Ecological Drought in the Northeast United States

Anticipating changes to iconic species, landscapes, and ecosystems

Northeast Climate Science Center Workshop
May 3-4, 2016
Amherst, MA

The Department of the Interior Climate Science Centers (CSCs) and their managing organization, the National Climate Change and Wildlife Science Center at the U.S. Geological Survey, have chosen the emerging climate science field of Ecological Drought as a research focus area. This workshop is part of a series of meetings at each of the nation's eight CSCs aimed at collating our existing knowledge of the ecological impacts, resistance, and recovery from drought. The eight CSCs provide a fantastic opportunity to compare the ecological effects of drought, related research activities, and management options at different regions, spatial scales, and biomes.

Droughts have happened and will happen again in the Northeast

The Northeastern and Midwestern United States is generally considered a well-watered region, yet droughts have happened in the past due to large-scale changes in atmospheric circulation. As recently as the 1960s and 1980s, widespread drought was experienced in this Northeast region. It is predicted that drought conditions in the region will become more prevalent as climate change influences temperature and precipitation patterns throughout the region.

Iconic seasonality and diversity define this region

The seasonality of the Northeast is iconic with its fall colors, snowy winters, colorful springs, and warm, humid summers. Much of the landscape is dominated by forest, but the region also includes grasslands, coastal zones, beaches and dunes, and wetlands. The Northeast experiences extreme events, including ice storms, floods, droughts, heat waves, hurricanes, tornadoes, and nor'easters; however, these vary greatly in both space and time. Annual precipitation varies across the region, with highest amounts in the mountains and coastal areas. As the climate changes, resource managers and the public are concerned about how the iconic landscapes and species of the regions will change.

National Park Service

Forests, freshwater systems, coastal ecosystems, and working landscapes are at risk

Much of the forested area within the Northeast developed over the last century, a period of ample water availability relative to previous centuries. This recent period of relatively wet and stable climate has contributed to an increase in the abundance and dominance of drought-intolerant species as well as motivated particular forestry and agricultural practices. Consequently, the ecosystems, livelihoods, and species reliant on this water regime are vulnerable to changes in precipitation (e.g., the marbled salamander that is dependent on seasonal wetlands).

Peter Paplanus, Flickr CC

Management is challenged by dense populations and transformed landscapes

Nearly half of the population of the United States lives in the Northeast region. This is one of the most developed landscapes in the world and contains a large network of supporting infrastructure. Human-impacted uses of water—for water supply, irrigation, and hydropower production—often compete with environmental flows for aquatic species and other ecological services during drought. Coordination of management action is complicated by the intertwining of diverse private and public land ownership. Even if supply (precipitation) increases, changes in human responses to drought can pose substantial threats to ecosystems.

NASA Earth Observatory

Characterizing drought in the well-watered Northeast

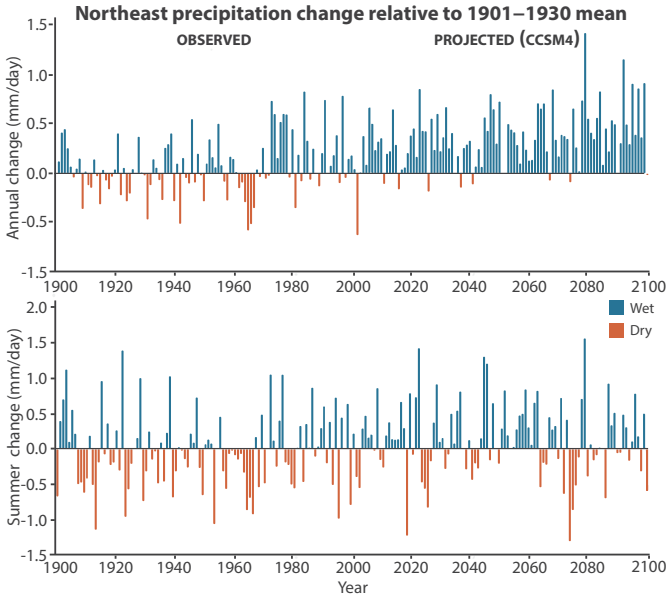
Droughts of the future may not be droughts of the past

The Northeast has a rich history of long-term research and monitoring of terrestrial and aquatic ecosystems, from headwater streams to coastal wetlands and fisheries. Paleoclimate records provide a unique perspective of drought within the region that looks very different from recent conditions. These records indicate that, historically (1960s, 1980s and early 2000s), droughts were more frequent and more severe in the Northeast U.S. than even those encountered in the distant past. It is anticipated that the frequency of droughts will increase in the future as temperatures rise and precipitation variability increases.

