Nitrogen Pollution in the Northeastern U.S.:
Linking Upland Watersheds and Coastal Ecosystems

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Center for Coastal Monitoring and Assessment
National Centers for Coastal Ocean Science
National Ocean Service
National Oceanic and Atmospheric Administration

Hubbard Brook Research Foundation

Science Links Program:
Linking Ecological Science with Policy Needs

Science Team Participants

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Policy Advisors

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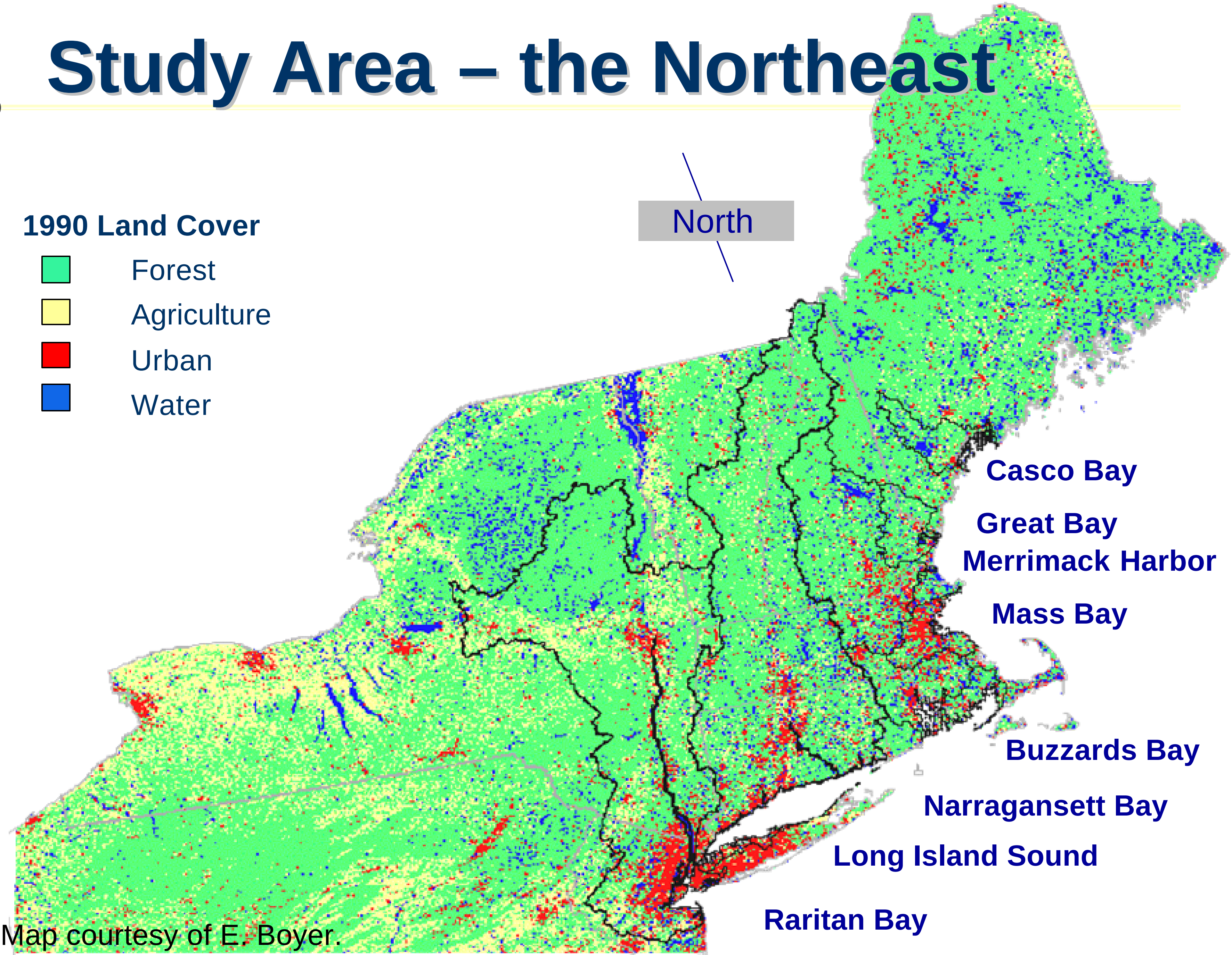
Dr. Debora Martin	U.S EPA
Dr. David Shaw	NY DEC
Paul Stacey	CT DEP

Study Area – the Northeast



Map courtesy of E. Boyer.

Critical Questions:

1. What are the sources of nitrogen pollution?

2. What are the ecological effects?

3. What are the most effective strategies for reducing nitrogen pollution and its effects?

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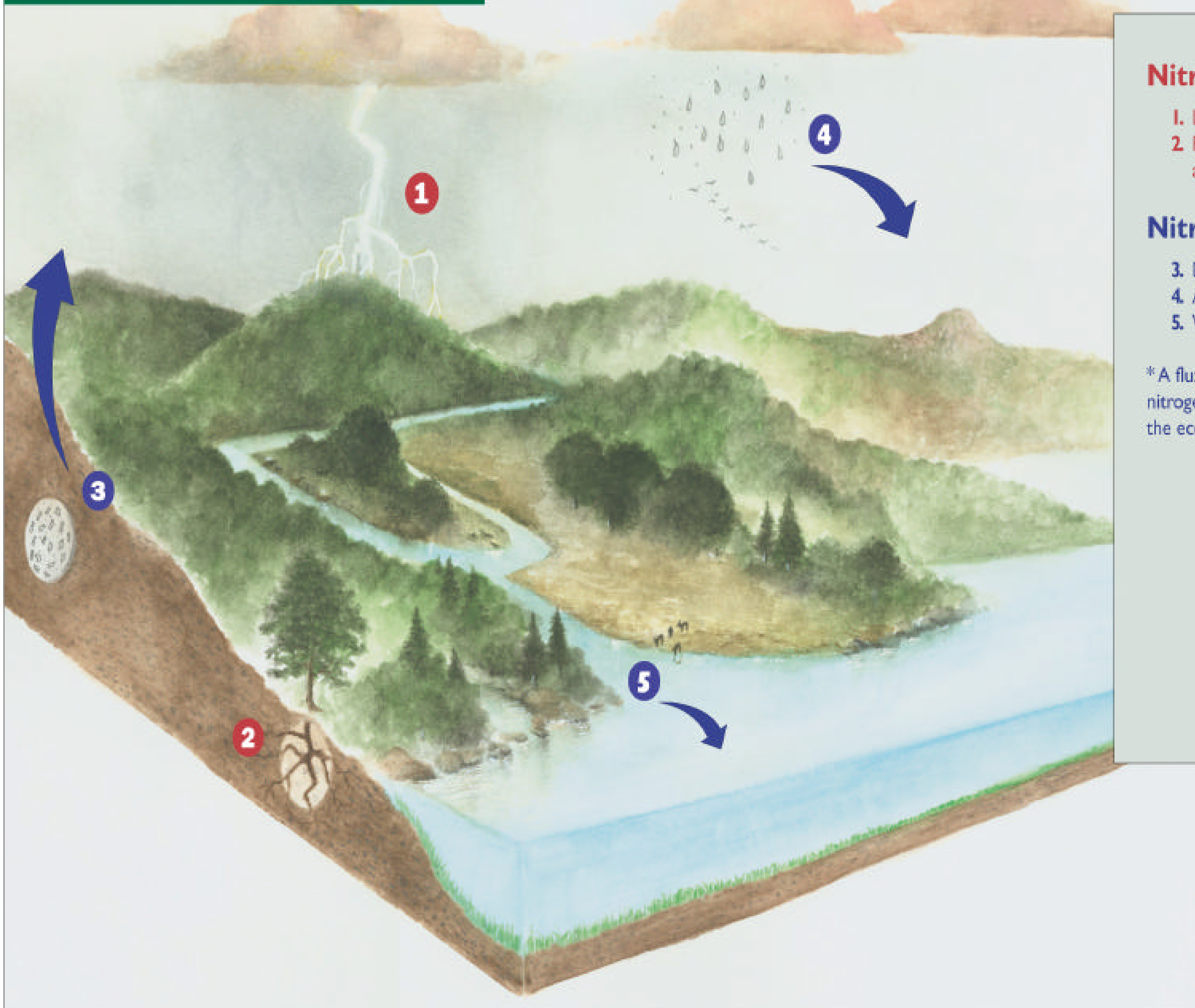
Nitrogen in a Pristine Landscape



Nitrogen Sources:

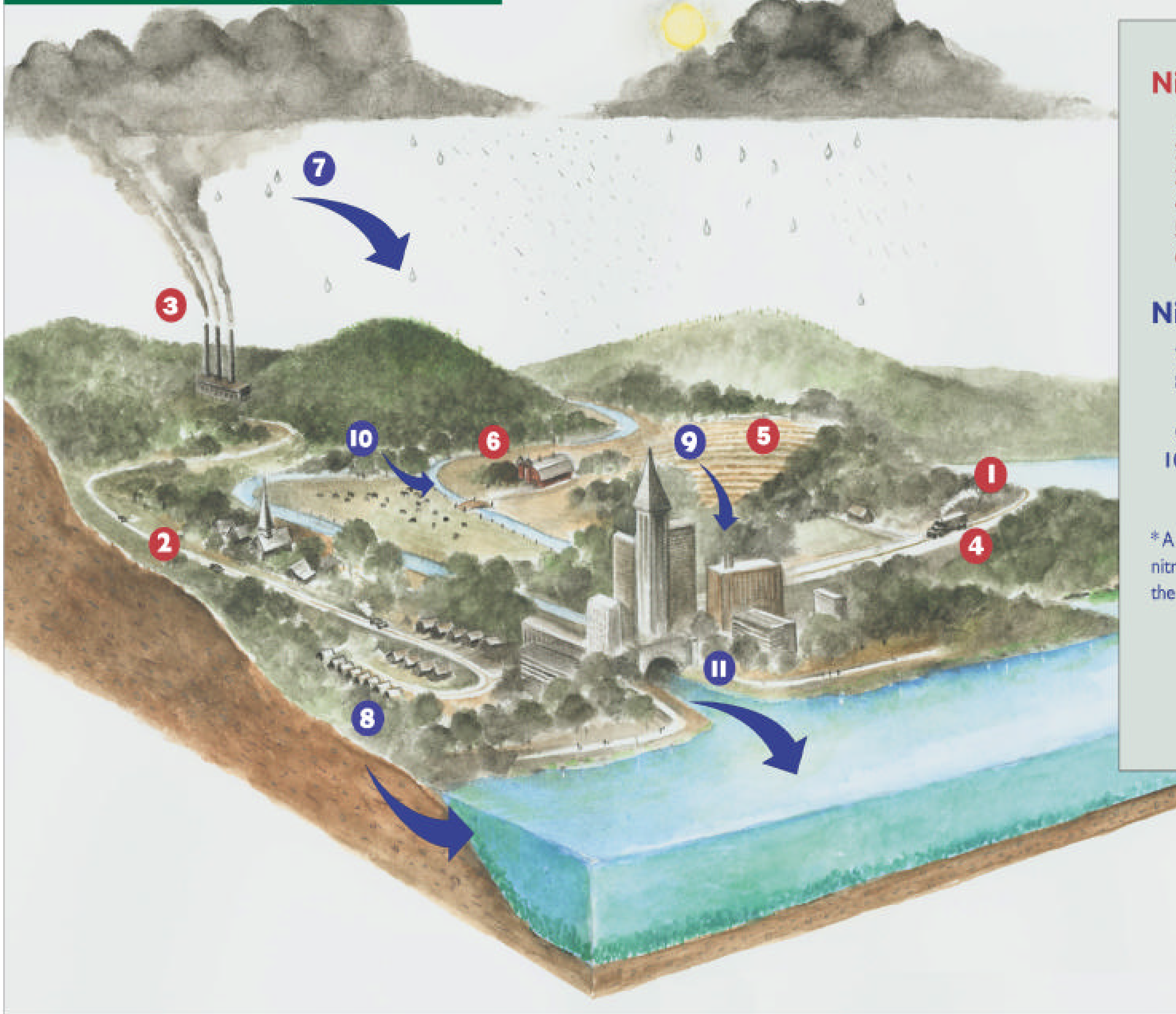
1. Lightening strikes
2. Fixation by plant-associated and soil bacteria

