Updated 2021 GLMM -standardised lobster CPUE from Inaccessible, Nightingale and Gough islands from the *Jasus tristani* fishery

S.J. Johnston and D.S. Butterworth

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

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ABSTRACT

The longline CPUE series for Inaccessible, Nightingale and Gough islands are GLMM standardised through to 2021. Year, month, area, trap-type, soak time, depth, sequential day 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), with that for Gough being substantially higher than the 2020 value.

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 instead of TACs were set for 2012 and 2013). Results presented here are updates 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. **X**α 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

Tables 2a-c provide standardised CPUE values derived from the GLMMs considered for each of the outer islands. For comparison, the nominal CPUE values are also reported. Figures 1a-c 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 1997-2020 period in the plots for comparative purposes. Figures 2a-c show the updated standardised CPUE series for each outer island, along with the current OMP Itar and Ilim values for each island. Figures 3a-c show the month effects, Figures 4a-c show the area effects and Figures 5a-c 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 to provide TAC recommendations for the 2022 season. The Inaccessible standardised CPUE for the 2021 season of 9.234 kg/trap remains high and considerably above the current Itar of 5 kg/trap. The general upward trend in CPUE at Inaccessible has thus continued since about 2011 (except for a dip in 2018, and a smaller dip in 2015). The Nightingale standardised CPUE for the 2021 season of 11.721 kg/trap is similarly on an upward trend and more than double the current Itar value.

The Gough CPUE for the 2021 season is considerably higher than the 2020 value, and well above the Itar value. All the fishing at Gough this season took place in Oct-Dec 2021, whilst virtually all the fishing occurred in Jan-May the previous season. There is a large difference in month effects for these two groups of months, with the Oct-Dec months having around twice the fishing effectiveness than the Jan-May months. This explains the large increase in nominal CPUE from the 2020 to this 2021 seasons (170% increase). The standardised CPUE (for which these month effects are taken into account) reflects and 80% increase.

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 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 (2020)**	**Standardised CPUE (2021)**
1997	238	2.986	2.778	2.743
1998	413	2.800	2.464	2.430
1999	406	3.492	2.829	2.805
2000	608	3.247	3.186	3.078
2001	584	3.362	3.722	3.737
2002	416	4.322	5.384	5.363
2003	225	6.704	6.008	5.887
2004	399	7.584	10.310	9.949
2005	435	7.010	7.886	7.823
2006	347	6.447	6.930	6.987
2007	669	4.853	4.480	4.374
2008	838	4.561	4.627	4.550
2009	1029	3.207	3.074	3.003
2010	624	2.437	2.560	2.472
2011	366	3.654	3.536	3.475
2012	534	5.172	5.259	5.182
2013	440	6.163	6.766	5.648
2014	418	7.026	7.049	7.084
2015	496	6.173	5.661	5.863
2016	418	7.645	6.799	6.803
2017	362	8.933	8.079	7.903
2018	530	5.732	4.930	4.868
2019	485	6.505	6.264	6.359
2020	454	8.48	9.680	9.731
2021	435	9.423	-	9.234

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	2.764	2.842
1998	501	2.660	3.040	3.042
1999	319	3.393	2.892	2.866
2000	380	4.004	4.752	4.679
2001	541	3.201	4.238	4.196
2002	470	3.314	4.563	4.514
2003	245	5.711	6.534	6.620
2004	479	5.647	7.114	7.008
2005	376	7.193	7.713	7.572
2006	204	6.118	5.727	5.664
2007	337	5.824	5.666	5.604
2008	433	4.827	4.416	4.353
2009	468	4.237	4.462	4.386
2010	361	4.862	4.071	4.017
2011	-	-	-	-
2012	-	9.62	-	-
2013	219	13.42	12.623	12.575
2014	232	10.94	10.501	10.465
2015	348	8.63	9.867	9.841
2016	240	12.50	14.215	14.020
2017	225	11.549	11.818	11.598
2018	327	8.009	8.100	8.017
2019	384	6.916	6.866	7.094
2020	389	8.49	10.049	9.984
2021	340	9.994	-	11.721

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 (2020)**	**Standardised CPUE (2021)**
1997	1190	2.343	2.986	2.999
1998	1017	2.292	2.673	2.683
1999	1269	1.605	2.124	2.134
2000	1497	1.319	1.994	2.004
2001	1487	1.307	1.997	2.008
2002	1831	1.286	1.824	1.838
2003	1633	1.426	2.008	2.016
2004	951	1.894	2.171	2.184
2005	658	2.641	3.831	3.850
2005	373	4.078	4.753	4.775
2007	404	5.000	5.993	6.005
2008	398	6.044	7.162	7.203
2009	322	8.247	8.898	8.918
2010	464	6.280	7.238	7.291
2011	372	7.887	8.007	8.047
2012	605	5.746	6.954	6.988
2013	684	5.311	5.987	6.018
2014	485	7.015	8.573	8.629
2015	522	6.801	8.420	8.475
2016	709	5.263	6.557	6.598
2017	965	3.605	3.984	4.010
2018	544	6.515	7.323	7.369
2019	777	4.565	5.080	5.112
2020	922	3.567	6.178	6.212
2021	345	9.167	-	11.190

