

Results for GLMM analyses of the South Coast penguin colony chick condition data

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Summary

The GLMM model to estimate the impact of fishing on penguins at the St Croix and Bird Island colonies is applied to the South Coast chick condition data. The results indicate a negative impact for St Croix and a mixed impact for Bird Island in terms of point estimates. However, none of these estimates is statistically significant, and standard errors of the estimates are large, ranging from 0.23 to 0.45, so that any inferences drawn from this analysis would not have great reliability.

Introduction

The GLMM model applied to the South Coast foraging data (FISHERIES/2019/NOV/SWG-PEL/27) is applied to the South Coast chick condition data, both for the catch and closure mixed effects models. The mixed effects model is given by the equation:

$$\ln(F_{y,i}) = \alpha_y + \beta_i + \lambda_i \frac{C_{y,i}}{\bar{C}_i} + \delta_i X_i + \epsilon_{y,i} \quad (1)$$

where

$F_{y,i}$	is the chick condition variable, which has been log-transformed ² ,
α_y	is a random year effect reflecting prevailing environmental conditions (assumed to be the same each year, random variation excepted, for both islands in a pair),
β_i	is an island effect,
λ_i	is a fishing effect occasioned by the size of the catch taken in the neighbourhood of the island,
$C_{y,i}$	is the sardine catch taken in year y in the 18.148km radius neighbourhood (the area effectively closed on occasion – see further discussion below) of island i ,
\bar{C}_i	is the average catch taken over the years for which island i was open to the fishery between 2008-2013,
δ_i	is a fishing effect occasioned by whether or not the neighbourhood around the island was closed to fishing,
X_i	is a vector with an entry of 1 in years where island i is open to the fishery, and 0 where the island is closed, and
$\epsilon_{y,i}$	is an error term.

For the Catch model δ is set to zero and for the Closure model λ is set to zero. R software was used for the analyses, using the lmer function from the lme4 package; this implements REML estimation which provides unbiased estimates of variance.

Table 1 lists the foraging data as they are currently available, excluding the 2016-2018 values which are under a confidentiality agreement between the data collectors and DEA for a period of six months. The 18.148km catch series used in these analyses are also listed in this Table.

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² Note that for foraging data (since longer or further foraging trips are less optimal for the penguins), these data were transformed taking the negative of the logarithm so that a larger negative number implies a more negative impact on the penguin population (equation 1 of FISHERIES/2019/NOV/SWG-PEL/27). Taking the negative is not necessary for chick condition as the direction of the relationship is reversed.

An analysis of the correlation between sardine catch and biomass is detailed in FISHERIES/2019/NOV/SWG-PEL/27, where the conclusion was made that there is no strong indication of a positive correlation; such a correlation would result in bias in the estimates of the fishing effect parameter from this form of analysis.

Results and Discussion

Table 2 presents the estimates of fishing effect (λ for the catch model and δ for the closure model) for chick condition data for the two islands. Figure 1 shows Zeh plots of the fishing effect along with the 95% confidence intervals. Figure 2a plots the data points along with the model predictions. The data points corresponding to 2016-2018 have been excluded in these plots in terms of a six-month confidentiality agreement with DEA. Figure 2b plots the corresponding standardised residuals of the fits.

For St Croix, both the closure and the catch model estimate is of a negative impact of the fishery on the penguin population, with the point estimate for the catch model lying below the -0.1 level, which has been used in the West Coast power analyses as the level below which the impact of fishery on the penguin population would be biologically meaningful. For Bird the impact is slightly negative for the closure model and positive for the catch model. However, none of these fishing effect impacts are estimated to be significantly different from zero, or from -0.1, and the standard errors for these estimates (see Table 2) are large, indicating that any inferences drawn from this analysis would not have great reliability.

References

Ross-Gillespie, A. and Butterworth, D.S. 2019. 2019 Updated GLMM results for the South Coast penguin colony foraging data. Fisheries Branch document FISHERIES/2019/NOV/SWG-PEL/27.

