UPDATED GLMM- AND GLM-STANDARDISED LOBSTER CPUE FROM THE TRISTAN DA CUNHA GROUP OF ISLANDS

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ABSTRACT

The longline CPUE series for Inaccessible and Gough islands are GLMM standardised through to 2011. For Nightingale, the standardisation it to 2010 only, as the fishery was closed for the 2011 season[1]. 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 to data for 1994-2012. After initial increases, the standardised CPUE indices show drops over the most recent years for all islands, although for Gough this decrease is seen only in the most recent two seasons' data. The analyses for the outer islands are based on the newly captured logsheet catch-effort database prepared by CAPFISH.

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 and Gough Islands for the period 1997-2011, and for the period 1997-2010 for Nightingale (whose fishery was closed in the 2011 season due to the grounding of the OLIVA in March 2011). For Tristan, for which the data are more limited, a simpler GLM approach is used applied to data for the 1994-2012 period. Results presented here are updated from those presented in Johnston *et al.* (2012), taking one more year's data into account for Inaccessible, Gough and Tristan, as well as including data from 2006 that had previously been mislaid. The underlying database has recently been recaptured electronically by CAPFISH and is slightly changed from that used previously (for example previously missing 1996 data have now been incorporated into the database).

[1] Note that 2011 refers to the split season 2011/12 for example.

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 the outer islands have been entered electronically into EXCEL spreadsheets. Logsheet data from the fishery are available for the Season-Years between 1997 and 2011, 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.

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 logsheet catches and effort is logsheet effort. (Note that this approach assumes that the logsheet data represent an unbiased sample of all of 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). The model is given by:

$$\ln(CPUE + \delta) = \mathbf{X}\alpha + \mathbf{Z}\beta + \varepsilon \qquad (1)$$

where:

α	is the unknown vector of fixed effects parameters (in this case this consists of the factors given by equation (2) 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:
$Cov(\ln(CPUE + \delta)) = \boldsymbol{V} = \boldsymbol{ZGZ^{T}} + \boldsymbol{R}$,
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:

$$\ln(CPUE + \delta) = \mu + \alpha_{year} + \beta_{month} + \gamma_{area} + \eta_{trap-type} + \lambda_{soaktime} + \theta_{depth} + \tau_{year\,x\,area} \qquad (2)$$

where:

μ	is the intercept,
year	is a factor with 15 levels for Gough and Inaccessible associated with the Season-Years 1997-2011, and 14 levels for Nightingale associated with the Season-Years 1997-2010,
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 = 6 areas, Nightingale = 5 areas, Inaccessible = 9 areas),
trap type	is a factor with levels associated with the trap type (monster and beehive),
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), and
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 "2" , depth category "2" and area = "1".

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:

$$CPUE_{year} = \left[\sum_{area}\left(\left(\exp\left(\mu + \alpha_{year} + \gamma_{area} + \tau_{year\,x\,area}\right) - \delta\right) * A_{area}\right)\right] / A_{total} \qquad (3)$$

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 the Tristan data

The powerboat CPUE database for Tristan contains information at a trip level for 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 (4)

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:

$$\ln(CPUE + \delta) = \mu + \alpha_{year} + \beta_{month} \quad (5)$$

where:

C	is the catch in kg,
E	is the effort in hours fished,
μ	is the intercept,
year	is a factor with 19 levels associated with the years (i.e. the Season-Years: 1994-2012),
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:

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

RESULTS

Table 2 provides standardised CPUE values derived from the GLMM/GLM considered. For comparison, the nominal CPUE values are also reported. Figure 1 compares the nominal CPUE with the updated 2013 standardised CPUE series, along with the 2012 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 2013 updated GLMM/GLM standardised CPUE series shown in Table 2 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 seen only in the most recent 2010 and 2011 seasons' data.

Generally the nominal, and the 2012 and 2013 standardised series are similar. For Gough and Nightingale some differences are evident in the most recent years.

