Non-point nitrogen sources in the Great Bay Watershed

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Nitrogen Issues in Great Bay – November 8, 2012 – Madbury, NH

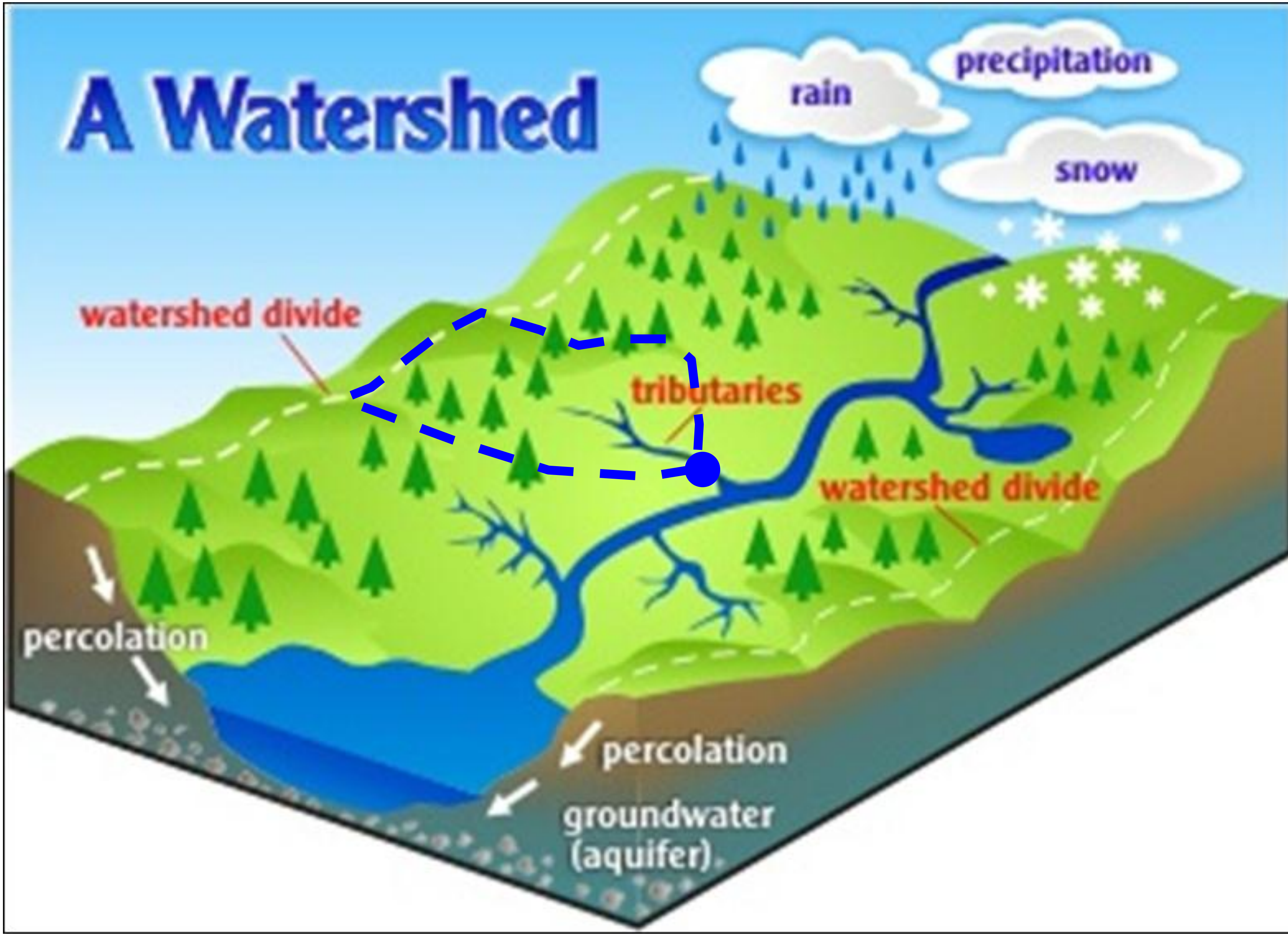
University *of* New Hampshire

LAMPREY RIVER ADVISORY COMMITTEE

AIRMAP

MAPPING NEW ENGLAND'S CHANGING CLIMATE AND AIR QUALITY

NEW HAMPSHIRE WATER RESOURCES RESEARCH CENTER


A Watershed
rain
precipitation
snow
watershed divide
tributaries
watershed divide
percolation
percolation
groundwater
(aquifer)

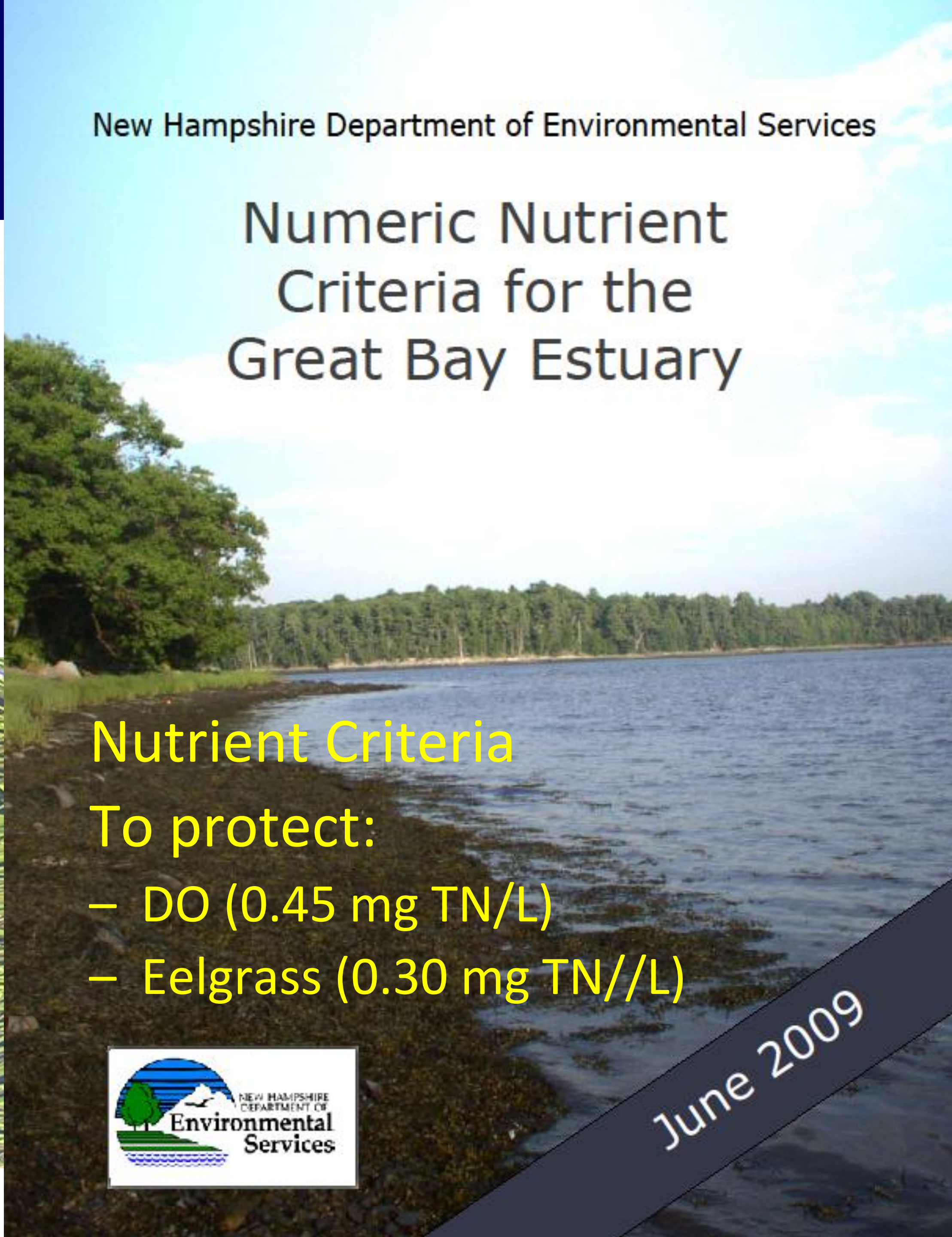
Outline

- Brief overview of Nitrogen (N) impairment and proposed total N (TN) reductions
- N budget for the Lamprey watershed
- Assessment of non-point nitrogen in the Lamprey and Oyster sub-watersheds
- Implications for managing N
- Current research projects examining non-point nitrogen sources and transport pathways

Great Bay

- NH's most significant estuary
- Loss of Eelgrass, clams and Oysters
- Long-term increase in nitrogen concentrations
- Low dissolved oxygen (DO)
- Decreased water clarity