Nitrogen Fluxes:*

3. Denitrification by bacteria
4. Atmospheric deposition
5. Watershed runoff

* A flux is the movement of nitrogen from one component of the ecosystem to another.

Nitrogen in a Human-Altered Landscape



Nitrogen Sources:

1. Imported food and feed
2. Vehicle emissions
3. Powerplant emissions
4. Fertilizer imports
5. Fixation in croplands
6. Agricultural emissions

Nitrogen Fluxes:*

7. Atmospheric deposition
8. Wastewater from septic tanks and treatment plants
9. Agricultural runoff
10. Forest runoff
    Urban runoff

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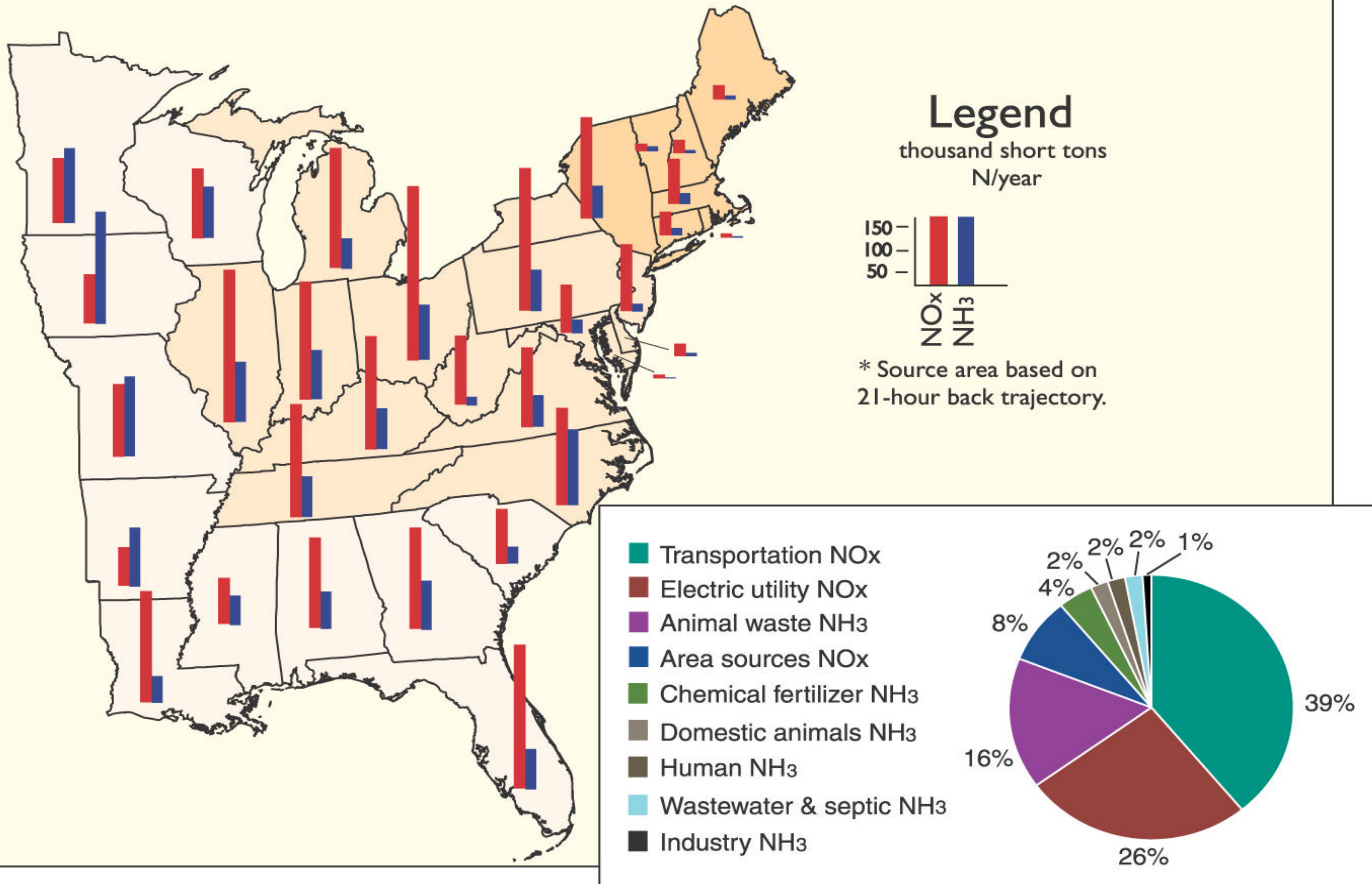
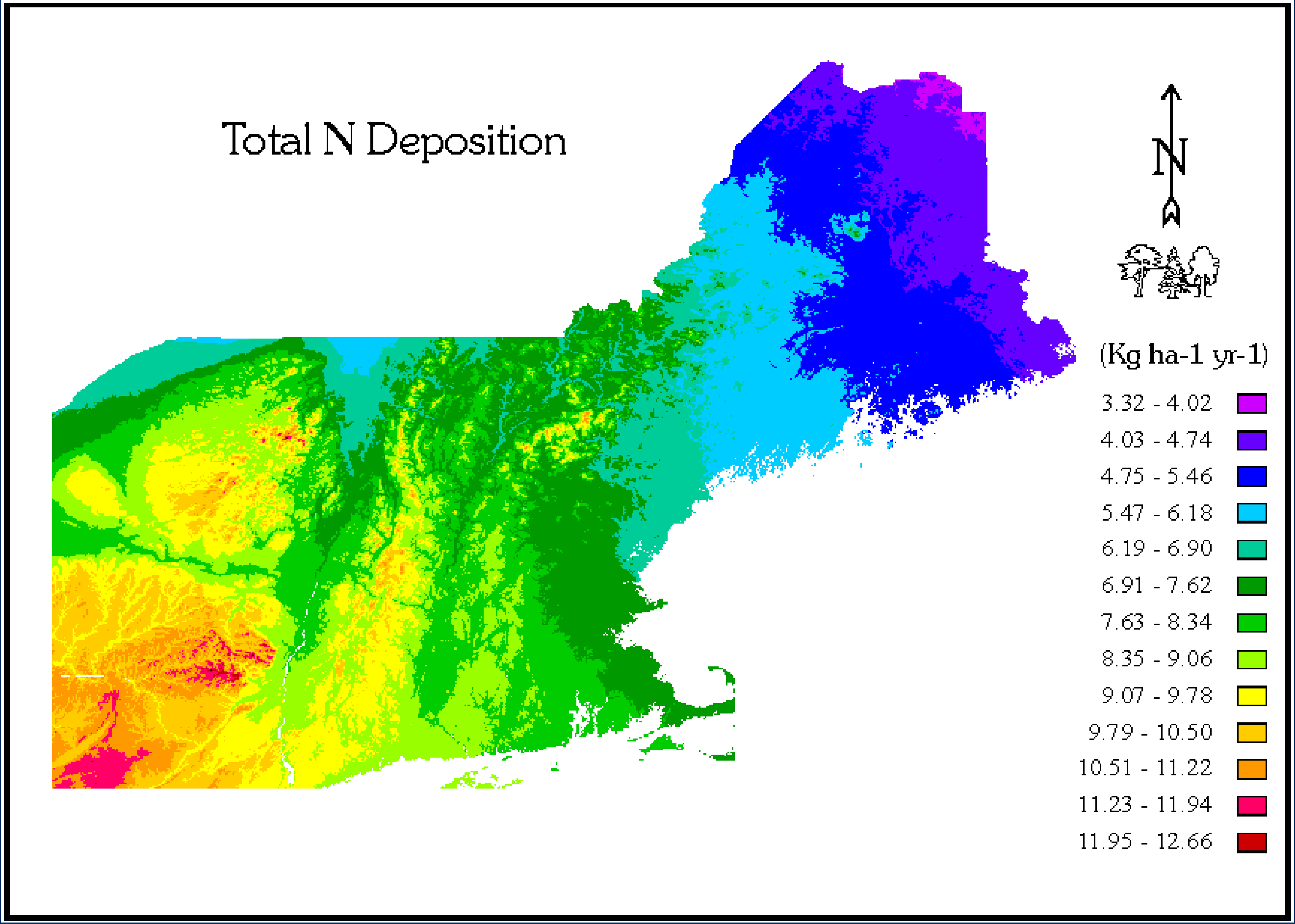
Distribution and Sources of Nitrogen Emissions

