Suburbanization, Water Quality and Property Values in Three Northern Forest Watersheds

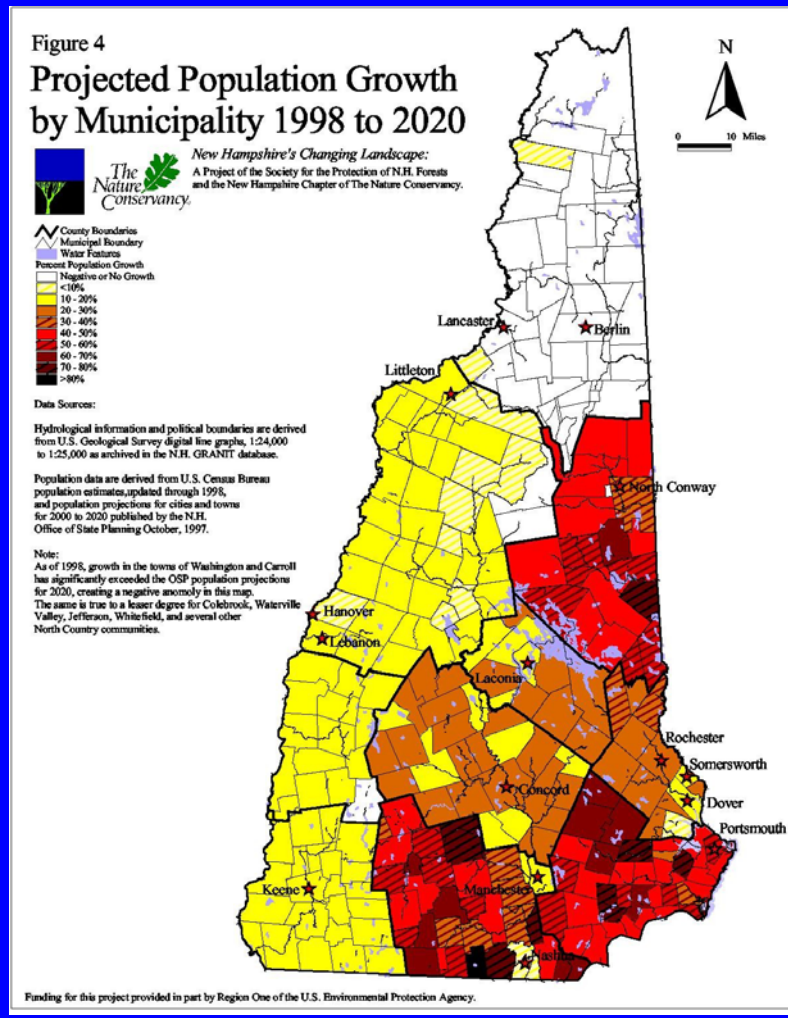
Principal Investigator(s): William H. McDowell
Affiliations/Institutions: University of New Hampshire
Email: bill.mcdowell@unh.edu
Mailing address: 219 James Hall, 56 College Rd., Durham, NH 03824 USA
Collaborators: Tracey Lesser
Completion date: 06/30/05

Human activities can have large impacts on water quality even in largely forested watersheds. Increases in human population density, urban land use and property value are directly related to increases in stream water nitrogen.

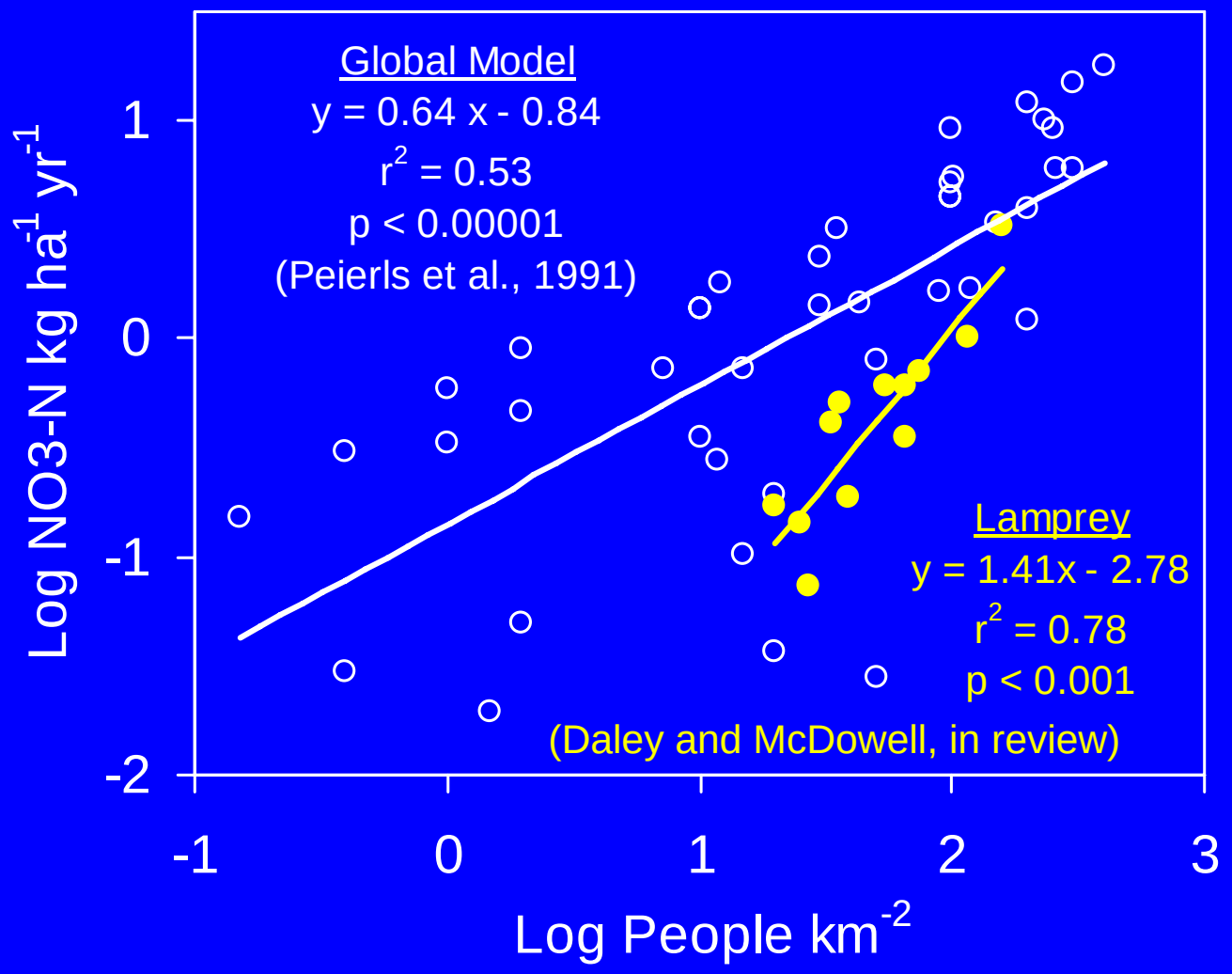
Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service. <http://www.uvm.edu/envnr/nsrc/>

Introduction

- Human activities can have large impacts on water quality (urbanization, sewage treatment, agriculture)
- The Northern Forests of NH are under large pressure for development as a result of population growth and urban sprawl
- The impact of dispersed development on water quality, is poorly understood



Nitrate vs. Population Density



Project Goal:

Examine the relationship between population density, property value and water quality among sub-basins of three watersheds in the northern forest

Hypothesis:

Property values will provide additional explanatory power in the previously established relationships between stream water nitrate and watershed population density. High property values, which are typically associated with large amounts of impervious surfaces (roofs and driveways), are hypothesized increase water quality impacts.

