UPDATED 2017 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 2016[1]. For Nightingale, the fishery was closed for the 2011 season and catches were set at precautionary levels for the 2011 and 2012 seasons. The Nightingale GLMM model thus excludes 2011 and 2012, although it now includes 2013-2016 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, and both show increases since the previous season. For Gough, the standardised CPUE value for the current season is lower than that of the previous season, but still well above the OMP target level Itar.

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 1997-2016, and for the period 1997-2016 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.* (2016), 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 2016, 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 fishery around each of these islands concluded well before August 2017 for the 2016 season.)

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 $\mathbf{Z}^T$ 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:

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

where

μ	is the intercept,
year	is a factor with 20 levels for Gough and Inaccessible associated with the Season-Years 1997-2016, and 18 levels for Nightingale associated with the Season-Years 1997-2016 (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 ≥ 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:

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

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. Figures 1a-c compare the nominal CPUE with the updated 2017 standardised CPUE series, along with the 2016 standardised CPUE series. The series have been renormalised to an average value of 1 over the 1997-2015 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 2017 season. An OMP for Nightingale will be developed for the first time to set the 2017 TAC and will use the GLMM CPUE data reported in this document as input. The GLMM CPUEs for Inaccessible and Nightingale continue to be optimistic, and are up compared with the previous season's values. For Gough, the GLMM CPUE value for the current season is somewhat lower than for the previous season (although well above the OMP Itar target value)..

REFERENCE

Johnston, S.J., Brandao, A. and D.S. Butterworth. 2016. Updated GLMM- and GLM-standardised lobster CPUE from the Tristan da Cunha group of islands. MARAM/Tristan/2016/MAY/09.

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)**	**Standardised CPUE (2017)**
1997	238	2.986	2.678	2.625	2.638
1998	413	2.800	2.350	2.302	2.309
1999	406	3.492	2.479	2.454	2.519
2000	608	3.247	2.972	2.870	2.783
2001	584	3.362	3.011	3.040	3.113
2002	416	4.322	4.060	4.028	4.046
2003	225	6.704	5.681	5.515	5.349
2004	399	7.584	9.057	8.776	8.606
2005	435	7.010	6.638	6.622	6.695
2006	347	6.447	6.158	6.260	6.263
2007	669	4.853	4.632	4.511	4.455
2008	838	4.561	4.528	4.418	4.374
2009	1029	3.207	2.931	2.824	2.805
2010	624	2.437	2.566	2.467	2.461
2011	366	3.654	3.596	3.470	3.464
2012	534	5.172	5.478	5.299	5.080
2013	440	6.163	5.826	5.606	5.692
2014	418	7.026	7.575	7.255	7.011
2015	496	6.173	-	5.580	5.523
2016	418	7.645		-	6.853

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 (2016)**	**Standardised CPUE (2017)**
1997	681	1.920	2.062	2.061
1998	501	2.660	2.386	2.361
1999	319	3.393	2.625	2.593
2000	380	4.004	4.020	3.990
2001	541	3.201	3.363	3.320
2002	470	3.314	3.381	3.344
2003	245	5.711	5.916	5.886
2004	479	5.647	5.770	5.708
2005	376	7.193	6.258	6.224
2006	204	6.118	4.995	4.934
2007	337	5.824	4.948	4.925
2008	433	4.827	3.779	3.766
2009	468	4.237	3.803	3.786
2010	361	4.862	3.537	3.504
2011		-	-	
2012	-	9.62	-	
2013	219	13.42	12.937	12.798
2014	232	10.94	10.694	10.646
2015	348	8.63	9.311	9.265
2016	240	12.50	-	12.965

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)**	**Standardised CPUE (2017)**
1997	1190	2.343	2.328	2.229	2.364
1998	1017	2.292	2.264	2.138	2.284
1999	1269	1.605	1.596	1.503	1.619
2000	1497	1.319	1.411	1.313	1.558
2001	1487	1.307	1.537	1.438	1.564
2002	1831	1.286	1.301	1.209	1.324
2003	1633	1.426	1.635	1.505	1.660
2004	951	1.894	1.611	1.495	1.633
2005	658	2.641	2.885	2.582	2.941
2005	373	4.078	4.072	3.705	4.162
2007	404	5.000	5.553	5.392	5.652
2008	398	6.044	5.949	5.485	5.996
2009	322	8.247	8.027	7.282	7.802
2010	464	6.280	5.032	4.724	5.181
2011	372	7.887	6.397	5.867	6.486
2012	605	5.746	5.819	5.296	5.744
2013	684	5.311	4.825	4.526	5.159
2014	485	7.015	7.011	6.284	7.278
2015	522	6.801	-	6.634	7.509
2016	709	5.263	-	-	5.667

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 1997-2015) for easier comparison of trends. Note that here and below the standardised 2017 results for certain 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.]

