Appendix S5: Effect of CID variance on breeding success

Circumpolar analysis of the Adélie penguin reveals the importance of environmental variability in phenological mismatch

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Intro

One proposed explanation for the evolution of coloniality in seabirds is the avoidance of predators (Darling 1938, Emlen and Demong 1975). A nest surrounded on all sides by other nests will experience less of an 'edge effect', making it easier to effectively defend against aerial predators, ultimately resulting in higher breeding success (Young 1994). It might be assumed that breeding synchrony among individuals is important to take full advantage of this strategy. We analyzed individual clutch initiation date (CID) and associated breeding success data to assess the importance of intra-colony synchrony in reproductive success.

Methods

Effect of breeding synchrony on breeding success

Data on clutch initiation at individual nests were collected at one site, Admiralty Bay, which permitted an analysis of the effect of within-site (intra-annual) breeding synchrony on population level breeding success. Variance in clutch initiation date was calculated for each year in which data were available (1986-2012). Nesting dates that fell outside of 3.5 standard deviations from the mean in each year were excluded from calculations of breeding success and CID variance to avoid bias in the variance component attributable to these extreme outliers. A linear model was used to examine the effect of breeding synchrony on breeding success:

$$
\begin{aligned}
y &\sim N(\alpha + \beta * X, \sigma^2) \qquad \text{(S1)}\\
\alpha &\sim N(0, 0.001)\\
\beta &\sim N(0, 0.001)\\
1/\sigma_2 &\sim Gamma(0.01, 0.01)
\end{aligned}
$$

where y is standardized breeding success, X is intra-annual variance in breeding phenology, α and β are the intercept and slope, respectively, and $1/\sigma^2$ is the or precision, or inverse-variance. Both α and β were given uninformative normal priors, while $1/\sigma^2$ was given an uninformative gamma prior.

Results

A decrease in breeding success is associated with a decrease in breeding synchrony (increase in CID variance; Fig. S1).

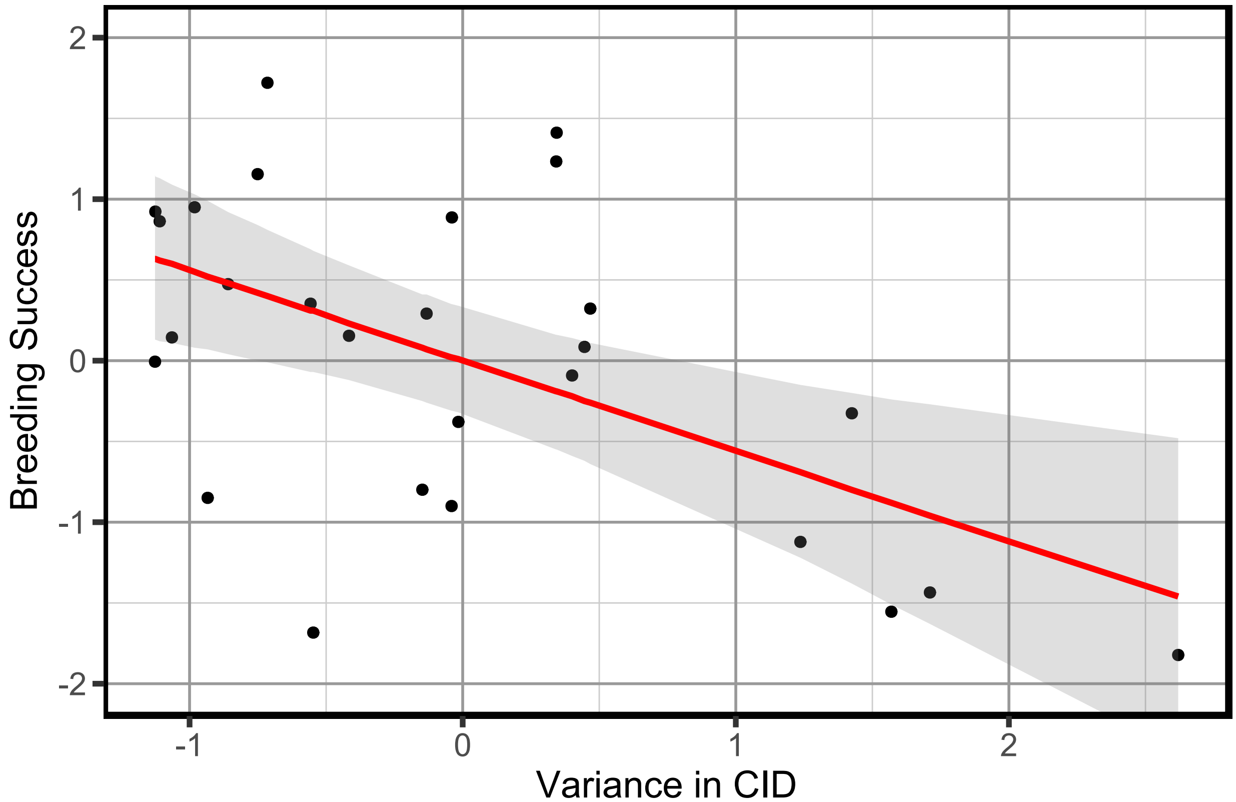

Figure S1: Breeding success as a function of intra-annual variance in CID at Admiralty Bay. Measures are standardized. Fit for linear model shown in red with credible intervals (95%) shown in gray.

Table S1: Parameter estimates (posterior mean and 95% credible intervals) for linear regression (Appendix S5: Eq 1).

Coefficient term	Estimate	Lower 95% CI	Upper 95% CI
α	5.901×10^{-4}	-0.332	0.331
β	-0.559	-0.907	-0.209

Discussion

These results suggest that breeding synchrony is important for highly successful breeding for Adélie penguins at this location. This is likely due to reduced predation experienced when all individuals initiate breeding at a similar time. Previous work has shown that predation by avian predators, such as brown skuas (*Catharacta lonnbergi*), kelp gulls (*Larus dominicanus*), and giant petrels (*Macronectes giganteus*), can significantly reduce breeding success of Adélie penguins (Emslie et al. 1995). Penguin nests on colony edges were found to be more vulnerable to predation due to lack of neighboring nests that facilitate predator resistance. While we show here synchrony to be important, rather than position in the colony, we suggest a similar mechanism is at play.

Literature Cited

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