

Conservation of a rare alpine plant (*Prenanthes boottii*) in the face of rapid environmental change

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Background

The northeast alpine zone is one of our region's rarest biological communities, comprised of a series of habitat islands totaling less than 35 km (figure 1; Capers et al. 2013). These mountaintop communities are hotbeds of local biodiversity, home to a suite of rare and endangered plant and animal species, including regional endemics as well as arctic species at the southern limit of their range. This biodiversity is now threatened by human-imposed environmental changes.

Climate change is considered by Sala et al. (2010) to be the most important driver of biodiversity change in alpine ecosystems. Alpine communities are predicted to be highly susceptible to climate change for several reasons. First, high-elevation areas are warming faster than low-elevation areas (Wang et al. 2013). Second, the effects of climate change are predicted to be most severe for communities at climatic extremes, such as alpine communities (Pauli et al. 1996, Sala et al. 2010). Finally, the alpine biome is expected to contract as treelines and lower-elevation species move upward in elevation (Parmesan et al. 2006). There is already some evidence of advancing treelines and invasion of lowland species in the northeast alpine (Harsch et al. 2009; Nancy Slack, pers. comm.).

In addition to climate change, northeast alpine species are threatened by high rates of nitrogen deposition and damage due to hiker trampling (Kimball and Weirach 2000).

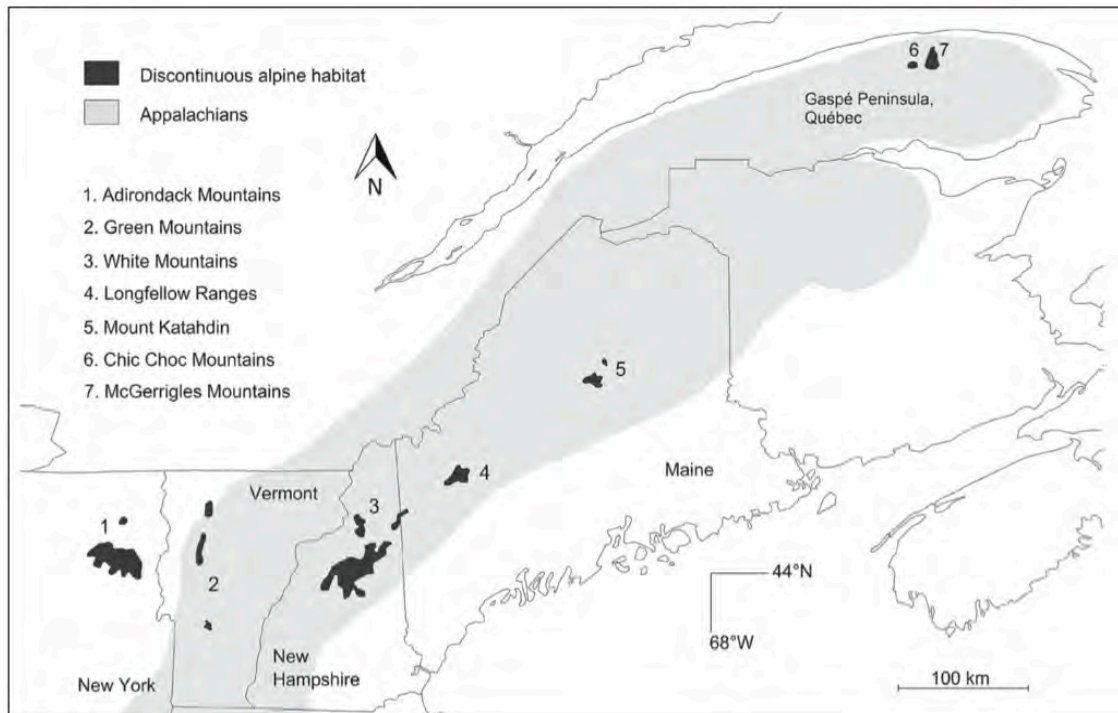


Figure 1. The Northeast Alpine Zone. Alpine habitat occurs in patches within each of the black shapes on the figure. Figure from Capers et al. 2013.

Individually, these three processes pose significant threats to the biodiversity and long-term persistence of the northeast alpine zone; alpine species must also respond to their combined and interactive effects (Capers et al. 2013). The necessity of responding simultaneously to multiple threats may constrain the ability of these species to respond optimally to any single threat, further increasing their vulnerability (Sala et al. 2000, Vinebrooke et al. 2004).

Species have three primary responses to environmental change if they are to avoid extinction: migration, evolutionary adaptation, and phenotypic plasticity (Jump and Peñuelas 2005, Chevin et al. 2010). Migration (long-term range shifts) allows species to track suitable habitat across the landscape, while adaptation and phenotypic plasticity allow species to persist *in situ* despite changing environmental conditions. Species' vulnerability to environmental change can be diagnosed by assessing their ability to respond via these three mechanisms.

The goal of this project is to assess the vulnerability of a rare endemic alpine plant species to rapid climate change by determining its intrinsic vulnerability to extinction and assessing its ability to respond to change via migration, adaptation, and phenotypic plasticity.

