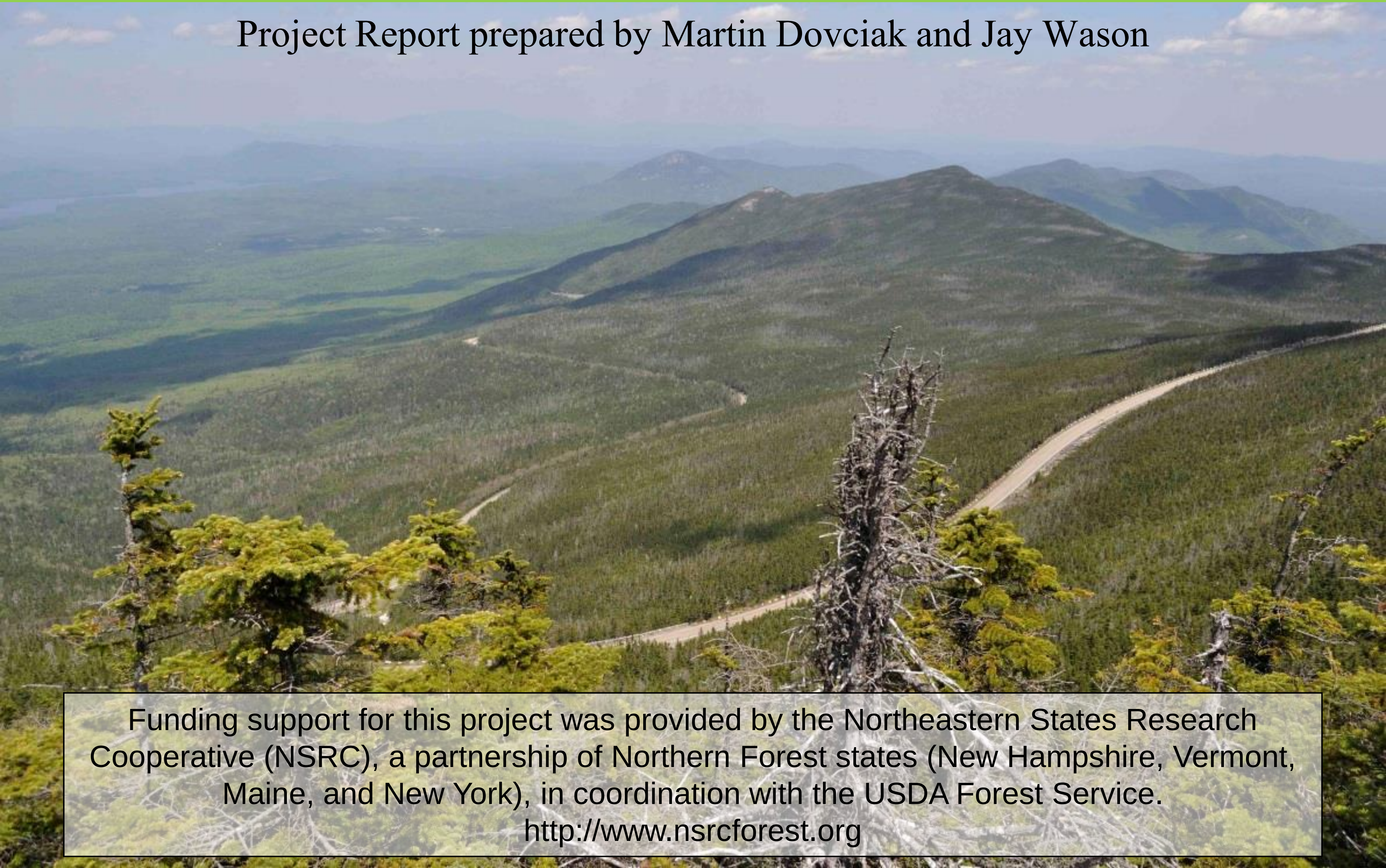
Global Change Fingerprints in Montane Boreal Forests: Implications for Biodiversity and Management of the Northeastern Protected Areas

