Comments on the benefit to penguins of fishing restrictions around Robben Island predicted by Weller *et al.* Robben Island penguin model simulations

William M. L. Robinson and Doug S. Butterworth
Email: rbnwil004@myuct.ac.za

MARAM (Marine Resource Assessment and Management Group)
Department of Mathematics and Applied Mathematics,
University of Cape Town

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Introduction

The following comments relate to results in a recent publication (Weller *et al.*, 2014) that are pertinent to the discussions of the Island Closure Task Team, specifically the impact of fishing around Robben Island on the penguin population. Three scenarios were explored in that paper, each starting with 3500 adult penguins.

- The first scenario considers a complete cessation of fishing around Robben Island for 20 years. That paper reports that this results, on average, in a population increase "of ~8% of starting numbers" (corresponding to an increase of 289 ± 713 adults).
- The second scenario considers the effect of a single three-year fishing closure with climate and flooding effects enabled, as well as oil spills in 1998 and 2000. A set of 20-year simulations were run, with the closure starting in each run in years incrementing from 1988 to 2006. The mean result was an increase of 0.6% of starting numbers (corresponding to 22 ± 142 adults).
- A variant where three-year closures alternated with three-year fishing periods over 20 years was also tested (leading to an increase of 52 ± 327 adults).

The authors conclude that "although restricting fishing around the island was on average beneficial to the penguin population, variability in population growth introduced by fluctuations in prey biomass tended to mask the outcome."[1]

These results nevertheless indicate a clear pattern: the greater the restrictions on fishing around Robben Island, the more likely a benefit to the penguins, and the greater this benefit is likely to be. This contrasts sharply with the results in Robinson (2013) where the values of the parameters of relationships between the extent of fishing and measures related to penguin reproductive success are estimated, with the majority showing positive correlations (i.e. fishing enhances rather than diminishes penguin reproductive success).

[1] Weller *et al*. (2014) make this choice of scenarios to relate to the current closure programme for Robben Island, which they state is "to examine the effect of closing the area around a penguin colony to fishing". But their comment about "masking" suggests that they have misunderstood the intent of this programme. This is not to estimate this effect directly (though some results obtained already do provide information on that), but instead to provide estimates of process variance to enable the power of experimental closure programmes to detect the effect of closure on penguins to be determined.

Given this marked difference, it is important to examine the basis for Weller *et al*.'s quantitative results, to check what inputs are driving them and how reliable these are.

Methods

In the Weller *et al*. model (see Table 1 for details of the symbols used which are pertinent to the discussion here), availability of food to penguins has an effect on the survival of eggs and of chicks. (The equations are provided in the supplementary material for the paper.) Here we consider the equations for egg survival (hatching success). (The equations for chick survival are similar.) Monthly egg survival S_e is modelled as a logistic function:

$$S_\mathrm{e} = \frac{1}{1+\exp(-A)} \tag{1}$$

where A is a function of predator and climate pressures P, a food availability effect F, and an index B of the prey abundance available to penguins in Zone 1, which extends 15 nmi (28 km) from the island:

$$A = e_0 + P - FB \tag{2}$$

Here, e_0 is related to the mean egg survival $\bar{S}_\mathrm{e} = 0.649$ (a value which was found to result in a stable population alongside "reasonable" choices for chick, immature, and adult survival):

$$e_0 = -\ln\left(\frac{1}{\bar{S}_\mathrm{e}} - 1\right) \tag{3}$$

The pressures P and food effect F are independent of fishery catches. The food effect is defined as:

$$F = -e_0 - \ln\left[\frac{1+\exp(-e_0)}{E} - 1\right] \tag{4}$$

where the source of the value of the effect on eggs $E = 0.5$ is advised to be "expert opinion". The prey abundance indices B are calculated from the biomass of anchovy and sardine between Cape Columbine and Cape Point (survey stratum D) estimated in the annual May acoustic surveys and catches made by the purse-seine fleet in pelagic fishing blocks roughly covering the area within 30 nautical miles of Robben Island. These calculations assume that the recruit biomass is evenly distributed throughout Stratum D.

Discussion

Figure 1 provides example plots which show the relationship between egg survival S_e and the prey abundance index B for different values of E. All these plots are conditioned to give the value of $S_\mathrm{e} = 0.649$ for an equilibrium at prey abundance index $B = 0$. The role of the E parameter is clear from this plot—essentially it determines the extent to which the S_e value changes with prey abundance. Thus, for example, the further the value of E is set below 1, the more S_e will drop below the value which results in a stable penguin population, the poorer penguin reproductive success, and the faster penguin abundance will drop.

Thus the effect of food availability on egg survival is directly dependent on the magnitude of the value input for the E parameter. Similarly, the effect of food availability on chick survival (fledging success) is directly dependent on the value input for the corresponding effect parameter (denoted

%feC in the article), which was also set at 0.5 based on "expert opinion". Choices of values for these two food effect parameters directly determine the magnitude of the rate at which penguin populations are projected to change under different closure scenarios.

