Some Robustness Tests to the Base Case Assessment of the South African Anchovy and Sardine Resources

C.L. Cunningham* and D.S. Butterworth*

Introduction

Base case results for Bayesian assessments of the South African anchovy and sardine resources have recently been presented (Cunningham and Butterworth 2004a,b). The results at the posterior mode for some robustness tests to these base case assessments are presented here.

Anchovy Robustness Tests

The robustness tests to the base case anchovy assessment considered in this document are as follows (see Table 1 for a summary):

A_0 – base case assessment (Cunningham and Butterworth 2004a)

A_{M1} – adult and juvenile natural mortality of 0.6 year^{-1}

A_{M2} – adult and juvenile natural mortality of 1.2 year^{-1}

A_{M3} – adult and juvenile natural mortality of 1.5 year^{-1}

A_{M4} – juvenile natural mortality of 1.5 year^{-1}

A_{HS} – hockey stick stock-recruitment curve with the inflection point estimated

A_{BH} – Beverton Holt stock-recruitment curve

A_R – Ricker stock-recruitment curve

A_{10} – 10cm cut-off length for calculating the proportion of 1-year-olds in the November survey

$A_{10.5}$ – 10.5cm cut-off length for calculating the proportion of 1-year-olds in the November survey

A_{11} – 11cm cut-off length for calculating the proportion of 1-year-olds in the November survey

A_{kegg1} – negatively biased egg surveys, i.e., $k_g^A = 0.75$

A_{kegg2} – positively biased egg surveys, i.e., $k_g^A = 1.25$

A_{lam1} – fix $\left(\lambda_r^A\right)^2 = 0$

A_{lam2} – estimate $\left(\lambda_N^A\right)^2$

For AHS, the prior distribution $\frac{b^A}{K^A} \sim U(0,1)$ is introduced. For A_{BH}, the prior $\frac{b^A}{K^A} \sim U(0,1)$ is again used and equation (A.5) of Cunningham and Butterworth (2004a) is replaced with

* MARAM (Marine Resource Assessment and Management Group), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701, South Africa. Email: c.l.cunningham@telkomsa.net, dll@maths.uct.ac.za.

$$N_{y,0}^{A} = \frac{a^{A} B_{y,N}^{A}}{b^{A} + B_{y,N}^{A}} e^{\varepsilon_y^A}, \qquad y = 1980, \ldots, 2002$$

and equation (A.9) is replaced with

$$K^{A} = a^{A} e^{\frac{1}{2}\left(0.4^2 + \left(\lambda_0^A\right)^2\right)} \left[\sum_{a=1}^{4} \overline{w}_a^A e^{-M_{ju}^A - (a-1) M_{ad}^A}\right] - b^{A}.$$

For A_R, equation (A.5) of Cunningham and Butterworth (2004a) is replaced with

$$N_{y,0}^{A} = a^{A} B_{y,N}^{A} e^{-b^A B_{y,N}^A} e^{\varepsilon_y^A}, \qquad y = 1980, \ldots, 2002$$

and equation (A.9) is replaced with

$$K^{A} = \frac{1}{b^{A}} \ln\left\{ a^{A} e^{\frac{1}{2}\left(0.4^2 + \left(\lambda_0^A\right)^2\right)} \left[\sum_{a=1}^{4} \overline{w}_a^A e^{-M_{ju}^A - (a-1) M_{ad}^A}\right]\right\}.$$

In addition, the prior distributions for the two stock-recruitment parameters in A_R are changed to $\ln(a) \sim U(-4,8)$ and $\ln\left(\frac{b^A}{1+b^A}\right) \sim U(-1000,1000)$.

