Hotspots of Nitrate Removal in Forested Intermittent Streams of Southern New England

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Excess nitrogen (N):
1) Stimulates algal growth: consumes $O_2$ and degrades coastal habitats
2) Generates a potent greenhouse gas, nitrous oxide ($N_2O = 300 \text{ CO}_2$ equivalents)
3) Drinking water contaminant
Forested headwater streams as N sinks

- “…streams exert control over nutrient exports to rivers, lakes and estuaries.” (Peterson et al. 2001)
- Denitrification inversely related to stream depth (Alexander et al. 2000)
- Denitrification positively correlated with water residence time (Seitzinger et al. 2006)
- More opportunities for denitrification in shallow streams with large ratios of benthic surface area to water volume with greater resistance to flow and more hyporheic storage (Alexander et al. 2007)

Debris dams
Surface water pools
Hyporheic exchange
Morphology and Hotspots

- Riparian deforestation causes channel narrowing thereby reducing water retention time, quality of dissolved organic matter, and in-stream N processing (Sweeney et al. 2004)

- Hyporheic zones more likely to serve as hotspots of N removal with higher “hydrologic connectivity” (Groffman et al. 2009)
Objectives

- Identify and characterize expanded stream networks – intermittent streams – the smallest forested streams
- Assess N removal potential (in situ and DEA) of these forested intermittent streams
- Relate N removal to hydrology and stream features
Forested intermittent streams

- Used ArcHydro/DEMs within GIS to identify expanded stream network in forested reaches
- Instrumented 6 intermittent streams with iButtons (temperature data loggers) at various depths in stream to indicate presence or absence of water

Expanded stream networks – result of storm event, snowmelt/spring runoff, & groundwater seepage (Wigington et al. 2008; Leibowitz et al. 2008.)
Hydroperiod of forested intermittent streams
(winter 2010 – spring 2011)

• Continuous flow at our sites from 12/20 – 6/20
• Difference when streams go dry in summer and rebound in fall
  – Summer hydroperiod: 16-91d
  – Fall hydroperiod: 45-91 d
Flow & Stream Features

• **Flow:** USGS Slug test method with conservative tracer Br\(^-\) (5L) over 30 m stream reach
• Measure pool volume (insight into retention time within pools)
• Count debris dams seasonally (carbon dynamics & stream features)
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<table>
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<tbody>
<tr>
<td><strong>Range in stream characteristics across the 6 intermittent streams:</strong></td>
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<tr>
<td>Depth (cm)</td>
<td>1.8 – 24.0</td>
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<tr>
<td>Flow (l/s)</td>
<td>0.4 – 16.7</td>
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<tr>
<td>Velocity (m/s)</td>
<td>0.010 – 0.083</td>
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<td>Retention time (min/30 m):</td>
<td>6 - 167</td>
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<td></td>
<td><em>Suggests hyporheic flow</em></td>
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<tr>
<td>Pool Volume (% of stream)</td>
<td>4.8 - 17.3</td>
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<tr>
<td># debris dams/reach(fall11)</td>
<td>3 - 9</td>
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<tr>
<td># debris dams/reach(sp12)</td>
<td>1 - 11</td>
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Nitrate-N Studies

Nitrate Disappearance:

• Add NO$_3^-$-N with Br$^-$ slug test at known ratio (target to raise concentration* to 1-2 mg N/L for potential rates)
• Deviation from known ratio in downstream samples allows calculation of N removal rate

DEAs in Fall 2011 (identify hotspots of N cycling):

• Debris dam material
• Sediment in pools
• Sediment in runs/riffles

*All ambient NO$_3^-$–N concentrations below detection (<0.02 mg N/L)
NO$_3^-$-N removal potential elevated at most sites

Each site represents 8 to 11 replicate slug tests in fall, winter or spring.
NO$_3^-$-N removal potential highest in fall

Mean Temp: 6.5°C 13.5°C 7.2 °C
DEA higher in pools/runs
Highest pool and run DEA isolated to two sites
$\text{NO}_3^-$-N disappearance correlated with flow, depth, velocity & retention time

N removal rates significantly correlated (Spearman rank) with:

- Depth ($r_s = -0.40$)
- Flow ($r_s = -0.75$)
- Velocity ($r_s = -0.54$)
- Retention time ($r_s = 0.54$)
Scaling up

• To scale up at each site, used 250 m reach of stream, average seasonal NO$_3^-$-N removal rates, and hydroperiod

• 0.6 – 22.5 kg NO$_3^-$-N removed over 250 m in fall, winter and spring
Take-Home Messages

• Forested intermittent streams contain unique structures – pools, debris dams, microhabitats and hyporheic flow – that enhance hydrologic retention and therefore NO$_3^-$-N removal potential.

• Higher organic matter in stream sediments may increase N removal.
Next steps

• Collect more summer and fall reps of NO$_3^-$ studies
• Data-loggers measuring stream height
• Look further into hyporheic connections & pools
• Quantify stream DOC
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