Assessment of the South African sardine resource using data from 1984 – 2010: posterior distributions for one base case hypothesis

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Abstract

The operating model (OM) for the South African sardine resource has been updated from that used to develop OMP-08 given four more years of data and a revised time series of commercial catches. The OM with results at the posterior mode has already been presented (de Moor and Butterworth 2011a). The posterior distributions for the base case hypothesis assuming constant (time-invariant) natural mortality are presented here.

Introduction

The operating model of the South African sardine resource has recently been updated to be used in developing and simulation testing OMP-13. The full model description is given in Appendix A of de Moor and Butterworth (2011a). Two base case hypotheses have been chosen, one assuming a constant adult natural mortality over time, S_{cstM}, and the other allowing for random effects about annual adult natural mortality, S_{HS}. de Moor and Butterworth (2011a) present results at the posterior mode for these two base case hypotheses as well as for some robustness tests. In this document the posterior distributions for these S_{cstM} are presented.

Bayesian Estimation

The objective function consisting of the negative log likelihood (equation (A.20) of de Moor and Butterworth 2011a) added to the negative of the log prior distributions was minimised using AD Model Builder (Otter Research Ltd. 2000) to fit the model to the observed data and estimate the parameters at the posterior mode. A glossary defining all parameters is given in Appendix C of de Moor and Butterworth (2011a) and the prior distributions utilised are listed in Table 1. The posterior probability distributions were estimated using Markov Chain Monte Carlo (Gelman *et al.* 1995) in AD Model Builder. Given a limited time to run the chains, only a chain of length 8 200 000 was run and full convergence was not attained for σ_r^S, the standard deviation of the residuals about the stock-recruitment relationship during non-peak years. The thinning and burn-in applied are given in Table 1. Results presented in this document are based on a random sample of 5 000 from the remaining chain.

Results and Discussion

The posterior medians, means and CVs of key model parameters and outputs for S^2_{cstM} are given in Table 2. The posterior distributions of key model parameters and outputs are plotted in Figure 1. The posterior

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distribution for σ_r^S is tightly constrained close to 0.4 (this result is not regarded as satisfactory and will be examined further).

Figure 2 plots the median and 95% posterior interval for 1+ biomass and spawning biomass over time, while Figure 3 plots the same for the numbers at age 0 in November each year.

Although the convergence of this chain is acknowledged to not yet be adequate, these results are to be used in initial comparative tests of OMP-13 for this workshop (de Moor and Butterworth 2011b).

References

de Moor, C.L., and Butterworth, D.S. 2011a. Assessment of the South African sardine resource using data from 1984-2010: results at the posterior mode for a single stock hypothesis. MARAM International Stock Assessment Workshop MARAM IWS/DEC11/P/OMP/P8. 40pp.

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Gelman, A., Carlin, J.B., Stern, H.S. & Rubin, D.B. 1995. Bayesian Data Analysis. Chapman & Hall. 552pp.

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Table 1. A list of the model parameters and their prior distributions (see Appendix A of de Moor and Butterworth (2011) for further details). Where population numbers are concerned, the units are billions.

