Sardine projections based on constant catch scenarios for 2022

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Short-term projections of the sardine resource are to be used as the basis for TAC and TAB recommendations during Exceptional Circumstances. This document provides these projections based on updated assessments using data available up to December 2021.

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

Introduction

As Exceptional Circumstances have been declared for sardine, the 2022 directed sardine TAC and TABs will again need to be set using ad hoc advice based on short-term projections (e.g. de Moor 2020b, de Moor 2021b,c). Following some initial testing by de Moor (2021e), this document provides updated short-term projections of the sardine resource based on data available up to December 2021, providing statistics upon which to inform catch advice for 2022.

Methods

The model used for projections is based on the most recent updated assessment of the sardine resource, without the inclusion of the parasite prevalence-at-length data (de Moor 2021d, 2022). Most of the population dynamics are similar to those assumed historically (Appendix A) except that catch is modelled to be taken in a single pulse during the year. Other assumptions made during these projections are detailed in Appendix A.

The assessment provides a single set of model parameters at the joint posterior mode, including numbers-at-length (age) and biomass in November 2021 from which projections are initiated. Using the same method as de Moor (2021b), initial variability is incorporated by sampling from normal distributions using the Hessian-based CV of the model predicted November biomass in 2021:

For S_1: $N^{S,i}_{1,2021,a} = N^{S}_{1,2021,a} e^{0.429\omega_{1,i} - 0.5*0.429^2}$ for $1 \le a \le 5^+$ and $B^{S,i}_{1,2021} = B^{S}_{1,2021} e^{0.429\omega_{1,i} - 0.5*0.429^2}$ [1], and

$N^{S,i}_{2,2021,a} = N^{S}_{2,2021,a} e^{0.341\omega_{2,i} - 0.5*0.341^2}$ for $1 \le a \le 5^+$ and $B^{S,i}_{2,2021} = B^{S}_{2,2021} e^{0.341\omega_{2,i} - 0.5*0.341^2}$.

For S_{1a}: $N^{S,i}_{1,2021,a} = N^{S}_{1,2021,a} e^{0.565\omega_{1,i} - 0.5*0.565^2}$ for $1 \le a \le 5^+$ and $B^{S,i}_{1,2021} = B^{S}_{1,2021} e^{0.565\omega_{1,i} - 0.5*0.565^2}$, and

$N^{S,i}_{2,2021,a} = N^{S}_{2,2021,a} e^{0.935\omega_{2,i} - 0.5*0.935^2}$ for $1 \le a \le 5^+$ and $B^{S,i}_{2,2021} = B^{S}_{2,2021} e^{0.935\omega_{2,i} - 0.5*0.935^2}$.

For S_2: $N^{S,i}_{1,2021,a} = N^{S}_{1,2021,a} e^{0.413\omega_{1,i} - 0.5*0.413^2}$ for $1 \le a \le 5^+$ and $B^{S,i}_{1,2021} = B^{S}_{1,2021} e^{0.413\omega_{1,i} - 0.5*0.413^2}$, and

$N^{S,i}_{2,2021,a} = N^{S}_{2,2021,a} e^{0.349\omega_{2,i} - 0.5*0.349^2}$ for $1 \le a \le 5^+$ and $B^{S,i}_{2,2021} = B^{S}_{2,2021} e^{0.349\omega_{2,i} - 0.5*0.349^2}$.

For S_{2a}: $N^{S,i}_{1,2021,a} = N^{S}_{1,2021,a} e^{0.494\omega_{1,i} - 0.5*0.494^2}$ for $1 \le a \le 5^+$ and $B^{S,i}_{1,2021} = B^{S}_{1,2021} e^{0.494\omega_{1,i} - 0.5*0.494^2}$, and

$N^{S,i}_{2,2021,a} = N^{S}_{2,2021,a} e^{0.955\omega_{2,i} - 0.5*0.955^2}$ for $1 \le a \le 5^+$ and $B^{S,i}_{2,2021} = B^{S}_{2,2021} e^{0.955\omega_{2,i} - 0.5*0.955^2}$.

For these analyses, 500 simulations i were run. There was little difference in results between S_1 and S_2 and between S_{1a} and S_{2a} in initial results (Appendix B). Results thus focus on models S_1 and S_{1a} only, which assume a survey estimate of 265 thousand tons west of Cape Agulhas in November 2021 with a CV of 0.380.

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[1] The effective spawning biomass in 2021 was similarly adjusted for the purpose of reporting statistics only.

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). In line with previous short-term projections (e.g. de Moor 2020b, 2021b), future recruitment was assumed to be according to the recent 'regime' (Appendix A).

It was previously decided that this set of projections would continue to assume the future proportion of sardine moving from the west to the south component is $\mathrm{move}_{y,1} = 0.35$ (de Moor 2021e), but with important consideration given to two alternatives:

i) $\mathrm{move}_{y,1} = 0.15$: The proportion of 1-year old sardine moving from the west to the south coast in November each year is 0.15 in all future years.

ii) $\mathrm{move}_{y,1} = 0.55$: The proportion of 1-year old sardine moving from the west to the south coast in November each year is 0.55 in all future years.

Note that for model S_1, movement has recently averaged 56%, while for S_{1a} recent movement has averaged 35%. One further alternative model was considered:

iii) Future November recruitment is drawn from the lowest three of the five most recent (west) or 2012 – 2016 (south) recruitments.

Results and Discussion

Figures 1 and 2 show the projected total west and south component biomass, respectively, compared to that estimated historically by the most recent assessment (de Moor 2022). The west component biomass for model S_{1a} is estimated to currently be higher than what was estimated for November 2020 based on data up to November 2020 (de Moor 2021a,c). However, whereas the biomass was previously projected to increase relatively rapidly under a no catch scenario, the biomass is now projected to decrease under a no catch scenario and stabilise at a lower level than that projected by de Moor (2021c) and used to recommend the 2021 TAC/Bs (Figure 1). The south component biomass for model S_{1a} is estimated to currently be substantially lower than what was estimated for November 2020 based on data up to November 2020 (de Moor 2021a,c). While the biomass is projected to increase under a no catch scenario, the increase stabilises at a level below that projected under a no catch scenario by de Moor (2021c) and used to recommend the 2021 TAC/Bs (Figure 2).

Similar patterns can be seen for the west and south component effective spawner biomasses (Figures 3 and 4, assuming 8% of south component biomass contributes to west component effective spawner biomass).

One reason for the lower projected levels of biomass for both the west and south components, compared to that expected a year ago, is due to the lower levels of recruitment estimated with the updated assessment (Figure 5).

Tables 1 to 4 provide a sub-set of the statistics previously considered by the SWG-PEL (e.g. by de Moor 2020b, 2021b,c), as agreed following initial testing by de Moor (2021e). The first statistic considered is the 20%ile of the ratio of the multiplicative change in the west or south component effective spawning biomass from November 2021 to 2022 to that under a no future catch scenario (Tables 1, 2). The second statistic considered is the 20%ile in the additive change in the west or south component total biomass from November 2021 to 2022 (Tables 3, 4). There are simulations where the

projected sardine numbers-at-age are not able to accommodate the full catch and/or bycatch. Shading and statistics indicating these cases are not indicated in these tables.

For model S_{1a} with the south component contributing 8% to the west component effective spawning biomass, and assuming a small sardine bycatch of 10 400t during 2022, a >14cm sardine catch west of Cape Agulhas of 14 450t during 2022 would result in a 20%ile of this ratio being 0.90-0.91, while a >14cm sardine catch west of Cape Agulhas of 19450t would result in a 20%ile of this ratio being 0.88 as previously selected in 2019 by the SWG-PEL for use in setting TAC/Bs with these short term projections under Exceptional Circumstances (Table 1). >14cm sardine catches of 24 450t and 29 450t have lower ratios (higher depletion) than that previously recommended by the SWG-PEL (Table 1). The ratios are similar under alternative movement scenarios and alternative assumptions about the proportion of south component spawner biomass that contributes to west component effective spawner biomass, differing by at most 4% (Table C1a), and slightly less under the alternative of lower recruitment (Table C1b).

The west component biomass is, however, projected at the 20%ile to decrease over the next year under all scenarios except one, even in the absence of catch (Table 3, C3).