Water Quality Parameters

Nitrate - NO_3^-

- Occurs naturally from nitrification of ammonium
- Contamination of drinking water causes Methemoglobenemia (blue baby syndrome)

Ammonium - NH_4^+

- Occurs naturally from breakdown of organic matter
- Preferred form of nitrogen for biological uptake

Phosphate (PO_4^{-3})

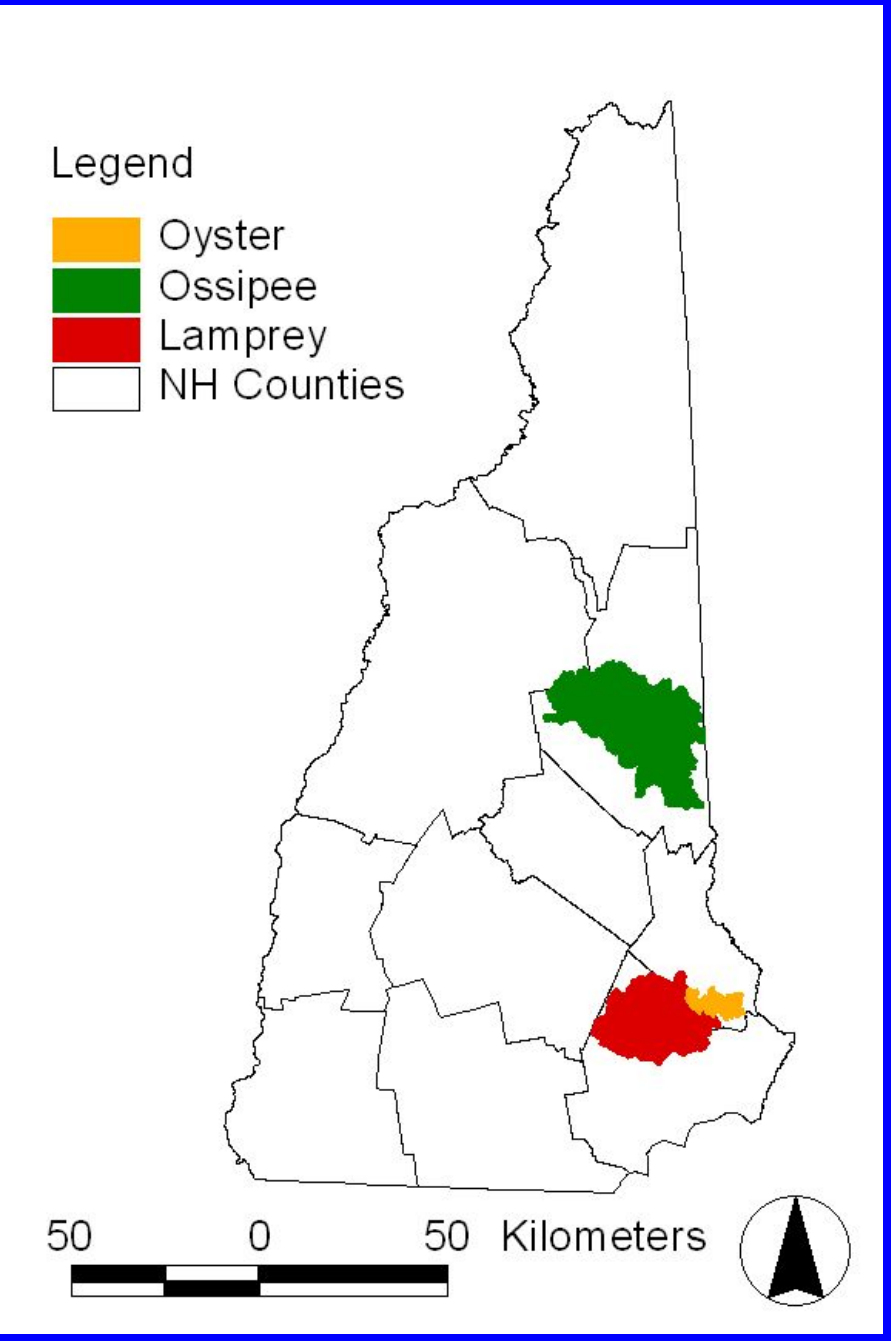
- Most biologically available form of phosphorus
- Typically very low in natural systems

Elevated concentrations of nitrogen and/or phosphorus indicate pollution from sewage, septic systems, fertilizer, agriculture runoff, or other human activities

Nutrient overloads can cause problematic algal blooms and fish kills (fresh waters are typically sensitive to phosphorus and coastal zones and marine systems tend to be sensitive to nitrogen loading)

Dissolved Organic Matter (DOM)

- Natural organic compounds contain carbon (C) and probably contain nitrogen (N)
- Quantity of DOM is indicated by dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) concentrations
- DOC and DON are generated in wetlands and forest soils
- DOM causes brown water, complexes metals and is an important part of the global carbon and nitrogen cycle
- Chlorination of high DOC water leads to trihalomethanes (known carcinogens)



Methods

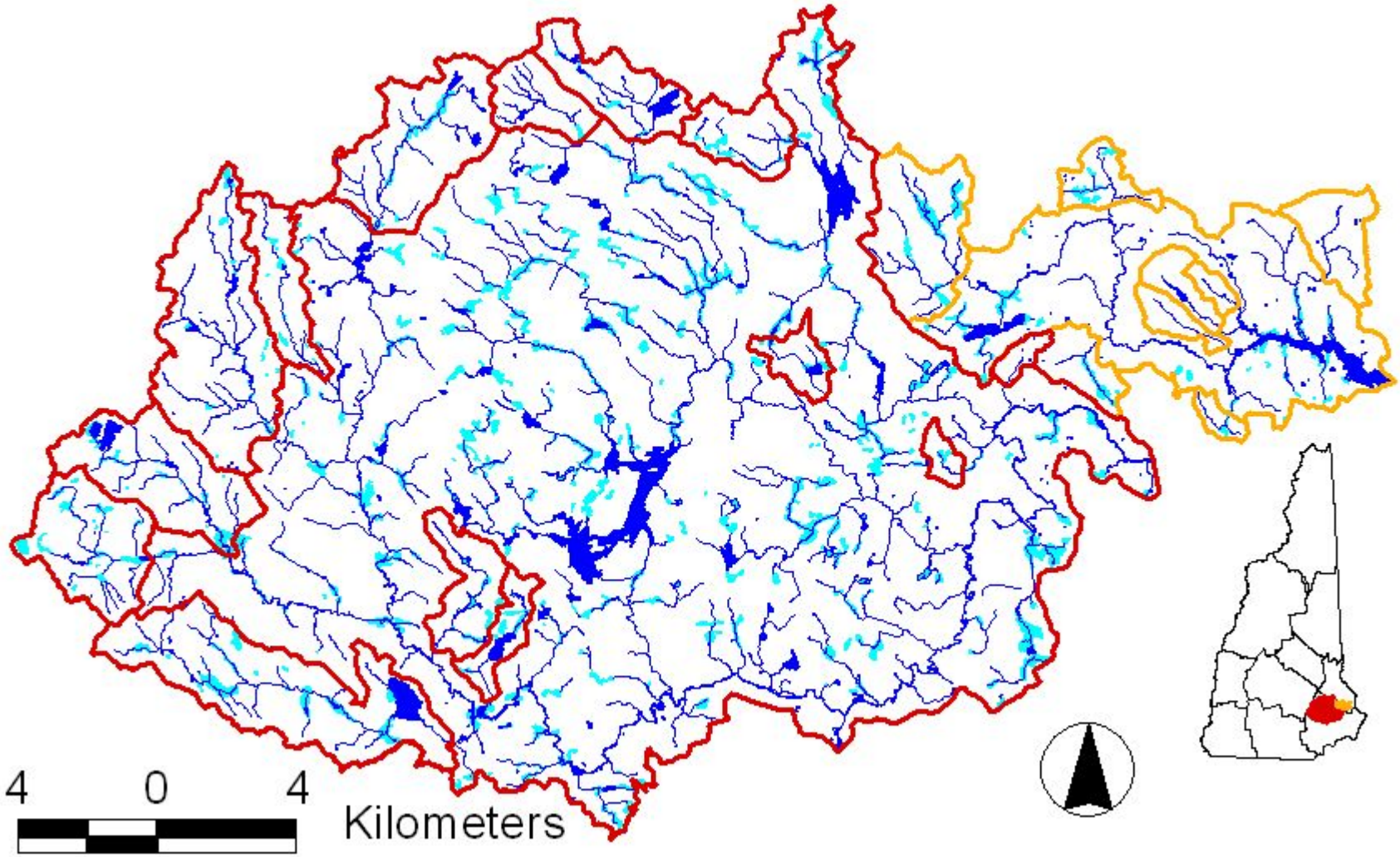
31 Sub-basins of three Northern Forest watersheds were selected for analysis

