92	0.93	0.95
	43.05	15.65	17	10.4	1.21	1.25	1.3	30	39	51	-15	10	43	0.91	0.93	0.94
45.05	16.65	18	10.4	1.21	1.24	1.3	29	39	51	-16	9	42	0.91	0.93	0.94	

Table 5b (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
$N_{w,0,2016,0}^S = 8.11$	0	0	0	0	1.28	1.32	1.39	43	53	65	16	41	74	1	1	1
	35.05	11.65	13	10.4	1.23	1.27	1.33	33	43	55	-5	20	53	0.93	0.95	0.96
	37.05	12.65	14	10.4	1.23	1.26	1.32	33	42	54	-6	19	52	0.93	0.94	0.95
	39.05	13.65	15	10.4	1.22	1.26	1.32	32	42	54	-7	18	51	0.92	0.94	0.95
	41.05	14.65	16	10.4	1.22	1.25	1.31	31	41	53	-9	16	49	0.92	0.93	0.95
	43.05	15.65	17	10.4	1.22	1.25	1.31	30	40	52	-10	15	48	0.91	0.93	0.94
	45.05	16.65	18	10.4	1.21	1.25	1.3	30	40	52	-11	14	47	0.91	0.93	0.94
$N_{w,0,2014,0}^S = 11.5$	0	0	0	0	1.29	1.33	1.4	45	55	67	32	57	90	1	1	1
	35.05	11.65	13	10.4	1.24	1.28	1.34	36	46	58	12	37	70	0.94	0.95	0.96
	37.05	12.65	14	10.4	1.24	1.28	1.34	35	45	57	10	35	68	0.93	0.94	0.95
	39.05	13.65	15	10.4	1.24	1.27	1.33	35	44	56	9	34	67	0.93	0.94	0.95
	41.05	14.65	16	10.4	1.23	1.27	1.33	34	44	56	8	33	66	0.92	0.94	0.95
	43.05	15.65	17	10.4	1.23	1.26	1.33	33	43	55	6	32	65	0.92	0.93	0.95
	45.05	16.65	18	10.4	1.23	1.26	1.32	33	42	54	5	30	63	0.91	0.93	0.94
$N_{w,0,2018,0}^S = 14.14$	0	0	0	0	1.29	1.34	1.42	47	57	69	44	69	102	1	1	1
	35.05	11.65	13	10.4	1.25	1.29	1.36	38	48	60	24	49	82	0.94	0.95	0.96
	37.05	12.65	14	10.4	1.25	1.29	1.35	37	47	59	22	47	80	0.93	0.94	0.96
	39.05	13.65	15	10.4	1.25	1.28	1.35	37	46	58	21	46	79	0.93	0.94	0.95
	41.05	14.65	16	10.4	1.24	1.28	1.34	36	46	58	20	45	78	0.92	0.94	0.95
	43.05	15.65	17	10.4	1.24	1.28	1.34	35	45	57	18	44	77	0.92	0.93	0.95
	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
Three highest	0	0	0	0	1.28	1.33	1.40	46	55	67	25	55	89	1	1	1
	35.05	11.65	13	10.4	1.24	1.28	1.34	36	46	58	4	34	69	0.94	0.95	0.96
	37.05	12.65	14	10.4	1.24	1.28	1.34	36	45	57	3	33	68	0.93	0.94	0.95
	39.05	13.65	15	10.4	1.23	1.27	1.33	35	45	56	2	32	66	0.93	0.94	0.95
	41.05	14.65	16	10.4	1.23	1.27	1.33	34	44	56	1	30	65	0.92	0.94	0.95
	43.05	15.65	17	10.4	1.23	1.27	1.32	34	43	55	-1	29	64	0.92	0.93	0.95
	45.05	16.65	18	10.4	1.22	1.26	1.32	33	43	54	-2	28	63	0.91	0.93	0.94

Table 5b (continued).

