Updated Sardine Assessment

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The previous full assessment of the SA sardine resource, used to develop OMP-08, was tuned to data up to and including November 2006 (Cunningham and Butterworth 2007, with further undocumented updates). Since then 2 further years of below average recruitment have been observed in the May recruitment surveys, together with a low November 2007 survey biomass estimate. This document presents an update of the sardine assessment (posterior modes only), now taking data up to October 2008 into account. This is to obtain a better understanding of the current status of the population and assist in 2009 directed sardine fishery planning.

Methods

The new data used in this assessment, other than those used in the previous assessment and documented in Cunningham *et al*. 2007, are detailed in the Appendix.

The base case model is identical to the model implemented to produce the Bayesian posterior distributions used to develop OMP-08 (Cunningham and Butterworth 2007, with further undocumented updates). This is the case for which the model was fitted to survey estimates of November biomass and May recruitment only. Selectivity was estimated to be near 0.43 for age 1 (year-dependent) and fixed at 1 for the remaining ages for all years and quarters, a result from the full model which included catch-at-length data. The additional variance parameters, λ_N^S and λ_R^S are set to zero and the proportions-at-age for the initial year are fixed ($Nprop_0^S = 0.31$, $Nprop_1^S = 0.23$, $Nprop_2^S = 0.45$, $Nprop_3^S = Nprop_{4+}^S = 0.01$).

Due to time constraints, only model runs to provide posterior modes have been carried out. Since past assessments have struggled to predict declines as large as suggested by the series of November biomass estimates over recent years, the main focus of sensitivity tests has been to see whether increasing the values previously input for natural mortality leads to improved model fits. Thus the following sensitivity tests are considered in addition to the base case:

i) estimating the additional variance parameters λ_N^S and λ_R^S;
ii) "Incr. M(1)" – an increase of 0.2 year^{-1} in the juvenile and adult natural mortality;
iii) "Incr. M(2)" – an increase of 0.4 year^{-1} in the juvenile and adult natural mortality;
iv) "Incr. M5+" – an increase in the natural mortality of age 5+ sardine to 100% more than that of ages 1 to 4;

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v) "Incr. both" – an increase of 0.2 $year^{-1}$ in the juvenile and adult natural mortality and an increase in the natural mortality of age 5+ sardine to 100% more than that of ages 1 to 4;

vi) "CV=0.1" – a hypothetical decrease in the observed CVs to 0.1 in the most recent 3 survey observations (May 2007, November 2007 and May 2008). This is to try to force the model to fit the last three survey observations more closely.

Results and Discussion

When the additional variance parameters are estimated instead of fixed at zero, the likelihood improves slightly, but there is little difference in the estimated parameter values from the base case.

The time series of model predicted sardine November 1+ biomass at the posterior mode from the updated base case assessment is compared to that of the previous assessment in Figure 1. Figure 2 compares this model predicted 1+ biomass in the most recent years between the updated base case assessment and sensitivity tests.

Although the sensitivity tests allowing for an increase in natural mortality result in a more rapid decrease in November 1+ biomass from the peak compared to the base case, the model predicted November 2007 1+ biomass is substantially higher than that observed (Figure 2, Table 1). Attempting to force the model to fit the most recent data points ("CV=0.1") results in a predicted November 2007 1+ biomass of 305 000t, much closer to the observed 257 000t than the base case, but the overall fit to the data is worse (Table 1). Attempting to force the model to fit the November 2007 observation only (i.e. not changing the CVs on the recent May recruitment surveys) predicts a November 2007 1+ biomass of 298 000t and that in November 2008 being 80% of 2007. However the fit to the observed data in this latter case is worse than the base case and thus results are not presented.

The time series of model predicted sardine May recruitments at the posterior mode from the updated base case assessment is compared to that of the previous assessment in Figure 3. Figures 4 and 5 show the negative residuals in the fit of the updated assessment to the observed survey data in the most recent years. The stock recruitment relationship is plotted in Figure 6 with associated recruitment residuals shown in Figure 7.