Lamprey – 15 sub-basins

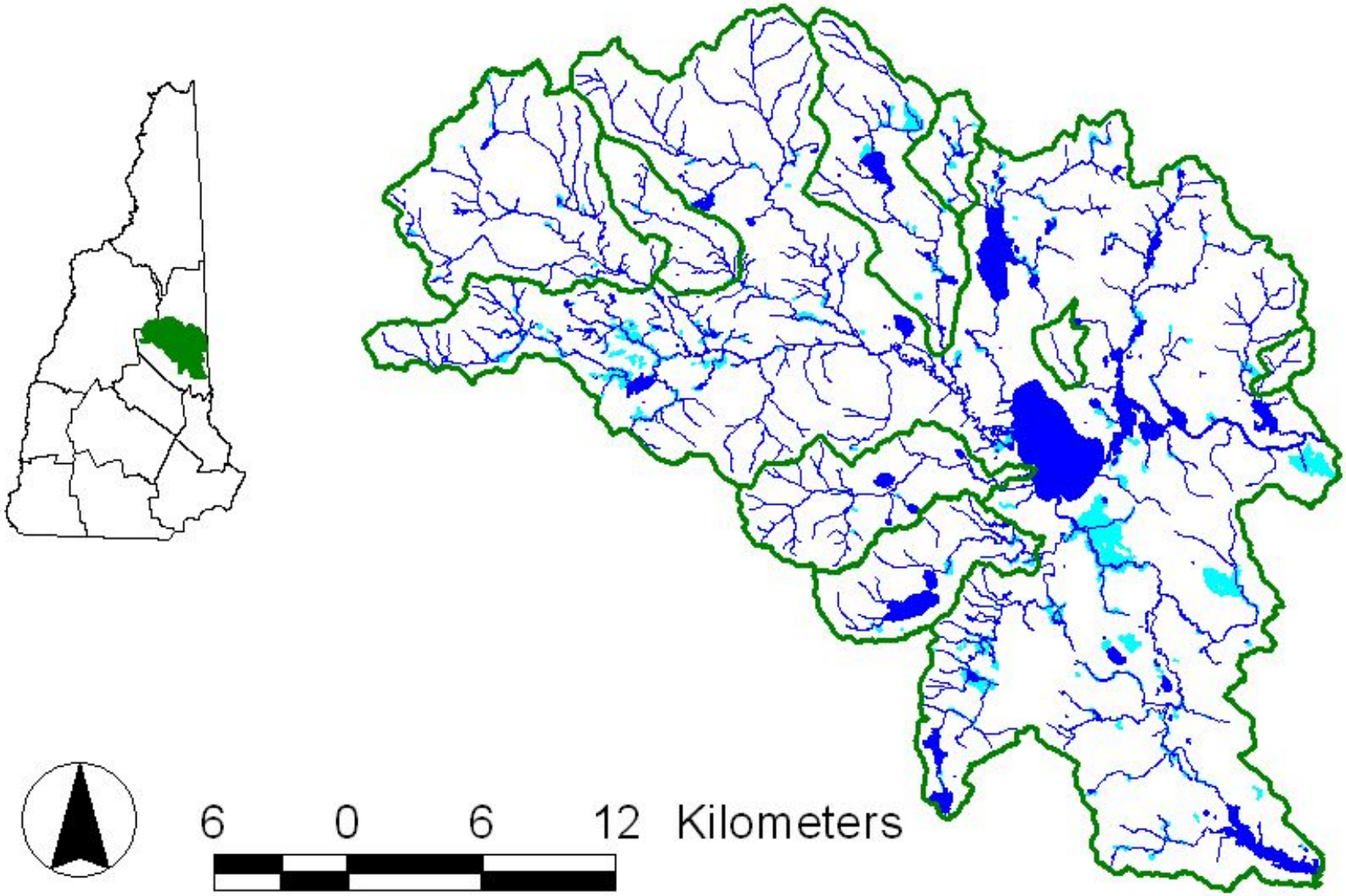
Oyster – 8 sub-basins

Ossipee – 8 sub-basins

Lamprey and Oyster Sub-basins



Ossipee Sub-basins



Stream Sampling

- Streams at sub-basin outlets were sampled once every two weeks during the 2003 calendar year
- Stream gauging was conducted once per week June to December