Project Report prepared by Martin Dovciak and Jay Wason



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http://www.nsrcforest.org

Project Summary

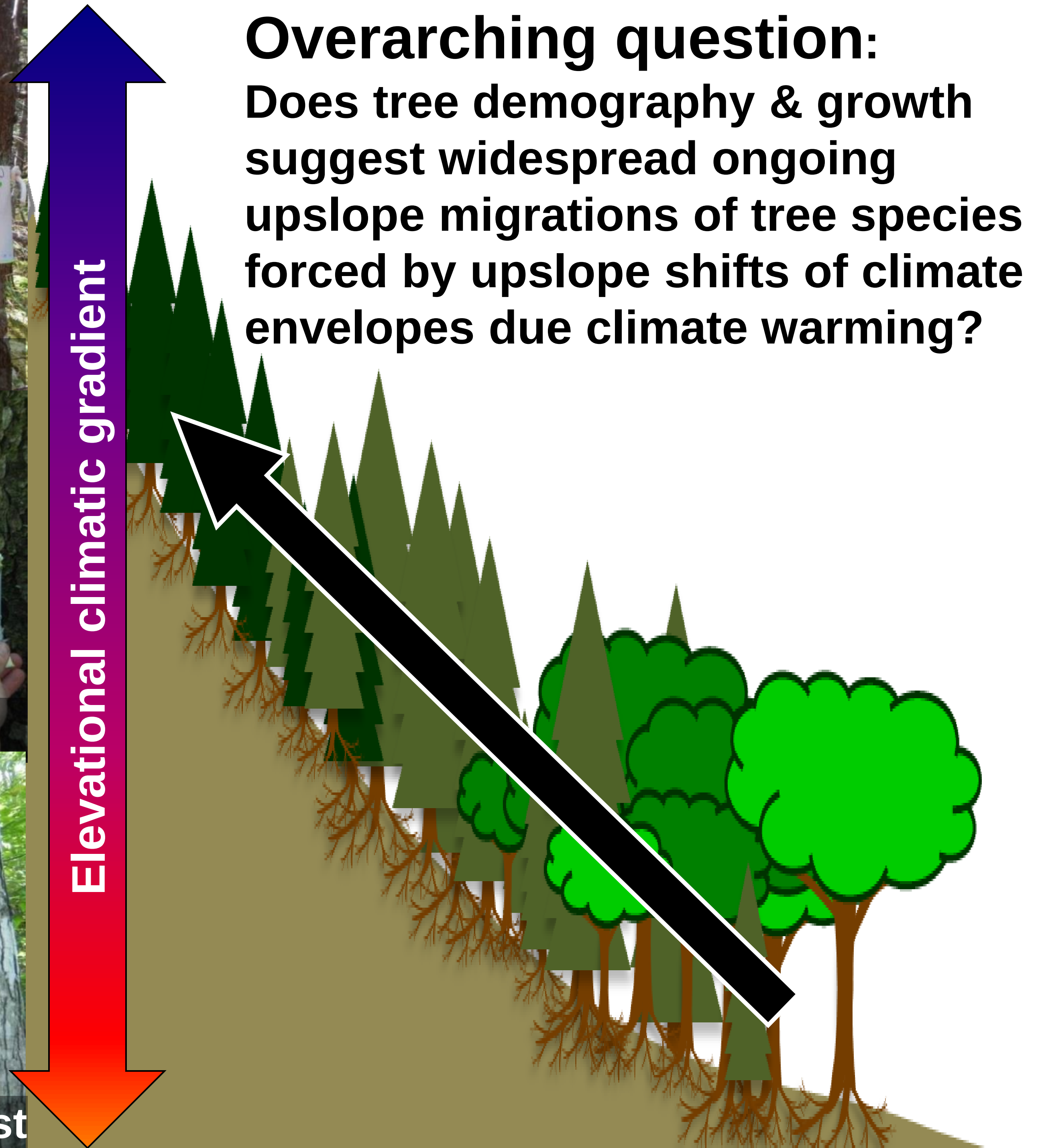
Substantial warming of the world's climate in recent decades is likely to affect the ecology of the Northern Forest where mountain forests occur along steep elevational climatic gradients. The overarching goal of the study was to improve biodiversity conservation and protected area management in the Northern Forest by providing information on the character and ecological mechanisms of ongoing changes in the region's mountain forests. We collected vegetation, climatic, and soil data on long-term plots on Whiteface Mtn. and on new plots across the Northern Forest, and we determined that while (a) climate envelopes have shifted substantially upslope, (b) tree species distributions and growth have not yet clearly responded to warming, although they responded to improving precipitation chemistry and exhibited successional dynamics by reinvading areas that were historically logged. However, climate warming is projected to be of sufficient magnitude to cause many mountains in the region to lose climate characteristic of spruce-fir zone by 2100. Red spruce showed continuing recovery with its increasing growth over time and gradual colonization of lower elevations. Adapting forest management and biodiversity conservation to changing environmental conditions and forest composition will pose challenges as tree species showed individualistic responses rather than synchronous upslope migration patterns.

Background and Justification

Climate in the Northeastern U.S. has warmed by 0.5°F per decade (1.3°F/decade in winter) since 1970, and annual temperatures are predicted to increase by another 3.5-12.5°F by 2100 (Frumhoff *et al*. 2007). Warmer climate can affect growth and survival of forest tree species, and particularly of cold-adapted mesic mountain spruce-fir forests that recently declined near their lower range limits and increased at their upper range limits (Beck et al. 2011). Mountain regions contain compressed elevational gradients in climate, and as a consequence, they are especially vulnerable to climate change. Lower range limits of montane spruce-fir forests should be particularly sensitive to climate change (Beckage *et al*. 2008). Rustad (2008) identified the integration of long-term studies with space-for-time studies, and the explicit consideration of 'tipping points' (ecosystem thresholds), as major research needs in the study of anthropogenic fingerprints of global climate change in terrestrial ecosystems. We integrated long-term studies on Whiteface Mt., NY, with a broader examination of tree species population structure and growth along elevational gradients in climate in the Northern Forest in order to identify changes occurring in tree species distributions as a result of changing climate and other factors (Fig. 1 a-d).

Overarching question:

Does tree demography & growth suggest widespread ongoing upslope migrations of tree species forced by upslope shifts of climate envelopes due climate warming?



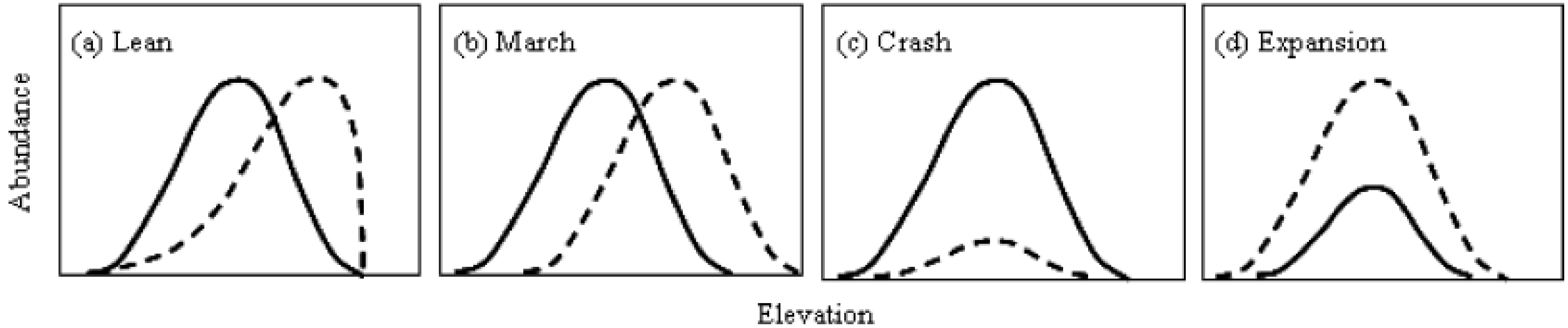


Fig. 1. Possible changes in species distribution along an elevational gradient between parental (solid line) and offspring (dashed line) cohorts: (a) Lean--species elevational range does not change but recruitment increases upslope while mortality increases downslope of the previous maximum abundance, (b) March--colonization of space above species upper elevational limit creates "leading edge" while mortality at the lower elevational limit creates "trailing edge" and species gradually shifts upslope, (c) Crash--widespread mortality and recruitment failure across species range may cause its range contraction and even eventual extinction, (d) Expansion--mortality decreases and recruitment increases throughout (and possibly outside) of species range as competing species decline. (a.-c.) adapted from Breshears *et al* (2008).

