RESCALED TRISTAN GLM-STANDARDISED LOBSTER CPUE TO TAKE ACCOUNT OF FISHING EFFICIENCY CHANGES

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

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

MAR 2016

ABSTRACT

The Powerboat CPUE series for Tristan was last updated in 2015 (MARAM/Tristan/2015/MAY/06) and took data for the 1994-2014[1] seasons into account. A GLM with year and month as fixed effects was applied to these data as has been done in the past. Data on both the areas fished and the fishermen's names are now available for recent seasons. A method is proposed whereby the full GLM for Tristan can be rescaled to take into account the overall fishing efficiency changes informed by these new data. The inclusion of the fishing efficiency changes results in a slightly less pessimistic CPUE trend over recent seasons.

INTRODUCTION

The commercial CPUE series for 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 factors besides density may influence the recorded values for CPUE. Where sufficient data exist, General Linear Model (GLM) 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 number of GLM standardisations to the *Jasus tristiani* lobster catch per unit effort data from the Tristan powerboat fishery for the period 1997-2014.

METHODOLOGY

The standard powerboat CPUE database for Tristan contains information at a trip level for all seasons for the following:

Year
Month
Number of traps
Number of hoops
Hours fished
Total catch (in kgs)

[1] The convention used here for split season is to use the first year, i.e. 2014 refers to the 2014/2015 season.

Note that for Tristan the "season" is assumed to start in July each year. In Johnston *et al.* (2010) a GLM was developed for which the CPUE is taken to be equal to:

$$CPUE = \frac{catch}{(number\ of\ gear)(hours\ fished)} \text{ kg/hour/gear} \quad (1)$$

where the number of gear is:

$$number\ of\ gear = traps + (0.5).hoopnets$$

(as estimated by James Glass pers. comm.) to allow for the different relative efficiency of the two types of gear. [Note that previous GLM analyses showed little sensitivity to alternate hoopnet scaling factors to this 0.5 value.]

Table 1 summarises the variables currently available for the Tristan CPUE GLM analysis. Note that data on *area* fished are now available from 2005, and data on the fishermen's *names* (two for each trip) are available for five seasons (2005-2007, 2013 and 2014). It is assumed here that both fishermen in a pair contribute fully to the catch and effort recorded for that trip (data do not provide details at the individual level, only at the pairs-level).

GLM1

The form of GLM model used in the past, and termed GLM1 here, is given by:

$$\ln(CPUE + \delta) = \mu + \alpha_{year} + \beta_{month} \quad (2)$$

where:

C	is the catch in kg,
E	is the effort in hours fished,
μ	is the intercept,
year	is a factor with 21 levels associated with the years (i.e. the Season-Years: 1994-2014),
month	is a factor with levels associated with the fishing month (1-12), and
δ	is taken to be 0.95 (used to prevent taking logs of zero).

The standardised CPUE series is obtained from:

$$CPUE_{year} = \exp\left(\mu + \alpha_{year} + \beta_{September}\right) - \delta \quad (3)$$

Three versions of this GLM have been run here (comparisons are given in the Appendix).

GLM1a: 1994-2014 (as reported in MARAM/Tristan/2015/May/06)
GLM1b: 2005-2014
GLM1c: 2005-2007, 2013, 2014.

GLM2

GLM2 is the same as GLM1 except that it takes "areas" into account in the standardisation:

$$\ln(CPUE + \delta) = \mu + \alpha_{year} + \beta_{month} + \gamma_{area} \quad (4)$$

where:

area is a factor with levels associated with each fishing area (A1, B2, C3 or D4), and

the standardised CPUE series is obtained from:

$$CPUE_{year} = \exp\left(\mu + \alpha_{year} + \beta_{September} + \gamma_{D4}\right) - \delta \quad (5)$$

Two versions of GLM2 have been run here (again comparisons are given in the Appendix).
GLM2b: 2005-2014
GLM2c: 2005-2007, 2013, 2014

GLM3

GLM3 is a further extension of GLM2 except it takes the fisherman's names into account in the standardisation:

$$\ln(CPUE + \delta) = \mu + \alpha_{year} + \beta_{month} + \gamma_{area} + \phi_{Name} \quad (6)$$

where:

Name is the factor associated with the fishermen's names.

