

Further results pertaining to the South African anchovy assessment

C.L. de Moor*

Correspondence email: carryn.demoor@uct.ac.za

Abstract

Some key sensitivity tests to the recent assessment of the South African anchovy resource are considered and the historical Dynamic B_0 time series is estimated.

Introduction

An updated assessment of the South African anchovy resource was given by de Moor (2020a). These results were considered initial, as, given time constraints, sensitivity to a number of model assumptions, prior distributions and fixed parameter values were not tested and were simply based on those used by de Moor (2016). This document considers some key uncertainties of the baseline assessment of de Moor (2020a), as identified by the SWG-PEL Task Group as being potentially influential in any short-term projections for management advice. Sensitivity testing to other model assumptions, prior distributions and fixed parameter values has again been delayed due to time constraints.

Sensitivity to the assumed stock recruitment relationship

One key assumption of de Moor (2020a) was the assumption of a Beverton Holt stock recruitment relationship during conditioning. Appendix A shows that this assumption was robust and does not substantially influence the model estimated recruitment. Even if no stock recruitment relationship was assumed during conditioning, there is little preference in the data between a Beverton Holt, Hockey Stick or Ricker relationship, and the Beverton Holt stock recruitment relationship estimated after conditioning was very similar to that estimated during conditioning (Appendix A).

Time-invariant maturity ogive

The time-invariant maturity ogive used by de Moor (2020a), with a length at 50% maturity of 10.61cm was derived using data sampled from the 1985 and 1986 November surveys (Figure A.1 of de Moor 2020a). Maturity ogives derived using data sampled from the 2015 to 2019 November surveys have a length at 50% maturity of about 8.5cm (Geja and Coetzee pers comm). Further work is underway to determine maturity ogives for other years. In the meantime, three sensitivity tests were run:

- i) A_0 : (Baseline) time invariant maturity ogive with length at 50% maturity of 10.61cm.
- ii) A_1 : time invariant maturity ogive with length at 50% maturity of 8.5cm.
- iii) A_2 : maturity ogive with length at 50% maturity of 10.61cm prior to (and including) 1995 and of 8.5cm from 1996 onwards.
- iv) A_3 : maturity ogive with length at 50% maturity of 10.61cm prior to (and including) 1998 and of 8.5cm from 1999 onwards.

There was some improvement in the objective function from A_0 to the alternatives, with the best fit to data achieved by A_1 and the lowest objective function by A_2 . Figure B.1 shows the change in estimated spawner biomass between A_0 and A_2 in 1996 and

* MARAM (Marine Resource Assessment and Management Group), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701, South Africa.

A₀ and A₃ in 1999. While the difference in estimated November recruitment is relatively small for A₀, A₂ and A₃, the difference is non-negligible for A₁ (Figure B.2). Model A₁ estimated the November survey bias close to 1 ($k_N^A = 0.98$), while A₀ suggested the survey substantially underestimates the true biomass ($k_N^A = 0.68$). As all short-term projections are to be based on a range of proportions of the historical recruitment average, and not a stock-recruitment relationship (de Moor 2020b), only sensitivity test A₁ was selected as an alternative to the baseline model of de Moor (2020a) for short-term projections for management advice.

Time-invariant natural mortality

The baseline model's inability to reconcile the high May recruitments in 2017 and 2019 with the inter-annual decreases in November biomass was the underlying reason for questioning the baseline time-invariant natural mortality assumption. Seven sensitivity tests were run:

