Confronting Our Changing Winters

Indicators of Winter Climate Change in the Northern Forest

Science Links
2019

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Authors

Sarah Garlick, *Hubbard Brook Research Foundation*
Alexandra R. Contosta, *University of New Hampshire*
Nora J. Casson, *University of Winnipeg*
Sarah J. Nelson, *Appalachian Mountain Club and University of Maine*
Matthew P. Ayres, *Dartmouth College*
Elizabeth A. Burakowski, *University of New Hampshire*
John Campbell, *USDA Forest Service Northern Research Station*
Irena Creed, *University of Saskatchewan*
Catherine Eimers, *Trent University*
Celia Evans, *Paul Smith's College*
Ivan Fernandez, *University of Maine*
Colin Fuss, *Cary Institute of Ecosystem Studies; Center for Earth and Environmental Science, SUNY-Plattsburgh*
Thomas Huntington, *United States Geological Survey*
Kaizad Patel, *University of Maine*
Rebecca Sanders-DeMott, *University of New Hampshire*
Kyongo Son, *Research Foundation of the City University of New York*
Pamela Templer, *Boston University*
Casey Thornbrugh, *United South and Eastern Tribes, Inc., and DOI Northeast & Southeast Climate Adaptation Science Centers*

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Confronting Our Changing Winters

Indicators of Winter Climate Change in the Northern Forest

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Winter Conditions are Changing Across the Northern Forest

A team of scientists from the United States and Canada examined one hundred years of winter temperature and precipitation data from weather stations across the forested areas of the northeastern U.S., eastern Canada, and Great Lakes region (Figure 1). Their results show a clear picture of fewer days with cold temperatures and declining snowpack over the last century (Figure 2). This loss of cold and snow, in a region historically adapted to cold, snowy winters, has profound implications for water, wildlife, forests, and people. "Whether precipitation falls as snow or rain makes a huge difference—whether you're a skier, a snowshoe hare, or a forest stream," said Dr. Alexandra Contosta, the lead author of the synthesis study. Winter climate change may fundamentally reshape the interconnected social and ecological systems of the northern forest.

This research provides a set of specific indicators of how winter conditions are changing, right now, on the ground, in northeastern North America. For example, the number of frost days per year are decreasing; the number of days when temperatures are cold enough to kill invasive mosquitoes or cold enough for ski areas to make snow are decreasing; and the number of bare-ground days in winter are increasing (see Table 1). These findings can inform the decisions of individuals, businesses, and communities about how to prepare for and adapt to human-caused climate change. This work also provides evidence for policymakers about how climate change is already affecting the people and ecosystems of the northern forest.

