Further GLM analyses of Nightingale, Inaccessible and Gough CPUE data to incorporate trip length data

Susan Johnston

MARAM

Department of Mathematics and Applied Mathematics

University of Cape Town

Rondebosch, 7701

Summary

This document compares the original GLM analyses applied to Nightingale and Inaccessible data to a new GLM formulation that takes into account the sequential day number of each day's fishing when this continues over a period of time. Results show that trip lengths have shortened over time at Inaccessible and Nightingale from historically 2 weeks or more, to around an average of 6 days in length since around 2011. A decline in fishing effectiveness is shown for all three islands as trip length increases – the effect is most appreciable at Nightingale with a 40% decline in catch rates by day 14. The overall impact of including sequential days as a factor in the GLM analyses is fairly small in the main, but the standardised CPUE for both Inaccessible and Nightingale becomes somewhat less for the last two years. It is recommended that in future the GLMs which take sequential fishing days into account should be used for the management of these fisheries.

Introduction

It has become evident over recent years that there may often be a pattern of CPUE decline over consecutive fishing days at Nightingale and Inaccessible islands. This is thought to be a result of the fishing activity scattering or disturbing the lobsters. If the ground is left unfished for a short while, the CPUE values have been reported to bounce back upwards again. In order to test this assertion objectively, a new GLMM formulation is applied to the data where the number of days of sequential fishing is taken into account.

Figure 1 plots the average trip length for the three outer islands since 2000. For both Nightingale and Inaccessible, a clear decline in trip length from 14+ days to 4-6 days occurred until around 2012. Since 2012 the average trip length has stabilized at 4-6 days. This trend is not evident for Gough where the average trip length has remained stable at around 12-14+ days. This is due to the fact that this island is far away from the others, so that trip lengths are required to be longer (often a month or more at a time). What then is the effect of trip length on the CPUE GLM analyses?

Methods

The CPUE data from the outer islands have traditionally been analysed using GLM standardization (Johnston and Butterworth 2020). The various factors that are considered as fixed effects in the GLM are evident from the following equation:

$$\ln(CPUE+\delta) = \mu + \alpha_{year} + \beta_{month} + \gamma_{area} + \eta_{trap-type} + \lambda_{soaktime} + \theta_{depth} + \tau_{year\,x\,area} \quad (1)$$

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 ≥ 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:

$$CPUE_{year} = \left\lfloor \sum_{area} \left(\left(\exp\left(\mu + \alpha_{year} + \gamma_{area} + \tau_{year\,x\,area}\right) - \delta \right) * A_{area} \right) \right\rfloor / A_{total} \quad (2)$$

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).

The new GLM model which takes into account the sequential day in a fishing trip makes two assumptions:

i) If only one day was skipped, the next day would be recorded as if that fishing tranche had not ended.

ii) If the fishing tranche was longer than 14 days, then these days would also be recorded as "14 days", i.e. a plus group at day 14 is assumed. Only the early years had such long tranches.

Equation (1) is modified as follows:

$$\ln(CPUE + \delta) = \mu + \alpha_{year} + \boldsymbol{\varphi_{sequential\ day}} + \beta_{month} + \gamma_{area} + \eta_{trap-type} + \lambda_{soaktime} + \theta_{depth} + \tau_{year\ area} \quad (3)$$

where

sequential day is a factor with values equal to the sequential day in each fishing trip/tranche (levels 1-14+).

In this application the CPUE has been standardised on the year 1998, month of *September*, trap type *Monster*, soak time "2" , depth category "2", area = "1" and sequential day "1".

Results and discussion

Figures 2a and b show the sequential days' effects from the new GLM models for the three outer islands. Nightingale and Gough show very similar trends over time with a steady declining effectiveness over days 1-14+. It is clear that there is a drop of some 40% in effectiveness of fishing by day 14 for those islands. This pattern is similar for Inaccessible but not as marked, with a drop of some 25% in effectiveness of fishing by day 14.

Fishing trips at Nightingale and Inaccessible since around 2011 have, however been of around 6 days in length on average: at Nightingale, day 7 of a trip is about 20% less effective than day 1, and at Inaccessible day 7 is about 5% less effective than day1. This change in fishing pattern in more recent years has thus lessened the negative effect that extended fishing trip lengths have on the CPUE.

