Testing the sardine assessment for use at the end of 2021

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The sardine assessment is updated to fit to data available up to November 2021. The model is tested using data available to date together with some alternative guesses for data which may result from the November 2021 hydro-acoustic survey.

Keywords: assessment, parasite prevalence data, sardine, survey

Background

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). However, due to the FRAP process, final TAC and TAB recommendations are required by the end of 2021 (K. Prochazka pers. comm). The process followed over the past three years whereby an updated assessment has been carried out after all the previous year's data have been finalised followed by short-term projections (e.g. de Moor 2020a,b, de Moor 2021a,b,c) can therefore not be followed this year. Instead, an assessment and short-term projections will need to be carried out in an extremely short time-frame during December, leaving little room for model testing, the consideration of alternative assumptions and in-depth discussion of projection impacts. This document considers some 'test' assessments, based on data available to date, to hopefully streamline the assessment which will be carried out once November/December 2021 survey data become available.

Methods and Data

The data available thus far are listed in the Appendix. Although some of these data are not finalised and will be updated during 2022, these data are considered sufficiently informative and accurate for the December 2021 assessment. The following alternative data for the November/December 2021 survey have been assumed for model testing purposes:

Model	Survey estimated biomass west of Cape Agulhas		Survey estimated biomass east of Cape Agulhas		Survey length frequency west of Cape Agulhas	Survey length frequency east of Cape Agulhas
	Biomass	CV	Biomass	CV		
S_0	51 678t	0.729	197 263t	0.606	Nov 2020	Nov 2020
S_1	30 000t	0.729	50 000t	0.606	Nov 2020	Nov 2020
S_2	51 678t	0.729	100 000t	0.606	Nov 2020	Nov 2020
S_3	100 000t	0.729	197 263t	0.606	Nov 2020	Nov 2020
S_4	30 000t	0.729	197 263t	0.606	Nov 2020	Nov 2020
S_5	100 000t	0.729	50 000t	0.606	Nov 2020	Nov 2020
S_6	51 678t	0.729	197 236t	0.606	Nov 2016 (small fish)	Nov 2020
S_7	51 678t	0.729	197 236t	0.606	Nov 2015 (medium fish)	Nov 2020
S_8	51 678t	0.729	197 236t	0.606	Nov 2011 (large fish)	Nov 2020
S_9	51 678t	0.729	197 236t	0.606	Nov 2020	Nov 2016 (small fish)
S_{10}	51 678t	0.729	197 236t	0.606	Nov 2020	Nov 2013 (medium fish)
S_{11}	51 678t	0.729	197 236t	0.606	Nov 2020	Nov 2011 (large fish)

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The methodology is based on models (i) and (iv) of de Moor (2021a), but extended for an additional year to November 2021. The model which includes parasite prevalence-at-length data (from November survey samples from 2010 – 2020 only; it will not be possible to get data from November 2021 by December 2021) is labelled S_{0P}, while the model which excludes parasite prevalence-at-length data is labelled S_0. S_{0P} has one change from model (iv) of de Moor (2021a) in that survey selectivity is taken into account when calculating model predicted proportions of sardine infected[1]:

$$P^S_{j,y,l} = \frac{{S^{survey}_{j,l}}{N^S_{j,l,y,l}}}{\sum_p {S^{survey}_{j,l}}{N^S_{j,p,y,l}}} \qquad y_1 \leq y \leq y_n, 7.5cm \leq l \leq 23cm$$

As a testing measure, some alternatives were run 'forcing' the model to fit certain data. This was done by setting the total CV (including survey and additional variance) to 0.01 for the data point of interest.

Finally, given the delay in the start to the November/December 2021 hydro-acoustic survey and the possible need to finalise the assessment, short-term projections and quota recommendations before the survey is completed, S_{12} excluded survey observations (biomass and length frequency) for east of Cape Agulhas in November 2021.

Results and Discussion

Figures 1 and 2 show the S_0 and S_{0P} model fits to the November and recruit survey estimates of abundance, respectively, and Table 1 gives the individual contributions to the objective function. Figures 3 to 10 show further standard assessment model output, including fits to other data. While S_0 does not fit the parasite prevalence-at-length data (Figure 9), the estimated west component growth curve for S_{0P} still results in average recruitment being modelled to occur much earlier in the year than expected (Figure 10; as previously noted by de Moor 2021a). Given the lack of time to investigate this further now, it is recommended that the 2022 TAC and TAB recommendations in December 2021 are based on models which are <u>not</u> conditioned on parasite prevalence-at-length data. (This matter is expected to be re-visited during 2022.)

With the assumed November 2021 data for S_0, the model predicts a lower west and south final biomass than that predicted with data available up to November 2020 (de Moor 2021a). However, the model substantially over-predicts the survey estimates of biomass east of Cape Agulhas in the past four years.

As a means to investigate this 'poor fit' to the survey biomass east of Cape Agulhas in recent years, the model was forced to fit the November 2020 survey estimate of biomass east of Cape Agulhas (Table 1, Figures 11 and 12). This resulted in a substantial improvement in the fit to the survey estimates of November biomass, at the cost of a poorer fit to survey estimates of recruitment, particularly on the west coast (Table 1, Figure 12). It thus appears that the S_0 model might handle the apparent conflict between the 'relatively high' survey estimates of recruitment west of Cape Infanta in some recent years, but remaining low November biomass west of Cape Agulhas, together with the assumption of time-invariant natural mortality, by allowing west component sardine to move to the south component, particularly as the CVs on the survey estimates of south biomasses are typically larger than those on the west.

[1] This has a negligible impact on these model results, but results in a model that is self-consistent once commercial selectivity is applied to calculating proportions infected to compare with prevalence-at-length estimated from commercial data.

'Forcing' the model to fit the June 2021 survey estimates of recruitment did not result in a substantial change in the model predicted biomass (results not shown herein).

Models S_1 to S_5 indicate how the model predicted biomass in November 2021 might change once the upcoming survey estimates of biomass are known (Table 1). The model predicted biomass in November 2021 also increases or decreases, but not to the same extent as the increase/decrease in the observation (Table 2). This is to be expected as the model predicted biomass takes into account a range of information from multiple data sources and not only the final year's November survey biomass estimate.

Models S_6 to S_{11} indicate how the recent model predicted biomass and recruitments might change once the upcoming survey length frequencies are included. These model values don't change substantially between the alternative models, although there are some differences in the likelihoods (Table 1, Figures 13 – 16).

Excluding the November 2021 survey observations east of Cape Agulhas (S_{12}) resulted in little change in the model fit to data west of Cape Agulhas, but an even higher model predicted biomass on the south coast (Table 1, Figures 17 and 18).

Conclusion

The testing of the sardine assessment using data available to date together with a few 'guesses' for observations from the upcoming November/December 2021 hydro-acoustic survey results in the following conclusions and recommendations:

- The upcoming assessment to be used for short-term projections and recommendations for 2022 sardine TAC and TABs should exclude parasite prevalence-at-length data from likelihood.
- One should be cautious in drawing conclusions about the biomass of sardine on the south coast. It is possible that the sardine biomass is (substantially) lower than that currently predicted by this model.
- For this reason, short-term management advice will be based on two primary models (in addition to some key sensitivity tests): one which fits to all data (excluding the parasite prevalence-at-length data) and one which forces the model to fit the November 2020 survey estimate of biomass on the south coast.
- Increases and decreases in November 2021 survey observations do not result in the same degree of increases/decreases in model predicted biomass – the effect is dampened due to the model fitting to a range of time-series of data and not only the final year's November survey biomass estimate.
- Should the assessment be tuned to November 2021 survey data west of Cape Agulhas only, one should be even more cautious about the model predicted south component biomass.

Acknowledgements

Janet Coetzee and Dagmar Merkle are thanked for providing the updated data listed in the Appendix.

References

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

de Moor CL. 2020b. Sardine projections based on constant catch scenarios. DEFF: Branch Fisheries Document FISHERIES/2020/APR/SWG-PEL/33.

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

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

de Moor CL. 2021c. Further sardine projections based on constant catch scenarios. DFFE: Branch Fisheries Document FISHERIES/2021/MAY/SWG-PEL/33.

de Moor CL, Butterworth DS, Coetzee JC. 2008. Revised estimates of abundance of South African sardine and anchovy from acoustic surveys adjusting for echosounder saturation in earlier surveys and attenuation effects for sardine. *African Journal of Marine Science* 30(2):219-232.

de Moor CL, Merkle D, Coetzee J, van der Lingen CD. 2021. The data used in the 2021 sardine assessment. DFFE: Branch Fisheries Document FISHERIES/2021/APR/SWG-PEL/22.

Table 1. The contributions to the objective function from likelihood (equations A32 – A36 of de Moor 2020a) and prior components for the models considered in this document. S_0^* denotes the version of S_0 which is 'forced' to fit the November 2020 estimate of survey biomass east of Cape Agulhas.

