Hydrologic connectivity, climate change, and nutrient delivery to receiving waters

Sujay S. Kaushal
University of Maryland
Center for Environmental Science

Peter M. Groffman
Cary Institute of Ecosystem Studies

Lawrence E. Band
University of North Carolina

Kenneth T. Belt
U.S. Forest Service
Rationale

- Nitrogen transport from river basins has doubled globally
- Increasing land use change and climate variability
- Contamination of drinking water supplies
- Currently 150 dead zones along coasts and the number is growing
Outline

I. Urbanization alters hydrologic "connectivity"

II. Urbanization and climate variability amplify nitrogen loads

III. Can we engineer "connectivity" with biogeochemical "hot spots" to reduce future nitrogen loads?
I. Urbanization alters hydrologic “connectivity”
Emphysema

Normal alveoli and bronchioles

Healthy lungs

Damaged alveoli in selected areas

Lungs with emphysema
Disappearing Streams?

Elmore and Kaushal (2008)
How will a highly “connected” landscape respond to climate variability?
II. Urbanization and climate variability amplify nitrogen loads
2003 Wet Year

WINTER WALLOP 2003

Germantown, MD

Seneca Creek, Baltimore County

Baltimore City
Kaushal et al. (2008)
Nitrate-N Export (kg/ha/y)

- POBR (Forest)
- GFCP (Urban)
- GFGB (Suburb)
- GFVN (Suburb/Urban)

Drought
- Normal
- Wet

Year
- 1998
- 2000
- 2002
- 2004
- 2006

Kaushal et al. (2008)
Medium-Sized Baltimore Watersheds

Kaushal et al. (2008)
Large Rivers of the Chesapeake Bay

Kaushal et al. (2008) from USGS RIM
• Human land use amplifies effects of climate
• Developed land less resilient to climate
• Record coastal hypoxia
III. Can we engineer "connectivity" with biogeochemical "hot spots" to reduce future nitrogen loads?
Stream restoration

Riparian “reconnection”

Increased denitrification and improved water quality
Urban Stream Degradation

- Nutrient inputs
- Removal of riparian zone
- Bank Incision

Increased Nitrogen Concentrations
Engineering Riparian “Connectivity”

- Re-vegetation
- Bank re-shaping
- Cross Vane
- Floodplain
Hypotheses

• Stream restoration increases rates of hyporheic denitrification

• Denitrification is stimulated by *riparian* hydrologic “connectivity”
High Bank
(Unrestored)
Low Bank
(Unrestored)
High non-connected bank (Restored)
Low “Connected” Bank (Restored)
Unrestored Reach

Restored Reach

Site

Denitrification Rate (μg/N kg/soil/day)

Kaushal et al. (2008)
Denitrification Rate (μg/N/kg soil/day)

Unrestored High Bank
Unrestored Low Bank
Restored High Un-connected Bank
Restored Low Connected Bank

Kaushal et al. (2008)
Groundwater Nitrate Concentrations

Kaushal et al. (2008)
Nitrogen removal in “engineered” streams?
Surface Water Velocity ($u$) and $\text{NO}_3^-$ Uptake Length ($S_w$)

Klocker et al. (In Press)
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{3}\textsuperscript{-} flux</td>
<td>182,000 mg-N d\textsuperscript{-1}</td>
</tr>
</tbody>
</table>

\[ \text{NO}_3^- \text{ flux} = 182,000 \text{ mg-N d}^{-1} \]

\( \sim 40\% \)

of the daily load was removed by denitrification over a 220.5 m reach

Klocker et al. (In Press)
Re-inventing the Urban River Continuum
Re-inventing the Urban River Continuum

Forest Pond Branch

Suburban Spring Branch

Urban Gywnns Run

Newcomer (Thesis)
Spring Branch Restoration

Denitrification Rate (μg N/kg soil/day)

Distance from Headwaters (m)

Stormwater Pond

"Connected" Streambank

Newcomer (Thesis)
Restoring Ecosystem Function Along the Urban River Continuum?

- **Socio-cultural template**
- **Water Quality Regulations**
- **Political Will**
  - **Social Will**

---

**External Drivers**
- **Pulses: Climate Variability**
- **Presses: Land Use Change**

---

**Ecosystem Services:**
- **Water Quality**

---

**Geophysical template**
- **Stream Network & Geomorphic Structure**
  - **Stream Ecosystem Functions**
Conclusion

- Urbanization has altered hydrologic "connectivity" to coastal waters
- Hydrologic "connectivity" has decreased nitrogen retention
- Can engineering "connectivity" with biogeochemical “hot spots” increase resilience to climate variability?
Acknowledgements

- National Science Foundation: NSF DEB-0423476, NSF award DBI 0640300
- Baltimore Ecosystem Study LTER site
- Dan Dillon (Cary Institute of Ecosystem Studies)
- Katie Delaney (University of Maryland)
- Tamara Newcomer (University of Maryland)
- Gwendolyn Stanko (University of Maryland)
- Catherine Shields (University of North Carolina)
- Paul Mayer (U.S. Environmental Protection Agency)
- Margaret Palmer (University of Maryland)
- Gary Fisher (U.S. Geological Survey)
- Richard Pouyat (U.S. Forest Service)
- Art Gold (University of Rhode Island)
- Claire Welty (University of Maryland Baltimore County)
- Maryland Sea Grant
- EPA Chesapeake Bay Program