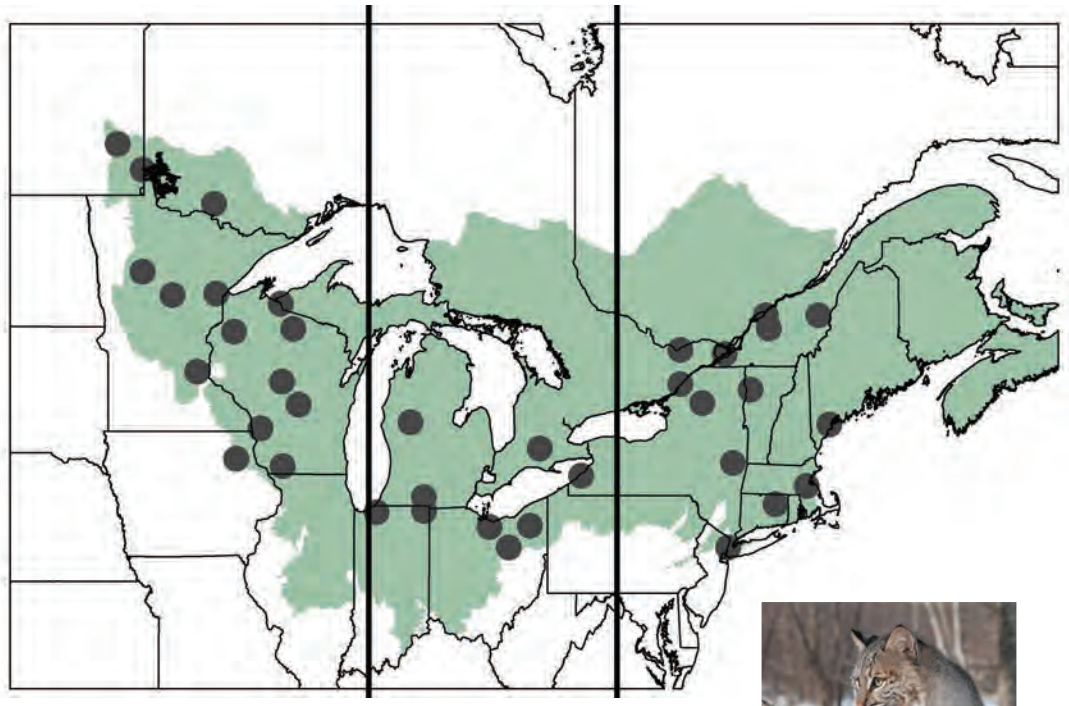


Figure 1: The northern forest region of northeastern North America. This region is dominated by hardwood and mixed forests and was identified using the ecoregion classification system of Omernik and Griffith (2014). Points show locations of weather station data used in the analysis.

Tyler Quinn-Smith

Division I Nordic Skier at the University of New Hampshire, Class of 2018

"As a Nordic skier, I'm directly reliant on the temperatures and precipitation throughout the winter. In the four years I spent at UNH, the winters were noticeably drier and warmer. That was really startling. To me that meant we spent a lot less time skiing and a lot more time driving to places where snow could be made. It also meant more time training indoors and on roller skis. I grew up out west and never would I have imagined that I'd have to roller ski in the winter."

Key Findings

1) We are losing the cold.

Researchers found overall declining trends in the indicators of "coldness." For example, there are now fewer ice days (when daytime temperatures never go above freezing), frost days (when nighttime temperatures dip below freezing and there is a frost), and extreme cold days (when temperatures go below 0 degrees F) than in the past 100 years. The loss of frost days over the past century was most apparent, with decreases of about 18 days in the eastern region of the northern forest, 15 days in the central region, and 11 days in the western region.

2) We are losing the snow.

Winters in the eastern areas of the northern forest have lost about 21 days of snow cover over the past century. Winters in the western areas have lost 17 days of snow cover over the past century. Weather stations in the central northern forest show mixed trends, with some sites near the Great Lakes gaining snow-covered days. Across the northern forest, the researchers saw overall increases in the number of "mud days" in winter: days when the ground is bare and daytime temperatures go above freezing.

3) Winters are getting shorter.

The cold period of the year has shortened by about three weeks across the northern forest. During the 1910s, the sustained cold period lasted about 146 days (range of 85–190 days across individual sites). During the 2010s, the sustained cold period was down to about 126 days (range of 9–194 days across individual sites). This shortening of the length of the cold, snowy period of the year is largely due to earlier onset of spring. Also, during this cold period, cold and snowy conditions have become more intermittent. For instance, in the central region in the 1910s, about three quarters of the sites had snow cover on January 1st, but by the 2010s only about half the sites had snow cover on January 1st.

