UPDATED 2014 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 2013[1]. For Nightingale, the standardisation remains to 2010 only, as the fishery was closed for the 2011 season and catches have been set at precautionary levels for the 2012 and 2013 seasons. 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 1994-2013 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 1997-2013, 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, and where only precautionary catch levels have been set for 2012 and 2013). For Tristan, for which the data are more limited, a simpler GLM approach is used applied to data for the 1994-2013 period. Results presented here are updated from those presented in Johnston *et al.* (2013), taking one more year's data into account for Inaccessible, Gough and Tristan.

[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 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 2013, 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. $\mathbf{X}\alpha$ 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 17 levels for Gough and Inaccessible associated with the Season-Years 1997-2013, 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 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:

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

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 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 20 levels associated with the years (i.e. the Season-Years: 1994-2013),
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 nominal CPUE values are also reported. Figure 1 compares the nominal CPUE with the updated 2014 standardised CPUE series, along with the 2013 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

The updated GLM/GLMM CPUE series report are to be used to provide inputs into the OMPs for Tristan, Inaccessible and Gough to provide TAC recommendations for the 2014 season.

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. 2013. Updated GLMM- and GLM-standardised lobster CPUE from the Tristan da Cunha group of islands. MARAM/Tristan/2013/Mar/05.

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 (2013)**	**Standardised CPUE (2014)**
1997	238	2.986	1.774	2.520
1998	413	2.800	2.204	2.640
1999	406	3.492	2.408	2.525
2000	608	3.247	3.136	3.075
2001	584	3.362	3.057	3.072
2002	416	4.322	4.117	4.123
2003	225	6.704	5.780	5.868
2004	399	7.584	9.521	9.352
2005	435	7.010	6.851	6.841
2006	347	6.447	6.268	6.275
2007	669	4.853	4.791	4.807
2008	838	4.561	4.730	4.702
2009	1029	3.207	3.000	3.049
2010	624	2.437	2.684	2.669
2011	366	3.654	3.732	3.729
2012	534	5.172	5.578	5.677
2013	440	6.163	-	6.054

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**	**Standardised CPUE (2013)**	**Standardised CPUE (2014)**
1997	1190	2.343	1.827	2.426
1998	1017	2.292	2.106	2.344
1999	1269	1.605	1.502	1.657
2000	1497	1.319	1.361	1.475
2001	1487	1.307	1.484	1.601
2002	1831	1.286	1.259	1.361
2003	1633	1.426	1.585	1.699
2004	951	1.894	1.643	1.660
2005	658	2.641	3.009	2.979
2005	373	4.078	4.050	4.241
2007	404	5.000	5.381	5.817
2008	398	6.044	5.825	6.123
2009	322	8.247	8.025	8.2
2010	464	6.280	5.127	5.135
2011	372	7.887	6.526	6.58
2012	605	5.746	5.718	6.030
2013	684	5.311		5.021

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	1138	0.269	0.265
1995	1139	0.264	0.229
1996	1241	0.280	0.268
1997	696	0.489	0.435
1998	446	0.712	0.533
1999	338	0.961	0.696
2000	324	1.019	0.898
2001	334	1.107	0.914
2002	335	1.397	1.286
2003	382	1.684	1.480
2004	385	1.726	1.662
2005	339	2.155	2.167
2006	284	2.840	2.502
2007	310	2.365	2.039
2008	486	1.453	1.201
2009	305	1.835	1.713
2010	484	1.317	1.200
2011	376	1.321	1.151
2012	344	1.104	0.992
2013	476	0.990	0.905

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.]