Key References:

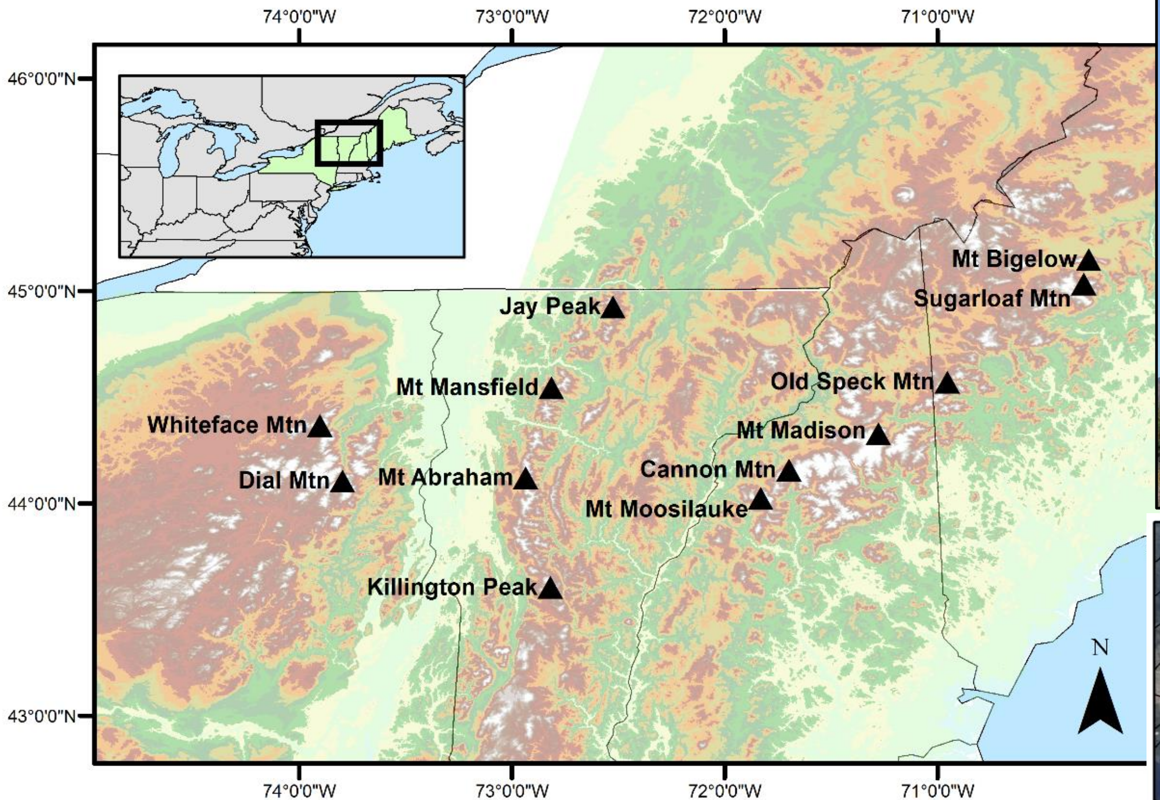
Beck PSA, Juday GP, Alix C, Barber VA, Winslow SE, Sousa EE, Heiser P, Herriges JD, Goetz SJ. 2011. Changes in forest productivity across Alaska consistent with biome shift. *Ecology Letters*. 14. 373–379.

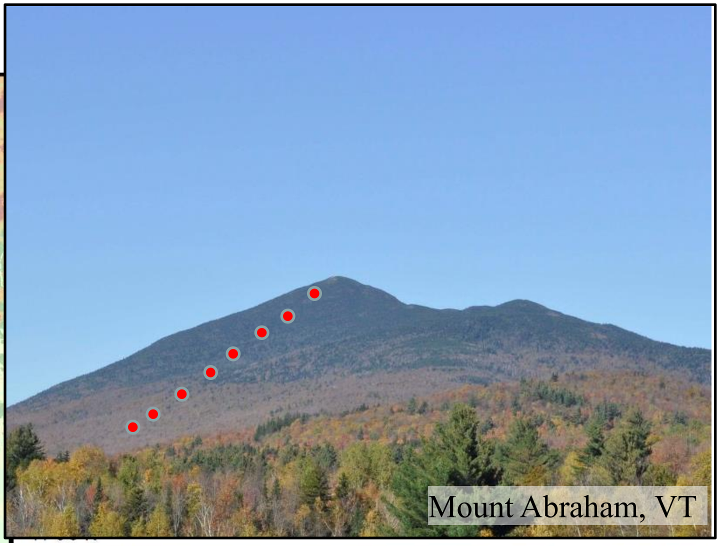
Breshears DD, Huxman TE, Adams HD, Zou CB, Davison JE. 2008. Vegetation synchronously leans upslope as climate warms. *PNAS,* 105, 11591–11592.

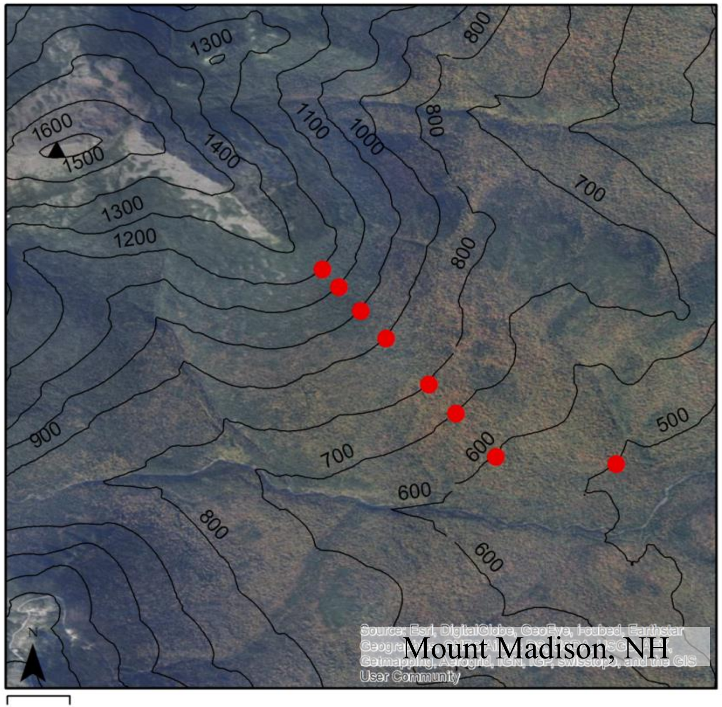
Frumhoff PC, McCarthy JJ, Melillo JM, Moser SC, Wuebbles DJ. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists (UCS).

