Updated 2020 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 2019[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 2013-2019 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 CPUE for Inaccessible continues to be high, and shows a slight increase since the previous season. For Nightingale and Gough, the standardised CPUE value for the current season is lower than that of the previous season, although the Nightingale CPUE remains well above the Itar value. The Gough CPUE has been below the Itar value for the past four seasons.

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 1997-2019, and for the period 1997-2019 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.* (2019), 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 2019, 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 23 levels for Gough and Inaccessible associated with the Season-Years 1997-2019, and 21 levels for Nightingale associated with the Season-Years 1997-2019 (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. Figures 1a-c compare the nominal CPUE with the updated 2020 standardised CPUE series, along with the 2019 standardised CPUE series. The series have been renormalised to an average value of 1 over the 1997-2018 period in the plots for comparative purposes. Figures 2a-c shows the month effects and Figures 3a-c shows the area effects for each island. Figures 4a-c show the updated standardised CPUE series for each outer island, along with the current OMP Itar and Ilim values for each island.

DISCUSSION

The updated GLMM CPUE series reported are to be used to provide inputs into the OMPs for Inaccessible, Gough and Nightingale to provide TAC recommendations for the 2020 season. The GLMM CPUEs for Gough and Nightingale have decreased slightly for the 2019 season compared with the previous season (Figures 4b and c). Nightingale remains well above the Itar value. For Gough, the 2020 GLMM CPUE value for the current season is below the Itar value (and has been now for the last four seasons). The Inaccessible 2020 CPUE has increased slightly from the previous season and remains well above the Itar value.

REFERENCE

Johnston, S.J., Brandao, A. and D.S. Butterworth. 2019. Updated 2019 GLMM- and GLM-standardised lobster CPUE from the Tristan da Cunha group of islands. MARAM/Tristan/2019/FEB/01.

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 (2019)**	**Standardised CPUE (2020)**
1997	238	2.986	2.686	2.685
1998	413	2.800	2.330	2.319
1999	406	3.492	2.556	2.543
2000	608	3.247	2.828	2.812
2001	584	3.362	3.163	3.131
2002	416	4.322	4.101	4.054
2003	225	6.704	5.430	5.393
2004	399	7.584	8.772	8.705
2005	435	7.010	6.863	6.810
2006	347	6.447	6.344	6.288
2007	669	4.853	4.416	4.384
2008	838	4.561	4.457	4.413
2009	1029	3.207	2.865	2.838
2010	624	2.437	2.451	2.436
2011	366	3.654	3.507	3.472
2012	534	5.172	5.147	5.096
2013	440	6.163	5.683	5.636
2014	418	7.026	7.092	7.074
2015	496	6.173	5.585	5.579
2016	418	7.645	6.988	6.960
2017	362	8.933	7.822	7.857
2018	530	5.732	6.203	6.130
2019	485	6.605	-	6.482

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 (2019)**	**Standardised CPUE (2020)**
1997	681	1.920	2.085	2.006
1998	501	2.660	2.365	2.305
1999	319	3.393	2.584	2.519
2000	380	4.004	4.063	3.921
2001	541	3.201	3.300	3.204
2002	470	3.314	3.324	3.233
2003	245	5.711	5.985	5.765
2004	479	5.647	5.780	5.621
2005	376	7.193	6.474	6.231
2006	204	6.118	5.036	4.909
2007	337	5.824	5.020	4.893
2008	433	4.827	3.873	3.752
2009	468	4.237	3.869	3.750
2010	361	4.862	3.569	3.477
2011	-	-	-	-
2012	-	9.62	-	-
2013	219	13.42	12.829	12.580
2014	232	10.94	10.879	10.651
2015	348	8.63	9.351	9.044
2016	240	12.50	13.101	12.102
2017	225	11.549	10.453	10.224
2018	327	8.009	8.136	7.945
2019	384	6.916	-	7.124

