Non-Point Nitrogen Sources and Transport in the Great Bay Watershed

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Eutrophication-associated dead zones and the human footprint

Decline in water quality and aquatic life in Great Bay

- New Hampshire’s most significant estuary
- Watershed is home to almost 25% of NH’s population
- Watershed intersects 52 communities
- Deterioration of water quality and aquatic life
  - Low dissolved oxygen (DO)
  - Increased suspended sediment and nitrogen
  - Loss of eelgrass
  - Loss of oysters and clams
  - Nitrogen impaired

Eelgrass Photo Credit: Fred Short
N loading to Great Bay

- 32% Point Sources
- 68% non-point sources
Objectives

Integrate research with stakeholders to ensure results are useful and accessible

Address these questions:

1. How do surface water nitrogen concentrations respond to varying watershed landscape characteristics and N inputs?
2. What non-point sources of N reach surface waters?
Integrate research with stakeholders

• Nitrogen sources collaborative advisory board (NSCAB)
  – 15 members
  – Approximately quarterly meetings
• Nitrogen Sources Newsbites – 150 diverse stakeholders
• NSCAB trust the science and advocate for improved management
Characterizing nitrogen concentrations...

- 5 extensive sampling campaigns (2010-2012)
- 236 stream sites
  - Urban, suburban and agricultural land use
- Median N concentrations:
  - Dissolved inorganic N (DIN)
    - Nitrate (NO$_3$)
    - Ammonium (NH$_4$)
  - Dissolved organic N (DON)
  - Total dissolved N (TDN)
...and watershed landscape features

**Human impact**
- Human population density (0-2,017/km²)
  - Septic
  - Sewer
- % Impervious (0-68%)
- % Developed (0-100%)
  - High intensity
  - Medium intensity
  - Low intensity
  - Open space

**Agriculture**
- Cultivated crops (0-17%)
- Pasture or hay (0-68%)

**Natural features**
- % Forest (0-91%)
- % Scrub shrub
- % Water (0-15%)
- % Wetland (0-37%)

**Data Sources:**
- Land Cover – NOAA Coastal Change Analysis Program (CCAP) 2006
- Population density – Census 2010 and NHDES GBNNPSS 2014
- Impervious cover – NH GRANIT 2010
DIN controlled by human impact and natural features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Coefficient</th>
<th>VIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population density</td>
<td>0.16</td>
<td>0.92</td>
</tr>
<tr>
<td>% Developed</td>
<td>0.08</td>
<td>1.09</td>
</tr>
<tr>
<td>Medium intensity</td>
<td>0.06</td>
<td>0.93</td>
</tr>
<tr>
<td>Low intensity</td>
<td>0.07</td>
<td>1.06</td>
</tr>
<tr>
<td>Open space</td>
<td>0.08</td>
<td>0.90</td>
</tr>
<tr>
<td>% Impervious cover</td>
<td>0.06</td>
<td>0.98</td>
</tr>
<tr>
<td>% Forest</td>
<td>-0.04</td>
<td>0.82</td>
</tr>
<tr>
<td>% Wetland</td>
<td>-0.26</td>
<td>1.24</td>
</tr>
</tbody>
</table>

Together explain 29% of the spatial variability in DIN

Human

24%

Natural

5%

High intensity development, agriculture, scrub shrub, and water not important predictors

*All variables except % forest and % wetland were log transformed
DIN increases with human population density and decreases with wetlands.
DON controlled by natural features and agriculture

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>VIP</th>
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<tbody>
<tr>
<td>% Wetland</td>
<td>0.56</td>
</tr>
<tr>
<td>% Cultivated Crops</td>
<td>0.10</td>
</tr>
<tr>
<td>% Pasture and Hay</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Human population density, development, impervious cover, forest, scrub shrub and water were not important predictors.

Together explain 36%
Characterizing watershed nitrogen inputs

- Used methodology from Great Bay Nitrogen Non-Point Source Study (Trowbridge et al. 2014)
- Atmospheric deposition
- Inputs associated with development
  - Human waste
  - Residential Fertilizer
  - Managed Turf Fertilizer
  - Pet waste (dogs and cats)
- Inputs associated with agriculture
  - Cropland Fertilizer
  - Animal waste (cattle and horses)
TDN and DIN increase with increasing N inputs

- Mainly from N inputs from developed areas
- TDN and DIN are not related to agricultural inputs
Slight increase in DON with increasing agricultural inputs

DON does not respond to increasing total or human N inputs

Slight increase in DON with increasing agricultural N inputs
Are 5 samples adequate?
Summary of N concentrations, landscape characteristics and N inputs

• Human development increases DIN in streams, forests and wetlands remove or retain DIN
  – Agriculture not a significant predictor of spatial variability at watershed scale

• Wetlands are the main source of DON, not human development
  – Slight influence from agriculture

• Models explained 29% of DIN and 36% of DON spatial variability (fair amount unexplained)
Watershed N inputs >> N outputs

What non-point sources of N reach surface waters?
Isotopic signature of Nitrate ($^{15}\text{N}^{18}\text{O}_3$) can be used to identify sources.

Kendall and McDonnell 1998
Nitrate isotopes in streams and groundwater

Kendall and McDonnell 1998

\[ \delta^{15}N - \text{NO}_3^{-} \]
<table>
<thead>
<tr>
<th>Stream sites</th>
<th>Human</th>
<th>Cow</th>
<th>Dog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>human waste removed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(9 sites, 26 samples)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suburban</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>human waste treated on-site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 sites, 13 samples)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td>X</td>
<td>✔</td>
<td>X</td>
</tr>
<tr>
<td>(1 site, 5 samples)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference</td>
<td>✔</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>(1 site, 5 samples)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Scent-trained canines to “sniff out” human waste

- Detect human waste in streams, culverts, storm drains etc.
- Dogs have different detection limits
- Human waste detected at 6 of 7 urban streams
- Human waste detected at 2 of 3 suburban streams
- Not detected at reference site

EPA approved method

Environmental Canine Services (ECS)
Conclusions

• Improvements in land management may reduce DIN, but unlikely to significantly reduce DON
• No silver bullet – all types of development matter
• Isotopic signatures of nitrate suggests that most of the nitrate in streams is processed (does not reflect unaltered atmospheric deposition)
• Leaky sewer lines and illicit connections may be an overlooked source of non-point nitrogen
Acknowledgements

Members of:
NSCAB
McDowell lab
Spatial variability is more predictable within the Lamprey

**Lamprey:**
\[ Y = 0.714 X - 2.46 \]
\[ r^2 = 0.63, p<0.01 \]

**Great Bay**
\[ Y = 0.489 X - 1.97 \]
\[ r^2 = 0.17; p<0.01 \]

**Lamprey:**
\[ Y = 2.41 X - 3.75 \]
\[ r^2 = 0.54, p<0.01 \]

**Great Bay**
\[ Y = 1.52 X - 2.73 \]
\[ r^2 = 0.20; p<0.01 \]