Sardine Robustness Tests

The robustness tests to the base case sardine assessment considered in this document are as follows (see Table 5 for a summary):

S_0 – base case assessment (Cunningham and Butterworth 2004b)

S_{kN1} – unbiased November spawner biomass surveys, i.e., $k_N^S = 1$

S_{kN2} – greater negatively biased November spawner biomass surveys, i.e., $k_N^S = 0.5$

S_{M1} – adult natural mortality of 0.3 year^{-1}

S_{M2} – adult natural mortality of 0.5 year^{-1}

S_{M3} – juvenile natural mortality of 0.6 year^{-1}

S_{M4} – juvenile natural mortality of 1.4 year^{-1}

S_{BH} – Beverton Holt stock-recruitment curve

S_R – Ricker stock-recruitment curve

S_{lam1} – fix $\left(\lambda_N^S\right)^2 = 0$

S_{lam2} – fix $\left(\lambda_N^S\right)^2 = 0$ and $\left(\lambda_r^S\right)^2 = 0$

For S_{BH}, the prior distribution for a^S is modified to $a^S \sim N\left(50, 1^2\right)$, equation (A.4) of Cunningham and Butterworth (2004b) is replaced with

$$N_{y,0}^{S} = \frac{a^{S} B_{y,N}^{S}}{b^{S} + B_{y,N}^{S}} e^{\varepsilon_y^S}, \qquad y = 1979, \ldots, 2002$$

and equation (A.11) is replaced with

$$K^S = a^S e^{\frac{1}{2}\left(0.4^2+\left(\lambda_0^S\right)^2\right)} \left[\sum_{a=1}^{5} \overline{w}_a^S e^{-M_{ju}^S-(a-1)M_{ad}^S} \right] - b^S .$$

For S_R, equation (A.4) of Cunningham and Butterworth (2004b) is replaced with

$$N_{y,0}^S = a^S B_{y,N}^S e^{-b^S B_{y,N}^S} e^{\varepsilon_y^S} , \qquad y = 1980, \ldots, 2002$$

and equation (A.11) is replaced with

$$K^S = \frac{1}{b^S} \ln\left\{ a^S e^{\frac{1}{2}\left(0.4^2+\left(\lambda_0^S\right)^2\right)} \left[\sum_{a=1}^{5} \overline{w}_a^S e^{-M_{ju}^S-(a-1)M_{ad}^S} \right] \right\} .$$

In addition, the prior distributions for the two stock-recruitment parameters in S_R are changed to $a^S \sim U(-1000,1000)$ and $\ln\left(\frac{b^A}{1+b^A}\right) \sim U(-1000,1000)$.

Results

Anchovy robustness tests

The results at the posterior mode are given in Tables 1 to 4. Although the value at the posterior mode is greater for A_{M2} and A_{M3}, compared to A_0, the higher natural mortality cases are assumed to be unrealistically high. In addition, for ease of comparability with the assessments used to construct OMP-02, it is suggested that the base case assessment natural mortality remain at 0.9 year^{-1}.

The Beverton-Holt and Ricker stock-recruitment curves provide a better fit to the model at the posterior mode than A_0. In addition, estimating the inflection point, b, also results in a better fit. The stock-recruitment curves and the predicted spawner biomass and recruitment are shown in Figure 1.

The alternative ageing methods have a worse fit at the posterior mode than A_0.

Sardine robustness tests

The results at the posterior mode are given in Tables 5 to 8. The Beverton-Holt and Ricker stock-recruitment curves do not currently fit the stock-recruitment data well (Figure 2). This may be due to model mis-specification and further testing of these cases is currently underway.

Discussion and Further Work

The results at the posterior mode for some sensitivity tests to the base case sardine and anchovy assessments have been presented in this document. Given these results at the posterior mode, MCMC chains have been simulated for A_{M2}, A_{BH}, and A_{kegg2}, in addition to the MCMC chain already simulated for A_0, from which current OMP-04 trade-off curves are being calculated. A_{BH} was chosen to provide one test where the stock-recruitment curve that is different in nature to A_0. Risk may be higher under the alternative with lower true biomass (A_{kegg2}) and both of these robustness tests have a greater value at the posterior mode than A_0. Posterior distributions for these selected cases are not presented here, but candidate OMP-04 trade-off curves under these robustness tests will be presented in forthcoming documents.

