Updated 2021 GLMM -standardised lobster CPUE from Inaccessible and Nightingale islands

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KEY WORDS: CPUE, GLMM, Inaccessible island, Nightingale island

ABSTRACT

The longline CPUE series for Inaccessible island is GLMM standardised through to 2020[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 2013-2020 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 recent standardised CPUEs for Inaccessible and Nightingale continue to be high (well above the Itar level), and show an increase since the previous season.

KEY WORDS: Inaccessible and Nightingale islands, *Jasus tristani*, GLMM, CPUE standardisation

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 Island for the period 1997-2020, and for the period 1997-2020 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

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

updated from those presented in Johnston *et al.* (2020), taking one more year's data into account.

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 2020, 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),
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),
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(β)=E(ε)=0, so that E(ln(*CPUE*+δ)) = **X**α. 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:

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

where

μ	is the intercept,
year	is a factor with 24 levels for Inaccessible associated with the Season-Years 1997-2020, and 22 levels for Nightingale associated with the Season-Years 1997-2020 (excluding 2011 and 2012),
month	is a factor with levels associated with the fishing month (1-5 and 9-12 for Nightingale, and 1-5 and 8-12 for Inaccessible),
area	is a factor with levels associated with groupings of fishing 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),
sequential day	is a factor with values equal to the sequential day in each fishing trip/tranche (levels 1-14+).
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 and Nightingale Islands.

RESULTS

Table 2 provides standardised CPUE values derived from the GLMMs considered. For comparison, the nominal CPUE values are also reported. Figures 1a-b compare the nominal CPUE with the updated 2021 standardised CPUE series, along with the 2020 standardised CPUE series. The series have been renormalised to an average value of 1 over the 1997-2019 period in the plots for comparative purposes. Figures 2a-b show the updated standardised CPUE series for each outer island, along with the current OMP Itar and Ilim values for each island. Figures 3a-b show the month effects, Figures 4a-b show the area effects and Figures 5a-b show the sequential fishing day effects for each island.

DISCUSSION

The updated GLMM CPUE series reported are to be used to provide inputs into the OMPs for Inaccessible and Nightingale to provide TAC recommendations for the 2021 season. The Inaccessible standardised CPUE for the 2020 season of 9.680 kg/trap is the second highest on record (since 1997) and considerably above the current Itar of 5 kg/trap. The general upward trend in CPUE at Inaccessible thus continues since around 2011. The Nightingale standardised CPUE for the 2020 season of 10.05 kg/trap is again on the upward trend and more than double the current Itar value.

REFERENCE

Johnston, S.J., Brandao, A. and D.S. Butterworth. 2020. Updated 2020 GLMM- and GLM-standardised lobster CPUE from the Tristan da Cunha group of islands. MARAM/Tristan/2020/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 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 (2020)**	**Standardised CPUE (2021)**
1997	238	2.986	2.685	2.778
1998	413	2.800	2.319	2.464
1999	406	3.492	2.543	2.829
2000	608	3.247	2.812	3.186
2001	584	3.362	3.131	3.722
2002	416	4.322	4.054	5.384
2003	225	6.704	5.393	6.008
2004	399	7.584	8.705	10.310
2005	435	7.010	6.810	7.886
2006	347	6.447	6.288	6.930
2007	669	4.853	4.384	4.480
2008	838	4.561	4.413	4.627
2009	1029	3.207	2.838	3.074
2010	624	2.437	2.436	2.560
2011	366	3.654	3.472	3.536
2012	534	5.172	5.096	5.259
2013	440	6.163	5.636	6.766
2014	418	7.026	7.074	7.049
2015	496	6.173	5.579	5.661
2016	418	7.645	6.960	6.799
2017	362	8.933	7.857	8.079
2018	530	5.732	6.130	4.930
2019	485	6.505	6.482	6.264
2020	454	8.48	-	9.680

