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

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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.

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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

Global Model
\[ y = 0.64x - 0.84 \]
\[ r^2 = 0.53 \]
\[ p < 0.00001 \]
(Peierls et al., 1991)

Lamprey
\[ y = 1.41x - 2.78 \]
\[ r^2 = 0.78 \]
\[ p < 0.001 \]
(Daley and McDowell, in review)
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 - $\text{NO}_3^-$
- Occurs naturally from nitrification of ammonium
- Contamination of drinking water causes Methemoglobinemia (blue baby syndrome)

Ammonium - $\text{NH}_4^+$
- 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 km² was calculated for each sub-basin

• Land use
  – Determined using GRANIT Land Cover Assessment 2001
Lamprey and Oyster Land Use

- Agriculture
- Cleared/Other Open
- Developed
- Forest
- Water
- Wetland
Ossipee Land Use
Results
Nitrate vs. Population Density

Ossipee
Lamprey and Oyster

Y = 0.94 X - 2.09
R² = 0.70
p < 0.01

All Basins
Y = 0.33 X - 0.82
R² = 0.21
p < 0.05

Lamprey and Oyster
Y = 0.94 X - 2.09
R² = 0.70
p < 0.01
Nitrate vs. Urban

Y = 0.51 X - 0.47
R^2 = 0.39
p < 0.01

Y = 0.67 X - 0.63
R^2 = 0.58
p < 0.01
Nitrate vs. Ag

All Basins
\[ Y = 0.40X - 0.40 \]
\[ R^2 = 0.25 \]
\[ p < 0.01 \]

Ossipee Lamprey and Oyster
\[ Y = 0.53X + 0.53 \]
\[ R^2 = 0.40 \]
\[ p < 0.01 \]
Multiple Regression Analysis
Used to Develop Best Model for Nitrate

**All Basins**

\[ Y = 0.498 \times \log \% \text{ Urban} - 0.029 \times \% \text{ Wetland} - 0.237 \]

\[ R^2 = 0.48, \ p < 0.01 \]

**Lamprey and Oyster**

\[ Y = 0.787 \times \log \text{Population Density} + 0.21 \times \log \text{Agriculture} - 1.889 \]

\[ R^2 = 0.74, \ p < 0.01 \]
Ammonium vs. Property Value

NH₄⁻N mg L⁻¹ vs. Log Property Value ($ km⁻²)

- **All Basins**
  - Equation: $Y = 0.018 X -0.084$
  - $R^2 = 0.61$
  - $p < 0.01$

- **Ossipee Lamprey and Oyster**
  - Equation: $Y = 0.025 X - 0.13$
  - $R^2 = 0.74$
  - $p < 0.01$

- **Lamprey and Oyster**
  - Equation: $Y = 0.025 X - 0.13$
  - $R^2 = 0.74$
  - $p < 0.01$
Phosphate vs. Population Density

Mean PO₄-P (mg L⁻¹) vs. Log People km⁻²
Phosphate vs. Agriculture

Mean $\text{PO}_4^2-$P (mg L$^{-1}$)

Log % Agriculture

Lamprey and Oyster
Ossipee
DOM vs. Wetlands

\[ Y = 0.32X + 3.17 \]
\[ R^2 = 0.48 \]
\[ p < 0.01 \]

\[ Y = 0.0077X + 0.12 \]
\[ R^2 = 0.31 \]
\[ p < 0.01 \]
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

<table>
<thead>
<tr>
<th>Year</th>
<th>Food Input</th>
<th>Fertilizer Input</th>
<th>DIN Atm Deposition</th>
<th>Total Input</th>
<th>DIN Output</th>
<th>% retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2.7</td>
<td>1.8</td>
<td>9.0</td>
<td>13.6</td>
<td>0.62</td>
<td>95%</td>
</tr>
<tr>
<td>2001</td>
<td>2.7</td>
<td>1.8</td>
<td>7.4</td>
<td>12.0</td>
<td>0.72</td>
<td>94%</td>
</tr>
<tr>
<td>2002</td>
<td>2.8</td>
<td>1.8</td>
<td>8.4</td>
<td>13.0</td>
<td>0.41</td>
<td>97%</td>
</tr>
<tr>
<td>2003</td>
<td>2.9</td>
<td>1.8</td>
<td>7.3</td>
<td>12.1</td>
<td>0.69</td>
<td>94%</td>
</tr>
</tbody>
</table>

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.
List of Products (continued)


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