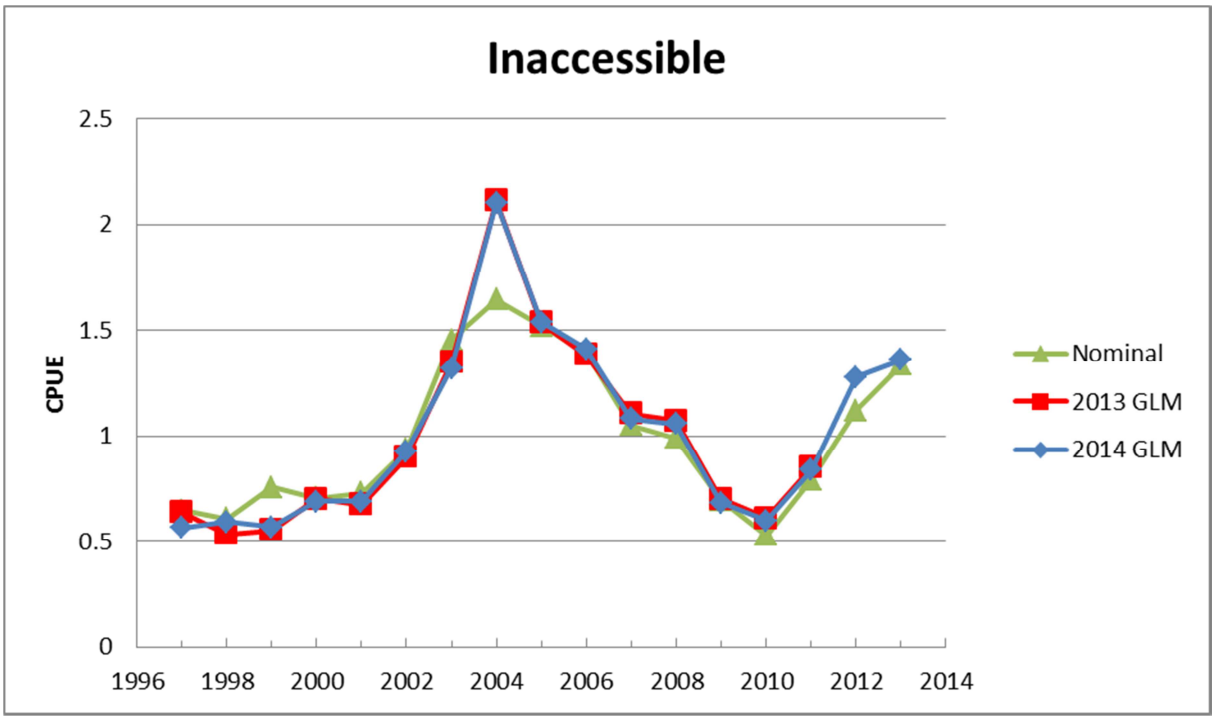

Figure 1b: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Nightingale** Island. All series have been renormalised to a mean of 1 (for 1997-2005) for easier comparison of trends.

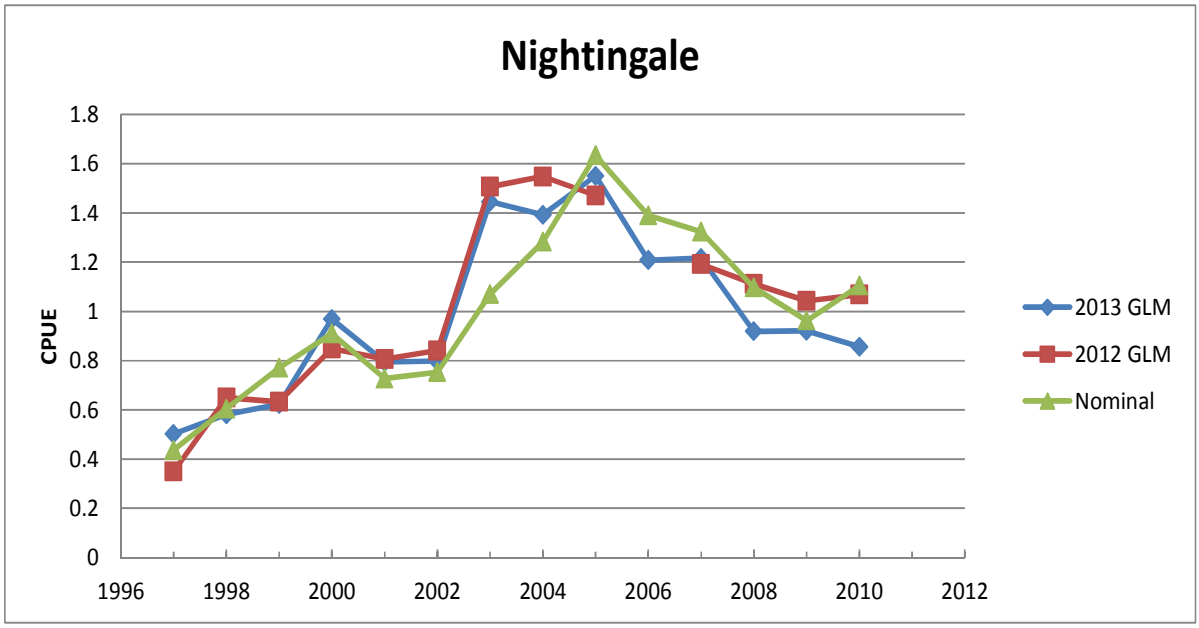

Figure 1c: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Gough** Island. All series have been renormalised to a mean of 1 (for 1997-2005) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 75mm in 2003.]

