Assessment of the South African anchovy resource using data from 1984 – 2009: attempts to resolve residual trends

C.L. de Moor* and D.S. Butterworth

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

Abstract

Further testing of the proposed baseline anchovy assessment, "A_0" from de Moor and Butterworth (2010) is undertaken. It is proposed that the assumption of two stock recruitment "regimes" (pre- and post-2000) be taken forward as a robustness test during OMP testing.

Introduction

de Moor and Butterworth (2010) presented an updated assessment of the South African anchovy resource. Possible trends in the residuals from the fit of the model to the survey estimated recruitment and the November survey estimate of proportion-at-age 1 were noted. This document attempts to resolve those apparent trends in residuals.

Methods

The population dynamics model used, with a Beverton Holt stock recruitment relationship, is unchanged from that detailed in Appendix A of de Moor and Butterworth (2010). Three potential reasons for the trends in the residuals have been proposed:

1) Natural mortality has increased from 2000.
2) A different stock recruitment regime has existed since 2000.
3) The survey estimates of proportion-at-age 1 incorrectly represent the proportion during years of high abundance and slower growth.

These were addressed as follows:

1a) M_{jinc} – a parameter denoting the increase in juvenile natural mortality from 2000 onwards was estimated, given a uniform prior between 0 and 1.

1b) M_{j18} – juvenile natural mortality from 2000 onwards was fixed at 1.8 $year^{-1}$, compared to 0.9 $year^{-1}$ before 2000 (and assumed for all years in A_0).

2) $H_{2SRcurves}$ - Two separate Beverton Holt stock recruitment curves were estimated, one pertaining to 1984 to 1999 and the other to 2000 to 2009.

3) H_{kprop} – The bias in the November survey estimated proportion at age 1 differs in years 1984 - 1999 compared to 2000 - 2009.

The third proposed reason arose from a time series of seven years of estimates of anchovy condition, in terms of body lipid content (van der Lingen and Hutchings, 2005). The latter two years of this time series,

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

corresponding to years of high anchovy biomass in comparison to the former years, exhibited a decline in the estimated lipid content compared to the former years. The proposal was that anchovy growth is density dependent. Given that an average 1992-1995 ALK, developed by Prosch, was used to calculate the proportion-at-age 1, this ALK may be biased for years of high biomass[1].

Results and Discussion

Allowing the increase in juvenile natural mortality from 2000 to be estimated resulted in a better overall fit (Table 1), with M_j^A estimated to be about 1.3 yr^{-1} from 2000 onwards, but the apparent increasing trend in the residuals from the model fit to the survey estimated recruitment is not removed (Figure 1). When the juvenile natural mortality was arbitrarily set at double its pre-2000 value, the apparent increasing trend in these residuals did fall away (Figure 1), but the overall fit to all the data and prior distributions was worse than that for A_0 (Table 1). For both of these scenarios, the decreasing trend in the residuals from the model fit to the survey estimated proportion at age 1, plotted against model estimated proportion at age 1, remained unchanged (Figure 2).

When separate regimes affecting recruitment were assumed for pre- and post-2000, the fit to the data was very slightly improved from that for A_0, but given the additional parameters estimated, the AICc selection criterion suggested A_0 is the better model choice (Table 1). The two stock recruitment curves are shown in Figure 3d. The trends in the residuals from the model fit to the survey estimated recruitment and proportion-at-age 1 in November are unchanged in this scenario compared to A_0 (Figures 1d and 2d).

For both M_{jinc} and M_{j18}, the carrying capacity, K^A, for anchovy is increased substantially from 4 million under A_0 to 9.9 million. When two separate stock recruitment curves are estimated in $M_{2SRcurves}$, K^A is estimated to be below that for A_0 for both time periods (Table 2). This highlights the sensitivity of the chosen stock recruitment curves and the need to maintain a variety of alternative stock recruitment curves for robustness testing.

When the bias on the November proportion at age 1 is assumed to differ pre- and post-2000, the estimated difference is just over 10% (Table 2). However, the trend in the residuals from the model fit to the proportion-at-age 1 plotted against model estimated proportion at age 1 remains unresolved (Figure 2e).