A >14cm sardine catch east of Cape Agulhas of 11 000t during 2022 would result in the 20%ile of the ratio of the multiplicative change in the south component effective spawning biomass from November 2021 to 2022 to that under a no future catch scenario being 0.84 – 0.90, depending on the catch taken west of Cape Agulhas and the proportion of west component biomass which moves to the south component (Table 2). This decreases to 0.78 – 0.86 for a >14cm sardine catch east of Cape Agulhas of 18 000t. The ratios are slightly lower under the alternative of lower recruitment and higher under S_1 (Table C2).

The south component biomass is also projected at the 20%ile to decrease over the next year under all scenarios except one, even in the absence of catch (Table 4, C4).

Figure 6 shows the historical exploitation rate on the western and southern components, as estimated at the joint posterior mode (de Moor 2022) and gives some indication of the exploitation rate that will result from alternative >14cm catch options for 2022. For example, the exploitation rate corresponding to a >14cm sardine catch of 19 450t west of Cape Agulhas in 2022 would be approximately 10.5% (median) or 16.3% (20%ile biomass), with 90% CI (4.3%, 25.2%). The exploitation rate corresponding to a >14cm sardine catch of 13 000t east of Cape Agulhas in 2022 would be approximately 8.1% (median) or 18.1% (20%ile biomass), with 90% CI (1.5%, 30.8%). Figure 7 plots the exploitation rate against the total biomass.

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Table 1. The 20%ile of the multiplicative change in **west component effective spawning biomass** (including 8% of south component spawner biomass) from November 2021 to 2022 under alternative catch options relative to the no catch option for model S_{1a}. The top rows give the comparative statistics under 2019, April 2020 and May 2021 TAC/Bs (de Moor 2019, 2020b and 2021c).

	Total	West	South	ByC	15%	35%	55%
2019	23	6.5	7	9.5		0.88	
2020	34.05	11.65	13	9.4		0.90	
	34.05[2]	13.65	13	7.4		0.90	
2021	42.85	14.45	18	10.4		0.87	
	35.95	14.45	11	10.5	0.91	0.91	0.91
	40.95	19.45	11	10.5	0.88	0.88	0.89
	45.95	24.45	11	10.5	0.86	0.86	0.86
	50.95	29.45	11	10.5	0.83	0.83	0.84
	37.95	14.45	13	10.5	0.91	0.91	0.91
	42.95	19.45	13	10.5	0.88	0.88	0.88
	47.95	24.45	13	10.5	0.86	0.86	0.86
	52.95	29.45	13	10.5	0.83	0.83	0.84
	42.95	14.45	18	10.5	0.91	0.90	0.91
	47.95	19.45	18	10.5	0.88	0.88	0.88
	52.95	24.45	18	10.5	0.85	0.85	0.86
	57.95	29.45	18	10.5	0.83	0.83	0.83
	47.95	14.45	23	10.5	0.90	0.90	0.90
	52.95	19.45	23	10.5	0.88	0.88	0.88
	57.95	24.45	23	10.5	0.85	0.85	0.85
	62.95	29.45	23	10.5	0.82	0.83	0.83

Table 2. As per Table 1, but for the **south component effective spawning biomass** (comprising 92% of south component spawner biomass).

	Total	West	South	ByC	15%	35%	55%
2020	34.05	11.65	13	9.4		0.95	
	34.05	13.65	13	7.4		0.95	
2021	42.85	14.45	18	10.4		0.95	
	35.95	14.45	11	10.5	0.86	0.89	0.90
	40.95	19.45	11	10.5	0.86	0.87	0.88
	45.95	24.45	11	10.5	0.85	0.86	0.87
	50.95	29.45	11	10.5	0.84	0.85	0.86
	37.95	14.45	13	10.5	0.84	0.87	0.89
	42.95	19.45	13	10.5	0.84	0.86	0.87
	47.95	24.45	13	10.5	0.83	0.85	0.86
	52.95	29.45	13	10.5	0.82	0.84	0.85
	42.95	14.45	18	10.5	0.80	0.84	0.86
	47.95	19.45	18	10.5	0.79	0.83	0.85
	52.95	24.45	18	10.5	0.78	0.82	0.83
	57.95	29.45	18	10.5	0.78	0.80	0.82
	47.95	14.45	23	10.5	0.74	0.80	0.83
	52.95	19.45	23	10.5	0.74	0.79	0.82
	57.95	24.45	23	10.5	0.73	0.78	0.81
	62.95	29.45	23	10.5	0.72	0.77	0.80

[2] The final (higher) TAC and TABs took into account additional information available from the within-year recruit survey.

Table 3. The 20%ile of the additive change in **west component biomass** from November 2021 to 2022 under alternative catch options for model S_{1a}. The top rows give the comparative statistics under April 2020 and May 2021 TAC/Bs (de Moor 2020b and 2021c).

	Total	West	South	ByC	15%	35%	55%
2020	0	0	0	0		-8	
	34.05	11.65	13	9.4		-20	
	34.05	13.65	13	7.4		-20	
2021	0	0	0	0		41	
	42.85	14.45	18	10.4		24	
	0	0	0	0	-94	-175	-261
	35.95	14.45	11	10.5	-114	-190	-272
	40.95	19.45	11	10.5	-117	-192	-273
	45.95	24.45	11	10.5	-120	-195	-275
	50.95	29.45	11	10.5	-124	-197	-277
	37.95	14.45	13	10.5	-114	-190	-272
	42.95	19.45	13	10.5	-117	-192	-273
	47.95	24.45	13	10.5	-120	-195	-275
	52.95	29.45	13	10.5	-124	-197	-277
	42.95	14.45	18	10.5	-114	-190	-272
	47.95	19.45	18	10.5	-117	-192	-273
	52.95	24.45	18	10.5	-120	-195	-275
	57.95	29.45	18	10.5	-124	-197	-277
	47.95	14.45	23	10.5	-114	-190	-272
	52.95	19.45	23	10.5	-117	-192	-273
	57.95	24.45	23	10.5	-120	-195	-275
	62.95	29.45	23	10.5	-124	-197	-277

Table 4. As per Table 3, but for the **south component biomass**.

	Total	West	South	ByC	15%	35%	55%
2020	0	0	0	0		46	
	34.05	11.65	13	9.4		26	
	34.05	13.65	13	7.4		26	
2021	0	0	0	0		-143	
	42.85	14.45	18	10.4		-165	
	0	0	0	0	-88	-22	38
	35.95	14.45	11	10.5	-99	-38	17
	40.95	19.45	11	10.5	-100	-39	16
	45.95	24.45	11	10.5	-100	-40	14
	50.95	29.45	11	10.5	-101	-41	12
	37.95	14.45	13	10.5	-101	-39	16
	42.95	19.45	13	10.5	-101	-41	14
	47.95	24.45	13	10.5	-102	-42	12
	52.95	29.45	13	10.5	-102	-43	10
	42.95	14.45	18	10.5	-104	-43	13
	47.95	19.45	18	10.5	-105	-44	11
	52.95	24.45	18	10.5	-105	-45	9
	57.95	29.45	18	10.5	-106	-46	7
	47.95	14.45	23	10.5	-108	-46	9
	52.95	19.45	23	10.5	-108	-48	7
	57.95	24.45	23	10.5	-109	-49	5
	62.95	29.45	23	10.5	-109	-50	3