Parameter	Description
$k_{ac}^{S} \sim N\left(0.714, 0.077^{2}\right)$	The multiplicative bias associated with the survey estimate of sardine abundance from the hydroacoustic surveys
$k_{\text{cov}}^{S} \sim U\left(0.3, 1\right)$	The multiplicative bias associated with the coverage of the recruits by the recruit survey in comparison to the 1+ biomass by the November survey
$k_{\text{cov}\,E}^{S} \sim U\left(0, 1\right)$	The multiplicative bias associated with the coverage of the east stock recruits by the recruit survey in comparison to the west stock recruits during the same survey
$\left(\lambda_{j,N/r}^{S}\right)^{2} \sim U\left(0, 10\right)$	Additional variance associated with the November/recruit survey
$\varepsilon_{j,y}^{S} \sim N\left(0, \left(\sigma_{r}^{S}\right)^{2}\right), y = y_1, \ldots, 1999, 2005, \ldots, y_{n-1}$ $\varepsilon_{j,y}^{S} \sim N\left(0, \left(\sigma_{r,peak}^{S}\right)^{2}\right), y = 2000, \ldots, 2004$	Annual lognormal deviation of sardine recruitment
$\left(\sigma_{r}^{S}\right)^{2} \sim U\left(0.16, 10\right)$	Standard deviation in the residuals about the stock recruitment curve during non-peak years
$\left(\sigma_{r,peak}^{S}\right)^{2} \sim U\left(0.16, 10\right)$	Standard deviation in the residuals about the stock recruitment curve during peak years
$N_{1983} \sim U(0, 50)$ billion	Numbers at age 0 in the initial year
$L_{j,\infty} \sim N\left(19.7416, 2^{2}\right)$	Maximum length of sardine
$\vartheta_{j,a} \sim U\left(0.01, 2\right)$	Standard deviation about the mean length
$\tilde{S}_{j,a} \sim U(0, 2)$	Commercial selectivity
$S_{j,a}^{survey} \sim U(0.9, 1.1)$	Survey selectivity
$\eta_{y}^{ad} \sim N\left(0, \sigma_{ad}^{2}\right)$	Normally distributed error used in calculating the annual residuals about adult natural mortality
$\eta_{y}^{j} \sim N\left(0, \sigma_{j}^{2}\right)$	Normally distributed error used in calculating the annual residuals about juvenile natural mortality
$\sigma_{ad} \sim U\left(0.20, 0.50\right)$	Standard deviation in the annual residuals about adult natural mortality
$\sigma_{j} \sim U\left(0.20, 0.50\right)$	Standard deviation in the annual residuals about juvenile natural mortaliy
$p \sim U\left(0, 1\right)$	Annual autocorrelation coefficient in annual residuals about adult natural mortality
$\ln(a_{j}^{S}) \sim U\left(0, 4.4\right)$	Log of the maximum median recruitment in the hockey stick stock recruitment curve
$\dfrac{b_{j}^{S}}{K_{j}^{S}} \sim U\left(0, 1\right)$	The biomass above which median recruitment is not impaired in the hockey stick stock recruitment curve as a proportion of carrying capacity

Table 2. The MCMC chain length, thinning and burn-in used to get a sample from the posterior distribution. The posterior means and CVs of key model parameters and outputs are also shown. Biomasses are given in thousands of tons and numbers in billions. Parameters fixed for MCMC runs are given in **bold** (initial testing showed very little movement in the chain from the posterior mode).

	S_{cstM}		
Total chain length	8 500 000		
Thinning	1000		
Chain excluded (eg for burn-in)	0		
Length of chain used for posterior	8 500		
Parameter	Median	Mean	CV
$k_{j,N}^{S} = k_{ac}^{S}$	0.73	0.73	0.10
k_{cov}^{S}	0.79	0.79	0.14
$k_{j,r}^{S}$	0.57	0.57	0.16
$\left(\lambda_N^S\right)^2$	**0.00**	**0.00**	**-**
$\left(\lambda_r^S\right)^2$	**0.00**	**0.00**	**-**
$S_{j,1}^{survey}$	1.00	1.00	0.06
$S_{j,2}^{survey}$	1.01	1.00	0.06
$S_{j,3}^{survey}$	1.00	1.00	0.06
$S_{j,4}^{survey}$	**1.00**	**1.00**	**-**
$S_{j,5+}^{survey}$	1.00	1.00	0.06
$S_{q,1}$,	**0.05 for 84-06, 0.15 for 07-10**	**0.05 for 84-06, 0.15 for 07-10**	**-**
$S_{q,2}$,	**0.62**	**0.62**	**-**
S_3	**0.87**	**0.87**	**-**
S_4	**1.00**	**1.00**	**-**
S_{5+}	**2.00 for 84-06, 1.19 for 07-10**	**2.00 for 84-06, 1.19 for 07-10**	**-**
N_{1983}^{S}	**3.0**	**3.0**	**-**
$\overline{B}_{Nov}^{S}$ [1]	598	617	0.22
K_{normal}^{S}	1686	1813	0.32
a^S	37	39	0.32
b^S	501	543	0.37
σ_r^S	0.40	0.40	0.01
$\sigma_{r,peak}^{S}$	1.73	1.80	0.33
η_{2009}^{S}	0.64	0.63	0.30
s_{cor}^{S}	0.38	0.37	0.30
L_∞	20.8	20.8	0.04
κ	**0.56**	**0.56**	**-**
t_0	**-1.71**	**-1.71**	**-**

[1] OMP-04 and OMP-08 were 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”.

