Back-tracking Biomass Estimates to 1932 using Results from a "Replacement Yield" Model Fit to Catch and Survey Data for the South Coast Kingklip Resource off South Africa for Estimates of Current Status Relative to MSY-related Reference Points

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ABSTRACT

Back-tracking biomass values to 1932 for each posterior replicate of a Bayesian "Replacement Yield" model applied to the total annual catches and the survey abundance estimates for the South African kingklip resource off the South coast by Brandão and Butterworth (2013) results in both a mean and median current (2012) depletion of about 40%. This suggests current status close to B_{MSY}, which taken together with the recent increasing trend in survey abundance estimates suggests a current fishing mortality less than F_{MSY}.

INTRODUCTION

Brandão and Butterworth (2013) applied a simple Bayesian "Replacement Yield" approach to modelling the dynamics of the South African kingklip resource. Annual catches and abundance indices from 1986 (the year from which survey indices become available) were used in this assessment, and trends in abundance over the last five years and replacement yields were estimated. This simple approach was applied pending time coming available to conduct a full age-structured model assessment as last conducted for this possible separate stock in Brandão and Butterworth (2008).

However the SASSI assessment process currently underway is desirably informed by estimates of current status (biomass *B* and fishing mortality *F*) relative to the corresponding MSY-related reference points, B_{MSY} and F_{MSY} respectively. A related concern is that the results in Brandão and Butterworth (2008) for which kingklip on the south coast was treated as a separate stock, estimated *B* for this component to be less than B_{MSY}.

To provide an immediate update of this result for the south coast which is consistent with the analyses of Brandão and Butterworth (2013), pending a full age-structured model analysis, this paper implements a simple approach to provide insights into current stock status relative to MSY-related reference points. This is achieved by back-tracking the results from Brandão and Butterworth (2013) from 1986 using past catches back to 1932 which historical data indicate to reflect the commencement of a (substantial) kingklip fishery, and hence may be assumed to reflect a resource close to its pre-exploitation level *K*.

DATA AND METHOD

The "data" consists of annual total catches for the trawl and the longline fisheries from 1932 (Table 1), posterior estimates of the biomass at the start of the period of the "Replacement Yield" model (B_{1986}) and of the replacement yield (*RY*) for each of the 9 000 iterations retained from a Markov Chain Monte Carlo (MCMC) algorithm used to generate random draws from the joint posterior distribution of the model parameters (Brandão and Butterworth, 2013).

For each given B_{1986} and *RY* value for a replicate, biomass values are back tracked to 1932 by applying the following method:

$$B_{y+1}^r = B_y^r + f\left(B_y^r\right)RY^r - C_y \qquad (1)$$

where:

B_y^r is the biomass at the start of year *y* for the replicate *r*,

C_y is the catch in year *y*,

RY^r is the replacement yield in year *y* for replicate *r*, and

$f\left(B_y^r\right)$ is a linear trend between B_{1932} and B_{1986} given by:

$$f\left(B_y^r\right) = \begin{cases} 1 & \text{if } B_y^r < B_{1986}^r \\ \dfrac{B_{1932}^r - B_y^r}{B_{1932}^r - B_{1986}^r} & \text{if } B_y^r > B_{1986}^r \end{cases}.$$

Note that this assumes a biomass decline in surplus production from *RY* from the 1986 biomass to zero for the 1932 biomass (assumed equal to *K* and therefore with zero surplus production). This linearity seems a reasonable assumption to make as for a stock for which recruitment does not drop immediately when fishing reduces *B* below *K* (i.e. relatively high steepness), surplus production, being related to the difference between the stock-recruitment function and the replacement line will vary near-linearly with *B*.

An estimate of the pre-exploitation biomass $\left(\hat{B}_{1932}^r\right)$ is obtained by minimising:

$$L = \left(\hat{B}_{1986}^r - B_{1986}^r\right)^2,$$

where $\left(\hat{B}_{1986}^r\right)$ is obtained by applying equation (1) for the given $\left(\hat{B}_{1932}^r\right)$.

RESULTS AND DISCUSSION

Table 2 gives the Bayesian mean, median and the 90% probability intervals for B_{1986} and *RY* for the South coast, as well as the 25th percentile for *RY* as given in Brandão and Butterworth (2013). Table 3 gives the posterior mean, median and 90% probability intervals for the pre-exploitation biomass (B_{1932}) and current (2012) depletion obtained from back tracking biomass values to 1932 for each of 9 000 replicates of B_{1986} and *RY*. This results in both a mean and median current depletion value of about 40%.