Implications for 2009 directed sardine TAC

The inability of the base case model and most sensitivity tests to explain the rapid decrease in biomass reflected by the November 2007 survey may imply that the result from that survey reflects random fluctuation below the true abundance arising from survey sampling error. The base case model predicted November 2008 1+ biomass is 440 000t. If the November 2008 survey returns this result, a 2009 directed sardine TAC recommendation of 90 000t would follow under OMP-08 (enforced by the minimum TAC constraint in the absence of exceptional circumstances being declared). However, in all but one of the

cases examined, the November 2008 1+ biomass is predicted to be lower than that in November 2007 (Figure 8, Table 1). The base case model predicted November 2008 1+ biomass is 86% of that predicted in November 2007. Such a decrease from the observed November 2007 1+ biomass would be 221 000t. If this is the result from the November 2008 survey, the initial 2009 directed sardine TAC recommendation under OMP-08 would be 19 000t, with an increase of between 0 and 23 000t after the May recruit survey results are known (enforced by the declaration of exceptional circumstances for sardine).

In summary then, the implications of this updated assessment for the likely 2009 directed sardine TAC are ambivalent. On the positive side, there are some indications that the abundance in November 2007 may have been higher than estimated by the survey at that time. However, on the negative side, the actual biomass in November 2008 is likely to be lower than that a year previously.

Acknowledgements

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References

Cunningham, C.L., and Butterworth, D.S. 2007. Base Case Assessment of the South African Sardine Resource. MCM/2007/SEP/SWG-PEL/06. 30pp.

Cunningham, C.L., van der Westhuizen, J.J., Durholtz D. and Coetzee, J. 2007b. A Record of the Generation of Data Used in the Sardine and Anchovy Assessments. MCM Document MCM/2007/SEPT/SWG-PEL/03. 28pp.

Table 1. Key model parameter values and model outputs estimated at the joint posterior mode (see Glossary for definitions). Fixed values are given in bold. Numbers are reported in billions and biomass in thousands of tonnes.

Parameter	Previous Assessment (Data up to Nov 2006)		Updated Assessment (Data up to Oct 2008)					
	Base Case	Input to OMP08	Base Case	Incr. M (1)	Incr. M (2)	Incr. M(5+)	Incr. both	CV=0.1
M_0^S	**1.0**	**1.0**	**1.0**	**1.2**	**1.4**	**1.0**	**1.2**	**1.0**
M_a^S, $a=1,\ldots,4$	**0.8**	**0.8**	**0.8**	**1.0**	**1.2**	**0.8**	**1.0**	**0.8**
M_{5+}^S	**0.8**	**0.8**	**0.8**	**1.0**	**1.2**	**1.6**	**1.5**	**0.8**
-ln(posterior)	9.28		15.81	13.57	12.96	14.43	12.82	17.81
-lnL over 1984-2006			14.39	15.86	20.24	14.26	16.28	17.27
k_N^S	0.75	0.75	0.75	0.76	0.76	0.76	0.75	0.81
k_r^S	0.34	0.34	0.37	0.27	0.19	0.38	0.26	0.49
k_r^S / k_N^S	0.46	0.46	0.50	0.35	0.25	0.50	0.35	0.60
$(\lambda_N^S)^2$	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**
$(\lambda_r^S)^2$	0	**0**	**0**	**0**	**0**	**0**	**0**	**0**
$\overline{B}_{Nov}^S$	555.7	552.8	545.7	571.3	577.6	559.3	571.7	475.1
$\hat{B}_{2007,N}^S$	N/A	N/A	511.3	456.8	446.2	462.5	442.4	304.9
$\hat{B}_{2008,N}^S$	N/A	N/A	440.2	429.6	468.4	394.8	419.8	256.9
$\hat{B}_{2008,N}^S / \hat{B}_{2007,N}^S$	N/A	N/A	0.86	0.94	1.05	0.85	0.95	0.84
K_{normal}^S	2874.5	2859.0	1878.4	2537.8	2344.3	2514.6	2420.6	1729.9
K_{peak}^S	4500.9	4500.2	4389.2	4173.2	4129.6	3908.6	4042.6	3753.6
a^S	77.7	77.9	46.3	101.0	142.9	68.3	101.9	39.8
b^S	788.6	786.0	507.4	732.3	585.2	866.7	724.6	470.7
c^S	72.6	72.7	67.5	99.9	147.6	64.5	101.1	51.5
σ_r^S (peak years)	0.42 (1.27)	**0.4** (1.27)	0.60 (1.30)	0.52 (1.31)	0.40 (1.30)	0.59 (1.33)	0.49 (1.32)	0.71 (1.39)
η_{2005}^S or η_{2007}^S	-1.032	-1.043	-1.359	-1.09	-1.155	-1.025	-1.037	-0.852
s_{cor}^S	0.319	0.329	0.333	0.403	0.452	0.378	0.408	0.372

