ESTIMATES OF SUSTAINABLE ROCK LOBSTER YIELD FOR THE FOUR ISLANDS OF THE TRISTAN DA CUNHA GROUP

S J Johnston and D.S. Butterworth

MARAM
Department of Mathematics and Applied Mathematics
University of Cape Town
Rondebosch 7701

June 2009

ABSTRACT

A simple replacement yield model is fitted to CPUE and annual catch data from 1997 for each of the four islands of the Tristan da Cunha group. The results suggest that the overall TAC for the four islands combined should not be changed substantially. There is a strong case for some increase at Gough Island, and perhaps at Nightingale Island. Allocations at Inaccessible and Tristan Islands should perhaps be reduced slightly.

INTRODUCTION

The data sources upon which to assess the rock lobster resources of the islands of the Tristan da Cunha group are very limited, with original records against which to check available essentially for the last decade only (Edwards, 2007), so that it is only over this period that data can be used with some confidence. At this stage, these amount to annual catch and CPUE data only, as detailed below. This necessitates that a rather simple model be applied to estimate sustainable yield. Details of this model, and results from its application to the updated data now available, are provided below.

DATA

The data upon which these assessments are based are listed in Tables 1 and 2, and consist of total catch and standardised CPUE series (Johnston 2009, Johnston *et al.* 2009).

Adjustments have been made to the CPUE series for Gough and Inaccessible Islands compared to the values provided in Johnston *et al.* (2009). These were necessary to retain comparability of an index of abundance (biomass) over time in circumstances when the size limits were changed at the start of the 2003/4 season, being then increased from 70 mm to 75 mm at Gough and decreased from 70 mm to 68 mm at Inaccessible. To allow for this, changes in the proportions of the catch by size class either side of this change time were examined. The average differences suggested to decrease the Inaccessible CPUE values by 2%, and to increase those for Gough by 5%, each from the 2003/4 season onwards, to better achieve comparability (see Annex).

Note that the GLMM standardised CPUE series produced for Inaccessible Island and the series used for Gough, Nightingale and Tristan Islands in 2008 incorporated data up to the 2005/06 Season-Year only. The database upon which these series were based also contained error regarding the Season-Years. In the 2008 database, the Season-Year started in May each year. The 2009 database has been corrected to reflect the correct fishing seasons for each island each year, and in most cases the Season-Year starts in September. Further the CPUE series are now all either GLMM or GLM standardised.

METHODOLOGY

Given the limited data available for each island, a simple age-aggregated population model is used and fitted to the CPUE data. The assumption is made that the surplus production *P* is constant over the period considered, so that an estimate of *P* provides an estimate of the annual sustainable yield for this period.

The model is:

$$B_{y+1} = B_y + P - C_y \qquad (1)$$

where B_y is the biomass at the start of Season-Year *y*, and
C_y is the catch by mass during Season-Year *y*.

The proportion of the biomass harvested each Season-Year, F_y, is then:

$$F_y = C_y / B_y \qquad (2)$$

The estimable parameters of the model are *P* and B_{init}, where B_{init} is the biomass at the start of the first Season-Year for which CPUE data are available. However there is insufficient information content in the data to estimate two parameters, so that B_{init} has to be fixed externally. Instead though, the equivalent process of fixing F_{init} for the proportion harvested in the first season is utilised.

The model is fitted to the CPUE data for each island under the assumption that CPUE is proportional to biomass *B*, with lognormally distributed observation error:

$$CPUE_y = q\, B_y\, e^{\varepsilon_y} \qquad \varepsilon_y \text{ from } N\left(0,\sigma^2\right) \qquad (3)$$

yielding a negative log-likelihood to be minimised of:

$$-\ell n\, L = \sum_{y=init}^{fin} \left[\ell n\, \sigma + \frac{1}{2\sigma^2} \left\{ \ell n\, CPUE_y - \ell n\, q - \ell n\, B_y \right\}^2 \right] \qquad (4)$$

Closed forms for estimates of q and σ result from this formulation so that, given a value for F_{init}, the minimisation is over the parameter P only.

