A "Replacement Yield" Model Fit to Catch and Survey Data for the South and West Coasts Kingklip Resource of South Africa

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ABSTRACT

A Bayesian "Replacement Yield" model is applied to the total annual catches and the survey abundance estimates for the South African kingklip resource off the South coast and that off the West coast over the 1986 to 2012 period. A posterior median replacement yield (*RY*) of 1 412 tonnes is estimated for the South coast and of 4 526 tonnes for the West coast; these values are suggested as upper bounds for the catch limit recommendations. Setting the catch limit at the 25th percentile of the posterior distribution results in 1 408 t and 3 856 t for the South and West coasts respectively. The corresponding posterior median rates of increase over the last five years are estimated at 2% and 3% for the South and West coasts respectively.

INTRODUCTION

Pending a full assessment, this paper updates the simple "Replacement Yield" approach to modelling the dynamics of the South African kingklip resource of Brandão and Butterworth (2008a). In this paper, the South and the West coast components of the kingklip resource are modelled separately. Trends in abundance over the last five years and replacement yields are also estimated.

DATA

Inputs to the "Replacement Yield" model include the annual total catches for the trawl and the longline fisheries and survey abundance indices. Annual catches and abundance indices from 1986 (the year from which survey indices are available) are used and these are listed in Table 1 for the South coast and Table 2 for the West coast. As in the base case of Brandão and Butterworth (2008b), no differentiation is made between the different gear types (old or new) and between vessels (the *Africana* or the *Nansen*) used during the surveys. Both the catch data and the survey abundance indices have recently been recalculated, so that the historical data differs from that listed in Brandão and Butterworth (2008a).

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 for the South coast component. A lognormal prior is assumed for the q_i parameters for the West coast, while non-informative priors are assumed for the other parameters.

The bounds placed on the uniform priors and the parameters of the normal distribution prior for ln(q_i) are set out in Table 3. 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. In Brandão and Butterworth (2008a) the q_i were set to their MLE (Equation (A.4)). In this paper, a uniform prior has been assumed for the q_i parameters for the South coast, with the bounds of the distribution given by the 95% confidence limits of the MLE estimate obtained from the Hessian matrix. For the West coast, the Bayesian mean and standard deviation for the South coast spring ln(q_i) has been used to provide the parameter values for the normal distribution prior for the West coast ln(*qi*)s. The resultant 90% probability intervals were calculated as the intervals between the 5th and the 95th percentiles of the posterior probability distributions.

Chains of length of 1 million iterations were generated, using the mode of the posterior as the initial parameter vector. The chains were "thinned" by taking every 100th 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 based on maximum likelihood estimation are shown in Table 4 for the South and in Table 5 for the West coast. The fit of the model to the South coast survey data is shown in Figure 1 and to the West coast in Figure 2. These analyses suggest that the replacement yield for South coast kingklip is 1 614 t, and 4 102 t for the West coast.

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 6. These suggest an average annual increase of about 2% in the abundance of kingklip on the South coast over the last five years and of 3% on the West coast. The posterior median estimates of abundance (over the last five years) and the 90% probability intervals are shown in Figures 3 and 4 for the South and West coasts respectively.

Table 7 gives the Bayesian mean, median and the 90% probability intervals for B_{1986} and *RY* for each coast, as well as the 25th percentile for *RY*.

An appropriate precautionary approach, given the simple nature of this analysis, would be to set catch limits at some percentile below 50% of the posterior distributions for RY, which would set 1 553 and 4 302 as the upper bounds on recommendations for the South and West coasts respectively. Setting the catch limit at the 25th percentile of the posterior distribution results in 1 408 t and 3 856 t for the South and West coasts respectively.

ACKNOWLEDGMENTS

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REFERENCES

Brandão A and Butterworth DS. 2008a. A “Replacement Yield” model fit to catch and survey data for the South coas kingklip resource of South Africa. Marine and Coastal Management document: 2008:WG-Dem:K:05.

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

Table 1. Annual catches (in tonnes) and abundance indices for the South African kingklip (in tonnes) of the South coast together with CVs obtained from surveys (separated by season) for the period 1986 to 2012. 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*.

