

Three decades of environmental change studies at alpine Finse, Norway: responses across ecological scales

Ruben E. Roos^{1,2}, Johan Asplund¹, Tone Birkemoe¹, Aud H. Halbritter^{3,4}, Siri Lie Olsen^{1,2}, Linn Vassvik^{1,5}, Kristel van Zuijlen^{1,6}, Kari Klønderud¹
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Introduction

- The International Tundra Experiment (ITEX), with many research sites throughout the world, was established in 1990 to understand how environmental change impacts Arctic and alpine ecosystems, and has resulted in high-impact across-site syntheses
- Various add-on projects in ITEX sites have resulted in increasing knowledge of many components of local ecosystems, which is a good starting point for within-site syntheses to better understand ecosystem responses to environmental change across ecological scales
- We have synthesized 80 studies on ecological responses to environmental change at the Finse ITEX site in alpine Norway

Main results



Conclusions

- Do add-on projects! They contribute something greater than the sum of their parts.
- Do syntheses! They increase our knowledge of responses across ecological scales and allow for comparisons of different approaches.
- Use syntheses to identify knowledge gaps! They can guide further research.

Further reading

Roos, R. E., Birkemoe, T., Asplund, J., Halbritter, R., Olsen, A. H., Olsen, S. L., Vassvik, L., van Zuijlen, K., & Klønderud, K. (2022). Three decades of environmental change studies at alpine Finse, Norway: climate trends and responses across ecological scales. *Arctic Science* 9: 430-450.

Heating the heath: 23 years of experimental warming in an alpine biodiversity hotspot

Gaute Eterjord¹, Siri Lie Olsen¹, Kari Klønderud¹

¹Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, Ås, Norway

Where, how and why?

Increased temperatures because of climate change will impact the biodiversity of alpine areas¹. One of the most diverse plant communities in Scandinavian mountains are Dryas heaths². We studied changes in a Dryas octopetala heath at Finse, SW Norway, after 23 years of experimental warming (Fig. 1). We expected warming to increase dwarf shrub and graminoid cover at the expense of lichen and bryophyte cover and richness.

Bryophytes and lichen cover declined, litter increased

There was significantly lower cover and richness of bryophytes and lichens with warming, as well as increased litter cover (Fig. 2-3). Vascular plant cover and richness were not significantly affected. Species composition differed with and without warming, and warmed plots had taller vegetation and lower soil moisture (Fig. 4).

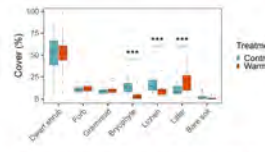


Fig. 1. Cover of vegetation groups. Bars are mean and error bars are standard error of the mean. Significance levels are indicated by asterisks: ** p < 0.01, *** p < 0.001.

Fewer lichens and bryophytes reduced richness



Fig. 2. Species richness in the dry heath at 46° 54'N, 15° 54'W. Bars are mean and error bars are standard error of the mean. Significance levels are indicated by asterisks: ** p < 0.01, *** p < 0.001.

Conclusions

Lichen and bryophyte cover and richness declined with warming, likely due to taller vegetation intercepting light and producing litter, along with reduced soil moisture. As a result, the Dryas heath was impoverished and lost diversity. Our findings show the importance of including lichens and bryophytes when studying the effect of climate change on alpine plant communities.

Plant sex expression, but not long-term experimental warming, affects the pollination success of *Silene acaulis*

Authors: Sara Linn Holgaard Thorsø¹, Kari Klønderud, Erik Thrane, Achim Högberg
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BACKGROUND

- Alpine ecosystems are defined by cold temperatures, strong winds and short growing seasons. These environments are sensitive to climate change, particularly rising temperatures.¹ *Silene acaulis* plays an important role in these habitats but is vulnerable to warming.²
- S. acaulis* exhibits sexual diversity, with mostly gynodioecious populations consisting of female and hermaphrodite individuals.^{3,4} "Mixed cushions", containing both female and hermaphrodite flowers on one individual, can also occur.⁵
- Studies have shown that *S. acaulis* may respond to increased temperatures with earlier flowering and changes in sex distribution.^{6,7} This highlights the need for research into how alpine flora adapts to the shifts in climate.

