UPDATED 2016 GLMM -STANDARDISED LOBSTER CPUE FROM THE TRISTAN DA CUNHA OUTER GROUP OF ISLANDS

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ABSTRACT

The longline CPUE series for Inaccessible and Gough islands are GLMM standardised through to 2015[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 2013-2015 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. The standardised CPUEs for Inaccessible and Nightingale continue to be optimistic, although slightly down on the previous season's values. For Gough, the standardised CPUE value for the current season is slightly higher than for the previous season.

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 1997-2015, and for the period 1997-2015 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). Results presented here are updated from those presented in Johnston *et al.* (2015), taking one more year's data into account.

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

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 2015, where a Season-Year is taken to run from September until August of the following year, i.e. Season-Year 2005 refers to the period from September 2005 to August 2006.

The General Linear Mixed Model

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 from 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). 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:

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

where

μ	is the intercept,
year	is a factor with 19 levels for Gough and Inaccessible associated with the Season-Years 1997-2015, and 17 levels for Nightingale associated with the Season-Years 1997-2015 (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, and 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 $\geq$ 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:

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

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.

RESULTS

Table 2 provides standardised CPUE values derived from the GLMMs considered. For comparison, the nominal CPUE values are also reported. Figure 1 compares the nominal CPUE with the updated 2016 standardised CPUE series, along with the 2015 standardised CPUE series. The series have been renormalised to an average value of 1 over the 1997-2014 period in the plots for comparative purposes. Figure 2 shows the month effects and Figure 3 shows the area effects for each island.

DISCUSSION

The updated GLMM CPUE series reported are to be used to provide inputs into the OMPs for Inaccessible and Gough to provide TAC recommendations for the 2016 season. The updated GLMM CPUE for Nightingale will be used in conjunction with other fishery data to make an informed management decision in order to set a suitable TAC (in the absence of an OMP for this island). The GLMM CPUEs for Inaccessible and Nightingale continue to be optimistic, although slightly down on the previous season's values. For Gough, the GLMM CPUE value for the current season is slightly higher than for the previous season.

REFERENCE

Johnston, S.J., Brandao, A. and D.S. Butterworth. 2015. Updated GLMM- and GLM-standardised lobster CPUE from the Tristan da Cunha group of islands. MARAM/Tristan/2015/MAY/06.

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 (2015)**	**Standardised CPUE (2016)**
1997	238	2.986	2.678	2.625
1998	413	2.800	2.350	2.302
1999	406	3.492	2.479	2.454
2000	608	3.247	2.972	2.870
2001	584	3.362	3.011	3.040
2002	416	4.322	4.060	4.028
2003	225	6.704	5.681	5.515
2004	399	7.584	9.057	8.776
2005	435	7.010	6.638	6.622
2006	347	6.447	6.158	6.260
2007	669	4.853	4.632	4.511
2008	838	4.561	4.528	4.418
2009	1029	3.207	2.931	2.824
2010	624	2.437	2.566	2.467
2011	366	3.654	3.596	3.470
2012	534	5.172	5.478	5.299
2013	440	6.163	5.826	5.606
2014	418	7.026	7.575	7.255
2015	496	6.173	-	5.580

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**	**Standardised CPUE (2013)**	**Standardised CPUE (2015)**	**Standardised CPUE (2016)**
1997	681	1.920	2.150	2.217	2.062
1998	501	2.660	2.488	2.590	2.386
1999	319	3.393	2.667	2.769	2.625
2000	380	4.004	4.145	4.340	4.020
2001	541	3.201	3.401	3.608	3.363
2002	470	3.314	3.414	3.570	3.381
2003	245	5.711	6.183	6.317	5.916
2004	479	5.647	5.958	6.174	5.770
2005	376	7.193	6.632	6.730	6.258
2006	204	6.118	5.170	5.306	4.995
2007	337	5.824	5.206	5.358	4.948
2008	433	4.827	3.930	4.062	3.779
2009	468	4.237	3.941	4.058	3.803
2010	361	4.862	3.663	3.802	3.537
2011		-	-	-	-
2012	-	9.62	-	-	-
2013	219	13.42	-	13.811	12.937
2014	232	10.94	-	11.589	10.694
2015	348	8.63	-	-	9.311