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. 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. 2012. GLMM- and GLM-standardised lobster CPUE from the Tristan da Cunha group of islands for the 1997-2010 period. MARAM/Tristan/2012/Jun/07.

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 nominal CPUE series for comparison.

Season-Year	*N*	**Nominal CPUE (2013)**	**Standardised CPUE (2012)**	**Standardised CPUE (2013)**
1997	239	2.986	1.925	2.929
1998	414	2.800	3.601	2.466
1999	407	3.492	3.864	2.540
2000	609	3.247	4.676	3.222
2001	585	3.362	4.298	3.101
2002	417	4.322	7.292	4.133
2003	226	6.704	6.097	6.187
2004	400	7.584	12.650	9.704
2005	436	7.010	12.559	7.055
2006	348	6.447		6.354
2007	670	4.853	7.109	5.078
2008	839	4.561	6.927	4.919
2009	1030	3.207	6.913	3.231
2010	625	2.437	4.053	2.802
2011	367	3.654		3.903

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 nominal CPUE series for comparison

Season-Year	*N*	**Nominal CPUE (2013)**	**Standardised CPUE (2012)**	**Standardised CPUE (2013)**
1997	681	1.920	0.831	2.150
1998	501	2.660	1.542	2.488
1999	319	3.393	-	2.667
2000	380	4.004	2.015	4.145
2001	541	3.201	1.914	3.401
2002	470	3.314	1.996	3.414
2003	245	5.711	3.575	6.183
2004	479	5.647	3.673	5.958
2005	376	7.193	3.490	6.632
2006	204	6.118	-	5.170
2007	337	5.824	2.829	5.206
2008	433	4.827	2.639	3.930
2009	468	4.237	2.475	3.941
2010	361	4.862	2.534	3.663

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 nominal CPUE series for comparison.

Season-Year	*N*	**Nominal CPUE (2013)**	**Standardised CPUE (2012)**	**Standardised CPUE (2013)**
1997	1191	2.343	2.093	2.267
1998	1018	2.292	1.795	2.184
1999	1270	1.605	2.209	1.519
2000	1498	1.319	1.389	1.368
2001	1488	1.307	1.449	1.495
2002	1832	1.286	1.351	1.266
2003	1634	1.426	1.524	1.595
2004	952	1.894	1.358	1.625
2005	659	2.641	2.490	2.975
2005	374	4.078	2.490	4.128
2007	405	5.000	5.412	5.536
2008	399	6.044	5.221	5.765
2009	323	8.247	9.962	7.627
2010	465	6.280	5.247	4.984
2011	373	7.887		6.466

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	0.323
1995	1253	0.246	0.286
1996	1222	0.278	0.312
1997	772	0.454	0.481
1998	502	0.650	0.569
1999	338	0.961	0.755
2000	324	1.019	0.953
2001	334	1.107	0.971
2002	335	1.397	1.338
2003	382	1.679	1.526
2004	385	1.728	1.705
2005	339	2.307	2.214
2006	284	2.828	2.554
2007	310	2.365	2.100
2008	456	1.497	1.271
2009	281	1.824	1.746
2010	484	1.317	1.247
2011	376	1.321	1.199
2012	344	1.104	1.043

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 1997-2005) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 68mm in 2003.]

