Preliminary Results from the Base Case Assessment of the South African Anchovy Resource

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

Introduction

The assessment of the South African anchovy resource is in the process of being updated. This document provides results from the fit of the base case assessment at the posterior mode. This base case assessment has been updated from the last assessment (Cunningham and Butterworth 2004) to take account of new data:

i) an update in the time series of November spawner biomass and May recruitment estimates from acoustic surveys, such that the new time series reflects uncapped estimates of biomass based on new target strength calculations,

ii) a new method of using a monthly cut-off length to split recruits from 1-year-olds in the commercial catch (previously recruits and 1-year-olds were assumed to be caught in different months), and

iii) new data for 2004 to 2006.

In addition, this assessment has been updated from previous assessments to include:

iv) a plus group of age 4 (previously anchovy were assumed to spawn at age 4 and then die),

v) accounting for the introduction of the additional season by assuming the juvenile catch was taken in a pulse on 15th June prior to 1999 and on 15th July from 1999 onwards,

iv) the adult catch now assumed to be taken in a pulse on 1st April (previously assumed to be taken halfway between November and March).

Bayesian Assessment Model

The population dynamics model used for the South African anchovy resource is detailed in Appendix A and the data and biological parameters used in the anchovy assessment model are listed in Appendix B. The prior distributions for the estimated parameters were chosen to be relatively uninformative. The objective function consisting of the negative log likelihood equation (A.6) added to the negative of the 31 prior distributions was minimised using AD Model Builder (Otter Research Ltd. 2000) to fit the model and estimate the parameters at the posterior mode.

* 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, doug.butterworth@uct.ac.za.

Results

The model fit to the data at the posterior mode is shown in Figure 1 for acoustic spawner biomass, Figure 2 for DEPM estimates of spawner biomass, Figure 3 for recruitment and Figure 4 for the proportion of 1-year-olds in the November survey. The model predicted November spawner biomass and recruitment at the posterior mode is shown in Figure 5, together with the model estimated hockey-stick stock-recruitment curve. The inflection point and maximum recruitment of the estimated curve are lower than that estimated by the last assessment (Table 1), with recruitment in November 1999 and 2000 being clear outliers.

Table 1 lists the values of some key model parameters and outputs at the joint posterior mode. Samples from the posterior distributions (not yet estimated, see below) of these parameters will be used to develop the new OMP. For comparative purposes, therefore, the corresponding values at the posterior mode from the last assessment used to develop OMP-04 are also given. The OMP will be tuned to specified risk criteria. When considering risk to the resource, the standard deviation in recruitment residuals is estimated to be a little higher than that used to develop OMP-04, while carrying capacity (assuming the hockey-stick curve) is lower. The average spawner biomass between 1984 and 1999, used to define risk to develop OMP-04 is 15% higher than before.

Ongoing Work

This document has detailed the model being used to assess the South African anchovy resource and provided results of the current base case hypothesis at the posterior mode. Further work is still required, including:

i) attempting to allow for early and late recruitment (centred around 1 November) using the mean weight of recruits observed during the recruit survey;

ii) testing alternative fixed values for juvenile and adult natural mortality, especially given the addition of a plus-group (alternative sets of fixed values will also be retained as robustness tests);

iii) testing robustness to alternative stock-recruitment models including Ricker and Beverton-Holt models;

iv) testing robustness to alternative methods of calculating the observed proportion-at-age 1 in the November survey (base case assumes a combined ALK while alternatives assume a cut-off length of 10cm, 10.5cm and 11cm);

The posterior distributions resulting from the finalised base case hypothesis and some key robustness tests will be used as input into the testing framework for the combined management procedure for sardine and anchovy to be finalised by the end of this year.

References

Cunningham, C.L., and Butterworth, D.S. 2004. Base Case Bayesian Assessment of the South African Anchovy Resources. MCM document WG/PEL/APR04/01. 19pp.

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.

Otter Research Ltd. 2000. An Introduction to AD Model Builder Version 4: For Use in Nonlinear Modeling and Statistics. Otter Research Ltd. (http://www.otter-rsch.com/)

Table 1. Key parameters and outputs at the joint posterior mode for the anchovy assessment for use in developing the OMP. Biomass is given in thousands of tonnes and numbers in billions.