- i) A₀: (Baseline) $M_j^A = M_{ad}^A = 1.2\text{year}^{-1}$ for all years.
- ii) A₄: M_j^A is estimated to increase from 1.2year^{-1} to a higher value in 2017 and onwards.
- iii) A₅: $M_j^A = M_{ad}^A$ is estimated to increase from 1.2year^{-1} to a higher value in 2017 and onwards.
- iv) A₆: $M_j^A = 3.0\text{year}^{-1}$ from 2017 onwards.
- v) A₇: $M_j^A = M_{ad}^A = 3.0\text{year}^{-1}$ from 2017 onwards.
- vi) A₈: $M_j^A = M_{ad}^A = 2.0\text{year}^{-1}$ from 2017 onwards.
- vii) A₉: $M_j^A = M_{ad}^A$ is estimated to increase from 1.2year^{-1} to a higher value in 2017 and onwards, in a model with no stock-recruitment relationship assumed during conditioning.
- viii) A₁₀: $M_j^A = M_{ad}^A = 2.0\text{year}^{-1}$ from 2017 onwards in a model with no stock-recruitment relationship assumed during conditioning.

An improved fit to the data was obtained when natural mortality was allowed to increase in 2017 and then remain at this higher level for subsequent years, and when this increase was applied to all ages, not just recruits (Table B.1). Model A₈ was selected as a sensitivity test for short-term projections for management advice, allowing for a recent increase in natural mortality, but maintaining that increase to a potentially more realistic range. As recruitment is higher in the most recent 5 years under these sensitivity tests, the historical average recruitment upon which future recruitment scenarios is based differs between model alternatives.

Historical harvest proportions, loss to predation and dynamic B₀

The model estimated loss to predation (Appendix C), assuming that all mortality other than fishing is 'natural' and due to predation, is given in Figure 1. An updated harvest proportion (Appendix C) from that of de Moor (2020a) is given in Figure 2. Figure 3 shows the historical timeseries of anchovy biomass assuming the parameter values fixed at those estimated by the baseline model, but with no historical (1984-2019) catch, i.e. "Dynamic B₀" (de Moor and Butterworth 2009). The primary driver of the difference between the Dynamic B₀ timeseries and that of the baseline model is the stock-recruitment relationship: as there is no historical catch under Dynamic B₀, the historical spawner biomass is higher and therefore recruitment is higher etc. As all model parameters, including initial numbers-at-age, are fixed at the values estimated by the baseline model (with catch) when calculating the Dynamic B₀ timeseries, the initial years of the time series are less reliable due to transient effects. This particularly so as the population was not at a stable equilibrium at the start of this time series. While a Kobe plot cannot currently be given as the SWG-PEL has not (yet) defined target reference points for anchovy, Figure 4 plots the historical harvest proportion against

relative biomass. The relative biomass considered is both spawner biomass against carrying capacity as estimated by the Beverton Holt stock recruitment relationship and biomass against Dynamic B_0 . Carrying capacity has been argued to be irrelevant for the management of small pelagics given its high dependence on the chosen stock recruitment relationship, time over which the stock recruitment relationship is estimated and high sensitivity to new data (e.g. de Moor and Butterworth 2012). In developing a target reference point for anchovy, it may, therefore, be more prudent to base such on a proportion of the average historical dynamic B_0 .

References

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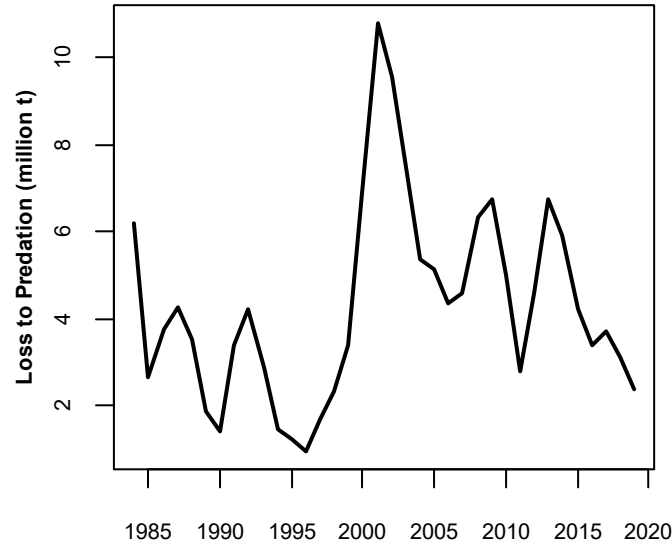


Figure 1. The annual anchovy loss to predation ('natural mortality') under the baseline model of de Moor (2020a).