Table 1: The data used for the South Coast chick condition analyses are listed in the table below. The Table shows the closure status of each island for each year (note that under Closure, 1 means open to the fishery and 0 means closed), the 18.148km catch series and the chick condition data. The newest data, for 2016-2018, have been included in the analyses, but are under a six-month confidentiality agreement with DEA and have thus not been shown in this table.

Island	Year	Closure	18.148km catches	Chick condition		
				Mean	se	n
St Croix	2008	1	264	0.51	0.031	179
	2009	0	159	0.23	0.023	245
	2010	0	1017	0.23	0.027	161
	2011	0	276	0.43	0.041	48
	2012	1	2732	0.03	0.031	121
	2013	1	2065	0.32	0.029	268
	2014	1	401	0.28	0.033	147
	2015	0	0	0.29	0.045	51
	2016	0	0			
	2017	0	479			
	2018	1	5182			
Bird	2008	1	1136	0.38	0.03	195
	2009	1	1135	0.24	0.027	272
	2010	1	598	0.28	0.036	129
	2011	1	19	0.31	0.035	103
	2012	0	40	0.3	0.029	167
	2013	0	0	0.31	0.014	568
	2014	0	0	0.17	0.035	69
	2015	1	0	0.14	0.024	123
	2016	1	90			
	2017	1	123			
	2018	0	0			

Note: J. Coetzee (*pers. comm*) advises that catches taken within the 18.148 km closed area during years in which islands are closed to fishing are located just inside the boundary circle in the majority of cases, and may arise from vessels passively drifting into the closed area during pursuing of the catch. Incorrect reporting of the catch position as well as deliberate disregard for the permit conditions cannot, however, always be ruled out.

Table 2: GLM estimates of the fishing effect parameter (δ for the Closure and λ for the Catch model) listed. Standard errors are given in brackets. Note that a negative value for either of these parameters implies fishing reduces penguin net reproductive success, and *vice versa*.

	St Croix	Bird
Closure model	-0.06 (0.43)	-0.02 (0.45)
Catch model	-0.25 (0.23)	0.20 (0.34)

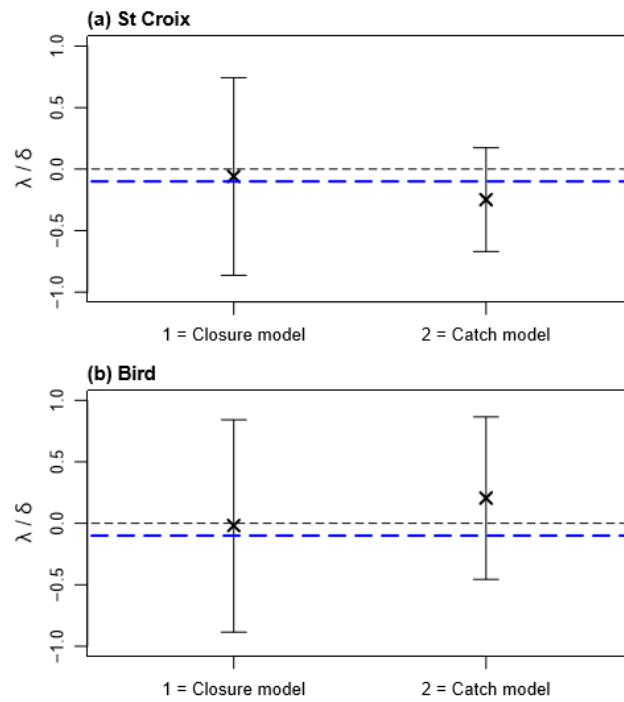


Figure 1: Zeh plots showing estimates of fishing effects in terms of λ (catch model) and δ (closure model) with their 95% confidence intervals. The black horizontal dashed line marks zero, while the blue dashed line marks the threshold value of -0.1, which was considered in the West Coast power analyses as the value below which the impact of fishing on the penguin population would be considered biologically meaningful.