	Previous Assessment (used to develop OMP-04)		Updated Assessment	
Starting numbers at age	$N^A_{2003,1}$	131.752	$N^A_{2006,1}$	60.738
	$N^A_{2003,2}$	45.570	$N^A_{2006,2}$	36.268
	$N^A_{2003,3}$	62.684	$N^A_{2006,3}$	12.990
			$N^A_{2006,4+}$	19.313
Starting spawner biomass	$B^A_{2003,Nov}$	3669	$B^A_{2006,Nov}$	2106
Juvenile natural mortality	M^A_{ja}	0.9 (fixed)	M^A_{ja}	0.9 (fixed)
Adult natural mortality	M^A_{ad}	0.9 (fixed)	M^A_{ad}	0.9 (fixed)
Biases for November survey	k^A_N	1.384	k^A_N	1.130
Bias for recruit survey	k^A_r	0.984	k^A_r	1.237
Stock-recruitment parameters	a^A	227.7	a^A	164.3
	b^A	461.3	b^A	350.3
	K^A	2307	K^A	1753
Last estimated recruitment residual	ε^A_{2002}	0.877	ε^A_{2005}	-0.123
Recruitment residual standard deviation	$\sqrt{0.4^2+(\lambda^A_0)^2}$	0.740	$\sqrt{0.4^2+(\lambda^A_0)^2}$	0.790
Recruitment serial correlation	s^A_{cor}	0.565	s^A_{cor}	0.579
Average 1984 – 1999 biomass[1]	$\overline{B}^A_{Nov}$	1023	$\overline{B}^A_{Nov}$	1172

[1] OMP-04 was 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".

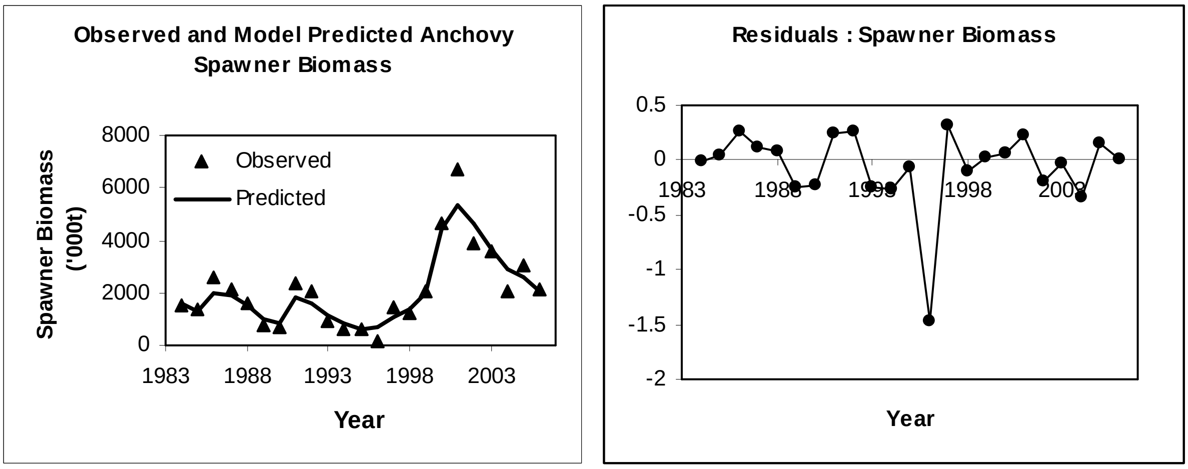

Figure 1. Acoustic survey observed and model predicted November anchovy spawner biomass from November 1984 to November 2006. The residuals from the fit are given in the right hand plot.