	Total	West	South	ByC	Multiplicative Δ in effSSB			Additive Δ in effSSB			Additive Δ in B			Relative Multiplicative Δ		
					5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile	5%ile	20%ile	50%ile
17.47	0	0	0	0	1.30	1.35	1.43	50	59	72	60	85	118	1	1	1
	35.05	11.65	13	10.4	1.26	1.30	1.37	40	50	62	39	64	97	0.94	0.95	0.96
	37.05	12.65	14	10.4	1.26	1.30	1.37	40	50	62	38	63	96	0.93	0.95	0.96
	39.05	13.65	15	10.4	1.26	1.30	1.36	39	49	61	37	62	95	0.93	0.94	0.95
	41.05	14.65	16	10.4	1.25	1.29	1.36	38	48	60	35	60	93	0.93	0.94	0.95
	43.05	15.65	17	10.4	1.25	1.29	1.35	38	48	59	34	59	92	0.92	0.93	0.95
	45.05	16.65	18	10.4	1.25	1.29	1.35	37	47	59	33	58	91	0.92	0.93	0.94

Table 6. The probability that the total sardine west and south component biomasses projected for November 2020 are equal to or greater than that estimated in November 2019 under the “random” recruitment scenario used in April 2020 from the baseline operating model, and the “Three highest” recruitment scenario.

Recruitment scenario		West Component			South Component				
		No catch	April 2020 34 050t	Current 35 050t	37 050t	No catch	April 2020 34 050t	Current 35 050t	37 050t
Recruitment scenario	“Random”	69%	56%	55%		97%	91%	90%	
	“Three highest”	71%	57%	56%	55%	99%	97%	96%	96%

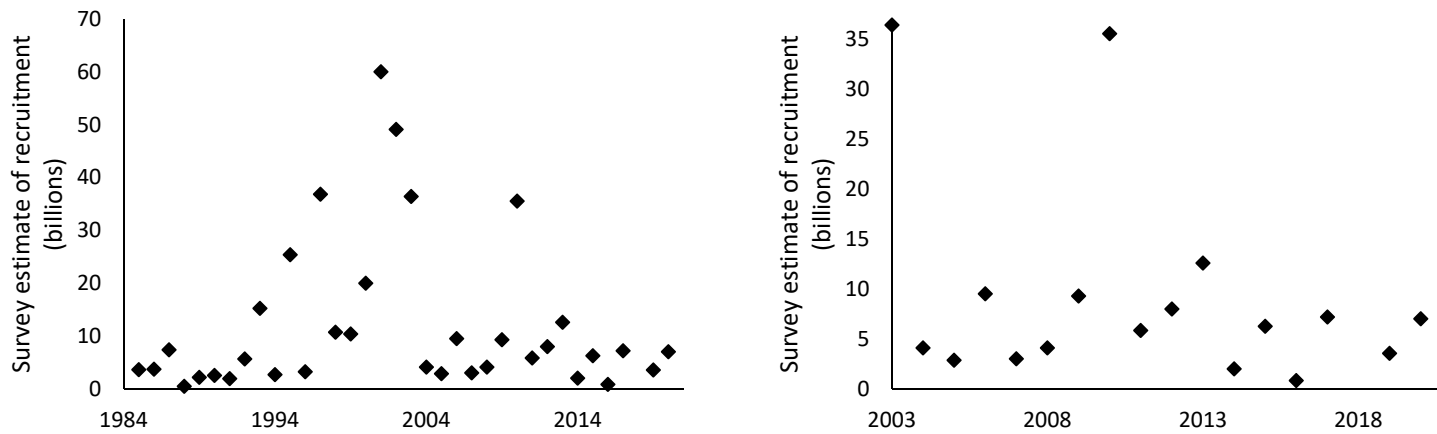


Figure 1. The hydro-acoustic survey estimated sardine recruitment west of Cape Infanta (Coetzee *et al.* 2020).