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 (2019)**	**Standardised CPUE (2020)**
1997	1190	2.343	2.430	2.409
1998	1017	2.292	2.311	2.283
1999	1269	1.605	1.666	1.650
2000	1497	1.319	1.616	1.608
2001	1487	1.307	1.619	1.612
2002	1831	1.286	1.363	1.360
2003	1633	1.426	1.702	1.694
2004	951	1.894	1.697	1.697
2005	658	2.641	3.052	3.070
2005	373	4.078	4.282	4.246
2007	404	5.000	5.735	5.711
2008	398	6.044	6.189	6.140
2009	322	8.247	8.431	8.453
2010	464	6.280	5.270	5.292
2011	372	7.887	6.726	6.759
2012	605	5.746	6.055	6.029
2013	684	5.311	5.031	5.022
2014	485	7.015	7.300	7.303
2015	522	6.801	7.627	7.600
2016	709	5.263	5.789	5.756
2017	965	3.605	3.396	3.407
2018	544	6.515	5.804	5.801
2019	777	4.564	-	4.144

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 1997-2018) for easier comparison of trends. Note that here and below the standardised 2019 results for certain years are not visible as they are covered by the values for standardisations in earlier years. [Note further that the minimum legal carapace size changed from 70mm to 68mm CL in 2003 and from 68mm to 66mm CL in 2012.]

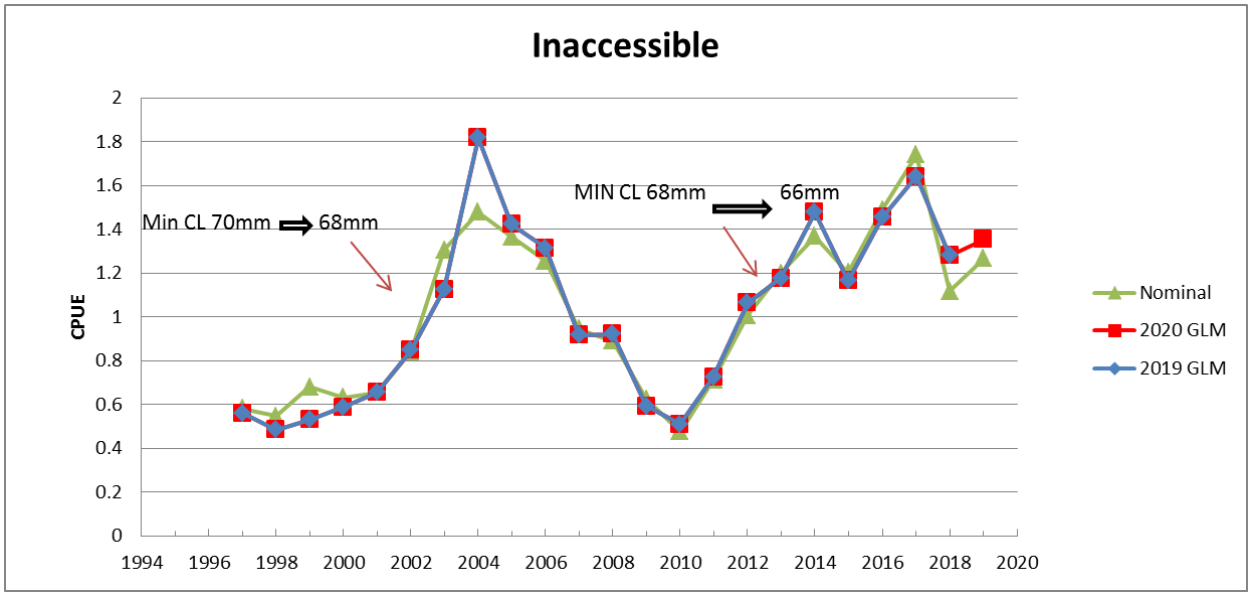

Figure 1b: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Nightingale** Island. All series have been renormalised to a mean of 1 (for 1997-2018) for easier comparison of trends.

