UPDATED 2015 GLMM- AND GLM-STANDARDISED LOBSTER CPUE FROM THE TRISTAN DA CUNHA GROUP OF ISLANDS

S.J. Johnston, A. Brandão, and D.S. Butterworth.

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

May 2014

ABSTRACT

The longline CPUE series for Inaccessible and Gough islands are GLMM standardised through to 2014[1]. For Nightingale, the fishery was closed for the 2011 season and catches were set at precautionary levels for the 2012 and 2013. The GLMM model thus excludes 2011 and 2012, although it now includes 2013 and 2014 for this island. 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 the 1994-2014 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 and Gough Islands for the period 1997-2014, and for the period 1997-2014 omitting seasons 2011 and 2012 for Nightingale (whose fishery was closed in the 2011 season due to the grounding of the OLIVA in March 2011, and where only precautionary catch levels have been set instead of TACs for 2012 and 2013). For Tristan, for which the data are more limited, a simpler GLM approach is used and applied to data for the 1994-2014 period. Results presented here are updated from those presented in Johnston *et al.* (2014), taking one more year's data into account for Inaccessible, Gough and Tristan, and extending the Nightingale series to include the 2013 and 2014 data.

[1] The convention used here for split season is to use the first year, i.e. 2013 refers to the 2013/2014 season.

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 nearly 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 2014, 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 retained catches 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:

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

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 18 levels for Gough and Inaccessible associated with the Season-Years 1997-2014, and 16 levels for Nightingale associated with the Season-Years 1997-2014 (excluding 2011 and 2012),
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 Bee hive),
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 "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:

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

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 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)

Note that for Tristan the "Season" is assumed to start in July each year. In Johnston *et al.* (2010) a GLM was developed for which the CPUE is taken equal to

$$CPUE = \frac{catch}{(number\ gear)(hours\ fished)} \text{ kg/hour/gear} \quad (4)$$

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 21 levels associated with the years (i.e. the Season-Years: 1994-2014),
month	is a factor with levels associated with the fishing month (1-12), and
δ	is taken to be 0.1 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 1 provides standardised CPUE values derived from the GLMM/GLMs considered. For comparison, the nominal CPUE values are also reported. Figure 1 compares the nominal CPUE with the updated 2015 standardised CPUE series, along with the 2014 standardised CPUE series (2013 for nightingale). 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 fairly recently been reported on the Tristan CPUE datasheets, so cannot be taken into account in these analyses).

DISCUSSION

The updated GLM/GLMM CPUE series reported are to be used to provide inputs into the OMPs for Tristan, Inaccessible and Gough to provide TAC recommendations for the 2015 season. The CPUE for all three outer islands continue to be very optimistic, whilst the CPUE for Tristan continues to decline.

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. 2014. Updated GLMM- and GLM-standardised lobster CPUE from the Tristan da Cunha group of islands. MARAM/Tristan/2014/MAY/08.

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**	**Standardised CPUE (2014)**	**Standardised CPUE (2015)**
1997	238	2.986	2.520	2.678
1998	413	2.800	2.640	2.350
1999	406	3.492	2.525	2.479
2000	608	3.247	3.075	2.972
2001	584	3.362	3.072	3.011
2002	416	4.322	4.123	4.060
2003	225	6.704	5.868	5.681
2004	399	7.584	9.352	9.057
2005	435	7.010	6.841	6.638
2006	347	6.447	6.275	6.158
2007	669	4.853	4.807	4.632
2008	838	4.561	4.702	4.528
2009	1029	3.207	3.049	2.931
2010	624	2.437	2.669	2.566
2011	366	3.654	3.729	3.596
2012	534	5.172	5.677	5.478
2013	440	6.163	6.054	5.826
2014	418	7.026	-	7.575