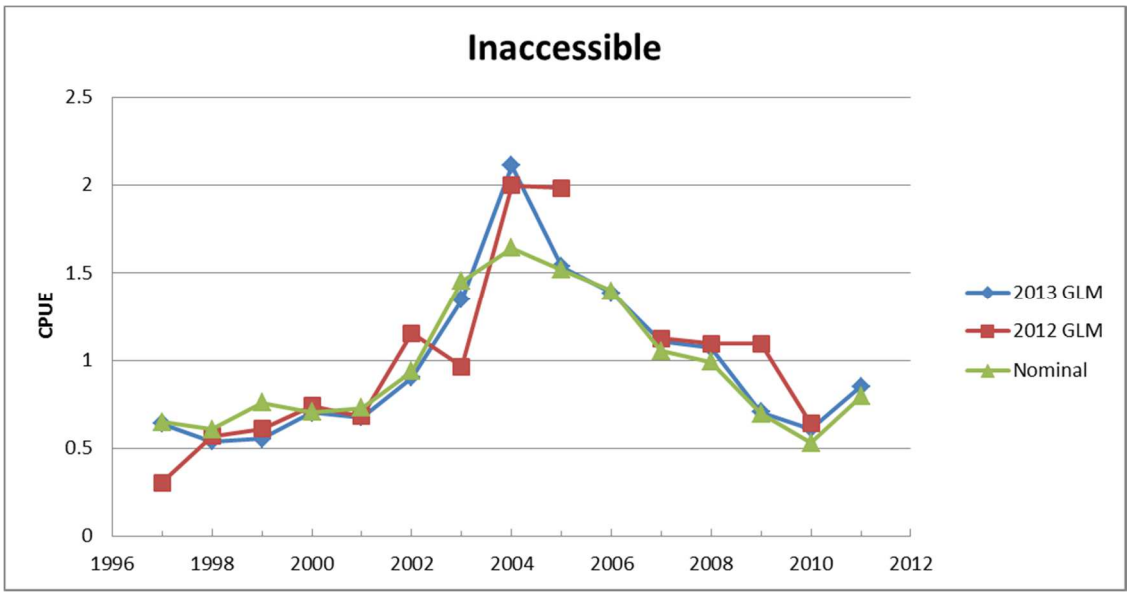

Figure 1b: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Nightingale** Island. All series have been renormalised to a mean of 1 (for 1997-2005) for easier comparison of trends.

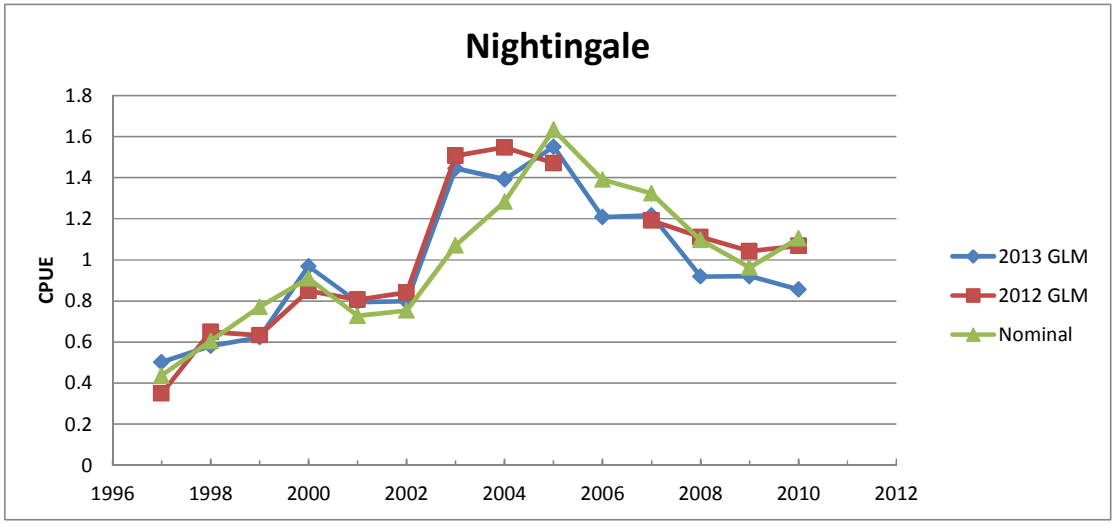

Figure 1c: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Gough** Island. All series have been renormalised to a mean of 1 (for 1997-2005) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 75mm in 2003.]