Summary

In summary, the alternative scenarios considered here have not adequately resolved the apparent trends in the residuals from the anchovy model fit to the survey estimates of recruitment and proportion at age 1. Although artificially increasing the juvenile natural mortality substantially does remove the trend in the residuals from the

[1] The robustness tests assuming a fixed cut-off length of 10, 10.5 and 11cm for age 1 would also be biased during years of high abundance.

fit to survey estimates of recruitment, this scenario results in a poorer overall fit to the data. The estimated increase in juvenile natural mortality after 2000 was about 0.4 yr^{-1} and had only a marginal effect on the apparent residual trend. Thus it is proposed that neither of these two scenarios be taken further during OMP testing.

Although AIC_C did not choose the two stock recruitment regime scenario over A_0, we do nevertheless suggest this scenario remains as a robustness test during OMP testing due to the potential impact a change from one regime to another could have on future projections. Estimating a different bias in the proportion-at-age 1 pre- and post-2000 did not resolve the trend in the residuals from the model fit to the November survey estimates of proportion at age 1. At this stage we also propose this scenario not be taken any further. However, the time series of anchovy body lipid content (van der Lingen and Hutchings 2005) is currently being updated (van der Lingen pers. comm.). The further years' data may provide the basis for a test to determine whether there is a significant relationship between anchovy biomass and mean fat stage to suggest that growth rates are reduced at high biomass.

References

de Moor, C.L. and Butterworth, D.S. 2010. Assessment of the South African anchovy resource using data from 1984 - 2009. MCM Document MCM/2010/SWG-PEL/38. 25pp.

van der Lingen, C.D. and Hutchings, L. 2005. Estimating the lipid content of pelagic fish in the southern Benguela by visual assessment of their mesenteric fat. African Journal of Marine Science 27:45-53.

Table 1. The contributions to the objective function at the posterior mode.

	A_0	A_{Mjinc}	A_{Mj18}	$A_{2SRcurves}$	A_{kprop}
Posterior	61.268	60.392	62.854	61.126	59.904
$-\ln(L_{Nov})$	-3.78	-2.12	-1.42	-3.99	-3.00
$-\ln(L_{Egg})$	7.96	8.45	8.93	7.87	8.03
$-\ln(L_{Rec})$	7.96	3.98	0.66	8.09	7.95
$-\ln(L_{Prop})$	26.94	26.45	26.42	26.98	25.06
-ln(Prior)	22.18	23.63	28.26	22.17	21.86
# parameters	36	36	36	38	37
Sample size (i.e. data points)	87	87	87	87	87
AIC	194.54	192.78	197.71	198.25	193.81
AIC_c	247.82	246.06	250.99	260.00	251.20

Table 2. Key parameter values estimated at the joint posterior mode together with key model outputs. Fixed values are given in **bold**. Numbers are reported in billions and biomass in thousands of tons.

	A_0	A_{Mjinc}	A_{Mj18}	$A_{2SRcurves}$	A_{kprop}
M_j^A, $y<1999$	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
M_j^A, $y \geq 2000$	**0.9**	**1.272**	**1.8**	**0.9**	**0.9**
M_{ad}^A	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
$N_{1983,0}^A$	156.43	154.67	149.96	157.12	159.90
$N_{1983,1}^A$	141.26	139.49	133.87	142.12	133.50
$N_{1983,2}^A$	0.0049	0.049	0.0049	0.0049	0.0049
$N_{1983,3}^A$	0.0048	0.048	0.0048	0.0048	0.0049
k_N^A	1.189	1.196	1.255	1.190	1.195
k_r^A	1.027	0.963	0.907	1.029	1.028
k_r^A / k_N^A	0.864	0.805	0.723	0.865	0.860
k_p^A, $y<1999$	0.963	0.965	0.965	0.963	0.908
k_p^A $y \geq 2000$	0.963	0.965	0.965	0.963	1.041
$(\sigma_p^A)^2$	0.465	0.448	0.447	0.467	0.403
$(\lambda_N^A)^2$	**0**	**0**	**0**	**0**	**0**
$(\lambda_r^A)^2$	0.081	0.051	0.031	0.082	0.081
$\hat{B}_{2009,N}^A$	3489	3425	3156	3491	3462
$\overline{B}_{Nov}^A$ [2]	1103	1101	1074	1104	1101
K^A	4094	9897	9897	2892	4141
h^A	0.339	0.320	0.369	0.37	0.34
K_{2000+}^A	N/A	N/A	N/A	3550	N/A
h_{2000+}^A	N/A	N/A	N/A	0.456	N/A
σ_r^A	0.588	0.623	0.749	0.587	0.580
η_{2008}^A	0.260	0.377	0.759	0.209	0.257
s_{cor}^A	0.221	0.243	0.416	0.243	0.228