Figures 3a-c show the results of including sequential days as factors in the GLM. The overall impact of including sequential days as a factor in the GLM analyses is fairly small in the main, but the standardised CPUE for both Inaccessible and Nightingale becomes somewhat less for the last two years. It is recommended that in future the GLMs which take sequential fishing days into account should be used for the management of these fisheries.

Reference

Johnston, S.J. and Butterworth, D.S. 2020. Updated 2020 GLMM -standardised lobster CPUE from the Tristan da Cunha outer group of islands. MARAM/TRISTAN/2020/MAY/09.

Figure 1: Average trip length each season at the three outer islands. Note that length "14" is a plus group for days 14 and longer.

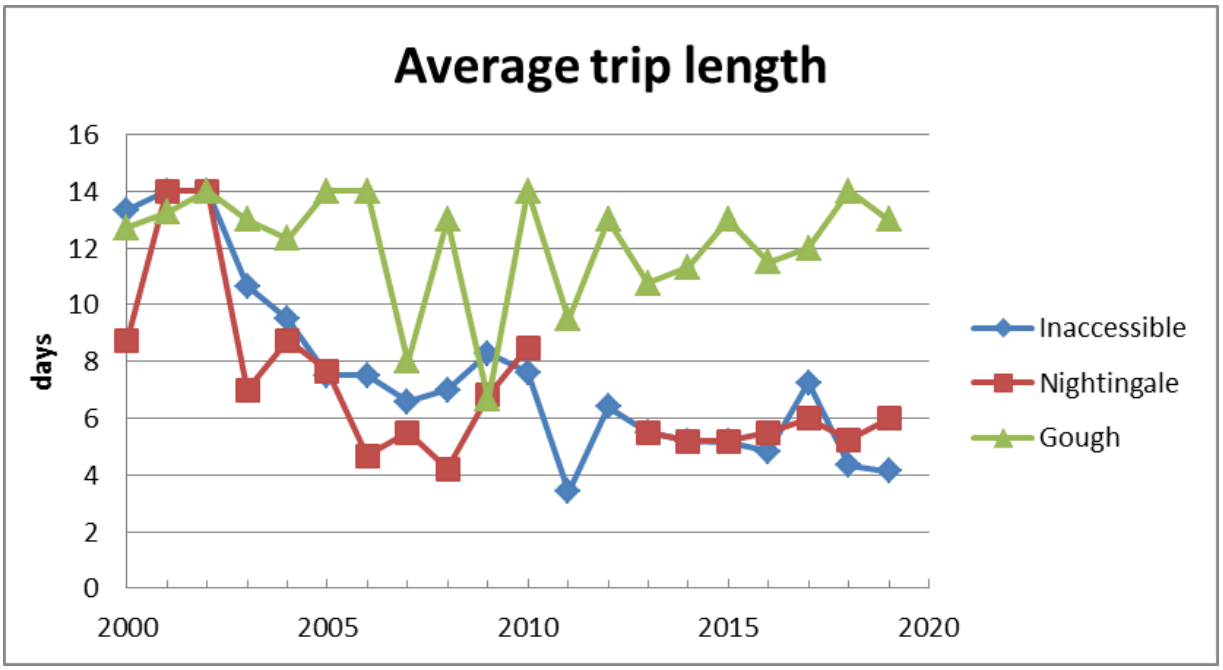

Figure 2a: The sequential day effects applying equation (3).