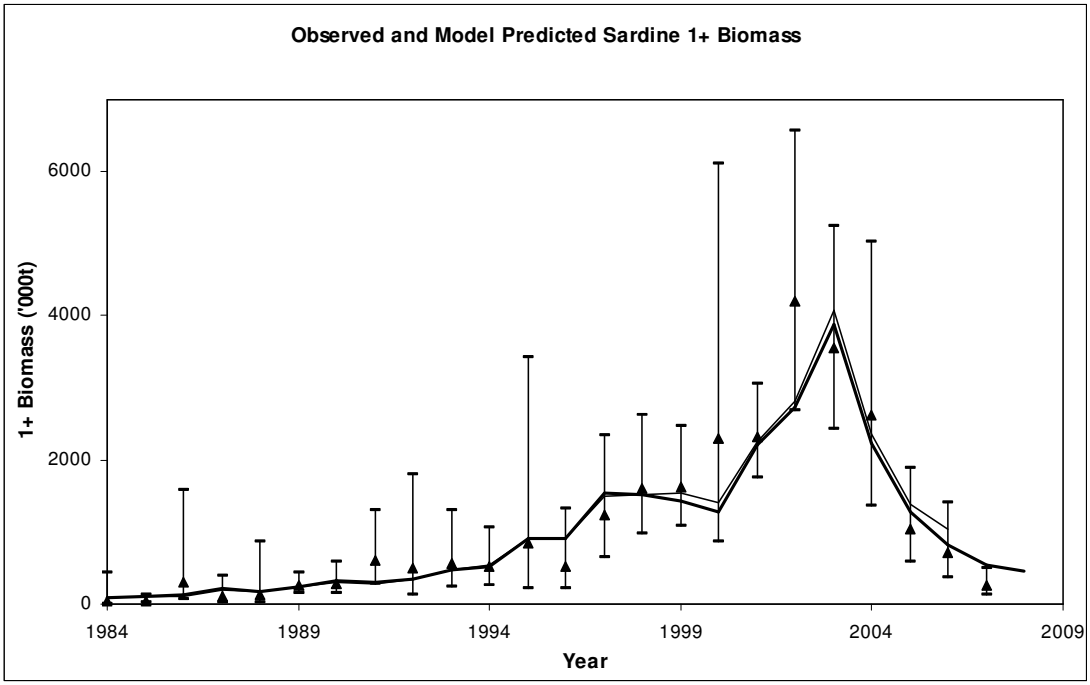

Figure 1. Observed and model predicted sardine 1+ biomass from the previous assessment (thin line) and the base case updated assessment (thick line). The observed indices are shown with 95% confidence intervals.