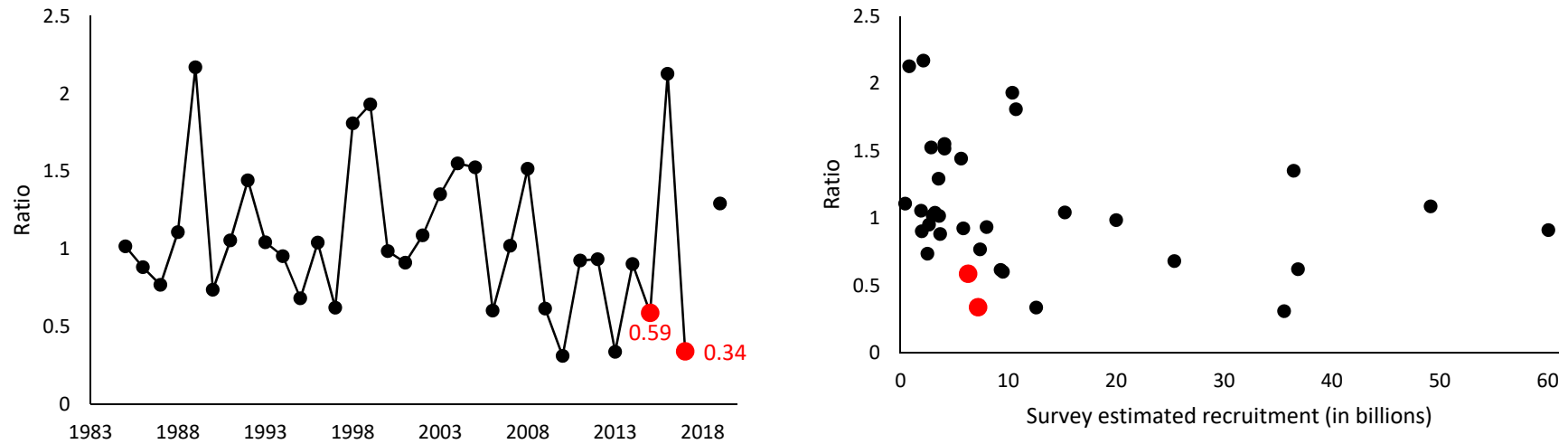


Figure 2. The ratio of the bias corrected model predicted recruitment at the time of the survey to the survey estimate of recruitment plotted (i) against year (left) and (ii) against the survey estimate of recruitment.

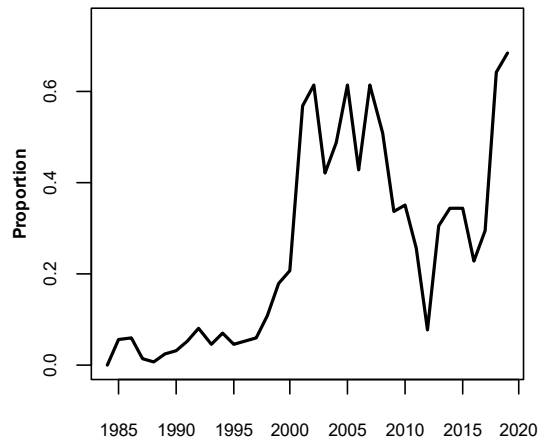


Figure 3. The proportion of west component effective spawner biomass (defined as west component spawner biomass combined with 8% of south component spawner biomass) that consists of south component spawner biomass (i.e. $SSB_{j=S,y}^S / SSB_{j=W,y}^{eff,S}$). Reproduced from de Moor (2020c).

