A revised summary of results for the island closure experiment

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Summary

A simple summary is offered of the results of the island closure experiment reported in Ross-Gillespie and Butterworth (2021a and b), which have implemented the suggestions of the December 2020 International Panel for now all the response variables in as consistent a manner as possible. A single result is selected for each island/response variable combination, with reasons provided for preferring the aggregated data approach for this, and with increases made to the CI estimates so as to correspond to the unbiased REML method. Integration across the results is problematic for various reasons, but a coarse summary indicates very little evidence for any impact (in either direction) of fishing in the neighbourhood of island colonies on penguin population growth rates. Given that the islands in the experiment have been closed for 50% of the period since 2008, some coarse predictions for the extent of improvement in annual population growth rates (on average over time) were these islands to be closed to fishing every year in the future, are: Dassen -0.25% (i.e. no improvement), Robben +0.25%, Bird 0% and St Croix +0.5%.

Key words: penguin, island closure, fishing impact, REML

Introduction

Ross-Gillespie and Butterworth (2021a) and Ross-Gillespie and Butterworth (2021b) (an update of the former) provide results for implementing the suggestions of the December 2020 International Panel for further analysis of the results from the island closure experiment. These suggestions included, in particular, the use the same data within a common framework to facilitate comparisons, and also the inclusion of month as a covariate via GLM-standardisation of the data.

However, those two documents are lengthy and complex, in part because the authors attempted a comprehensive analysis and to keep the results and their summarisation "opinion-free".

This document consequently attempts a simple summarisation by providing (in nearly all cases) what the authors consider to be the single "best" estimate with a 95% CI for each island/response variable combination, and then proceeds to draw some overview inferences from these. In doing so though, certain of the selections made arguably involve some subjective elements, and other scientists might reasonably advance alternatives. Note that this document is a revision of Butterworth and Ross-Gillespie (2021), taking some of the additions and corrections of Ross-Gillespie and Butterworth (2021b) into account.

Results

Table 1 and Figure 1 show results for what are considered (for reasons given below) to be these "best" estimates and associated 95% CIs (approximated by two se's either side of the estimate) of the change in population growth rate (expressed as an annual percentage). These are based on the A3 approach of Ross-Gillespie and Butterworth (2021a) for all response variables other than fledging success and chick survival. Approach A3 applies the standard island-closure GLM with sample-size-weighted and island-dependent variance to month-standardised aggregated data. For fledging success and chick survival, unstandardised data are used, as information on month is not currently available for these two variables; furthermore, no disaggregated data are available as such, rendering attempts at sample size weighting

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problematic. Approach A2 of Ross-Gillespie and Butterworth (2021a) (no sample size weighting and island independent variance) was therefore applied for these two variables. More details on the reasons for this choice can be found in Appendices B and C of Ross-Gillespie and Butterworth 2021b.

Approach A3 was fit in ADMB rather than R, to allow for the variance parameter to be adjusted in relation to the sample size[2]. One disadvantage of ADMB is that it uses the Maximum Likelihood (MLE) method for estimating variance, while the Restricted Maximum Likelihood (REML) method is to be preferred as it provides unbiased estimates of variance. The MLE-derived CI's for the first six response variables in Figure 1 have consequently been scaled to approximate what the REML CI's would likely have been. To calculate this scaling factor, the ratios of the standard errors predicted by a similar application of a REML method (approach A2 of Ross-Gillespie and Butterworth 2021a) to those predicted by the equivalent MLE model were calculated (Table 7b of Ross-Gillespie and Butterworth 2021a). However, for fledging success and chick survival where sample size proved problematic to take into account directly, the models were coded in R to implement REML directly.

The estimates of percentage change in population growth rate are derived from the estimates of the fishing effect δ (or $\tilde{\delta}$) from the island closure GLM. More details of the derivation of these relationships can be found in Appendix A of Ross-Gillespie and Butterworth (2021b).

