Climate change impacts in high-elevation northeastern boreal forest plant communities

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Summary of Proposed Work

The Canadian boreal forest reaches its lower limit in the northeastern United States where it is isolated in high elevation mountains. At lower elevations the forest transitions to northern-hardwoods. These mountain forests provide a critical ecosystem service through watershed protection and support a relatively high amount of biodiversity in a small geographical area. Changing climate is expected to impact these geographically unique forests and the species that depend on them. To conserve these protected mountain forests with changing climate, we need to better understand their relationships to climate and how they may already be responding to change.

The goals of my research are to a) determine how climate affects population and community dynamics of plant species in high elevation boreal forests and b) determine growth responses of dominant tree species to recent climate changes.

Narrative of Work Completed

In the summer of 2013 I sampled vegetation at 76 sites on 11 mountains in the northeastern US to add to my extensive dataset collected on Whiteface Mountain, NY in 2012 (Figure 1, Table 1). Sampling included measurements of mature, sapling, and seedling size classes of all tree species present (dead and alive), collecting tree cores from red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*), and deploying iButton temperature/humidity loggers to record for approximately one year.

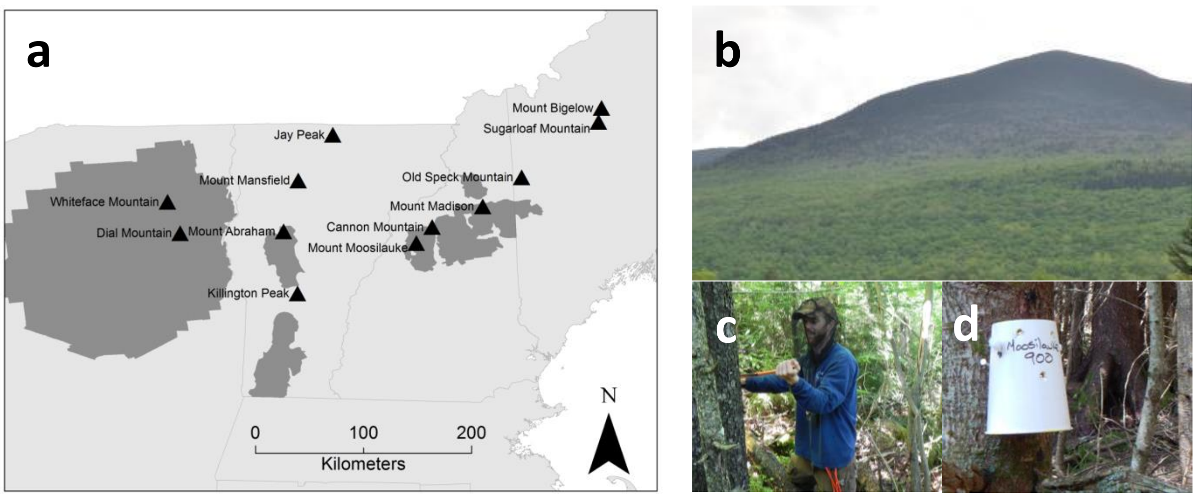

Figure 1. **a)** Location of 11 mountains sampled summer 2013 and original study location (Whiteface Mountain, NY). At each mountain between 6 and 8 sites were established from low to high elevations. Dark shaded areas represent Adirondack State Park, North and South Green Mountain National Forest, and White Mountain National Forest for reference; **b)** Western slope of Mount Abraham, Vermont showing dark green spruce-fir forest and light green northern hardwood forest; **c)** Extracting a tree core using an increment borer; **d)** Protective case covering an iButton temperature sensor attached to a tree.

From mid-May to early June 2013, sites were established on each mountain. Establishment included locating the center point of each site using a GPS, tagging three trees with aluminum tags to facilitate relocation, and deploying an iButton temperature/humidity sensor in a protective case (Figure 1d). From June through August 2013 all sites were revisited to collect vegetation data, site characteristics, and tree cores (Figure 1c).

At each site (elevation) 15 subplots were spaced 15 meters apart along the elevation contour. At each subplot the point-quarter method was used for mature (DBH ≥ 10.16 cm; DBH = diameter at breast height) and sapling (10.16 cm > DBH ≥ 2.54 cm) individuals to estimate basal area, density, and frequency. The closest dead down tree in each half of each subplot was also measured to estimate dead down trees. A 1x1m quadrat was placed at each subplot and all tree seedlings within were counted below 50 cm tall and below 200 cm tall (excluding first year germinants).

Table 1. Description of mountains and sites sampled in 2012 and 2013.