Photo credit: Dr. Fred Short



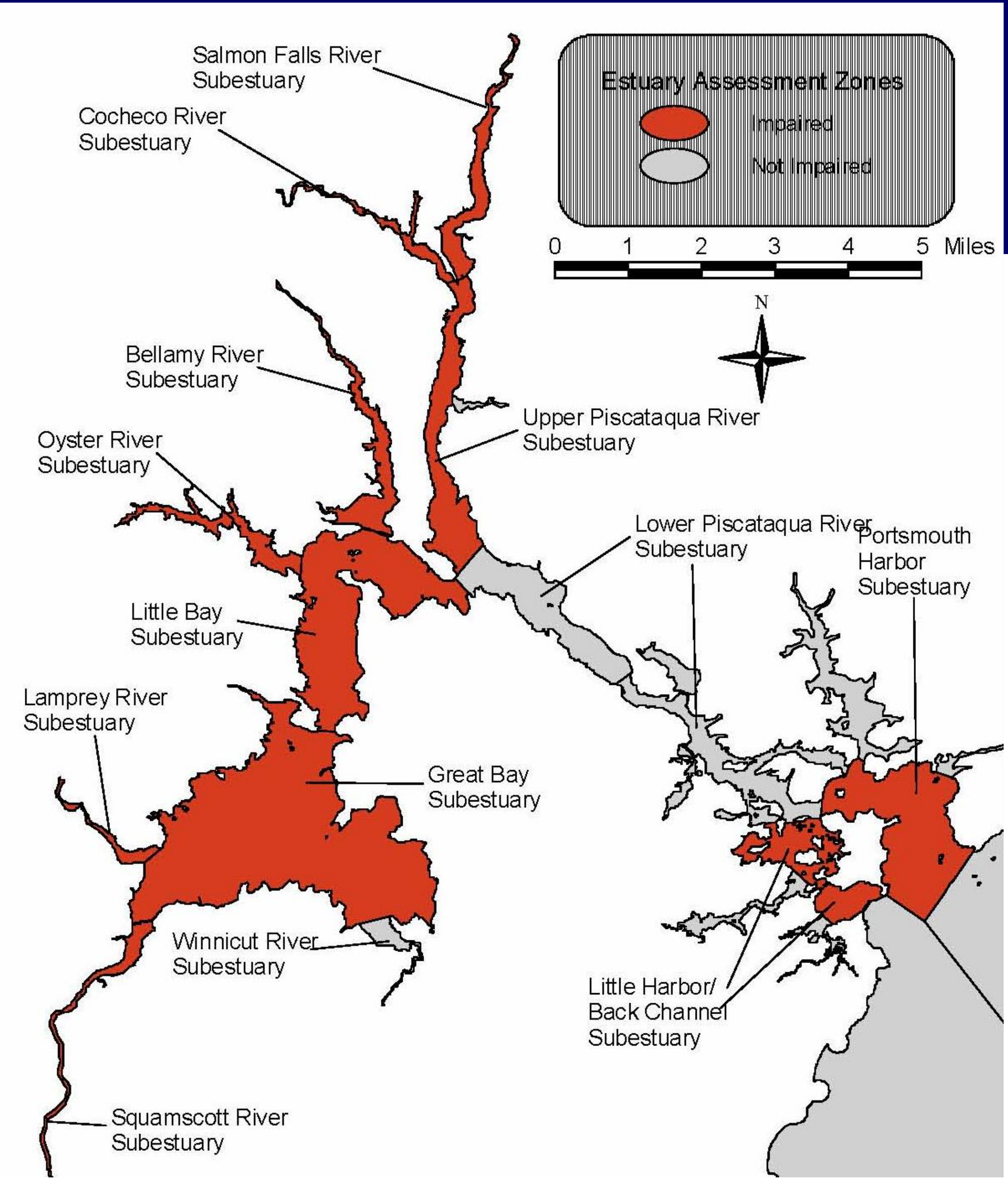
Nutrient Criteria

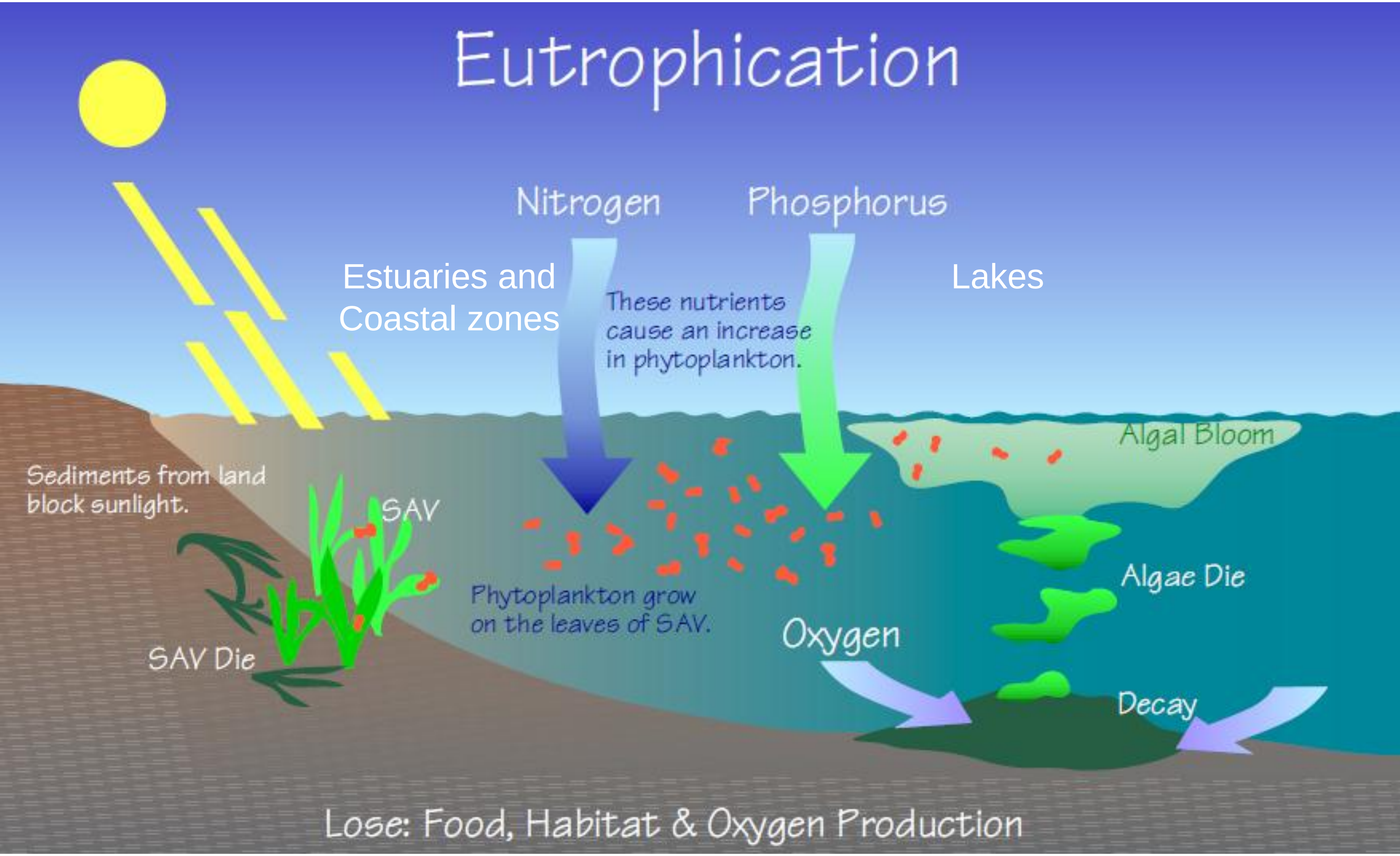
To protect:

- DO (0.45 mg TN/L)
- Eelgrass (0.30 mg TN//L)

Nitrogen Impairments for Great Bay Estuary

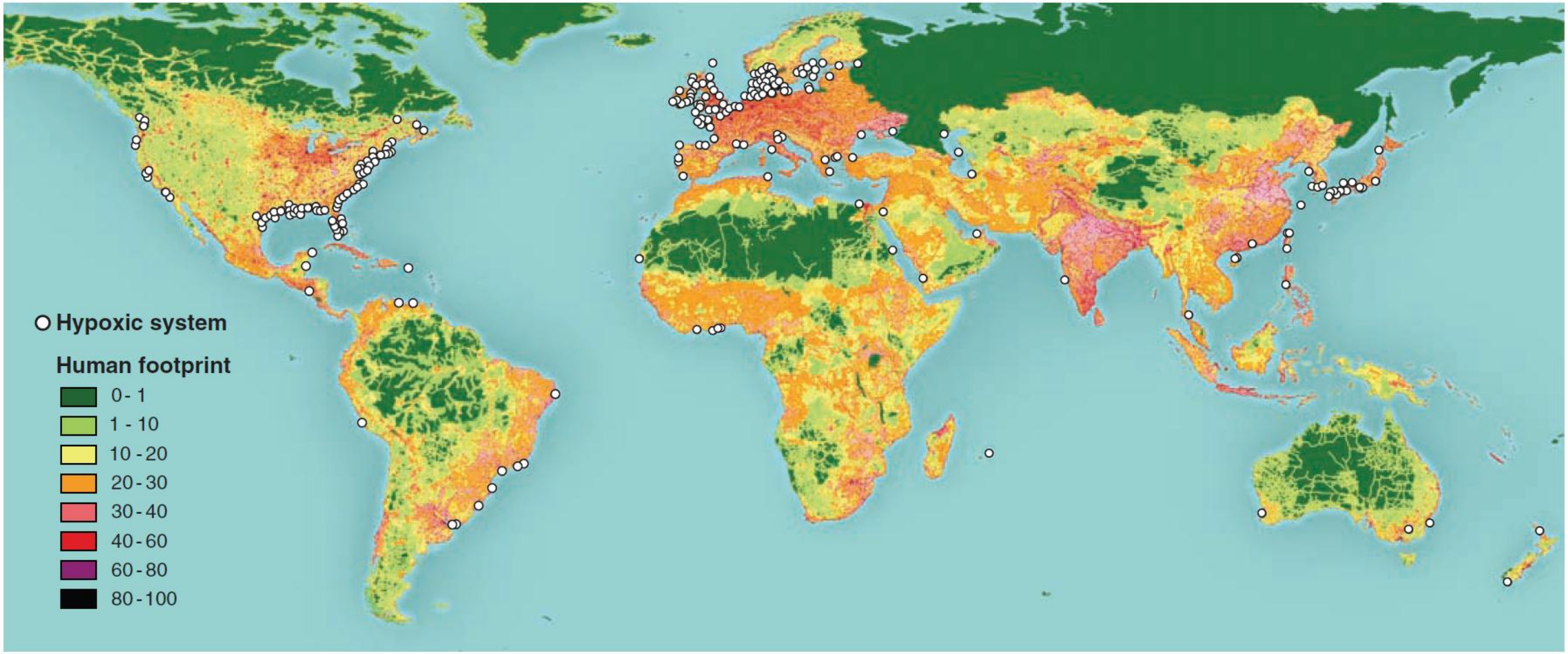
Violation of Clean Water Act





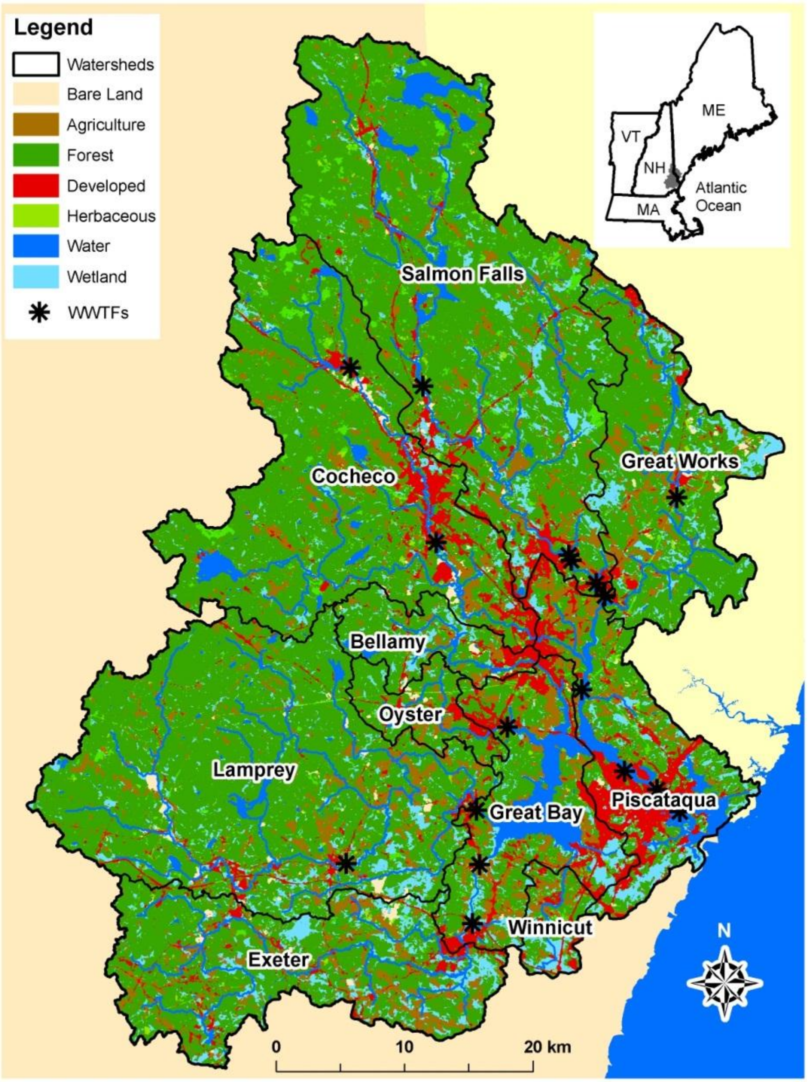
SAV – Submerged Aquatic Vegetation e.g. Eelgrass
http://www.fiu.edu/~envstud/labs/imageJ1B.JPG

Eutrophication-associated dead zones and the human footprint



Diaz and Rosenberg. 2008. Spreading dead zones and consequences for marine ecosystems. Science 321:926-929.

Great Bay Watershed



- Home to 22% of NH's population
- Drains 2 towns (42 in NH 10 in ME)
- Mostly forested, no big agriculture and some people
- Point sources - 18 WWTF
  - 10 discharge directly to estuary
  - 8 discharge to tributaries
- Non-point N sources
  - Septic systems and leaky sewer lines
  - Fertilizers
  - Pets and livestock
  - Atmospheric deposition
  - Wetlands, forests and soils

Great Bay Nitrogen (N) Impairment

- 2003-2008 TN load to Great Bay
  - 27% Point Sources (WWTFs)
  - 73% non-point point sources
- July – September WWTFs contribute more than 50% of the TN load to Great Bay
- 31% TN reduction needed to protect DO in tidal rivers and restore eelgrass in the bay (45% to protect DO and restore eelgrass in all areas; Trowbridge 2010 Draft Report)

➢ **Even if removed all WWTF effluent, still need to reduce non-point N**

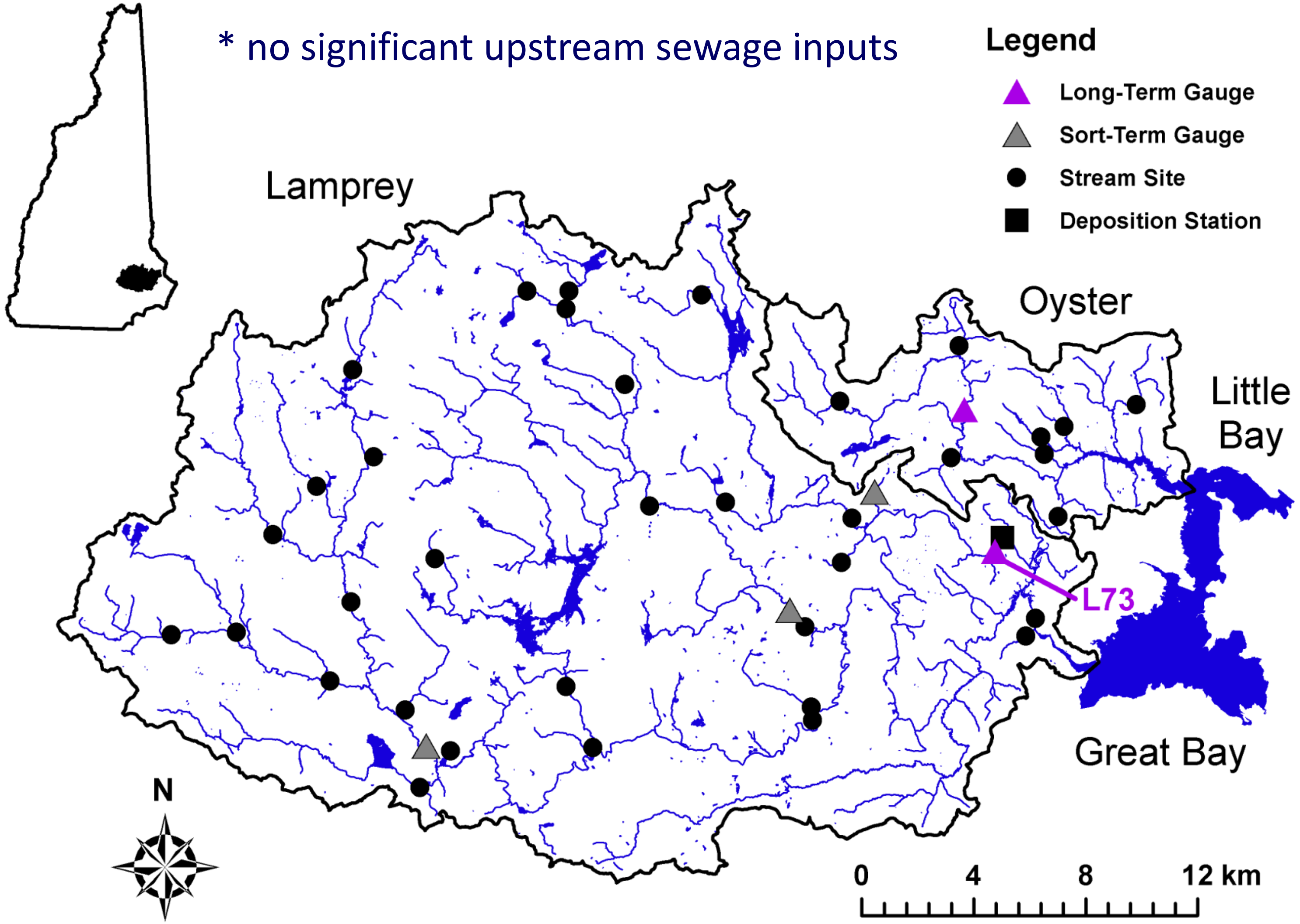
Lamprey River Hydrologic Observatory (LRHO) - the Largest Tributary to Great

