FEMC

Forest Ecosystem Monitoring Cooperative

Long-Term Regional Monitoring Update 2016

Providing the information needed to understand, manage, and protect forested ecosystems in a changing global environment

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The Forest Ecosystem Monitoring Cooperative Regional Monitoring Update - 2016
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The Forest Ecosystem Monitoring Cooperative Editorial Staff

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Introduction

Established in 1990 as a partnership among the USDA Forest Service, the State of Vermont Agency of Natural Resources and The University of Vermont (UVM), the Forest Ecosystem Monitoring Cooperative (FEMC) facilitates collaboration among federal, state, non-profit, professional and academic institutions for long-term monitoring of forested ecosystems across the region and an improved understanding of forest ecosystems in light of the many threats they face.

Forest ecosystems are complex entities supporting many organisms and providing a wealth of ecosystem services. Because a healthy forest system is also dynamic in response to natural climate variability, disturbances and succession, long-term monitoring is necessary in order to distinguish normal year to year variability from emergent forest health issues or subtle changes indicative of chronic stress.

Driven by its mission to aggregate the information necessary to monitor forest health, detect chronic or emergent forest health issues and assess their impacts on forested ecosystems, the FEMC staff have expanded its long-term monitoring and reporting to encompass the larger region, including Maine, Massachusetts, New Hampshire, New York and Vermont. Building on its experience developing monitoring reports for the Vermont (see the 2016 Vermont report at https://www.uvm.edu/femc/products/long_term_update/2016/vermont) FEMC staff have brought in additional data on an initial subset of reignoal monitoring programs to expand the focus of its work and provide more insight into trends in ecosystem processes at a larger scale. This Regional Monitoring Update offers a sampling of three key long-term data sets that represents the basic structure, condition and function of the forested ecosystem. Our goal is to include both a summary of the latest year's data on key forest, wildlife, water, and air quality metrics, along with an analysis of the long-term patterns and trends in the data in order to provide a relevant and timely source of information on the current state of the region's forested ecosystems. This allows us to quantify metrics collected in 2016 in the context of long-term monitoring datasets.

The information in this Regional Monitoring Update is intended to be a snapshot of the larger body of monitoring and research that has been amassed over time, and which is growing daily. As an organization, FEMC believes that the regular analysis and reporting of such information is critical to identify emerging forest health issues, as well as understand the drivers and impacts of ecosystem change.

Staff Writer: Alexandra Kosiba

Precipitation Chemistry and Acid Deposition

National Atmospheric Deposition Program/National Trends Network

Automated Precipitation Collector at the FEMC Air Quality Site in Underhill. Sampling at this site started in 1984.

The ecological consequences of atmospheric acid deposition have been well studied in the Northeastern US. Through these investigations, acid rain has led to the decline of red spruce in the 1970s and 80s, the leaching loss of calcium and other cations from soil, and the acidification of lakes and streams. Two measures of acid deposition are sulfate (SO_4) and nitrate (NO_3); when emitted as air pollutants, these molecules can form acids through reactions with water in the atmosphere, creating what we know as 'acid rain'. Recognizing this serious environmental threat, regulations were enacted to control emissions of sulfur and nitrogen oxides, which react in the atmosphere to produce acidic compounds; as a result, acidic deposition has declined and ecosystem recovery is underway.

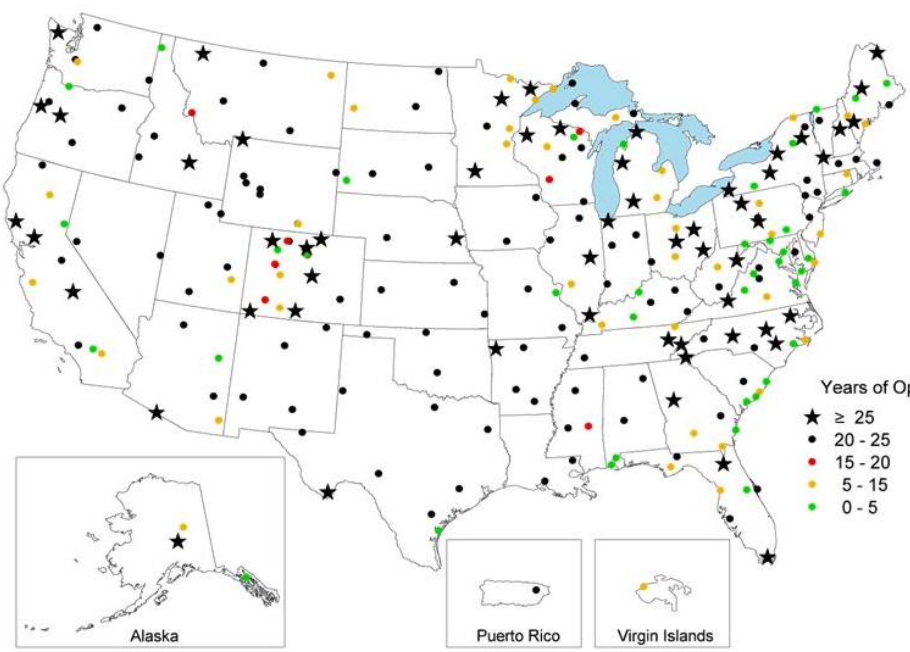

Figure 1. Locations of National Trends Network monitoring sites. Source: NADP.

Staff Writer: Alexandra Kosiba

The Data

National Atmospheric Deposition Program (NADP) has been monitoring precipitation chemistry in the US since 1978 through the National Trends Network (NTN) program. The 250 national NTN sites collect data on the amounts, trends, and geographic distributions of acids, nutrients, and base cations in precipitation.