State	Mountain	Summit elevation (m)	Number of sites (low - high elevation, m)	Transect Aspects	Tree cores (approx.)
New York	Whiteface Mountain*	1,466	46 (~400-~1,400)	Multiple	300
	Dial Mountain	1,215	6 (700-1,200)	Northwest	30
Vermont	Jay Peak	1,148	6 (600-1,100)	South	30
	Mount Mansfield	1,337	7 (500-1,100)	South	30
	Mount Abraham	1,207	7 (600-1,200)	West	30
	Killington Peak	1,288	7 (600-1,200)	Southwest	30
New Hampshire	Mount Moosilauke	1,468	6 (700-1,200)	Southeast	30
	Cannon Mountain	1,228	6 (600-1,100)	North	30
	Mount Madison	1,620	8 (500-1,200)	East	30
Maine	Old Speck Mountain	1,263	8 (500-1,200)	North	30
	Sugarloaf Mountain	1,290	7 (600-1,200)	West	30
	Mount Bigelow	1,227	8 (500-1,200)	North	30
	Total or Average	1,313	46 (2012), 76 (2013)	-	300 (2012), 330 (2013)

*Note: Whiteface Mountain samples conducted in summer 2012 and Whiteface Mountain iButtons collected in spring 2013.

At subplots 1, 5, 10, and 15 canopy openness, soil depth, slope, and aspect were measured. Tree cores were collected from five trees at a high, middle, and low elevation site on each mountain (representing the local extent of that species elevation range) for balsam fir and red spruce (15 cores /species /mountain).

As of fall 2013, the vegetation and site characteristics data have been entered and prepared for analysis. During the 2013 field season 9,120 standing trees, 2,010 down dead trees, and 5,209 seedlings were measured. The 330 tree cores are being processed and the 76 iButtons are still logging at all sites to be collected in spring 2014.

Preliminary Results and Conclusions

Front theory (Solomon DS and Leak WB. Migration of tree species in New England based on elevational and regional analyses. *USDA Forest Service Report*. 1994) can be applied along elevation distributions to detect recent shifts in species ranges (Figure 2). If seedling and sapling individuals extend beyond the range of large living and dead trees this suggests that the species may be extending its range (advancing front). Conversely, a lack of regeneration at the edge of a species range and large dead trees may suggest a range retraction (retreating front). Overlapping distributions of all sizes classes and dead trees indicate no movement (stationary front).

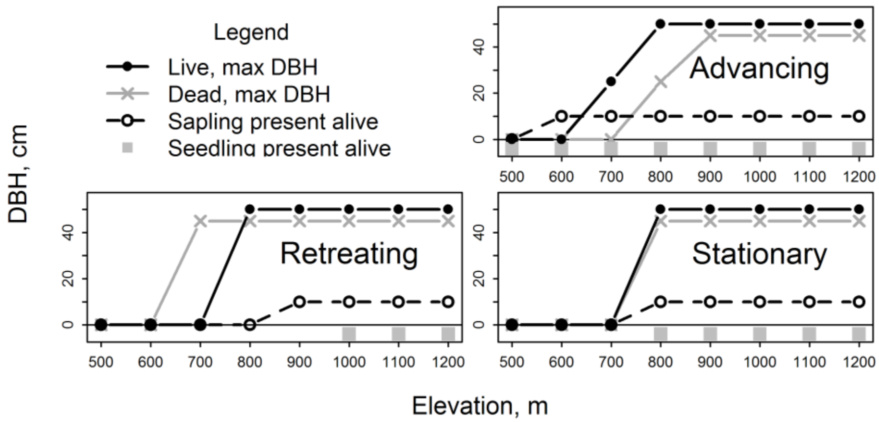

Figure 2. Conceptual diagram of front theory at a lower range margin using elevation distributions of living, dead, sapling, and seedling individuals depicting an advancing front, retreating front, and stationary front. DBH = diameter breast height.

Front theory was applied to the elevational distribution of balsam fir (a high elevation species) and sugar maple (*Acer saccharum*; a low elevation northern-hardwood species) on the 11 mountains sampled in 2013 (Figure 3). The lower front of balsam fir and upper front of sugar maple were classified as advancing, stationary, or retreating (Table 2).

Balsam fir shows a mixed response at low elevations with some sites advancing downslope but most remaining stationary (Figure 3a, Table 2). This is contrary to the hypothesis that the lower range margin of balsam fir is moving upslope (retreating) with climate change. Sugar maple shows evidence of an advancing front (Figure 3b, Table 2) consistent with climate change expectations however multiple factors may be driving observed distributions. Differences in land use history, life history characteristics of the species, tree decomposition rates, recent red spruce decline, and variation in soil characteristics could all influence these results. Future analysis will address the impact of these additional drivers on the observed distributions.

