Monitoring the Adirondack Alpine: Soils and Plant Abundance in New York's Highest Ecosystem

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Arctic-alpine ecosystems are rare in the continental United States, and are under increased threat from both recreational use and climate change. Alpine summits in the Northeast, particularly in the Adirondacks, are notably low in elevation (approx. 1300 m) for their mid-latitude location. This rare ecosystem is supported by ice storms and other factors that inhibit the growth of dwarfed trees (krummholz). The health of mid-latitude alpine zones is expected to be a climate change indicator, because as the climate warms and ice storm intensities change, non-alpine species may expand their range into previously unsuitable territory. Tree expansion into historical alpine areas has already been observed as a function of changes of temperature and precipitation in Sweden and Russia (Kullman 2008, Moiseev and Shiyatov 2003). Alpine tundra plant communities in the Adirondacks, however, are much smaller size (Carlson et al. 2011) and face possible extirpation due to upward migration of non-alpine species such as fir/spruce krummholz and lowland generalists.

The Adirondack alpine is spread thinly across 21 summits that are frequently travelled by recreators, which can be highly damaging to the vegetation and soils. The Adirondack High Peaks Summit Stewardship Program (SSP), supported by the Adirondack Mountain Club, the Nature Conservancy, and the NYS Department of Environmental Conservation, was established in 1989 to rehabilitate and protect alpine areas in the High Peaks from erosion and trampling. The soils, which hold the ecosystem together, can be lost to the wind when the vegetation is trampled. Before the establishment of the program, alpine meadows were being heavily impacted, and the outreach efforts of the SSP have significantly reduced trampling and have facilitated the regrowth of native sedges, grasses, and other herbaceous plants on the rehabilitated alpine soils (Goren and Monz 2011, Ketchledge et al. 1985).

Populations of alpine plant communities on these summits were modeled based on species abundance data from stratified plots and GIS layers, such as flow length, insolation, and western exposure. To investigate if soil depth was a useful model parameter, this past summer I hiked to 189 plots on six remote summits (Wright Peak, Algonquin Peak, Boundary Peaks, Mt. Colden, Mt. Marcy, and Whiteface Mt.), estimated the abundance of 17 target species, and took 19 soil depth measurements in each plot. Deer's hair Sedge (*Trichophorum cespitosum*), mountain firmoss (*Huperzia appressa*), pincushion plant (*Diapensia lapponica*), black crowberry (*Empetrum nigrum*), alpine blueberry (*Vaccinium boreale*), northern bentgrass (*Agrostis mertensii*), Bigelow's sedge (*Carex bigelowii*), and bearberry willow (*Salix uva-ursi*) were found in more than ten plots and were useful for analysis. I measured soil depth using a thin, graduated 50 cm rod, which I pushed to the bedrock at one meter intervals along the perimeter of each plot and along 1.4 m intervals across the NW hypotenuse of the plot.

I hypothesized that most alpine species (those with sufficient sample sizes) will show either a tendency to grow in medium or shallow soil depths. A better understanding of the role soil depth plays in the arctic-alpine ecosystem could modify expected changes to the ecosystem due to climate change, provide support for programs like the SSP, and increase our ecological knowledge of New York's highest ecosystem.

I found that alpine plants grow in significantly shallower soil depths than krummholz vegetation (M_{alpine} = 13.06 cm, $M_{krummholz}$ = 26.64 cm, $p < 0.0001$; Figure 1). The maximum average soil depth in alpine habitat recorded was is 37.3 cm, but most populations were found within the 5 to 20 cm range. Krummholz migration into alpine tundra environment due to climate change may be impeded by this difference in soil depth, perhaps lowering the 'invasibility' of the trees. Lowland generalist plants associated with 'snowbank communities,' or lower elevation shrubs and herbs that can exist in the alpine zone in cirques or other areas sheltered from the wind and late season frosts, might be more likely to colonize historically alpine ecosystems because they can grow in similarly shallow soil depths.

