Standardisation of the CPUE series for toothfish (*Dissostichus eleginoides*) in the Prince Edward Islands EEZ using finer scale fishing areas

Anabela Brandão and Doug S. Butterworth

Marine Resource Assessment & Management Group (MARAM)

Department of Mathematics and Applied Mathematics
University of Cape Town

Rondebosch, 7701, South Africa

June 2014

Abstract

The toothfish CPUE data for the Prince Edward Islands are re-standardised using fishing areas defined at a finer spatial scale. Three key features of the results are: i) no indication of systematic year-area effects, suggesting that it remains justified to treat the resource as a single stock; ii) no evidence of systematic shifts in fishing effort from one area to another over time, indicating that the fishery has not developed on the basis of sequential depletion of successive fishing areas; and iii) a larger drop in abundance as indexed by standardised CPUE over the last five years than had been indicated by earlier longline CPUE standardisations based on larger areas.

Introduction

In previous standardisations of toothfish CPUE in the Prince Edward Islands (PEI), the fishing areas in the PEI EEZ had been broadly defined as four spatially distinct blocks defined by longitude and latitude ranges Brandão and Butterworth (2011). The preferred depth zone for the presence of toothfish had not been taken into account when defining these areas. New, finer scale fishing areas have now been defined so that they reflect more closely the preferred depth zones for the occurrence of toothfish. These new areas are shown in Figure 1.

This paper addresses two issues:

1. obtaining a standardised CPUE series for toothfish using more appropriately defined areas of fishing; and
2. addressing the issue of whether PEI toothfish can be considered as one stock across the different areas, or whether each area represents a different stock

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 October 2013, and a total of 7 628 sets are available for analyses (Table 1a). Trotline CPUE data are available for the 2008 to November 2013 period. 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 1 289 trotline sets (Table 1b) is available for analyses.

For the present analyses, some areas have been combined if their data were similar and some contained few sets. Thus, area 11 has been combined with area 10, areas 21 and 22 with area 20 and area 104 with area 103.

Methods

The General Linear Mixed Model (GLMM) of Brandão and Butterworth (2011) has been applied to standardise the longline (Spanish) CPUE data for toothfish in the Prince Edward Islands EEZ for which data are now available until October 2013. The same form of GLMM has also been applied to the trotline CPUE data that are available since 2008 until November 2013.

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 = 0.0166 for longline and = 0.152 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
Ross Mar
South Princess
Suidor One

Only two vessels have operated trotlines: the *Koryo Maru 11* and the *El Shaddai.*

year is a factor with 17 levels associated with the years 1997–2013 for longlines or with 6 levels associated with the years 2008–2013 for trotlines,

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

area is a factor with 19 levels associated with the new spatially distinct fishing areas shown in Figure 1. Trotlines have only been used in 14 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:

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

year×area	is the interaction between year and area (this allows for the possibility of different changes with time for 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($\ln(CPUE+\delta)$) = $\mathbf{X}\alpha$. We denote the variance-covariance matrix for the residual errors (ε) 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

Figures 2 and 3 show the year$\times$area interaction effects for longlines and trotlines respectively obtained from fitting a GLMM to the CPUE data. These plots do not show any indication of systematic effects, except perhaps for a slight indication for areas 50 and 60 for trotlines and area 90 for longlines. However the same evidence is not present in these areas for the alternative fishing gear. Given this absence of evidence of different trends in different areas, there continues to be justification to treat the PEI toothfish as a single stock.

Figures 4 and 5 show the proportion of effort in each area by longlines and trotlines respectively. A linear trend to each plot has been included as a rough visual aid. There does not seem to be any one area in which most of the effort is concentrated, except for area 103; this had a high proportion of (longline) effort in the start of the fishery which has dropped since then. These plots do not suggest any systematic shift in effort from area to area, and hence provide no indication that the fishery has progressed on the basis of sequential depletion of successive localised aggregations.

Figures 6 and 7 show the relative abundance indices for toothfish provided by the standardised commercial longline and trotline CPUE series for the Prince Edward Islands EEZ respectively. For comparison the relative abundance indices obtained by Brandão and Butterworth (2013) which use the old definition of fishing areas are also shown. There is a larger drop in abundance as indexed by standardised longline CPUE over the last five years than had been indicated by earlier CPUE standardisations based on larger areas

Acknowledgements

Thanks to Tracey Mc Gahey and Rob Leslie for providing the data of the new areas as well as for the production of the map depicting the Prince Edward Islands toothfish fishing areas.