Figure 1 shows median biomass trajectories and 90% probability envelopes for the period 1986 to 2012 as estimated in Brandão and Butterworth (2013), back-tracking of these trajectories to 1932 for the kingklip off the South coast of South Africa. Figure 2 shows these trajectories for the first ten replicates. Figure 3 shows median and 90% probability envelopes for surplus production (i.e. f(*B*)*RY*) as a function of biomass *B*. Figure 4 shows the surplus production as a function of biomass for the first five replicates.

Brandão and Butterworth (2008) give results for west and south coast kingklip (treated as separate stocks) for values of steepness *h* of 0.5 and 0.75 which lead in turn to values of B_{MSY}/K of between about 0.38 to 0.44. Given the results reported here (Table 3) suggesting estimates of *B/K* at present of close to 0.4, it seems reasonable to take this resource as indicated to be currently very close to its MSY-biomass. Furthermore then, given the recent upward trend in survey estimates of abundance (Brandão and Butterworth, 2013), it would follow that the current *F* is less than F_{MSY}.

REFERENCES

Brandão A and Butterworth DS. 2008. An updated assessment of the South African kingklip resource including some sensitivity tests. Marine and Coastal Management document: MCM/2008/FEB/SWG-DEM:K:03(rev2).

Brandão A and Butterworth DS. 2013. A “Replacement Yield” model fit to catch and survey data for the South and West coasts kingklip resource of South Africa. DAFF Branch Fisheries document: FISHERIES/2013/SEP/SWG-DEM/51(rev).

Table 1. Total annual catches (in tonnes) of South African kingklip off the South coast taken by the trawl and longline fisheries.

Year	South coast		Year	South coast		Year	South coast	
	Trawl	Longline		Trawl	Longline		Trawl	Longline
1932	164	0	**1970**	795	0	**2008**	1 307	111
1933	110	0	**1971**	1 343	0	**2009**	958	132
1934	110	0	**1972**	1 426	0	**2010**	1 057	114
1935	192	0	**1973**	1 590	0	**2011**	891	108
1936	192	0	**1974**	956	0	**2012**	1 272	94
1937	192	0	**1975**	982	0			
1938	192	0	**1976**	952	0			
1939	192	0	**1977**	737	0			
1940	192	0	**1978**	1 759	0			
1941	164	0	**1979**	1 532	0			
1942	164	0	**1980**	878	0			
1943	164	0	**1981**	963	0			
1944	164	0	**1982**	721	0			
1945	356	0	**1983**	1 169	200			
1946	274	0	**1984**	1 034	1 159			
1947	302	0	**1985**	1 650	5 656			
1948	411	0	**1986**	399	7 453			
1949	493	0	**1987**	392	4 504			
1950	521	0	**1988**	408	3 311			
1951	658	0	**1989**	223	2 209			
1952	768	0	**1990**	266	708			
1953	740	0	**1991**	680	0			
1954	548	0	**1992**	676	0			
1955	631	0	**1993**	884	0			
1956	548	0	**1994**	1 560	48			
1957	411	0	**1995**	1 275	48			
1958	466	0	**1996**	1 981	60			
1959	548	0	**1997**	2 128	120			
1960	411	0	**1998**	1 366	87			
1961	576	0	**1999**	1 737	171			
1962	466	0	**2000**	1 465	103			
1963	493	0	**2001**	2 210	57			
1964	384	0	**2002**	2 479	202			
1965	685	0	**2003**	2 558	160			
1966	1 014	0	**2004**	2 539	141			
1967	877	0	**2005**	1 851	121			
1968	795	0	**2006**	1 322	127			
1969	795	0	**2007**	1 223	85			

Table 2. Posterior mean and median for B_{1986} and RY obtained from Bayesian analysis for Replacement Yield assessment. The 90% probability intervals are also given.

Parameter estimates		**South coast**
$\boldsymbol{B_{1986}}$	Mean	38 891
	Median	37 856
	90% PI	(22 976; 57 526)
$\boldsymbol{RY}$	Mean	1 520
	Median	1 553
	25^{th} percentile	1 408
	90% PI	(1 148; 1 778)

Table 3. Distribution mean and median for B_{1932} and B_{2012}/B_{1932} obtained from back-tracking from the start of the Replacement Yield assessment (1986) to 1932 for each replicate obtained from the Bayesian analysis for Replacement Yield assessment. The 90% probability intervals are also given.