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 (2015)**	**Standardised CPUE (2013)**	**Standardised CPUE (2015)**
1997	681	1.920	2.150	2.217
1998	501	2.660	2.488	2.590
1999	319	3.393	2.667	2.769
2000	380	4.004	4.145	4.340
2001	541	3.201	3.401	3.608
2002	470	3.314	3.414	3.570
2003	245	5.711	6.183	6.317
2004	479	5.647	5.958	6.174
2005	376	7.193	6.632	6.730
2006	204	6.118	5.170	5.306
2007	337	5.824	5.206	5.358
2008	433	4.827	3.930	4.062
2009	468	4.237	3.941	4.058
2010	361	4.862	3.663	3.802
2011		-	-	-
2012	-	9.62	-	-
2013	219	13.42	-	13.811
2014	232	10.94	-	11.589

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**	**Standardised CPUE (2014)**	**Standardised CPUE (2015)**
1997	1190	2.343	2.426	2.328
1998	1017	2.292	2.344	2.264
1999	1269	1.605	1.657	1.596
2000	1497	1.319	1.475	1.411
2001	1487	1.307	1.601	1.537
2002	1831	1.286	1.361	1.301
2003	1633	1.426	1.699	1.635
2004	951	1.894	1.660	1.611
2005	658	2.641	2.979	2.885
2005	373	4.078	4.241	4.072
2007	404	5.000	5.817	5.553
2008	398	6.044	6.123	5.949
2009	322	8.247	8.2	8.027
2010	464	6.280	5.135	5.032
2011	372	7.887	6.58	6.397
2012	605	5.746	6.030	5.819
2013	684	5.311	5.021	4.825
2014	485	7.015	-	7.011

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)**	**2014 Standardised CPUE (kg/hour/gear)**	**2015 Standardised CPUE (kg/hour/gear)**
1994	1138	0.269	0.265	0.273
1995	1139	0.264	0.229	0.238
1996	1241	0.280	0.268	0.276
1997	696	0.489	0.435	0.444
1998	446	0.712	0.533	0.542
1999	338	0.961	0.696	0.711
2000	324	1.019	0.898	0.912
2001	334	1.107	0.914	0.928
2002	335	1.397	1.286	1.302
2003	382	1.684	1.480	1.496
2004	385	1.726	1.662	1.680
2005	339	2.155	2.167	2.191
2006	284	2.840	2.502	2.518
2007	310	2.365	2.039	2.057
2008	486	1.453	1.201	1.214
2009	305	1.835	1.713	1.732
2010	484	1.317	1.200	1.216
2011	376	1.321	1.151	1.167
2012	344	1.104	0.992	1.004
2013	476	0.990	0.905	0.919
2014	366	0.704	-	0.650

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 1997-2013) for easier comparison of trends. Note that here and below the standardised 2015 results for earlier years are not visible as they are covered by the values for standardisations in earlier years. [Note that the minimum legal carapace size changed from 70mm to 68mm CL in 2003 and from 68mm to 66mm CL in 2012.]

