

A simple summary of the penguin island closure analyses

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This document attempts to summarise in 'lay-mans' terms the results currently available from two different sets of analyses about the penguin island closure experiment to assist SWG-PEL participants in management and potentially further analysis/experiment recommendations.

Much of the debate about the analyses undertaken to determine if purse-seine fishing around penguin colonies has a negative impact on penguin reproductive success has been very technical and detailed. Rigorous technical debate is not a bad thing. However, the detail of the debates has resulted in the number of Small Pelagic Scientific Working Group (SWG-PEL) participants involved in such discussions becoming very small. Management recommendations are going to need to be made by the whole SWG-PEL. This document is therefore my brief 'lay-mans' summary of the analyses currently available and their corresponding results in an effort to involve more participants in the management decision process.

To start with some history first (though Coetzee 2019a provides this in more accurate detail), a feasibility study was initially held with the objective to "assist the design of an experiment which could have the potential to achieve adequate power within a realistic time period to confirm the effects of closure [to pelagic fishing in areas near to colonies] on African penguins" (Butterworth 2010). That feasibility study ended at the end of 2015 with the experiment continuing with 3-year rotational closures after feasibility study results indicated that this experiment "could yield definitive conclusions regarding the impact of fishing close to penguin breeding islands on penguin populations" (Dunn *et al.* 2015). The 2019 international review panel recommended "shifting the debate from estimation models to the consequences of the estimates." (Die *et al.* 2019). The SWG-PEL received and discussed a proposal to make a recommendation with regards to future island closures by the end of 2020 and it is my understanding that there was general agreement to this proposal (Coetzee 2019b, DAFF 2019).

The primary question that the SWG-PEL will need to address in the next couple of months is whether 20km radius areas around penguin islands should be closed to purse-seine fishing. The sub-question(s) include which islands should be closed / open, for what period of the year and for how many consecutive years the closure should be in force until a review is undertaken.

All of what is mentioned below is already available in various detailed documents. I am simply attempting to pull out key summaries here.

There are two primary sets of analyses currently available to the SWG-PEL. Both analyses use general(ised) linear mixed-effects models (GLMMs) to evaluate whether the 2008-2018 experiment presently shows any [biologically meaningful] negative impact of purse-seine fishing for sardine and anchovy on penguins. Reworded, they are evaluating whether the [temporary] cessation of purse-seine fishing around the islands ("closure") is beneficial to penguins. The GLMMs use "fixed" and "random" effects. In most

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cases, the variables of interest (for our management decision purposes) are fixed effects. Some sources of variation which should be modelled but require a large number of parameters to estimate as fixed effects can rather be estimated as random effects.

Both sets of analyses use data from the duration of this 2008-2018 experiment (Sherley using “individual” data and Butterworth and Ross-Gillespie using “annual aggregated” data), although Butterworth and Ross-Gillespie sometimes additionally use data from before 2008 – this is noted in the Appendix.

There are two primary parts to the Butterworth and Ross-Gillespie analyses. The first part is as mentioned in the previous paragraph. Their GLMM considers a random intercept using year (random effect), an island (fixed effect), and an ‘island closure’ interaction (fixed effect) and an error term for each year and island. The key results are the estimate of the “fishing effect” (a MLE estimate with associated SE) for each set of ‘penguin performance’ data. The second part calculates the power of this experiment to detect any such impacts – if they exist - in the future from this same experiment, should it continue unchanged. This second part has only been undertaken for West Coast Islands.

Sherley’s GLMMs consider nested random intercepts (the exact random effect depends on the structure of the dataset), an island (fixed) effect, a closure (fixed) effect, an ‘island closure’ interaction (fixed effect) , a sardine biomass (fixed) effect, and an anchovy biomass (fixed) effect, and the residual standard error. For maximum distance and path length models, an additional brood mass fixed effect is also added (MARAM/IWS/DEC19/Peng/P4). The key results are the estimates of the “fishing effect” (a Bayesian posterior mean and associated 95% HPDI) for each set of ‘penguin performance data’.

While neither set of analyses is “perfect” – not that any model ever is (Box 1976) – Table 1 is my attempt at summarising what can currently be usefully said about the impact of closure on penguins based on this experiment. The original values from each of the different sets of analyses that underlie this summary table are given in the Appendix. Figure 1 is a graphical representation to understand how one can determine whether these analyses can suggest if fishing is having an effect on penguins or if, for example, the experiment can’t provide such information.