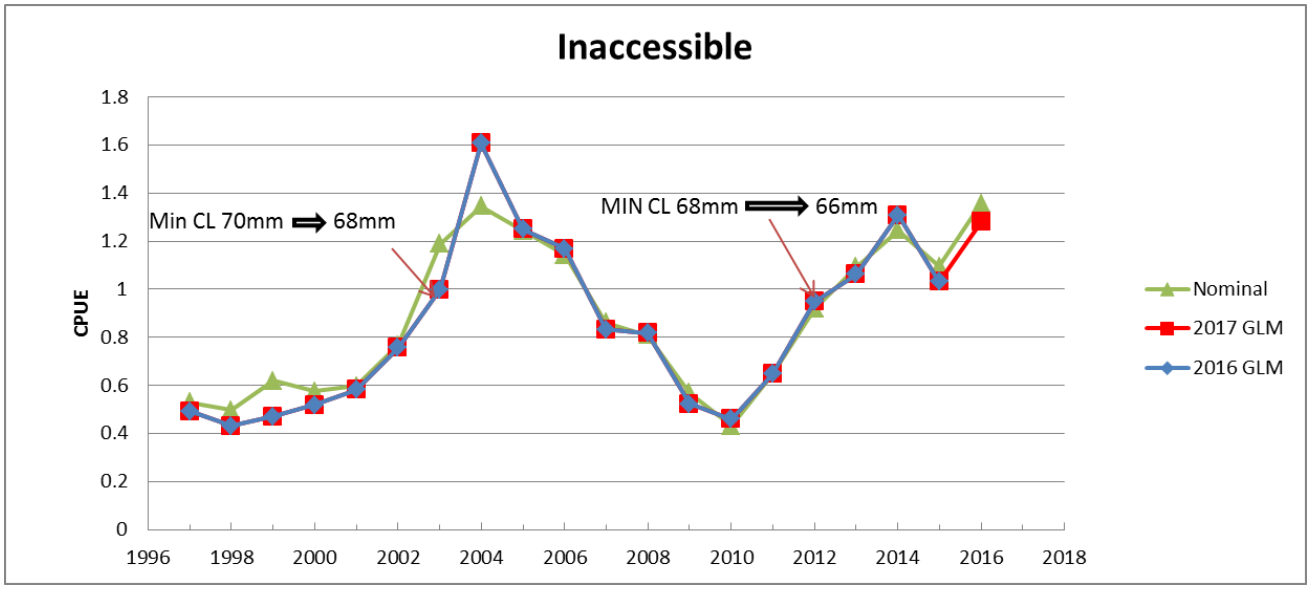

Figure 1b: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Nightingale** Island. All series have been renormalised to a mean of 1 (for 1997-2015) for easier comparison of trends.

