

The South African anchovy assessment with annual maturity ogives

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The assessment of South African anchovy has been updated to include time varying annual maturity ogives, in addition to the recent inclusion of an informative prior distribution on the hydro-acoustic survey bias. The model continues to assume a Beverton Holt stock recruitment relationship, time-invariant natural mortality of 1.2year^{-1} and that the Daily Egg Production Method indices of abundance provide absolute estimates of anchovy spawner biomass. This updated assessment estimates the resource abundance to be almost two thirds of the historical (1984-2019) average, with a total biomass of 1.5 million tons, in November 2019.

Introduction

One of the key uncertainties underlying the assessment of South African anchovy – and associated short-term projections used to provide management advice earlier this year – were the assumptions surrounding the anchovy maturity ogive (de Moor 2020a,b). Given data now provided by Geja *et al.* (In Prep), this document provides an updated anchovy assessment using annual maturity ogives.

Methods

The assessment model is detailed in Appendix A of de Moor (2020a), with the following differences:

- i) an informative prior of $\ln(k_{ac}^A) \sim N(-0.158, 0.112^2)$ (de Moor 2020c)
- ii) the negative log-likelihood functions include additional acoustic survey variance, $(\phi_{ac}^A)^2 = 0.197^2$ (de Moor 2020c):

$$-\ln L^{Nov} = \frac{1}{2} \sum_{y=y_1}^{y_n} \left\{ \frac{(\ln \hat{B}_y^A - \ln(k_{NB_y}^A))^2}{(\sigma_{y,N}^A)^2 + (\phi_{ac}^A)^2 + (\lambda_N^A)^2} + \ln \left(2\pi \left((\sigma_{y,N}^A)^2 + (\phi_{ac}^A)^2 + (\lambda_N^A)^2 \right) \right) \right\}$$

$$-\ln L^{rec} = \frac{1}{2} \sum_{y=y_1+1}^{2017,2019} \left\{ \frac{(\ln \hat{N}_{y,r}^A - \ln(k_{rN_{y,r}}^A))^2}{(\sigma_{y,r}^A)^2 + (\phi_{ac}^A)^2 + (\lambda_r^A)^2} + \ln \left(2\pi \left((\sigma_{y,r}^A)^2 + (\phi_{ac}^A)^2 + (\lambda_r^A)^2 \right) \right) \right\}$$

- iii) maturity ogives with annual $L_{50,y}$, but time-invariant steepness, δ , are used (Appendix).

The assumption that the Daily Egg Production Method (DEPM) indices of abundance provide absolute estimates of anchovy spawning biomass – as was historically assumed for anchovy assessments – is maintained (de Moor *et al.* 2020).

Results and Discussion

Model fits to the data, some key estimated relationships and time series of interest are shown in Figures 1 to 13. While annual $L_{50,y}$ s produced a better fit to the maturity data than assuming a time invariant $L_{50,y} = L_{50}$ (model (ii) compared to (i) in the Appendix), Table 1 indicates that there is no statistically significant difference between these alternatives' ability to fit the assessment data (Table 1), despite the linear interpolation used for $L_{50,y}$ for years of missing maturity data.

The anchovy biomass in November 2019 is estimated to be 1.5 million tons (similar to that estimated by A_1 with an informative prior, de Moor (2020c), and lower than that estimated by A_0).

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Acknowledgements

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Table 1. Contributions to the objective function at the joint posterior mode for the alternative models. The prior distribution assumed for the logarithm of the multiplicative bias on the hydro-acoustic survey, k_{ac}^A , is given, together with the estimated multiplicative biases associated with the November, k_N^A , and May, k_r^A , surveys and the assumed multiplicative bias for the DEPM indices of abundance, k_g^A .

		$\ln(k_{ac}^A)$	Obj fn	-log likelihood						-lnprior				Survey bias		
			$-\ln L$	$-\ln L^{Nov}$	$-\ln L^{Egg}$	$-\ln L^{rec}$	$-\ln L^{sur}$	$-\ln L^{com}$	ε_y^A	All growth parameters	δ_1 and δ_3	$N_{1983,a}^A$	k_N^A	k_r^A	k_g^A	
From de Moor (2020c)	A_0	$U(-100,0.7)$	-725.7	-767.9	-17.9	6.1	25.9	-479.0	-303.1	35.5	-2.0	-2.0	10.8	0.68	0.58	1
		$N(-0.158, 0.112^2)$	-718.6	-758.9	-1.1	7.4	20.9	-483.3	-302.8	34.1	-1.8	-2.0	10.8	0.76	0.64	1
	A_1	$U(-100,0.7)$	-727.1	-769.0	-16.4	6.3	25.7	-481.8	-302.9	35.0	-1.9	-2.0	10.8	0.98	0.80	1
		$N(-0.158, 0.112^2)$	-721.7	-761.1	0.5	6.8	19.3	-485.2	-302.5	33.3	-1.5	-2.0	10.8	0.89	0.73	1
Updated model	$L_{50,y}$	$N(-0.158, 0.112^2)$	-721.8	-761.5	0.4	6.6	19.4	-485.2	-302.6	33.6	-1.5	-2.0	10.8	0.89	0.74	1
	L_{50}	$N(-0.158, 0.112^2)$	-721.5	-760.9	0.5	7.0	19.3	-485.2	-302.5	33.3	-1.5	-2.0	10.8	0.89	0.73	1