NTN sites are predominantly located away from urban areas and point sources of pollution. Each site is equipped with a precipitation chemistry collector and gage. The automated collector ensures that the sample is exposed only during precipitation (wet-only-sampling). Site operators follow standard operational procedures to help ensure NTN data is comparable. All samples are analyzed and verified by the Central Analytical Laboratory (CAL) at the Illinois State Water Survey (ISWS). Measurements include acidity (H^+ as pH), conductance, calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), and ammonium (NH_4^+). Deposition is expressed as a concentration of the pollutant, which reflects the amount of water in which it is transported. The continental scale of NTN sites reveals spatial and temporal trends in acid deposition in Vermont and the Northeast and allows comparison with other regions of the U.S. Today, this information is necessary to understand how air quality policies have ameliorated acid deposition across the region, and to inform future policy and management decisions to sustain the health of the region's forested ecosystems.

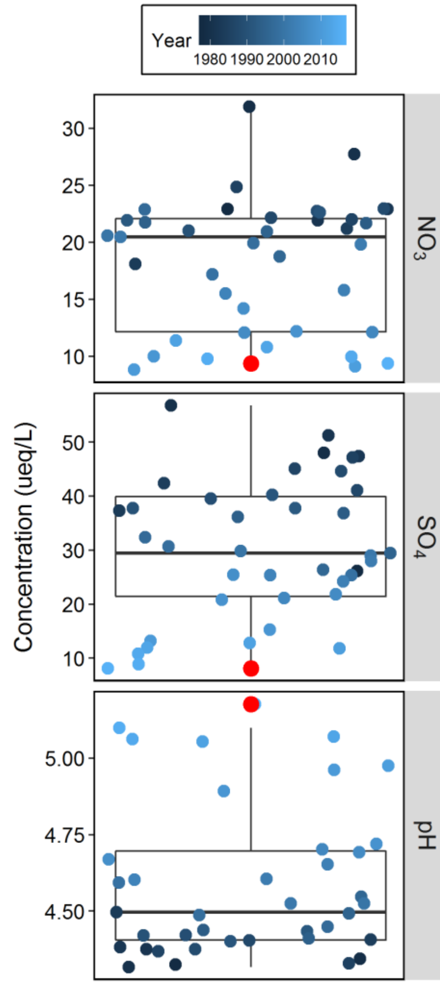

Figure 2. Mean annual deposition of nitrate (NO_3), sulfate (SO_4), and pH for the region, displayed with quantile box plots. The most recent year's measurements (2016) are indicated in red, and shades of blue correspond to the year, with lighter values corresponding to more recent data. Solid horizontal line indicates the long-term mean; any points outside vertical bars at top and bottom of boxes show values that are statistically outside of the range for that parameter.

2016 in Summary

For all three metrics of acid deposition (NO_3, SO_4, pH), 2016 continued the trend of reduced pollution concentrations over historical measurements in the region (Figure 2).

While mean deposition of NO_3 in 2016 was not the lowest value observed in the record (Figure 2), it was the third lowest at 9.3 ueq/L, and was a considerable decline from the record high of 31.9 ueq/L in 1979. Further, for every year in the most recent decade (2006 on), precipitation contained the lowest measured concentrations of NO_3.

In 2016, we saw the lowest concentration of SO_4 in the record (8.1 ueq/L). This is a dramatic decline from the historical high of 56.8 ueq/L in 1980. Unlike the historical record, in 2016 deposition of SO4 was lower than that of NO3.

The average pH was the highest on record at 5.2, which indicates that precipitation in the form of rain, snow, or ice is less acidic than in 2015. While the pH has increased considerably from the record's low of 4.3 in 1980, "unpolluted" rain typically has a pH of 5.6. Therefore, there is still room for continued improvement in lowering the acidic of precipitation. As pH is a logarithmic scale, this increase represents a roughly fivefold improvement in precipitation acidity.

In the early years of acid rain monitoring, sulfates accounted for about 66% of the acidity in precipitation, while nitrates contribute the other 33%. While upwind emissions of both sulfur oxides (SO_X) and nitrogen oxides (NO_X) have declined over time, reductions in SO_X have been greater than NO_X. While the stress imposed by SOx deposition has been greatly reduced, it is unclear how the continued deposition of NOx will impact forested ecosystems.

Long-term Trends

Since precipitation chemistry was first measured in the region, rain has become less acidified (Figure 3). These changes reflect declines in sulfur- and nitrogen-based emissions due to the Clean Air Act (1977) and subsequent amendments (1990). The most significant reductions have occurred for sulfate deposition, which has fallen from nearly 56.8 ueq/L in 1980 to less than 10 ueq/L currently. Note that for certain years, there is higher variability, which shows the variation in the region from west to east (Figure 4) and that the number of stations has increased recently (Figure 1).