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 (2015)**	**Standardised CPUE (2016)**
1997	1190	2.343	2.328	2.229
1998	1017	2.292	2.264	2.138
1999	1269	1.605	1.596	1.503
2000	1497	1.319	1.411	1.313
2001	1487	1.307	1.537	1.438
2002	1831	1.286	1.301	1.209
2003	1633	1.426	1.635	1.505
2004	951	1.894	1.611	1.495
2005	658	2.641	2.885	2.582
2005	373	4.078	4.072	3.705
2007	404	5.000	5.553	5.392
2008	398	6.044	5.949	5.485
2009	322	8.247	8.027	7.282
2010	464	6.280	5.032	4.724
2011	372	7.887	6.397	5.867
2012	605	5.746	5.819	5.296
2013	684	5.311	4.825	4.526
2014	485	7.015	7.011	6.284
2015	522	6.801	-	6.634

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 1997-2014) for easier comparison of trends. Note that here and below the standardised 2016 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.]

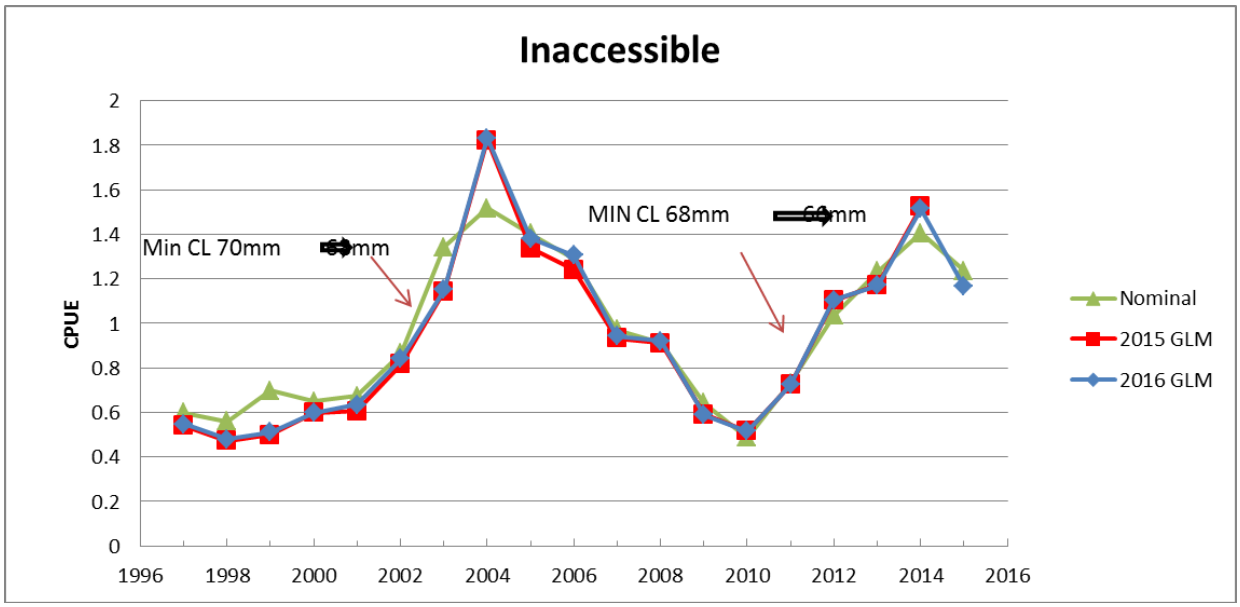

Figure 1b: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Nightingale** Island. All series have been renormalised to a mean of 1 (for 1997-2014) for easier comparison of trends.