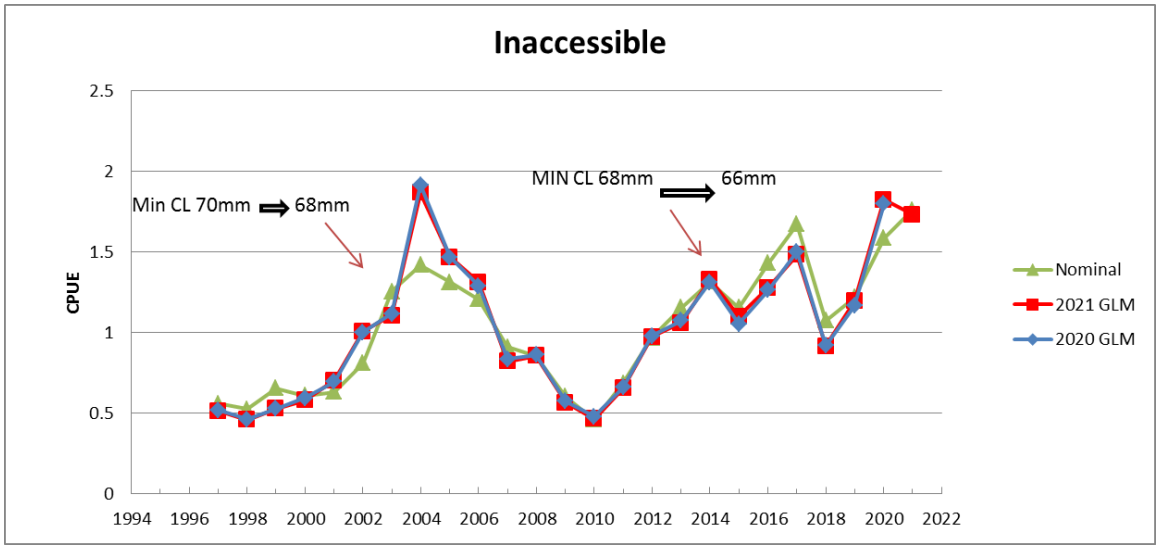

Figure 1a: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Inaccessible** Island. All series have been renormalised to a mean of 1 (for 1997-2020) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 68mm CL in 2003 and from 68mm to 66mm CL in 2012.]

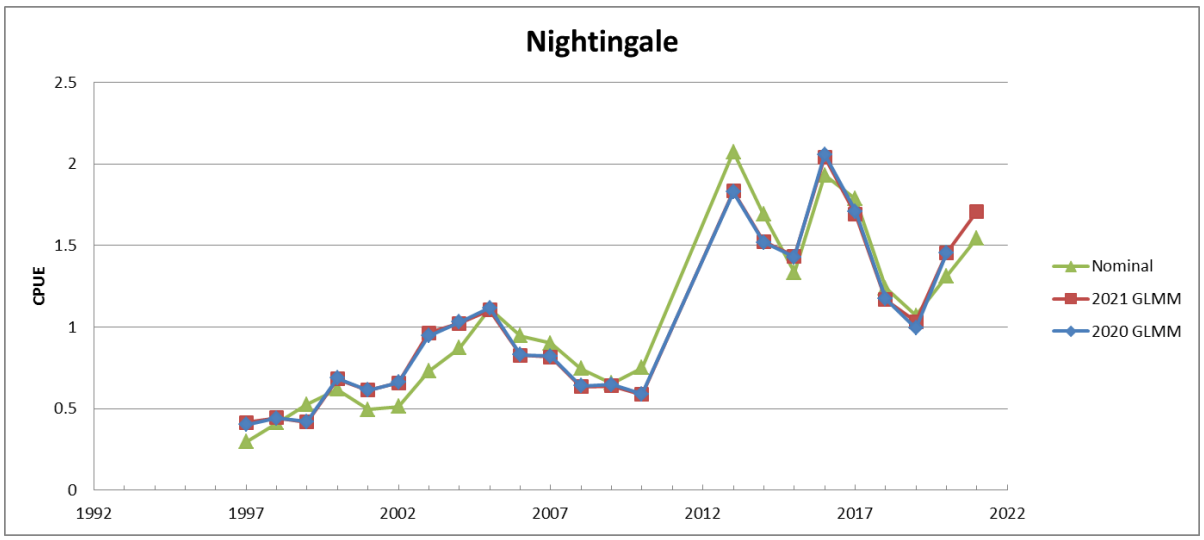

Figure 1b: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Nightingale** Island. All series have been renormalised to a mean of 1 (for 1997-2020) for easier comparison of trends.