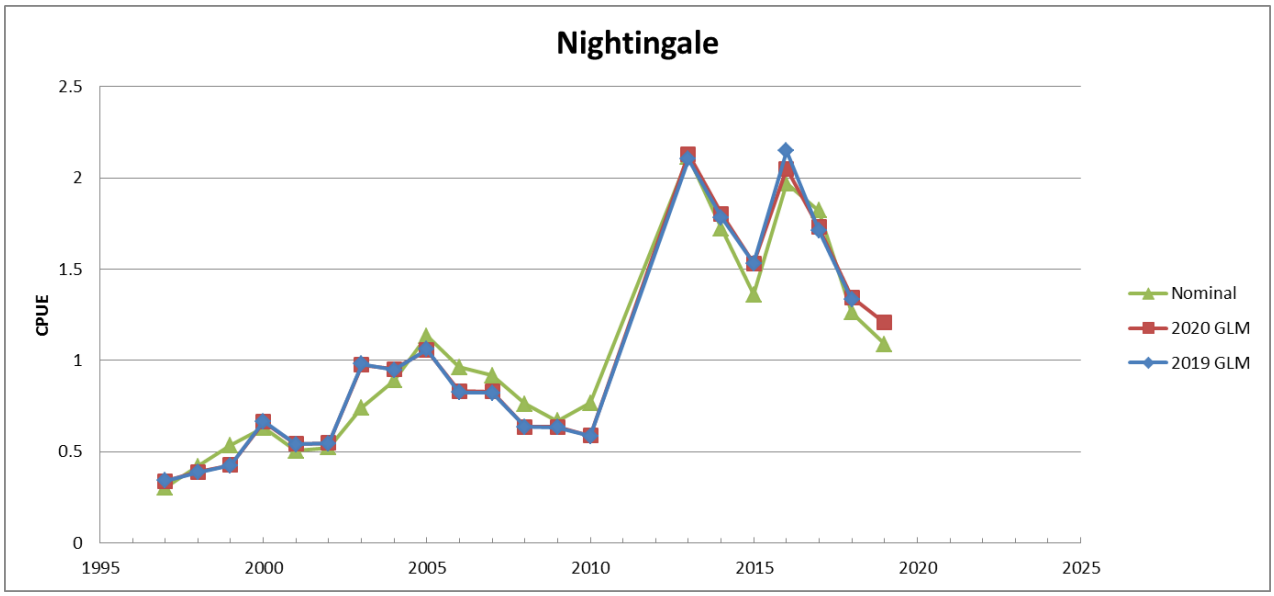

Figure 1c: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Gough** Island. All series have been renormalised to a mean of 1 (for 1997-2018) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 75mm in 2003.]