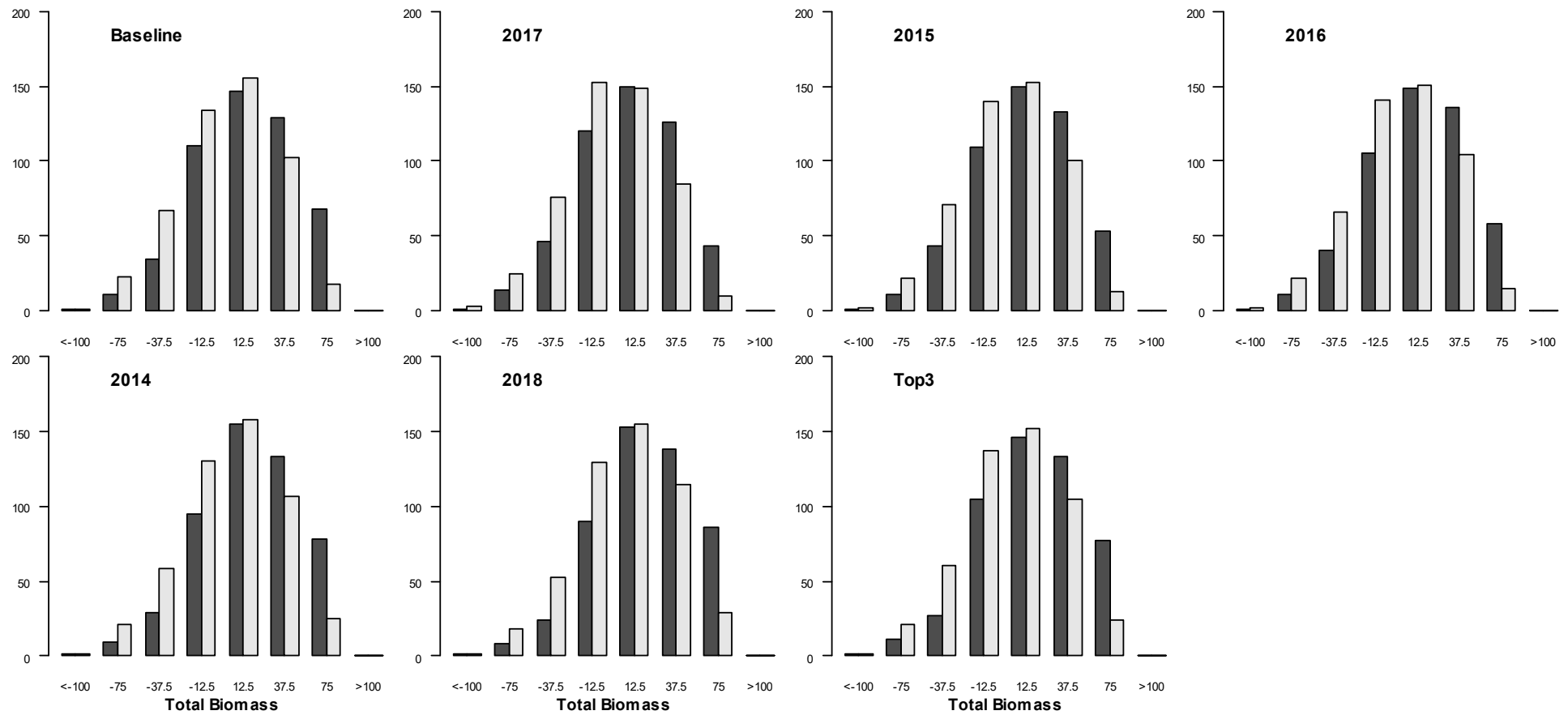


Figure 4a. The histogram of the additive change (growth or shrinkage) in the **west component total biomass** from November 2019 to November 2020 under a zero catch option (dark grey) and the current TAC/B option (light grey, total 35 050t) and the baseline model with alternative 2019 November recruitment scenarios. Note that the bin widths are not equal.