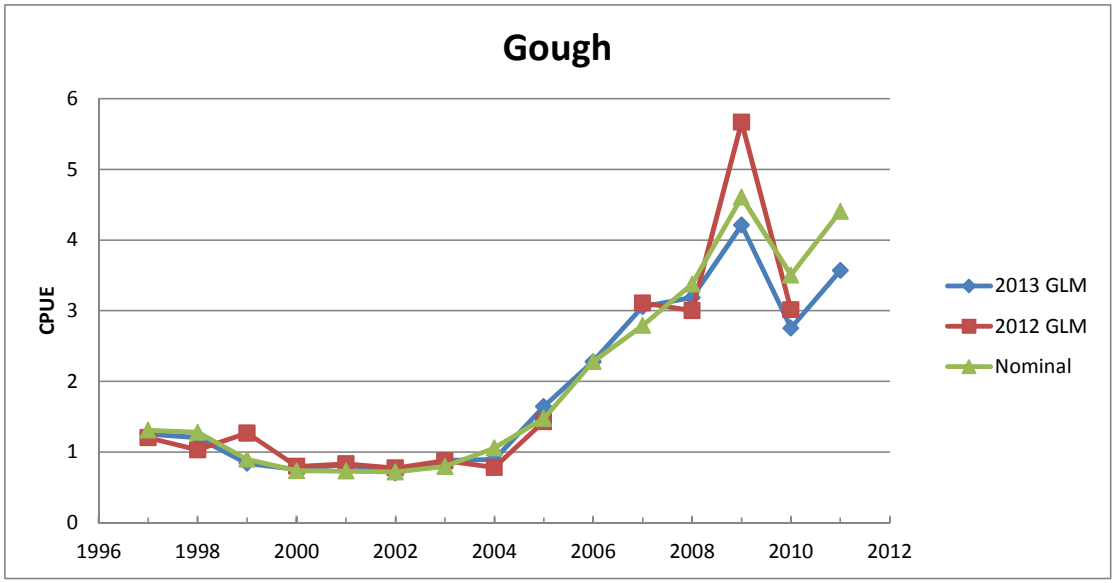

Figure 1d: Comparative plot of the nominal and GLM standardised powerboat CPUE series for **Tristan** Island. Both series have been renormalised to a mean of 1 (for 1994-2010) for easier comparison of trends. Note that the GLM 2013 results sit almost identically onto of the GLM 2012 results.

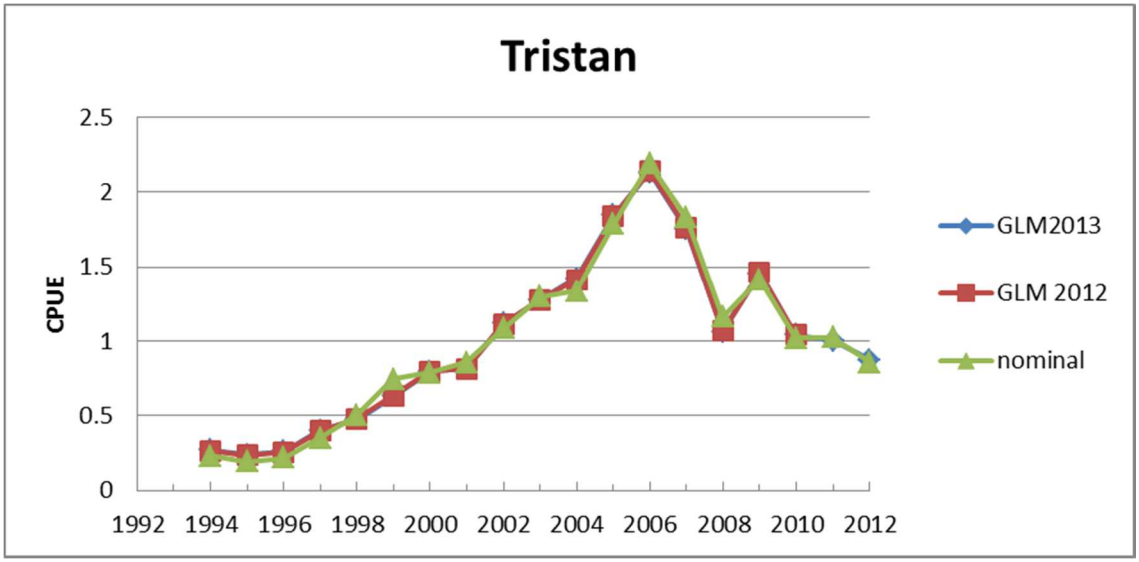

Figure 2a: GLMM month effects for **Inaccessible** Island.