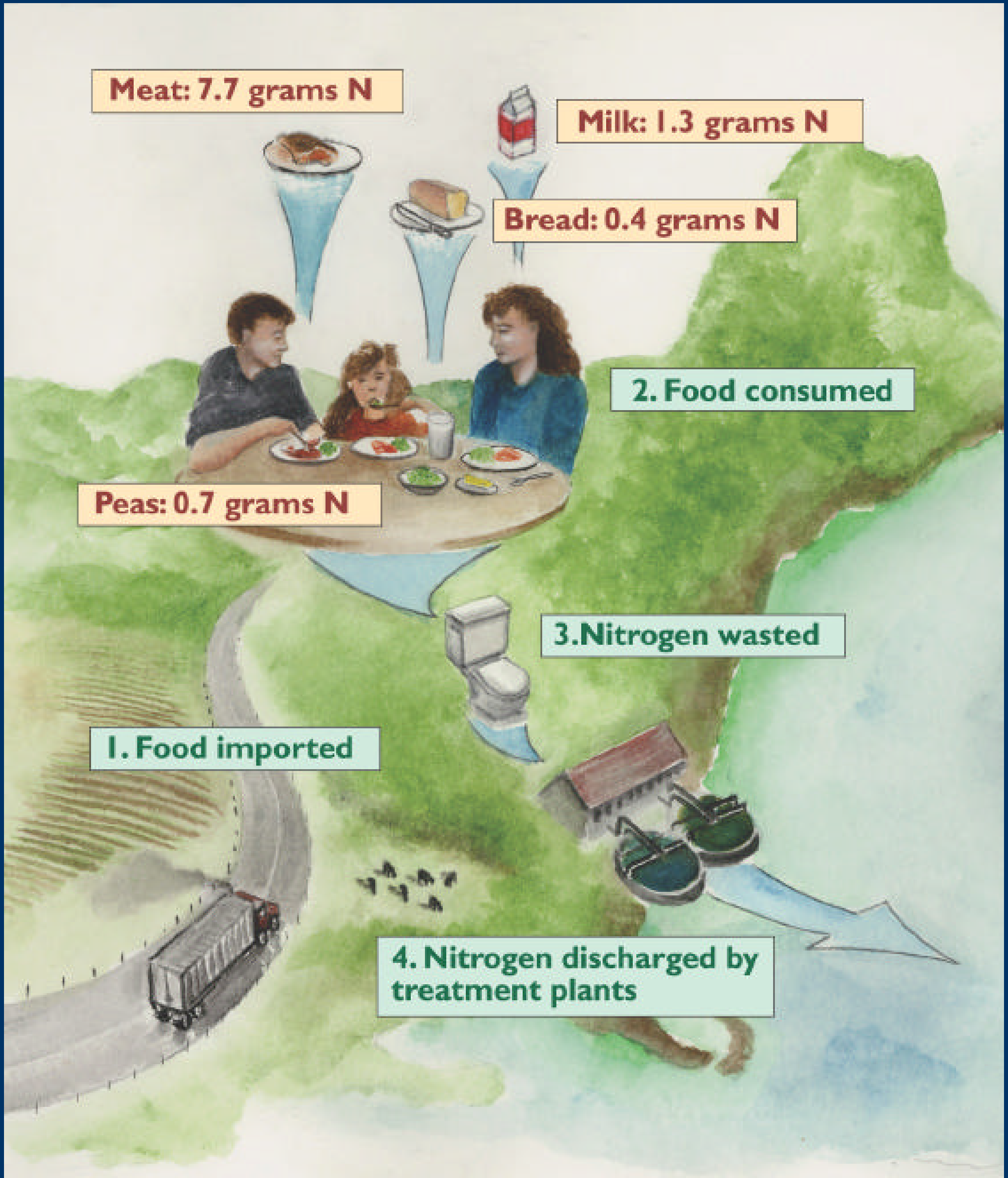


Nitrogen Deposition

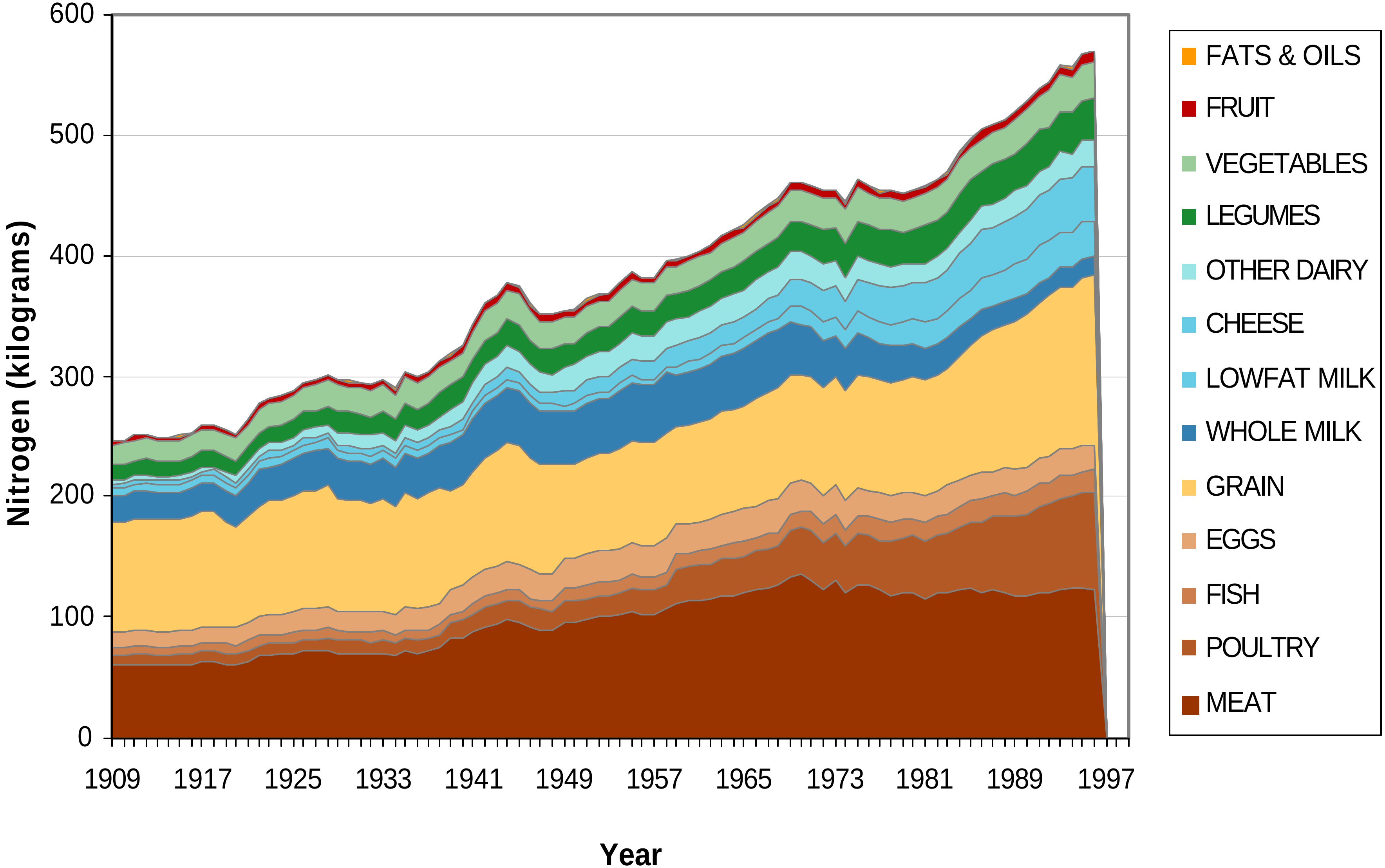


Map courtesy of S. Ollinger.

Nitrogen and the Food Cycle



Daily Nitrogen Consumption in Food
New England and New York, 1909-1997

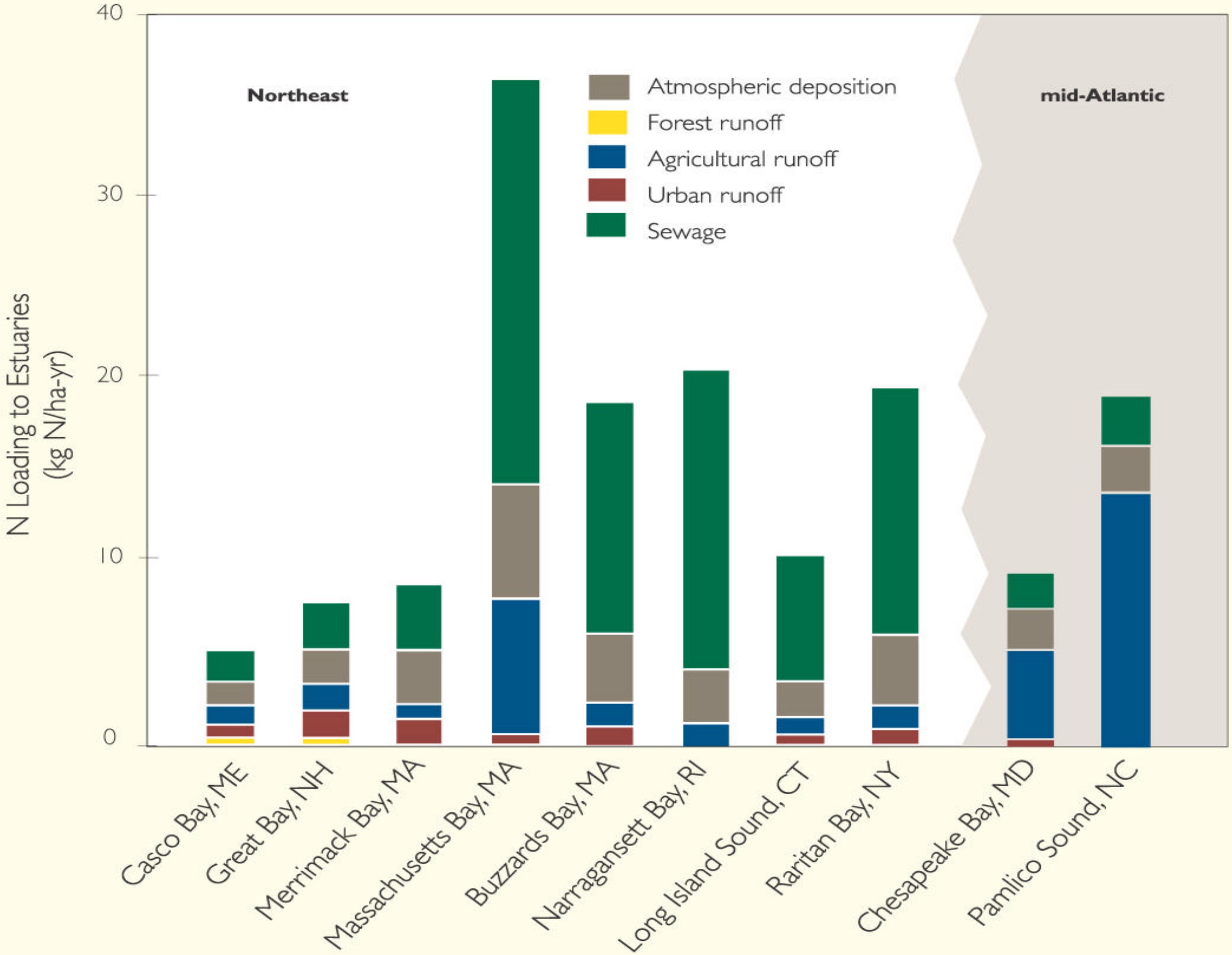


Where does the nitrogen go?

