Island closure feasibility study power analysis results for Dassen and Robben islands[1]

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Abstract

The power analysis for penguin responses to fishing around Dassen and Robben islands has been completed. Response variables considered are chick condition, active nest proportion, fledging success, chick growth, foraging path length, and foraging trip duration. Although complete results are given here only for the first two of these variables, overall there are clear indications regarding the residual variances associated with these variables. Those variances are now estimable for Dassen and Robben islands with sufficient reliability to allow a decision on whether an experimental closure programme could yield definitive conclusions regarding the impact of fishing close to island colonies on penguin demographics within a realistic time span. Thus the purpose of the feasibility study has been achieved and the study can be concluded, with the island closure experiment commenced for these two islands. Definitive results from the experiment can be expected for both islands with about 2–4 years' additional data.

Introduction

This paper provides a power analysis for various penguin response (to the effects of fishing) variables for Dassen and Robben islands. Statistical power reflects the probability that an experiment will detect an effect if it exists. This work follows on from the GLM analyses reported in Robinson (2013). A key component of those analyses was estimation of residual variances, and of the precision of those variance estimates; both of these are key prerequisites for being able to conduct a power analysis reliably.

Method

The GLM conducted for a penguin response variable *F* is

$$\ln\left(F_{y,i}\right) = \alpha_y + \beta_i + \lambda_i \frac{C_{y,i,p}}{\bar{C}_{i,p}} + \varepsilon_{y,i} \quad (1)$$

for year *y* and island *i*, where

α_y is a year effect reflecting prevailing environmental conditions,

[1] Results of the power analyses for four of the six response variables are not shown in Tables 4–7 of this paper, because collectors of those data have recently indicated requests that those data not be used for these analyses (at least at this time). The matter of the acceptability or otherwise of such a withdrawal of data is a matter for the ICTT and PWG to decide. Should that decision be that it is not acceptable to withdraw these data in this way at this stage, an alternative version of this document which provides those additional tabular results, together with an associated revision of the Results and Conclusions sections of this paper, will be tabled at the meeting concerned.

β_i is an island effect,

λ_i is a fishing 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

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

Following Brandão and Butterworth (2007), future penguin response data are generated as follows:

$$\ln(F_{y,i}) = \hat{\alpha}_y + \hat{\beta}_i + \hat{\lambda}_i \frac{\hat{C}_{y,i,p}}{\bar{C}_{i,p}} + \hat{\varepsilon}_{y,i} \quad (2)$$

where

$\hat{\alpha}_y$ are generated by sampling with replacement from estimates for α_y,

$\hat{\beta}_i$ are the best estimates of β_i,

$\hat{\lambda}_i$ are the best estimates of λ_i,

$\hat{C}_{y,i,p}$ are generated by sampling with replacement from the time-series of observed catches for years in which the island concerned is "open" to fishing, and zero[2] otherwise, and

$\hat{\varepsilon}_{y,i}$ are generated from $N(0, \hat{\sigma}_\varepsilon^2)$, where $\hat{\sigma}_\varepsilon^2$ is the variance of the residuals when the model is fit to the historic data.

The future data are appended to the historic time-series. The GLM is fit to the full (historic plus future generated) data series to obtain estimates for λ_i and the associated *t*-probability. The process is repeated a large number of times (e.g. 500). 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.

Response variables

A variety of penguin response series of different lengths are available for Dassen and Robben islands (Table 1). The analyses reported below evaluate the power of detecting a fishing effect for the first two of these series. For better power, longer existing series and lower residual variance are desirable.

With each response variable, six pelagic catch series have been considered, namely sardine, anchovy, and the combined total taken within either the 20 nmi or 30 nmi fishing blocks around the island concerned. In each case, the estimate of the fishing effect λ is given, with the associated standard error and *t*-probability (Table 2). A *t*-probability of less than 0.05 indicates that the λ estimate is significantly different from zero at the 5% level.

[2] Because in reality some fishing typically does take place around an island in years that it is "closed" (as the closed area is smaller than the area that contributes to the catch series), power is likely to be overestimated slightly.

