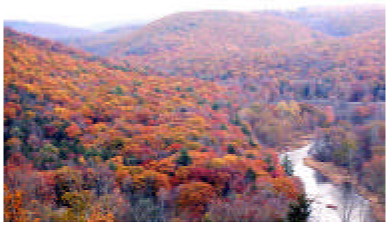
Nitrogen sources to rivers & estuaries of New York



Elizabeth W. Boyer, State University of New York, Syracuse
Robert W. Howarth, Cornell University, Ithaca, NY
Richard B. Alexander, U.S. Geological Survey, Reston, VA

Collaborators

Rich Alexander, U.S. Geological Survey, VA
Jim Galloway, University of Virginia
Christy Goodale, Cornell University, NY
Bob Howarth, Cornell University, NY
Kate Lajtha, Oregon State University, OR
Bernhard Mayer, University of Calgary, Canada
Keith Paustian, Colorado State University, CO
Greg Schwarz, U.S. Geological Survey, VA
Sybil Seitzinger, Rutgers University, NJ
Dick Smith, U.S. Geological Survey, VA
Nico vanBreemen, Wageningen, the Netherlands

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

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

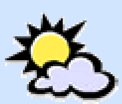
Water quality impacts:
- Elevated acidification of lakes and streams
- Groundwater contamination
- Over-enrichment of coastal ecosystems

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

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

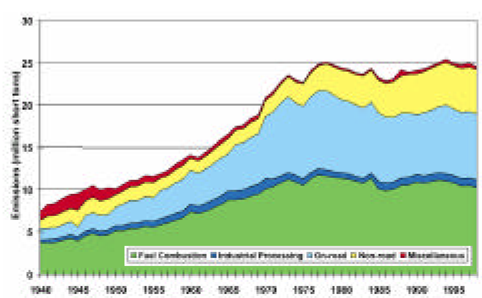
Impacts table from Driscoll et al. 2003, Hubbard Brook Research Foundation

Challenges for understanding atmospheric N inputs to terrestrial & aquatic ecosystems



- **Multiple reactive N species**
- **Multiple emissions sources**
- **Multiple transport pathways**
- **Quantifying atmospheric N deposition**

Challenge: multiple sources of N emissions



NO_x Emission Data from EPA National Air Pollution Emission Trends

Challenge: multiple atmospheric N species

- **Reduced nitrogen, NH_x**

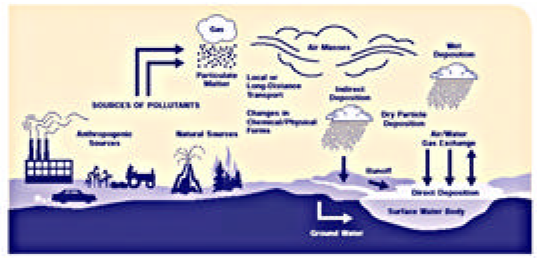
  Typically dominated by ammonia species (e.g., NH_3 and NH_4^+)

- **Oxidized nitrogen, NO_x**

  Composed primarily of nitrogen oxide species, representing primarily nitric oxides (NO_3^- and HNO_3) and nitrogen dioxide (NO_2)

- **Organic nitrogen, AON**

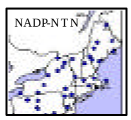
Challenge: multiple input pathways



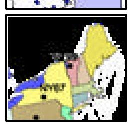
- **Wet deposition** is the fraction contained in precipitation—predominantly rain and snow.
- **Dry deposition** is the fraction deposited in dry weather through such processes as settling, impaction, and adsorption.

Quantifying Atmospheric Deposition

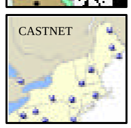
National Atmospheric Deposition Program National Trends Network (NADP-NTN): Wet deposition monitoring, designed to determine geographical patterns & long-term trends in precipitation chemistry. 9 active sites in NY; most since ~ 1980.