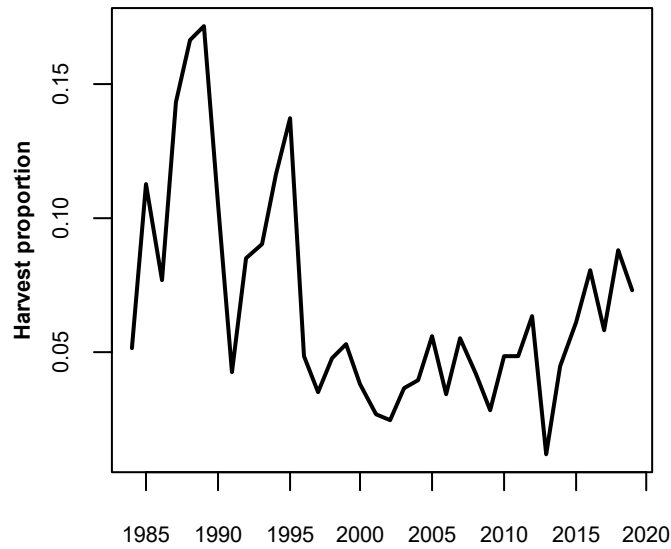


Figure 2. The updated harvest proportion of anchovy from the baseline model of de Moor (2020a).

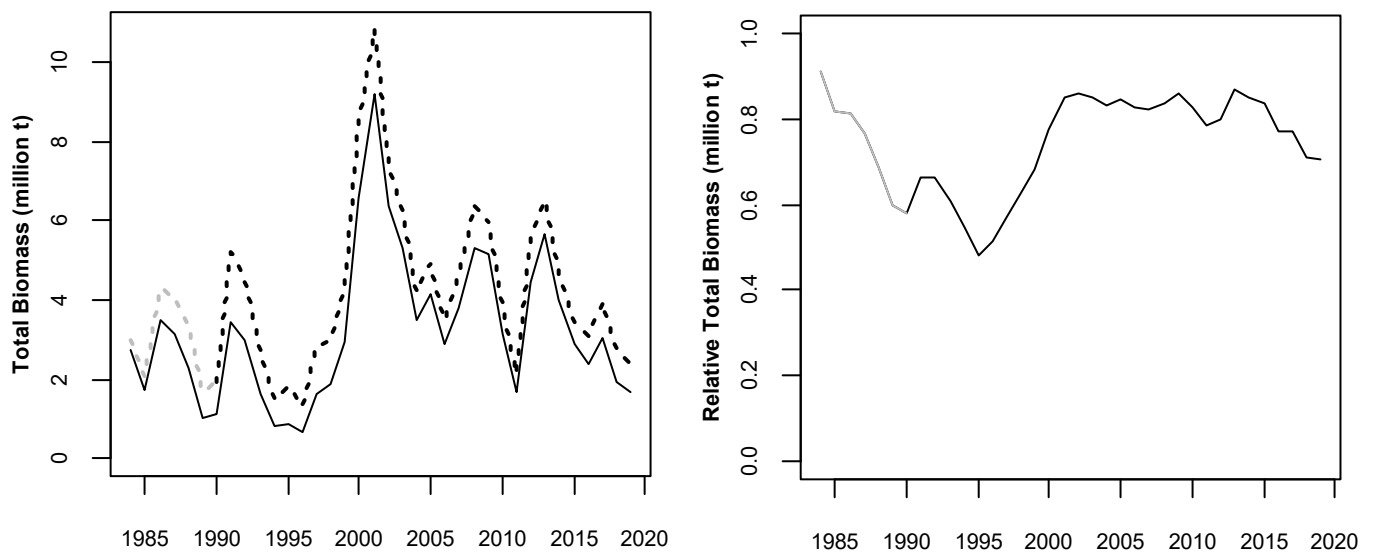


Figure 3. The historical total anchovy biomass under de Moor (2020) (solid) and that calculated for the same model, but assuming no historical catch (Dynamic B_0) (dashed). The historical biomass relative to the Dynamic B_0 time series is also shown. The initial years are less reliable due to transient effects and are plotted in grey.