METHODS

Site: Sanddalsheia, Finse, Norway

Long-term experimental warming setup: Open Top Chambers (OTCs) and control plants outside of the OTCs, established in 2000.

Temperature loggers:

- TeraLoggers
- DIY Science!
- Arduino based
- Surface and ambient temperature
- Measures and logs every 15 minutes

RESEARCH QUESTION

How does experimental warming and plant sex expression affect the pollination success of *Silene acaulis*?

RESULTS

Ambient and Plant Surface Temperature Parameters

Plant Sex Proportion

Sex	OTCs	Control	OTCs	Control
Female	0.54	0.54	0.54	0.54
Hermaphrodite	0.46	0.46	0.46	0.46

Pollination Success (N° Seed Capsules / N° Flower)

FINDINGS AND DISCUSSION

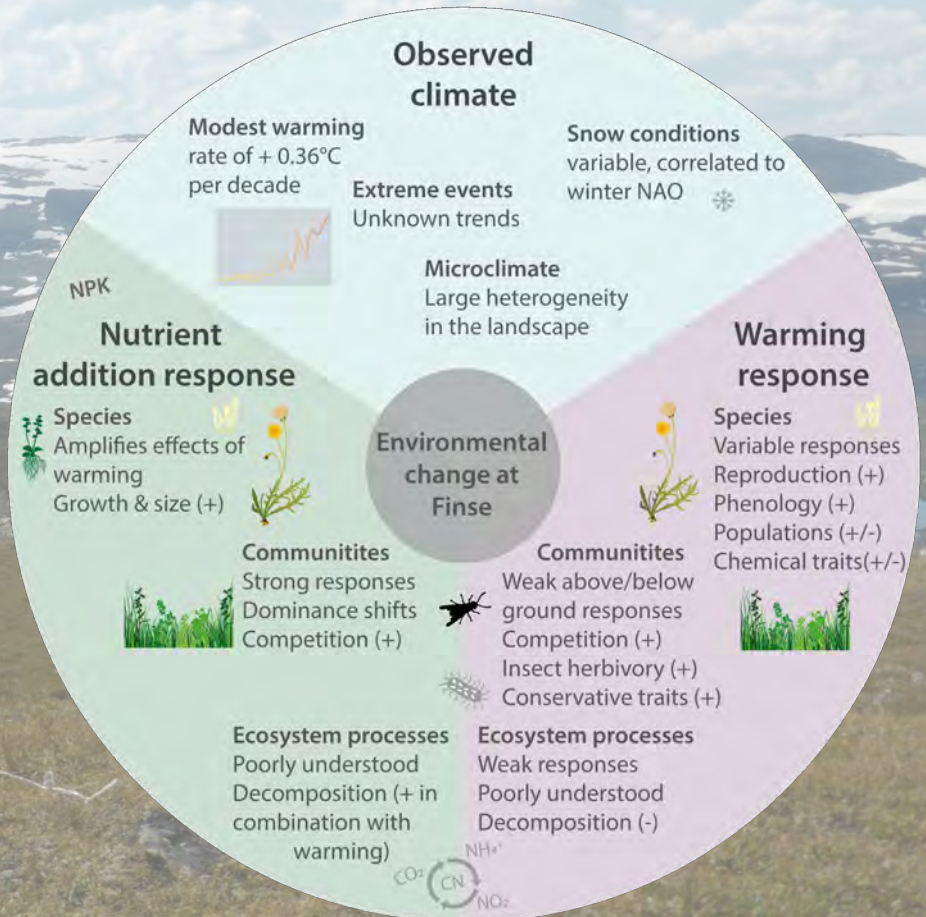
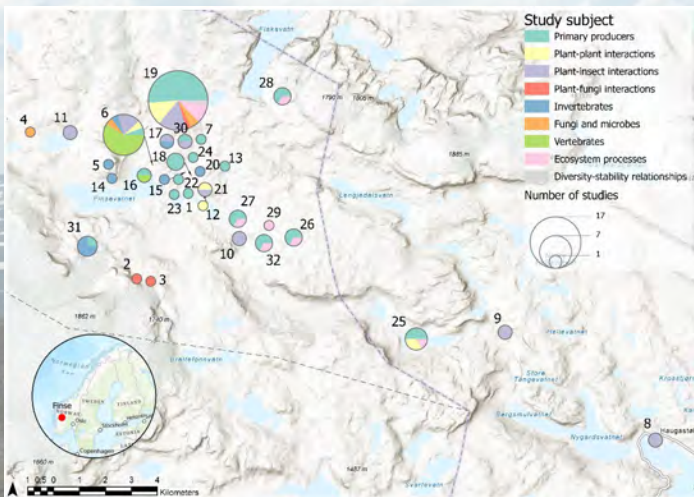
- The OTC treatment significantly increased the ambient and plant surface temperatures compared to the control plants. The average daily mean was increased by around 1°C and the average daily mean was around 3°C. When analyzing the effect of OTC treatment on the pollination success, no effect was found.
- Plant sex had a pronounced effect on pollination success: Hermaphrodite plants had significantly lower success compared to female plants (p < 0.001).
- Male-acting hermaphrodites?
 - The lack of pollination success in hermaphrodites may be attributed to a resource allocation strategy: Producing pollen is more energy efficient than seed production. If the resources were limited, plants may re-allocate resources towards male function, with a reduction in seed capsule production as a result.⁸
- Outgoing evolution?
 - Hermaphrodites constitute a small portion of the studied *S. acaulis* population. As the only pollen producers, the mating system dynamics may be shaped by the limited availability of pollen. The genetic contribution of hermaphrodites would therefore be particularly important, suggesting an evolutionary trend driving resource allocation towards male function.
 - Future research is needed to understand how plant sex expression and warming may affect the pollination success of *Silene acaulis*, with a particular focus on an adaptive response in resource allocation between male and female functions in hermaphrodites.