It therefore appears that:

- Both sets of analyses currently show that the closure of Robben Island to fishing will benefit penguins.
- Both sets of analyses currently show that the closure of St. Croix Island to fishing will benefit penguins.
- Both sets of analyses currently show that the closure of Dassen Island to fishing will benefit penguin chick survival, but the overall benefit is not clear given some results from Butterworth and Ross-Gillespie which suggest the closure of Dassen Island to fishing may be detrimental to chick growth, path length and trip duration?
- Sherley’s results suggests this experiment could not inform on the impact of fishing to penguins on Bird Island, while a power analysis from Butterworth and Ross-Gillespie may help ascertain whether extending the experiment at this Island may produce more informative results.

If the above summary is correct, this would help guide the SWG-PEL in what recommendations can currently be made and where any future analyses, if required, should be focused.

Finally, it is worth stepping back and noting that these analyses have evaluated the ability to detect impacts of fishing around the penguin islands based from *this particular experiment*. The 3-year rotational open-closed design was selected partly opportunistically and partly as an attempt to balance maximising contrast (rapid opening/closing) and effectively measuring the impact on parameters (some ‘penguin performance’ data were argued to likely improve after multiple (3-6) consecutive years of closure). *This particular experiment* has shown that closure of some islands to fishing benefits some penguin performance data. One needs to remember that for the cases where impacts have not been detected, this does not imply these impacts could not potentially be detected with a different experiment (e.g. 2 or 4 year opening/closing or 5 year closed-2 year open rotation etc.). While I’m not suggesting we start a completely new experiment, I am simply noting the ‘limitations’ of these results.

Acknowledgements

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Table 1. Has the experiment conducted thus far shown that fishing around the island has a “biologically meaningful” negative impact on the following penguin performance parameters (which are taken to be (directly or indirectly) indicative of penguin reproductive success; some may additionally affect other demographic components):

Island	Penguin performance parameter	Butterworth and Ross-Gillespie	Sherley
Robben	Chick growth	Experiment can't inform	
	Chick condition	Yes	Yes
	Fledging success	Yes	
	Path length	Experiment can't inform	
	Trip duration	Experiment can't inform	
	Max. distance	Experiment can't inform	Experiment can't inform
	Chick survival	No ^{Δ*}	Yes
Dassen	Chick growth	Is fishing benefiting penguins?	
	Chick condition	Experiment can't inform	Experiment can't inform
	Fledging success	Experiment can't inform	
	Path length	Is fishing benefiting penguins?	
	Trip duration	Is fishing benefiting penguins?	
	Max. distance	Experiment can't inform	Experiment can't inform
	Chick survival	Yes	Yes
St. Croix	Chick condition		Experiment can't inform
	Path length	Yes [#]	Yes
	Trip duration	Not yes. Need power analysis to advise if experiment could inform or not	
	Max. distance	Yes	Yes
Bird	Chick condition		Experiment can't inform
	Path length	Possibly no. Need power analysis to advise if experiment could inform or not	Experiment can't inform
	Trip duration	Yes [#]	
	Max. distance	Possibly no. Need power analysis to advise if experiment could inform or not	Experiment can't inform

[#] Although below the 10% threshold to be “biologically meaningful”, the SE is still wide meaning this is not conclusive.

^Δ Has a negative impact, but not below the 10% threshold to be “biologically meaningful”.

* The experiment needs to continue for 2 to 5 years before a biologically meaningful fishing effect is likely to be detected, if it is present.