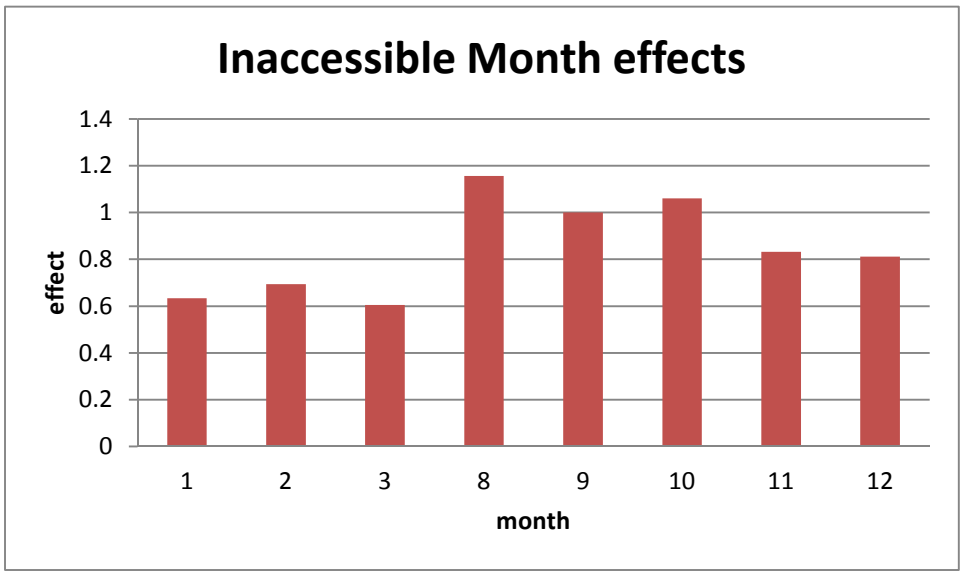

Figure 2b: GLMM month effects for **Nightingale** Island.

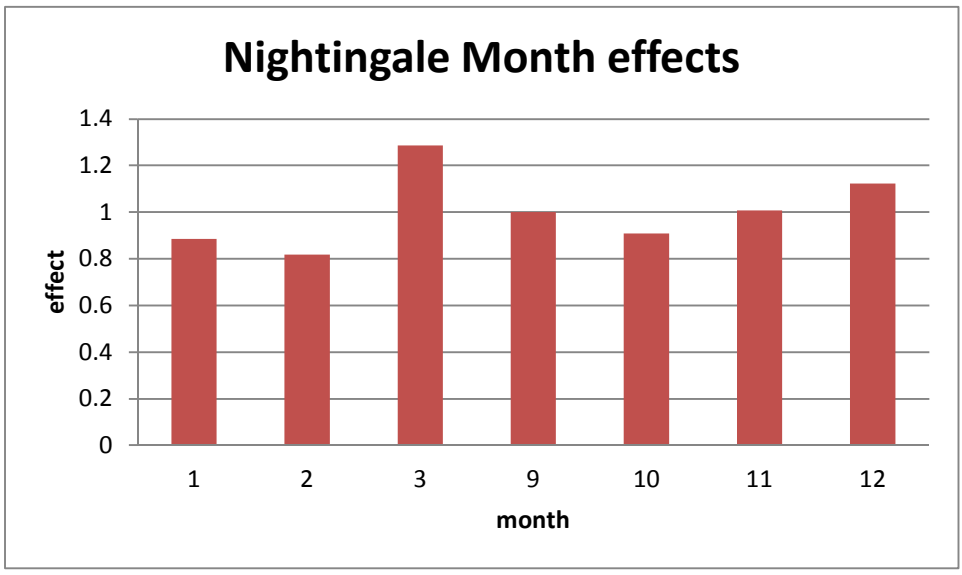

Figure 2c: GLMM month effects for **Gough** Island.