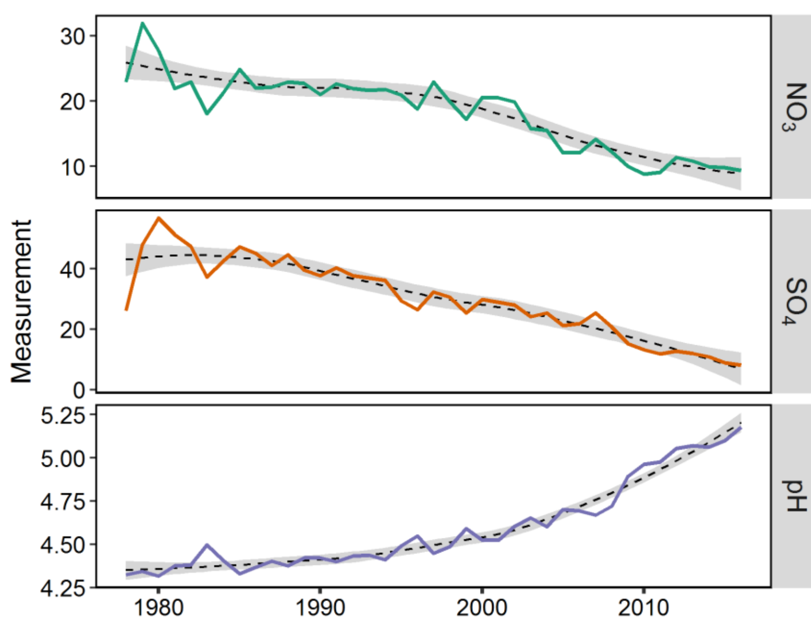

Figure 3. Long-term precipitation chemistry showing annual mean concentrations (ueq/L) of nitrate (NO3) and sulfate (SO4), and mean pH (solid colored lines) for the region. Black dotted line shows trend (LOESS function) with 95% confidence intervals (grey shading).

More modest changes have been measured for nitrate deposition. This is primarily due to the relative difficulty of removing nitrogen compounds from flue gases and their diffuse pollution sources such as motor vehicle exhaust and agricultural activities. Sulfuric emissions have been easier to control through regulation of emissions from the burning of coal, natural gas, and other fossil fuels.

Concurrently, there has been a dramatic increase in precipitation pH (Figure 3). Since pH is on a logarithmic scale, increasing pH by a value of 1 signifies a substantial change in precipitation acidity.

Looking forward, it is likely that reductions in SO_4 may continue (Figure 3), along with resultant decreases in precipitation acidity. However, it appears that reductions in NO_3 concentrations may have plateaued. Because nitrogenous pollution primarily comes from diffuse sources such as automobile exhaust, fertilizer use, and confinement farming such as feedlots and poultry operations in agricultural regions, continued reductions may require additional legislative or regulatory action.

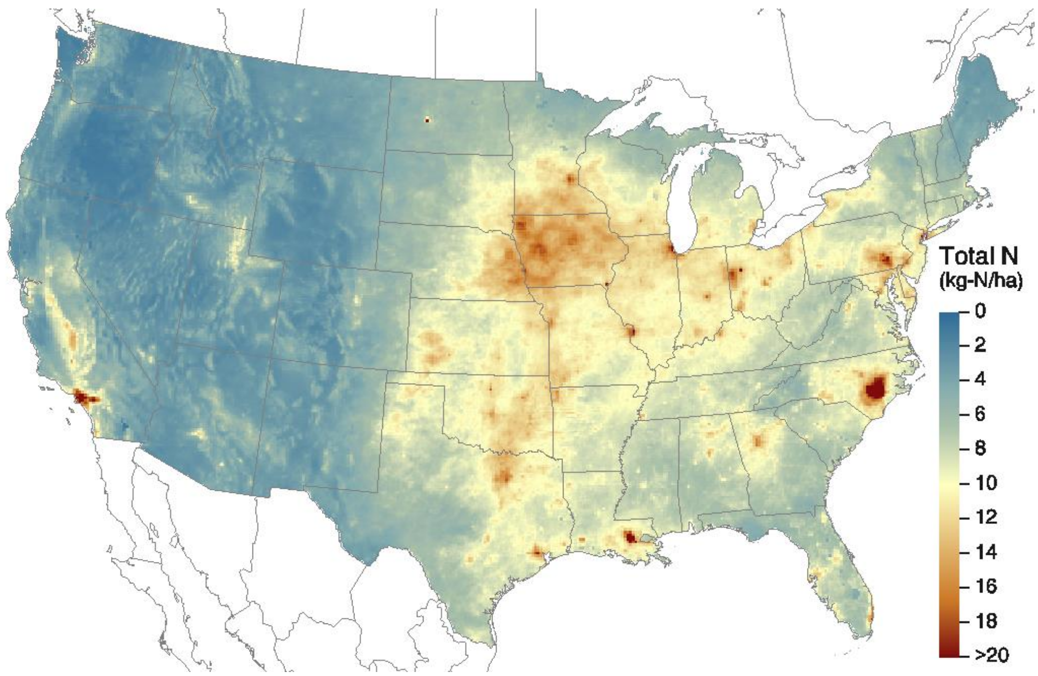

Figure 4. Spatial distribution of total nitrogen deposition (kg/ha) across the continental US in 2015. Source: US EPA.

Implications

The region is in relatively good shape compared to nitrogen pollution loads nationwide (Figure 4). However, high elevation forests are still at risk from additional acidic inputs due to more frequent exposure to acid mist in clouds, higher amounts of precipitation, and relatively shallow acidic soils. Further, there are some areas of the region, particularly western and southern portions of New York, that have continued to receive elevated nitrogen deposition (Figure 4).

As nitrogen becomes a more important constituent of acid deposition, monitoring networks and modelers are combining resources to better understand the spatial and temporal patterns of nitrogen deposition and its impacts on terrestrial and aquatic ecosystems. Continued reductions in nitrogen deposition may require additional regulation to control point sources.

