Updated 2021 GLMM -standardised lobster CPUE from Gough Island of the Tristan da Cunha outer group of islands

S.J. Johnston and D.S. Butterworth.

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

May 2021

ABSTRACT

The longline CPUE series for Gough island is GLMM standardised through to 2020[1]. Year, month, area, trap-type, soak time, depth, sequential day of fishing and year-area interactions are treated as fixed effects, and year-month interactions treated as a random effect. The standardised CPUE value for the current season is higher than that of the previous season. The Gough CPUE is now just above the Itar value. A large difference exists between the nominal CPUE value for the 2020 season, compared with the standardised CPUE value. This is due to the majority of the 2020 season's catch being taken in months for which the relative catchability is very poor, as well as longer tranches taken in these later months (which will reduce the nominal CPUE value).

KEY WORDS: *Jasus tristani*; Gough Island; CPUE; GLMM 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 Gough Island for the period 1997-2020. Results presented here are updated from those presented in Johnston *et al.* (2020), taking one more year's data into account. The GLMM also takes into account the "sequential day" of fishing as a factor (as described in detail in Johnston 2020).

[1] The convention used here for split seasons is to use the first year, i.e. 2020 refers to the 2020/2021 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 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, 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 Gough and Inaccessible associated with the Season-Years 1997-2020,
month	is a factor with levels associated with the fishing month (1-12),
area	is a factor with levels associated with groupings of fishing areas (6 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.

RESULTS

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

DISCUSSION

The Gough CPUE for the 2020 season is just above the Itar value. A large difference exists between the nominal CPUE value for the 2020 season (3.57 kg/trap), compared with the standardised CPUE value (6.18 kg/trap). This is due to the majority of the 2020 season's catch being taken in months for which the relative catchability is very poor (see Figure 3) where for example catchability in April is ~33% of the catchability in October, as well as longer tranches being taken in these later months (which will reduce the nominal CPUE value but be taken into account in the standardisation). The Appendix provides further plots and an explanation for the difference between the 2020 nominal and standardised CPUE values.

The updated GLMM CPUE series reported are to be used in the OMP-2021 development. They will also provide inputs into the OMP-2021 to provide the TAC recommendation for the 2020 season.

REFERENCES

Johnston, S.J. 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.

Johnston, S.J. 2020. Further GLM analyses of Nightingale, Inaccessible and Gough CPUE data to incorporate trip length data. MARAM/Tristan/2020/NOV/15.

Table 1: 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 2: 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	3.040	2.986
1998	1017	2.292	2.716	2.673
1999	1269	1.605	2.096	2.124
2000	1497	1.319	2.027	1.994
2001	1487	1.307	2.016	1.997
2002	1831	1.286	1.870	1.824
2003	1633	1.426	2.007	2.008
2004	951	1.894	2.187	2.171
2005	658	2.641	3.877	3.831
2005	373	4.078	4.756	4.753
2007	404	5.000	6.040	5.993
2008	398	6.044	7.139	7.162
2009	322	8.247	8.887	8.898
2010	464	6.280	7.139	7.238
2011	372	7.887	8.887	8.007
2012	605	5.746	7.294	6.954
2013	684	5.311	8.019	5.987
2014	485	7.015	6.978	8.573
2015	522	6.801	6.032	8.420
2016	709	5.263	8.491	6.557
2017	965	3.605	6.863	3.984
2018	544	6.515	4.122	7.323
2019	777	4.565	7.319	5.080
2020	922	3.567	5.060	6.178