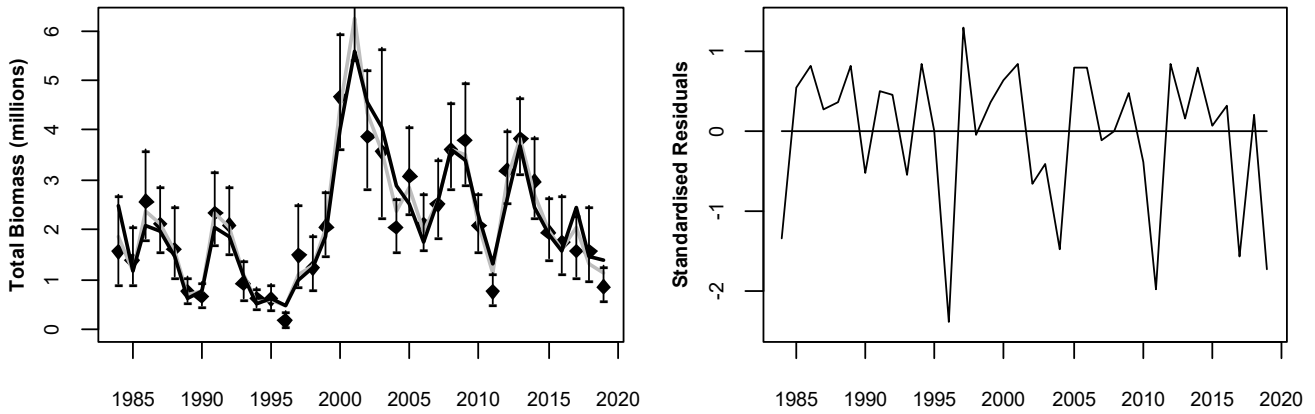


Figure 1. Acoustic survey and bias corrected model estimated for November anchovy biomass from 1984 to 2019. The survey indices are shown with 95% confidence intervals reflecting survey inter-transect variance. The standardised residuals are given in the right hand plot. The A_0 November anchovy biomass estimated by de Moor (2020a) is shown in grey.

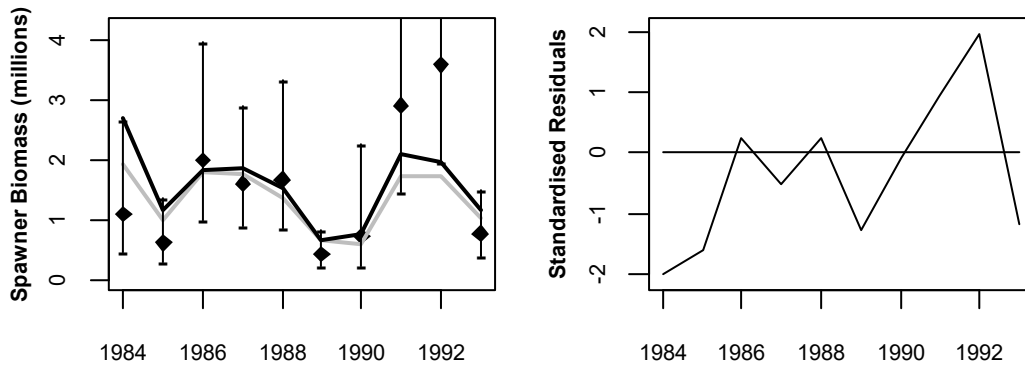


Figure 2. Daily egg production method and bias corrected model estimated November anchovy spawner biomass from 1984 to 1993. The survey indices are shown with 95% confidence intervals. The standardised residuals are given in the right hand plot. The A_0 November anchovy spawner biomass estimated by de Moor (2020a) is shown in grey.

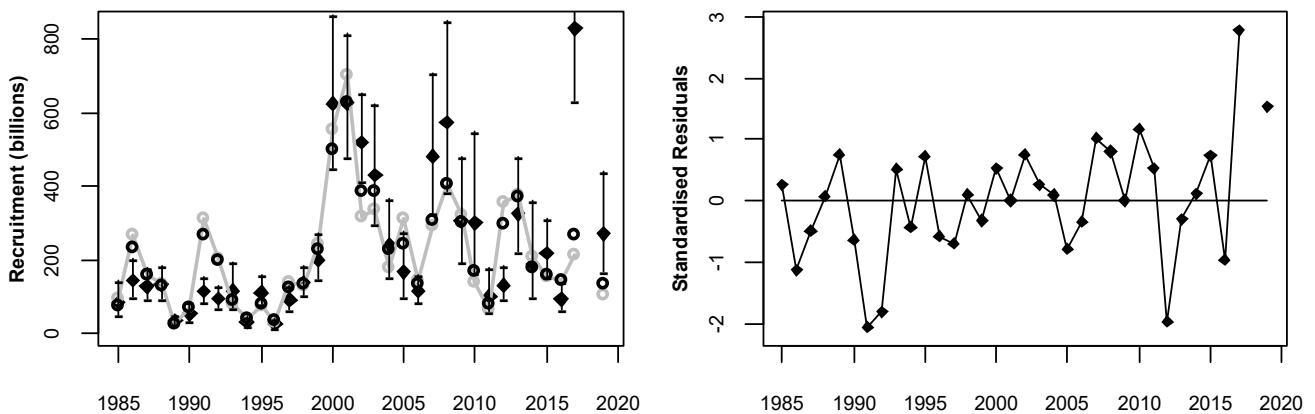


Figure 3. Acoustic survey and bias corrected model estimated (black with open circles) anchovy recruitment numbers from May 1985 to May 2019. The survey indices are shown with 95% confidence intervals reflecting survey inter-transect. Note that additional survey variance is estimated included in the model, and not shown in this figure. The standardised residuals are given in the right hand plot. The A_0 anchovy recruitment estimated by de Moor (2020a) is shown in grey.

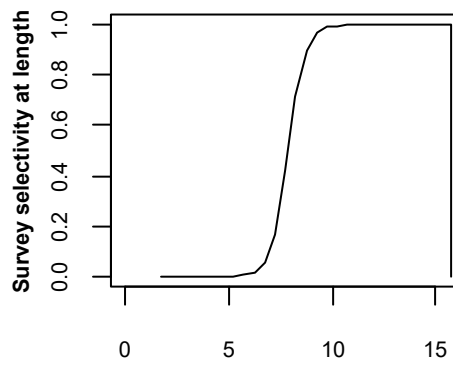


Figure 4. Model estimated trawl survey selectivity at length.