The standardised CPUE series (GLM3) is obtained from:

$$CPUE_{year} = \exp\left(\mu + \alpha_{year} + \beta_{September} + \gamma_{D4} + \phi_{Name12}\right) - \delta \quad (7)$$

Note that GLM3 can be run only for those years for which the fishermen's names are available, i.e. for 2005-2007, 2013 and 2014.

Note the intercept in the GLMs includes 2005, September, Area D4, and fishermen number 12 (who is a fisherman who operated over each of the five years with data on names) where applicable.

Strictly equation (6) should read:

$$\ln(CPUE + \delta) = \mu + \alpha_{year} + \beta_{month} + \gamma_{area} + 0.5(\phi_{Name1} + \phi_{Name2}) \quad (8)$$

making the assumption the fishermen efficiencies are additive on the log scale as a basis for simplicity. Unfortunately however, GLM packages are unable to implement equation (8) directly. This was achieved by importing each data record twice to a GLM based on equation (6), where the name of the first fisherman listed was used with the first record, and where the name of the second fisherman for the second record. This should achieve unbiased estimates but overestimate the degree of precision (variance). The latter is however not a concern here as variance estimates are not used in the further analyses of this paper.

Rescaling of GLM1

The approach taken here is that GLM1a continues to be the most appropriate GLM to be used as the reference case GLM for the Tristan powerboat CPUE as it takes data for the full 1994-2014 period into account. GLM3 however has the advantage that it takes both the area fished and the fishermen's names into account; however is

available for only five years, 2005-2007, 2013 and 2014. GLM3 thus has the important ability to inform on changes in the overall fishing efficiency over this period.

A reasonable way to incorporate this useful information on fishing efficiency changes, is to use GLM1a as the underlying GLM for Tristan, but to rescale the CPUE decline observed from the 2005-2014 period in line with what is estimated by GLM3 (which is able to take any fishing efficiency changes into account).

GLM1a results in a ratio $\frac{CPUE_{13-14}}{CPUE_{05-07}}$=**0.35**, where $CPUE_{05-07}$ is the average CPUE over the 2005-2007 period and $CPUE_{13-14}$ is the average CPUE over the 2013-2014 period.

GLM3 results in a ratio $\frac{CPUE_{13-14}}{CPUE_{05-07}}$=**0.42**, indicating a somewhat lesser decline in CPUE over the 2005-2014 period than does GLM1a because of a decline in the overall average of the fishermen's efficiency.

The GLM1a values are **rescaled** from 2005 to 2014 using a linear function in the year as a multiplier which does not change the value for 2005 but achieves a $\frac{CPUE_{13-14}}{CPUE_{05-07}}$ ratio that equals 0.42.

RESULTS

Table 2 reports both the (unscaled) GLM1a standardised CPUE series, as well as the rescaled GLM1a series.

Figure 1 plots the standardised CPUE for GLM1a and GLM3 (where the GLM3 values are renormalized so that the average CPUE for the 2005-2007 period are identical to that for GLM1a). Figure 2 plots the standardised CPUE for GLM1a and for the rescaled GLM1a. Figure 3 shows the scaling vector applied to the GLM1a standardised CPUE values to produce the rescaled GLM1a values.

Figure 4a shows the month effects estimated for GLM1a and GLM3 with Figure 4b reporting the number of data for each month/GLM; month effects are generally higher for August to December. Figure 4c shows the area effects estimated by GLM3 – this shows that area effects are minimal. Figure 4d shows the "Name" effects for GLM3.

The Appendix reports further comparisons of the various GLM models. There is little sensitivity to either the period chosen for the standardisation or to the inclusion of an area factor.