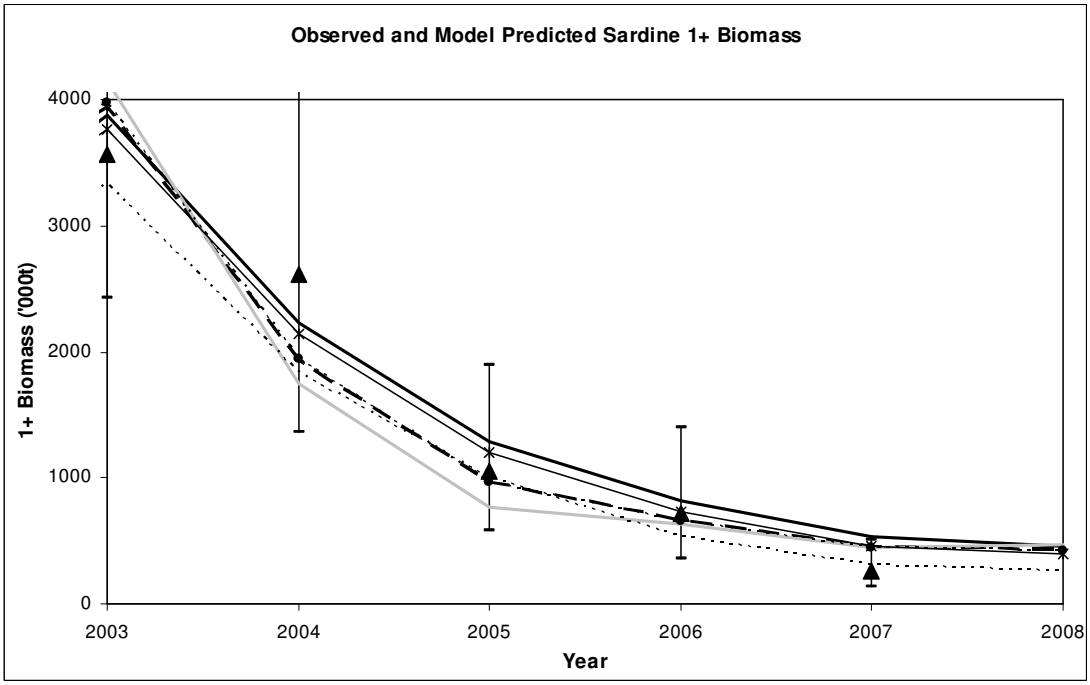

Figure 2. Observed and model predicted sardine 1+ biomass from 2003-2008 only, from the base case updated assessment (thick line), and sensitivity tests Incr. M(1) (thick dashed line), Incr. M(2) (thick grey straight line), Incr. M(5+) (thin straight line with stars), Incr. both (dotted line with circles), CV=0.1 (dotted line). The observed indices are shown with 95% confidence intervals.

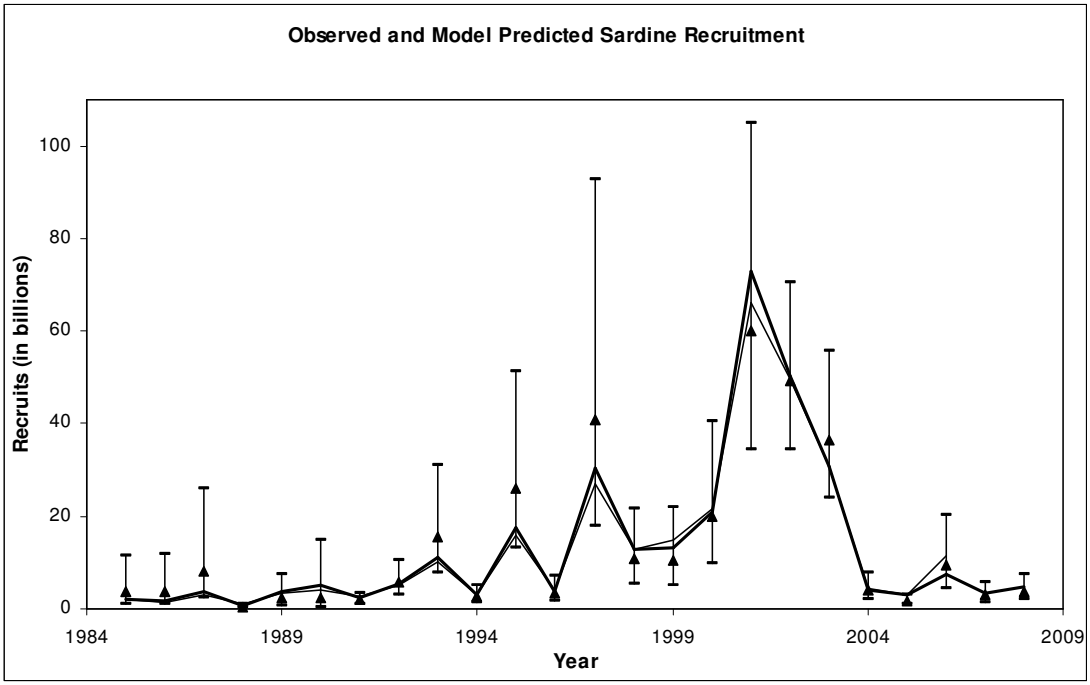

Figure 3. Observed and model predicted sardine May recruitment from the previous assessment (thin line) and the base case updated assessment (thick line). The observed indices are shown with 95% confidence intervals.