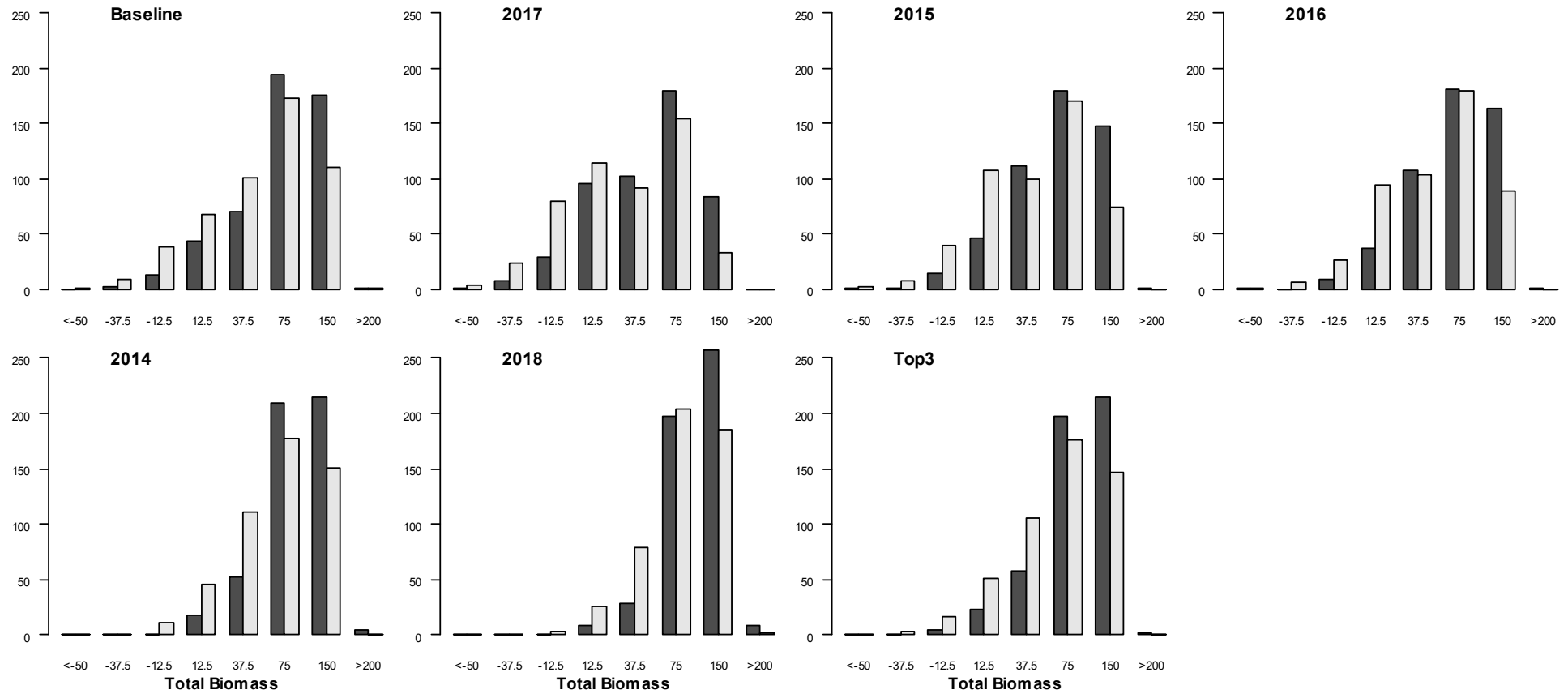


Figure 4b. The histogram of the additive change (growth or shrinkage) in the **south component total biomass** from November 2019 to November 2020 under a zero catch option (dark grey) and the current TAC/B option (light grey, total 35 050t) and the baseline model with alternative 2019 November recruitment scenarios. Note that the bin widths are not equal.

Addendum: Updated survey estimate of recruitment

The June 2020 survey estimate of recruitment has recently been revised to 11.777 billion recruits west of Cape Infanta (Coetzee pers comm.).

The most recent survey estimate now closest to this value is that of 12.59 billion from May 2013 (Figure 1). The corresponding November 2012 recruitment was estimated at 12.75 billion (de Moor 2020c, Figure 2).

The recruitment in November 2019 was also back-projected from a survey estimate of 11.777 billion in June 2020 using Equation (1) and three alternative values for model predicted recruitment at the time of the survey:

- a) No survey or additional uncertainty, $k_{w,r}^S N_{w,NI,2020,r}^S = N_{w,2020,r}^{obs}$
- b) One SE difference using the 2020 survey CV of 0.418: $k_{w,r}^S N_{w,NI,2020,r}^S = (1 - 0.418)N_{w,2020,r}^{obs}$
- c) Multiplicative differences between the survey observation and the bias corrected recruitment based on that estimated in recent years and close to 12 billion recruits (Figure A.1): $k_{w,r}^S N_{w,NI,2020,r}^S = 0.34N_{w,2020,r}^{obs}$.

This predicts a range of November 2019 recruitment from 14 to 38 billion fish (Table A.1), with 14 billion corresponding to the recent survey estimates of around 12 billion fish in May 2013 as was similarly estimated in June 2020.

In selecting which of the set(s) of results might best reflect true recruitment in November 2019, the first option above would suggest focusing on the $N_{w,0,2014,0}^S = 11.5$ and $N_{w,0,2018,0}^S = 14.14$ scenarios, while the second option above would suggest focusing on the $N_{w,0,2018,0}^S = 14.14$ scenario alone, which is the highest of the most recent five years.

The following bullet points revisit the earlier sardine TAC/B recommendation process given this update, assuming recruitment in November 2019 corresponded to $N_{w,0,2018,0}^S = 14.14$ billion fish:

- Considering an increase to the west coast small bycatch (Table 2), the small bycatch option of 12 400t has a west component impact factor of 0.91 and corresponds closest to the additive change in west component biomass selected in April 2020⁵.
- Considering an increase to the west coast large catch only (Table 3), the west large catch options of 14 650t and 15 650t have a west component impact factor of 0.90 and these options and 14 650t have a south component impact factor of 0.95. The west large catch option of 15 650t corresponds closest to the additive change in west component biomass selected in April 2020.
- Considering an increase to the south coast large catch only (Table 4), the south large catch options of 15 000t to 18 000t have a west component impact factor of 0.91 and the options of 13 000t and 14 000t have a south component impact factor of 0.95. The south large catch options from 13 000t to 18 000t all result in a similar additive change in west component biomass.

