

Updated and Extended GLM results for the South Coast penguin colony foraging data

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Summary

The GLM model to estimate the impact of fishing on penguins at the St Croix and Bird Island colonies is updated given further data. While the additional data result in little change to the results for Bird Island, they suggest a lesser negative impact of fishing around St Croix on penguins than was the case previously. This seems mainly attributable to relatively poor values for penguin response variables at St Croix in 2016 when the neighbourhood of the island was closed to fishery.

Introduction

New foraging data have become available for the major penguin colonies on the South Coast: St Croix and Bird islands. The catch and closure mixed random effects models are applied to these new data (as in MARAM/IWS/DEC14/Peng/B12rev), and also to the old data for comparison purposes. (A different method is now used to analyse and summarise these data.)

Methods

The random effects model is given by the equation

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

where

- $F_{y,i}$ is the foraging trip response variable (one of foraging trip length, duration and maximum foraging trip distance), which has been transformed by taking the negative of the logarithm so that a larger negative number implies a more negative impact on the penguin population,
- 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,
- $C_{y,i}$ is the sardine catch taken in year y in the 20nm neighbourhood of island i ,
- \bar{C}_i is the average catch taken over the years for which island i is open to the fishery between 2008-2013, which corresponds to a value of 2746.67 for St Croix Island and 2227.5 for Bird Island for the 20nm catches, and 1870 for St Croix Island and 358 for Bird Island for the 18.148km catches,
- δ_i is a fishing effect,
- 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 close, 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. This model is applied to three data sets: the old data (which span 2008-2013 and were used to obtain the results reported in MARAM/IWS/DEC14/Peng/B12rev), the new data restricted to this same 2008-2013 period, and the full set

of new data covering 2008-2016. Note that first catches within 20nm were used rather than the 18.148km “closure” catches since the former are consistent with the catches utilised in MARAM/IWS/DEC14/Peng/B12rev. A subsequent implementation of the Catch model uses a 18.148km radius to define catches in the neighbourhood of an island, as this is better representative of the area to which the fishery closures correspond.

Table 4 presents the results of these model fits. Figure 1 shows plots of the new data along with the model predictions when the mixed models are applied to the full set of new data.

Discussion

Table 3 indicates some catches within 20nm of the islands in years of closure. Comparison with catch figures for distances within the 18.148km radius show that to an often large extent these reflect catches outside the closure area but within the 20nm, but this is not the case for St Croix over the 2009-2011 closures.

One might “expect” the catch model to be negatively biased as regards identifying a positive fishing impact on penguins because of the “Bergh effect” (which results from a positive correlation between catch and resource biomass as was found for anchovy off Robben and Dassen Islands). However in this instance the correlations are generally negative, particularly for the period to which the analyses refer (see **Error! Reference source not found.**, where the third option of considering the average of the biomass estimates at (roughly) the start and the end of the year seems the most appropriate given that catches are taken throughout the year). This is the case even when the biomass estimates are based (in part (b) of the Table) on the biomass east of Mossel Bay rather than on the complete region east of Agulhas. This warrants further discussion – possibly the survey biomass estimates used, even for the smaller area to the east of Mossel Bay, are inadequate for providing an indication of sardine in the neighbourhood of the islands. On the other hand, this perhaps weakens the basic reason for preferring results from the Closure to those from the Catch model.

Though results have been included for the maximum trip distance as this extra information was also provided, those results should probably be accorded less weight as a maximum distance is a less robust summary statistic than the means used for the other two response variables because of its sensitivity to outlier values.

For the Closure model, results in Table 4 for 2008-2013 differ little depending whether the “old” or “new” data are used, except for suggesting slightly less (positive) effects of fishing for Bird Island for this model.

Extending the data to 2016 makes little difference to the results for Bird Island. However for St Croix, the previous indications that fishing has a negative effect on reproductive success become weaker. The main reason for this is clear from Figure 1, which shows the poor results observed for response variables for St Croix in 2016, despite the island being closed to fishing that year; in contrast, data and model results for Bird Island in 2016 compare well.

The main features of the Catch model results are essentially the same as those for the Closure model, except perhaps for a tendency for the Catch model estimates of the parameter indicating the impact of fishing on penguins at Bird Island to become more positive (i.e. a lesser effect). Changing from catches within 20nm to ones within 18.148km tends to reduce the magnitude of these estimates slightly.