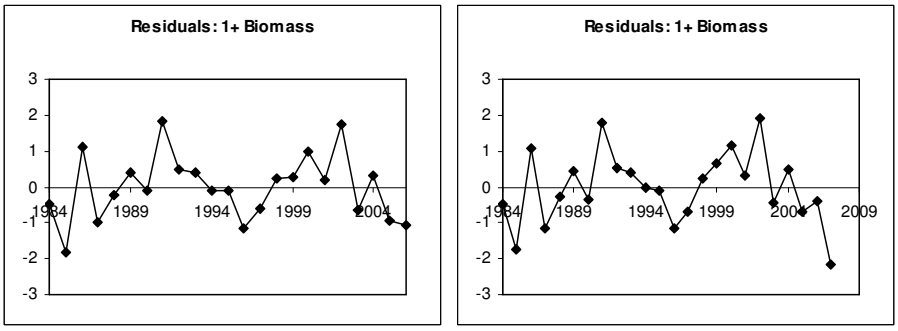

Figure 4. Standardised residuals of the model fit to the November 1+ biomass data from the previous assessment (left panel) and the base case updated assessment (right panel).

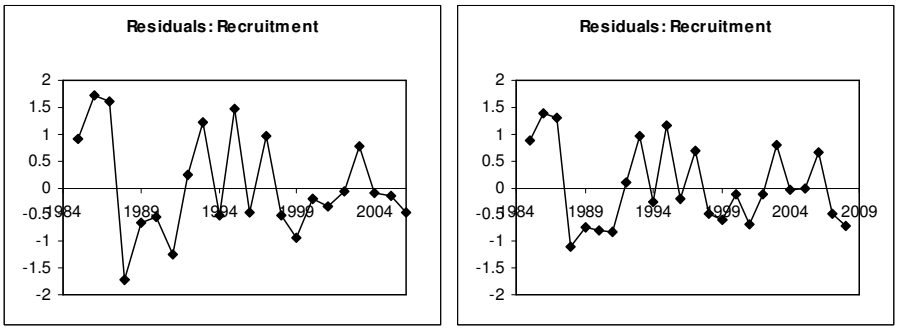

Figure 5. Standardised residuals of the model fit to the May recruitment data from the previous assessment (left panel) and the base case updated assessment (right panel).