Model	Obj fn	$-lnL$	$-lnL^{Nov}$	$-lnL^{rec}$	$-lnL^{com\ propl}$	$-lnL^{sur\ propl}$	$-lnL^{prev}$	$ln(k_{ac}^S)$	$move_{y,1}$	η_y^t	$\bar{l}_{1,y}$
S_{0P}	1205.47	1127.99	64.14	42.77	-457.73	-401.06	1879.87	-1.29	-32.98	-12.54	124.05
S_0	-715.28	-783.41	57.53	39.37	-463.71	-416.60	3488.37	-1.40	-33.89	-20.94	124.28
S_0^* [2]	-722.61	-791.01	48.19	41.08	-463.54	-416.74	3506.72	-1.39	-33.87	-20.70	124.25
S_1	-712.49	-780.64	59.72	39.25	-463.15	-416.47	3564.97	-1.40	-33.88	-20.91	124.27
S_2	-714.16	-782.28	58.32	39.32	-463.47	-416.45	3623.00	-1.40	-33.89	-20.94	124.28
S_3	-714.94	-783.03	57.58	39.54	-463.73	-416.42	3534.11	-1.40	-33.90	-20.97	124.28
S_4	-715.43	-783.58	57.56	39.28	-463.69	-416.73	3334.95	-1.40	-33.87	-20.93	124.28
S_5	-712.12	-780.21	59.47	39.51	-463.14	-416.05	3721.76	-1.40	-33.90	-20.96	124.28
S_6	-719.52	-787.50	58.25	40.33	-465.61	-420.46	3527.16	-1.41	-33.83	-21.19	124.30
S_7	-717.08	-785.49	58.72	38.86	-462.66	-420.40	3572.49	-1.36	-33.85	-20.78	124.31
S_8	-717.41	-785.39	58.17	38.94	-461.53	-420.98	3245.41	-1.37	-33.89	-20.90	124.05
S_9	-712.65	-780.84	57.33	39.43	-463.52	-414.08	3508.96	-1.40	-33.89	-20.87	124.27
S_{10}	-714.65	-782.83	57.73	39.85	-465.51	-414.91	7607.80	-1.41	-33.93	-20.85	124.28
S_{11}	-716.33	-784.39	57.66	38.86	-463.55	-417.35	3718.49	-1.40	-33.86	-21.01	124.23
S_{12}	-712.00	-780.08	56.97	38.99	-464.22	-411.81	3462.16	-1.40	-33.87	-21.02	124.27

[2] This run had a non-positive definite Hessian.

Table 2. The alternative November 2021 survey 'observations' for models S_0 to S_5, together with the corresponding model predicted biomass and bias-corrected biomass (the latter being that which is fit to the survey estimates).

	S_0	S_1	S_2	S_3	S_4	S_5
$\hat{B}^S_{west,2021}$	51 678t	30 000t	51 678t	100 000t	30 000t	100 000t
$\hat{B}^S_{south,2021}$	197 263t	50 000t	100 000t	197 263t	197 263t	50 000t
$\sigma^S_{west,2021,Nov}$	0.729	0.729	0.729	0.729	0.729	0.729
$\sigma^S_{south,2021,Nov}$	0.606	0.606	0.606	0.606	0.606	0.606
$B^S_{west,2021}/k^S_{west,N}$	52 000t	37 000t	54 000t	79 000t	34 000t	86 000t
$B^S_{south,2021}/k^S_{south,N}$	528 000t	423 000t	469 000t	516 000t	537 000t	392 000t
$B^S_{west,2021}$	39 000t	28 000t	40 000t	60 000t	26 000t	65 000t
$B^S_{south,2021}$	397 000t	318 000t	353 000t	389 000t	404 000t	295 000t

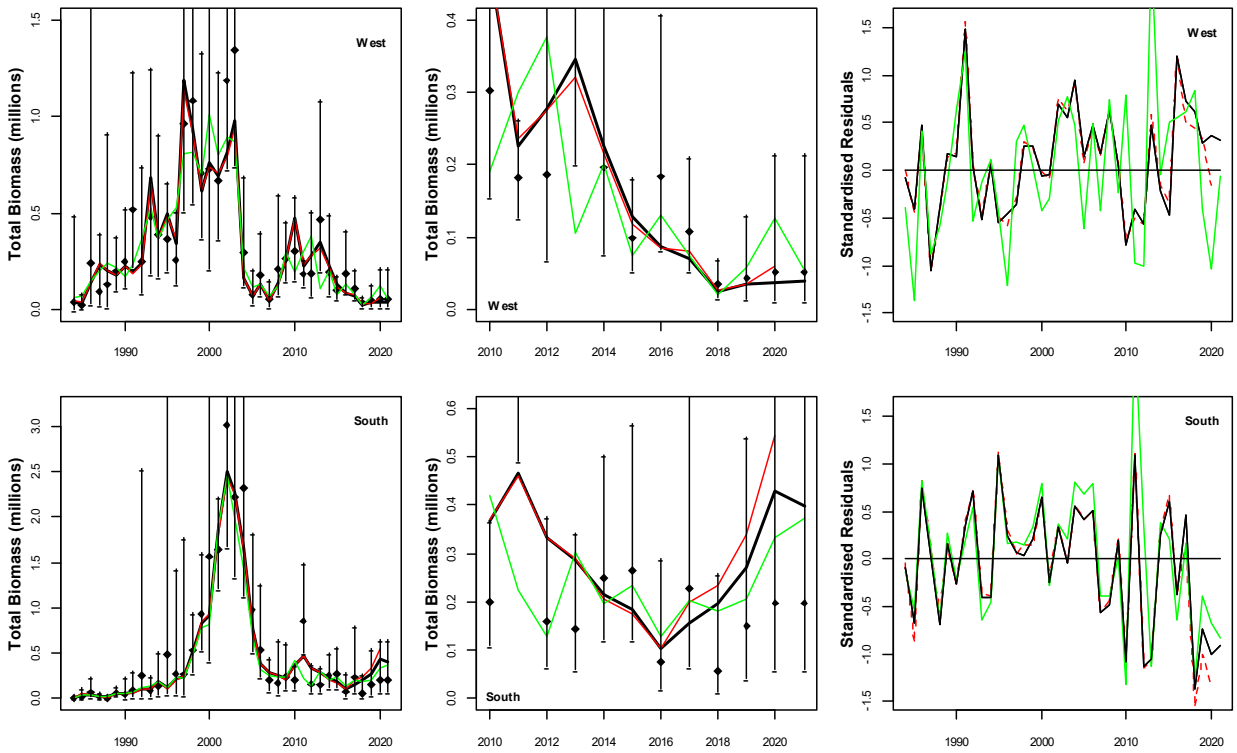

Figure 1. Acoustic survey estimated and model predicted November sardine total biomass from 1984 to 2021 for S_0 (black; model option i) without conditioning on parasite prevalence data) compared S_{0P} (green; model option iv) with conditioning to parasite prevalence data). The observed indices are shown with 95% confidence intervals. The centre plot shows only the most recent years of the left hand plot. The standardised residuals (i.e. the residual divided by the corresponding standard deviation, including additional variance where appropriate) from the fits are given in the right hand plots. The red lines indicate the November biomass predicted by model i) of de Moor (2021a) and associated residuals.

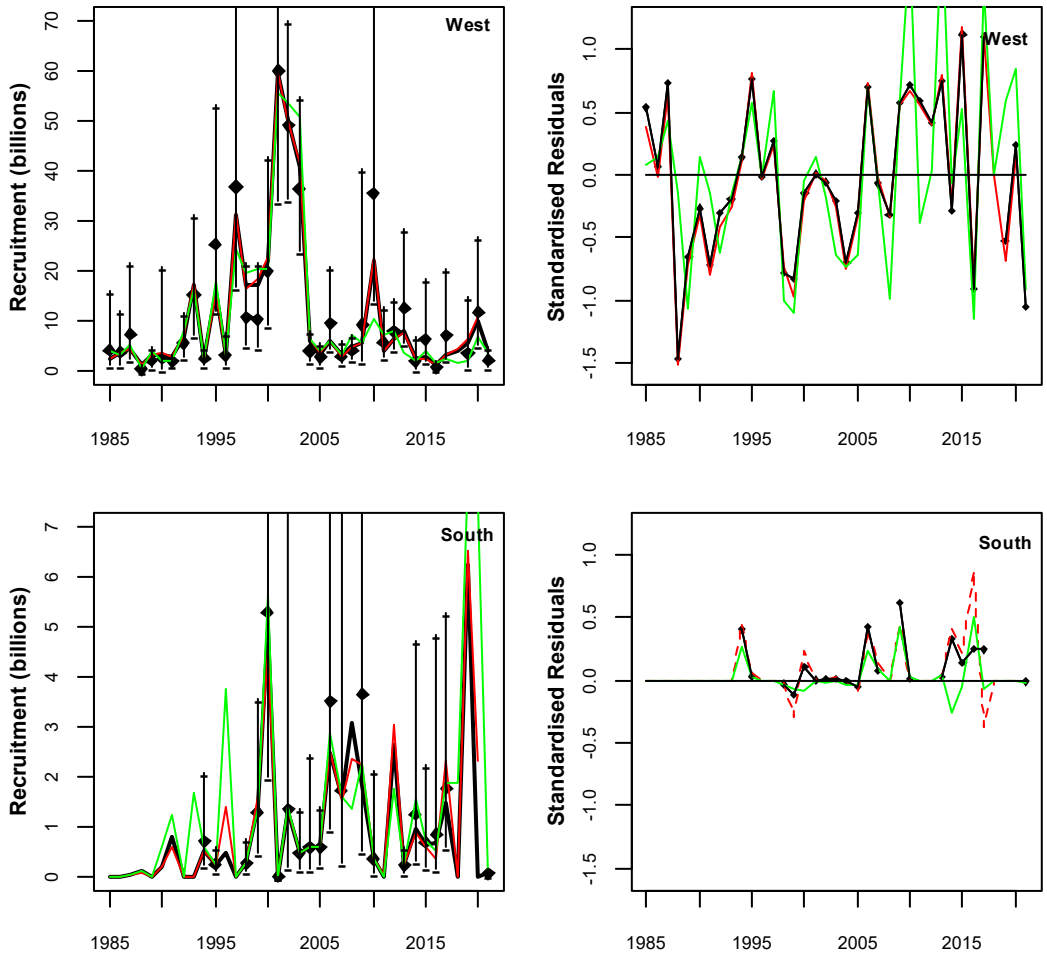

Figure 2. Acoustic survey estimated and model predicted sardine recruitment numbers from May/June 1985 to 2021 for S_0 (black) compared to S_{0P} (green). There was no survey observation in 2018; the model predicted value corresponds to the recruitment predicted at 8th June 2018 which is the average start date of the survey from 2016, 2017 and 2019 surveys. The survey indices are shown with 95% confidence intervals. The standardised residuals from the fit are given in the right hand plots. The red lines indicate the May recruitment predicted by model i) of de Moor (2021a) and associated residuals.