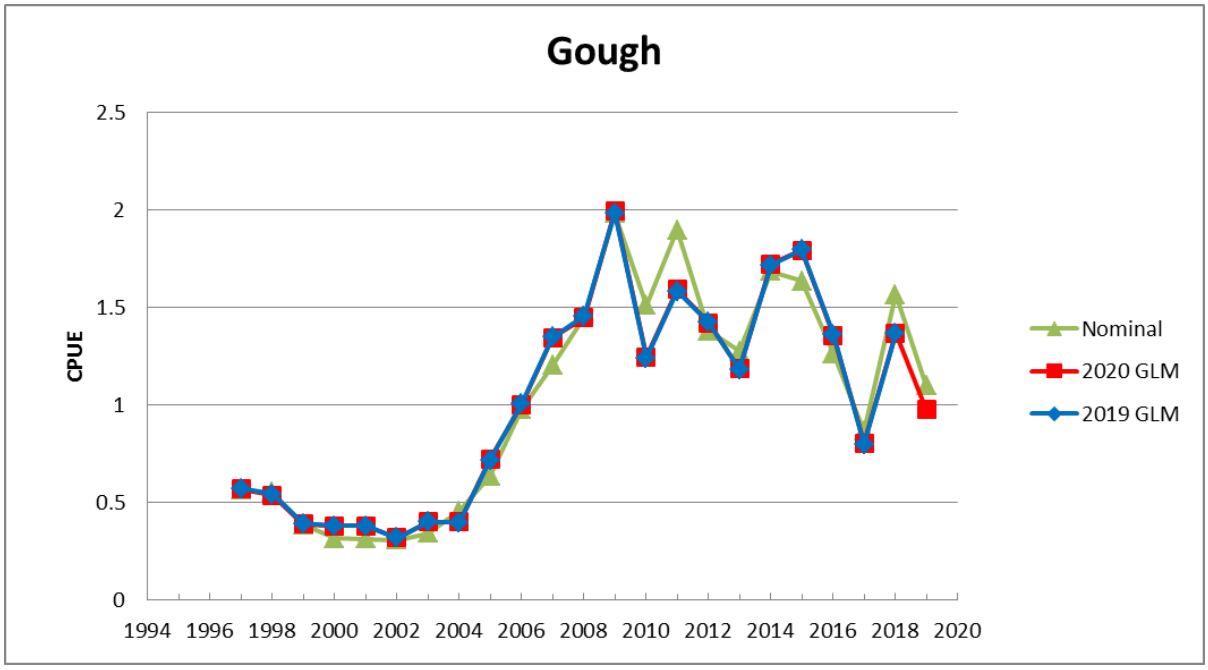

Figure 2a: GLMM month effects for **Inaccessible** Island.

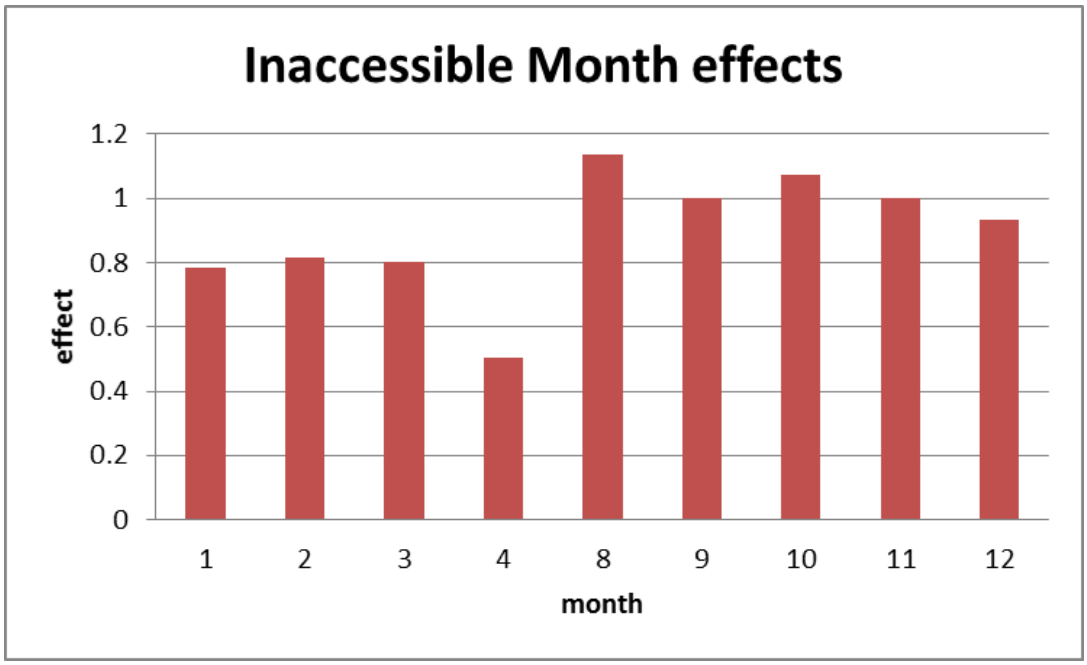

Figure 2b: GLMM month effects for **Nightingale** Island.