Rustad LE. 2008. The response of terrestrial ecosystems to global climate change: Towards an integrated approach. *Science of the Total Environment*, 404, 222–235.

Methods: Tree demography across Northern Forest (NF)

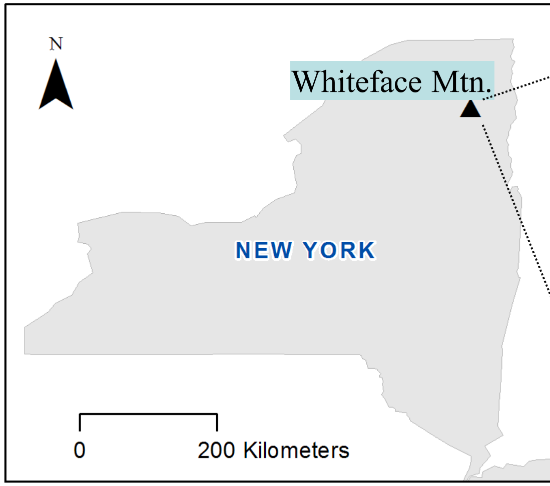


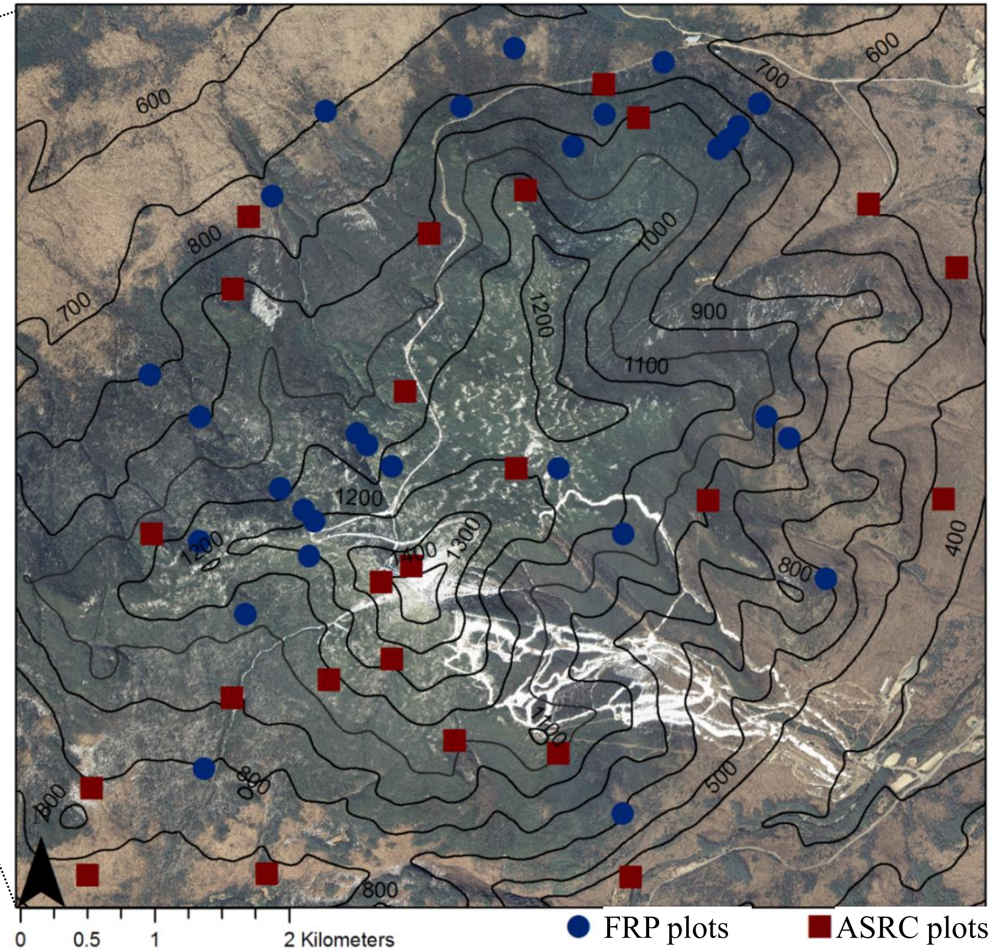




- 12 mountains across four states (2-4 per state)
- 6-8 NF plots at 100 m elevation intervals per mtn. in northern hardwood and spruce-fir forests (~500 to 1,200 m a.s.l.) = 83 plots in total
- Plots selected to avoid recent forest management

Methods: Historical tree demography on Whiteface Mtn.





47 historical plots resurveyed between 500 m a.s.l. and summit

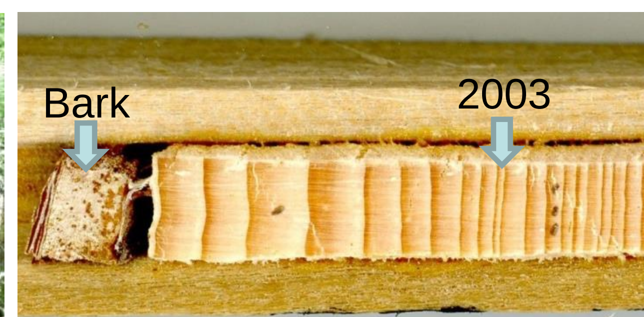
- 24 Forest Response Program (FRP) plots from 1986-87 (Battles *et al.* 2003)
- 23 Atmospheric Sciences Research Center (ASRC) plots from 1964-1966 (Holway et al. 1969).
- 35 microclimate (*i*Button) stations established and tree cores collected near FRP plots

Battles JJ, Fahey TJ, Siccama TG, Johnson AH (2003) Community and population dynamics of spruce-fir forests on Whiteface Mountain, New York: recent trends, 1985-2000. *Canadian Journal of Forest Research* 33, 54–63.