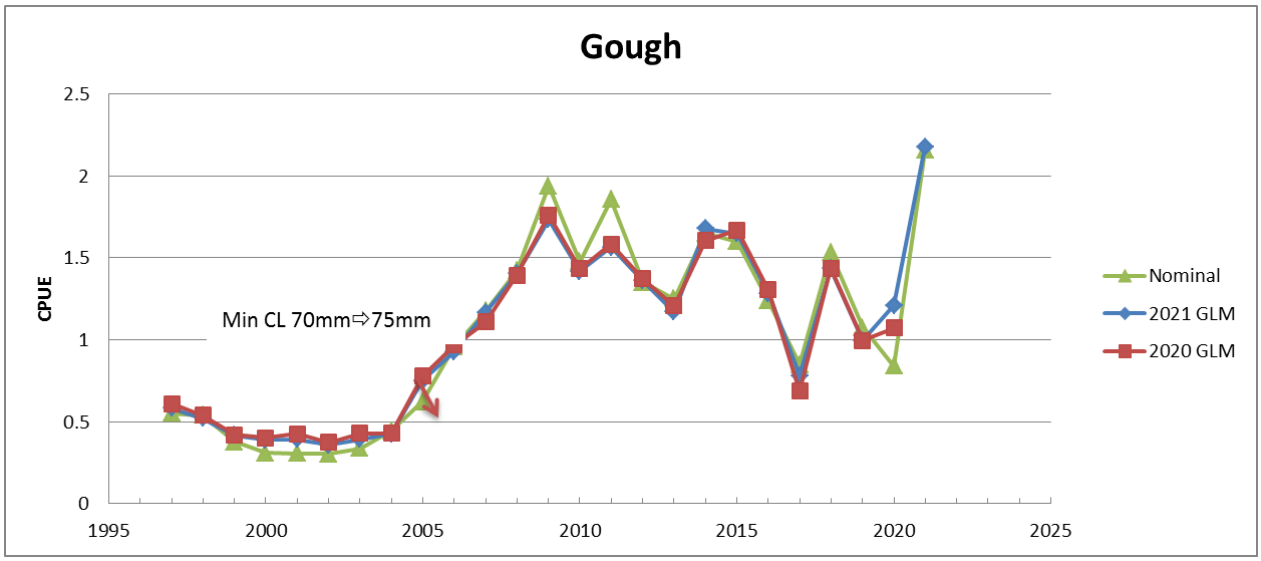

Figure 1c: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Gough** Island. All series have been renormalised to a mean of 1 (for 1997-2020) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 75mm in 2003.]

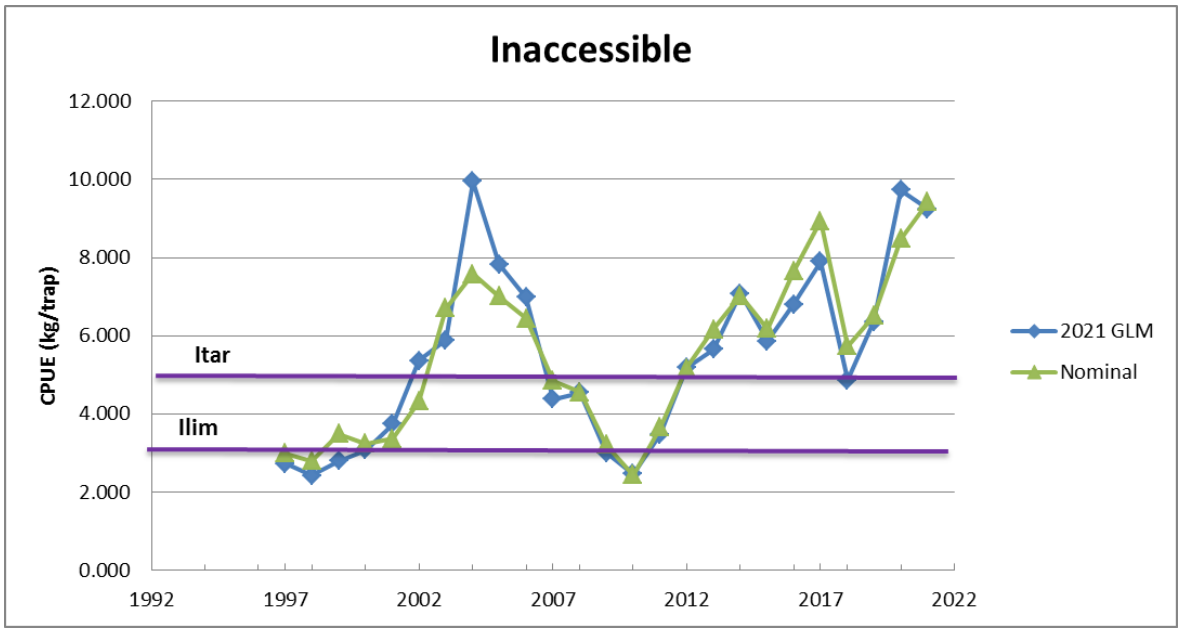

Figure 2a: Inaccessible standardised CPUE shown alongside the current Itar (5 kg/trap) and Ilim (3 kg/trap) values (shown as purple horizontal lines). The nominal series is also shown.