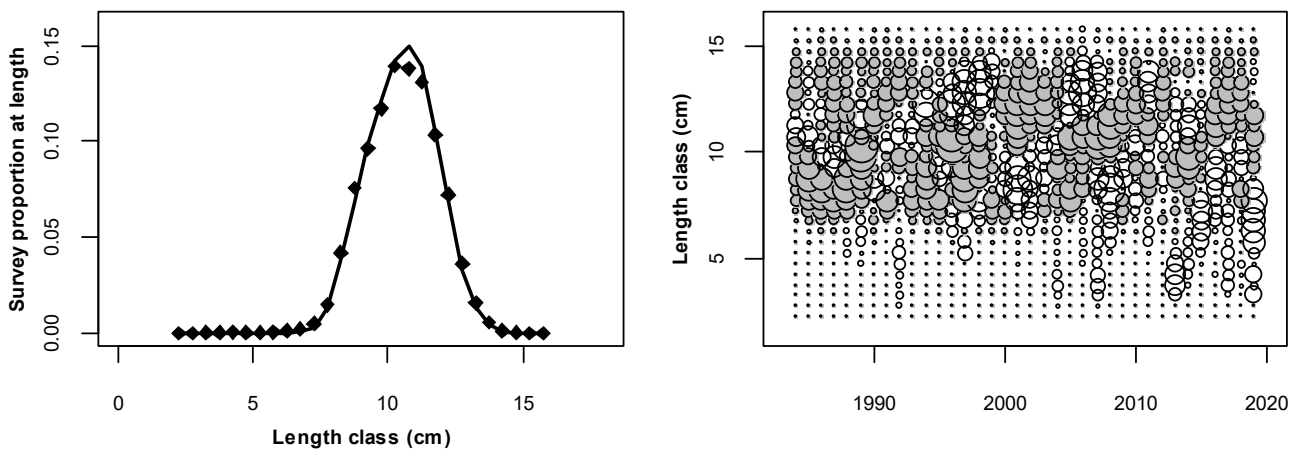


Figure 5. Average (over all years) model predicted and observed proportions-at-length in the November survey trawls. The standardised residuals are given in the bubble plot; the size of the bubbles are proportional to the absolute value of the residuals, while the shaded bubbles show negative and the unshaded bubbles show positive residuals.

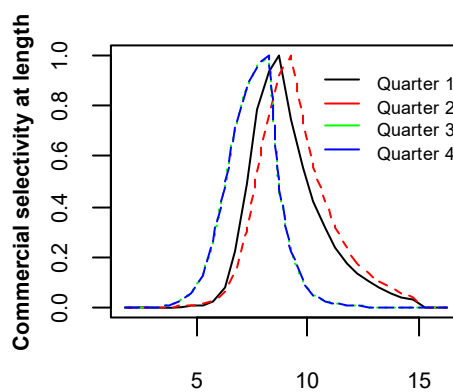


Figure 6. Model estimated quarterly commercial selectivity at length.