⁵ The statistics reported in Table 2, reflecting a change in the population after just one year, will not give an accurate reflection of the impact of small sardine bycatch on the population. Small sardine bycatch is assumed to consist of only recruits in the model. The 2019 recruits will contribute relatively less to the November 2020 biomass due to the lower weight of 1-year olds than 2+ year olds, and few 1-year-olds will form part of the November 2020 spawner biomass. The impact of small sardine bycatch during 2019 will be better reflected in changes in the population after a few years.

- Considering increases to both the west and south coast large catches (Table 5), the total catch options of 39 050t and 41 050t have a west component impact factor of 0.90 and the total catch option of 35 050t has a south component impact factor of 0.95. The total catch option of 41 050t corresponds closely to the additive change in west component biomass selected in April 2020, while a higher catch option of 43 050t has a greater probability of a decrease in west component biomass from November 2019 to 2020 from that ‘accepted’ in April 2020 (Table A.2).

Table A.1. The November 2019 back-projected recruitment based on alternative levels of recruit catch and recruitment at the time of the June 2020 survey.

$k_{w,r}^S N_{w,NI,2020,r}^S$		$C_{w,2020,1,0}^S$		
		0.0	0.4	1.0
	$N_{w,2020,r}^{obs}$	37	37	38
	$(1 - 0.354)N_{w,2020,r}^{obs}$	24	25	26
	$0.34N_{w,2020,r}^{obs}$	14	15	15

Table A.2. The probability that the total sardine west and south component biomasses projected for November 2020 are equal to or greater than that estimated in November 2019 under the “random” recruitment scenario used in April 2020 from the baseline operating model, and the “Three highest” recruitment scenario.

		West Component					South Component				
		No catch	April 2020 34 050t	Current 35 050t	41 050t	43050t	No catch	April 2020 34 050t	Current 35 050t	41 050t	43050t
Recruitment scenario	“Random”	69%	56%	55%			97%	91%	90%		
	$N_{w,0,2018,0}^S = 14.14$	75%	60%	60%	59%	58%	~100%	99%	99%	99%	98%

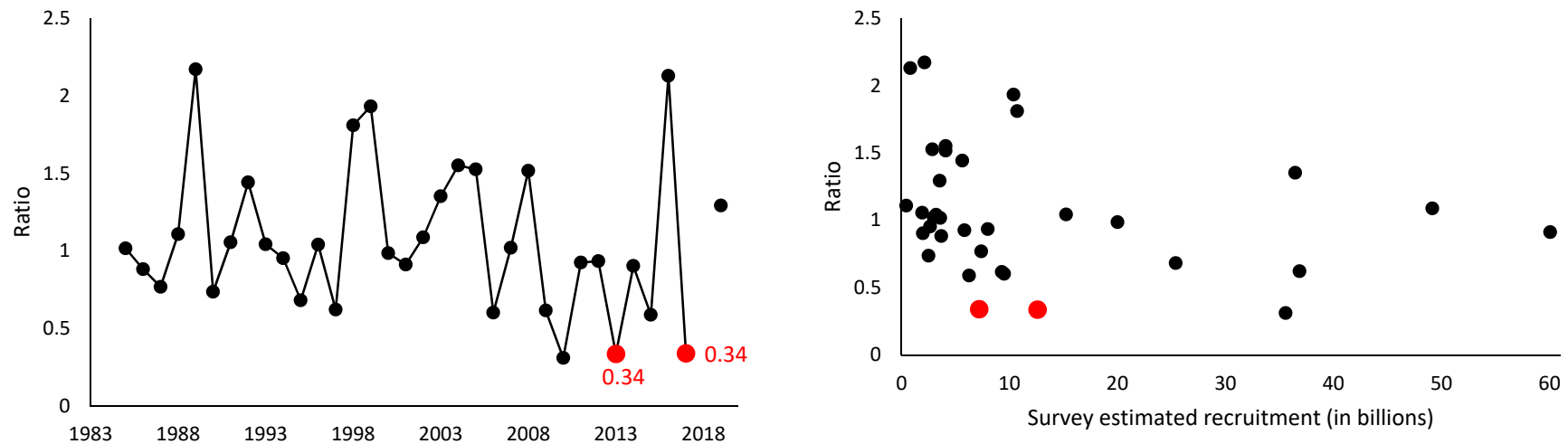


Figure A.1. The ratio of the bias corrected model predicted recruitment at the time of the survey to the survey estimate of recruitment plotted (i) against year (left) and (ii) against the survey estimate of recruitment.