DISCUSSION

It is proposed that the updated assessment of the Tristan lobster fishery be run using both the re-scaled GLM1a CPUE series and the old GLM1a standardised CPUE series. The re-scaled GLM1a series is considered to be a more reliable CPUE series as both the full time series of data is taken into account and the new data on areas and fishing names are also incorporated. The rescaled GLM1a thus takes the fishing efficiency changes informed by these new data into account. The inclusion of the fishing efficiency changes results in a slightly less pessimistic CPUE trend over recent seasons.

REFERENCE

Johnston, S.J., Brandao, A. and D.S. Butterworth. 2010. GLMM- and GLM-standardised lobster CPUE from the Tristan da Cunha group of islands for the 1997-2008 period. MARAM/Tristan/2010/May/04.

Table 1: Table showing for which seasons different variables are available for CPUE GLM standardisation analysis.

	Season	Month	Area	Name	Nominal CPUE
1997					
1998					
1999					
2000					
2001					
2002					
2003					
2004					
2005					
2006					
2007					
2008					
2009					
2010					
2011					
2012					
2013					
2014					

Table 2: Standardised powerboat CPUE series for **Tristan** Island using the original GLM1a model as well as the rescaled GLM1a which takes fisherman efficiency into account. The number of data records for each Season-Year (*N*) is listed, along with nominal CPUE series for comparison.

Season-Year	*N*	**Nominal CPUE (kg/hour/gear)**	**GLM1a Standardised CPUE (kg/hour/gear)**	**Rescaled GLM1a Standardised CPUE (kg/hour/gear)**
1994	1138	0.269	0.273	0.273
1995	1139	0.264	0.237	0.237
1996	1241	0.280	0.276	0.276
1997	696	0.489	0.444	0.444
1998	446	0.712	0.542	0.542
1999	338	0.961	0.711	0.711
2000	324	1.019	0.911	0.911
2001	334	1.107	0.928	0.928
2002	335	1.397	1.301	1.301
2003	382	1.684	1.495	1.495
2004	385	1.726	1.680	1.680
2005	339	2.155	2.194	2.194
2006	284	2.840	2.532	2.532
2007	310	2.365	2.055	2.055
2008	486	1.453	1.213	1.247
2009	305	1.835	1.731	1.829
2010	484	1.317	1.215	1.319
2011	376	1.321	1.167	1.302
2012	344	1.104	1.003	1.150
2013	476	0.990	0.919	1.083
2014	366	0.704	0.650	0.787

Figure 1: Comparative plot of the GLM1a and GLM3 standardised powerboat CPUE series for **Tristan** Island. GLM3 takes account of fishermen efficiency and is renormalised to the GLM1a mean for the 2005-07 period for easier comparison of trends.