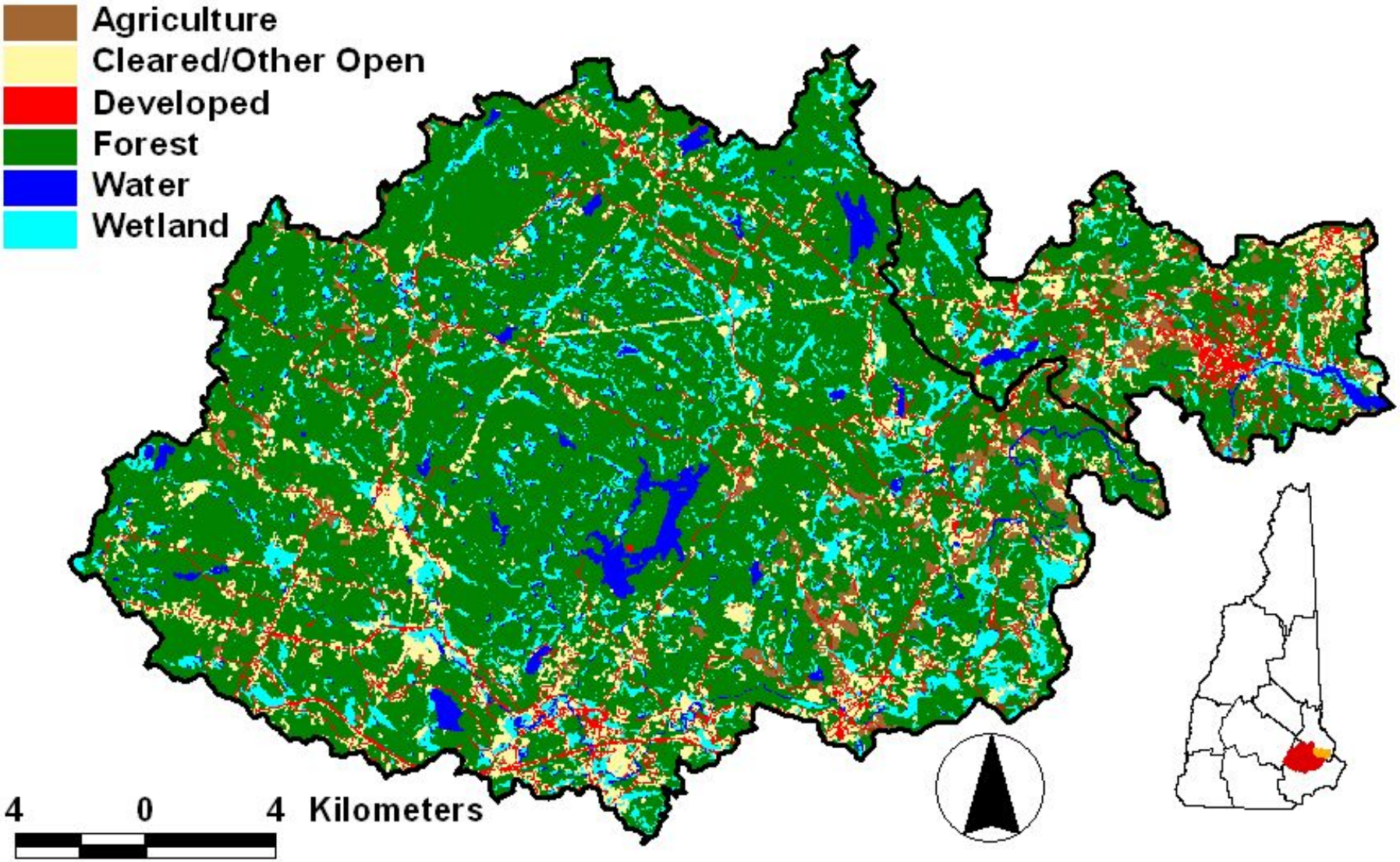
Sample Analysis in UNH Water Quality Lab

- Dissolved Organic Carbon (DOC)
- Dissolved Organic Nitrogen (DON)
- Nitrate
- Ammonium
- Phosphate

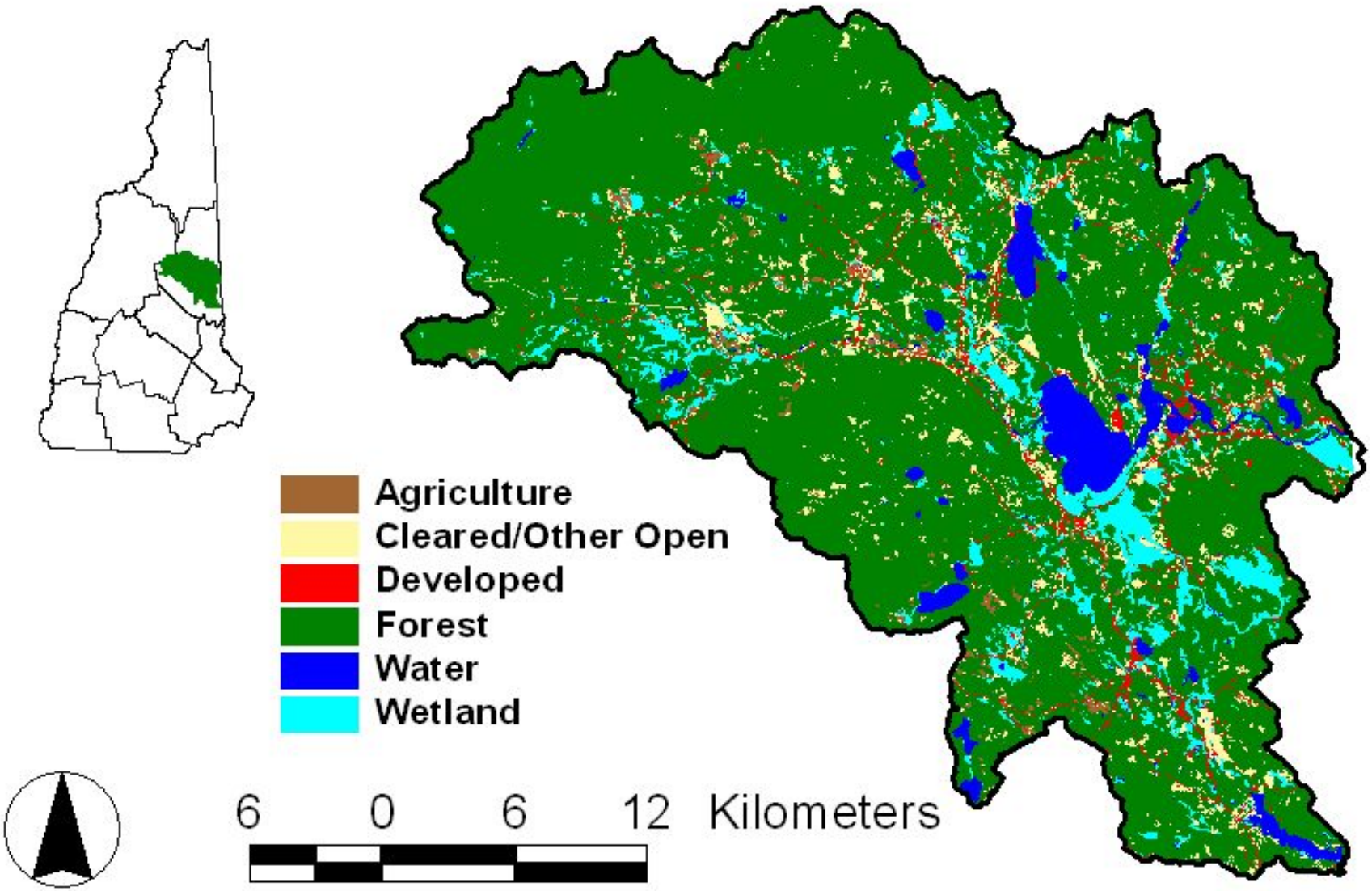
Landscape Characteristics

- Population Density
  - Census 2000 block data
- Property Values
  - Town tax map data used to find assessed property value for each parcel in each sub-basin
  - Town values were equalized using state-wide equalization rates
  - Average property value per km^2 was calculated for each sub-basin
- Land use
  - Determined using GRANIT Land Cover Assessment 2001

