PROJECT UPDATE

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New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Effects of Atmospheric Deposition of Sulfur, Nitrogen, and Mercury on Adirondack Ecosystems

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Project Location

Adirondack region outlined.

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For more information on this project see:

http://www.nyserda.org/programs/environment/emep

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Keywords

- Fish species richness
- Nitrogen fixation
- Riparian vegetation
- Speckled alder (Alnus rugosa)
- Wetlands

PROJECT FOCUS

This project was designed to clarify the causes and long-term effects of acidic deposition in the Adirondacks and investigate the factors that have slowed the recovery of Adirondack Lakes from acidification. It also addressed mercury (Hg) pollution by assessing historical and current rates of Hg deposition and fish species richness in lakes and streams in the region.

The evaluation of ecosystem response to future reductions in atmospheric deposition involves a number of factors that need to be better understood. Especially important are the biogeochemical links between vegetation and surface water chemistry. The composition of wetland vegetation affects nitrogen (N) concentrations in soil and surface waters and contributes to the diverse responses of Adirondack ecosystems. The project specifically aimed to further the analysis of temporal and spatial patterns in the chemistry of major solutes in Adirondack waters, including the role of dissolved organic nitrogen (DON), and to estimate the abundance of speckled alder (Alnus rugosa) and its N contribution to wetlands. In addition, time-series analyses, mass-balance estimates, and modeling were undertaken using available data.

CONTEXT

The Adirondack region of New York State, located directly downwind of major coal-burning sources in the Midwest, receives elevated levels of atmospheric sulfur (S), nitrogen, and mercury, which has resulted in the acidification of waters and increased uptake of Hg in fish. As a result, this region has been a focal point for numerous research efforts designed to identify the processes involved in these effects, and contribute information needed for analyzing impacts of current and potential regulations on environmental recovery.
Ongoing measurements show that the wet deposition of sulfate (SO_4^{2-}) to the Adirondacks has decreased over the past two decades, as expected from reductions in sulfur dioxide (SO_2) emissions mandated by the Clean Air Act (CAA) and its 1990 Amendments (CAAAs). In contrast, there has been little change in the wet deposition of nitrate (NO_{3-}) or ammonium (NH_{4+}) over the monitoring period, consistent with the limited changes in NO_x and NH_3 emissions from polluting sources. To date, researchers have found that despite reduced sulfate deposition, surface waters in the Adirondacks have shown limited recovery from acidification. Additional reductions in emissions and deposition, as well as a timeframe of several decades, may be necessary for the recovery of the more sensitive of these waters. However, the emission reduction levels that would be needed and resulting impacts on recovery are as yet unknown.

METHODOLOGY

Time series of precipitation and lake chemistry were analyzed and mass balance estimates (lake input and output) were made, using data obtained from the Adirondack Lakes Survey Corporation and other sources. The project also addressed the:

- Role of DON in Adirondack watersheds, including the relationships between DON and other solutes, especially dissolved organic carbon (DOC).
- Distribution and abundance of speckled alder, its retention of atmospheric N ("nitrogen fixation"), and its N contribution to Adirondack wetlands. Using data gathered at a number of sites, the range of N fixation, its resulting input of nitrogen to alder wetlands, and alder-related N inputs at the regional watershed scale were estimated.
- Current and historical rates of Hg deposition in Adirondack lakes. Sediment cores were collected from eight lakes and analyzed to determine Hg concentrations over time. Current levels were analyzed through a new monitoring station established at Huntington Forest.
- Recovery of fish species in response to changes in atmospheric deposition, assessed in the North Branch of the Moose River (NBMR). Comprehensive surveys were conducted on 16 lakes and 11 streams within the NBMR watershed in 2000 and compared with the results of earlier studies.

Modeling (PnET-BGC) of several representative sites in the Adirondacks and Catskills simulated the response of surface waters to deposition. The model also evaluated the response of five forest ecosystems to changes in atmospheric deposition and land disturbances and predicted the ecosystem responses to three emission control scenarios.