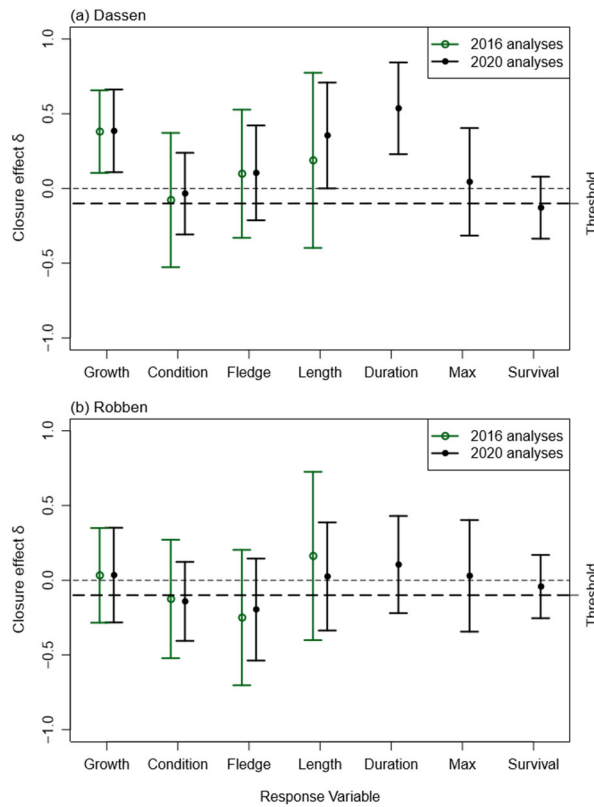


Figure 1a. This is Figure 2 of Ross-Gillespie and Butterworth (2020) – the green lines can be ignored for this summary. Dots (GLM-bias-adjusted estimates of the closure effect) below the thick horizontal line (-0.1 threshold) indicate a ‘meaningful biological effect’. The extent to which the $\pm 2SE$ bars extend over both the negative and positive range indicate how precisely the closure effect is estimated (or not) and thus how confident the analysts can be in suggesting if there is a negative effect of fishing around islands on the ‘penguin performance’ parameter.

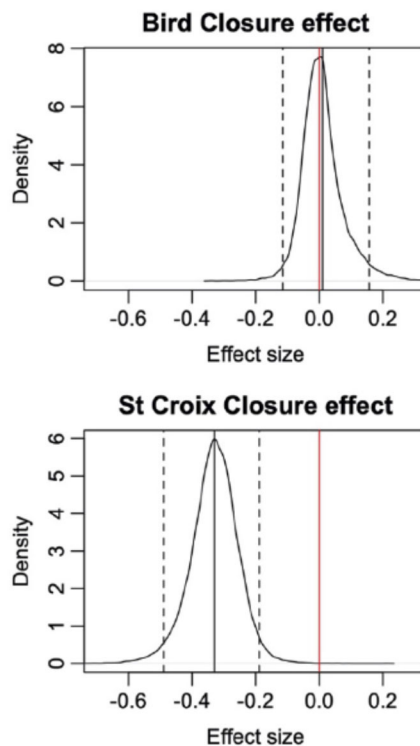


Figure 1b. This is from Figure 3 of Sherley (2020a). The solid line (mean) below -0.10 indicate a ‘meaningful biological effect’. The extent to which the dashed lines (95% HPDI) extend over both the negative and positive range indicate how precisely the closure effect is estimated (or not) and thus how confident the analyst can be in suggesting if there is a negative effect of fishing around islands on the ‘penguin performance’ parameter.

Appendix: Key tables of results extracted from papers

From MARAM/IWS/2019/PENG/P2. GLMM estimates of the fishing effect parameter for different foraging trip response variables¹. 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 $z = \delta - (-0.1)/SE$ values using rounded inputs are given in the **red**.

	St Croix		Bird	
Length	-0.19 (0.12)*	-0.75	0.06 (0.12)	1.33
Duration	-0.03 (0.13)	0.54	-0.14 (0.13)	-0.31
Max distance	-0.30 (0.10)**	-2.00	0.08 (0.11)	1.64

From FISHERIES/2020/JAN/SWG-PEL/09rev. GLMM and GLMM-bias-corrected estimates of the fishing effect parameter for different indices of penguin reproductive success. Again a negative value implies fishing reduces penguin reproductive success. The $z = \delta - (-0.1)/SE$ values using rounded inputs are given in the **red**.

Island	Data type	δ_{data}^{EM} (se)	δ_{data}^{EM*} (se)	
Dassen	Chick growth [^]	0.38 (0.14)	0.39 (0.14)	3.50
	Chick condition ⁺	-0.04 (0.14)	-0.03 (0.14)	0.50
	Fledging success ^{&}	0.10 (0.16)	0.10 (0.16)	1.25
	Forage length [§]	0.36 (0.18)	0.35 (0.18)	2.50
	Forage duration [§]	0.53 (0.15)	0.54 (0.15)	4.27
	Max length	0.05 (0.18)	0.04 (0.18)	0.78
	Chick survival [!]	-0.13 (0.10)	-0.13 (0.10)	-0.30
Robben	Chick growth [^]	0.03 (0.16)	0.03 (0.16)	0.81
	Chick condition ⁺	-0.14 (0.13)	-0.14 (0.13)	-0.31
	Fledging success ^{&}	-0.20 (0.17)	-0.20 (0.17)	-0.59
	Forage length [§]	0.03 (0.18)	0.03 (0.18)	0.72
	Forage duration [§]	0.11 (0.16)	0.10 (0.16)	1.25
	Max length	0.04 (0.19)	0.03 (0.19)	0.68
	Chick survival [!]	-0.03 (0.11)	-0.04 (0.11)	0.55