Lamprey and Oyster Land Use

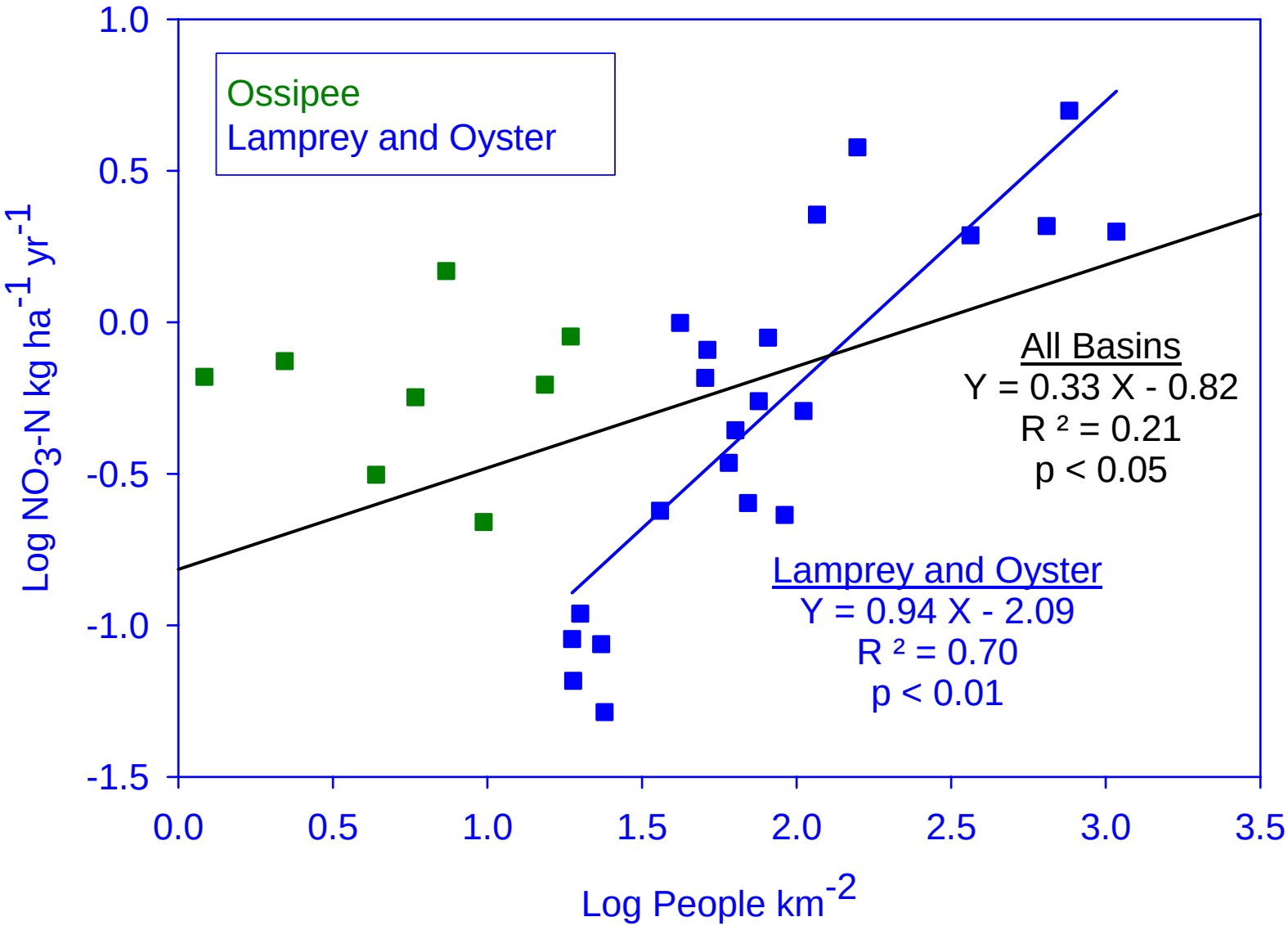


Ossipee Land Use

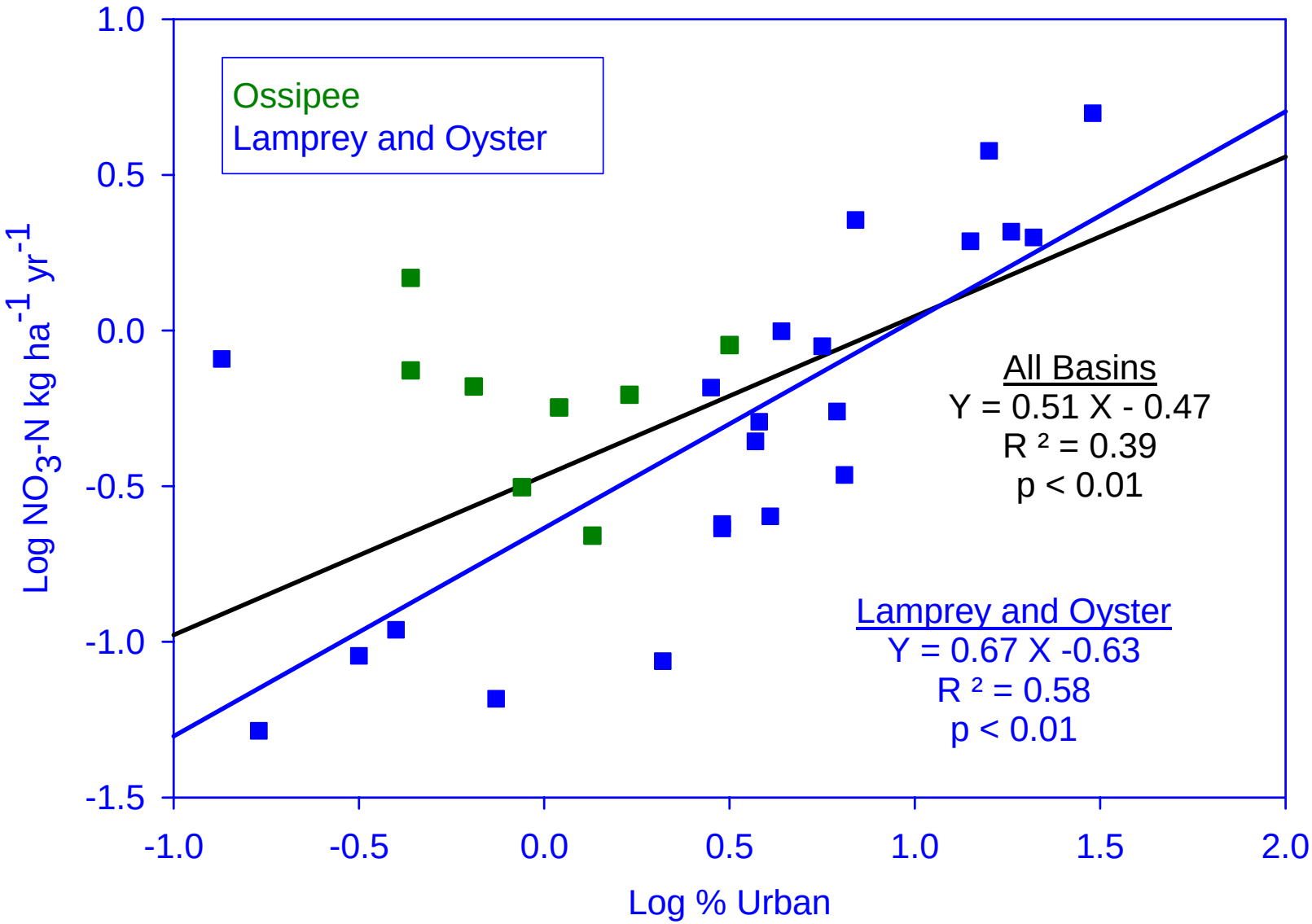


Results

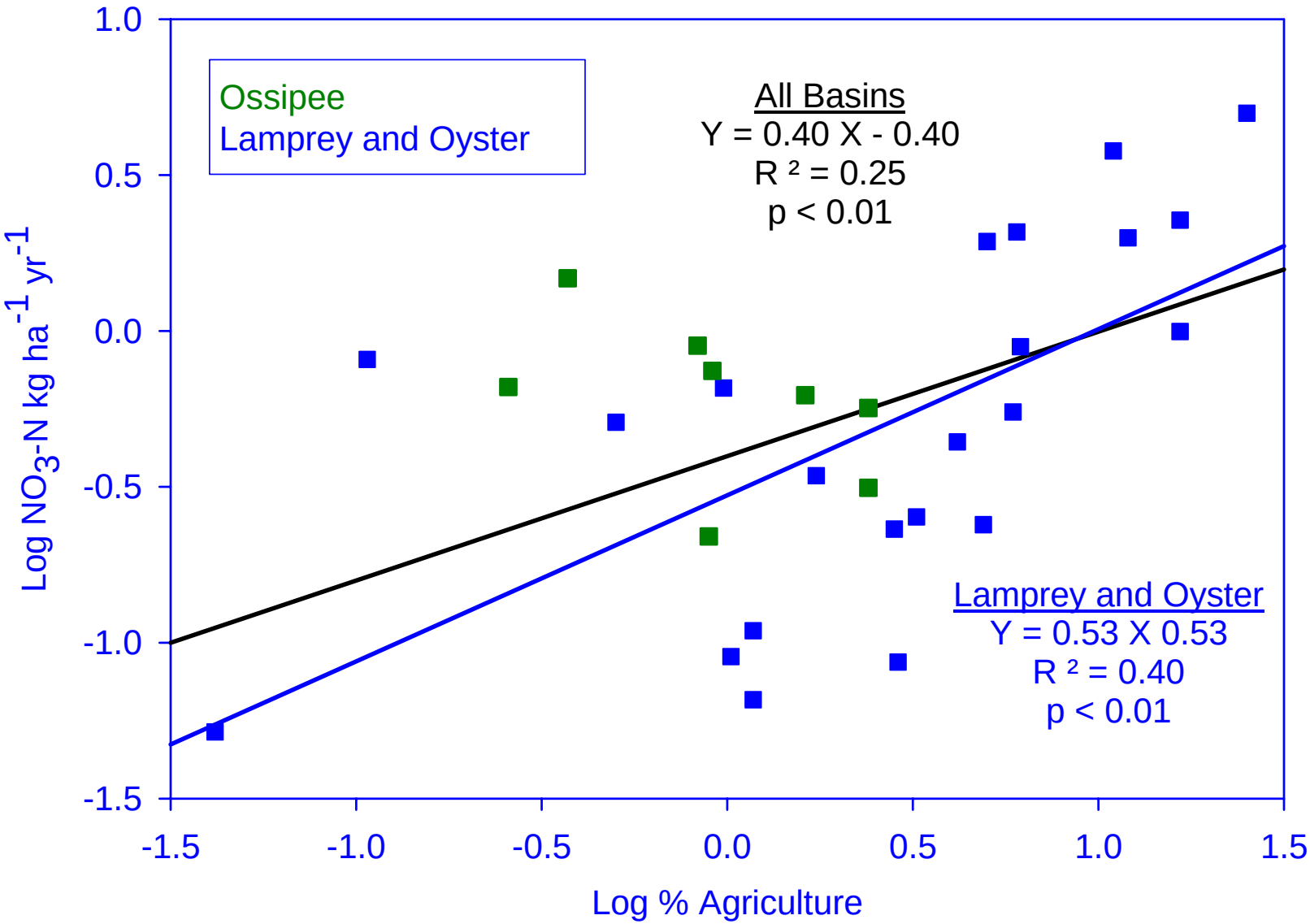