Power after *n* years

In cases where the estimate of λ is not significantly different from zero, the probability of obtaining such a result with *n* additional years of data is calculated. As an illustration of how power increases with *n*, such results are tabulated for the chick condition response variable (Table 3).

Variations

1. Experimental power can be compared for different closure patterns. For chick condition we report the power after *n* years for the current pattern of alternating three-year closed and open periods (Table 3a), as well as for permitting fishing in all years (Table 3b). For each response variable we report the number of years required to achieve 95% power in each case (Table 4).
2. There is uncertainty about the true residual variance σ_ε^2. When generating future data with equation (2), the current estimate of the residual standard deviation $\hat{\sigma}_\varepsilon$ is used, but the true value may be higher, resulting in lower power. As a worst case scenario, we test power using the upper 95% confidence limit[3] for the residual standard deviation (Table 3c and Table 4).
3. Instead of using the best estimates of λ_i for $\hat{\lambda}_i$ in equation (2), alternatives for this effect size could be tested. The reason for suggesting this is that the process above indicates power only for the case that the current best estimate of λ_i happens to be exactly correct. Thus if this estimate is positive (fishing benefits penguins), we discover only how long it will take to confirm that possibility. In most instances however (Robinson, 2013), the current best estimate is not significantly different from zero, i.e. the lower 95% confidence bound for the estimate is negative (fishing disadvantages penguins). We report the results of repeating the power computations for that lower bound, to show how long it would take to confirm a situation that that negative number lies within a distribution 95% of which is negative (i.e. sufficient to confirm the interaction is affecting penguins negatively). Correspondingly, for cases where $\hat{\lambda}_i < 0$ but is not significantly different from zero, we report the results assuming that the upper 95% confidence limit is the true value (Table 5).

Results

Table 6 and Table 7 list the catch series which achieve 95% power in the shortest time for each of the response variables. These results indicate that the catch series associated with the shortest time to achieve the requisite power varies widely both in respect of species and distance from the island. With the current pattern of fishing closures:

- Active nest proportion already has a significantly positive estimate for λ_{Robben} with each of the anchovy and total 20/30 nmi catch series. This contrasts with minimally 2 further years of data required for chick condition.
- In cases where the current estimates for λ are not significantly different from zero, achieving 95% power takes 1–4 years longer without island closures (chick condition: 2–4 years longer, active nest proportion: 1 year).
- In cases where the current estimates for λ are not significantly different from zero, if the residual variance is at the upper 95% confidence limit, achieving 95% power takes 0–3 years longer with chick condition, and 2 years longer with active nest proportion.

[3] Given by adding two standard errors to the point estimate for σ_ε.

- In cases where the current estimates of λ_{Dassen} are positive but not significantly different from zero, if these estimates have the wrong sign, it would need at least 9 further years to confirm that (chick condition: >20 years, active nest proportion: 9 years).
- In cases where the current estimates of λ_{Dassen} are negative but not significantly different from zero, if these estimates have the wrong sign, it would not be possible to confirm this within a further 20 years for chick condition.
- In cases where the current estimates of λ_{Robben} are positive but not significantly different from zero, if these estimates have the wrong sign, it would need at least 10 further years to confirm that (chick condition: 10 years, fledging success: 17 years).
- In cases where the current estimates of λ_{Robben} are negative but not significantly different from zero, if these estimates have the wrong sign, it would need at least 6 further years to confirm that for chick condition.

Conclusions

- If the current estimates for λ and σ_ε reflect the actual values, then power analysis indicates that estimates for λ which are significantly different from zero can be expected within:
  - 2 further years for Dassen Island with for chick condition (active nest proportion already significant);
  - 4 further years for Robben Island for chick condition (active nest proportion already significant).
- Without fishing closures, obtaining estimates for λ which are significantly different from zero would typically take about 1–4 years longer.
- Power is similar to that indicated in the first bullet point in the case where the upper 95% confidence limit is used for σ_ε, with a further period of 0–2 years required for statistical significance.
- If the estimate for λ is positive/negative and the true value of λ is at the current lower/upper 95% confidence limit, then showing that the true value is significantly different from zero will likely take substantially (typically at least a decade) longer.
- At this stage the active nest proportion response variable already gives some statistically significant results.