[2] OMP-04 and OMP-08 were developed using Risk defined as "the probability that adult anchovy biomass falls below 10% of the average adult anchovy biomass between November 1984 and November 1999 at least once during the projection period of 20 years".

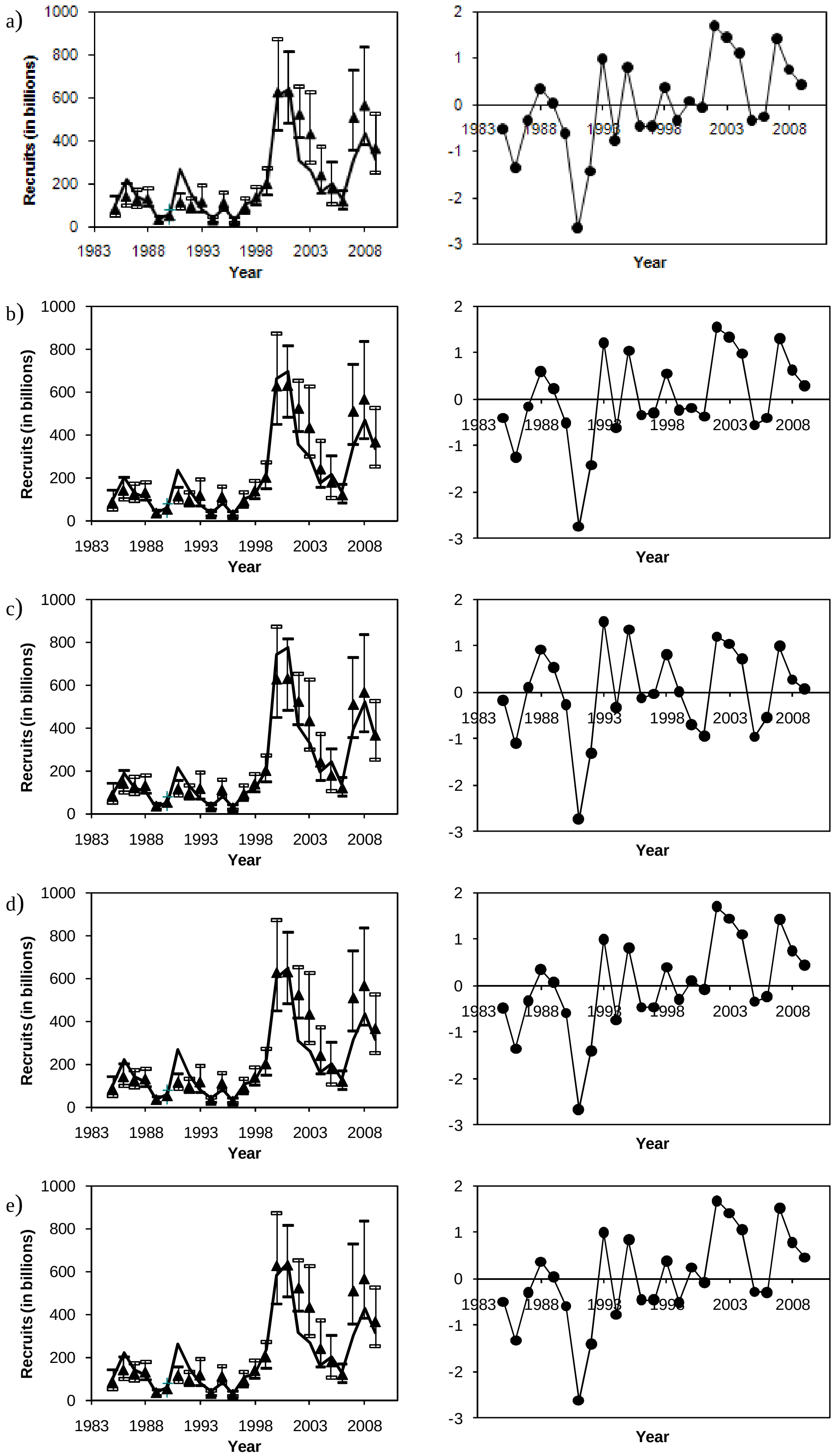


Figure 1. Acoustic survey results and model estimates for anchovy recruitment numbers from May 1985 to May 2009 for a) A_0, b) A_{Mjinc}, c) M_{j18}, d) $M_{2SRcurves}$ and e) M_{2kprop}. The survey indices are shown with 95% confidence intervals. The standardised residuals from the fit are given in the right hand plots.

