Robben Island Penguin model extended to include further tag data and to estimate immigration

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Introduction

Since the previous document concerning this work (document FISHERIES/2011/SWG-PEL/01) was submitted, tag-sighting data for adult birds for earlier years has been included in the model likelihood as described in document FISHERIES/2011/SWG-PEL/02 (after consultation with the holders of the tagging data, it was confirmed that our previous interpretation of the capture history database was appropriate). Also, some immigration has been allowed over the period 1989 to 1999 as the additional tag-recapture data provide the further information required to render this immigration estimable.

Methodology

The Appendix describes the statistical distribution for the variability of penguin adult mortality about the value suggested by the assumed relationship with pelagic fish abundance.

Tag data for the full model period (1989–2009) have now been included using a multinomial likelihood following the procedure described in document MCM/2010/SWG-PEL/53. Over-dispersion has been estimated using MARK applied to these data in isolation. In addition, the likelihood contribution of the tag data has been down-weighted by a factor of 10 so that the fits to the moult count data remain satisfactory.

After some exploration of more complex possibilities, it was decided to allow immigration of three-year-old birds (pre-breeders) to Robben Island in the following way: I_1 birds in each of 1989 and 1990, I_2 birds in each of 1992–1994, and I_3 birds in each of 1996–1999. I_1, I_2 and I_3 are estimable parameters. There is some evidence from tagging data that there was a net immigration of penguins to Robben Island during this period (Wittington *et al*., 2005).

Results

Results are shown for the choice $n=2$ for the assumed relationship between adult mortality and fish abundance (see Appendix). The abundance index taken here is the sardine November survey spawner biomass west of Cape Agulhas. Figure 1 illustrates how the modifications to the model have led to reduced estimated survival rates in earlier years so that now all but one of the penalised maximum likelihood estimates are well below the upper bound on the prior, unlike the situation earlier which had previously been a cause for concern.

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Figure 2 shows the penalised maximum likelihood estimates of the numbers of birds immigrating to Robben Island.

Figure 3 and Figure 4 show various fitted parameters and relationships of interest.

Discussion

The main purpose of this paper is to demonstrate the effects on adult survival of the inclusion of the earlier tag data and allowing some immigration. The model is not yet entirely satisfactory. One concern is that few random effects on adult mortality are negative (see Figure 4, top row). Alternative forms of the relationship in the Appendix will be explored further.

With regard to the tag data, records of dead recoveries have not been incorporated at this stage, though the number of these is very small. Neither has there been an estimation of “transients”, i.e. birds banded which do not return to the colony, which would bias the survival rate in the first year after banding.

Work on extensions of the model specified at the December 2010 International Stock Assessment Workshop is in progress.

References

Robinson W, Butterworth DS. 2010. Penguin survival estimates from tag data using a multinomial likelihood. MCM/2010/SWG-PEL/53.

Robinson W, Butterworth DS. 2011. Update of penguin model development. Document FISHERIES/2011/SWG-PEL/01.

Robinson W, Butterworth DS. 2011. Proposed timing approach to penguin tag-recapture data. Document FISHERIES/2011/SWG-PEL/02.

Whittington PA, Randall RM, Crawford RJM, Wolfaardt AC, Klages NTW, Randall BM, Bartlett PA, Chesselet YJ, Jones R. 2005. Patterns of immigration to and emigration from breeding colonies by African penguins. *African Journal of Marine Science* 27: 205–213.

Appendix

Revised statistical model for variability in penguin annual adult mortality

We have found that using the beta distribution for adult survival will not serve our purposes in the Robben Island case, since a unimodal beta distribution can only have a very small variance when the mean is close to the boundary. This gives a high weight to years in which survival values want to go close to the maximum, which itself drives estimates towards the upper boundary. This is undesirable since it implies that when prey biomass is high, survival can only be very close to the maximum. Subsequently, the following approach has been explored and found to work satisfactorily.

Set

$$S_y = e^{-M_y}$$

where M_y is the annual natural mortality rate, modelled as follows:

$$M_y = M_{\min} + \left[M^*_{\min} + f\left(B_y\right) \right] e^{X_y}$$

where X_y is distributed $N\left(0, \sigma_y^2\right)$, and

$$\sigma_y = \sqrt{e^{\tilde{\sigma}^2 / \left(M^*_{\min} + f\left(B_y\right)\right)^2} - 1}$$

Thus we have a log-normal random effect, but since the σ_y depend on the biomass B_y, the M_y distributions will have exactly the same standard deviation. This is useful since data related to each year receives roughly equal weighting, and, when projecting, high biomass does not force low mortality.