For Tristan Island, for which the CPUE values are not comparable over the full period considered because the daily fishing time was restricted after the 2002/03 Season-Year (see Table 2d), the value of q is assumed to change from the 2002/03 to the 2003/04 Season-Year, but the same σ is taken to apply throughout for more robust estimation.

RESULTS

Results for the estimates of sustainable yield P are given in Table 3a. The corresponding fits of the model to the CPUE data are shown in Figure 1 and all appear broadly reasonable. They are provided for three different choices for F_{init}, and standard error estimates are also listed. Table 3b shows how results for Gough Island change if estimates of IUU catches by Andrew James (Johnston 2009) are taken into account, while Table 4 compares current estimates with those from last year. Table 4 shows that differences of results from those of last year are more due to changes in the database than to the extra data point from a further year.

DISCUSSION AND MANAGEMENT IMPLICATIONS

Estimates of sustainable yield P increase as F_{init} is decreased, so clearly an appropriate choice for F_{init} is crucial to the provision of sound management advice.

F_{init} cannot be greater than 1, as that would correspond to catching the complete population. Given that average catches over the last decade must have been less than sustainable levels (as CPUE has increased for all four islands), and that sustainable fishing proportions would be expected to be typically in the region of at most 10-20% for a relatively long-lived species such as rock-lobster, one might expect a value for F_{init} = 0.3 to be about the maximum plausible.

However, until this matter is further researched, and given the simplicity and uncertainties associated with the approach used, it seems best to take a more conservative approach, and as last year focus on F_{init}=0.7.

Specifically such an approach suggests the following TAC changes:

Gough	65 to not more than 87 tons (or 99 if IUU catches are factored in)
Nightingale	72 to not more than 79 tons
Inaccessible	110 to not less than 105 tons
Tristan	190 to not less than 180 tons

The substantial increase in the CPUE at Gough Island is likely in part a response of the resource to a 30MT TAC reduction in 2004. Care should be taken in interpretation of the results for Nightingale Island, as these may be influenced to some extent by the impact of a change in fishing strategy there from 2002 (see Johnston *et al.* 2009). This TAC reduction has allowed the resource to rebuild, though the model fit suggests that the high CPUE for 2007/08 reflects not only an increase in abundance but also an environmentally induced upward fluctuation in catchability.

FUTURE DEVELOPMENTS

A priority is to develop an approach to provide insight on an appropriate value for F_{init} (specifically in relation to a realistic upper bound) to use in sustainable yield computations of the type above. Plans are to move to a simple age-structured model so that available (though limited) information on biological parameters for the population (growth curve, weight-at-age, etc.), together with the size-at-first-capture in the fishery, can be incorporated. This will provide insight on the extent of relative reduction of the spawning biomass as a function of F_{init} and so provide a basis for selecting a more realistic upper bound for that quantity. Work to capture information on the size structure of the industry's catch is planned, and would inform such evaluations.

REFERENCES

Butterworth, D.S., Rademeyer, R.A. and Johnston, S.J. 2008. Estimates of sustainable rock lobster yield for the four islands of the Tristan da Cunha group. MARAM document, MARAM/Tristan/08/Jun/01.

Edwards, C T T. 2007. Sources of data from the lobster fisheries on Inaccessible, Nightingale, Gough and Tristan da Cunha. MARAM document MARAM/Tristan/07/Dec/05.

Johnston, S.J. 2009. Catch data for the stock assessment of lobster at the Tristan da Cunha group of islands. MARAM document, MARAM/Tristan/09/May/02.

Johnston, S J, Brandão, A, and Butterworth, D S. 2009. Standardised lobster CPUE from The Tristan da Cunha group of islands for the 1997-2007 period. MARAM document MARAM/Tristan/09/June/03.