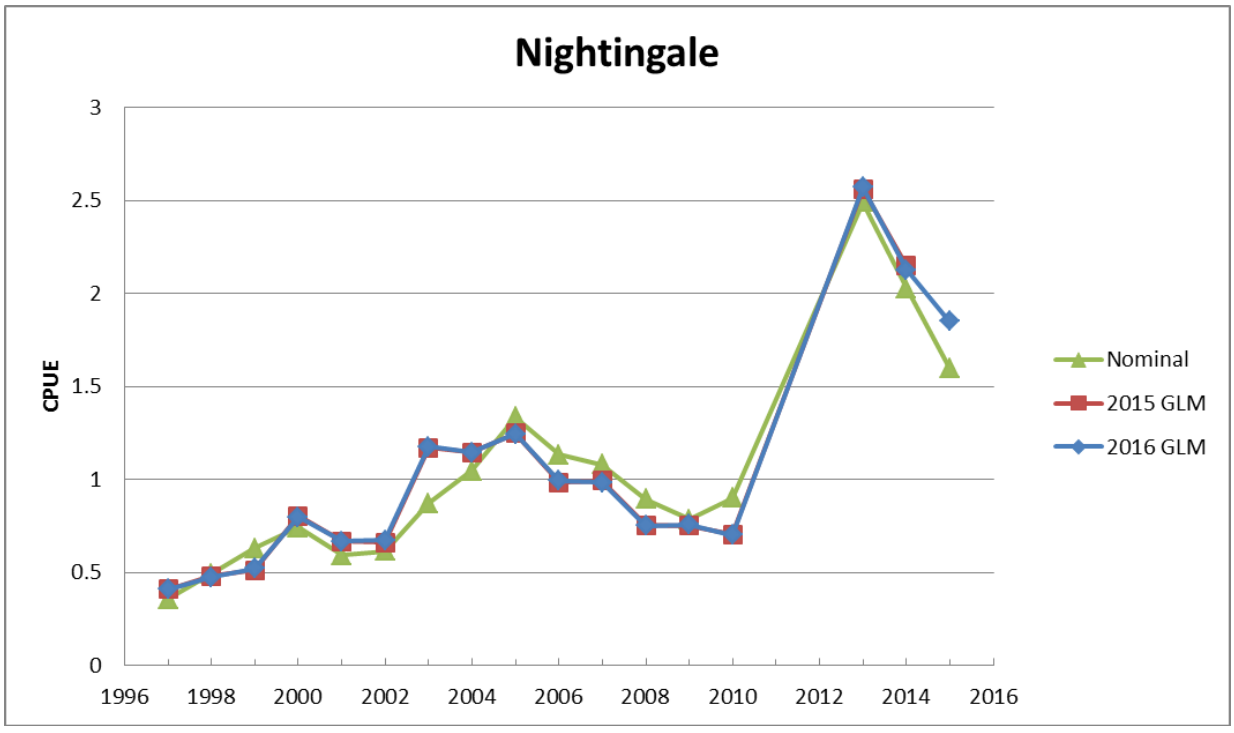

Figure 1c: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Gough** Island. All series have been renormalised to a mean of 1 (for 1997-2014) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 75mm in 2003.]

