PENGUIN POWER ANALYSIS METHODOLOGY – DRAFT[1]

Penguin Island Closure Task Team[2]

This document indicates how the analyses which estimate the fishing effect parameters λ_i or δ_i are extended to estimate the power of an Island Closure Experiment. Statistical power reflects the probability that an experiment will detect an effect if it exists.

Methods

The estimator for a reproductive success parameter F is some variant of either the sub-regional biomass surrogate model:

$$\ln(F_{y,i,s}) = K + \alpha_y + \gamma_s + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \delta_i X_{y,i} + \varepsilon_{y,i,s} \tag{1}$$

or the regional biomass model:

$$\ln(F_{y,i,s}) = \psi B_y + \gamma_s + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \delta_i X_{y,i} + \varepsilon_{y,i,s} \tag{2}$$

for year y, island i, and data series s, where

$\widehat{K}_y$ is the best estimate of K,

α_y is a year effect reflecting prevailing environmental conditions,

ψ is a biomass effect,

B_y is the biomass within the pertinent region (e.g. SA coast west of Cape Agulhus for Dassen and Robben islands),

γ_s is a series effect (subsuming an island effect),

λ_i is a fishing effect,

δ_i is a closure effect,

$C_{y,i,p}$ is the catch taken in year y in the neighbourhood of island i of pelagic species p,

$\bar{C}_{i,p}$ is the average catch taken over the years considered, and (excluding years for which fishing was prohibited), and

$\varepsilon_{y,i,s}$ is an error term.

Future penguin response data for the biomass surrogate model of equation (1) are generated as follows:

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[1] This document is presented as "DRAFT" as the Task Team had insufficient time to discuss all aspects in full.

[2] The Task Team consisted of M.O. Bergh, D.S. Butterworth, K.L. Cochrane (chair), T.L. Morris, R.B. Sherley and H. Winker. A. Ross-Gillespie undertook, on behalf of the Team, all the analyses and tests, under the supervision of D.S. Butterworth.

$$\ln(F_{y,i,s})=\hat{K}+\hat{\alpha}_y+\hat{\gamma}_s+\hat{\lambda}_i\frac{C_{y,i,p}}{\bar{C}_{i,p}}+\hat{\delta}_i X_{y,i}+\varepsilon_{y,i,s} \quad (3)$$

where the basis for generating the quantities on the right hand side of this equation is as specified following equation (3) of MARAM/IWS/DEC15/PengD/P1; in future years when the island is taken to be closed to fishing, the final section of this document sets out the procedures to specify catches. Similar procedures are followed when the regional biomass model of equation (2) is being used.

The future data are appended to the historic time-series and extended for 20 years.

The data generated are fit to obtain estimates for λ_i and/or δ_i, and the associated *t*-probability using the estimator concerned.

The process is repeated a large number of times (1000 repetitions will be used).

Experimental power is calculated as the number of λ_i estimates which are statistically significant (at the 5% level) divided by the number of simulations performed.

Obviously power is not evaluated for cases where the estimate of the fishing effect is already significantly different from zero at the 5% level. Where this is not so, the probability of obtaining such a result with *n* additional years of data is calculated, with this *n* value being reported when this probability reaches 80% (reported as 20+ if not achieved after 20 years of further data).

Effect size

Effectively the approach outlined above is taking the effect size for the power analysis to be equal to the current best estimate of the fishing effect parameter λ_i or δ_i. This does however raise the problem that if that estimate is very small (perhaps so small as not to be meaningfully different from zero biologically), it is of no real interest to ascertain the exact value of the rather large number of years which would be needed to collect sufficient data to determine that the value had been distinguished from zero at the 5% significance level.

Instead therefore, for cases where the point estimate of λ_i or δ_i is small, it has been replaced by a fixed value, of the same sign as the point estimate of λ_i or δ_i, but of a magnitude which is (arguably) biologically meaningful. The actual fixed value chosen is 0.1. The justification for this choice comes from the following consideration of penguin population dynamics.