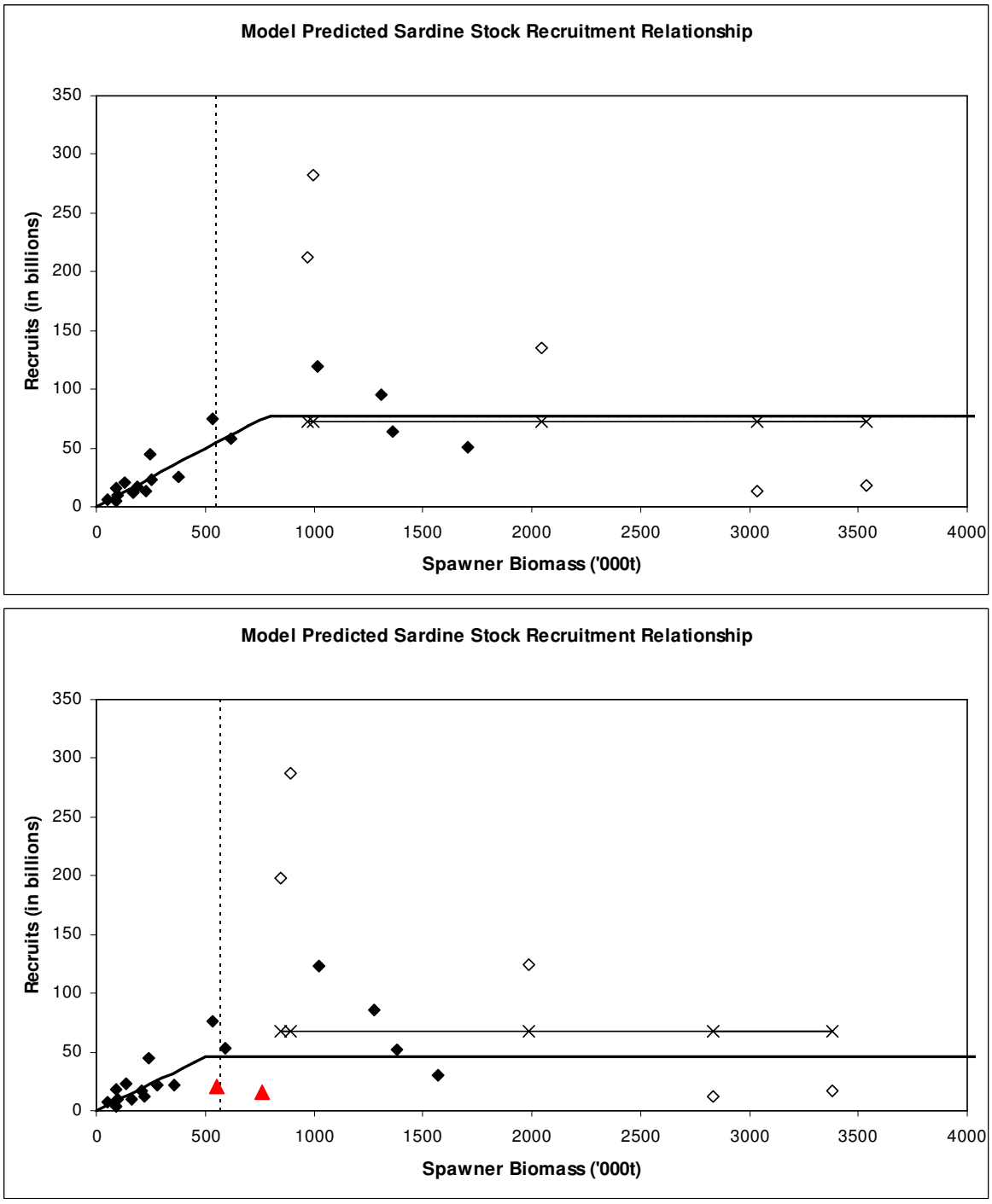

Figure 6. Model predicted sardine recruitment (in November) plotted against spawner biomass from November 1984 to November 2005 (previous assessment, left panel) and to November 2007 (updated assessment, right panel), with the 'hockey-stick' stock-recruit curve and the constant relationship between 2000 and 2004 also shown. The open circles denote the 2000 to 2004 November spawner biomass and recruitment. The red triangles in the left panel indicate the recruitment in November 2006 and 2007. The dashed line indicates the average 1991 to 1994 1+ biomass (used in the definition of risk in OMP-04).