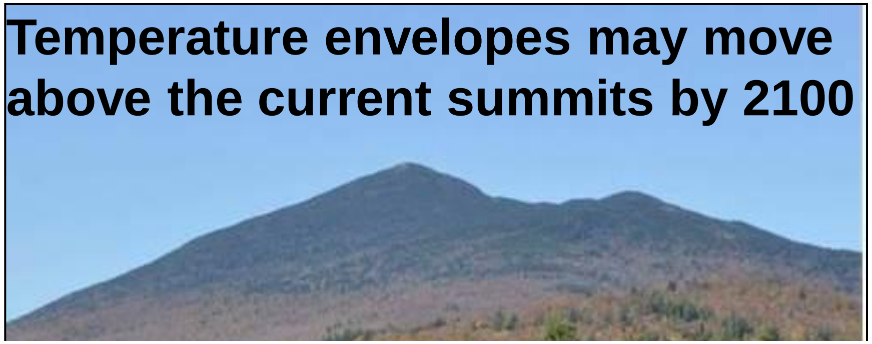
Holway JG, Scott JT, Nicholson S (1969) Vegetation of the Whiteface Mountain region of the Adirondacks. *Atmospheric Sciences Research Center Report* 92, 1–49.

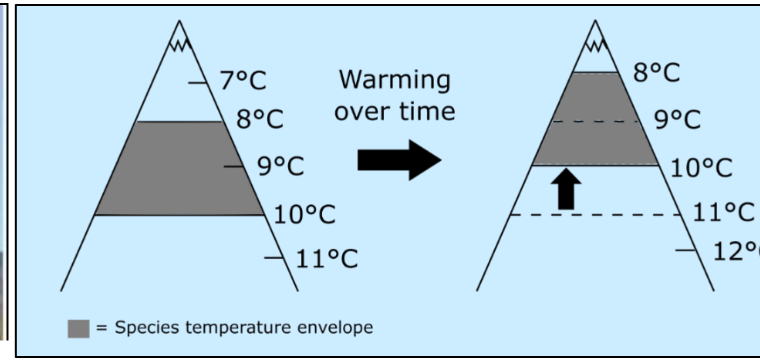
Methods: **Field measurements-trees, soils, microclimate**

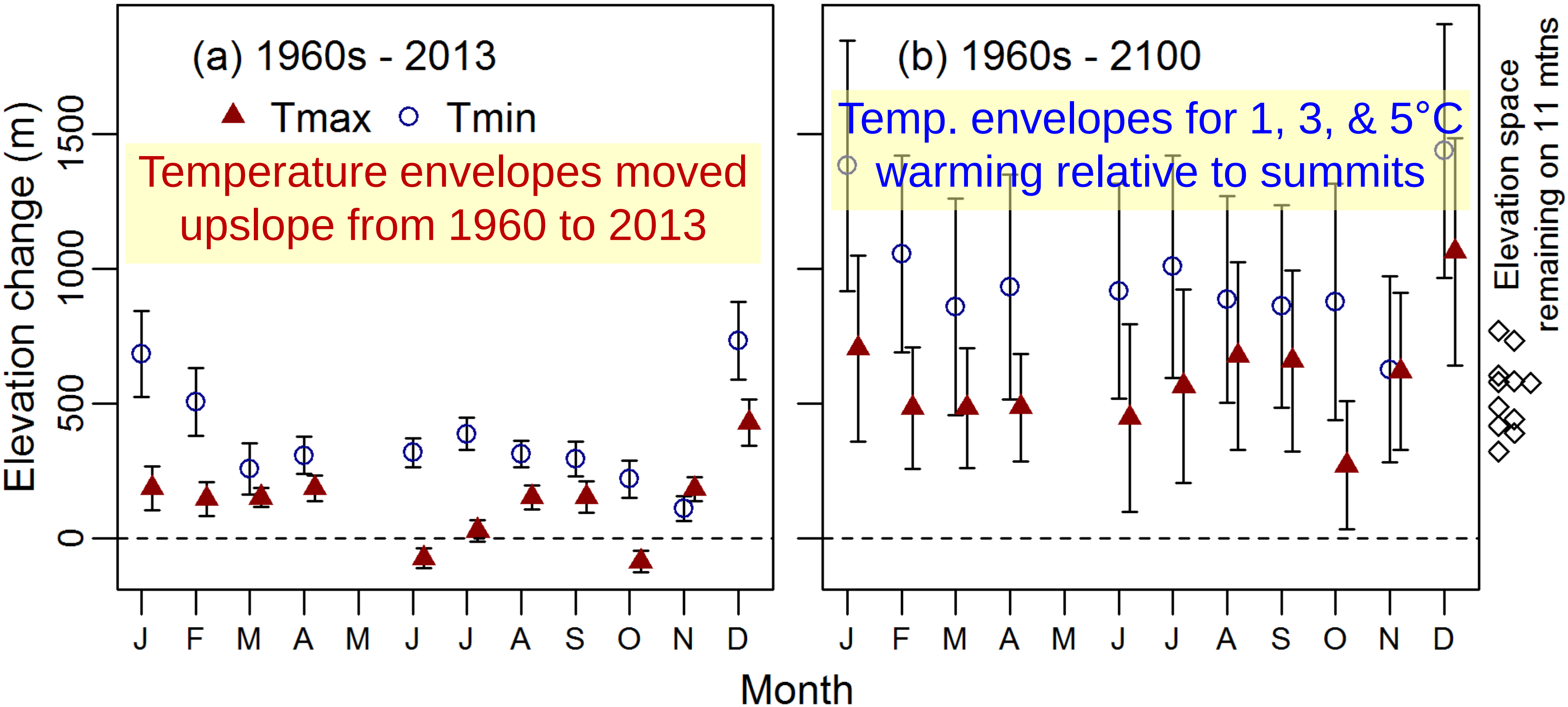
- NF & ASRC plots = 225 m long transects with 15 sampling points
- FRP plots = 20 × 20 m plots
- Tree demography measured at sampling points on NF & ASRC plots w/point centered quarter method; all trees measured on FRP plots (DBH > 2.5 cm)
- One iButton microclimate station per plot measured temperature & humidity at 2-hourly intervals for nearly 1 year
- Soil depth measured with a soil probe
- Tree cores (2) extracted from dominant or co-dominant spruce and fir (up to 3 trees per plot and species)



