GLMM- AND GLM-STANDARDISED LOBSTER CPUE FROM THE TRISTAN DA CUNHA GROUP OF ISLANDS FOR THE 1997-2010 PERIOD

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ABSTRACT

The longline CPUE series for the three outer islands are GLMM standardised through to 2010. Year, month, area, trap-type, soak time, depth and year-area interactions are treated as fixed effects, and year-month interactions treated as a random effect. For Tristan, for which the available powerboat data are more limited, a GLM with year and month as fixed effects is applied. After initial increase, the standardised CPUE indices show drops over the most recent years for all islands – although for Gough, this decrease is only seen in the most recent 2010 season’s data.

INTRODUCTION

The commercial CPUE series of a resource is often used as an index of population density and consequently to inform on population abundance when modelling the dynamics of the underlying population. It is known, however, that a number of other factors besides density may influence the recorded values of CPUE. Where sufficient data exist, General Linear Mixed Model (GLMM) standardisation is able to take some of these further effects into account, thereby producing a more reliable index of abundance. This document reports the application of a GLMM standardisation to *Jasus tristiani* lobster catch per unit effort data from around Inaccessible, Nightingale and Gough Islands for the period 1997-2010. For Tristan, for which the data are more limited, a simpler GLM approach is used applied to data for the 1994-2010 period. Results presented here are updated from those presented in Johnston *et al.* (2010a, b), taking two more years data into account.

For the outer islands, only longline CPUE data are considered (i.e. the powerboat data are ignored for reasons given below). For Tristan, where normally all fishing occurs using powerboats, the CPUE series relates to powerboat effort where here the unit of effort is a combination of the amount of gear used and the time fished.

METHODOLOGY

Data

Raw Logsheet data
The logsheet data for all islands have been entered electronically into EXCEL spreadsheets. Logsheet data from the fishery are available for the Season-Years between 1996 and 2010, where a Season-Year is taken to run from September until August the following year, i.e. Season-Year 2005 refers to the period from September 2005 to August 2006. Unfortunately logsheet data for 2006 have been misplaced (James Glass, pers. comm.). Logsheet data are also incomplete for Season-Year 1996 (Edwards and Glass, 2007) for the three outer islands (Gough, Nightingale and Inaccessible), and thus 1996 is also omitted from these analyses.

Summary sheet data
Data summary sheets recorded by the Agriculture and Natural Resources Department on Tristan da Cunha are available from Season-Years 1996 to 2010. These contain summary data from both the logsheets (total catch and total effort) and factory reports (Edwards, 2007).

Accounting for inaccurate records for the three outer islands

Although logsheet data are valuable as they record details of the catches, e.g. location and soak-time which are needed for standardisation, the logsheet entries are known to be inaccurate (Edwards, 2007). In particular, longline catch and powerboat effort are unreliable. Furthermore there is currently insufficient information concerning the different catch rates for longline monster and powerboat traps, thereby precluding the standardisation of the catch rate across different types of fishing. All powerboat data were therefore excluded from the analyses presented here for Inaccessible, Nightingale and Gough.

Because of inaccurate longline catch records, the total logsheet catch for each Season-Year differs from the actual catch taken. A more accurate (best) estimate of the total longline catch in Season-Year y (C_y) is provided by subtracting the total powerboat catch from the total packed weight (both recorded on the Summary sheets), where the packed weight is scaled upwards to account for weight lost during processing (Edwards, 2007). This catch estimate can then be used to adjust the longline catch records so that the total catches from both sources are equal. Unfortunately there are logsheets missing for some years. An adjustment coefficient k_y was therefore developed using the ratio of total recorded effort for the Summary sheets and logsheets, to scale adjustments.

Adjusted logsheet catches were calculated as follows:

$$c_{i,y} \rightarrow c^*_{i,y} = c_{i,y} k_y = c_{i,y} \frac{C_y}{C_y^{LS} \frac{E_y^{SS}}{E_y^{LS}}} \tag{1}$$

where

- $c_{i,y}$ is the i'th logsheet longline catch record for Season-Year y,
- C_y^{LS} is the total logsheet longline catch for Season-Year y,
- C_y is the best estimate of the total longline catch for Season-Year y (based on summary sheets),
- E_y^{LS} is the total logsheet longline effort for Season-Year y, and
- E_y^{SS} is the total Summary sheet longline effort for Season-Year y.

Adjusted catches were then used to calculate Adjusted CPUE values (I_y^*) for each Season-year:

$$I_y = \frac{1}{n_y}\sum_i \frac{c_{i,y}}{e_{i,y}} \rightarrow \frac{1}{n_y}\sum_i \frac{c_{i,y}^*}{e_{i,y}} = I_y^* \qquad (2)$$

where

- I_y is the nominal CPUE for Season-Year y,
- $e_{i,y}$ is the i'th logsheet longline effort record for Season-Year y, and
- n_y is the number of logsheet records for Season-Year y.