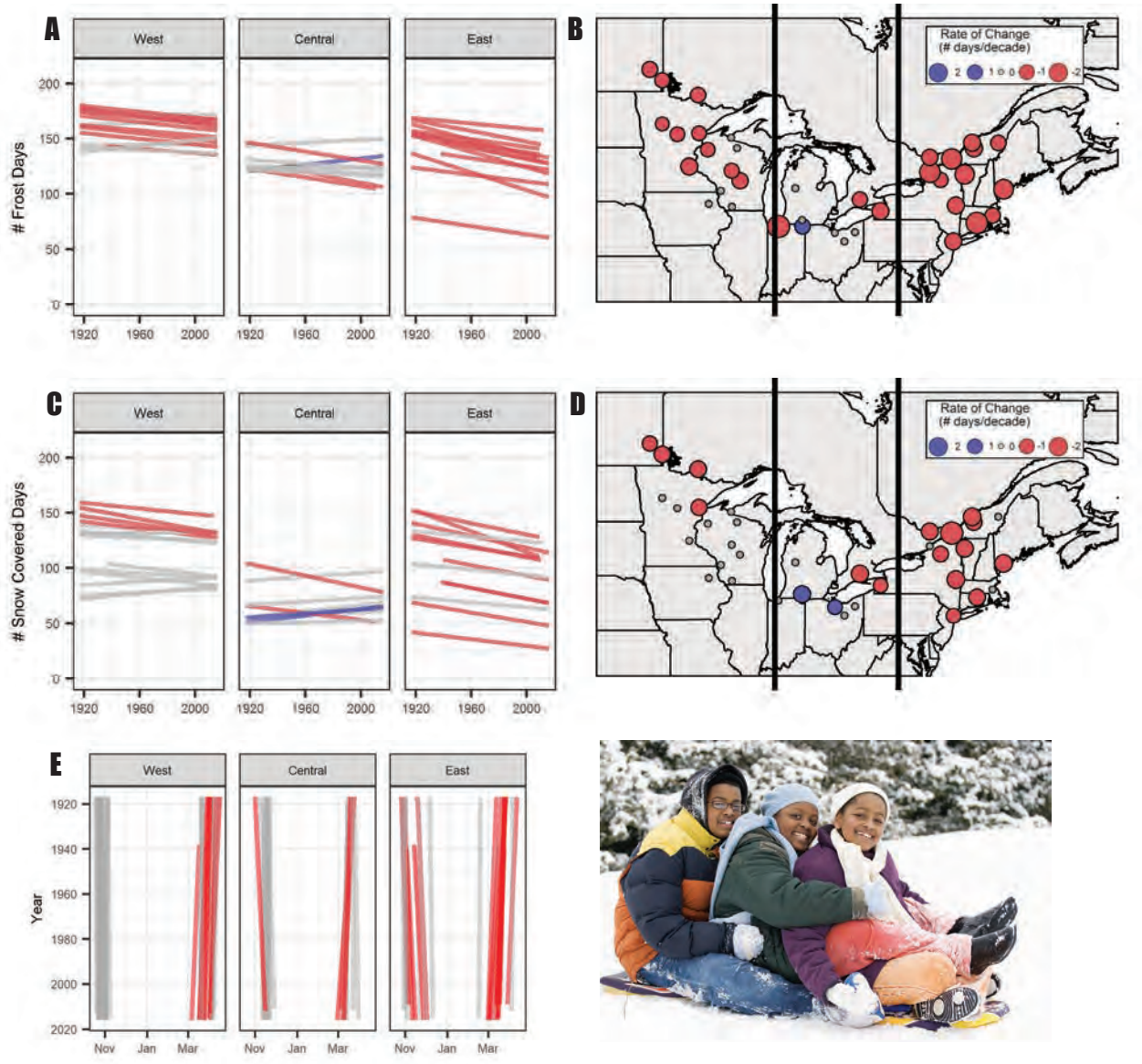
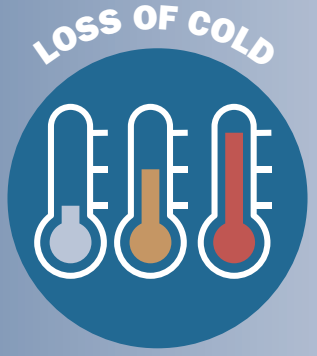


Figure 2: Change over a 100-year period from 1917 to 2016 in the number of frost days (panels A and B), the number of snow-covered days (panels C and D), and length of the cold period (panel E). Red lines show decreasing trends over the time series. Blue lines indicate increasing trends, while gray lines indicate a lack of significant change over time. Sites are grouped into three geographic subregions:, west, central, and east. Maps display rates of change over the entire study area, with red dots showing negative trends, blue dots showing positive trends, and gray dots showing no significant change. The size of the dot illustrates the magnitude of change. The strength of the trend toward fewer cold days, fewer snow-covered days, and shorter winters varies across the region, with the Northeast showing some of the largest losses in these winter indicators.

