Disturbance impacts on alpine populations at elevational and climatic limits

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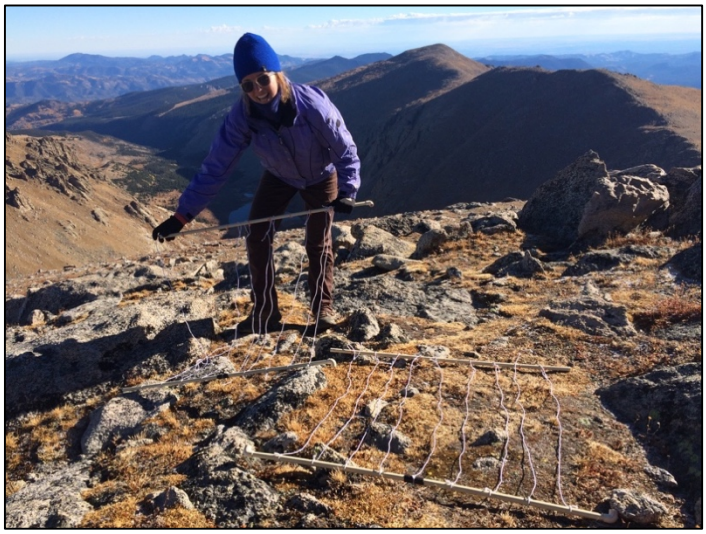
Introduction: Every climber and dedicated hiker appreciates an alpine sunrise, and as a community ecologist studying extreme environments I see these unique artworks on my daily commute to the alpine world. Located above tree line, this is a world where abiotic, or non-living, factors such as climate determine who succeeds and fails. This is a world blanketed by snow for the majority of the year, and life only has 3-4 months to thrive in the summer. Even then, the conditions here are so harsh that plants rely on each other to survive on the alpine tundra. This alpine tundra is one of nature's masterpieces, as despite its low moisture, gusting winds, low temperatures, and poor soil nutrients, life here has adapted unique traits to survive. With the pressures of climate change, which particularly affects alpine regions, and increased human disturbance, this masterpiece is being transformed by our very own actions. A community ecologist interested in extreme environments, I study the effect of anthropogenic perturbations on plant communities and my research is currently focused on North American and European alpine regions.

← Alpine sunrise on Quandary Peak, en route to upper field site at 14,000 ft.

Research: Range limits are fundamental species traits as well as basic biogeographical units. As every organism possesses these distributional 'edges' along altitudinal and latitudinal as well as longitudinal gradients, they dictate the organization of the entire biological world. Understanding where and why range limits occur is now critical for predicting how individual species and entire communities may respond to climate change. Although the importance of this topic has inspired a recent surge in range limit research, precisely where and why species range limits occur is still surprisingly poorly understood. One great source of uncertainty regarding current range limits involves the interaction of our changing climate with the various other disturbances that humans increasingly exert even in the most isolated regions of the globe. Understanding the synergistic, or perhaps opposing, effects of anthropogenic impacts on range limits would enable us to better predict geographic shifts in species' ranges with projected future disturbances, thereby greatly informing environmental policy.



Field assistant Clea Bertholet assembles our sampling quadrat on Greys Peak. →

A PhD candidate in the Environmental Studies Program at the University of Colorado, Boulder, I study how human perturbations, namely climate change and trail disturbances, affect alpine plant communities. One aspect of this research was generously supported by the American Alpine Club in 2016, to allow me to finish my fieldwork on Colorado's popular 14ers. In this study, I collected extensive data

on population parameters (e.g., plant size) of the alpine cushion plant moss campion (*Silene acaulis*, Caryophyllaceae) along trails using sampling quadrats within 10 m transects, and compared these populations to undisturbed populations away from the trail. In order to analyze the effect of climate on this species, I set up field sites at the lower, mid, and upper elevation range location for moss campion at each of my sample summits. As elevational gradients in mountain environments are a good proxy for temperature, these range locations correspond to warm, cool, and cold environments, respectively. Climate change predictions clearly show that temperatures will increase, and therefore warm environments give us an insight to how species will respond to warmer temperatures. Conversely, cold environments represent climate regimes that might disappear in the future. To perform fine-scale analyses on the effect of temperature on moss campion, I buried small temperature loggers at each site and will retrieve them one year later in order to have a year-long temperature profile.

Using statistical modeling software, I am analyzing exactly how disturbance affects moss campion plant size and how these effects change with elevation. My preliminary data analyses show that hiker disturbance significantly reduces vegetation at lower elevations, which allows moss campion to grow larger. This suggests a shift in competitive interactions, as cushion plants are usually outcompeted at at these elevations. I predict that at higher elevations, the impact of disturbance will be negative overall, and I am currently working on analyzing this now-completed dataset.

← *10 m trail-side sampling transect at moss campion's upper elevational range limit on Mount Yale.*

Relevance: The dataset I compiled with support from the AAC is the foundation of one of my dissertation chapters for my PhD, in which I explore the role hiker disturbance plays in the geographic distribution of alpine plants. As my chosen study sites represent trampling disturbance identical to that found in climbing areas, my results will be particularly relevant in helping the AAC meet its goals of understanding the conservation impact of climbers. This will be invaluable in reducing climber impacts in alpine ecosystems, a topic that is certainly of increasing concern with the rise in American alpinism.

This study has fueled further questions in my research of disturbance in alpine systems, such the fundamental one of how disturbance affects important community interactions. To this end, I recently started a community-wide study aiming to quantify such interactions in Switzerland. This will allow me to make important comparisons with the Colorado dataset, in order to analyze if the patterns I see in Colorado are global ones.

In order to involve other climbers, hikers, and other outdoor recreationists in alpine research and gather meaningful data on plant occurrences, I have developed an app for iOS and Android that allows users to identify plant species with a field guide and upload their observations to the Niwot Long-Term Ecological Research database.

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