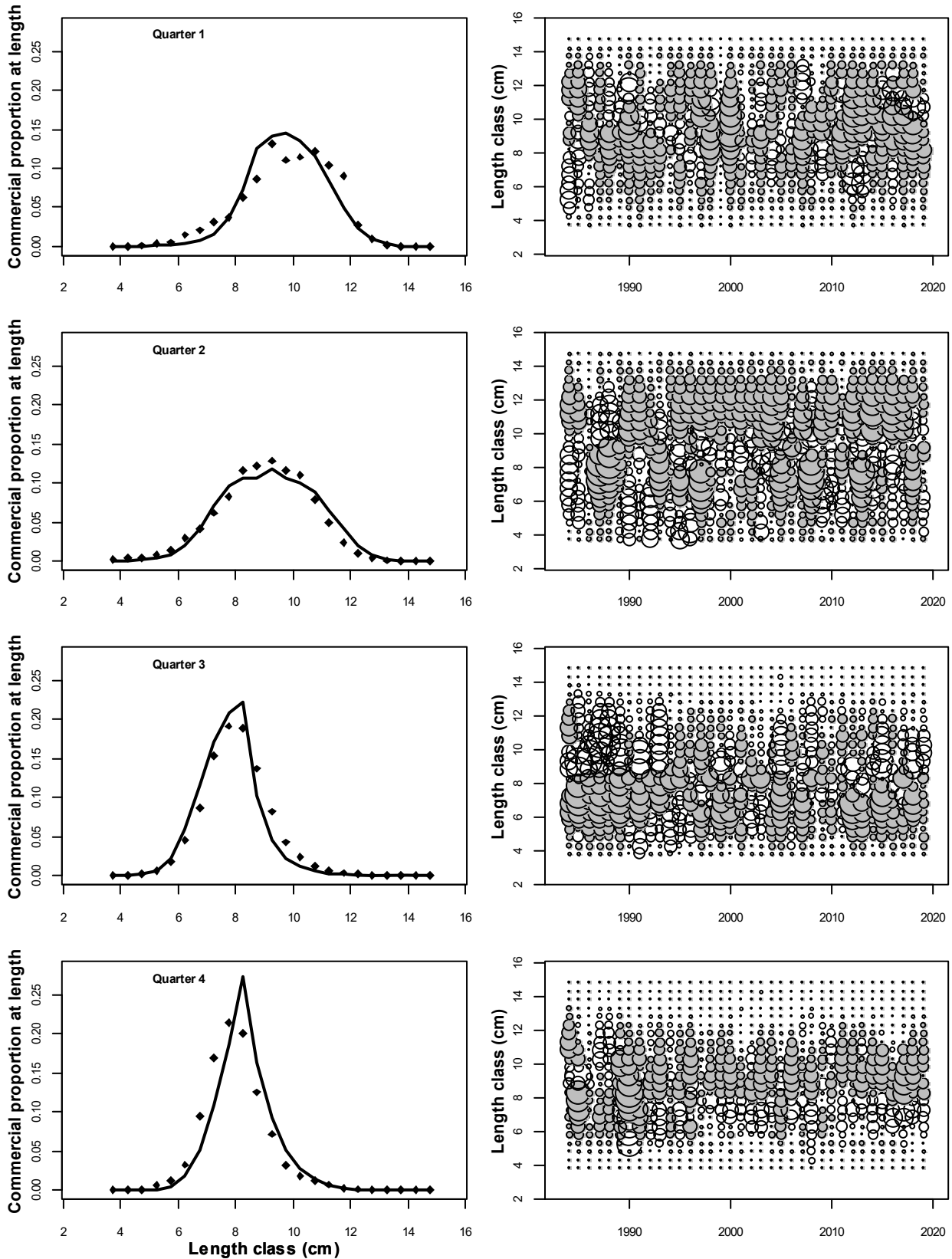


Figure 7. Average (over all years) model predicted and observed proportions-at-length in the quarterly commercial catch. The standardised residuals are given in the bubble plot; the size of the bubbles are proportional to the absolute value of the residuals, while the shaded bubbles show negative and the unshaded bubbles show positive residuals.

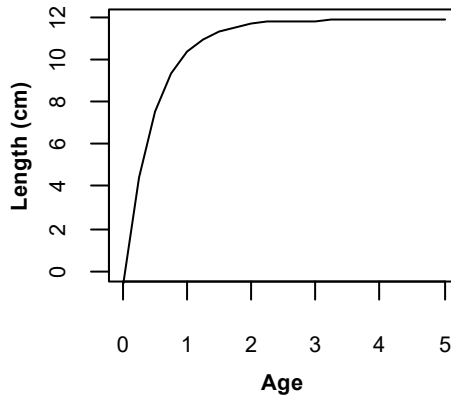


Figure 8. The model estimated von Bertalanffy growth curve, where integer ages are taken to correspond to November.

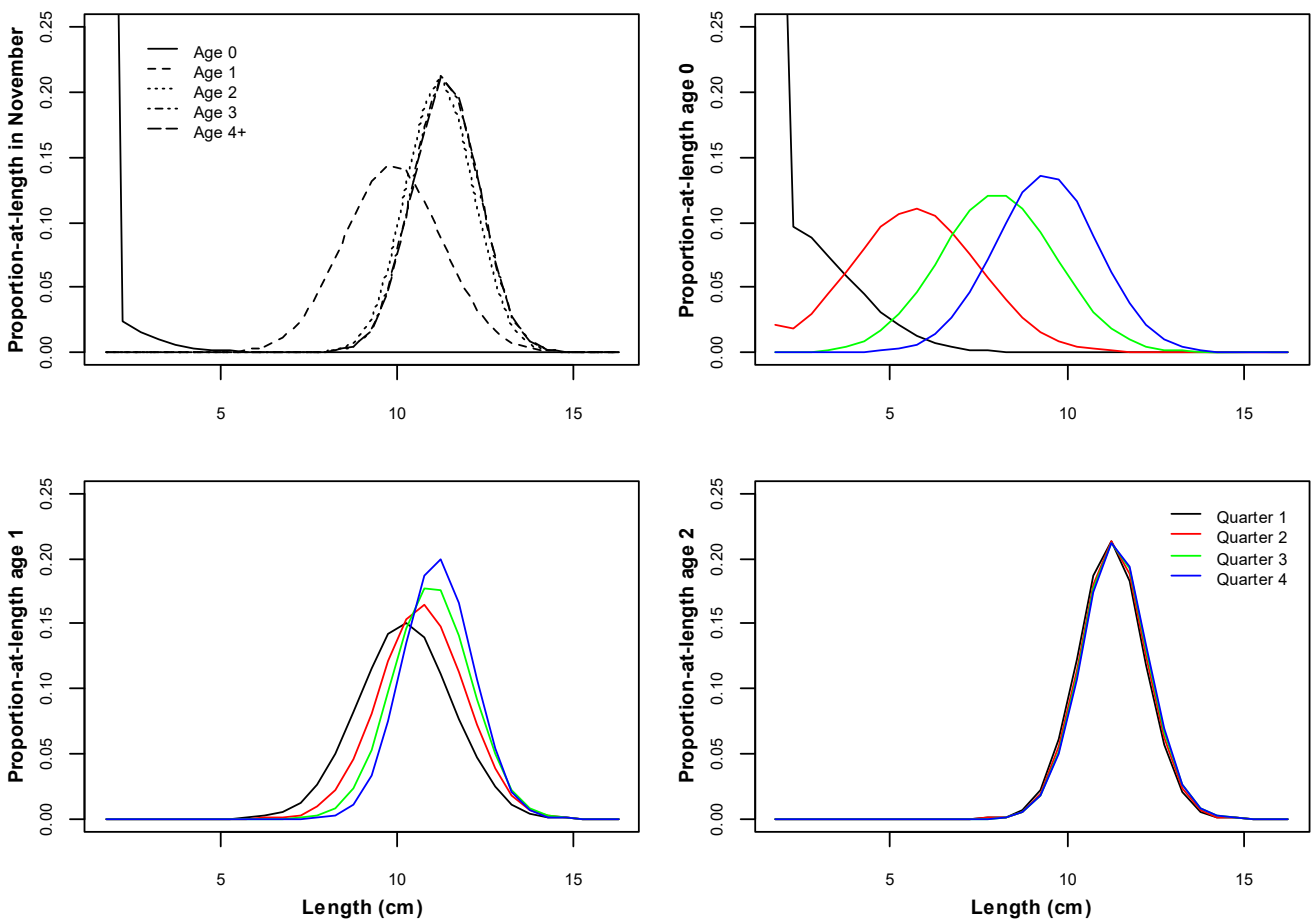


Figure 9. The model estimated distributions of proportions-at-length for each ages 0, 1 and 2, given at the middle of each quarter of the year (corresponding to the times commercial catch is modelled to be taken) and the distributions for all ages at 1 November (corresponding to the time of the biomass survey).