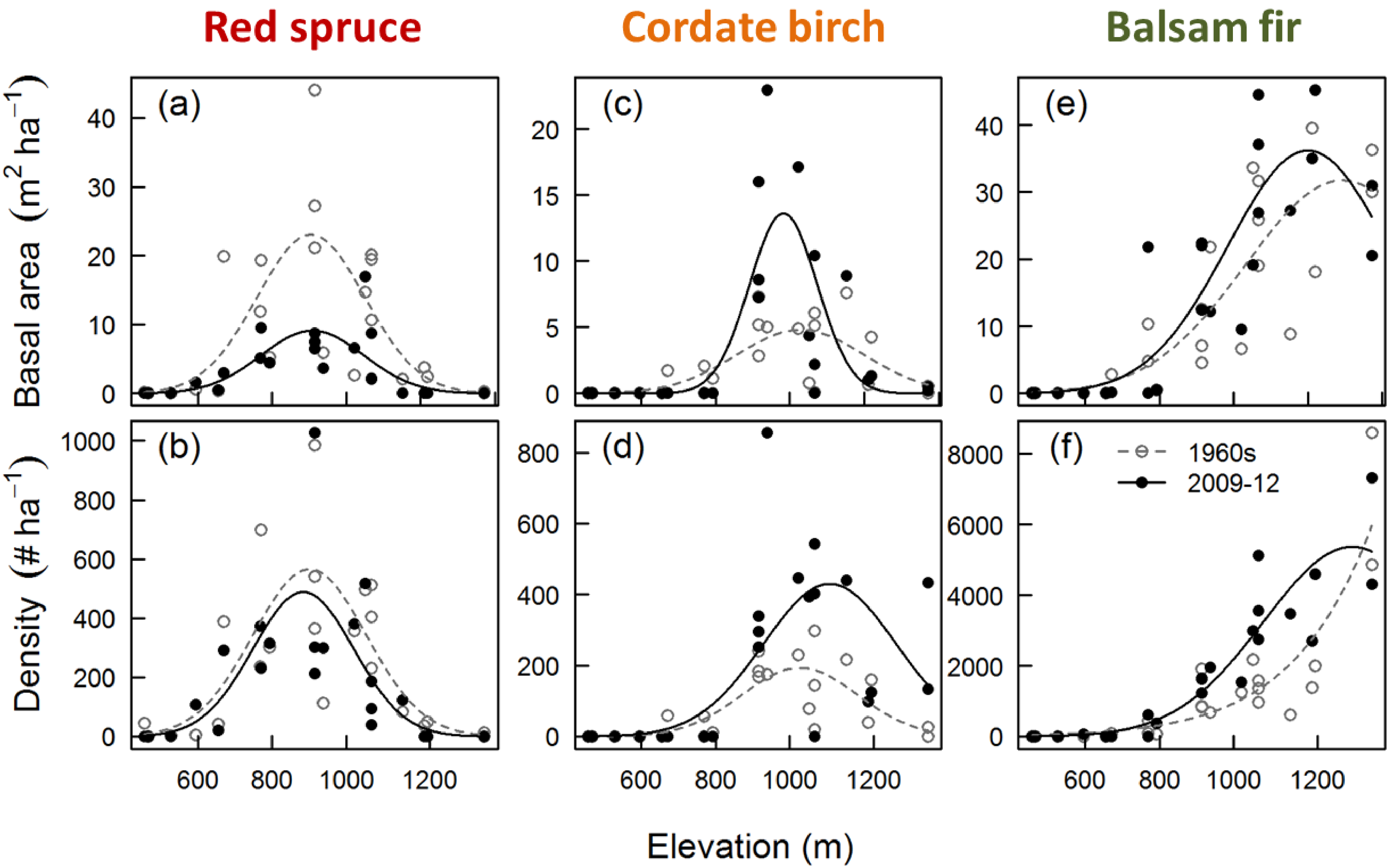
Results: Changing spruce-fir climate envelopes over time