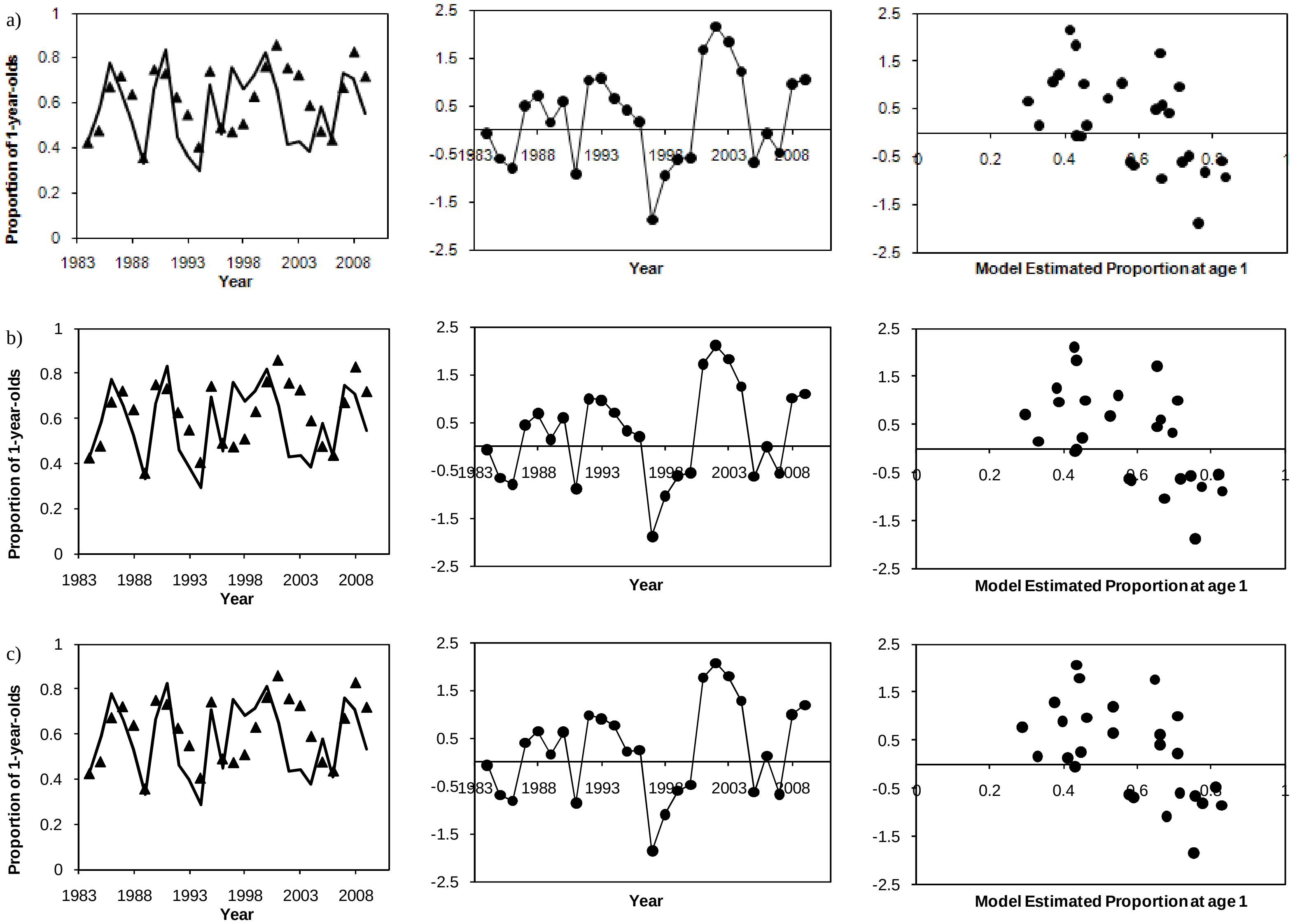
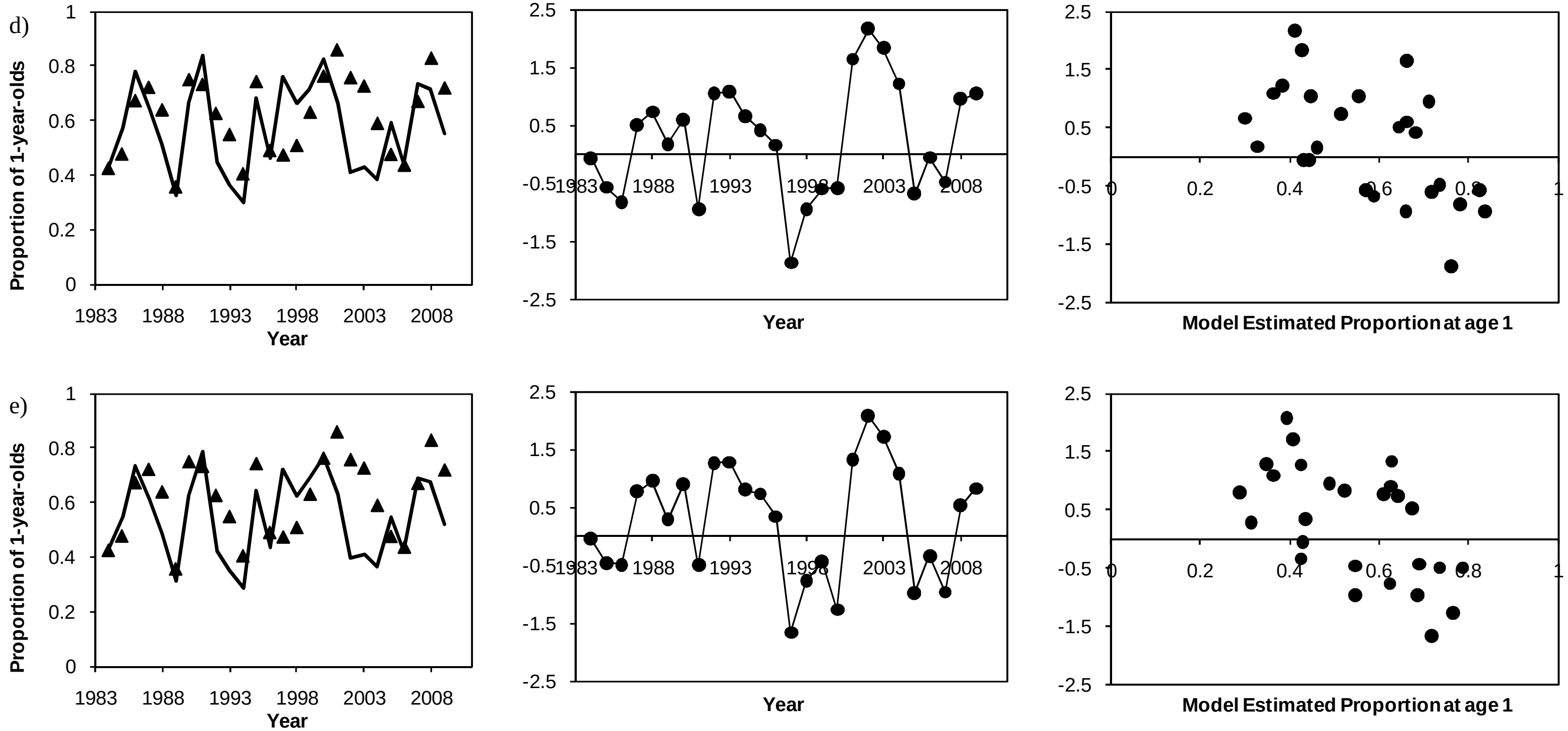


Figure 2. Acoustic survey results and model estimates for proportions of 1-year-olds in the November survey from 1984 to 2009 for a) A_0, b) A_{Mjinc}, c) M_{j18}, d) $M_{2SRcurves}$ and e) M_{2kprop}. The standardised residuals from the fit are given in the middle and right hand plots, against year and against model estimates of proportions at age 1.