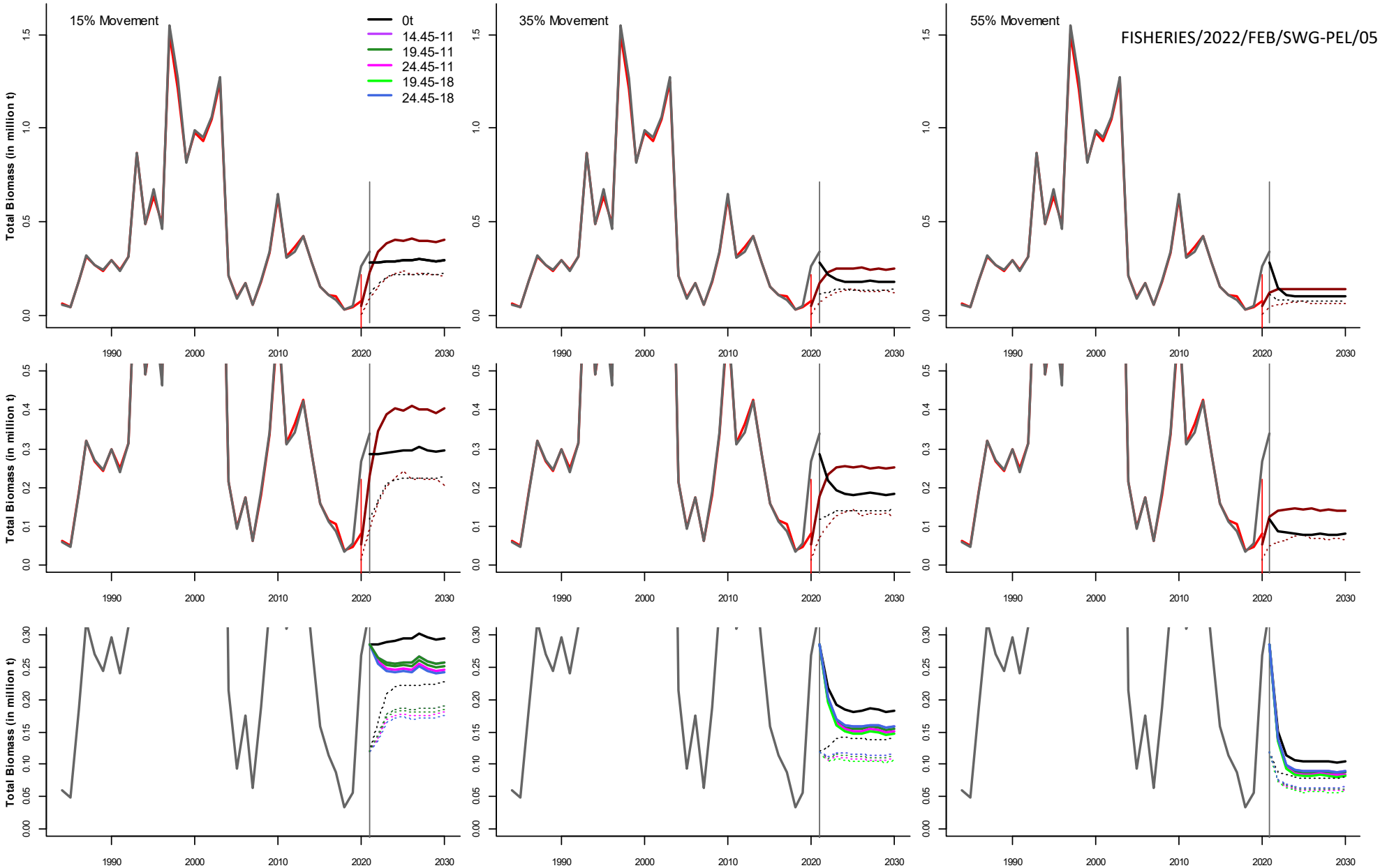

Figure 1. Model S_{1a} estimated historical **west component total biomass** at the joint posterior mode (from de Moor 2022), with the 95% CI in 2021 indicated by the vertical grey line, together with projected medians and 5%iles from 2021 to 2030 under a no catch and five alternative constant catch scenarios. The comparable estimates and projections from de Moor (2021c) are shown in red (historical) and brown (future). The lower set of panels is a repeat of the upper set, but with a shorter vertical axis range.

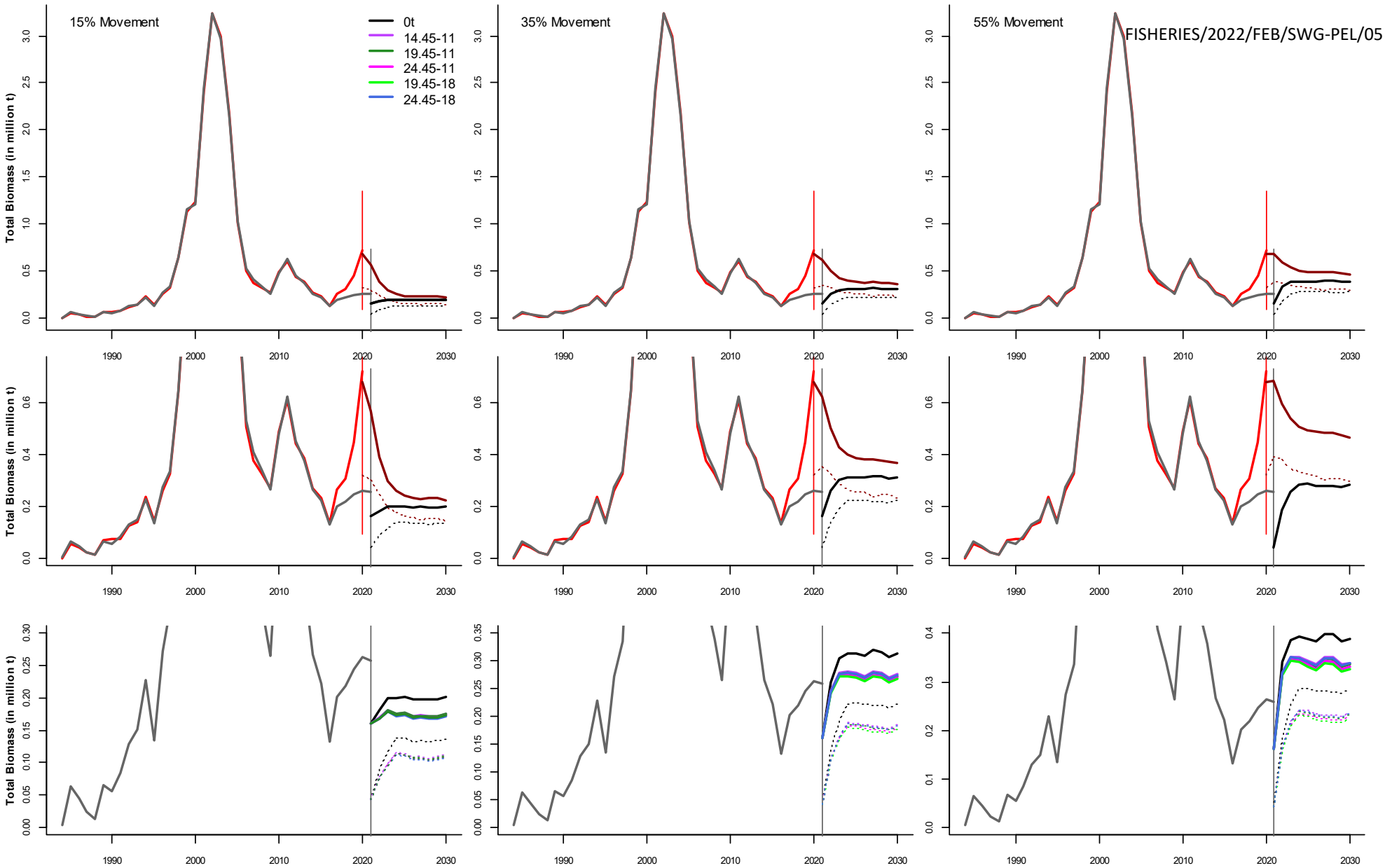

Figure 2. Model S_{1a} estimated historical **south component total biomass** at the joint posterior mode (from de Moor 2022), with the 95% CI in 2021 indicated by the vertical grey line, together with projected medians and 5%iles from 2021 to 2030 under a no catch and five alternative constant catch scenarios. The comparable estimates and projections from de Moor (2021c) are shown in red (historical) and brown (future). The lower set of panels is a repeat of the upper set, but with a shorter vertical axis range.

