Exploring causes of increasing nitrate concentrations in the Lower St. Croix River

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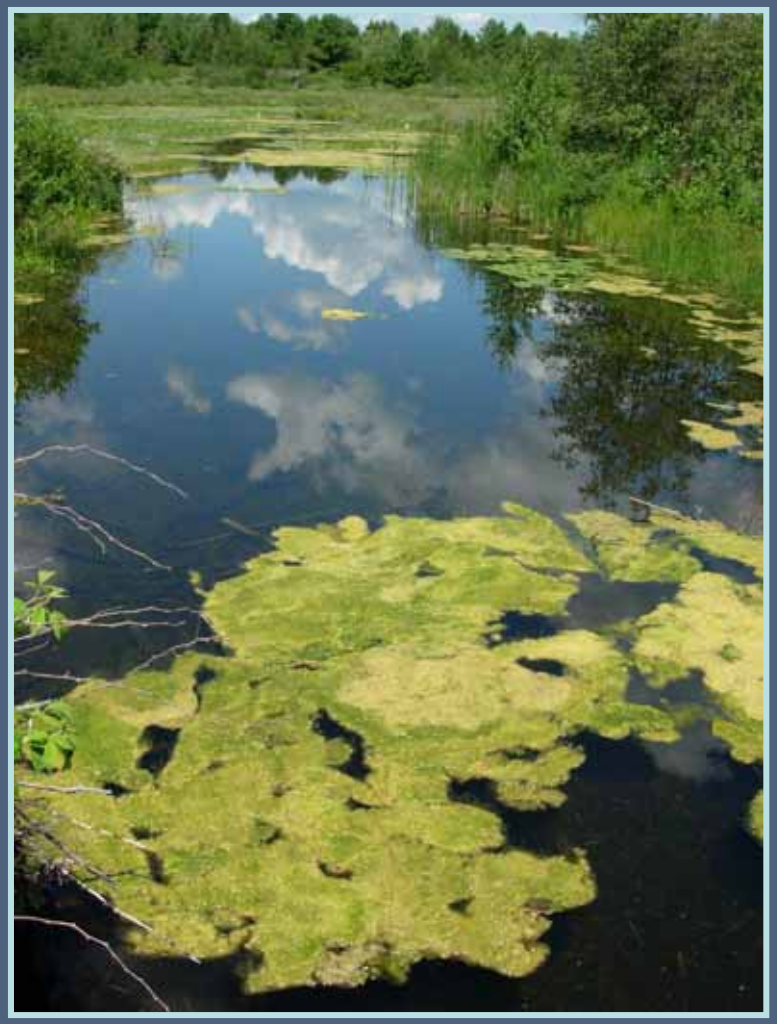
Why N?



- Like P, N can be a limiting nutrient
- Excess N (or changes in N:P) can lead to nuisance blooms

Coastal Dead Zones

- Spread exponentially since 1960s
- 400 ecosystems
- Result of coastal eutrophication
- Fertilizer runoff
- Serious ecological consequences

Diaz and Rosenberg. 2008. Science 321:926-929.

Gulf of Mexico Hypoxia

- Noticed since 1950s, monitored since 1970s
- Driven by increases in nitrate (NO_3-N) – fertilizer
- 56% of nitrate from Upper Mississippi
- 30% reduction in N loading required

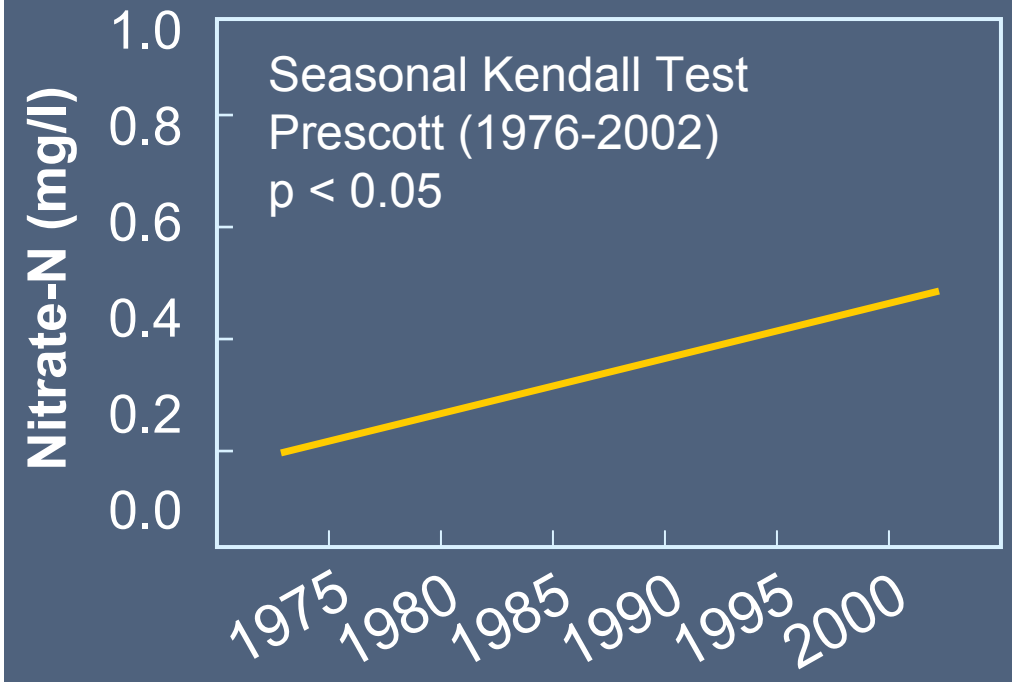
Goolsby (2000) Eos.