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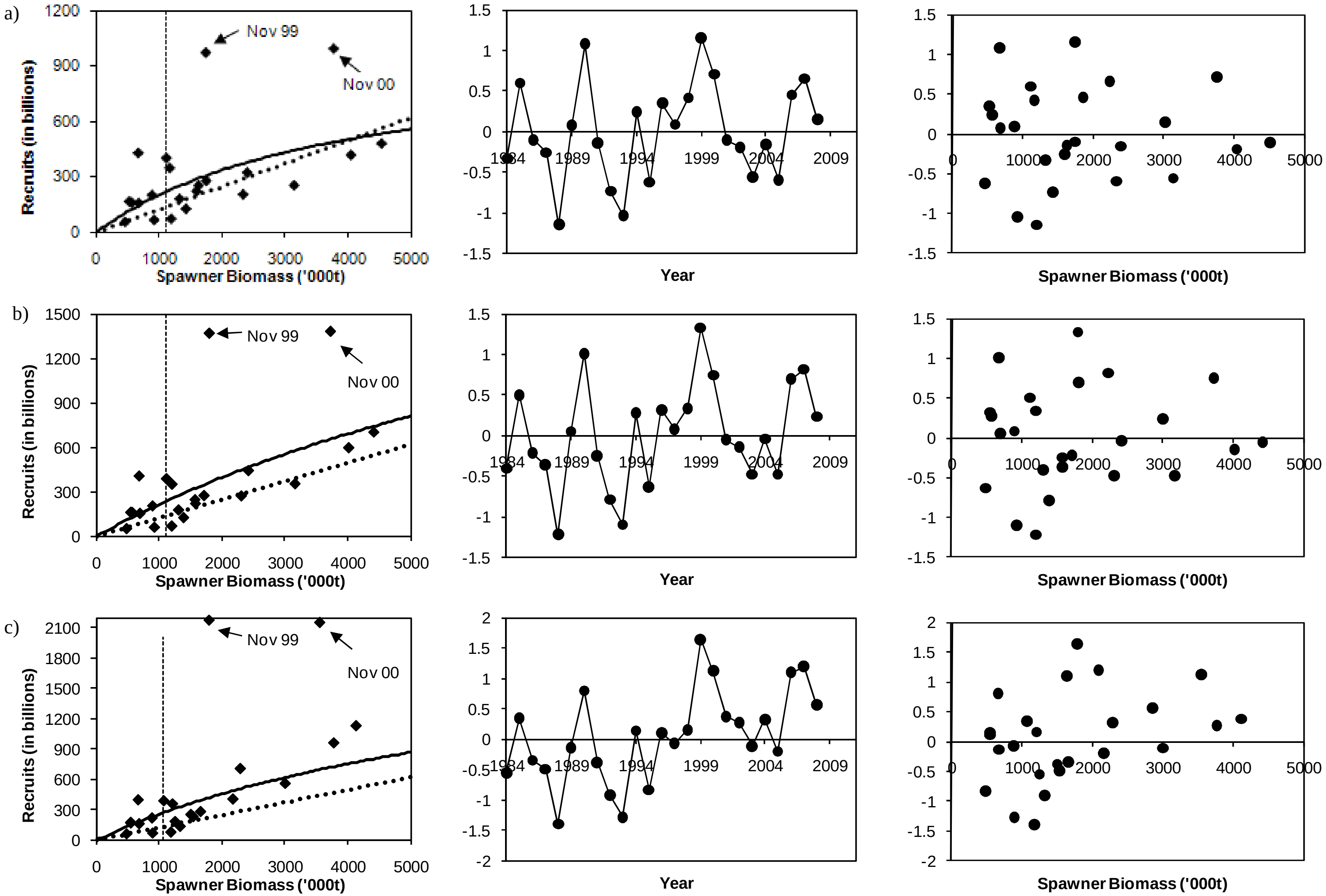

