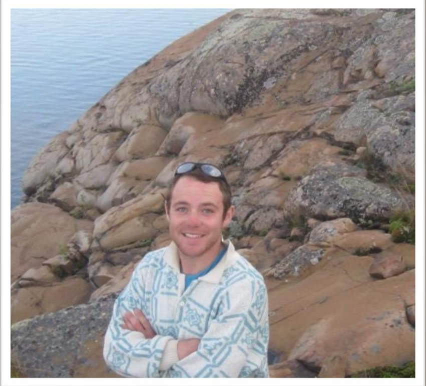


Phenological changes are driven by phenotypic plasticity in Mandt's Black Guillemot

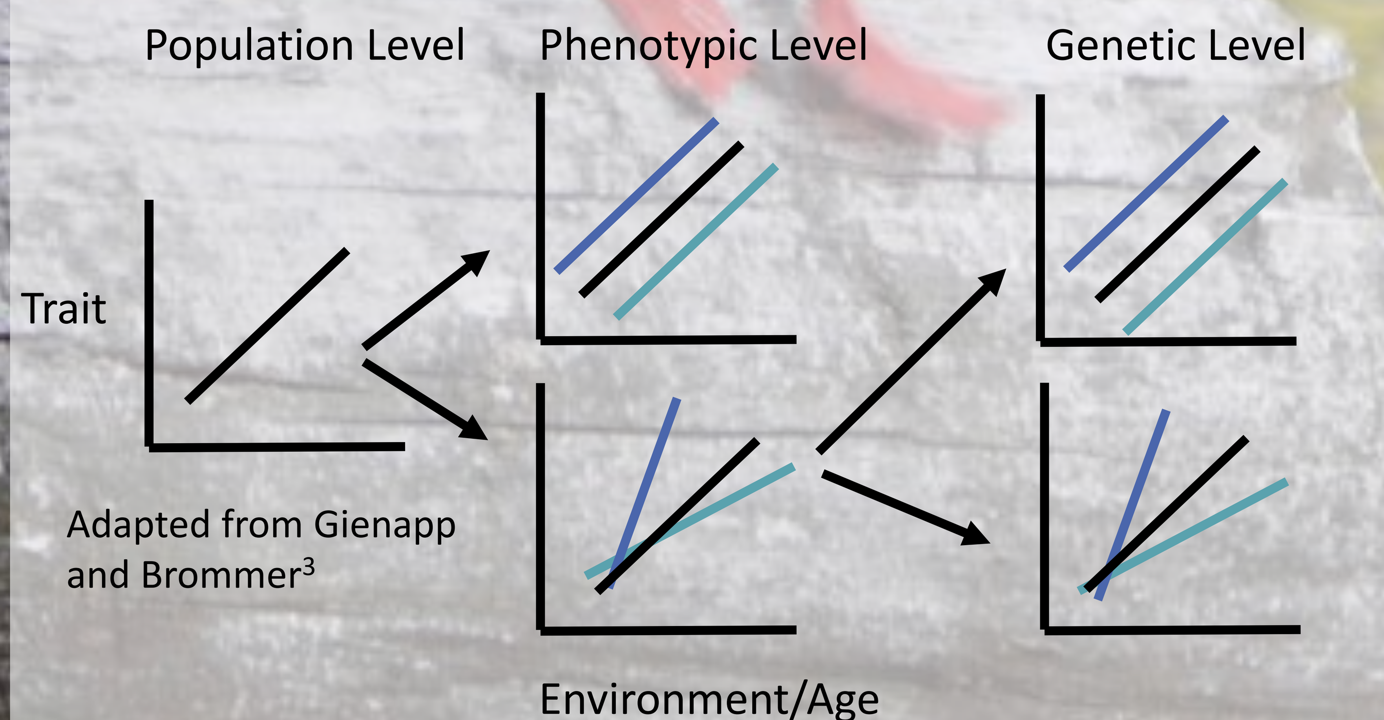
Drew Sauve, George Divoky, Vicki Friesen

Background

To persist under environmental change populations will need to adjust the timing of reproduction (phenology) to respond to changing resource conditions[1]. **Phenotypic plasticity** and **microevolutionary** change are the possible drivers of phenotypic change in phenology[2].