Nitrate vs. Population Density



Nitrate vs. Urban



Nitrate vs. Ag



Multiple Regression Analysis Used to Develop Best Model for Nitrate

All Basins

Y = 0.498 * Log % Urban – 0.029 * % Wetland – 0.237

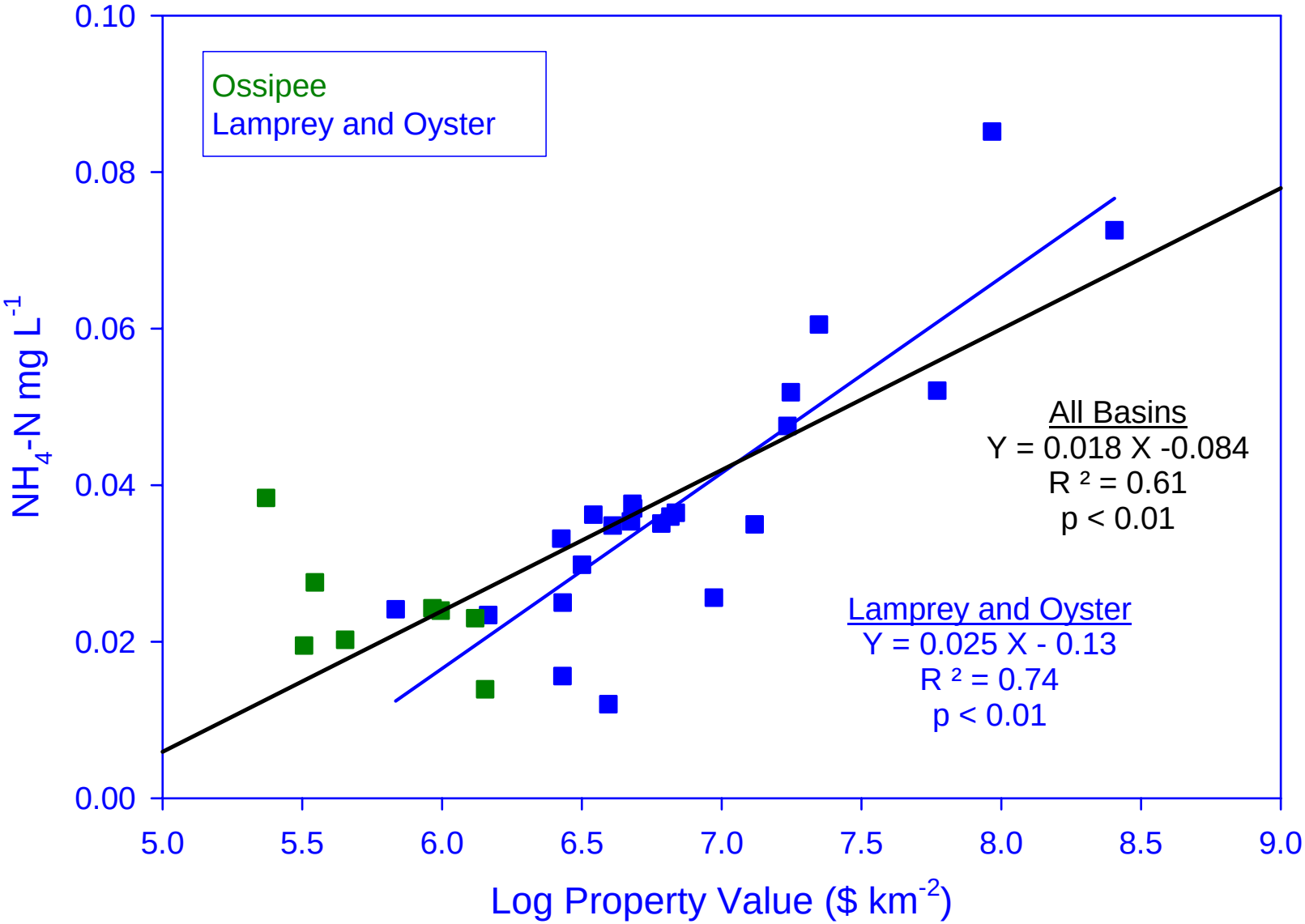
$R^2 = 0.48$, $p < 0.01$

Lamprey and Oyster

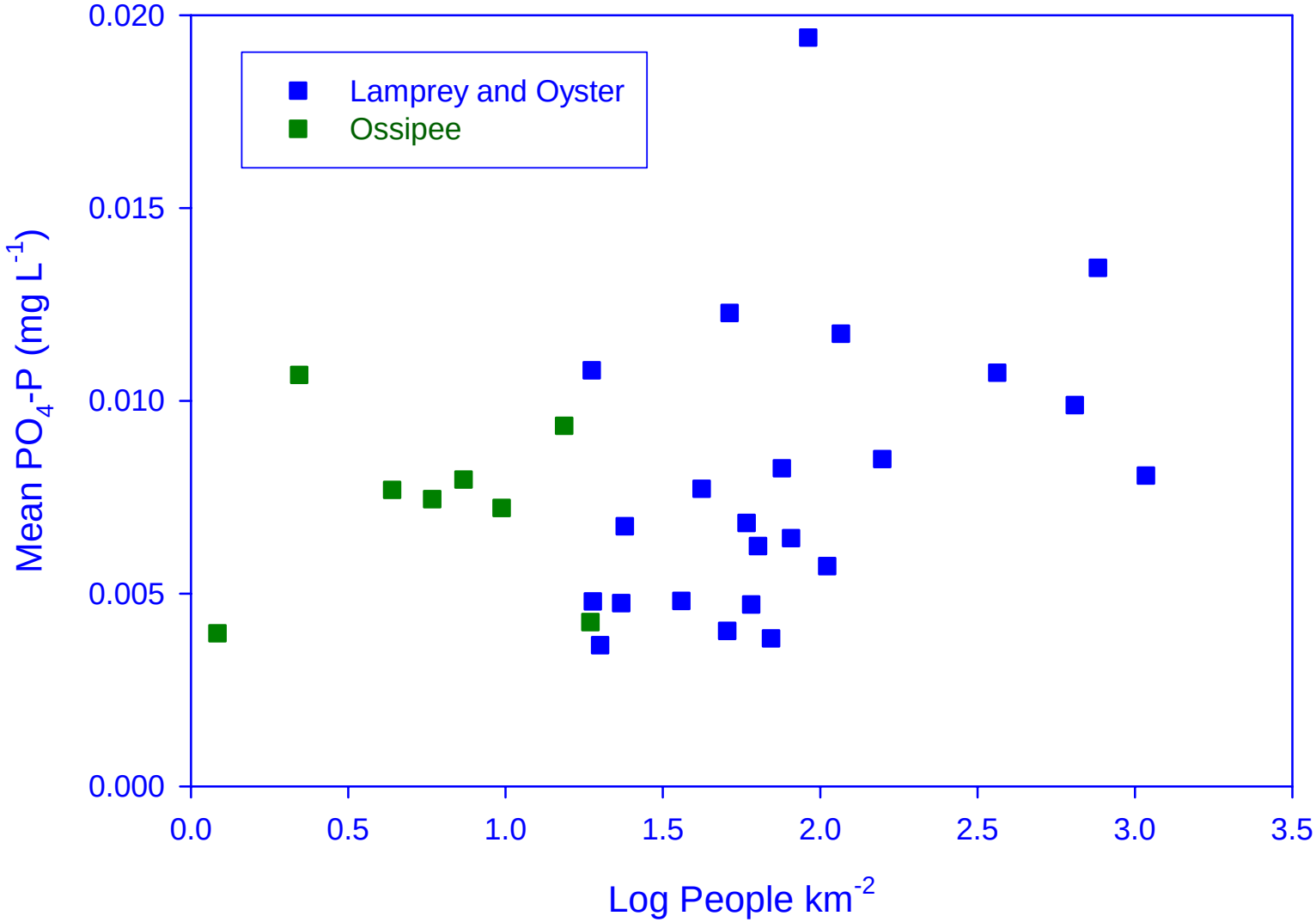
Y = 0.787 * Log Population Density + 0.21 * Log Agriculture – 1.889