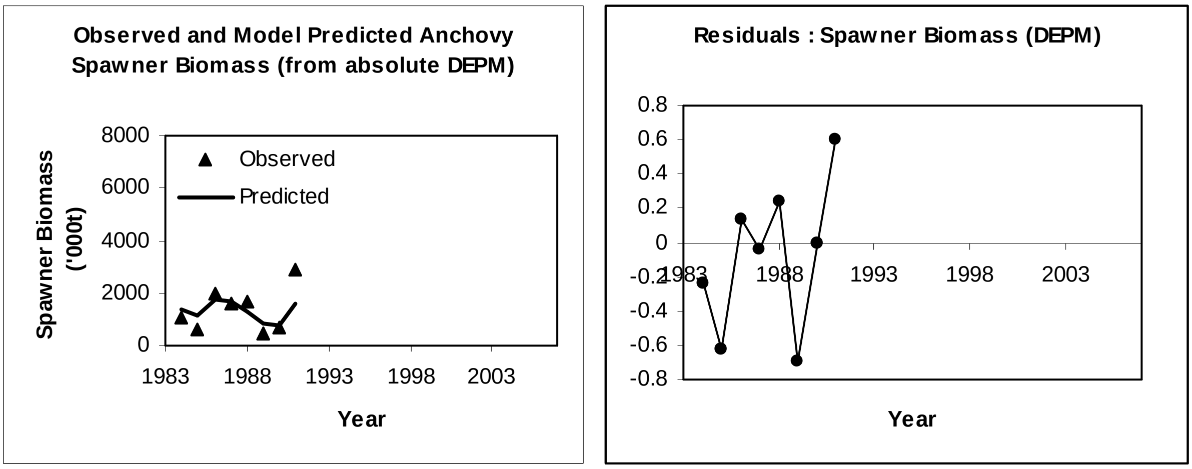

Figure 2. Egg survey observed and model predicted November anchovy spawner biomass from November 1984 to November 1991. The residuals from the fit are given in the right hand plot.

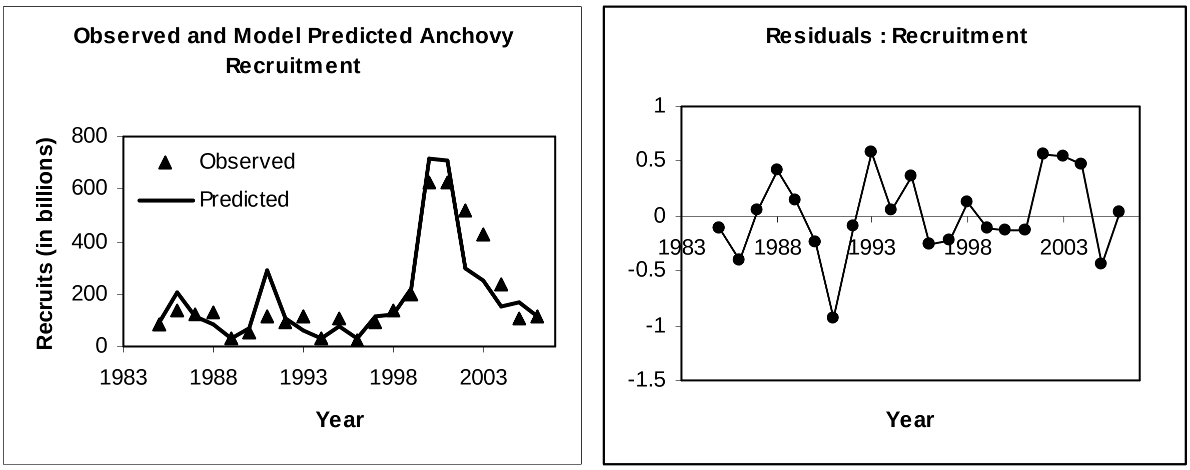

Figure 3. Observed and model predicted anchovy recruitment numbers from May 1985 to May 2006. The residuals from the fit are given in the right hand plot.

