Results for 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

Given the addition of updated and further data, the previous approach used to compute replacement yields (RY) for kingklip no longer provides satisfactory estimates of survey catchability *q*. Over a range of *q* values on the South coast from 0.1 to 0.7, the estimated RY increases from 760 to 1814 tons, compared to the previous estimate of 1614 tons. Correspondingly for the West coast, the RY decreases from 4253 to 2435 tons, compared to the previous estimate of 4102 tons. Suggestions are made of how the DWG might take this matter forward to develop catch limit recommendations based on the RY approach.

INTRODUCTION

This paper discusses difficulties encountered in updating the simple “Replacement Yield” (RY) approach to modelling the dynamics of the South African kingklip resource of Brandão and Butterworth (2013), given further data now available. In this paper, the South and the West coast components of the kingklip resource are modelled separately.

DATA

Inputs to the “Replacement Yield” (RY) 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. No differentiation is made between the different gear types (old or new) and between vessels used to conduct the surveys. Both the catch data and the survey abundance indices have recently been recalculated, so that the historical data differ from those listed in Brandão and Butterworth (2013).

MODEL

Detailed specification of the RY model used is given in the Appendix. In the previous RY assessment (Brandão and Butterworth, 2013) a Bayesian estimation procedure was implemented for the Ry model. This requires the specification of prior distributions for all estimable parameters. Non-informative priors were assumed for all these parameters for the South coast component. A lognormal prior was assumed for the q_i parameters for the West coast, while non-informative priors were assumed for the other parameters. For the South coast the bounds of the uniform prior distribution were given by the 95% confidence limits of the MLE (maximum likelihood estimate) obtained from the Hessian matrix. For the West coast, the Bayesian mean and standard deviation for the South coast spring ln(q_i) were used to provide the parameter values for the normal distribution prior for the West coast ln(*qi*)s.

Unfortunately, however, the further/updated data now available for the South Coast no longer lead to an MLE for *q* for the autumn survey within [0, 1]. This precludes application of the approach used in 2013, including the use of a "posterior" for *q* on the South Coast as a "prior" for *q* on the West coast. The further/updated data for the West coast do now provide an MLE for *q* for the summer survey, but the value seems unrealistically low. Hence the Replacement Yield models presented in this paper for both the South and the West coasts are based here on MLE (only) for different fixed values of *q* for both coasts, i.e. the penalties associated with a "prior" for *q* for the West coast are no longer added to the negative of the log-likelihood function.

RESULTS AND DISCUSSION

Over a range of *q* values for the autumn survey on the South coast from 0.1 to 0.7, the estimated RY increases from 760 to 1814 tons, compared to the previous estimate of 1614 tons (Table 3). Correspondingly for the West coast and the summer survey, the RY decreases from 4253 to 2435 tons, compared to the previous estimate of 4102 tons (Table 4).

The "difficulty" with the estimation on the South coast arises from the low survey results now available for the most recent two years. There is however a problem in interpreting these – are they indicative of decreased abundance, or instead a reflection of a period of low catchability (i.e. the same problem as has arisen in interpretation of sole and horse mackerel results)? For both coasts, there is the further difficulty that catchability for the industry vessel used for recent surveys may be less than that for the *Africana* used previously (e.g. for hake the *Andromeda* catchability has been estimated as 0.75 compared to that of the *Africana*, Rademeyer and Butterworth (2015)).

The way forward will need discussion in the DWG. From the analysis side, all that might be possible in the time available might be to repeat the computations of this paper making the "hake adjustment" for the *Andromeda* catchability. Even so, final advice will likely depend on a discussion in the DWG of plausible values for kingklip catchability.

ACKNOWLEDGMENTS

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Rademeyer, R.A. and Butterworth, D.S. 2015. Estimating the *Andromeda* catchability compared to the *Africana* for South African hake in an update of the Reference Case assessment. DAFF Branch Fisheries document: FISHERIES/2015/AUG/SWG-DEM/16.