- Denitrification
- Biomass storage
- Soil storage
- Groundwater storage
- Export to estuaries

From Howarth et. al, 2002.

Nitrogen Loading to 10 Major Estuaries



In forested watersheds, nitrogen pollution originates predominantly from atmospheric emissions and deposition.

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Non-Coastal Effects of N Pollution

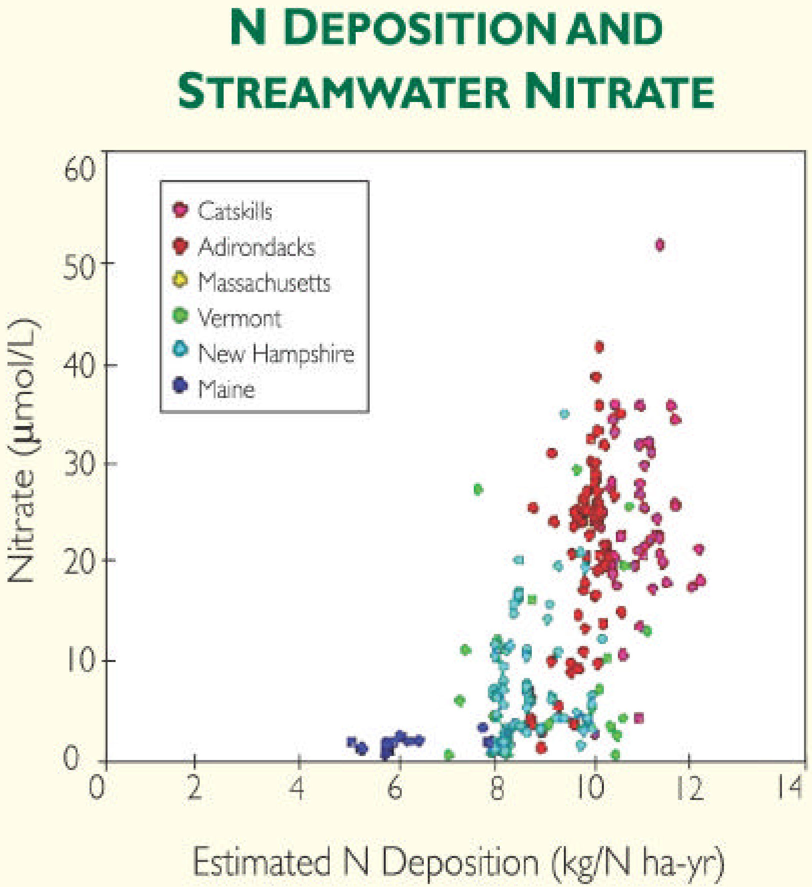
- Tropospheric ozone formation

- Loss of forest productivity
    - Due to ozone
    - Loss of nutrients (e.g. Ca^{2+}) from soil

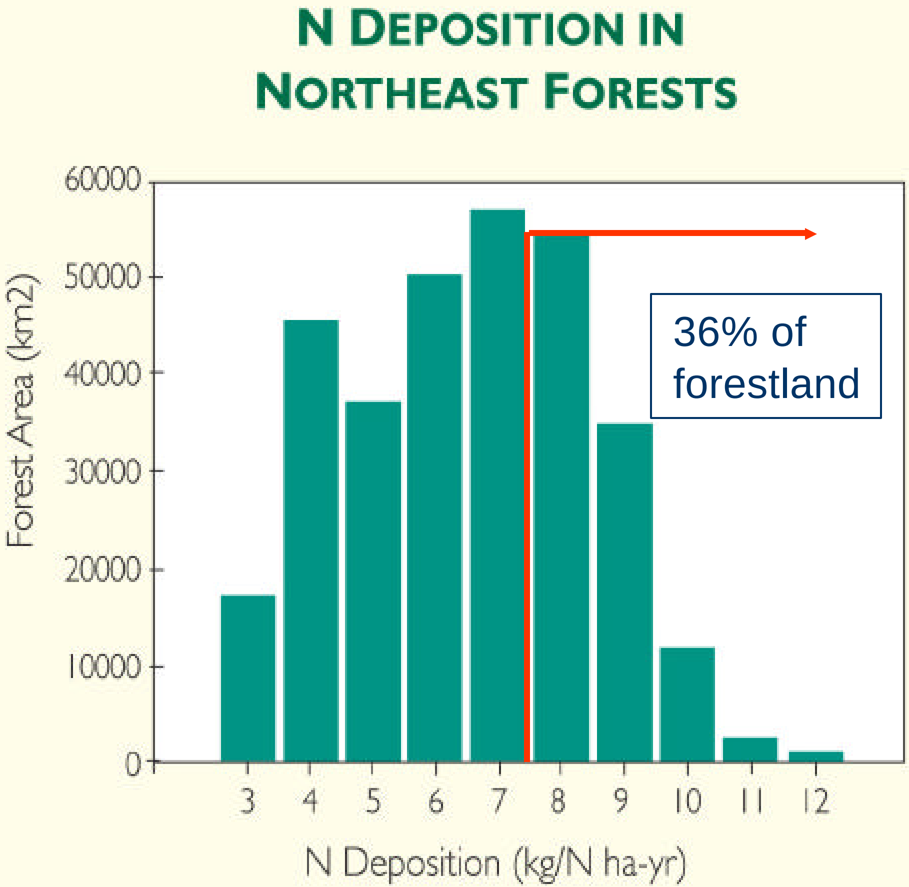
- Acidification of lakes and streams
    - Acid sensitive fish species
    - Mobilization of monomeric aluminum (toxic to fish)

- Human health concerns
    - Air quality (ozone and particulates)
    - NO_3^- in groundwater (Methemoglobinemia)

“Leaky” Forests



Areas with 8 kg N/ha-yr or more tend to show high nitrate in streamwater.



36% of Northeast forests receive >8 kg N/ha-yr

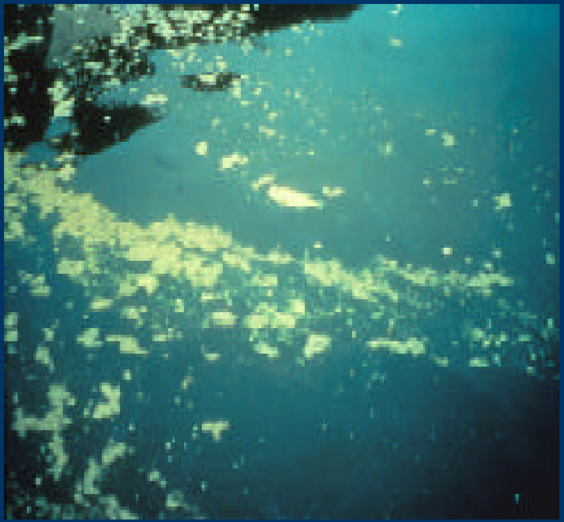
From Aber et al. 2003 and Ollinger.

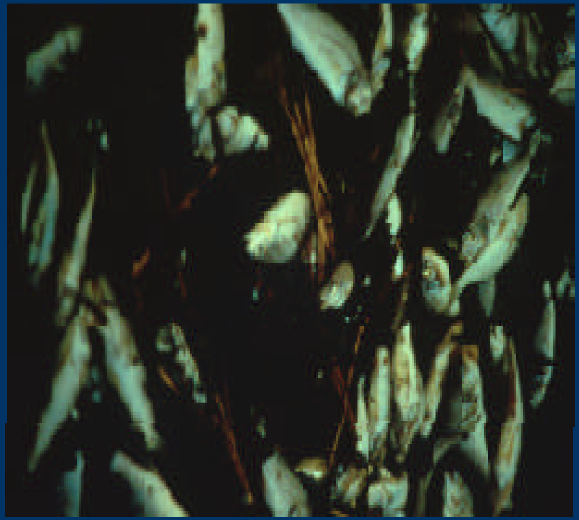
Ecological Impacts of Nitrogen in Coastal Waters

Photo credit W. Bennett, U.S.G.S.

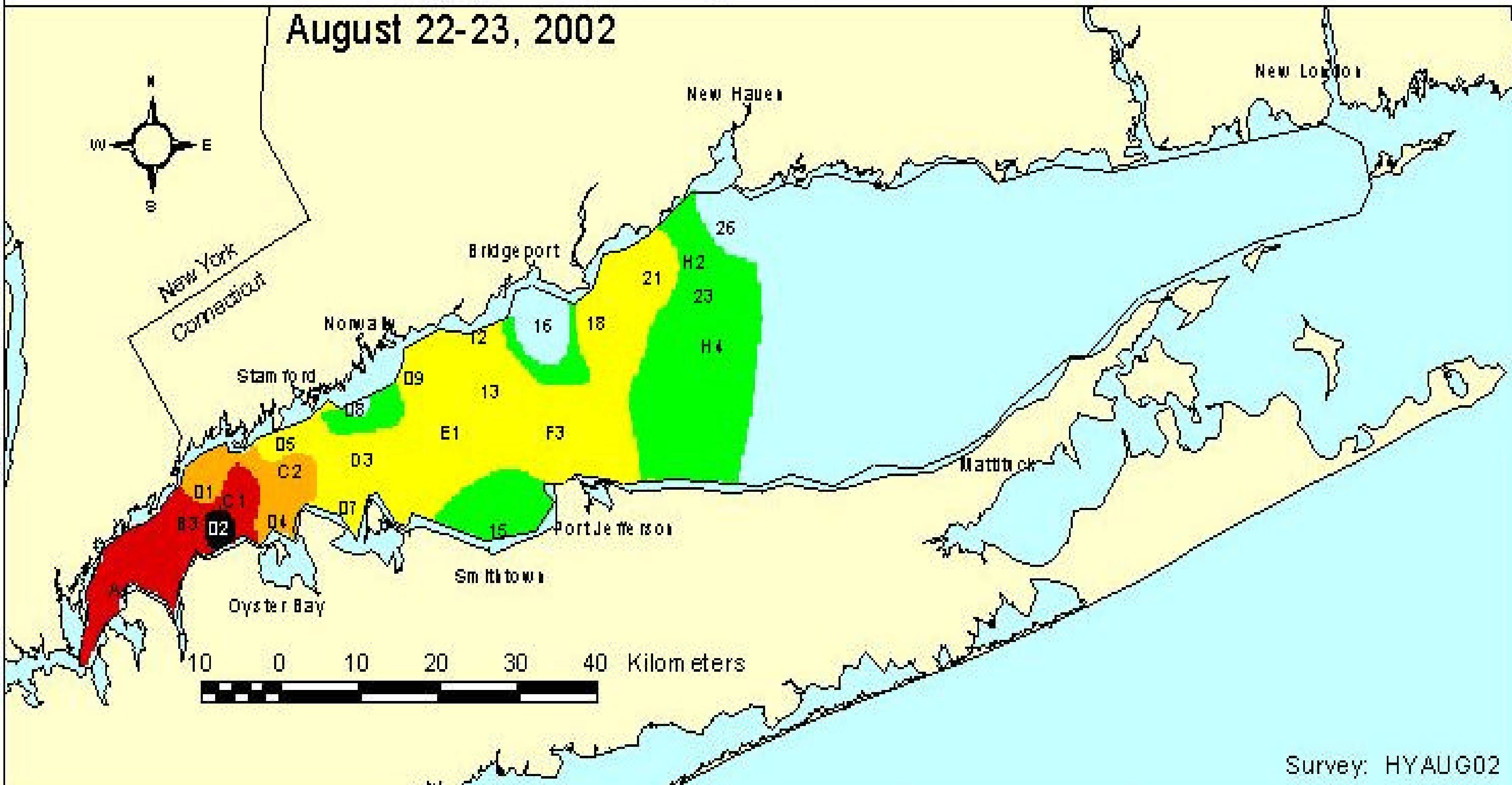
The Coastal Problem: Eutrophication

Nitrogen inputs	Effects	Consequences
Increased Nitrogen	Increased Primary Production	Loss of Habitat Low Oxygen Algal Blooms