The purpose of the feasibility study has been to estimate the residual variances associated with penguin response variables with sufficient precision that experimental power can be determined with adequate reliability. This is to be able to decide on whether an experimental closure programme could yield definitive conclusions regarding the impact of fishing close to island colonies on penguin demographics within a realistic time span (which would probably be taken to be within one or possibly two decades). The results above indicate clearly that such a determination is now possible for Dassen and Robben islands for the chick condition and active nest proportion variables. The estimates of residual variance and the associated precision for the other four variables (see Table 1) are sufficiently similar to those for these two variables as to indicate that the same conclusion would apply for the other four as well. It thus follows that the feasibility study can now be concluded and the island closure experiment commenced for these two islands. Definitive results from this experiment can be expected for both islands with about 2–4 years' additional data. (These include data for 2013 which are not yet available.)

Future work

A similar analysis could be performed to calculate the power of the Algoa Bay island closure experiment involving St Croix and Bird islands. The available time-series are foraging path length and trip duration.

References

Brandão A and Butterworth DS. 2007. An initial analysis of the power of monitoring certain indices to determine the effect of fishing on penguin reproductive success from an experiment where pelagic fishing is prohibited in the neighbourhood of Robben Island, but continues around Dassen Island. Unpublished report, Marine and Coastal Management, South Africa. Report No. EAFWG/OCT2007/STG/04.

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.

Table 1: Penguin response series available for assessing the power of the island closure experiment at Dassen and Robben islands, the number of past data points n, and the number of model parameters estimated p. For the models with the Total 30 nmi catch series, the standard error of the residuals σ_ε and the upper 95% confidence limit for this standard error $\sigma_{\varepsilon,+95}$ are given.

Penguin response	n	p	σ_ε	$\sigma_{\varepsilon,+95}$
Chick condition	11	9	0.108	0.176
Active nest proportion	27	17	0.338	0.453
Fledging success	32	27	0.051	0.067
Chick growth	15	14	0.033	0.050
Foraging path length	11	9	0.039	0.063
Foraging trip duration	11	9	0.110	0.178

Table 2: Fishing effect parameters λ with associated standard errors and t-probabilities. The effect of fishing in the vicinity of a colony is indicated as positive or negative according as λ is positive or negative. Bold type indicates the coefficients that are significant at the 5% level.