Table 1. 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 2015. 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 *Andromeda*.

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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	7 453	2 780	0.239		
1987	392	4 504	3 416	0.182		
1988	408	3 311			6 478	0.455
1989	223	2 209				
1990	266	708	1 104	0.352		
1991	680	0	2 148	0.273	7 499	0.146
1992	676	0	1 692	0.218	3 064	0.399
1993	884	0	1 135	0.201	8 759	0.393
1994	1 560	107	1 333	0.276	34 989	0.664
1995	1 275	99	1 152	0.427	20 623	0.409
1996	1 981	164			3 502	0.189
1997	2 128	332			5 103	0.268
1998	1 366	279				
1999	1 737	507			11 350	0.611
2000	1 465	354				*0.257*
2001	2 210	272	*2 033*	*0.292*		
2002	2 479	581				
2003	2 558	702	**4 291**	**0.586**	8 690	0.745
2004	2 539	627	**497**	**0.360**	**716**	**0.346**
2005	1 851	634			**7 472**	**0.886**
2006	1 322	86	1 774	0.444	1 297	0.249
2007	1 223	79	**958**	**0.272**	**3 297**	**0.475**
2008	1 307	71	**4 896**	**0.204**	**3 066**	**0.220**
2009	958	100			**6 072**	**0.302**
2010	1 057	174			7 347	0.349
2011	891	92			**4 879**	**0.392**
2012	1 272	73				
2013	1 995	54				
2014	1 584	9			***1 842***	***0.609***
2015	1 441	3			***1 353***	***0.266***

Table 2. Annual catches (in tons) and abundance indices for the South African kingklip (in tons) of the **West coast** together with CVs obtained from surveys (separated by season) for the period 1986 to 2015. 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 *Andromeda*..