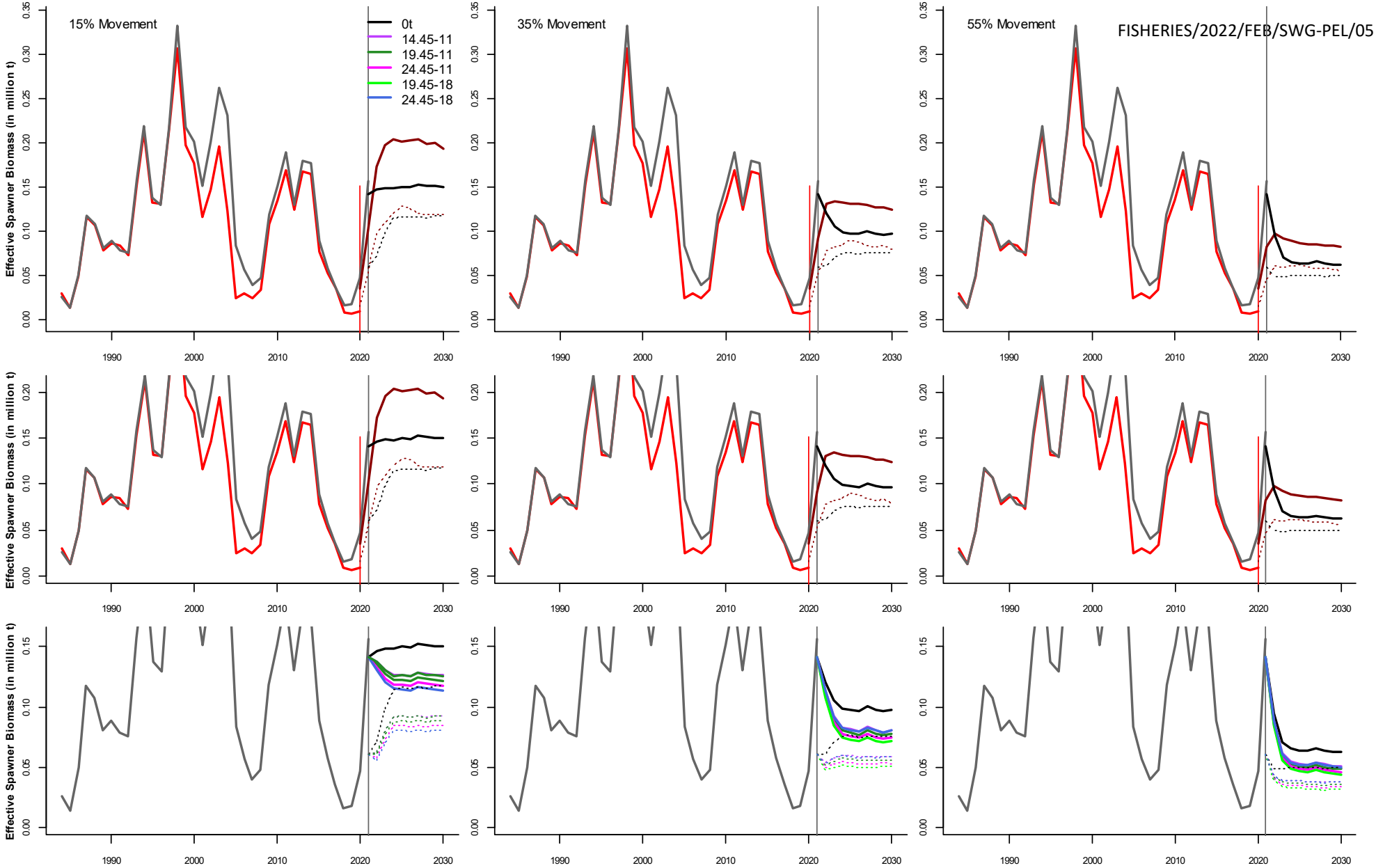

Figure 3. Model S_{1a} estimated historical **west component effective spawning biomass** (p=0.08) at the joint posterior mode (from de Moor 2022), with the 95% CI in 2021 indicated by the vertical grey line, together with projected medians and 5%iles from 2021 to 2030 under a no catch and five alternative constant catch scenarios. The comparable estimates and projections from de Moor (2021c) are shown in red (historical) and brown (future). The lower set of panels is a repeat of the upper set, but with a shorter vertical axis range.

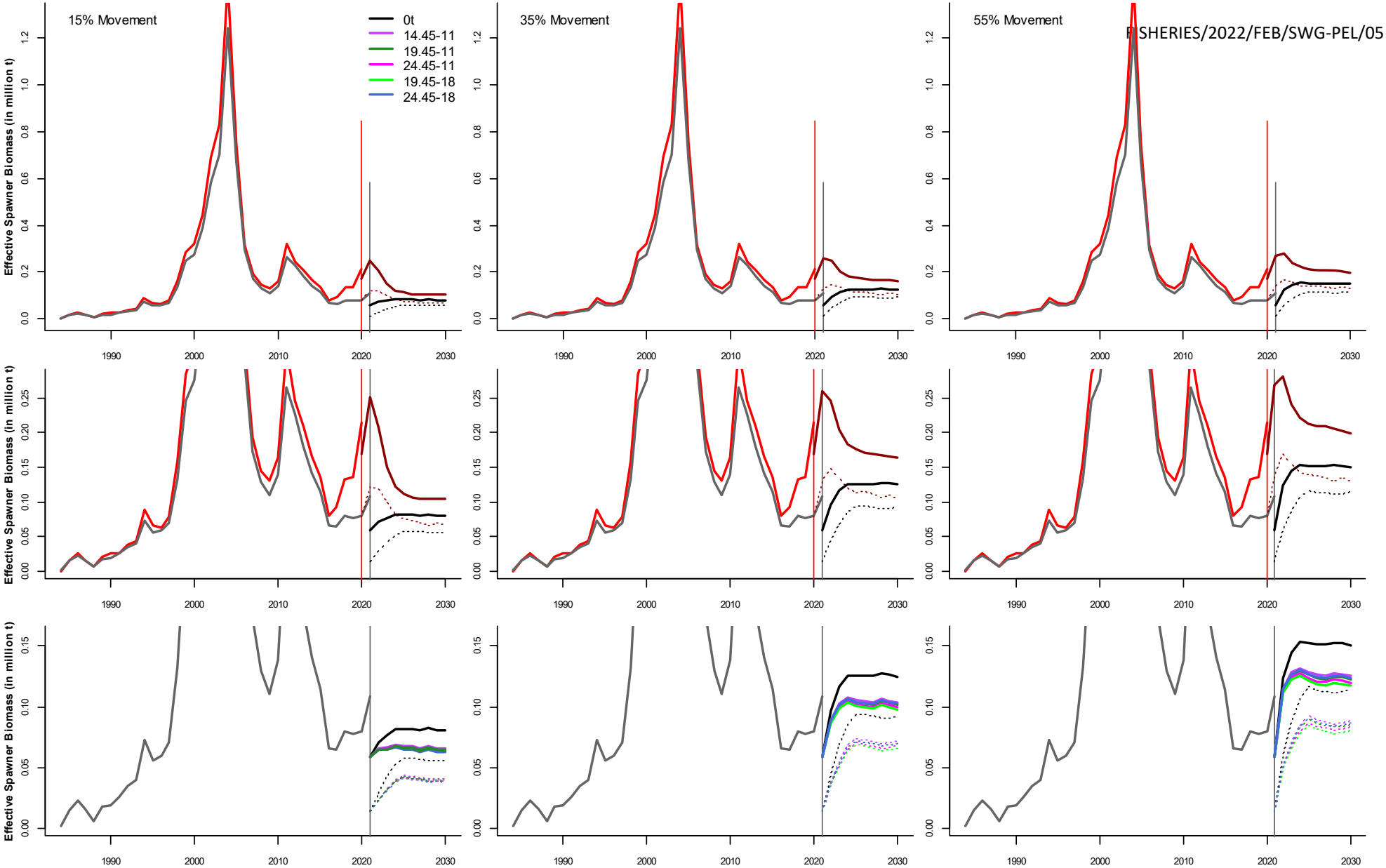

Figure 4. Model S_{1a} estimated historical **south component effective spawning biomass** (p=0.08) at the joint posterior mode (from de Moor 2022), with the 95% CI in 2021 indicated by the vertical grey line, together with projected medians and 5%iles from 2021 to 2030 under a no catch and five alternative constant catch scenarios. The comparable estimates and projections from de Moor (2021c) are shown in red (historical) and brown (future). The lower set of panels is a repeat of the upper set, but with a shorter vertical axis range.