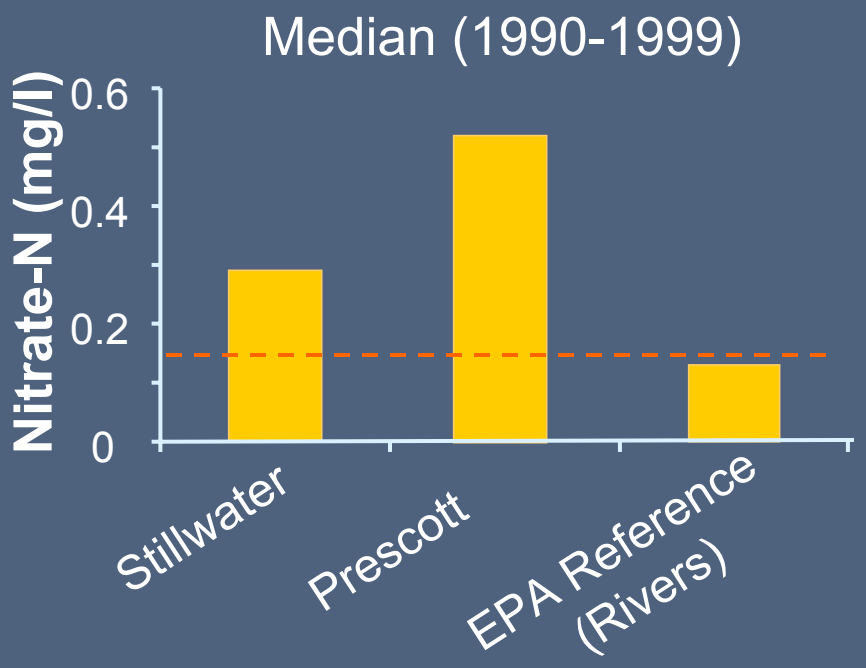
Rabalais et al. (2002) BioScience.

Lake St. Croix Nitrate

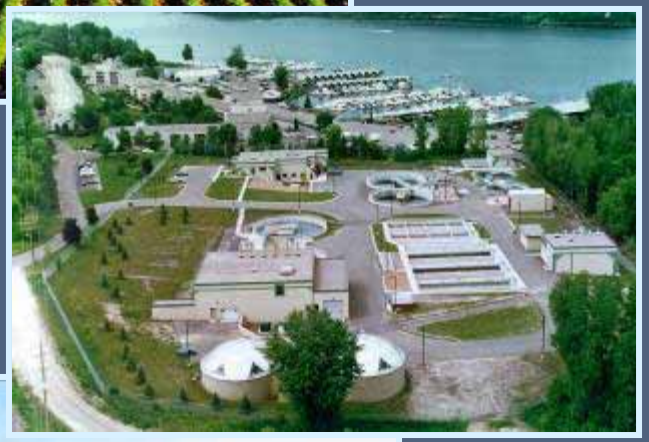
Median values for SC 0.3 and MR 796.9, 2000-2004.