Indicator	Definition	Trend and Rate of Change Arrows indicate direction of change. **Red colors indicate warmer conditions; Blue colors indicate colder conditions; Gray means no change.** Intensity of color corresponds with strength of the trend across the region. Darker colors mean more sites in the region with the same significant trend; lighter colors mean fewer sites in the region with the same significant trend. Number indicates the rate of change, calculated in number of days more (+) or fewer (-) over the past 100 years.		
		Upper midwest region of the U.S. and southern prairies region of Canada (West in Fig. 2-3)	Great Lakes Region (Central in Fig. 2-3)	Northeastern U.S. and Atlantic Canada (East in Fig. 2-3)
Length of Winter	Number of days between the onset and the end of winter (the sustained cold period)	- 14 days	- 24 days	- 21 days
Frost Day	Min daily temp below freezing	- 11 days	- 15 days	- 18 days
Ice Day	Max daily temp below freezing	- 13 days	+ 13 days	- 14 days
Thaw Day	Max daily temp above freezing	+ 12 days	- 12 days	+ 18 days
Extreme Cold Day; Pine Beetle Kill Day	Min daily temp below 0°F (-18°C)	- 14 days	+ 6 days	- 15 days
Hemlock Woolly Adelgid Kill Day	Min daily temp below -22°F (-30°C)	- 5 days	no change	no change
Snowmaking Days Before Christmas	Min daily temp below 23°F (-5°C) before 25 Dec., a key period for ski area operations	- 15 days	+ 14 days	- 16 days
Invasive Mosquito Kill Day	Min daily temp below 23°F (-5°C)	- 9 days	+ 1 day	- 15 days
Snow-Covered Day	Snow depth greater than 0 mm	- 17 days	no change	- 21 days
Rain-on-Snow Day	Precipitation falls as rain & snow depth is greater than 0 mm	+ 1 day	no change	- 5 days
Frozen Ground Day	Bare ground plus ice: Max daily temp below freezing and snow depth = 0 mm	no change	- 4 days	no change
Mud Day	Bare ground plus thaw: Max daily temp above freezing and snow depth = 0 mm	+15 days	no change	+20 days

Why It Matters: Impacts of Changing Winters

The loss of cold and snow in places historically adapted to cold, snowy winters may reshape our social and ecological systems.



Up to 18 fewer days below freezing

Up to 3 fewer weeks of snow cover

Winter shortened by up to 24 days

OUTDOOR RECREATION & TOURIST ECONOMIES

- Shorter snow-based recreation season
- Disrupted winter tourism patterns
- Increased reliance on snowmaking

CULTURAL TRADITIONS & SENSE OF PLACE

- Changing experiences of December holidays
- Mismatch between timing of cold & snowy conditions and expectations of these conditions for Indigenous cultural practices
- Disruptions in suitable conditions for subsistence hunting

WATER QUALITY & FLOODING

- Winter rain causes ice jams & flooding
- Rain on snow causes runoff & acidic pulses in water supplies
- Earlier ice-out dates for lakes

WILDLIFE

- Loss of snow disrupts habitat for small mammals, shifting predator–prey relationships
- Camouflage misalignment for snowshoe hare

PUBLIC HEALTH

- Expanding range for ticks
- Expanding range for invasive mosquitoes

FOREST HEALTH & FOREST PRODUCTS

- Declining conditions suitable for winter logging
- Expanding range of damaging invasive forest pests

Water

Changing winter conditions can affect the amount and timing of municipal water supplies, the quality and safety of stream water, the risk of winter flooding events, and the duration and thickness of lake ice.