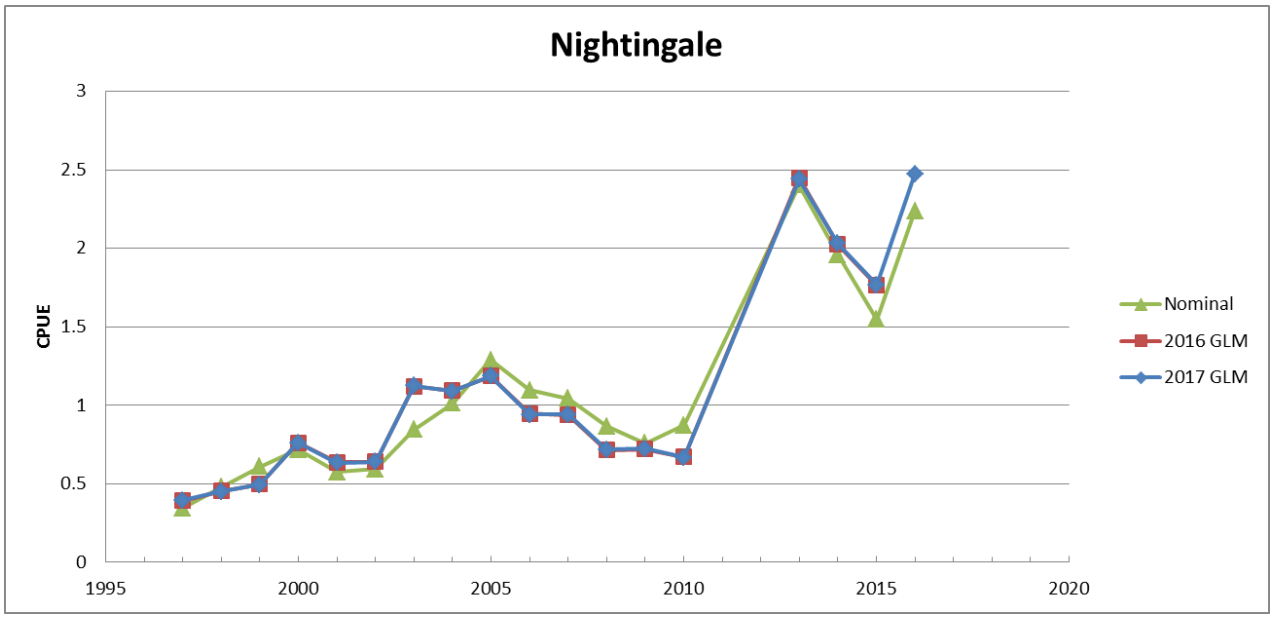

Figure 1c: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Gough** Island. All series have been renormalised to a mean of 1 (for 1997-2015) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 75mm in 2003.]

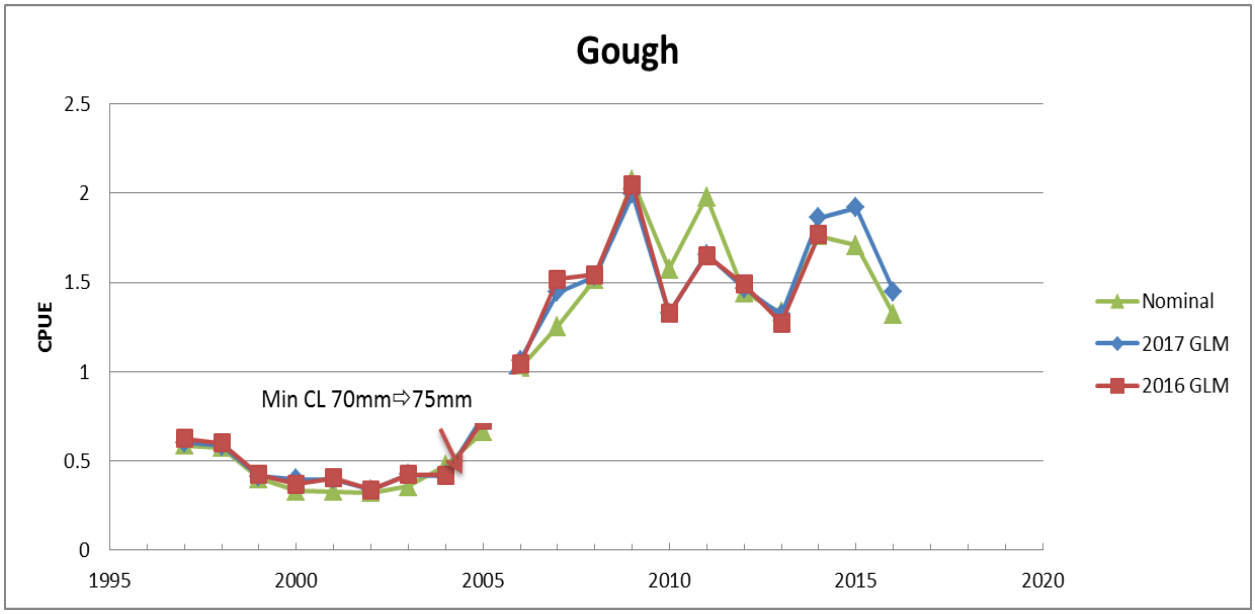

Figure 2a: GLMM month effects for **Inaccessible** Island.