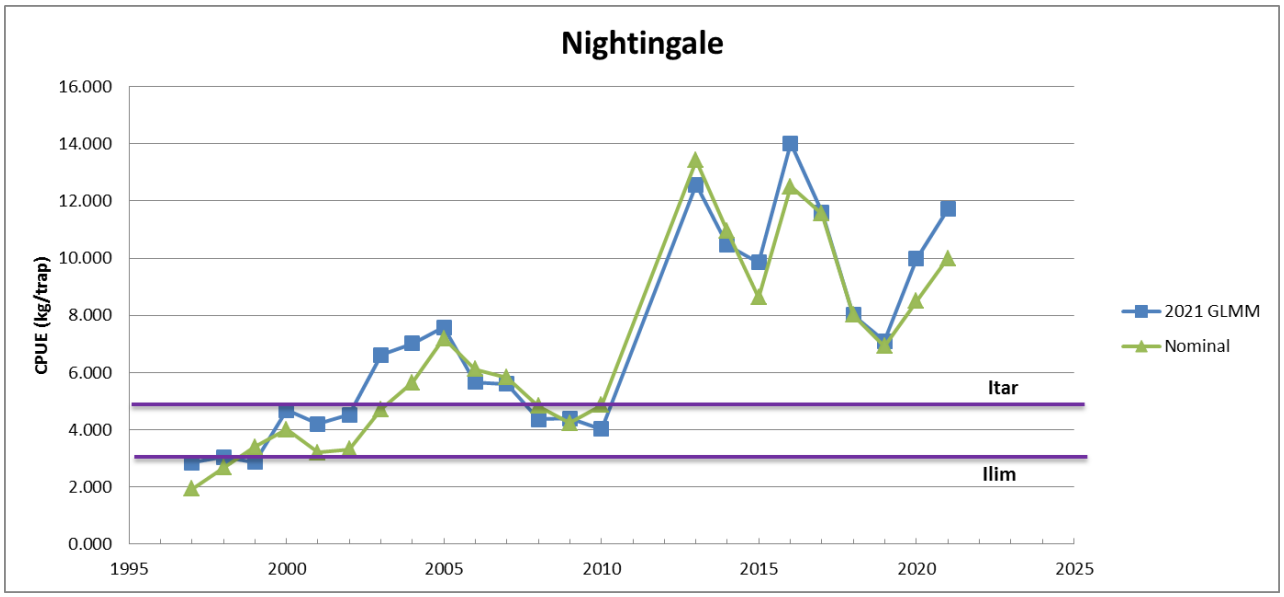

Figure 2b: Nightingale standardised CPUE shown alongside the current Itar (5 kg/trap and Ilim (3 kg/trap) values (shown as purple horizontal lines). The nominal series is also shown.

