A "REPLACEMENT YIELD" MODEL FIT TO CATCH AND SURVEY DATA FOR THE SOUTH COAST KINGKLIP RESOURCE OF SOUTH AFRICA

A. Brandão and D.S. Butterworth

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

February 2008

ABSTRACT

A "Replacement Yield" model is applied to the total annual catches and the survey abundance estimates for the South African kingklip component of the South coast over the 1986 to 2007 period. A replacement yield (*RY*) of some 1 670 tonnes is estimated. An average decline of about 7% per year in the abundance of kingklip in the South coast over the last five years is indicated.

INTRODUCTION

This paper investigates the simple "Replacement Yield" approach to modelling the dynamics of the South coast component of the South African kingklip resource. Trends in abundance over the last five years are also evaluated.

DATA

Inputs to the "Replacement Yield" model include the annual total catches for the trawl and the longline fisheries and the survey abundance indices. Annual total catches and abundance indices from 1986 (the year from which survey indices are available) are used and these are listed in Table 1. The total annual catches for 2007 were not available for the present analysis; however, to be able to include the information from surveys for 2007, the assumption was made to set the total annual catches for 2007 to be the same as for 2006. As in the base case of Brandão and Butterworth (2008), no differentiation is made between the different gear types (old or new) and between vessels (the *Africana* or the *Nansen*) used during the surveys.

MODEL

Detailed specification of the "Replacement Yield" model used is given in the Appendix. A Bayesian estimation procedure has been implemented for the "Replacement Yield" model to investigate trends in abundance over the last five years and the associated uncertainty in the estimates. This requires the specification of prior distributions for all estimable parameters. Non-informative priors have been assumed for all these parameters. The bounds placed on the uniform priors are set out in Table 2. A Markov Chain Monte Carlo (MCMC) algorithm (as available in the ADMB package) has been used to generate random draws from the joint posterior distribution of the model parameters, except that the q_i were set to their MLE (Equation (A.4)). The resultant 90% probability intervals were calculated as the intervals between the 5th and the 95th percentiles of the probability distributions.

Chains of length of 10 million iterations were generated, using the mode of the posterior as the initial parameter vector. The chains were "thinned" by taking every 1 000th value in the chain, and the results of the first 1 000 iterations were discarded to allow for a "burn-in" period.

Convergence of the MCMC chains was checked using the Bayesian Output Analysis (BOA) package.

The distribution of the trend in abundance of the South Coast kingklip over the last five years was determined by estimating the slope of the regression fit against time to each realisation of the posterior distribution of the natural logarithm of the model biomass.

RESULTS AND DISCUSSION

Results of the Replacement Yield model are shown in Table 3. The fit of this model to the survey data is shown in Fig. 1. This analysis suggests that the replacement yield for the South coast kingklip is some 1 670 t.

The posterior means and medians of the average percentage change in abundance per annum (over the last five years) together with 90% probability intervals are shown on Table 4. This suggests an average annual drop of about 7% in the abundance of kingklip on the South coast over the last five years. The posterior median estimates of abundance (over the last five years) and the 90% probability intervals are shown in Fig. 2.

ACKNOWLEDGMENTS

Dr. Rob Leslie is acknowledged for kindly providing the catch and biomass survey data.

REFERENCES

Brandão A and Butterworth DS. 2008. An updated assessment of the South African kingklip resource. Marine and Coastal Management document: 2008:WG-Dem:K:02.

Table 1. Total annual catches (in tons) and abundance indices for the South African kingklip (in tons) of the South coast together with CVs obtained from surveys (separated by season) for the period 1986 to 2007 (R. Leslie, pers. commn). Values in bold denote biomass estimates obtained using the new rather than the old gear on *Africana*, while italicised values denote biomass estimates obtained from surveys carried out on the *Nansen*.

.

Year	**South coast**				
	Annual total catches	**Sep/Oct (spring) (0 – 200 m)**		**May/Jun (autumn) (0 – 500 m)**	
		Biomass	**CV**	**Biomass**	**CV**
1986	8 430	4 800	0.229		
1987	5 303	3 551	0.172		
1988	3 974			6 373	0.450
1989	2 695				
1990	1 236	1 258	0.357		
1991	978	1 992	0.248	8 140	0.148
1992	1 043	2 001	0.217	4 415	0.372
1993	1 144	1 210	0.205	10 047	0.392
1994	1 870	1 319	0.276	30 494	0.596
1995	1 706	1 290	0.434	19 606	0.408
1996	2 446			3 714	0.176
1997	2 755			5 077	0.257
1998	1 698				
1999	2 660			11 479	0.604
2000	2 245			*12 807*	*0.256*
2001	3 223	*1 581*	*0.198*		
2002	3 642				
2003	3 322	1 735	0.352	6 256	0.523
2004	3 030	**530**	**0.334**	**3 598**	**0.555**
2005	2 207			**4 133**	**0.759**
2006	1 736	1 966	0.433	2 213	0.378
2007	1 736†	**729**	**0.298**	**4 118**	**0.391**

† Catch data for 2007 assumed to be the same catch as for the previous year.

