Spanish longline and trotline standardised CPUE series for toothfish (*Dissostichus eleginoides*) in the Prince Edward Islands EEZ to be used as input for the assessment

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Abstract

GLMM standardisations of longline and trotline toothfish CPUE data are presented based on a "fishing" year rather than a calendar year. Updated standardisation of the trotline CPUE data shows a drop in the 2014 season, which is the lowest in this 2008-2014 series.

Introduction

Brandão and Butterworth (2014a) presented results for the GLMM (General Linear Mixed Model) standardisations of longline and trotline to be used in the assessment of toothfish. This GLMM standardisation of the longline and of the trotline CPUE data is based on a "fishing year" and assumes that the two *Koryo Maru* vessels are identical in terms of power (rendered reasonable by the fact that the same skipper operated on both vessels). The GLMM analysis of longline CPUE data also includes different fixed month effects prior- and post-2000 (the year when cetacean depredation first became noticeable) rather than including the year-month interaction as a random effect, to provide a quantitative surrogate for the extent of cetacean depredation.

This paper presents results for the updated GLMM standardised CPUE for longlines and for trotlines.

The Data

Longline commercial catch data (as kg green weight), and effort data (as total number of hooks set) are available for the period 1997 to 2013. Although there no further longline sets have been deployed since 2013, the previous GLMM standardised CPUE series for longlines is updated in this paper because some duplicate entries have been removed from the records. A total of 7 610 sets are available for analyses (Table 1). Trotline CPUE data are available for the 2008 to 2014 period. The available data for 2015 was not used to base the analysis as only a "full" years series. 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 1 887 trotline sets (Table 1) is available for analyses.

Methods

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

The GLMM applied to the longline (and to trotline) CPUE data is of the form:

$$\ln\left(CPUE+\delta\right)=X\alpha+Z\beta+\varepsilon\,, \tag{2}$$

where

CPUE is the longline/trotline catch per unit effort,

δ is a small constant (10% of the average of all CPUE data values = 0.0170 for longline and = 0.139 for trotline) added to the toothfish CPUE to allow for the occurrence of zero CPUE values,

α is the unknown vector of fixed effects parameters which includes:

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

μ is the intercept,

vessel is a factor with 9 levels associated with each of the vessels that have operated in the longline fishery (to an appreciable extent):

Aquatic Pioneer
Arctic Fox
El Shaddai
Eldfisk
Isla Graciosa
Koryo Maru 11 (which represents the old and the new *Koryo Maru* vessels)
Ross Mar
South Princess
Suidor One

Where only two vessels have operated trotlines: the *Koryo Maru 11* (which also represents the old and the new *Koryo Maru* vessels) and the *El Shaddai,*

year is a factor with 17 levels associated with the years 1997–2013 for longlines or with 7 levels associated with the years 2008–2014 for trotlines,

month is a factor with 12 levels (January– December) for trotlines and 23 levels for longlines, reflecting the months prior to 2000 and the months on and after 2000,

area is a factor with 20 levels associated with the new spatially distinct fishing areas shown in Figure 1 of Brandão and Butterworth (2014b). Trotlines have been used in only 17 of these areas,

X is the design matrix for the fixed effects,

β is the unknown vector of random effects parameters which includes the following interaction terms:

$\eta_{year \times area} + \theta_{year \times month} + \phi_{month \times area}$, for trotline sets and

$\eta_{year \times area} + \phi_{month \times area}$, for longline sets, where

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($\ln\left(CPUE+\delta\right)$) = **X**α. 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:

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

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

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

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

The estimation of the variance components (**R** and **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 **R** and **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 2 and Figure 1 show the relative abundance indices for toothfish provided by the standardised commercial longline CPUE series for the Prince Edward Islands EEZ that considers the old and new *Koryo Maru* to be the same, includes split month factors prior and post-2000, and for which the year factor is based on a “fishing” year. The month and vessel effects for this GLMM are also shown, all with 95% confidence intervals. Figure 2 shows monthly differences between the post and prior-2000 point estimates. There is a reduction in the month factors post-2000 for the months of June to September, which might be a surrogate for cetacean depredation in the winter months. However the prior-2000 July effect is lower than those for adjacent months, which may indicate that cetacean depredation is not the only factor influencing a drop in abundance at that time of the year.