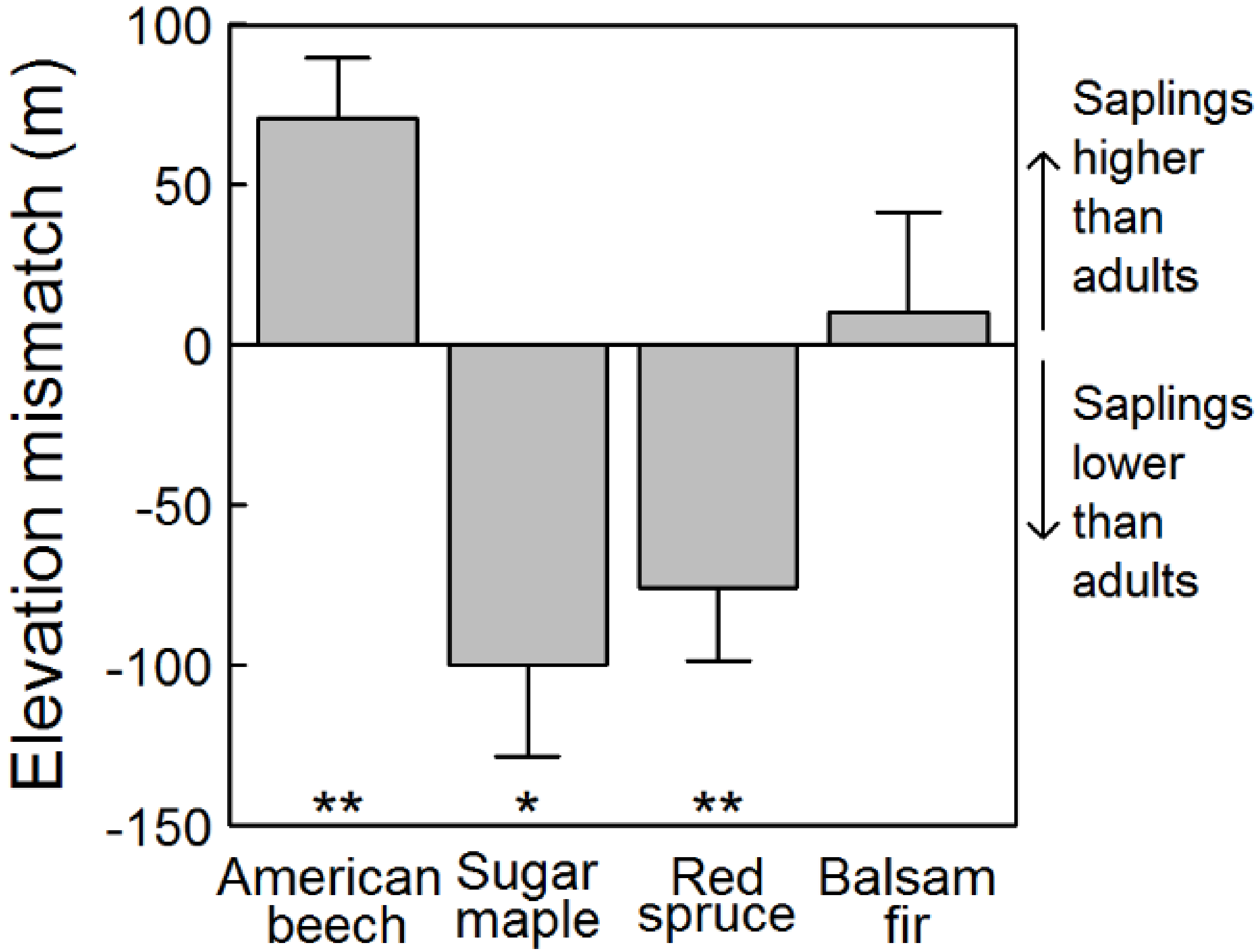




Results: Individualistic rather than synchronous changes in species elevational distributions on Whiteface Mtn.

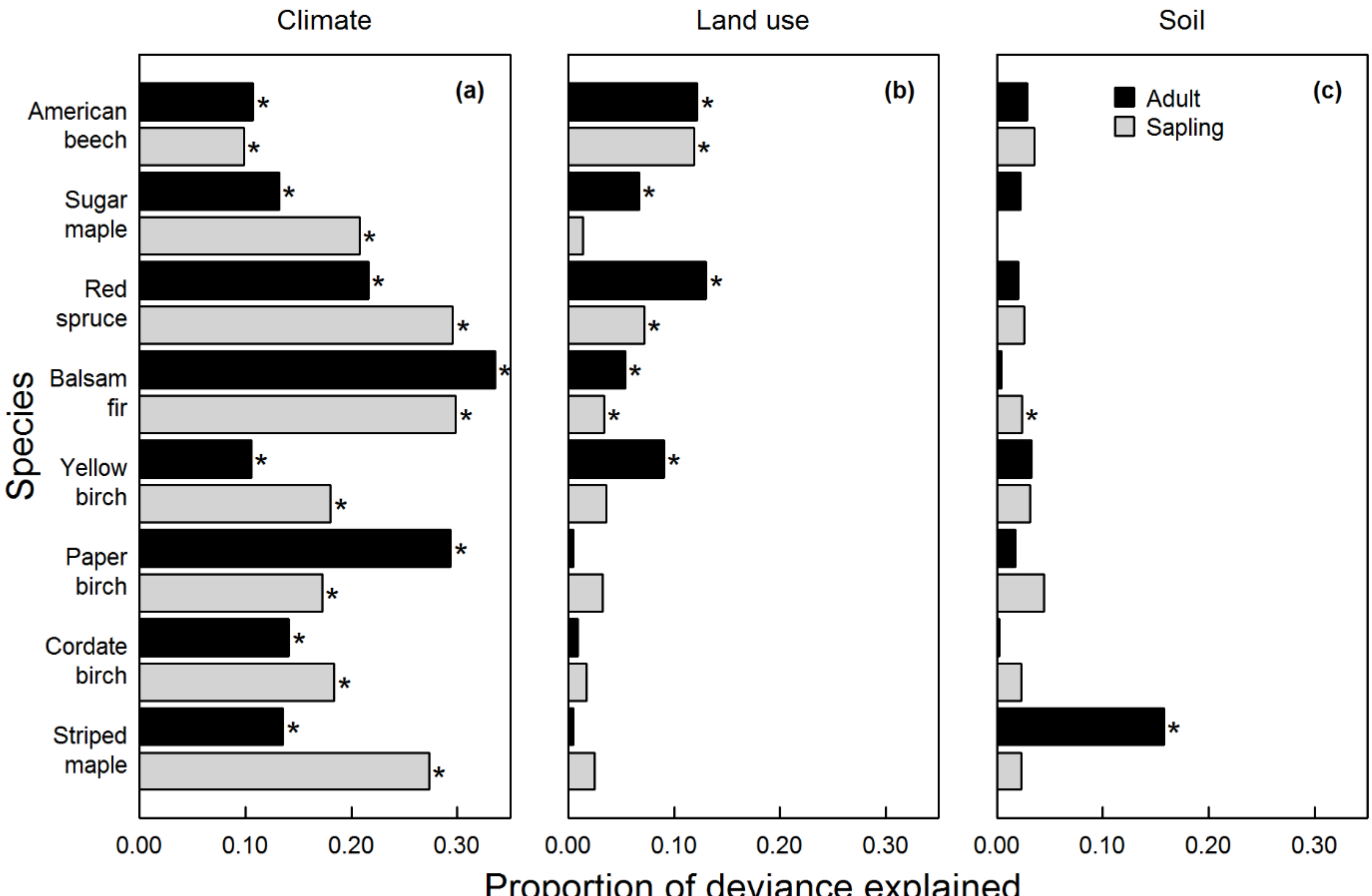


Results: Varied distributions of saplings relative to adult populations of tree species across Northern Forest