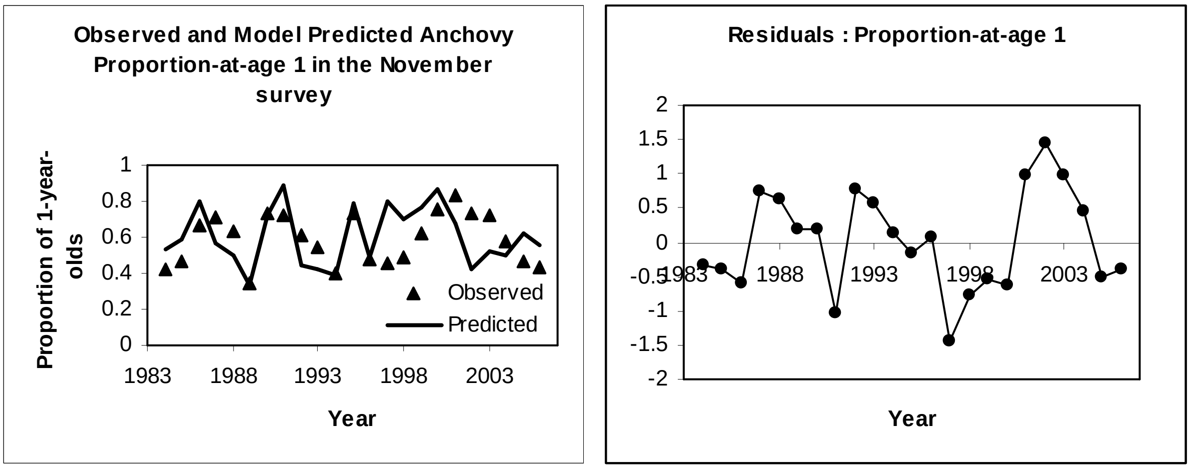

Figure 4. Observed and model predicted proportion of 1-year-olds in the November survey from November 1984 to November 2006. The residuals from the fit are given in the right hand plot.

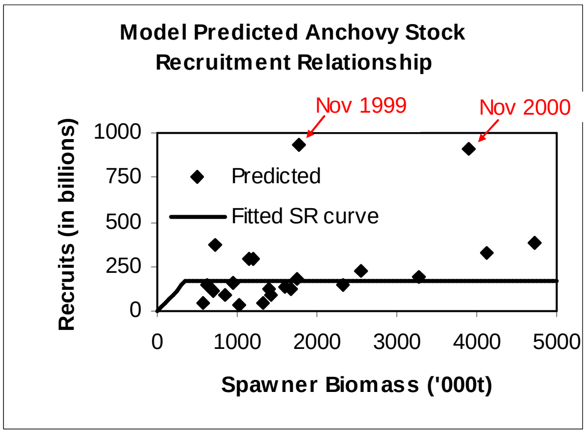

Figure 5. Model predicted anchovy recruitment (in November) plotted against spawner biomass from November 1984 to November 2005, with the 'hockey-stick' stock-recruitment curve.

APPENDIX A: Bayesian Assessment Model for the South African Anchovy Resource

Model Assumptions

1) All fish have a theoretical birthdate of 1 November.
2) Anchovy spawn for the first time (and are called adult anchovy) when they turn one year old.
3) A plus group of age 4 is assumed.
4) Two surveys are held each year: the first takes place in November and surveys the adult stock; the second is in May/June (known as the recruit survey) and surveys juvenile anchovy.
5) The November survey provides a relative index of abundance of unknown bias.
6) The recruit survey provides a relative index of abundance of unknown bias.
7) The egg survey observations (derived from data collected during the November survey) provide absolute indices of abundance.
8) The survey strategy is such that it results in surveys of invariant bias over time.
9) Pulse fishing occurs five months after 1 November for 1-year-old anchovy and 7½ months after 1 November for 0-year-old anchovy prior to 1999, 8½ months after 1 November from 1999 onwards; these are the only ages targeted by the fishery.
10) Catches are measured without error. (It is highly likely that selectivity of age 0 and age 1 anchovy varies from year to year. This would prove problematic were model predicted catch to be estimated and fitted to observed catch.)
11) Natural mortality is year-invariant for juvenile and adult fish, and age-invariant for adult fish.

Population Dynamics

Assuming that 1-year-olds are caught in a pulse at 1 April and that 0-year-olds are caught in a pulse at 1 June, the basic dynamic equations for anchovy are as follows.

Numbers-at-age at 1 November

$$N^A_{y+1,1} = (N^A_{y,0} e^{-(7.5)M^A_{ju}/12} - C^A_{y+1,0}) e^{-(4.5)M^A_{ju}/12} \qquad y = 1980, \ldots, 1998$$

$$N^A_{y+1,1} = (N^A_{y,0} e^{-(8.5)M^A_{ju}/12} - C^A_{y+1,0}) e^{-(3.5)M^A_{ju}/12} \qquad y = 1999, \ldots, 2006$$

$$N^A_{y+1,2} = (N^A_{y,1} e^{-5M^A_{ad}/12} - C^A_{y+1,1}) e^{-7M^A_{ad}/12} \qquad y = 1981, \ldots, 2006$$

$$N^A_{y+1,3} = N^A_{y,2} e^{-M^A_{ad}} \qquad y = 1982, \ldots, 2006$$

$$N^A_{y+1,4+} = N^A_{y,3} e^{-M^A_{ad}} \qquad y = 1983$$

$$N^A_{y+1,4+} = N^A_{y,4+} e^{-M^A_{ad}} + N^A_{y,3} e^{-M^A_{ad}} \qquad y = 1984, \ldots, 2006 \qquad \text{(A.1)}$$

where

$N^A_{y,a}$ is the number (in billions) of anchovy of age *a* at the beginning of November in year *y*;

$C^A_{y,a}$ is the number (in billions) of anchovy of age *a* caught from 1 November in year $y-1$ to 31 October in year y;

M^A_{ju} is the natural mortality (in year^{-1}) of juvenile anchovy (i.e. fish of age 0); and

M^A_{ad} is the natural mortality (in year^{-1}) of adult anchovy (i.e. fish of age 1+).