			Dassen Island			Robben Island		
Penguin response	Fish	Area	λ	s.e.	t-pr.	λ	s.e.	t-pr.
Chick condition	Sardine	20 nmi	0.229	0.259	0.469	0.086	0.391	0.846
		30 nmi	0.347	0.243	0.290	0.416	0.506	0.497
	Anchovy	20 nmi	-0.295	0.216	0.305	-0.049	0.179	0.809
		30 nmi	-1.045	1.086	0.437	-0.607	0.845	0.547
	Total	20 nmi	-0.284	0.280	0.418	-0.043	0.219	0.864
		30 nmi	-0.192	1.261	0.893	0.069	0.909	0.947
Active nest proportion	Sardine	20 nmi	1.164	0.886	0.218	0.702	0.481	0.175
		30 nmi	0.774	1.071	0.486	0.593	0.737	0.440
	Anchovy	20 nmi	0.034	0.381	0.930	***1.328***	***0.303***	***0.001***
		30 nmi	0.445	0.848	0.611	***1.464***	***0.611***	***0.038***
	Total	20 nmi	0.450	0.419	0.309	***1.264***	***0.314***	***0.002***
		30 nmi	1.000	0.868	0.276	***1.843***	***0.718***	***0.028***
Fledging success	Sardine	20 nmi	0.187	0.136	0.228	0.248	0.187	0.241
		30 nmi	0.387	0.367	0.340	0.286	0.313	0.402
	Anchovy	20 nmi	0.146	0.099	0.200	0.026	0.113	0.827
		30 nmi	***0.435***	***0.164***	***0.046***	0.375	0.196	0.114
	Total	20 nmi	0.208	0.130	0.170	0.038	0.137	0.795
		30 nmi	0.503	0.242	0.092	0.356	0.261	0.232
Chick growth	Sardine	20 nmi	-0.288	0.351	0.562	-0.465	0.403	0.454
		30 nmi	***-0.402***	***0.010***	***0.016***	***-1.808***	***0.041***	***0.014***
	Anchovy	20 nmi	-0.039	0.141	0.827	0.083	0.147	0.672
		30 nmi	-0.055	0.682	0.948	0.030	0.403	0.953
	Total	20 nmi	-0.092	0.212	0.740	0.093	0.149	0.645
		30 nmi	-0.473	0.676	0.612	-0.152	0.394	0.765
Foraging path length	Sardine	20 nmi	0.160	0.187	0.480	0.048	0.135	0.755
		30 nmi	0.266	0.133	0.185	0.142	0.111	0.331
	Anchovy	20 nmi	-0.281	0.194	0.285	-0.182	0.086	0.167
		30 nmi	0.151	0.674	0.843	0.110	0.532	0.855
	Total	20 nmi	0.067	0.176	0.742	-0.090	0.109	0.496
		30 nmi	0.480	0.536	0.465	0.268	0.470	0.627
Foraging trip duration	Sardine	20 nmi	0.635	0.781	0.502	0.383	0.564	0.568
		30 nmi	0.121	0.912	0.906	0.004	0.762	0.996
	Anchovy	20 nmi	-0.663	0.348	0.197	-0.448	0.154	0.100
		30 nmi	0.399	1.319	0.791	0.605	1.042	0.620
	Total	20 nmi	0.441	0.444	0.426	0.233	0.275	0.485
		30 nmi	1.143	1.509	0.528	1.016	1.325	0.523

Table 3: Chick condition: power of the Island Closure Experiment after 1–10 years assuming that the current estimates for λ are the true values. Three cases are considered. Bold type indicates power over 0.95. Note that point estimates of λ are positive for the sardine series and the Total 30 nmi series at Robben Island, and otherwise negative.

(a) Alternating three-year closures

Pelagic series			Power after n years									
Fish	Area	Island	1	2	3	4	5	6	7	8	9	10
Sardine	20 nmi	Dassen	0.00	0.00	0.05	0.35	0.59	0.77	0.87	0.93	**0.95**	**0.97**
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.05
	30 nmi	Dassen	0.00	0.68	**0.97**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
		Robben	0.00	0.07	0.32	0.78	**0.95**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**
Anchovy	20 nmi	Dassen	0.00	0.28	0.83	**0.95**	**0.98**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
	30 nmi	Dassen	0.73	**0.98**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
		Robben	0.01	0.42	0.82	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Total	20 nmi	Dassen	0.00	0.00	0.33	0.64	0.82	0.88	**0.96**	**0.98**	**0.99**	**0.99**
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 nmi	Dassen	0.00	0.00	0.00	0.02	0.06	0.10	0.18	0.27	0.34	0.41
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01

(b) Both islands open

Pelagic series			Power after n years									
Fish	Area	Island	1	2	3	4	5	6	7	8	9	10
Sardine	20 nmi	Dassen	0.00	0.00	0.02	0.12	0.33	0.50	0.64	0.74	0.80	0.87
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
	30 nmi	Dassen	0.00	0.20	0.68	0.91	**0.97**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**
		Robben	0.00	0.04	0.22	0.50	0.69	0.82	0.90	0.94	**0.97**	**0.98**
Anchovy	20 nmi	Dassen	0.00	0.01	0.27	0.61	0.83	0.92	**0.96**	**0.98**	**0.99**	**0.99**
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
	30 nmi	Dassen	0.04	0.42	0.79	0.92	**0.98**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**
		Robben	0.00	0.16	0.49	0.73	0.90	**0.95**	**0.98**	**0.99**	**1.00**	**1.00**
Total	20 nmi	Dassen	0.00	0.00	0.03	0.15	0.37	0.55	0.68	0.78	0.84	0.89
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	30 nmi	Dassen	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.03	0.05
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01

(c) Alternating three-year closures, true residual standard deviation 2 standard errors above current estimate.