LR Watershed = 550 km^2

Google Earth
Panoramio.com

Sites in the Lamprey and Oyster watershed

* no significant upstream sewage inputs



Forms of Nitrogen (N)

Particulate N

(Measured Since Oct 2002 - 0.07 mg/L)

Attached to sediment and increases with flow; no data on land use

Dissolved N

(Measured since Sept. 1999)

"Reactive" Nitrogen Associated with Human Activity

Dissolved Inorganic Nitrogen (DIN; 0.12 mg/L)

Nitrate (NO_3^-)

Ammonium (NH_4^+)

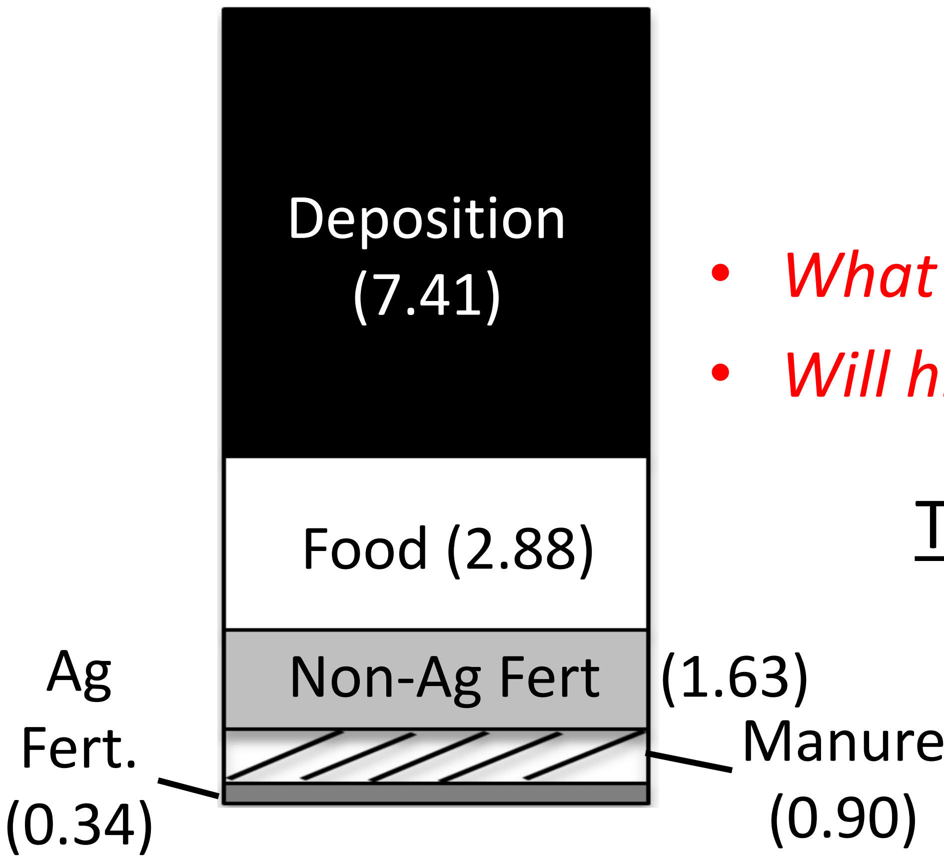
Dissolved Organic Nitrogen (DON; 0.21 mg/L) Associated with wetlands

Use 10+ yrs. of data to examine trends in dissolved N in the Lamprey

Nitrogen budget for the Lamprey watershed (L73)

(Median 2000-2009)

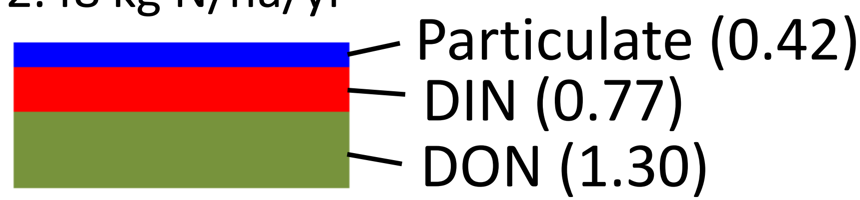
Total N Input
13.2 kg/ha/yr



81% N Retained
(10.72 kg N/ha/yr)

- *What happens to 81% of the inputs?*
- *Will high N retention rates continue?*

Total N Output
2.48 kg N/ha/yr



N can be lost to the atmosphere (denitrification) in…

wetlands

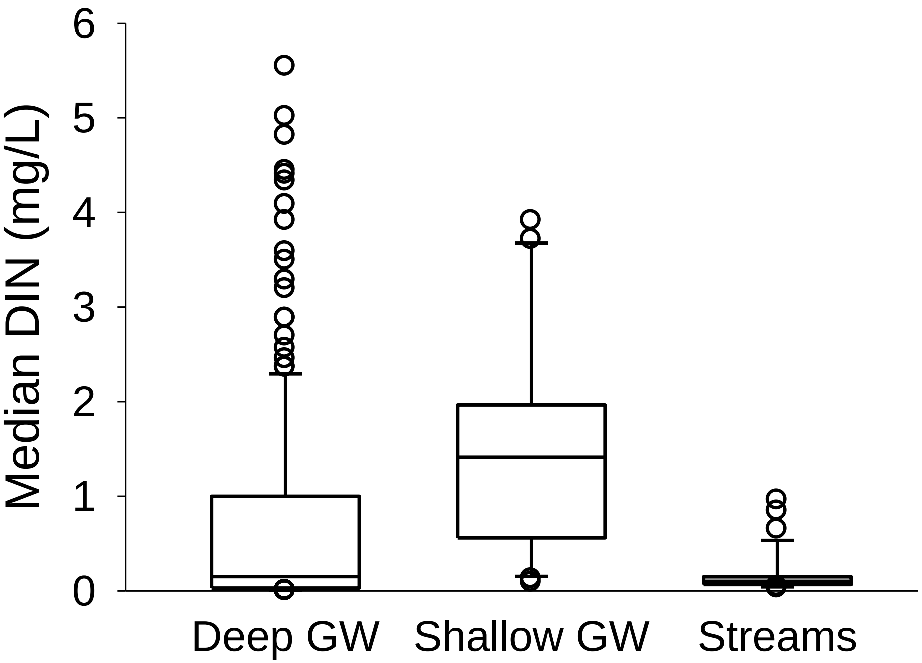
stream channels

riparian zones

Is this a significant component of N retention?

N can be temporarily stored in vegetation and/or groundwater

Will these systems become saturated? What is the lag time for groundwater?



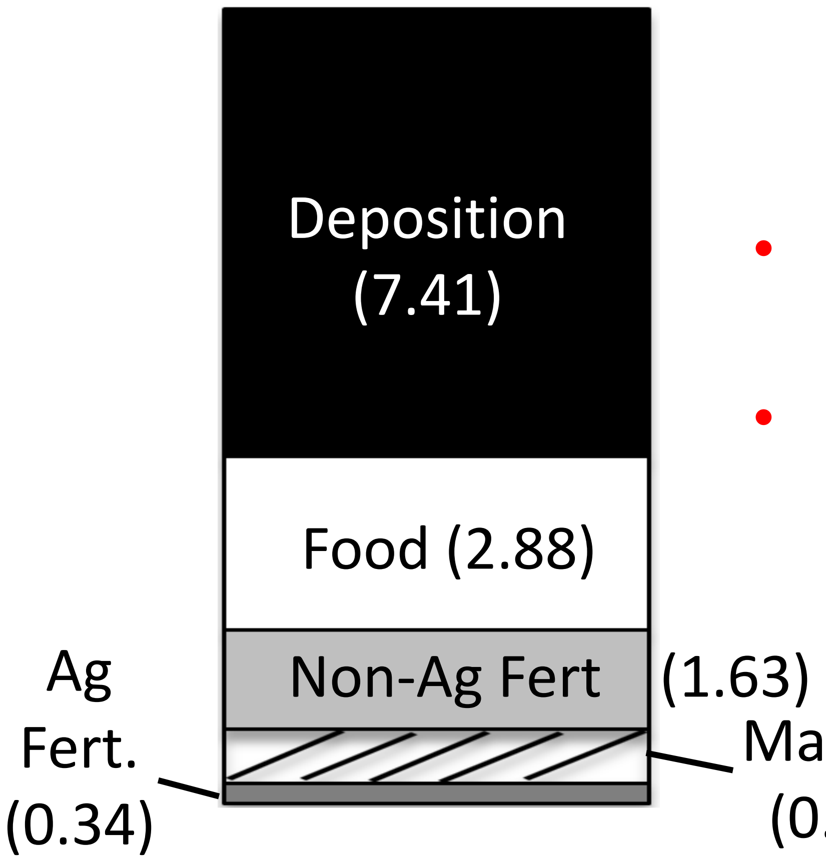
Lamprey groundwater N is higher than stream water N

Nitrogen budget for the Lamprey watershed (LMP73)

(Median 2000-2009)

Total N Input

13.2 kg/ha/yr



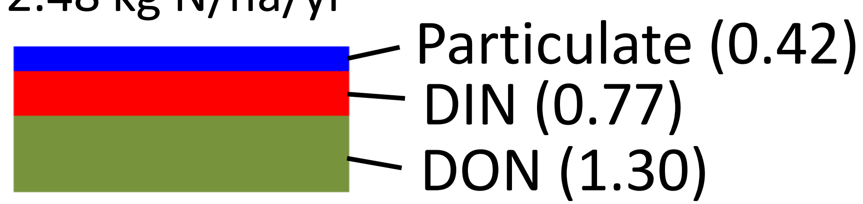
81% N Retained

(10.72 kg N/ha/yr)

- *How do the N outputs respond to the human footprint among sub-basins?*
- *Which inputs become outputs?*

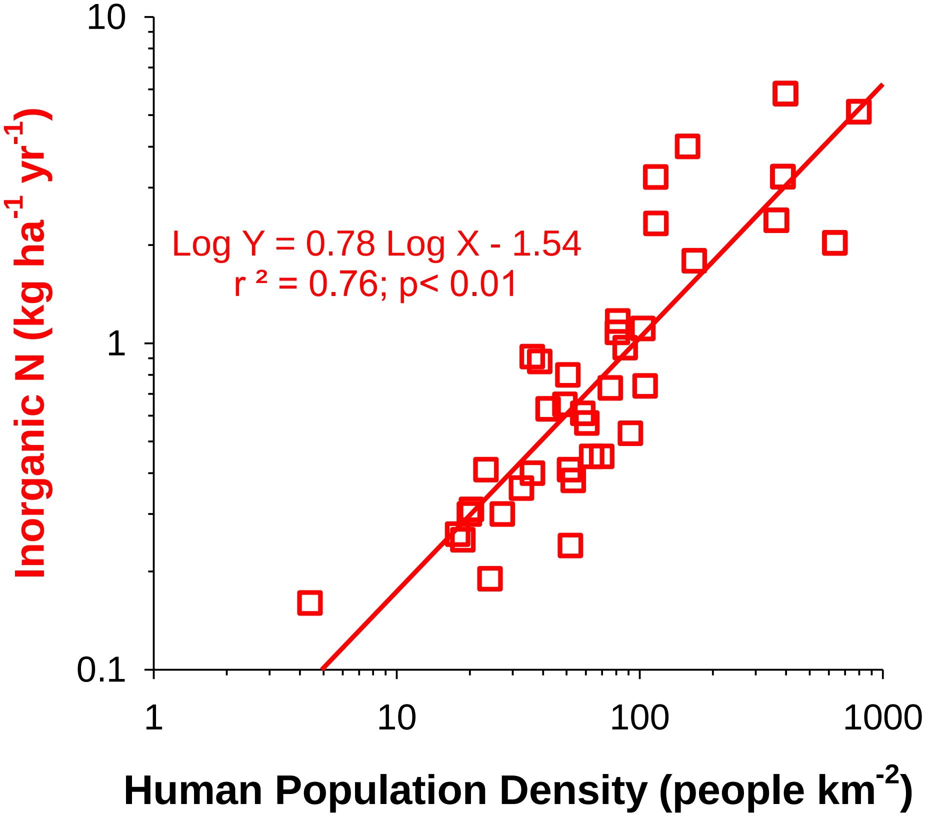
Total N Output

2.48 kg N/ha/yr



Non-point inorganic N responds to the human footprint – MANAGEABLE

(Nitrate + ammonium in individual Lamprey and Oyster sub-basins with no significant sewage inputs)