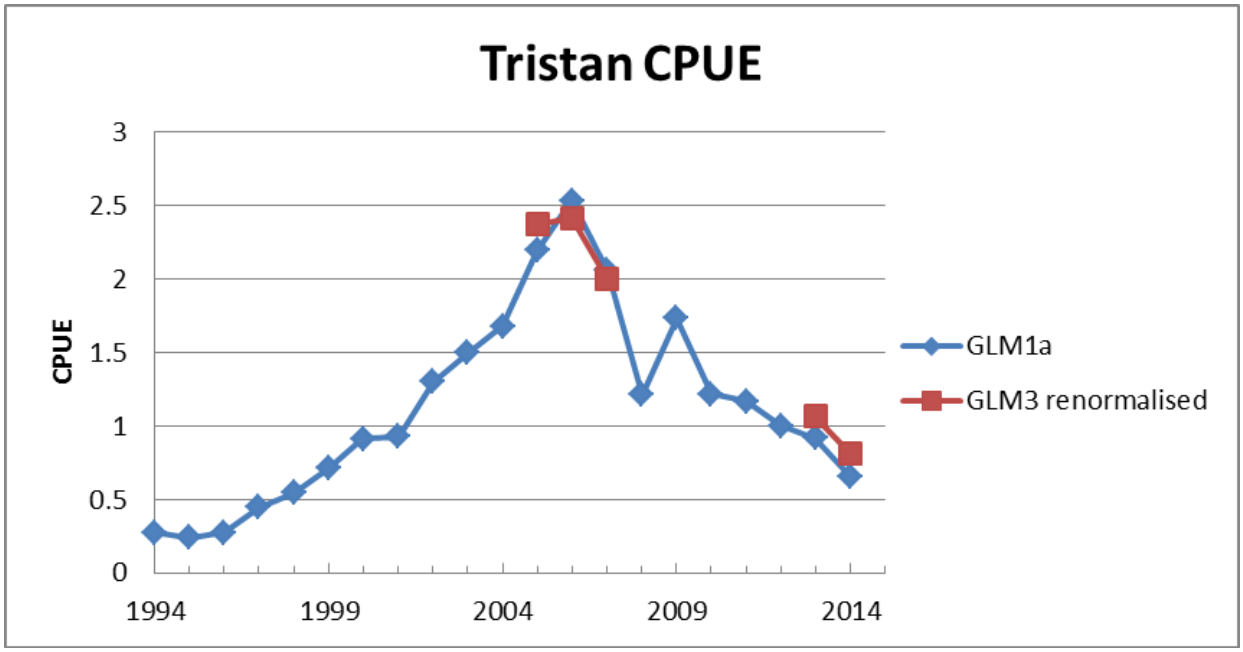


Figure 2: Comparative plot of the GLM1a and rescaled GLM1a powerboat CPUE series for **Tristan** Island.

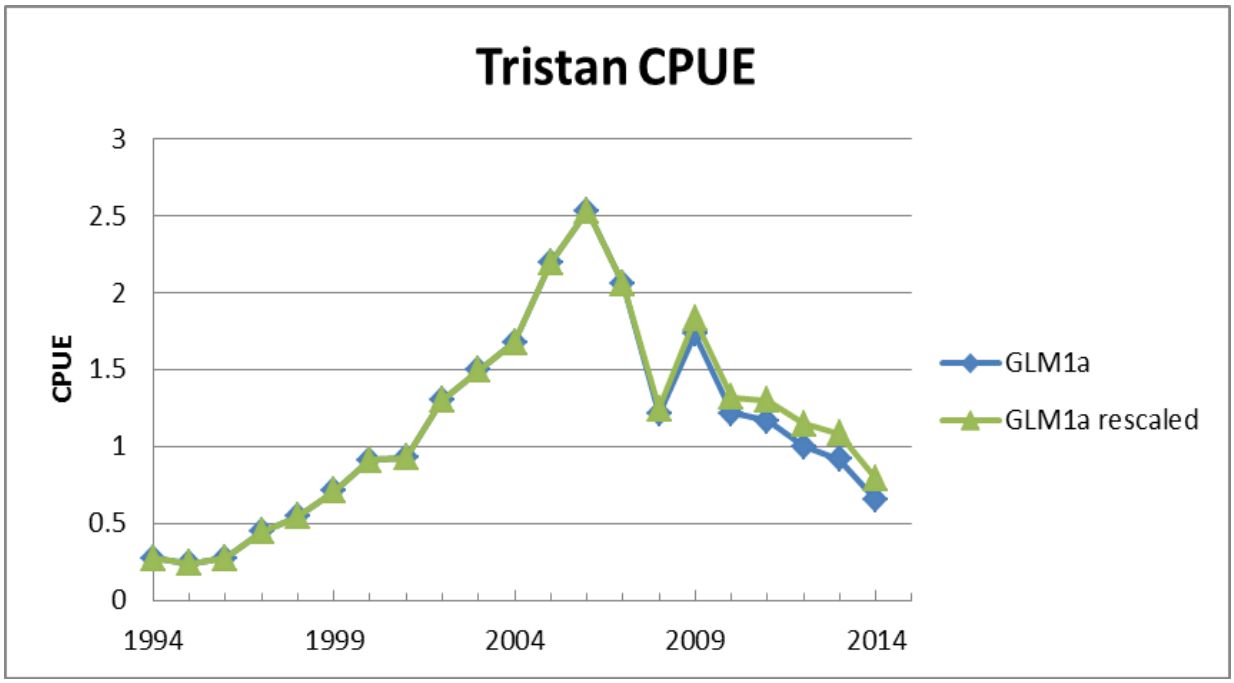


Figure 3: The scaling vector required to be applied to the GLM1a standardised CPUE values to produce the rescaled GLM1a values