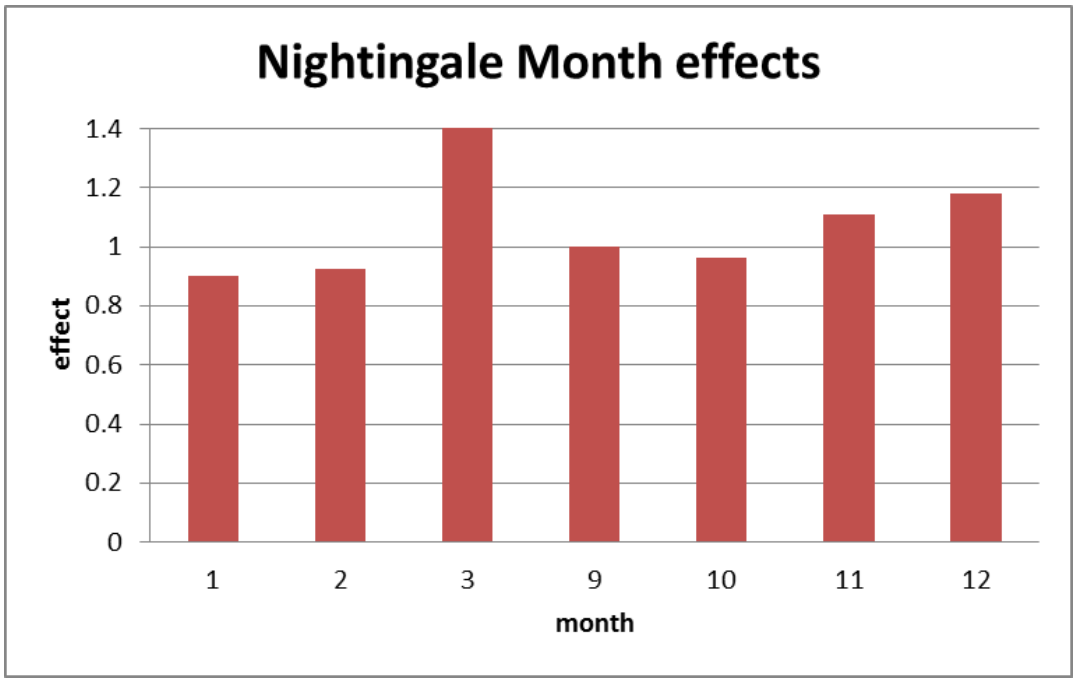

Figure 2c: GLMM month effects for **Gough** Island.

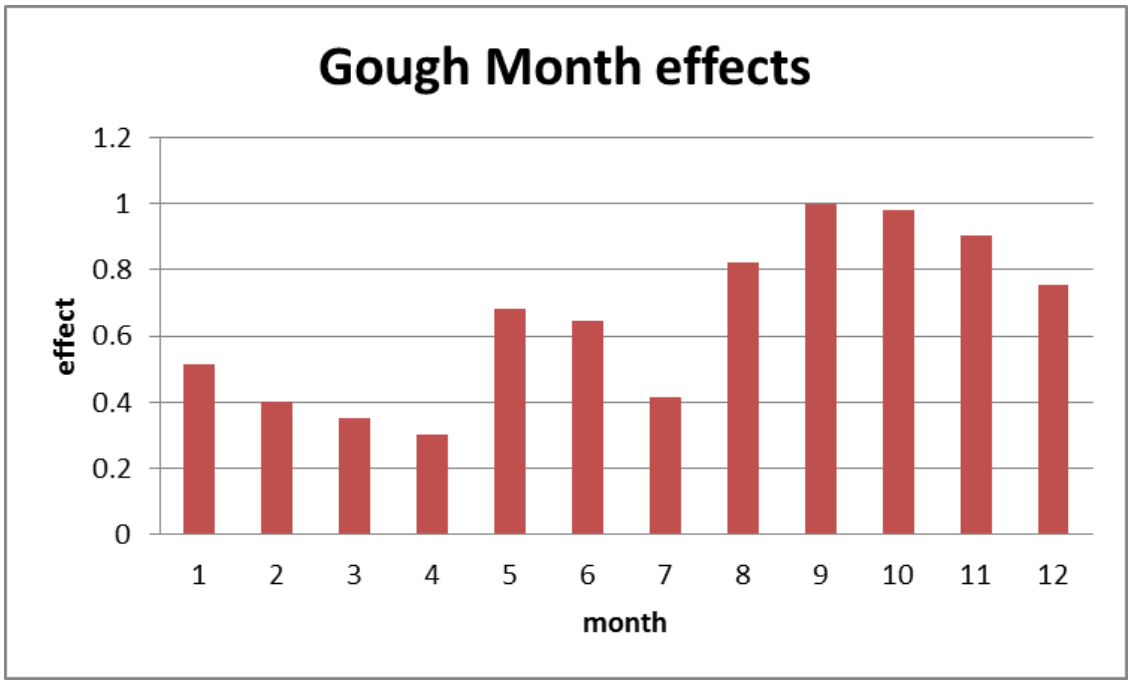

Figure 3a: GLMM area effects for **Inaccessible** Island (see Table 1a for area definitions).