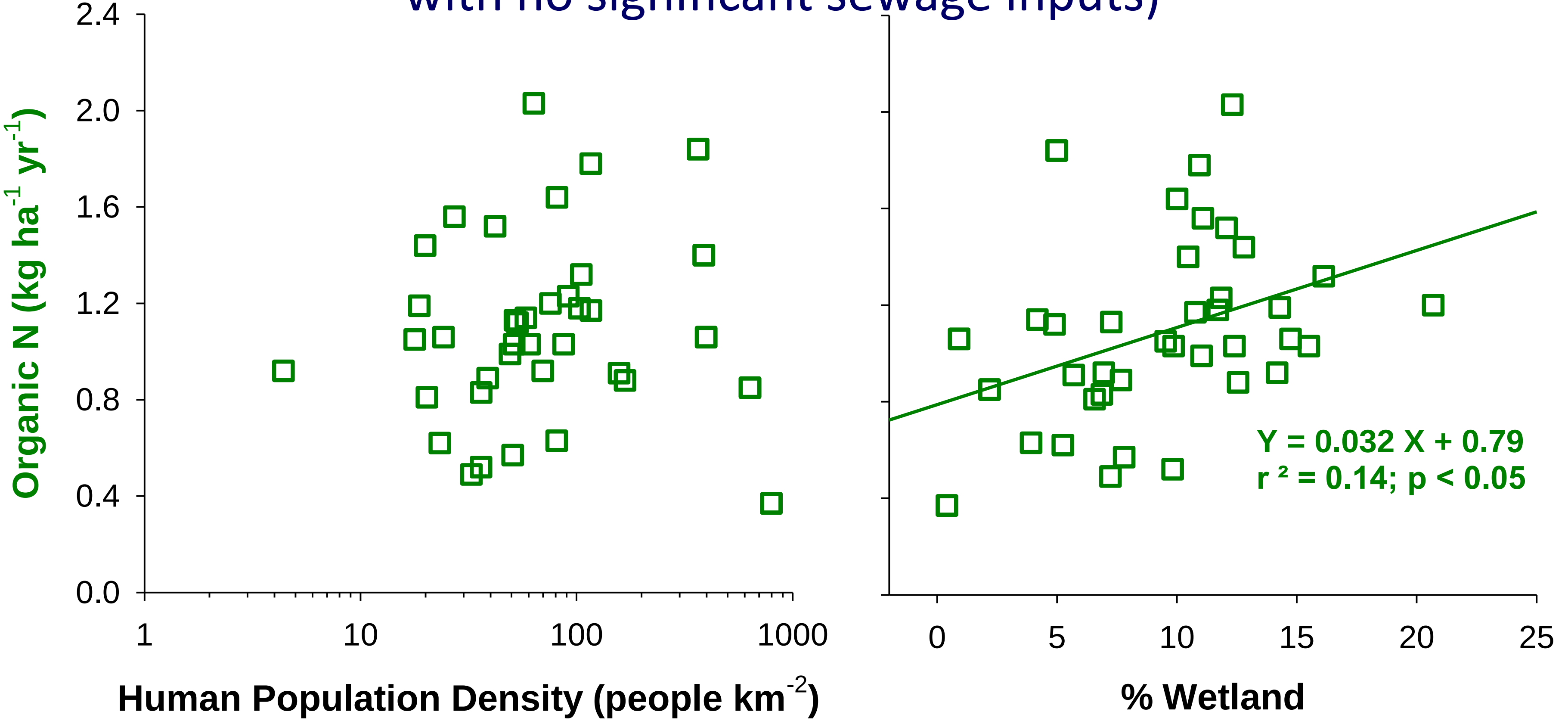


Potential Sources to Manage:

- Septic Systems
- Leaky sewer lines
- Pet waste
- Fertilizers
  - Residential
  - Commercial
  - Recreational
- Atmospheric deposition delivered from impervious surfaces
- Interspersed agriculture
  - Fertilizers
  - Manure

Non-point organic N does NOT respond to the human footprint – NOT MANAGEABLE

(Dissolved organic N in individual Lamprey and Oyster sub-basins with no significant sewage inputs)

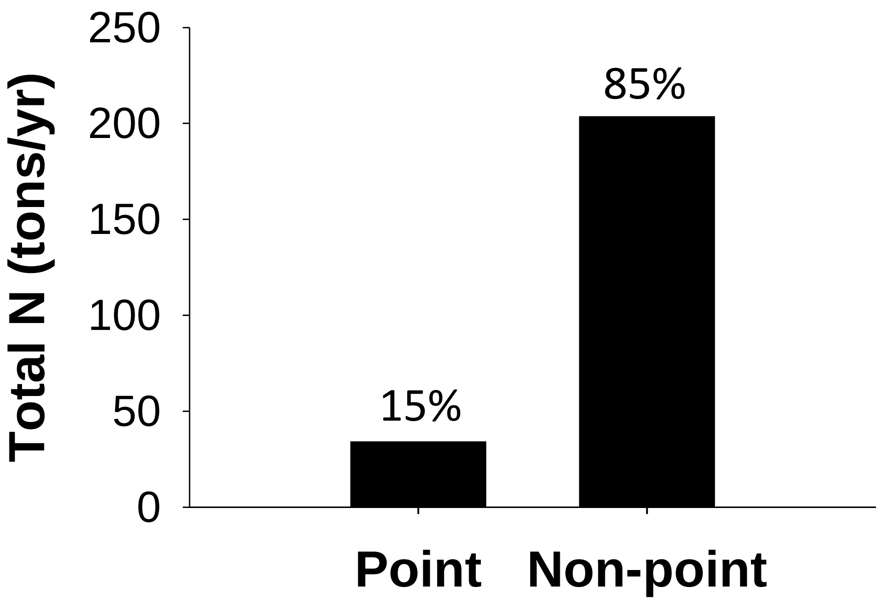


Implications for managing N to reduce loads to Great Bay

Total and Manageable N in the Lamprey

Total N

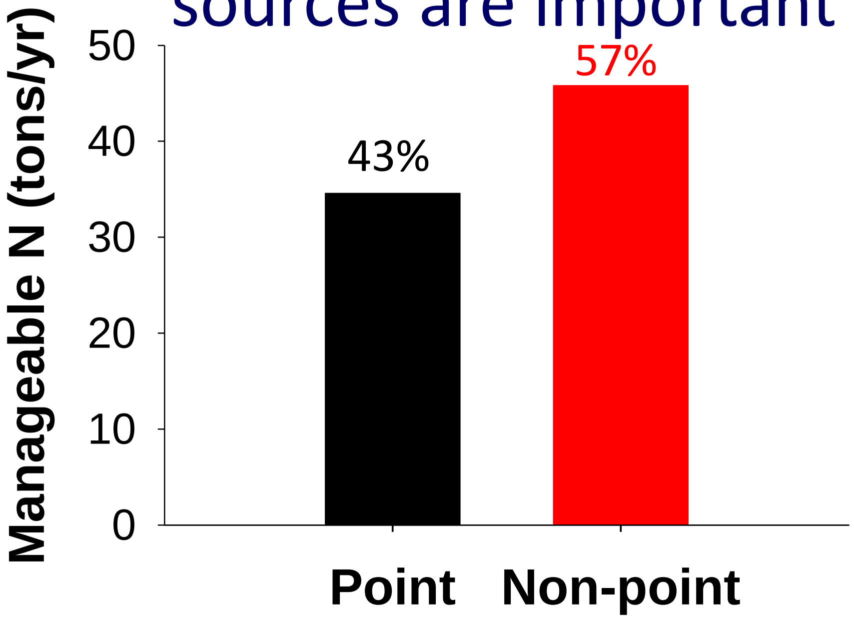
Non-point sources dominate the problem



Manageable N

(fraction that responds to human footprint)

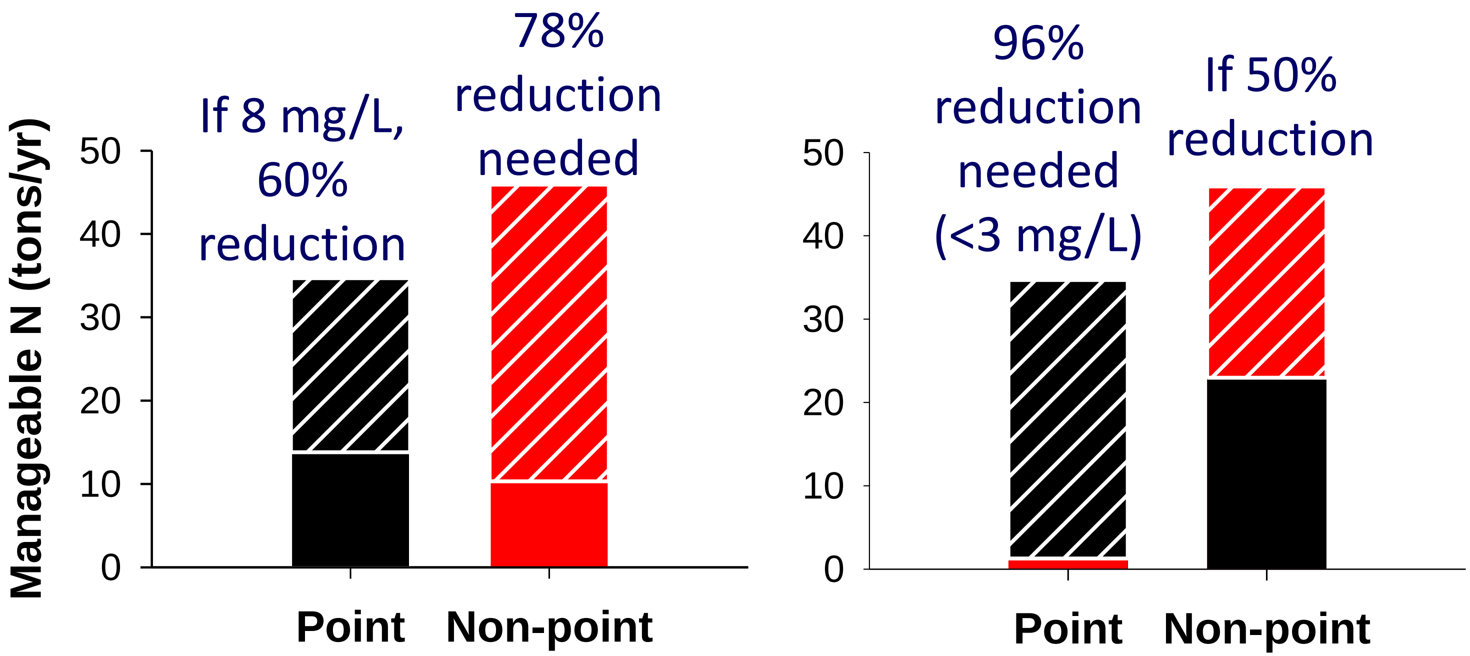
Both point and non-point sources are important



~23-30% of non-point N in the Lamprey is potentially manageable

Lamprey manageable N reduction scenarios

% Reduction to protect DO in tidal river and eelgrass in the bay

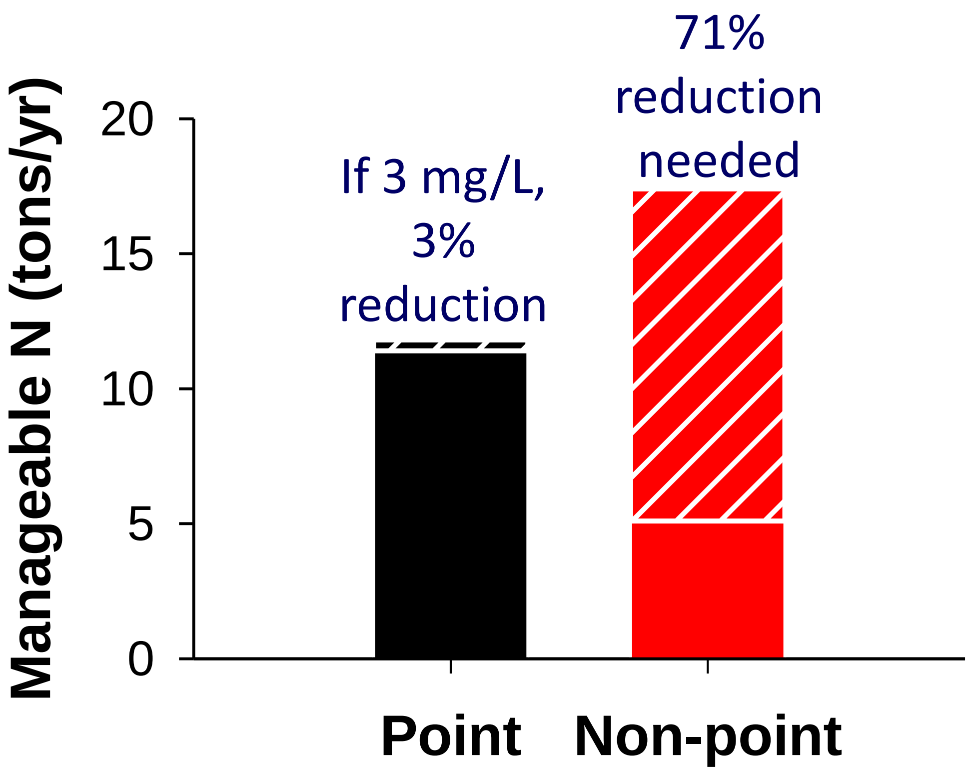


More than 50% reduction in manageable non-point N is unlikely; must use available technology to reduce point sources.