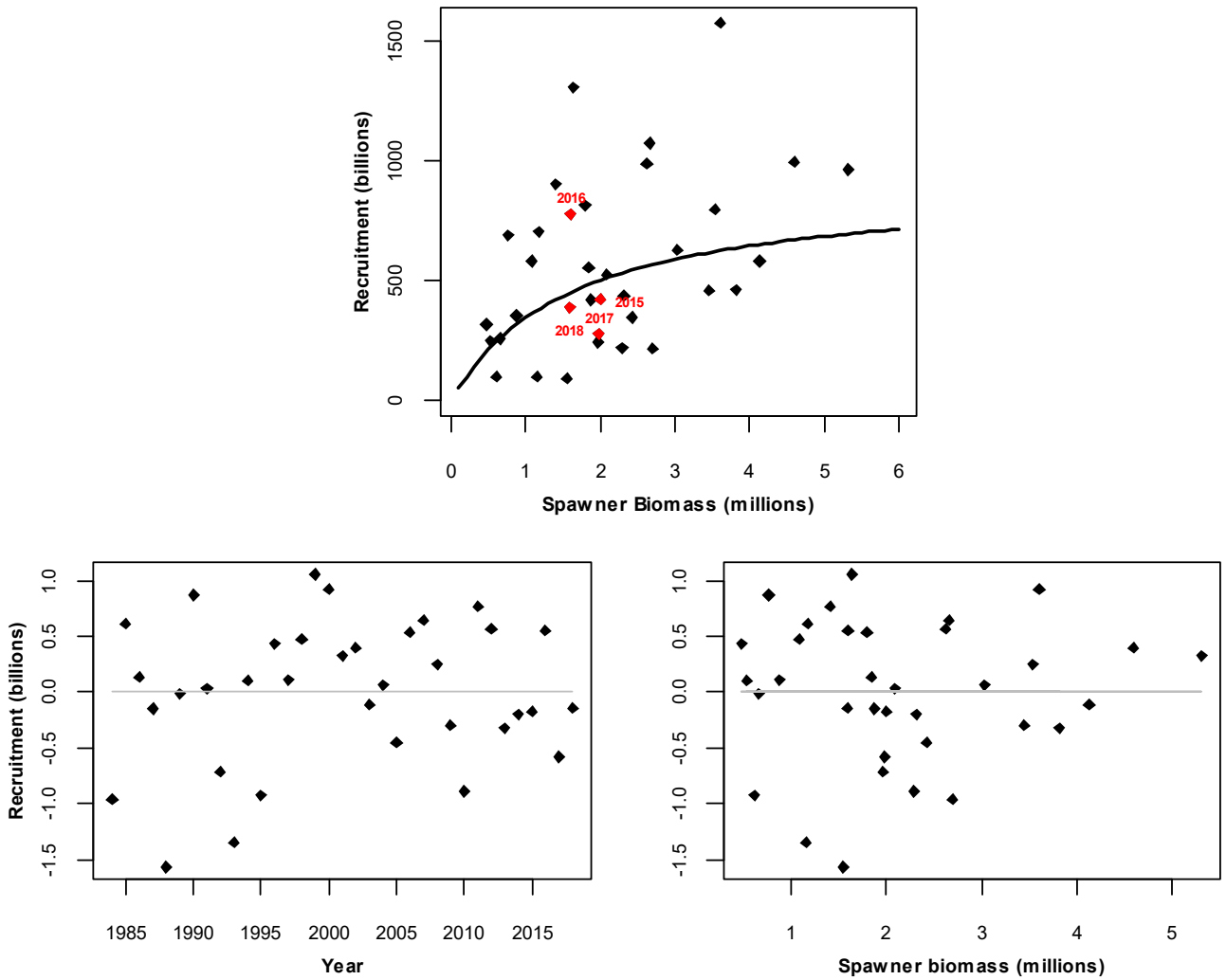


Figure 10. Model predicted anchovy recruitment (in November) plotted against spawner biomass from November 1984 to November 2018 with the Beverton Holt stock recruitment relationship. The standardised residuals from the fit are given in the lower plots, against year and against spawner biomass.

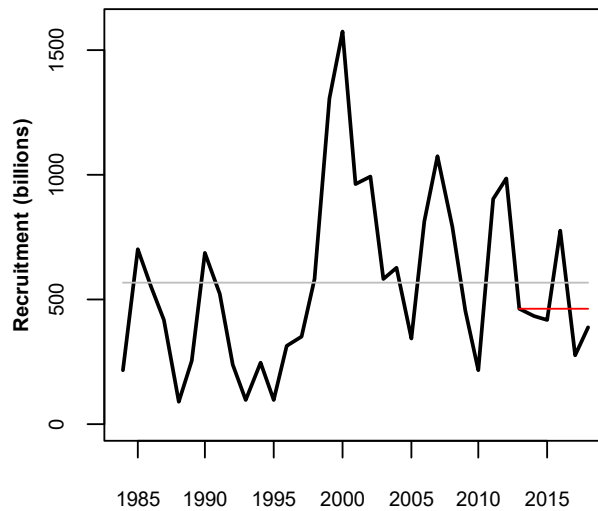


Figure 11. The timeseries of November recruitments. The grey and red lines indicate the average over the full timeseries and the most recent 6 years, respectively.

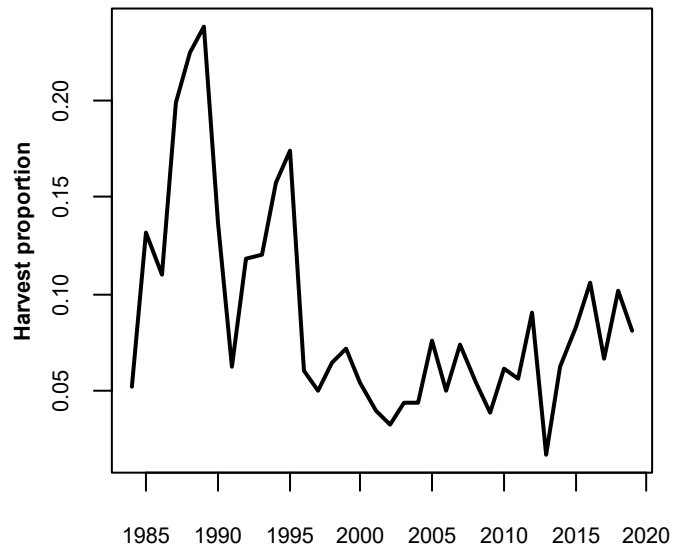


Figure 12. The model estimated historical harvest proportion (catch by mass as a proportion of total biomass).