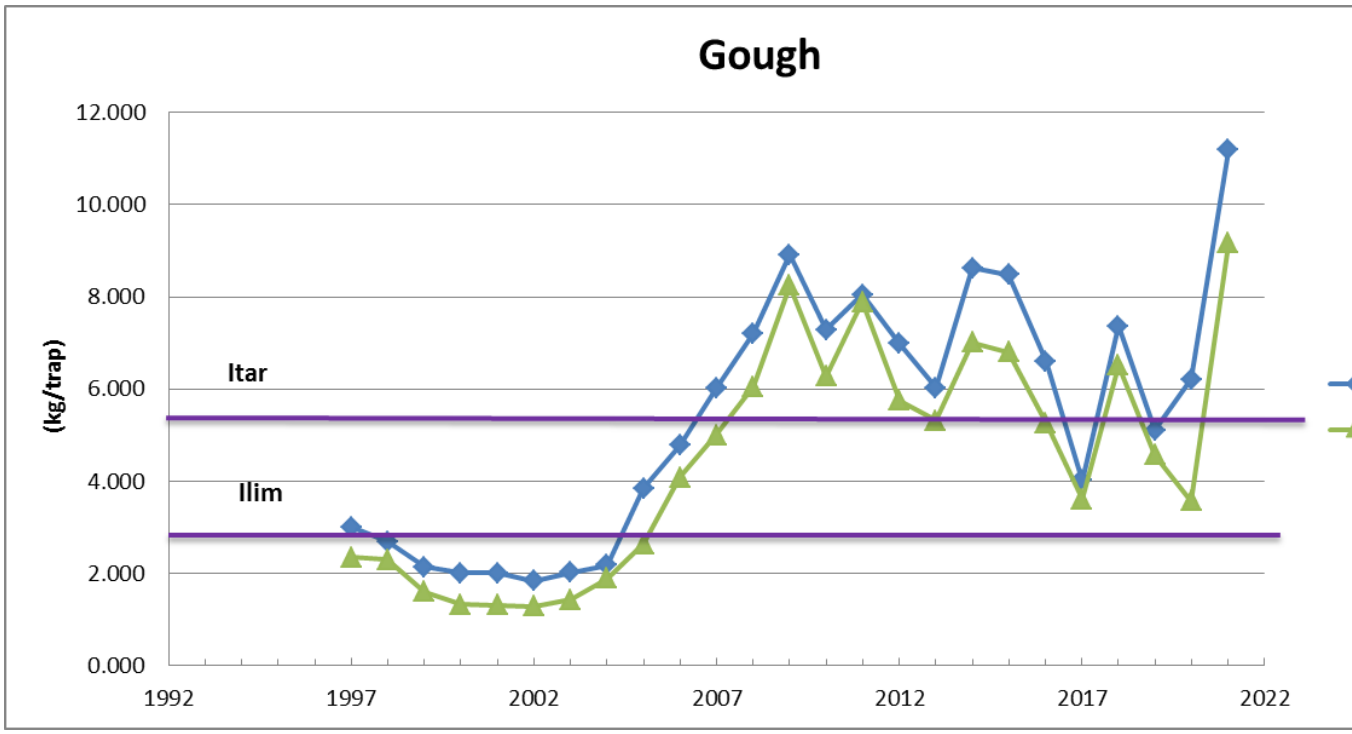

Figure 2c: Gough standardised CPUE shown alongside the current Itar and Ilim values (shown as purple horizontal lines). The nominal series is also shown.

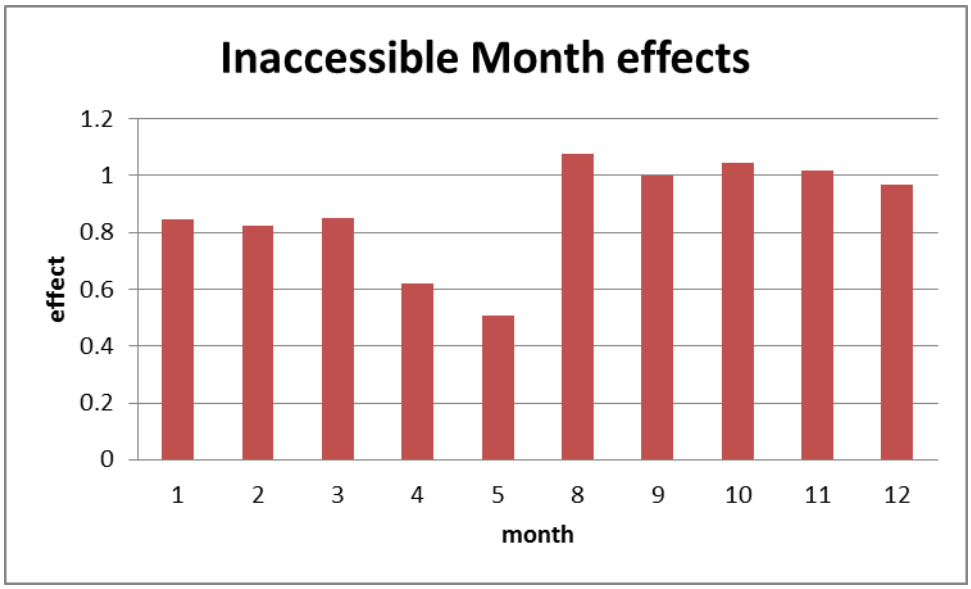

Figure 3a: GLMM month effects for **Inaccessible** Island.

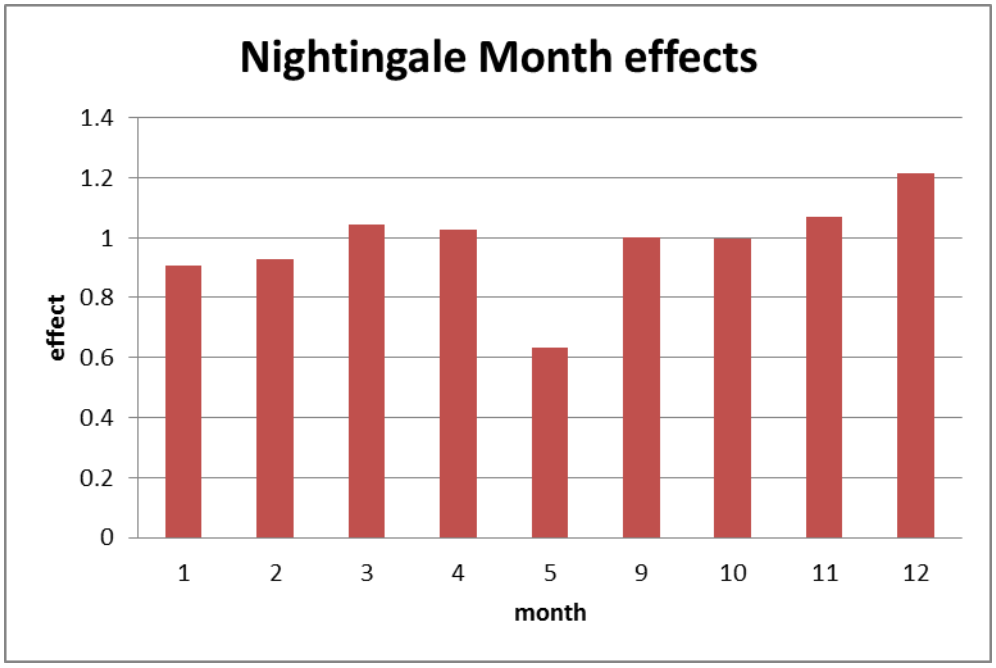

Figure 3b: GLMM month effects for **Nightingale** Island.

