Spatial and Temporal Variability in Nitrogen Concentrations, Export and Retention in the Lamprey River Watershed

Michelle Daley
Bill McDowell
University of New Hampshire
Why Nitrogen?

- Overall health of NH Estuaries is declining
- Population growth and associated increased nutrient loads is the largest threat
- N concentrations in and loads to Great Bay have increased
  - TN Loads 42% in 5 yrs
  - DIN concentrations 44% in 28 yrs
  - Eelgrass decline
  - Low dissolved oxygen
- Drinking water contaminant
  - MCL NO₃-N 10 mg/L MCL
  - Gastric cancer 4 mg N/L (Ward et al. 1996)
Great Bay Nutrient Criteria

Tidal Lamprey Impaired
- Low dissolved oxygen
- Eelgrass loss

N Criteria
To protect:
- DO (0.45 mg TN/L)
- Eelgrass (0.3 mg TN/L)

Photo credit: Texas A&M

New Hampshire Department of Environmental Services

Numeric Nutrient Criteria for the Great Bay Estuary

June 2009
Land Use in the Lamprey River Watershed

69% Forested
14% Water and Wetlands
Current and Predicted Human Population Density in the Lamprey River Watershed

Overall Population Density in 2000
53 people km\(^{-2}\)

Predicted Population Density in 2020
85 people km\(^{-2}\)

60 % Increase
In suburban areas... residents rely on private wells and septic systems.
Houses are often tucked into the trees....

with some multiunit buildings relying on communal septic systems
In urban areas...

- Public water supply
- Centralized sewers
- Stormwater removed via storm drains
• Streams are armored by culverts and sometimes piped underground
Nitrogen Research Questions

1. What is the nitrogen budget for the Lamprey watershed?
2. Are there long-term trends in Lamprey River nitrogen concentrations driven by suburbanization?
3. Can variability in sub-basin surface water and groundwater chemistry be predicted by watershed attributes?
4. What drives long-term N retention in the Lamprey River watershed?
Lamprey Watershed Nitrogen Budget (2005)

Total N Input 15.4 kg/ha/yr

- Food: 3.1 kg/ha/yr
- Fertilizer: 1.8 kg/ha/yr
- Rain and dry deposition: 10.5 kg/ha/yr

Total N Output 2.4 kg/ha/yr

N Retention 13.0 kg/ha/yr

84% of inputs stored or lost to atmosphere

Which inputs become outputs? What if this changes?

Total River N (ranged from 1.6-3.5 kg/ha/yr)
Total Nitrogen in the Lamprey

Particulate N
Source: sediment
14%

Dissolved Organic Nitrogen (DON)
Sources: Wetlands and Forest Soils
48%

Dissolved Inorganic Nitrogen (DIN)
Sources: Rain, Snow, Air Pollution, Animal Waste, Sewage, Septic Systems and Fertilizers
83% Undisturbed

TN 0.36 mg/L in Lamprey River 5 km from tidal portion

33% Nitrate (NO₃⁻)
38% Ammonium (NH₄⁺)
5%
Long-Term Increase in Lamprey River Nitrate

Increased septic systems, sewage, fertilizers and impervious surfaces. Could also be a bleeding out of dirty groundwater?

No Change in DON

\[ \tau = 0.31, \ p < 0.01 \]
Surface water DON is best predicted by sub-basin % wetland Cover

\[ Y = 8.51X + 0.11 \]
\[ r^2 = 0.30; p < 0.01 \]

Wetland outlet
Surface water DON is best predicted by sub-basin % wetland Cover

- Lamprey 60%
- Wetland Outlet 88%
- 63%
- 5%

Mean DON (mg L$^{-1}$)

Watershed % Wetland Cover
Surface water nitrate is best predicted by sub-basin human population density

\[ Y = 0.98X - 2.76 \]

\[ r^2 = 0.67; p < 0.01 \]

Source?
Dirty Rain and Snow
Septic Systems, Sewage
Fertilizers

Sewered
Surface water nitrate is best predicted by sub-basin human population density

- Urban: 60-90% (70-95% DIN)
- Sub-Urban: 83-87%
- Lamprey: 30%
- Undeveloped: 4%

% of TDN as NO₃
Nitrate (NO₃⁻) Isotope Data Indicates Rain is Processed Before Reaching Streams
Maximum Nitrate Levels in Homeowner Wells...What Predicts Spatial Variability?

Nitrate Levels (mg N/L)
- Green: 0 - 1.9
- Yellow: 2 - 3.9
- Purple: 4 - 9.9
- Red: > 10.0

EPA MCL
10 mg N/L

- 1 Well > MCL
- 5% > 4 mg/L
- 15% > 2 mg/L
- 20% Elevated
Sub-basin groundwater Nitrate is best predicted by human population density.

Groundwater Nitrate >> Surface Water

Could this GW storage be a ticking time bomb?

**Groundwater**

$r^2 = 0.36; \ p < 0.05$

**Surface Water**

$r^2 = 0.70; \ p < 0.01$
What drives long-term N retention in the Lamprey River watershed?
How much N is temporarily assimilated in vegetation?

~ 6.0 kg N/ha/yr for Rockingham County (Goodale et al. 2002)

...or in groundwater?
How much N is permanently lost to the atmosphere via denitrification in wetlands?
...in stream channels?
...in riparian zones?
Ways to Reduce Nitrogen in the Lamprey

- Fix leaky sewer pipes (13% residents use public sewer system)
- Improve septic system design to include denitrification step
- Protect and maintain intact riparian zones**
- Protect small streams – 1st order or headwater streams**
  ** active zones for denitrification – permanent removal
- Wise use of fertilizers
- Maintain vegetated buffers
- Prevent erosion
- Rain gardens to remove N from storm water
- TMDL – Total Maximum Daily Load Process - $$

http://www.emmitsburg.net/gardens/articles/adams/2008/rain_garden.htm
Acknowledgments

• Funding from EPA, NOAA AIRMAP, LRAC USFS – NSRC, NH WRRC and UNH AES
• Direction and oversight form PI Dr. Bill McDowell is gratefully acknowledged
• Jeremy Blumberg, Tracey Lesser, Lauren Buyofsky, Jeff Merriam and Jody Potter also made significant contributions to the project
A River is a Reflection of its Watershed

Questions?
Michelle Daley
603-862-1794
mldaley@unh.edu
83% of Lamprey watershed residents use septic systems.
N Retention Declines with Increased Human Inputs

\[ y = -1.10x + 101 \]
\[ r^2 = 0.82, p<0.01 \]
Sub-basin groundwater Nitrate is best predicted by human population density

Groundwater
\[ r^2 = 0.29; \ p < 0.05 \]
LRHO Nitrogen Summary

- 84% of N entering the LRHO is stored or lost to the atmosphere
- 48% of N leaving the LRHO is from wetlands
- 38% of N leaving the LRHO is manageable (i.e., associated with human activity) but this varies spatially and is increasing over time
- Nitrate in groundwater is >> surface water

How do we reduce N loading to Great Bay

- Reduce N Inputs
  - Sewage and septage
  - Fertilizers
  - Rain and storm water (e.g., pet waste)
- Maintain high level of N retention