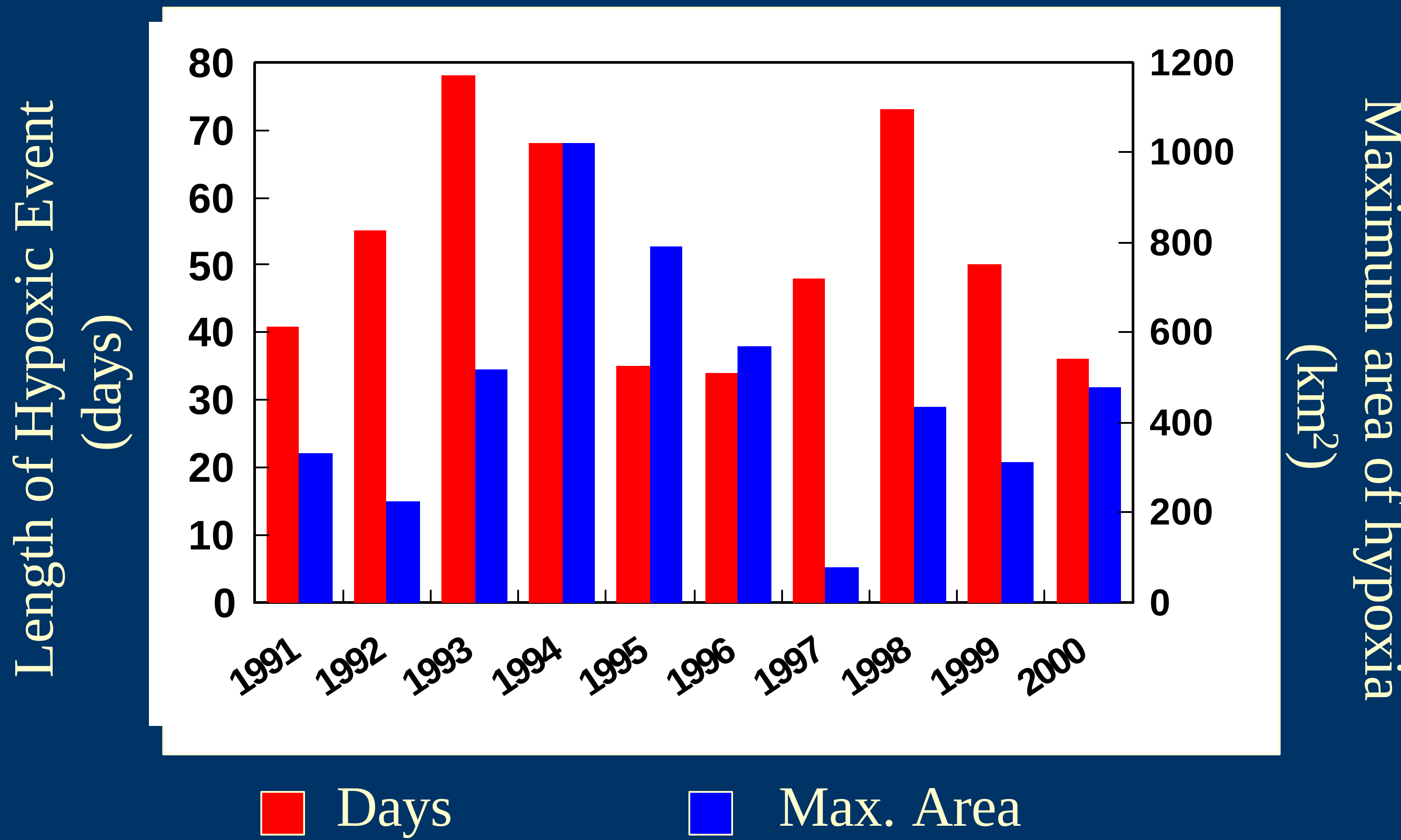
Dissolved Oxygen in Long Island Sound Bottom Waters



Dissolved Oxygen	Severity of impact
0.0 - 0.99 mg/L	Severe
1.0 - 1.99mg/L	Moderately severe
2.0 - 2.99 mg/L	Moderate
3.0 - 3.49 mg/L	Marginal
3.5 - 4.79 mg/L	Interim management goal
4.8 + mg/L	Excellent - Supportive of marine life

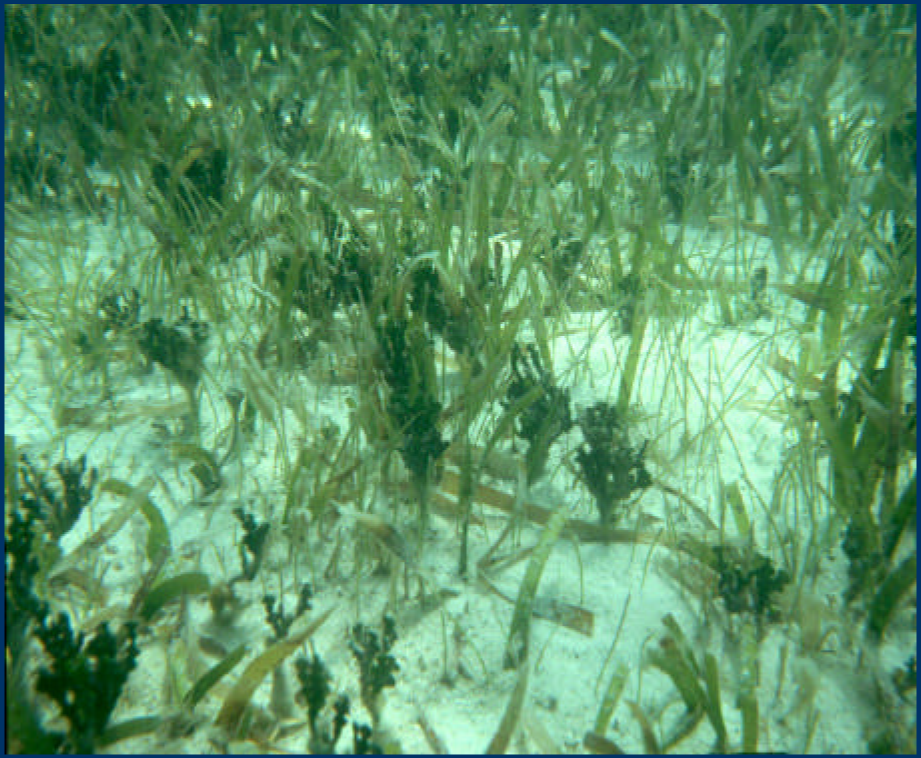
Source: CT Dept. of Environmental Protection

Length and Max. Area of Hypoxia in Long Island Sound



Courtesy of Connecticut Department of Environmental Protection. 2001.

Decline of Seagrass Beds



Pristine

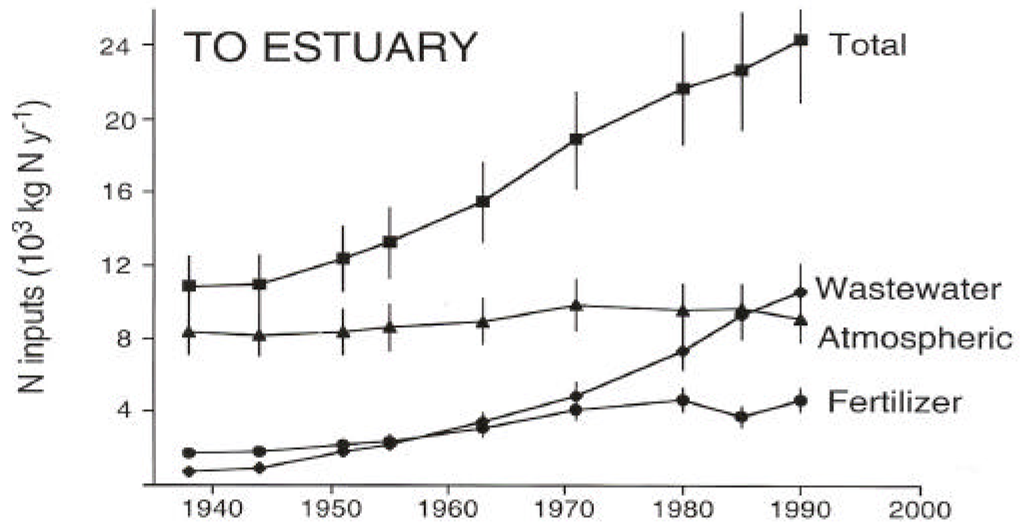
First stage of decline

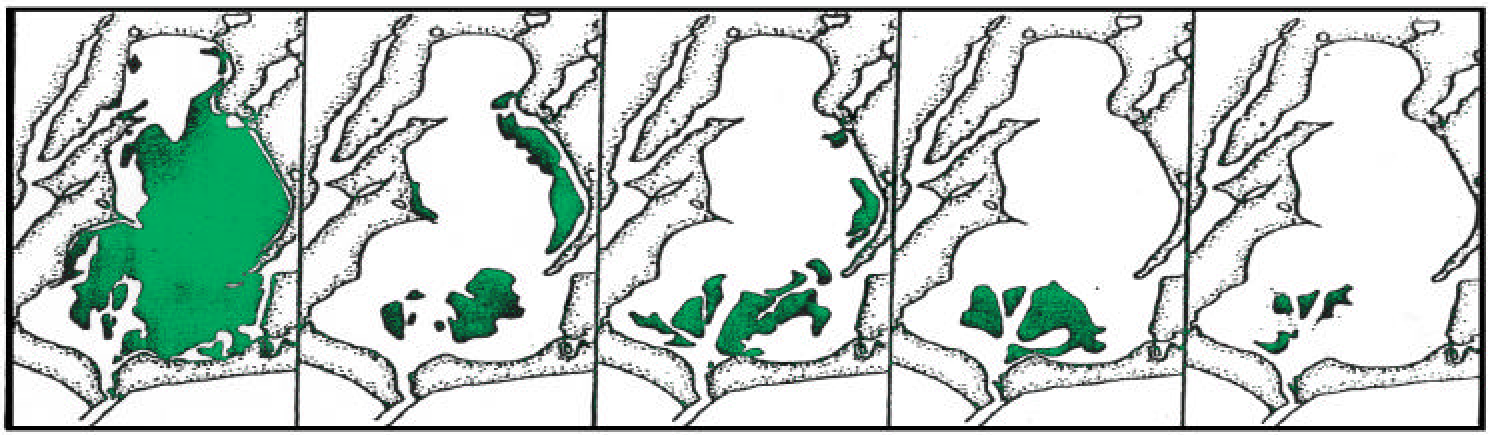
Epiphytes on blades

Water column algal blooms

Photo credit R. Howarth.