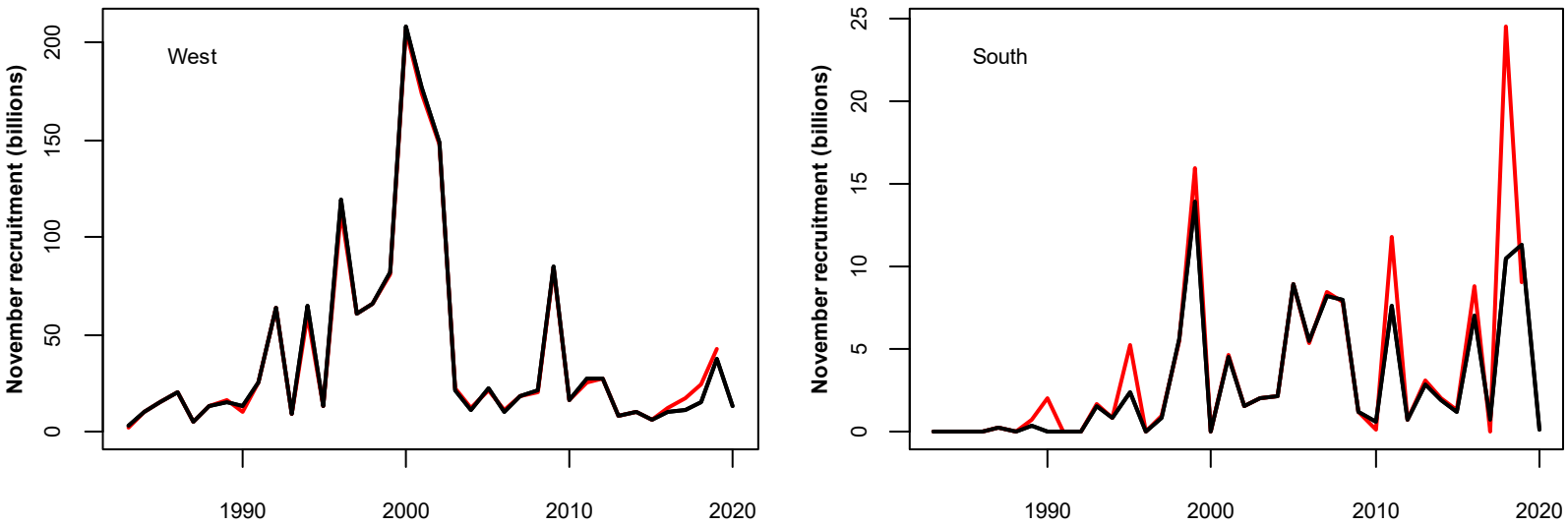

Figure 5. The recruitment estimated in November each year by the assessment using data up to November 2021 (black, de Moor (2022)) and that using data up to November 2020 (red, de Moor (2021c)).

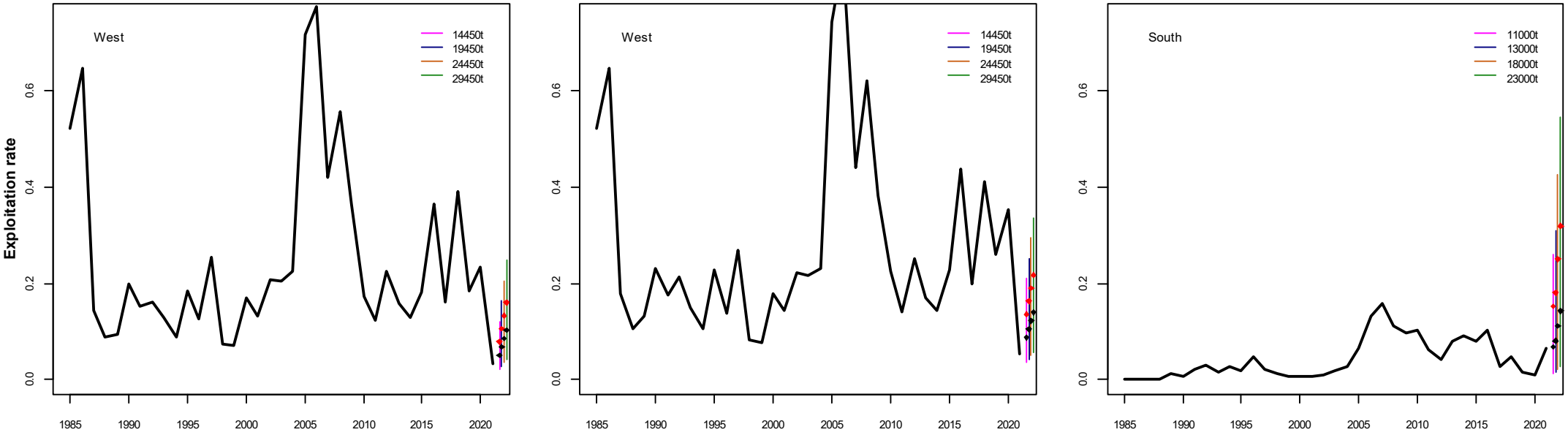

Figure 6. The historical exploitation rate on the western and southern components of South African sardine at the joint posterior mode for S_{1a} (de Moor 2022). The left plot excludes small sardine bycatch while the middle plot includes these landings. The 5%ile – 95%ile range of the exploitation rate corresponding to four >14cm catch alternatives for 2022 are given by vertical lines. The exploitation rate corresponding to the 20%ile and 50%ile of November 2021 biomass is indicated by the red and black diamonds, respectively.

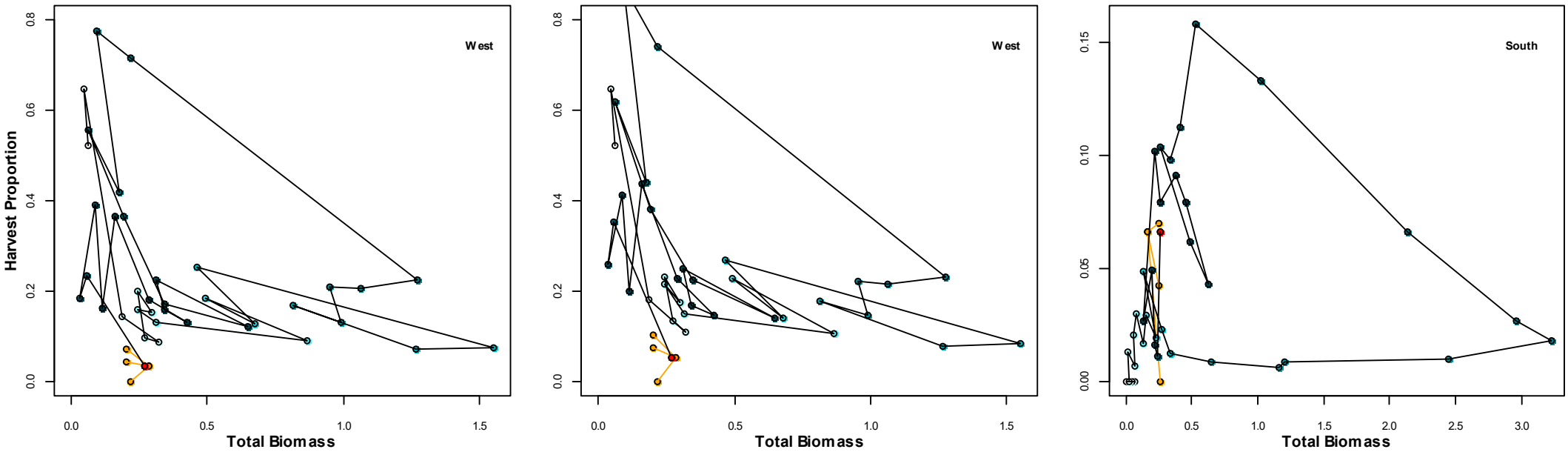

Figure 7. The historical exploitation rate plotted against total biomass estimated at the joint posterior mode (de Moor 2022) for S_{1a}, with lighter colours reflecting earlier years from 1984 and darker colours reflecting later years up to 2021. The 2021 point is shown in red. The points corresponding to 2021 and 2022 using median biomasses are shown in orange, for a no catch option (with a zero exploitation rate in 2022) and the catch option of 14 450t and 24 450t to be taken west of Cape Agulhas and 11 000t and 18 000t to be taken east of Cape Agulhas. The left plot excludes small sardine bycatch while the middle plot includes these landings (of 10 500t in the 2022 catch option).