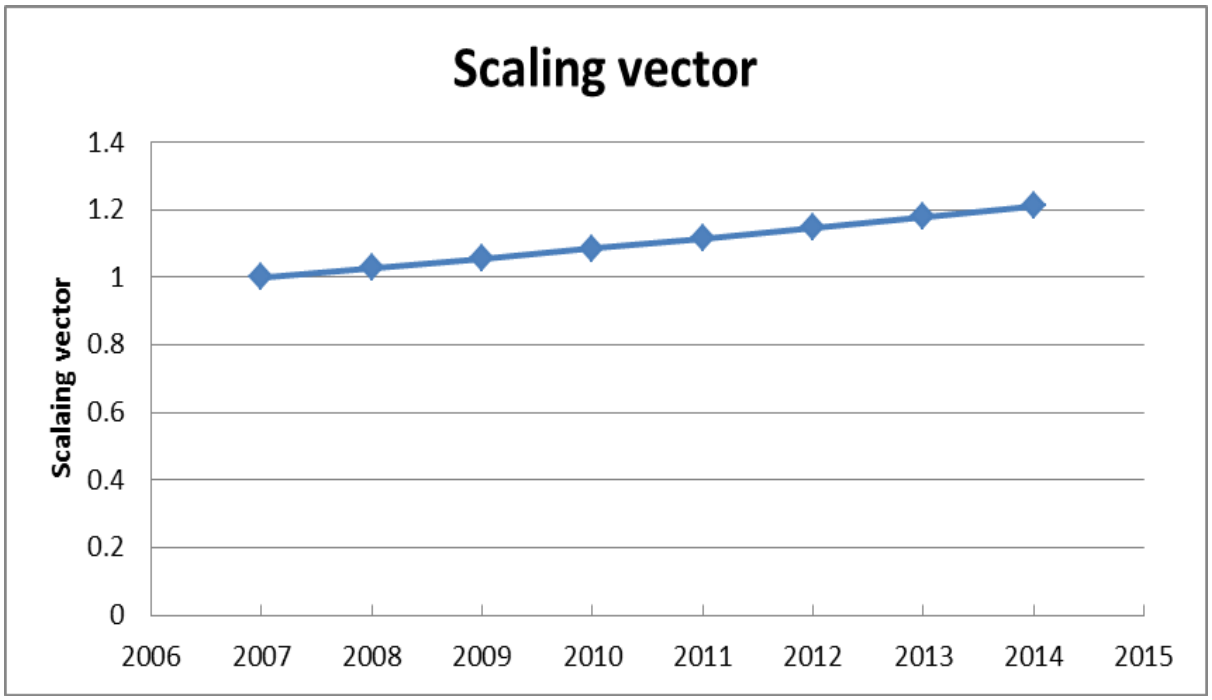


Figure 4a: GLM month effects for the **Tristan** Island for both GLM1a and GLM3.