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

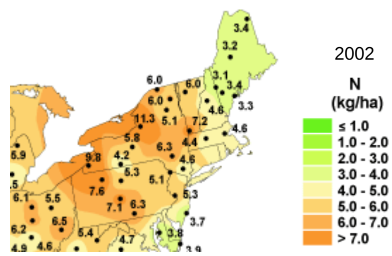


Clean Air Status and Trends Network (CASTNET): provides dry deposition & ground-level ozone monitoring data. 2+ active sites in NY since ~ 1990.



How much N deposition does NY receive?

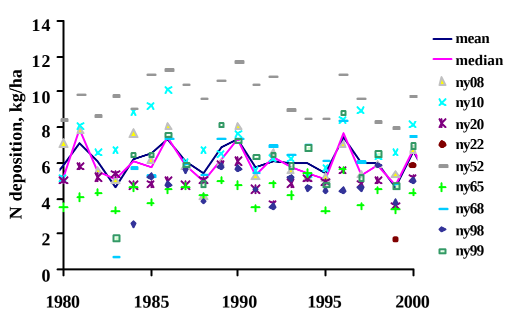
Inorganic nitrogen wet deposition at monitoring sites



Data from National Atmospheric Deposition Program - National Trends Network

How much N deposition does NY receive?

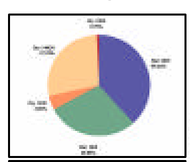
Inorganic nitrogen wet deposition at monitoring sites

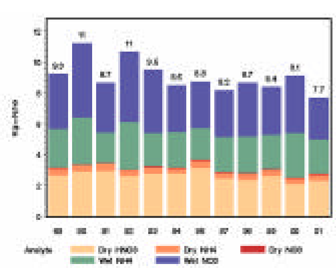


Data from National Atmospheric Deposition Program - National Trends Network

How much N deposition does NY receive?

Inorganic nitrogen wet & dry deposition

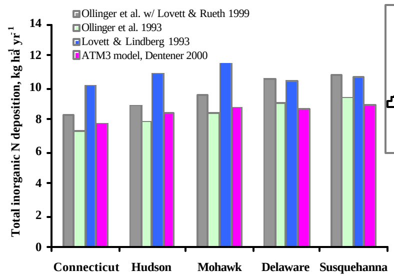


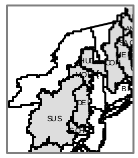


Data from Clean Air Status and Trends Network, Monitoring station at Connecticut Hill, CTH110

Challenge: scaling up from monitoring sites

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

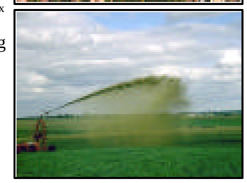




Boyer et al. 2002

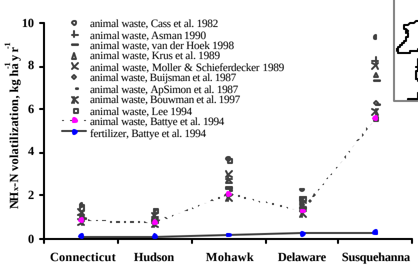
Challenge: underestimating atmospheric N?

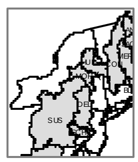
- Deposition in coastal, urban, & agricultural areas? Monitoring in in rural areas, to assess relationships between regional pollution and deposition patterns.
- Underestimating ammonium? Comparisons of AIRMON and NADP data suggest loss of wet NH_x species due to biological activity in collection buckets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



Challenge: quantifying agricultural volatilization

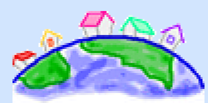
How much is transported long-range versus re-deposited locally?