[^] Data from 1989-2014 ⁺ 2004 data may also be used? [&] Data from 1989-2015 [§] Data from 2003-2018 [!] Data from 2001-2015

¹ Which enter the regression as the negative of the logarithm of the variable.

From FISHERIES/2020/JUL/SWG-PEL/53rev. Posterior mean and +- 95% HPDI GLMM estimates of the fishing effect parameter for different parameters of penguin performance² for the best fitting model. Note a positive value for chick condition and survival and a negative value for max distance implies closure benefits penguin reproductive success.

	Robben	Dassen	St Croix	Bird
Chick condition ³	0.07 (-0.01,0.14)	0.03 (-0.03,0.10)		
Chick survival	0.38 (0.21,0.55)	0.38 (0.21,0.55)		
Max distance ⁴			-0.32 (-0.43,-0.21)	-0.01 (-0.08,0.07)

From FISHERIES/2020/JUL/SWG-PEL/53rev. Percentage GLMM estimates of the fishing effect parameter for different parameters of penguin performance resulting from averaging over all models using PSIS-LOO stacking weights. Note a positive value implies closure benefits penguin reproductive success.

	Robben	Dassen	St Croix	Bird
Chick condition ⁵	24% (-5%,52%)	13% (-12%,39%)		
Chick survival	10% (1%,18%)	10% (0%,20%)		
Max distance ⁶			32% (21%,43%)	1% (-7%,8%)

From FISHERIES/2020/SEP/SWG-PEL/87 (text) and FISHERIES/2020/SEP/SWG-PEL/89 (text and tables). Posterior mean and +- 95% HPDI GLMM estimates of the fishing effect parameter for different parameters of penguin performance for the best fitting model. Note a positive value for chick condition and survival and a negative value for max distance implies closure benefits penguin reproductive success.

	Robben	Dassen	St Croix	Bird
Chick condition ⁷	0.07 (-0.01,0.14)	0.03 (-0.03,0.10)	-0.08 (-0.19,0.03)	-0.04 (-0.15,0.08)
Chick survival	0.37 (0.16,0.57)	0.41 (0.11,0.70)		
Max distance ⁸	-0.03 (-0.14,0.09)	-0.01 (-0.15,0.14)	-0.32 (-0.43,-0.21)	-0.01 (-0.08,0.07)
Path length ⁹			-0.19 (-0.41,0.03)	-0.02 (-0.22,0.18)

From FISHERIES/2020/SEP/SWG-PEL/87 (text) and FISHERIES/2020/SEP/SWG-PEL/89 (text and tables). Percentage GLMM estimates of the fishing effect parameter for different parameters of penguin performance resulting from averaging over all models using PSIS-LOO stacking weights. Note a positive value implies closure benefits penguin reproductive success.

	Robben	Dassen	St Croix	Bird
Chick condition	24% (-5%,52%)	13% (-12%,39%)	-23% (-56 ¹⁰ %,10%)	-8.5% (-62%,49%)
Chick survival	10% (4%,16%)	11% (2%,20%)		
Max distance	2.4% (-9.5%,13.7%)	0% (-15%,15%)	32% (21%,43%)	1% (-7%,8%)
Path length			19% (-3%,41%)	2% (-18%,22%)

² All of these parameters should/could be considered as a proxy for penguin reproductive success in some direct or indirect way. Some (e.g. chick condition and the foraging metrics) additionally affect other demographic components.

³ Island nested in Year nested in Month random effects model.

⁴ BirdID random effects model.

⁵ Island nested in Year nested in Month random effects model.

⁶ BirdID random effects model.

⁷ Island nested in Year nested in Month random effects model.

⁸ Island nested in Year nested in BirdID random effects model.

⁹ Island nested in Year random effects model.

¹⁰ Updated/corrected from that reported in FISHERIES/2020/SEP/SWG-PEL/89.