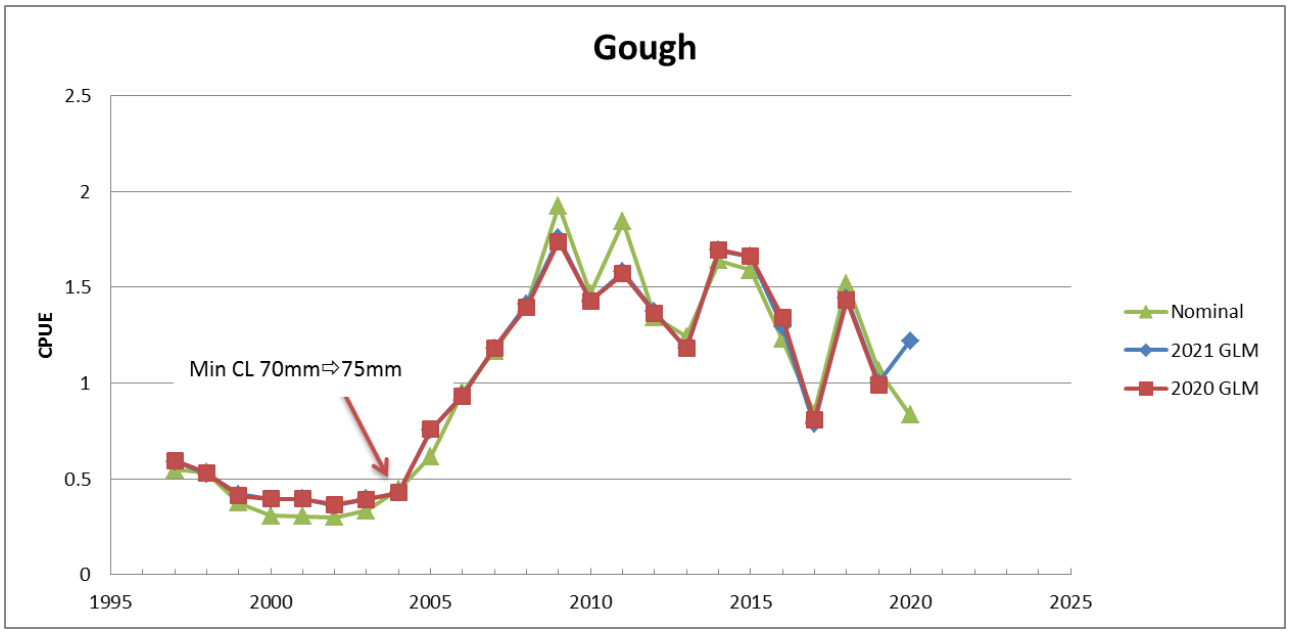

Figure 1: Comparative plot of the adjusted nominal and GLMM standardised longline CPUE series for **Gough** Island. All series have been renormalised to a mean of 1 (for 1997-2019) for easier comparison of trends. [Note that the minimum legal carapace size changed from 70mm to 75mm in 2003.]

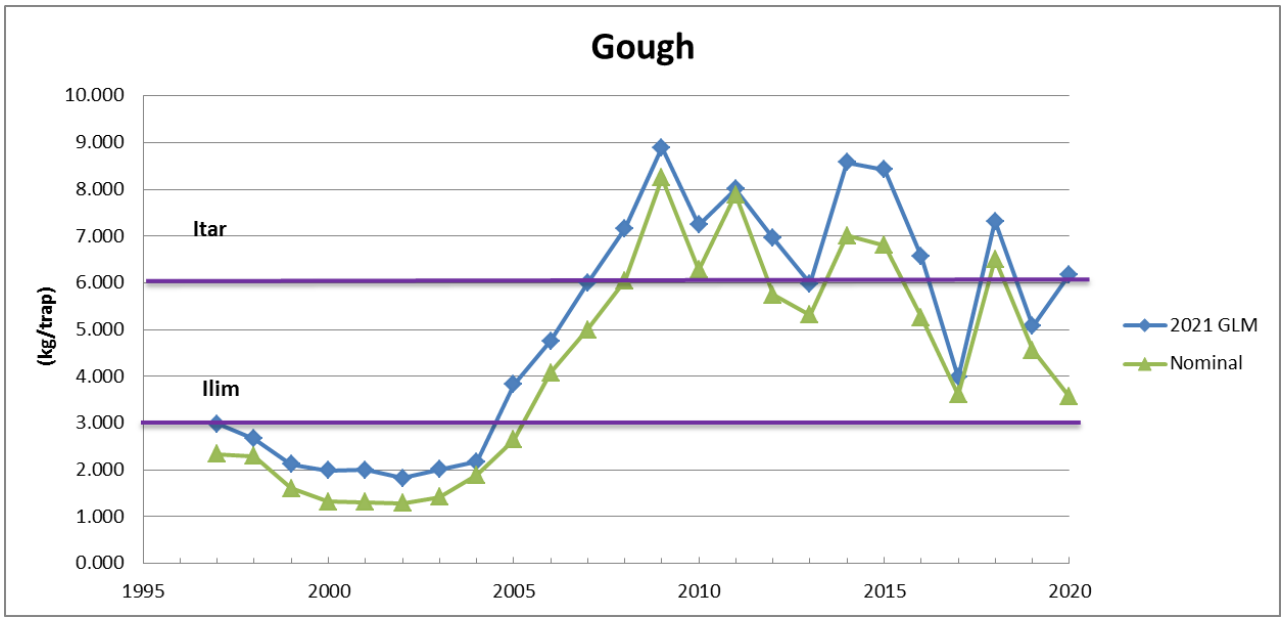

Figure 2: Gough standardised CPUE shown alongside the current Itar and Ilim values (shown as purple horizontal lines).