Boyer et al. 2002

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

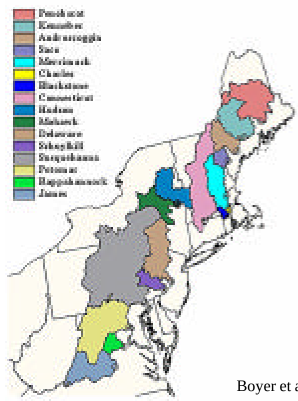
- **Quantify new inputs of N** (N that is newly fixed within, or newly transported into, each region)
  - atmospheric deposition
  - application of nitrogenous fertilizers
  - biological N fixation by crops
  - net import or export of N in food & feed
- **Quantify outputs of N in streamflow**
- **Quantify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

Howarth et al. 1996, Boyer et al.2002

Mass balance model: fate of N inputs?

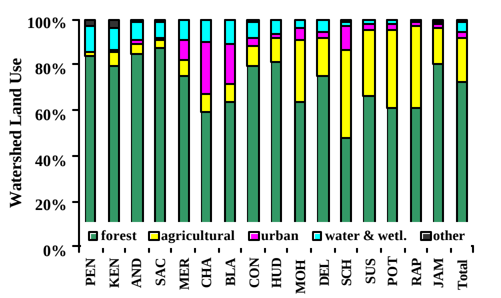
- Uptake by vegetation
- Storage in soils or groundwater
- Conversion and loss to atmospheric forms through denitrification & volatilization
- Export in streamflow

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



Boyer et al. 2002

Watershed land use, from north to south



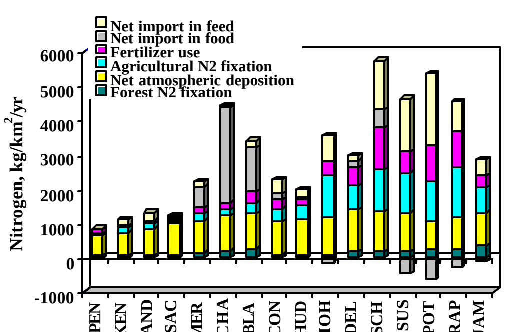
Boyer et al.2002

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** from the National Atmospheric Deposition Program
- **Nitrogenous fertilizer use** 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

Mass balance model

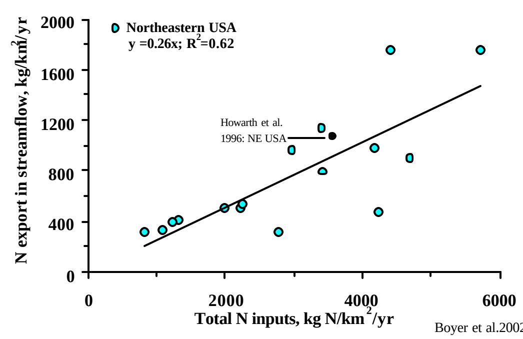
Total N inputs in 16 northeastern catchments



Boyer et al.2002

Mass balance model

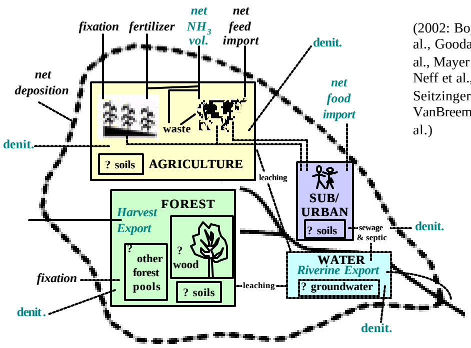
Total N inputs to catchments are related to riverine export



Boyer et al.2002

Mass Balance Model

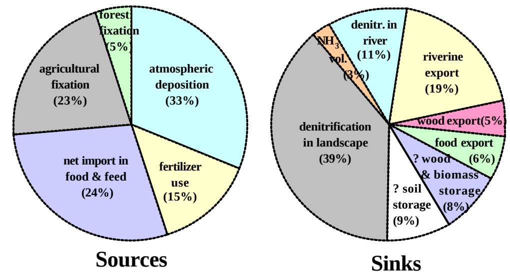
Nitrogen Sources, Storages, & Losses



(2002: Boyer et al., Goodale et al., Mayer et al., Neff et al., Seitzinger et al., VanBreemen et al.)