The Quabbin Reservoir (Massachusetts) level on October 13, 1966. Courtesy of Massachusetts DCR Archives.

More drought in a warmer, wetter world

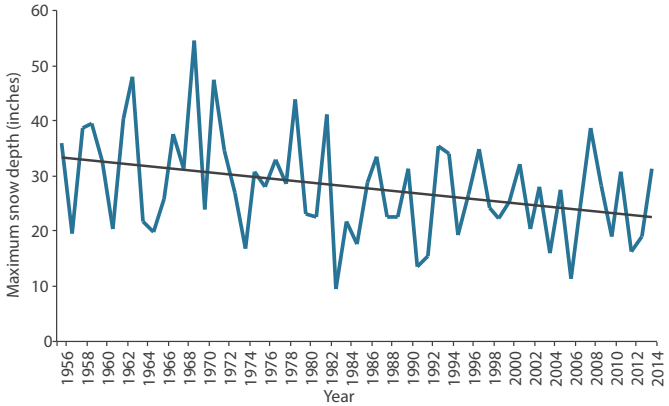
Over the last century, average temperatures in the Northeast have risen by almost 2°F (1°C), and precipitation has increased five inches (12.7cm), with a greater proportion falling in extreme events. Projections of future precipitation changes are less certain than projections of temperature, but most models indicate conditions will become wetter in the future. The Northeast has experienced a greater recent increase in extreme precipitation than any other region in the United States. Between 1958 and 2010, the Northeast saw more than a 70% increase in the amount of precipitation falling in very heavy events. Although it is expected that overall annual precipitation totals will increase over the Northeast and Midwest throughout the century, warming and less frequent precipitation events favor an increase in drought intensity. Therefore, increases in the frequency of short-term (1–3 months) droughts are projected. Northeast ecosystems are closely linked to water availability, therefore it is important to consider not just how much water is available on average, but where, when, and how it is delivered to the system.



Annual projections indicate an overall increase in precipitation, with continued summer dry spells. This figure, based on a single model, is only one of many possible futures, and does not provide a prediction of timing of future dry periods, only an indication of the expected variability of summer rainfall in relation to past variability. Data provided by Ambarish Karmalkar, NE CSC.

Precipitation, but not as we know it

Northeastern ecosystems depend on abundant and relatively predictable water regimes. Shifts in seasonality and increases in variability and unpredictability in precipitation may cause ecological impacts on species and ecosystems that are ill-prepared to deal with them. Climate change projections include shorter, warmer winters and drier summers punctuated by intense rainfall events. Summer rainfall variability is expected to be similar to the past; but with higher temperatures leading to greater evapotranspiration, future drought risk will increase. With increasing temperatures causing more precipitation to fall as rain in winter and earlier spring snowmelt, a longer growing season, less snow, and worse summer droughts are expected. Droughts that alter water availability and flows during typically high flow periods are particularly challenging to species and ecosystems.