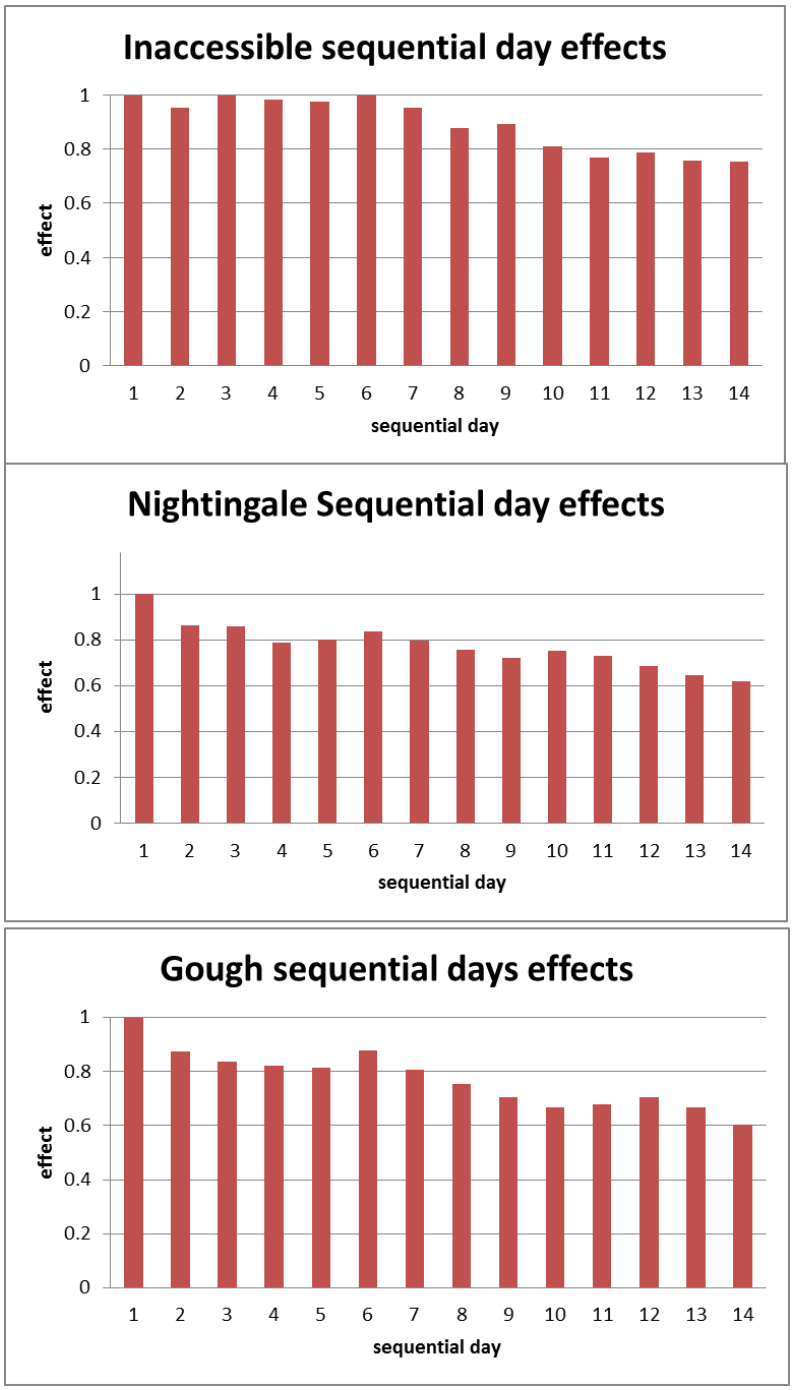

Figure 2b: Comparison of the sequential day effects applying equation (3) for each of the outer islands.