Table 1: Catch (in tons) information available for assessment of the rock lobster resources at the four islands of the Tristan da Cunha group.

Season-Year	Gough	Nightingale	Inaccessible	Tristan
1997/8	79.097	52.474	62.521	112
1998/9	99.628	51.812	61.492	114
1999/0	93.647	52.623	64.176	122
2000/1	73.617	52.536	66.637	124
2001/2	90.133	57.037	70.512	127
2002/3	76.608	56.614	70.775	133
2003/4	94.868	57.472	77.283	138
2004/5	65.245	61.368	84.484	158
2005/6	57.071	62.276	92.945	160
2006/7	56.646	62.333	103.281	180
2007/8	62.060	65.584	114.566	187
2008/9	66.015	72.259	114.465	180

Table 2a: CPUE information available for assessment of the rock lobster resource at Inaccessible Island. The CPUE have been renormalized over their respective periods, so that their average is 1, and the CPUE for 2003+ decreased by 2% to take account of a minimum size change. Note that here and for the Tables following, Season-Years are not exactly comparable for the 2008 and 2009 analyses for reasons detailed in the text

Season-Year	2008 GLMM	2009 GLMM
1996/7	0.39	
1997/8	0.26	0.30
1998/9	0.47	0.65
1999/0	0.66	0.67
2000/1	0.63	0.79
2001/2	0.77	0.69
2002/3	1.36	1.22
2003/4	1.42	0.62
2004/5	2.31	2.16
2005/6	1.74	1.68
2006/7		
2007/8		1.25

Table 2b: CPUE information available for assessment of the rock lobster resource at Nightingale Island. The CPUE have been renormalized over their respective periods so that their average is 1.

Season-Year	2008 Nominal	2009 Nominal	2009 GLMM
1996/97	0.49		
1997/8	0.30	0.33	0.37
1998/9	0.64	0.70	0.67
1999/0	0.66		
2000/1	0.96	0.91	0.77
2001/2	0.73	0.70	0.81
2002/3	0.76	0.73	0.84
2003/4	1.40	1.38	1.45
2004/5	1.38	1.34	1.52
2005/6	1.71	1.63	1.39
2006/7	1.97		
2007/8		1.27	1.20

Table 2c: CPUE information available for assessment of the rock lobster resource at Gough Island. The CPUE have been renormalized over their respective periods, so that their average is 1, and the CPUE for 2003+ increased by 5% to take into account minimum size change.

Season	2008 Nominal	2009 Nominal	2009 GLMM
1996/97			
1997/8	0.96	1.07	0.93
1998/9	0.96	0.87	0.86
1999/0	1.02	0.83	0.97
2000/1	0.69	0.66	0.65
2001/2	0.64	0.56	0.71
2002/3	0.71	0.60	0.63
2003/4	0.74	0.65	0.73
2004/5	0.93	0.76	0.66
2005/6	1.38	1.27	1.25
2006/7	1.99		
2007/8		2.74	2.62

Table 2d: CPUE information available for assessment of the rock lobster resource at Tristan Island. The CPUE have been renormalized over their respective periods, so that their average is 1. Note that as from 2003/04 operating time restrictions were placed on powerboats at Tristan, so that values from that time are not comparable to earlier values.

Season-Year	2008 Nominal	2009 Nominal	2009 GLM
1996/97			
1997/8	0.52	0.44	0.57
1998/9	0.53	0.95	0.86
1999/0	1.31	1.32	1.14
2000/1	1.33	1.41	1.44
2001/2	1.36	1.39	1.45
2002/3	1.42	1.45	1.55
2003/4	1.73	0.61	0.59
2004/5	0.48	0.68	0.82
2005/6	0.61	0.79	0.83
2006/7	0.96	1.05	0.99
2007/8	0.76	0.91	0.77

Sources:

Gough, Nightingale and Inaccessible: GLMM standardised longline CPUE – Johnston *et al.* (2009)

Tristan: GLM standardised catch per large powerboat day CPUE – Johnston *et al.* (2009)

Table 3a: Estimates of sustainable yield *P* (in tons), with Hessian-based standard errors in parentheses, from a simple age-aggregated population model fit to the 2009 GLMM CPUE data for each of the four islands of the Tristan da Cunha group. Estimates are given in relation to an assumed value for F_{init} , which is the proportion of available abundance harvested in the first Season-Year for which a CPUE value is available (1997).