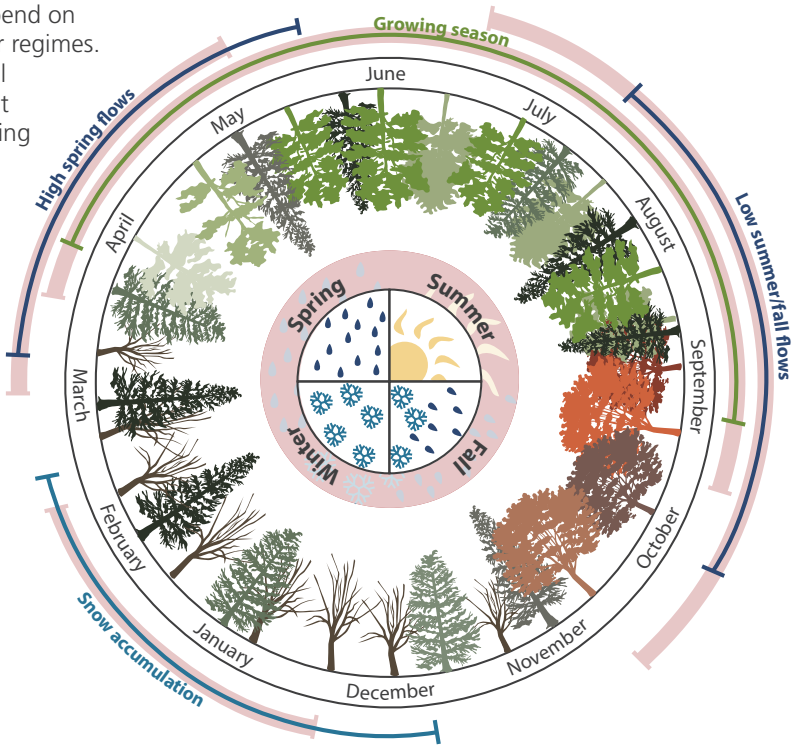


Maximum snow depth observed at Hubbard Brook Experimental Forest from 1955-2015. Data provided by John Campbell, United States Forest Service.

Shifts in seasonal water regimes

The landscapes of the Northeast and Midwest depend on abundant and relatively predictable seasonal water regimes. Human uses of water compete with environmental flows for aquatic species, especially during drought periods. With increasing temperatures and increasing precipitation variability, low water levels could occur earlier in spring and summer months, causing earlier droughts that persist longer into the growing season. Higher temperatures result in shorter, milder winters. A shift from snowfall to rainfall in winter months will lead to changes in snow depth, snow hardness, and rain on snow events. As the frequency and period of low stream flows increase, the stress for flora and fauna dependent on water levels and seasonal wetlands will also increase. Combined with more successive days of higher than normal temperatures, this will result in increased cumulative heat stress, particularly in spring, summer, and fall. An increase in rainfall from heavy precipitation events leads to increased flooding and sediment scouring, and delivery of nutrients and pollutants to aquatic systems and downstream coastal habitats.

Northeast and Midwest seasonal patterns



Shifted season projected from increasing temperatures and precipitation changes

Landscapes dependent on seasonality are susceptible to drought

Northeast forests matured during periods of high water availability

Forests of the Northeast are not well-adapted to drought. Drought causes reduced uptake and movement of nutrients, reduced fine root biomass, leaving trees vulnerable to other threats (e.g., insects/pathogens, invasive species, fire). Within soils, a lack of moisture availability can change soil physical properties, slow microbial activity, and reduce soil nutrient concentrations. The range of economically important tree species, like sugar maple, is expected to shrink within the U.S. as their preferred climate shifts north. Warmer temperatures are also increasing outbreaks of forests pests and pathogens, including hemlock woolly adelgid. Warmer winters and reduced snow cover result in more deer and damage to understory layers.

Drought threatens global waterfowl populations

The Prairie Pothole region, which is shared between the Northeast and North Central CSC regions, is an area characterized by a high density of shallow wetlands that produces 50–80% of the continent's ducks. Climate models project increased drought conditions for this region, resulting in northward shifts in breeding distributions, lower reproduction, higher mortality, and dramatically reduced populations across the rest of the country.

Coastal resources and economies are at risk

The Northeast region includes vast amounts of coastline, from the Great Lakes to the Atlantic Ocean. Atlantic coast and Great Lakes fishing and shipping are major drivers of Northeast economies. Droughts impact coastal systems by reducing river flow and freshwater delivery to downstream habitats, altering nutrient delivery, estuarine biogeochemistry and food web productivity. A decrease in freshwater flows would allow for high saltwater intrusion into the system, potentially reducing habitat for aquatic species. Changes in the delivery of freshwater and nutrients to coastal waters will also affect the timing, magnitude, and strength of mixing (stratification), and likely increase hypoxia (low oxygen) events.