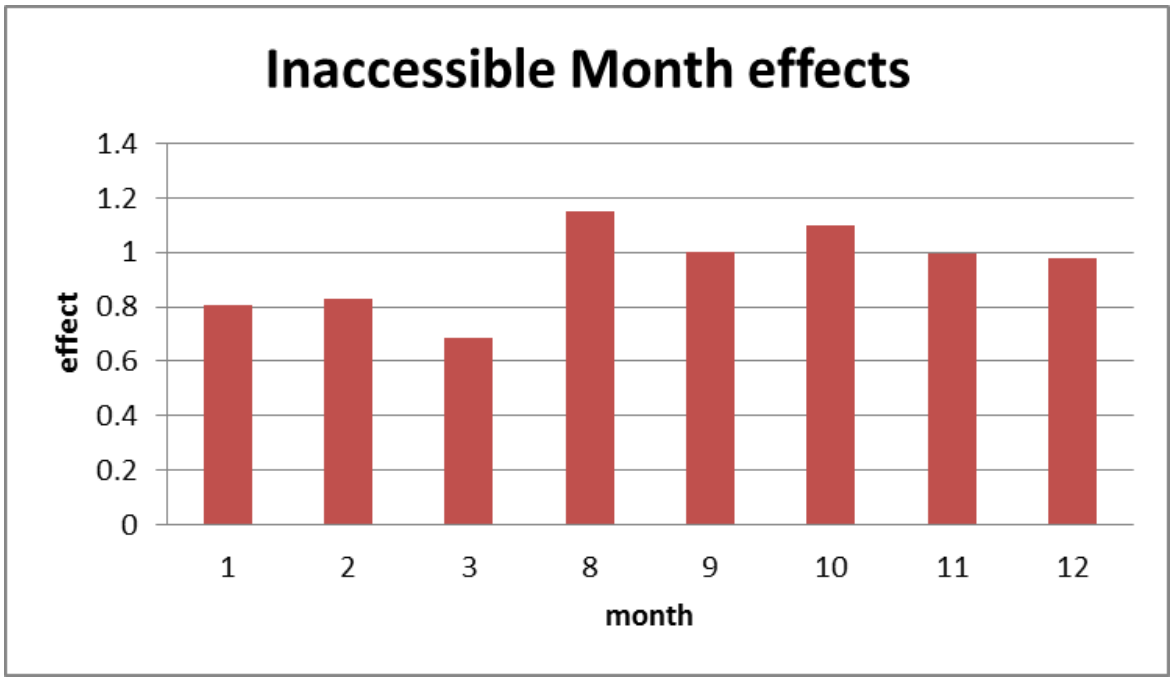

Figure 2b: GLMM month effects for **Nightingale** Island.