	2008/9 TAC	F_{init} 0.7	0.5	0.3
Gough	65	86.4 (3.8)	88.9 (6.4)	95.5 (12.3)
Nightingale	72	79.0 (6.6)	88.8 (9.3)	111.7 (15.5)
Inaccessible	110	105.4 (16.2)	120.2 (22.8)	155.0 (38.4)
Tristan	190	180.0 (7.1)	203.0 (10.6)	257.9 (18.9)
TOTAL	437	450.8 (19.4)	500.9 (27.6)	620.1 (47.2)

Table 3b: Comparison of estimates of sustainable yield *P* (in tons), with Hessian-based standard errors in parentheses from a simple age-aggregated population model fit to the 2009 GLMM CPUE data from Gough Island. Results are produced with or without taking IUU catch estimates by A. James (see Johnston 2009) into account. Estimates are given in relation to an assumed value of $F_{init} = 0.7$, which is the proportion of available abundance harvested in the first Season-Year for which a CPUE value is available (1997).

	2008/09 TAC	F_{init}=0.7
Gough no IUU	65	86.4 (3.8)
Gough plus IUU	65	98.2 (5.6)
Difference		11.8

Table 4: Sustainable yield (*P* in tons) statistics obtained in these analyses compared to those obtained one year previously by Butterworth *et al.* (2008) for the case $F_{init} = 0.7$.

	A	B	C	A-B	A-C
	2009 analysis	2009 analysis without the 2007 datapoint	2008 analysis	Difference arising from extra data point	Difference (2009-2008)
Gough	86.4	84.1	88.8	2.3	-2.4
Nightingale	79.0	84.0	81.8	-5	-2.8
Inaccessible	105.4	111.3	126.1	-5.9	-20.7
Tristan	180.0	180.2	186.2	-0.2	-6.2
Total	**450.8**	**459.6**	**482.9**	**-8.8**	**-32.1**

Figure 1a: Model fits to Gough Island CPUE for F_{init} =0.3, F_{init} =0.5 and F_{init} =0.7.

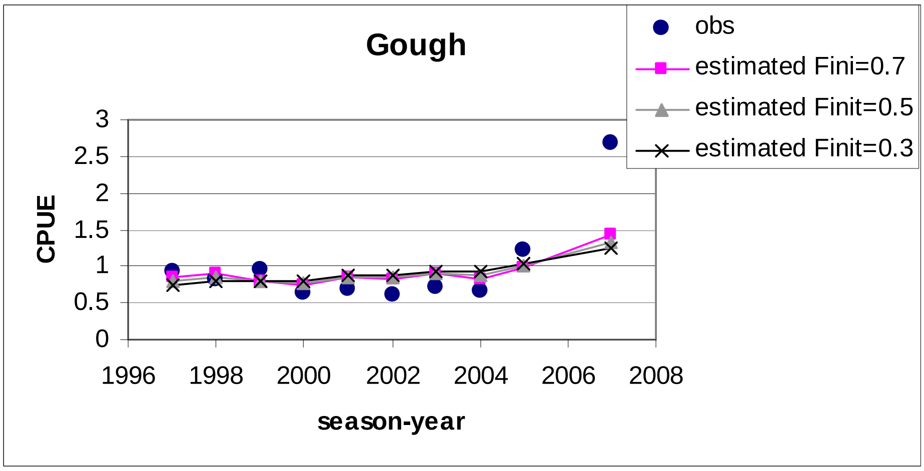


Figure 1b: Model fits to Nightingale Island CPUE for F_{init} ==0.3, F_{init} =0.5 and F_{init} =0.7.