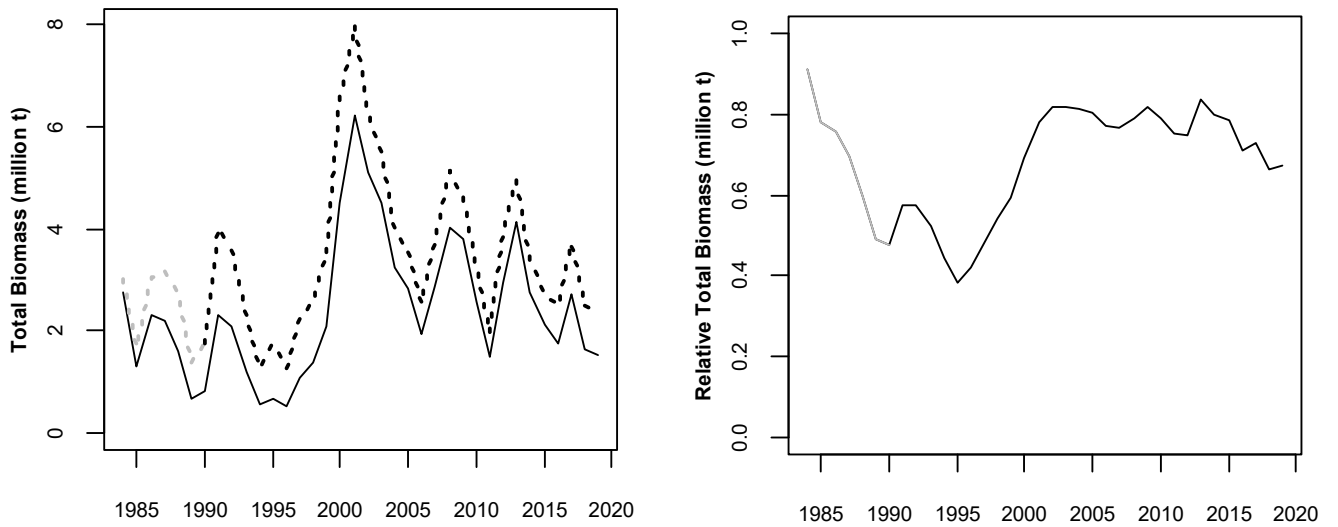


Figure 13. The historical total anchovy biomass under this updated model (solid) and that calculated for the same model, but assuming no historical catch (Dynamic B₀) (dashed). The historical biomass relative to the Dynamic B₀ time series is also shown. The initial years are less reliable due to transient effects and are plotted in grey.

Appendix: Annual Maturity Ogives

The proportion mature was taken to correspond to the mid-point of each length class, i.e. $f_{y,lmid}^{pred} = 1/1 + e^{-(lmid-L_{50,y})/\delta_y}$. The maturity ogives were estimated by minimising the sum of squares for the square root of the proportions, i.e. $SS =$

$$\sum_y \sum_l \left(\sqrt{f_{y,lmid}^{pred}} - \sqrt{f_{y,lmid}^{obs}} \right)^2.$$

This is a simple approximation to assuming an over-dispersed multinomial likelihood. The

following alternative models were fit to the annual proportion mature by length class data provided by Geja *et al.* (In Prep):

- i) Time-invariant maturity ogives: $L_{50,y} = L_{50}$ and $\delta_y = \delta$
- ii) Time-invariant steepness in the maturity ogives: $L_{50,y}$ and $\delta_y = \delta$
- iii) Annually varying maturity ogives: $L_{50,y}$ and δ_y
- iv) Annually varying maturity ogives with prior on steepness: $L_{50,y}$ and $\delta_y \sim U(0.2, 0.5)$
- v) Annually varying maturity ogives with prior on steepness: $L_{50,y}$ and $\delta_y \sim N(\delta, 5^2)$

As to be expected, the best fit to the data was achieved by (iii), with the poorest fit by (i) (Table A1). However, some of the δ_y estimated by (iii) are likely far too small to be biologically realistic (Figure A1). Alternatives (iv) and (v) provided more realistic δ_y s. For use in the assessment, alternatives (iii), (iv) and (v) require values for $L_{50,y}$ and δ_y for 1993, 1996-7, 1999-2001 and 2003, for which data are not yet available¹. A time-invariant δ (alternative (ii)) was therefore preferred as the fit was not much worse than (iii) – (v) and provides a more stable δ value for years of missing data. Linear interpolation was used to inform $L_{50,y}$ in these years of missing data. The annual maturity ogives estimated by (ii) are shown in Figure A2, and compared to the time-invariant maturity ogive (i).

Table A1. The objective function associated with each of the alternative sets of maturity ogives estimated.

Alternative	Objective function (SS and any prior on δ_y)
i)	7.732
ii)	4.000
iii)	3.081
iv)	3.308
v)	3.288

¹ Data for these years should be available once Geja *et al.* (In prep) is completed.