Pelagic series			Power after n years									
Fish	Area	Island	1	2	3	4	5	6	7	8	9	10
Sardine	20 nmi	Dassen	0.00	0.00	0.09	0.25	0.38	0.49	0.57	0.63	0.71	0.72
		Robben	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.05	0.06	0.05
	30 nmi	Dassen	0.01	0.55	0.83	0.93	**0.97**	**0.98**	**0.99**	**1.00**	**1.00**	**1.00**
		Robben	0.00	0.09	0.25	0.61	0.80	0.91	0.92	**0.95**	**0.97**	**0.98**
Anchovy	20 nmi	Dassen	0.00	0.24	0.56	0.73	0.81	0.84	0.91	0.94	**0.97**	**0.97**
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.02
	30 nmi	Dassen	0.70	**0.97**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
		Robben	0.03	0.35	0.66	**0.97**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Total	20 nmi	Dassen	0.00	0.04	0.28	0.42	0.56	0.65	0.70	0.78	0.82	0.85
		Robben	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
	30 nmi	Dassen	0.00	0.01	0.02	0.07	0.10	0.11	0.15	0.17	0.20	0.23
		Robben	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.03

Table 4: For each of Dassen Island and Robben Island, the number of years required to achieve λ estimates that are significant at the 5% level with 95% probability is given for three cases: alternating three-year closures (N_{C}), no closures (N_{O}), and three-year closures with residual standard deviations σ_ε which are two standard errors above the current estimates (N_+). Here it is assumed that the current best estimate for λ is the true value. Zeros indicate models that already have estimates for λ which differ significantly from zero at the 5% level. Bold type indicates instances where the estimates for λ are negative.

			Dassen Island			Robben Island		
Response	Fish	Area	N_{C}	N_{O}	N_+	N_{C}	N_{O}	N_+
Chick condition	Sardine	20 nmi	9	13	> 20	> 20	> 20	> 20
		30 nmi	3	5	5	5	9	8
	Anchovy	20 nmi	**5**	**7**	**8**	> **20**	> **20**	> **20**
		30 nmi	**2**	**5**	**2**	**4**	**7**	**4**
	Total	20 nmi	**7**	**13**	**15**	> **20**	> **20**	> **20**
		30 nmi	> **20**	> **20**	> **20**	> 20	> 20	> 20
Active nest proportion	Sardine	20 nmi	9	8	11	8	7	10
		30 nmi	13	12	18	13	12	17
	Anchovy	20 nmi	> 20	> 20	> 20	0	0	0
		30 nmi	> 20	> 20	> 20	0	0	0
	Total	20 nmi	> 20	> 20	> 20	0	0	0
		30 nmi	7	> 20	9	0	0	0
Fledging success	Sardine	20 nmi						
		30 nmi						
	Anchovy	20 nmi						
		30 nmi						
	Total	20 nmi						
		30 nmi						
Chick growth	Sardine	20 nmi						
		30 nmi						
	Anchovy	20 nmi						
		30 nmi						
	Total	20 nmi						
		30 nmi						
Foraging path length	Sardine	20 nmi						
		30 nmi						
	Anchovy	20 nmi						
		30 nmi						
	Total	20 nmi						
		30 nmi						
Foraging trip duration	Sardine	20 nmi						
		30 nmi						
	Anchovy	20 nmi						
		30 nmi						
	Total	20 nmi						
		30 nmi						

Table 5: There is uncertainty about the true value of the fishing effect, of which the current best estimate $\hat{\lambda}$ has standard error σ_λ. As a worst case scenario, we calculate the power in the case that the true fishing effect is $\hat{\lambda} + 2\sigma_\lambda$ if $\hat{\lambda}$ is negative, and $\hat{\lambda} - 2\sigma_\lambda$ if $\hat{\lambda}$ is positive (thus the alternative value has the opposite sign to $\hat{\lambda}$). When testing this alternative value of λ for one island, the true λ for the other island is kept at the current estimate. N_{Dassen} and N_{Robben} are the number of years required to achieve λ estimates that are significant at the 5% level with 95% probability for the respective islands.