Appendix A: Baseline projections using constant catch assumptions (repeated from de Moor (2021))

The projections will be run from November $y_1 = 2021$ to November $y_n = 2040$. The notation is the same as that of Appendix A and Tables A1 and A2 of de Moor (2020c). The following assumptions were made:

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

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

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

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

and

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

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

- 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 $\mathrm{move}_{\mathrm{y,1}}$ =0.35[3].
- Future recruitment is generated from the past 5[4] 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. As there was no May recruitment survey on the south coast in 2018, 2019 or 2020, 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 (2020c) equation (A8).
- Growth curves at the mid-point of each quarter (de Moor (2020c) equation A16) and therefore the quarterly commercial selectivity-at-age functions (de Moor (2020c) equation A15) are the same[5] for all future years.
- Growth curves in November (de Moor (2020c) 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:

$$S^{S}_{j,a} = 0.25 \sum_{q=1}^{4} \sum_{l=2.5^-}^{24^+} A^{com}_{j,2021,q,a,l} S_{j,q,l} = 0.25 \quad 0 \le a \le 5^+ \qquad \text{(A4)}$$

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

[3] The average over the past 5 years is 0.34 for the base case model, and 0.41 over 2015-2019 and 0.38 over 2014-2018. The average over the past 10 years is 0.32.
[4] The most recent 5 or 10 years are frequent choices for the "recent past" in projection analyses internationally.
[5] 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 (2020c) 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[6]) 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:

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

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

$$C_{j,p,y,a}^{S} = C_{j,p,y,a}^{bycatch} + C_{j,p,y,a}^{dir} \qquad p = I, NI, y > y_n, 1 \le q \le 4, 0 \le a \le 5^+ \text{(A7)}$$

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

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

[6] de Moor (2020b).

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

$C_{j,p,y,3}^{dir} = 0.95\left(N_{j,p,y-1,3}^{S} e^{-M_{y,3}^{S}/2} - C_{j,p,y,3}^{bycatch}\right) < Directed + LargeBycatch - \sum_{a=4}^{5+} C_{j,p,y,a}^{dir} w_{j,a}^{catch}$

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

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

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

$C_{j,p,y,2}^{dir} = 0.95\left(N_{j,p,y-1,2}^{S} e^{-M_{y,2}^{S}/2} - C_{j,p,y,2}^{bycatch}\right) < Directed + LargeBycatch - \sum_{a=3}^{5+} C_{j,p,y,a}^{dir} w_{j,a}^{catch}$

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

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

$C_{j,p,y,a}^{dir} = \frac{Directed+Large\ Bycatch-\sum_{a=3}^{5+} C_{j,p,y,a}^{dir} w_{j,a}^{catch}}{\sum_{a=0}^{1}\sum_{p=I,NI}\left(N_{j,p,y-1,a}^{S} e^{-M_{y,a/2}^{S}} - C_{j,p,y,a}^{bycatch}\right) S_{j,a}^{S} w_{j,a}^{catch}} \times \left(N_{j,p,y-1,a}^{S} e^{-M_{y,a/2}^{S}} - C_{j,p,y,a}^{bycatch}\right) S_{j,a}^{S}$ for $0 \leq a \leq 1$, else $C_{j,p,y,a}^{dir} = 0.95\left(N_{j,p,y-1,a}^{S} e^{-M_{y,2}^{S}/2} - C_{j,p,y,a}^{bycatch}\right)$ for $0 \leq a \leq 1$[7]

[7] Cases where the full catch is not realised because this equation reaches the constraint, even after the modifications to the selectivity are made are indicated by dark grey shading in the results tables.

Appendix B: Initial results

Table B.1. The 20%ile of the multiplicative change in **west component effective spawning biomass** (including 8% of south component spawner biomass) from November 2021 to 2022 under alternative catch options relative to the no catch option for the alternative models considered. The top rows give the comparative statistics under 2019, April 2020 and May 2021 TAC/Bs (de Moor 2019, 2020b and 2021c).

	Total	West	South	ByC	S_1 15%	S_1 35%	S_1 55%	S_{1a} 15%	S_{1a} 35%	S_{1a} 55%	S_2 15%	S_2 35%	S_2 55%	S_{2a} 15%	S_{2a} 35%	S_{2a} 55%
2019	23	6.5	7	9.5		0.88[8]			0.88			0.88			0.88	
2020	34.05	11.65	13	9.4		0.90			0.90			0.90			0.90	
	34.05[9]	13.65	13	7.4		0.90			0.90			0.90			0.90	
2021	42.85	14.45	18	10.4		0.87			0.87			0.87			0.87	
	36.05	7.65	18	10.4	0.95	0.95	0.95	0.94	0.94	0.94	0.95	0.95	0.95	0.94	0.94	0.94
	11.65	11.65	0	0	0.95	0.95	0.96	0.94	0.94	0.94	0.95	0.96	0.96	0.94	0.95	0.95
	22.05	11.65	0	10.4	0.94	0.94	0.94	0.93	0.93	0.93	0.94	0.94	0.95	0.93	0.93	0.94
	29.65	11.65	18	0	0.94	0.94	0.94	0.93	0.93	0.93	0.95	0.95	0.95	0.94	0.94	0.93
	38.05	9.65	18	10.4	0.94	0.94	0.94	0.93	0.93	0.93	0.94	0.94	0.94	0.94	0.93	0.93
	40.05	11.65	18	10.4	0.93	0.93	0.93	0.92	0.92	0.92	0.93	0.94	0.94	0.93	0.92	0.92
	42.05	13.65	18	10.4	0.92	0.92	0.92	0.91	0.91	0.91	0.93	0.93	0.93	0.92	0.92	0.91
	44.05	15.65	18	10.4	0.91	0.91	0.92	0.90	0.90	0.90	0.92	0.92	0.92	0.91	0.91	0.91

Table B.2. As per Table B.1, but for the **south component effective spawning biomass** (comprising 92% of south component spawner biomass).

	Total	West	South	ByC	S_1 15%	S_1 35%	S_1 55%	S_{1a} 15%	S_{1a} 35%	S_{1a} 55%	S_2 15%	S_2 35%	S_2 55%	S_{2a} 15%	S_{2a} 35%	S_{2a} 55%
2020	34.05	11.65	13	9.4		0.838			0.838			0.838			0.838	
	34.05	13.65	13	7.4		0.830			0.830			0.830			0.830	
2021	42.85	14.45	18	10.4		0.771			0.771			0.771			0.771	
	36.05	7.65	18	10.4	0.95	0.95	0.95	0.80	0.85	0.88	0.95	0.95	0.95	0.80	0.85	0.88
	11.65	11.65	0	0	1.00	0.99	0.99	0.98	0.98	0.97	1.00	0.99	0.99	0.98	0.98	0.97
	22.05	11.65	0	10.4	1.00	0.99	0.99	0.98	0.97	0.96	1.00	0.99	0.99	0.98	0.97	0.96
	29.65	11.65	18	0	0.95	0.95	0.95	0.80	0.85	0.88	0.95	0.95	0.95	0.80	0.85	0.88
	38.05	9.65	18	10.4	0.95	0.95	0.95	0.80	0.85	0.87	0.95	0.95	0.95	0.80	0.85	0.87
	40.05	11.65	18	10.4	0.95	0.95	0.95	0.80	0.84	0.87	0.95	0.95	0.95	0.79	0.84	0.87
	42.05	13.65	18	10.4	0.95	0.94	0.94	0.80	0.84	0.86	0.94	0.94	0.94	0.79	0.84	0.86
	44.05	15.65	18	10.4	0.94	0.94	0.94	0.79	0.83	0.86	0.94	0.94	0.94	0.79	0.83	0.86

[8] This was the ratio of the 20%ile of the multiplicative change in west component effective spawning biomass from November 2018 to 2019 under the catch scenario to the 20%ile of the multiplicative change in west component effective spawning biomass from November 2018 to 2019 under the no catch scenario.

[9] The final (higher) TAC and TABs took into account additional information available from the within-year recruit survey.

Table B.3. The 20%ile of the additive change in **west component biomass** from November 2021 to 2022 under alternative catch options for the alternative models considered. The top rows give the comparative statistics under April 2020 and May 2021 TAC/Bs (de Moor 2020b and 2021c).