Total and Manageable N in the Oyster

Total N (60.4 tons/yr) - 20% Point, 80% non-point

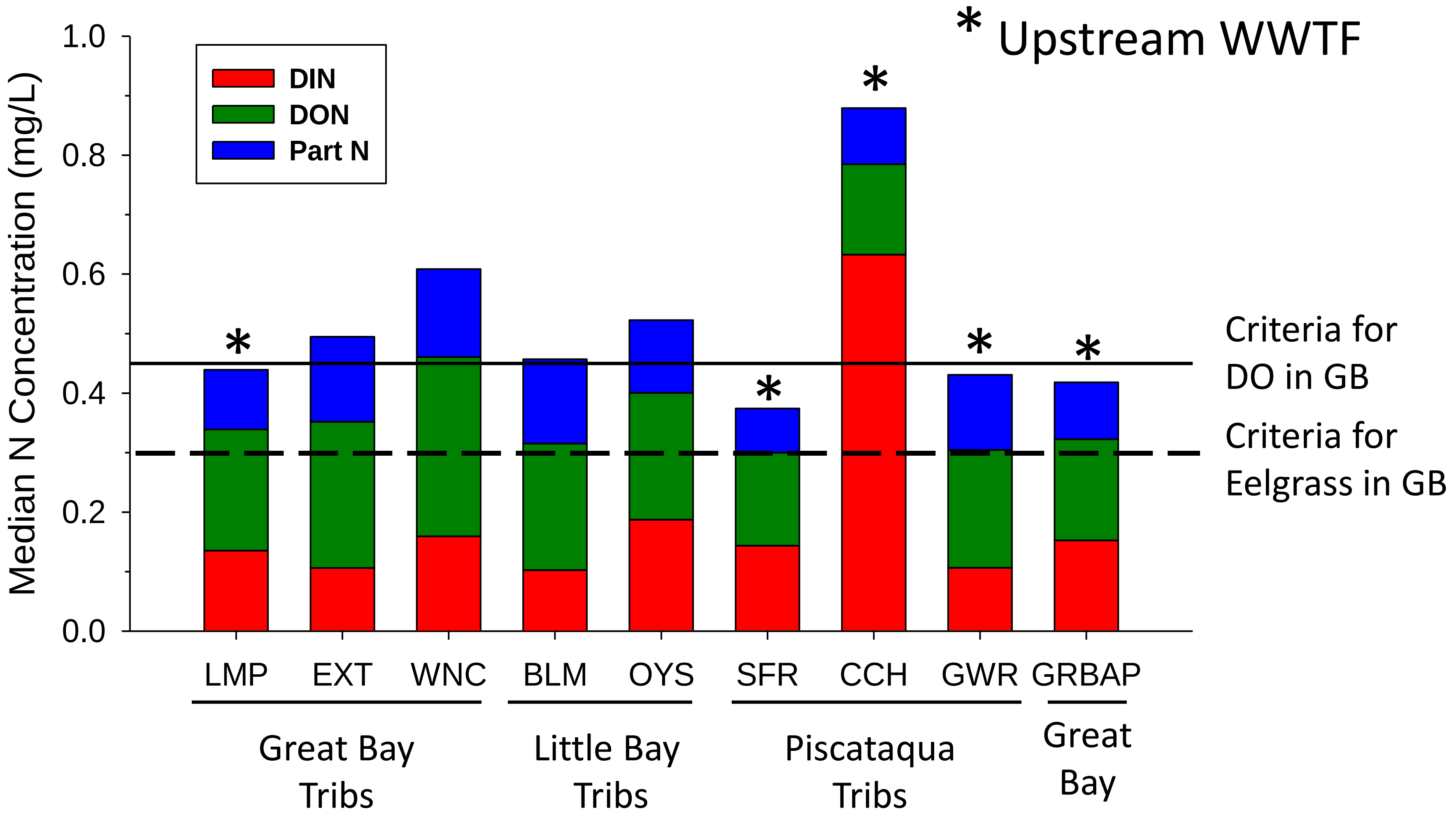
Manageable N (29.2 tons/yr) - 40% Point, 60% non-point



% Reduction to protect DO in tidal river and eelgrass in the bay

~38% of non-point N in the Oyster is potentially manageable

Not all tributary watersheds are equally amenable to N management



Key Nitrogen Lessons and Challenges

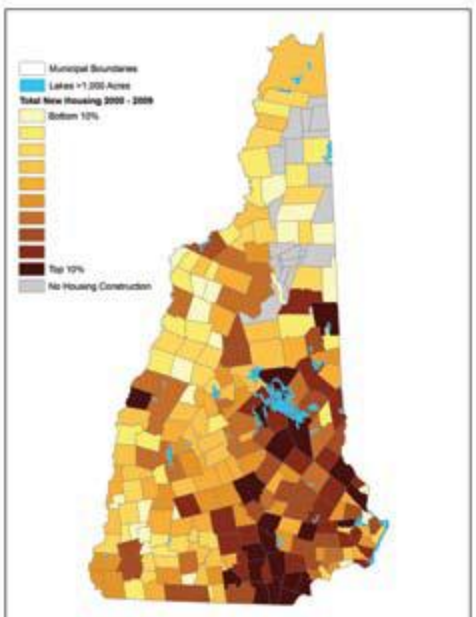
- Most (81%) of the N imported to the Lamprey watershed never makes it to the stream (or to Great Bay)
- As watersheds urbanize N delivered to streams (and downstream to Great Bay) increases
- Not all forms of non-point N in the stream respond to human activity in the watershed and are therefore manageable
  - DIN responds to human footprint (manageable)
  - DON responds to wetlands not the human footprint (not manageable)
- Uncertainty as to which N sources imported to watersheds become outputs and if some sources are preferentially exported
- Lack of understanding of the controls on long-term watershed N retention
- Legacy of past land use and/or future growth could offset N reduction strategies

Reduce N Loading in the face of continued population growth?

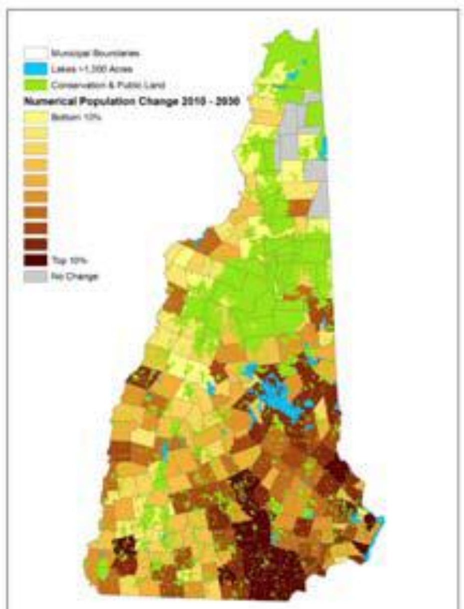
NH's population is projected to increase by 180,000 persons from 2010 to 2030.

Roughly 70% of that growth will occur in the four southeastern counties.

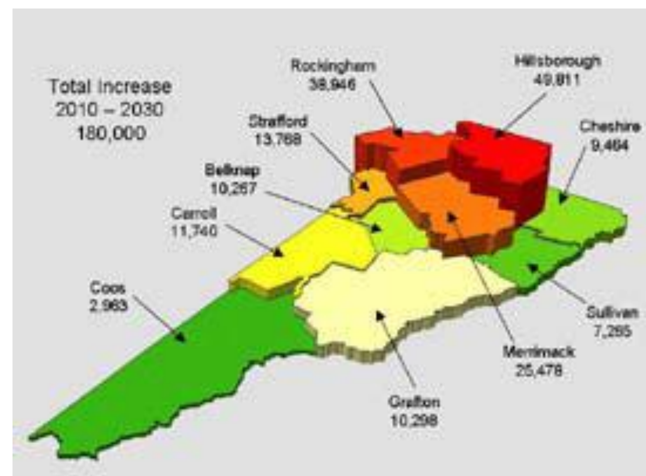
Total New Housing 2000-2009



% Population Change 2010-2030

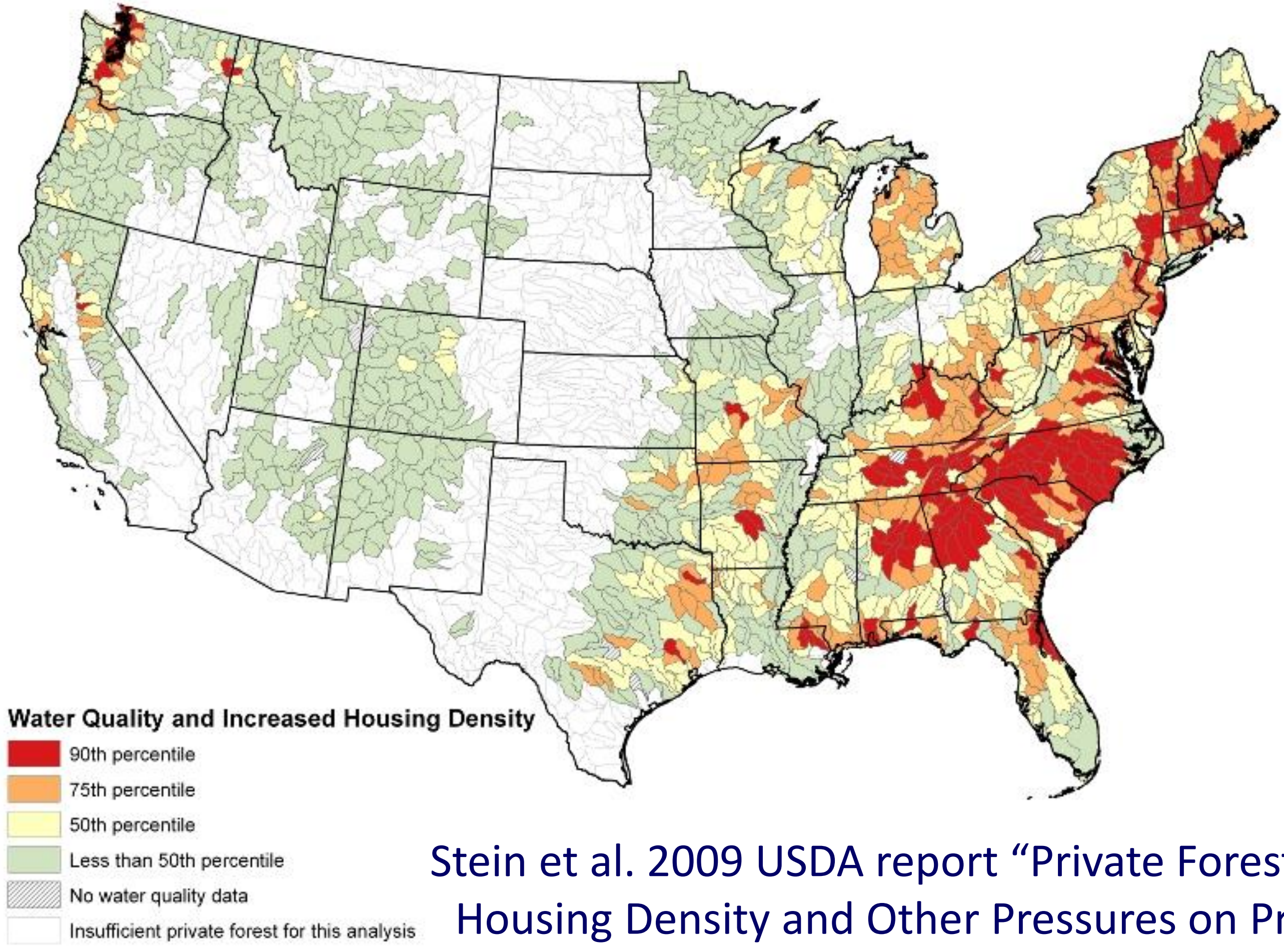


Total Population Increase 2010-2030, 180,000 persons



2010 Population Growth and Land Use Change Report by SPNHF

Watersheds projected to experience largest declines in water quality due to increased housing density on private forest lands

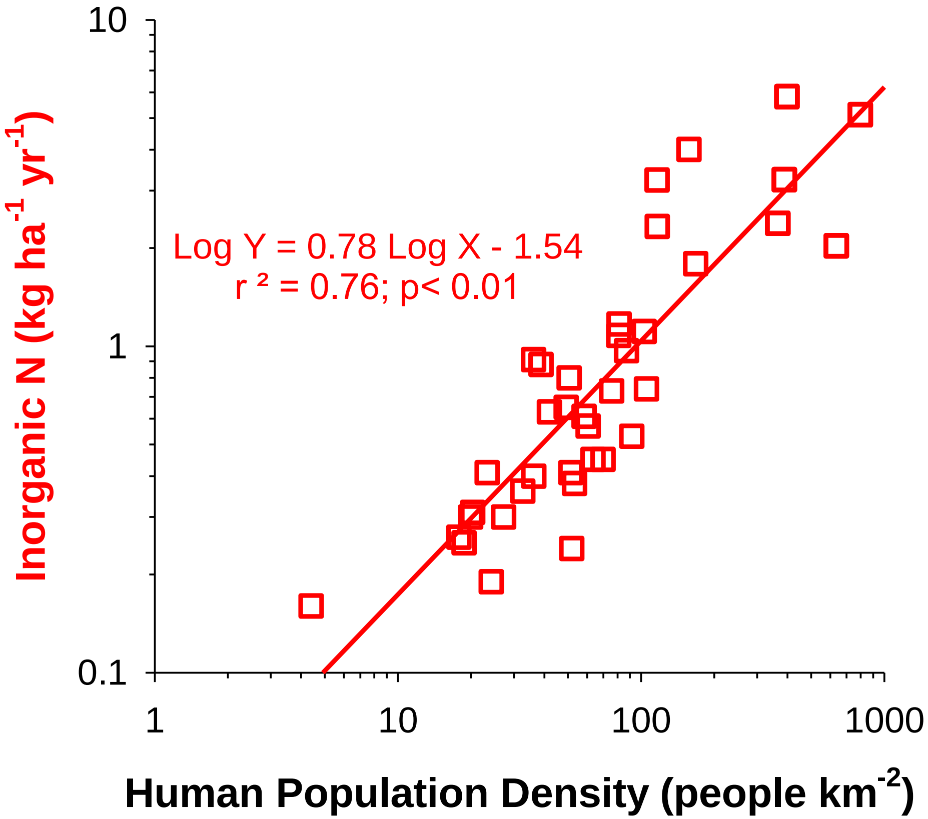


- Piscataqua-Salmon Falls watershed ranked highest in the nation
- 3 of the 4 highest ranked watersheds occur at least partially in New Hampshire

Stein et al. 2009 USDA report "Private Forests, Public Benefits: Increased Housing Density and Other Pressures on Private Forest Contributions"

Moving towards solutions:

How do we break down the relationship between population and N?