References

Brandão, A. and Butterworth, D.S. 2011. General Linear Model and General Linear Mixed Model standardisation of the toothfish (*Dissostichus eleginoides*) CPUE in the Prince Edward Islands vicinity over the period 1997–2010. DAFF Branch Fisheries document: FISHERIES/2011/OCT/SWG-DEM/48.

Brandão, A. and Butterworth, D.S. 2013. Obtaining a standardised CPUE series for toothfish (*Dissostichus eleginoides*) in the Prince Edward Islands EEZ calibrated to incorporate both longline and trotline data over the period 1997-2013. DAFF Branch Fisheries document: FISHERIES/2013/OCT/SWG-DEM/57.

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

Year	**Month**												**Total**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
1997	34	80	3	11	72	25	11	38			77	112	463
1998	135	223	213	150	13	35	118	87	89	227	63	81	1434
1999	48	34	30	69	167	64	13	176	163	123	194	54	1135
2000	148	182	136	170	134	64	156	126	152	198	99	43	1608
2001		39	56	14	119	149	47	90	5	28	15	9	571
2002	2	32	70	12	11				30	66	63		286
2003		34	47		17	83	105		39	151	37		513
2004		15	49		45	114	24		5	54	58	19	383
2005		10	45	2					14	48	42		161
2006		20	46					7	43	32			148
2007		25	53	22	135	65	23	87	12	47	39		508
2008		27	40							26	13		106
2009				2						23	33		58
2010	2	41	39							1			83
2011				2									2
2012				7	12		23	5	14	9			70
2013		8	16	21	14		3	5	7	25			99

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

Year	**Month**												**Total**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
2008			6							9	45	2	62
2009										26	29		55
2010		8	19	2					12	71	63	5	180
2011	58	2	50	44	30		13	20	84	16	40	15	372
2012				20	37		33	53	57	47			247
2013		23	48	44	39	35	63	41	11	46	23		373