Parameter estimates		**South coast**
$\boldsymbol{B_{1932}}$	Mean	58 881
	Median	57 511
	90% PI	(40 897; 81 242)
$\boldsymbol{B_{2012}/B_{1932}}$	Mean	0.408
	Median	0.400
	90% PI	(0.290; 0.545)

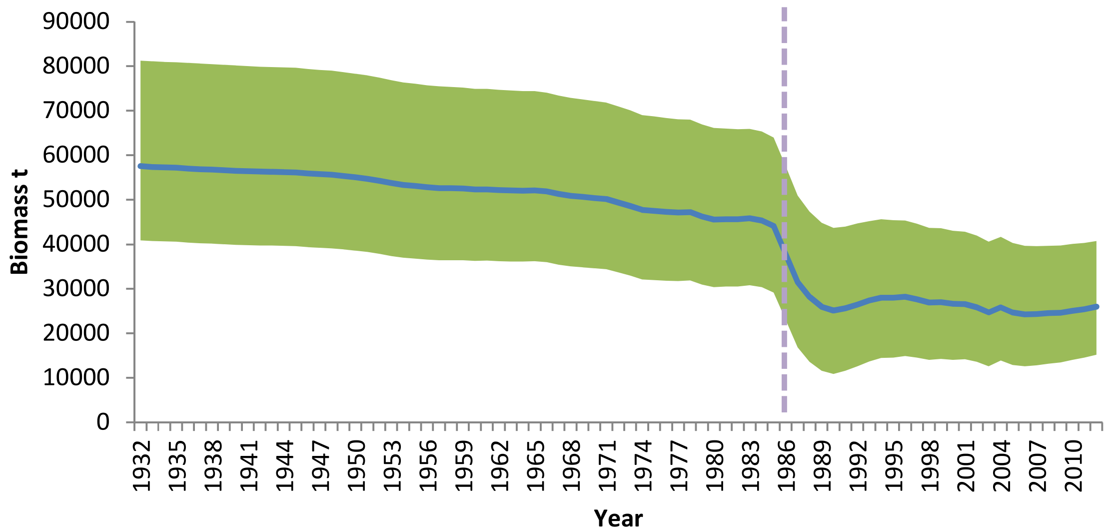

Figure 1. Median biomass trajectories and 90% probability envelopes for the period 1986 to 2012 as estimated in Brandão and Butterworth (2013), together with back-tracking of these trajectories to 1932 for the kingklip off the South coast of South Africa. The back-tracking is to the left of the vertical dashed line.