Table 1: The old annual foraging data from MARAM/IWS/DEC15/PengD/BG1 used to obtain the results of Appendix B of MARAM/IWS/DEC14/Peng/B12rev. Note: Under Closure, 1 means open to the fishery and 0 means closed.

Island	Year	Closure	Length	Duration
St Croix	2008	1	69.3	22.5
	2009	0	50.2	17.1
	2010	0	69.2	27.1
	2011	0	67.8	20.1
	2012	1	102.5	27.1
	2013	1	77.9	22.2
Bird	2008	1	36.5	15.3
	2009	1	40.0	18.4
	2010	1	52.1	20.5
	2011	1	55.7	23.4
	2012	0	62.6	20.0
	2013	0	40.4	13.2

Table 2: The new annual updated foraging data set (J. Coetzee *pers. comm.*)

Island	Year	Closure	Length			Duration			Max		
			Mean	se	n	Mean	se	n	Mean	se	n
St Croix	2008	1	79.39	6.74	20	22.88	1.62	20	33.18	2.02	20
	2009	0	47.88	4.54	15	16.36	1.08	14	19.67	1.87	15
	2010	0	66.79	5.81	18	26.11	2.19	17	24.90	1.66	22
	2011	0	64.19	3.60	20	20.05	1.06	23	21.86	1.59	21
	2012	1	92.30	4.54	20	27.10	2.27	20	36.72	1.50	20
	2013	1	75.38	2.66	66	21.88	0.83	68	27.74	1.09	70
	2014	1	79.06	6.41	26	27.29	2.13	28	30.53	1.91	28
	2015	0	57.38	5.83	14	21.00	1.77	14	21.00	2.23	13
	2016	0	110.45	13.45	11	42.55	5.03	12	35.96	6.32	12
Bird	2008	1	37.73	2.04	30	14.91	0.80	20	14.33	1.23	30
	2009	1	41.02	2.20	15	18.19	1.19	15	12.71	0.97	22
	2010	1	51.99	5.14	26	20.20	1.42	18	15.37	1.37	35
	2011	1	41.06	3.51	26	20.70	1.60	20	15.42	1.53	48
	2012	0	56.03	1.56	45	18.88	0.63	20	16.02	0.87	55
	2013	0	38.89	1.70	77	12.59	0.61	66	12.30	0.48	82
	2014	0	54.83	2.88	25	18.43	1.10	26	16.70	0.65	30
	2015	1	43.93	2.35	29	15.95	1.09	14	14.32	0.83	31
	2016	1	44.13	2.49	27	17.52	1.15	11	12.85	0.75	27

Table 3: Catch (tons) and closure data are given for the two islands. A closure value of 1 means the island was open to the fishery and a value of 0 that it was closed. The catches correspond to the sardine 20nm catches and the sardine catches taken within an 18.148km radius around each island, corresponding to the area closed to the fishery in closed years (see Tables 9 and 16 of FISHERIES/2017/DEC/SWG-PEL/32; the data provider is Jan van der Westhuizen (DAFF)).

St Croix				Bird			
Year	Closure	Catch (20nm)	Catch (18.148km)	Year	Closure	Catch (20nm)	Catch (18.148km)
1987	1	0	0	1987	1	0	0
1988	1	0	0	1988	1	0	0
1989	1	12	7	1989	1	0	0
1990	1	163	108	1990	1	40	5
1991	1	471	302	1991	1	16	3
1992	1	231	144	1992	1	58	8
1993	1	143	92	1993	1	0	0
1994	1	355	234	1994	1	31	0
1995	1	509	316	1995	1	0	0
1996	1	614	421	1996	1	0	0
1997	1	36	25	1997	1	0	0
1998	1	2660	1757	1998	1	0	0
1999	1	1482	1065	1999	1	0	0
2000	1	668	435	2000	1	0	0
2001	1	1100	749	2001	1	20	0
2002	1	4105	2813	2002	1	12	2
2003	1	14818	10097	2003	1	0	0
2004	1	3976	2679	2004	1	90	11
2005	1	1071	708	2005	1	125	15
2006	1	9485	6188	2006	1	5570	209
2007	1	2606	1638	2007	1	5854	627
2008	1	491	312	2008	1	3600	601
2009	0	320	197	2009	1	3214	218
2010	0	1736	1230	2010	1	2028	568
2011	0	678	617	2011	1	68	45
2012	1	4466	3149	2012	0	205	40
2013	1	3283	2149	2013	0	420	0
2014	1	479	407	2014	0	9	0
2015	0	0	0	2015	1	0	0
2016	0	308	126	2016	1	511	106