Pelagic series		Current estimates		λ_{Robben} fixed			λ_{Dassen} fixed		
Fish	Area	λ_{Dassen}	λ_{Robben}	True λ_{Dassen}	N_{Dassen}	N_{Robben}	True λ_{Robben}	N_{Dassen}	N_{Robben}
Chick condition									
Sardine	20 nmi	0.229	0.086	-0.288	> 20	> 20	-0.696	> 20	10
	30 nmi	0.347	0.416	-0.140	> 20	> 20	-0.595	> 20	14
Anchovy	20 nmi	-0.295	-0.049	0.136	> 20	> 20	0.309	> 20	16
	30 nmi	-1.045	-0.607	1.127	> 20	6	1.083	7	6
Total	20 nmi	-0.284	-0.043	0.277	> 20	> 20	0.396	> 20	16
	30 nmi	-0.192	0.069	2.330	> 20	5	-1.750	2	> 20
Active nest proportion									
Sardine	20 nmi	1.164	0.702	-0.608	> 20	> 20	-0.260	> 20	> 20
	30 nmi	0.774	0.593	-1.367	18	> 20	-0.882	> 20	> 20
Anchovy	20 nmi	0.034	1.328	-0.728	9	1	–	–	–
	30 nmi	0.445	1.464	-1.250	10	> 20	–	–	–
Total	20 nmi	0.450	1.264	-0.388	> 20	1	–	–	–
	30 nmi	1.000	1.843	-0.737	14	> 20	–	–	–
Fledging success									
Sardine	20 nmi	0.187	0.248	-0.085			-0.125		
	30 nmi	0.387	0.286	-0.347			-0.339		
Anchovy	20 nmi	0.146	0.026	-0.052			-0.200		
	30 nmi	0.435	0.375	–			-0.018		
Total	20 nmi	0.208	0.038	-0.052			-0.236		
	30 nmi	0.503	0.356	0.019			-0.167		
Chick growth									
Sardine	20 nmi	-0.288	-0.465	0.413			0.341		
	30 nmi	-0.402	-1.808	–			–		
Anchovy	20 nmi	-0.039	0.083	0.242			-0.211		
	30 nmi	-0.055	0.030	1.308			-0.777		
Total	20 nmi	-0.092	0.093	0.332			-0.205		
	30 nmi	-0.473	-0.152	0.880			0.635		
Foraging path length									
Sardine	20 nmi	0.160	0.048	-0.213			-0.221		
	30 nmi	0.266	0.142	-0.001			-0.081		
Anchovy	20 nmi	-0.281	-0.182	0.108			-0.011		
	30 nmi	0.151	0.110	-1.197			-0.955		
Total	20 nmi	0.067	-0.090	-0.286			0.128		
	30 nmi	0.480	0.268	-0.591			-0.673		
Foraging trip duration									
Sardine	20 nmi	0.635	0.383	-0.928			-0.746		
	30 nmi	0.121	0.004	-1.704			-1.519		
Anchovy	20 nmi	-0.663	-0.448	0.034			-0.141		
	30 nmi	0.399	0.605	-2.240			-1.478		
Total	20 nmi	0.441	0.233	-0.448			-0.316		
	30 nmi	1.143	1.016	-1.876			-1.634		

Table 6: As a summary of Table 4, the catch series which achieve 95% power in the shortest number of years y for each of the response variables are listed. Results are given separately for cases where λ estimates are positive and negative, and for Dassen and Robben islands. Zeros indicate that the corresponding estimate for λ is already significantly different from zero, and dashes indicate cases for which none of the six catch series considered yields a λ estimate with that sign.