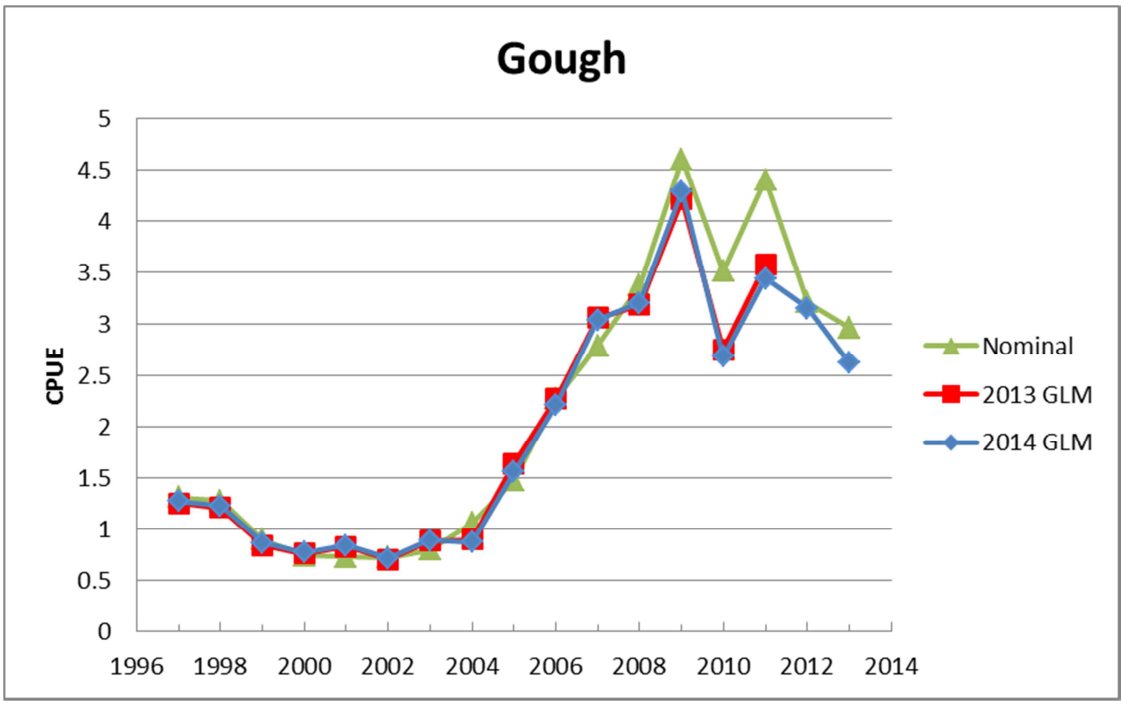

Figure 1d: Comparative plot of the nominal and GLM standardised powerboat CPUE series for **Tristan** Island. Both series have been renormalised to a mean of 1 (for 1994-2012) for easier comparison of trends.