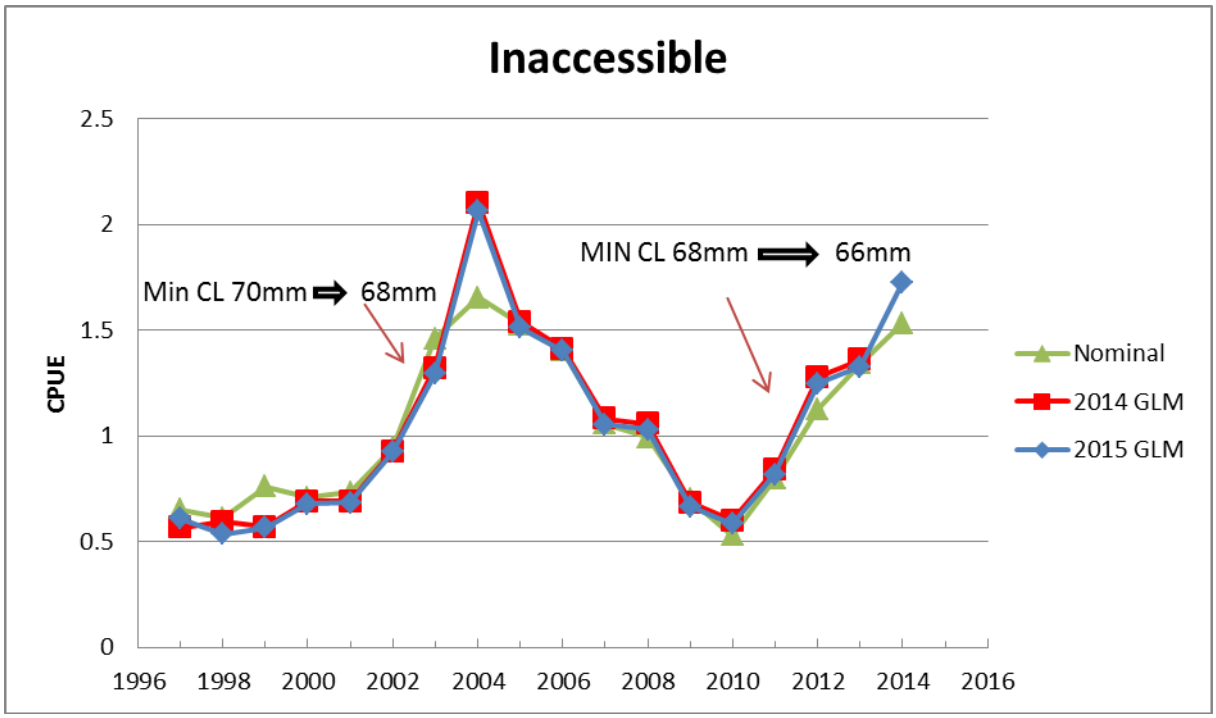

Figure 1b: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Nightingale** Island. All series have been renormalised to a mean of 1 (for 1997-2010) for easier comparison of trends.

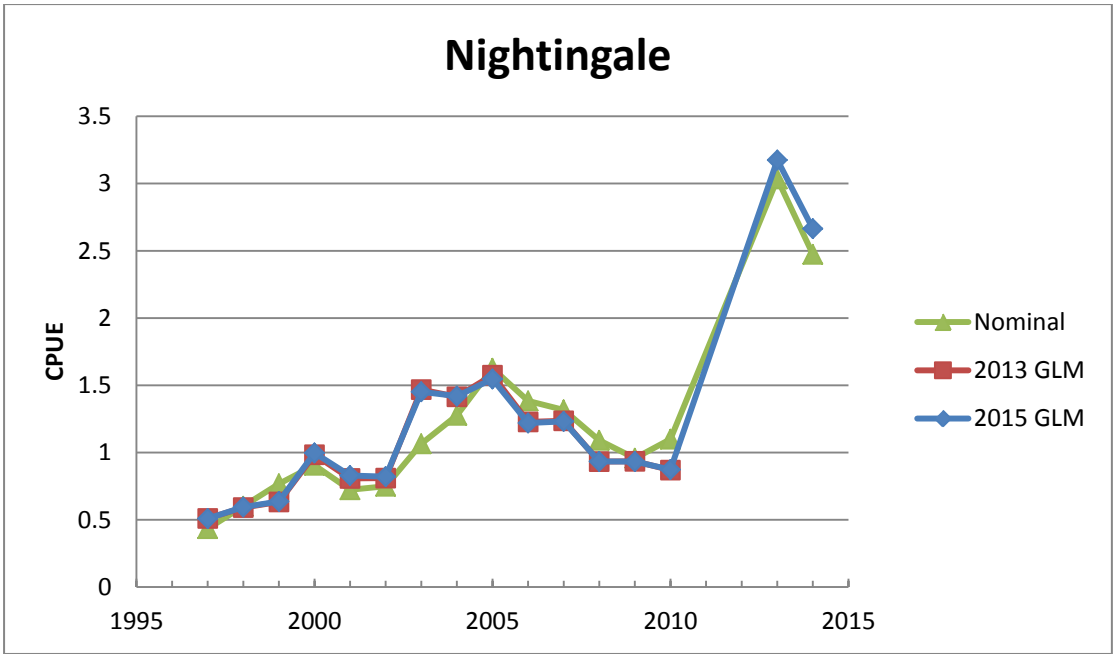

Figure 1c: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Gough** Island. All series have been renormalised to a mean of 1 (for 1997-2013) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 75mm in 2003.]