- Warmer winter temperatures result in more frequent melting events and earlier spring snow melt.[1, 2]
- More frequent winter rains and increased winter runoff can increase nitrate export in stream water [3, 4, 5] and cause potential acid pulses.[6]
- More frequent winter rains can cause ice jams and damaging floods.
- Across North America and the globe, lake ice-out dates are occurring earlier in the year. The loss of lake ice negatively impacts lake ecology and can disrupt winter recreation, including snowmobiling, ice fishing, and pond hockey.[7, 8]

Wildlife

Changing winter conditions can affect wildlife habitat, wildlife populations, predator–prey relationships, and vulnerability of wildlife to parasites and diseases.

- Changes in the depth, physical characteristics, and timing of the snowpack can negatively affect under-snow habitat and reduce small mammal abundance. This can lead to enhanced competition among predators, for example allowing red fox to outcompete Arctic fox for food resources.[9]
- Reduced snow depth or formation of ice crusts in warmer and wetter winters could impede the ability of ruffed grouse to snow roost, potentially leading to population decline.[10, 11]
- Changes in the length of the snow-covered season can create camouflage mismatch for snowshoe hare,[12] which is important prey for Canada lynx and other predators including coyotes, goshawks, and great horned owls.[13]
- Moose have been affected by parasites such as winter tick that can flourish during warmer winters.[14] White-tailed deer survival, on the other hand, can increase with warmer winters.[15]

- For freshwater aquatic organisms, decreases in coldness or snow cover may alter the availability of spring insect prey to fish such as brook trout and Atlantic salmon.

[1] Hodgkins et al. 2003
[2] Dudley et al. 2017
[3] Casson et al. 2012
[4] Kurian et al. 2013
[5] Crossman et al. 2016
[6] Eimers et al. 2007
[7] McBoyle et al. 2007
[8] Scott et al. 2008
[9] Penczykowski et al. 2017
[10] Thompson and Fryzel 1988
[11] Zimmerman et al. 2008
[12] Zimova et al. 2016
[13] Feierabend and Kielland 2015
[14] Dunfey-Ball 2017
[15] Lavigne 1999

Casey Thornbrugh

Tribal Climate Science Liaison – United South and Eastern Tribes Inc. & the DOI Northeast/Southeast Climate Adaptation Science Centers, Citizen of the Mashpee Wampanoag Tribe, Mashpee, MA

"Life is a cycle and every season has its purpose. My ancestors have lived in the Northern woods and the Atlantic coast since time immemorial. We saw the land and coastlines change and the climate evolve from the last glacial maximum into the four seasons we know of today. Our New Year begins in the Spring, when the River Herring return to spawn and the forests come back to life. The Summer offers warmth, ease of travel, farming/gardening, and playing outdoors. The Fall provides the harvest and the relief from summer heat and humidity. The Winter allows the land, waters, and life to "rest." For the people, Winter is time spent with family and loved ones, telling stories, and making plans for the New Year. As a child, I actually didn't like winter, I wished it were always warm like Florida or California. However, now as an adult, rooted in my Tribal culture, I am grateful for my home with the Winter and all the four seasons that created our culture as "Wopanaak" (the People of the Dawn)."

Forests

Changing winter conditions can affect forest soils, nutrient availability, tree health, and vulnerability to invasive forest insects and diseases.

- Paradoxically, loss of the insulating snowpack can lead to frozen soils, which can damage tree roots and cause decreased growth the following season.[16]
- Frozen soils can also change the ability of trees to retain nutrients and carbon.[17, 18]
- Increases in mud days and winter rainfall can result in wet soils. If refrozen, this can lead to concrete frost formation, altering soil carbon and nitrogen availability, reducing permeability, and increasing surface water runoff.[19, 20]
- The ranges of invasive and damaging forest pests like the southern pine beetle and the hemlock woolly adelgid are constrained by cold winter temperatures that kill off many of the pests.[21, 22]

- For the forest products industry, the loss of snowpack and an increase in mud days mean fewer days when conditions are suitable for winter logging. Without a protective snowpack, the ground is vulnerable to damage from logging equipment.[23]

People

Changing winter conditions have direct impacts on people. Human health, cultural practices and traditions, winter recreation and tourism, and winter logging operations and the forest products industry are all affected by loss of cold and snow.

