Updated GLMM standardised trotline CPUE series for the toothfish resource in the Prince Edward Islands EEZ to include data up to the 2020 season

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Abstract

An updated GLMM standardisation of trotline toothfish CPUE data is presented which includes new data for the 2020 "fishing"-year. After a marked decrease in CPUE from 2015 to 2017, there has been a notable increase in the 2018 index, which is close to the larger values estimated for the first four years (2010-2013) of the series. Since 2018, the indices show a decline, but are still higher than the lowest values of the index for 2016 and 2017.

Keywords: Toothfish, Standardised CPUE, General Linear Mixed Model, trotline

Introduction

This paper presents results for an update of the GLMM (General Linear Mixed Model) proposed by Brandão and Butterworth (2014a) to standardise toothfish CPUE for trotlines, with the previous updated indices given in Brandão and Butterworth (2020). The standardisation presented here is based on a "fishing"-year[1] for better comparability with the structure of the toothfish assessment, and also assumes that the two *Koryo Maru* vessels are identical in terms of power (considered reasonable because the same skipper operated on both vessels).

The trotline CPUE series shows relatively low values for the first two years (2008 and 2009). These low values might reflect a "learning use of new gear" aspect rather than depicting a lower abundance of

[1] A "fishing"- year *y* is defined to be from 1 December of year *y*-1 to 30 November of year *y*.

toothfish. The DWG has previously agreed that the standardised CPUE series to be considered should omit the first two years of trotline CPUE data from the GLMM analysis.

The Data

Trotline CPUE data are now available for the 2010 to 2020 “fishing”-years. The effort for a trotline is defined as:

$$\left(\frac{\text{Length of line}}{\text{Spacing of droppers}}\right) \times \text{Number of clusters per dropper.}$$

A total of 4 614 trotline sets (Table 1) is available for analyses. No further longline sets have been deployed since 2013 and so it is not necessary to update the GLMM standardised CPUE series for longlines presented in Brandão and Butterworth (2015).

Methods

The changes to the General Linear Mixed Model (GLMM) of Brandão and Butterworth (2013) to standardise the trotline CPUE data for toothfish in the Prince Edward Islands EEZ are detailed below.

The GLMM applied to the trotline CPUE data is of the form:

$$ln(CPUE + \delta) = X\alpha + Z\beta + \varepsilon, \quad (2)$$

where

$CPUE$ is the trotline catch per unit effort for a set,

δ is a small constant (10% of the average of all CPUE data values = 0.123 for trotlines) added to the toothfish CPUE to allow for the occurrence of zero CPUE values,

α is the vector of fixed effects parameters (whose values are unknown) which includes:

$\mu + \kappa_{vessel} + \omega_{year} + \gamma_{month} + \lambda_{area}$, where

μ is the intercept,

$vessel$ is a factor with 2 levels associated with each of the vessels that have operated in the trotline fishery:

El Shaddai

Koryo Maru 11 (which represents the old and the new *Koryo Maru* vessels)

year is a factor with 11 levels associated with the "fishing"-years 2010–2020 for trotlines,

month is a factor with 12 levels (January – December),

area is a factor with 18 levels associated with the new spatially distinct fishing areas shown in Figure 1 of Brandão and Butterworth (2014b),

X is the design matrix for the fixed effects,

β is the vector of random effects parameters whose values are unknown, which includes the following interaction terms:

$\eta_{year \times area} + \theta_{year \times month} + \phi_{month \times area}$,

year×area is the interaction between year and area (this allows for the possibility of different trends in abundance with time in the different areas),

year×month is the interaction between year and month,

month×area is the interaction between month and area,

Z is the design matrix for the random effects, and

ε is an error term assumed to be normally distributed and independent of the random effects.

It is assumed that both the random effects and the error term have zero mean, i.e. E(β) = E(ε) = 0, so that $E(ln(CPUE + \delta)) = \boldsymbol{X}\alpha$. The variance-covariance matrix for the residual errors (ε) is denoted by **R** and the variance-covariance matrix for the random effects (β) by **G**. In the analyses of this paper, it is assumed that the residual errors as well as the random effects are homoscedastic and are uncorrelated, so that both **R** and **G** are diagonal matrices given by:

$$\boldsymbol{R} = \sigma_{\varepsilon}^{2}\boldsymbol{I}$$
$$\boldsymbol{G} = \sigma_{\beta}^{2}\boldsymbol{I}$$

where **I** denotes an identity matrix. Thus, in the mixed model, the variance-covariance matrix (**V**) for the response variable is given by:

$$\mathrm{Cov}(ln(\,CPUE + \delta)) = \boldsymbol{V} = \boldsymbol{ZGZ}^{T} + \boldsymbol{R},$$

where $\boldsymbol{Z^T}$ denotes the transpose of the matrix $\mathbf{Z}$.

The estimation of the variance components ($\mathbf{R}$ and $\mathbf{G}$), the fixed effects (α) and the random effects (β) parameters in GLMM requires two steps. First the variance components are estimated. Once estimates of $\mathbf{R}$ and $\mathbf{G}$ have been obtained, estimates for the fixed effects parameters (α) can be obtained as well as predictors for the random effects parameters (β). Variance component estimates are obtained by the method of residual maximum likelihood (REML) which produces unbiased estimates for the variance components as it takes the degrees of freedom used in estimating the fixed effects into account.