Prenanthes boottii (Boott's Rattlesnake-root) is endemic to the northeastern United States, and is one of the species of highest conservation concern in New York's alpine zone (figure 2; NatureServe 2014). It is ranked S1G2 throughout its range: critically imperiled at the state level, and imperiled at the global level. A combination of demographic and population genetic techniques will be used to assess the extinction vulnerability of *P. boottii* in the face of environmental change, including population counts, flowering rates, and measures of intra- and inter-population genetic diversity.



Figure 2. *Prenanthes boottii* in flower on Whiteface Mountain, summer 2014.

Summary of Proposed Work

During the summer of 2014, I planned to visit all extant populations of *P. boottii* for which I was able to obtain a collecting permit to conduct population counts, estimate flowering

rate, and collect leaf tissue samples for future genetic work. Additionally, I planned to participate in alpine botany training by Julia Goren with the 2014 Summit Stewards, and molecular techniques training by Dr. Sean Robinson from SUNY Oneonta.

Narrative of Completed Work

During the summer of 2014, I visited 17 populations of *P. boottii* in New York and New England (figure 3).

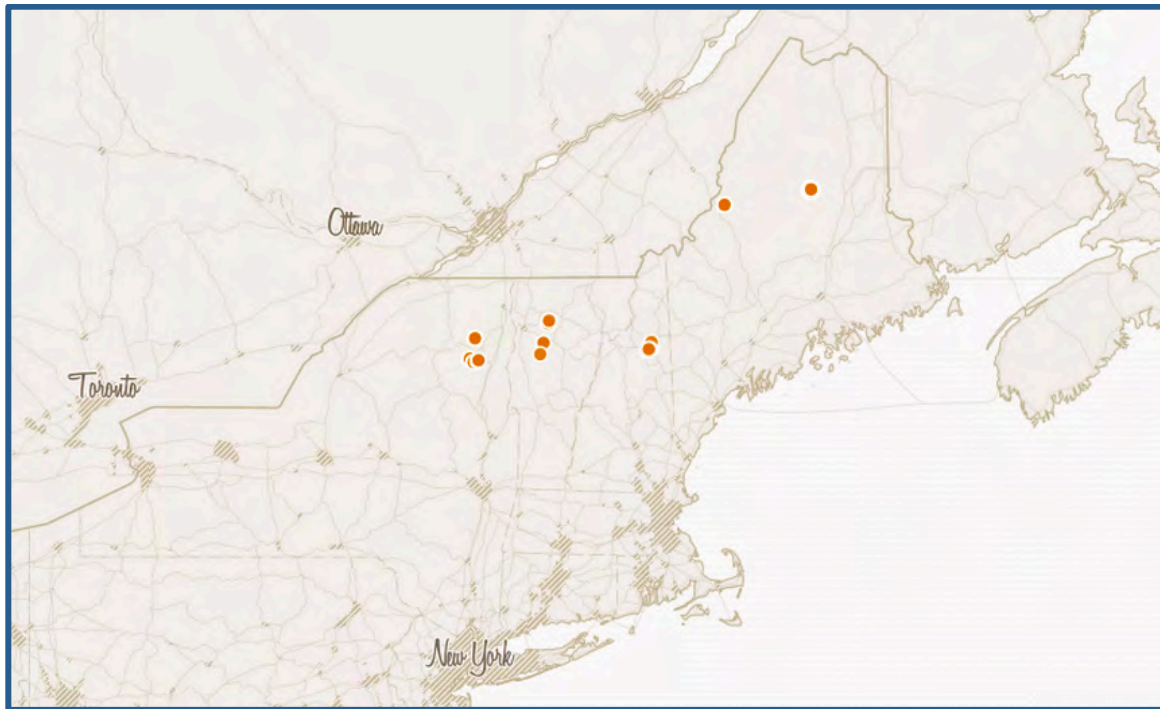


Figure 3a. Field sites for *P. boottii* work, summer 2014.



Figure 3b.
Counterclockwise from top left: the view of Algonquin Peak from Wright (NY), the summit of Camel's Hump (VT), view toward Lakes of the Clouds Hut and Mt. Monroe (NH), view of Baxter Peak from Hamlin Peak on Katahdin (ME).

Population sizes were determined through a direct count, except for populations greater than 10,000 individuals. In the latter case, direct counts of basal leaves and stalks in a test patch and population-wide counts of flowering stalks were used to estimate total population size. Flowering rates were determined using direct counts in small populations and using a test patch in large populations. It should be noted that in both cases, each basal leaf was counted as a distinct individual; this may or may not be true for *P. boottii*, but is the method typically employed for this species (Julia Goren, pers. comm.). Data are as follows:

Population	Census	Flowering rate
New York		
Algonquin	464	4.74%
Wright	67	4.48%
Mt. Marcy*	30	0%
Whiteface	4,998	4.40%
Gothics	250	0.38%
Vermot		
Camel's Hump	1,337	0.45%
New Hampshire		
Mt. Monroe	1,500	2.13%
Lakes of the Clouds	26,833	3.60%
Cow Pasture	53,625	0.80%
Alpine Garden	28,360	2.50%
New Eisenhower	167	2.40%
Edmands col	3,842	1.90%
Maine		
Boundary Bald	6,015	0.03%
Katahdin	1,792	0.45%
Total	129,280	2.02%

Table 1. Population size (counted for population < 10,000, estimated for populations > 10,000) and flowering rate for sampled populations. A total of 17 sites were visited, but collection occurred at only the above fourteen sites. *Note that a few subpopulations on Mt. Marcy were located far from trails, and were not sampled in order to avoid trampling of alpine vegetation. Therefore, this count is not representative of the entire summit population.