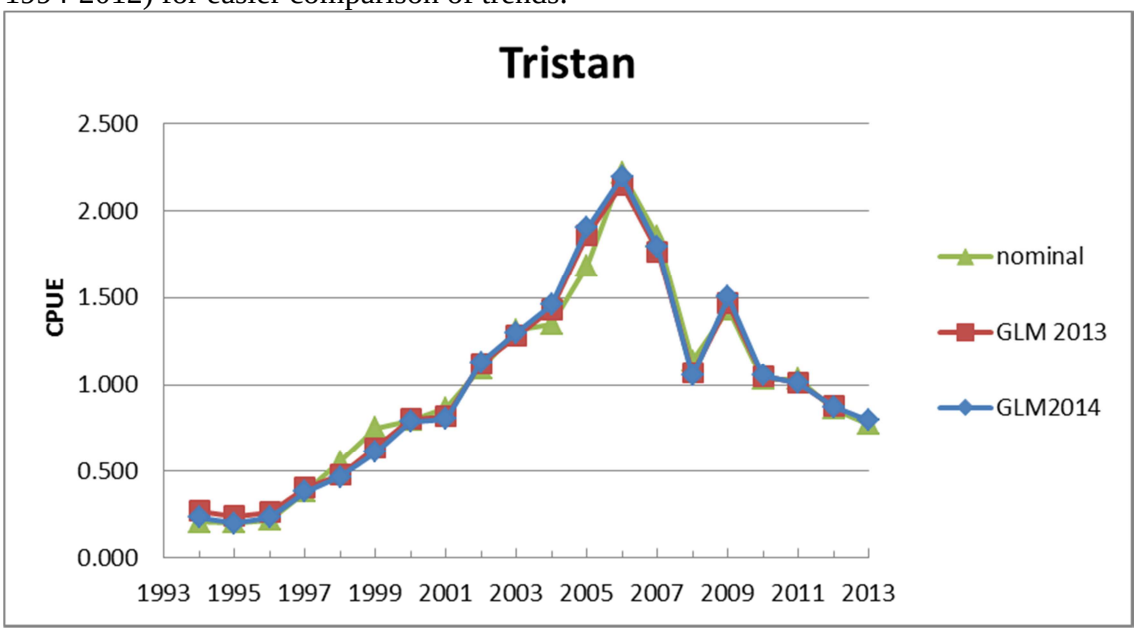

Figure 2a: GLMM month effects for **Inaccessible** Island.

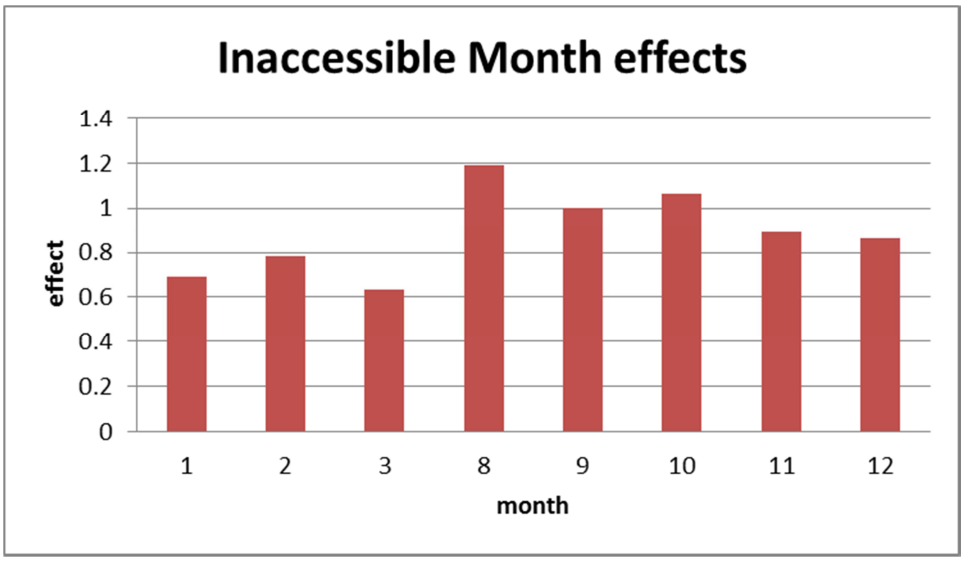

Figure 2b: GLMM month effects for **Nightingale** Island.