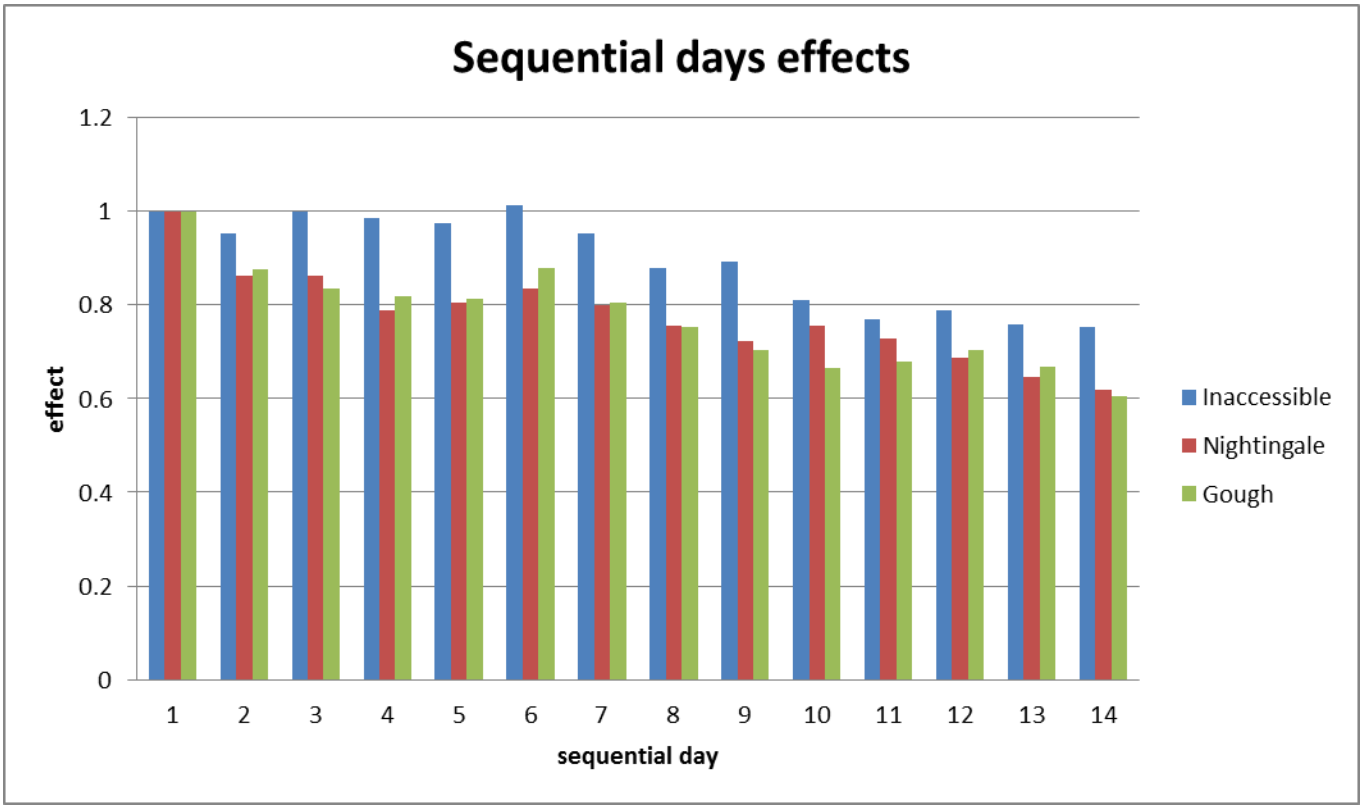

Figure 3a: Inaccessible standardized CPUE values using either the original GLMM (equation (1)) or a GLMM with sequential days as a factor (equation (3)). Both series are renormalized to their means.

