Denitrification Hotspots in Fluvial Systems

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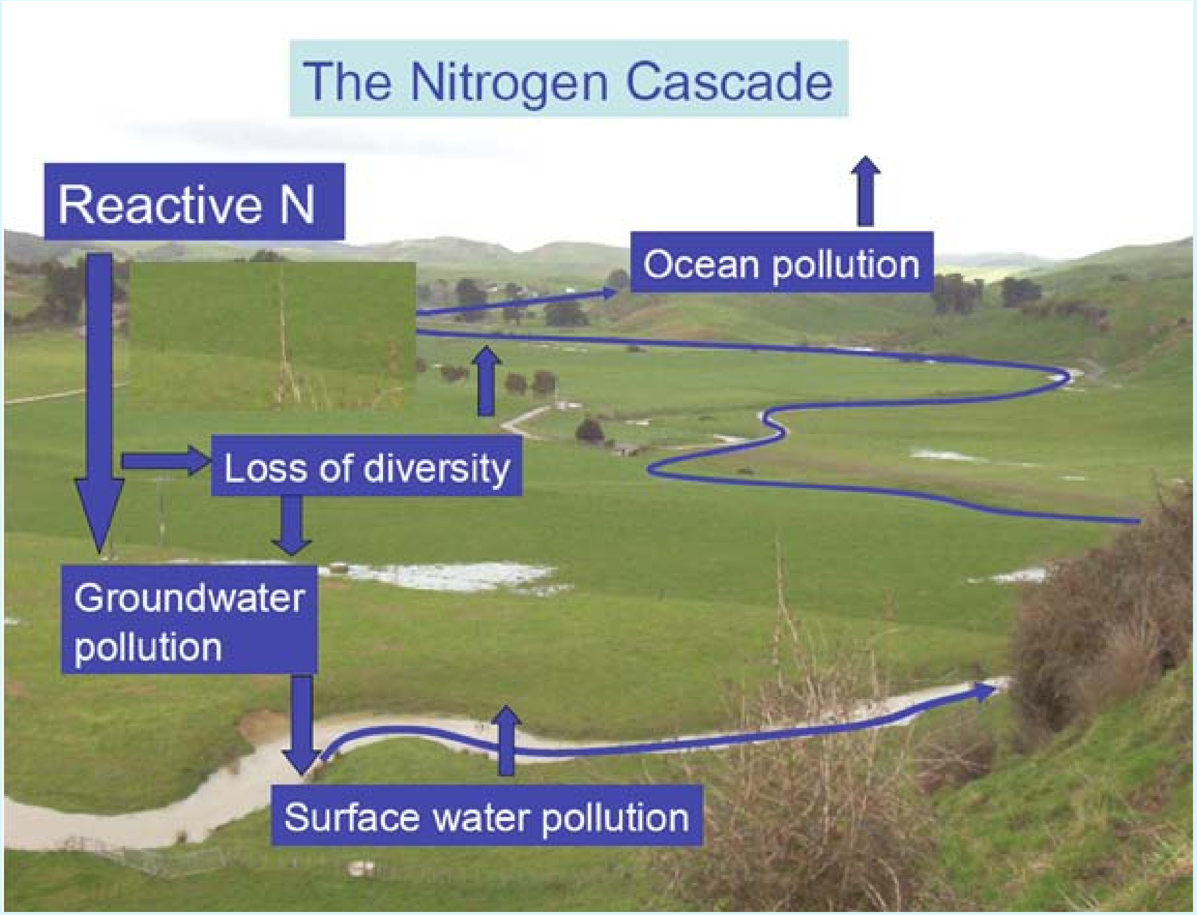
Why do we care about Nitrogen?

- Limiting nutrient in marine systems
- Human manipulations of N cycle are intense
- N can be a drinking water pollutant and can cause coastal eutrophication
- N gases contribute to the greenhouse effect

Anthropogenic N Loading

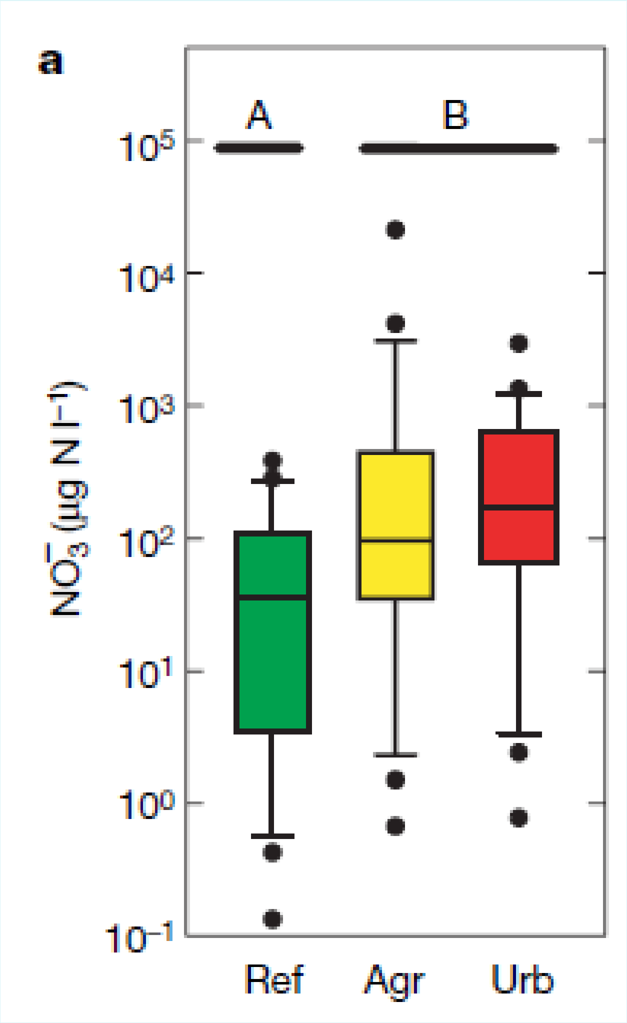
- Cultural N increase
- Terrestrial N saturation
- More N entering ground and surface water