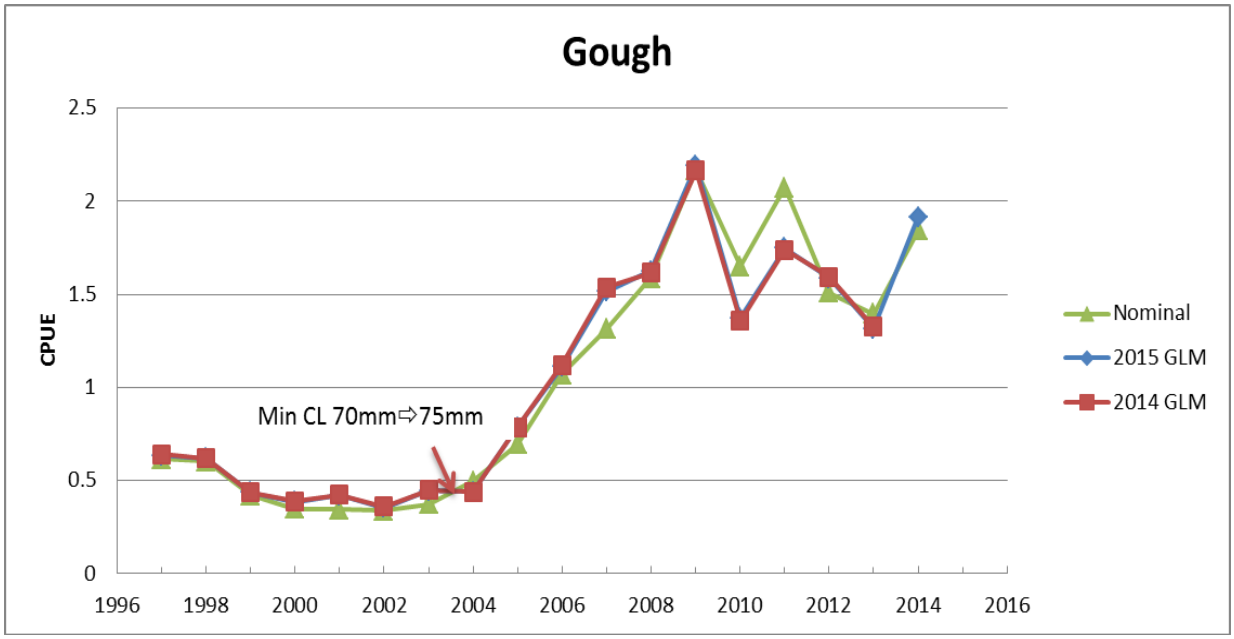

Figure 1d: Comparative plot of the nominal and GLM standardised powerboat CPUE series for **Tristan** Island. Both series have been renormalised to a mean of 1 (for 1994-2013) for easier comparison of trends.