Figure 3 (and Table 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.

There has been a drop in CPUE from the 2013 to the 2014 fishing season, with the 2014 value being the lowest in the 2008-2014 series.

References

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Brandão, A. and Butterworth, D.S. 2014a. Final standardised CPUE series for toothfish (*Dissostichus eleginoides*) in the Prince Edward Islands EEZ to be used as input for the assessment. DAFF Branch Fisheries document: FISHERIES/2014/AUG/SWG-DEM/32.

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Table 1. The number of data entries per year available for the GLMM analysis to standardise the commercial Spanish longline and the trotline toothfish CPUE series .

Year	Longline	Trotline
1997	404	—
1998	1 395	—
1999	1 162	—
2000	1 619	—
2001	605	—
2002	295	—
2003	513	—
2004	3664	—
2005	180	—
2006	148	—
2007	508	—
2008	106	60
2009	58	57
2010	83	175
2011	2	333
2012	70	260
2013	98	374
2014	—	628

Table 2. Relative abundance indices for toothfish provided by the standardised commercial CPUE series for the Prince Edward Islands EEZ for the Spanish longline and for the trotline fisheries CPUE series.

Year	GLMM *CPUE*	
	Longline fishery	**Trotline fishery**
1997	3.412	
1998	1.467	
1999	1.288	
2000	1.000	
2001	0.581	
2002	0.706	
2003	0.425	
2004	0.557	
2005	0.735	
2006	0.614	
2007	0.673	
2008	0.601	0.690
2009	0.641	0.826
2010	0.531	1.276
2011	0.159	1.000
2012	0.334	1.017
2013	0.333	0.925
	—	0.666