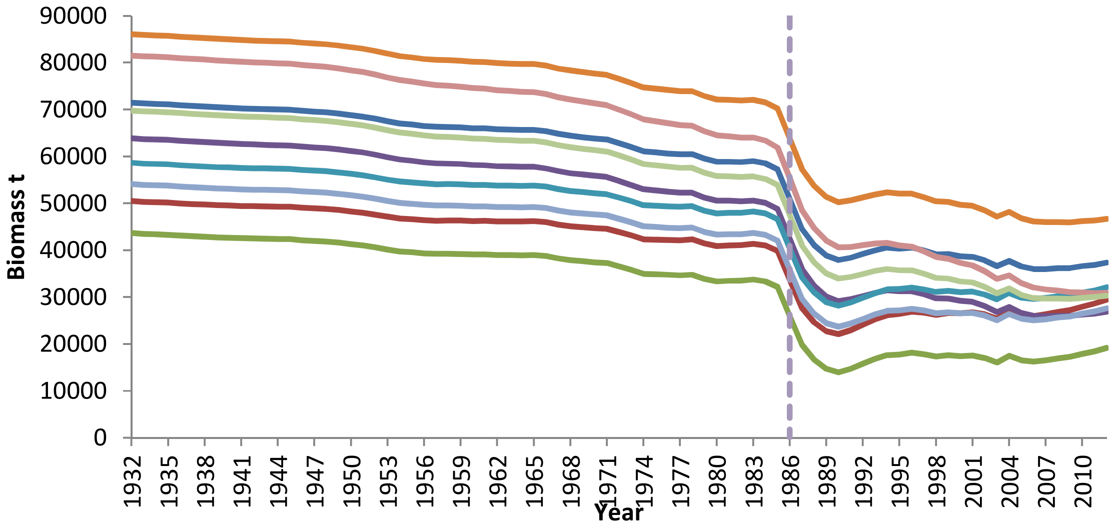

Figure 2. Biomass trajectories for the first ten replicates for the period 1986 to 2012, as estimated in Brandão and Butterworth (2013), together with back-tracking of these trajectories to 1932 for the kingklip off the South coast of South Africa. The back-tracking is to the left of the vertical dashed line.

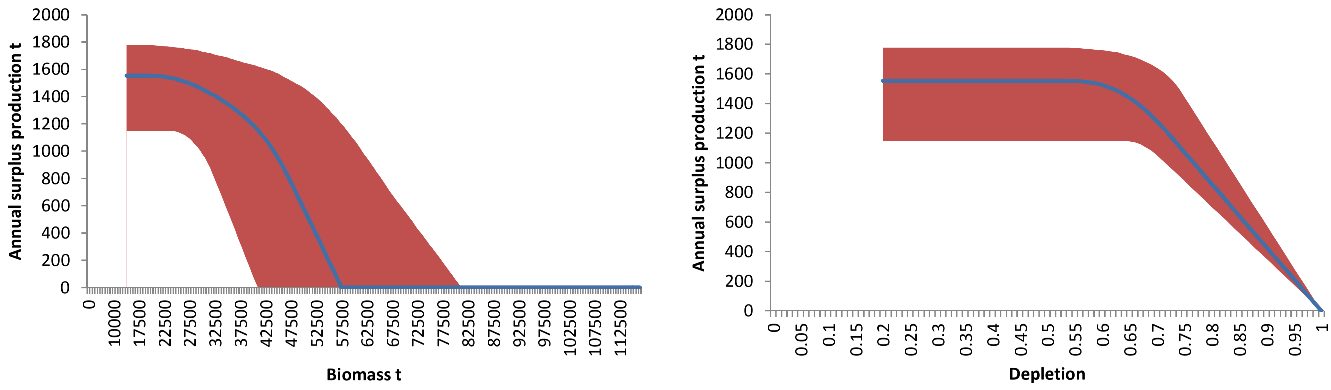

Figure 3. Median and 90% probability envelopes for surplus production (i.e. f(B)RY) as a function of B and of $B/B_{1932} = B/K$.

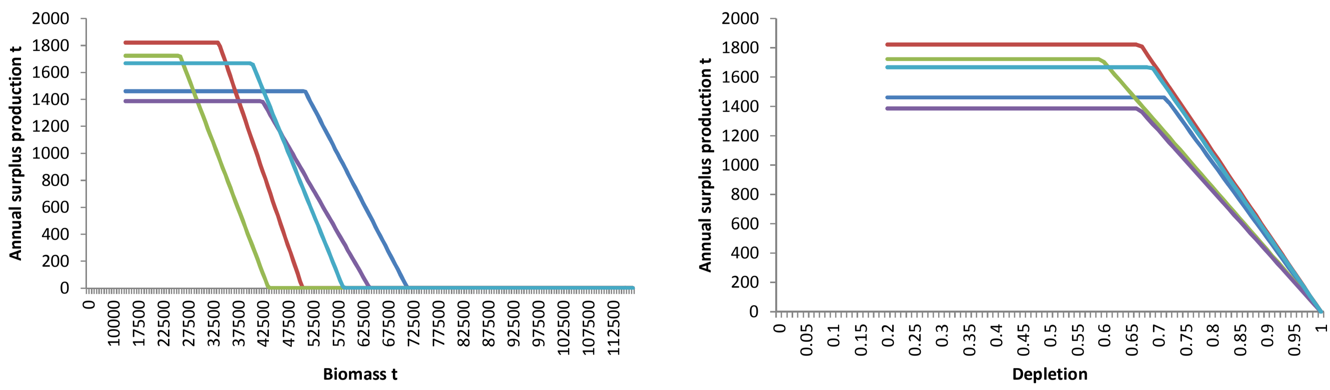

Figure 4. Surplus production (i.e. f(B)RY) as a function of B and of $B/B_{1932} = B/K$ for the first five replicates.