PROJECT UPDATE

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New York State Energy Research
and Development Authority

Environmental Monitoring, Evaluation,
and Protection Program

NYSERDA
New York State Energy Research and Development Authority

Evaluation of the Recovery from Acidification of Adirondack Ecosystems

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Project Location

Adirondack region outlined

Contact Information

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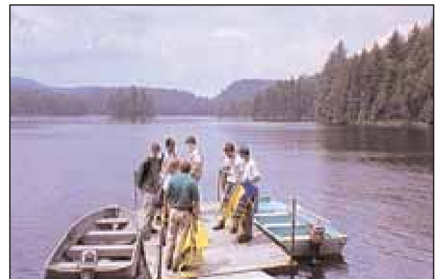
Keywords

- Acid neutralizing capacity (ANC)
- Dissolved organic nitrogen (DON)
- Nitrate (NO_3)
- Sulfate (SO_4^{2-})
- Watershed

PROJECT FOCUS



SUNY ESF students prepare to conduct field work at the Arbutus Lake inlet

This "synthesis" project focused on the integration and analysis of long-term data related to surface water chemistry and atmospheric deposition at the Arbutus Lake watershed (AW) in Huntington Forest (HF), located in the center of the Adirondack region. Its primary objective was to evaluate the relationship between changes in the amount of nitrogen (N) and sulfur (S) exported from AW (i.e., drainage losses) and changes in climate and atmospheric deposition. A further goal of the study was to investigate causes of the substantial differences in soil and surface water chemistry in subcatchments of AW, especially with respect to nitrate and calcium.

Investigations at AW have played a critical role in national and international efforts to evaluate the impact of air pollutants on ecosystem health. Over the past two decades, HF has been the site of a large number of studies on forest ecosystems. It is the only site in the Adirondacks that has the history, instrumentation, and background necessary for comprehensive analyses of atmospheric, chemical, hydrological, and biotic components.

CONTEXT

Combustion processes are major contributors to atmospheric sulfur dioxide (SO_2) and nitrogen oxide (NO_x) pollution. These compounds are chemical precursors of other forms of sulfur and nitrogen, such as sulfate (SO_4^{2-}) and nitrate (NO_3^-) ions, which may ultimately be deposited in bodies of water as strong acids, contributing to their acidification. The Adirondack region of New York State, located directly downwind of major coal-burning sources in the Midwest, is subject to elevated levels of S and N deposition and may be the region most sensitive to acidification in North America, partly owing to its geological and soil characteristics. As a result, the region has been the focus of numerous research efforts designed to identify the processes involved in acidification and its effects on surface waters, and to evaluate the effectiveness of emissions controls.

Recent research has shown marked decreases in sulfate concentrations in Adirondack lakes, following decreases in atmospheric emissions and deposition of S in the region over the last 20 years. While atmospheric N deposition has not changed over the same period, nitrate concentrations have also decreased in many of the same lakes. The possible causes of this decrease, which indicates a retention of N in the lake watershed, are not evident. In the waters of the region, these marked decreases in sulfate and nitrate concentrations have resulted in increases in pH. Nevertheless, the recovery of surface waters from acidification has been limited. At current rates of decrease in acidic deposition, however, the timeframe of chemical recovery at these lakes will still be several decades.

METHODOLOGY

This project included interpretation and analyses of data on wet and dry deposition, weather, water chemistry and discharge at the AW inlet and outlet, and biogeochemical attributes of lake subcatchments. Wet and dry deposition data on N and S were compiled by evaluating previously collected data. The project continued baseline monitoring at the inlet and outlet of Arbutus Lake. Throughfall (dry litter), soil water, groundwater, and stream parameters were measured weekly during the snow-free season (May–August) and monthly during the winter season (September–April) for two subcatchments. Temporal trends in air chemistry, dry deposition, wet deposition, and surface water chemistry were evaluated.

In total, the range of biogeochemical information available at HF/AW includes the influences of atmospheric inputs, vegetation effects, soil water, ground water, and wetlands on the chemistry of surface waters, including both spatial and temporal patterns. Through a synthesis of these data, the biogeochemical response of AW to atmospheric pollutants was analyzed. Using the comprehensive database developed, a model was used to predict patterns in the water chemistry.

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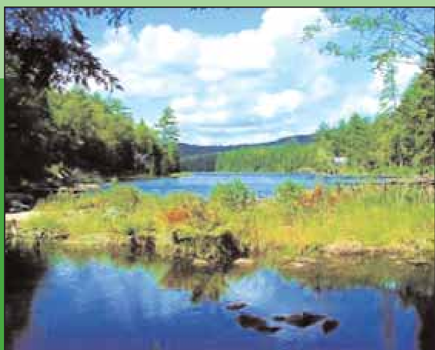
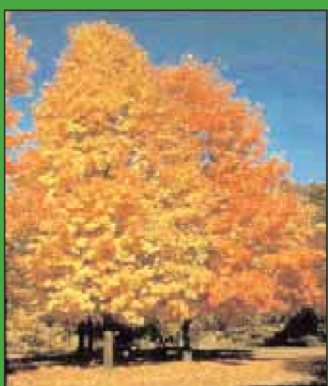


Arbutus Lake



The sugar maple: an important indicator species.