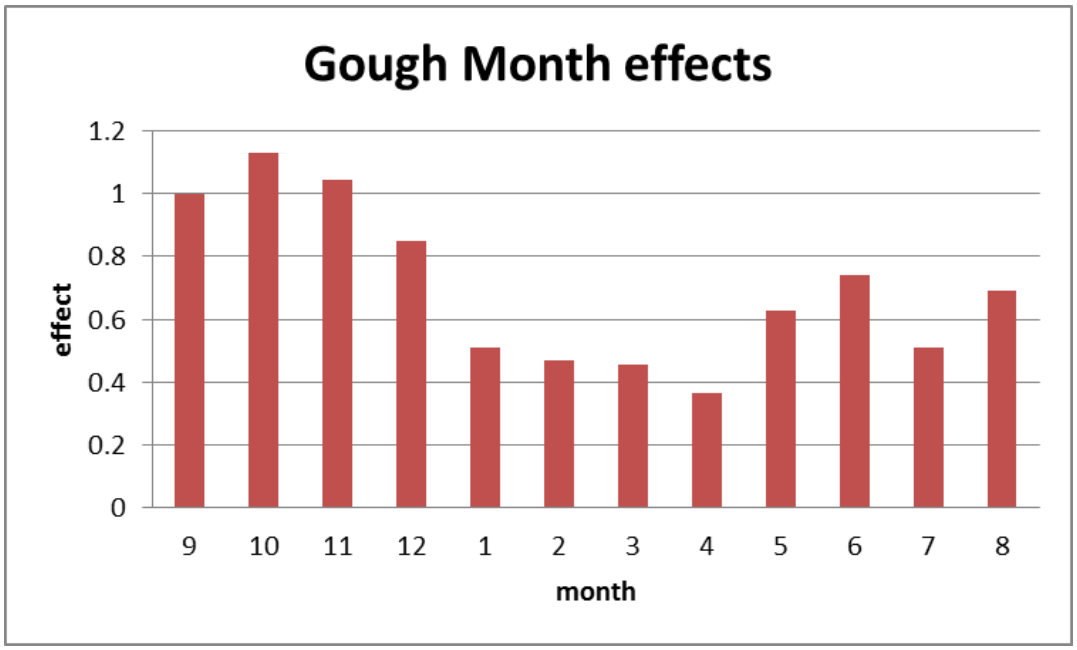

Figure 3: GLMM month effects for **Gough** Island.

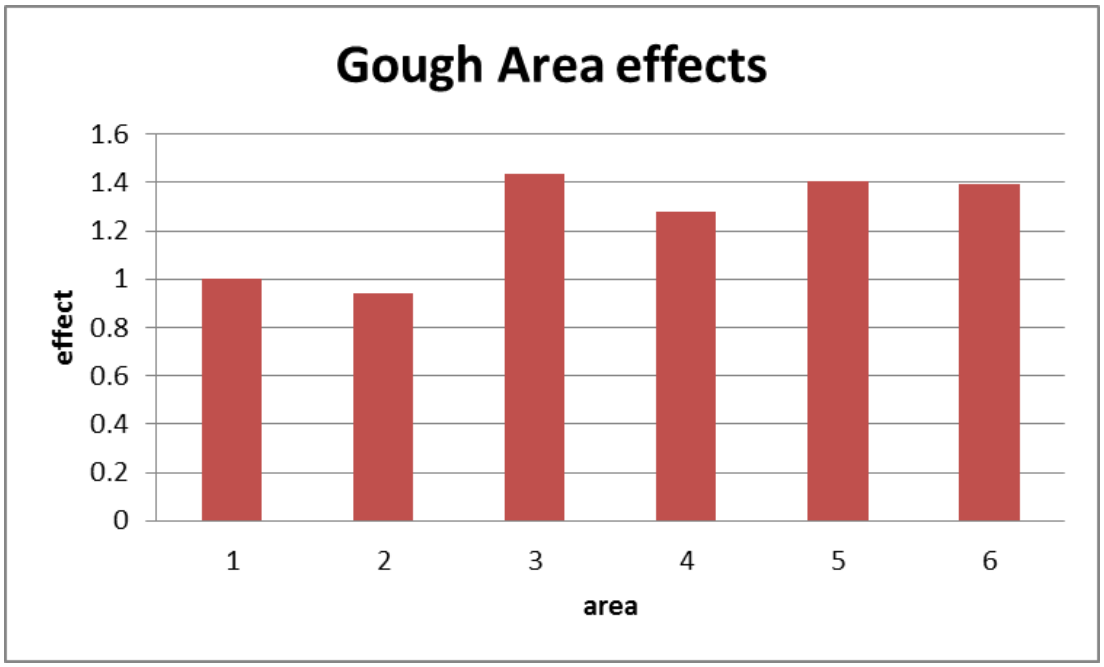

Figure 4: GLMM area effects for **Gough** Island (see Table 1 for area definitions).