Biomass associated with the November survey

$$B^A_{y,N} = \sum_{a=1}^{4+} N^A_{y,a} w^A_{y,a} \qquad y = 1984, \ldots, 2006 \qquad \text{(A.2)}$$

where:

$B^A_{y,N}$ is the biomass (in thousand tons) of adult anchovy at the beginning of November in year *y*, associated with the November survey; and

$w^A_{y,a}$ is the mean mass (in grams) of anchovy of age *a* sampled during the November survey of year *y*.

Recruitment

For the base case assessment a Hockey-Stick (or Single-Sloped) stock-recruitment curve is assumed. Recruitment at the beginning of November is assumed to fluctuate lognormally about the stock-recruitment curve. Thus recruitment in November is given by:

$$N^A_{y,0} = \begin{cases} a^A e^{\varepsilon^A_y} & , \quad \text{if } B^A_{y,N} \geq b^A \\ \dfrac{a^A}{b^A} B^A_{y,N} e^{\varepsilon^A_y} & , \quad \text{if } B^A_{y,N} < b^A \end{cases} \qquad y = 1980, \ldots, 2005 \qquad \text{(A.3)}$$

where

a^A is the maximum recruitment (in billions);

b^A is the spawner biomass above which there should be no recruitment failure risk in the hockey stick model; and

ε^A_y is the annual lognormal deviation of anchovy recruitment.

Number of recruits at the time of the recruit survey

The following equation projects $N^A_{y,0}$ to the start of the recruit survey, taking natural and fishing mortality into account, and assuming pulse fishing of juveniles half way between 1 November and the start of the recruit survey.

$$N^A_{y,r} = (N^A_{y,0} e^{-0.5(6+t^A_y)M^A_{ju}/12} - C^A_{y,0bs}) e^{-0.5(6+t^A_y)M^A_{ju}/12} \qquad y = 1984,\ldots,2006 \qquad \text{(A.4)}$$

where

$N^A_{y,r}$ is the number (in billions) of juvenile anchovy at the time of the recruit survey in year *y*;

$C^A_{y,0bs}$ is the number (in billions) of juvenile anchovy caught between 1 April and the day before the start of the recruit survey in year *y*;

t^A_y is the time lapsed (in months) between 1 May and the start of the recruit survey that provided the estimate $N^A_{y,rec}$ in year *y*.

Proportions of 1-year-olds associated with November survey

$$p^A_{y,1} = \frac{N^A_{y,1}}{\sum_{a=1}^{4} N^A_{y,a}} \qquad y = 1984,\ldots,2006 \qquad \text{(A.5)}$$

where

$p^A_{y,1}$ is the proportion of 1-year-old anchovy at the beginning of November in year *y*, associated with the November survey.

<u>Fitting the Model to Observed Data (Likelihood)</u>

The observations are assumed to be log-normally distributed, and sampling CVs (squared) of the untransformed survey observations are used to approximate the "sampling" component of the total variance of the corresponding log-distributions. The proportions of 1-year-olds are first logit-transformed before being used in the likelihood. Thus we have:

$$\begin{aligned} -\ln L = & \tfrac{1}{2} \sum_{y=1984}^{2006} \left\{ \frac{\left(\ln B^A_{y,Nov} - \ln(k^A_N B^A_{y,N})\right)^2}{(\sigma^A_{y,Nov})^2 + (\lambda^A_N)^2} + \ln\left[2\pi\left((\sigma^A_{y,Nov})^2 + (\lambda^A_N)^2\right)\right] \right\} \\ & + \tfrac{1}{2} \sum_{y=1984}^{1990} \left\{ \frac{\left(\ln B^A_{y,egg} - \ln(k^A_g B^A_{y,N})\right)^2}{(\sigma^A_{y,egg})^2} + \ln\left[2\pi(\sigma^A_{y,egg})^2\right] \right\} \\ & + \tfrac{1}{2} \sum_{y=1985}^{2006} \left\{ \frac{\left(\ln N^A_{y,rec} - \ln(k^A_r N^A_{y,r})\right)^2}{(\sigma^A_{y,rec})^2 + (\lambda^A_r)^2} + \ln\left[2\pi\left((\sigma^A_{y,rec})^2 + (\lambda^A_r)^2\right)\right] \right\} \\ & + \frac{1}{2} \sum_{y=1984}^{2006} \left\{ \frac{\left(\ln\left(p^{A,meth}_{y,1,Nov} \big/ \left(1 - p^{A,meth}_{y,1,Nov}\right)\right) - \ln\left(k^A_p \times p^A_{y,1} \big/ \left(1 - p^A_{y,1}\right)\right)\right)^2}{\left(\sigma^A_p\right)^2} + \ln\left[2\pi\left(\sigma^A_p\right)^2\right] \right\} \end{aligned} \qquad \text{(A.6)}$$

where

$B^{A}_{y,Nov}$ is the acoustic survey estimate (in thousand tons) of adult anchovy biomass from the November survey in year *y*, with associated CV $\sigma^{A}_{y,Nov}$ and constant of proportionality (multiplicative bias) k^{A}_{N};

$B^{A}_{y,egg}$ is the egg survey estimate (in thousand tons) of adult anchovy biomass from the November survey in year *y*, with associated CV $\sigma^{A}_{y,egg}$ and constant of proportionality k^{A}_{g};

$N^{A}_{y,rec}$ is the acoustic survey estimate (in billions) of anchovy recruitment from the recruit survey in year *y*, with associated CV $\sigma^{A}_{y,rec}$ and constant of proportionality k^{A}_{r};

$p^{A,meth}_{y,1,Nov}$ is an estimate of the proportion (by number) of 1-year-old anchovy in the November survey of year *y*, derived by one of two methods (*meth*=Prosch uses the Prosch age length keys, and *meth*=10/10.5/11cm uses a cut-off length in the raised length frequencies for the corresponding survey);

k^{A}_{p} is a multiplicative bias associated with the proportion of 1-year-olds in the November survey;

$(\lambda^{A}_{N/r})^2$ is the additional variance (over and above the survey sampling CV $\sigma^{A}_{y,Nov/rec}$ that reflects survey inter-transect variance) associated with the November/recruit surveys;

σ^{A}_{p} is the standard deviation associated with the proportion of 1-year-olds in the November survey, which is estimated in the fitting procedure by:

$$\sigma^{A}_{p} = \sqrt{\sum_{y=1984}^{2006}\left[\ln\left(p^{A,meth}_{y,1,Nov}\Big/\left(1-p^{A,meth}_{y,1,Nov}\right)\right)-\ln\left(k^{A}_{p}\times p^{A}_{y,1}\Big/\left(1-p^{A}_{y,1}\right)\right)\right]^2 \Big/ \sum_{y=1984}^{2006}1}$$

<u>Fixed Parameters</u>

Four parameters are fixed externally in this assessment:

$M^{A}_{ju} = M^{A}_{ad} = 0.9$ (De Oliveria 2003),

$\left(\lambda^{A}_{N}\right)^2 = 0$, and

$k^{A}_{g} = 1$, as the egg survey estimates of abundance are assumed to be absolute.

In the base case assessment, it is assumed that $b^A = 0.2K^A$, where carrying capacity, K^A, is defined as:

$$K^{A} = a^{A} e^{\frac{1}{2}\left(0.4^2+\left(\lambda^{A}_{0}\right)^2\right)}\left[\sum_{a=1}^{4+}\overline{w}^{A}_{a} e^{-M^{A}_{ju}-(a-1)M^{A}_{ad}}\right] \qquad \text{(A.7)}$$

where

$\overline{w}^{A}_{a}$ is the average of $w^{A}_{y,a}$ defined above.

The $e^{\frac{1}{2}\left(\sigma_r^A\right)^2}$ factor (see below for definition) in the above equation corrects for log-normal distribution bias.