- Acid deposition continued to decline in 2016
- The average pH of precipitation was 5.2, well above the historical low
- Nitrate deposition reductions may have plateaued and should continue to be monitored

Additional Resources

National Atmpospheric Deposition Program. http://nadp.sws.uiuc.edu/NTN/

EARTH: The Science Behind the Headlines. American Geosciences Institute. http://www.earthmagazine.org/

FEMC Project Database Links

Vermont National Atmospheric Deposition Program/National Trends Network (NADP/NTN): https://www.uvm.edu/femc/data/archive/project/national-atmospheric-deposition-programnational-trends-network

Staff Writer: Ali Kosiba

Water Quality in Acid-Sensitive Lakes

The Acid Lakes Long Term Monitoring Program

Acid rain was first detected as a serious environmental problem in the late 1960s. Emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_X) react with water, oxygen, and other chemicals in the atmosphere to form sulfuric and nitric acids. Resulting hydrogen ions in acid rain leach plant-necessary cations (e.g., calcium, magnesium, potassium, phosphorus) from the soil and into water bodies, and make toxic cations, like aluminum, more available. Such changes have been shown to negatively affect all levels of ecosystem health, from trees to soil microorganism.

The Data

When high-elevation lakes in geologically sensitive areas were becoming acidified, the Environmental Protection Agency (EPA) enacted the Acid Lakes Monitoring Program in Vermont, New York, and Maine under the Long-Term Monitoring Program (LTM). Note that data from Maine only extends up to 2014 and not all yearly parameter values were available from each state.

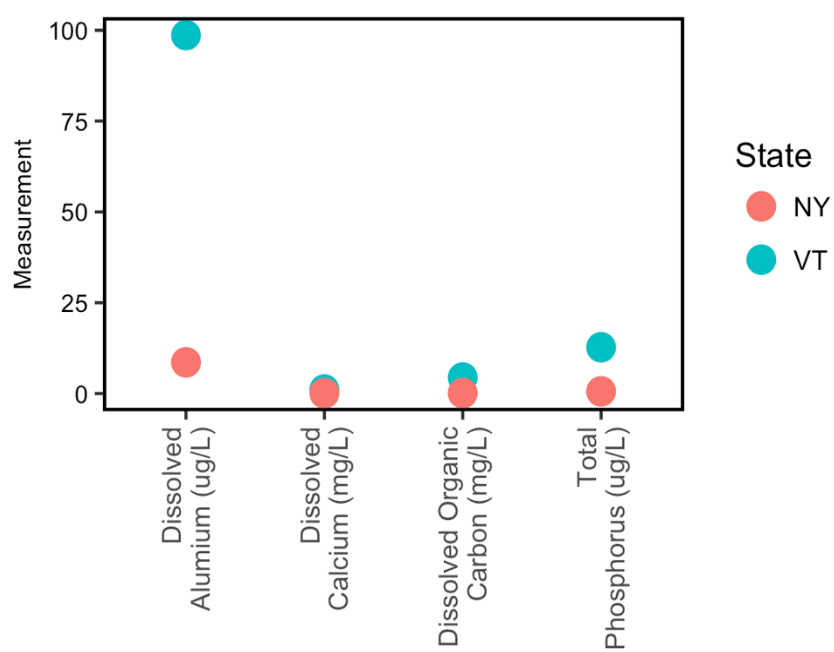

Figure 5. 2016 water quality measurements from acid lakes/ponds in Vermont (blue) and New York (red) for four selected variables. Note that Maine Acid Lakes data was only available up to 2014.

Water quality samples are collected three times a year (spring, summer, and fall). Measurements include pH, transparency, temperature, color, and concentrations of calcium, magnesium, sodium, potassium, aluminum, nitrate, sulfate, chloride and dissolved organic carbon (DOC). For most measurements, the methods of collection, processing, and analysis have remained consistent for nearly 30 years, providing us long-term records water quality in the region and throughout the US.

2016 in Summary

In 2016, we saw a range of values for water quality measurements in the lakes and ponds in the regional Acid Lakes Monitoring Program. This reflects the variability in the different water bodies in the region, as well as in the natural variability in the parameters measured. For some, but not all of the measured water quality parameters, average values among the regional Acid Lakes improved from 2015.

A good indicator of improving water quality, dissolved aluminum has continued to decrease precipitously, although we see a large range in values depending on location (Figure 5). Vermont Acid Lakes contain a great deal more dissolved aluminum compared to Acid Lakes in New York. As we do not have access to 2016 data in other states, we cannot assess if there are similarities with other states. Yet, in 2014 Maine Acid Lakes showed a range of dissolved aluminum values that are similar to Vermont's mean concentration, which may indicate that New York concentrations are on the low end regionally.

For both New York and Vermont, dissolved calcium concentrations are similar in 2016 (Figure 5), and show a slight reduction from the previous year. This is a positive sign of decreasing acid deposition.