If penguin reproductive maturity is assumed to occur at age 4, the basic equation used by Robinson (2013) for the mature female component of the population (numbering *N* in year *y*) may be written:

$$N_{y+1}=N_yS+H_{y-3}S^3N_{y-3} \quad (4)$$

where *S* is the mature female annual survival proportion and *H* is a measure related to the product of egg production and fledging success. In a situation where the population is changing at a steady rate:

$$\eta=N_{y+1}/N_y \quad (5)$$

then

$$\eta^4=\eta^3S+HS^3 \quad (6)$$

which if *H* changes by Δ*H* leads to a corresponding change in penguin growth rate Δη given by:

$$\Delta\eta=\frac{S^3}{4\eta^3-3\eta^2S}\Delta H \quad (7)$$

Now results in Robinson (2013) suggest that for S=0.88, the Robben island penguin population abundance was approximately steady, so that substituting η=1 in equation (6) yields H = 0.176, and hence from equation (7):

$$\Delta\eta/\eta = 0.088\ \Delta H/H \qquad (8)$$

Now from differentiating equation (1), the relative change in the penguin response variable F arising from a suspension of fishing (C changes from $\bar{C}$ to 0, or X changes from 1 to 0) will be given by:

$$\Delta F/F = -\lambda \text{ or } -\delta \qquad (9)$$

so that if one assumes as a first approximation that a relative change in F results in the same relative change in H (i.e. $\Delta H/H = \Delta F/F$), it then follows that:

$$\Delta\eta/\eta = -\ 0.088\ \lambda\ \sim\ -0.1\lambda \quad (\text{or } \delta \text{ instead of } \lambda) \qquad (10)$$

If then 1% is to regarded as a meaningful change in the penguin population growth rate (to be achieved, conceivably, by a suspension of fishing in the neighbourhood of the colony concerned), it follows that the corresponding value for the magnitude of λ or δ is about 0.1, which is why this value was chosen for what is in effect a default minimum effect size above.

Future closure sequences

At the International Panel Review meeting in 2010 when the feasibility study was discussed (Parma *et al.*, 2010), the schedule of alternating closures, each of three years' duration, which was agreed was for Robben and then Dassen Island commencing in 2011. For St Croix, a three year closure period was to be completed by a further closure in 2011, which then was to be followed by three years of closure around Bird Island.

This schedule was implemented, with closures extending, approximately, for an 18km circular region around the islands. Thus closures are assumed to impact only the catch within this area, which is reduced to zero. However for models fitted to catches over greater distances from the islands, such as 20 and 30 nm, it is assumed that closures have no impact, as any catch that would have been made within the 18 km distance from the island seems most likely simply to be displaced to the area between 18 km and 20 nm from the island (i.e. procedure i) as set out following equation (7) of MARAM/IWS/DEC15/PengD/P1).

Example applications

The results from four example applications of the procedures above are reported in Table 1 below. Note that these results do not attempt any explicit process for taking account of estimator bias.

Table 1: Estimated number of further years after 2013 (the last year considered in the current forage trip duration analyses) that are required until at least 80% of the λ (TD0) or δ (TD2) estimated from 1000 generated data sets are significantly different (i.e. more than 2 times the standard error estimate away) from zero. The original biomass surrogate model estimates with their associated standard errors in parenthesis are provided. TD1 is the scenario modelling forage trip duration, catch only with anchovy catches at 20nm, while TD2 corresponds to forage trip duration, closure only with anchovy catches at 20nm (see section 8 of MARAM/IWS/DEC15/PengD/P2 for a fuller description of these scenarios). A * indicates that the value of 0.1 was used instead of the model estimate to generate the pseudo data – this in terms of the minimum effect size specification procedure detailed above. A value of zero (e.g. TD2, Dassen) indicates that the model estimate is already statistically significant at the 5% level. The variable ϕ denotes the value of the catch-biomass correlation used when generating future pseudo-data..

	Island	Original estimate (se)	Required years with $\phi = 0$	Required years with $\phi = 0.4$
TD0 (λ)	Dassen	0.18 (0.19)	>20	16
	Robben	0.32 (0.20)	8	4
TD2 (δ)	Dassen	0.45 (0.19)	0	0
	Robben	0.07* (0.19)	>20	>20

References

Parma A, Punt AE and Stefansson G. 2010 International Review Panel report of the 2010 International Fisheries Stock Assessment Workshop, 29 November – 3 December. Document MARAM/IWS/DEC10/REP/1: 1-14.

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