Table 2. Prior distributions assumed for the estimable parameters for the Bayesian assessments.

Parameter	**Distribution**
$\ln(B_{1986})$	U [2, 20]
RY	U [0, 100 000]

Table 3. Maximum likelihood estimated model parameters for the South coast kingklip component of the resource. 95% confidence intervals calculated from the Hessian matrix are also shown.

Parameter estimates	**South coast**
-ln *L*: Total	4.037
-ln *L*: Survey (spring)	-3.582
-ln *L*: Survey (autumn)	7.619
B_{1986}	29 340 (12 569; 46 111)
RY	1 671 (1 110; 2 231)
q_{survey}^{spring}	0.112 (0.030; 0.195)
q_{survey}^{autumn}	0.430 (0.109; 0.751)

Table 4. Posterior mean and median of the average percentage change in abundance per annum (over the last five years) obtained from Bayesian analyses framework. The 90% probability interval is also given.

Parameter estimates	**South coast**
Mean	-6.86
Median	-6.77
90% PI	(-8.64; -5.42)

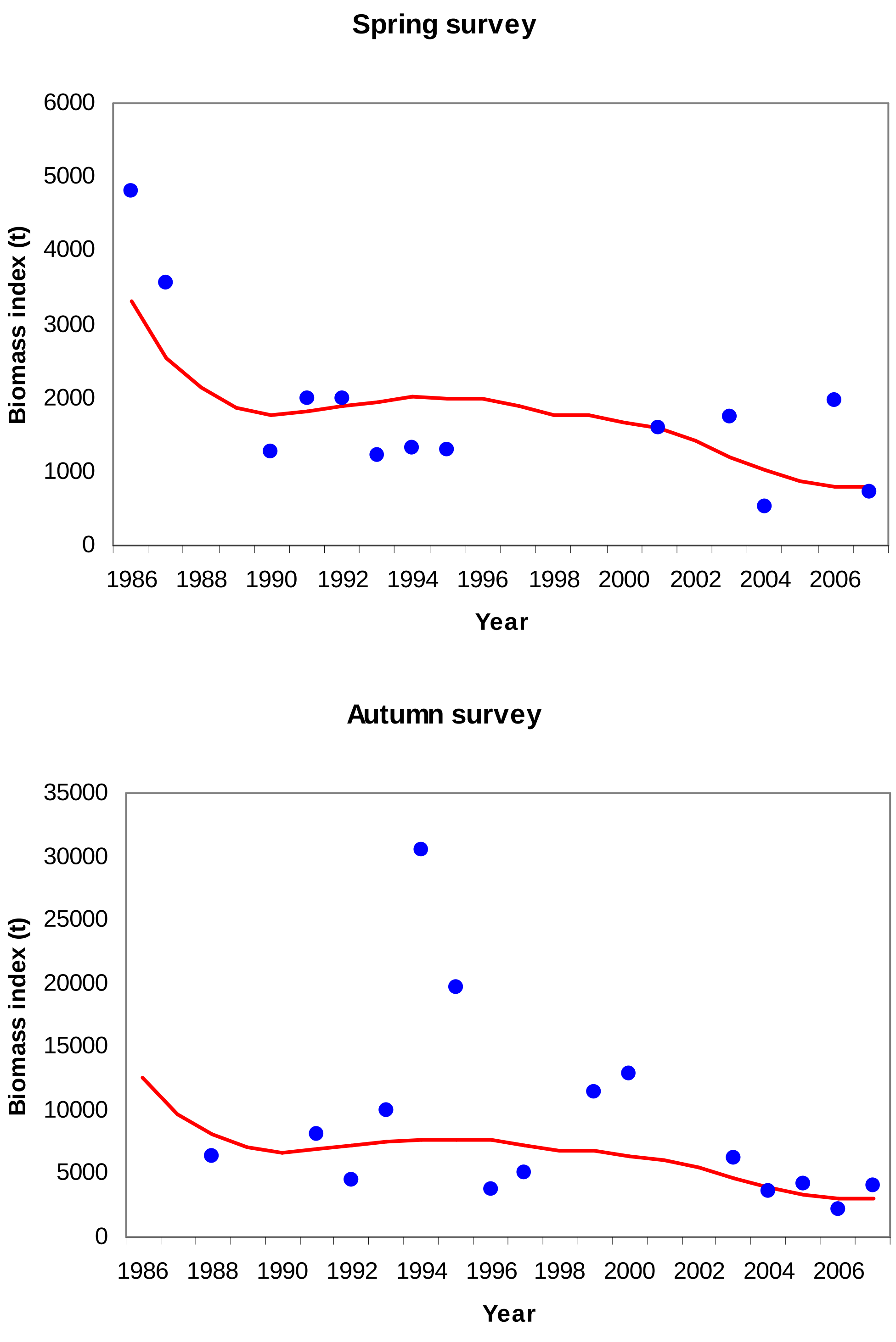

Figure 1. Observed (dots) and estimated (line) trend of abundance indices fitted to data for the period 1986 to 2007 for the South coast kingklip of South Africa.