(a) Current closure pattern

	$\lambda > 0$				$\lambda < 0$			
	Dassen Island		Robben Island		Dassen Island		Robben Island	
Response	Series	y	Series	y	Series	y	Series	y
Chick condition	Sardine 30	3	Sardine 30	5	Anchovy 30	2	Anchovy 30	4
Active nest proportion	Total 30	7	A/T 20/30	0	—		—	
Fledging success								
Chick growth rate								
Foraging path length								
Foraging trip duration								

(b) No closures

	$\lambda > 0$				$\lambda < 0$			
	Dassen Island		Robben Island		Dassen Island		Robben Island	
Response	Series	y	Series	y	Series	y	Series	y
Chick condition	Sardine 30	5	Sardine 30	9	Anchovy 30	5	Anchovy 30	7
Active nest proportion	Sardine 20	8	A/T 20/30	0	—		—	
Fledging success								
Chick growth rate								
Foraging path length								
Foraging trip duration								

(c) Upper 95% confidence limit for residual variance

	$\lambda > 0$				$\lambda < 0$			
	Dassen Island		Robben Island		Dassen Island		Robben Island	
Response	Series	y	Series	y	Series	y	Series	y
Chick condition	Sardine 30	5	Sardine 30	8	Anchovy 30	2	Anchovy 30	4
Active nest proportion	Total 30	9	A/T 20/30	0	—		—	
Fledging success								
Chick growth rate								
Foraging path length								
Foraging trip duration								

Table 7: As a summary of Table 5, the catch series which achieve 95% power in the shortest number of years y for each of the response variables are listed. Results are given separately for cases where λ estimates are positive and negative, and for Dassen and Robben islands. The lower 95% confidence limit is used if λ is positive, and the upper 95% confidence limit is used if λ is negative. Zeros indicate that the corresponding estimate for λ is already significantly different from zero, and dashes indicate cases for which none of the six catch series considered yields a λ estimate with that sign.

(a) 95% confidence limit for λ_{Dassen} used as the true value, keeping λ_{Robben} fixed.

	$\lambda_{\text{Dassen}} > 0$		$\lambda_{\text{Dassen}} < 0$	
Response	Series	y	Series	y
Chick condition	Sardine 20/30	> 20	Anchovy/Total 20/30	> 20
Active nest proportion	Anchovy 20	9	—	
Fledging success				
Chick growth rate				
Foraging path length				
Foraging trip duration				

(b) 95% confidence limit for λ_{Robben} used as the true value, keeping λ_{Dassen} fixed.

	$\lambda_{\text{Robben}} > 0$		$\lambda_{\text{Robben}} < 0$	
Response	Series	y	Series	y
Chick condition	Sardine 20	10	Anchovy 30	6
Active nest proportion	Anchovy/Total 20/30	0	—	
Fledging success				
Chick growth rate				
Foraging path length				
Foraging trip duration				

ADDENDUM to: Island closure feasibility study power analysis results for Dassen and Robben islands

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Abstract

This Addendum updates results from the original paper using an improved method of residual variance estimation.

Introduction

It was pointed out at the ICTT meeting on Monday 10 March that some of the estimates of residual variance used for the power analysis might lack reliability because of the small number of degrees of freedom available for the fixed year effects approach used. This Addendum recalculates these variances treating year as a random effect, so as to increase the number of degrees of freedom. It then investigates the implications for the power calculations reported previously for the chick condition and active nest proportion variables at Dassen and at Robben islands.

Results

Table 1 compares the earlier estimates of residual standard deviations under the fixed year effects approach with those under the random year effects method. The latter has the advantage not only of increasing the number of degrees of freedom for improved estimation, but also of accounting for small sample bias via the REML approach to provide unbiased estimates of variance. Typically estimates of residual standard deviation are about 50% larger under this approach compared to the earlier fixed year effects method.

Table 2 duplicates Table 4 of the original paper, which provided estimates of power in terms of the number of years required to achieve λ estimates significant at the 5% level with 95% probability using fixed year effects based estimates of residual standard deviations. Table 3 shows the equivalent results where the more reliable estimates of these standard deviations based on a random year effects model are used instead.