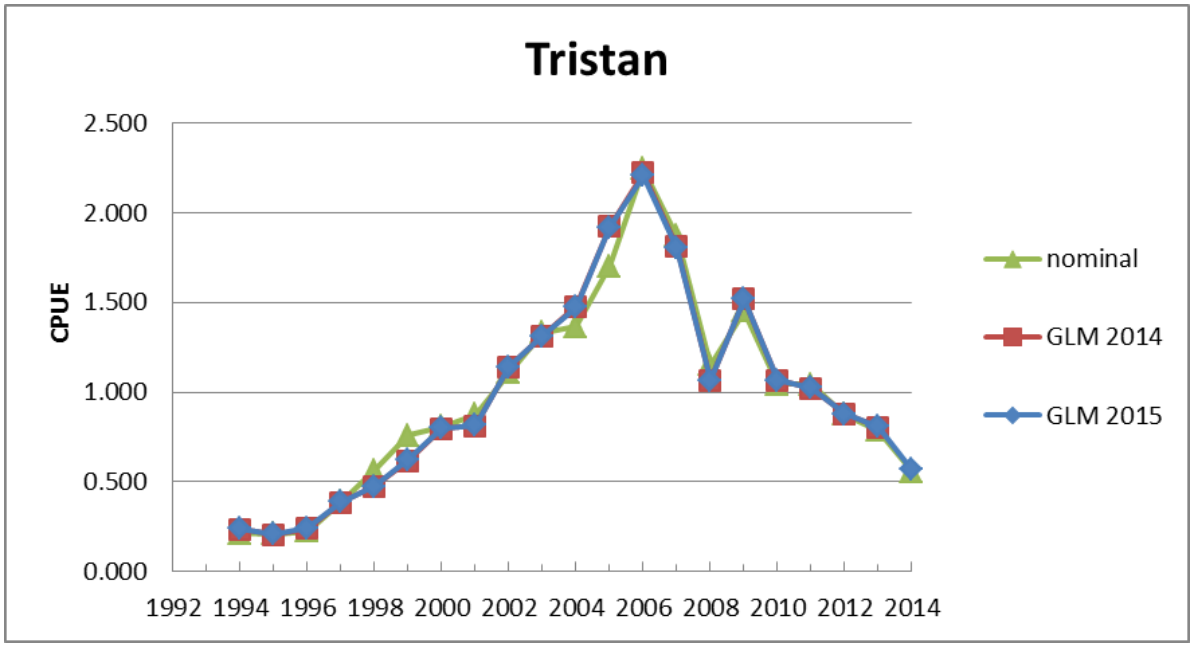

Figure 2a: GLMM month effects for **Inaccessible** Island.

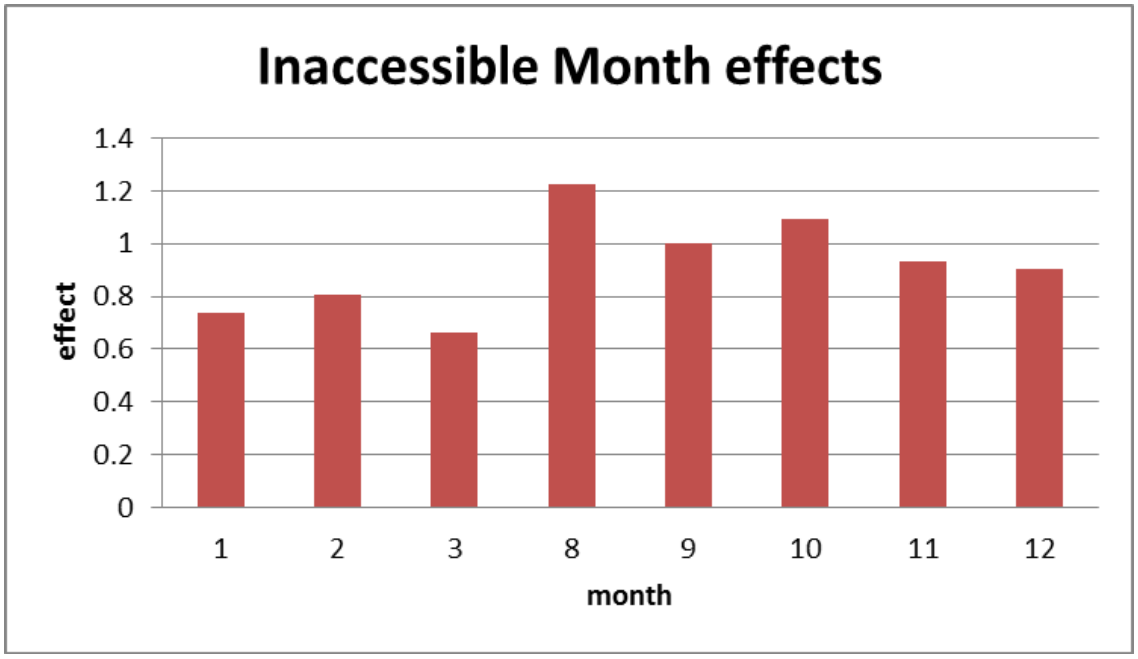

Figure 2b: GLMM month effects for **Nightingale** Island.