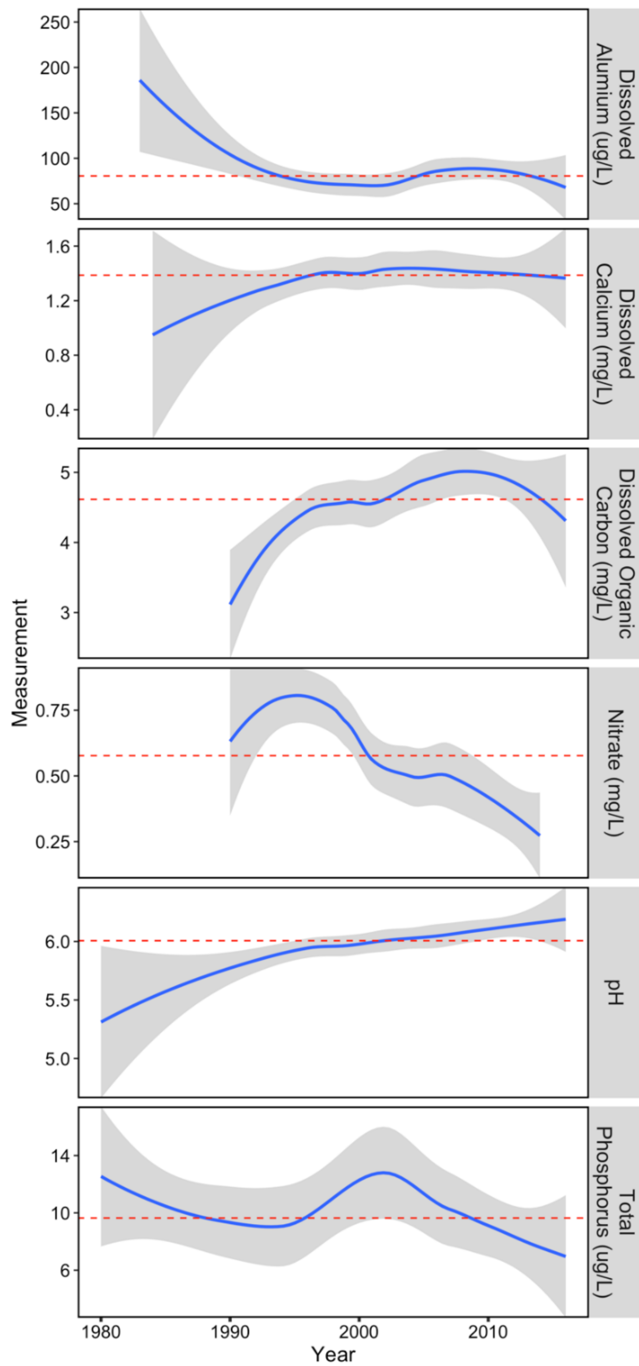

Figure 6. Average water quality measurements from the lakes/ponds in the regional (VT, NY, and ME) Acid Lake Monitoring Program (blue line, smoothed with LOESS function), plus 95% confidence interval (grey shading). Red dashed line indicates the long-term average per measurement type.

Dissolved organic carbon is a broad grouping of organic molecules resulting from decomposing organic matter. It is not only a food source for aquatic microorganisms, but is an indicator of terrestrial health. In 2016, Vermont had much a higher mean concentration of DOC compared to New York (4.4

and 0.08 mg/L, respectively) (Figure 5), with both states showing a decrease from the previous year. For context, mean DOC concentration in Maine in the most recent year of data (2014) was comparable to those of Vermont. Why New York Acid Lakes contain much less DOC is unclear.

Algal bloom in Shelburne Pond, VT

Vermont also had higher concentrations of phosphorus compared to New York (12.7 and 0.6 ug/L, respectively; Figure 5). Vermont values were slightly lower than in 2015; but as there are no phosphorus concentrations reported for New York in 2015, we cannot assess change from previous year.

Long-term Trends

The data from the regional Acid Lakes show evidence that acid accumulation and cation leaching have declined over the long-term record (1980-2016). Water pH has been increasing over time and has surpassed the regional mean of 6.0 in recent years (Figure 6). Concurrently, dissolved aluminum has been decreasing precipitously since it was first measured in the mid 1980s. Surprisingly, we are not seeing a similar regional reduction in dissolved calcium, although concentrations have plateaued and are declining in the last few years. This may reflect the spatial variability among the states, including different bedrock materials and soil types.

Another good indicator of ecosystem health, dissolved organic carbon has been increasing since it was first measured in the early 1990s; however, in recent years there is a slight decline in this trend (Figure 6). Mean nitrate concentration has been showing a declining trend, which is a good indication of less acid loading.

Total phosphorus shows a varied pattern, but overall there is a decrease in concentration from a peak in 2003 (Figure 6). The concentrations detected in the regional Acid Lakes are below the threshold for ecosystem issues. Phosphorus, which is easily transported in water, is an essential nutrient for all life, however, excessive concentrations can lead to algal blooms.

Implications

Trends in increasing pH and declining dissolved cations are evident across the region. These long-term data are proof of ecosystem recovery following the Clean Air Act and subsequent amendments, which have substantially reduced deposition of sulfur and nitrate – two components that react in the atmosphere to produce acid rain.

As acid rain was first discovered in the mid-1960s, we lack records of water quality prior to acidification. As a result, it is uncertain what measurement values designate full ecosystem recovery. Further, acid rain has not completely vanished, as we are still seeing deposition of sulfur and nitrogen on the landscape. Despite this uncertainty, the relatively quick recovery of our lakes and ponds compared to values in the 1980s supports regulation to combat acidic pollutants and continued monitoring to help protect our valuable resources. Moving forward, as the threat of acid rain declines, other types of pollutants are becoming more problematic, such as phosphorus loading in our large water bodies.

- In 2016, most water quality indices have improved but limited data records mean that results should be taken lightly
- The long-term data (1980-2016) suggest vulnerable lakes in the region are recovering from decades of acid rain
- Moving forward, phosphorus may become more problematic as acidic inputs decline

Additional Resources

Vermont Department of Envrionmental Conservation. Vermont Integrated Watershed Information System. Accessible at https://anrweb.vt.gov/DEC/IWIS/

Adirondack Lakes Survey Corporation website, http://www.adirondacklakessurvey.org/

EPA Clean Air Markets – Monitoring Surface Water Chemistry: https://www.epa.gov/airmarkets/clean-air-markets-monitoring-surface-water-chemistry

FEMC Project Database Links

Long-term Monitoring of Acid Sensitive Lakes: https://www.uvm.edu/femc/data/archive/project/long-term-monitoring-acid-sensitive-lakes

Staff Writer: Ali Kosiba

Data Credits

The US EPA–USGS LTM/TIME and portions of the HELM project was funded by EPA ORD to J.S. Kahl, W. McDowell, S.J. Nelson, K.E. Webster; and EPA CAMD to W.H. McDowell, J.S. Kahl, S.J. Nelson (IAG 06HQGR0143), processed through Grant/Cooperative Agreement G11AP20128 from the United States Geological Survey

Staff Writer: Alexandra Kosiba

Broad-Scale Forest Disturbance

Aerial Detection Surveys of Forest Disturbance

Damage to trees caused by insects, disease, animals, and weather, are a natural and common occurrence in the region's forests. Such disturbances can result in changes to biodiversity and species composition, and allow for cycling of nutrients from trees to soil, but can also negatively affect timber quality and other important ecosystem services. There is also concern that climate change and further introduction of non-native pests and pathogens may alter disturbance patterns.