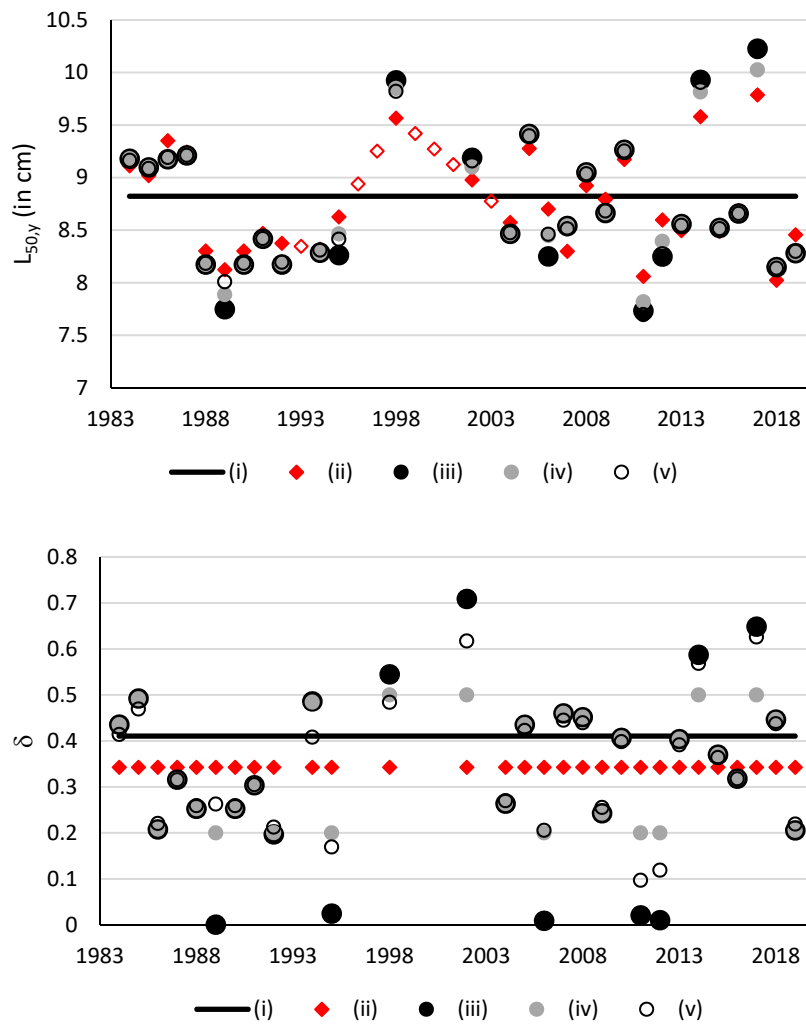


Figure A1. The $L_{50,y}$ and δ_y estimated by the alternative models. The open diamonds for $L_{50,y}$ for alternative (ii) are calculated by linearly interpolating between estimated values.

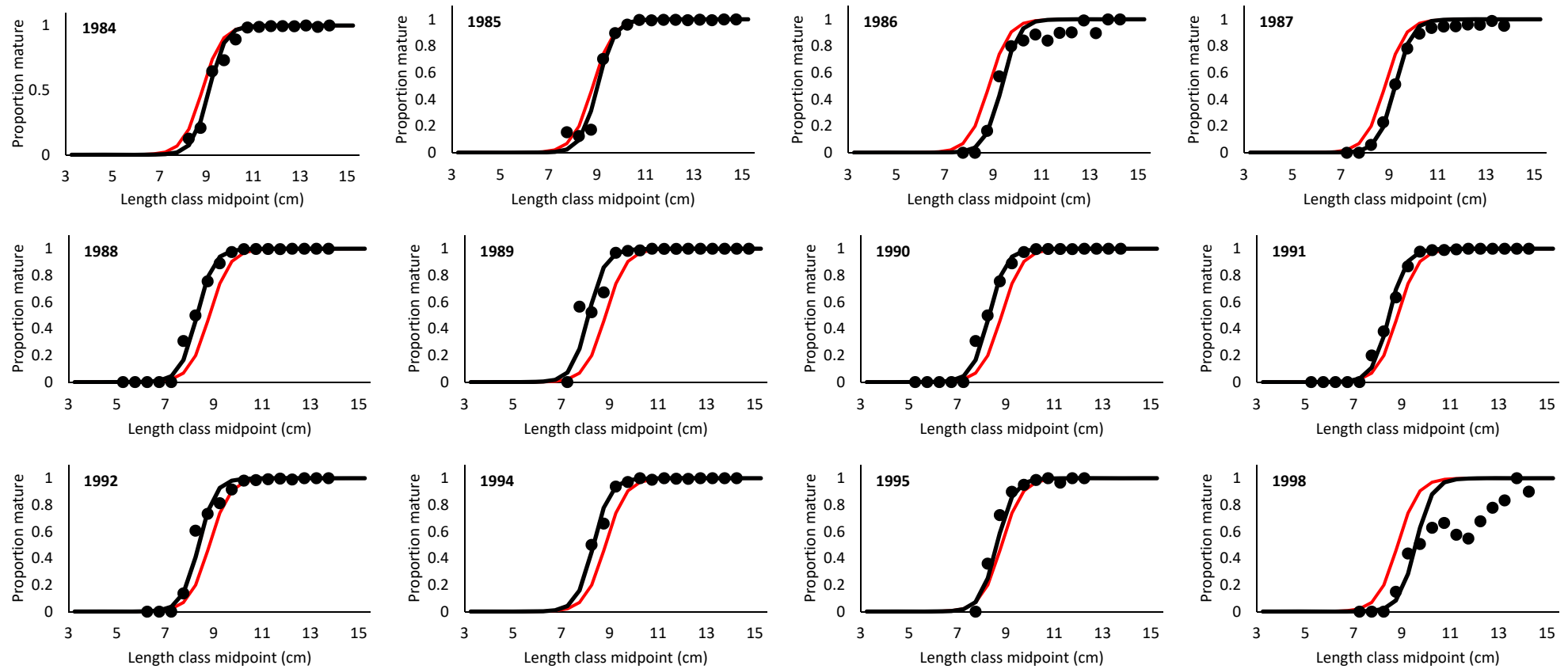


Figure A2. The annual observed proportions mature at length for South African anchovy (no data are currently available for 1993, 1996-7, 1999-2001, 2003) with the estimated maturity ogives assuming a time invariant $\delta_y = \delta$ and either (i) estimating $L_{50,y}$ annually (black line) or (ii) estimating a time invariant $L_{50,y} = L_{50}$ (red line).