Species rely on drought-sensitive habitats

The rarity of drought in the Northeast may place some species at unusual risk. Higher rates of mortality in bat species have been observed with drought. Freshwater mussels, one of the most imperiled wildlife groups in the Northeast, are particularly sensitive to drought. Salamanders and other species reliant on drought-sensitive habitats like vernal pools could be negatively affected, as breeding success is reduced when pools dry up too early in the spring. Increasing temperatures and reduced water availability have the potential to influence the timing of important ecological events, causing birds to migrate sooner and plants to bloom and leaf out earlier. The result is a mismatch between food availability and key species.

Ecological vulnerability to drought in a well-watered, but warming region

Droughts present a significant risk to ecological systems in the Northeast. Severe and extended droughts have periodically occurred throughout this large and diverse region, such as the drought of the 1960's. However, these past drought events have not fundamentally changed the currently drought-vulnerable nature of Northeast flora and fauna.

Conversations with stakeholders indicate natural resource managers are concerned about climate-associated drought risk and interested in actionable science related to this issue. A recent workshop brought together a wide range of experts to review our understanding of risk in the Northeast. Several factors suggest increases in drought risk in a warmer, wetter climate: 1) increases in temperature will likely outweigh potential increases in total precipitation, resulting in an increase in the frequency and intensity of droughts; 2) predicted changes in the seasonal timing and form of precipitation (snow vs. rain) could significantly influence species and habitats that are strongly adapted to predictable patterns of water and snow availability; 3) increases in competition for ecologically available water as a result of human responses to drought can pose substantial threats to ecosystems.

It appears that the biggest drought risk to our ecosystems may be from 'novel' drought—decreases in water availability that interact with other emerging climate-driven stressors (e.g., higher temperatures, altered flow regimes and snowpack, increased precipitation variability and extremes) to impact ecosystems vulnerable to these changes. Important forested, aquatic, and coastal ecosystems will be faced with many other impacts as well, including invasive pests and pathogens, sea level rise, changing urban patterns, and more. We will continue to engage stakeholders and meet managers where they are now to better refine our understanding of their science needs, and to help inform actions and adaptations to this aspect of climate risk.

– Mary Ratnaswamy, Director, Northeast Climate Science Center

Iconic and valuable forest species such as sugar maple, unique amphibian and waterfowl assemblages in seasonal wetlands, native brook trout in headwater streams, and important diadromous fish such as sturgeon, Atlantic salmon, and American shad migrating through our large rivers and coasts will see the impacts of a changing climate. Photos: Sugar maple, U.S. Forest Service; Wood frog, Brian Gratwicke, Flickr; Roseate Tern, Atlantic Salmon U.S. Fish and Wildlife.

For more information regarding ongoing research and activities at the Northeast Climate Science Center, visit *necsc.umass.edu*

Participants at the Northeast Climate Science Center workshop held in Amherst, Massachusetts in May 2016.

Workshop participants

Keith Nislow, Lindsey Rustad, *United States Forest Service*.
Alex Bryan, Gardner Bent, Shawn Carter, Evan Grant, Ben Letcher, Elda Varela Minder, Toni Lyn Morelli, Pete Murdoch, Mary Ratnaswamy, Michelle Staudinger, Laura Thompson, *United States Geological Survey.*
Scott Steinschneider, *Cornell University*.
Neil Pederson, *Harvard Forest*.
Chris Neill, *Marine Biological Laboratory*.
Paul Barten, Ray Bradley, Christine Hatch, Ambarish Karmalkar, Richard Palmer, Patrick Ray, Marcelo Somos Valenzuela, *University of Massachusetts at Amherst*.
Adam Coble, *University of New Hampshire.*
Tony D'Amato, *University of Vermont*.
Erika Rowland, *Wildlife Conservation Society*.

Science communication, layout, and design:

Simon Costanzo, William Dennison, Brianne Walsh, *University of Maryland Center for Environmental Science.*

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Oak trees in Southern Vermont, Tony D'Amato

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