Lake St. Croix Nitrate





Potential Causes

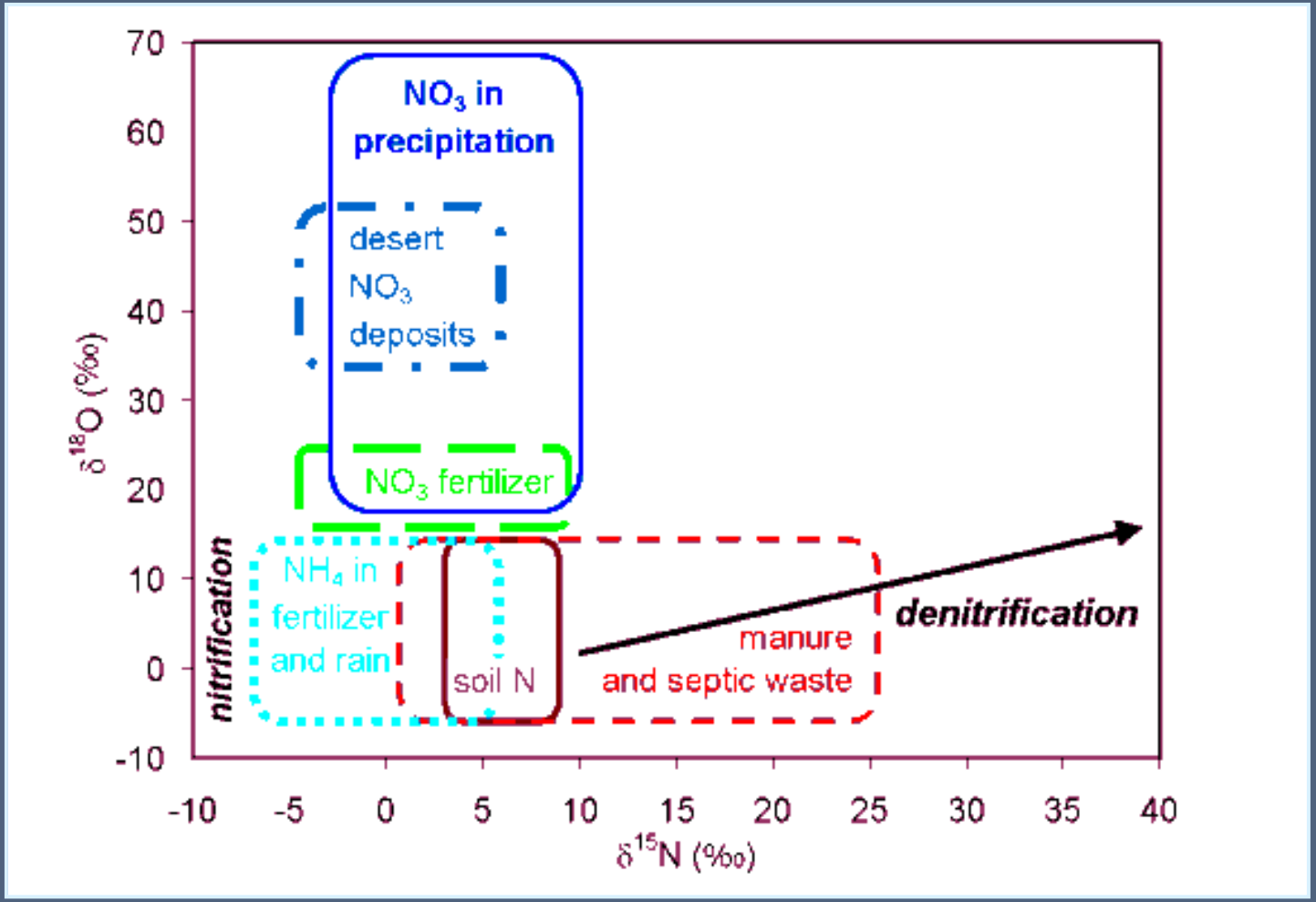


- Increases in fertilizer use
- Changes in wastewater treatment ($NH_3 \rightarrow NO_3$)
- Atmospheric deposition
- Changes in soil denitrification processes

Stable Isotope Analysis

- What are stable isotopes?
  - Different forms of the same element
  - Not radioactive
  - Common ones = C, N, O, S, H
- Relative proportions used to infer things about ecosystem structure and process
- Isotopes of N and O useful for tracking nitrate
  - ^{14}N and ^{15}N
  - ^{16}O, ^{17}O, and ^{18}O

Nitrate Stable Isotopes



C. Kendall. 1998. Tracing nitrogen sources and cycling in catchments. Chapter 16 *in* C. Kendall and J.J. McDonnell, eds., Isotope tracers in catchment hydrology. Elsevier Science B.V.