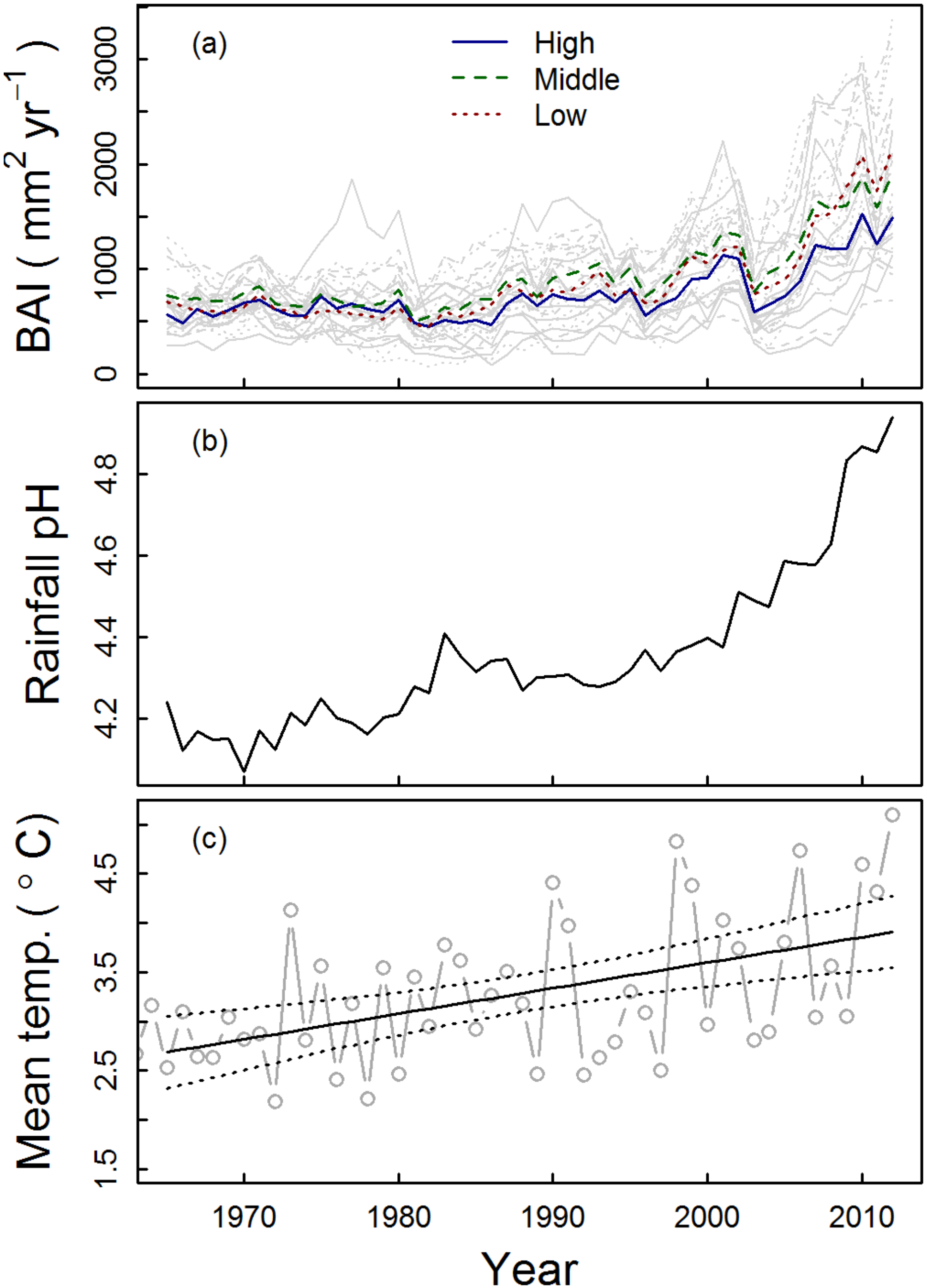


Results:

Tree species distributions shaped mainly by climate, but also by land-use history and soils



Results:



Red spruce growth increased over time across elevations and mountains as a function of increasing temperature and rainfall pH (acid rain decline)

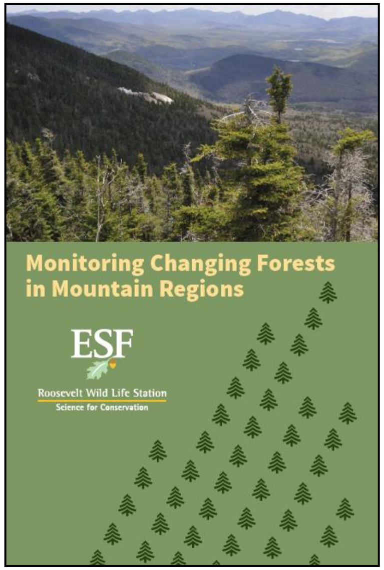
Implications and applications in the Northern Forest region

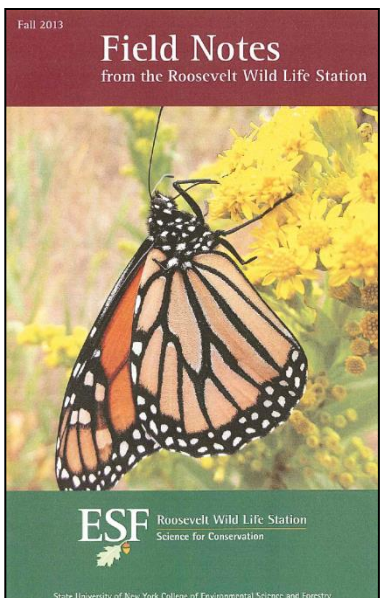
- Climate warming that occurred in the region, and that will occur by 2100, had and will continue having dramatic effects on upslope movement of tree species climatic envelopes. Many mountains are likely to lose climate characteristic of spruce-fir zone by 2100.
- Yet, the effects of climate on changes in tree demography, species distributions over time and tree growth appear to be masked so far by other environmental factors such as land-use history (logging) and changing precipitation chemistry (decline in acid rain).
- Red spruce shows continuing recovery as a foundational species with its increasing growth over time and gradual colonization of lower elevations where canopy trees were removed in the past by logging (at times combined with mortality caused by acid rain).
- Adapting forest management and biodiversity conservation to gradually changing environmental conditions and forest composition will pose challenges as tree species show individualistic responses rather than synchronous upslope migration patterns.

Future directions

- We established an extensive monitoring network and baseline data for tracking tree species migrations along elevational climatic gradients forced by changing climate or successional dynamics in forests of post-logging origin.
- To improve our current understanding of tree growth and population responses along elevational gradients it would be useful to complement this monitoring network
    - (a) monitoring of precipitation quantity and chemistry
    - (b) characterizing soil chemistry in greater detail
    - (c) adding permanent monitoring stations at selected elevational gradients across the region
- To increase our understanding of whole ecosystem dynamics across elevational gradients monitoring of other groups of organisms should be added, including understory herbs and fauna particularly sensitive changes in both climate and vegetation (e.g., ants).

Outreach & Education





- An outreach pamphlet and a news piece on Monitoring Changing Forests in northeastern United States were produced by SUNY ESF Office of Communications (left, distributed at a couple of major conferences and regionally, reaching >150 people)

- Photos and some of the results were included in a SUNY ESF course *Plant Ecology & Global Change* annually taught to ~ 30-50 undergraduate and graduate students

- 12 presentations (5 invited) were given on the project findings cumulatively to >300 people, including:
  - Forest managers and researchers
  - Botanists (professional and lay)
  - General public
  - Undergraduate students in biology/environmental science
  - Researchers in ecology and natural resource management

- A list of presentations is provided in the List of Products