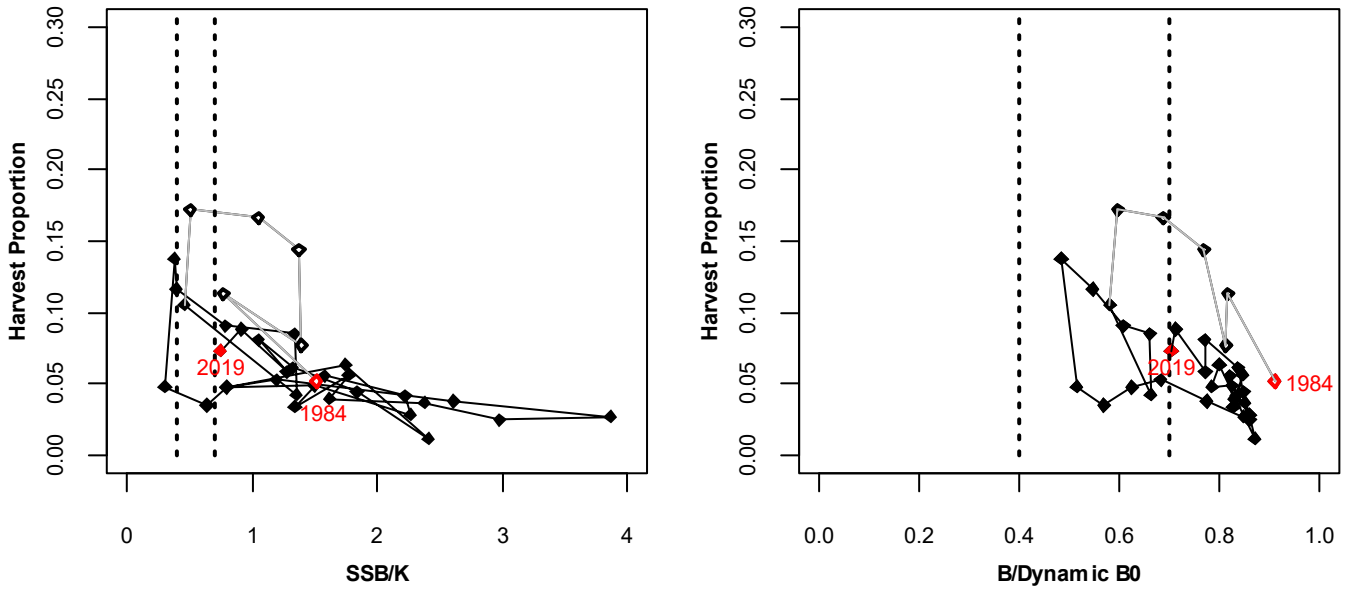


Figure 4. The historical harvest proportion plotted against the ratio of spawner biomass to carrying capacity (left) and the ratio of biomass to dynamic B_0 . The initial years are less reliable due to transient effects and are shown by grey lines / open diamonds. The dashed lines correspond to 40% and 70% of carrying capacity/dynamic B_0 .

Appendix A: Testing the assumption of using a Beverton Holt stock recruitment relationship

An alternative model was run in which recruitment was estimated using a prior of $\ln(N_{y,0}^A) \sim U(3,10)$ and no stock recruitment relationship was estimated during conditioning. Given the additional ‘freedom’ to estimate annual recruitment without a stock-recruitment relationship, this model results in a better fit to the data (Table A.1). After conditioning the model, three stock recruitment relationships were fit to the model estimated time series of November recruitment and spawner biomass using a lognormal likelihood. The Beverton Holt relationship was preferred, though not significantly so (Figure A.1, Table A.2) and the estimated stock recruitment parameters were very similar to those estimated by the baseline model ($\alpha^A = 1075$ and $\beta^A = 1231$ from de Moor (2020a)).