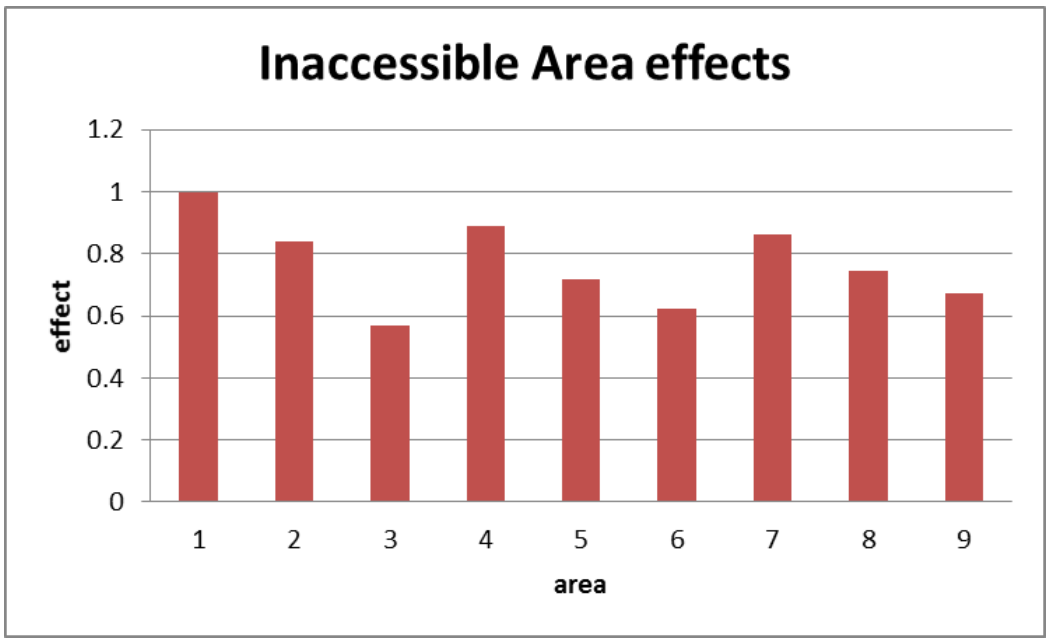

Figure 3b: GLMM area effects for **Nightingale** Island (see Table 1b for area definitions).

