

**Experimental test of the ability of plants to regulate their
temperatures under climate change: Using transplanted
communities, thermal imaging, and arcGIS across an elevation
gradient**

Sophie Buchholz

Brian Enquist

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Abstract:

The question of thermoregulation in plants is increasingly important in a rapidly changing climate. Plants have long been considered poikilotherms, where internal temperatures are decided by the external environment. However, observations show that plants have some ability to thermoregulate. If plants are heterotherms, then they have the potential to be more resilient to the warming climate. This project seeks to examine thermoregulation through technology, specifically FLIR imagery. At three different sites in Washington Gulch, plants were moved to examine the effects of a warmer or cooler environment. This project will use thermal imagery on those transplants in order to study how the temperature of plant communities change when moved to a new climate.

Introduction:

As climate change advances, plant physiology and demographics are expected to shift. Plants that prefer a colder environment will lose habitat and face a decreased range. Oppositely, plants in a warmer environment will have an expanded range. As mountains warm, plants are migrating upwards and creating an increase in total alpine species number.¹ Furthermore, studies conducted in Norway found that high-alpine plants with more specific habitat needs had declining populations.² Thus, high alpine plants face a declining niche, and must adapt to warmer temperatures or face extinction.³

Transplanted plots have been compared to the stationary plants to observe how a small community might change at different elevations. One important facet of the changing habitat is temperature, and how plants will adjust to new environments. Plants are often thought to function optimally across a wide range of body temperatures that are in equilibrium with the environment. Many studies in physiology, ecology, and climate science still regard plants as poikilotherms – with temperatures that are determined solely by the environment.⁴ Indeed, it is commonly assumed that plant temperatures are equal to the ambient air temperature. In the face of variable environmental temperatures many plants can thermoregulate to maintain relatively stable tissue temperatures.⁵ Furthermore, empirical data conducted by Michaletz et al. show that plants are actually limited homeotherms that do thermoregulate.⁶ Their experiment was conducted along an air temperature gradient of ~50°C where 68 leaves were collected and measured.⁷ Their results supported a theory of limited heterothermy of leaves across a

¹ Georg Grabherr, Michael Gottfried, and Harald Pauli, "Climate Effects on Mountain Plants," *Nature* 369, no. 6480 (June 1994): 448–448, <https://doi.org/10.1038/369448a0>.

² Kari Klanderud and H.j.b. Birks, "Recent Increases in Species Richness and Shifts in Altitudinal Distributions of Norwegian Mountain Plants," *Holocene* 13, no. 1 (January 2003): 1–6, <https://doi.org/10.1191/0959683603hl589ft>.

³ Gerald Jurasinski and Jürgen Kreyling, "Upward Shift of Alpine Plants Increases Floristic Similarity of Mountain Summits," *Journal of Vegetation Science* 18, no. 5 (2007): 711–18.

⁴ J. Levitt, *Responses of Plants to Environmental Stresses*, 2d ed, Physiological Ecology (New York: Academic Press, 1980).

⁵ James R. Mahan and Dan R. Upchurch, "Maintenance of Constant Leaf Temperature by Plants—I. Hypothesis-Limited Homeothermy," *Environmental and Experimental Botany* 28, no. 4 (October 1988): 351–57, [https://doi.org/10.1016/0098-8472\(88\)90059-7](https://doi.org/10.1016/0098-8472(88)90059-7).

⁶ Sean T. Michaletz et al., "Plant Thermoregulation: Energetics, Trait-Environment Interactions, and Carbon Economics," *Trends in Ecology & Evolution* 30, no. 12 (December 2015): 714–24, <https://doi.org/10.1016/j.tree.2015.09.006>.

⁷ Michaletz et al.

temperature and climate gradient.⁸ This project examined if spatial measurements of meadow temperatures can be used to assess if plants can potentially adjust their functioning to a change in temperatures.

In order to examine the relationship between plants and elevation, Lorah Seltzer from the Enquist lab began a plant transplant experiment in 2017. Three sites were established along an elevational gradient in Washington Gulch, each with 25 marked plots. The plots either remained stationary, moved within the site, or moved to a higher or lower elevation site. This project examined whether or not plants can mitigate the effects of climate change by adjusting their leaf temperatures. Two potential hypotheses were that if there is leaf homeothermy, experimentally transplanted communities from either cooler or hotter environments will modulate their leaf temperatures so as to more closely approximate their home site temperature than their destination community. Secondly, if there is no leaf homeothermy, experimentally transplanted communities from either cooler or hotter environments will not modulate their leaf temperatures and that their leaf temperatures will more closely approximate their destination site temperature than their home community.

Methods:

This project was conducted using thermal images of the 29 plots at each of the three sites. In 2020, a FLIR camera captured the infrared heat of both transplanted and controlled turfs. The FLIR images were then uploaded into FLIR tools and the pixels were consequently assigned a temperature value. The data from the pixels was exported from FLIR tools as a .csv file and analyzed in R. The developed temperature rasters are also a part of a larger online public ArcGIS project for the Enquist Lab. Other data observed historically, such as carbon and water fluxes and community makeup, will also be included in the map.