The General Linear Mixed Model for the three outer islands

A GLMM which includes both fixed and random effects is used to standardise the lobster CPUE data for the three outer islands, where catches are the adjusted logsheet catches of Equation (1) and effort is logsheet effort. (Note that this approach assumes that the logsheet data represent an unbiased sample of all the fishery in each Season-Year.). This model allows for possible annual differences in the areal distribution of the lobsters (which is considered to be a fixed effect) and for annual differences in each month (considered as a random effect). This model is given by:

$$\ln(CPUE + \delta) = \mathbf{X}\alpha + \mathbf{Z}\beta + \varepsilon \qquad (3)$$

where:

- α is the unknown vector of fixed effects parameters (in this case this consists of the factors given by equation (4) below),
- $\mathbf{X}$ is the design matrix for the fixed effects,
- β is the unknown vector of random effects parameters (which in this application consists of a year-month interaction),
- $\mathbf{Z}$ is the design matrix for the random effects,
- δ is a small constant added to the rock lobster CPUE to allow for the occurrence of zero CPUE values (0.1 kg/trap in this case, being about 10% of the average nominal values), and
- ε is an error term assumed to be normally distributed and independent of the random effects.

This approach assumes that both the random effects and the error term have zero mean, i.e. $E(\beta)=E(\varepsilon)=0$, so that $E(\ln(CPUE+\delta)) = \mathbf{X}\alpha$. The variance-covariance matrix for the residual errors (ε) is denoted by **R** and that for the random effects (β) by **G**. The analyses undertaken here assume that the residual errors as well as the random effects are homoscedastic and uncorrelated, so that both **R** and **G** are diagonal matrices given by:

$$\mathbf{R} = \sigma_{\varepsilon}^{2}\mathbf{I}$$

$$\mathbf{G} = \sigma_{\beta}^{2}\mathbf{I}$$

where **I** denotes an identity matrix. Thus, in the mixed model, the variance-covariance matrix (**V**) for the response variable is given by:

$$\mathrm{Cov}(Incr) = \mathbf{V} = \mathbf{ZGZ}^{\mathrm{T}} + \mathbf{R},$$

where $\mathbf{Z}^{\mathrm{T}}$ denotes the transpose of the matrix **Z**.

The sum of the factors that are considered as fixed effects (i.e. **X**α in equation (1)) in the GLMM is given by the following:

$$\ln(CPUE + \delta) = \mu + \alpha_{year} + \beta_{month} + \gamma_{area} + \eta_{trap-type} + \lambda_{soaktime} + \theta_{depth} + \tau_{year\,x\,area} \qquad (4)$$

where:

μ	is the intercept,
year	is a factor with 13 levels associated with the years (i.e. the Season-Years: 1997-2010, omitting 2006),
month	is a factor with levels associated with the fishing month (1-12 for Gough, 1-3 and 9-12 for Nightingale, 1-3 and 8-12 for Inaccessible),
area	is a factor with levels associated with groupings of fishing areas (Gough = 7 areas, Nightingale = 6 areas, Inaccessible = 10 areas),
trap type	is a factor with levels associated with the trap type (monster and Bee hive for Inaccessible, and Monster only for Gough and Nightingale),
soak time	is a factor with 3 levels associated with the soak time period (“1”=0.0–0.49 days, “2”= 0.5–1.9 days and “3” for 2 or more days),
depth	is a factor with 4 levels associated with fishing depth ranges (“1” for depths < 10m, “2” for 10–39.9m, “3” for 40–89.9m, and “4” for depths ≥ 90 m),
year x area	is the interaction between year and area.

In this application the CPUE has been standardised on the year 1998, month of *September*, trap type *Monster*, soak time “1” , depth category “1” and area = “0”.

For this model, because of the fixed effect interaction of area with year (which implies changing spatio-temporal distribution patterns), an index of overall abundance needs to integrate the different trends in density in each area over the size of these areas. Accordingly the standardised CPUE series is obtained from:

$$CPUE_{year} = \left[\sum_{area}\left(\left(\exp\left(\mu + \alpha_{year} + \gamma_{area} + \tau_{year\,x\,area}\right) - \delta\right) * A_{area}\right)\right] / A_{total} \qquad (5)$$

where:

A_{area} is the surface size of the area concerned,

A_{total} is the total size of the fishing ground considered (the division by A_{total} is to keep the units and size of the standardised CPUE index comparable with those of the nominal CPUE), and

δ is taken to be 0.1 kg/trap (about 10% of the nominal average values).

Table 1 provides the A_{area} values for Inaccessible, Nightingale and Gough Islands.