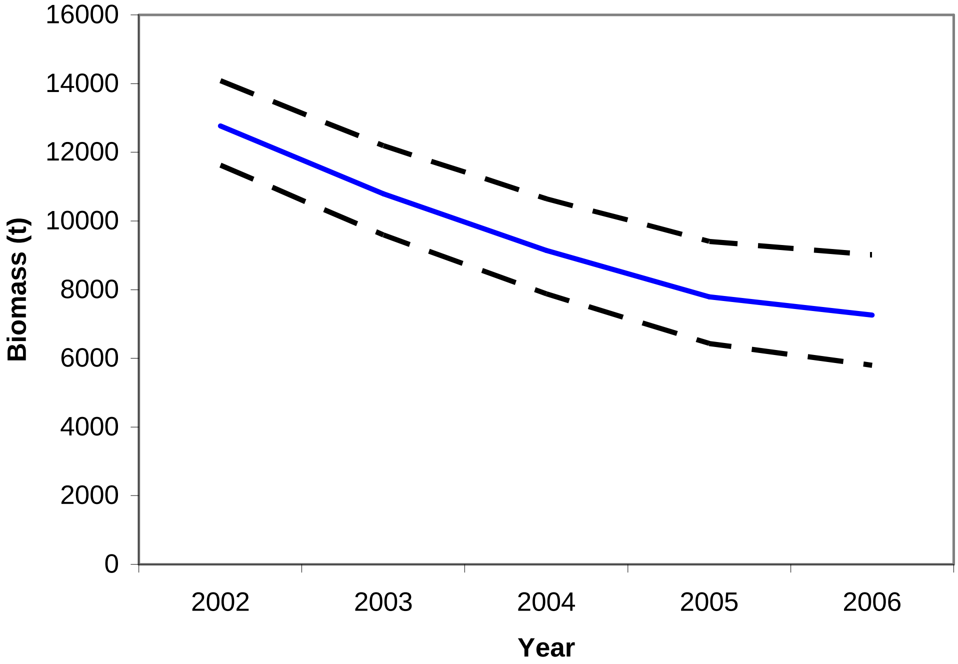

Figure 2. Bayesian posterior medians of abundance over the last five years for the South coast kingklip of South Africa. 90% probability interval envelopes are shown as dashed lines.

APPENDIX

REPLACEMENT YIELD MODEL FOR KINGKLIP

THE POPULATION DYNAMICS

The kingklip resource dynamics are modelled by the following equation:

$$B_{y+1} = B_y + RY - C_y \tag{A.1}$$

where:

B_y is the biomass at the start of year *y*,

C_y is the catch in year *y*, and

RY is the replacement yield in year *y*, which is assumed to be constant over the period considered.

THE LIKELIHOOD FUNCTION

The model is fitted to survey abundance indices. Contributions by each of these to the negative of the log-likelihood ($-\ln L$) are as follows.

Survey abundance data

The likelihood is calculated assuming that the observed abundance indices are log-normally distributed about their expected value:

$$I_y^i = \hat{I}_y^i e^{\varepsilon_y^i} \quad \text{or} \quad \varepsilon_y^i = \ell n\left(I_y^i\right) - \ell n\left(\hat{I}_y^i\right) \tag{A.2}$$

where:

I_y^i is the abundance index for year *y* and survey series *i*,

$\hat{I}_y^i = \hat{q}_i \hat{B}_y$ is the corresponding model estimated value,

$\hat{q}_i$ is a constant of proportionality (catchability) for abundance index *i*, and

ε_y^i is the observation error for survey *i* in year *y*, which is assumed to be normally distributed: $N\left(0,\left(\sigma_y^i\right)^2\right)$.

For the surveys, an estimate of the CV is available for each survey and the associated σ_y^i are given by $\ln\left(1+\left(CV_y^i\right)^2\right)$, where the CV_y^i are the coefficients of variation of the resource abundance estimate for index *i* for year *y*. These CVs are input and are given in Table 1.

The contribution of the survey abundance data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ln L_{survey} = \sum_i \sum_y \left[\ln \sigma_y^i + \left(\varepsilon_y^i\right)^2 \Big/ 2\left(\sigma_y^i\right)^2 \right] \tag{A.3}$$

The catchability coefficient q_i for the survey abundance index *i* is estimated by its maximum likelihood value and is given by:

$$\ln \hat{q}_i = \frac{\sum_y \left\{ \ln I_y^i - \ln \hat{B}_y \right\} \left(1 \Big/ \left(\sigma_y^i\right)^2 \right)}{\sum_y 1 \Big/ \left(\sigma_y^i\right)^2} \tag{A.4}$$