Table 4: GLM estimates of the fishing effect parameter (δ for the Closure and λ for the Catch model) are given for these models applied to different data sets and foraging trip response variables. Standard errors are given in brackets. (Note that a negative value for either of these parameters implies fishing reduces penguin reproductive success, and *vice versa*.) The Closure model (A) and the Catch model (B and C) were applied to the old data set for the 2008-2013 year range, the new data set restricted to the 2008-2013 year range and the full new data set (2008-2016). The foraging trip response variables were foraging trip length, duration and maximum foraging trip distance (note that these enter the regressions as the negative of the logarithm of the variable). Since the maximum foraging trip distance data are not available in the old data set, these entries are blank in the table. The catch model was implemented using the catches within 20nm (B) and within 18.148km (C). The significance levels indicated are approximate because there are different views of how to account for degrees of freedom in random effects models.

(A) Closure model			
Data set	Response variable	St Croix	Bird
Old data 2008-2013	Length	-0.39 (0.08)**	0.06 (0.08)
	Duration	-0.20 (0.15)	-0.16 (0.16)
	Max		
New data 2008-2013	Length	-0.39 (0.11)**	0.10 (0.12)
	Duration	-0.24 (0.14)*	-0.15 (0.15)
	Max	-0.41 (0.06)**	0.01 (0.06)
New data 2008-2016	Length	-0.21 (0.13)*	0.13 (0.14)
	Duration	-0.05 (0.16)	-0.09 (0.16)
	Max	-0.28 (0.11)**	0.05 (0.11)
(B) Catch model (20nm)			
Data set	Response variable	St Croix	Bird
Old data 2008-2013	Length	-0.32 (0.11)**	0.21 (0.09)**
	Duration	-0.23 (0.13)*	0.09 (0.12)
	Max		
New data 2008-2013	Length	-0.26 (0.13)**	0.08 (0.11)
	Duration	-0.22 (0.13)*	0.04 (0.12)
	Max	-0.26 (0.11)**	0.09 (0.10)
New data 2008-2016	Length	-0.14 (0.13)	0.08 (0.11)
	Duration	-0.04 (0.15)	0.01 (0.13)
	Max	-0.17 (0.11)*	0.05 (0.10)
(C) Catch model (18.148km)			
Data set	Response variable	St Croix	Bird
Old data 2008-2013	Length	-0.30 (0.13)**	0.11 (0.10)
	Duration	-0.21 (0.14)*	0.05 (0.11)
	Max		
New data 2008-2013	Length	-0.26 (0.13)**	0.00 (0.11)
	Duration	-0.20 (0.13)*	0.00 (0.11)
	Max	-0.24 (0.12)*	-0.00 (0.10)
New data 2008-2016	Length	-0.12 (0.13)	0.03 (0.11)
	Duration	-0.03 (0.14)	-0.02 (0.12)
	Max	-0.16 (0.11)	-0.00 (0.10)

**Estimate is more than 1.96se's away from zero (~5% significance level)

*Estimate is more than 1.44se's away from zero (~15% significance level)

Table 5: The Pearson correlation coefficient for the catch-biomass regression is given for the two islands for (a) a regression between the sardine catches within 20nm and the sardine biomass east of Agulhas and (b) the catches within 18.148km and biomass from Mossel Bay to Port Alfred (see Table 9 and 16 for catches and Table 11 for biomass estimates in FISHERIES/2017/DEC/SWG-PEL/32). The regressions were conducted using (i) catch in year y regressed against biomass in year y , (ii) catch in year y regressed against biomass in year $y-1$, and (iii) catch in year y regressed against the average biomass from year y and year $y-1$. The correlation coefficients are shown for all the available data from 1987-2016 and for the data subset from 2008-2016

	St Croix			Bird		
(a) 20nm	(i) C_y to B_y	(ii) C_y to B_{y-1}	(iii) C_y to $(B_{y-1}+B_y)/2$	(i) C_y to B_y	(ii) C_y to B_{y-1}	(iii) C_y to $(B_{y-1}+B_y)/2$
1987-2016	0.49	0.65	0.60	-0.20	-0.07	-0.14
2008-2016	-0.66	0.18	-0.69	-0.42	-0.53	-0.71
(b) 18km	(i) C_y to B_y	(ii) C_y to B_{y-1}	(iii) C_y to $(B_{y-1}+B_y)/2$	(i) C_y to B_y	(ii) C_y to B_{y-1}	(iii) C_y to $(B_{y-1}+B_y)/2$
1987-2016	0.49	0.51	0.55	-0.21	-0.18	-0.22
2008-2016	-0.42	0.10	-0.12	-0.34	-0.61	-0.65