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 (2020)**	**Standardised CPUE (2021)**
1997	681	1.920	2.006	2.764
1998	501	2.660	2.305	3.040
1999	319	3.393	2.519	2.892
2000	380	4.004	3.921	4.752
2001	541	3.201	3.204	4.238
2002	470	3.314	3.233	4.563
2003	245	5.711	5.765	6.534
2004	479	5.647	5.621	7.114
2005	376	7.193	6.231	7.713
2006	204	6.118	4.909	5.727
2007	337	5.824	4.893	5.666
2008	433	4.827	3.752	4.416
2009	468	4.237	3.750	4.462
2010	361	4.862	3.477	4.071
2011	-	-	-	-
2012	-	9.62	-	-
2013	219	13.42	12.580	12.623
2014	232	10.94	10.651	10.501
2015	348	8.63	9.044	9.867
2016	240	12.50	12.102	14.215
2017	225	11.549	10.224	11.818
2018	327	8.009	7.945	8.100
2019	384	6.916	7.124	6.866
2020	389	8.49	-	10.049

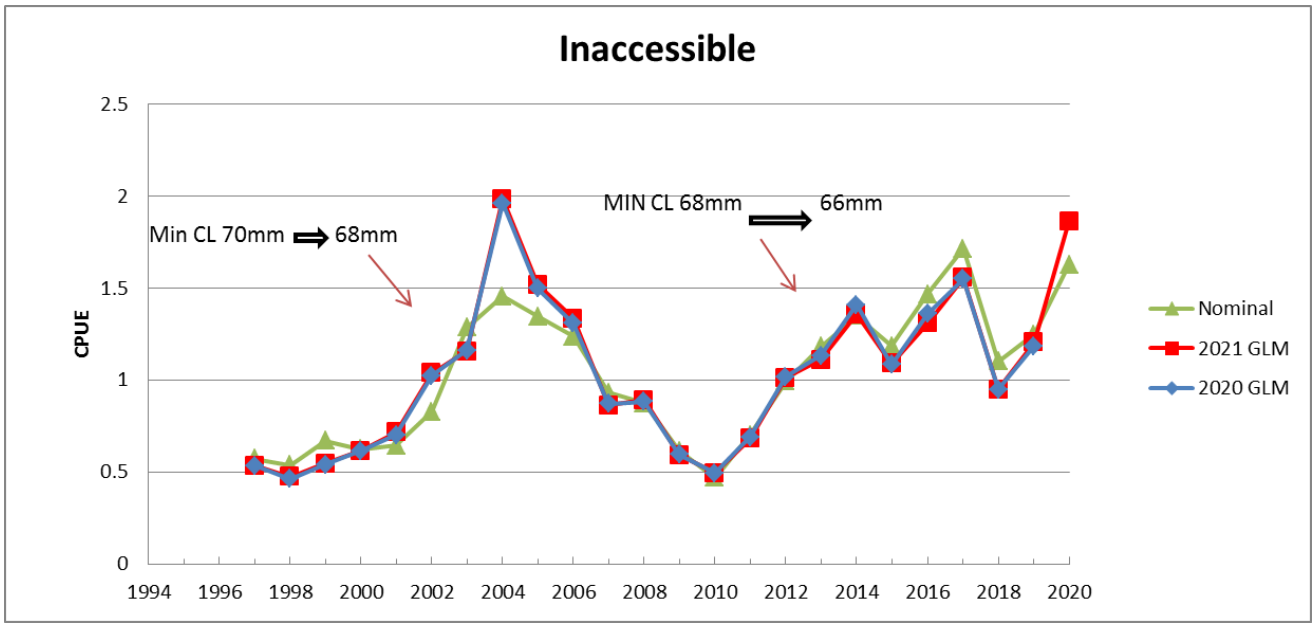

Figure 1a: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Inaccessible** Island. All series have been renormalised to a mean of 1 (for 1997-2019) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 68mm CL in 2003 and from 68mm to 66mm CL in 2012.]