S_{lam2} has a bad fit to the data (Table 5) and S_{lam1} makes little difference to the results, so these tests will not be considered further. As mentioned above, S_{BH} and S_R still need to be finalised. The effect of the sardine robustness results at the posterior mode on future projections under the base case candidate OMP-04 will first be investigated prior to MCMC chains being simulated on the tests, which may prove to have a greater effect.

References

Cunningham, C.L., and Butterworth, D.S. 2004a. Base Case Bayesian Assessment of the South African Anchovy Resource. MCM document WG/PEL/APR04/01.

Cunningham, C.L., and Butterworth, D.S. 2004b. Base Case Bayesian Assessment of the South African Sardine Resource. MCM document WG/PEL/APR04/02.

De Oliveira, J.A.A. 2003. The Development and Implementation of a Joint Management Procedure for the South African Pilchard and Anchovy Resources. PhD Thesis, University of Cape Town, South Africa.

Table 1. Assumptions and likelihood and prior values for the anchovy robustness tests at the posterior mode. Blank cells indicate no change from A_0.

Test	M_{ad}^{A}	M_{ja}^{A}	S-R curve	Ageing Method	k_g^A	$(\lambda_r^A)^2$	$(\lambda_N^A)^2$	Neg. Posterior	Neg. lnL	Neg. lnL_{Nov}	Neg. lnL_{Egg}	Neg. lnL_{Rec}	Neg. lnL_{Prop}	Neg. $lnPr(k_N)$	Neg. $lnPr(k_r)$	Neg. lnPr(del)	Neg. $lnPr(k_{prop})$
A_0	0.9	0.9	Hockey Stick	Prosch	1.0	estimated	fixed=0	45.86	20.62	-6.59	3.67	10.83	12.72	0.76	0.21	23.69	0.58
A_{M1}	0.6	0.6						50.43	27.02	-2.42	4.79	11.50	13.15	0.82	0.65	21.77	0.18
A_{M2}	1.2	1.2						43.34	17.18	-7.19	3.17	9.70	11.49	0.68	0.11	23.95	1.43
A_{M3}	1.5	1.5						42.67	15.02	-8.10	2.83	9.12	11.17	0.67	0.27	24.02	2.70
A_{M4}		1.5						47.15	21.57	-5.53	3.78	11.22	12.09	0.72	0.10	24.18	0.58
A_{HS}			Hockey Stick, b estimated					43.95	21.13	-5.44	4.18	10.40	12.00	0.79	0.21	21.23	0.59
A_{BH}			Beverton Holt					42.47	21.34	-4.49	4.37	9.56	11.90	0.74	0.20	19.60	0.59
A_R			Ricker					42.61	21.45	-4.42	4.46	9.59	11.83	0.75	0.20	19.62	0.60
A_{10}				10cm				47.20	19.96	-6.33	3.44	11.79	11.05	0.76	0.22	23.92	2.33
$A_{10.5}$				10.5cm				47.19	21.72	-6.88	3.45	10.98	14.16	0.74	0.21	23.99	0.54
A_{11}				11cm				47.63	22.56	-7.00	3.60	10.59	15.37	0.73	0.21	23.96	0.17
A_{kegg1}					0.75			47.05	21.79	-5.46	3.88	10.86	12.51	0.26	0.10	24.37	0.52
A_{kegg2}					1.25			44.95	19.84	-6.69	3.56	10.61	12.36	1.33	0.39	22.74	0.64
A_{lam1}						fixed=0		55.35	29.90	10.30	5.93	2.32	11.35	0.51	0.13	24.26	0.55
A_{lam2}							estimated	45.86	20.62	-6.59	3.67	10.83	12.72	0.76	0.21	23.69	0.58

Table 2. Key model parameters for the anchovy robustness tests at the posterior mode.