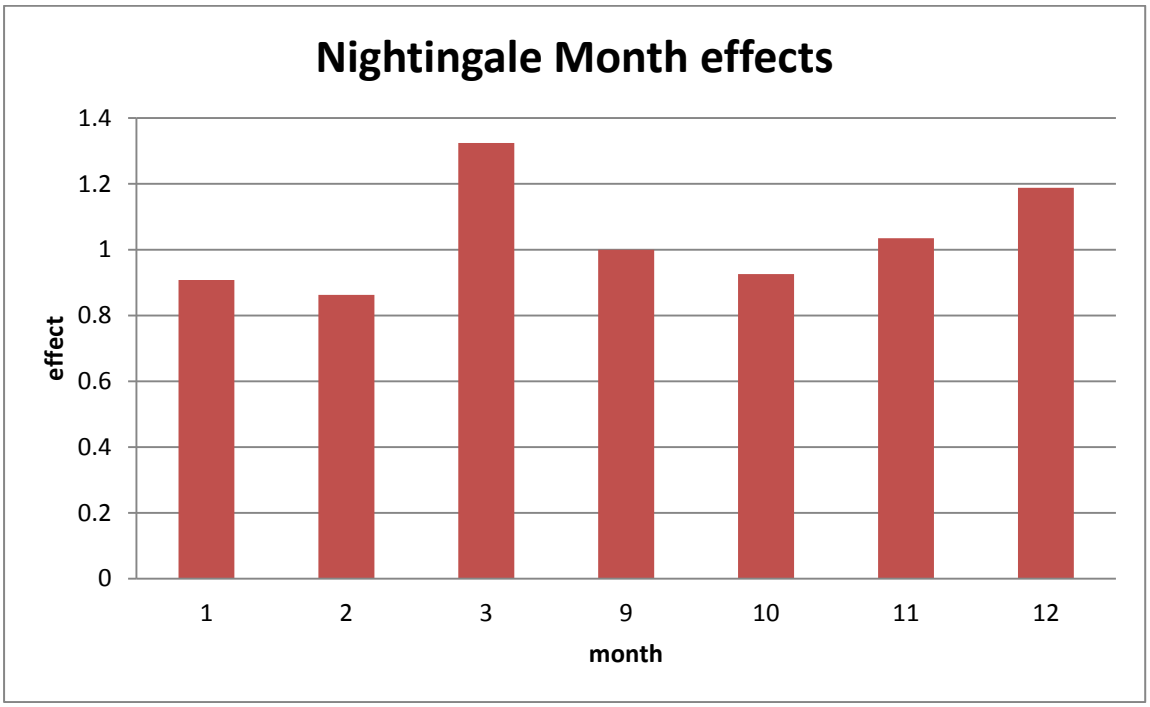

Figure 2c: GLMM month effects for **Gough** Island.