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Year	**South coast**					
	Trawl catches	**Longline catches**	**Sep/Oct (spring) (0 – 200 m)**		**May/Jun (autumn) (0 – 500 m)**	
			Biomass	**CV**	**Biomass**	**CV**
1986	399	7453	2867	0.229		
1987	392	4504	3617	0.171		
1988	408	3311			6401	0.448
1989	223	2209				
1990	266	708	1262	0.357		
1991	680	0	2012	0.247	8158	0.148
1992	676	0	2007	0.217	4419	0.372
1993	884	0	1204	0.206	10184	0.393
1994	1560	48	1328	0.275	30532	0.595
1995	1275	48	1293	0.434	19612	0.408
1996	1981	60			3723	0.176
1997	2128	120			5167	0.257
1998	1366	87				
1999	1737	171			11484	0.603
2000	1465	103			*12707*	*0.257*
2001	2210	57	*1586*	*0.198*		
2002	2479	202				
2003	2558	160	**1741**	**0.352**	6257	0.523
2004	2539	141	**522**	**0.327**	**3600**	**0.554**
2005	1851	121			**4134**	**0.759**
2006	1322	127	1898	0.431	2113	0.368
2007	1223	85	**728**	**0.299**	**4055**	**0.350**
2008	1307	111	**5050**	**0.210**	**3402**	**0.211**
2009	958	132			**7881**	**0.235**
2010	1057	114			8230	0.237
2011	891	108			**7619**	**0.367**
2012	1272	94				

Table 2. Annual catches (in tonnes) and abundance indices for the South African kingklip (in tonnes) of the West coast together with CVs obtained from surveys (separated by season) for the period 1986 to 2012. Values in bold denote biomass estimates obtained using the new rather than the old gear on *Africana*.

Year	West coast					
	Trawl catches	Longline catches	Jan/Feb (summer)		Jul/Aug (winter)	
			Biomass	CV	Biomass	CV
1986	2287	1231	3748	0.159	2917	0.156
1987	2083	1948	2881	0.184	5798	0.250
1988	1519	2091	6153	0.199	1650	0.266
1989	1407	1607			996	0.324
1990	1002	557	3884	0.258	1443	0.397
1991	1271	0	3467	0.306		
1992	1884	0	8475	0.193		
1993	2207	0	10155	0.180		
1994	1445	92	8161	0.184		
1995	1863	65	7640	0.256		
1996	1596	170	12721	0.282		
1997	1972	155	7021	0.218		
1998	1632	53				
1999	2104	141	14323	0.276		
2000	2166	199	14976	0.415		
2001	2651	183	8778	0.264		
2002	2280	312	12670	0.160		
2003	1870	317	13531	0.246		
2004	1823	266	**7461**	**0.180**		
2005	1790	255	**5643**	**0.156**		
2006	1476	109	9444	0.382		
2007	1213	106	**5436**	**0.228**		
2008	1122	95	**5409**	**0.121**		
2009	1153	146	**10486**	**0.165**		
2010	1405	232	13727	0.124		
2011	1540	229	**14058**	**0.167**		
2012	1866	286	**7633**	**0.169**		

Table 3. Prior distributions assumed for the estimable parameters for the Bayesian assessments.

Coast	Parameter	Distribution
South and West coasts	$\ln(B_{1986})$	U [2, 20]
South and West coasts	RY	U [0, 100 000]
South coast	$\ln q_{survey}^{spring}$	U [-3.214, -1.385]
South coast	$\ln q_{survey}^{autumn}$	U [-1.982, -0.096]
West coast	$\ln q_{survey}^{summer/winter}$	N(-2.534, 0.398^2)

Table 4. 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	26.28
-ln *L*: Survey (spring)	16.46
-ln *L*: Survey (autumn)	9.82
B_{1986}	29 344 (9 832; 48 856)
RY	1 614 (1 328; 1 900)
q_{survey}^{spring}	0.100 (0.009; 0.192)
q_{survey}^{autumn}	0.354 (0.020; 0.687)

Table 5. Maximum likelihood estimated model parameters for the West coast kingklip component of the resource. 95% confidence intervals calculated from the Hessian matrix are also shown.