Test	k_N^A	k_r^A	k_N^A/k_r^A	k_q^A	$(\lambda_N^A)^2$	$(\lambda_r^A)^2$	$(\lambda_p^A)^2$	$(\lambda_0^A)^2$	$(\sigma_q^A)^2$
A_0	1.384	0.984	0.711	1.268	0.000	0.154	0.254	0.388	0.16
A_{M1}	1.416	1.315	0.929	0.945	0.000	0.167	0.283	0.292	0.16
A_{M2}	1.331	0.736	0.553	1.758	0.000	0.133	0.183	0.357	0.16
A_{M3}	1.325	0.583	0.440	2.435	0.000	0.123	0.167	0.360	0.16
A_{M4}	1.362	0.786	0.578	1.270	0.000	0.161	0.216	0.367	0.16
A_{HS}	1.398	0.987	0.706	1.279	0.000	0.145	0.211	0.243	0.16
A_{BH}	1.371	0.970	0.708	1.280	0.000	0.130	0.205	0.179	0.16
A_R	1.380	0.975	0.706	1.281	0.000	0.131	0.201	0.184	0.16
A_{10}	1.383	0.997	0.721	2.240	0.000	0.173	0.161	0.397	0.16
$A_{10.5}$	1.371	0.988	0.721	1.244	0.000	0.157	0.357	0.401	0.16
A_{11}	1.367	0.984	0.720	0.649	0.000	0.150	0.463	0.400	0.16
A_{kegg1}	1.035	0.791	0.764	1.233	0.000	0.154	0.241	0.377	0.16
A_{kegg2}	1.705	1.138	0.667	1.310	0.000	0.150	0.232	0.341	0.16
A_{lam1}	1.226	0.880	0.717	1.250	0.000	0.000	0.176	0.371	0.16
A_{lam2}	1.384	0.984	0.711	1.268	0.000	0.154	0.254	0.388	0.16

Table 3. Key outputs from the anchovy robustness tests at the posterior mode (numbers in billions and biomass in thousands of tonnes).

Test	$N_{2003,1}^A$	$N_{2003,2}^A$	$N_{2003,3}^A$	Average 84-99 Biomass
A_0	131.8	45.6	62.7	1022.6
A_{M1}	86.8	43.4	74.9	994.0
A_{M2}	178.0	46.1	44.8	1068.0
A_{M3}	214.9	42.3	28.5	1077.9
A_{M4}	130.7	45.2	63.1	1039.5
A_{HS}	130.5	46.5	61.1	1010.9
A_{BH}	141.6	52.1	61.6	1028.1
A_R	141.7	50.9	61.5	1022.6
A_{10}	129.2	43.5	63.0	1023.6
$A_{10.5}$	132.3	45.6	63.1	1030.4
A_{11}	133.5	46.5	62.7	1031.0
A_{kegg1}	173.1	61.0	82.8	1368.4
A_{kegg2}	106.4	36.8	51.1	829.2
A_{lam1}	198.1	105.2	67.2	1120.6
A_{lam2}	131.8	45.6	62.7	1022.6

Table 4. Key stock-recruitment parameters and outputs for the anchovy robustness tests at the posterior mode.

Test	K^A	a^A	b^A	$\sqrt{0.4^2 + \left(\lambda_0^A\right)^2}$	ε_{2002}^A	s_{cor}^A
A_0	2306.6	227.7	461.3	0.740	0.877	0.565
A_{M1}	2492.3	145.9	498.5	0.672	0.812	0.548
A_{M2}	2082.1	342.7	416.4	0.719	1.041	0.581
A_{M3}	1987.8	507.3	397.6	0.721	1.101	0.596
A_{M4}	2111.4	383.6	422.3	0.726	0.913	0.564
A_{HS}	2475.8	262.7	1083.3	0.635	0.786	0.337
A_{BH}	2976.1	503.5	1619.5	0.582	0.472	0.307
A_R	3158.7	0.3	0.0	0.587	0.465	0.288
A_{10}	2306.0	226.6	461.2	0.746	0.857	0.537
$A_{10.5}$	2330.8	228.5	466.2	0.749	0.866	0.543
A_{11}	2338.0	229.4	467.6	0.748	0.871	0.545
A_{kegg1}	2747.9	272.7	549.6	0.733	0.926	0.566
A_{kegg2}	1973.0	199.4	394.6	0.707	0.887	0.561
A_{lam1}	2451.0	243.9	490.2	0.729	1.233	0.614
A_{lam2}	2306.6	227.7	461.3	0.740	0.877	0.565