Nitrogen and Eelgrass Cover in Waquoit Bay, MA





1951 1971 1978 1987 1992

From Costa in Valiela et al. 1992.

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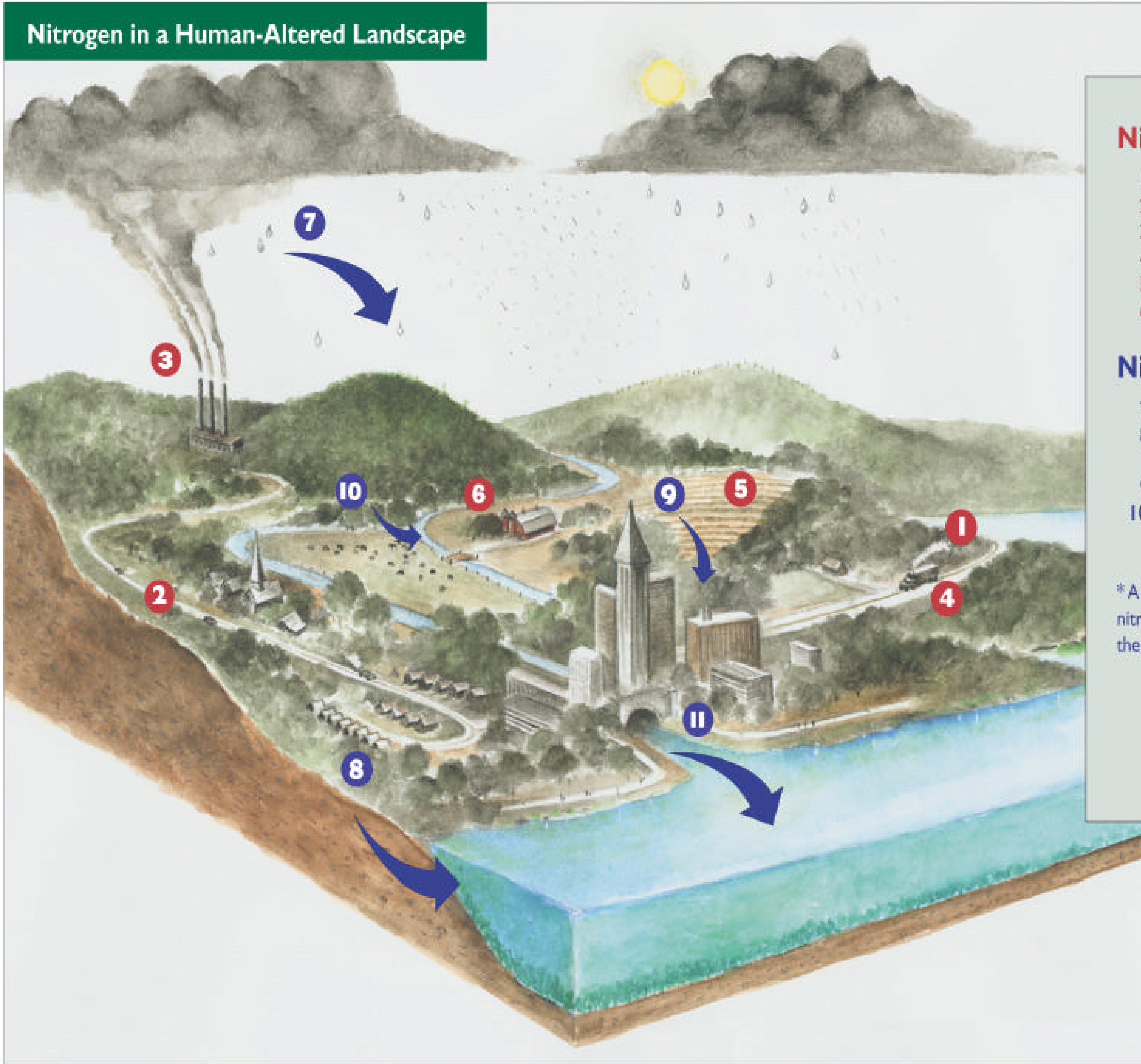

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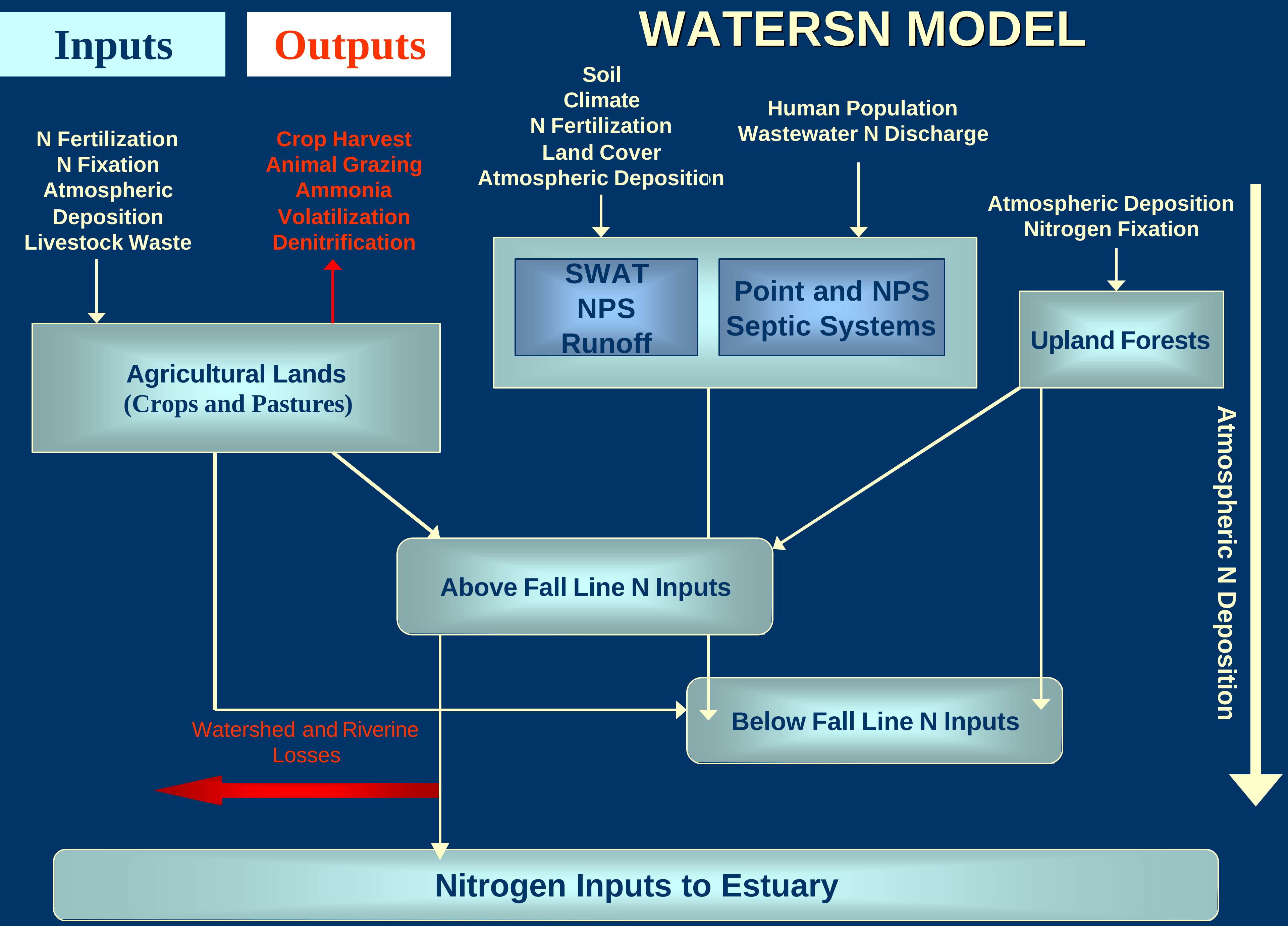

Inputs
Outputs
WATERSN MODEL
Soil
Climate
N Fertilization
Land Cover
Atmospheric Deposition
Human Population
Wastewater N Discharge
N Fertilization
N Fixation
Atmospheric
Deposition
Livestock Waste
Crop Harvest
Animal Grazing
Ammonia
Volatilization
Denitrification
SWAT
NPS
Runoff
Point and NPS
Septic Systems
Atmospheric Deposition
Nitrogen Fixation
Upland Forests
Agricultural Lands
(Crops and Pastures)
Atmospheric N Deposition
Above Fall Line N Inputs
Below Fall Line N Inputs
Watershed and Riverine
Losses
Nitrogen Inputs to Estuary

Reducing Nitrogen Loading to Estuaries

Management options evaluated:

1. Reduced N emissions:
   - 75% reduction in utilities NO_x .
   - EPA Tier 2 reductions in vehicle emissions.
   - 90% reduction above Tier 2 in NO_x from cars.
   - 34% reduction in agriculture NH_3.
2. Biological Nitrogen Removal (BNR) for WWTPs.
3. Septic system improvements.
4. Offshore pumping of waste.
5. Agricultural Best Management Practices (33% reduction in runoff N).