Simple GLM (for Tristan data)

The powerboat CPUE database for Tristan contains information at a trip level of the following:

Year
Month
Number of traps
Number of hoops
Hours fished
Total catch (in kgs)

In Johnston *et al.* (2010) a GLM was developed for which the CPUE is taken equal to $CPUE = \frac{catch}{(number\ gear)(hours\ fished)}$ kg/hour/gear (6)

where the number of gear is:

$$number\ of\ gear = traps + (0.5).hoopnets$$

(as estimated by James Glass pers. comm.) to allow for the different relative efficiency of the two types of gear.

The model used here is given by:

$$\ln(CPUE + \delta) = \mu + \alpha_{year} + \beta_{month} \quad (7)$$

where:

C	is the catch in kg,
E	is the effort in hours fished,
μ	is the intercept,
year	is a factor with 17 levels associated with the years (i.e. the Season-Years: 1994-2010),
month	is a factor with levels associated with the fishing month (1-12), and
δ	is taken to be 0.95 kg/hour/gear (about 10% of the nominal average values).

For Tristan Island the CPUE has been standardised on the month of *September*. Further, as no *area*year* interactions are included, the standardised CPUE series is obtained from:

$$CPUE_{year} = \exp(\mu + \alpha_{year} + \beta_{September}) - \delta \quad (6)$$

RESULTS

Table 1 provides standardised CPUE values derived from the GLMM/GLM considered. For comparison, the adjusted nominal CPUE values are also reported. Figure 1 compares the adjusted nominal CPUE with the updated 2012 standardised CPUE series, along with the 2010 standardised CPUE series. The series have been renormalised for comparative purposes. Figure 2 shows the month effects for each island, and Figure 3 shows the area effects for each of Inaccessible, Nightingale and Gough Islands (area data have only recently been reported on the Tristan CPUE datasheets).

DISCUSSION

From the analyses of this paper, the 2012 updated GLMM/GLM standardised CPUE series shown in Table 1 are put forward as the best upon which to base assessment of the resource.

Note that care should be taken in interpreting the post 2002 increase in standardised CPUE at Nightingale Island as entirely an abundance-related effect. Before that time with two vessels fishing, catching was near continuous. Subsequently only one vessel fished for series of short periods. This allowed the lobster to redistribute into the limited fishable areas, thus inflating catch rates.

For all four islands, the standardised CPUE indices show an initial increase, followed by drops over the most recent years – although for Gough, the decrease is only seen in the most recent 2010 season’s data.

FUTURE WORK

The further information now available for Tristan also includes a breakdown of the numbers of traps and hoops used. These data need to be analysed further to try to use them to estimate and take due account of the relative fishing power of these two catching devices.

Area information (four areas defined) associated with the catch and effort data for Tristan have been collected since 2005. The GLM for Tristan could be extended to take area fished into account.

REFERENCES

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

Edwards, C.T.T. and Glass, J.P. 2007. Reconciliation of data from the lobster fisheries on Inaccessible, Nightingale, Gough and Tristan da Cunha. Technical Report MARAM/Tristan/07/Dec/06, Ovenstone Fisheries.

Johnston, S.J., Brandao, A. and D.S. Butterworth. 2010a. GLMM- and GLM-standardised lobster CPUE from the Tristan da Cunha group of islands for the 1997-2008 period. MARAM/Tristan/2010/May/04.

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Table 1a: The size (km^2) of each fishing area around **Inaccessible** Island.

Area	Name	Size
1	Bank	53.58
2	North point	5.88
3	Salt beach	1.10
4	East Point	10.14
5	Toms beach and Black spot	3.60
6	South Hill	3.60
7	Pyramid rock and Blinder	5.23
8	West point	5.04
9	Blendon Hall	4.32

Table 1b: The size (km^2) of each fishing area around **Nightingale** Island.

Area	Name	Size
1	North	12.13
2	North East	3.29
3	South East	3.02
4	South	9.00
5	West	5.87

Table 1c: The size (km^2) of each fishing area around **Gough** Island.

Area	Name	Size
1	Cave Cove	6.48
2	Hawkins Bay	8.53
3	SE pt	8.01
4	SW pt	9.11
5	Gaggins pt	10.38
6	N pt	3.69

Table 2a: Standardised longline CPUE series for **Inaccessible** Island using the GLMM model detailed in the text. The number of data records for each Season-Year (*N*) is provided, along with the adjusted nominal CPUE series for comparison. The adjustment coefficient values (k_y) by which the logsheet catches are scaled are also provided.

Season-Year	*N*	**Adjustment coefficient k_y**	**Adjusted Nominal CPUE (kg/trap)**	**Standardised CPUE**
1997	617	0.903	1.671	1.925
1998	733	0.984	2.371	3.601
1999	371	0.757	2.846	3.864
2000	668	0.876	2.922	4.676
2001	562	0.958	3.356	4.298
2002	427	1.063	4.759	7.292
2003	246	0.863	5.607	6.097
2004	655	0.909	6.598	12.650
2005	263	1.022	7.640	12.559
2007	720	0.937	4.678	7.109
2008	816	0.996	4.701#	6.927
2009	1075	1.110	3.640	6.913
2010	646	1.079	2.744	4.053

This value has been updated since 2010. Updated information led to an update to the "*k*" scaling parameter.

Table 2b: Standardised longline CPUE series for **Nightingale** Island using the GLMM model detailed in the text. The number of data records for each Season-Year (*N*) is provided, along with the adjusted nominal CPUE series for comparison. The adjustment coefficient values (k_y) by which the logsheet catches are scaled are also provided.

Season-Year	*N*	**Adjustment coefficient k_y**	**Adjusted Nominal CPUE (kg/trap)**	**Standardised CPUE**
1997	784	0.438	1.566	0.831
1998	549	1.173	3.147	1.542
2000	196	0.900	4.052	2.015
2001	201	0.954	3.093	1.914
2002	585	0.963	3.252	1.996
2003	497	1.062	6.115	3.575
2004	513	1.040	5.920	3.673
2005	415	1.002	7.221	3.490
2007	353	0.982	5.756	2.829
2008	439	1.017	5.307#	2.639
2009	496	1.163	4.954	2.475
2010	385	1.054	5.186	2.534

This value has been updated since 2010. Updated information led to an update to the "*k*" scaling parameter.

Table 2c: Standardised longline CPUE series for **Gough** Island using the GLMM model detailed in the text. The number of data records for each Season-Year (*N*) is provided, along with the adjusted nominal CPUE series for comparison. The adjustment coefficient values (k_y) by which the logsheet catches are scaled are also provided.

Season-Year	*N*	**Adjustment coefficient k_y**	**Adjusted Nominal CPUE (kg/trap)**	**Standardised CPUE**
1997	1207	0.945	2.495	2.093
1998	1304	0.788	1.798	1.795
1999	2113	1.124	1.913	2.209
2000	2116	0.990	1.501	1.389
2001	1585	0.884	1.222	1.449
2002	1911	1.023	1.374	1.351
2003	1691	0.890	1.383	1.524
2004	1076	0.892	1.615	1.358
2005	754	1.023	2.714	2.490
2007	410	1.149	5.825	5.412
2008	414	1.005	6.203#	5.221
2009	320	1.286*	10.507	9.962
2010	473	1.055	6.730	5.247

This value has been updated since 2010. Updated information led to an update to the "*k*" adjustment coefficient.
*This value is surprisingly high; the associated data were rechecked and appear to be in order.

Table 2d: Standardised powerboat CPUE series for **Tristan** Island using the GLM model detailed in the text. The number of data records for each Season-Year (*N*) is provided, along with nominal CPUE series for comparison.

Season-Year	*N*	**Nominal CPUE (kg/hour/gear)**	**Standardised CPUE (kg/hour/gear)**
1994	1017	0.295	0.315
1995	1253	0.246	0.278
1996	1222	0.278	0.304
1997	772	0.454	0.473
1998	502	0.650	0.568
1999	338	0.961	0.755
2000	324	1.019	0.946
2001	334	1.107	0.968
2002	335	1.397	1.325
2003	382	1.679	1.518
2004	385	1.728	1.683
2005	339	2.307	2.187
2006	284	2.828	2.548
2007	310	2.365	2.096
2008	456	1.497	1.268
2009	281	1.824	1.736
2010	484	1.317	1.235

Figure 1a: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Inaccessible** Island. All series have been renormalised to a mean of 1 (for 1997-2008) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 68mm in 2003.]