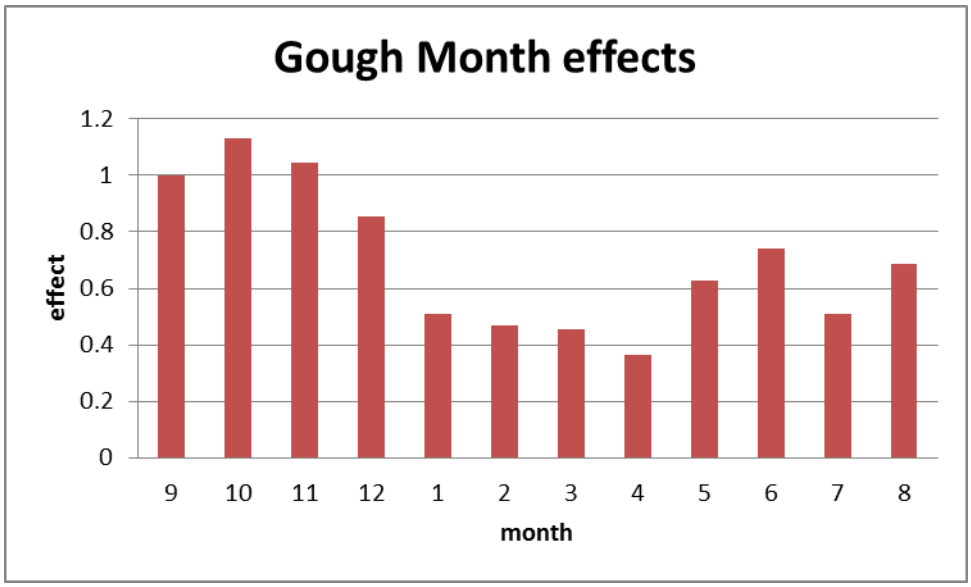

Figure 3c: GLMM month effects for **Gough** Island.

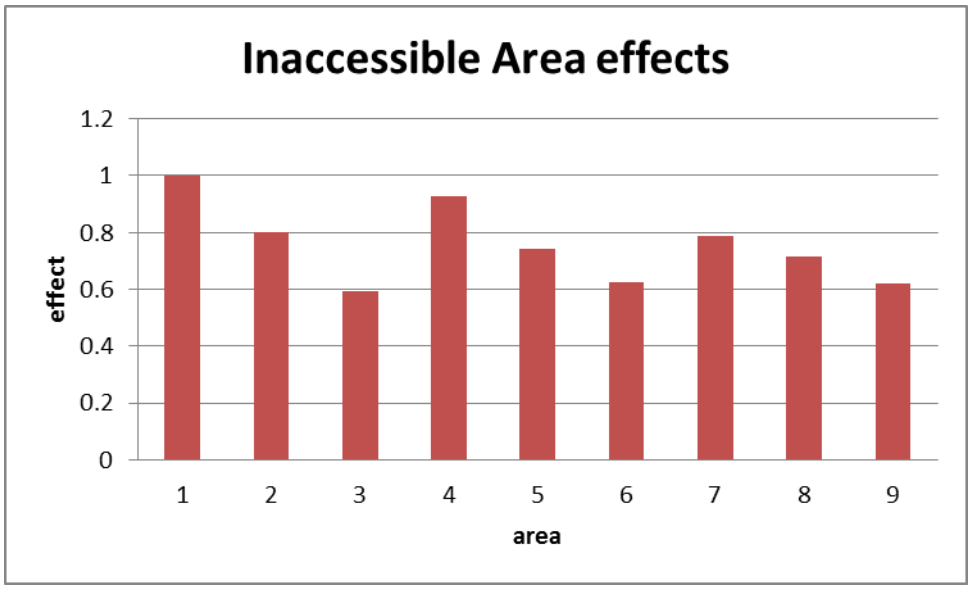

Figure 4a: GLMM area effects for **Inaccessible** Island (see Table 1a for area definitions).