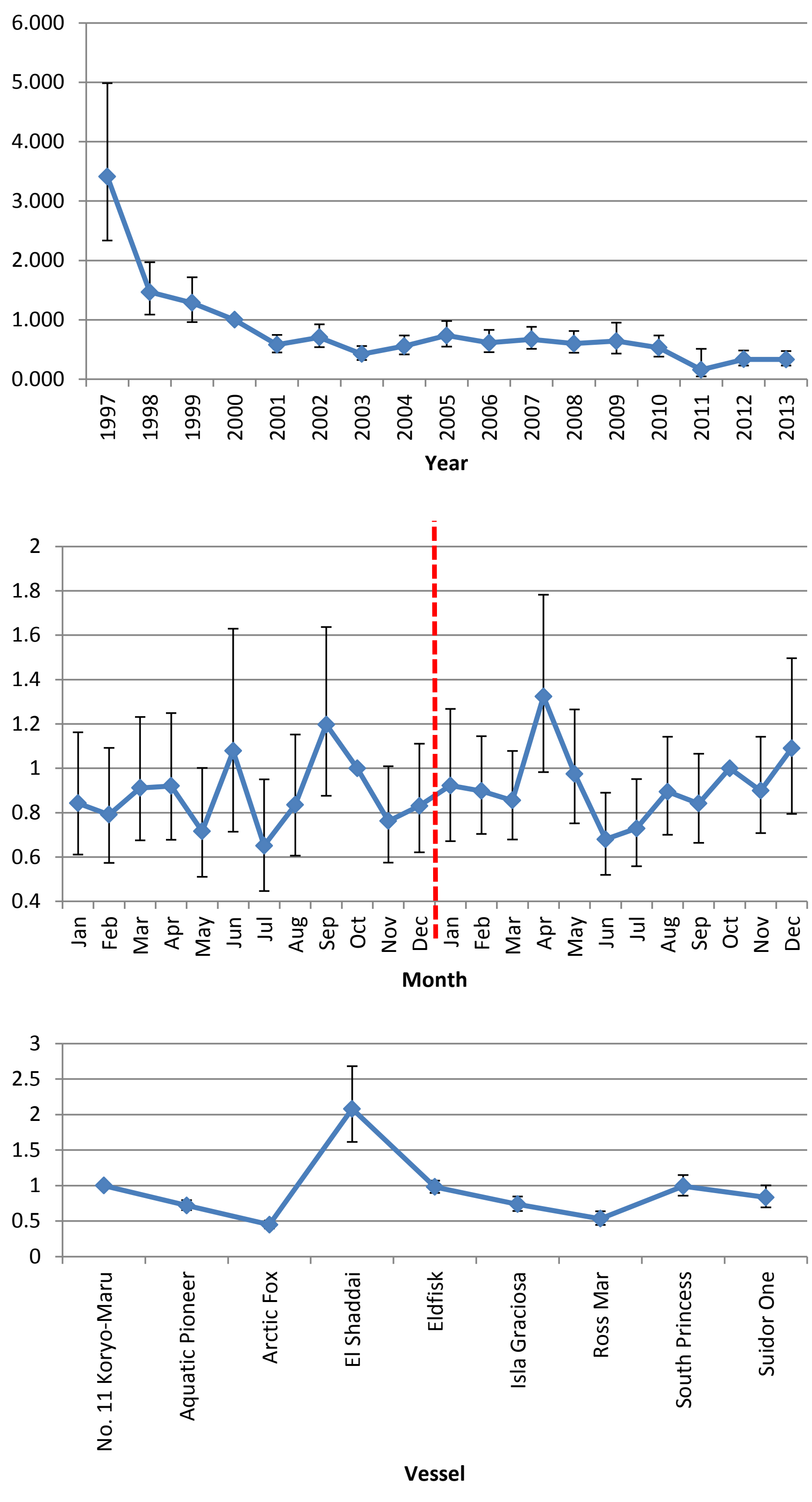

Figure 1. GLMM-standardised CPUE trends (top), month effects (middle) and vessel effects (bottom) together with 95% confidence intervals for the Spanish **longline** toothfish fisheries for the Prince Edward Islands EEZ when the old and new *Koryo Maru* are considered to be the same, the month factors are split prior and post-2000 (demarcated by the dashed vertical line), and the year factor relates to a "fishing" year. Note that CIs are given relative to 2000 for CPUE, post-2000 October (set at 1) for the month effect, and the *Koryo Maru* (set at 1) for the vessel effect.

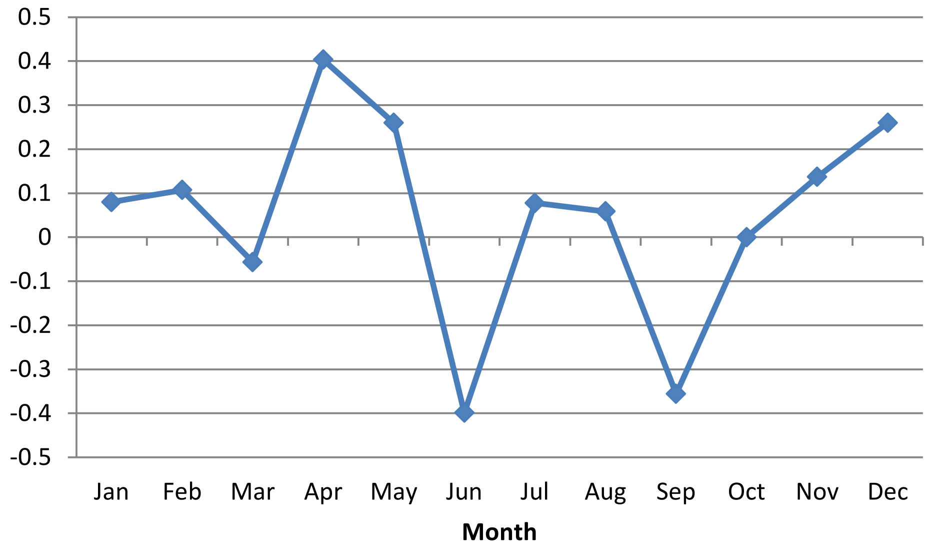

Figure 2. Monthly differences between post and prior-2000 point estimates.