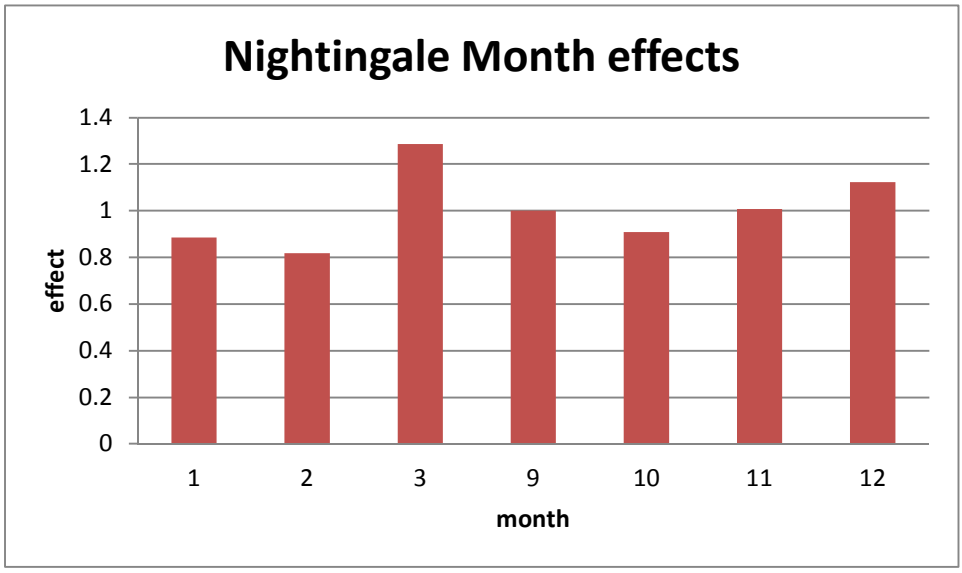

Figure 2c: GLMM month effects for **Gough** Island.

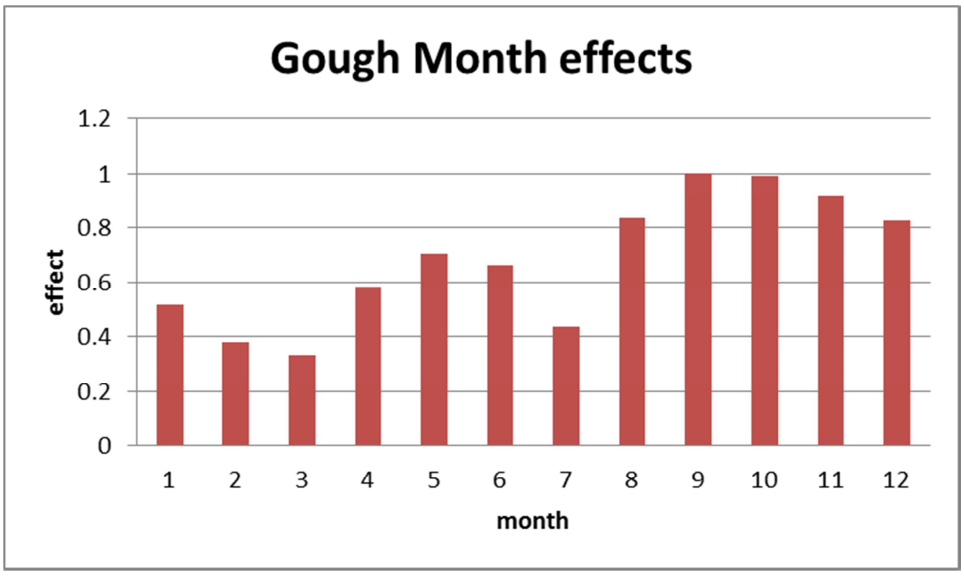

Figure 2d: GLM month effects for the **Tristan** Island.

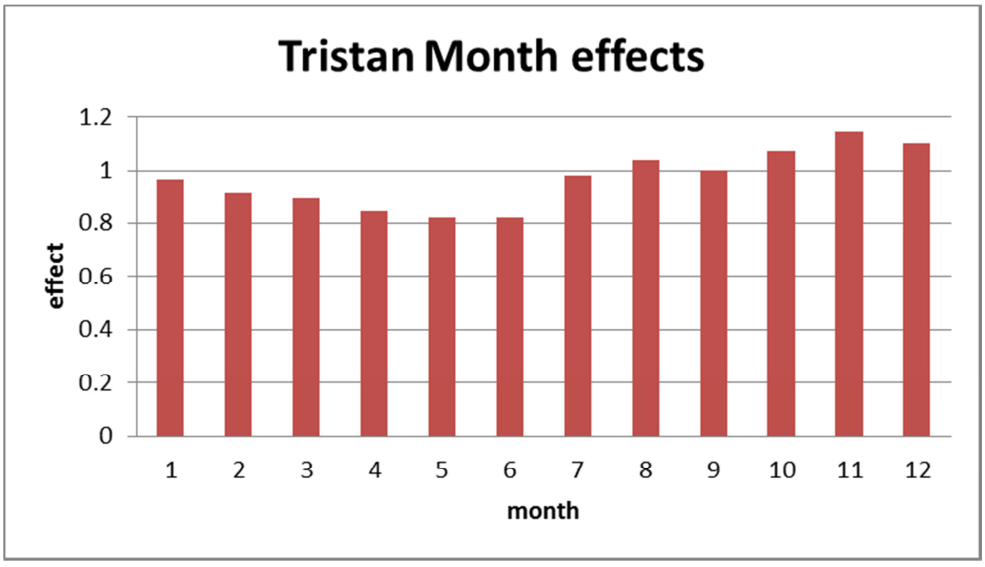

Figure 3a: GLMM area effects for **Inaccessible** Island (see Table 1a for area definitions).