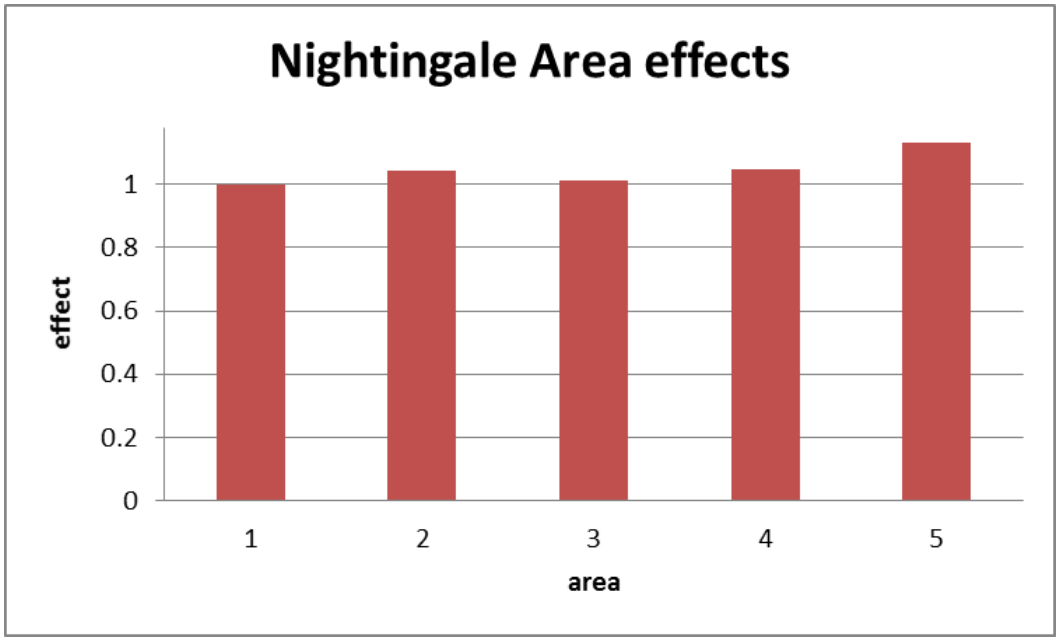

Figure 3c: GLMM area effects for **Gough** Island (see Table 1c for area definitions).

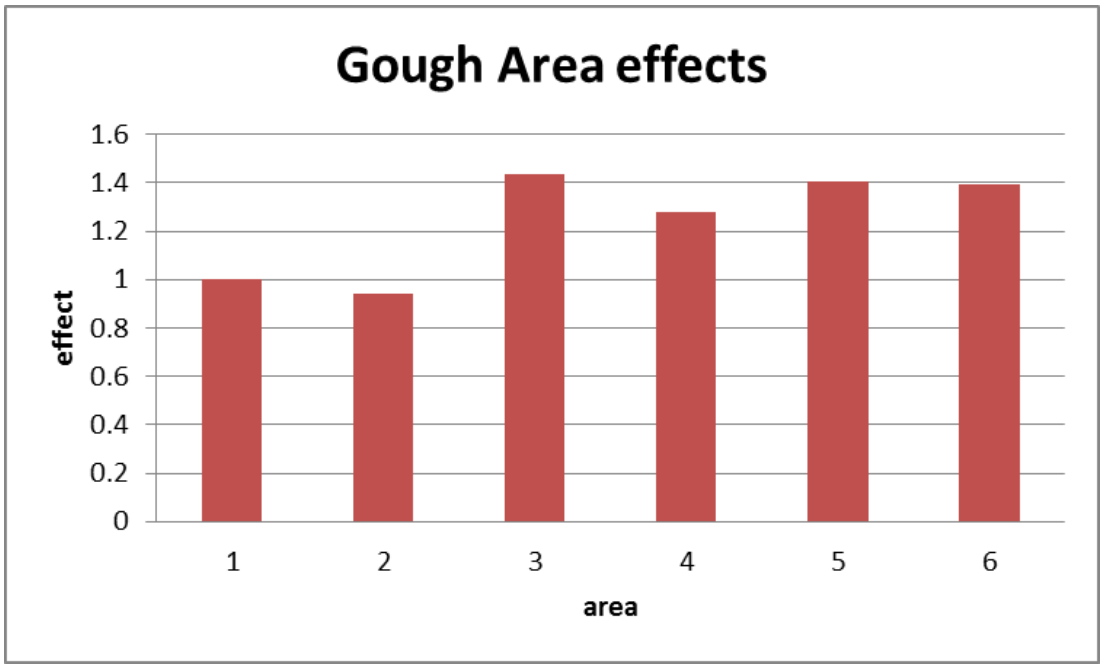

Figure 4a: Inaccessible standardised CPUE shown alongside the current Itar and Ilim values (shown as purple horizontal lines).