Reduce inputs

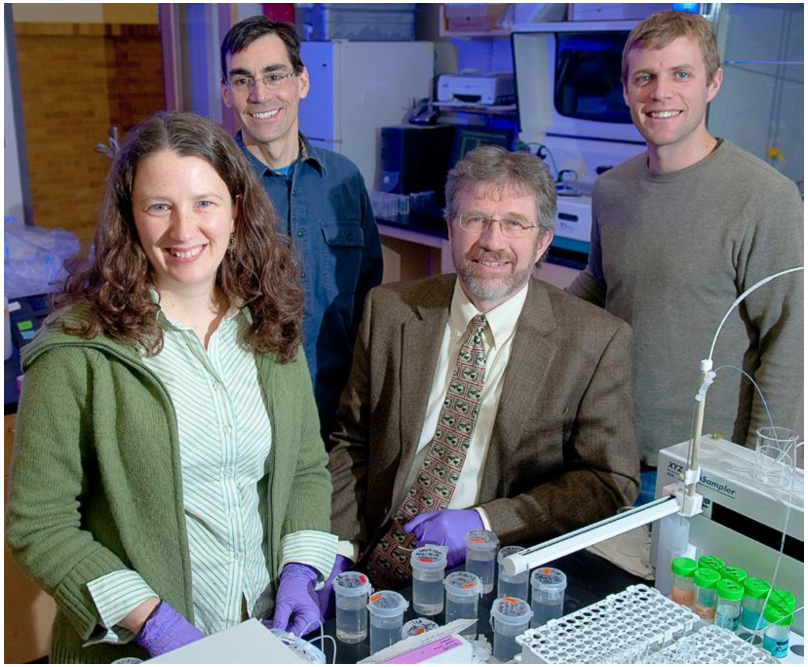
- Reduce fertilizer application (ban/tax)
- Reduce air pollution (local and long-range)
- Reduce N imported in food and feed (reduce meat consumption)

Increase retention or removal

- Improve WWTFs
- Improve new septic systems, retrofit old ones and improve maintenance
- Fix leaky sewer lines and correct illicit discharges
- Improve stormwater management
- Protect and restore vegetated riparian zones

NERRS Science Collaborative Project

Nitrogen Sources and Transport Pathways: Science and Management Collaboration to Reduce Nitrogen Loads in the Great Bay Estuarine Ecosystem



Investigators: Dr. William H. McDowell, Dr. John Bucci, Dr. Erik Hobbie, Dr. Charlie French, Michelle Daley, Jody Potter and Steve Miller

Non-Point N Questions for Great Bay watershed

- What forms of N respond to human activity?
  - Does organic N or particulate N respond to the human footprint in other Great Bay sub-watersheds?
- Are there “hot spots” of N throughout the watershed?
  - How high are N concentrations?
  - Are concentrations higher than expected?
- What N sources are delivered to the stream? What is the delivery pathway?
  - In the Lamprey, only 19% of the N imported to the watershed makes it to the stream
- How efficient is the stream network at removing N?

Great Bay Nitrogen Pollution Source Study
NH DES - Philip.Trowbridge@des.nh.gov

- Modify the **Nitrogen Loading Model[1] (NLM)** developed for Waquoit Bay (Cape Cod) to predict nitrogen inputs and outputs for the 40 HUC12 watersheds in the Great Bay watershed.
- Develop custom N inputs and data layers for the NLM.
  - Septic systems (2010 Census blocks and town sewer lines and surveys)
  - Managed turf (municipal turf (e.g. ball fields) and golf course surveys)
  - Residential turf (determined % of developed area that is turf)
  - Agricultural lands (2011 USDA cropland data for fertilizer)
  - Animal feed inputs (2007 census of agriculture, pets registrations)
  - Impervious surfaces (total and directly connected)
  - atmospheric deposition (local and out-of-state sources)
- Modify retention and loss coefficients along flowpath and validate model using measured loads at 8 major tributary stations

[1] Valiela et al. 1997. *Ecological Applications* 7: 358-380.

In Summary….

- Great Bay is impaired by nitrogen
- Nitrogen issues are complex
- Socioeconomic issues are complex
- Solutions will be equally complex and there is no "silver bullet"
  - Significant reduction in both point and non-point N sources are required
  - Must be innovative
- low impact development and smart growth can help offset population growth

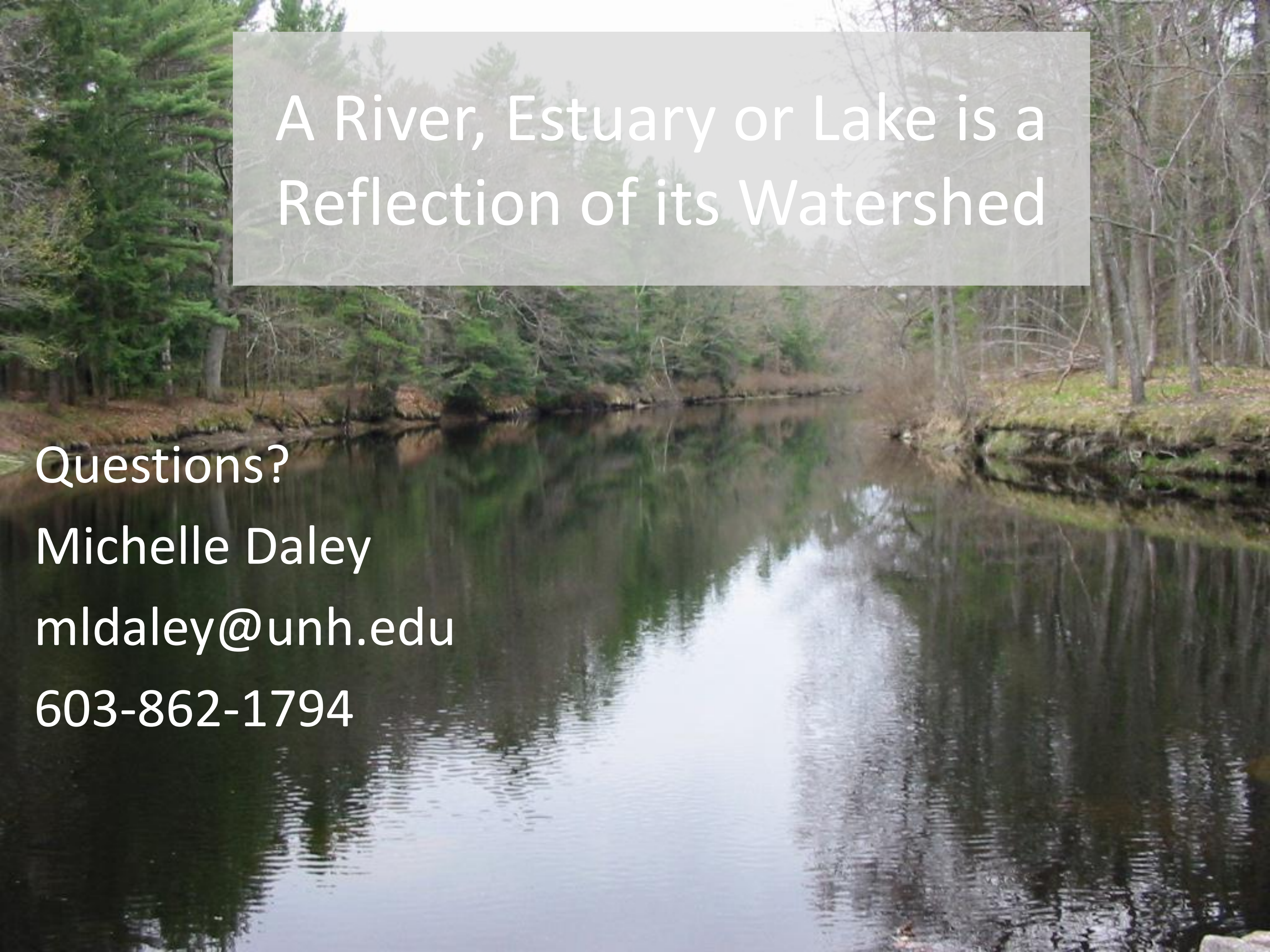
You can do your part at your own home

- Reduce or eliminate fertilizer
- Inspect, maintain and consider upgrading your septic system
- Install rain garden
- Pick up pet waste
- Support WWTF improvements
- Support land conservation

Acknowledgments

- Jeff Merriam, Jody Potter for laboratory assistance
- EPA, NH WRRC, NOAA, UNH Agricultural Experiment Station and LRAC for funding
- Graduate students including Paul Proto, Tracey O'Donnell, and Lauren Buoyofsky
- Undergraduates including Rachael Skokan, Jillana Robinson, Heather Gilbert and Liz Holden

A River, Estuary or Lake is a Reflection of its Watershed



Questions?

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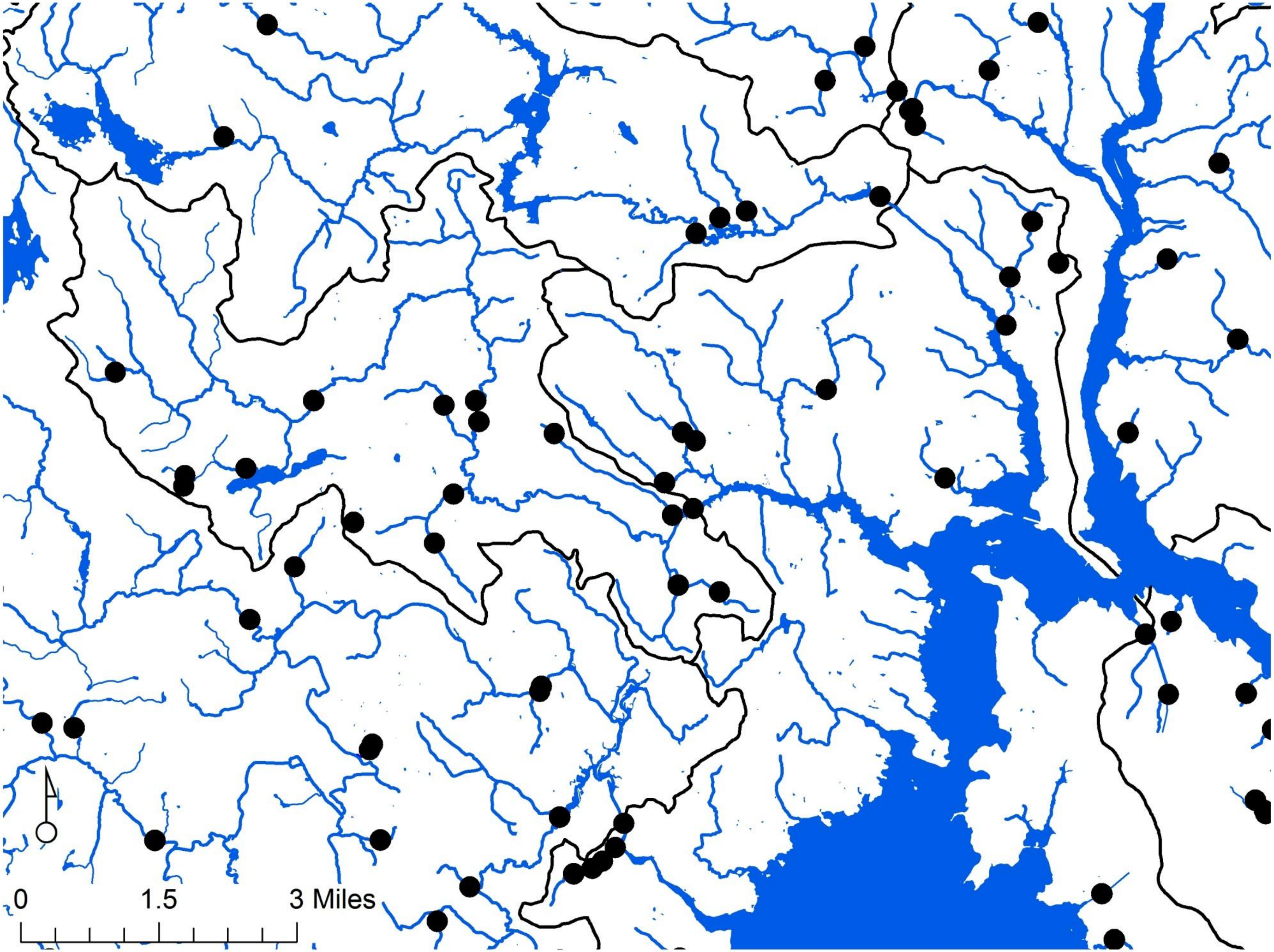
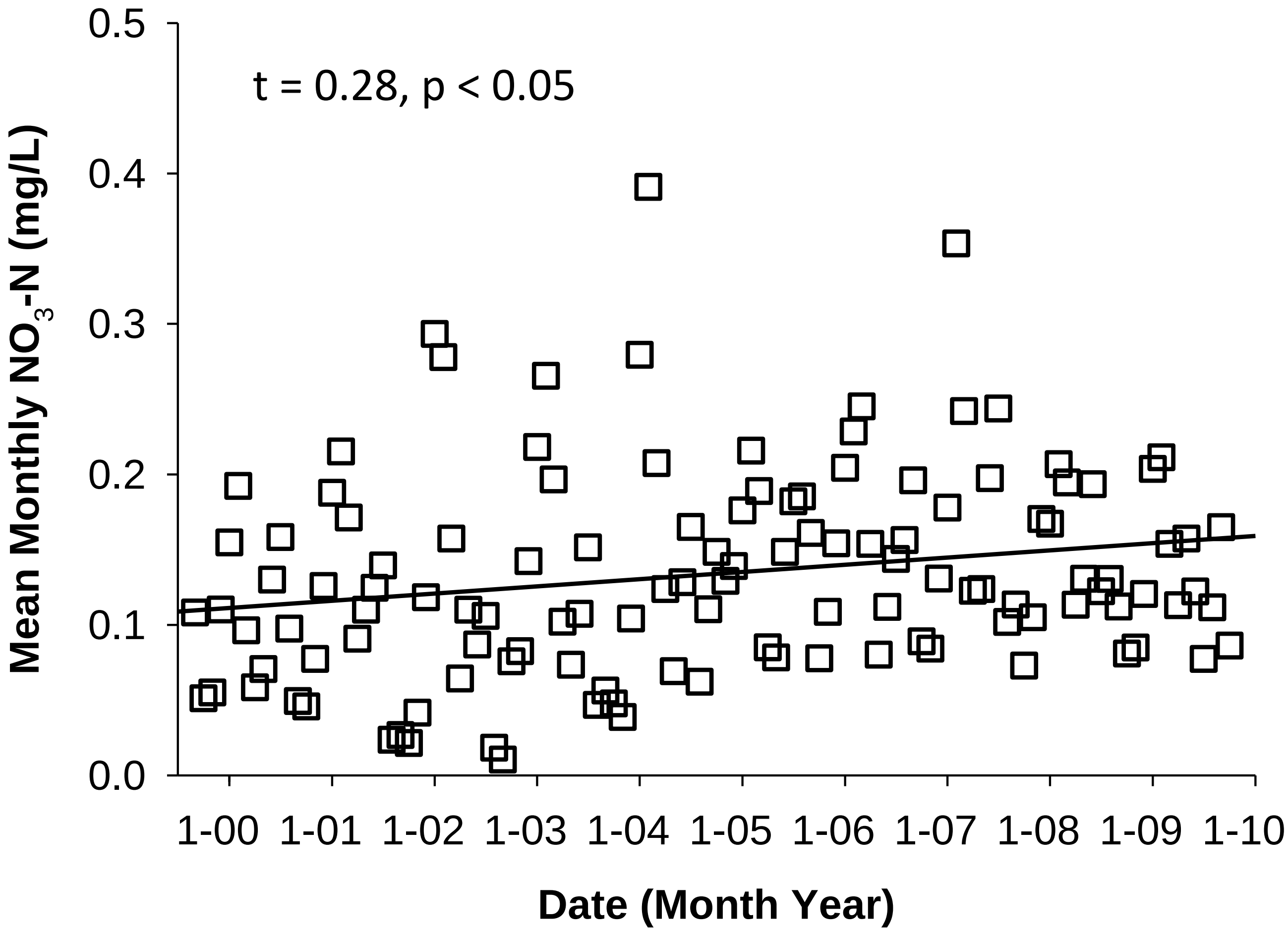