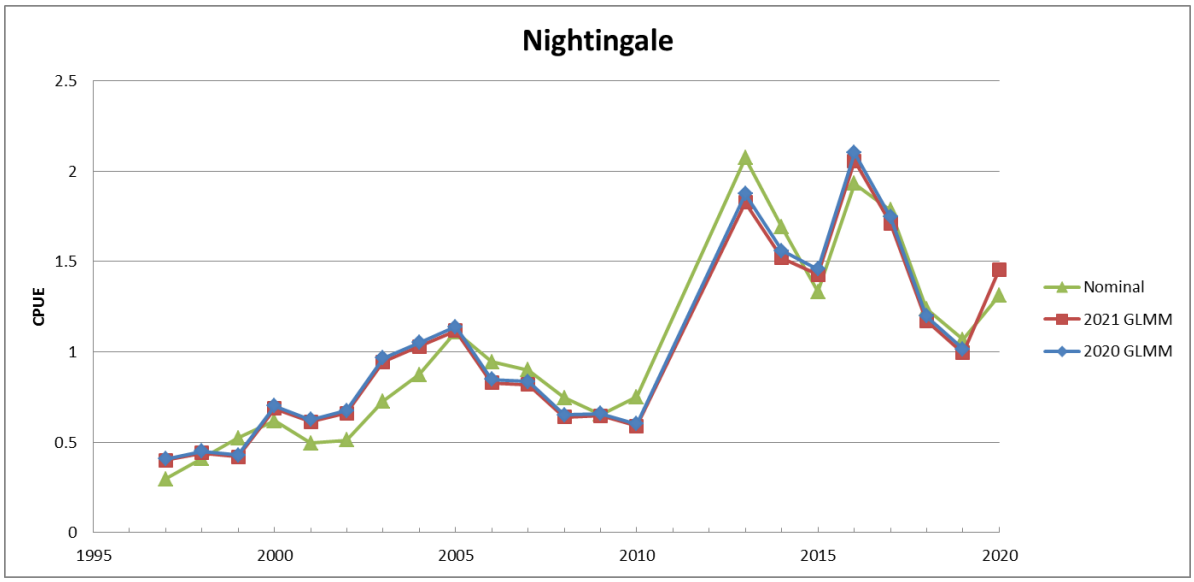

Figure 1b: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Nightingale** Island. All series have been renormalised to a mean of 1 (for 1997-2019) for easier comparison of trends.

