

# Summary

## Introduction

Rapid environmental change, IPCC, estimated temperature rise.

Trend to precocity in plants, flowering time, etc. Advance in phenology.

**Problem:** Understanding (and predicting?) long-lived plant adaptation to climate change

Based on previously developed demographic and quantitative genetics model (see ), added fluctuating environments. Made theoretical predictions. Estimated fluctuations using data from phenological data (PHENOFIT).

## Materials and Methods

### Population model

We used a previously developed model with stage-structure (Cite XXXXX Sandell et al.). We have two classes in our simulated tree population: immatures (I) and matures (M). Explain the parameters. The corresponding Lefkovitch matrix is:

$$A = \begin{pmatrix} a_{II} & a_{IM} \\ a_{MI} & a_{MM} \end{pmatrix} = \begin{pmatrix} s_0 m f_1 + s_I(1 - m) & s_0 f_2 \\ s_M m & s_M \end{pmatrix} \quad (1)$$

### Life-history traits

We considered certain life-history trait  $s_I, f_1, f_2$  as gaussian for each individual such as: ...

Thus at the population level, the mean is: ...

**Density-dependence!**  $s_0$

### Iterations at each timestep

Using the given parameters, the mean phenotype in each class can be described as (Barfield et al., 2011) ...

When there is a reproduction event, the phenotype of the newborn is computed as such: ...

### Approximation under weak selection

From (Engen et al., 2011) and Sandell et al. we get the following approximation of the mean phenotype in the population:

$$z = \dots \quad (2)$$

### Fluctuating environment

To mimic a fluctuating environment, the optimums are fluctuating in various ways around a mean.

Under fluctuations we get another approximation supposing weak selection (Engen et al., 2011):

...

### Trend in change

...

## Phenofit data

PHENOFIT is phenology model...

On 6 localities (see map .) we had modelled budburst date and predicted fitnesses  $\pm 21$  days around this date, from these data we predicted the optimums fluctuations: ... All statistical analysis were made using R, for the plots we used the package ggplot2.

## Results

### Constant environment and density-dependence

From Sandell et al., we simulated populations. With the introduction of density-dependence, the blablabla...

**Figure1:** 2 panels, one side with phenotype/time the other with demography/time with and without DD

Introduction of DD should decrease mean phenotype (lower  $s_0$ ) and limit population size

### Fluctuating optimums

The noises were drawn from a bivariate normal distribution to make the optimums fluctuate. We varied the correlation between them.

**Figure2:** 3 panels, each with one value of noise correlation  $\rho_N + \overline{s_I}, \overline{f_1}, \overline{f_2}$ /time with their values in constant environment.

Explain in the text correlation of  $z_I$  with  $\theta_s(t)$

### Trend in the environment

Decreasing optimums through time to mimic the advance in phenology with climate change.

**Figure:** Trend 2 panels with and without fluctuations, simulations results phenotype/time (with and without DD)

### Estimation of the fluctuations

From phenofit.

**Figure:** Map of the localities, with panels for each of the optimums variations + graph showing fitness landscape with negative optimums

**Table:** table with slope and noise variance estimates for all years, years before 2001 (simulated climate close to real one), after 2001 (projection in climate evolution)

## Discussion

Difference in  $\bar{z}$  and  $\bar{g}$  with fluctuations because of selection on viability.

Increasing number of extreme events from predictions.

## **Authors Contributions and Acknowledgments**

## **References**

- Barfield, M., Holt, R. D. and Gomulkiewicz, R. (2011). Evolution in Stage-Structured Populations (2 versions). *The American Naturalist* 177, 397--409.
- Engen, S., Lande, R. and Sæther, B.-E. (2011). Evolution of a Plastic Quantitative Trait in an Age-Structured Population in a Fluctuating Environment. *Evolution* 65, 2893--2906.



Figure 1: General Fig