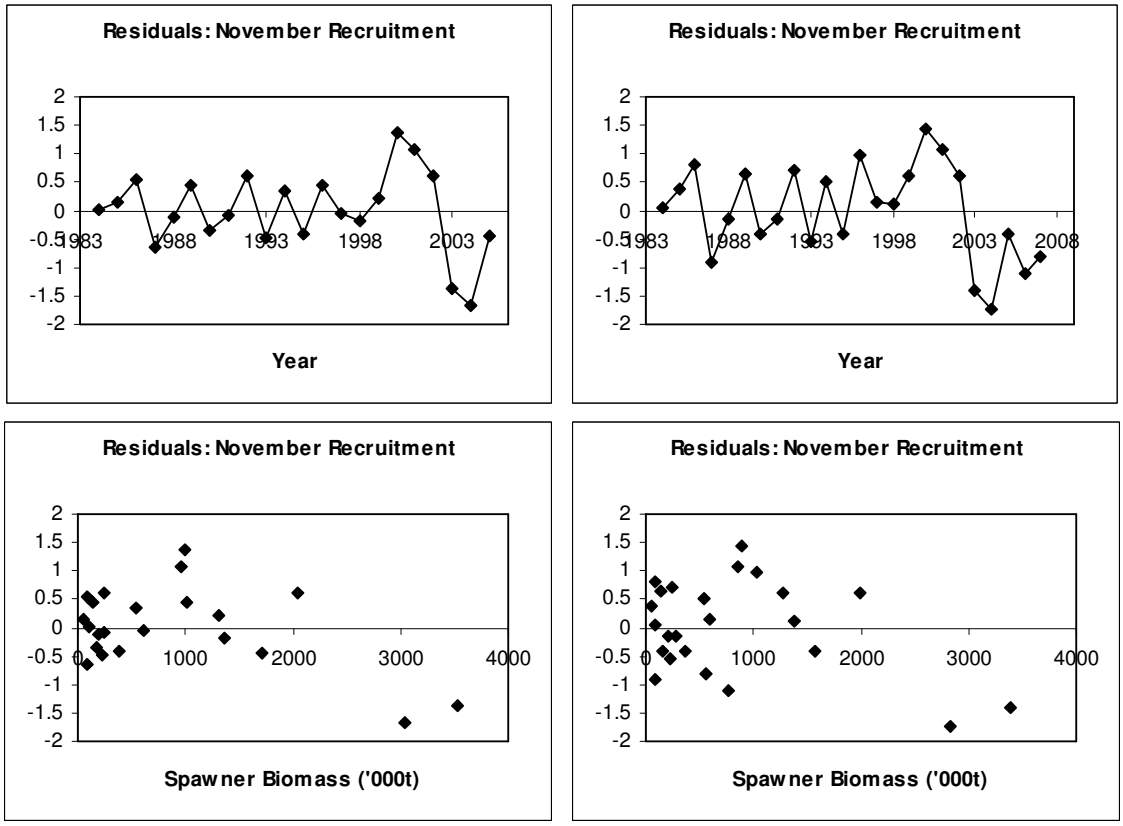

Figure 7. Standardised November recruitment residuals from the previous assessment (left panel) and the base case updated assessment (right panel), plotted against time (upper panel) and against spawner biomass (lower panel).

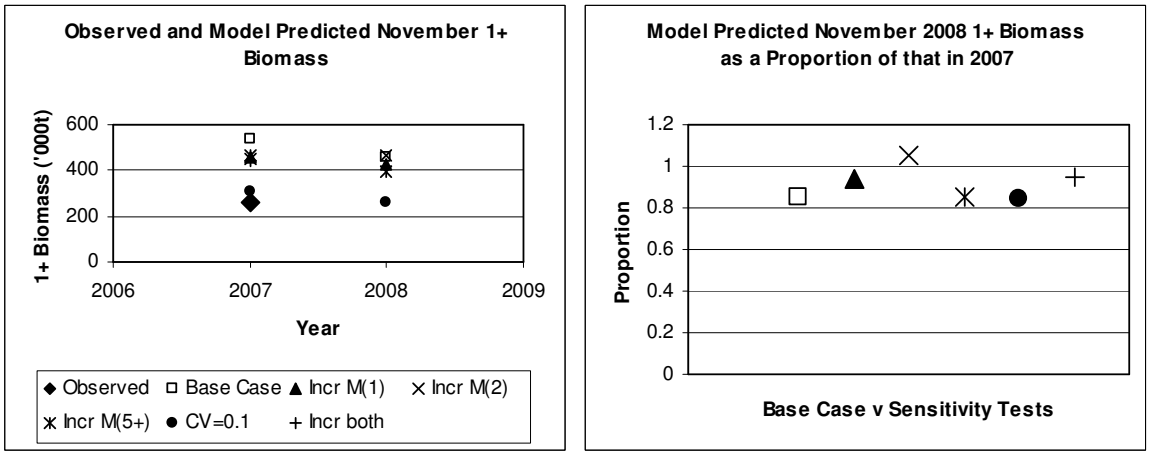

Figure 8. A comparison of the model predicted November 1+ biomass in 2007 to the observed biomass, and to that predicted for November 2008 for the updated base case assessment and sensitivity tests. The right hand plot shows the predicted November 2008 1+ biomass as a proportion of that in November 2007.

Glossary of Model Parameters

M_a^S the rate of natural mortality (in year^{-1}) of sardine of age a.

$k_{N/r}^S$ the constant of proportionality (multiplicative bias) associated with the November / recruit survey.

$(\lambda_{N/r}^S)^2$ the additional variance (over and above the survey sampling CV $\sigma_{y,Nov/rec}^S$ that reflects survey inter-transect variance) associated with the November/recruit surveys.

$\overline{B}_{Nov}^S$ the average 1+ sardine biomass between November 1991 and November 1994; OMP-04 was developed using Risk defined as "the probability that 1+ sardine biomass falls below the average 1+ sardine biomass between November 1991 and November 1994 at least once during the projection period of 20 years".

$\hat{B}_{y,N}^S$ the biomass (in thousand tonnes) of adult sardine at the beginning of November in year *y*, associated with the November survey.

K_{normal}^S the carrying capacity during "normal" years.

K_{peak}^S the carrying capacity during "peak" abundance (2000-2004).

a^S the maximum recruitment (in billions) (i.e. median of the distribution in question).

b^S the spawner biomass above which expected recruitment is constant in the hockey stick model.

c^S the constant recruitment (distribution median) during the "peak" years of 2000 to 2004.