Phenotypic Plasticity

Phenotypic plasticity is the suite of phenotypes a population/individual/genotype can produce across environmental conditions. If genetic variation in phenotypic plasticity exists, there is potential for phenotypic plasticity to evolve.



Adapted from Gienapp and Brommer[3]

Microevolutionary change

The evolutionary response (R) of a trait is dependent on the proportion of a trait explained by additive genetic variance (heritability, h^2), and the selection (S) acting on the trait. Therefore, the amount of additive genetic variation in a trait is an indication of it's adaptive potential.

$$R = h^2 S$$

Study System

Long-term data and pedigree information is required to estimate plasticity and evolutionary parameters in the wild. The 40-year pedigree of Black Guillemots on Cooper island contains:

- 6 Generations
- 3704 Lay dates
- 714 Mothers/650 Fathers

Cooper Island Black Guillemots prey on Arctic Cod. Warming of Arctic waters is decreasing prey abundance and breeding success[4].

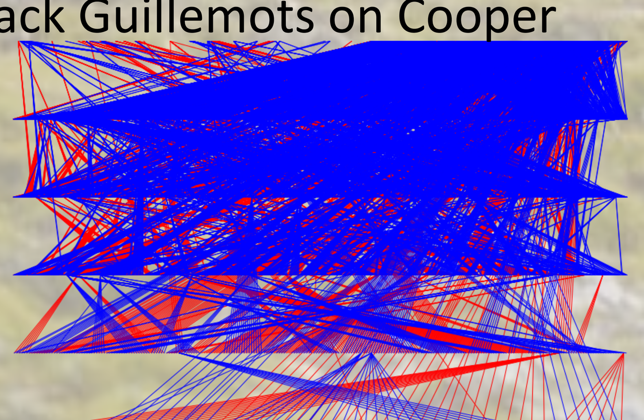


Fig. 1 : Pedigree of Black Guillemots on Cooper Island. Blue lines are paternities and red lines are maternities.

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Results

Phenological, environmental, and demographic changes

Over the study period:

- Mean clutch initiation advanced ~7 days (Fig. 2A).
- Snow melt advanced 7 days (Fig. 2B).
- Mean female breeding experience increased by ~4 years (Fig. 2C).