Table 5. Assumptions and likelihood and prior values for the sardine robustness tests at the posterior mode. Blank cells indicate no change from S_0.

Test	M^S_{ad}	M^S_{ju}	S-R curve	k^S_N	$(\lambda^S_r)^2$	$(\lambda^S_N)^2$	Neg. Posterior	Neg. lnL	Neg. lnL_{Nov}	Neg. lnL_{Rec}	Neg. lnL_{Prop}	Neg. $lnPr(k_r)$	Neg. lnPr(del)	Neg. $lnPr(k_{prop})$	Neg. $lnPr(var_{prop})$	Neg. lnPr(a)	Neg. $lnPr(a_2)$
S_0	0.4	1.0	Hockey Stick	0.7195	estimated	estimated	69.44	47.17	1.42	14.75	30.99	0.61	7.42	4.50	3.08	5.44	1.23
S_{kN1}				1.0			71.16	48.67	2.17	14.56	31.94	0.93	7.32	4.66	3.14	5.24	1.20
S_{kN2}				0.5			69.01	46.23	1.06	14.82	30.35	0.38	7.96	4.35	3.01	5.78	1.29
S_{M1}	0.3						74.67	48.07	1.52	14.75	31.80	0.75	10.44	4.09	3.14	7.75	0.44
S_{M2}	0.5						70.21	46.58	1.31	14.68	30.59	0.50	8.23	5.12	3.01	5.51	1.26
S_{M3}		0.6					68.01	47.28	1.85	14.34	31.09	0.80	6.36	4.48	3.07	5.21	0.81
S_{M4}		1.4					71.80	46.96	1.05	14.96	30.95	0.46	9.33	4.49	3.07	5.85	1.63
S_{BH}			Beverton Holt				92.50	47.55	3.06	14.94	29.56	0.65	32.55	4.41	2.96	4.38	N/A
S_R			Ricker				88.98	47.60	3.15	14.88	29.56	0.64	33.38	4.42	2.95	N/A	N/A
S_{lam1}						fixed=0	71.94	47.54	2.12	14.48	30.94	0.59	9.18	4.46	3.06	5.92	1.20
S_{lam2}					fixed=0	fixed=0	81.51	56.86	-0.01	15.04	41.83	0.72	8.88	4.53	4.08	5.53	0.91

Table 6. Key model parameters for the sardine robustness tests at the posterior mode.