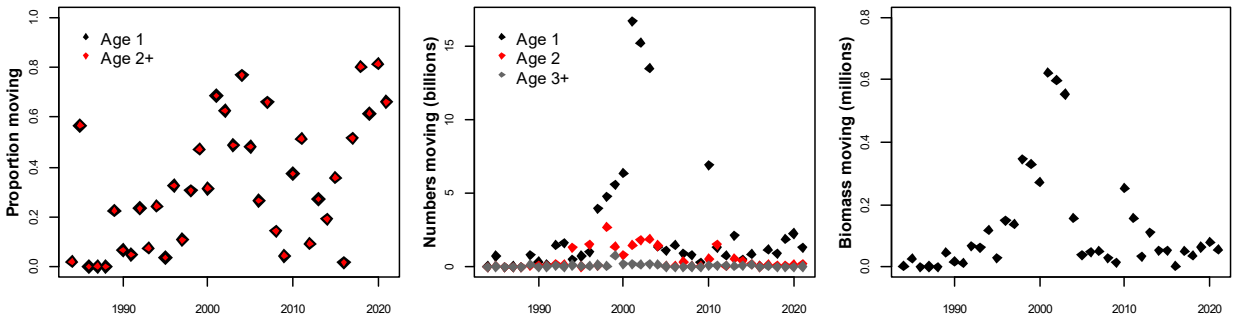

Figure 3. The model estimated annual proportion of west component fish (by proportion, numbers and biomass) that move to the south component for S_0.

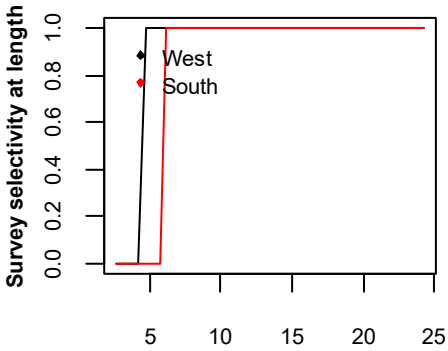

Figure 4. The model estimated November survey selectivity-at-length for S_0.

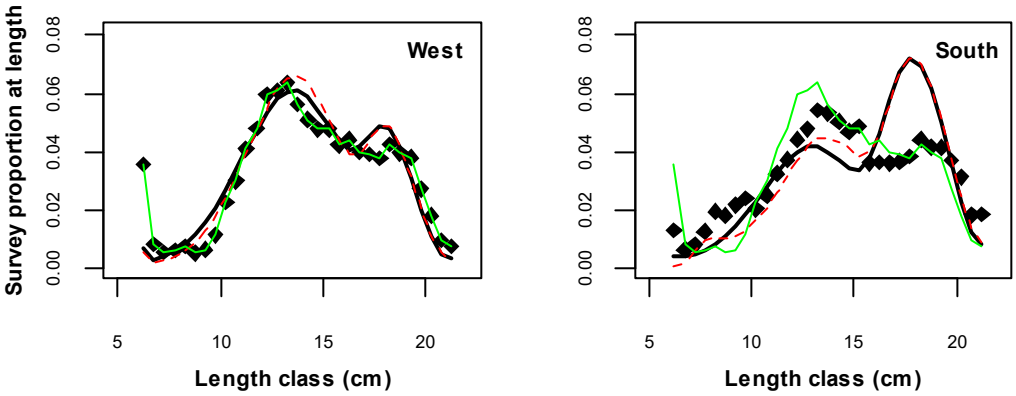

Figure 5. Average (over all years) model predicted and observed proportion-at-length in the November survey for S_0 (black) and S_{0P} (green), with the red lines indicating that predicted by model i) of de Moor (2021a).

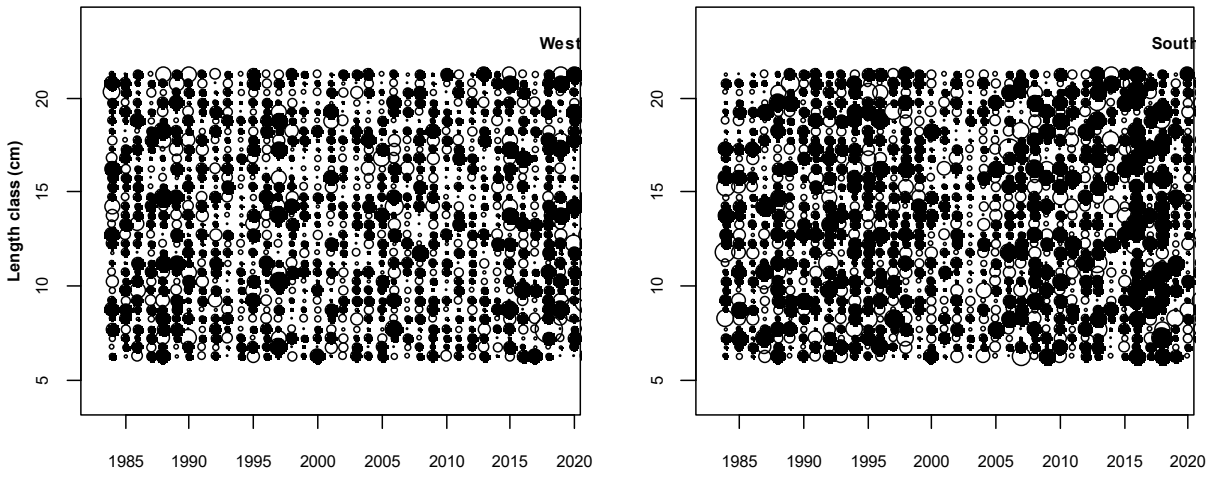

Figure 6. Residuals from the fit of the model predicted proportions-at-length in the November survey to the hydroacoustic survey estimated proportions for S_0.

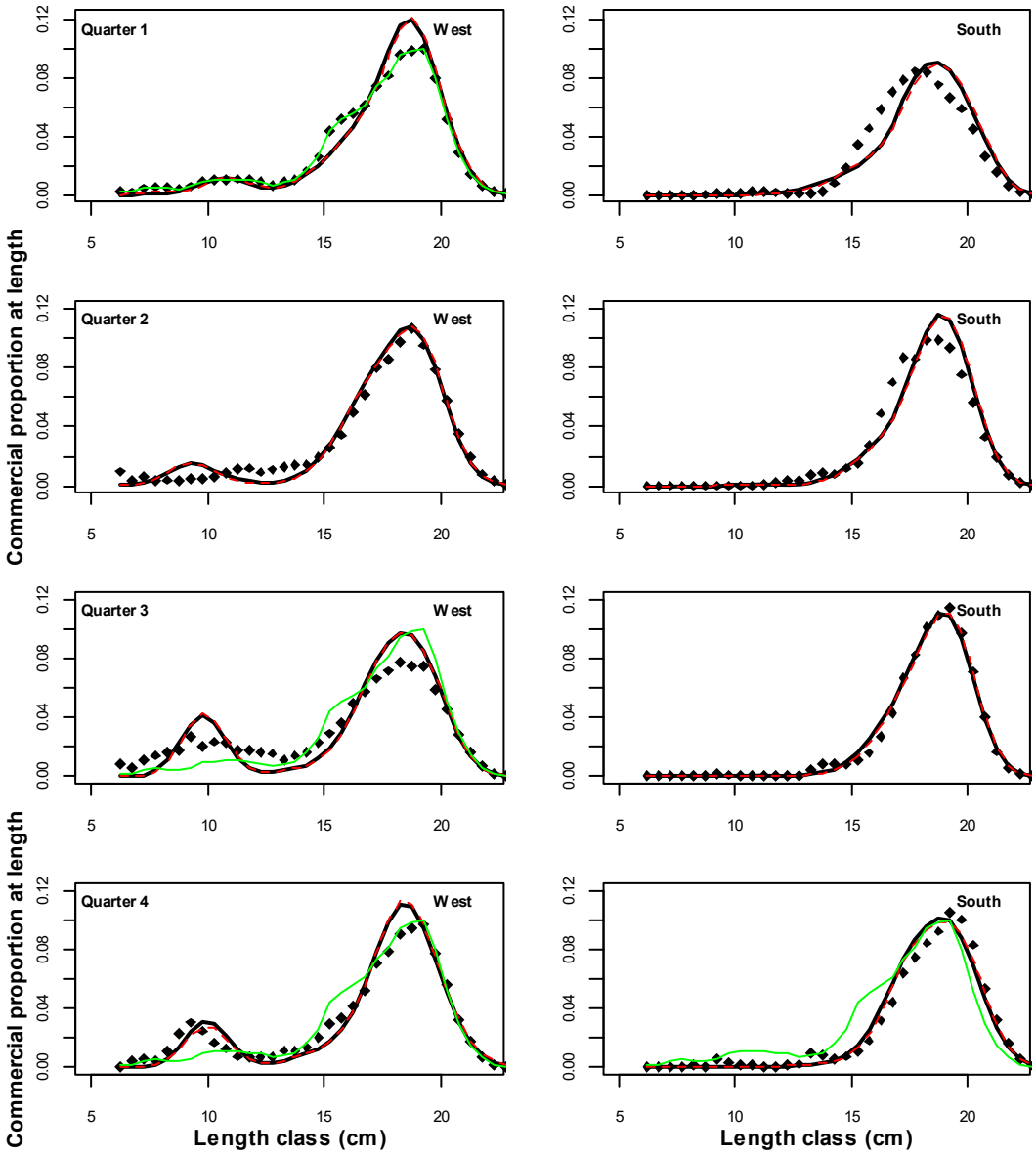

Figure 7. Average (over all years) quarterly model predicted and observed proportion-at-length in the commercial catch for S_0 (black) and S_{0P} (green), with the red lines indicating that predicted by model i) of de Moor (2021a).