Table 2 (continued).

	S_{cstM}		
Parameter	Median	Mean	CV
ϑ_1	0.34	0.46	0.78
ϑ_2	0.10	0.10	0.36
ϑ_3	0.11	0.23	0.33
ϑ_4	0.81	0.87	0.69
ϑ_{5+}	0.88	0.92	0.58
$N^S_{2010,1}$	13.4	14.4	0.38
$N^S_{2010,2}$	3.6	3.8	0.41
$N^S_{2010,3}$	1.10	1.17	0.40
$N^S_{2010,4}$	0.27	0.29	0.49
$N^S_{2010,5+}$	0.14	0.16	0.61
$B^A_{2010,N}$	1050	1088	0.29

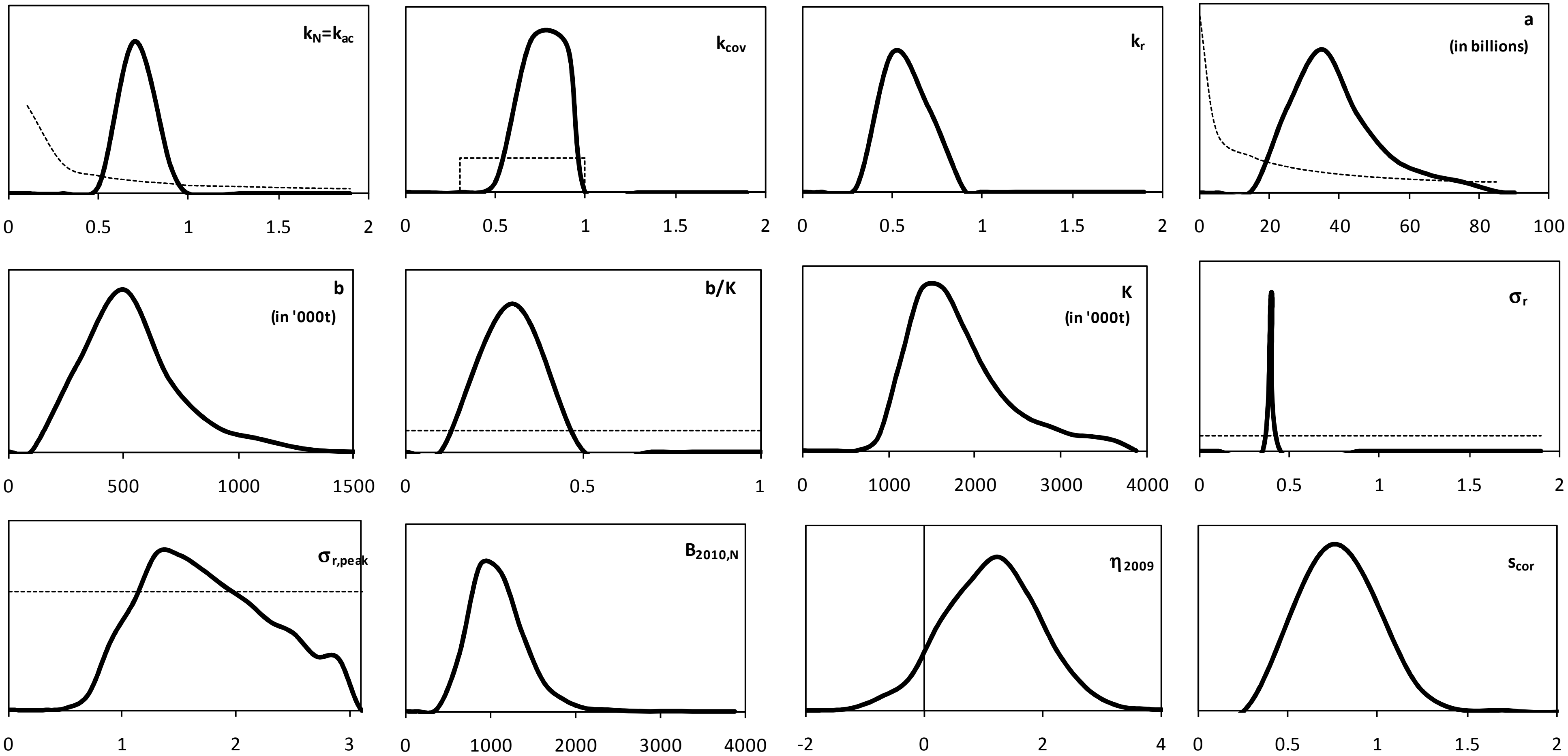

Figure 1. Posterior distributions for key model parameters and outputs for the base case hypotheses S^2_{cstM}. The prior distributions for model parameters estimated are