- Milder winter temperatures play a role in the geographic distribution of the blacklegged tick that carries the bacteria that causes Lyme disease.[24, 25]
- Winter temperatures also control the geographic distribution of the invasive Asian tiger mosquito, which can carry dengue and chikungunya fevers as well as eastern equine encephalitis.[26]

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[16] Reinmann and Templer 2016
[17] Templer et al. 2017
[18] Sanders-DeMott et al. 2018
[19] Patel et al. 2018
[20] Shanley and Chalmers 1999
[21] Dodds et al. 2018
[22] Fitzpatrick et al. 2012
[23] Evans et al. 2016
[24] Brownstein et al. 2003
[25] Levi et al. 2015
[26] Ogden et al. 2014

Si Balch

Licensed Forester, State of Maine, and Forestry Consultant to the Manomet Climate Smart Land Network

"So far, we're seeing the impacts of changing winters in two ways. First is the biological side, which will change slowly. New and increased forest insects, ticks and diseases are the more easily noticeable biological changes. The cold that controlled their populations is diminishing. There's southern pine beetle in Connecticut now! We are talking with landowners and telling them to be on the watch. We don't always know what's coming but we know we have to keep watching. Plant biological changes will be much slower to become evident.

Second, on the business side, there's uncertainty about conditions, which adds cost to operations. People who are actively managing land depend on consistency. We all have these mental pictures of the seasons and management activities are based on an assumption of consistency of those seasons. Now people are having to be more nimble, to be able to pull up stakes and move somewhere else. They're looking at their equipment mix, deciding whether to buy snowshoes or not, or if they should buy a million-dollar piece of equipment that allows them to be more nimble. The uncertainty adds to costs and affects everyone."

- The northern forest region is the original homeland of many Indigenous peoples whose cultural practices and traditional knowledge are interconnected with specific places, ecological processes, and species. The ecological impacts of climate change are thus compounded within these communities, including impacts on physical and mental health. Further exacerbating these effects are stressors related to colonialism, systemic racism, and forced relocation.[27, 28]
- Winter recreation is a multi-billion-dollar industry in the U.S. and Canada. Many ski area operators are adapting to changing winter conditions with snowmaking. The technology for snowmaking has, thus far, continued to improve, allowing snowmaking outputs to increase despite the decreases in suitable snowmaking days.[29]
- However, not all winter recreation pursuits can benefit from snowmaking, like snowmobiling. This means a significant potential loss of winter tourism revenue to many towns in the northern forest.