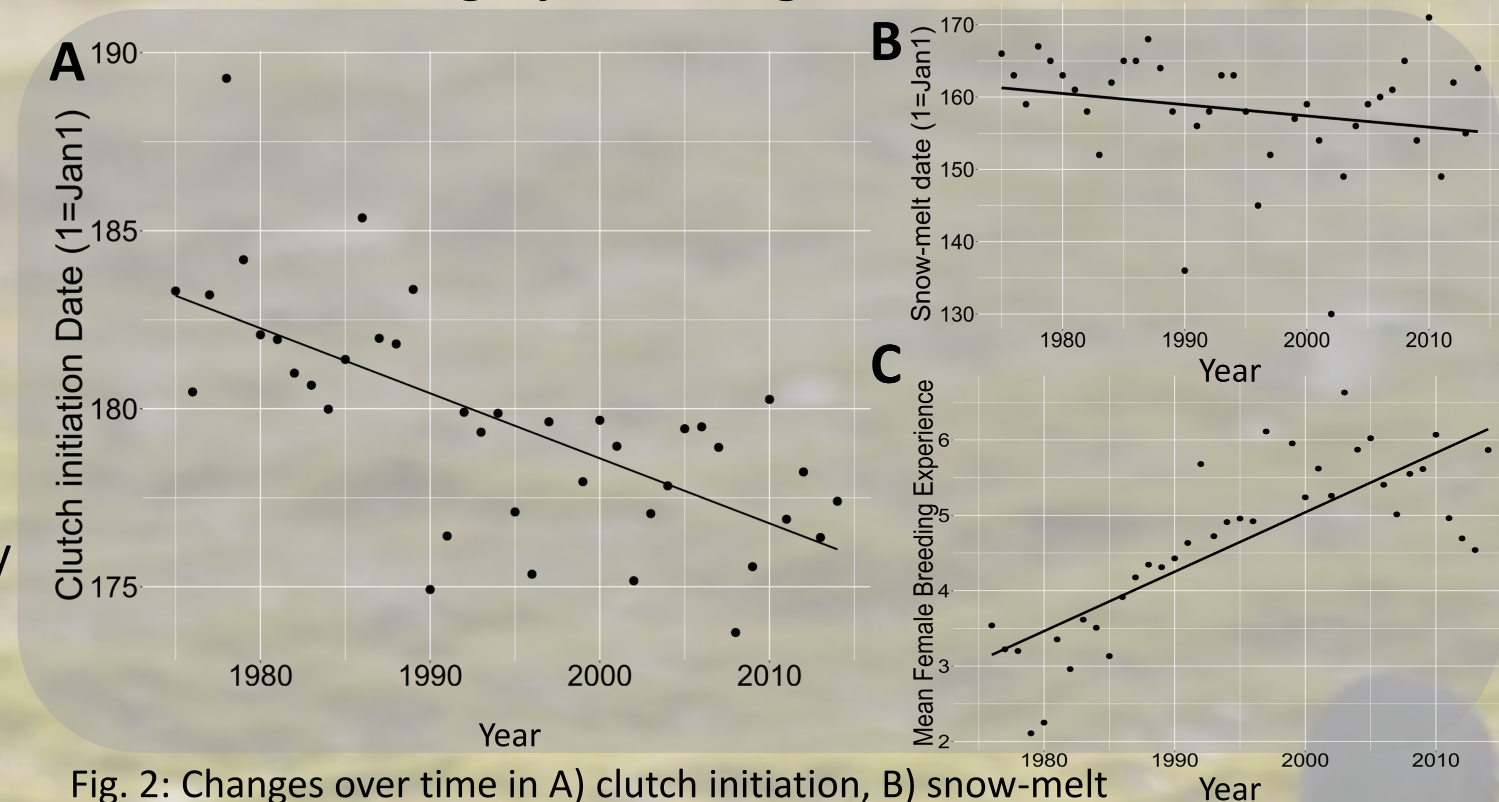

Fig. 2: Changes over time in A) clutch initiation, B) snow-melt date, and C) mean female breeding experience.

Population Plasticity

Earlier clutch initiation is associated with:

- Earlier snow melts (Fig. 3).
- Experienced mothers (Fig. 4).

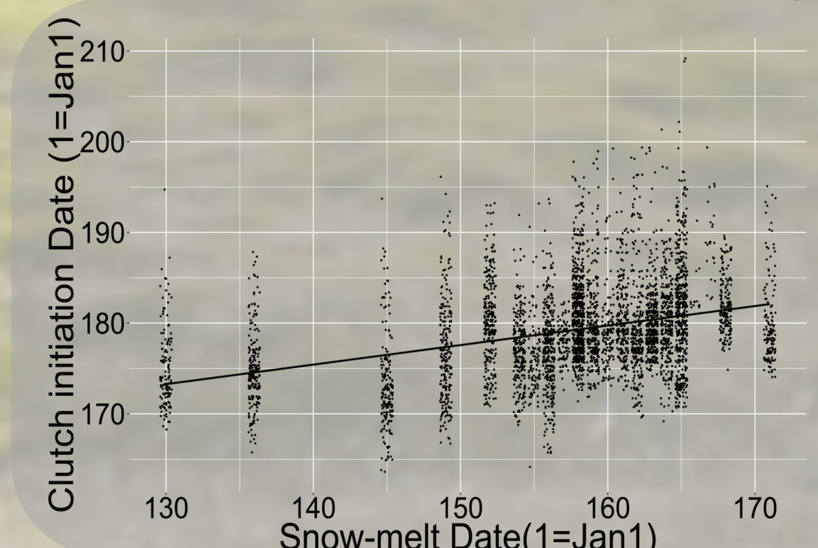

Fig. 3: Clutch initiation date in response to snow-melt date.