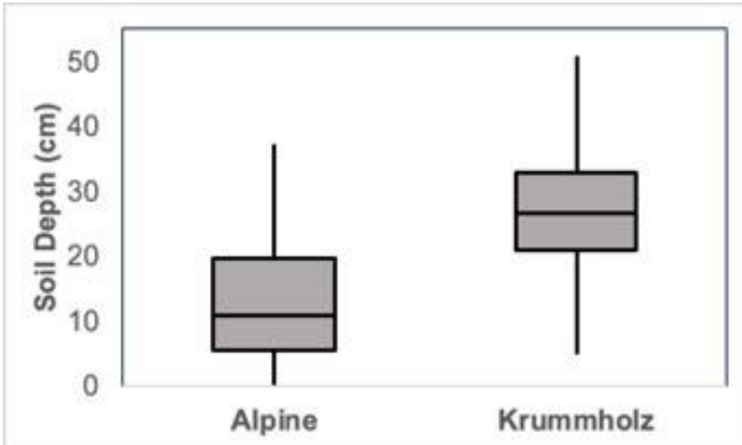

Figure 1. Alpine and krummholz soil depth. (Alpine communities were found in shallower average soil depths than krummholz communities.)

Most major target species exhibited a large variance when comparing abundance to soil depth. *Agrostis mertensii*, however, showed a significant, simple linear relationship with average soil depth, indicating that abundance decreased with soil depth (M = 9.12 cm; Figure 2). This model was determined to be a higher quality fit than any multiple or polynomial models, assessed with Akaike information criterion (AIC) values for model selection.

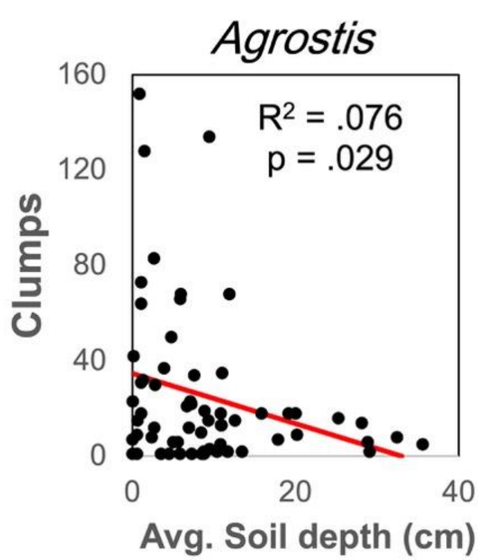

Figure 2. Scatter plot showing abundance of *Agrostis mertensii* against average soil depth.

When all species were evaluated at shallow soil depths (0 to 5 cm), only *Trichophorum cespitosum* showed a significant relationship, for which a simple, second order regression was the highest quality relationship, evaluated using AIC values. At both shallow and total average soil depths, *Trichophorum cespitosum* shows a tendency to grow in medium soil depths ($M_{shallow}$ = 1.80 cm; M_{total} = 13.05 cm; Figure 3). I was surprised to find that this relationship was not significant, either linearly or polynomially, with any of the other major target species. This could be due to error, sample size, or another factor.