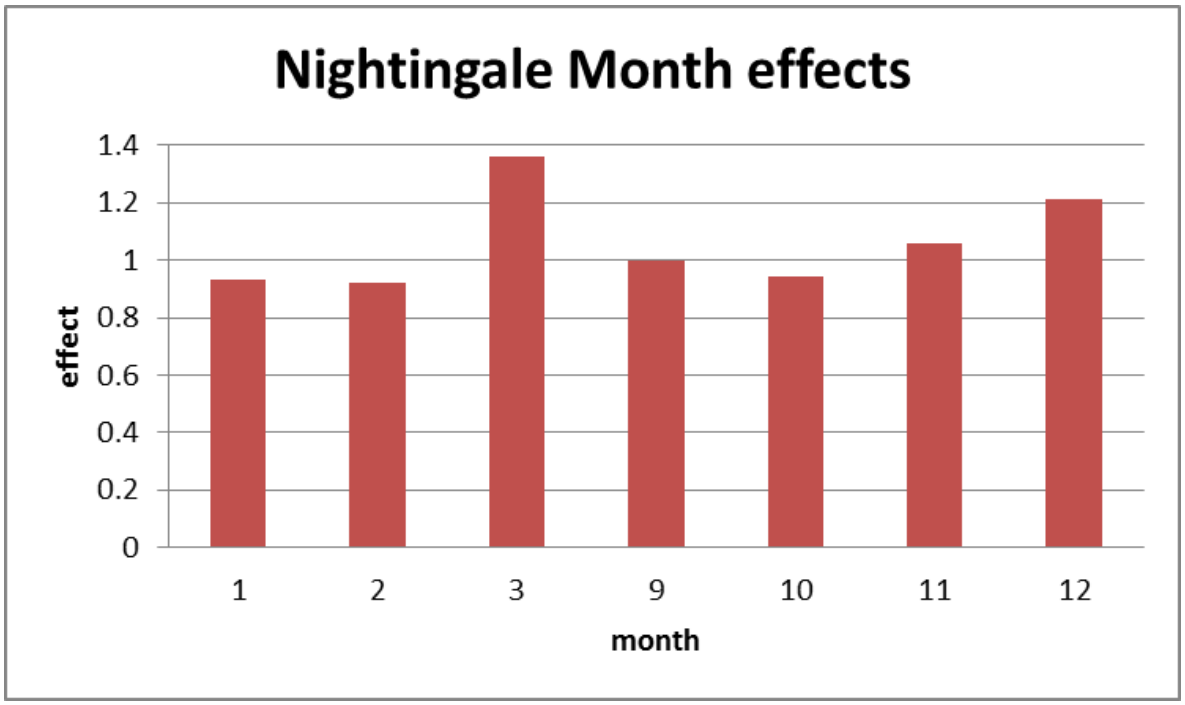

Figure 2c: GLMM month effects for **Gough** Island.

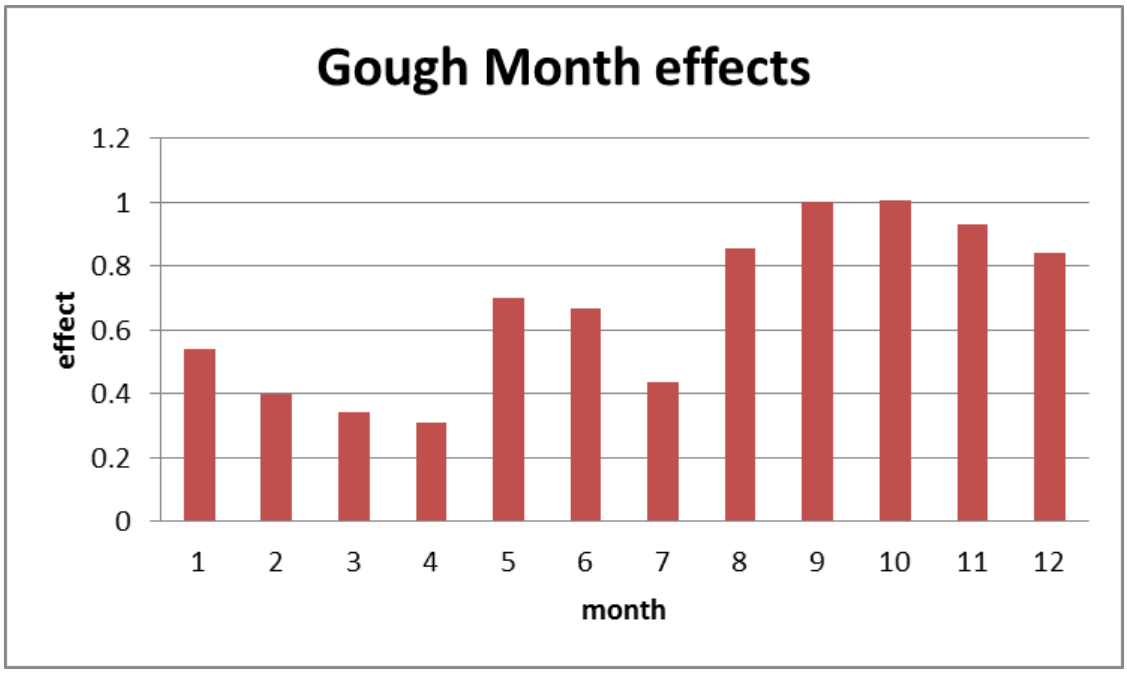

Figure 3a: GLMM area effects for **Inaccessible** Island (see Table 1a for area definitions).