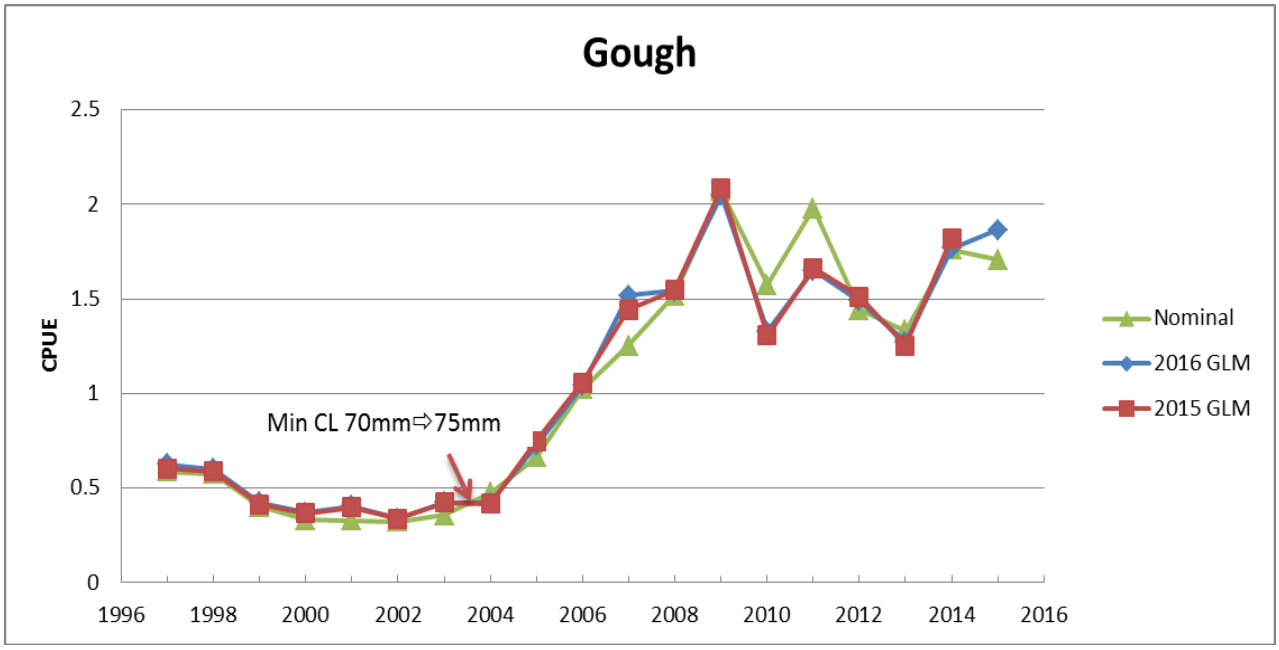

Figure 2a: GLMM month effects for **Inaccessible** Island.