Integrated management option includes…

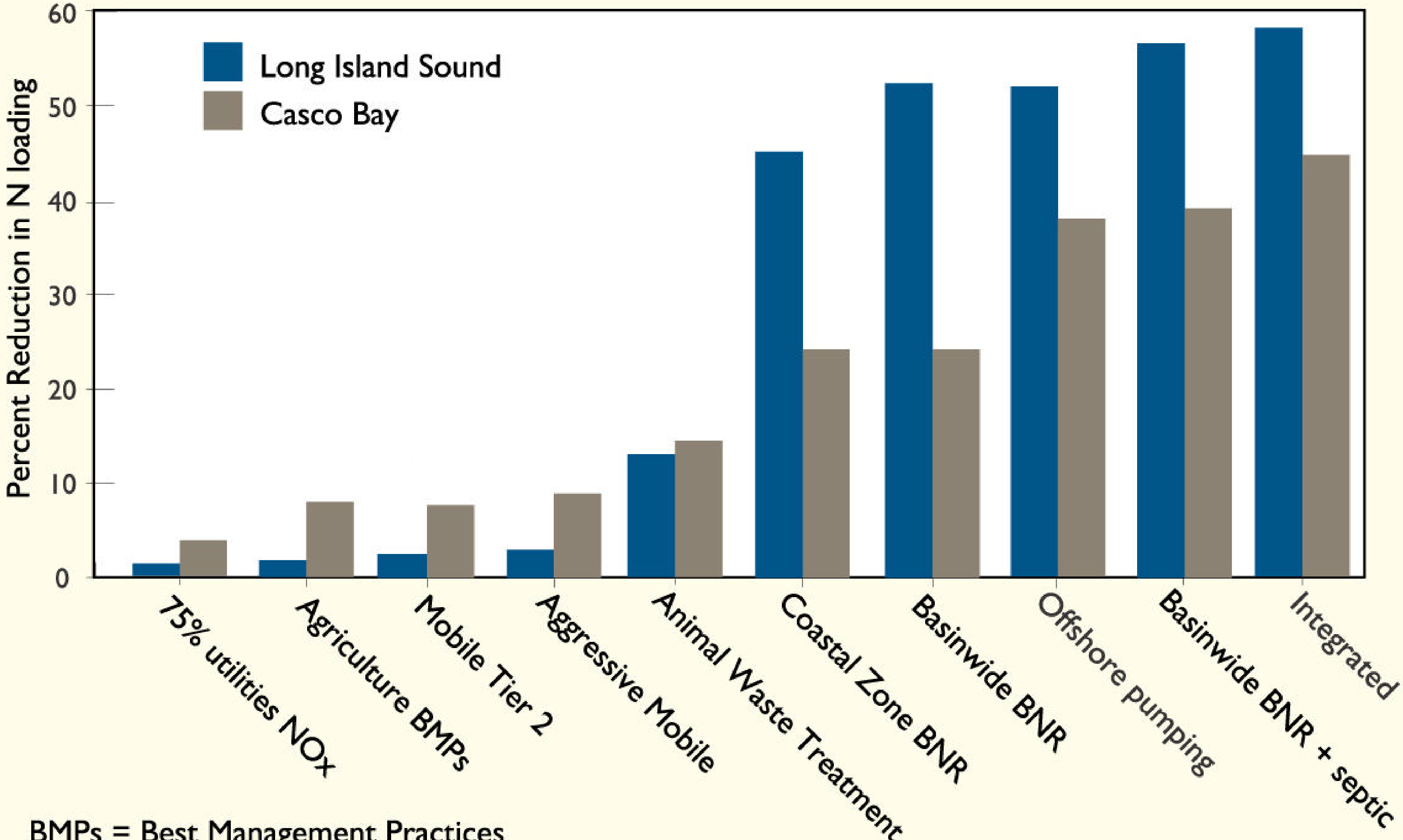
Basinwide tertiary wastewater treatment +

expanded sewers to reduce septic +

Aggressive mobile cuts (90% above Tier 2) +

Aggressive utility cuts -75% reduction of NO_x emissions.

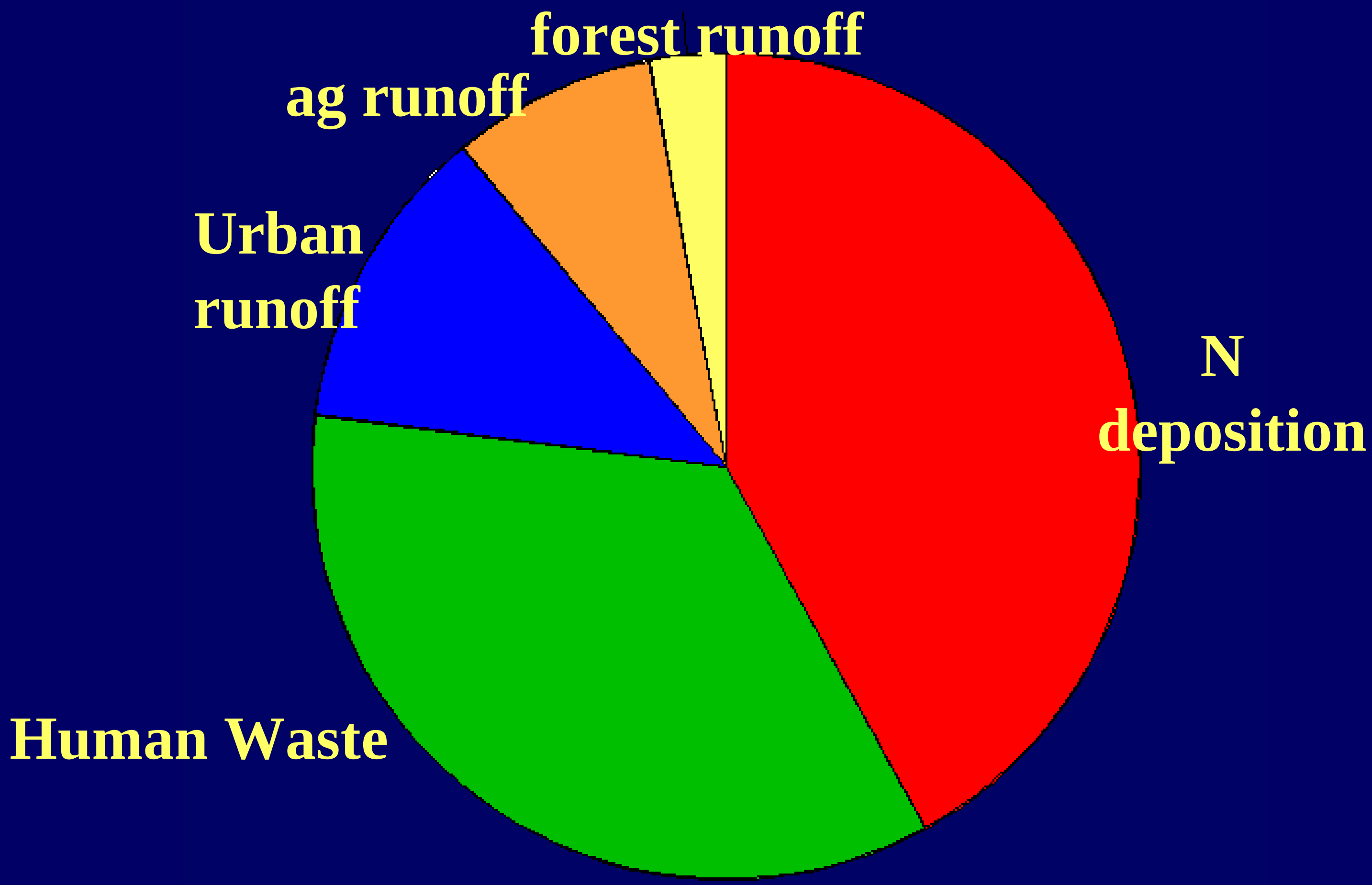
REDUCTIONS IN NITROGEN LOADING TO LONG ISLAND SOUND AND CASCO BAY



BMPs = Best Management Practices

BNR= Biological Nitrogen Removal

“Residual N”for Long Island Sound



Ecosystem Protection for minimizing N inputs and runoff

- Wetlands protection.
- Conservation of forested and non-urbanized areas.
- Farmland reserve programs to reduce fertilizer and waste inputs in sensitive lands.

Coastal waters

- Nitrogen pollution to Northeast estuaries is dominated by wastewater effluent (36-81%) and atmospheric deposition (14-35%).
- Over-enrichment by nitrogen has caused low-oxygen, loss of habitat and algal blooms in some Northeast estuaries (such as Waquoit Bay, MA).
- Improved wastewater treatment results in the largest reduction in nitrogen pollution in our two case studies (up to 57% for Long Island Sound).
- Emissions reductions of NO_x from utilities and vehicles has the added benefit of reducing nitrogen pollution to coastal waters (up to 14% for Casco Bay).
- An integrated management plan that includes nitrogen controls on several sources achieves maximum reductions in nitrogen pollution.

Publications

- BioScience 53: 358-374
- Environment 45: 8-22
- Paper on forest modeling in press at CJFAS
- Paper on watershed N loading submitted to SOTE

This nitrogen projects is a **Science Links** project, organized by **Hubbard Brook Research Foundation** to advance scientific understanding and bridge the gap between science and policy

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- John Merck Fund
- Merck Family Fund
- Harold Whitworth Pierce Charitable