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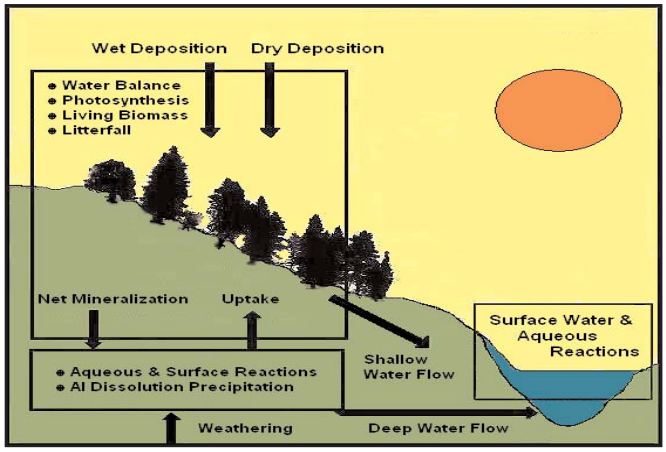

The PnET-BGC model simulates the response of surface waters to deposition, evaluates the response of ecosystems to changes in deposition, and predicts ecosystem responses to emission control scenarios.

Credit: Mark Watson
Dr. Raynal inspects the nitrogen-fixing root nodules of speckled alder.

PROJECT FINDINGS

Acidification. Acidic deposition over 150 years has resulted in the acidification of soil and water in the Adirondack region. Some chemical recovery has taken place in the last 30 years, as a result of mandated emission reductions. However, projections suggest that under current deposition patterns, lakes either will continue to acidify or will recover at a very modest rate. Model predictions suggest that additional reductions in SO_2 and NO_x emissions will boost the recovery rate, but also that the period of chemical recovery will be decades.

Mass balance estimates. Spatial patterns in N deposition and landscape features (e.g., presence of wetlands and water flow paths) all play a role in N retention and drainage loss.

DON. Mean annual concentrations and fluxes of DON were strongly related to the concentrations and fluxes of DOC. DON and DOC concentrations and fluxes were higher at lake watersheds with larger wetland areas.

Speckled Alder. Speckled alder fixes substantial quantities of N along the lake inlets. Wetlands with abundant alder had 6 times higher nitrate accumulation than reference wetlands without alder. Surface waters in alder-dominated wetlands contained approximately 3 times more nitrate than non-alder counterparts. In specific alder-dominated wetlands, nitrogen addition from alder exceeds atmospheric deposition by as much as 3 times.

Hg Deposition. Analyses showed marked increases in sediment Hg deposition, beginning in the 19th Century. Sediment Hg deposition generally peaked during the period 1973–1995, with rates that were on average 5.8 times greater than pre–Industrial Revolution values. In the last 20 years, the region experienced a decrease in Hg deposition of approximately 33%.

Fish Species Richness. Comparisons with earlier studies show that declines in species richness have stabilized and the trend may be reversing. Future surveys could ascertain whether there is a pattern of biological recovery following decreases in acidic deposition and improvements in water chemistry.

Modeling. Atmospheric deposition was the dominant source of acidity (>90%), while mineral weathering was the major source of improved acid neutralizing capacity for all the sites. Simulations indicated that these ecosystems would show little recovery after 2010 under the 1990 Clean Air Act Amendments.

PROJECT IMPLICATIONS

While there have been improvements in the water chemistry of many Adirondack lakes, the rate of improvement remains relatively low. Declines in sulfate deposition, coupled with steady nitrate deposition and concentrations, suggest that NO_x emissions have come to play a more important role in determining precipitation acidity and its effects. Project findings highlight the importance of several factors that affect aquatic N concentrations, such as the biogeochemical attributes of the watershed and landscape, including the presence of alder-dominated wetlands. The effectiveness of measures to reduce N emissions and deposition will depend on these factors. The project confirms the need for additional controls, beyond the current provisions of CAA, on emissions and deposition to improve the rate of recovery of Adirondack ecosystems. Currently, no caps are placed on NO_x emissions, which could increase considerably as population size and the demand for transportation and electricity grow. With regard to mercury, understanding long-term and recent changes in deposition is particularly critical in interpreting future changes in deposition in relation to long-term Hg patterns in the region.

Credit: Mark Watson
Deer Lake Inlet, Huntington Forest
Speckled alder in the foreground.

Project Status

- Initiated 2000
- Completed 2004

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