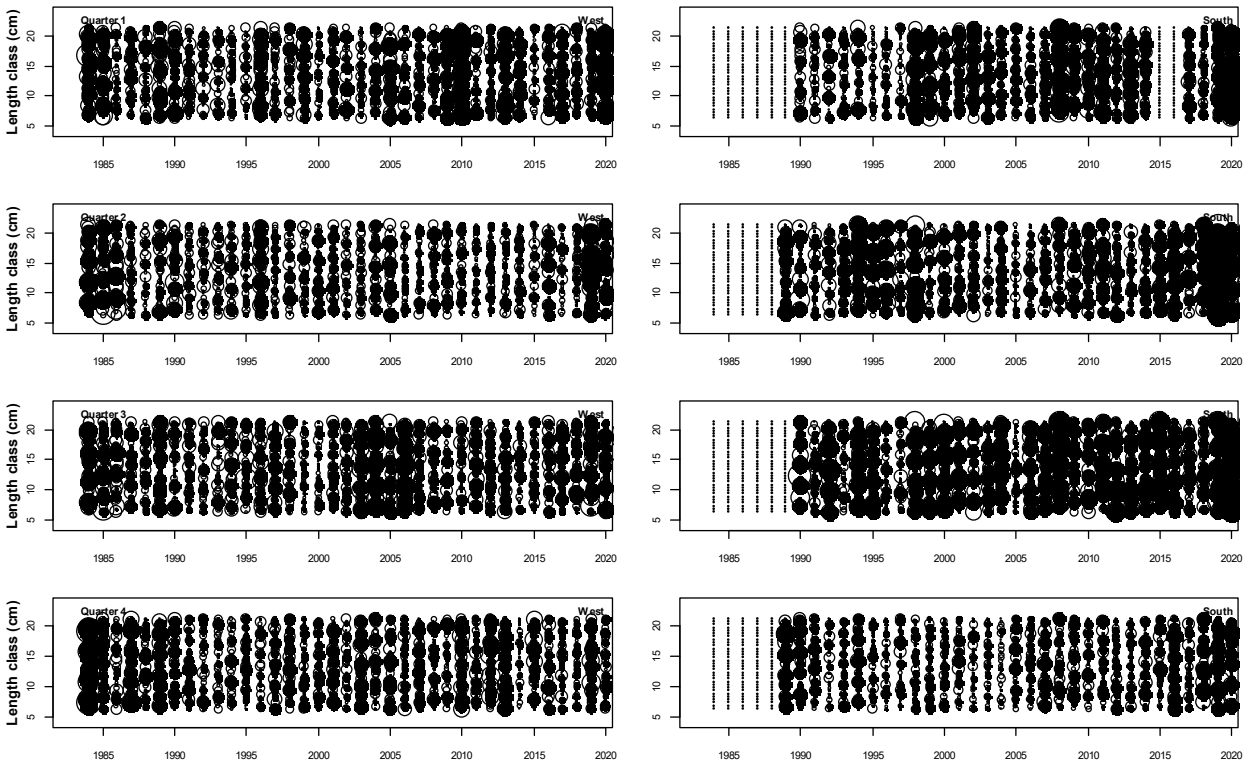

Figure 8. Residuals from the fit of the model predicted proportions-at-length in the quarterly commercial catch to the observed proportions for S_0.

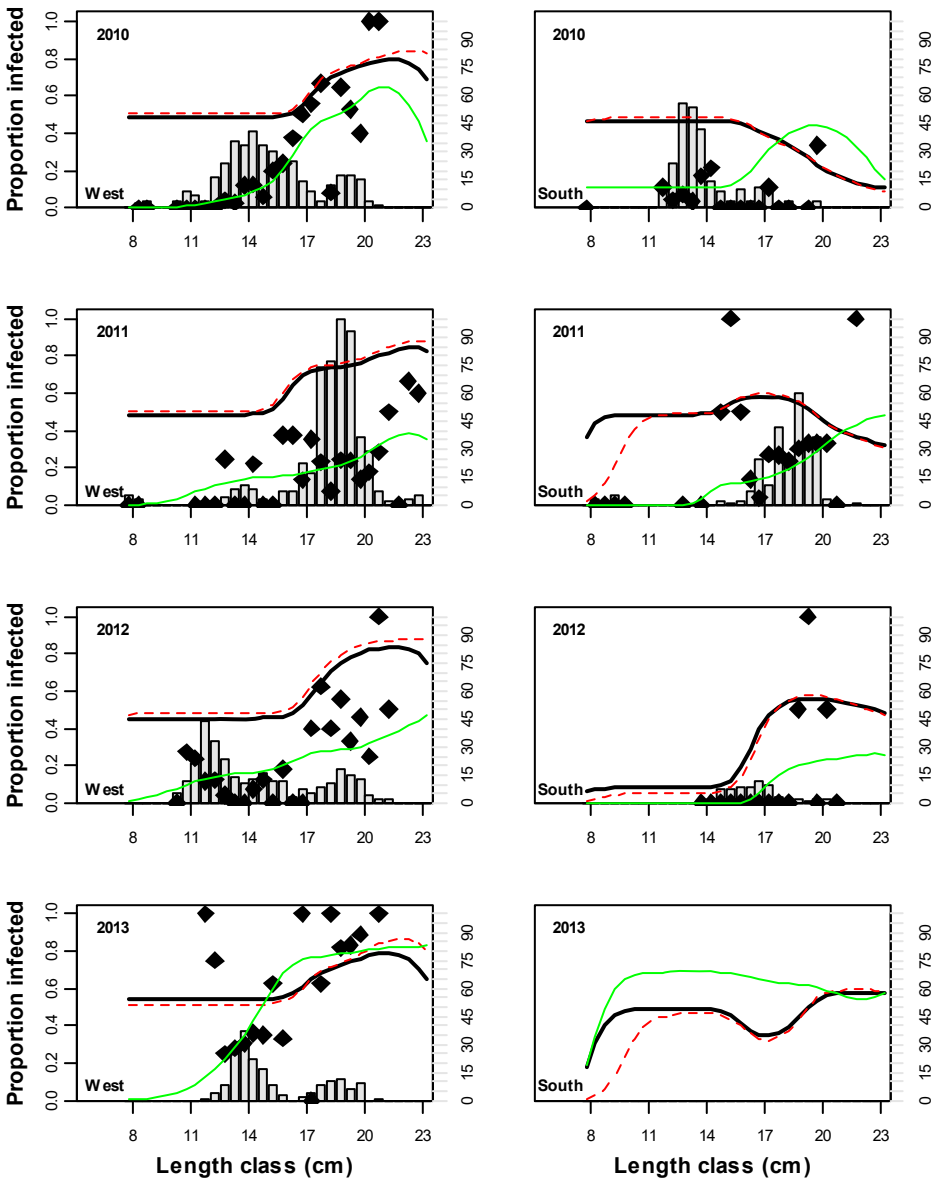

Figure 9. The model estimated proportions-at-length of west and south stock sardine infected with the parasite (i.e. parasite prevalence-by-length) between 2010 and 2020, together with the observed proportions-at-length. Results are shown for S_0 (black; not conditioned on prevalence-at-length data) compared to S_{0P} (green; conditioned on prevalence-at-length data), with the red lines indicating the proportions predicted by model i) of de Moor (2021a). The sample size for each length class is given by the grey bars, plotted against the right vertical axis.