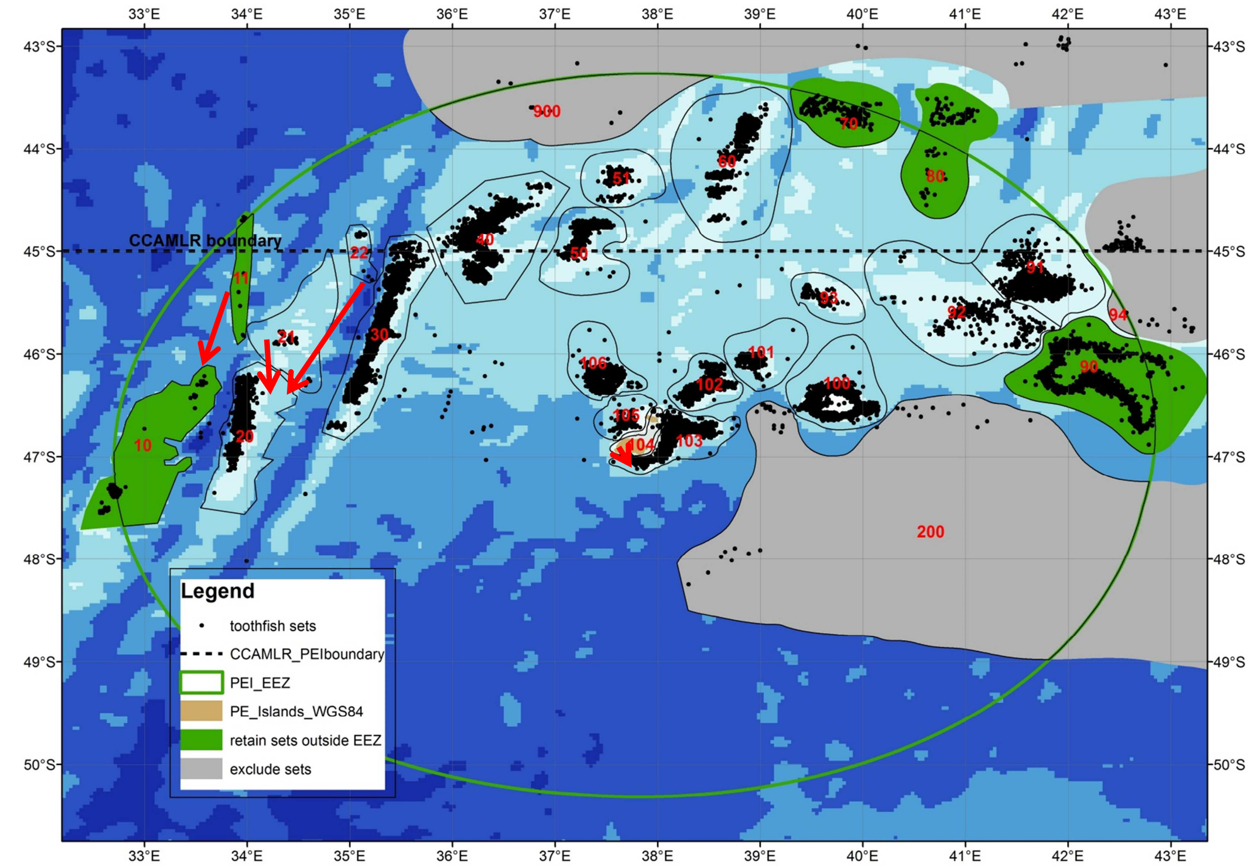

Figure 1. Map of the Prince Edward Island toothfish fishing sets together with the new defined fishing areas and the PEI EEZ. Arrows indicate the areas that have been combined for the GLMM analyses (i.e. area 11 has been combined with area 10, areas 21 and 22 with area 20 and area 104 with area 103).