The reason that the $M^*_{\min}$ term is introduced is that when calculating M_y the possibility that the term additional to $M_{\min}$ could go to zero is excluded. The lower bound on achieved M_y remains $M_{\min}$, but the lower bound on the median of its distribution is $M_{\min} + M^*_{\min}$.

The model currently uses the following:

$\tilde{\sigma} = 0.1$

$M_{\min} = 0.03$

$M^*_{\min} = 0.02$

$f\left(B_y\right) = \left(a + \frac{B_y}{b} \right)^{-n}$, where $n = 2$ has been used in the analysis reported here.

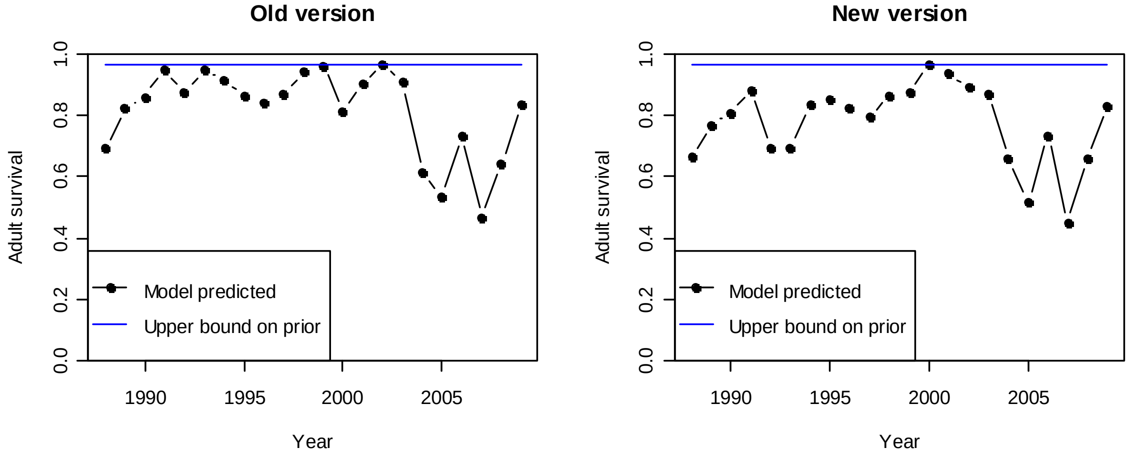

Figure 1: Comparison of adult survival rates from the previous model version and the current version which includes immigration and tagging data.

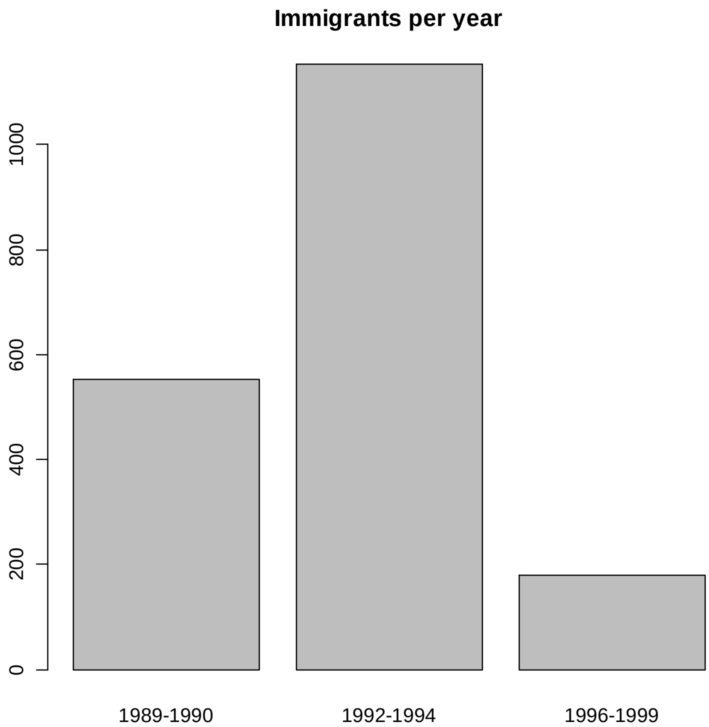

Figure 2: Penalised maximum likelihood estimates of numbers of three-year-old female penguins immigrating to Robben Island per year.