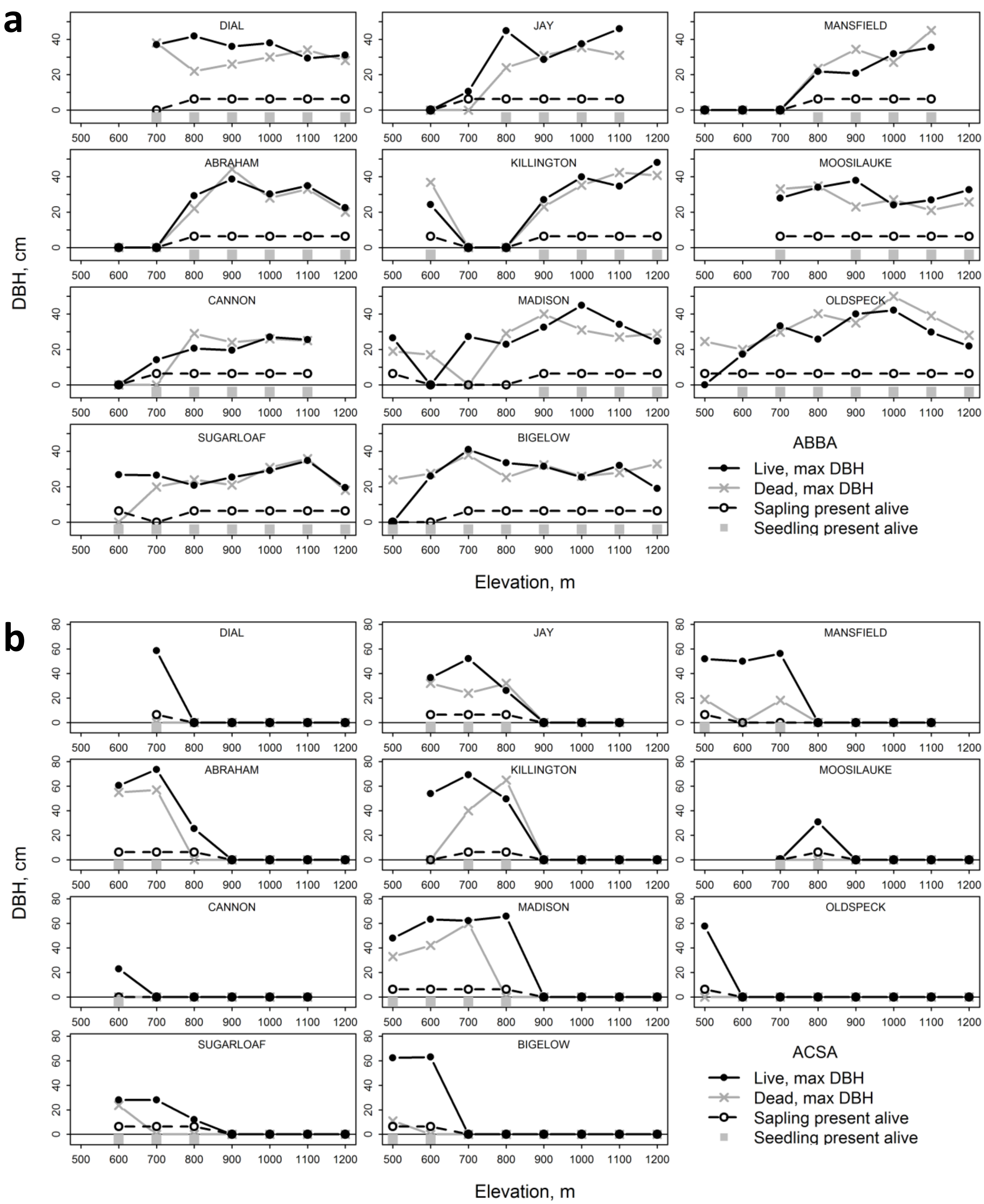

Figure 3. Elevational distribution of a) balsam fir (*Abies balsamea*) and b) sugar maple (*Acer saccharum*): maximum living DBH, maximum dead DBH (standing or down), sapling presence, and seedling presence on 11 mountains (see Table 1 for mountain descriptions and text for methods). DBH = diameter at breast height.

Table 2. Front classifications for balsam fir and sugar maple on 11 mountains in the northeast. A = advancing, S = stationary, and R = retreating. Classifications derived from Figure 3.

	Mountain	Balsam fir (lower range margin)	Sugar maple (upper range margin)
	Dial Mountain	S	A
	Jay Peak	A	S
	Mount Mansfield	S	A
	Mount Abraham	S	A
	Killington Peak	S	S
	Mount Moosilauke	S	A
	Cannon Mountain	A	A
	Mount Madison	R	A
	Old Speck Mountain	S	A
	Sugarloaf Mountain	A	A
	Mount Bigelow	S	A
Totals	Advancing	**3**	**9**
	Stationary	**7**	2
	Retreating	1	0

Future Work

Front theory will be applied to the other dominant species on these mountains to determine if there is further evidence of range shifts. Tree cores from these fronts will be used to determine growth rate trends that may support evidence of front movement. iButton temperature and humidity data will be used to evaluate relative climate differences among sites. These data will be used to determine climate change impacts on mountain forest plant communities.

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