Table A.1. The contributions to the objective function from (1) the baseline model (de Moor (2020a)) and (2) the model without a stock recruitment relationship estimated during conditioning.

	Objective fn	Negative log likelihood					Negative log priors			
		$-\ln L^{Nov}$	$-\ln L^{Egg}$	$-\ln L^{rec}$	$-\ln L^{surpropL}$	$-\ln L^{compropL}$	Rec residuals	Growth params	Selectivity params	Initial N params
(1)	-725.7	-17.9	6.1	25.9	-479.0	-303.0	35.5	-2.0	-2.0	10.8
(2)	-764.4	-19.2	5.5	28.7	-483.5	-302.9	-	-1.7	-2.0	10.8

Table A.2 The negative log likelihood and estimated parameter values when fitting a stock-recruitment relationship to the model estimated spawner biomass and November recruitment after conditioning.

	$-\ln L$	α^A	β^A	σ_r^A
Beverton Holt	35.5	1051	1171	0.67
Hockey Stick	36.7	644	1048	0.69
Ricker	36.1	0.607	0.0003	0.68

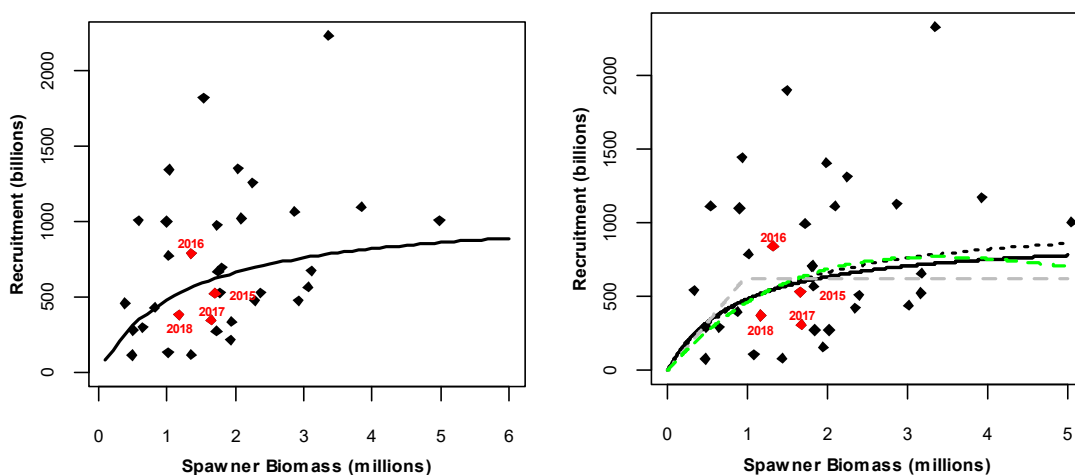


Figure A.1. Model estimated anchovy recruitment (in November) plotted against spawner biomass from November 1984 to November 2018 from (left) de Moor (2020a) and (right) the assessment model without any stock recruitment relationship assumed during conditioning. The Beverton Holt (black), Ricker (green dashed) and Hockey Stick (grey dashed) stock recruitment relationships estimated after conditioning are also shown on the right panel together with the Beverton Holt estimated during conditioning (black dotted).

Appendix B: Sensitivity Tests to the Anchovy Assessment

Table B.1. Contributions to the objective function from alternative maturity ogive assumptions and alternative natural mortality assumptions.