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Recent work from the Finse ITEX site

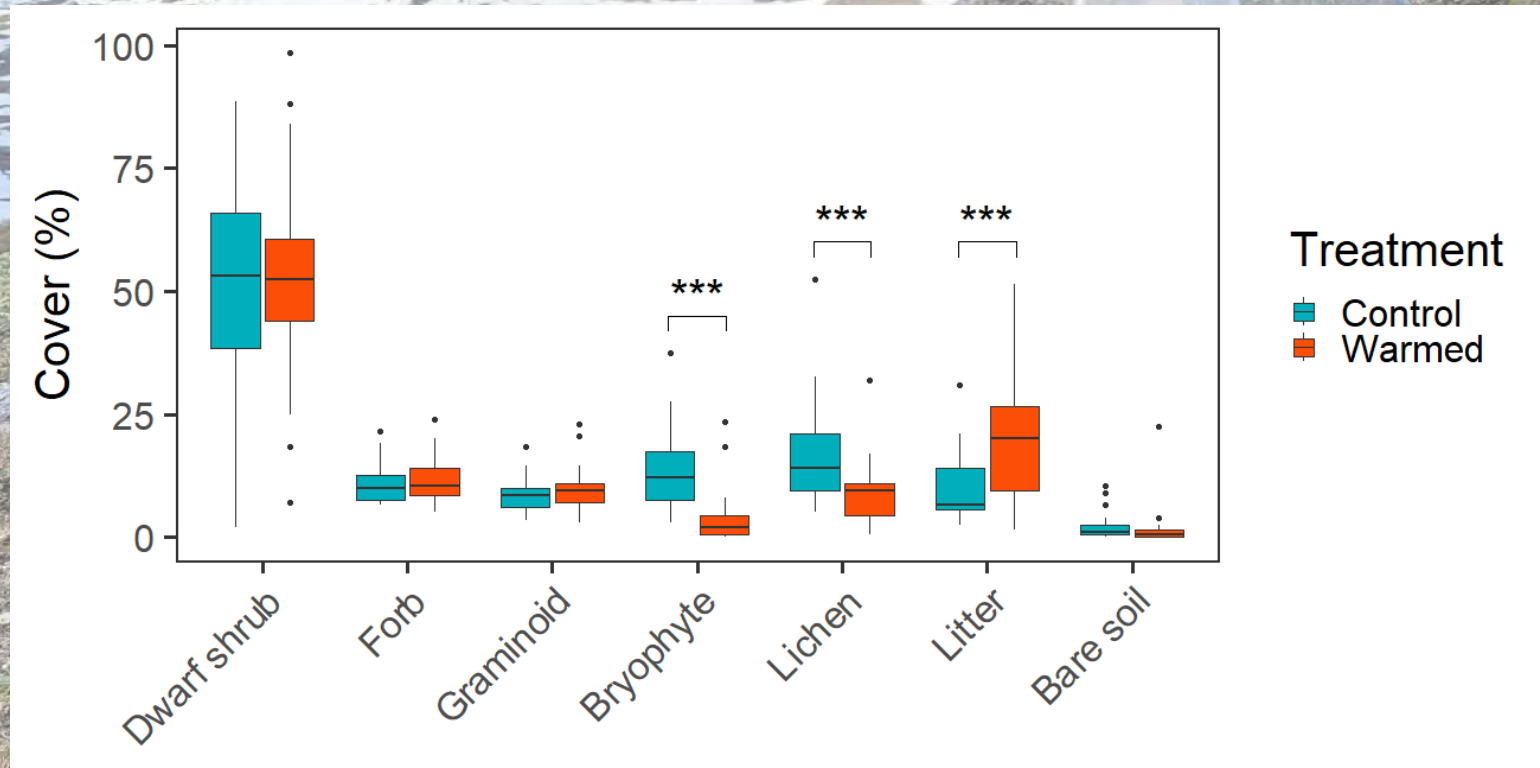
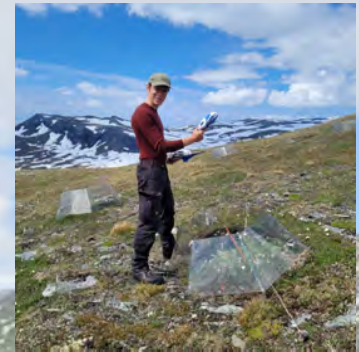