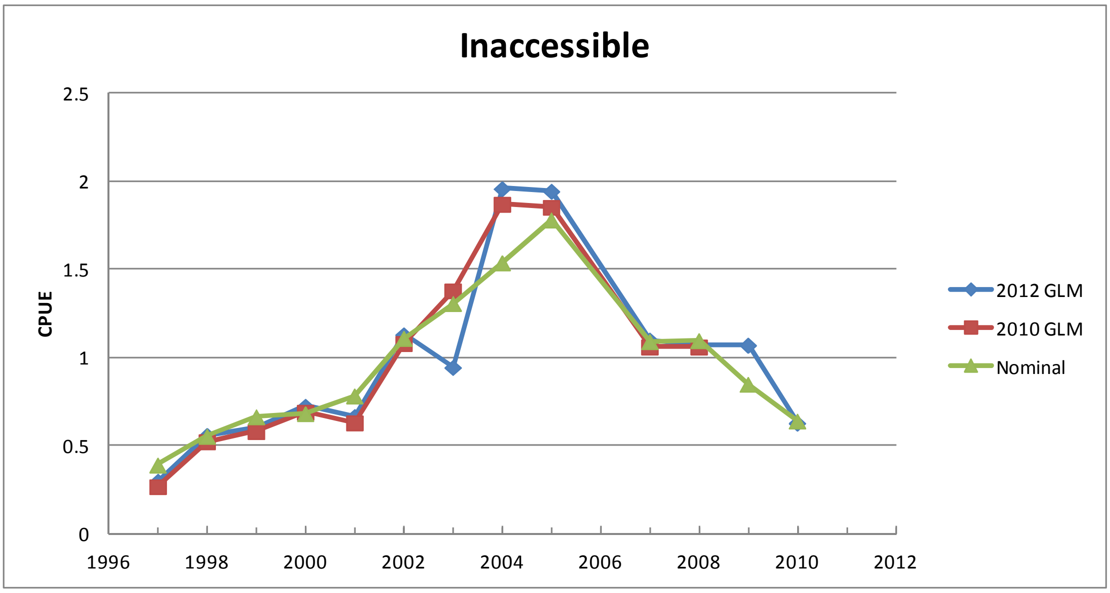

Figure 1b: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Nightingale** Island. All series have been renormalised to a mean of 1 (for 1997-2008) for easier comparison of trends.

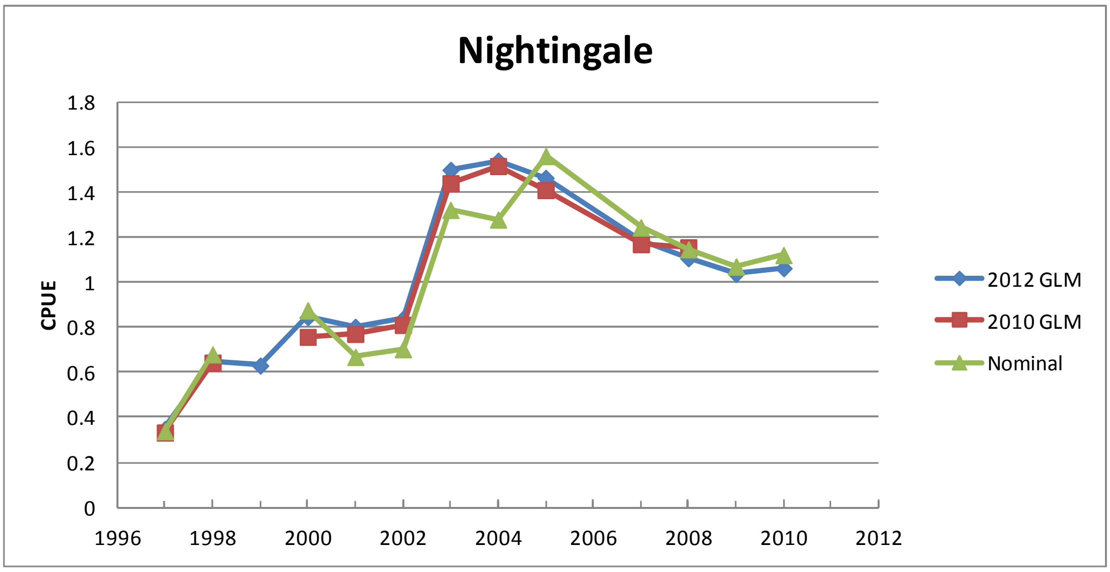

Figure 1c: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Gough** Island. All series have been renormalised to a mean of 1 (for 1997-2008) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 75mm in 2003.]