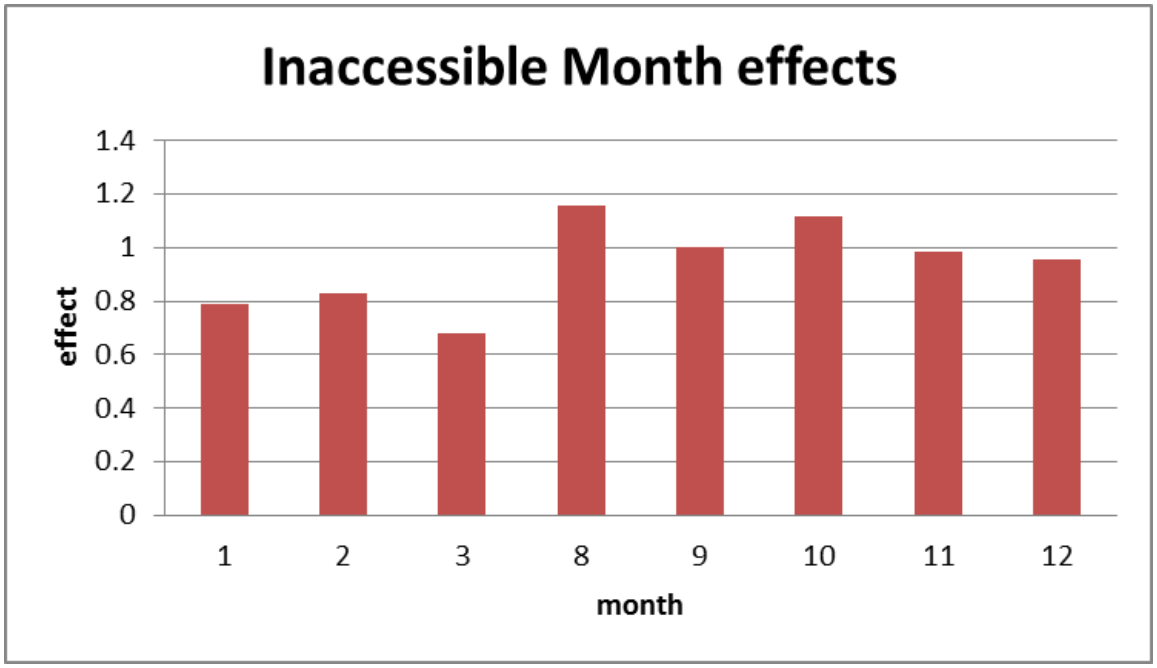

Figure 2b: GLMM month effects for **Nightingale** Island.

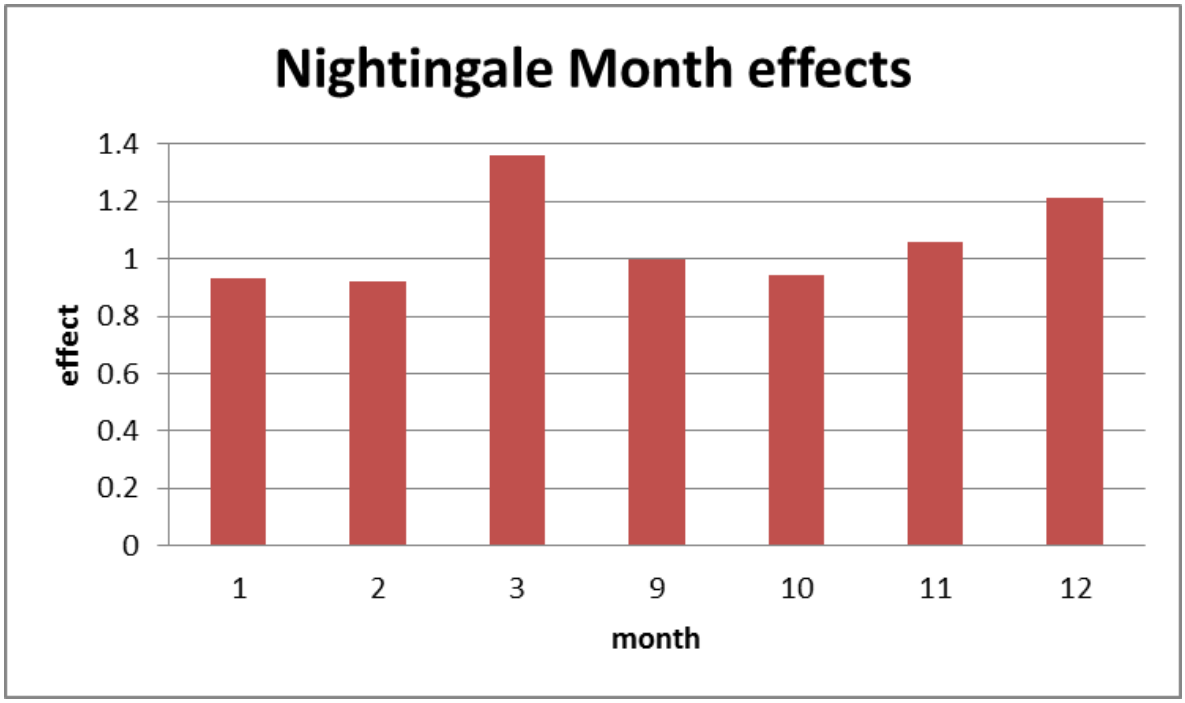

Figure 2c: GLMM month effects for **Gough** Island.