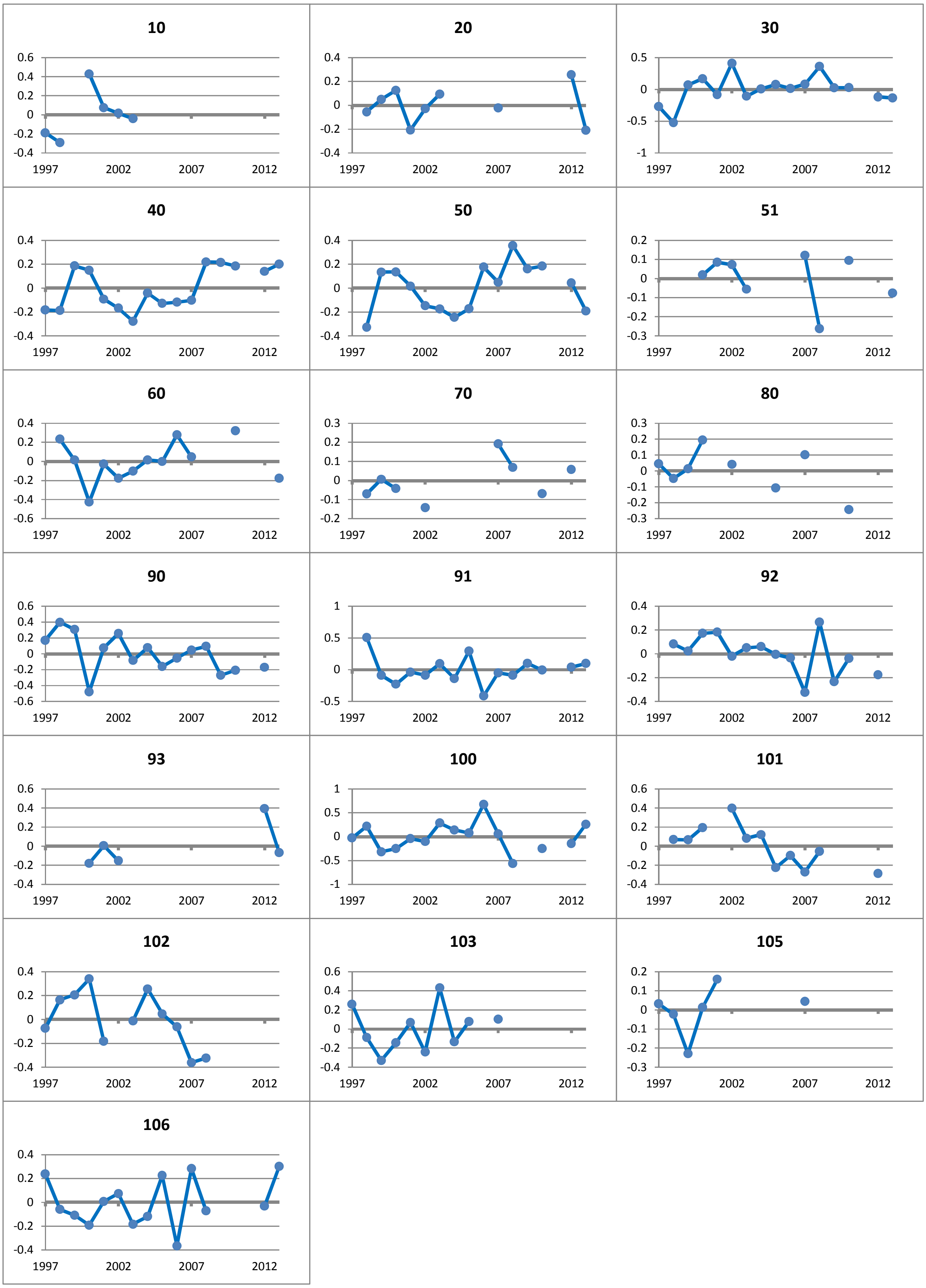

Figure 2. Plot of the year×area interaction effects for **longlines** obtained from fitting a GLMM to the CPUE data.