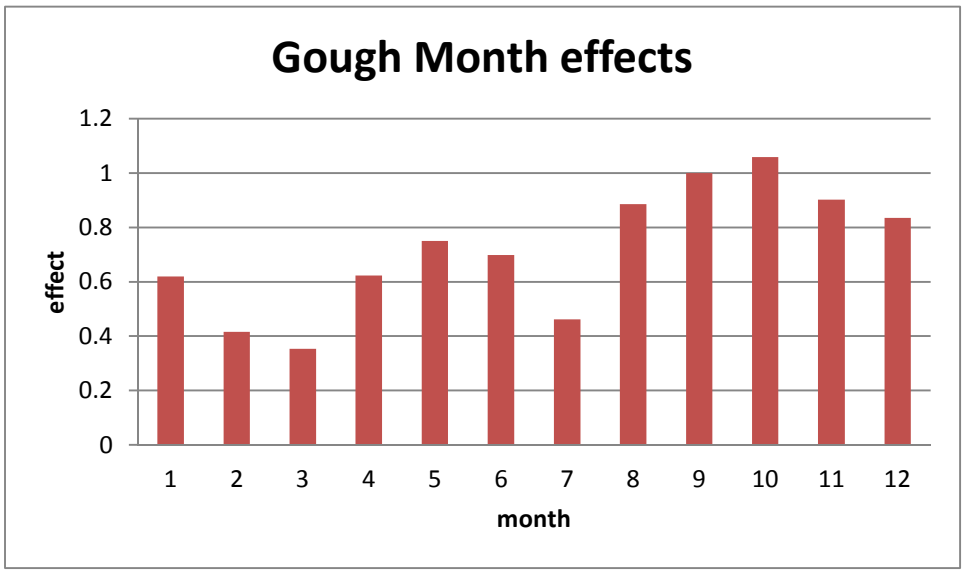

Figure 2d: GLM month effects for **Tristan** Island.

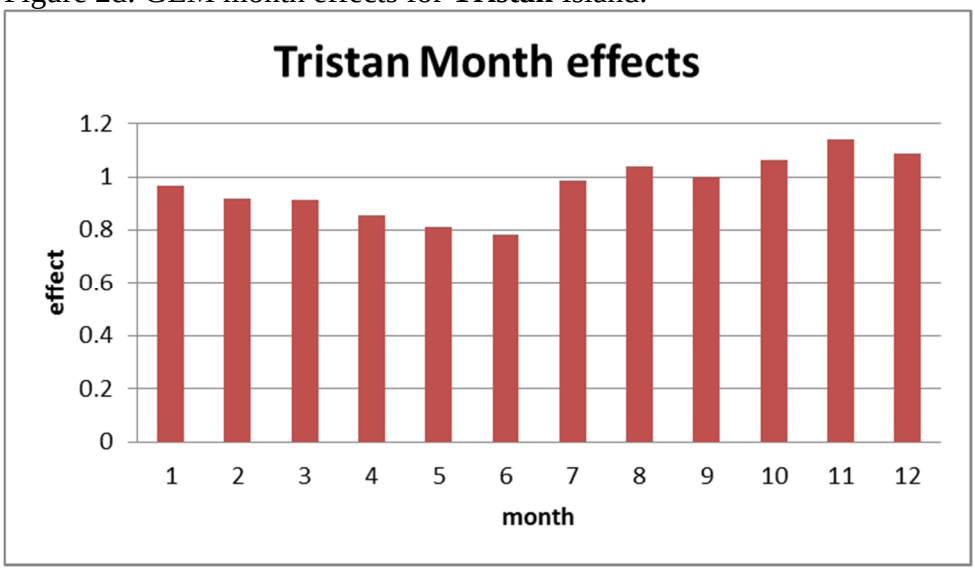

Figure 3a: GLMM area effects for **Inaccessible** Island (see Table 1a for area definitions).