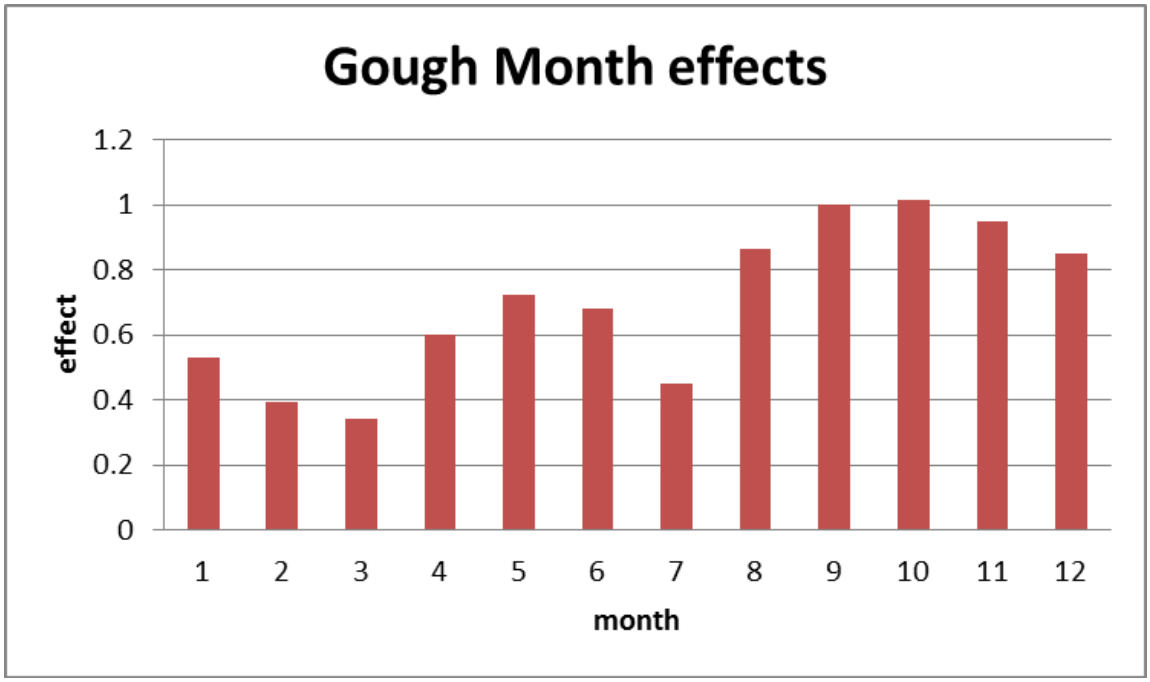

Figure 3a: GLMM area effects for **Inaccessible** Island (see Table 1a for area definitions).