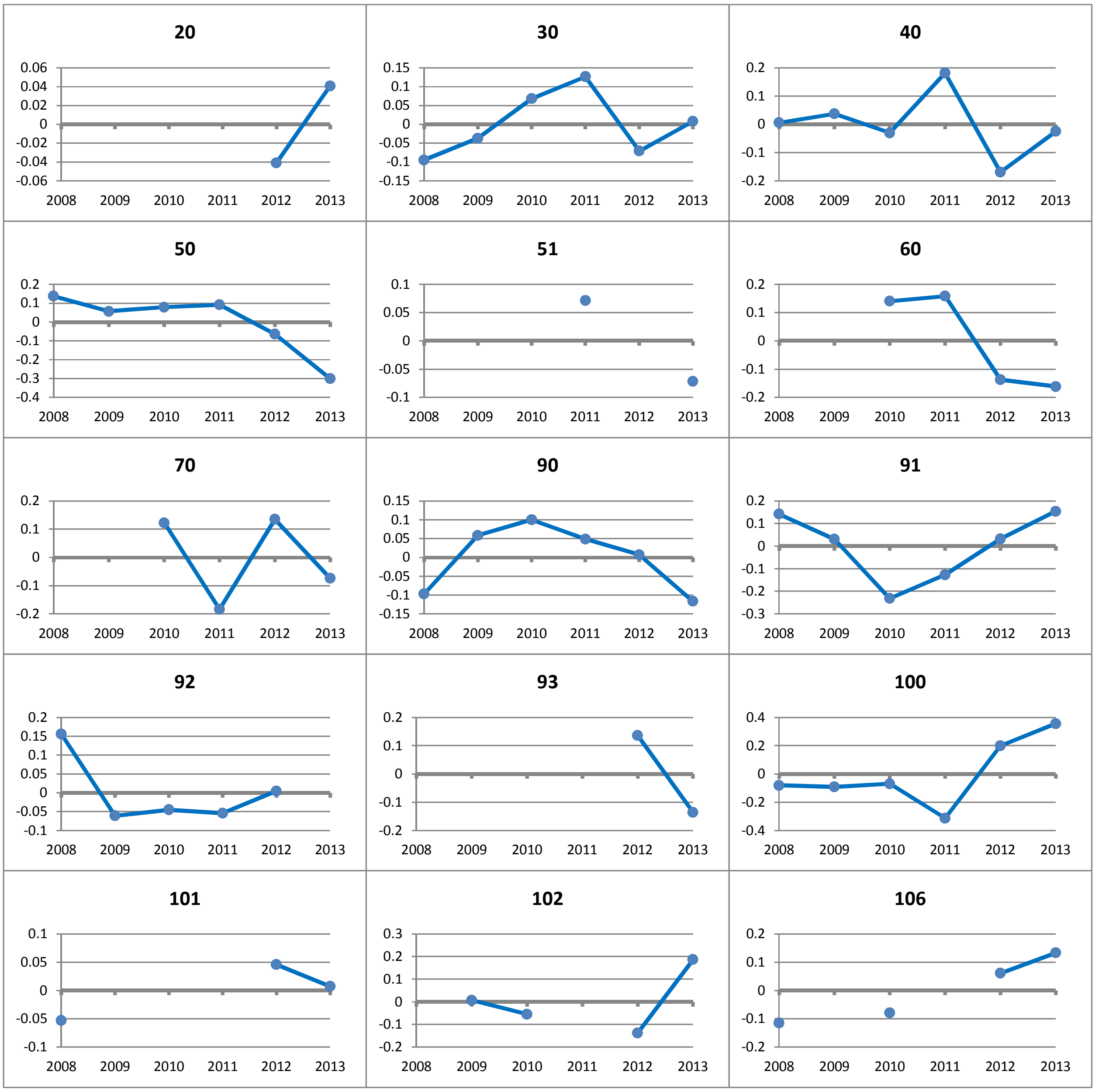

Figure 3. Plot of the year×area interaction effects for **trotlines** obtained from fitting a GLMM to the CPUE data.