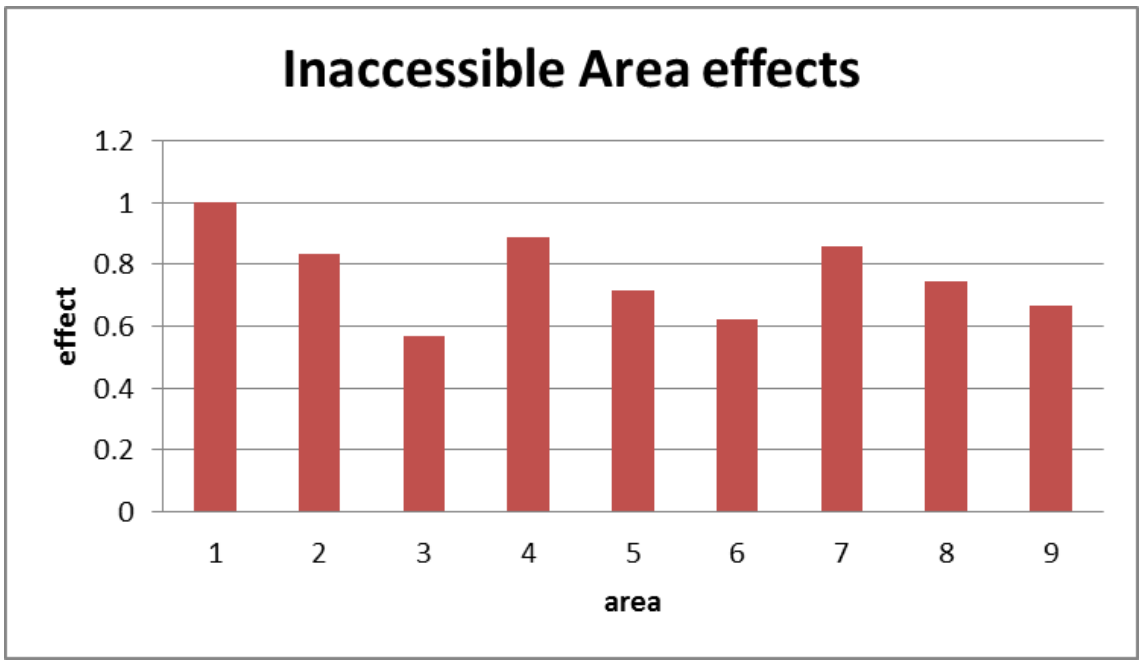

Figure 3b: GLMM area effects for **Nightingale** Island (see Table 1b for area definitions).

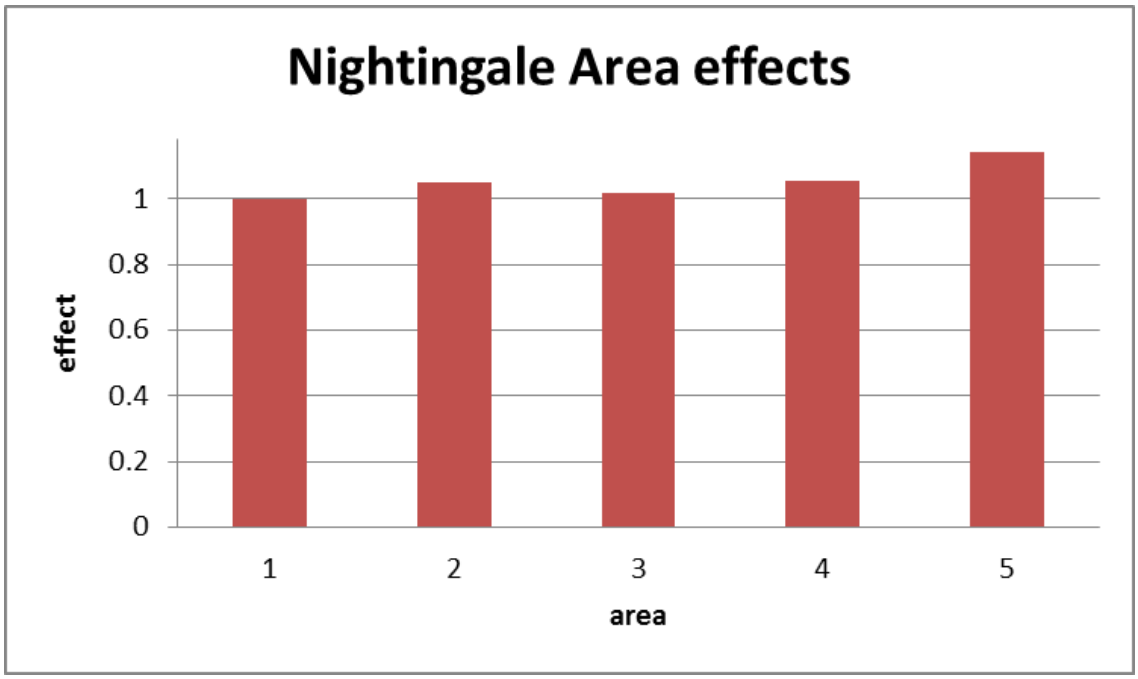

Figure 3c: GLMM area effects for **Gough** Island (see Table 1c for area definitions).