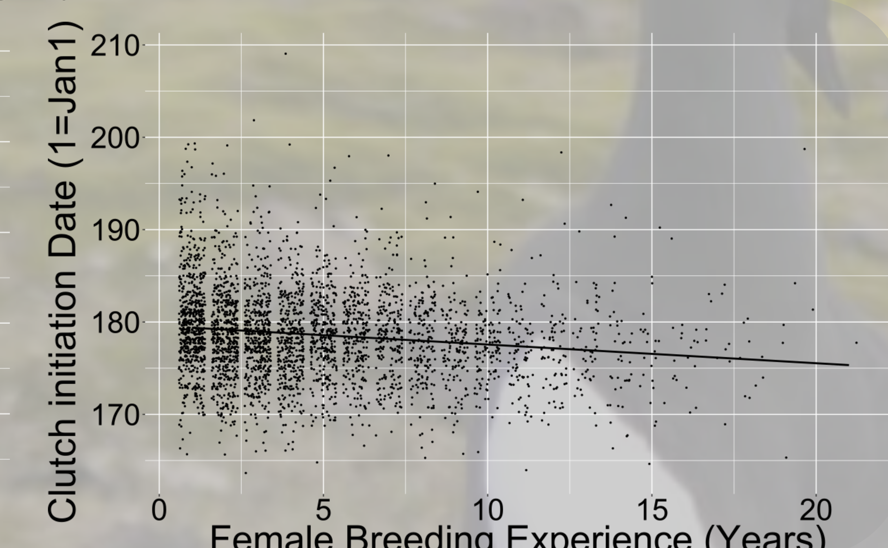

Fig. 4: Change in clutch initiation date by female breeding experience.

Individual Plasticity

Individuals adjust clutch initiation:

- Similarly in response to snowmelt (Fig. 5).
- Differently over their lives (Fig. 6).

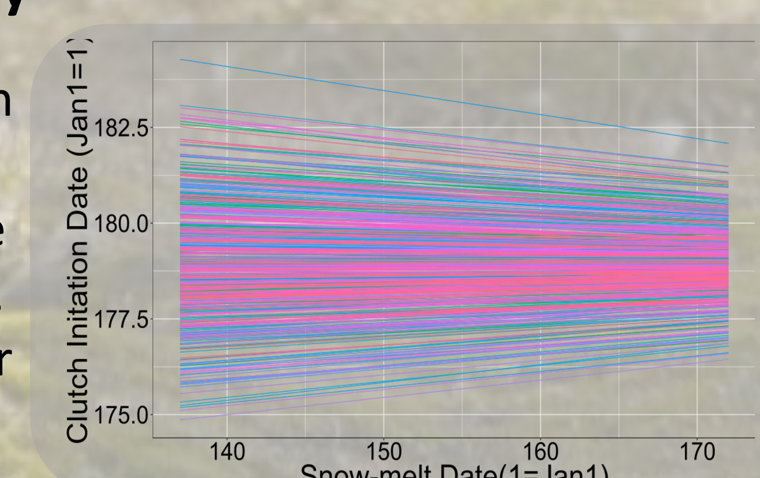

Fig. 5 : Predicted reaction norms of individual black guillemot mothers in response to snow-melt.

