New York State Energy Research
and Development Authority

Environmental Monitoring, Evaluation,
and Protection Program

Status and Effects of Nitrogen Pollution in the Northeastern United States

PROJECT UPDATE

August 2005

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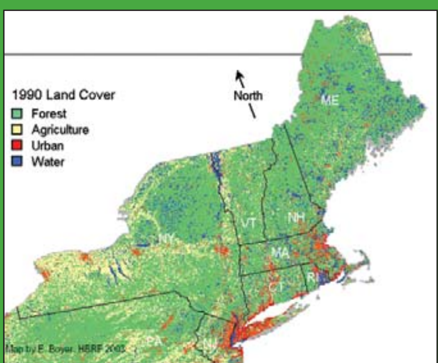
Project Location



Credit: Beth Boyer

Contact Information

For more information on this project see:
www.nyserda.org/programs/environment/emep

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Keywords

- Estuary
- Eutrophication
- Nitrogen cascade
- Nitrogen loading
- Reactive Nitrogen

PROJECT FOCUS

Improved understanding of the complex ways in which ecosystems respond to elevated levels of nitrogen is essential for developing successful policies to mitigate nitrogen pollution. The goal of this project was to provide an integrated assessment of nitrogen pollution across New York State (NYS) and New England that will contribute to the formulation of effective mitigation strategies. The investigation identified the relative contributions of sources and the full spectrum of effects, ranging from the acidification of headwater streams to the eutrophication of coastal estuaries. The data were reviewed and synthesized within the context of current and proposed public policies in order to compare the effectiveness s of these different options in the long term, with regard to ecosystem and human health. Specifically, the project considered the

- Value of seasonal versus year-round NO_x controls in reducing pollutant effects (e.g., acidification and eutrophication);
- Response of sensitive ecosystems, such as the Adirondacks and Catskills, to proposed power-plant emission reductions;
- Effectiveness of different emission reduction scenarios targeting utilities, transportation, and non-point sources (e.g., fertilizer application and wastewater treatment plants) in controlling the input of nitrogen to surface waters and estuaries.

CONTEXT

Over the past century, environmental concentrations of reactive nitrogen, the form of nitrogen used by all living organisms, have greatly increased as a result of human activity. The primary anthropogenic sources are the manufacture and application of fertilizer, the combustion of fossil fuels, and the production of human and animal waste. Thus, energy generation and both the production and consumption of food generate reactive nitrogen as a byproduct. A certain amount of nitrogen is needed for all living organisms, and supports higher crop yields and greater energy production; but when this amount exceeds what can be assimilated, reactive nitrogen released into the environment degrades air, land, and water resources. In fact, a single nitrogen atom can set off a chain of adverse environmental effects known as the “nitrogen cascade” (see chart). With these effects, nitrogen pollution, which is currently increasing in the northeastern United States, contributes to a wide array of environmental problems.

METHODOLOGY

Using long-term research from the Hubbard Brook Experimental Forest (HBEF) and other sites across the Northeast, data on the effects of nitrogen pollution were synthesized and ecosystem responses to reductions were assessed. Eight large watersheds in the Northeast were also analyzed in order to determine the sources of reactive nitrogen that cause nitrogen pollution.

To evaluate the effects that current and future policies may have on airborne nitrogen pollution in the Northeast, the project team used a mathematical model that incorporates climate data, atmospheric emissions and deposition, and known forest processes to predict resulting soil and stream conditions. Researchers applied the model to two well-studied watersheds: the HBEF in New Hampshire and the Biscuit Brook watershed (BBW) in New York. Different policy scenarios were used to evaluate the effects of emission reductions from transportation, utilities, and agriculture on different indicators of chemical stress that are associated with nitrogen pollution over time.

Several scenarios for reducing the input of reactive nitrogen to northeastern estuaries were evaluated with a model for assessing watershed nitrogen reduction scenarios. Two estuaries with different land-use characteristics were used as case studies: Long Island Sound in Connecticut and New York, and Casco Bay in Maine. Researchers defined the nitrogen reduction scenarios by targeting different contributing sources in each scenario.