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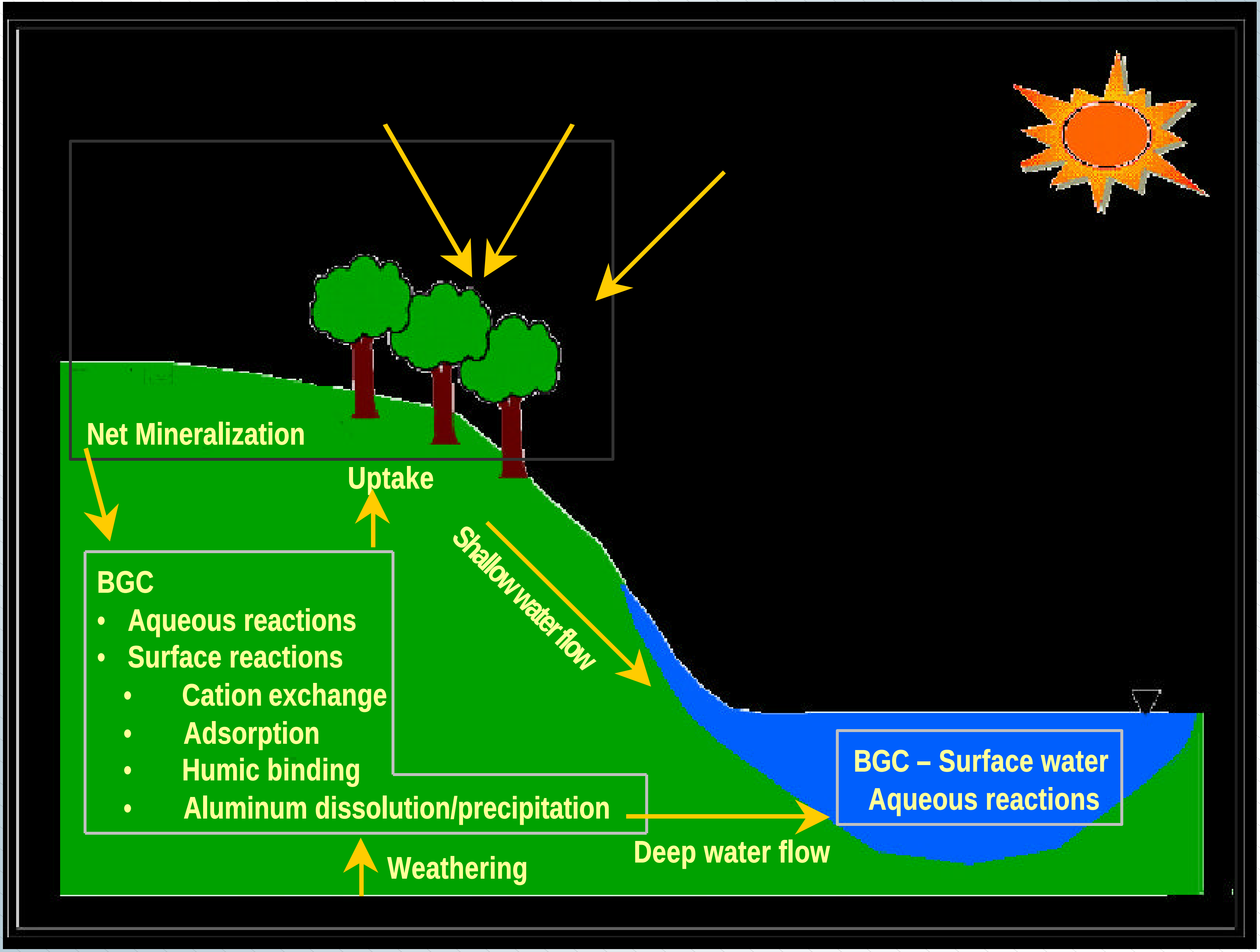
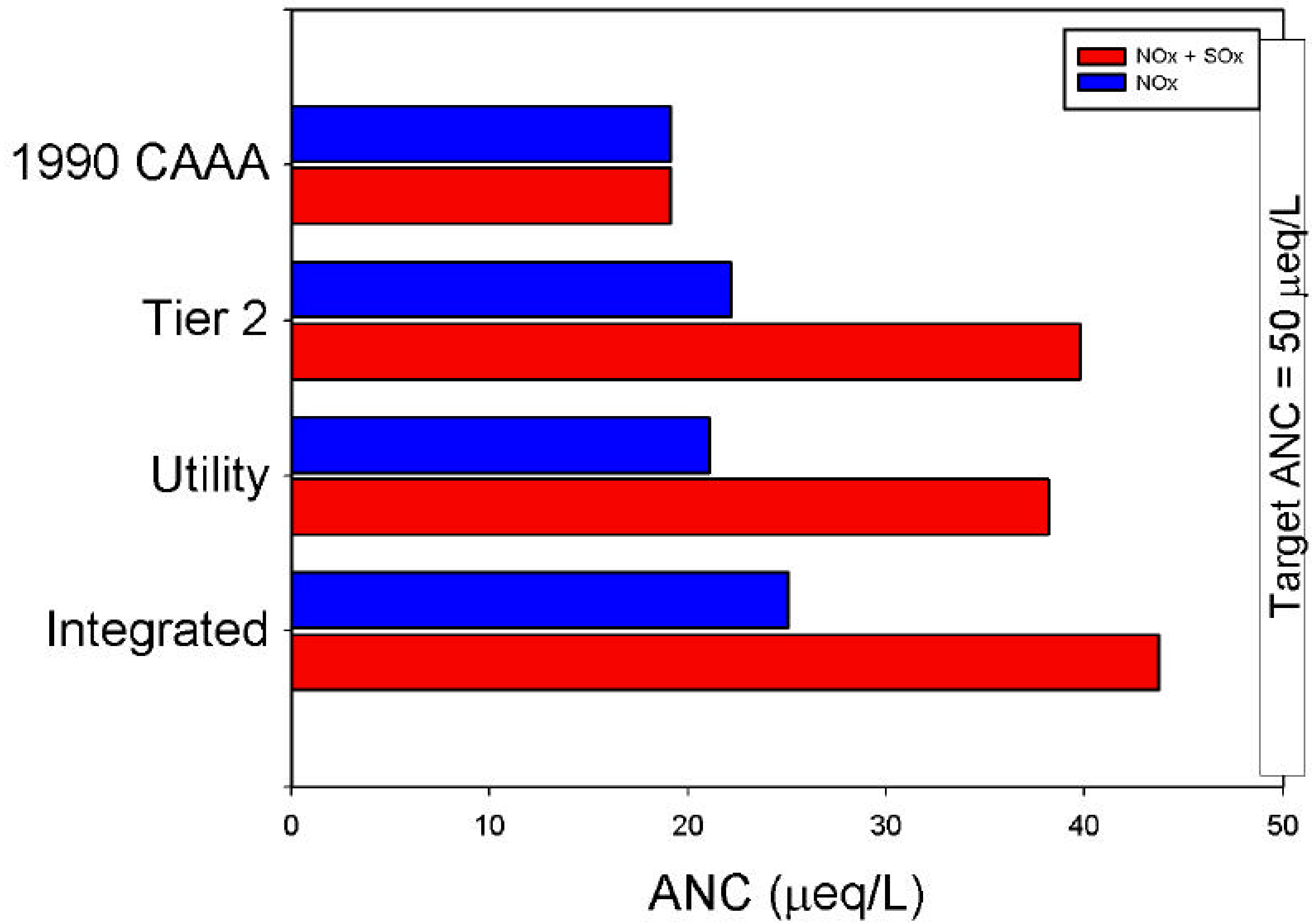
Center for Coastal Monitoring and Assessment
National Ocean Service

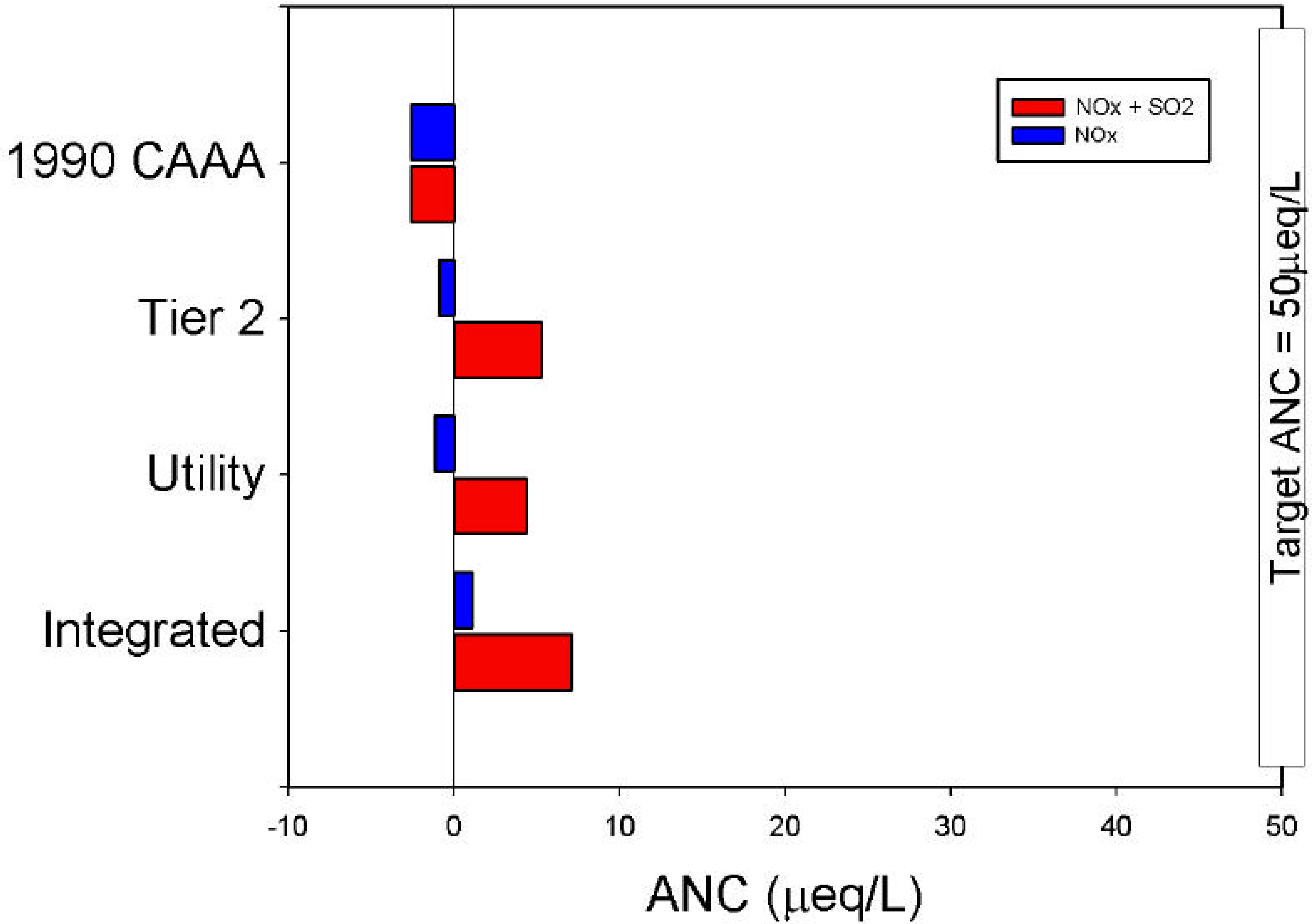
PnET BGC (Biogeochemical) Model



Biscuit Brook, NY



Hubbard Brook Experimental Forest, NH



Forests

- Nitrogen pollution to NE forests is dominated by emissions from transportation (39%) and electric utilities (26%).
- Nitrogen pollution deposited on forests has not decreased since measurements began at the Hubbard Brook Experimental Forest, NH in the 1960s.
- Current ozone levels are projected to reduce forest productivity in the NE by 4-14% per year.
- 36% of forestland in the NE receives N deposition above levels which result in elevated nitrate leaching – an early indication of saturation.
- 40% of lakes in the Adirondacks and 15% in New England are still chronic or seasonally acidic.
- An additional 30% cut in nitrogen emissions is needed to reduce deposition below levels at which nitrate runoff occurs.
- Only N cuts combined with a 75% reduction in utility sulfur dioxide emissions would allow for significant improvements in acid-impacted watersheds.