Nitrogen sources to rivers & estuaries of New York

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Outline

• Need to understand importance of atmospheric N in terrestrial & aquatic ecosystems
• Challenges for estimating atmospheric N deposition
• Approaches for quantifying significance of atmospheric N inputs & their fate
• Implications & Future Directions

Challenges for understanding atmospheric N inputs to terrestrial & aquatic ecosystems

• Multiple reactive N species
• Multiple emissions sources
• Multiple transport pathways
• Quantifying atmospheric N deposition

The cascading effects of N pollution -- Significance of atmospheric N deposition?

Air quality impacts:
– Elevated ground-level ozone
– Increased particles in the air
– Reduced visibility
– Increased acid rain and nitrogen deposition

Forest impacts:
– Increased acidity of forest soils
– Nitrogen saturation of forest ecosystems
– Ozone damage to forests

Water quality impacts:
– Elevated acidification of lakes and streams
– Groundwater contamination
– Poisoning of aquatic ecosystems

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

Challenge: multiple sources of N emissions

NOx Emission Data from EPA National Air Pollution Emission Trends

Impacts table from Driscoll et al. 2003, Hubbard Brook Research Foundation
Challenge: multiple atmospheric N species

- **Reduced nitrogen, NH\textsubscript{x}**
  Typically dominated by ammonia species (e.g., NH\textsubscript{3} and NH\textsubscript{4}\textsuperscript{+})

- **Oxidized nitrogen, NO\textsubscript{x}**
  Composed primarily of nitrogen oxide species, representing primarily nitric oxides (NO\textsubscript{3} and HNO\textsubscript{3}) and nitrogen dioxide (NO\textsubscript{2})

- **Organic nitrogen, AON**

Challenge: multiple input pathways

- **Wet deposition** is the fraction contained in precipitation—predominantly rain and snow.
- **Dry deposition** is the fraction deposited in dry weather through such processes as settling, impaction, and adsorption.

Quantifying Atmospheric Deposition

**National Atmospheric Deposition Program National Trends Network (NADP-NTN):** Wet deposition monitoring, designed to determine geographical patterns & long-term trends in precipitation chemistry. 9 active sites in NY; most since ~ 1980.

**Atmospheric Integrated Research Monitoring Network (AIRMoN):** Wet deposition monitoring, designed to determine daily and storm-event trends. 1 site in NY since 1992.

**Clean Air Status and Trends Network (CASTNET):** provides dry deposition & ground-level ozone monitoring data. 2+ active sites in NY since ~ 1990.

How much N deposition does NY receive?

Inorganic nitrogen wet deposition at monitoring sites

How much N deposition does NY receive?

Inorganic nitrogen wet & dry deposition

Data from National Atmospheric Deposition Program - National Trends Network

Data from Clean Air Status and Trends Network, Monitoring station at Connecticut Hill, CTH 110
Challenge: scaling up from monitoring sites

How to estimate dry deposition at wet-only sites?
How to interpolate sparse data over space & time?

Boyer et al. 2002

Challenge: underestimating atmospheric N?

- Deposition in coastal, urban, & agricultural areas? Monitoring in rural areas, to assess relationships between regional pollution and deposition patterns.
- Underestimating ammonium? Comparisons of AIRMON and NADP data suggest loss of wet NH₃ species due to biological activity in collection buckets during week-long storage. Underestimated >15%, Meyers et al. 2001
- Underestimating atmospheric Organic N? ~30% of total in northeast, Neff et al. 2003

Approaches to quantifying significance & fate of atmospheric N in terrestrial & aquatic ecosystems

- Mass balance model: TNNI
- Empirical model: SPARROW

Major Watersheds of NY

Mass balance model: total net N inputs

- Quantify new inputs of N (N that is newly fixed within, or newly transported into, each region)
  - atmospheric deposition
  - application of nitrogenous fertilizers
  - biological N fixation by crops
  - net import or export of N in food & feed
- Quantify outputs of N in streamflow
- Quantify fate of remainder…

Howarth et al. 1996, Boyer et al. 2002
Mass balance model: fate of N inputs?
• Uptake by vegetation
• Storage in soils or groundwater
• Conversion and loss to atmospheric forms through denitrification & volatilization
• Export in streamflow

Quantified N inputs, storages, and losses for 16 coastal watersheds in the northeast USA

Primary data sources
• Topography & catchment boundaries delineated from USGS 1° DEMs
• National Land Cover Database of the Multi-Resolution Land Characteristics Interagency Consortium (MRLC).
• Population data & characteristics from the Census Bureau, 1990
• Discharge and N concentration data from USGS (Alexander et al. 1998)
• Atmospheric deposition data from the National Atmospheric Deposition Program
• Nitrogenous fertilizer use data from USGS spatial database on agricultural chemical use in the US (Battaglin & Goolsby 1994)
• Livestock and crop information, for calculating agricultural transfers of N in food and feedstocks, from the 1992 USDA Census of Agriculture
• Forest growth data from USDA Forest Service’s Forest Inventory and Analysis (FIA) program
• River reach characteristics from USGS national hydrologic dataset

Watershed land use, from north to south

Mass balance model
Total N inputs in 16 northeastern catchments

Mass balance model
Total N inputs to catchments are related to riverine export
Mass Balance Model
Nitrogen Sources, Storages, & Losses

Mass balance model
N inputs from uplands to the coastal zone

SPARROW (SPAtially Referenced Regression on Watershed Attributes)
Terrestrial Landscape Aquatic Landscape Monitoring Data

SPARROW water quality model prediction of N fluxes in NY stream reaches

SPARROW water quality model
**Implications for the changing future**

- Do we have a broad understanding of the N Cycle? Yes.
- Do we know the source of new nitrogen? Yes.
- Do we know the rate of N accumulation?
  - In the atmosphere? Yes
  - In forests? Yes
  - In soils and groundwater? No. Not well.
- What are the big uncertainties? Storage & Denitrification
- Is knowledge on the consequences of N accumulation adequate to begin to make policy decisions?
  - In the atmosphere? Yes.
  - In the terrestrial landscape? Yes.
  - In rivers and coastal waters? Yes.

**Priorities for research on N sources**

1. Accounting & improved, long-term monitoring of nutrient sources.
2. Quantify nutrient inputs and fates under different land-use scenarios.
3. Watershed-scale analyses of the role of groundwaters, surface waters, riparian zones, and wetlands as sinks, sources, and transformers of nutrients.
4. Improved models for managers of nutrient fluxes from the landscape under current and future conditions.
5. Determine most effective policy and management approaches for nutrient reduction, and quantification of the costs, trade-offs, and benefits of controlling nutrient pollution.

**Questions?**

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**At the End of the Day**

**Quantifying Atmospheric Nitrogen Sources with New Stable Isotope Techniques**

/w colleagues:
Carol Kendall
Beth Boyer
Doug Burns
Greg Michalski
Rick Carleton

& contributions from:
Tom Butler
Greg Lawrence
Pat Phillips

Data based on Alexander et al. 2000

**SPARROW water quality model**

Prediction of N source shares (%) in NY catchments

<table>
<thead>
<tr>
<th>Source</th>
<th>Seneca 8919 km²</th>
<th>Mohawk 8,935 km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmos. dep.</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Urban land</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Forest land</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Organic pop.</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Agri. waste</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Sewer.</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Animal waste</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Thanks, NYSERDA!**

- Are isotopic approaches the panacea for elucidating atmospheric N sources? Considering $^{18}O$ and $^{15}N$ of nitrate in water and air samples?)

After Howarth et al. 2003