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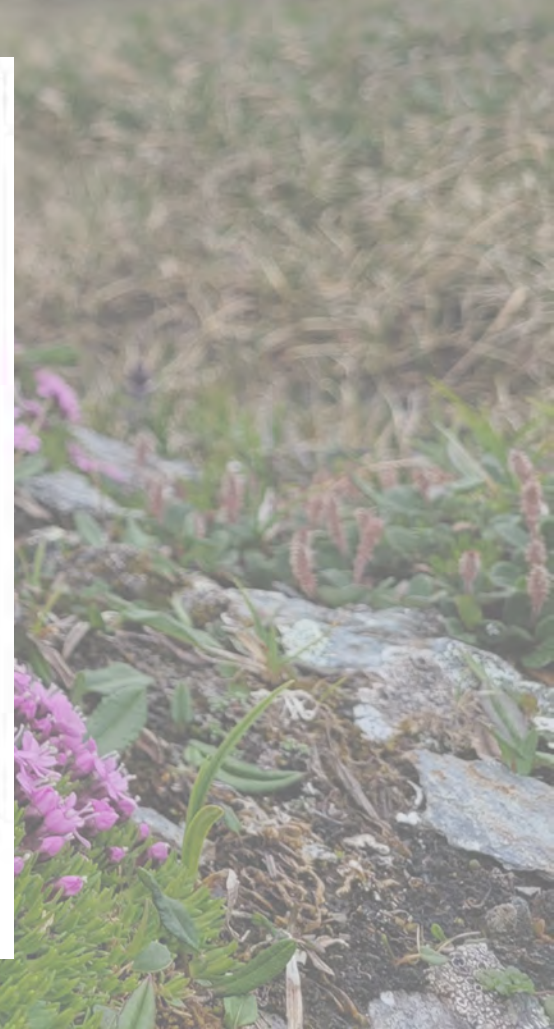
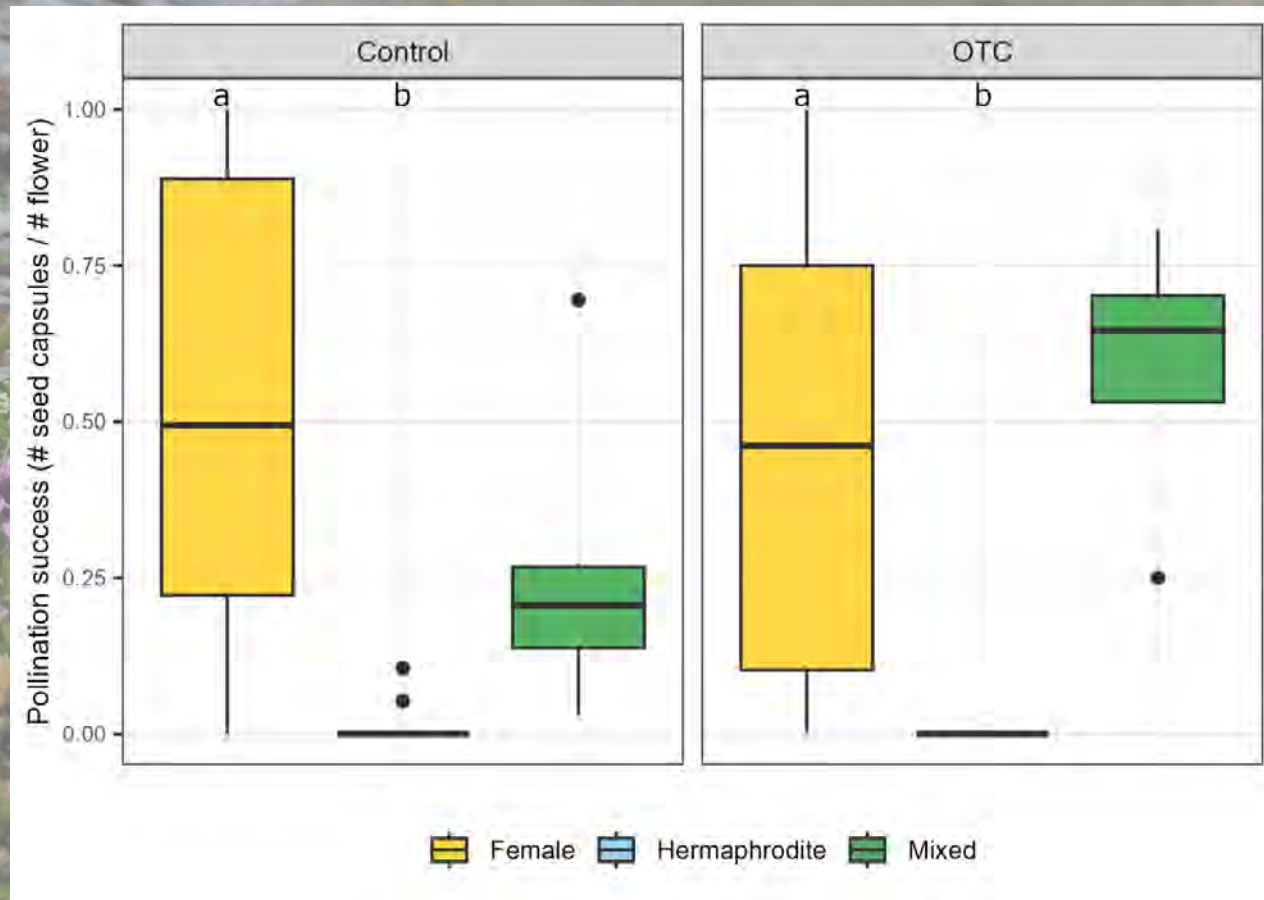
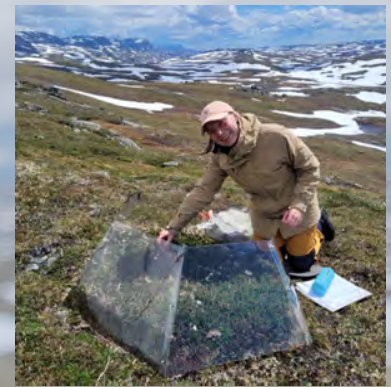
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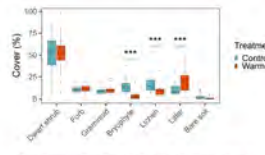
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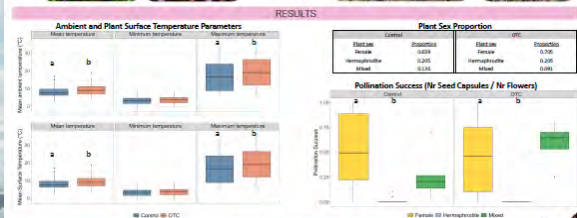
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