Test	k_N^S	k_r^S	k_N^S/k_r^S	$k_{p,1}^S$	$k_{p,2}^S$	$k_{p,3}^S$	$k_{p,4}^S$	$k_{p,5}^S$	$(\lambda_N^S)^2$	$(\lambda_r^S)^2$	$(\lambda_0^S)^2$	$(\sigma_q^S)^2$
S_0	0.720	1.045	1.453	1.189	0.781	1.043	0.884	1.006	0.000	0.230	0.000	6.582
S_{kN1}	1.000	1.331	1.331	1.168	0.771	1.068	0.937	1.115	0.000	0.222	0.009	6.742
S_{kN2}	0.500	0.783	1.565	1.207	0.783	1.014	0.832	0.918	0.000	0.233	0.000	6.425
S_{M1}	0.720	1.174	1.632	1.298	0.783	0.942	0.724	0.736	0.000	0.236	0.035	6.733
S_{M2}	0.720	0.931	1.295	1.099	0.784	1.155	1.090	1.402	0.000	0.230	0.000	6.416
S_{M3}	0.720	1.221	1.697	1.189	0.778	1.036	0.877	0.998	0.000	0.219	0.000	6.573
S_{M4}	0.720	0.893	1.241	1.185	0.779	1.042	0.883	1.008	0.000	0.239	0.000	6.568
S_{BH}	6.289	0.720	1.081	1.502	1.193	0.783	1.026	0.856	0.957	0.000	0.248	0.668
S_R	0.720	1.051	1.460	1.184	0.783	1.035	0.873	0.996	0.000	0.241	0.953	6.295
S_{lam1}	0.720	1.025	1.425	1.190	0.776	1.035	0.867	0.991	0.000	0.219	0.016	6.534
S_{lam2}	0.720	1.152	1.601	1.241	0.759	1.018	0.902	1.008	0.000	0.000	0.000	9.258

Table 7. Key outputs from the sardine robustness tests at the posterior mode (numbers in billions and biomass in thousands of tonnes).

Test	$N_{2003,1}^S$	$N_{2003,2}^S$	$N_{2003,3}^S$	$N_{2003,4}^S$	Average 91-94 Biomass	S_1	S_2	S_3	S_4
S_0	31.0	22.6	15.7	7.9	898.1	0.648	1.000	0.865	0.342
S_{kN1}	23.3	16.6	11.4	5.7	662.6	0.645	1.000	0.892	0.362
S_{kN2}	43.3	32.2	22.6	11.7	1288.9	0.653	1.000	0.842	0.325
S_{M1}	37.2	22.9	16.7	9.3	874.6	0.697	1.000	0.780	0.276
S_{M2}	34.7	23.7	14.7	6.6	912.5	0.587	1.000	0.959	0.422
S_{M3}	32.4	23.5	16.5	7.9	899.0	0.638	1.000	0.873	0.346
S_{M4}	30.6	22.3	15.6	7.9	901.2	0.650	1.000	0.864	0.341
S_{BH}	22.8	20.4	18.8	6.2	3.5	952.9	0.635	1.000	0.914
S_R	27.2	22.8	18.1	6.7	933.7	0.627	1.000	0.908	0.356
S_{lam1}	37.4	25.6	17.6	7.6	893.0	0.617	1.000	0.885	0.350
S_{lam2}	32.0	23.3	15.4	7.8	907.9	0.712	1.000	0.852	0.332

Table 8. Key stock-recruitment parameters and outputs for the sardine robustness tests at the posterior mode.

Test	K^S	a^S	$a^S_{1979-1983}$	b^S	$\sqrt{0.4^2+\left(\lambda^S_0\right)^2}$	ε^S_{2002}	s^S_{cor}
S_0	6267.0	91.811	3.273	2569.6	0.400	-0.037	0.236
S_{kN1}	4891.4	71.352	3.076	1953.1	0.411	-0.062	0.232
S_{kN2}	8581.2	125.713	3.559	3845.7	0.400	-0.035	0.204
S_{M1}	31775.7	380.609	2.715	12710.4	0.442	-0.645	0.282
S_{M2}	5694.8	98.550	3.393	2288.4	0.400	0.051	0.298
S_{M3}	6921.5	67.970	2.715	2928.2	0.400	-0.143	0.190
S_{M4}	6065.4	132.560	3.798	2572.0	0.400	-0.019	0.255
S_{BH}	2063.4	25.351		353.0	0.910	1.169	0.817
S_R	3148.8	0.045	N/A	0.0005	1.038	1.228	0.715
S_{lam1}	9678.1	140.632	3.262	3871.2	0.420	-0.631	0.206
S_{lam2}	6887.8	100.890	3.130	2757.3	0.400	-0.199	0.202