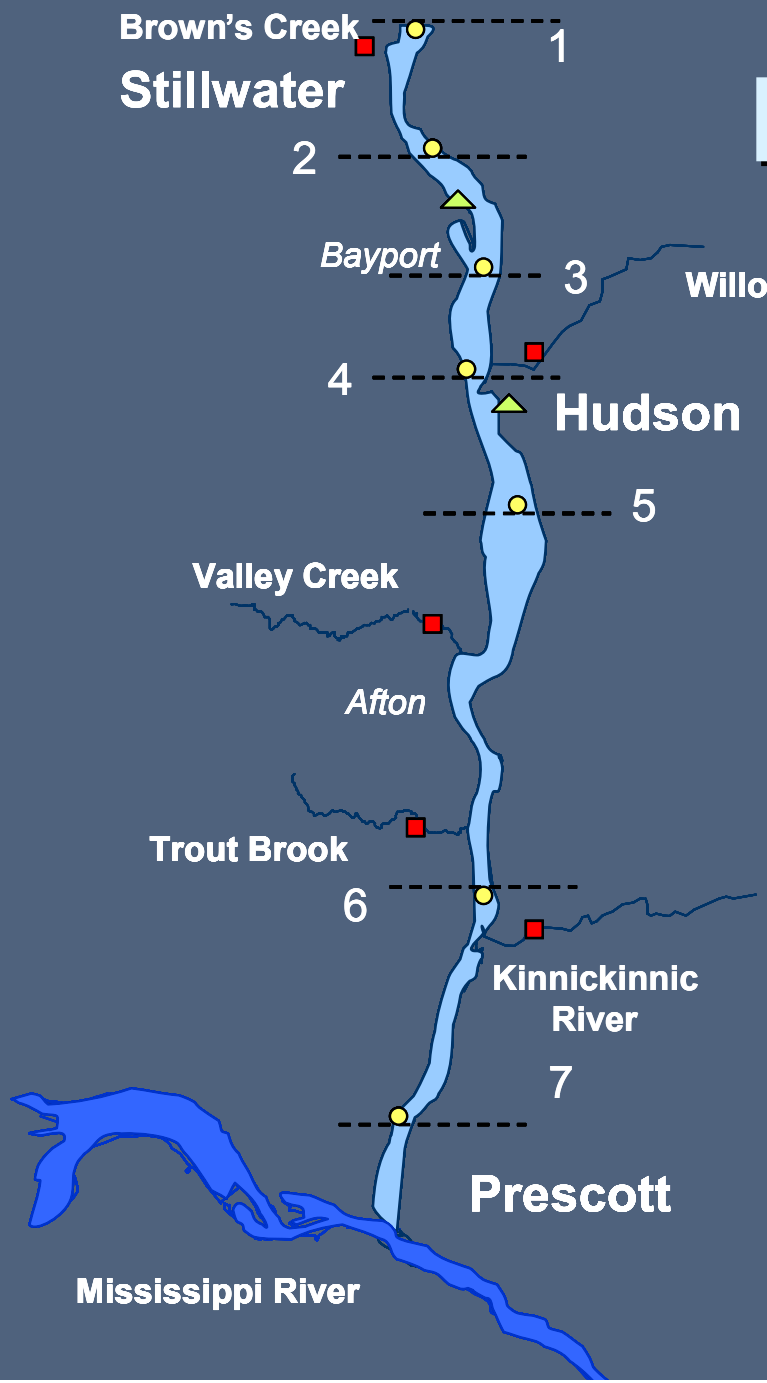
Study Goals

1. Characterize patterns in nitrate concentration
   - Mainstem Lake St. Croix
   - Tributaries
   - Wastewater Treatment Plants
2. Identify nitrate sources
3. Evaluate usefulness of biological proxies

Hypotheses

- NO_3-N concentrations are highest in downstream tributaries and WWTPs
- $\delta^{15}N$ and $\delta^{18}O$ suggest wastewater influence at upstream sites, fertilizer downstream
- $\delta^{15}N$ is more stable in zebra mussels than in water or phytoplankton over season

Design



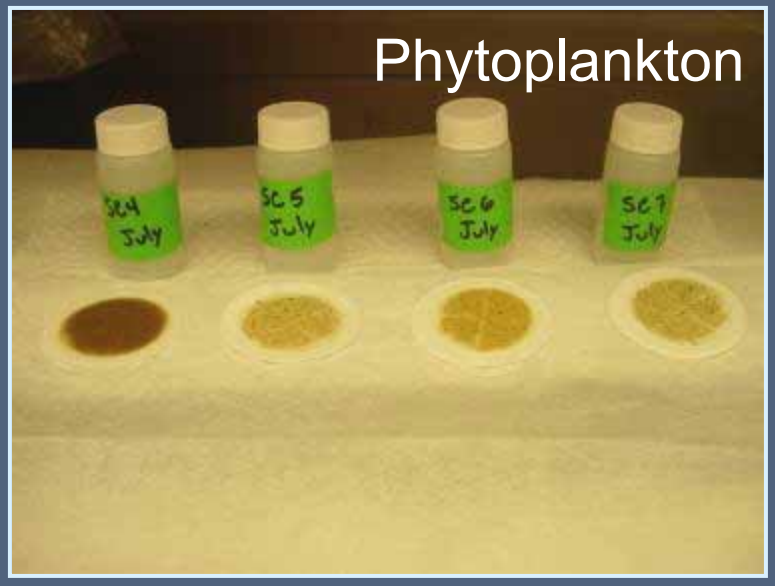
- 14 sites
  - 7 mainstem
  - 5 tributaries
  - 2 wastewater plants
- 5 sampling events
- 3 components
  - Water (nitrate)
  - Phytoplankton
  - Zebra mussels