Estimable Parameters and Prior Distributions

The recruitments are assumed to fluctuate lognormally about the stock-recruitment curve. The parameterisation for the multi-dimensional search is structured in such a way that the search is actually performed over $\varepsilon_{1981}^A, \ldots, \varepsilon_{2005}^A$, with

$$\varepsilon_{1980}^A = -\sum_{y=1981}^{2005} \varepsilon_y^A .$$

For the estimable recruitment residuals we have

$$\varepsilon_y^A \sim N\left(0, \left(\sigma_r^A\right)^2\right) \quad , \qquad y = 1981, \ldots, 2005$$

where $\left(\sigma_r^A\right)^2 = 0.4^2 + \left(\lambda_0^A\right)^2$

$(\lambda_0^A)^2$ is the additional variance (over and above the fixed variance of 0.4^2) associated with the recruitment residuals, where the fixed variance has been introduced to avoid the overall variance being estimated to be unrealistically small.

The remaining estimable parameters are defined as having the following near non-informative prior distributions:

$k_N^A \sim \log N\left(1, 0.5^2\right)$[2]

$k_r^A \sim \log N\left(1, 0.5^2\right)$

$k_p^A \sim \log N\left(1, 0.5^2\right)$

$\left(\lambda_r^A\right)^2 \sim U(0, 10000)$

$\left(\lambda_0^A\right)^2 \sim U(0, 10000)$

$\log(a) \sim U(0, 8)$

Further Outputs

Recruitment serial correlation:

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[2] Here the convention is used that in x ~ logN(m,σ^2), m denotes the median of x and σ^2 denotes the variance of the logarithm of x.

$$s_{cor}^{A} = \frac{\sum_{y=1984}^{2004} \varepsilon_y \varepsilon_{y+1}}{\sqrt{\left(\sum_{y=1984}^{2004} \varepsilon_y^2\right)\left(\sum_{y=1984}^{2004} \varepsilon_{y+1}^2\right)}} \qquad \text{(A.8)}$$

and the standardised recruitment residual value for 2005:

$$\eta_{2005}^{A} = \frac{\varepsilon_{2005}^{A}}{\sigma_r^{A}}\,. \qquad \text{(A.9)}$$

are also required as input into OMP-04.

Appendix B: Tables of Data Used in the Anchovy Assessment

Table B.1. Anchovy catch-at-age (in billions) and weights-at-age in the catch (in grams), where $C^A_{y,a}$ *is the catch-at-age a from 1 November in year y-1 to 31 October in year y and* $w^A_{y,ac}$ *is the corresponding mean weights-at-age.*

Year	$C^A_{y,0}$	$C^A_{y,1}$	$w^A_{y,0c}$	$w^A_{y,1c}$
1981	0.000179	-	7.85	-
1982	0.000199	0.000107	5.80	10.81
1983	0.000164	0.000027	6.97	10.63
1984	0.029988	0.009416	5.65	10.21
1985	0.035277	0.008544	5.24	11.11
1986	0.050114	0.006250	4.54	11.57
1987	0.028038	0.034025	6.52	12.27
1988	0.048451	0.021237	5.73	13.75
1989	0.019001	0.014283	6.41	12.30
1990	0.032169	0.001118	4.29	11.99
1991	0.024742	0.001475	5.51	9.95
1992	0.059421	0.007874	4.26	12.20
1993	0.031857	0.009229	4.08	11.46
1994	0.021612	0.005470	4.36	11.29
1995	0.040036	0.001632	4.04	9.27
1996	0.006142	0.001418	4.77	9.29
1997	0.012015	0.000060	4.96	13.03
1998	0.021878	0.000764	4.54	11.11
1999	0.035061	0.000428	4.97	11.00
2000	0.045941	0.002839	5.12	11.37
2001	0.055658	0.002652	4.67	9.59
2002	0.043362	0.003340	4.18	10.39
2003	0.062091	0.001167	3.90	11.68
2004	0.039136	0.001605	4.55	8.99
2005	0.032838	0.008917	5.75	10.46
2006	0.029488	0.001331	4.08	10.86

Table B.2. Summary of annual uncapped estimates for the anchovy spawner biomass surveys, using the new target strength expression (in thousands of tonnes). Biomass and CVs from 1984 to 1996 have been calibrated on a regression of data from 1997 to 2006. Estimates of abundance (in thousands of tonnes) from daily egg production methods are also given with their associated CVs. The mean masses-at-age, $w^A_{y,a}$, observed during the spawner biomass survey are also given, based on a combined age-length-key (ALK) from ALKs developed by Prosch for 1992 to 1995 (MCM Unpublished data). The estimated proportion of 1-year-old from the November survey, $p^{A,Prosch}_{y,1,Nov}$, using the same combined ALK is also given.