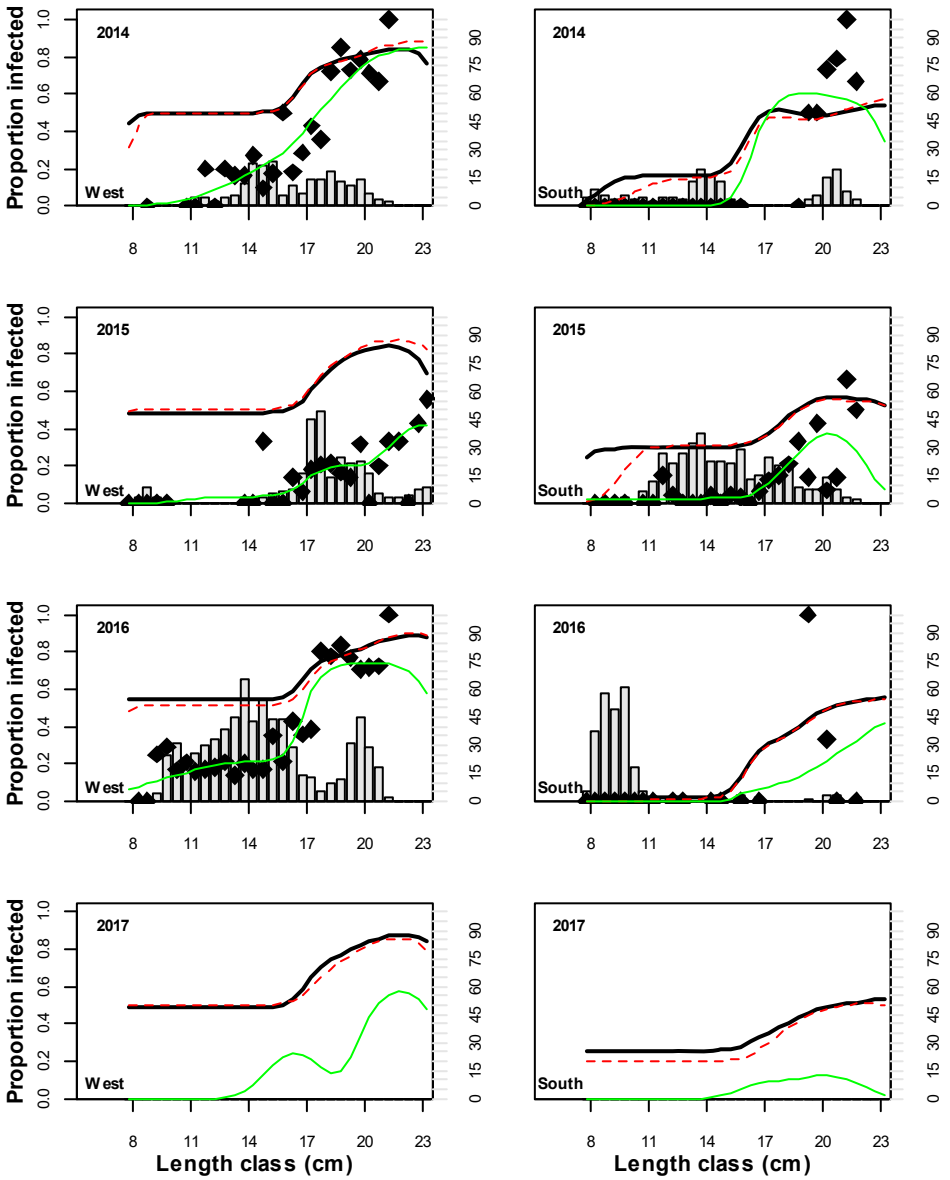

Figure 9 (continued)**.**

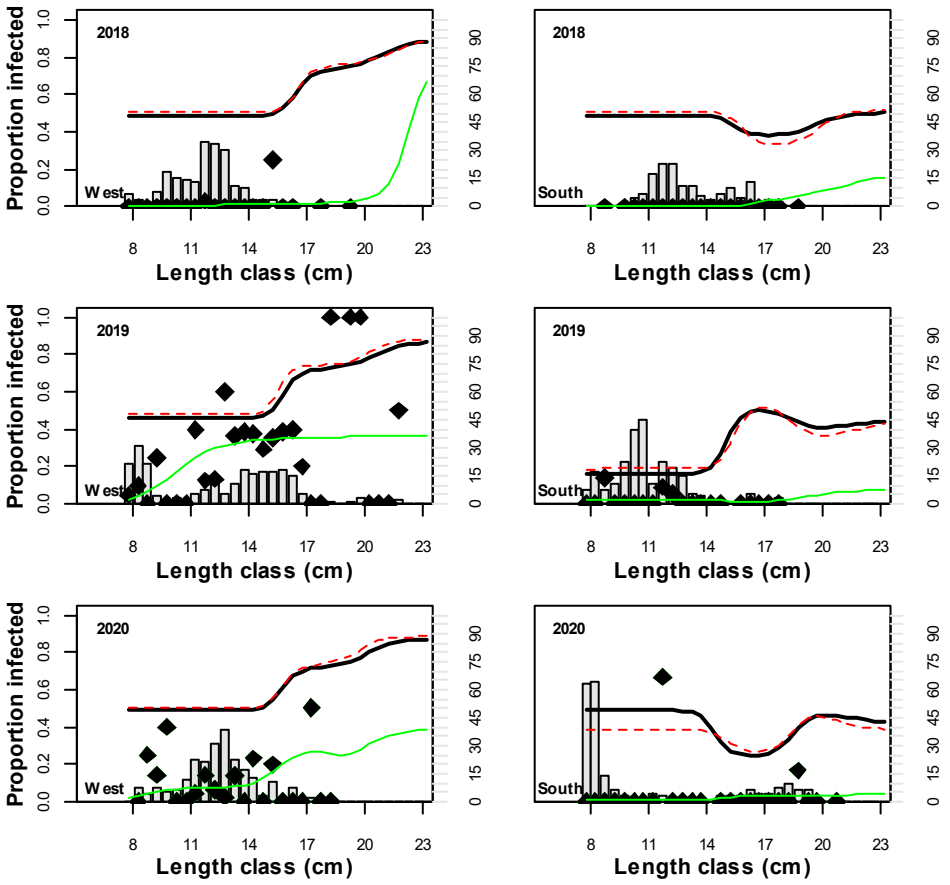

Figure 9 (continued)**.**

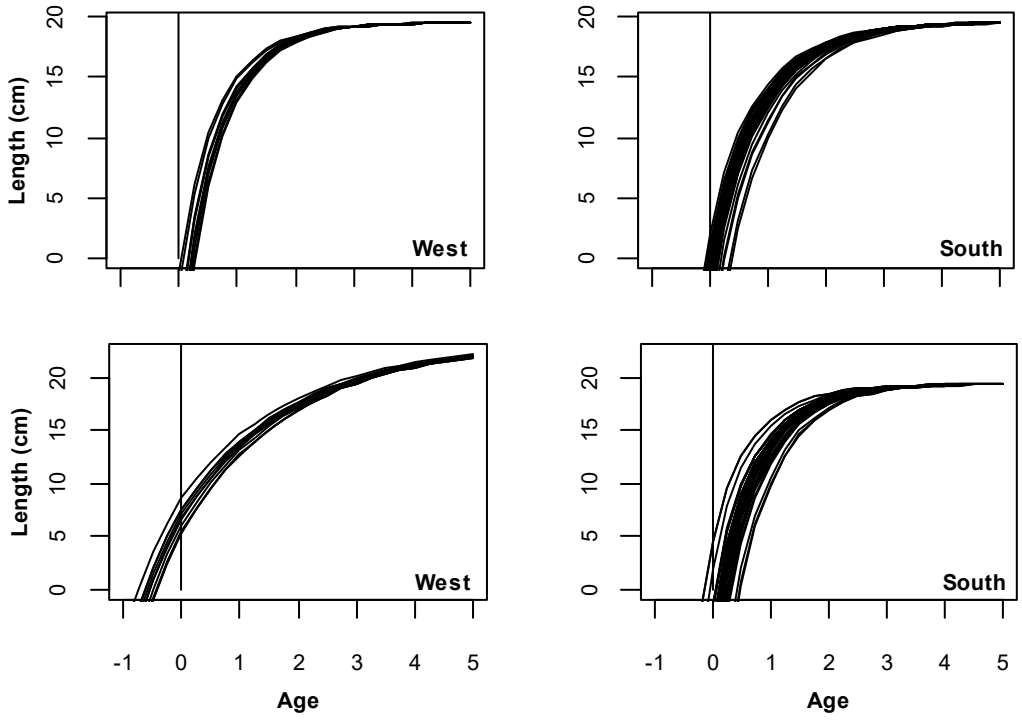

Figure 10. The von Bertalanffy growth curves (by cohort) estimated for S_0 (above) and S_{0P} (below) by allowing for auto-correlated residuals for the variation about the age at which length is zero.

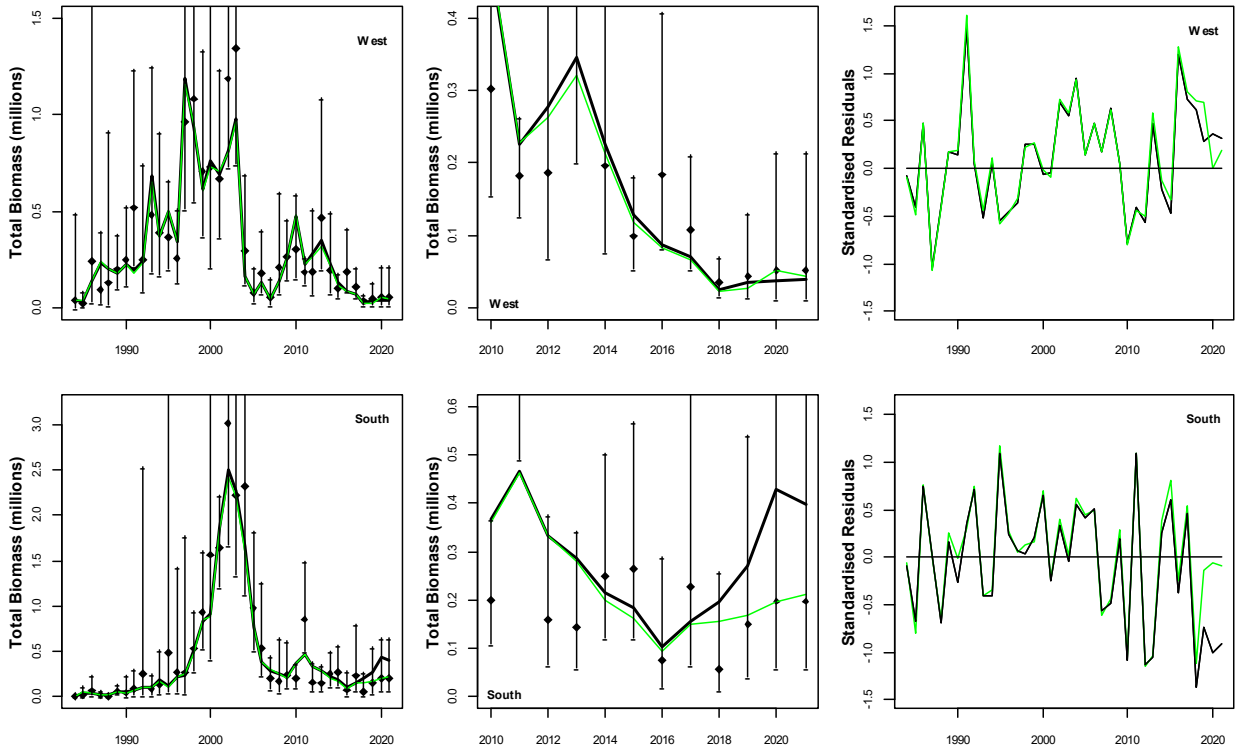

Figure 11. Acoustic survey estimated and model predicted November sardine total biomass from 1984 to 2021 for S_0 (black) compared a model which is 'forced' to fit the November 2020 south estimate (green). The observed indices are shown with 95% confidence intervals. The centre plot shows only the most recent years of the left hand plot. The standardised residuals from the fits are given in the right hand plots.