The independent variables are the plots, and the corresponding temperature is the dependent variable. Treatments for the plots include: untouched, warmed two steps, warmed one step, cooled two steps, cooled one step, and moved within the site. Turfs moved between sites will be compared to the untouched turfs at both the origin and destination sites.

The temperature information obtained by the pixel analysis done in R was then inserted into a distribution graph. This was done both for each plot, and then cumulatively by treatment in order to see the temperature distributions of the different turfs. It was then possible to compare the control plots to the treated plots. This will be done by performing an ANOVA test comparing the temperature distribution of the treatments to the temperature distribution of the control plots.

Results:

The results of the pixel analysis determined that the plots that were warmed were warmer than both the averages of both the origin and destination control sites (Table One). Opposingly, the sites that were cooled were in between the average temperatures of the origin and destination control sites, but closer to the destination sites (Table One).

The results of the ANOVA test are yet to be determined but will utilize the information found in Figure One.

Discussion:

⁸ Michaletz et al.

The results for the six different treatments were divided between the warmed and cooled treatments. Cooled turfs were only slightly warmer in temperature compared to the control turfs at their destination which suggests that plants may have some way of retaining control of temperature, or homeothermy. As they are not completely the same as their original site's temperature, the emphasis must remain on the word limited. However, since the warmed turfs are even warmer than their destination site, no homeothermy is indicated. A potential reason for this is that plants become more stressed in the warmer temperature, and their stomata may be shutting down and reducing photosynthesis. The stress due to the temperature change may have further limited the plants' ability to thermoregulate.

There remain several avenues for further research. Primarily, it would be worthwhile to study the functional traits of plants that might regulate plant temperature. In their study, Michaletz et al looked specifically at the link between homeothermy and photosynthesis, specifically the trait-based approach.⁹ Specifically, energy budgets are linked to the functional traits that are studied in plants to better understand the theory of limited homeothermy.¹⁰ As leaf traits are frequently studied by the Enquist Lab, it would not be difficult to add this research. Furthermore, it would be interesting to further define the phrase "limited homeothermy" and where it falls on the spectrum between poikilothermy and homeothermy.

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⁹ Michaletz et al.

¹⁰ Michaletz et al.

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Tables and Figures:

Table One: Mean Comparison of the Treatments

	Origin Mean Temp.	Treatment Mean Temp.	Destination Mean Temp.
Monument to Pfeiler	19.78	31.49	30.25
Monument to Upper Montane	19.78	39.07	36.87
Pfeiler to Upper Montane	30.25	41.70	36.87
Pfeiler to Monument	30.25	20.92	19.78
Upper Montane to Pfeiler	36.87	31.70	30.25
Upper Montane to Monument	36.87	21.76	19.78

Figure One:

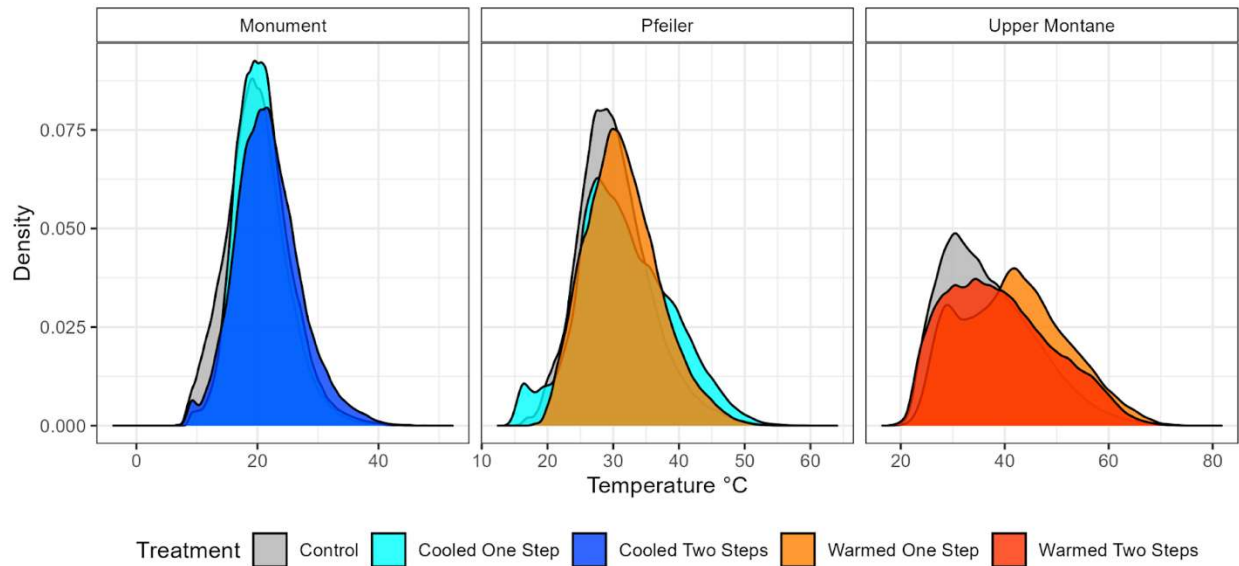


Figure Two:

