Effects of cold-air pooling microclimates on species composition in New England forests

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Background & Objectives

Cold-air pooling is a globally occurring meteorological phenomenon that results in temperature inversions with lower temperatures at low relative to high elevations[1]. These inversions are often formed when radiative surface cooling after sunset forms dense, cold air that drains downslope and pools in sheltered, low-lying areas, like depressions or valleys. Cold-air pools can be diurnal or may persist for days and, due to a lack of vertical mixing, air in these inversions becomes partly decoupled from the overlying free atmosphere[2]. Thus, cold-air pooling areas may serve as microrefugia that buffer organisms from climate change by enabling species persistence and facilitating species range shifts[3]. By favoring and excluding certain tree species, cold-air pooling may also influence ecosystem functions linked to plant traits, such as soil carbon storage[1].

We aimed to determine whether cold-air pooling influences the vegetation composition of northern forests. We hypothesized that sites with more frequent cold-air pooling would display unexpected patterns in vegetation composition across elevation, such as more cold-adapted species at low elevations.

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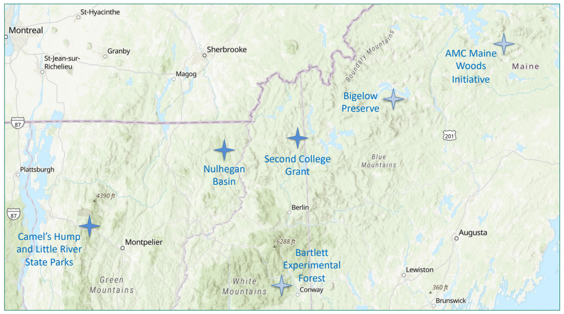
Pastore et al. (2022) Ecology[1]

Methods

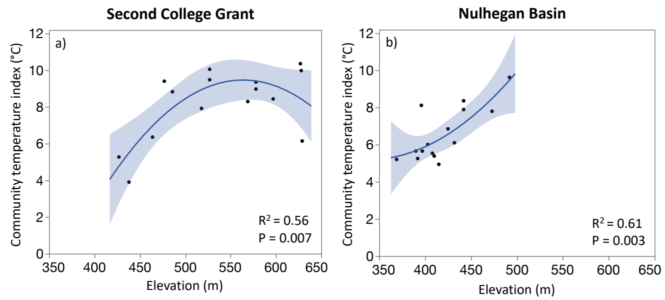


Above: Map of study locations across Vermont, New Hampshire, and Maine. Light blue sites were added this summer and are not included in the results.

Approach:

- Established elevation transects at each location spanning cold-air pooling gradients
- Surveyed plot forest composition and converted to 'Community Temperature Index' using historical distribution and climate data[4]
- Measured soil carbon, nitrogen, pH, and other site characteristics
- Deployed high-frequency sensors, such as iButtons that measure air temperature 1.5 m above the ground surface

Results



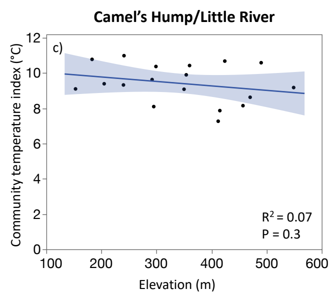


Figure 1. Community temperature index (CTI) for each plot at a site. CTI is the community weighted mean of species' temperature preferences. Best fits shown in panels a and b were achieved using quadratic fits, and a linear fit is shown for c. Shaded areas represent 95% confidence intervals. Seasonal cold-air pooling metrics for each transect within a site are provided in Fig. 2.

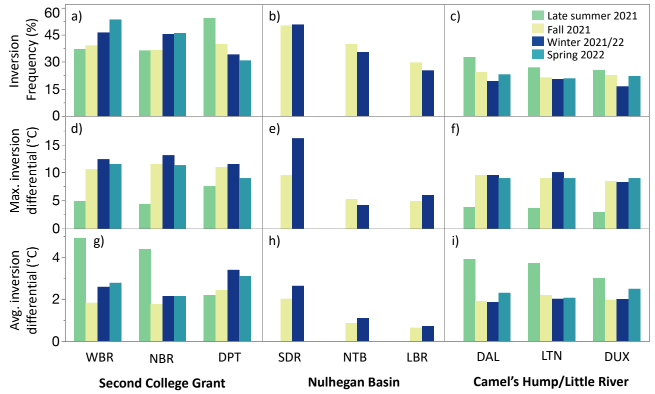


Figure 2. Cold-air pooling metrics for each transect by season: (a-c) frequency of temperature inversions, calculated as a percentage of hourly timesteps; (d-f) maximum temperature differential between the highest and lowest plot during temperature inversions; (g-i) average temperature differential between the highest and lowest plot during temperature inversions. No data were collected for summer and spring at the Nulhegan Basin.

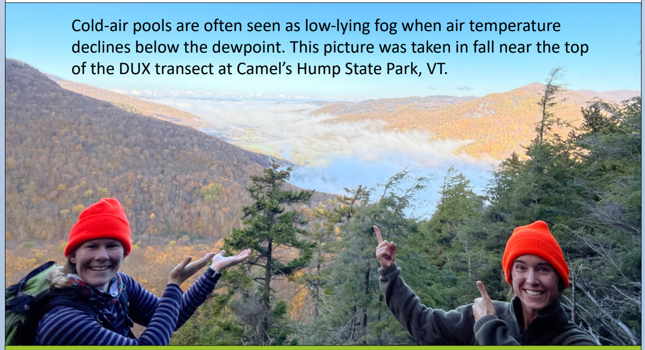
Key Findings

Sites with more **cold-air pooling** displayed **inverted forest composition** patterns across **elevation.**

- Cold-air pooling occurred at all sites, but was most frequent at the Nulhegan Basin and Second College Grant (Fig. 2).
- Where cold-air pooling was frequent, the lowest elevations were dominated by cold-preference species and higher elevations were dominated by warm-preference species (Fig. 1). The nonlinearity observed at Second College Grant suggests that the highest plots are above the cold-air pooling boundary (Fig. 1a). No strong vegetation pattern across elevation was observed in the westernmost site where cold-air pooling was less common (Fig. 1c).
- Forest stands in cold-air pooling areas were composed of species with traits that facilitate slow organic carbon turnover. These areas may therefore maintain plant communities linked to key ecosystem functions like carbon storage in the face of climate change.

Within cold-air pool → Above cold-air pool

Above: Forest composition transitions from evergreen to deciduous as elevation increases along the SDR transect at the Nulhegan Basin, VT.



Acknowledgments

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