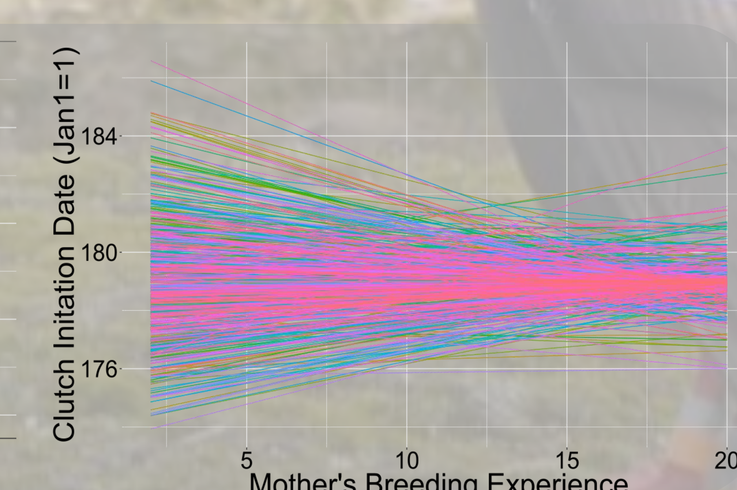

Fig. 6 : Predicted reaction norms of individual black guillemot mothers over their lives.

Selection

- Selection is acting on the environmental, but not genetic component of egg-laying date (Fig. 7).
- Individuals that tend to lay early tend to have higher annual fitness (Fig. 8).
- Individuals that lay early when inexperienced tend to have higher fitness (Fig. 9).

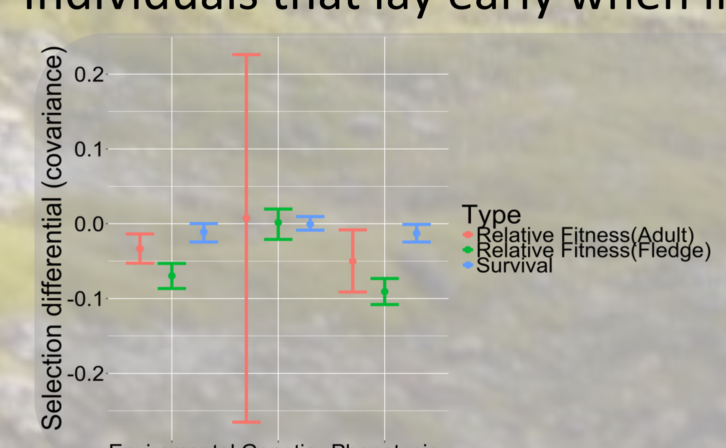

Fig. 7 : Selection via fitness and survival for clutch initiation date. Selection is divided into environmental, genetic and phenotypic components. Error bars are 95% CI.

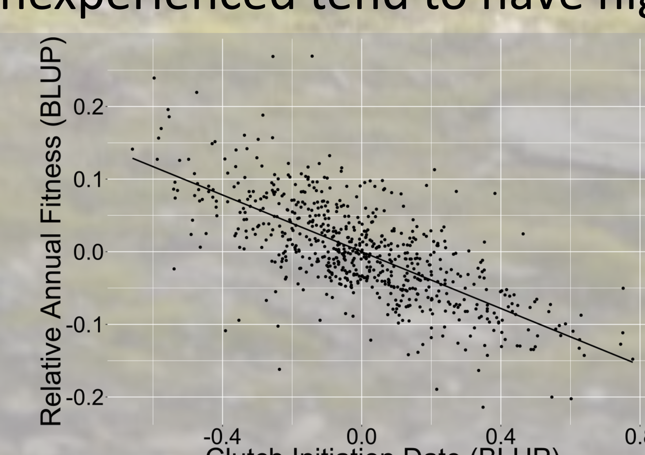

Fig. 8 : Correlation between relative annual fitness ((fledgling success + survival)/2) and clutch initiation.