Results and Discussion

Table 1 and Figure 1 show the relative abundance indices for toothfish provided by the standardised commercial trotline CPUE series for the Prince Edward Islands EEZ that considers the old and new *Koryo Maru* to be the same, and for which the year factor is based on a "fishing"-year. The month factors for this GLMM are also shown, all with 95% confidence intervals. After a marked decrease in CPUE from 2015 to 2017, there has been a notable increase in the 2018 index, which is close to the larger values estimated for the first four years (2010-2013) of the series. Since 2018, the values of the index show a decline, but remain higher than the lowest values of the index for 2016 and 2017.

References

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Table 1. The number of data entries (*n*) per year available for the GLMM analyses and the relative abundance indices for toothfish provided by the standardised commercial trotline CPUE series for the Prince Edward Islands EEZ.

"Fishing"-year	***n***	**GLMM *CPUE***
2010	175	1.209
2011	333	1.000
2012	260	1.151
2013	374	0.949
2014	628	0.783
2015	772	0.833
2016	648	0.545
2017	343	0.547
2018	481	0.906
2019	208	0.847
2020	399	0.687

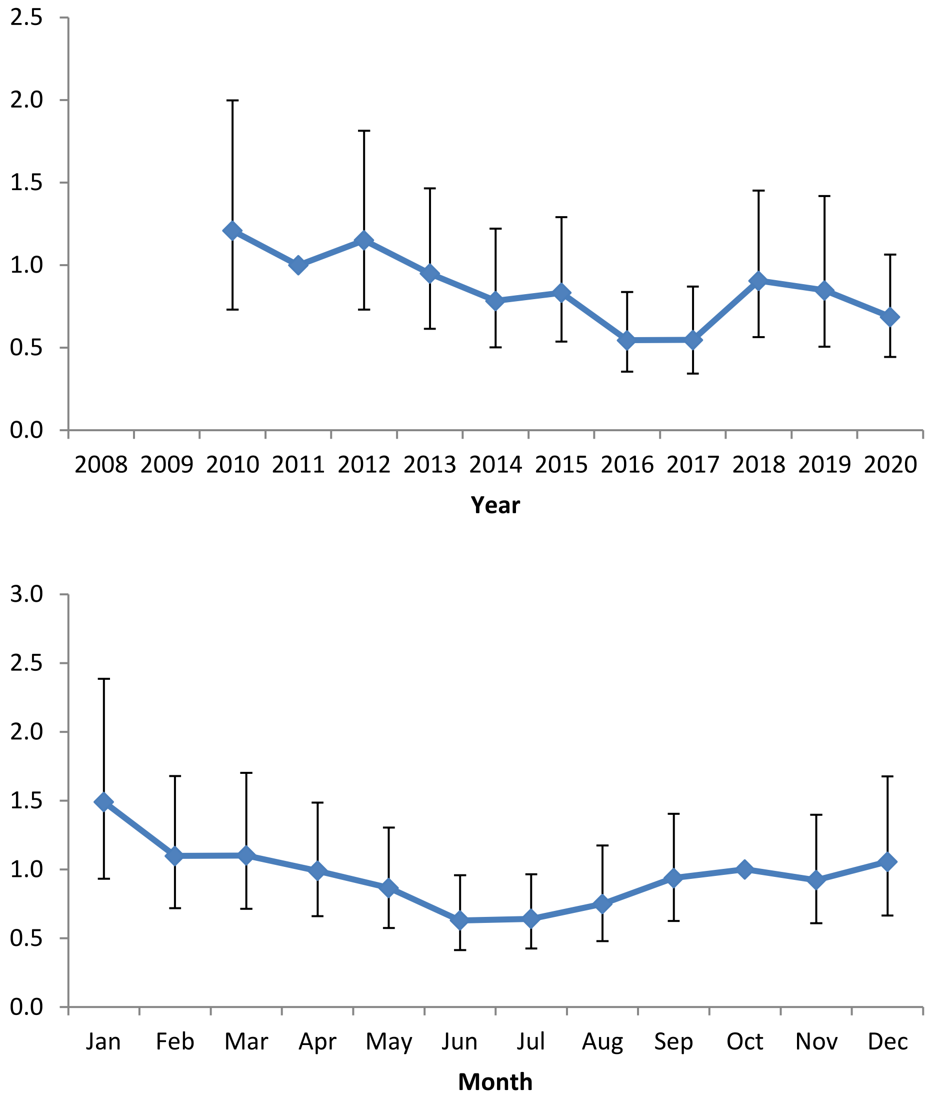

Figure 1. GLMM-standardised CPUE trends (top) and month effects (bottom) together with 95% confidence intervals for the **trotline** toothfish fisheries for the Prince Edward Islands EEZ when the old and new *Koryo Maru* are considered to be the same and the year factor relates to a "fishing"-year. Note that CIs are given relative to 2011 for CPUE and October (set at 1) for the month effect.