Methods

Water – NO_3-N

Zebra Mussels

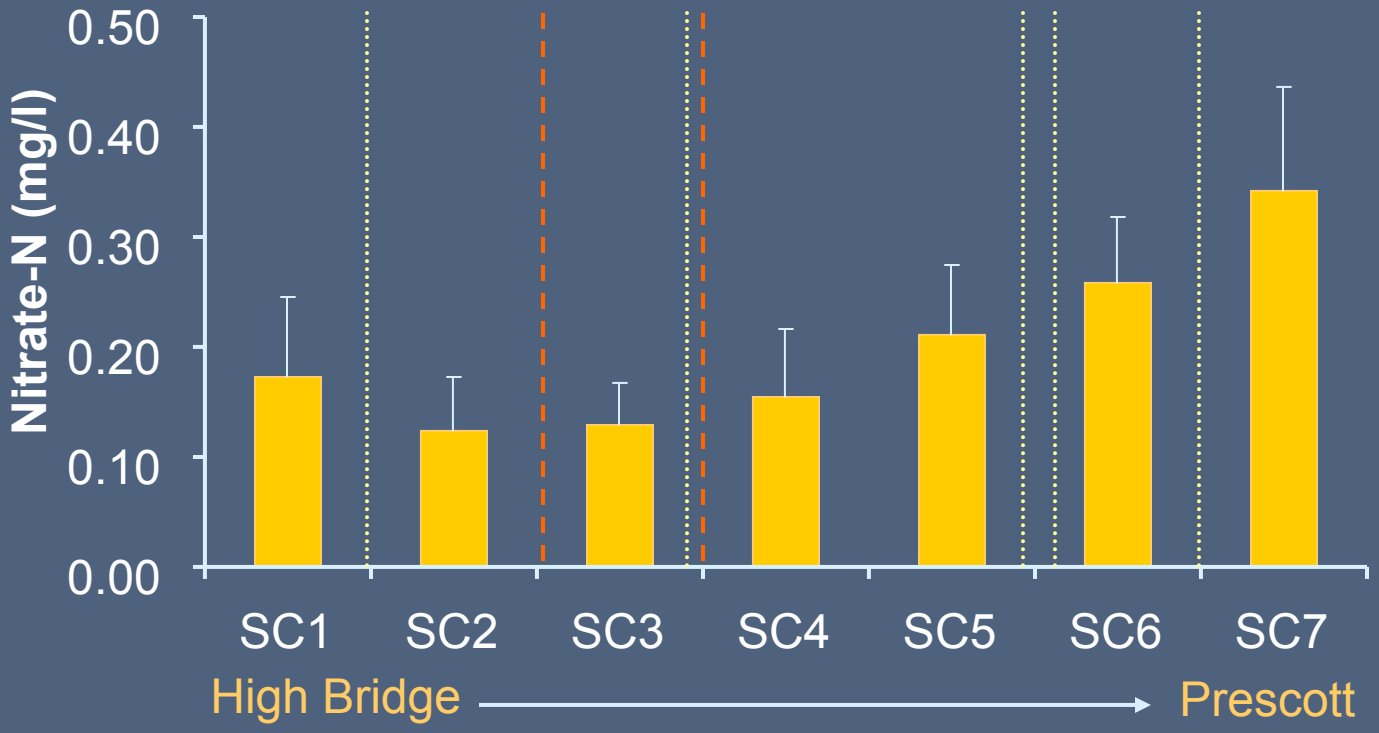
Phytoplankton



Methods

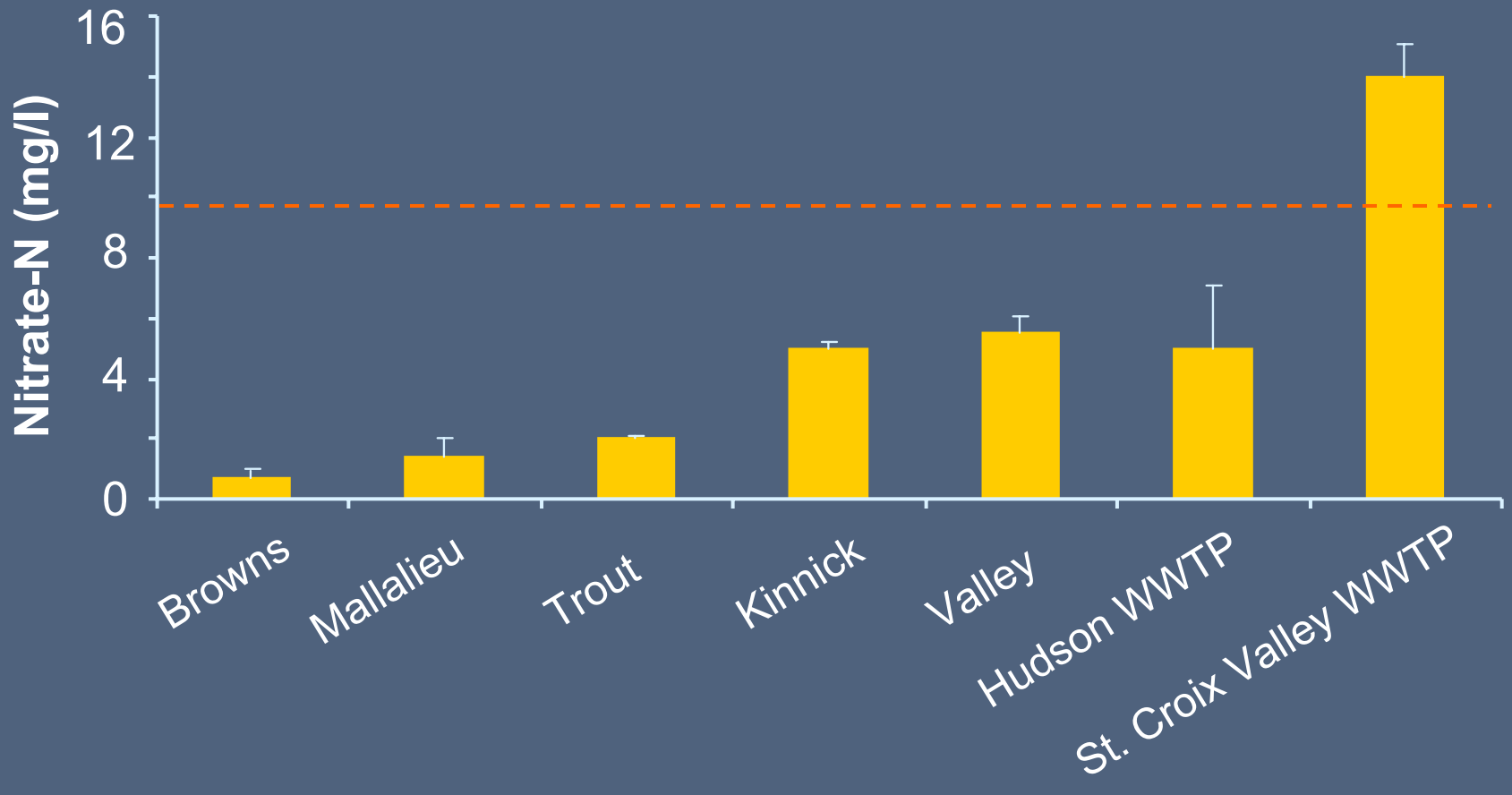
- Water analyzed for nitrate concentration and stable isotopes of N and O
  - Diffusion technique ($\delta^{15}N$)