	Total	West	South	ByC	S_1 15%	S_1 35%	S_1 55%	S_{1a} 15%	S_{1a} 35%	S_{1a} 55%	S_2 15%	S_2 35%	S_2 55%	S_{2a} 15%	S_{2a} 35%	S_{2a} 55%
2020	0	0	0	0		-8			-8							
	34.05	11.65	13	9.4		-20			-20							
	34.05	13.65	13	7.4		-20			-20							
2021	0	0	0	0		41			41							
	42.85	14.45	18	10.4		24			24							
	0	0	0	0	42	-31	-105	-94	-175	-261	35	-46	-121	-93	-171	-252
	36.05	7.65	18	10.4	26	-43	-114	-110	-187	-269	19	-58	-130	-108	-183	-260
	11.65	11.65	0	0	34	-36	-110	-102	-180	-265	27	-52	-126	-100	-176	-256
	22.05	11.65	0	10.4	24	-45	-115	-112	-189	-271	16	-60	-131	-111	-185	-262
	29.65	11.65	18	0	34	-36	-110	-102	-180	-265	27	-52	-126	-100	-176	-256
	38.05	9.65	18	10.4	25	-44	-115	-111	-188	-270	17	-59	-131	-109	-184	-261
	40.05	11.65	18	10.4	24	-45	-115	-112	-189	-271	16	-60	-131	-111	-185	-262
	42.05	13.65	18	10.4	22	-46	-116	-114	-190	-271	15	-61	-132	-112	-186	-262
	44.05	15.65	18	10.4	21	-47	-117	-115	-191	-272	13	-62	-133	-113	-187	-263

Table B.4. As per Table B.3, but for the **south component biomass**.

	Total	West	South	ByC	S_1 15%	S_1 35%	S_1 55%	S_{1a} 15%	S_{1a} 35%	S_{1a} 55%	S_2 15%	S_2 35%	S_2 55%	S_{2a} 15%	S_{2a} 35%	S_{2a} 55%
2020	0	0	0	0		46			46							
	34.05	11.65	13	9.4		26			26							
	34.05	13.65	13	7.4		26			26							
2021	0	0	0	0		-143			-143							
	42.85	14.45	18	10.4		-165			-165							
	0	0	0	0	-349	-288	-291	-88	-22	38	-342	-279	-206	-86	-21	41
	36.05	7.65	18	10.4	-363	-306	-240	-104	-41	15	-357	-298	-227	-102	-40	18
	11.65	11.65	0	0	-350	-291	-223	-89	-25	34	-343	-282	-210	-87	-24	37
	22.05	11.65	0	10.4	-351	-295	-229	-91	-30	26	-345	-286	-217	-89	-29	29
	29.65	11.65	18	0	-362	-303	-236	-102	-37	21	-356	-295	-223	-100	-36	24
	38.05	9.65	18	10.4	-364	-307	-241	-104	-42	14	-357	-298	-228	-102	-41	18
	40.05	11.65	18	10.4	-364	-307	-242	-104	-42	14	-357	-299	-229	-102	-41	17
	42.05	13.65	18	10.4	-364	-308	-243	-104	-43	13	-358	-299	-230	-102	-42	16
	44.05	15.65	18	10.4	-364	-308	-243	-104	-43	12	-358	-300	-231	-102	-42	15

Appendix C: Full results

Table C.1a. The 20%ile of the multiplicative change in **west component effective spawning biomass** (including 0%, 8% or 30% of south component spawner biomass) from November 2021 to 2022 under alternative catch options relative to the no catch option for the alternative models considered. The top rows give the comparative statistics under 2019, April 2020 and May 2021 TAC/Bs (de Moor 2019, 2020b and 2021c).

	Total	West	South	ByC	Including 0% south component						Including 8% south component						Including 30% south component					
					S_1			S_{1a}			S_1			S_{1a}			S_1			S_{1a}		
					15%	35%	55%	15%	35%	55%	15%	35%	55%	15%	35%	55%	15%	35%	55%	15%	35%	55%
2019	23	6.5	7	9.5		0.84			0.84			0.88[10]			0.88			0.93			0.93	
2020	34.05	11.65	13	9.4		0.83			0.83			0.90			0.90			0.93			0.93	
	34.05[11]	13.65	13	7.4		0.77			0.77			0.90			0.90			0.92			0.92	
2021	42.85	14.45	18	10.4		0.78			0.78			0.87			0.87			0.94			0.94	
	35.95	14.45	11	10.5	0.91	0.91	0.91	0.91	0.91	0.91	0.92	0.92	0.93	0.91	0.91	0.91	0.94	0.94	0.94	0.91	0.91	0.91
	40.95	19.45	11	10.5	0.88	0.88	0.88	0.88	0.88	0.88	0.90	0.90	0.91	0.88	0.88	0.89	0.92	0.93	0.93	0.89	0.89	0.89
	45.95	24.45	11	10.5	0.85	0.85	0.85	0.85	0.85	0.85	0.88	0.88	0.89	0.86	0.86	0.86	0.91	0.91	0.92	0.87	0.87	0.87
	50.95	29.45	11	10.5	0.83	0.83	0.83	0.82	0.82	0.82	0.85	0.86	0.87	0.83	0.83	0.84	0.89	0.90	0.91	0.85	0.85	0.85
	37.95	14.45	13	10.5	0.91	0.91	0.91	0.91	0.91	0.91	0.92	0.92	0.92	0.91	0.91	0.91	0.94	0.94	0.94	0.91	0.91	0.91
	42.95	19.45	13	10.5	0.88	0.88	0.88	0.88	0.88	0.88	0.90	0.90	0.91	0.88	0.88	0.88	0.92	0.92	0.93	0.89	0.89	0.89
	47.95	24.45	13	10.5	0.85	0.85	0.85	0.85	0.85	0.85	0.87	0.88	0.89	0.86	0.86	0.86	0.91	0.91	0.92	0.86	0.87	0.87
	52.95	29.45	13	10.5	0.83	0.83	0.83	0.82	0.82	0.82	0.85	0.86	0.87	0.83	0.83	0.84	0.89	0.90	0.90	0.84	0.85	0.85
	42.95	14.45	18	10.5	0.91	0.91	0.91	0.91	0.91	0.91	0.92	0.92	0.92	0.91	0.90	0.91	0.93	0.93	0.93	0.90	0.90	0.90
	47.95	19.45	18	10.5	0.88	0.88	0.88	0.88	0.88	0.88	0.89	0.90	0.90	0.88	0.88	0.88	0.92	0.92	0.92	0.88	0.88	0.88
	52.95	24.45	18	10.5	0.85	0.85	0.85	0.85	0.85	0.85	0.87	0.88	0.88	0.85	0.85	0.86	0.90	0.90	0.91	0.86	0.86	0.86
	57.95	29.45	18	10.5	0.83	0.83	0.83	0.82	0.82	0.82	0.85	0.86	0.86	0.83	0.83	0.83	0.89	0.89	0.90	0.84	0.84	0.84
	47.95	14.45	23	10.5	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.92	0.92	0.90	0.90	0.90	0.93	0.93	0.93	0.89	0.89	0.89
	52.95	19.45	23	10.5	0.88	0.88	0.88	0.88	0.88	0.88	0.89	0.90	0.90	0.88	0.88	0.88	0.91	0.91	0.91	0.87	0.87	0.87
	57.95	24.45	23	10.5	0.85	0.85	0.85	0.85	0.85	0.85	0.87	0.87	0.88	0.85	0.85	0.85	0.90	0.90	0.90	0.85	0.85	0.85
	62.95	29.45	23	10.5	0.83	0.83		0.82	0.82	0.82	0.85	0.85	0.86	0.82	0.83	0.83	0.88	0.89	0.89	0.83	0.83	0.83

[10] This was the ratio of the 20%ile of the multiplicative change in west component effective spawning biomass from November 2018 to 2019 under the catch scenario to the 20%ile of the multiplicative change in west component effective spawning biomass from November 2018 to 2019 under the no catch scenario.

[11] The final (higher) TAC and TABs took into account additional information available from the within-year recruit survey.

Table C.1b. As per Table C.1a, but for the alternative option using the lowest three (out of five) recruitments.