	M_j^A 2007-	M_{ad}^A 2007-	Objective fn	Negative log likelihood					Negative log priors			
				$-\ln L^{Nov}$	$-\ln L^{Egg}$	$-\ln L^{rec}$	$-\ln L^{surpropL}$	$-\ln L^{compropL}$	Rec residuals	Growth params	Selectivity params	Initial N params
A ₀	1.2	1.2	-726	-18	6	26	-479	-303	36	-2	-2	11
A ₁	1.2	1.2	-727	-16	6	26	-482	-303	35	-2	-2	11
A ₂	1.2	1.2	-727	-18	6	26	-479	-303	33	-2	-2	11
A ₃	1.2	1.2	-727	-18	6	26	-479	-303	34	-2	-2	11
A ₄	2.0	1.2	-727	-18	6	24	-479	-303	36	-2	-2	11
A ₅	1.8	1.8	-729	-18	6	23	-480	-302	36	-2	-2	11
A ₆	3.0	1.2	-725	-18	6	21	-479	-302	41	-2	-2	11
A ₇	3.0	3.0	-724	-19	6	20	-481	-301	44	-2	-2	11
A ₈	2.0	2.0	-729	-18	6	22	-481	-302	37	-2	-2	11
Appendix A (2)	1.2	1.2	-764	-19	5	29	-483	-303	-	-2	-2	11
A ₉	3.0	3.0	-769	-20	6	22	-483	-300	-	-2	-2	11
A ₁₀	2.0	2.0	-768	-20	6	25	-484	-302	-	-2	-2	11

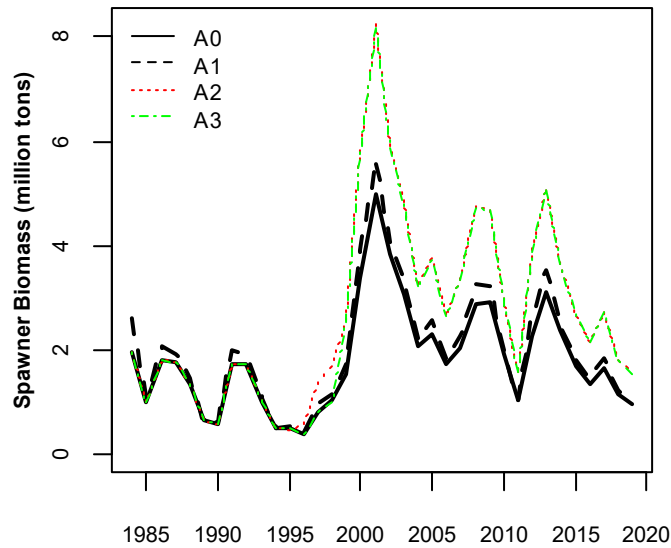


Figure B.1. Model estimated spawner biomass for the maturity ogive sensitivity tests.

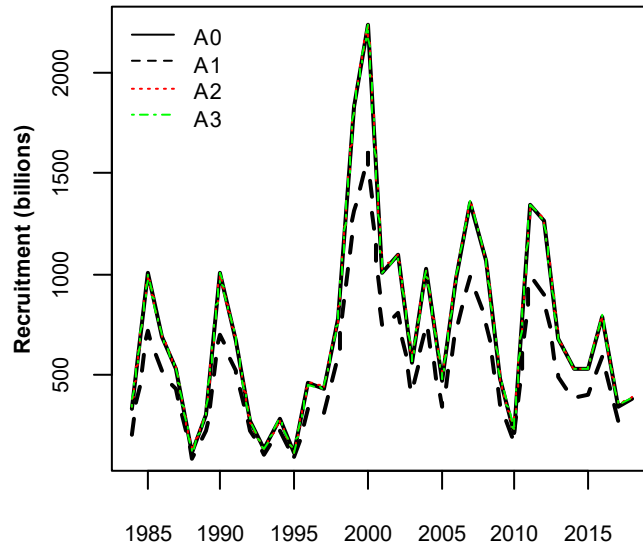


Figure B.2. Model estimated November recruitment for the maturity ogive sensitivity tests, with average 1984 – 2018 recruitment being 724 (A_0), 530 (A_1), 728 (A_2) and 725 (A_3) billion.