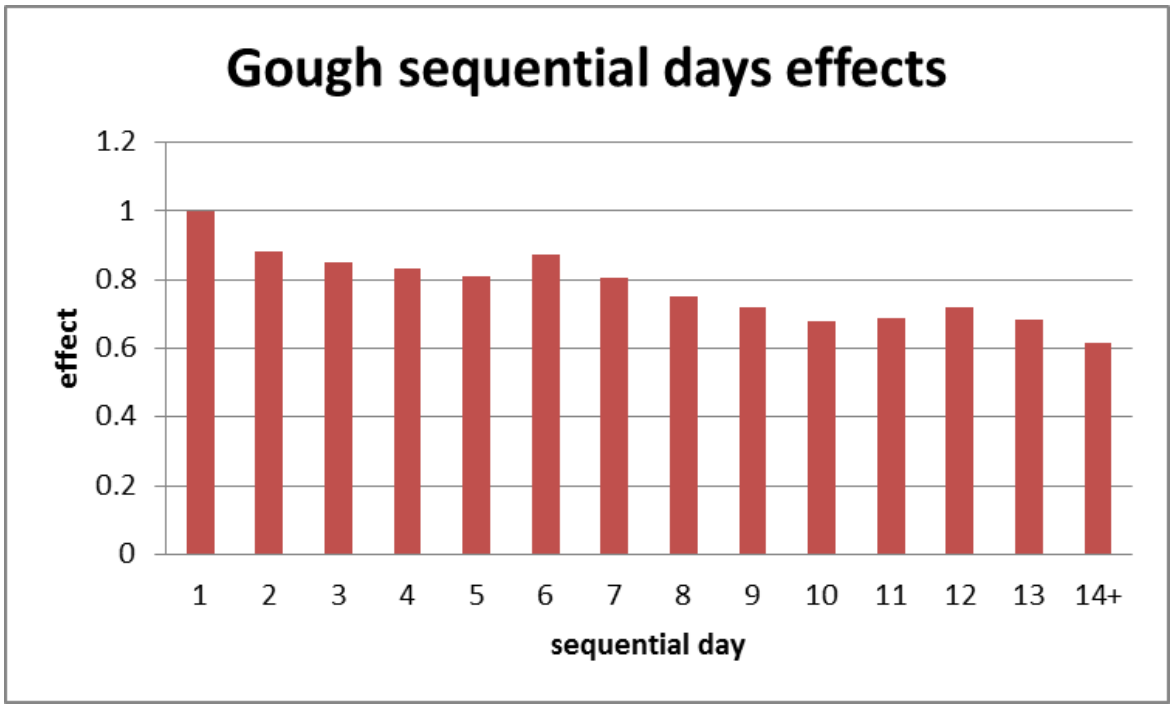

Figure 5: GLMM sequential day effects for **Gough** Island.

Appendix: Explanation of why the 2020 nominal and GLMM values are rather different

Figure A1 below is presented to assist in understanding why the recent 2020 GLMM value (of 6.18 kg/trap) is considerably larger than its nominal value (of 3.57 kg/trap).

The key reason is the different distribution of fishing effort during the 2020 season. The top panel shows what happens normally – over 70% of the fishing effort is expended before the new year. Indeed, for the 2019 season over 80% of the fishing effort occurred before January (second panel). But the 2020 season was VERY different – 95% of the fishing effort occurred AFTER the new year (the third panel).

Now CPUE at Gough changes dramatically during the season each year. Though the abundance will change only slightly during the year, the CPUE drops substantially (some environmental factors must change making the lobsters less inclined to take the bait in the traps). This is what the month factors (or efficiencies, provided by the GLMM standardisation) shown in the fourth panel reflect: specifically, that the same abundance during September to December will yield CPUEs that are some 2-3 times larger than the CPUEs during January to May. Consequently, the low nominal CPUE value for the whole 2020 season is misleading, because the associated catches came almost entirely from the period after the new year. One must adjust for this month factor effect, which is exactly what the standardisation exercise is designed to do, and indicates that the CPUE for the 2020 season would have been almost double the nominal value of 3.58 kg/trap had the pattern of fishing over the season been similar to that in preceding years, with most fishing taking place before the end of the year.