  - Denitrifier method ($\delta^{15}N$ and $\delta^{18}O$)
- Phytoplankton and zebra mussel tissue analyzed for $\delta^{15}N$ ($\delta^{13}C$)

Mainstem Concentrations



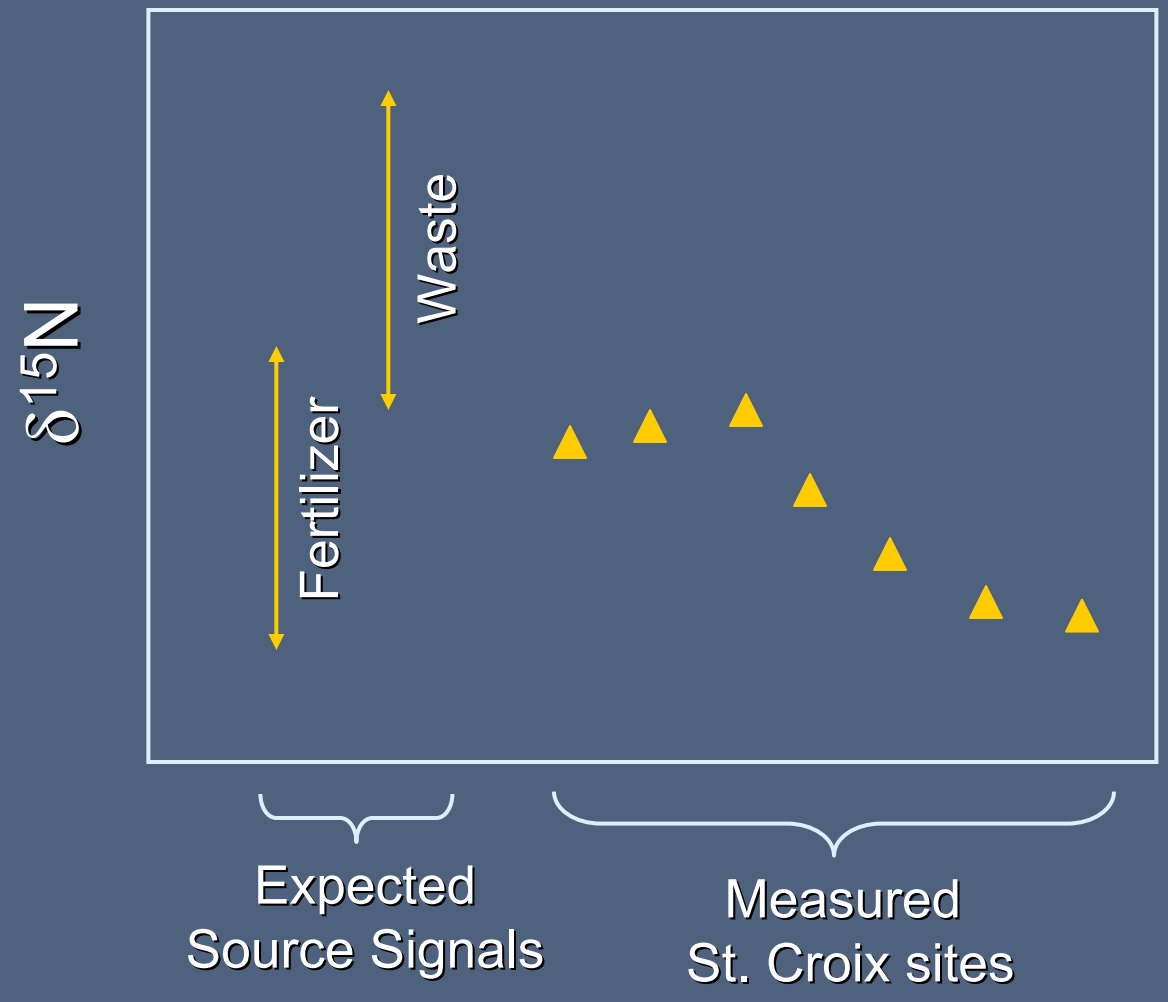
Means and StDevs, May-Aug 2008
Note: detection limit = 0.2 mg/l