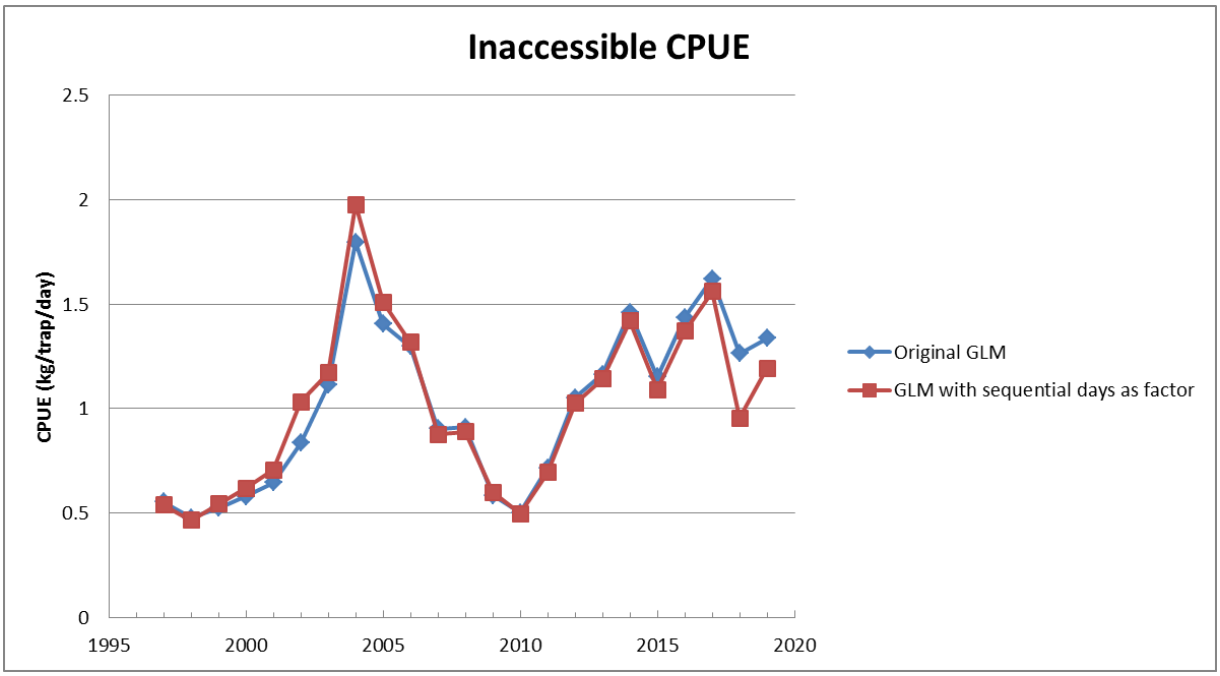

Figure 3b: Nightingale standardized CPUE values using either the original GLMM (equation (1)) or a GLMM with sequential days as a factor (equation (3)). Both series are renormalized to their means.

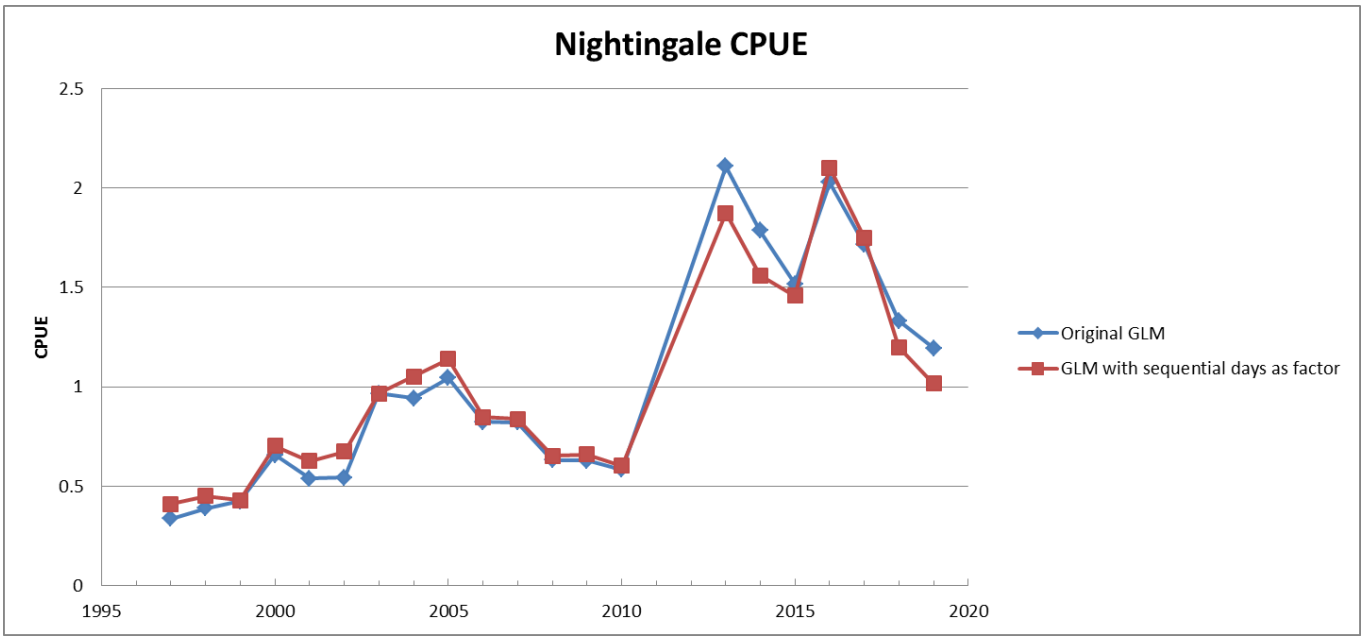

Figure 3c: Gough standardized CPUE values using either the original GLMM (equation (1)) or a GLMM with sequential days as a factor (equation (3)). Both series are renomalised to their means.