Mass Balance Model

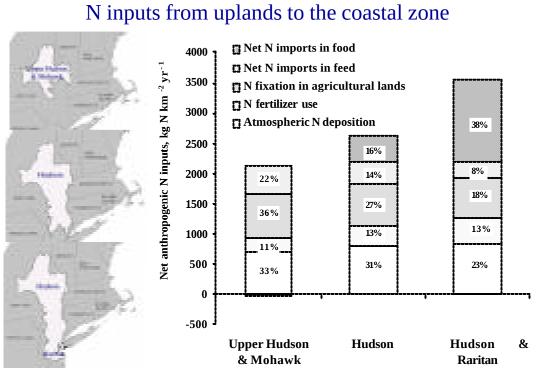
N Sources, Storages, & Losses in 16 NE catchments



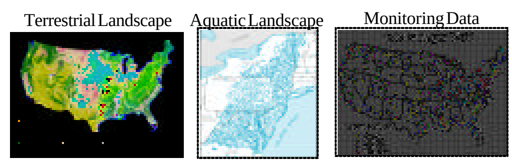
VanBreemen et al. 2002, Boyer et al. 2002

Mass balance model

N inputs from uplands to the coastal zone



SPARROW (SPAtially Referenced Regression on Watershed Attributes)

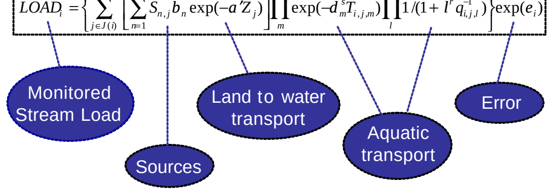


- Statistically estimates origin & fate of contaminants
- Model predictions include: flux, yield, concentration and sources in streams; stream & reservoir losses; uncertainty measures

Smith et al. 1997

SPARROW water quality model

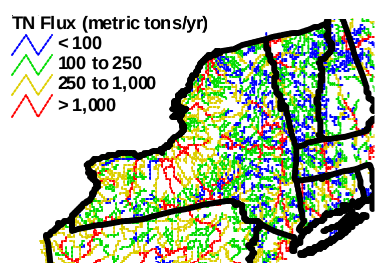
$$LOAD_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} b_n \exp(-\alpha' Z_j) \right] \prod_m \exp(-d_m^s T_{i,j,m}) \prod_l 1/(1 + I^r q_{i,j,l}^{-1}) \right\} \exp(e_i)$$



Smith et al. 1997, Alexander et al. 2000

SPARROW water quality model

prediction of N fluxes in NY stream reaches



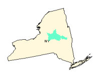
Data based on Alexander et al. 2000

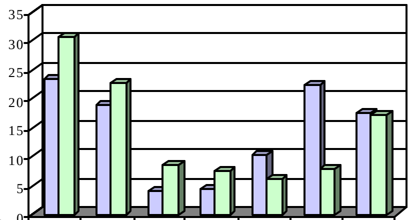
SPARROW water quality model

prediction of N source shares (%) in NY catchments

Seneca
8919 km^2

Mohawk
8,935 km^2





	atmos. dep.	urban land	forest land	sewer. pop.	organic matter	synth. fertilizer	animal waste
SENECA	23	19	4	4	10	22	17
MOHAWK	31	23	8	7	6	8	17

Data based on Alexander et al. 2000

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

Are isotopic approaches the panacea for elucidating atmospheric N sources? Considering $\delta^{17}O$ $\delta^{18}O$ and $\delta^{15}N$ of nitrate in water and air samples)

Thanks, NYSERDA!

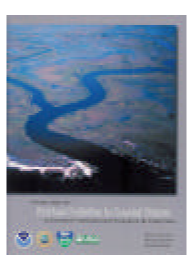
Implications for the changing future

At The End of the Day

- **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.**
  - **In rivers and coastal waters? 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.

After Howarth et al. 2003

Questions?

ewboyer@syr.edu