$R^2 = 0.74$, $p < 0.01$

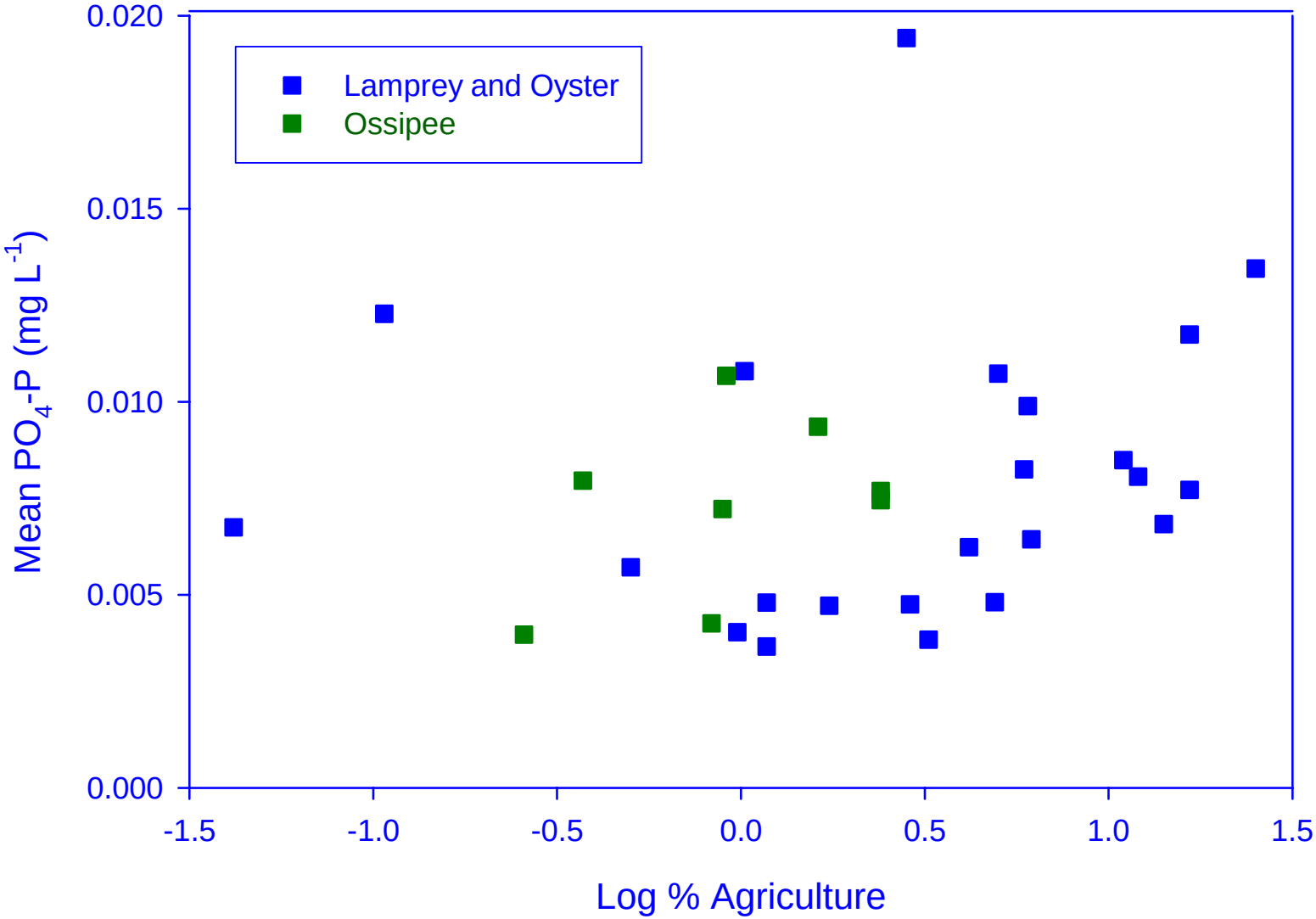
Ammonium vs. Property Value



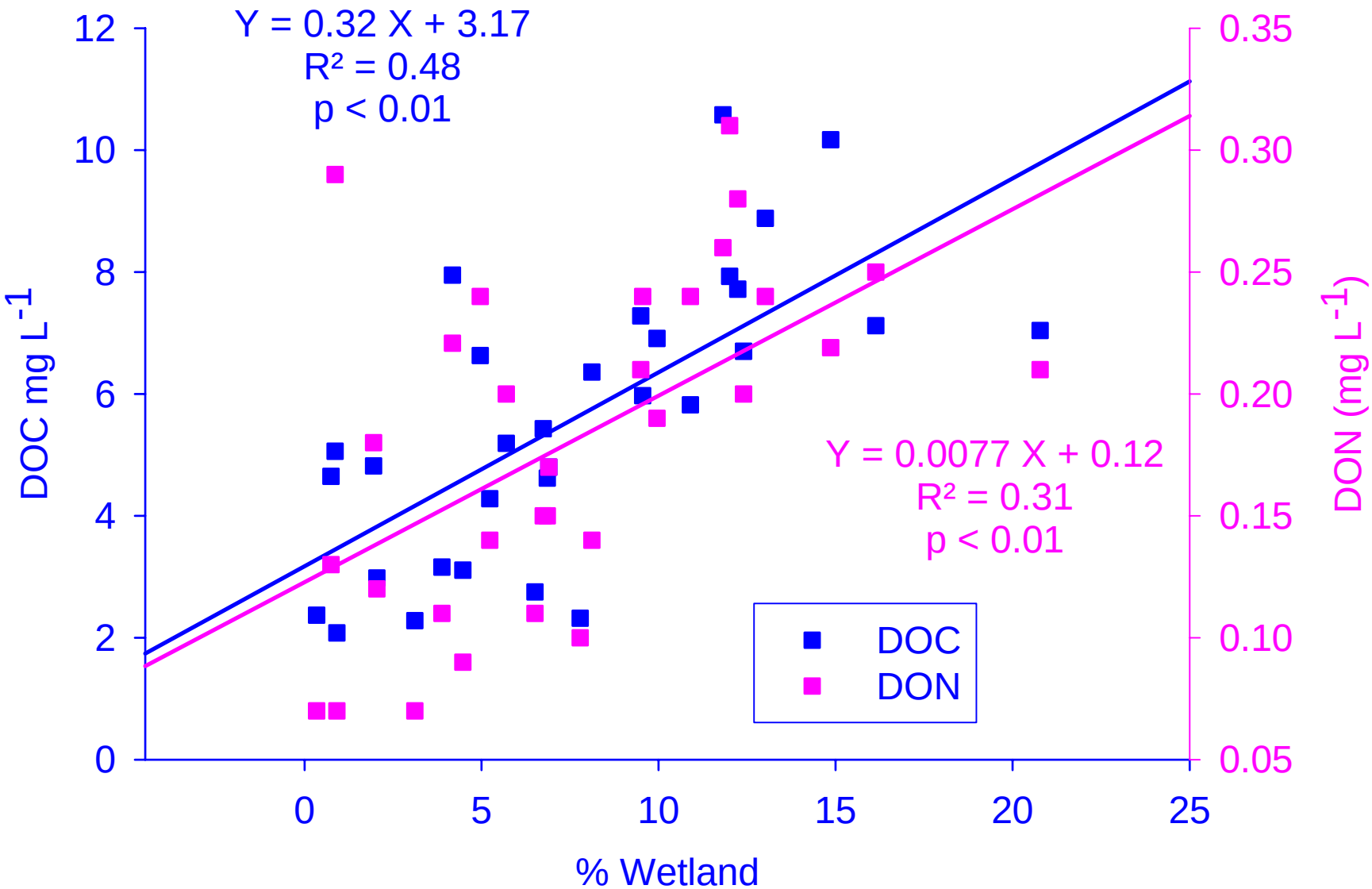
Phosphate vs. Population Density



Phosphate vs. Agriculture



DOM vs. Wetlands



Implications and applications in the Northern Forest region

- With projected increases in human population and urbanization in New Hampshire's Northern Forests, we can expect a corresponding increase in stream water nitrate
- Increases in stream water ammonium will correlate to increases in property value associated with infrastructure and impervious surfaces
- Phosphate remains relatively low in New Hampshire's Northern Forest streams and is not impacted by current development patterns

Future directions

- If population density and urban land use have negative impacts on surface water quality, are there also negative impacts on groundwater quality?
- Currently, there is a large amount of nitrogen retention in New Hampshire's Northern Forests (i.e. Nitrogen Inputs to watersheds via atmospheric deposition, septage/sewage and fertilizers >> Nitrogen outputs in stream water).
- Wetlands, forest soils, riparian zones and in-stream processes can retain/transform nitrogen. *However*, the mechanisms controlling nitrogen retention and transformations are poorly understood.
- Changes in nitrogen retention could exacerbate impacts of population growth. Understanding these mechanisms is critical to making accurate predictions about future water quality.

Nitrogen Inputs and Outputs from the Lamprey River Basin

Year	Food Input	Fertilizer Input	DIN Atm Deposition	Total Input	DIN Output	% retention
2000	2.7	1.8	9.0	13.6	0.62	95%
2001	2.7	1.8	7.4	12.0	0.72	94%
2002	2.8	1.8	8.4	13.0	0.41	97%
2003	2.9	1.8	7.3	12.1	0.69	94%

Units = kg N ha^{-1} yr^{-1}

List of products

- Lesser and McDowell, in prep. Using socioeconomic factors to predict water quality in Northern Forest watersheds.
- O'Donnell T.E. 2004. Suburbanization, water quality and property values in three northern forest watersheds. Thesis, University of New Hampshire, Durham, NH
- McDowell, W.H.. 2005. Biogeochemistry of suburban basins- putting people into the landscape. University of Vermont, Water in the Environment seminar series, April 2005
- McDowell, W.H. 2005. Biogeochemistry of suburban basins- putting people into the landscape. Institute of Ecosystem Studies, Millbrook NY, March 2005

List of Products (continued)

- O'Donnell, T.E. 2004. Suburbanization, water quality and property values in three northern forest watersheds. Northeastern Ecosystem Research Cooperative Conference. Durham, NH. November 2004.
- McDowell, W.H. 2004. Suburbanization and water quality in New Hampshire. Soul of Agriculture 4th Annual Conference, Durham, NH. November, 2004.
- O'Donnell, T.E., W.H. McDowell and M.L. Daley. 2004. Suburbanization, water quality and property values in three northern forest watersheds. 10th Annual Maine Water Conference, April 2004
- Spin-off grant – Connecticut River Airshed-Watershed Consortium, U.S. EPA Cooperative Agreement. 2002-2007. Land Surface-Groundwater interface Research. $944,430

If shorter presentation is desired, delete slides 4, 9, 11, 12, 16, 17, 18, 21, 25, 29