0
1.5
3 Miles

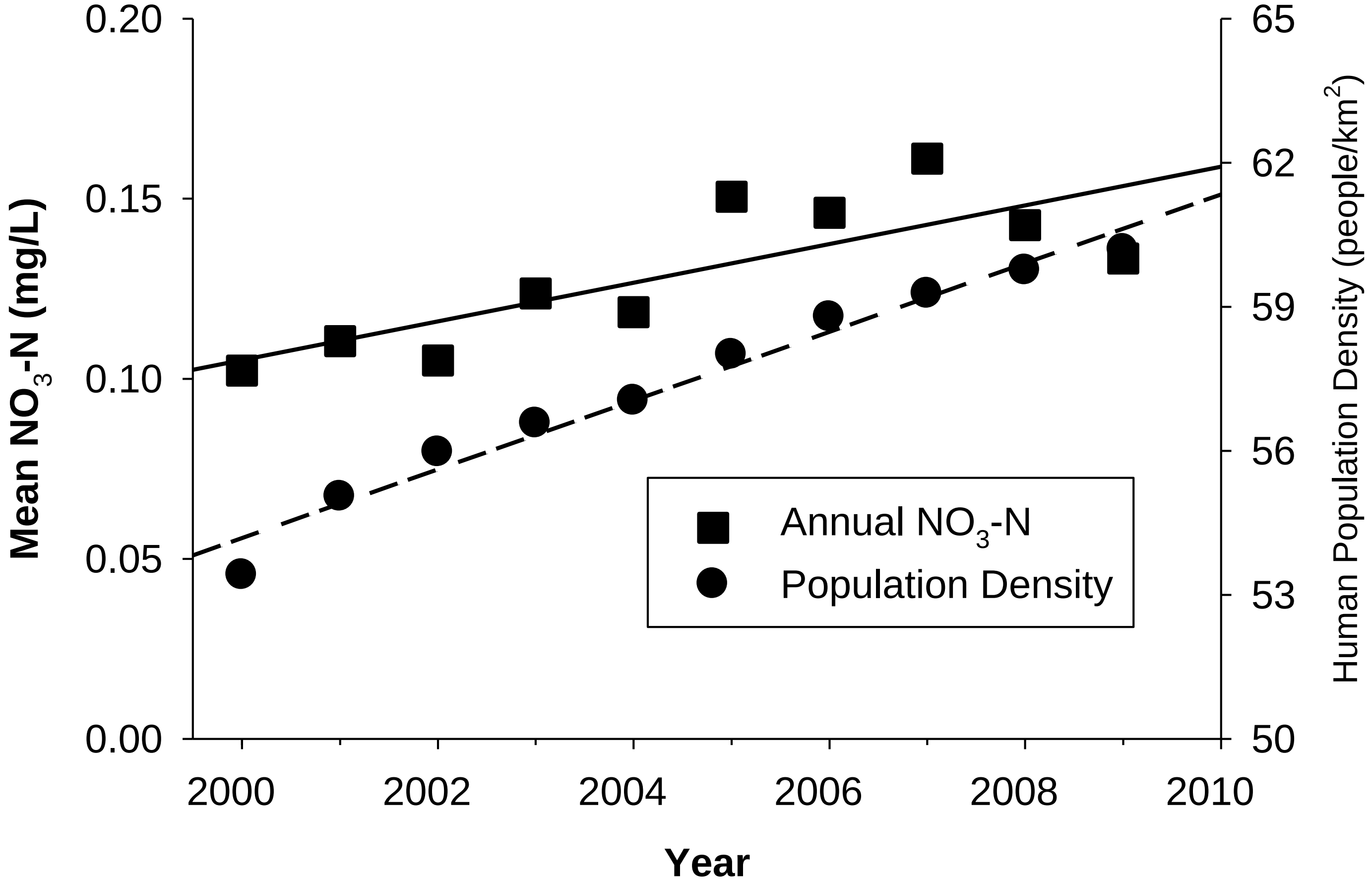
LRHO Nitrogen Research Questions

1. Are there *long-term trends* in LRHO stream chemistry?
   – Weekly, storm event stream water N since 1999 at L73
2. What is the *N budget* for the LRHO?
   – Quantify N inputs, outputs and retention from 2000-2009
3. How do N outputs (and retention) vary for Lamprey and Oyster *sub-basins with different landscape attributes and levels of inputs?*
   – Quantify N budgets, population density, land use and impervious surfaces for various sub-basins

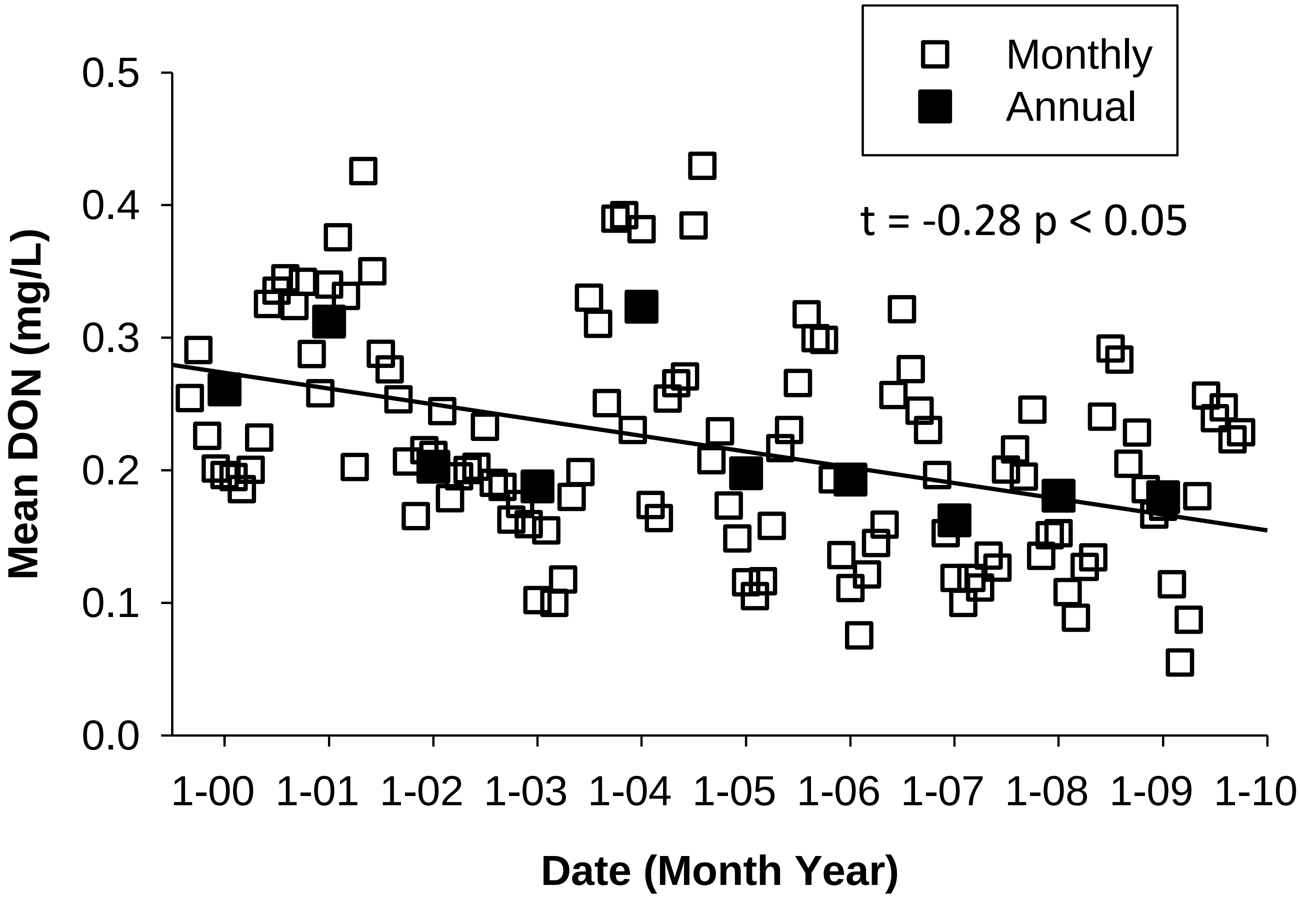
Nitrate (NO_3^-) is increasing in the Lamprey