Evaluating the relative plausibilities of the contradictory results of Weller *et al*. (2014) and Robinson (2013) thus boils down to an evaluation of the justification underlying the values selected for the food effect parameters in the former using "expert opinion". To be able to evaluate the credibility of those selections, there needs to be an explanation of how these experts were able to estimate the magnitudes of these effects, and with results which must differ appreciably from most of the corresponding effects estimated directly from data by Robinson (2013) because of the diametrically opposed conclusions of the two analyses.

References

Robinson, W. M. L. 2013. Modelling the impact of the South African small pelagic fishery on African penguin dynamics. PhD thesis, University of Cape Town. xiv + 207 pp.

Weller, F., Cecchini, L.-A., Shannon, L. J., Sherley, R. B., Crawford, R. J. M., Altwegg, R., Scott, L., Stewart, T., and Jarre, A. 2014. A system dynamics approach to modelling multiple drivers of the African penguin population on Robben Island, South Africa. Ecological Modelling, 277: 38–56.

Table

Table 1: Symbols used in this document and in Weller *et al.* (2014).

Parameter	Symbol used here	Symbol in article	Value
Monthly egg survival	S_{e}	S_t^e	
Mean egg survival	$\bar{S}_{\mathrm{e}}$	mean egg survival	0.649
Egg survival logit	A	egg survival logit	
	e_0	e0	
Predator and climate pressure	P	catE∗cat abundance + sharkE∗shark abundance + heatE∗climate Heat + coldE∗climate Cold	
Food availability effect	F	food effect E	
Zone 1 prey abundance	B	z1	
Food availability effect on eggs	E	*%feE*	0.5
Food availability effect on chicks		*%feC*	0.5

Figure

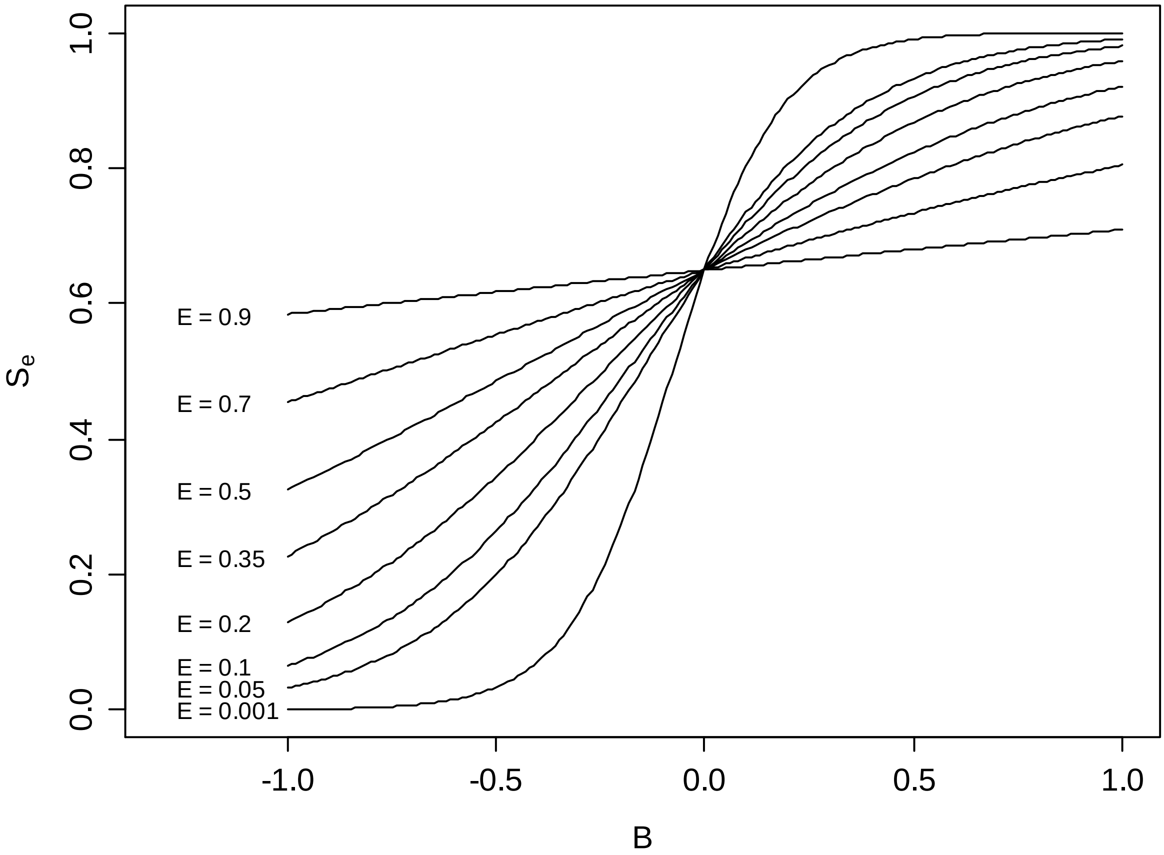

Figure 1: Egg survival as a function of the abundance index B for a range of values of the food effect size E, assuming average predator and climate pressures ($P = 0$). $B = 0$ corresponds to the median sardine and anchovy abundance (biomass) from Cape Columbine to Cape Point estimated in the annual May survey. $B = -1$ corresponds to no fish, and $B = 1$ corresponds to an abundance three standard deviations above the median. *B* varies piecewise linearly between these three points.