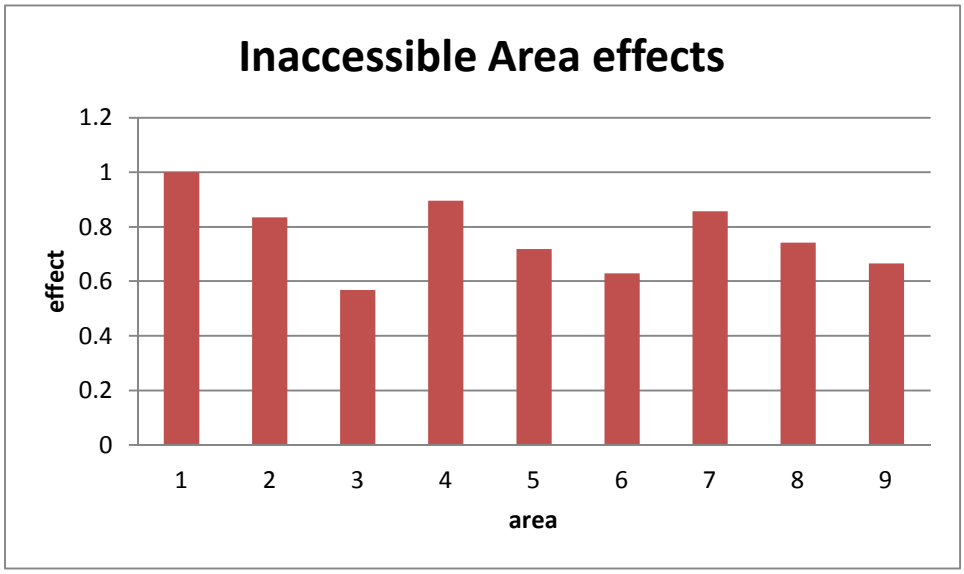

Figure 3b: GLMM area effects for **Nightingale** Island (see Table 1b for area definitions).

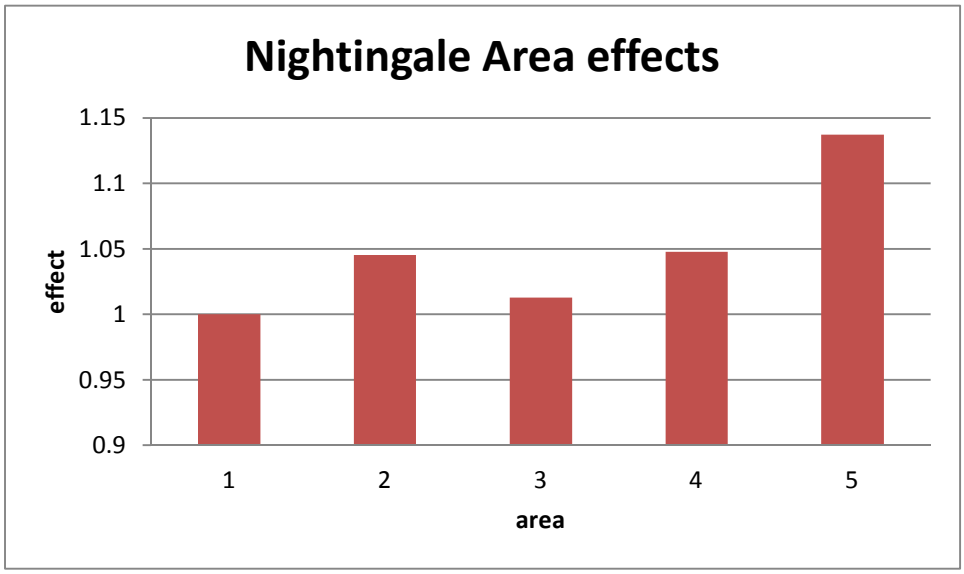

Figure 3c: GLMM area effects for **Gough** Island (see Table 1c for area definitions).