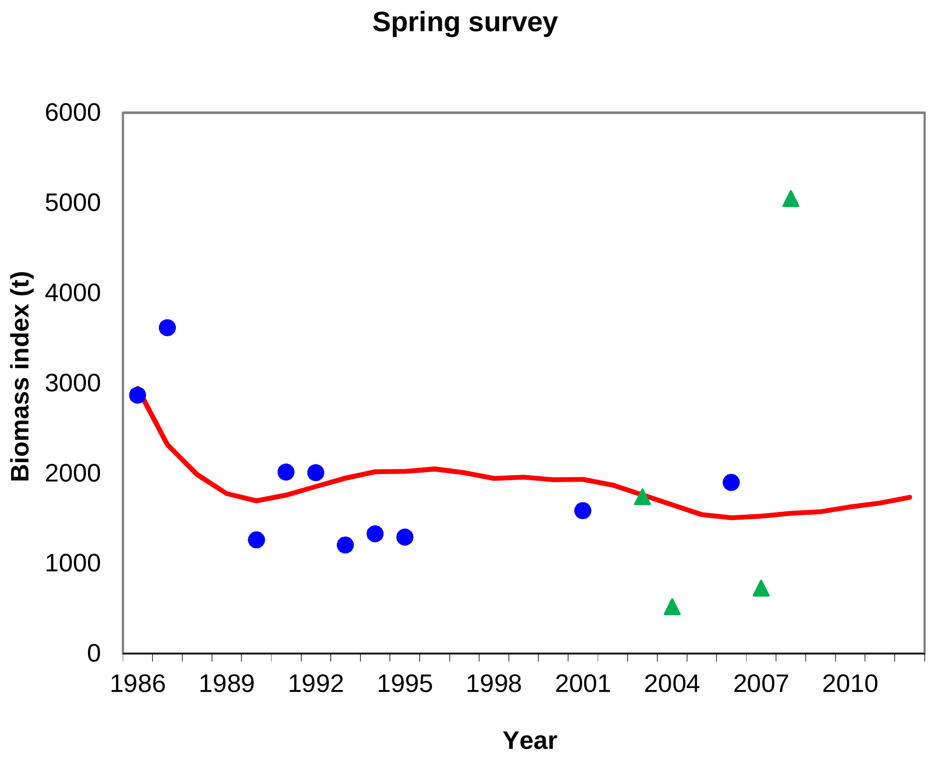
Parameter estimates	West coast
-ln *L*: Total	21.05
-ln *L*: Survey (summer)	14.24
-ln *L*: Survey (winter)	6.81
B_{1986}	43 896 (20 354; 67 438)
RY	4 102 (2 796; 5 408)
q_{survey}^{summer}	0.113 (0.049; 0.176)
q_{survey}^{winter}	0.058 (0.026; 0.091)

Table 6. Posterior mean and median of the average percentage change in abundance per annum (over the 2008 to 2012 period) obtained from Bayesian analyses framework. The 90% probability interval is also given.

Parameter estimates	South coast	West coast
Mean	1.879	2.888
Median	1.660	2.887
90% PI	(-0.044; 4.470)	(2.457; 3.340)

Table 7. Posterior mean and median for B_{1986} and *RY* obtained from Bayesian analyses framework. The 90% probability interval is also given.

Parameter estimates		**South coast**	**West coast**
B_{1986}	Mean	38 891	49 422
	Median	37 856	47 455
	90% PI	(22 976; 57 526)	(30 485; 74 545)
RY	Mean	1 520	4 416
	Median	1 553	4 302
	25^{th} percentile	1 408	3 856
	90% PI	(1 148; 1 778)	(3 348; 5 874)