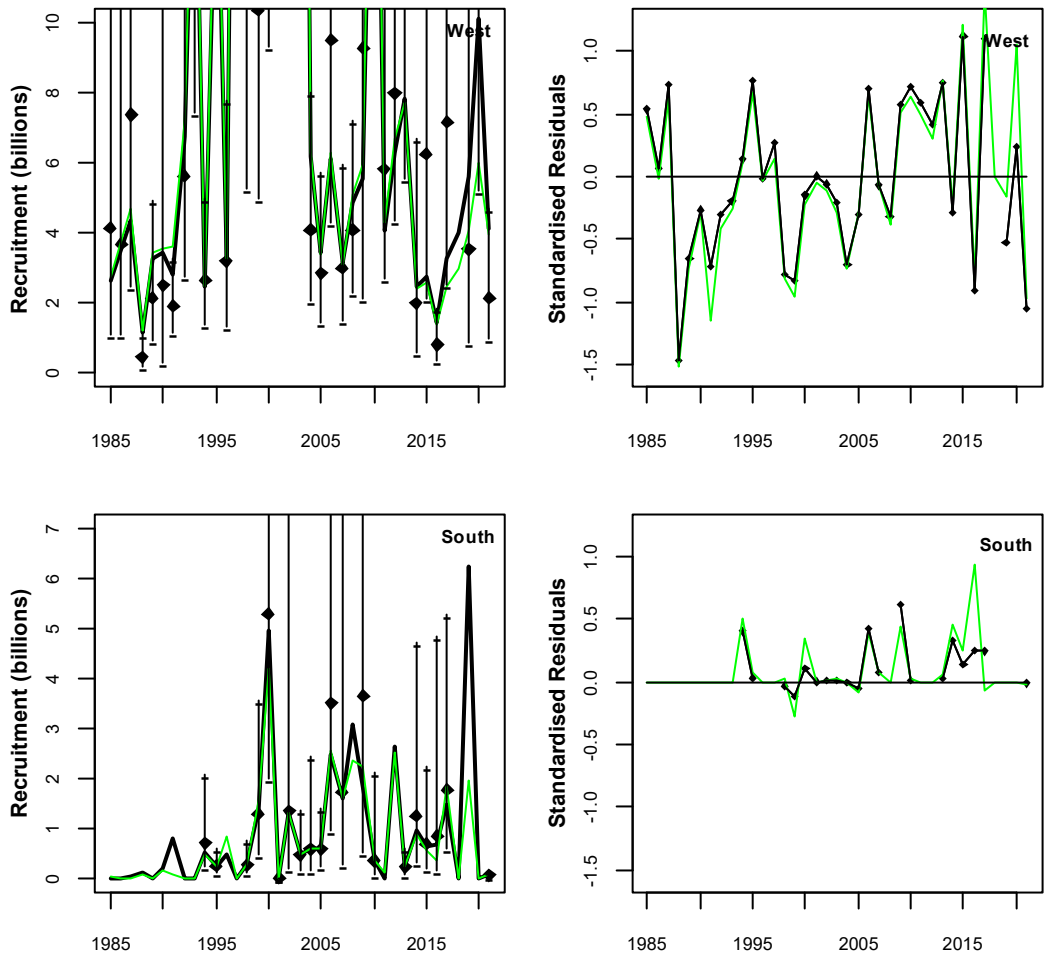

Figure 12. Acoustic survey estimated and model predicted sardine recruitment numbers from May/June 1985 to 2021 for S_0 (black) compared a model which is 'forced' to fit the November 2020 south estimate (green). The survey indices are shown with 95% confidence intervals. The standardised residuals from the fit are given in the right hand plots.

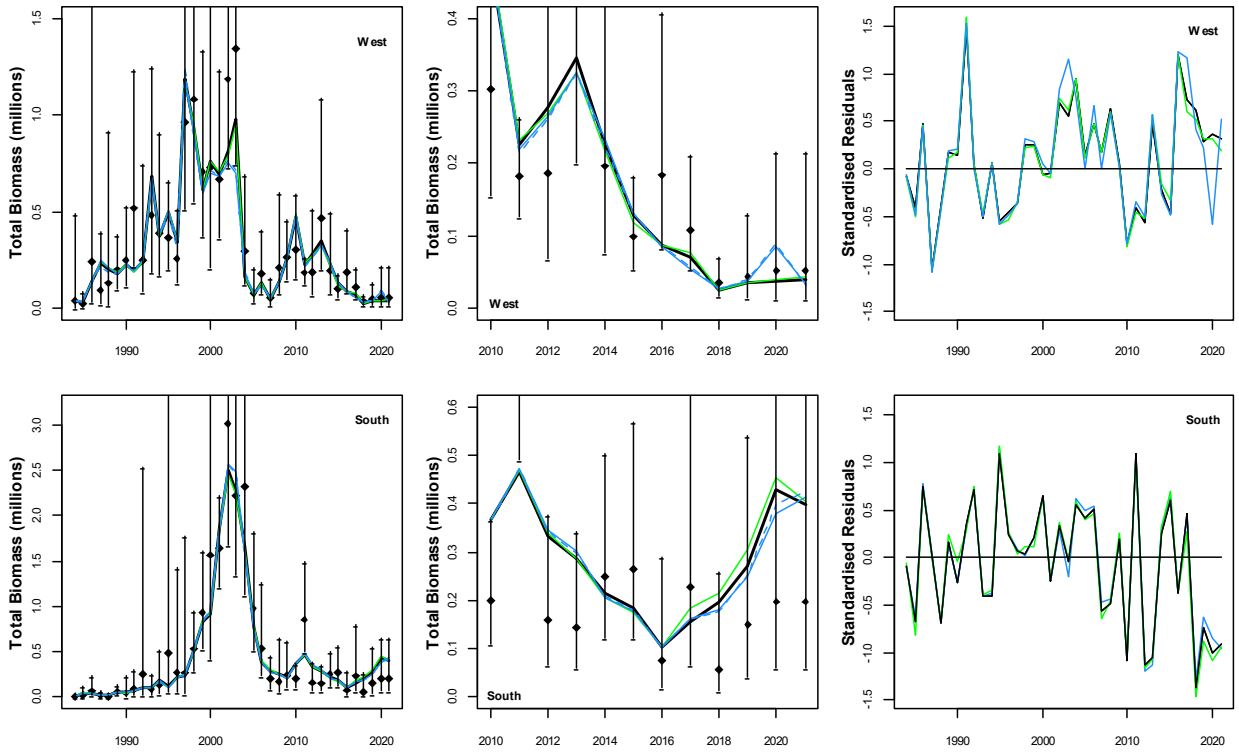

Figure 13. Acoustic survey estimated and model predicted November sardine total biomass from 1984 to 2021 for S_0 (black) compared to models S_6 (green), S_7 (blue) and S_8 (blue dashed) with alternative length frequencies for the west component in November 2021. The observed indices are shown with 95% confidence intervals. The centre plot shows only the most recent years of the left hand plot. The standardised residuals from the fits are given in the right hand plots.

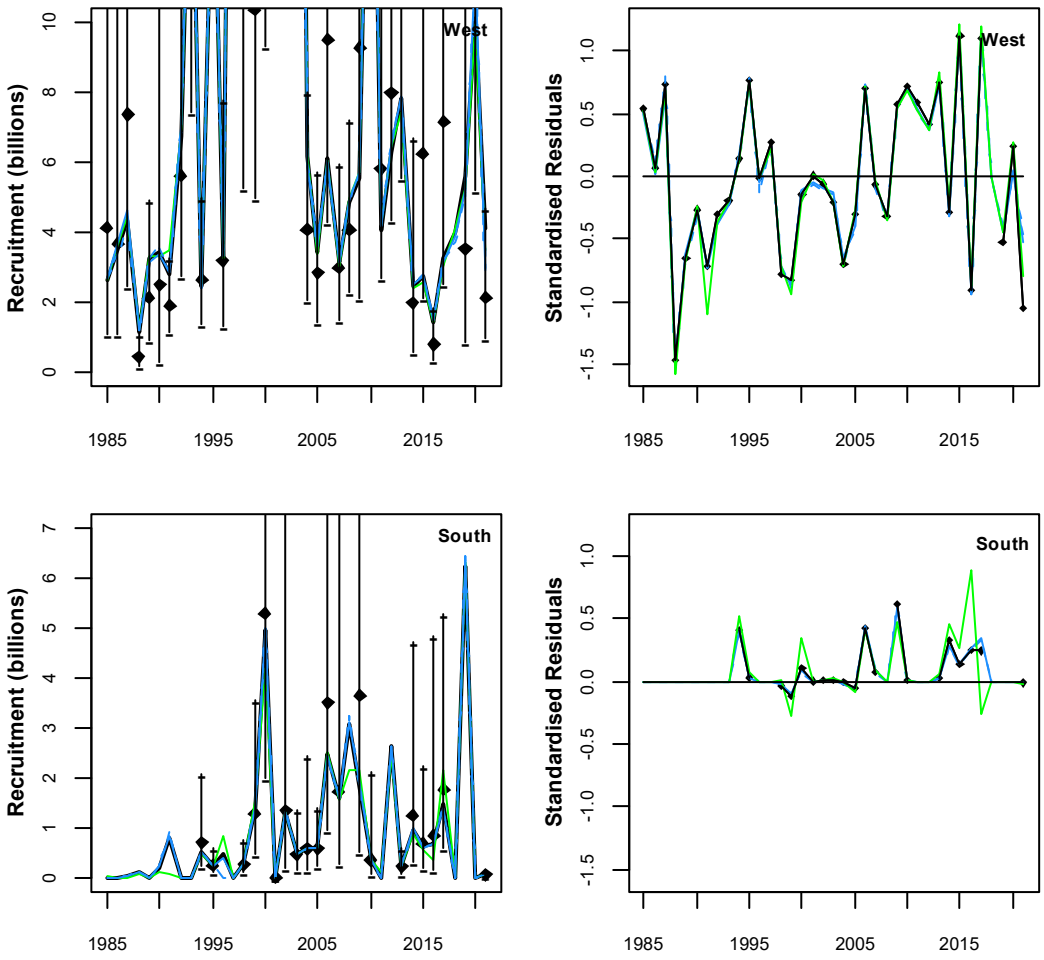

Figure 14. Acoustic survey estimated and model predicted sardine recruitment numbers from May/June 1985 to 2021 for S_0 (black) compared to models S_6 (green), S_7 (blue) and S_8 (blue dashed) with alternative length frequencies for the west component in November 2021. The survey indices are shown with 95% confidence intervals. The standardised residuals from the fit are given in the right hand plots.