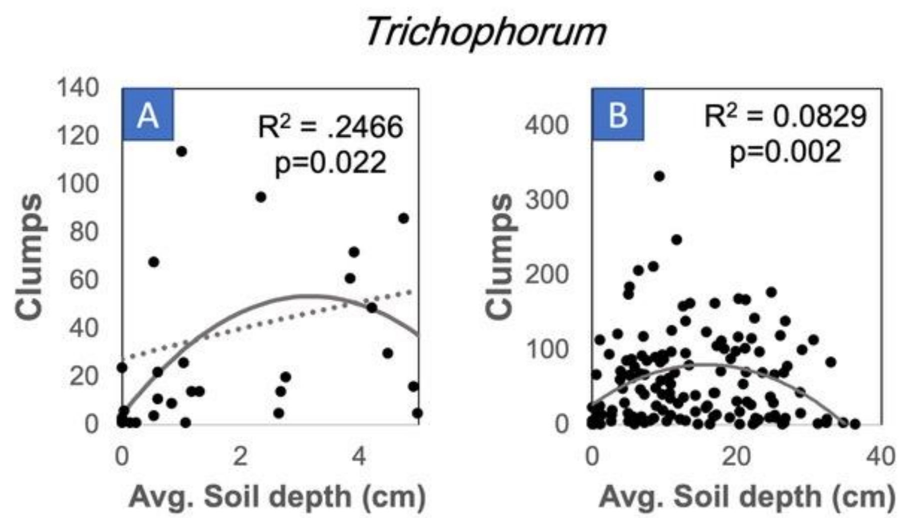

Figure 3. Scatter plots showing abundance of *Trichophorum cespitosum* against shallow (0-5cm; A) and all average soil depths (B). The solid gray lines represent a simple 2nd order regression, which was the highest quality regression for the species at shallow soil depths and is significant at all average soil depths. The dotted gray line in the shallow soil depth scatter is the regression line for the entire *Trichophorum* soil depth range, shown on the right graph as a solid line.

The Summit Steward program has a high profile in the local and visiting public eye, because stewards talk with visitors about minimizing soil erosion and staying off the vegetation; in 2018, Summit Stewards spoke with 38,033 individuals (White 2018). For Summit Stewards and recreational visitors who encountered researchers in the field, the project provided exposure to active conservation research being conducted on summit lands. Under the watch of the public eye, it was important to maintain proper Leave No Trace (LNT) behaviors and good stewardship of this iconic ecosystem. Additionally, LNT research is important because it shows that scientists are caring for the resource in the same short-term way that the general public is encouraged to, in addition to the long-term conservation benefits of research. Recreators are an increasingly varied audience--ethnically, racially, socioeconomically, and politically--and this increased access could translate to increased public interest in conservation.

This project was conducted as a part of a larger study on monitoring and modeling plant populations in the Adirondacks managed by Tim Howard and Julia Goren, who served as my research mentors. These data may help sharpen models of alpine communities, and ultimately help establish conservation priorities in the Adirondack High Peaks.

References

Carlson, B. Z., Munroe, J.S., & Hegman, W. (2011) Distribution of Alpine Tundra in the Adirondack Mountains of New York, U.S.A.. *Arctic, Antarctic, and Alpine Research 43*(3), 331-342.

Goren, J. and Monz, C. (2011) Monitoring Vegetation Changes in Historical Photos over a 45+ Year Period in the Adirondack Alpine Zone. *Adirondack Journal of Environmental Studies 17*.

Ketchledge, E. H., Leonard, R. E., Richards, N. A., Craul, P. F., & Eschner, A. R. (1985). Rehabilitation of alpine vegetation in the Adirondack Mountains of New York State. Research Paper NE-553. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 6 p.

Kullman, L. (2008). Thermophilic tree species reinvade subalpine Sweden – early responses to anomalous late Holocene climate warming. *Arctic, Antarctic, and Alpine Research* 40(1), 104–110.

Moiseev, P. A. & Shiyatov, S. G. (2003). Vegetation dynamics at the treeline ecotone in the Ural highlands, Russia. In: Nagy, L., Grabherr, G., Körner, Ch. and Thompson, D. B. A. (eds) *Alpine biodiversity in Europe*. Ecological Studies 167. Berlin: Springer, pp. 423–435.

White, K. (2018). *2018 Summit Steward End of Season Report*. Retrieved from https://www.adk.org/wp-content/uploads/2018/10/2018-End-of-Season-Report-Summit-Steward-Program.pdf?fbclid=IwAR1jwTVWFDIpl2UCeLZYv5epxtZRFNSmJiCPtsOpdLuqGsQ3rggu9dJpdXs

Sampling in the alpine zone.