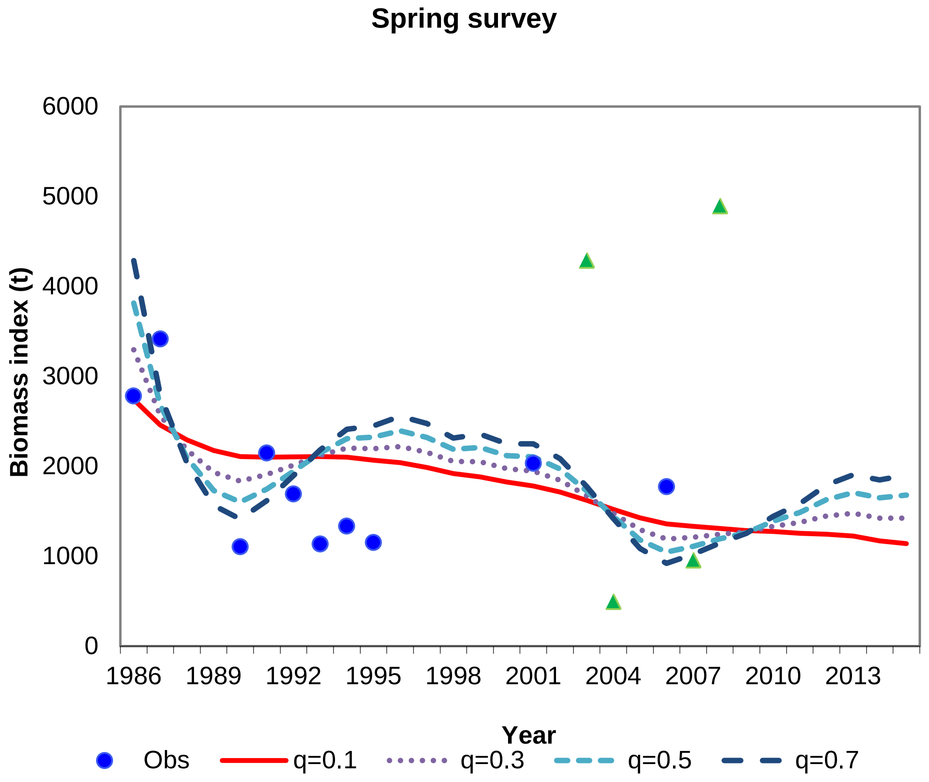
Year	**West coast**					
	Trawl catches	**Longline catches**	**Jan/Feb (summer)**		**Jul/Aug (winter)**	
			Biomass	**CV**	**Biomass**	**CV**
1986	2 287	1 231	3 708	0.160	2 462	0.151
1987	2 083	1 948	2 829	0.192	5 251	0.243
1988	1 519	2 091	5 538	0.209	1 690	0.243
1989	1 407	1 607			1 082	0.337
1990	1 002	557	4 041	0.263	1 311	0.451
1991	1 271	0	3 490	0.299		
1992	1 884	0	7 576	0.187		
1993	2 207	0	10 182	0.186		
1994	1 445	260	8 175	0.179		
1995	1 863	206	7 314	0.257		
1996	1 596	537	11 856	0.299		
1997	1 972	501	6 001	0.218		
1998	1 632	162				
1999	2 104	389	14 724	0.302		
2000	2 166	210				
2001	2 651	157				
2002	2 280	382	13 236	0.165		
2003	1 870	286	14 080	0.314		
2004	1 823	246	**7 472**	**0.181**		
2005	1 790	224	**5 616**	**0.165**		
2006	1 476	75	8 083	0.296		
2007	1 213	40	**5 662**	**0.258**		
2008	1 122	61	**4 843**	**0.138**		
2009	1 153	81	**10 922**	**0.186**		
2010	1 405	72	13 474	0.137		
2011	1 540	242	**15 780**	**0.165**		
2012	1 866	289	**7 576**	**0.168**		
2013	1 801	287	***7 629***	***0.275***		
2014	1 525	310	***8 728***	***0.153***		
2015	1 610	330	***11 473***	***0.334***		

Table 3. Maximum likelihood estimated model parameters for the South coast kingklip component of the resource. The *q* values that are fixed are given in bold. The log-likelihood values that are not comparable (because the data fitted previously differ from the current new data) are shown in square brackets. The biomasses and replacement yields are in units of tons.

Parameter estimates	-ln *L*: Total	-ln *L*: Survey (spring)	-ln *L*: Survey (autumn)	B_{1986}	*RY*	q^{spring}_{survey}
$q^{autumn}_{survey} = 0.354$ **(Previous)**	[26.28]	[16.46]	[9.82]	29 344	1 614	0.100
$q^{autumn}_{survey} = \mathbf{0.1}$	53.30	22.76	30.54	68 772	760	0.040
$q^{autumn}_{survey} = \mathbf{0.3}$	56.20	23.53	32.67	28 265	1 593	0.117
$q^{autumn}_{survey} = \mathbf{0.5}$	61.44	25.45	35.99	20 516	1 751	0.186
$q^{autumn}_{survey} = \mathbf{0.7}$	68.34	28.06	40.28	17 371	1 814	0.247

Table 4. Maximum likelihood estimated model parameters for the **West coast** kingklip component of the resource. The *q* values that are fixed are given in bold. The log-likelihood values that are not comparable (because the data fitted previously differ from the current new data) are shown in square brackets. The biomasses and replacement yields are in units of tons.