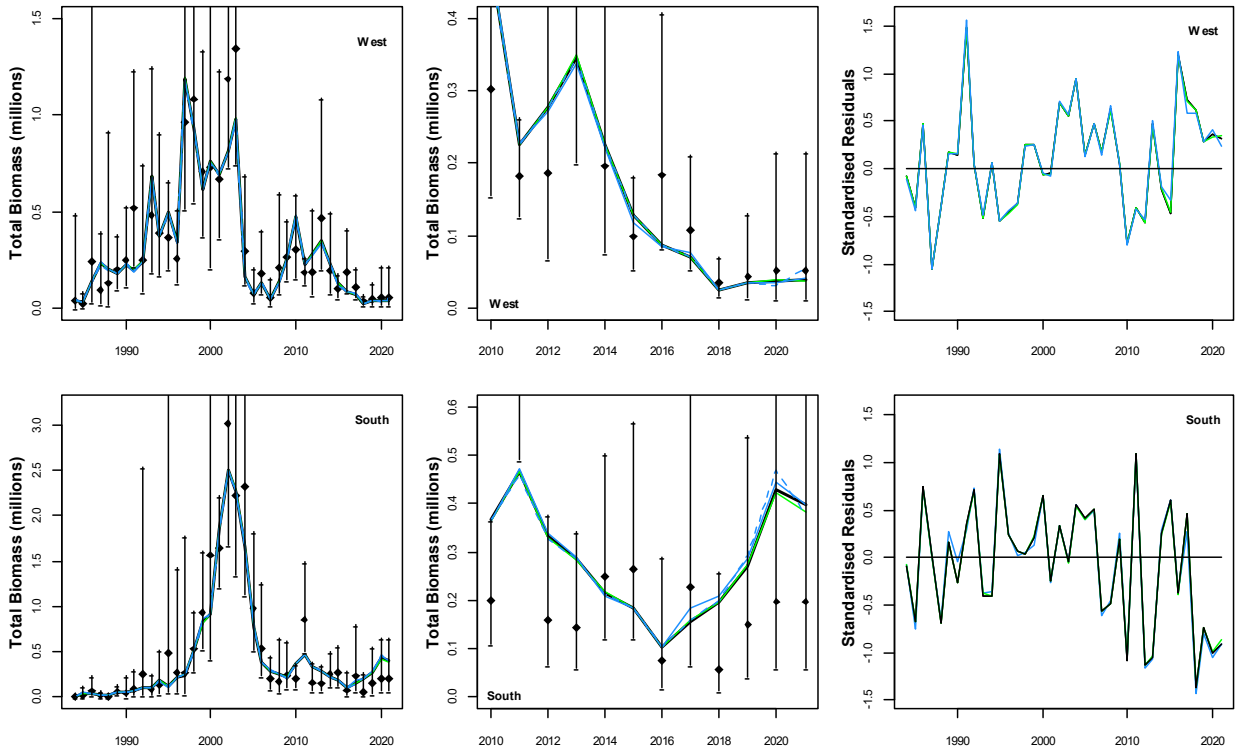

Figure 15. Acoustic survey estimated and model predicted November sardine total biomass from 1984 to 2021 for S_0 (black) compared to models S_9 (green), S_{10} (blue) and S_{11} (blue dashed) with alternative length frequencies for the south component in November 2021. The observed indices are shown with 95% confidence intervals. The centre plot shows only the most recent years of the left hand plot. The standardised residuals from the fits are given in the right hand plots.

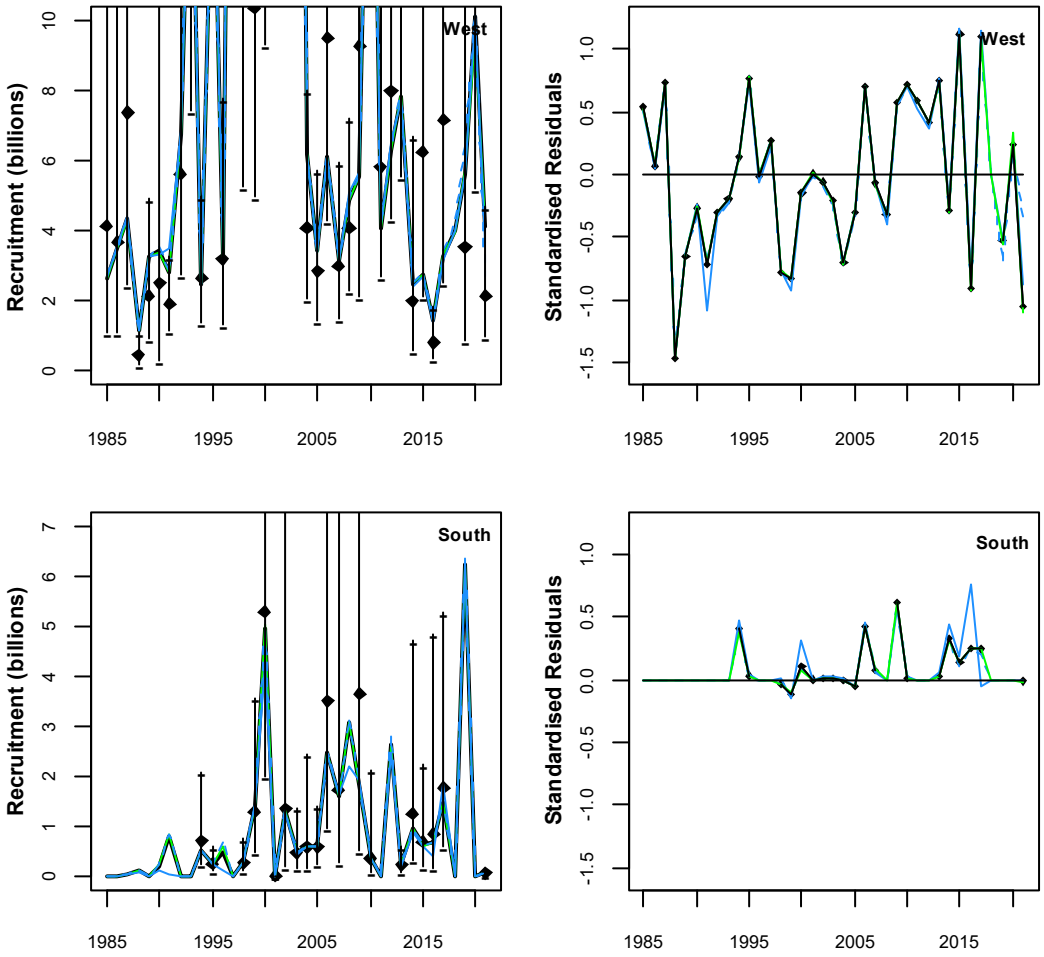

Figure 16. Acoustic survey estimated and model predicted sardine recruitment numbers from May/June 1985 to 2021 for S_0 (black) compared to models S_9 (green), S_{10} (blue) and S_{11} (blue dashed) with alternative length frequencies for the west component in November 2021. The survey indices are shown with 95% confidence intervals. The standardised residuals from the fit are given in the right hand plots.