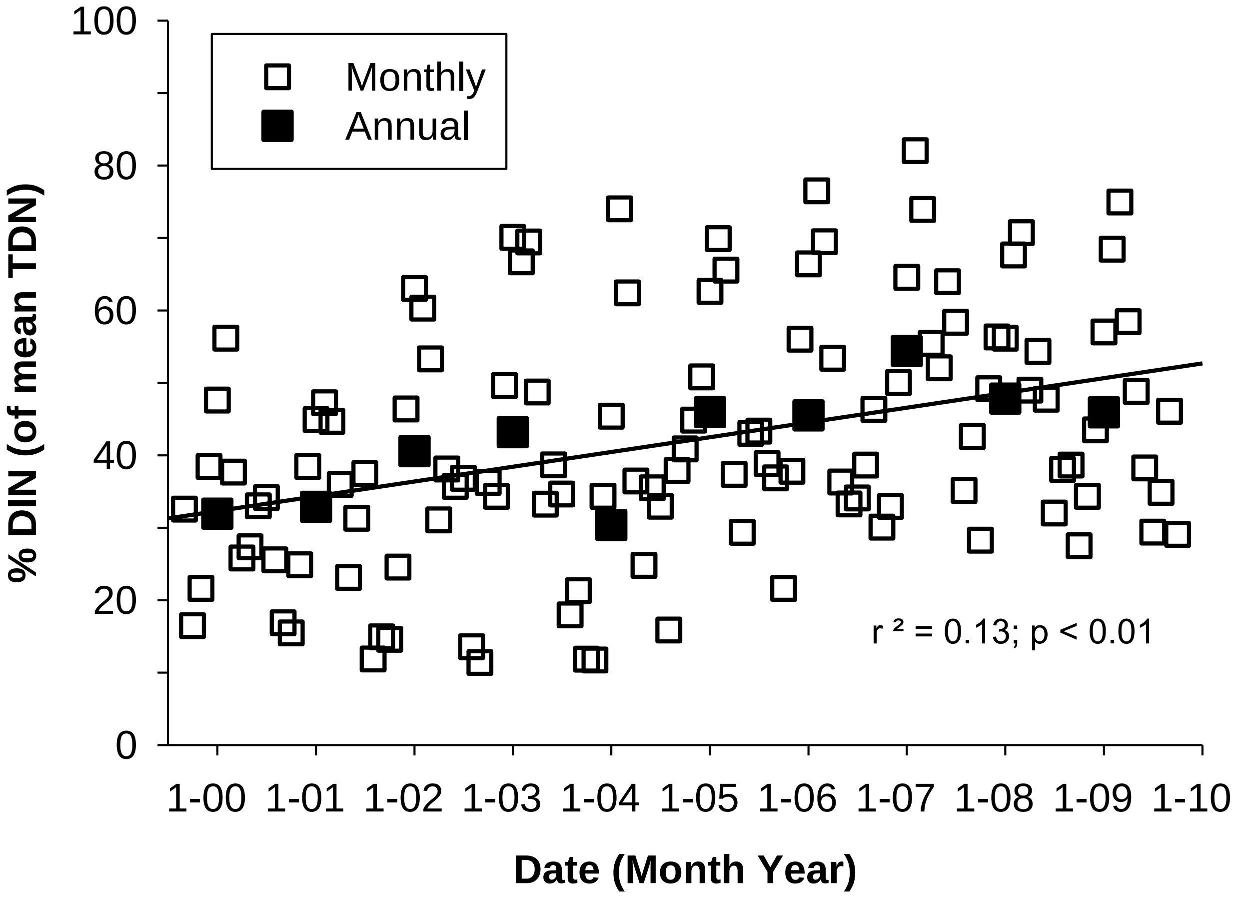
Increase is associated with increasing human population density



Dissolved Organic Nitrogen (DON) is decreasing at L73



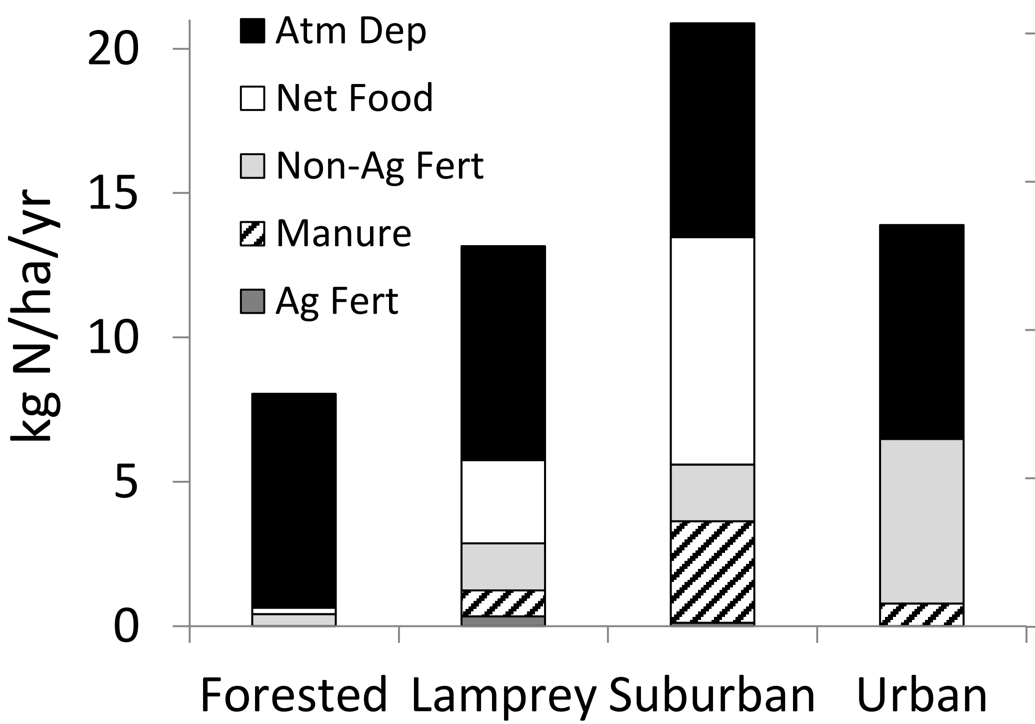
% Dissolved Inorganic Nitrogen (DIN) is increasing at L73



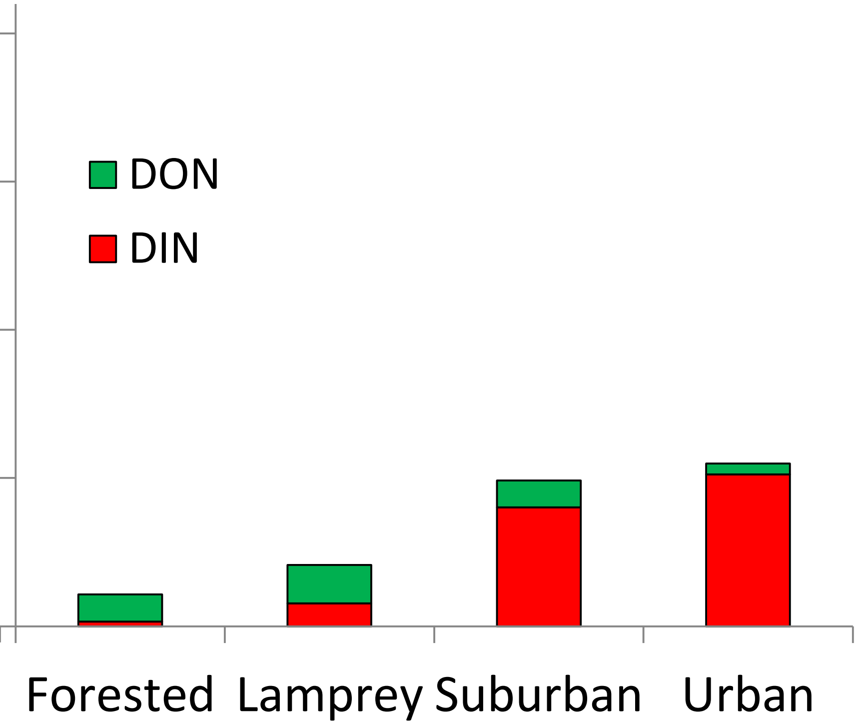
Nitrogen in the Lamprey River is shifting to the most "reactive" or biologically available form - DIN ($NH_4 + NO_3$)

As Watersheds Urbanize...

N Inputs Change

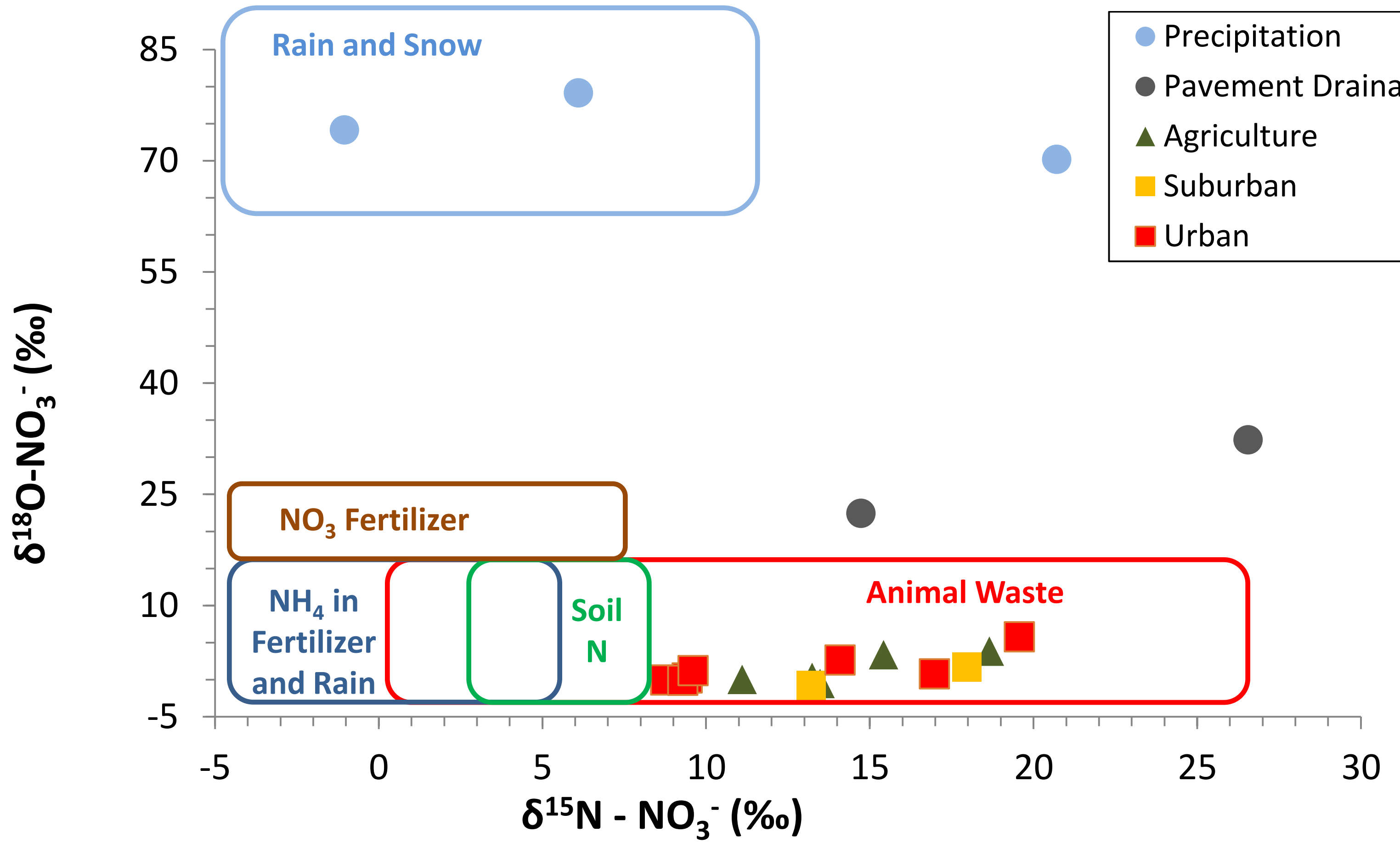


N Outputs Increase



% N Retention Decreases **87%** **81%** **76%** **61%**

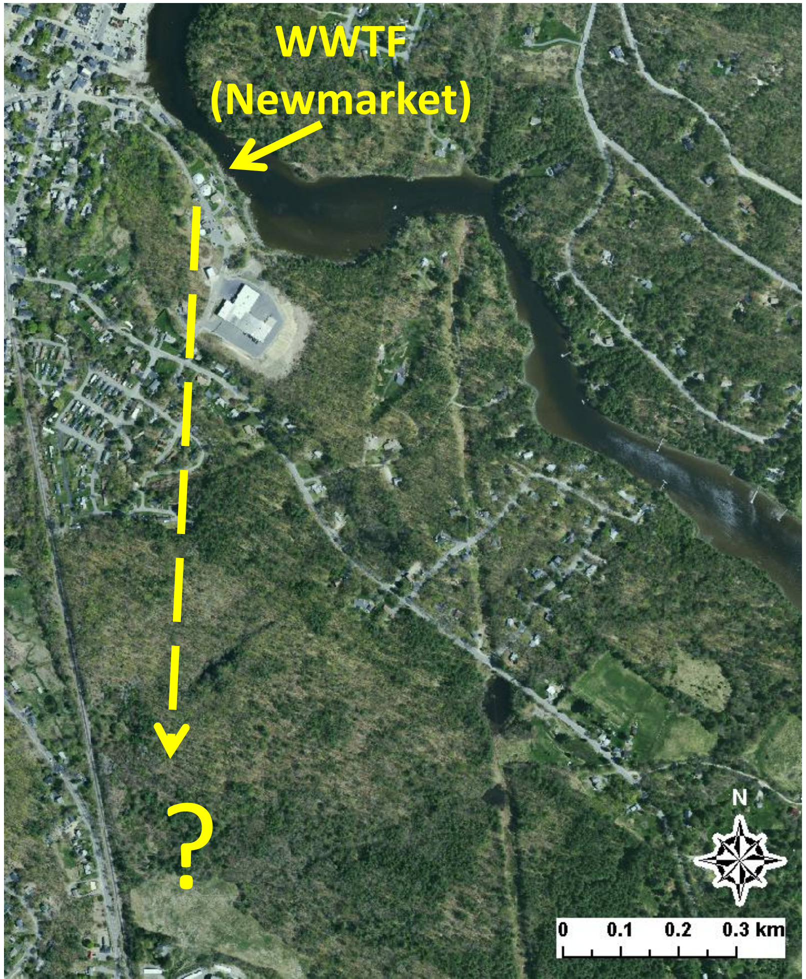
Preliminary nitrate Isotope results indicate animal waste source



Nitrate isotope signatures identified by Kendall 1998

Potential ways to reduce costs of WWTF upgrades

Improve WWTF land apply effluent to use watershed retention capacity?



Produce biofuel from WWTFs effluent?