LESLIE MATRIX BASED ESTIMATES OF MAXIMUM GROWTH RATE FOR THE AFRICAN PENGUIN POPULATION

D S Butterworth and É E Plagányi

MARAM
Department of Mathematics and Applied Mathematics
University of Cape Town
Rondebosch, 7701

Log linear regressions of breeder numbers of African penguins over 1996-2005 for Robben Island and the Western Cape as a whole (ASWS/JUL07/PENG/DAT/1, Table 1) reflect annual increase rates of 11.4% and 9.6% respectively. How consistent are these values with separate estimates of demographic parameters for the species?

If N_t = the number of adult female (age 3+) penguins in year t, all of which first breed at age 3 then:

$$N_{t+1} = N_t S + N_{t-2} P_{t-2} \tfrac{1}{2} \cdot C_{t-2} S_j S^2 \qquad (1)$$

where:
  S_j is the first year survival rate;
  S is the post-first-year ("adult") annual survival rate;
  P_t is the proportion of females that breed in year t; and
  C_t is the fledging success per pair in year t.

Leslie matrix analysis readily provides values of the maximum steady annual growth rate (R) of which a population is capable given values for its demographic parameters. These are obtained by solving the following equation (readily derived from a generalization of equation 1):

$$\exp[RT] = \exp[R(T-1)]S + 0.5\, P\, C\, S_j\, S^{T-1} \qquad (9)$$

where T is the age at first breeding.

Substituting the values (as advanced in, e.g., SWG/EAF/SEABIRDS/13APR/01) based primarily on existing estimates of demographic parameters (ASWS/JUL07/PENG/DAT/1, Table 4), *viz.* $T=3$, $P=0.97$, $C=1$, $S_j=0.51$, and $S=0.85$ yields $R=2.0\%$, far below the observed rates.

Results for some alternative inputs are of interest:

  i) Increase S from 0.85 to 0.9 : $R=7.0\%$
  ii) Increase S_j to equal $S=0.85$: $R=9.3\%$
  iii) Decrease $T=3$ to $T=2$: $\quad R=11.8\%$
  iv) Adopt $T=3$, $P=0.97$, $C=0.8$, $S_j=0.7$, $S=0.9$ (as suggested per Res Altwegg email 23 April): $\quad R=8.3\%$
  v) Case iv) with $T=4$: $\quad R=6.2\%$
  vi) Case iv) with $C=1.15$ $\quad R=13.3\%$

Reconciliation options

What options are available to reconcile demographic parameter estimates and the high increase rates observed over 1996-2005 of some 10% p.a., without pushing adult survival S unrealistically high? (Note that in any case S will be constrained from going too high in fitting the Plagányi-Butterworth spatial model of the Western Cape penguin population (ASWS/JUL07/PENG/ASS/2) by the need to fit information on relative numbers of juvenile and adult moulters.) It is important to appreciate that one cannot simply ignore existing estimates for some of these parameters; if this were to be done, cogent reasons for bias in the original estimates need to be advanced.

a) Increase S above 0.9, as long as relative numbers in moult counts remain fit?
b) Increase S_j, maximally to S? But i) are Randall (1983), La Cock and Hänel (1987), and Whittington (2002) estimates negatively biased to such an extent? As these (ranging from 0.31 to 0.69) are well below direct estimates of adult survival, are they not indicative that S_j is appreciably below S?
c) Decrease T? How far? Below 3 seems unrealistic. How would this be reconciled with estimates generally >3 reported in Crawford *et al*. (1999)?
d) Increase P? But this is already suggested to be 0.97 and it cannot exceed 1.
e) Increase C, perhaps over 1? Even if there is some evidence for multiple breeding within a year at Dassen Island, are regular proportions of over 1 fledged chick a year per pair consistent with the data?
f) Strong transient effects? The Plagányi-Butterworth model takes due account of these.
g) Temporal variations in parameter values? This possibility is taken into account by considering random effects components of survival rates in the Plagányi-Butterworth model, but even if this mechanism can admit high increase rates in the short-term, for biological realism the random components would need to show reasonable correlation with measures of potentially related factors such as food abundance, as will be tested through fitting functional relationships in the Plagányi-Butterworth model.
h) Temporal bias in trends in abundance indices (i.e. was there an undetected increase in count efficiency, or has the proportion of the population counted varied, over 1996-2005)? The counts should be standardized by making allowance, if indicated, for possible co-variates such as different observers having differing efficiencies. (This is planned to the extent that co-variates recorded with the counts allow.)
i) Immigration? Immigration of juveniles from Dyer Island may account for some of the increase at Robben Island, but for the Western Cape as a whole one would need appreciable immigration from the Algoa Bay colonies or from Namibia.

Clearly identification of which of these factors most likely accounts for the current inconsistency between demographic parameters and trends has important implications for the modeling exercise, and also the interpretation of the marked reductions in counts over the last two years.

REFERENCES

Crawford, R.J.M, Barham, P.J., Underhill, L.G., Shannon, L.J., Coetzee, J.C., Dyer, B.M., Leshoro, T.M., and Upfold, L. 2006. The Influence of Food Availability on Breeding Success of African Penguins *Spheniscus demersus* at Robben Island. *Biological Conservation* 132: 119–125.

La Cock, G.D., Hänel, C., 1987. Survival of African penguins *Spheniscus demersus* at Dyer Island, southern Cape, South Africa. Journal of Field Ornithology 58, 284-287.

Randall, R.M. 1983. Biology of the Jackass penguin *Spheniscus demersus* at St Croix island, South Africa. PhD thesis, University of Cape Town. 262 pp.

Whittington, P.A., 2002. Survival and movements of African penguins, especially after oiling. Unpublished PhD Thesis, University of Cape Town. 286 pp.