New Hampshire harbors the largest state-wide population of *P. boottii*, with nearly 90% of the global population. Intuitively, this makes sense, as New Hampshire harbors the largest swath of alpine habitat in the Northeast United States (Capers et al. 2013). Three populations on Mt. Washington contain 84% of the global population of this species: Lakes of the Clouds, Cow

Pasture, and Alpine Garden. While these three populations certainly appear robust, the fact that the entire species is concentrated in so small an area means that as a whole, it is more vulnerable to extinction.

The average flowering rate for populations in each state follows:

State	Flowering Rate
New York	4.23%
Vermont	0.45%
New Hampshire	1.94%
Maine	0.13%

Table 2. Average flowering rate of *P. boottii* per state.

These data indicate that the Vermont and Maine populations may have increased vulnerability due to low reproductive rates. *P. boottii* primarily reproduces clonally, but sexual reproduction is important for longer distance dispersal and maintenance of genetic diversity within populations. The New York populations may be slightly less vulnerable than expected based on population counts because of the high rate of flowering. However, a few populations within New York had extremely low flowering rates (e.g. Mt. Marcy), so this conclusion is not reflective of all populations the state.

Fifteen leaf tissue samples were collected from widely spaced individuals in each population, except for Whiteface Mountain in New York, from which 40 samples were taken representing 4 subpopulations. Samples roughly the size of two hole punches were torn from basal leaves, placed in coin envelopes, and preserved with silica gel in the field for later DNA analysis.

Over the course of the field work, two new populations were discovered in New Hampshire (New Eisenhower and Edmands col). Several populations could not be relocated (e.g. Great Gulf in New Hampshire, Bigelow Preserve historical population). These findings suggest that this species, known to flourish on disturbed sites, may perhaps survive in a metapopulation of frequent extinctions and colonizations in some parts of its range.

Although not a primary objective of the study, I also recorded associated species in each population. As the following table demonstrates, the alpine community inhabited by *P. boottii* varied state to state, and was more diverse in New Hampshire:

Species	Common Name	NY	VT	NH	ME
<i>Prenanthes trifoliolatus</i>	three-leaved rattlesnake-root	x		x	x
<i>Vaccinium uliginosum</i>	alpine bilberry	x			x
<i>Trichophorum cespitosum</i> ssp. <i>cespitosum</i>	deer's hair sedge	x			x
graminoids		x	x	x	x
<i>Sibbaldiopsis tridentata</i>	three-toothed cinquefoil		x	x	x
mosses (non-sphagnum)				x	x
<i>Solidago cutleri</i>	Cutler's alpine goldenrod			x	x
<i>Campanula rotundifolia</i>	Harebell			x	
<i>Geum peckii</i>	mountain avens			x	

<i>Veratrum viride</i>	Indian poke			x	
lichens				x	x
<i>Salix uva-ursi</i>	bearberry willow			x	
<i>Vaccinium vitis-idaea</i>	mountain cranberry			x	x
<i>Vaccinium oxycoccos</i>	small cranberry			x	x
<i>Abies balsamea</i>	balsam fir				x
<i>Diapensia lapponica</i>	Diapensia				x

Table 3. Species and plant groups associated with *P. boottii* in each state.

Other field observations:

- A variety of potential pollinators were observed visiting *P. boottii*, including flies, bumblebees, moths and hummingbird hawkmoths and unknown hymenopterans.
- As previously noted, *P. boottii* appears to thrive near old concrete structures. The reason for this is unknown—it may be the physical disturbance, or a change in soil chemistry created by the concrete.
- I found evidence in several populations of missing flowering stalks. This could be due to herbivory (snowshoe hare?) or human interference (picking).
- I found large variation in basal leaf size—leaves ranged from ~5mm to 10+ cm. Some populations were dominated by very large basal leaves and some were composed of very small leaves. This species has been variously reported as diploid and polyploidy—perhaps this great size variability could be due to ploidy level?

Future Directions:

The findings of the demographic study serve two important functions: they improve our understanding of the intrinsic vulnerability of *P. boottii* to extinction, and provide a standardized benchmark of population size across the range of the species that can be used in examining population trends.

The second part of this study, which involves population genetic analyses of the collected leaf tissue samples, will inform us about the vulnerability of this species with specific reference to environmental change. DNA extraction has begun, and analyses will continue for several months after extraction is complete.

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Standing by a patch of *P. boottii* under a ledge on Armstrong Mountain (NY).