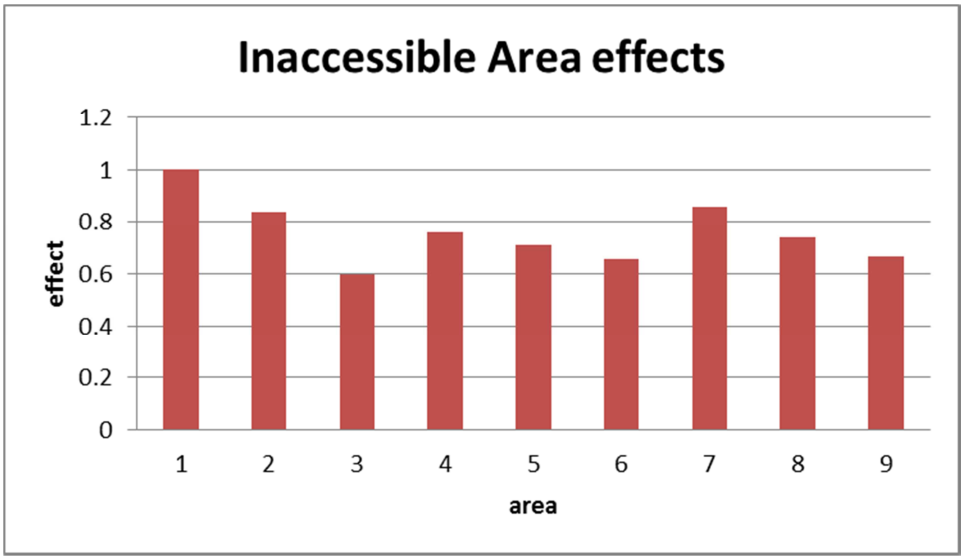

Figure 3b: GLMM area effects for **Nightingale** Island (see Table 1b for area definitions).

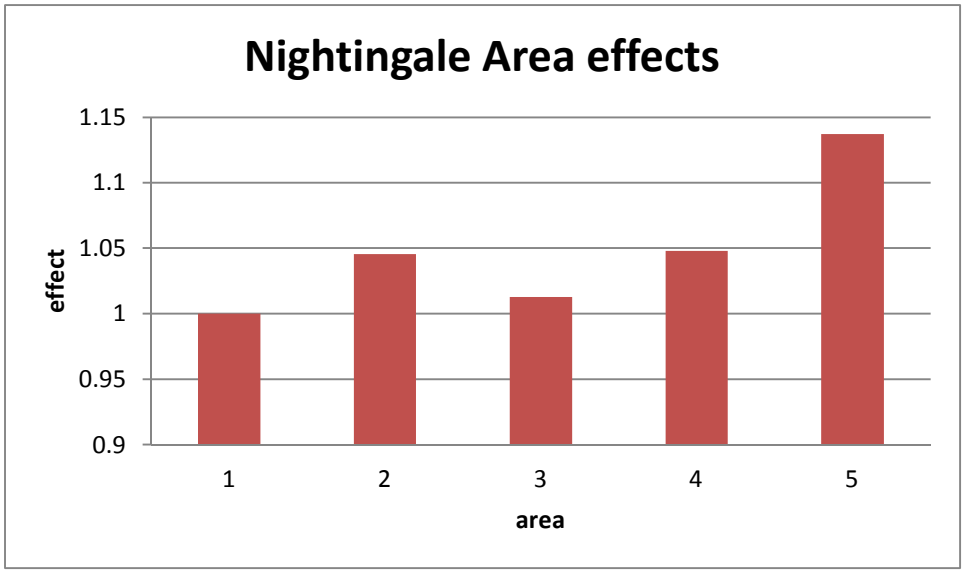

Figure 3c: GLMM area effects for **Gough** Island (see Table 1c for area definitions).