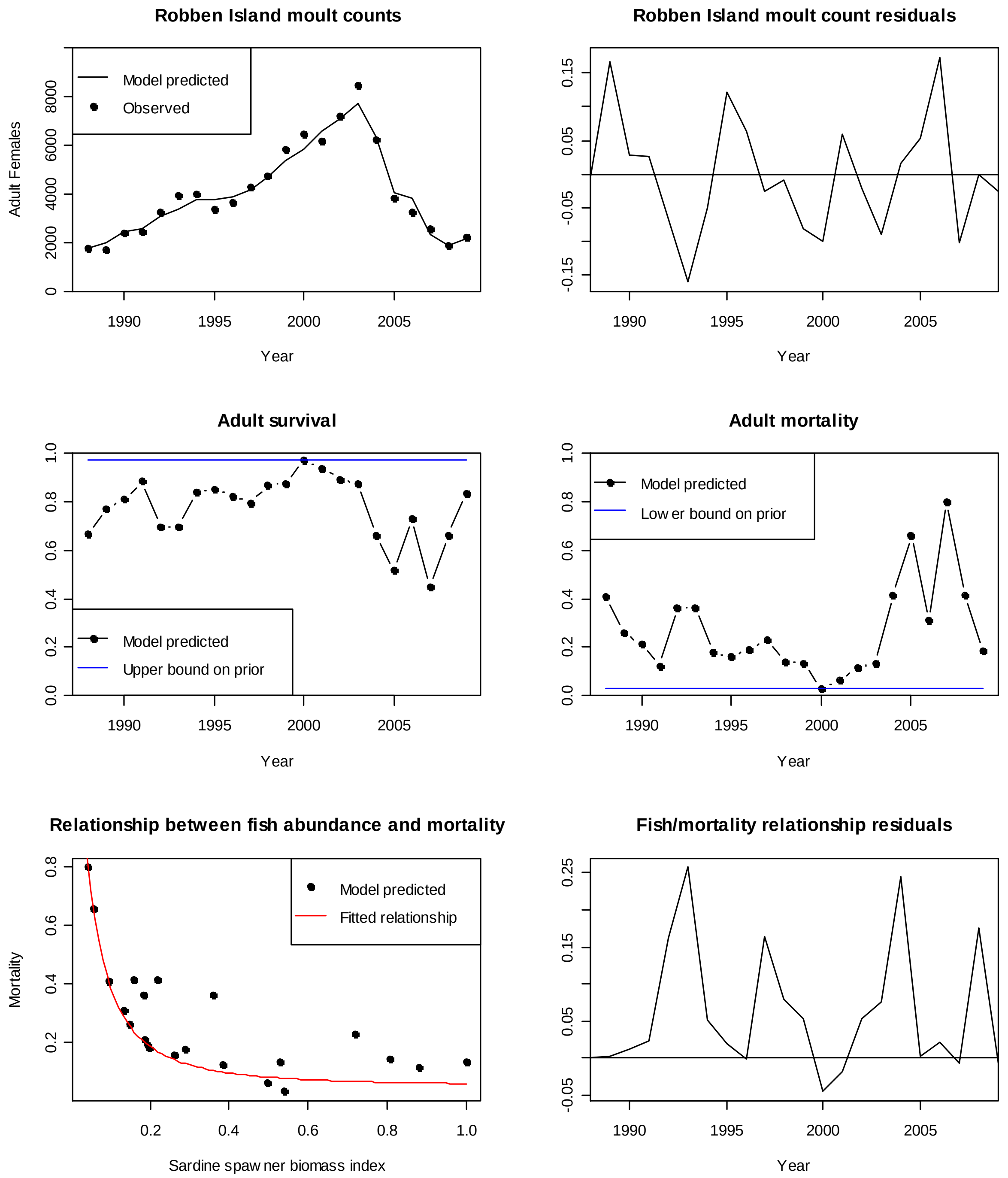

Figure 3: Top: fit to moult count data and the residuals. Middle: model estimated adult survival and mortality rates. Bottom: fitted relationship between fish abundance and penguin adult mortality, and the time series of residuals for this relationship (due to random effects on adult mortality).