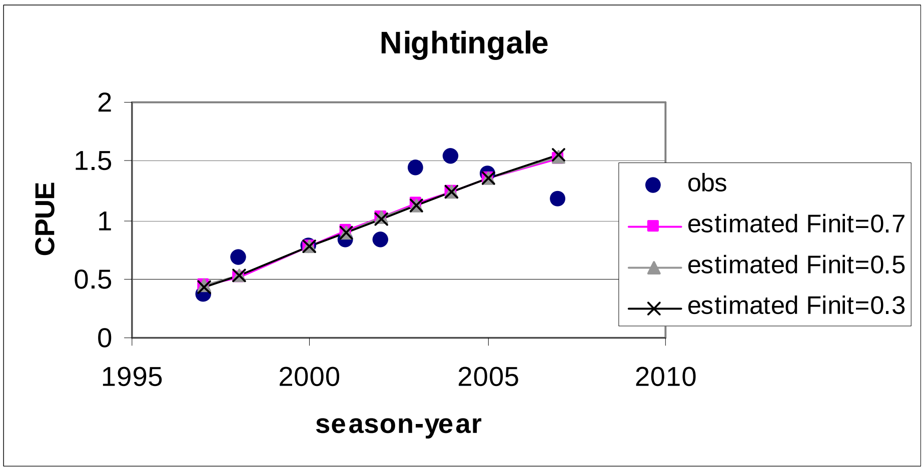


Figure 1c: Model fits to Inaccessible Island CPUE for $F_{init} = 0.3$, $F_{init} = 0.5$ and $F_{init} = 0.7$.

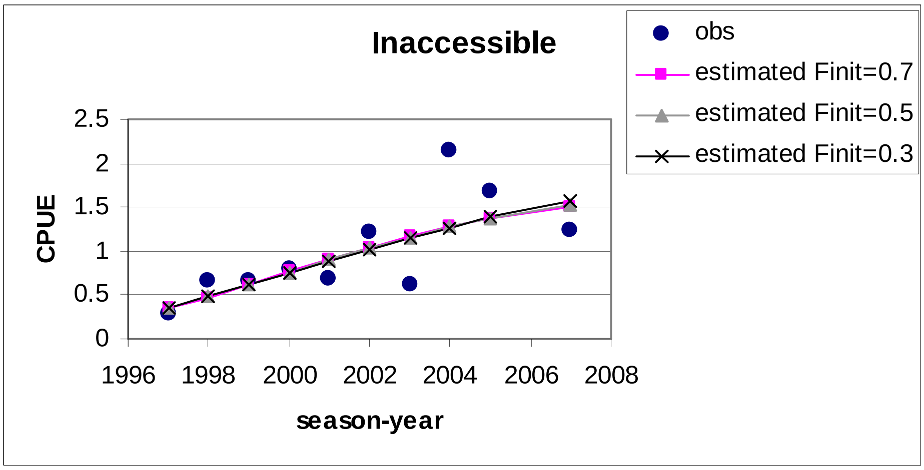
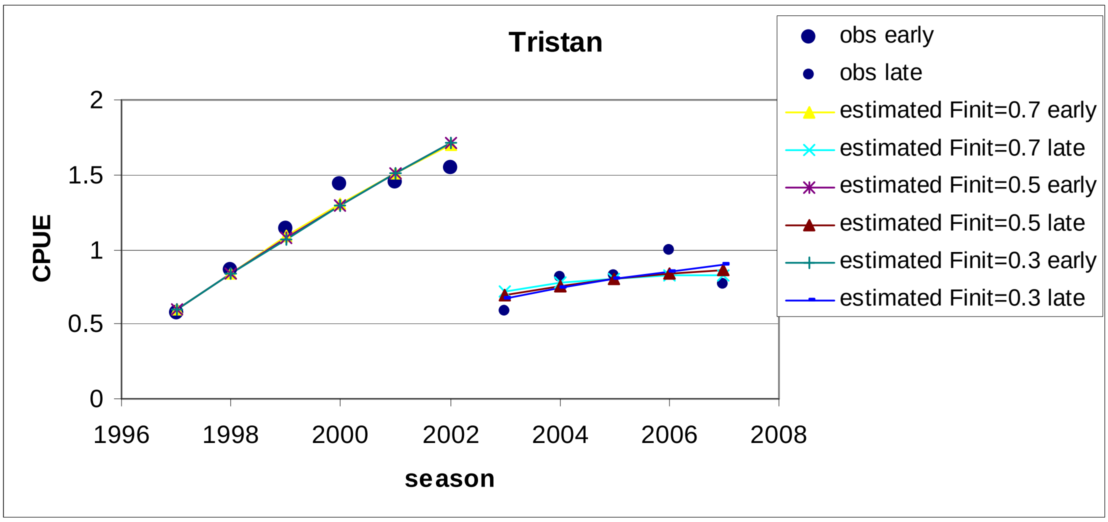