Parameter estimates	-ln *L*: Total	-ln *L*: Survey (summer)	-ln *L*: Survey (winter)	B_{1986}	*RY*	q^{winter}_{survey}
$q^{summer}_{survey} = 0.113$ **(Previous)**	[21.05]	[14.24]	[6.81]	43 896	4 102	0.058
$q^{summer}_{survey} = 0.075$ **(MLE)**	14.97	10.74	4.23	63 235	4 939	0.036
$q^{summer}_{survey} = \mathbf{0.1}$	14.99	11.03	3.96	48 257	4 253	0.048
$q^{summer}_{survey} = \mathbf{0.3}$	16.24	14.16	2.08	18 099	2 854	0.137
$q^{summer}_{survey} = \mathbf{0.5}$	19.31	18.59	0.72	12 293	2 565	0.213
$q^{summer}_{survey} = \mathbf{0.7}$	23.96	24.10	-0.15	9 948	2 435	0.278



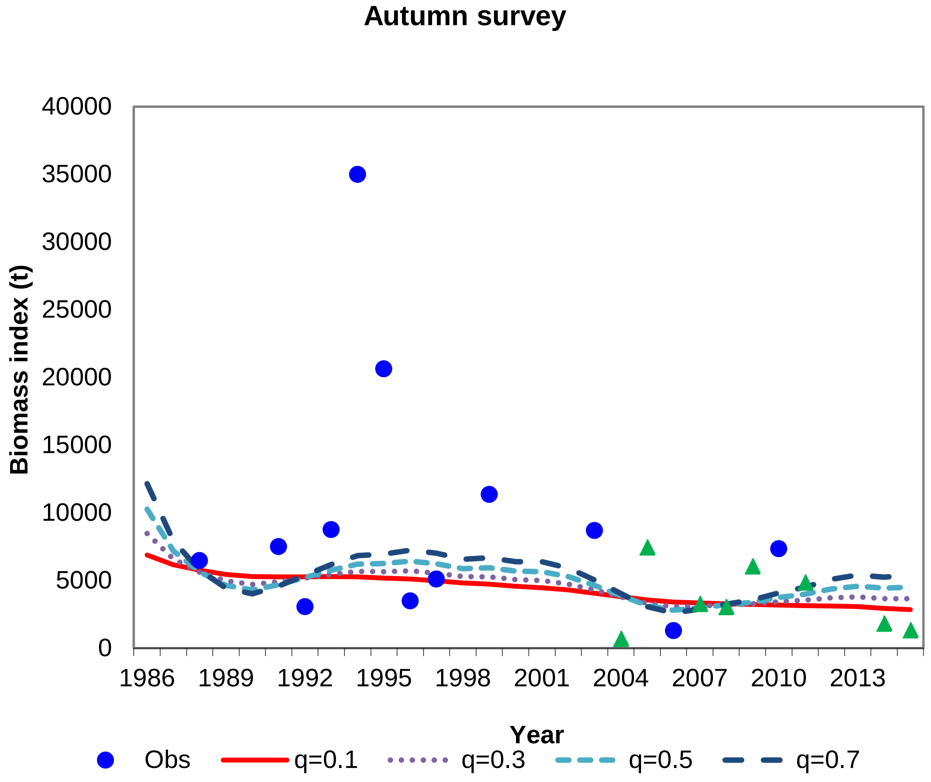
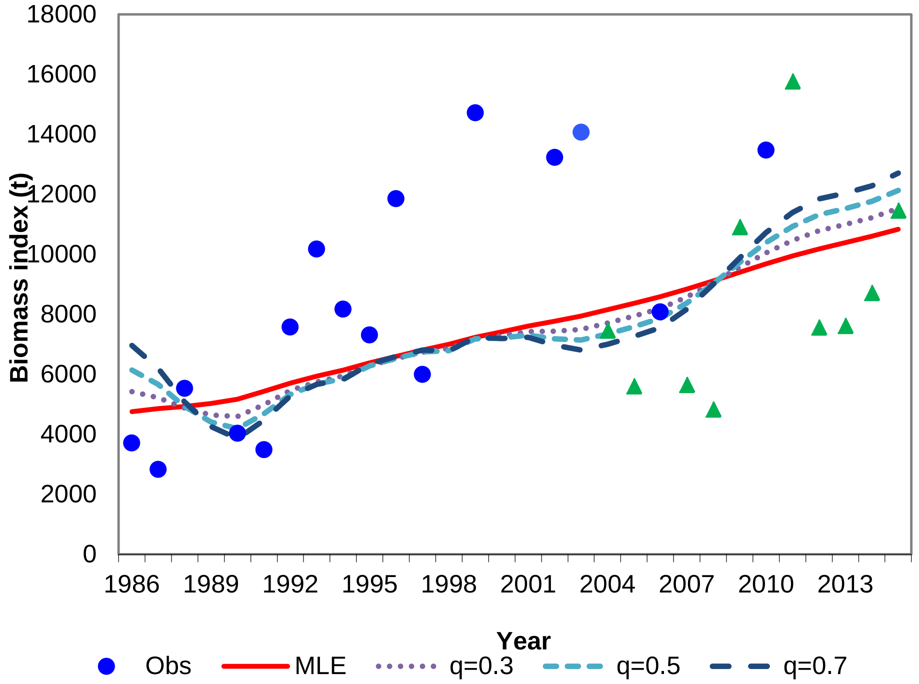


Figure 1. Observed (dots for the old gear and triangles for the new gear) and model estimated (curves) trends for biomass from of *Africana* survey abundance indices fitted to data for the period 1986 to 2015 for the kingklip off the **South coast** of South Africa under different fixed *q* values (shown in the legend) for the summer survey.

Summer survey



Winter survey

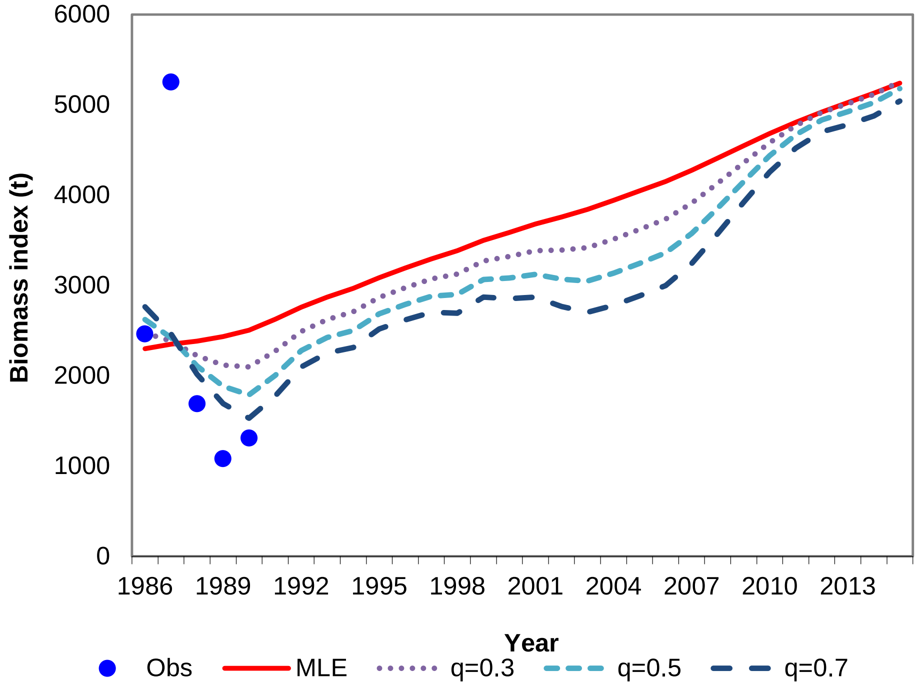


Figure 2. Observed (dots for the old gear and triangles for the new gear) and model estimated (curves) trends for biomass from *Africana* survey abundance indices fitted to data for the period 1986 to 2015 for the kingklip off the **West coast** of South Africa under different fixed *q* values (shown in the legend) for the summer survey, as well as for the estimated MLE value.

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:

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