The Data

Aerial detection surveys (ADS) have been used to map the cause and extent of forest disturbances in the US for many years.

Annual sketch-mapping surveys are collected by state agencies, and by the US Forest Service on federal lands, via fixed-wing airplane by trained technicians. The US Forest Service Forest Health Monitoring Program set survey methods and standards. Resulting mapped polygons include information on the disturbance cause, type, size, and severity, and are confirmed with ground assessments. Causal agents of disturbance can range from insects and disease, to weather events, wild animals, and humans.

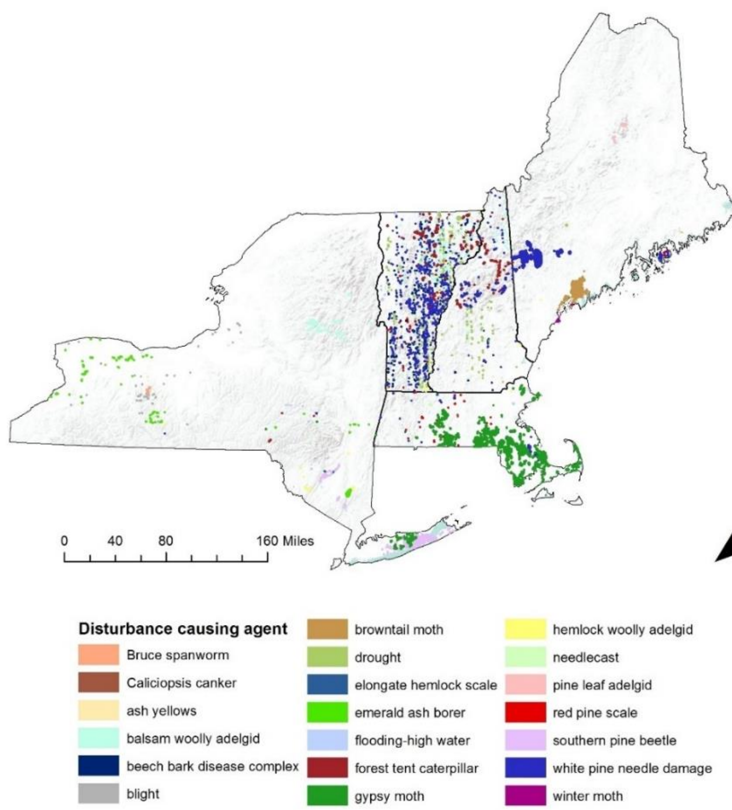

Figure 7. Locations of select forest disturbance agents in 2016 from region-wide aerial detection surveys. Disturbance polygons were increased in size for visibility. Only agents with considerable disturbance area are shown for clarity. States have differing quantities of disturbance polygons recorded, which is a combination of variable disturbance occurrence and agency priorities.

Surveys are a cost-effective and vital tool for detecting emerging forest health issues and tracking trends. However, surveys are not comprehensive of all forest damage and cannot capture subtle disturbance or light decline. Here for the first time we examine forest disturbances via ADS for the northeastern temperate forest region (Massachusetts, Maine, New Hampshire, New York, and Vermont). Please note that survey scope and coverage are not uniform between the five states; therefore, it can appear that some states have more disturbances than others which is a result of differing priorities during surveys.

2016 in Summary

In 2016, 333,640 hectares (824,441 acres) of forest disturbance were mapped in the Northern Forest region. This amounts to less than 2% of the region's forestland (Figure 7). This is a slight increase from 2015 when 297,051 ha were mapped, and below the average disturbance rate of 3% of the region's forestland per year (599,015 ha/year) between 1997 and 2016.

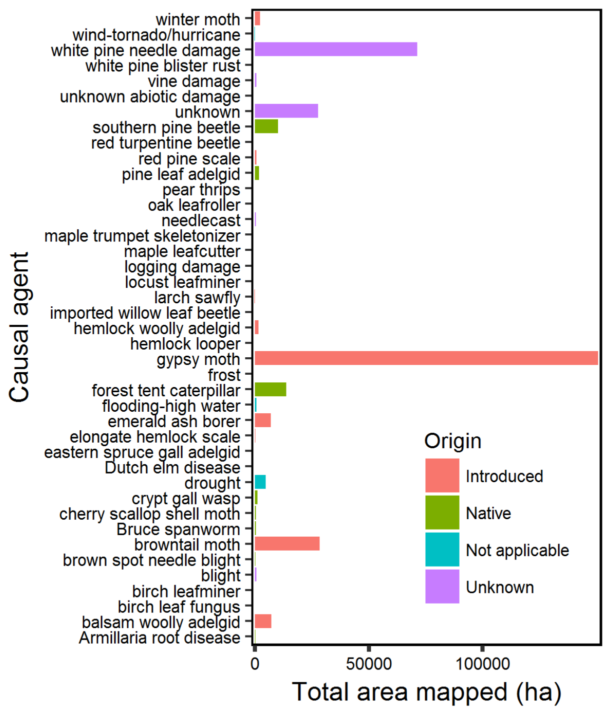

Figure 8. Total mapped disturbance (hectares) by causal disturbance agent from 2016 aerial detection surveys in the Northern Forest region. Color corresponds to origin of agent.