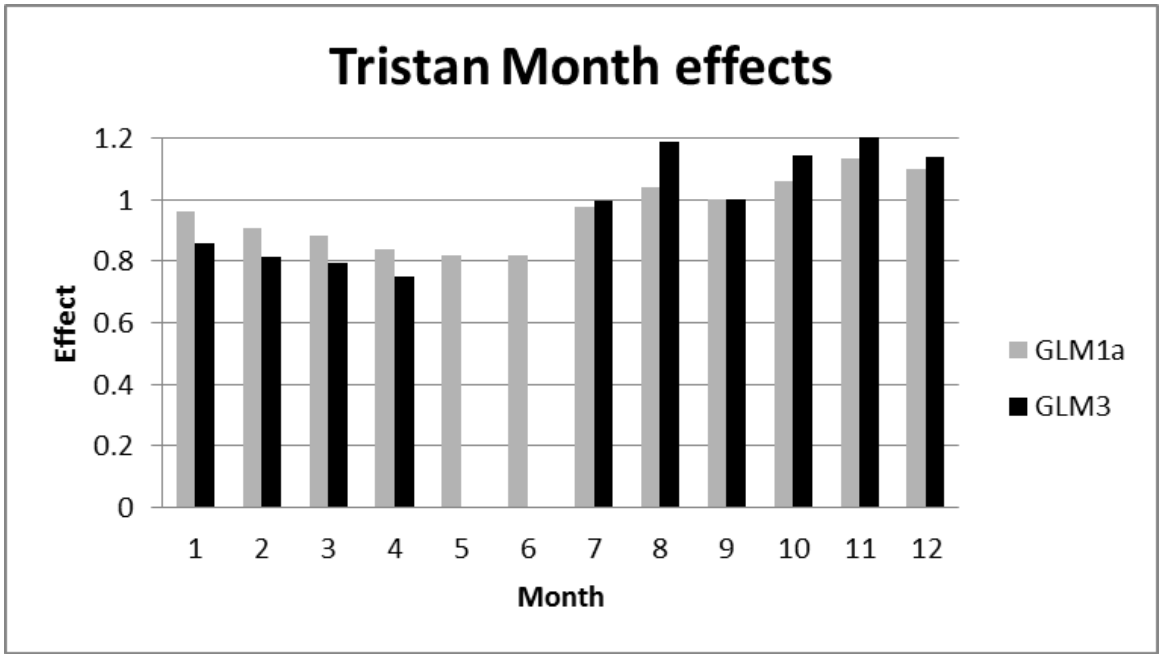


Figure 4b: Number of data for each month/GLM analysis.

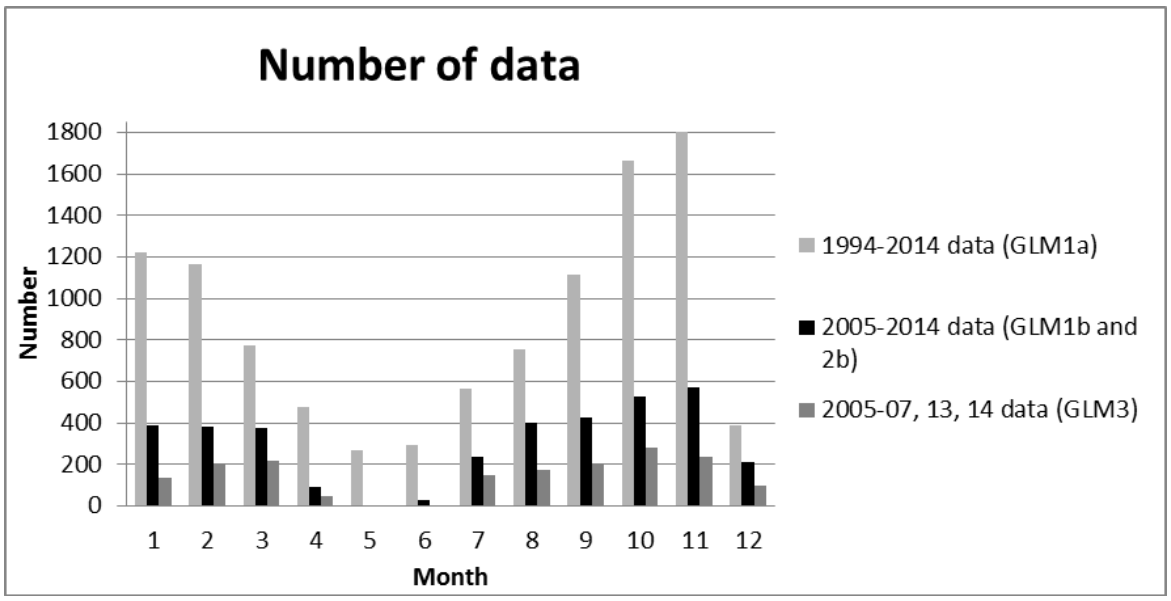


Figure 4c: GLM3 area effects for the **Tristan** Island.