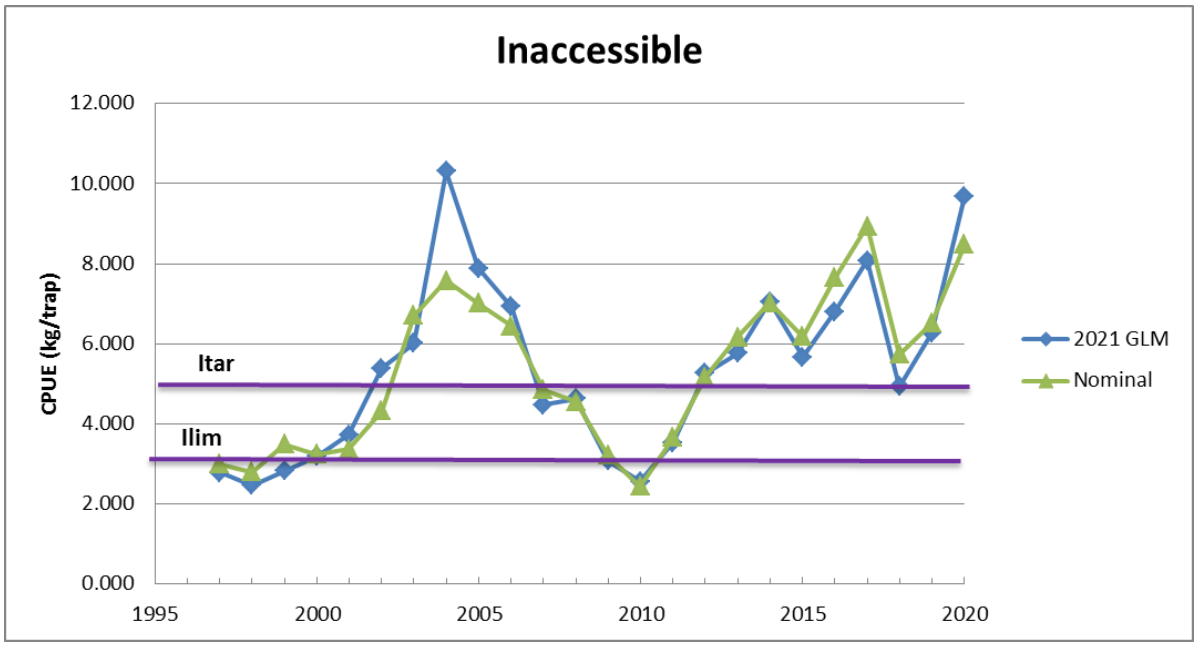

Figure 2a: Inaccessible standardised CPUE shown alongside the current Itar (5 kg/trap) and Ilim (3 kg/trap) values (shown as purple horizontal lines).

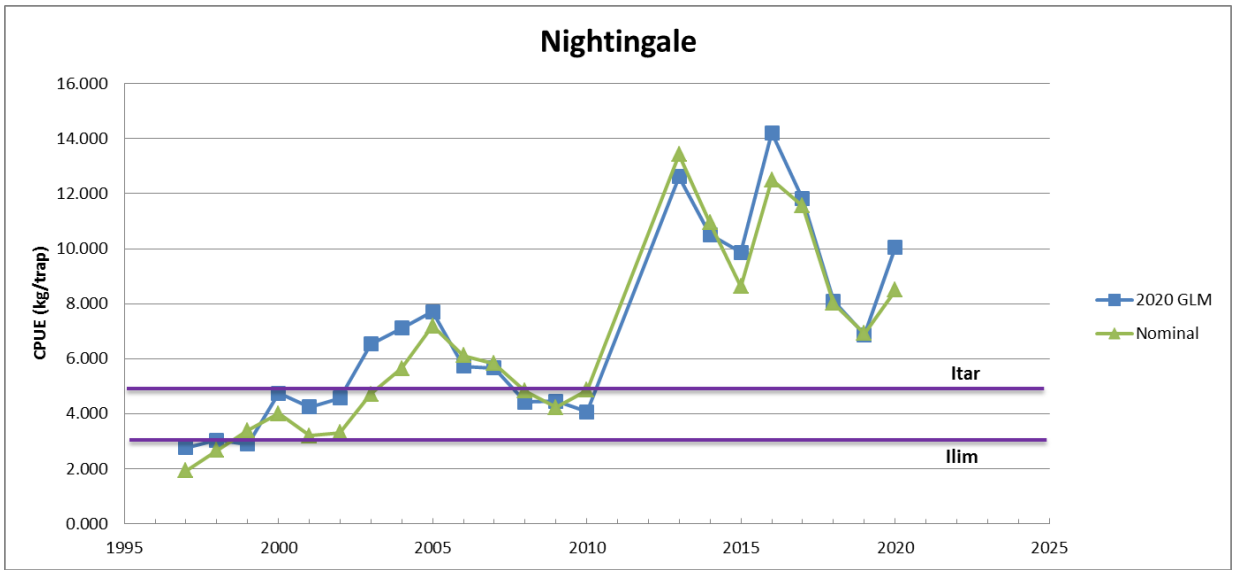

Figure 2b: Nightingale standardised CPUE shown alongside the current Itar (5 kg/trap and Ilim (3 kg/trap) values (shown as purple horizontal lines).