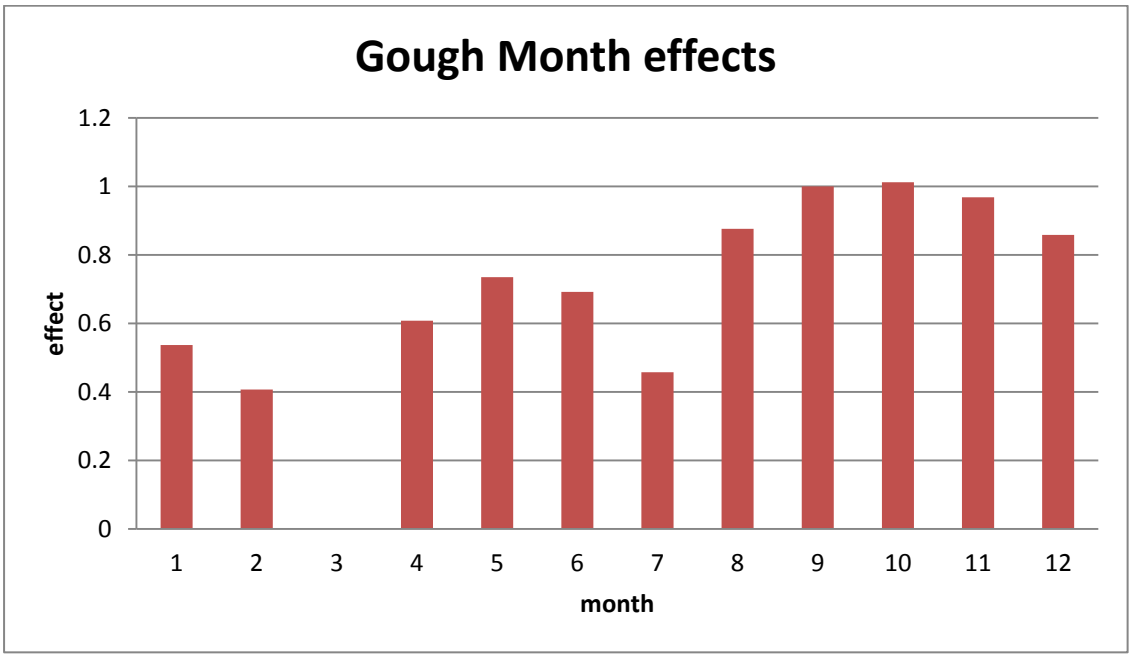

Figure 2d: GLM month effects for the **Tristan** Island.

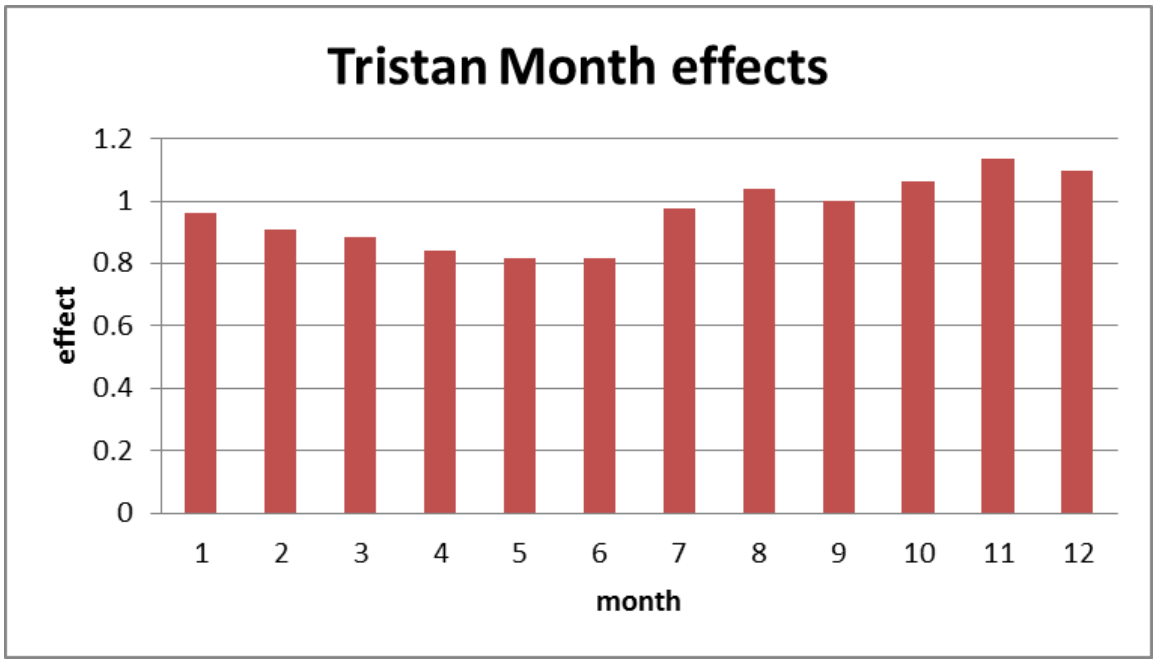

Figure 3a: GLMM area effects for **Inaccessible** Island (see Table 1a for area definitions).