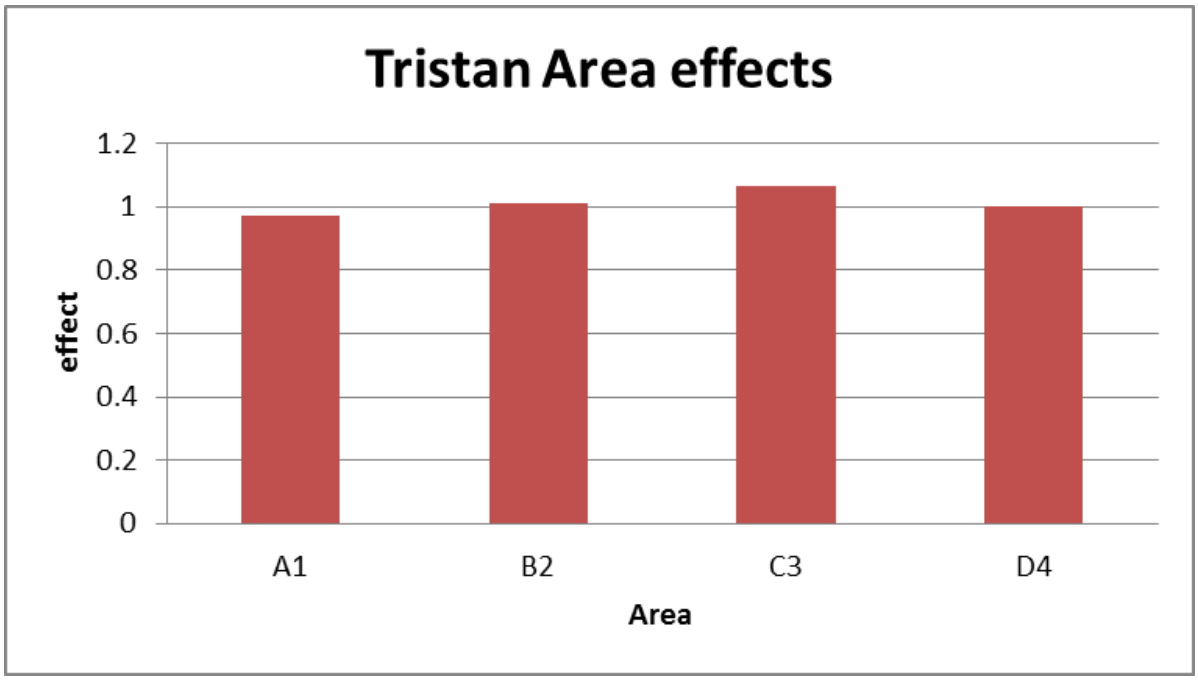
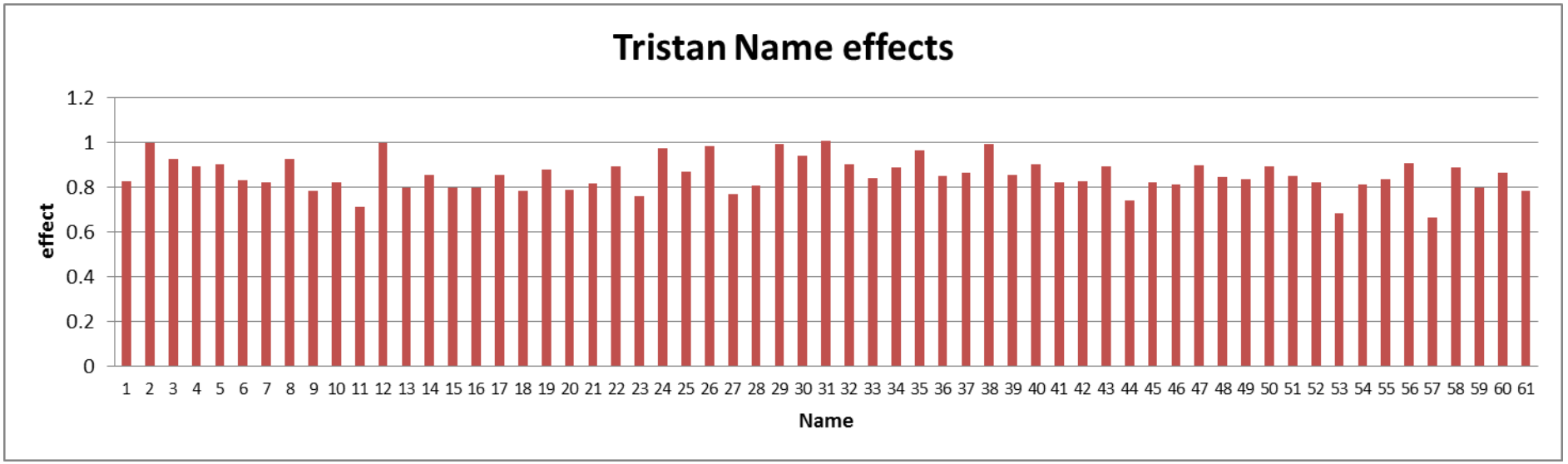