The data underlying the results in Figure 1 all correspond to the years from 2008 onwards (the first year of the island closure experiment is 2008) and have all been standardised for month, with the exception of fledging success and chick survival for which month information is not currently available. The results for fledging success and chick survival are thus for unstandardised data. Additionally, the results obtained when applying the island closure model for the whole period for which data are available (1989-2015) have been included for fledging success, as this is the one sensitivity that did show a marked difference, with the fishing effect estimated for the two islands switching signs (Ross-Gillespie and Butterworth, 2021a).

The motivations for selections made in providing "best" results for Figure 1 are as follows.

- Analysis of aggregated data (approach A) is preferred over analysis of disaggregated data (approach D), as the negative aspect of A (the adjustment for sample size is approximate) is outweighed by negatives for D (the concern for negative biases in CIs from pseudo-replication remains, plus the associated additional random effects lead to greater concern about estimation stability). The first two reasons are in line with the views expressed by the Panel for the December 2020 review, while the third (the estimation instability) has become evident during subsequent analyses.
- Month standardisation should be included (as indeed was recommended by the Panel) as it does impact the results in some cases. Approach A3 incorporates this and the other suggestions by the Panel. Where no month information is available directly (chick survival and fledging success), the simpler A2 approach (no sample-size weighting and island independent variance) has been implemented for the reasons set out in Appendices B and C of Ross-Gillespie and Butterworth (2021b).
- The REML approach is preferred as it give unbiased CI estimates, whereas those from MLE will be negatively biased (more so for smaller sample sizes).
- The analyses for the 2008+ data are generally preferred (i.e. excluding data prior to the start of the island closure experiment in 2008), as the addition of earlier data generally makes little difference to estimates and hardly reduces the CIs to the extent that might have been expected (Ross-Gillespie and Butterworth, 2021a). For fledging success however, the earlier data do have an impact, but there is not a clear basis to make the choice of whether including or excluding these early data might be considered more "representative"; accordingly both results are shown in Figure 1.

Discussion

There are some reasons why the results for some response variables might be accorded greater weight than others.

[2] By aggregating data annually, the standard estimation approach loses the information about the annual sample sizes. This can be addressed to a reasonable extent by adjusting the variance parameter by the inverses of these sample sizes each year (see Appendix A of Ross-Gillespie and Butterworth 2021a).

- The estimates for change in population growth rate caused by fishing are more reliable in absolute terms for chick condition, fledging success and chick survival, as there is a demographic model basis to link them directly to the population growth rate, rather than to have to rely on an assumption that a change in the value of the variable is related to a change in juvenile survival by a straight line through the origin.
- The chick growth series has not been continued after 2014.
- The CIs are generally large in the context of the result of interest (the change in the annual population growth rate related to fishing), though those for the chick condition and chick survival for the west coast islands are notably smaller (so that the associated estimates are more precisely determined).
- Only in one case for Robben, one for Dassen and two for St Croix are estimates of the effect of fishing on the population growth rate statistically significantly less than zero at the 5% level (though only marginally so for three of these four cases). In one case for Dassen the estimate is significantly greater than zero (again only marginally so).
- Of the three foraging related variables, maximum distance would *a priori* seem the least reliable, as maximum distance is a less statistically robust measure than others which integrate over the foraging trajectory in question.
- Results for the three foraging related variables will not be statistically independent, and similarly chick condition and growth together with fledging success and chick survival will be related to some extent. This needs to be considered in any attempt at integrating the results, as it implies that not every variable considered should be equally weighted *a priori* (i.e. before taking estimation precision into account). In essence, there are only three or fewer “independent” sources of information for each colony, related to chick growth, adult foraging and chick survival.

Summary comments

Given the difficulties arising from the points listed above, it seems unwise to offer any single detailed algorithm for integrating across all the results from the closure experiment. Instead some views (which clearly could be debated) are offered, based on “human integration” of the results shown in Figure 1, to provide a broad overview.