σ_r^S the standard deviation in the annual lognormal deviation of sardine recruitment.

η_y^S the standardised recruitment residual value for year y.

s_{cor}^S the recruitment serial correlation.

$Nprop_a^S$ the proportion numbers-at-age a in the initial year of the model (November 1983).

Appendix : Updated Data

Acoustic Survey Data

The new data included in this assessment are listed in the below table

November Acoustic Survey			May Recruitment Survey		
Year	1+ Biomass ('000t)	CV	Year	Recruitment (billions)	CV
2007	256.73	0.345	2007	9.598	0.342
			2008	12.793	0.325

Commercial Catch Data

In the last sardine assessment (Cunningham and Butterworth 2007), 0-year old and 1+-year-old quarterly catch tonnage was calculated using the "full" sardine assessment that was fit to commercial catch proportions-at-length data, and input into the "short" assessment which was not fit to commercial catch data.

As the "full" sardine assessment has not been updated, the quarterly catch tonnage split between 0-year-olds and 1+-year-olds for the additional years now added (2006-2008) has been calculated as follows:

The data available for these calculations include the number of fish in length class l in month m, $N^c_{l,m}$, and the observed tonnage in month m, $ObsT_m$ from Nov 2006 to Oct 2008[1]. The October 2008 observed tonnage was doubled for use in this assessment to account for further catch that would occur before the end of the month.

Expected mass (in kilograms) by length class (in centimetres) and month is calculated as: $EM_{l,m} = 0.0096 \times l_{mid}^{3.075} \times N^c_{l,m}$

where l_{mid} is the mid-point of the length class considered and $N^c_{l,m}$ is the number of fish in length class l in month m.

Adjusted mass by length class and month is calculated as: $AM_{l,m} = \frac{EM_{l,m}}{\sum_l EM_{l,m}} \times ObsT_m$

Average monthly adjusted mass per individual fish by length class and month is calculated as:

$$\overline{AM}_{l,m} = \frac{AM_{l,m}}{N^c_{l,m}} = \frac{\frac{EM_{l,m}}{\sum_l EM_{l,m}} \times ObsT_m}{N^c_{l,m}}$$

[1] As much as had been recorded up to mid-October 2008.

Making the assumption that all sardine <15.5cm are juveniles and those >=15.5cm are 1+ adults, the average juvenile and adult mass per individual fish by month is calculated as: $FM_m^{juv} = \frac{\sum_{l<15.5} \overline{AM}_{l,m} \times N_{l,m}^c}{\sum_{l<15.5} N_{l,m}^c}$ and $FM_m^{ad} = \frac{\sum_{l\geq15.5} \overline{AM}_{l,m} \times N_{l,m}^c}{\sum_{l\geq15.5} N_{l,m}^c}$

The juvenile catch tonnage by month is therefore $FM_m^{juv} \times \sum_{l<15.5} N_{l,m}^c$, while the 1+ adult catch tonnage by month is $FM_m^{ad} \times \sum_{l\geq15.5} N_{l,m}^c$.

A check is performed on the calculations such that:

$$FM_m^{juv} \times \sum_{l<15.5} N_{l,m}^c + FM_m^{ad} \times \sum_{l\geq15.5} N_{l,m}^c = ObsT_m .$$

The recruit catch between 1 May and the day before the survey (1-17 May 2007 and 1-20 May 2008) was estimated as follows:

The data available for these calculations include the number of fish in length class *l* for this period and associated observed tonnage. The adjusted mass by length class, average adjusted mass per individual fish by length class, and average juvenile mass per individual fish is calculated as above, but using only the length classes up to and including 15cm. Dividing this average mass into the observed tonnage gives the estimated recruit catch in billions prior to the survey.

Table A. New sardine catch data used in the updated assessment

	Quarterly recruit catch ('000t)	Quarterly 1+ catch ('000t)	Recruit catch during May prior to the survey (billions)
Nov06-Jan07	2.208	31.196	
Feb07-Apr07	3.500	46.768	
May07-Jul07	4.498	49.139	0.000175
Aug07-Oct07	1.029	22.981	
Nov07-Jan08	0.806	7.208	
Feb08-Apr08	1.212	34.909	
May08-Jul08	3.223	25.092	0.000205
Aug08-Oct08	1.612	5.625	