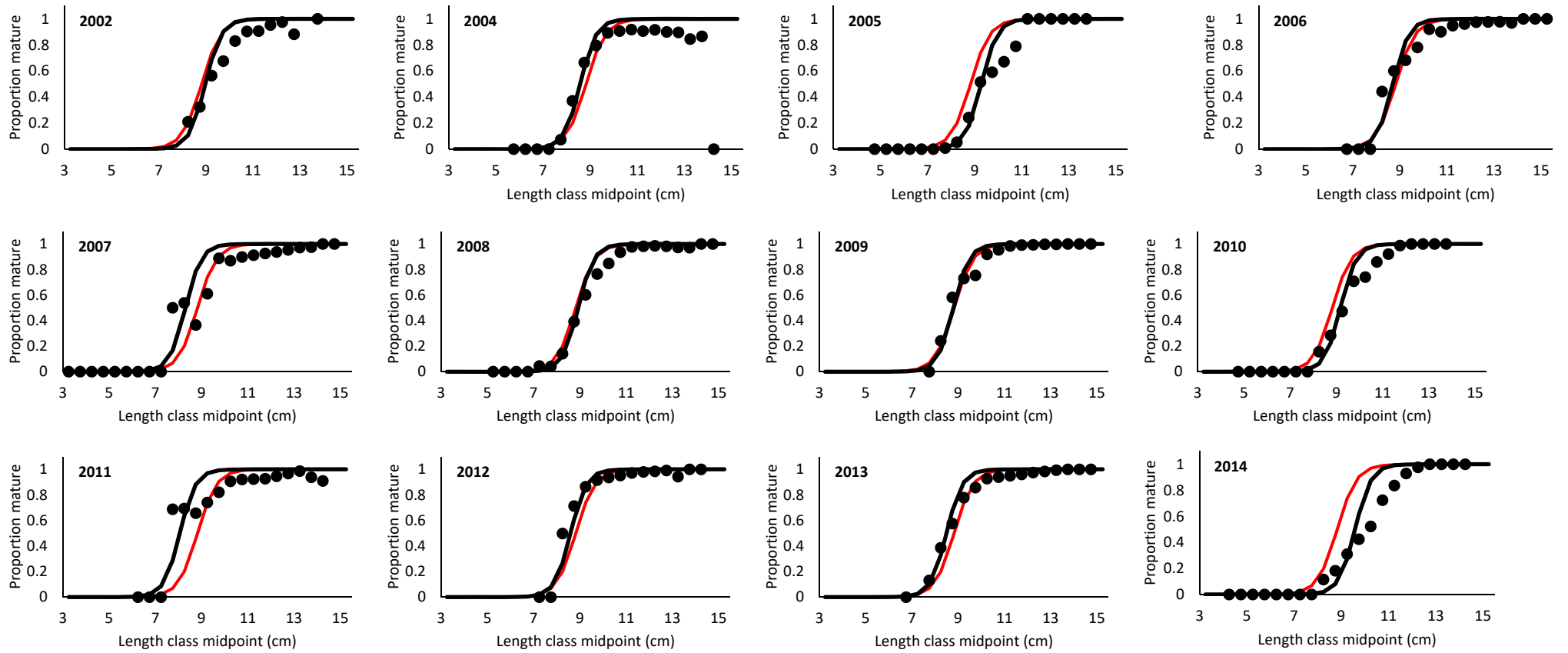


Figure A2 (cont).

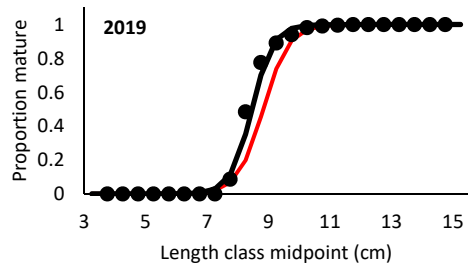
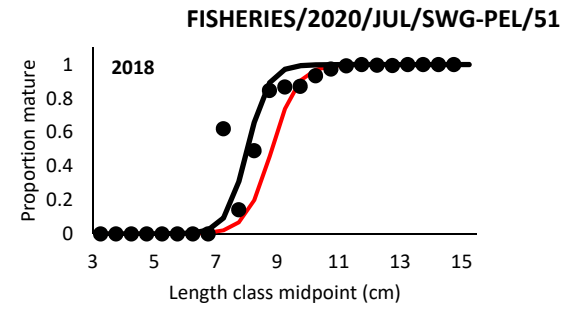
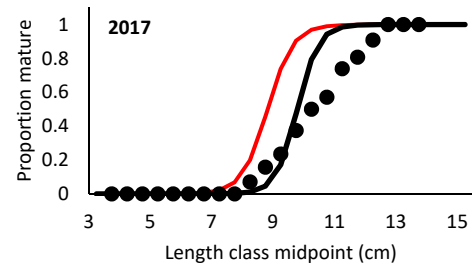
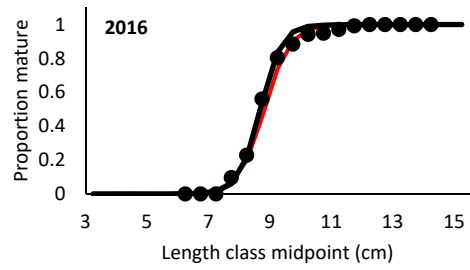
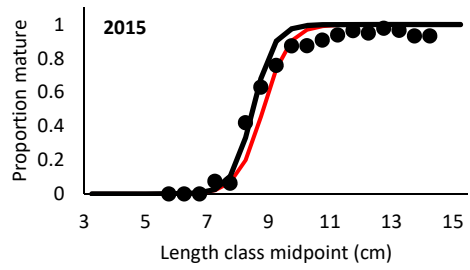


Figure A2 (cont).