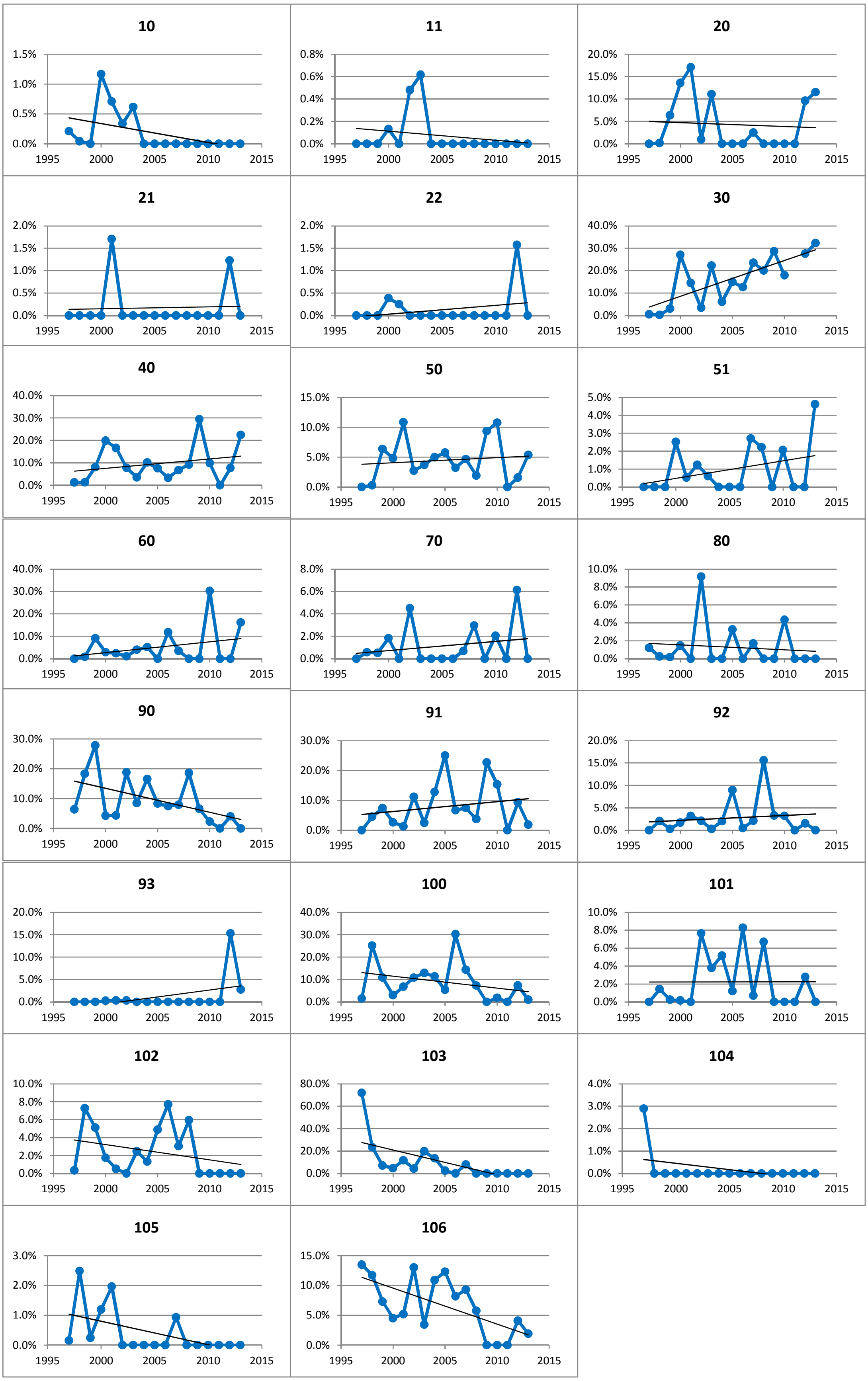

Figure 4. Proportion of effort by the **longlines** in each of the new areas. A linear trend line is also included as a visual aid.