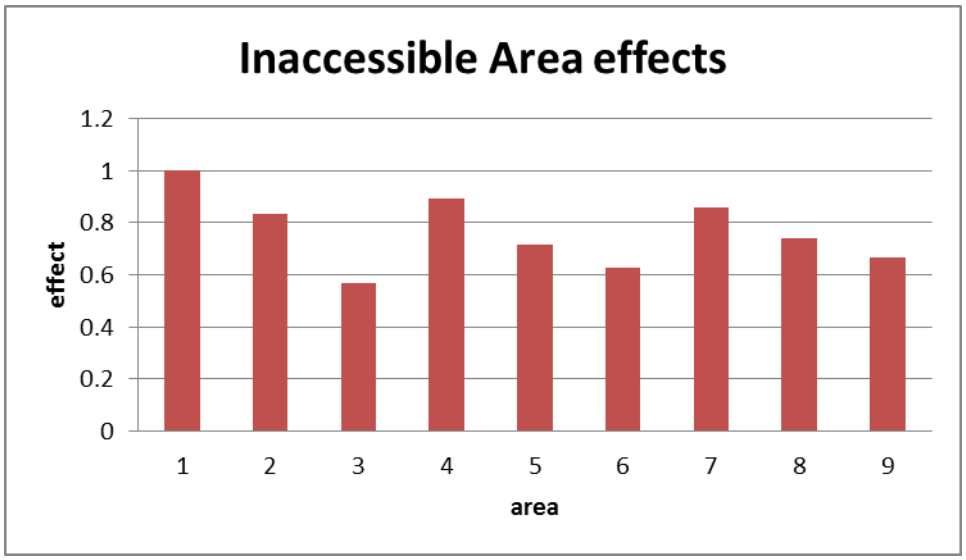

Figure 3b: GLMM area effects for **Nightingale** Island (see Table 1b for area definitions).

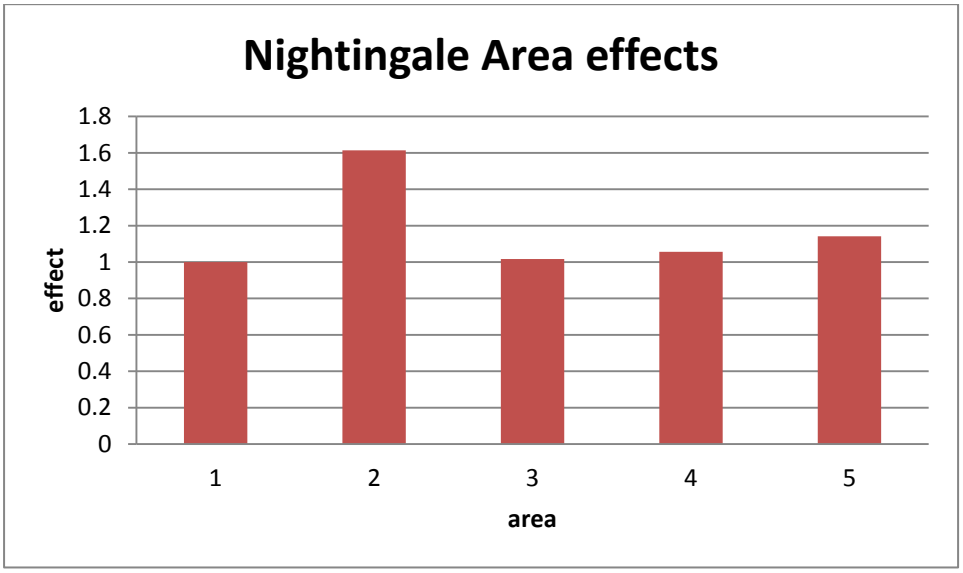

Figure 3c: GLMM area effects for **Gough** Island (see Table 1c for area definitions).