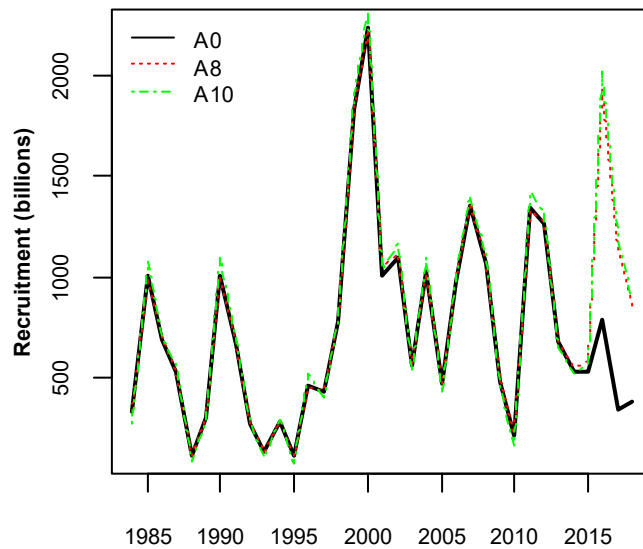


Figure B.3. Model estimated November recruitment for two alternative natural mortality sensitivity tests, with average 1984 – 2018 recruitment being 724 (A_0), 797 (A_8) and 813 (A_{10}) billion.

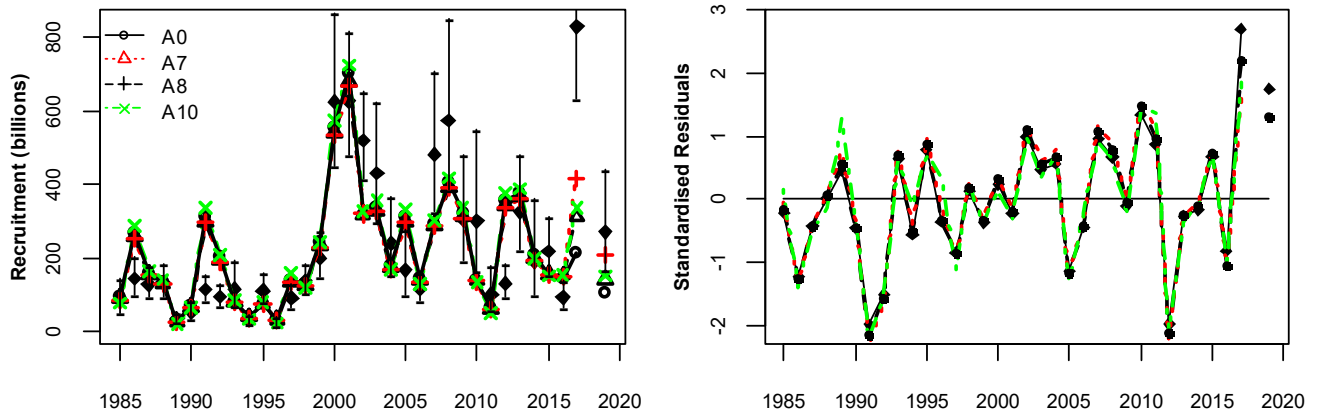


Figure B.4. Acoustic survey and bias corrected model estimated anchovy recruitment numbers from May 1985 to May 2019 for three alternative natural mortality sensitivity tests. The survey indices are shown with 95% confidence intervals reflecting survey inter-transect. Note that additional survey variance is estimated in the model, and not shown in this figure. The standardised residuals are given in the right hand plot.