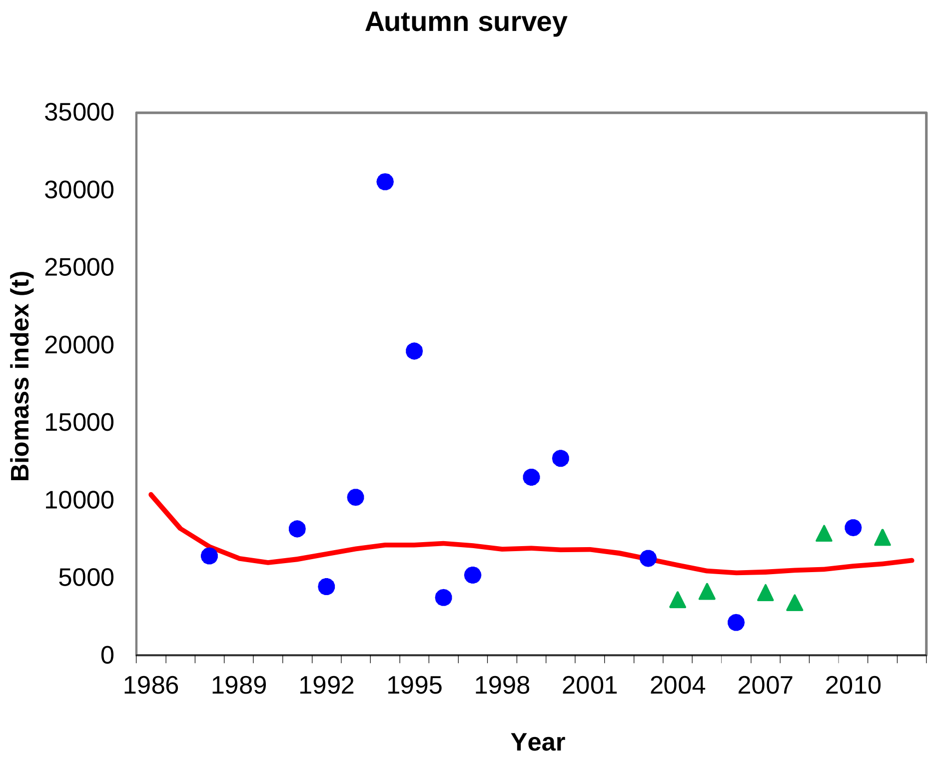
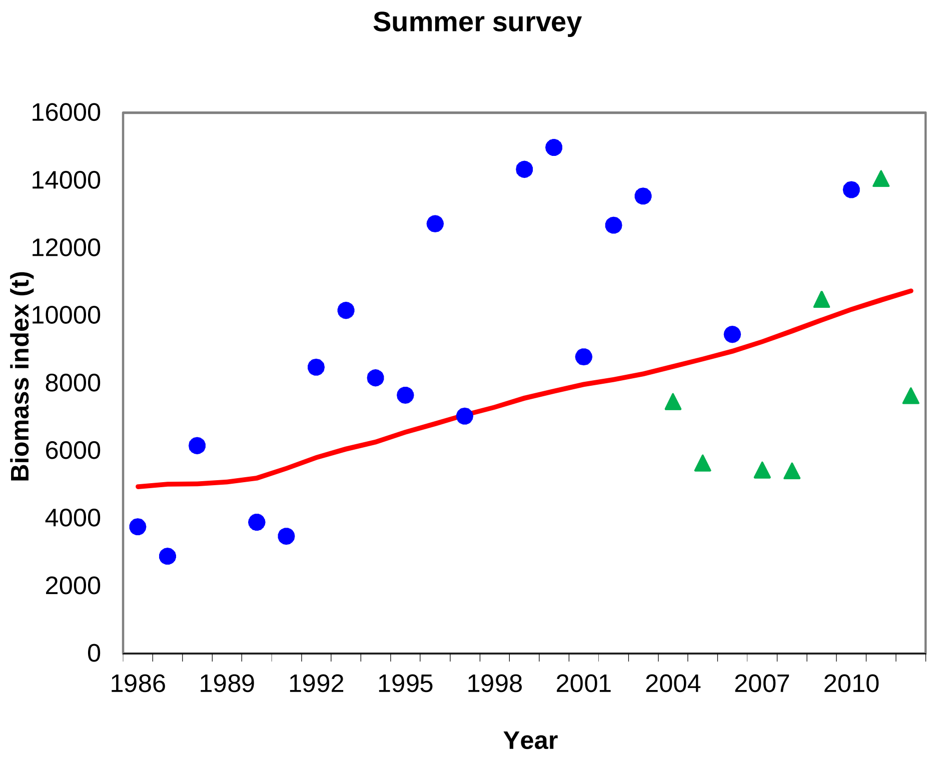


Figure 1. Observed (dots for the old gear and triangles for the new gear) and model estimated (line) trend of *Africana* survey abundance indices fitted to data for the period 1986 to 2012 for the kingklip off the South coast of South Africa.