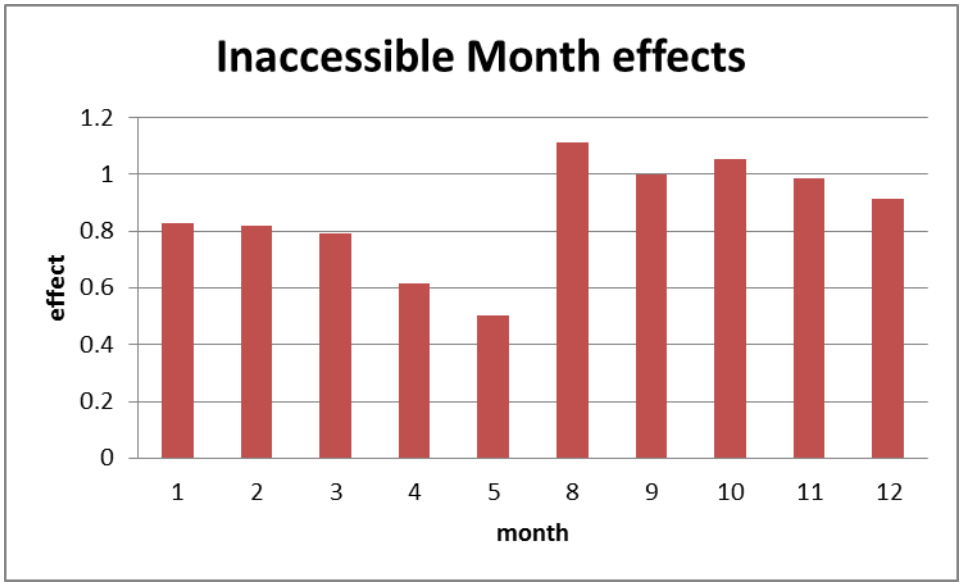

Figure 3a: GLMM month effects for **Inaccessible** Island.

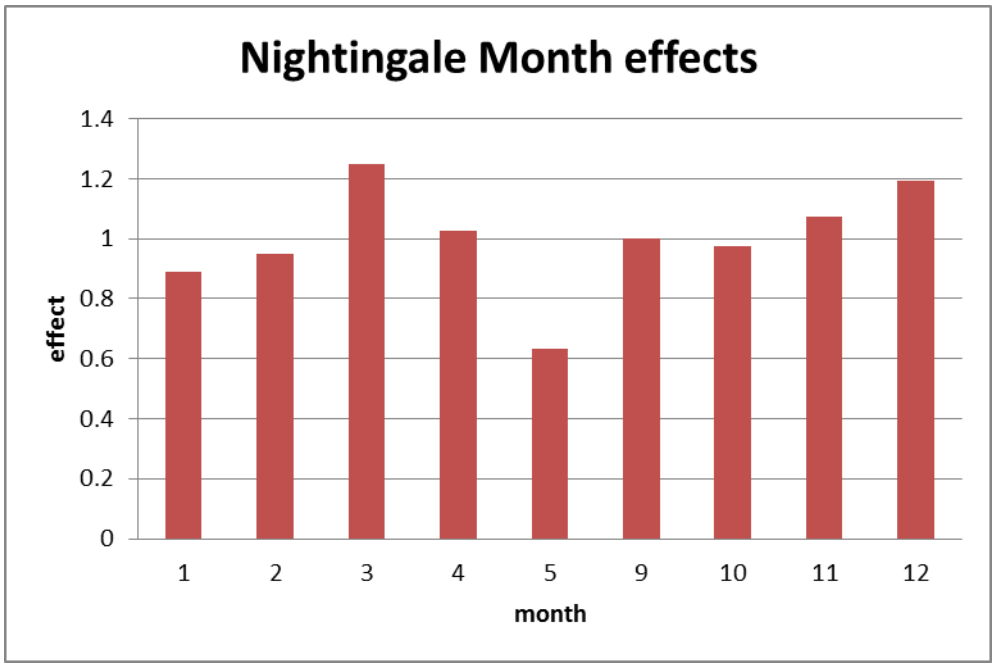

Figure 3b: GLMM month effects for **Nightingale** Island.