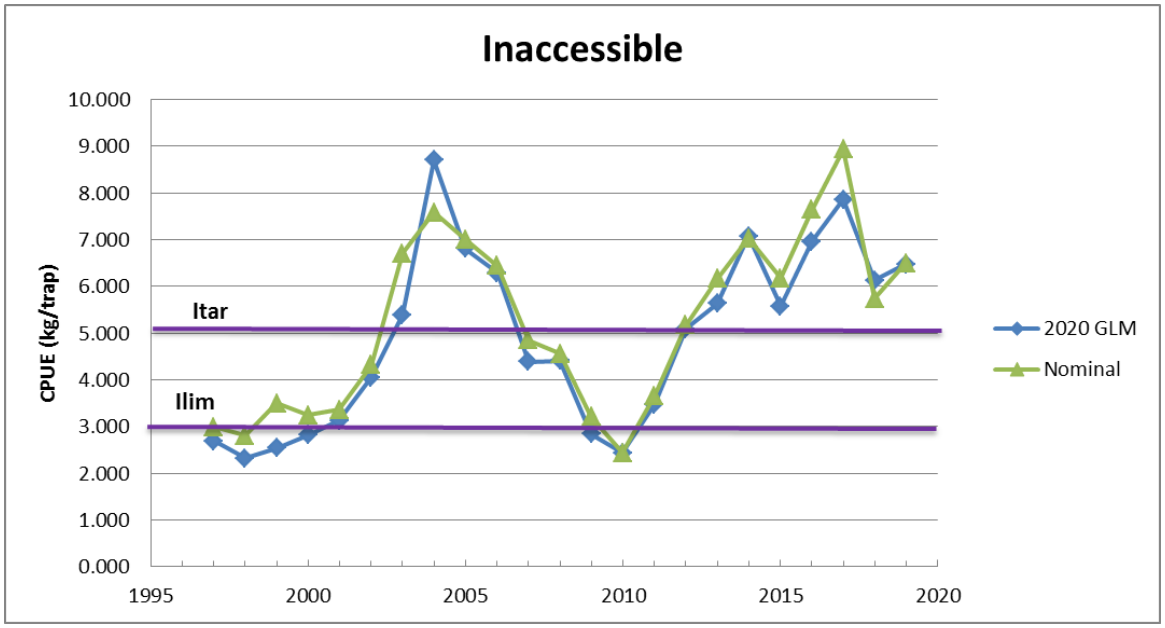

Figure 4b: Nightingale standardised CPUE shown alongside the current Itar and Ilim values (shown as purple horizontal lines). [Note a new OMP for Nightingale will be developed for 2020.]

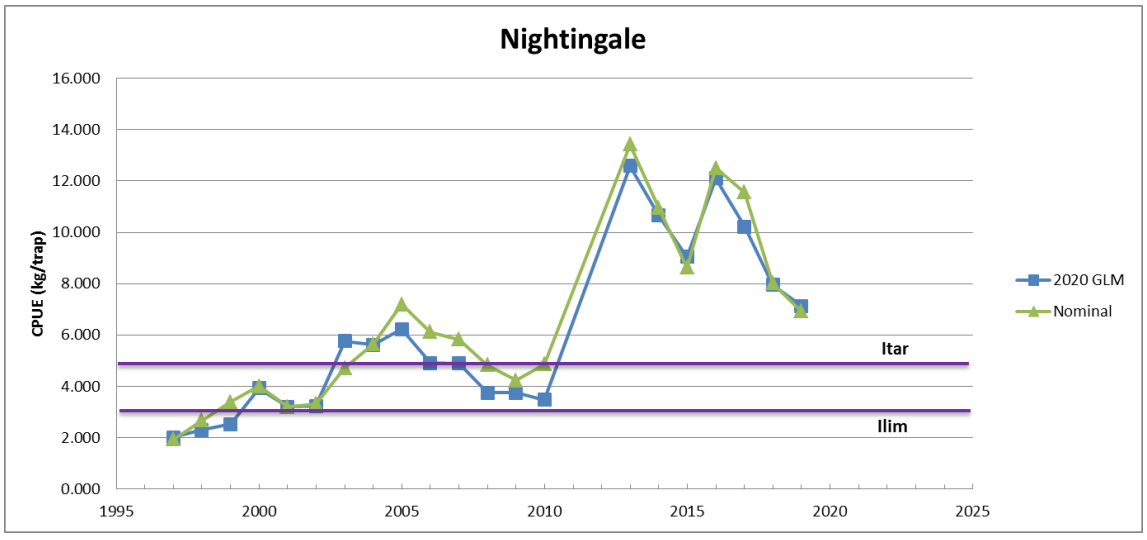

Figure 4c: Gough standardised CPUE shown alongside the current Itar and Ilim values (shown as purple horizontal lines).