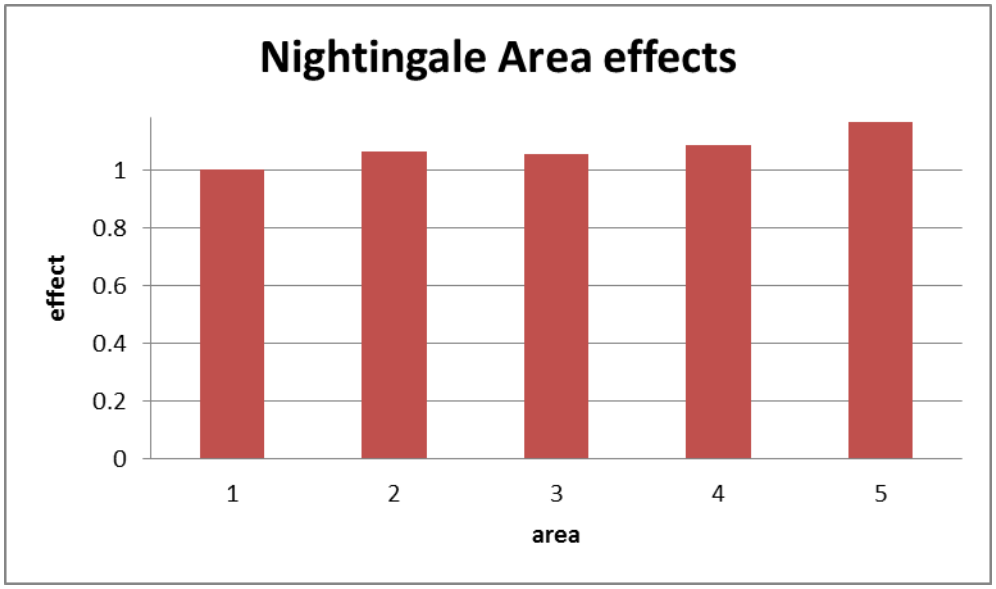

Figure 4b: GLMM area effects for **Nightingale** Island (see Table 1b for area definitions).

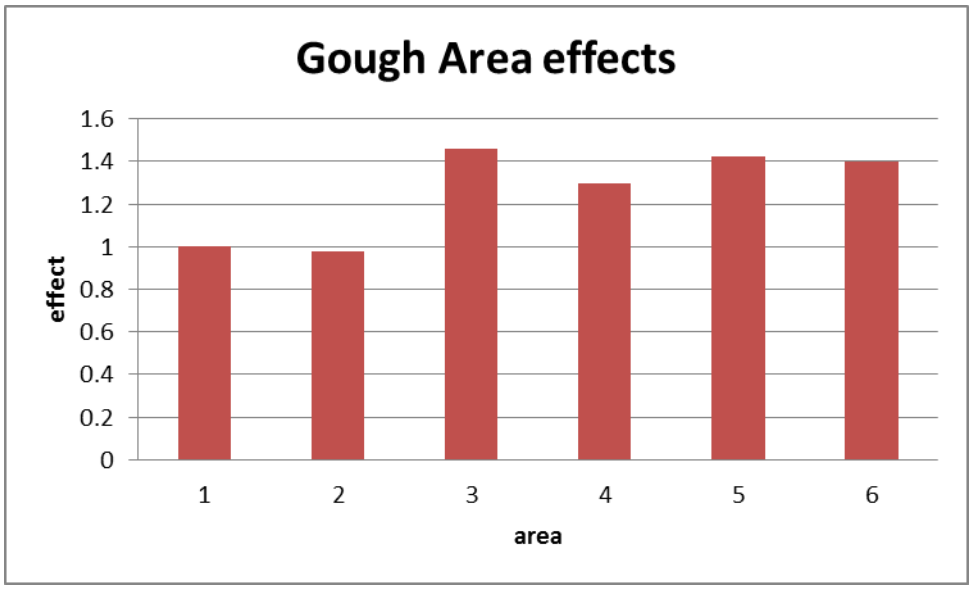

Figure 4c: GLMM area effects for **Gough** Island (see Table 1 for area definitions).

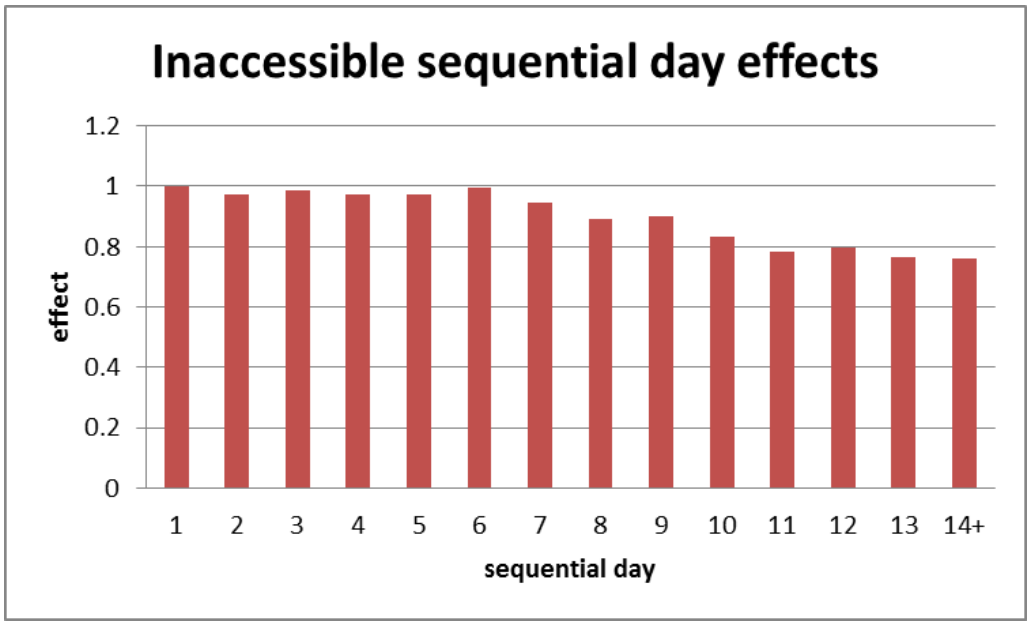

Figure 5a: GLMM sequential fishing day effects for **Inaccessible** Island.