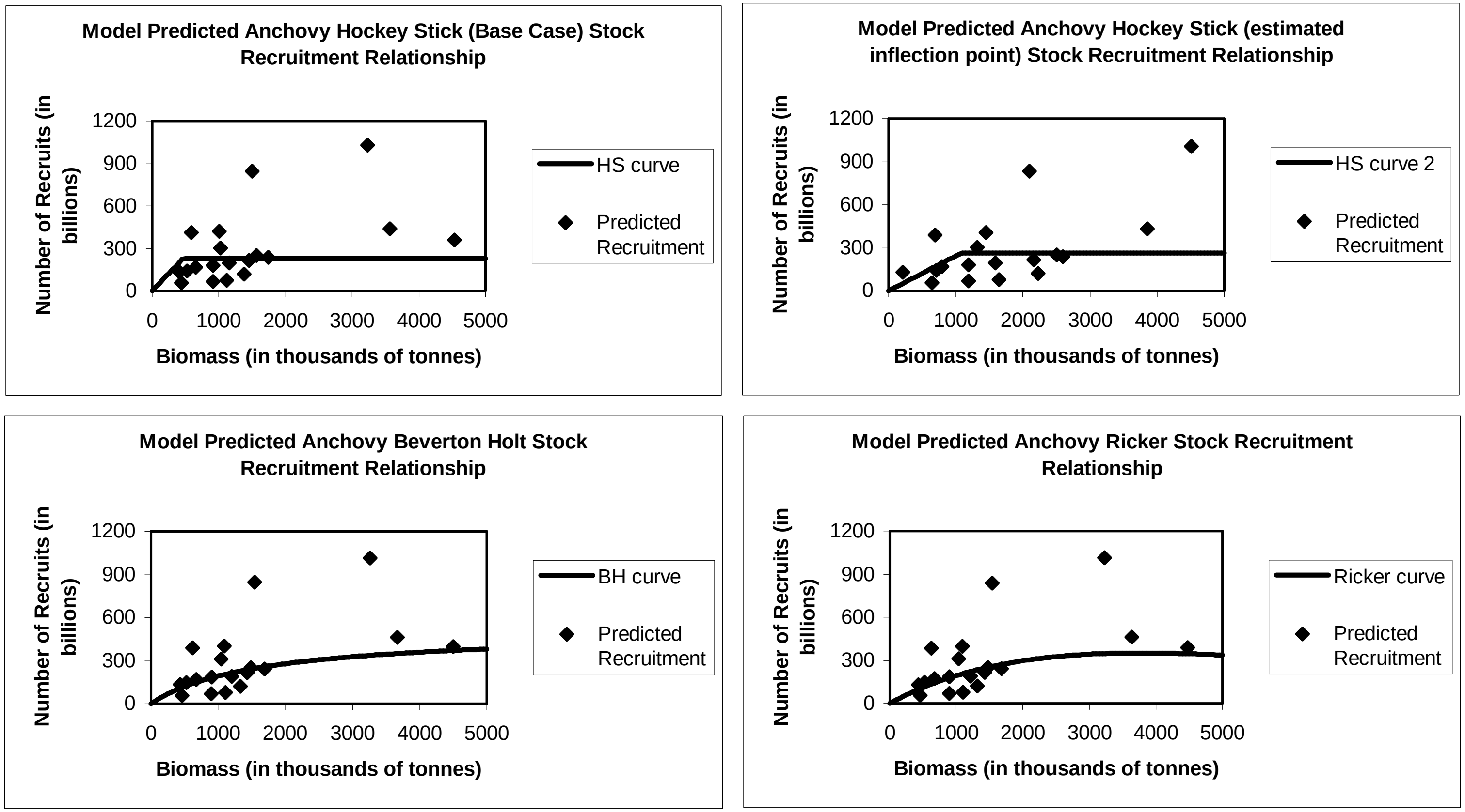

Figure 1. Model predicted November anchovy spawner biomass and recruitment with the fitted stock-recruitment curves.