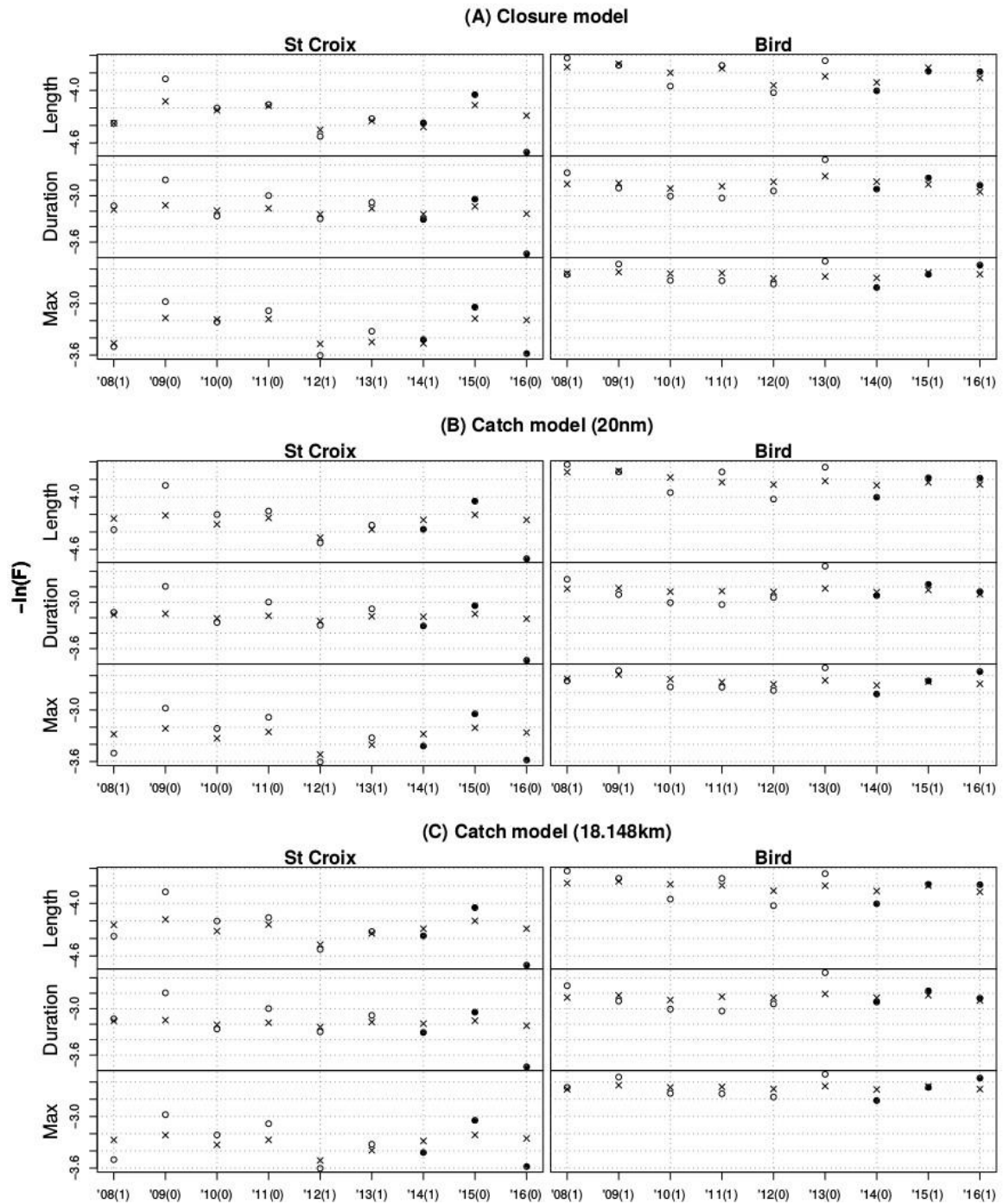


Figure 1: Plots of the data points (open circles for data up to 2013 and closed circles for data post 2013) and the model fits for when the mixed model is applied to the full new data set (crosses). The horizontal axis indicates the year and whether the island was open (1) or closed (0) to the fishery.