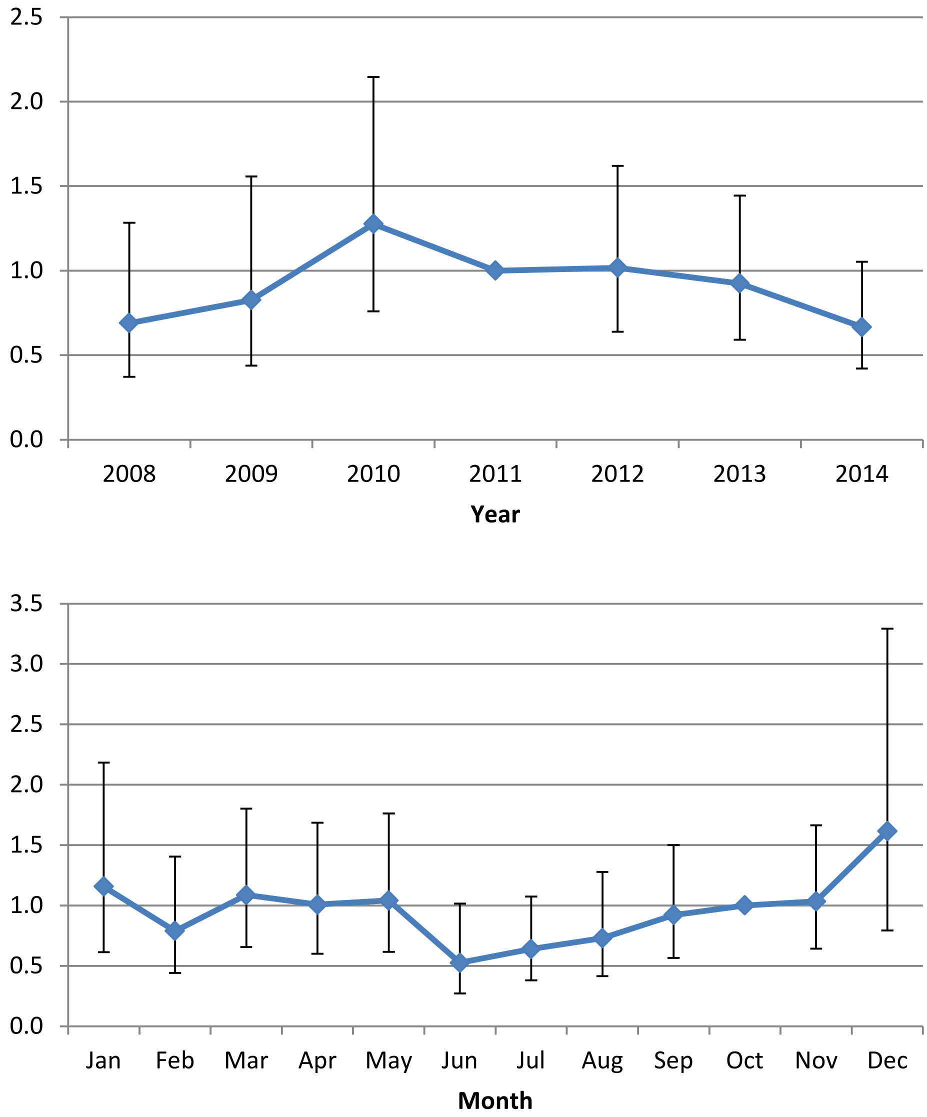

Figure 3. GLMM-standardised CPUE trends (top) and month effects (bottom) together with 95% confidence intervals for the **trotline** toothfish fisheries for the Prince Edward Islands EEZ when the old and new *Koryo Maru* are considered to be the same and the year factor relates to a "fishing" year. Note that CIs are given relative to 2011 for CPUE and October (set at 1) for the month effect.