shown by the thin dashed lines. The prior distribution for η^{ad}_{2010} is not plotted as it depends on the distribution of σ^2_{ad}, as $\eta^{ad}_y \sim N\left(0, \sigma^2_{ad}\right)$.

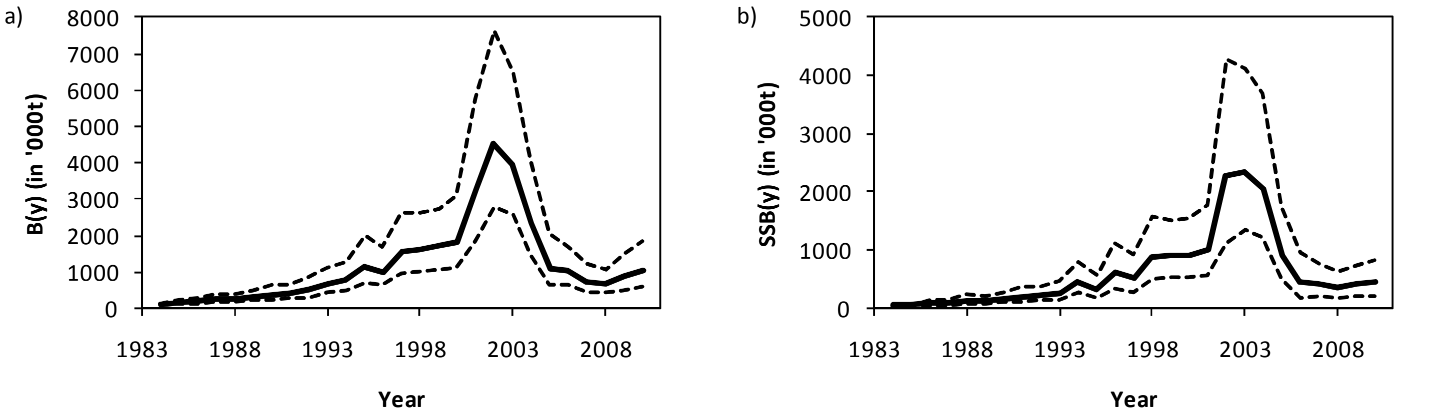

Figure 2. The posterior median and 95% probability intervals of the annual sardine November a) 1+ biomass and b) spawning biomass for S^2_{cstM}.

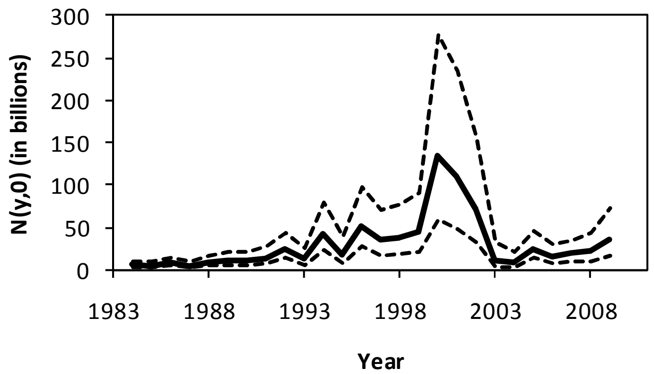

Figure 3. The posterior median and 95% probability intervals of the annual numbers of sardine at age 0 in November for S^2_{cstM}.