- Patterns for the foraging related variables are not fully consistent over the four islands. There is some tendency for the changes in population growth rate, given fishing, to be positive for Dassen and negative for St Croix, with these values averaging close to zero for the other two islands.
- At a non-parametric level, considering the point estimates shown, there are equal numbers of positive and negative estimates of these changes in population growth rate, i.e. overall the indications from the experiment are that there is very little evidence for any impact (in either direction) of fishing in the neighbourhood of island breeding colonies of penguins.
- For the west coast colonies, there is weak preponderance of evidence for a negative effect of fishing compared to closure on penguins at Robben, but the reverse holds for Dassen.
- For the east coast colonies, there is some preponderance of evidence for a negative effect of fishing compared to closure on penguins at St Croix, but none at Bird. St Croix provides the only instance of a relatively large and statistically significantly negative effect of fishing (for the foraging maximum distance variable), but this is not mirrored by the results for the other two foraging variables for that island, which are arguably (see above) more reliable.

If offering “integrated” (though still very coarse) “best” numerical estimates of the percentage effect of fishing compared to closure on population annual growth rates from these results (where a negative value means that fishing results in a lower population growth rate), these might be:

Dassen	+0.5%	(i.e. closure does not benefit penguins)
Robben	-0.5%	
Bird	0%	
St Croix	-1%	

One must bear in mind, however, that the neighbourhoods of these four islands have already been closed to fishing for 50% of the time for somewhat longer than the last decade. Hence, if these islands were now to be closed for every year in the future, the changes to current penguin annual growth rates (on average over an extended period of years) would be predicted to be only half of the values shown.

References

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Table 1: Estimates of percentage change in annual population growth rate as a result of fishing (i.e. a negative value indicates that fishing reduces the penguin population growth rate compared to closure), along with the lower and upper bound of the approximate 95% confidence intervals (given by $\pm 2se$). The corresponding Zeh plots can be seen in Figure 1. The estimates for chick condition, chick growth and the foraging data are from Approach A3 with REML adjustment. The estimates for fledging success and chick survival are from Approach A2 with REML implemented directly. More details of these approaches are given in the main text. The estimated change in annual population growth rate was converted from the fishing effect estimated by island-closure GLM using the conversion factors detailed in Appendix A of Ross-Gillespie and Butterworth (2021b).

Island	Response variable	Estimate	Lower CI bound	Upper CI bound
Dassen	Condition	0.06	-0.77	0.90
	Growth	1.74	-0.99	4.48
	Maximum distance	-0.73	-2.92	1.46
	Path length	1.26	-0.79	3.31
	Trip duration	2.86	0.09	5.64
	Fledging success ≥ 2008	-0.73	-2.35	0.89
	Fledging success all data	0.92	-1.87	3.71
	Survival	-1.20	-2.29	-0.10
Robben	Condition	-0.92	-1.75	-0.09
	Growth	0.25	-2.67	3.16
	Maximum distance	-0.16	-2.24	1.92
	Path length	-0.77	-2.65	1.11
	Trip duration	0.37	-2.34	3.07
	Fledging success ≥ 2008	0.32	-1.35	1.99
	Fledging success all data	-1.75	-4.75	1.25
	Survival	-0.10	-1.20	0.99
Bird	Condition	-0.26	-1.85	1.33
	Maximum distance	0.21	-1.03	1.46
	Path length	0.87	-0.77	2.52
	Trip duration	-1.35	-2.84	0.13
St Croix	Condition	0.65	-0.83	2.14
	Maximum distance	-3.18	-4.52	-1.83
	Path length	-1.92	-3.64	-0.20
	Trip duration	0.03	-1.43	1.49