Year	Acousic Spawner Abundance	CV	$w^P_{y,1}$	$w^P_{y,2}$	$w^P_{y,3}$	$w^P_{y,4+}$	DEPM Spawner Abundance	CV	$p^{A,Prosch}_{y,1,Nov}$
1984	1553.8	0.28	12.80	15.15	16.62	17.20	1100	0.45	0.421
1985	1366.3	0.21	10.81	13.97	16.10	16.44	616	0.40	0.470
1986	2568.6	0.17	10.03	14.13	16.27	17.33	2001	0.35	0.667
1987	2108.8	0.16	10.00	14.05	16.42	17.77	1606	0.30	0.715
1988	1607.1	0.22	10.26	13.09	15.35	16.83	1679	0.35	0.634
1989	751.5	0.17	12.47	14.38	15.41	15.62	421	0.35	0.350
1990	651.7	0.18	8.83	13.52	16.18	17.70	723	0.58	0.738
1991	2327.8	0.16	8.40	12.07	14.04	15.29	2931	0.35	0.723
1992	2088.0	0.16	9.02	12.62	14.00	14.98	-	-	0.614
1993	916.4	0.21	9.63	12.65	14.18	14.90	-	-	0.544
1994	617.3	0.16	11.10	14.62	15.90	16.07	-	-	0.401
1995	601.3	0.22	7.02	11.27	13.56	14.16	-	-	0.734
1996	162.0	0.41	9.85	16.41	17.85	17.74	-	-	0.478
1997	1482.6	0.27	10.68	15.53	18.04	17.63	-	-	0.459
1998	1229.1	0.22	9.65	17.15	19.99	19.41	-	-	0.492
1999	2052.2	0.16	9.66	15.20	18.58	18.13	-	-	0.623
2000	4653.8	0.13	8.13	12.08	14.31	15.28	-	-	0.756
2001	6720.3	0.11	6.92	11.60	14.14	15.52	-	-	0.837
2002	3867.6	0.15	8.22	12.14	13.70	15.10	-	-	0.733
2003	3563.2	0.24	8.49	11.98	14.31	16.91	-	-	0.718
2004	2044.6	0.13	10.30	13.52	15.30	16.36	-	-	0.580
2005	3077.0	0.14	10.48	16.27	18.30	18.09	-	-	0.470
2006	2106.3	0.14	10.26	16.47	18.75	19.27	-	-	0.428
		Average:	9.72	13.94	16.01	16.73			

Table B.3. Summary of annual uncapped estimates of anchovy recruitment, using the new target strength expression (in billions). Recruitment and CVs from 1985 to 1996 have been calibrated on a regression of data from 1997 to 2006. The mean weight of the recruits during the survey is given (in grams) together with the time of the recruit survey after 1 May, t_y^A*, and the recruit catch taken prior to the commencement of the recruit survey (in billions),* $C_{y,0bs}^A$.

Year	Recruitment	CV	Mean Weight of Recruits	t_y^A	$C_{y,0bs}^A$
1985	83.46	0.26	4.18	0.613	0.014446
1986	139.30	0.18	4.43	1.300	0.021078
1987	124.44	0.16	5.44	2.613	0.013610
1988	129.01	0.16	4.35	1.867	0.012445
1989	33.14	0.20	4.87	1.233	0.012421
1990	51.15	0.23	3.32	1.700	0.031131
1991	113.58	0.15	4.58	0.194	0.012328
1992	93.71	0.17	4.57	0.387	0.012865
1993	115.07	0.26	3.90	0.645	0.001212
1994	30.56	0.18	3.53	0.129	0.004234
1995	110.40	0.18	3.55	1.300	0.012511
1996	25.97	0.23	2.80	1.133	0.004051
1997	90.40	0.19	4.47	0.516	0.000166
1998	136.52	0.15	3.31	0.613	0.006083
1999	199.23	0.16	4.08	0.290	0.001843
2000	624.68	0.17	3.97	0.452	0.008120
2001	627.20	0.13	3.23	0.129	0.005803
2002	520.41	0.12	2.96	0.129	0.001620
2003	430.31	0.19	3.23	0.419	0.003067
2004	238.57	0.22	4.45	0.226	0.003871
2005	107.40	0.27	3.01	0.387	0.004292
2006	117.46	0.18	2.21	0.581	0.000908