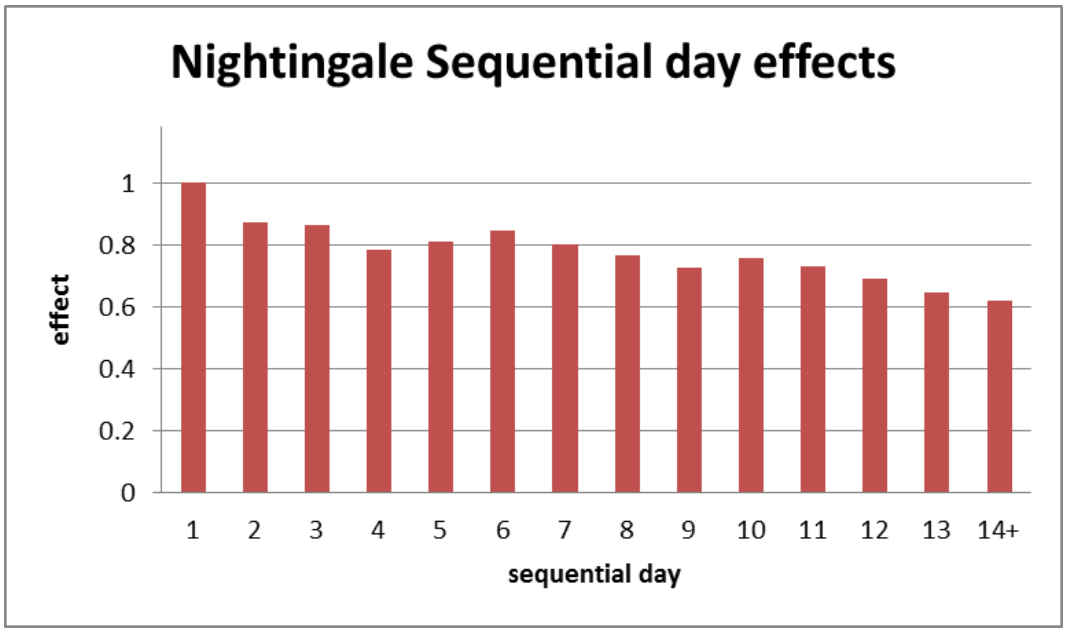

Figure 5b: GLMM sequential fishing day effects for **Nightingale** Island.

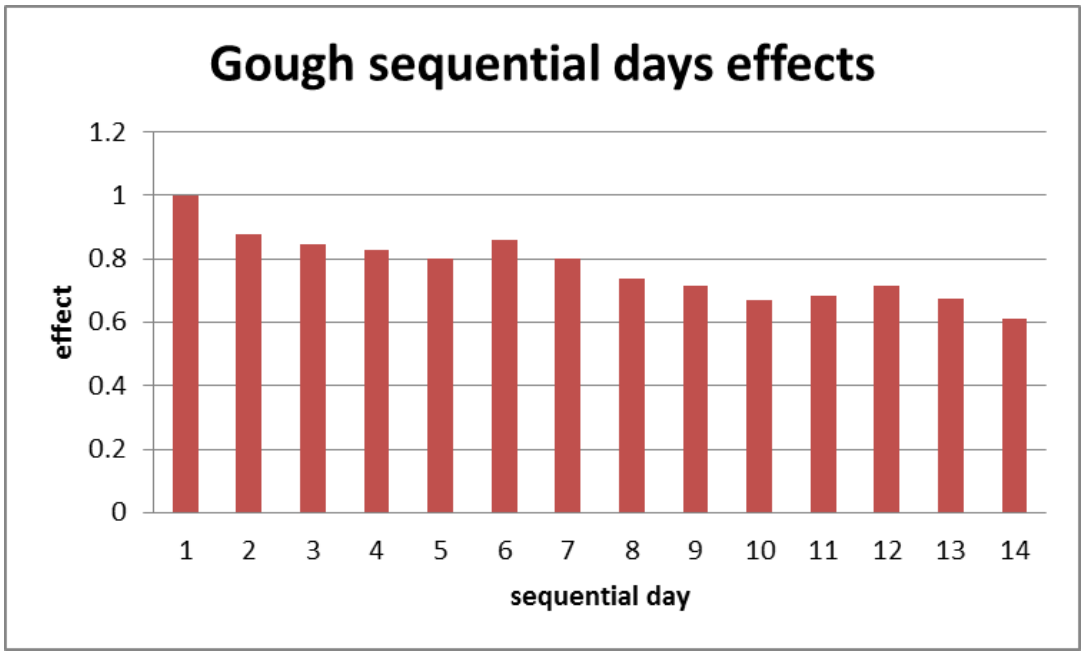

Figure 5c: GLMM sequential day effects for **Gough** Island.