Figure 3. Model predicted anchovy recruitment (in November) plotted against spawner biomass from November 1984 to November 2008, with the Beverton Holt stock-recruit relationship, for a) A_0, b) A_{Mjinc}, c) M_{j18}, d) $M_{2SRcurves}$ and e) M_{2kprop}. The vertical thin dashed line indicates the average 1984 to 1999 spawner biomass (used in the definition of risk in OMP-04 and OMP-08). The dotted line indicates the replacement line. The standardised residuals from the fit are given in the middle and right hand plots, against year and against spawner biomass.

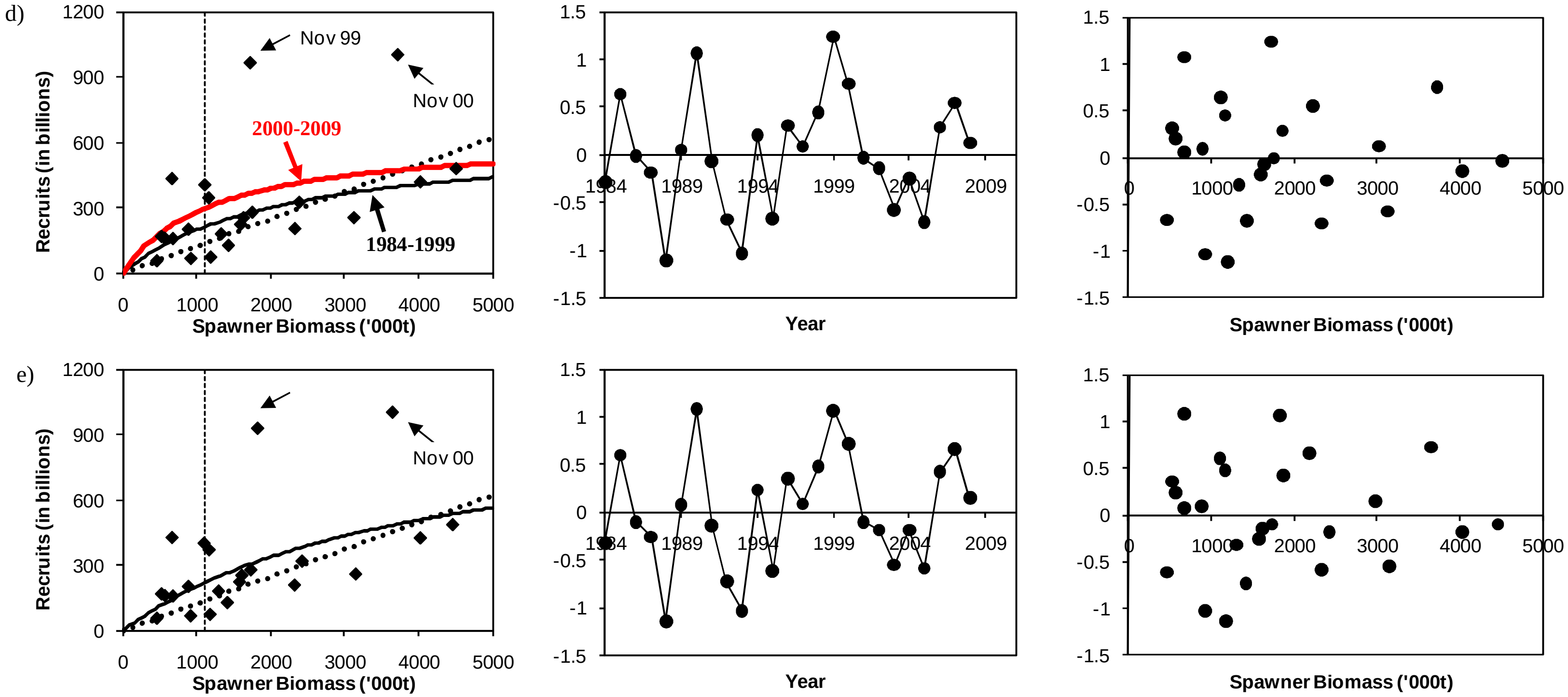

Figure 3 (cont.).