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THE CASCADE EFFECT OF NITROGEN POLLUTION

Air Quality
- Elevated ground-level ozone
- Increased concentrations of particles in air
- Reduced visibility
- Increased acid rain and nitrogen deposition

Forests
- Increased acidity of forest soils
- Nitrogen saturation of forest ecosystems
- Ozone damage to forests

Water Quality
- Elevated acidification of lakes and streams
- Groundwater contamination
- Over-enrichment of coastal ecosystems

Other
- Increased production of greenhouse gases contributing to global climate change
- Adverse human health effects from particulate matter and ground-level ozone

Project Status

- Initiated 2001
- Completed 2003

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

The Hubbard Brook Stream during high flow.

Major contributors to nitrogen pollution in the northeastern United States are nitrogen in food imported into the region (released as sewage), emissions into the air through combustion processes, and nitrogen fertilizer use.

WATERSHED NITROGEN SOURCES: In the eight studied coastal watersheds in the Northeast, nitrogen pollution was traced to a variety of sources, including (in order of priority) food imports, nitrogen fertilizer, and atmospheric deposition. Nitrogen
entering estuaries downstream of the analyzed watersheds is dominated by wastewater effluent (36–81%) and atmospheric deposition (14–35%). The analysis shows that the rate at which reactive nitrogen is added to the watersheds varies widely. Nitrogen sources also vary significantly in forested headwaters compared to densely populated coastal zones.

WATERSHED NITROGEN REDUCTION SCENARIOS (Long Island Sound and Casco Bay): The model shows that improved wastewater treatment results in the largest reduction in the reactive nitrogen input to Long Island Sound (~55%) and Casco Bay (40%). Differences in land use and population size also have a substantial impact on the relative effectiveness of the reduction scenarios. Of all scenarios considered, an integrated management plan that includes nitrogen controls on both air and water sources achieves the maximum reductions, reducing reactive nitrogen loading to Long Island Sound by 60% and Casco Bay by ~45%.

ATMOSPHERIC EMISSION REDUCTION SCENARIOS (HBEF and BBW): Controls on NO_x emissions from transportation and power generation produce the largest reductions in airborne nitrogen pollution to the two watersheds analyzed in the study. The model shows that emissions reductions called for in the 1990 Clean Air Act Amendments (CAAA) will not reduce nitrogen deposition below a target level of 8 kg per hectare per year at either site, and they will be insufficient to mitigate elevated nitrogen runoff or acid rain effects. Additional reductions in emissions (~30%) would reduce nitrogen runoff to less harmful levels. When additional nitrogen emission reductions and a simultaneous 75% cut in SO_2 emissions from electric utilities beyond the 1990 CAAAs are considered, it is predicted that by 2050 HBEF would experience marked improvement in soil conditions and water quality and BBW would achieve nearly full chemical recovery.

PROJECT IMPLICATIONS

Reactive nitrogen originates from numerous sources and has a complex relationship with other pollutants. It therefore requires integrated management strategies and policies addressing multiple rather than individual sources. It is important to note that there is currently no water quality standard that limits the total loading of reactive nitrogen to surface waters and no air quality standard for ammonia. Moreover, since the CAAA did not cap total NO_x emissions from electrical utilities, it is possible that emissions will actually increase in the future as energy generation increases.

This project's assessment of nitrogen pollution in the region shows that the current CAAA has not had a substantial effect on airborne nitrogen emissions. Together with efforts to reduce SO_2, CO_2, and other pollutants, nitrogen in the Northeast can be further decreased through a number of strategies: reducing power-plant nitrogen emissions, improving wastewater treatment to remove nitrogen from effluent, reducing the use and increasing the efficiency of nitrogen fertilizers, and creating and restoring natural nitrogen sinks in wetlands and floodplains. A number of innovative nutrient management projects currently being implemented on farms throughout the region provide hopeful examples.

Wastewater treatment is an effective means of reducing nitrogen loading. Wards Island wastewater treatment system

Modeling results offer insight into the relationship between different emissions reduction scenarios and ecosystem recovery. Appraisal of the rate of recovery of different Northeast ecosystems under a variety of policy scenarios indicates that:

- Controls on vehicle and electric utility NO_x emissions produce the largest reductions in airborne nitrogen pollution.
- Nitrogen removal from wastewater at a basin-wide scale is the single most effective means of reducing nitrogen loading to estuaries in the Northeast.