Figure 4d: GLM3 name (i.e. fisherman efficiency) effects for the **Tristan** Island. Names have been replaced by numerics for reasons of confidentiality.



Appendix: Details and comparisons of GLM1a-c, GLM2a-b and GLM3c.

Table A1: The $\frac{CPUE_{13-14}}{CPUE_{05-07}}$ values for each GLM option.

	GLM1a	GLM1b	GLM1c	GLM2b	GLM2c	GLM3
$\frac{CPUE_{13-14}}{CPUE_{05-07}}$	0.35	0.36	0.37	0.37	0.37	0.42

Figure A1: Comparison of GLM1a-c standardised CPUE values to show the effect of choosing different time periods.

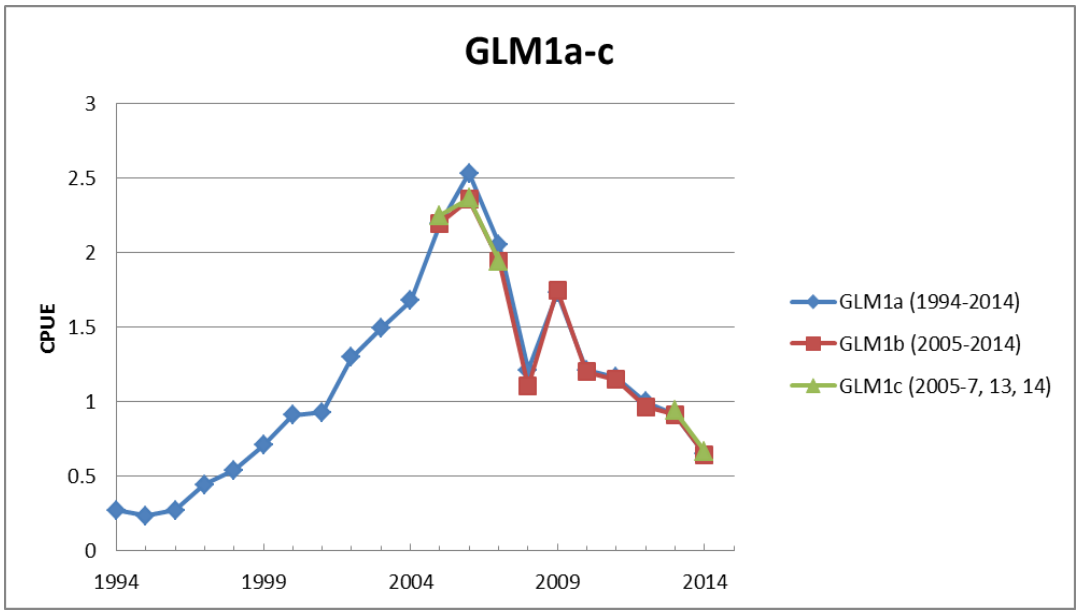


Figure A2: Comparison of GLM1b and GLM2b standardised CPUE values to show the effect of including an area factor.