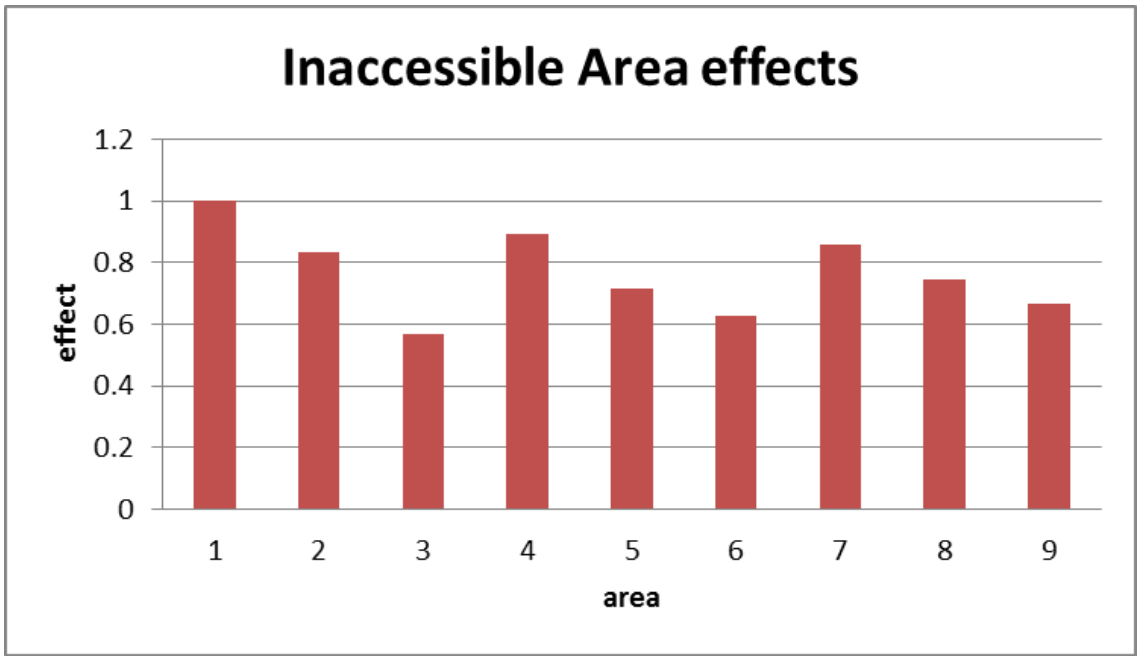

Figure 3b: GLMM area effects for **Nightingale** Island (see Table 1b for area definitions).

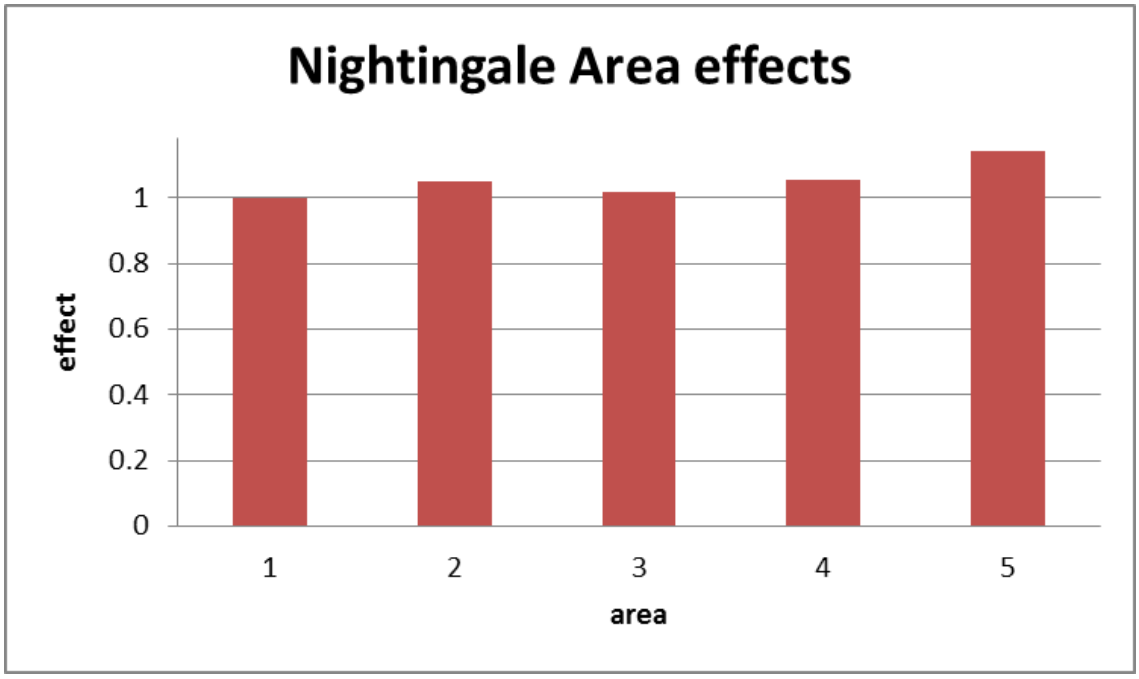

Figure 3c: GLMM area effects for **Gough** Island (see Table 1c for area definitions).