[27] Norton-Smith et al. 2016
[28] Whyte 2017
[29] Scott and McBoyle 2007

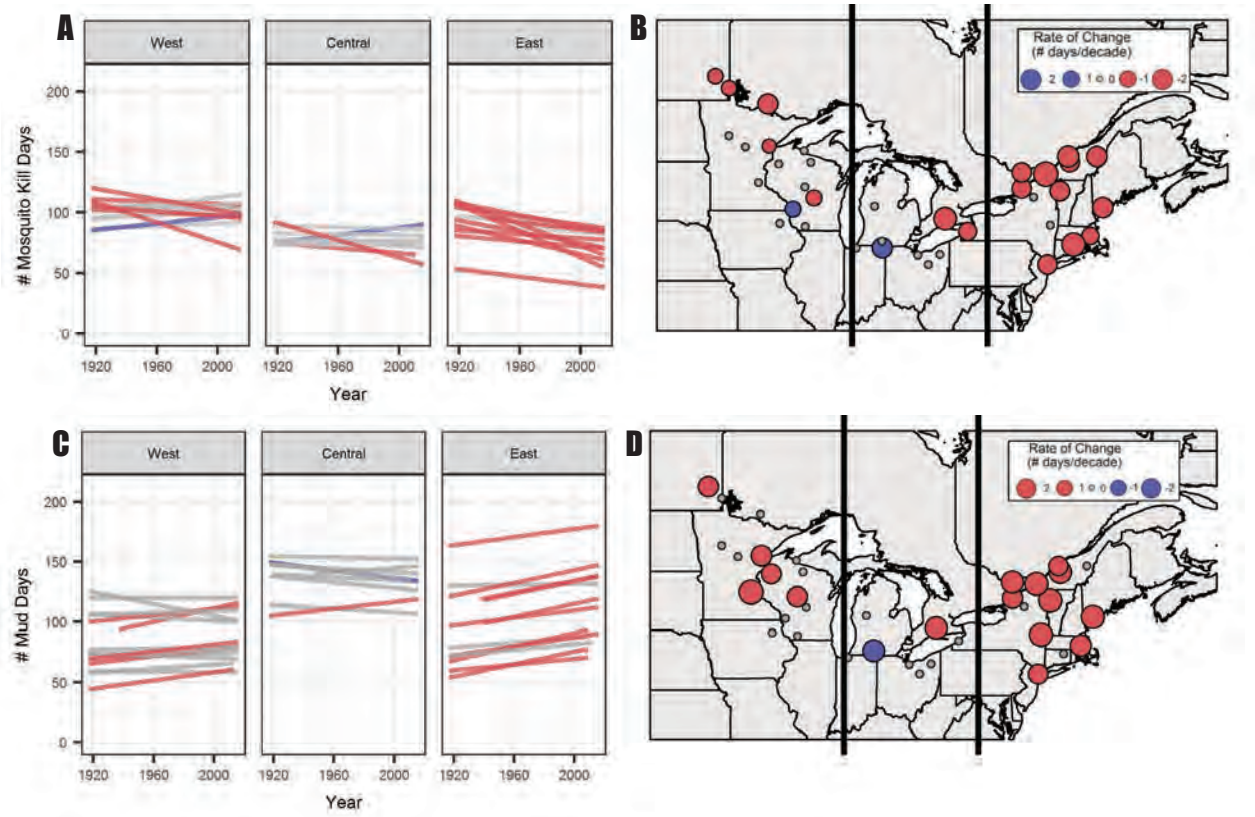

Figure 3: Change over a 100-year period from 1917 to 2016 in the number of days with conditions suitable for killing invasive mosquitoes (panels A and B) and the number of mud days: days in the winter with bare ground and temperatures above freezing (panels C and D). Red lines show decreasing mosquito-kill days and increasing mud days; blue lines show increasing mosquito-kill days and decreasing mud days; gray lines indicate lack of significant change over time. Maps display rates of change over the entire study area. The size of the dot illustrates the magnitude of change.

Allison Gardner

Assistant Professor of Arthropod Vector Biology, University of Maine

"As a disease ecologist, I'm concerned about the spread and establishment of disease vectors. Often the focus of vector-borne disease research is on summers because that is when vectors like blacklegged ticks and mosquitoes are active and interacting with people. But changing winter conditions have very real implications for human health. This is a major focus of my research."

Conclusion

Winters across northeastern North American forests are losing their cold and snow, with one- to three-fewer weeks of cold and snow each year now than a century ago. Although the strength of the trends varies across the region, the overall picture is one of declining winter conditions. This loss of cold and snow has profound implications for water, wildlife, forests, and people—and may ultimately reshape the ecological and social fabric of the northern forest region. The changes shared in this report are not forecasts for the future, they are what we are seeing now. And we are also seeing that people are taking action. Snowmobilers are building trails through the woods that allow them to ride on a thinner snowpack. Timber harvesting operations are shifting into the dry parts of summer instead of relying only on the winter. Community members are inspiring collective action in their towns to lower greenhouse gas emissions. Scientific synthesis reports like the one summarized here can inform these efforts and communicate to policymakers about the tangible ways climate change is having an impact, on the ground, right now.

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HUBBARD BROOK RESEARCH FOUNDATION

Administrative Office:
30 Pleasant Street, Woodstock, VT 05091
(802) 432-1042

Field Office:
Pleasant View Farm
25 Dobson Hill Road, Thornton, NH 03285

https://hubbardbrook.org/hubbard-brook-research-foundation