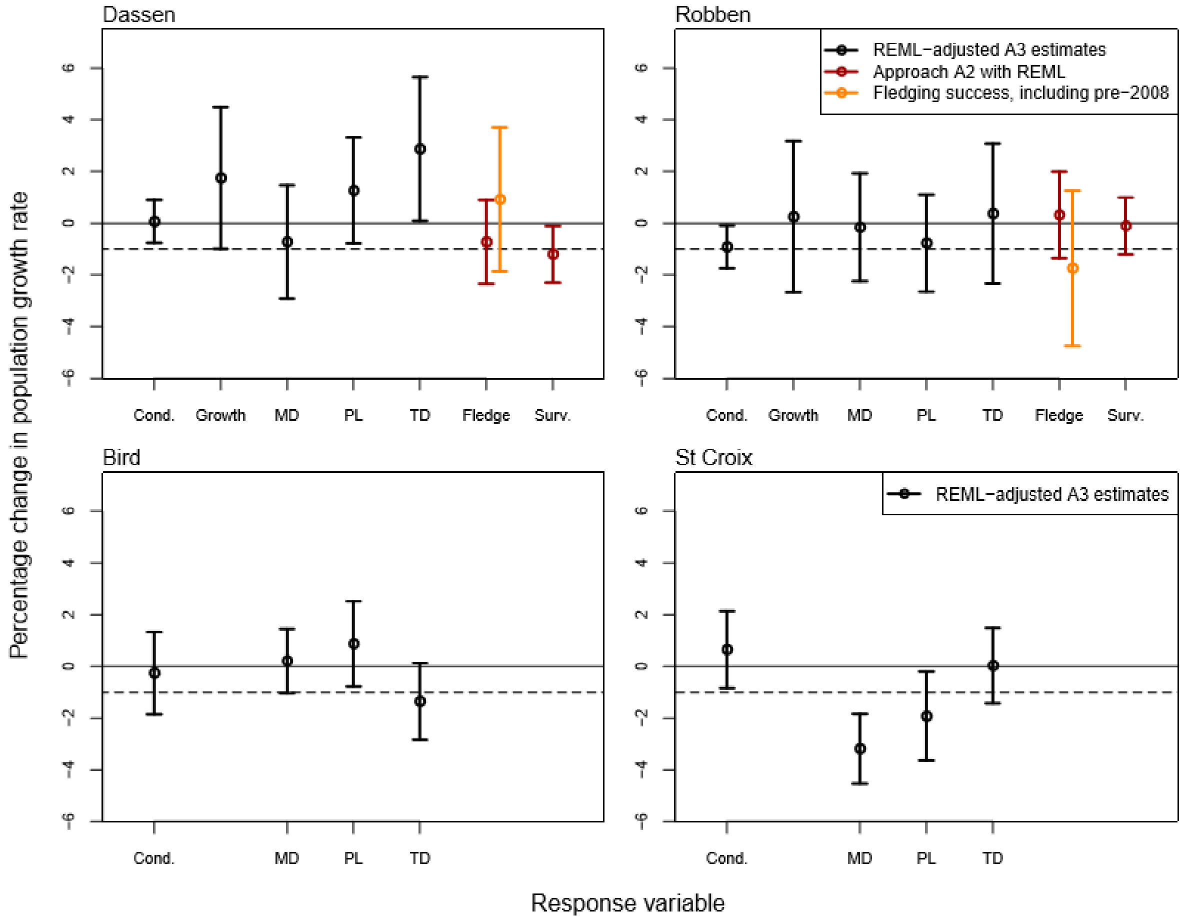

Figure 1:. Zeh plots of the estimates of change in population growth rate as a result of fishing (expressed as a percentage per annum) for the A3 approach of Ross-Gillespie and Butterworth (2021b), which for reasons given in the text is considered to provide the best results from the closure experiment. The response variables MD, PL and TD from the foraging data refer respectively to maximum foraging distance, path length and trip duration respectively. Except for fledging success and survival rate for which REML estimates are available directly, the black error bars have been expanded to reflect the preferred REML rather than MLE method for (95%) CI calculation in the manner explained in the text. All results are for the period commencing in 2008, except that the yellow point indicates the results for fledging success when the pre-2008 data are also included in the analysis.