	Total	West	South	ByC	Including 0% south component			Including 8% south component			Including 30% south component		
					S_{1a}			S_{1a}			S_{1a}		
					15%	35%	55%	15%	35%	55%	15%	35%	55%
2019	23	6.5	7	9.5		0.84			0.88			0.93	
2020	34.05	11.65	13	9.4		0.83			0.90			0.93	
	34.05[12]	13.65	13	7.4		0.77			0.90			0.92	
2021	42.85	14.45	18	10.4		0.78			0.87			0.94	
	35.95	14.45	11	10.5	0.90	0.90	0.90	0.90	0.90	0.90	0.91	0.91	0.91
	40.95	19.45	11	10.5	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.89	0.89
	45.95	24.45	11	10.5	0.85	0.85	0.85	0.85	0.85	0.85	0.86	0.86	0.87
	50.95	29.45	11	10.5	0.82	0.82	0.82	0.82	0.82	0.83	0.84	0.84	0.84
	37.95	14.45	13	10.5	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	42.95	19.45	13	10.5	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.88
	47.95	24.45	13	10.5	0.85	0.85	0.85	0.85	0.85	0.85	0.86	0.86	0.86
	52.95	29.45	13	10.5	0.82	0.82	0.82	0.82	0.82	0.83	0.84	0.84	0.84
	42.95	14.45	18	10.5	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.89
	47.95	19.45	18	10.5	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	52.95	24.45	18	10.5	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	57.95	29.45	18	10.5	0.82	0.82	0.82	0.82	0.82	0.82	0.83	0.83	0.83
	47.95	14.45	23	10.5	0.90	0.90	0.90	0.90	0.90	0.90	0.89	0.89	0.88
	52.95	19.45	23	10.5	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.86
	57.95	24.45	23	10.5	0.85	0.85	0.85	0.84	0.84	0.84	0.84	0.84	0.84
	62.95	29.45	23	10.5	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82

Table C.2. As per Table C.1a, but for the **south component effective spawning biomass** (comprising 100%, 92% or 70% of south component spawner biomass).

	Total	West	South	ByC	Baseline						Lowest 3 Rec		
					S_1			S_{1a}			S_{1a}		
					15%	35%	55%	15%	35%	55%	15%	35%	55%
2020	34.05	11.65	13	9.4		0.95			0.95			0.95	
	34.05	13.65	13	7.4		0.95			0.95			0.95	
2021	42.85	14.45	18	10.4		0.95			0.95			0.95	
	35.95	14.45	11	10.5	0.96	0.96	0.96	0.86	0.89	0.90	0.85	0.88	0.89
	40.95	19.45	11	10.5	0.96	0.96	0.95	0.86	0.87	0.88	0.84	0.87	0.87
	45.95	24.45	11	10.5	0.96	0.95	0.95	0.85	0.86	0.87	0.84	0.86	0.86
	50.95	29.45	11	10.5	0.96	0.95	0.94	0.84	0.85	0.86	0.83	0.84	0.85
	37.95	14.45	13	10.5	0.96	0.96	0.95	0.84	0.87	0.89	0.83	0.86	0.88
	42.95	19.45	13	10.5	0.96	0.95	0.95	0.84	0.86	0.87	0.82	0.85	0.86
	47.95	24.45	13	10.5	0.96	0.95	0.94	0.83	0.85	0.86	0.82	0.84	0.85
	52.95	29.45	13	10.5	0.95	0.95	0.94	0.82	0.84	0.85	0.81	0.83	0.84
	42.95	14.45	18	10.5	0.95	0.94	0.94	0.80	0.84	0.86	0.77	0.83	0.85
	47.95	19.45	18	10.5	0.94	0.94	0.94	0.79	0.83	0.85	0.77	0.81	0.83
	52.95	24.45	18	10.5	0.94	0.94	0.93	0.78	0.82	0.83	0.76	0.80	0.82
	57.95	29.45	18	10.5	0.94	0.93	0.93	0.78	0.80	0.82	0.75	0.79	0.81
	47.95	14.45	23	10.5	0.93	0.93	0.93	0.74	0.80	0.83	0.72	0.79	0.82
	52.95	19.45	23	10.5	0.93	0.93	0.93	0.74	0.79	0.82	0.71	0.78	0.81
	57.95	24.45	23	10.5	0.93	0.92	0.92	0.73	0.78	0.81	0.71	0.77	0.79
	62.95	29.45	23	10.5	0.93	0.92	0.92	0.72	0.77	0.80	0.70	0.76	0.78

[12] The final (higher) TAC and TABs took into account additional information available from the within-year recruit survey.

Table C.3. The 20%ile of the additive change in **west component biomass** from November 2021 to 2022 under alternative catch options for the alternative models considered. The top rows give the comparative statistics under April 2020 and May 2021 TAC/Bs (de Moor 2020b and 2021c).

					Baseline						Lowest 3 Rec		
						S_1			S_{1a}			S_{1a}	
	Total	West	South	ByC	15%	35%	55%	15%	35%	55%	15%	35%	55%
2020	0	0	0	0		-8			-8			-8	
	34.05	11.65	13	9.4		-20			-20			-20	
	34.05	13.65	13	7.4		-20			-20			-20	
2021	0	0	0	0		41			41			41	
	42.85	14.45	18	10.4		24			24			24	
	0	0	0	0	42	-31	-105	-94	-175	-261	-120	-200	-281
	35.95	14.45	11	10.5	22	-46	-116	-114	-190	-272	-140	-216	-292
	40.95	19.45	11	10.5	18	-49	-118	-117	-192	-273	-143	-218	-293
	45.95	24.45	11	10.5	15	-51	-120	-120	-195	-275	-146	-220	-295
	50.95	29.45	11	10.5	12	-54	-122	-124	-197	-277	-149	-223	-297
	37.95	14.45	13	10.5	22	-46	-116	-114	-190	-272	-140	-216	-292
	42.95	19.45	13	10.5	18	-49	-118	-117	-192	-273	-143	-218	-293
	47.95	24.45	13	10.5	15	-51	-120	-120	-195	-275	-146	-220	-295
	52.95	29.45	13	10.5	12	-54	-122	-124	-197	-277	-149	-223	-297
	42.95	14.45	18	10.5	22	-46	-116	-114	-190	-272	-140	-216	-292
	47.95	19.45	18	10.5	18	-49	-118	-117	-192	-273	-143	-218	-293
	52.95	24.45	18	10.5	15	-51	-120	-120	-195	-275	-146	-220	-295
	57.95	29.45	18	10.5	12	-54	-122	-124	-197	-277	-149	-223	-297
	47.95	14.45	23	10.5	22	-46	-116	-114	-190	-272	-140	-216	-292
	52.95	19.45	23	10.5	18	-49	-118	-117	-192	-273	-143	-218	-293
	57.95	24.45	23	10.5	15	-51	-120	-120	-195	-275	-146	-220	-295
	62.95	29.45	23	10.5	12	-54	-122	-124	-197	-277	-149	-223	-297

Table C.4. As per Table C.3, but for the **south component biomass**.

					Baseline						Lowest 3 Rec		
						S_1			S_{1a}			S_{1a}	
	Total	West	South	ByC	15%	35%	55%	15%	35%	55%	15%	35%	55%
2020	0	0	0	0		46			46			46	
	34.05	11.65	13	9.4		26			26			26	
	34.05	13.65	13	7.4		26			26			26	
2021	0	0	0	0		-143			-143			-143	
	42.85	14.45	18	10.4		-165			-165			-165	
	0	0	0	0	-349	-288	-219	-88	-22	38	-106	-54	1
	35.95	14.45	11	10.5	-359	-303	-238	-99	-38	17	-118	-70	-20
	40.95	19.45	11	10.5	-360	-305	-240	-100	-39	16	-118	-71	-22
	45.95	24.45	11	10.5	-360	-306	-242	-100	-40	14	-119	-72	-23
	50.95	29.45	11	10.5	-361	-307	-244	-101	-41	12	-119	-74	-25
	37.95	14.45	13	10.5	-361	-305	-240	-101	-39	16	-119	-72	-21
	42.95	19.45	13	10.5	-361	-306	-242	-101	-41	14	-120	-73	-23
	47.95	24.45	13	10.5	-362	-307	-244	-102	-42	12	-120	-74	-25
	52.95	29.45	13	10.5	-362	-308	-246	-102	-43	10	-121	-75	-27
	42.95	14.45	18	10.5	-364	-308	-243	-104	-43	13	-122	-75	-25
	47.95	19.45	18	10.5	-365	-309	-245	-105	-44	11	-123	-76	-26
	52.95	24.45	18	10.5	-365	-311	-247	-105	-45	9	-124	-77	-28
	57.95	29.45	18	10.5	-366	-312	-249	-106	-46	7	-124	-78	-30
	47.95	14.45	23	10.5	-368	-311	-246	-108	-46	9	-126	-78	-28
	52.95	19.45	23	10.5	-368	-313	-248	-108	-48	7	-127	-80	-30
	57.95	24.45	23	10.5	-369	-314	-250	-109	-49	5	-127	-81	-32
	62.95	29.45	23	10.5	-369	-315	-252	-109	-50	3	-128	-82	-34