Project Status

- Initiated 1999
- Project ongoing

New York Energy Smart[SM]

Public Service Commission NYSERDA

Since 1975, the New York State Energy Research and Development Authority (NYSERDA) has developed and implemented innovative products and processes to enhance the State's energy efficiency, economic growth, and environmental protection. One of NYSERDA's key efforts, the Environmental Monitoring, Evaluation, and Protection (EMEP) Program, supports energy-related environmental research. The EMEP Program is funded by a System Benefits Charge (SBC) collected by the State's investor-owned utilities. NYSERDA administers the SBC program under an agreement with the Public Service Commission.

RECENT FINDINGS

SULFUR: Sulfate concentrations in lake discharge markedly decreased in the 1990s, reflecting declining patterns in both wet and dry S deposition. Despite decreases in atmospheric deposition and hydrologic losses, sulfate was still the dominant negatively charged ion in drainage water, and therefore a cause of declines in concentrations of positively charged ions. Declining surface water concentrations of base positively charged ions will have a great impact on future trends in surface water recovery from acidification. In addition, watershed S loss was found to greatly exceed the total S input. This discrepancy could be attributed to internal soil processes, e.g., mineral weathering, desorption, and mineralization of organic S. Results indicate that organic S export could represent another important pathway of S loss from the internal S cycling through soil organic pools.

NITROGEN: In contrast to the case of sulfates, no long-term trend in nitrate concentrations in lake discharge was found in the 1990s. However, nitrate concentrations were found to be correlated to interannual changes in air temperature (1983–2001). The strong relationship between air temperature and watershed nitrate loss (January–March) suggests that snowmelt responses to winter temperature fluctuations play a critical role in nitrate loss variability in different years. The contrasting seasonal patterns that were observed might be explained by the high biological demand for nitrate and the microbial production of dissolved organic nitrogen (DON) during warm summer months. The close relationship observed between temperature and nitrate/DON loss suggests that the biotic and hydrological processes affecting N loss may be especially sensitive to changes in climate, as well as to changes in atmospheric N deposition. This response of watershed N to variations in climate and atmospheric deposition may determine the long-term patterns of N loss from the watershed.

The inclusion of both dry deposition and organic N substantially elevates estimates of N retention in AW. This result, along with very low summer NO_3^- concentrations in drainage water, suggests that there is a strong biological retention of both organic and inorganic N in this watershed. In addition, the lowest NO_3^- concentrations have been found in subcatchments with the highest proportion of wetlands, suggesting the importance of wetlands as sites of denitrification.

FOREST SPECIES COMPOSITION: Results show that species composition is a critical factor in forest nutrient dynamics, especially with respect to the processing of N. Thus, factors that change the forest community (e.g., pests; climate change) could have a dramatic impact on how the Adirondacks respond to atmospheric pollutant deposition. The influence of species composition has been shown clearly in a study of subcatchments within the Arbutus Watershed. A subcatchment with a large component of sugar maple and white ash (species that show high rates of nitrogen mineralization and nitrification) exhibited greater losses of nitrate than other subcatchments. While American beech and sugar maple were the predominant species in terms of biomass, red maple was the only species to increase in biomass. However, total aboveground biomass decreased during the period, while annual litter production remained constant.

MODELING RESULTS: Simulations of internal fluxes of major elements at AW compared well to previously published measured values. The measured and simulated S budget for the Arbutus watershed indicated little S retention and considerable temporal variability in N retention. Atmospheric deposition was found to be the largest source of acidity, while the exchange of positively charged ions, mineral weathering, net mineralization, and in-lake processes all contributed to acid neutralizing capacity (ANC).

PROJECT IMPLICATIONS

The results of this project, which clearly indicate the effects of atmospheric deposition of S and N in the Adirondacks, are important in evaluating the effectiveness of the present regulatory regime, including the 1990 Clean Air Act Amendments (CAAAs). Although some recovery is evident, the Adirondack region continues to be at high risk from acidic deposition. Findings show that current regulations are likely inadequate to protect the most sensitive waters in the region from its effects. These results, and continued monitoring at HF/AW, will not only provide critical information for assessments of forest and aquatic resources in the region, but also prove useful in predicting and evaluating the impact of policy options and future legislation on Adirondack air and water quality. Importantly, this study also shows how the effects of changes in atmospheric pollutant concentrations need to be placed in the context of other environmental influences, such as changes in climate and forest biota, in order for us to understand the major factors influencing the environmental health of the Adirondacks.