Tribs and WWTPs



Means and StDevs, May-Aug 2008

Stable Isotope Results
(Hypothetical)



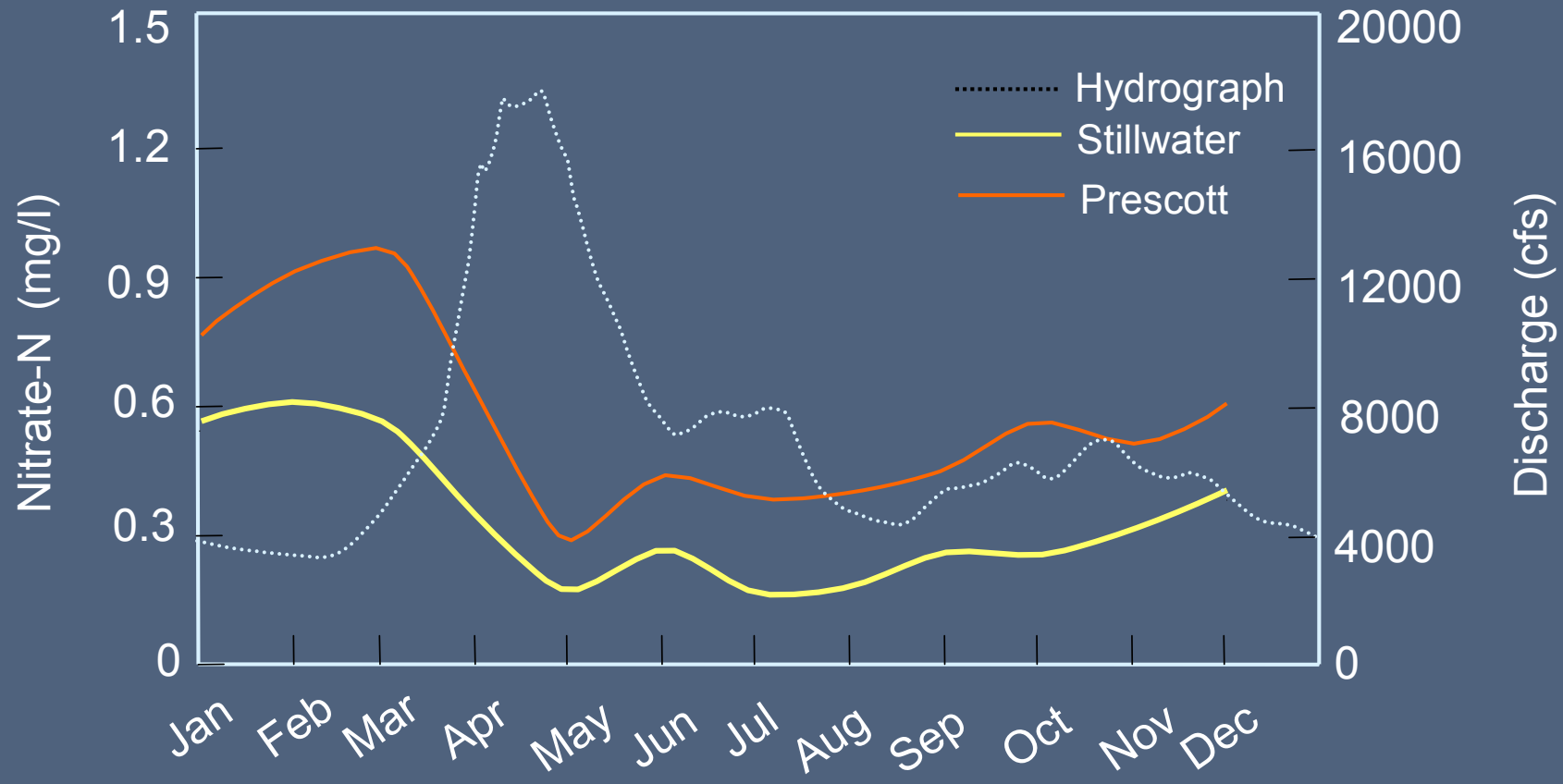
Preliminary Findings

- Nitrate increases systematically
  - Largest increases downstream
  - Lake St. Croix tributaries and tributary land use important