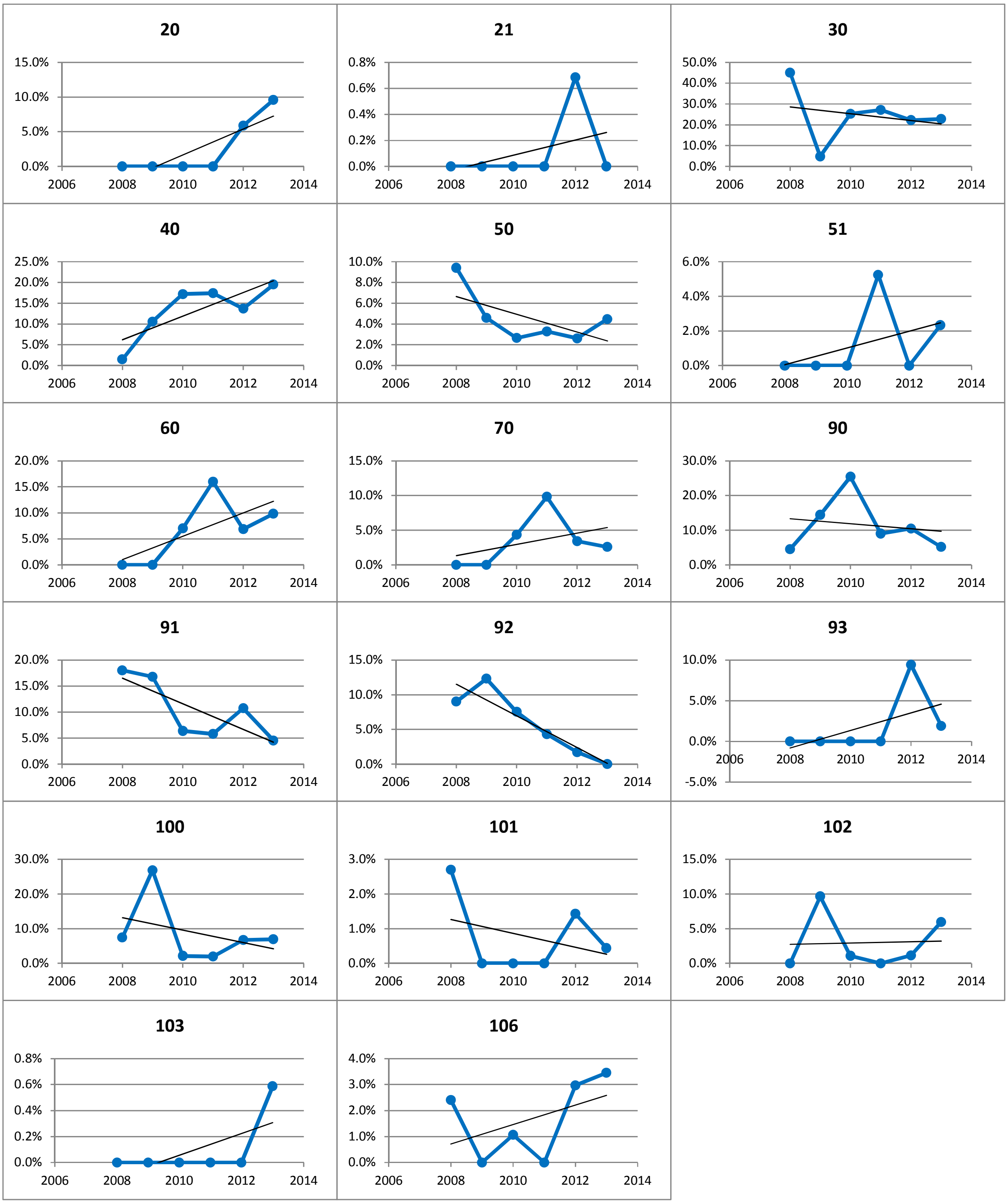

Figure 5. Proportion of effort by the **trotlines** in each of the new areas. A linear trend line is also included as a visual aid.

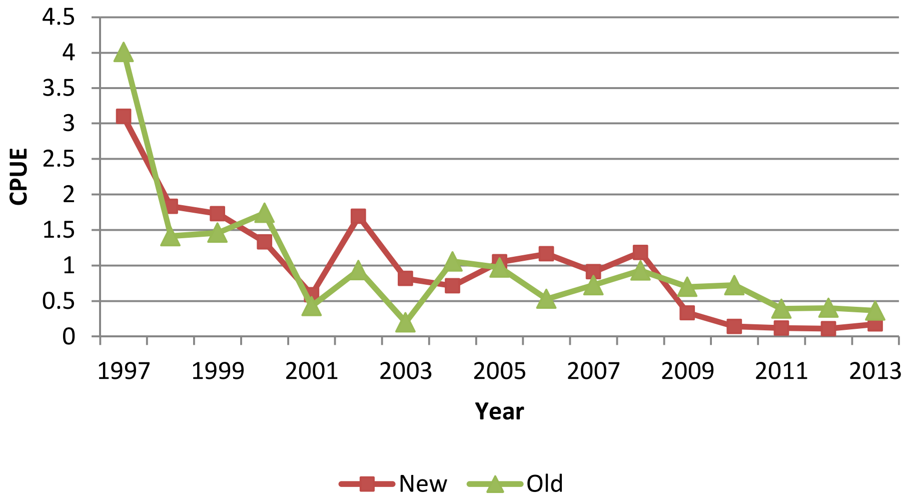

Figure 6. GLMM-standardised CPUE trends for the Spanish **longline** toothfish fisheries for the Prince Edward Islands EEZ when applying the new fishing area definition compared to that using the old areas (both are normalised to their mean over the 1997 to 2013 period).

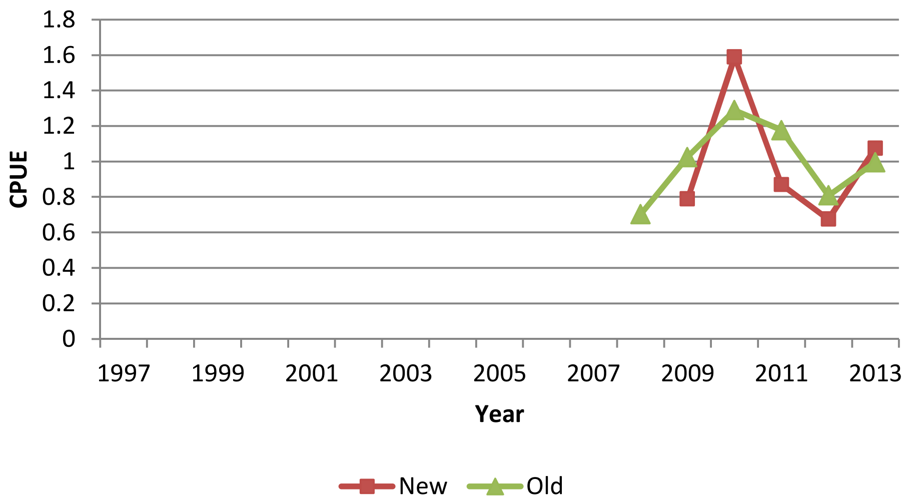

Figure 7. GLMM-standardised CPUE trends for the **trotline** toothfish fisheries for the Prince Edward Islands EEZ when applying the new fishing area definition compared to that using the old areas (both are normalised to their mean over the 2008 to 2013 period).