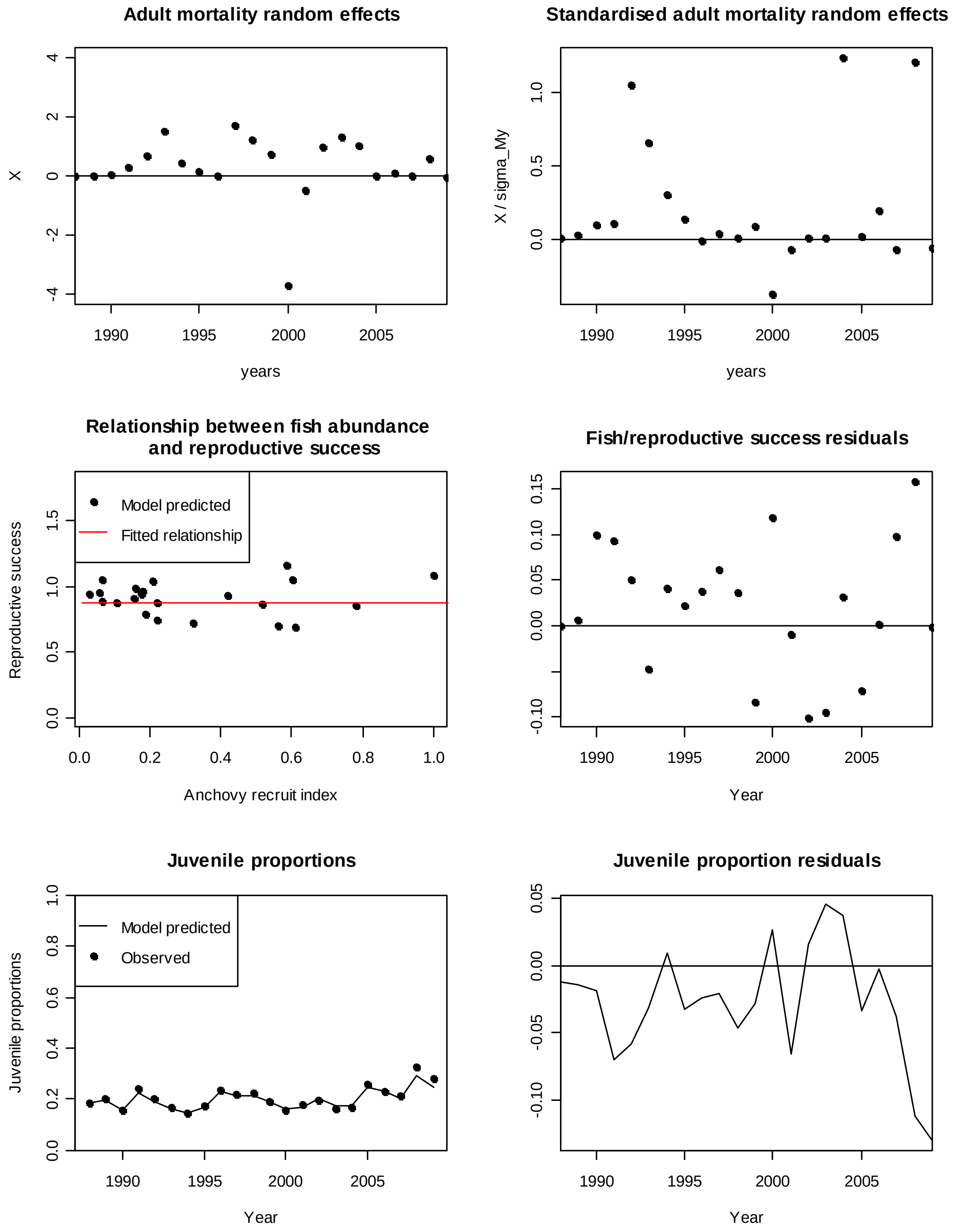

Figure 4: Top: time series of random effects on adult mortality. The random effects are standardised by dividing each by its standard deviation, which is related to the expected natural mortality (see the Appendix). Middle: fitted relationship between fish abundance and penguin reproductive success, and residuals for this relationship. Bottom: fit to the proportion of juveniles in the moult count and residuals for this fit.