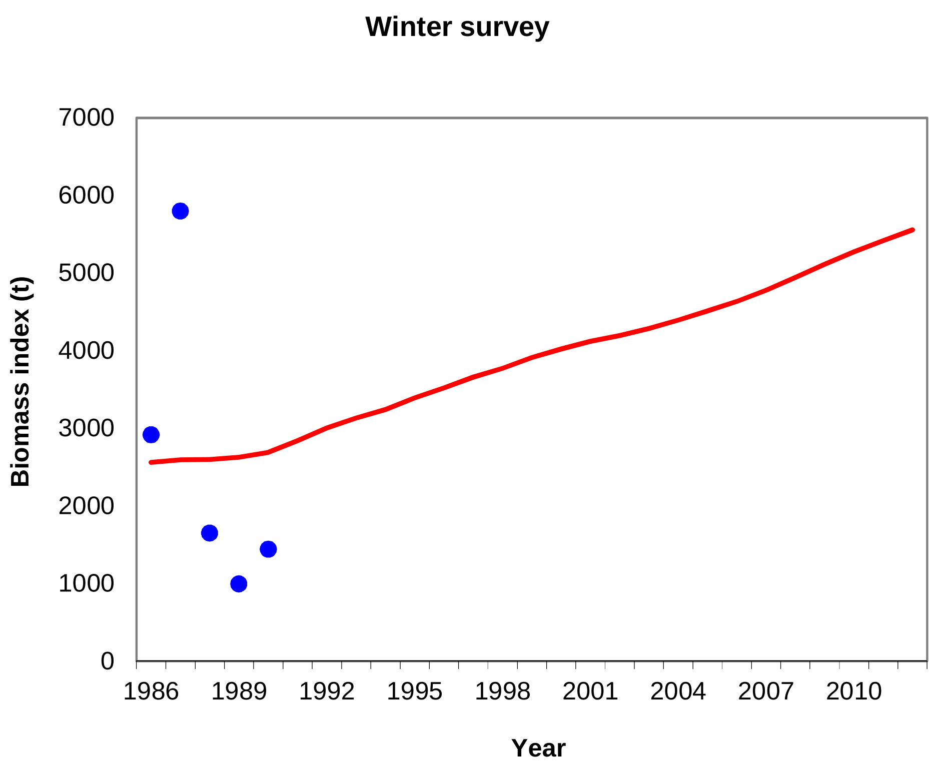


Figure 2. Observed (dots for the old gear and triangles for the new gear) and model estimated (line) trend of *Africana* survey abundance indices fitted to data for the period 1986 to 2012 for the kingklip off the West coast of South Africa.