Figure 1d: Model fits to Tristan Island CPUE for $F_{init} = 0.3$, $F_{init} = 0.5$ and $F_{init} = 0.7$.



Annex: Method to determine effect of minimum size change on CPUE

At the start of the 2003/04 season the following minimum size changes occurred:

Gough Island – minimum size **increased** from 70mm to 75mm
Inaccessible Island– minim size **decreased** from 70mm to 68mm

Clearly these changes will have an impact on the CPUE data series for each of these islands, and a relevant CPUE scaling factor to be applied to the 2003+ CPUE needs to be calculated for both islands.

Table 1 contains information obtained from production data of both "whole" and "tail" product. It is considered (Andrew James, pers. commn) that the whole and tail grades that would be affected by the size limit adjustments are:

Gough Island: Tails grades = M, Kz and K
Whole counts = grades 72, 68, 64 and 60

Inaccessible Island: Tails grades = Kz and K
Whole counts = grades 72 and 68

Table A1 reports the proportion of the above grades as a percentage of the total production for both islands. The approach is to compare the average percentages before and after the 2003 minimum size change.

Gough Island
As expected the percentage drops in the "tails" product from around 16% to 10% (a reduction of 6%) as a result of the minimum size reduction in 2003. A smaller reduction of around 4% down to 1 % (a reduction of 3%) is seen in the "whole" product. If one takes the average over these two products, a rounded value of a 5% reduction to be applied to 2003+ CPUE to render it comparable to earlier years is obtained.

Inaccessible Island
At Inaccessible there is no clear trend in the "tails" data – and if anything, the reverse change to that expected is shown in the pre-2003 to 2003+ averages, with a decrease in the proportion of small tail grades (Kz and K) as a percentage of total product, when the minimum size was decreased in 2003. This effect expected is however seen in the "whole" production, with an increase in those grades' percentage contribution increasing from around 2% to 6% (a 4% change).

Given the anomalous result for 'tails", it was decided to treat this as a zero change, leading to a net 2% figure for adjusting the CPUE when averaging with the result for "whole" product.

Table A1: The percentage of the total production for the grades affected by minimum size change for Gough and Inaccessible Islands, for both "tails" and "whole" product.

	TAILS		**WHOLE**	
	Gough	**Inaccessible**	**Gough**	**Inaccessible**
2001	14.87	22.07	4.68	1.04
2002	16.30	26.27	2.31	2.50
2003	20.57	13.96	3.05	6.94
2004	8.43	16.90	0.10	7.25
2005	10.48	22.56	0.03	4.78
2006	5.11	21.07	0.00	6.12
2007	4.49	26.36	0.00	6.41
pre 2003	16	24	4	2
2003+	10	20	1	6
change	-6	-4	-3	4