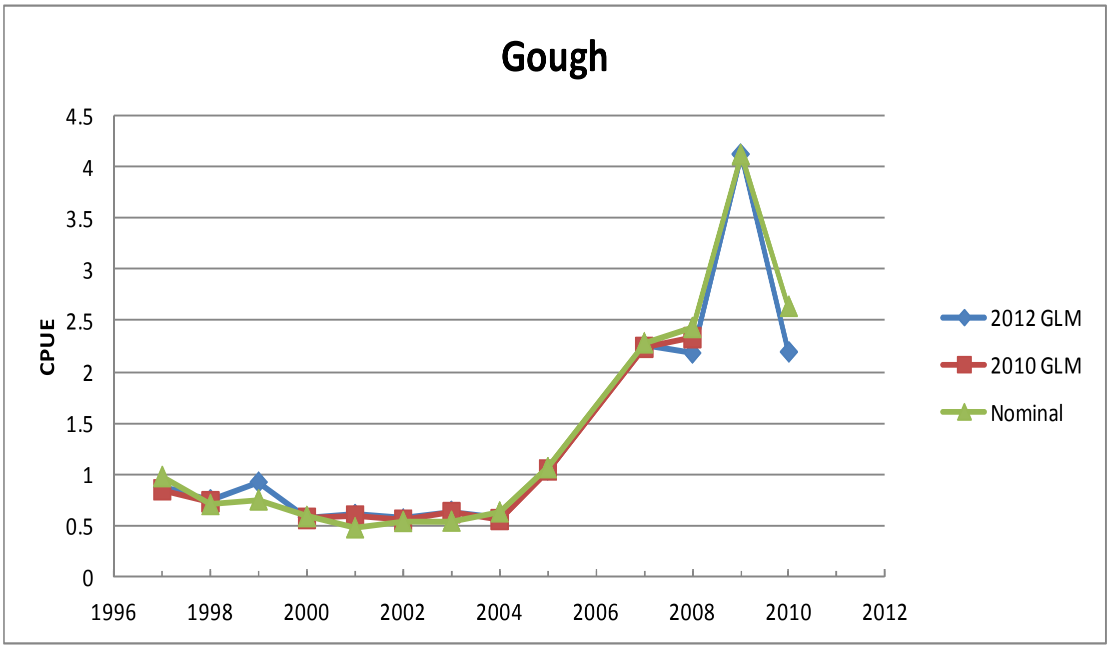

Figure 1d: Comparative plot of the adjusted nominal and GLM standardised powerboat CPUE series for **Tristan** Island. Both series have been renormalised to a mean of 1 (for 1994-2009) for easier comparison of trends.

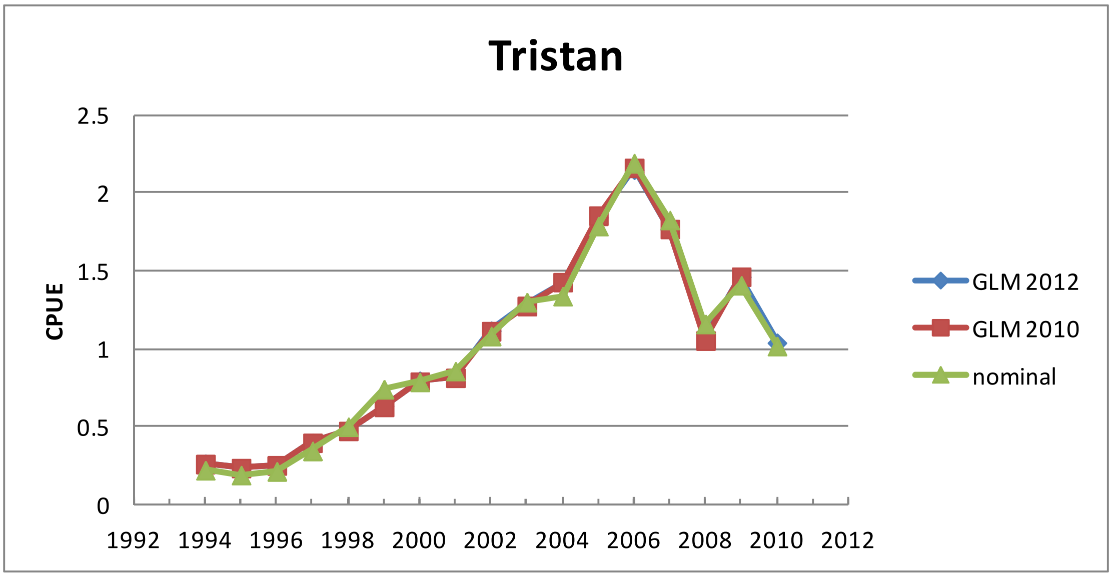

Figure 2a: GLMM month effects for the **Inaccessible** Island.

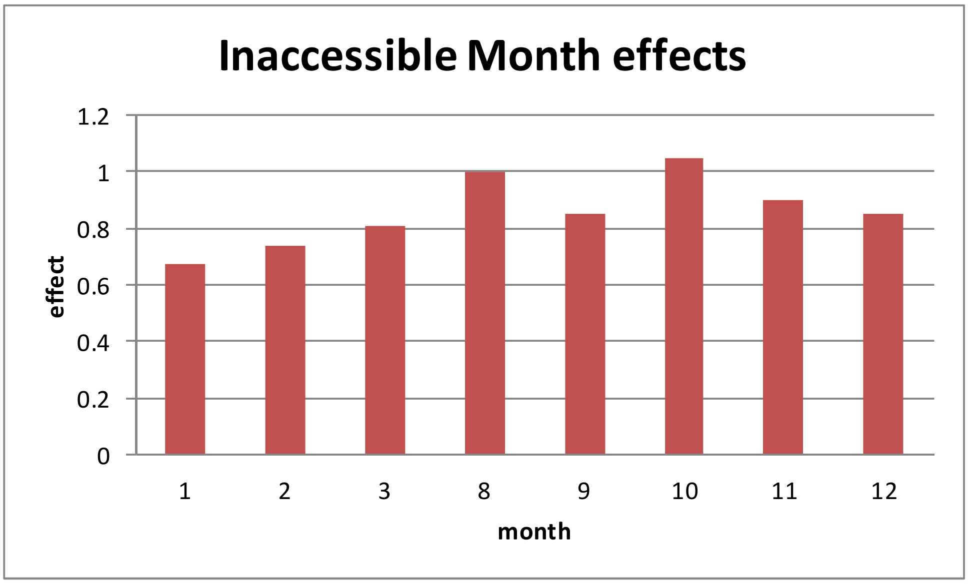

Figure 2b: GLMM month effects for the **Nightingale** Island.