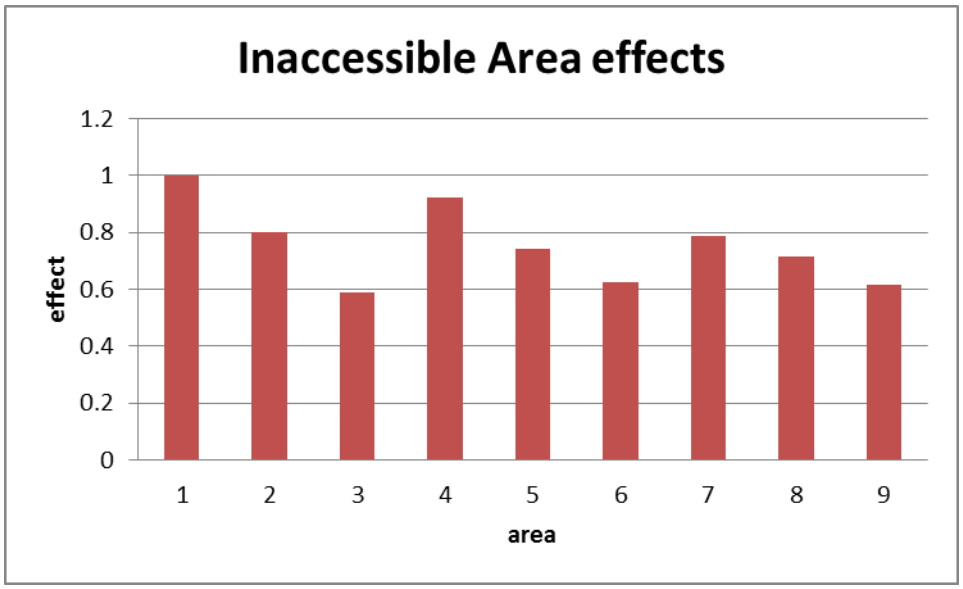

Figure 4a: GLMM area effects for **Inaccessible** Island (see Table 1a for area definitions).

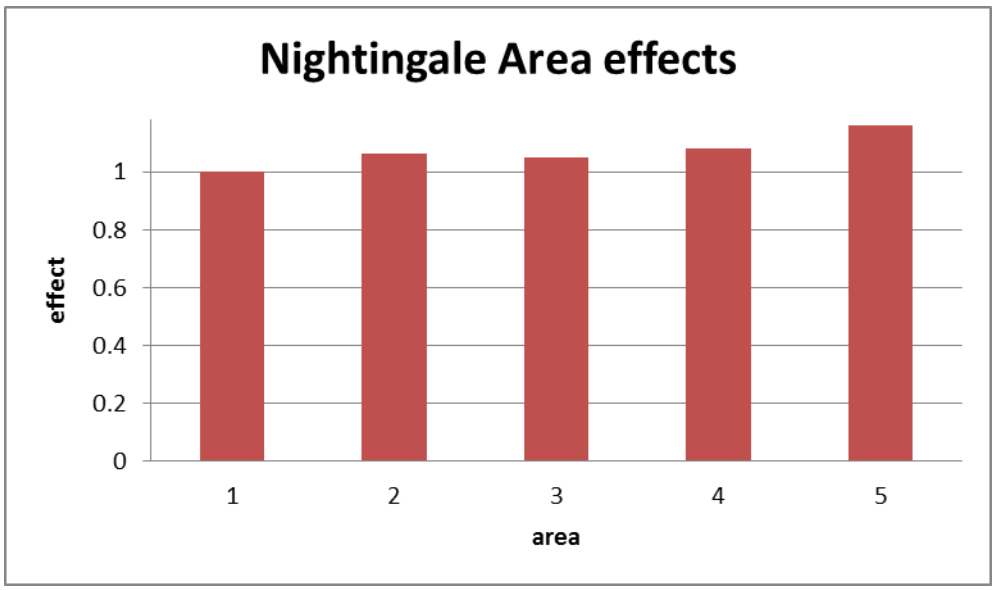

Figure 4b: GLMM area effects for **Nightingale** Island (see Table 1b for area definitions).

