Does a changing climate alter Yellow Rattle (*Rhinanthus minor*) lifetime reproductive success?

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Hypothesis

- Yellow rattle populations would show declined reproductive success (measured by seed viability and emergence) if transplanted from low elevation to higher elevation sites.
- Margin of the decline would be reduced if populations were transplanted under warming condition.

Introduction

Edge populations of plants may be able to expand species' ranges if they are able to adapt to changing conditions. Populations of *Rhinanthus minor* were transplanted to different elevations to test relative plant fitness, measured by seed emergence and lifetime reproductive success. Some plants were placed in warming chambers to separate temperature from elevational effects. This study was carried out on two peaks, Nakiska (NK) and Hailstone butte (HB), to investigate whether climate changes could modify plants' ability of local adaptation for range expansion.

Questions

1. Does climate determine range and phenological adaptation?

2. Do transplanted plants vary in their lifetime reproductive success between site and treatment?

3. Do plants transplanted to warmer ranges seed earlier than plants in cooler ranges? Does this change between NK and HB?

Methods

- **Climate data**
- **Input:** HargreavesEcolLett data hobo&ibutton summary by site.csv
- Clim -> clim.winter + clim.not.winter using grepl()
- Distance matrix map
- **Output:** #days with snowpack & mean July temperature comparisons between years, sites, transects.

- **Lifetime reproductive success data**
- **Input:** HargreavesEcolLett data ltrsHB/ltrsNK.csv
- PCA
- Factor analysis using FAMD() & fviz_famd_ind();
- **Output:** Boxplot - Leaf growth comparisons between treatments, transplantations.

- **Seed emergence data**
- **Input:** HargreavesEcolLett data prop&LTFHB/NK.csv
- GLMM with random intercepts for plot pair (i.e. paired control and OTC plots) to monitor the transplants;
- Matrix models to calculate density-independent population growth rates of the plants.
- **Output:** Barplot – seed emergence comparison

1

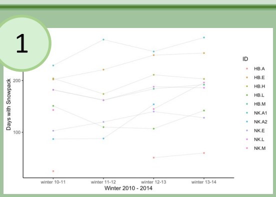

Fig. 1. Comparison of the total days with snowpack in winter among sites sampled from elevational transect NK and HB. Grey solid lines indicate the change in days across years.

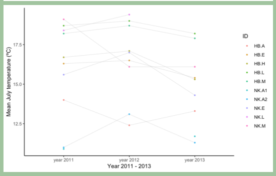

Fig. 2. Comparison of the mean July temperature (°C) among sites sampled from elevational transect NK and HB. Grey solid lines indicate the change across years from 2011 to 2013.

Table 1. Principle component analysis

	Eigenvalue	Comp. 1	Comp. 2	Comp. 3
Proportion*		0.632	0.326	0.041
Loadings				
Total leaf nodes	1.897	0.693	0.167	0.701
Total fruits	0.979	0.701		-0.710
Average seeds	0.123	-0.165	-0.984	

*Proportion of variance

Table. 1. Principle component analysis for seed viability; greater loadings suggest a higher level of importance.

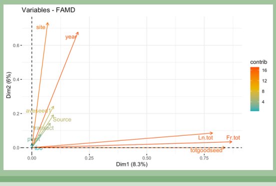

Fig. 3. Graph of variables based on factor analysis. Positive correlated variables point to the same side of the plot.

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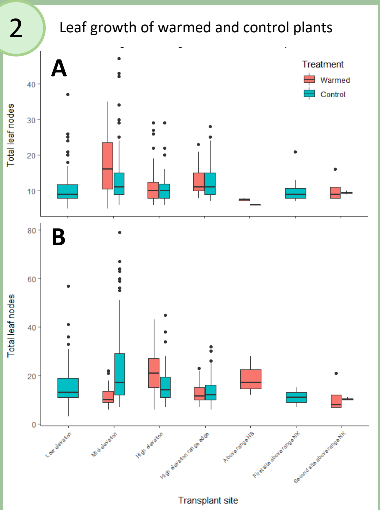

Fig. 4. Boxplot showing leaf nodes in transplanted plants from (**A**) high elevation and (**B**) mid-elevation sourced plants in warmed and control treatments across transplant sites. Warmed and control group do not appear to significantly differ, but some differences may be present at mid- and high elevation sites.

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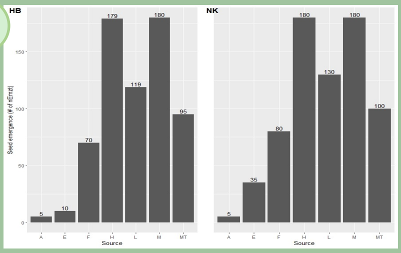

Fig. 5. Side-to-side bar plots depicting seed emergence (nEmzt) vs. sources with distinct elevations (Source) for both HB and NK peaks. Grey bars indicates the number of emerged plants across sources.

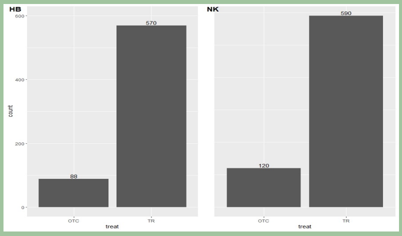

Fig. 6. Side-to-side bar plots counting the number of affected plants with two methods of treat for both HB and NK peaks. OTC on the x-axis represents warming chamber, and TR stands for controlled group.

Conclusions

- In the principal component analysis, the most prominent biological factor (eigenvalue: 1.897, total variance explained: 63.2%) was total leaf nodes, including primary, secondary and tertiary stems （table.1).
- Leaf nodes were additionally shown to increase when high elevation sourced plants were transplanted to warmed mid-elevation sites and when mid-elevation sourced plants were transplanted to warmed high elevation sites, likely due to being within more optimal temperature ranges. Mid-elevation plants transplanted to mid-elevation warmed sites showed decreased leaf growth, possibly due to being in a warmer temperature than optimal (Fig. 4).
- Plants from higher elevations transplanted to warmer ranges will seed earlier. Plants from lower elevations transplanted to cooler ranges will seed later (Fig. 5, Fig. 6).

Future Directions

- For future analyses of these data, we would recommend further examination of differences between plant character (leaf nodes, fruits, viable seeds) across sites to determine if plants under similar transplant treatments exhibit similar characters.
- Furthermore, experimental treatments were not uniform across all sites; low elevation transplanted plants were not divided between warming and control groups, so it is unsure if leaf nodes differed at low elevations as well.
- Additional studies including warming chambers at more experimental sites would help to constrain the observed patterns.

References

Hargreaves, Anna L.; Eckert, Chris G.; Eckert, Christopher G. (2018), Data from: Local adaptation primes cold-edge populations for range expansion but not warming-induced range shifts, Dryad, Dataset, https://doi.org/10.5061/dryad.3bd420c

Hargreaves, Anna L.; Eckert, Chris G.; Eckert, Christopher G. (2018). Local adaptation primes cold-edge populations for range expansion but not warming-induced range shifts. Ecology Letters 22: 78-88. https://doi.org/10.1111/ele.13169