Acknowledgements

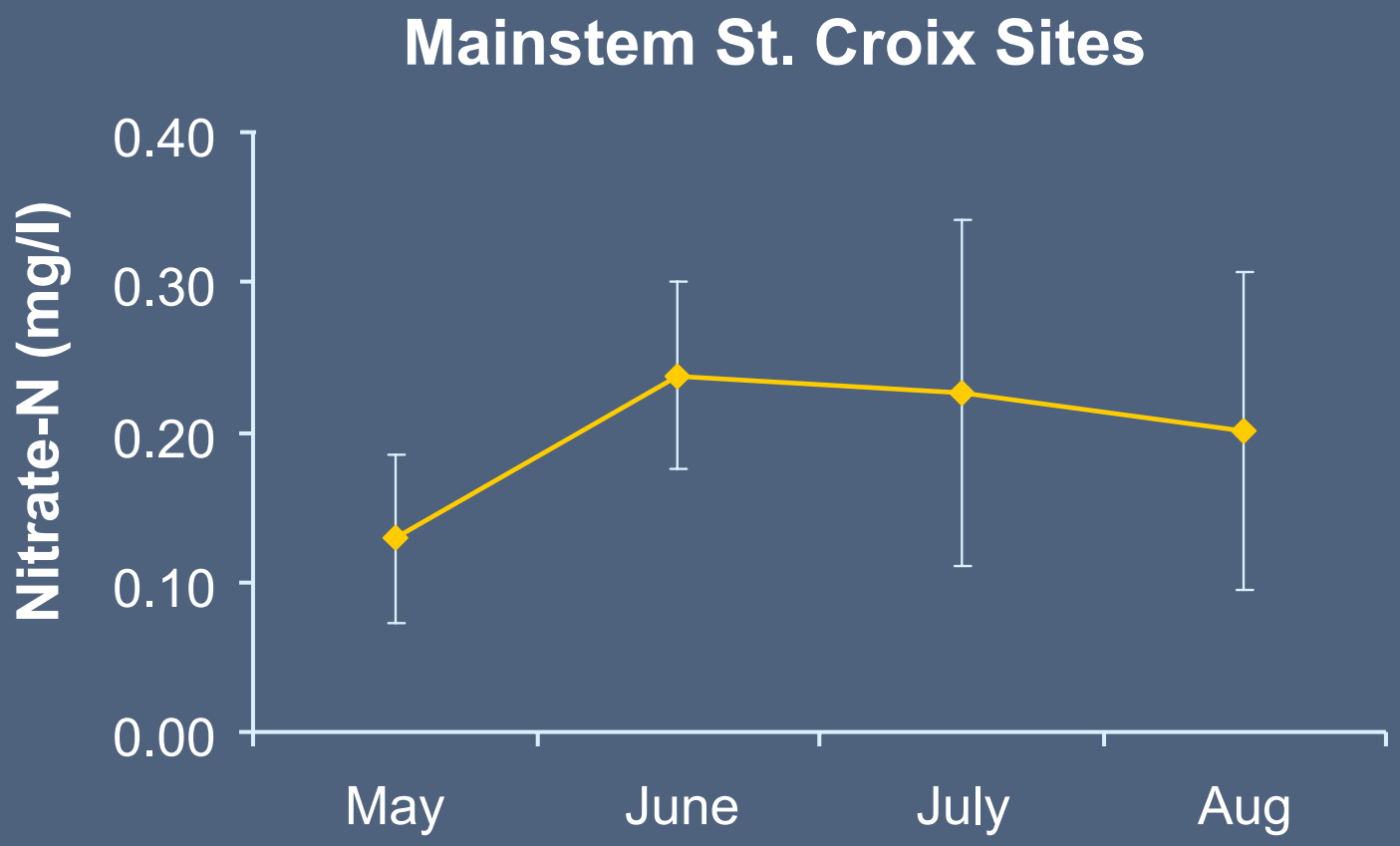
- U.S. Army Corps of Engineers
- National Park Service
- SCWRS
- Metropolitan Council
- Colorado Plateau Stable Isotope Lab
- Dennis Lindeke, Jim Schreiber
- David VanderMeulen
- Toben Lafrancois and the Youth River Action Program

Seasonal Patterns



Long-term means (1976-2002)

Seasonal Patterns



Means and StDevs, May-Aug 2008