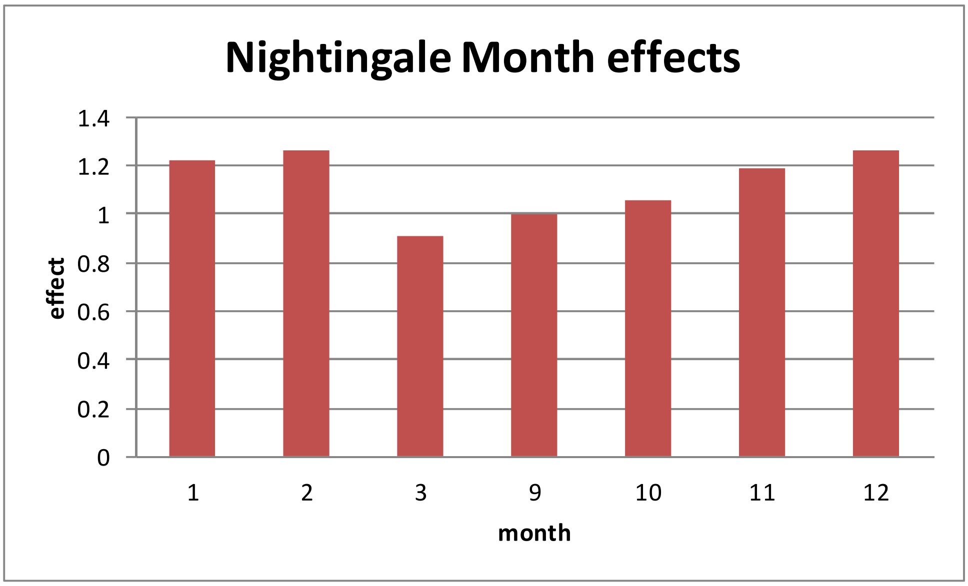

Figure 2c: GLMM month effects for the **Gough** Island.

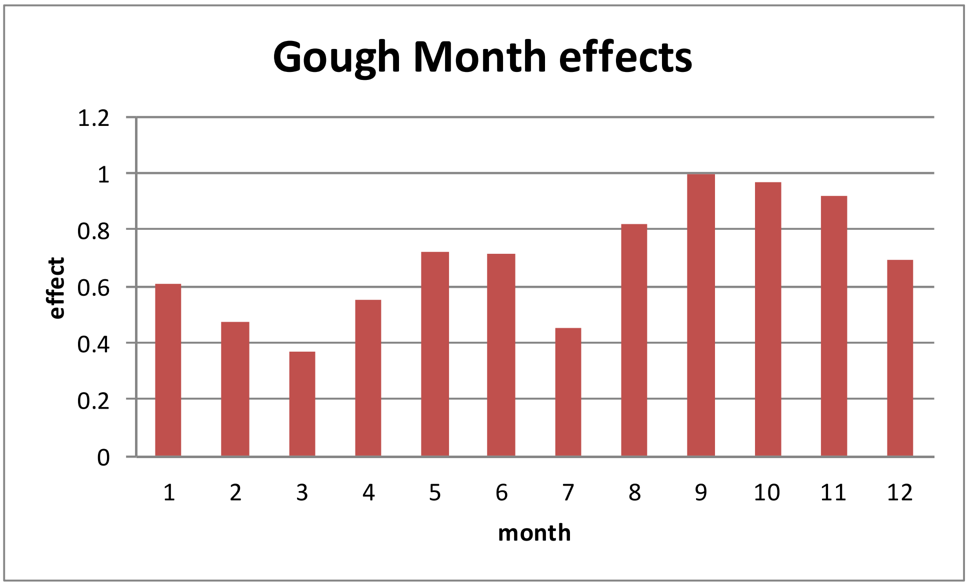

Figure 2d: GLM month effects for the **Tristan** Island.