Substantial damage was caused by two introduced (non-native) insects, gypsy moth (*Lymantria dispar*; 150,510 ha) and browntail moth (*Euproctis chrysorrhoea*; 28,329 ha) (Figure 8). While both insects have caused disturbance every year in the region between 1997 and 2016, in 2016, we saw the largest amount of disturbance attributed to these insects in the record. In fact, in 2016 introduced insects and diseases caused nearly 7 times more disturbance (198,145 ha) compared to those of native origin (28,607 ha, Figure 8). White pine needle damage was much more widespread (Figure 7) and severe than in previous years (71,364 ha mapped) (Figure 8). Understanding the cause of this damage is ongoing. For more information, see the document from UMass Extension (2016).

Long-term Trends

Summing all disturbances per year (1997-2016) reveals substantial year to year variability (Figure 9). This is partially to do with divergent forest health priorities and differing amount of forested land surveyed between the five states. But also, several disturbances are episodic, particularly abiotic weather events (e.g., late spring frost events, drought) and many insect outbreaks. The year of the highest disturbance area occurred in 2005 during an outbreak of the non-native insect, balsam wooly adelgid (1,860,334 ha affected in 2005; *Adelges piceae*). Only two agents have been detected regionally every year in the 20-year period: gypsy moth and flooding/high water damage (Figure 10).

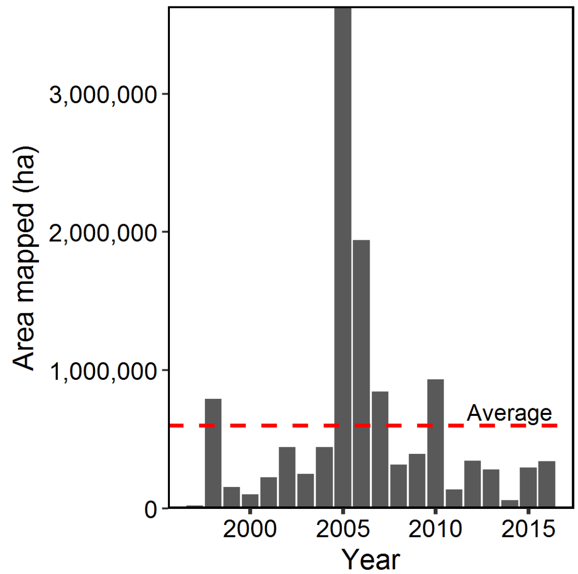

Figure 9. Total annual area mapped as disturbed (grey bars; hectares) during aerial detection surveys in the Northern Forest region. Red dashed line indicates the average disturbance (1997-2016).

In total, 194 different damage agents have been mapped in the region since 1997. When the maximum extent of damage caused by specific damage agents is compared to number of years they were mapped, agents have varying impacts in the landscape (Figure 10). In general, insects and abiotic agents have had the largest effect on the region's forests. The most damaging agents overall have been insects: balsam wooly adelgid (3,147,304 ha), forest tent caterpillar (1,521,682 ha; *Malacosoma disstria*), and skeletonizer (1,107,655 ha; species unknown).

Abiotic disturbance agents, like ice and frost events and drought, can indiscriminately affect trees regardless of species (although there can be reasons why specific species may be more harmed in abiotic events, due to branching structure, wood density, or habitat, for example) and as a result can cause widespread disturbance. Most other disturbance agents have only affected a small area of regional forestland. Only twelve agents out of 194 have resulted in total damage greater than 100,000 ha in the 20-year period. Many tree diseases identified in the region have not caused large disturbance extents despite frequent occurrence (Figure 10). Of diseases, beech bark disease (a complex between *Cryptococcus fagisuga* scale and *Neonectria* fungi (*N. faginata* and *N. ditissima*)) and anthracnose (G*nomonia* spp.) have resulted in the largest disturbance area. Forest fire is an infrequent event regionally, and when it does occur, the extent is small.

The large effect of introduced insects and diseases over the 20-year period is cause for concern: introduced agents affected two times the amount of forest (4,452,361 ha) compared to those of native origin (2,100,723 ha). However, as new pests and pathogens emerge, often the origins of agents are unknown; agents of unknown origin have caused substantial disturbance overall (3,810,792 ha). These results demonstrate the destructive nature of introduced pests and support the need for continued monitoring of emergent pests.