As might be expected, the basic effect of using these larger standard deviation estimates in the power calculations is to extend the period expected until statistically significant results are achieved. Key changes to conclusions reported in the previous paper are:

- This period remains at 2 further years at Dassen Island, but for Robben Island extends from 4 to 9 years.
- Without fishing closures, obtaining estimates for λ which are significantly different from zero would typically take 0–5 years longer compared to the 1–4 years longer reported in the original paper.

Table 1: Penguin response series available for assessing the power of the island closure experiment at Dassen and Robben islands, the number of past data points n, the number of model parameters estimated p, the standard error of the residuals σ_ε, and the upper 95% confidence limit for this standard error $\sigma_{\varepsilon,+95}$.

(a) GLM A: Fixed year effects.

Penguin response	n	p	σ_ε	$\sigma_{\varepsilon,+95}$
Chick condition	11	9	0.108	0.176
Active nest proportion	27	17	0.338	0.453
Fledging success	32	27	0.051	0.067
Chick growth	15	14	0.033	0.050
Foraging path length	11	9	0.039	0.063
Foraging trip duration	11	9	0.110	0.178

(b) Random year effects.

Penguin response	n	p	σ_ε	$\sigma_{\varepsilon,+95}$
Chick condition	11	4	0.205	0.334
Active nest proportion	27	4	0.397	0.532
Fledging success	32	5	0.083	0.108
Chick growth	15	4	0.052	0.079
Foraging path length	11	4	0.040	0.065
Foraging trip duration	11	4	0.163	0.265

Table 2: For each of Dassen Island and Robben Island, the number of years required to achieve λ estimates that are significant at the 5% level with 95% probability is given for three cases: alternating three-year closures (N_{C}), no closures (N_{O}), and three-year closures with residual standard deviations σ_{ε} which are two standard errors above the current estimates (N_{+}). Here it is assumed that the current best estimate for λ is the true value. Zeros indicate models that already have estimates for λ which differ significantly from zero at the 5% level. Bold type indicates instances where the estimates for λ are negative. These calculations are based upon estimates of residual variance obtained from a fixed year effects model.

			Dassen Island			Robben Island		
Response	Fish	Area	N_{C}	N_{O}	N_{+}	N_{C}	N_{O}	N_{+}
Chick condition	Sardine	20 nmi	8	8	7	> 20	> 20	> 20
		30 nmi	2	4	3	4	6	5
	Anchovy	20 nmi	**3**	**4**	**2**	**> 20**	**> 20**	**> 20**
		30 nmi	**1**	**4**	**1**	**2**	**4**	**4**
	Total	20 nmi	**5**	**7**	**7**	**> 20**	**> 20**	**> 20**
		30 nmi	**14**	**> 20**	**> 20**	> 20	> 20	> 20
Active nest proportion	Sardine	20 nmi	4	1	4	4	1	4
		30 nmi	7	5	6	5	5	6
	Anchovy	20 nmi	> 20	> 20	> 20	0	0	0
		30 nmi	14	> 20	12	0	0	0
	Total	20 nmi	9	16	6	0	0	0
		30 nmi	3	9	4	0	0	0

Table 3: The power calculations for Table 2 are repeated using variances estimated with the random effects models.

			Dassen Island			Robben Island		
Response	Fish	Area	N_{C}	N_{O}	N_{+}	N_{C}	N_{O}	N_{+}
Chick condition	Sardine	20 nmi	9	13	> 20	> 20	> 20	> 20
		30 nmi	3	5	5	5	9	9
	Anchovy	20 nmi	**4**	**7**	**10**	**> 20**	**> 20**	**> 20**
		30 nmi	**2**	**5**	**2**	**4**	**6**	**4**
	Total	20 nmi	**7**	**12**	**16**	**> 20**	**> 20**	**> 20**
		30 nmi	**> 20**	**> 20**	**> 20**	> 20	> 20	> 20
Active nest proportion	Sardine	20 nmi	9	8	11	8	7	10
		30 nmi	13	13	17	13	12	15
	Anchovy	20 nmi	> 20	> 20	> 20	0	0	0
		30 nmi	> 20	> 20	> 20	0	0	0
	Total	20 nmi	> 20	> 20	> 20	0	0	0
		30 nmi	7	> 20	9	0	0	0