Appendix C: Calculating the loss to predation and annual exploitation rate

The biomass of anchovy annually lost to predation, P_y^A , is calculated assuming catch is taken half way through each quarter (de Moor (2020a):

$$\begin{aligned}
 P_y^A = & \sum_{a=1}^4 \left\{ N_{y-1,a-1}^A \left(1 - e^{-M_{y,a-1}^A/8} \right) (0.9375w_{a-1}^A + 0.0625w_a^A) \right. \\
 & + \left(N_{y-1,a-1}^A e^{-M_{y,a-1}^A/8} - C_{y,1,a-1}^A \right) \left(1 - e^{-M_{y,a-1}^A/4} \right) (0.8125w_{a-1}^A + 0.1875w_a^A) \\
 & + \left(\left(N_{y-1,a-1}^A e^{-M_{y,a-1}^A/8} - C_{y,1,a-1}^A \right) e^{-M_{y,a-1}^A/4} - C_{y,2,a-1}^A \right) \left(1 - e^{-M_{y,a-1}^A/4} \right) (0.5625w_{a-1}^A + 0.4375w_a^A) \\
 & + \left(\left(\left(N_{y-1,a-1}^A e^{-M_{y,a-1}^A/8} - C_{y,1,a-1}^A \right) e^{-M_{y,a-1}^A/4} - C_{y,2,a-1}^A \right) e^{-M_{y,a-1}^A/4} - C_{y,3,a-1}^A \right) \left(1 - e^{-M_{y,a-1}^A/4} \right) \\
 & - e^{-M_{y,a-1}^A/4} \right) (0.3125w_{a-1}^A + 0.6875w_a^A) \\
 & + \left(\left(\left(\left(N_{y-1,a-1}^A e^{-M_{y,a-1}^A/8} - C_{y,1,a-1}^A \right) e^{-M_{y,a-1}^A/4} - C_{y,2,a-1}^A \right) e^{-M_{y,a-1}^A/4} - C_{y,3,a-1}^A \right) e^{-M_{y,a-1}^A/4} - C_{y,4,a-1}^A \right) \left(1 - e^{-M_{y,a-1}^A/8} \right) \\
 & - e^{-M_{y,a-1}^A/8} \right) (0.0625w_{a-1}^A + 0.9375w_a^A) \left. \right\} + N_{y-1,4}^A \left(1 - e^{-M_{y,4}^A/8} \right) w_4^A \\
 & + \left(N_{y-1,4}^A e^{-M_{y,4}^A/8} - C_{y,1,4}^A \right) \left(1 - e^{-M_{y,4}^A/4} \right) w_4^A \\
 & + \left(\left(N_{y-1,4}^A e^{-M_{y,4}^A/8} - C_{y,1,4}^A \right) e^{-M_{y,4}^A/4} - C_{y,2,4}^A \right) \left(1 - e^{-M_{y,4}^A/4} \right) w_4^A \\
 & + \left(\left(\left(N_{y-1,4}^A e^{-M_{y,4}^A/8} - C_{y,1,4}^A \right) e^{-M_{y,4}^A/4} - C_{y,2,4}^A \right) e^{-M_{y,4}^A/4} - C_{y,3,4}^A \right) \left(1 - e^{-M_{y,4}^A/4} \right) w_4^A \\
 & + \left(\left(\left(\left(N_{y-1,4}^A e^{-M_{y,4}^A/8} - C_{y,1,4}^A \right) e^{-M_{y,4}^A/4} - C_{y,2,4}^A \right) e^{-M_{y,4}^A/4} - C_{y,3,4}^A \right) e^{-M_{y,4}^A/4} - C_{y,4,4}^A \right) \left(1 - e^{-M_{y,4}^A/8} \right) w_4^A
 \end{aligned}$$

The harvest proportion rate is now calculated half way through the year to partially account for the fishery primarily targeting recruits:

$$ER_y = \frac{C_y^{\text{tonnage}}}{\sum_{a=1}^{4+} \left(N_{y-1,a-1}^A e^{-0.5M_{y,a-1}^A} \times 0.5(w_{a-1}^A + w_a^A) \right) + N_{y-1,4}^A e^{-0.5M_{y-1,4}^A} \times w_4^A}$$