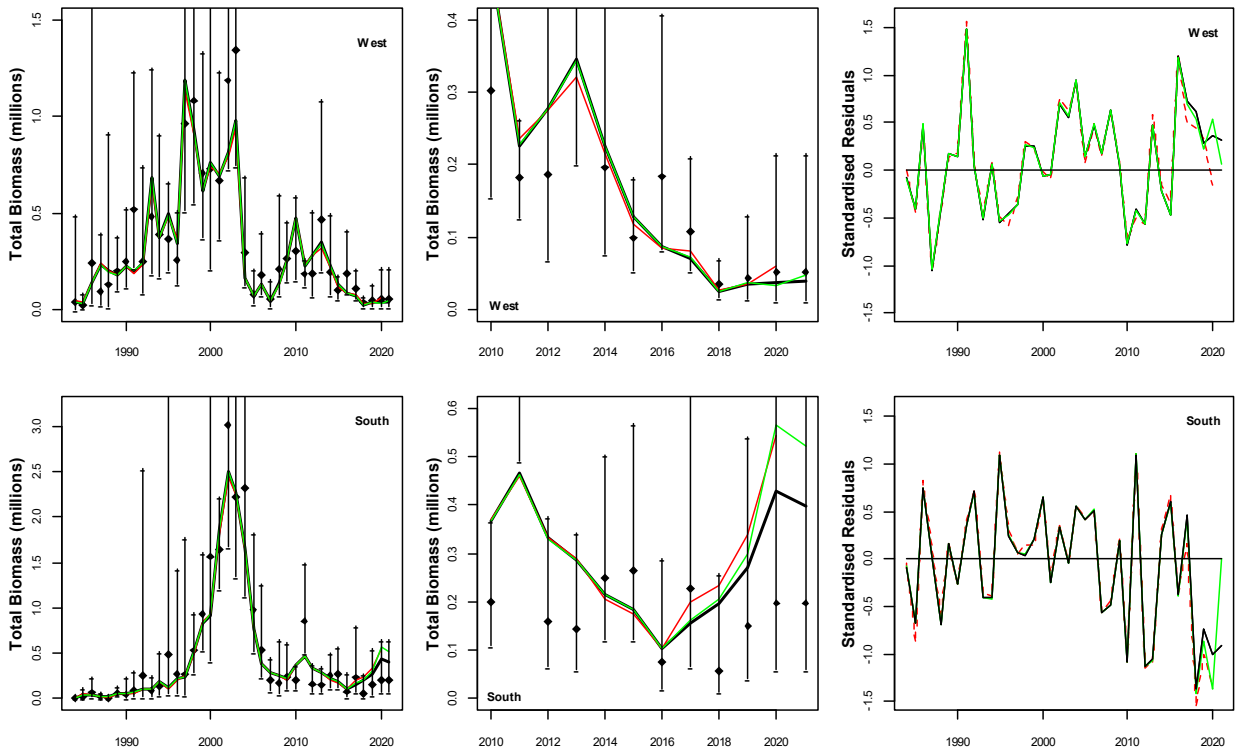

Figure 17. Acoustic survey estimated and model predicted November sardine total biomass from 1984 to 2021 for S_0 (black) compared to S_{12} which does not fit to November 2021 survey observations east of Cape Agulhas (green). The observed indices are shown with 95% confidence intervals. The centre plot shows only the most recent years of the left hand plot. The standardised residuals from the fits are given in the right hand plots.

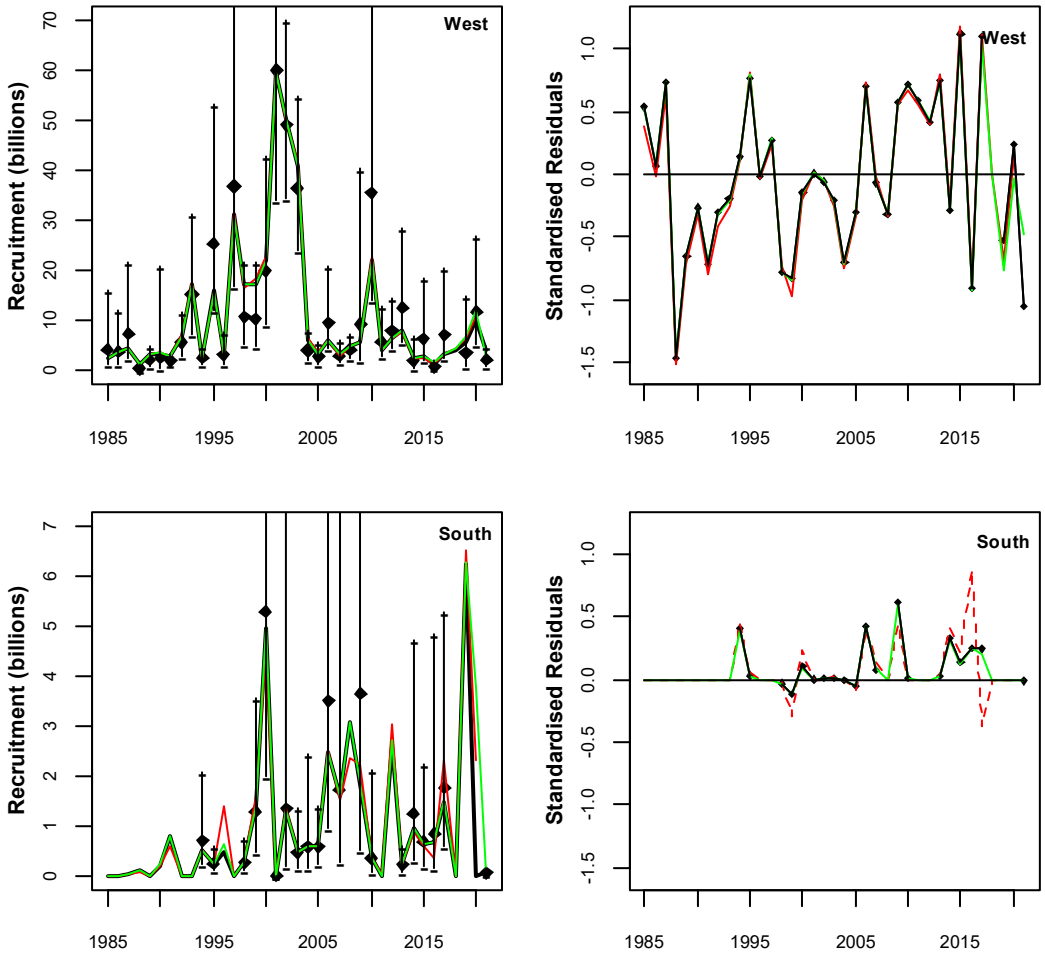

Figure 18. Acoustic survey estimated and model predicted sardine recruitment numbers from May/June 1985 to 2021 for S_0 (black) compared to S_{12} which does not fit to November 2021 survey observations east of Cape Agulhas (green). The survey indices are shown with 95% confidence intervals. The standardised residuals from the fit are given in the right hand plots.

Appendix: New and revised data

The data and assumptions about missing data used in this assessment that differ from that recorded by de Moor *et al*. (2021) are the following:

- November 1984, 1985 and 2010 biomasses and inter-transect CV due to changes in strata boundaries and subsequent re-assignment of transects by strata.
- May 1985 recruit numbers and inter-transect CV due to changes in strata boundaries and subsequent re-assignment of transects by strata.
- As the total CVs incorporating the additional variance due to the adjustment from capped to uncapped data for Novembers 1984 and 1985 and May 1985 cannot be recalculated according to de Moor *et al*. (2008) in the time available, total CVs west and east of Cape Agulhas were approximated with
  $CV\left(B_{j,y}^{i}\right) = \sqrt{CV^{tot}\left(B_{j,y}^{i}\right)^{2} + CV\left(\hat{B}_{y}^{i}\right)^{2} + CV^{tot}\left(B_{j,y}^{i}\right)CV\left(\hat{B}_{y}^{i}\right)}$, where
  $CV^{tot}\left(B_{j,y}^{i}\right) = \sqrt{CV^{samp}\left(B_{j,y}^{i}\right)^{2} + CV^{cal}\left(B_{y}^{i}\right)^{2} + CV^{samp}\left(B_{j,y}^{i}\right)CV^{cal}\left(B_{y}^{i}\right)}$, $CV^{samp}\left(B_{j,y}^{i}\right)$ is the updated inter-transect CV for area j in year y, and $CV\left(\hat{B}_{y}^{i}\right)$ and $CV^{cal}\left(B_{y}^{i}\right)$ are taken from Tables App 1.1 and App 1.2 of de Moor *et al*. (2008). This approximate method likely over-estimates the total CV.
- Revised survey length frequencies in Novembers 1984, 1985, 2010.
- June 2021 recruit numbers with CVs and recruit cut-off length.
- Commercial length frequencies from November 2020 to October 2021
  - Data available for November 2020 to October 2021, excluding July 2021.
  - July 2021 commercial length frequency for >14cm directed catches east of Cape Agulhas is taken to be the average of the June and August 2021 length frequencies east of Cape Agulhas.
  - October 2021 commercial length frequencies west/east of Cape Agulhas are taken to be the average 2011-2020 commercial length frequencies west/east of Cape Agulhas, where west corresponds to directed and >14cm bycatches with round herring while east corresponds to directed catches only. No length frequency is required for ≤14cm bycatch (see below).
- Commercial catch tonnages for November 2020 to October 2021[3]
  - Monthly ≤14cm bycatches up to September 2021 are taken from the tonnages associated with the length frequencies in Sybase.
  - Monthly directed catches and >14cm bycatches west of Cape Agulhas up to September 2021 are taken from the tonnages associated with the length frequencies in Sybase.
  - Monthly directed catches east of Cape Agulhas are taken from the tonnages reported by Johan de Goede (MRM) on 2nd November 2021 based on emailed catch statistics from Right Holders, as some landing sheets are still to be collected and entered into Sybase.

[3] Catch data are routinely entered into the scientific Sybase database from landings sheets that are completed at the offload site. On the West Coast, these sheets are collected regularly from factories by field station staff and entered. Factories also send catch statistics to Johan de Goede (MRM) to aid in daily management of catches/bycatches of individual Right Holders. These data sometimes contain duplicates as a vessel's catch is frequently reported by all Right Holders for whom that vessel offloaded on a particular day. These data therefore also need verification with the Sybase catches once all catch data have been captured in the Sybase database. For these reasons, the Sybase reported catches (up until the end of September) on the West Coast are considered more reliable.

On the South Coast, the Department does not have dedicated field staff at all of the offloading sites and hence relies on Right Holders and inspectors to post/deliver those landings sheets to Foretrust Cape Town for entry into the Sybase database, often in batches. For this reason, final catch statistics from the South Coast are not all entered into Sybase (and verified) until early the following year, once all landings sheets have been received. Given the absence of verified data on the South Coast in the Sybase database, catches reported by Right Holders to Johan de Goede are considered more reliable at this time.

- October 2021 catches and bycatches are taken to be that reported by Johan de Goede (MRM) on 2nd November 2021: 24t of >14cm sardine west of Cape Agulhas; 1112t of >14cm east of Cape Agulhas; 0t of ≤14cm sardine.
- Start date of June 2021 survey and recruit catch from 1 May to the day before the survey estimated from recruit cut-off lengths.

The data still required to conduct a final assessment on data up to November 2021 are:

- November 2021 survey biomass and CVs (west and east of Cape Agulhas)
- November 2021 survey length frequencies (west and east of Cape Agulhas)