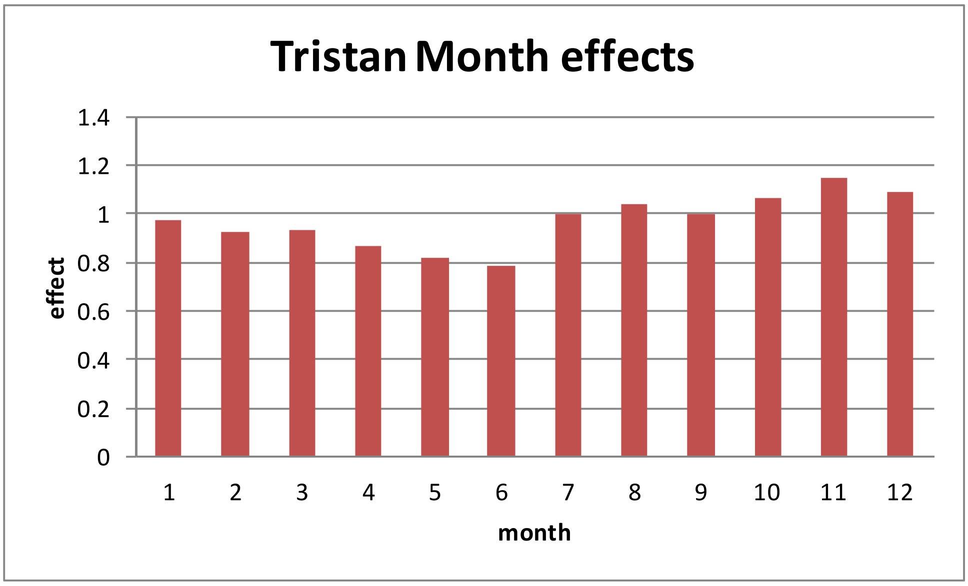

Figure 3a: GLMM area effects for **Inaccessible** Island (see Table 1a for area definitions; A0 being unknown area).

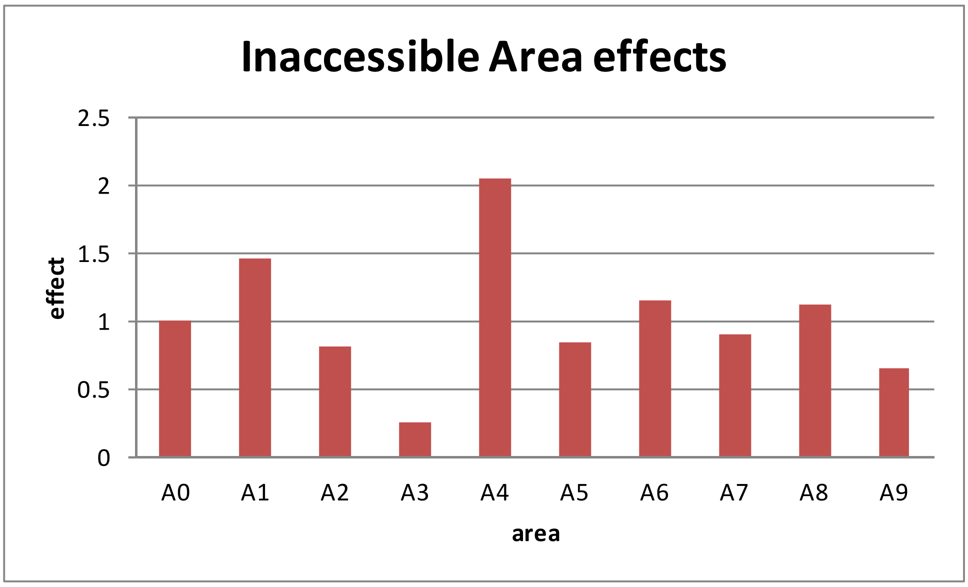

Figure 3b: GLMM area effects for **Nightingale** Island (see Table 1b for area definitions; A0 being unknown area).

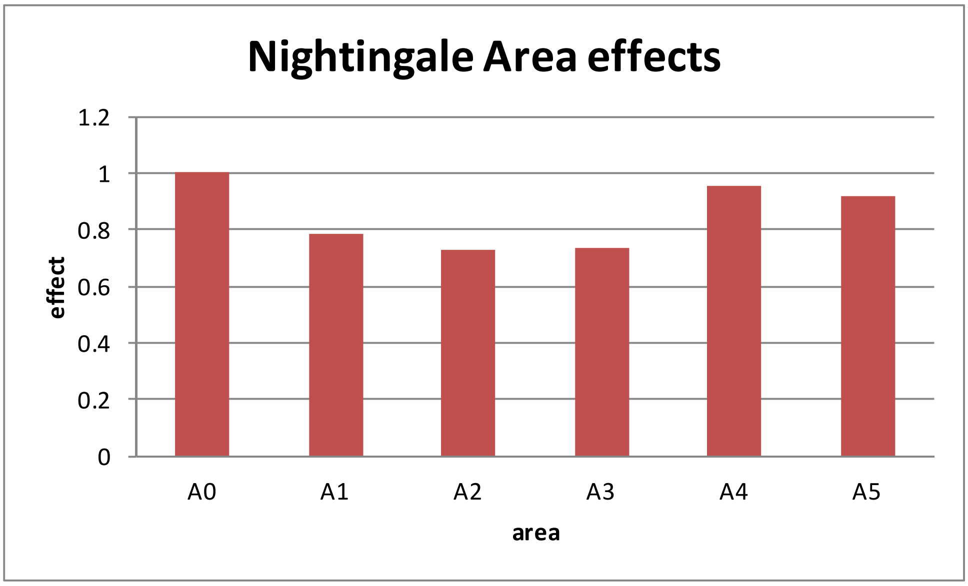

Figure 3c: GLMM area effects for **Gough** Island (see Table 1c for area definitions; A0 being unknown area).