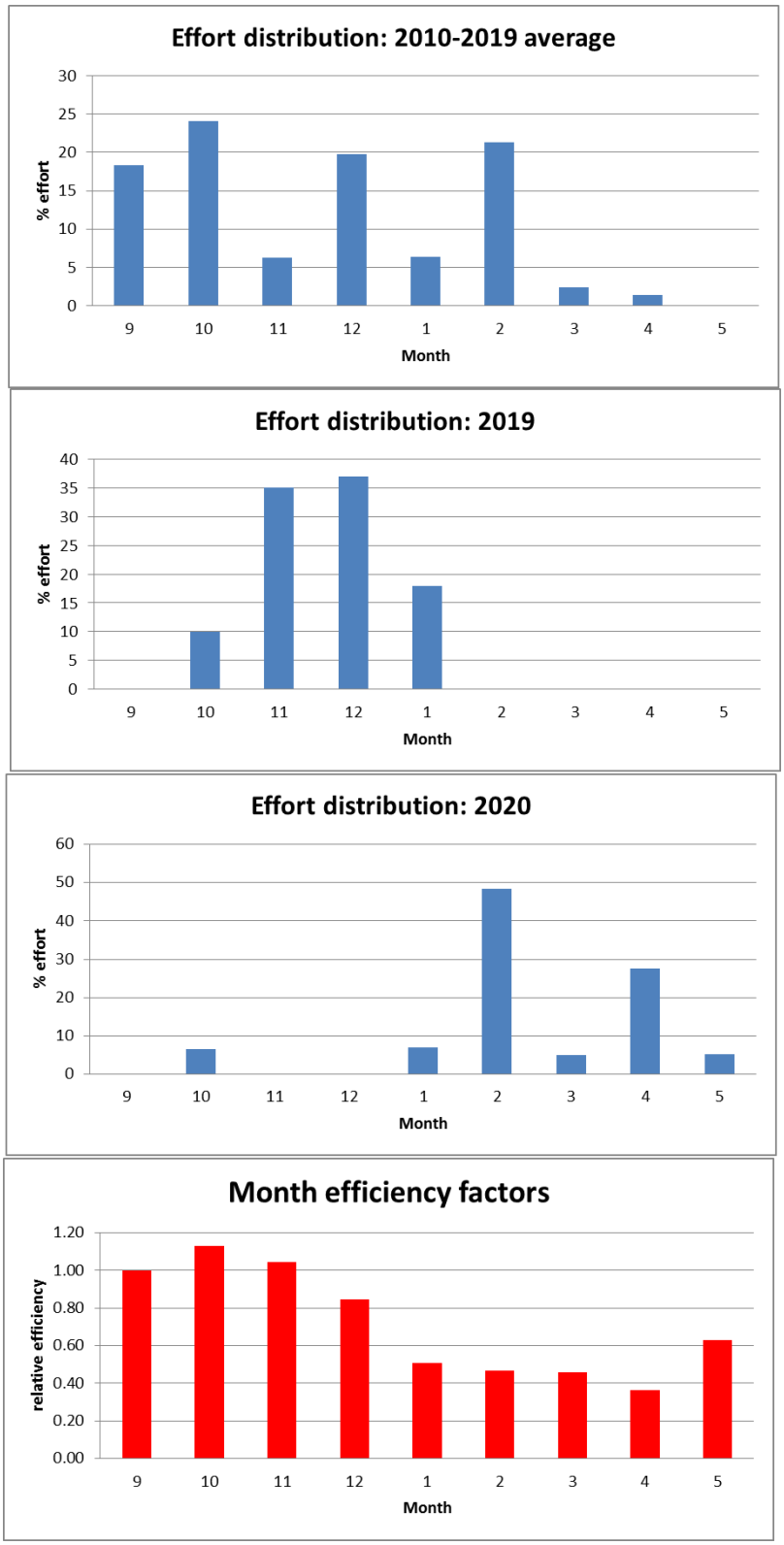

Figure A1: Plot of the average monthly effort distribution over the 2010-2019 period, along with the monthly distribution of effort in 2019 and 2020. The monthly efficiency factors obtained from the GLMM of Gough CPUE and effort data are also plotted in the bottom panel.