

## Appendix S4: Spatial scale for Bloom Mismatch Index and Sea-ice Mismatch Index

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

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While we initially used a 250 km radius around each colony to calculate the sea-ice adjusted light (as a proxy for phytoplankton bloom timing) and sea-ice retreat, we also analyzed these metrics at a 150 km radius around each colony. These values were used to calculate Bloom Mismatch Index and Sea-ice Mismatch Index values for 150 km as well as the initial 250 km. A quadratic 85th quantile regression implemented in a Bayesian framework (see Methods, equation 2), was used to model breeding success as a function of Bloom Mismatch Index and Sea-ice Mismatch Index at each of these scales. Data from all sites were used to conduct the analyses.

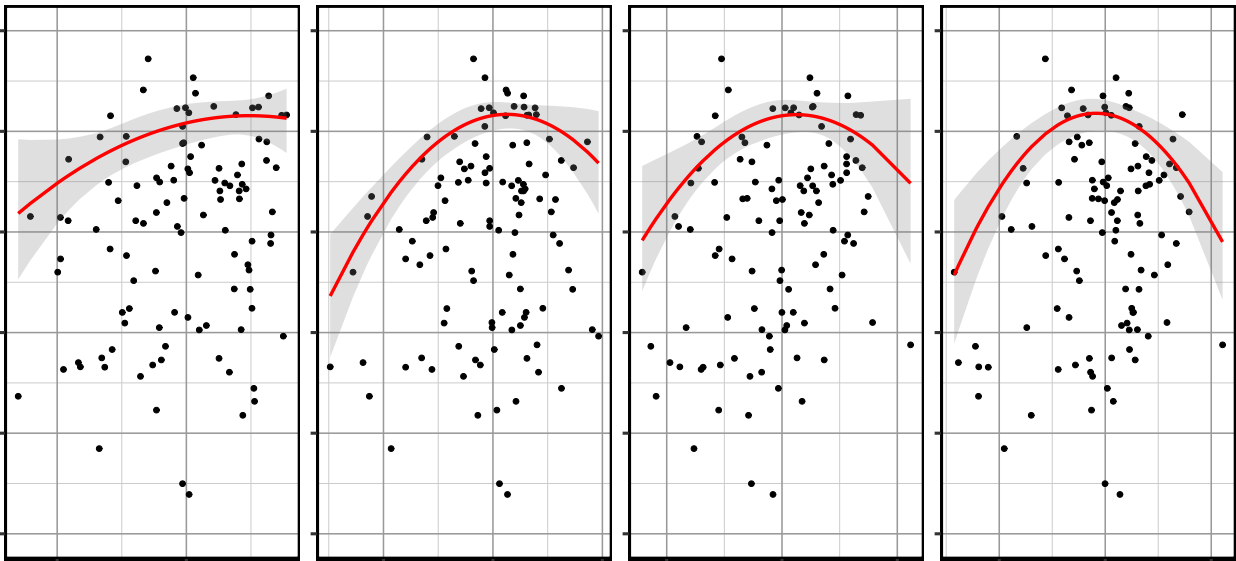


Figure S1: Breeding success as a function of: a) Bloom Mismatch Index using a 150 km radius, b) Bloom Mismatch Index using a 250 km radius, c) Sea-ice Mismatch Index using a 150 km radius, and d) Sea-ice Mismatch Index using a 250 km radius. Model fit for 85th quantile regression shown in red with credible intervals (95%) shown in grey. All measures are normalized. Data points from all sites are shown.

Table S1: Parameter estimates (posterior mean and 95% credible intervals) for model of breeding success (BS) as a function of Bloom Mismatch Index (BMI) and Sea-ice Mismatch Index (SMI) obtained from a quantile regression.

Model	Scale	Coef term	Estimate	Lower 95% CI	Upper 95% CI
BS ~ BMI	150km	$\beta_1$	0.15	$-2.8 \times 10^{-4}$	0.29

Model	Scale	Coef term	Estimate	Lower 95% CI	Upper 95% CI
BS ~ BMI	150km	$\beta_2$	-0.08	-0.19	0.05
BS ~ BMI	250km	$\beta_1$	0.09	-0.06	0.24
BS ~ BMI	250km	$\beta_2$	-0.17	-0.27	-0.08
BS ~ SMI	150km	$\beta_1$	0.09	-0.07	0.24
BS ~ SMI	150km	$\beta_2$	-0.17	-0.3	-0.02
BS ~ SMI	250km	$\beta_1$	-0.08	-0.22	0.08
BS ~ SMI	250km	$\beta_2$	-0.22	-0.32	-0.12

Results show that the mismatch indices are not good predictors of mean breeding success at any scale, but that the ‘necessary but not sufficient’ pattern, in which the indices set an upper limit on breeding success is more apparent at 250 km, than at 150 km. As these metrics were derived from satellite sensors, we ultimately believe that larger spatial scales more accurately capture measures of environmental phenology - values will be integrated over more pixels. The sensitivity of the mean to the value of any one pixel will be reduced using a larger radius in this way, and incorporate more pixels potentially used by penguins as determined using their maximum foraging range.