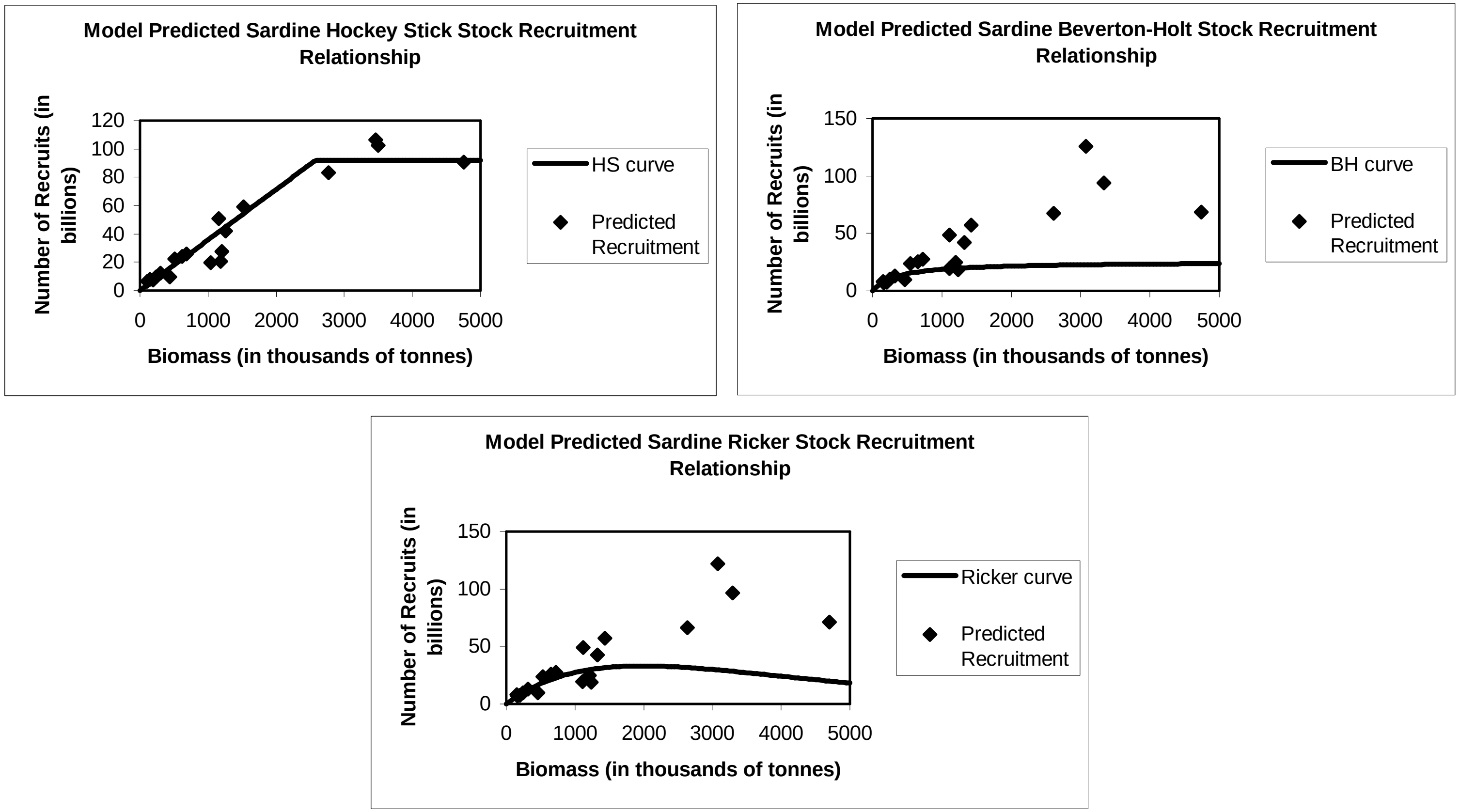

Figure 2. Model predicted November sardine spawner biomass and recruitment with the fitted stock-recruitment curves.