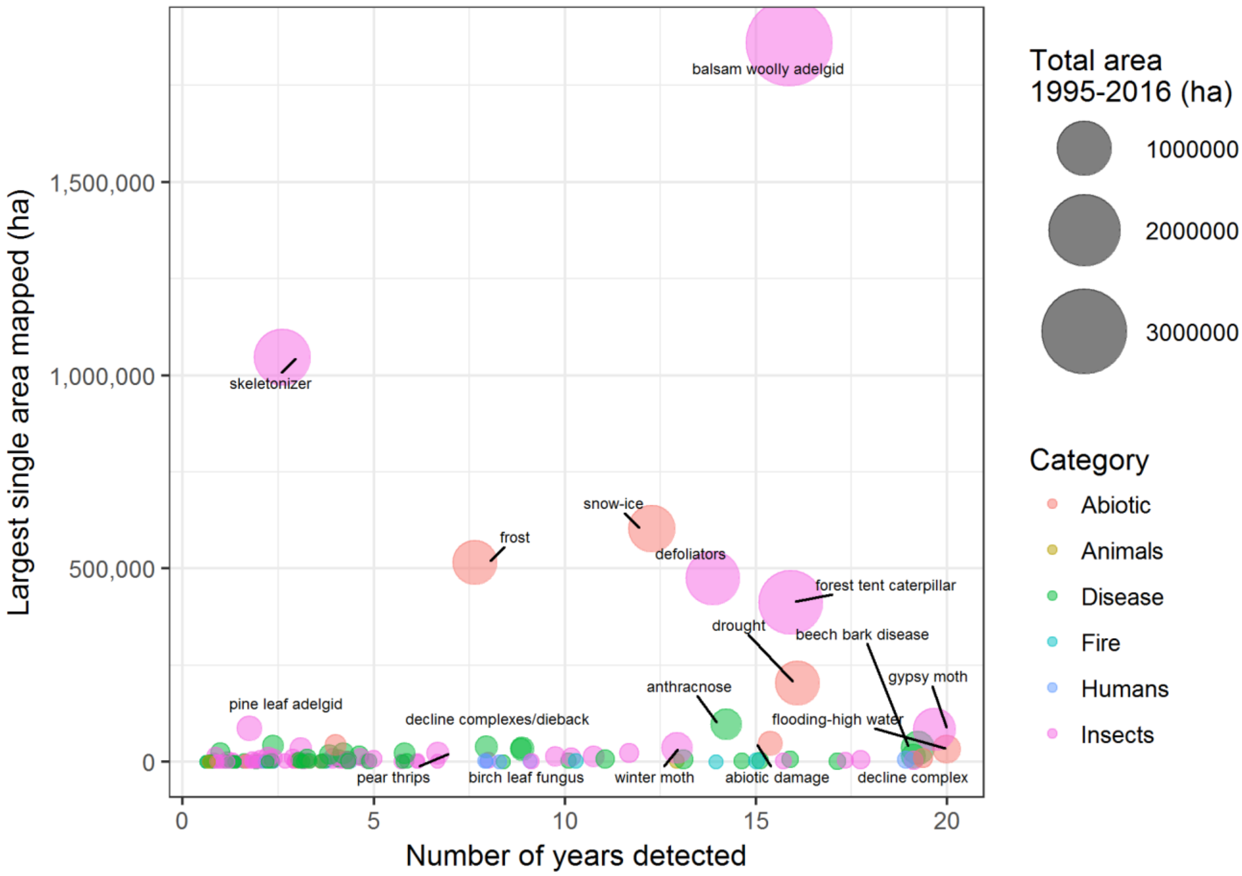

Figure 10. Mapped disturbance agents according to region-wide aerial detection surveys (1997-2016) plotted by the frequency (number of years detected) and largest single area mapped (ha; e.g., largest single polygon). Circle size corresponds to the total area recorded for that agent over the 20-year period and color corresponds to the agent category. Only agents that have affected >50,000 ha in total are labeled for clarity.

Implications

ADS data provides the longest region-wide annual record of forest disturbances. Over the past 20 years, relatively low levels of total forest disturbance have been mapped. Most disturbances cause small damage extents and minor total damage.

In total, 194 different causes of disturbance have been mapped, which reflects the varied nature of the region's forests. Causal agents that lead to repeat and extensive damage are more likely to have significant impacts on forest health. Many biotic agents tend to be chronic or episodic, while abiotic events are often less predictable, yet can result in large disturbed areas. As our climate continues to change, it is projected that extreme weather events will become more frequent, which may mean more storms, wind, ice, frost, or flood events. Elevated summer temperatures, along with changes to rainfall patterns, could lead to more severe and frequent droughts. See the Climate Change Indictors Dashboard (Vermont ANR 2017) for more information. Such abiotic events can cause large areas of damage to multiple tree species (Figure 10). Continued monitoring of disturbances over time is needed to understand the patterns of various types of events and how they may be changing.

Many invasive insects and diseases have been detected in the region, or have been detected nearby. These pests and pathogens have caused much more disturbance to the region's forests than those of native origin, and we could see widespread declines of specific species, such as ash (*Fraxinus* spp.) with the spread of emerald ash borer. The good news is that we are not seeing increases in total disturbance over time. The high species diversity in many forest stands and continued vigilant monitoring may be helping to mitigate widespread issues and to identify problems before they become widespread.

- 2016 regional forest disturbance was less than the long-term record
- Non-native insects caused substantial damage region-wide
- Continued monitoring is essential to examine trends and detect novel agents

Additional Resources

UMass Extension, Plant Diagnosis Laboratory. 2016. Dramatic needle browning and canopy dieback of eastern white pine (Pinus strobus) in southern New England. Available online at https://ag.umass.edu/sites/ag.umass.edu/files/content-files/alerts-messages/2016_white_pine_update.pdf

Vermont Agency of Natural Resources. 2017. Climate Change in Vermont. Available online at http://climatechange.vermont.gov/vermonts-changing-climate

FEMC Project Database Links

Northeastern Regional Aerial Detection Surveys:
https://www.uvm.edu/femc/data/archive/project/northeastern_ads

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New York Aerial Forest Health Surveys:
https://www.uvm.edu/femc/data/archive/project/nydec-aerial-survey

Vermont Aerial Sketchmapping:
https://www.uvm.edu/femc/data/archive/project/statewide-aerial-sketchmapping-tree-defoliation-mortality

Image Credits

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Precipitation Chemistry and Acid Deposition

Automated Precipitation Collector. 2017. John Truong

Forest Ecosystem Monitoring Cooperative. Dead alpine tree.

Water Quality in Acid Sensitive Lakes

Shelburne Pond, Shelburne, Vermont. 2016. Lisa B. (NEEF).

River. 2016. Ali Kosiba.

Broad-Scale Forest Disturbance

VT Forest Parks and Recreation. Aerial survey image.

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VERMONT AGENCY OF NATURAL RESOURCES

USDA FOREST SERVICE

The University of Vermont