USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Northern Research Station

Rooted in Research

ISSUE 16 | JULY 2023

Long-Term Climate Monitoring Sheds Light on Complex Forest and Freshwater Systems

Together, forests and freshwater ecosystems provide many services that people rely on such as erosion and flood control, carbon sequestration, drinking water, wildlife habitat, and recreation. Scientists are trying to understand how climate change is altering the composition and functioning of these complex and critical systems.

Studying the impacts of climate change is often limited by a lack of available long-term data. That is where the National Science Foundation's Long-Term Ecological Research (LTER) network comes in. From Alaska's North Slope to New England's hardwood forests, and from Puerto Rico's tropical rainforests to Antarctica, scientists have been collecting ecological data at 28 LTER sites, in some cases since 1980 when the program was established, or even longer. LTER data can provide valuable insights about climate change and its ecological impacts in a way that shorter-term studies cannot.

Living Laboratories

"Long-term monitoring is the bread and butter of the long-term ecological research program," says John Campbell, a research ecologist at the U.S. Department of Agriculture, Forest Service, Northern Research Station. In recognition of the LTER network's 40th anniversary, Campbell and colleagues published a paper on forests and freshwater ecosystems in the journal BioScience in September 2022. Other articles in the same issue focus on how climate change has affected coastal, dryland, and marine pelagic ecosystems.

The flux tower in Hubbard Brook Experimental Forest in New Hampshire collects valuable data about the atmosphere and energy exchanges. USDA Forest Service photo.

KEY FINDINGS

- Average temperatures are rising at all study sites across the country, while yearly rainfall is increasing in some places and decreasing in others.
- Mean annual air temperature increased significantly at all nine study sites between 1950 and 2019.
- Expected changes in climate at some sites are characteristic of a completely different biome.
- Based on expected changes in average rainfall and temperatures, the study sites most likely to experience a biome shift are in Alaska, Oregon, Colorado, Maryland, and North Carolina.
- Long-Term Ecological Research network sites provide vital data and insights into climate trends over time, as well as the cascading and complex consequences of climate change.

Campbell and his coauthors examined nine forest and freshwater sites from different ecosystems in the LTER network, including a tropical rainforest in Puerto Rico, a temperate rainforest in Oregon, boreal forests in Colorado and Alaska, and five temperate forests in the eastern United States. These sites had considerable variability, with average annual air temperatures ranging from -3 to 23 degrees Celsius and mean annual precipitation from 270 to 3500 millimeters.

The researchers found that between 1950 and 2019, mean annual air temperature rose at all nine locations. The site temperature at Alaska's Bonanza Creek rose at a rate of 0.39 degrees Celsius per decade. Another boreal forest, Niwot Ridge in Colorado, is at a far lower latitude, and the average temperature there rose

only 0.09 degrees Celsius per decade. These findings further demonstrate that the areas near the North and South poles are warming more rapidly than places closer to the Equator, a finding consistent with other published studies. The authors wrote, "Climate change is amplified toward the Earth's poles; therefore, boreal forests may act as sentinels of global warming."

Precipitation patterns across the LTER sites were more mixed. Since 1980, annual precipitation has increased in the northeastern United States but decreased in areas like Alaska and the Pacific Northwest region.

A Shifting Future

Climate changes have not yet generally caused forests to shift to a different biome, but biome shifts are possible in the future. The authors noted that temperature and precipitation changes from the past 70 years or so are minor compared to changes expected during the rest of this century. Based on temperature and precipitation data, the following sites are most likely to experience biome shifts in the future: Maryland's Baltimore Ecosystem Study, Alaska's Bonanza Creek, Colorado's Niwot Ridge, Oregon's H.J. Andrews, and North Carolina's Coweeta.

Changes in climate, especially when gradual and over long periods of time, can cause ecosystems to respond in ways that are difficult to decipher and analyze, especially when complex interactions with other changes, such as increasing atmospheric carbon dioxide and recovery from acidic deposition, are involved. Extreme climate-related events, such as wildfires, massive storms, droughts, and extreme heat, can also cause impacts that are more readily apparent than changes in temperature or precipitation over time, so all these factors should be evaluated. "You can't just look at temperature and precipitation," Campbell says. "You have to look at other factors. Much broader changes are occurring along with climate change, and when that happens you get very complex interactions."

Hubbard Brook, located in Hubbard Brook Experimental Forest, is a key component of the Long-Term Ecological Research Network. Scientists have collected data from the area for more than 60 years. USDA Forest Service photo.

Long-term ecological research sites, like Hubbard Brook Experimental Forest in New Hampshire's White Mountains, allow scientists to monitor climate and make observations such as when ice melts on Mirror Lake in the spring. USDA Forest Service photo.

In the coming decades, LTER sites will continue to provide scientists with living laboratories to study temperature, precipitation, streamflow, carbon storage, nutrient and water cycling, and altered ecosystem processes, as well as cascading effects and feedback loops. However, Campbell also notes that despite the impacts of a changing climate, ecosystems may be able to adapt in some ways. "These systems are incredibly resilient—we don't want to lose sight of that," Campbell says.

Project Lead

John Campbell is a research ecologist with the Northern Forest Science and Applications Unit. Learn more about Campbell's work at: https://www.fs.usda.gov/research/about/people/jlcampbell.

FURTHER READING

Campbell, John L; Driscoll, Charles T; Jones, Julia A; Boose, Emery R; Dugan, Hilary A; Groffman, Peter M; Jackson, C Rhett; Jones, Jeremy B; Juday, Glenn P; Lottig, Noah R; Penaluna, Brooke E; Ruess, Roger W; Suding, Katharine; Thompson, Jonathan R; Zimmerman, Jess K. 2022. Forest and Freshwater Ecosystem Responses to Climate Change and Variability at US LTER Sites. BioScience. 72(9): 851-870. https://doi.org/10.1093/biosci/biab124.

Forest Service Research and Development (FS R&D) works with partners to deliver the knowledge and tools that land managers need to sustain the health, diversity, and productivity of our Nation's forests and grasslands for present and future generations. The Northern Research Station (NRS), one of seven FS R&D units, is rooted in the geography of the Northeast and Midwest. NRS science supports a sustainable future. For more information visit https://www.fs.usda.gov/research/nrs.

Susbscribe online to the Northern Research Station's Rooted in Research at: https://www.fs.usda.gov/research/nrs/products/rooted-research.