RESEARCH BRIEF

Winter Climate Change

HUBBARD BROOK ECOSYSTEM STUDY

When many of us think about climate change, we think about hot summer days. But in many mid- and high-latitude areas of the world, including the northeastern U.S., air temperatures have warmed more in winter than in summer. This warming affects multiple ecosystem services provided by northern forests. At the Hubbard Brook Experimental Forest in New Hampshire, the USDA Forest Service has been monitoring winter climate, including snow and soil frost, since the 1950s. Hubbard Brook scientists have used both long-term climate data and experiments to better understand how changes in winter climate affect tree growth, wildlife, and the quantity and quality of streamwater. This winter climate change research at Hubbard Brook has provided important opportunities to engage with local community members who have unique and valuable observations about the nature and extent of changes in winter climate and their effects on the forests and human communities of the region. This work has also provided the opportunity for Hubbard Brook scientists to work with decision-makers.

Why It Matters

Changes in winter climate affect multiple ecosystem services provided by northern forests. With less snow, soils are less insulated from cold winter air and freeze more frequently and more deeply, which damages tree roots and diminishes their ability to absorb water and nutrients from the soil. As a result, tree growth is reduced, and nutrients are lost in percolating water and in gaseous fluxes, which can degrade water quality and add greenhouse gases to the atmosphere. Reductions in snow also increase the susceptibility of young vegetation to moose browsing, which affects the composition of future forests. Soil freezing leads to reductions in the diversity and abundance of insects that live in the forest floor. The loss of extreme cold temperatures fosters the movement of southern species into northern forests, including forest pests and pathogens. Changes in winter climate can also negatively affect people of northern regions and cause economic losses in associated activities such as maple sugaring, timber harvesting, road maintenance, downhill and cross-country skiing, and snowmobiling.

Key Findings

- Winter is changing! Long-term monitoring at Hubbard Brook shows that days of snow cover, snow depth, and the amount of water held in the snowpack have significantly declined since the mid 1950s. Extreme cold temperatures that were typical in past winters (e.g., -25 oC/-13 oF) have also become much rarer.
- A lack of snow increases the frequency and depth of soil freezing, which damages tree roots, increases nutrient losses, and decreases forest productivity. Surprisingly, we are getting "colder soils in a warmer world" because soils have lost their insulating blanket of snow in winter.
- Soil freezing has damaged sugar maple trees more than other northern hardwood forest species. This species appears to be more sensitive to root damage by soil freezing which creates a cascade of effects leading to nutrient losses and reductions in productivity.
- Reductions in snow depth leaves young vegetation exposed and susceptible to moose browsing. Reductions in snow cover thus create "multiple stressors" for some species, with soil freezing stress from below interacting with moose browsing stress from above.

The Hubbard Brook Ecosystem Study is one of the longest running and most comprehensive ecological research programs in the world, taking place within the Hubbard Brook Experimental Forest, a 7,800-acre research site in the White Mountains of New Hampshire.

The USDA Forest Service operates the site and the research program at Hubbard Brook is supported by the National Science Foundation. This research brief is an outreach product of the Hubbard Brook Research Foundation, a nonprofit organization that builds two-way linkages between environmental science and society.

- Reductions in snow depth leaves young vegetation exposed and susceptible to moose browsing. Reductions in snow cover thus create “multiple stressors” for some species, with soil freezing stress from below interacting with moose browsing stress from above.
- Less snowpack and deeper and greater frequency of soil freezing leads to decreased diversity and abundance of insects that live in the forest floor.
- Stakeholders have observed and experienced the effects of winter climate change. Loggers, road supervisors, downhill and cross-country ski operators, maple sugar producers, snowmobilers, and others have unique perspectives on just how the climate is changing during winter and how these changes affect multiple ecological, social and economic factors.

Methods

Interest in winter climate change at Hubbard Brook began when high nitrate concentrations were observed in streams across the northeastern U.S. during the summer of 1990. High nitrate concentrations are concerning since they are associated with soil acidification, nutrient imbalances in trees, and at very high levels harmful impacts on human health. Scientists suspected that these nitrate pulses were related to several soil-freezing events during the winter of 1989 that occurred during periods without snow. These observations led to the development of experiments in which snow was removed via shoveling from small, 10-by-10-meter plots and compared with unshoveled reference plots. In these studies, the manipulated plots were kept snow-free through the end of January, which was long enough to cause deep soil freezing. In addition to the snow-shoveling experiments, the scientists recognized a natural gradient of winter conditions in the experimental forest created by elevation and aspect: forest stands in low-elevation, south-facing locations experience warmer conditions than forest stands in high-elevation, north-facing locations. The natural elevation/aspect gradient at Hubbard Brook has provided an opportunity for studying winter climate change. Across elevation and aspect within the Hubbard Brook Valley, there is significant variation in mean annual temperature, snow depth and cover, and soil freezing. To date, these studies have shown that warmer summers cause trees to grow more, but this increase almost entirely disappears when the trees also experience a smaller winter snowpack and greater frequency of soil freeze/thaw cycles in winter.

Looking Forward

- Will we really have colder soils in a warmer world? Will the climate warm enough to overcome the effects of loss of the insulating snow blanket?
- Will the negative effects of a smaller winter snowpack be offset by warmer soils in summer?
- Why are forest ecosystems changing their response to soil freezing events?
- How will people perceive, be affected by, and adapt to winter climate change? There is a strong need for participatory, community-driven science that will improve our understanding of the nature and extent of winter climate change and its effects on multiple ecosystem services in the region.

Photo by Brendan Leonardi