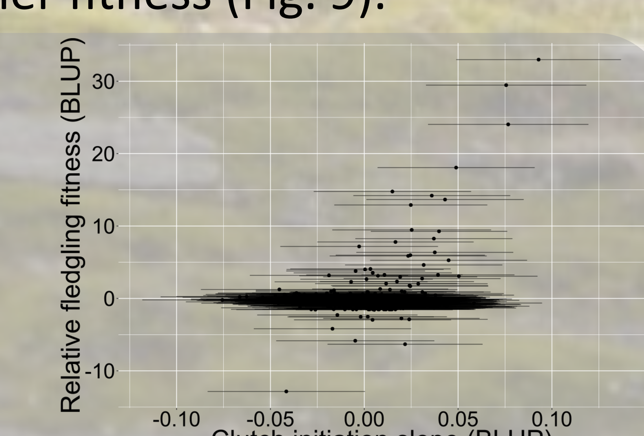

Fig. 9 : Fitness of a mother's breeding experience slope. Error bars are 95% CI.

Microevolution

Heritability of egg-laying date was low ($h^2 = 0.08[0.03\text{-}0.12]$) and there is no trend in breeding values for egg-laying date over time (Fig. 10)

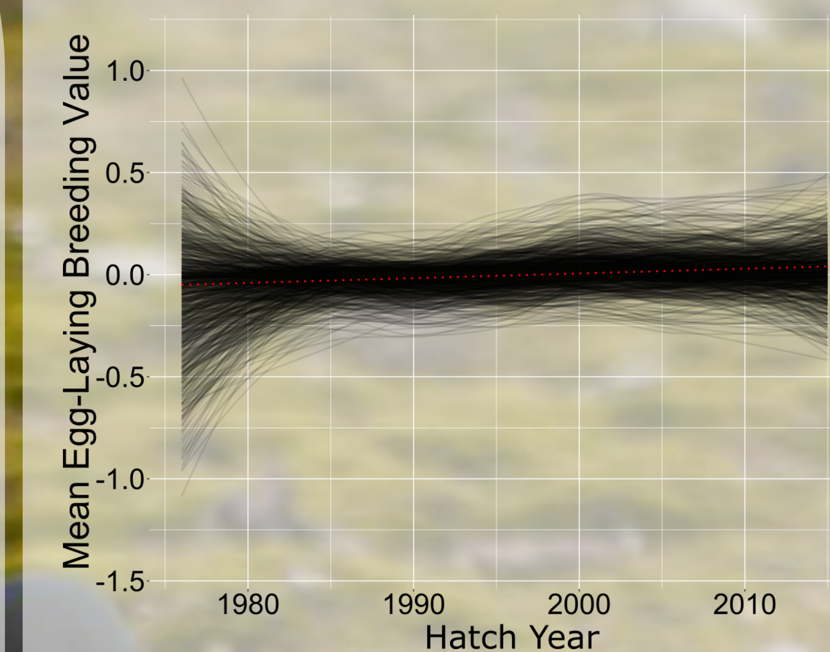

Fig. 10: Posterior distributions of clutch initiation breeding values regressed on time. This method conservatively estimates evolutionary change over time[5].

Discussion

Preliminary results suggest:

- Phenological change in Black Guillemots is driven by plasticity in response to environment and breeding experience
- Individual phenotypic plasticity analyses indicates there may be potential for evolutionary change in individual by age reactions, but not in individual by environment reactions
- Selection is not driving evolutionary change in laying date
- Low heritability of phenology may indicate little potential for adjustment in phenology beyond phenotypic plasticity.

Future Work

Predicting Phenotypic Change

Phenotypic plasticity and heritability of traits could parametrize models used to estimate the potential of phenology to respond to environmental change[6].

Genetic Co-variance

Selection on correlated traits[7] and genetic covariation[8] of traits can impact phenotypic response. Using tri-variate animal models I'd like to try to estimate multivariate selection and genetic covariation of phenology with egg-volume.

Genomics Tools

Genomic data generated via double digest restriction site associated sequencing will be used to assess the ability of pedigree-free methods to estimate additive genetic variance[9].

Dispersal

As dispersal is another major response to environmental change I'd like to use genomic data to estimate source-sink dynamics[10] on Cooper Island.

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Background photo by Mike Morrison