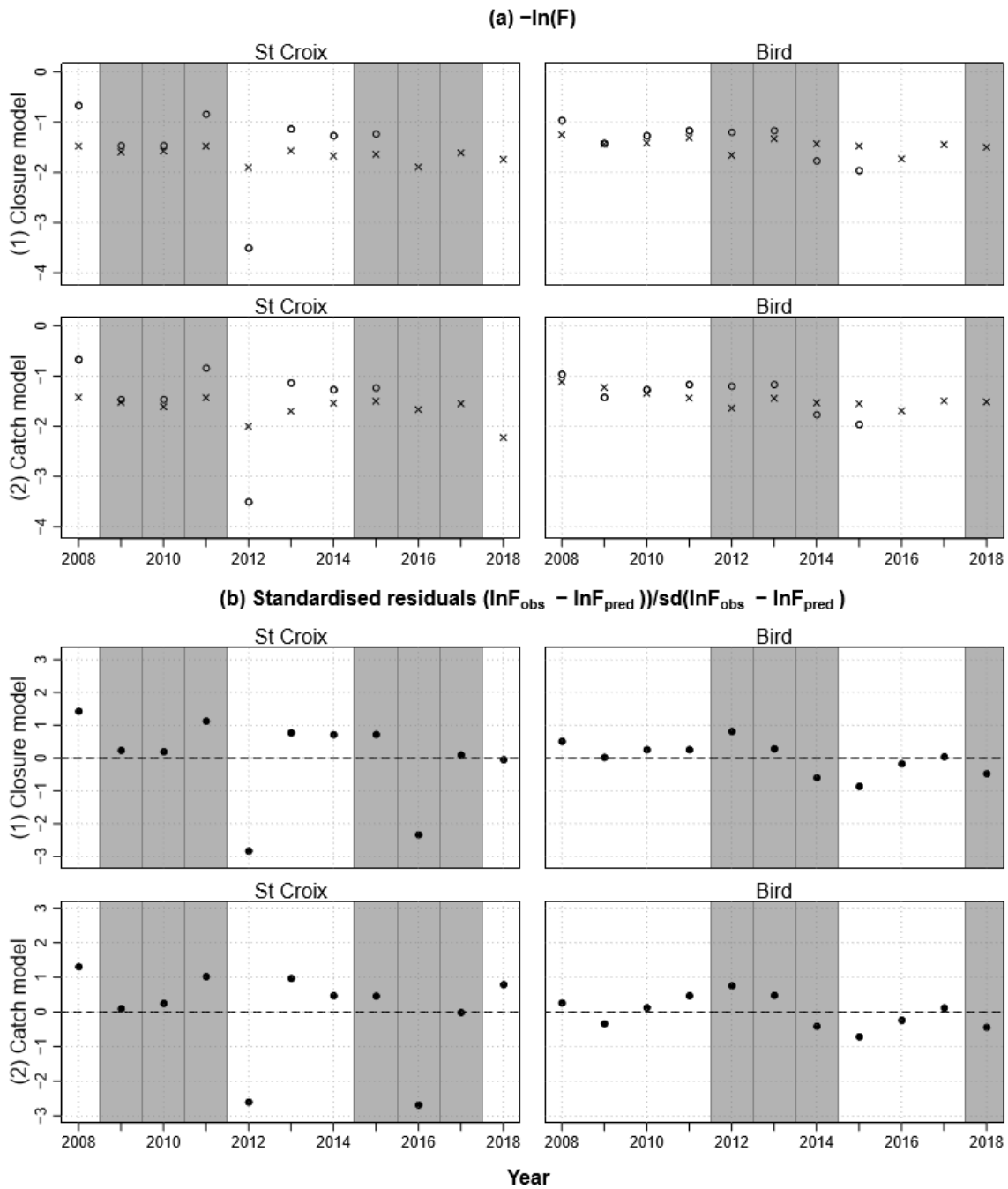


Figure 2: Section (a) shows plots of the data points (open circles) and the model fits (crosses) for when the mixed model is applied to South Coast chick condition data. Section (b) shows the associated standardised residuals. The grey shaded blocks mark the years for which the island in question was closed. Note that the 2016-2018 data points have been excluded from the plots in section (a) in terms of a six-month confidentiality agreement with DEA.