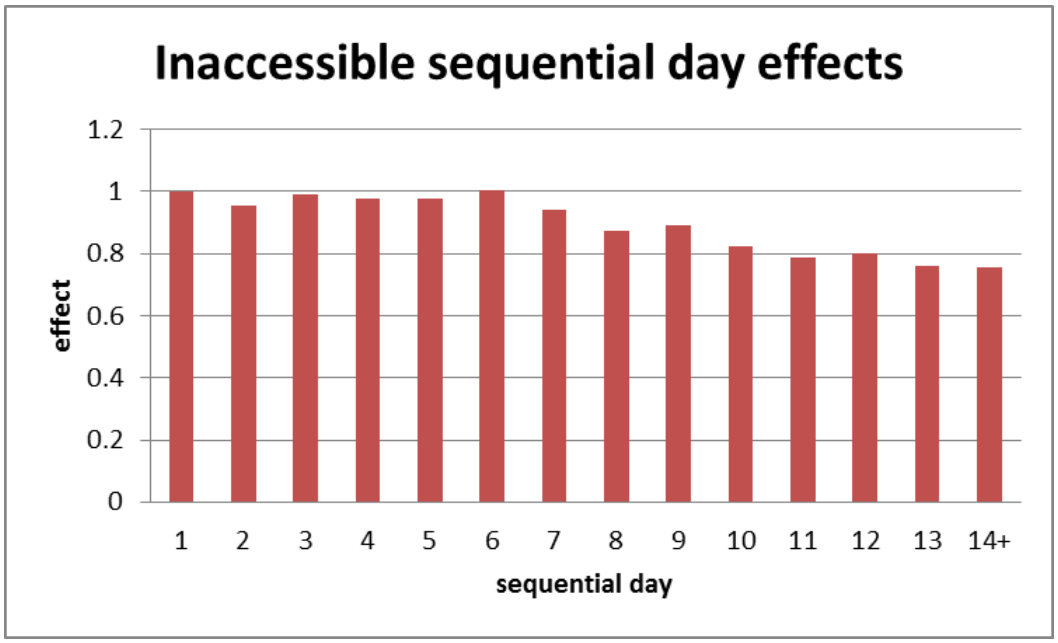

Figure 5a: GLMM sequential fishing day effects for **Inaccessible** Island.

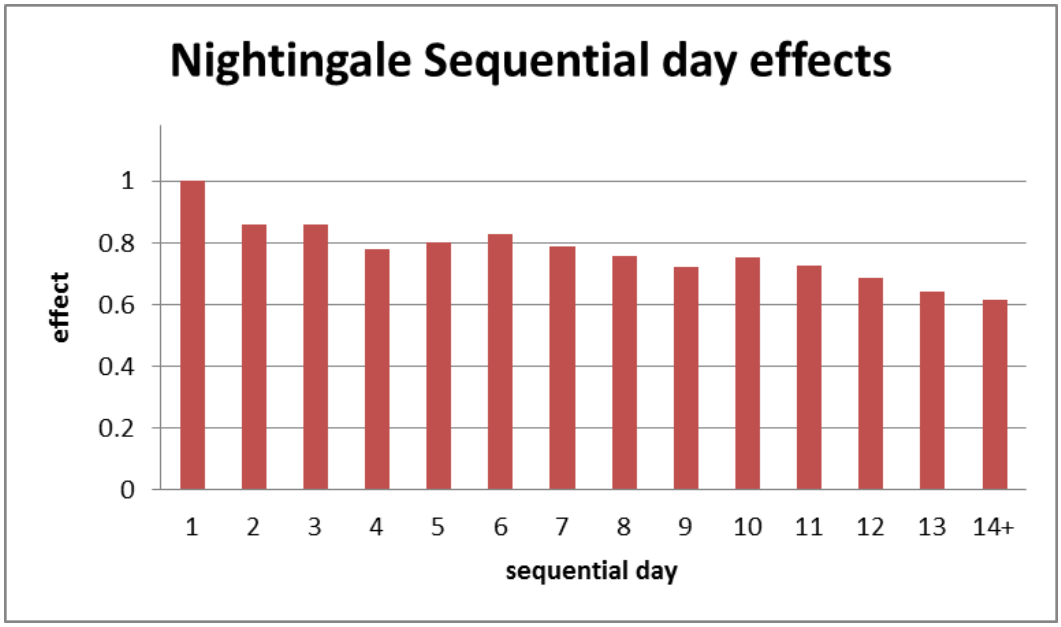

Figure 5b: GLMM sequential fishing day effects for **Nightingale** Island.