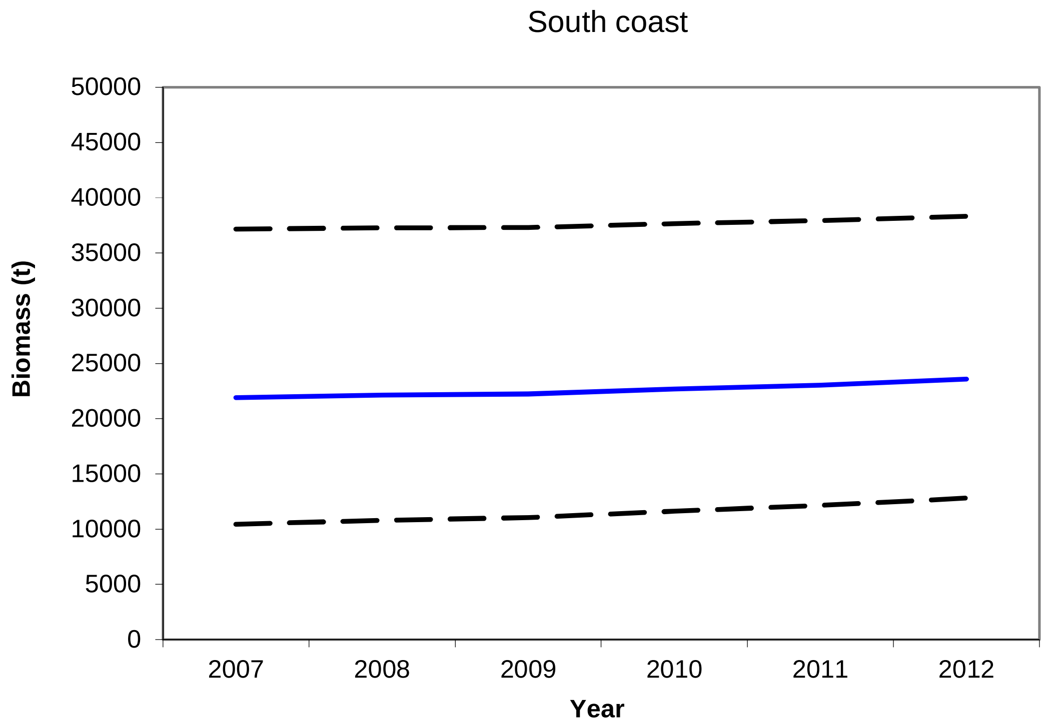


Figure 3. Bayesian posterior medians of abundance over the last five years for the South coast kingklip resource off South Africa. 90% probability interval envelopes are shown as dashed lines.

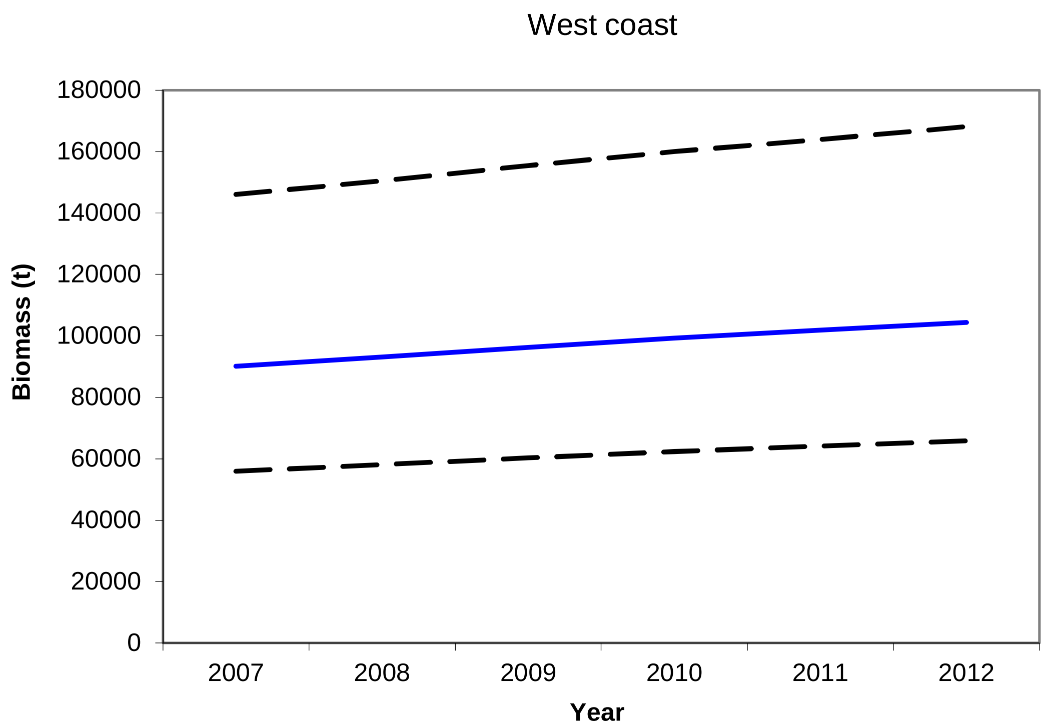


Figure 4. Bayesian posterior medians of abundance over the last five years for the West coast kingklip resource off South Africa. 90% probability interval envelopes are shown as dashed lines.

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:

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

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

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