Mulholland et al., 2008



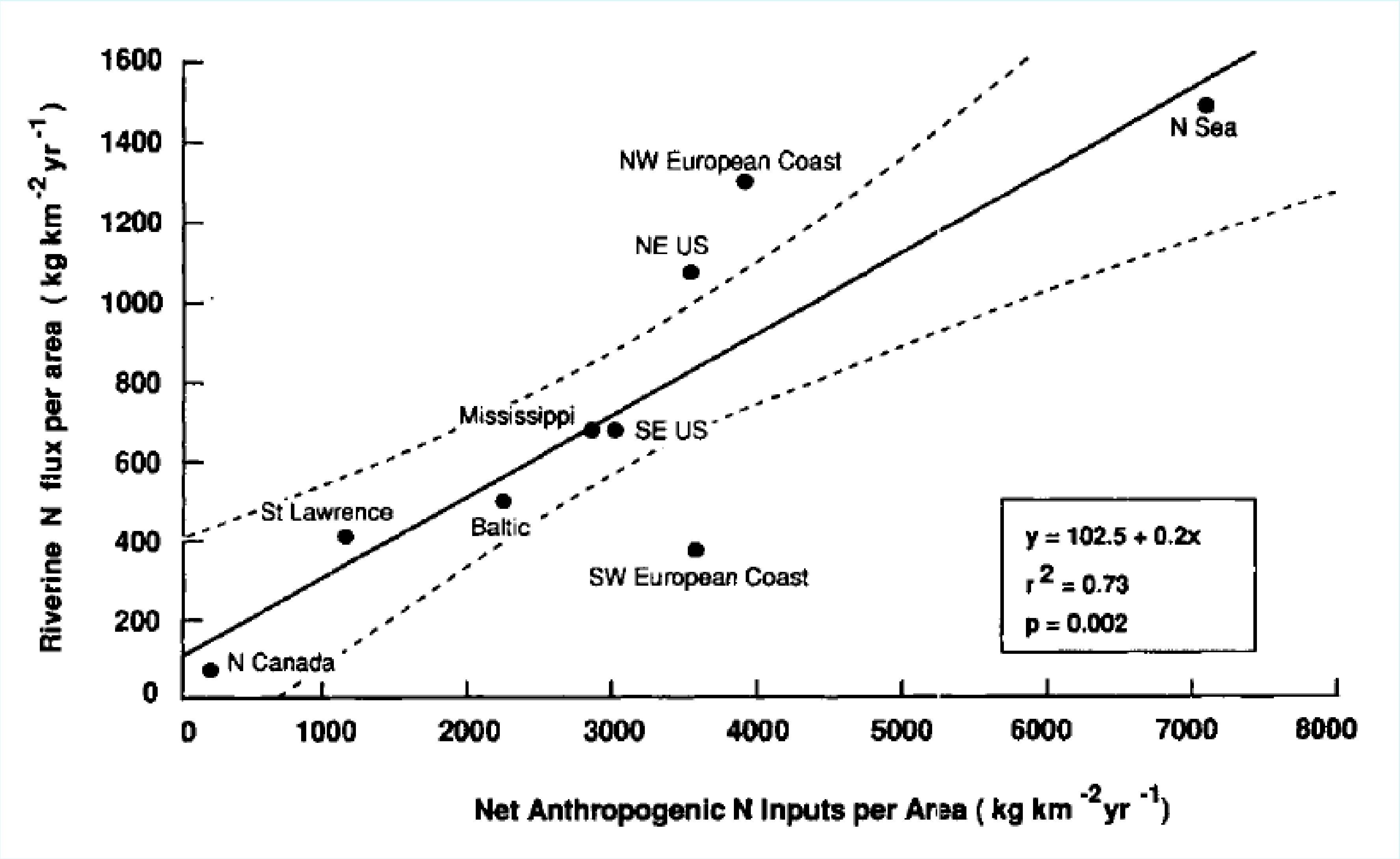
Schipper, 2009

Land use has a significant effect on NO_3^- concentration, *p≤0.005*



Mulholland et al., 2008

20-25% of N added to biosphere is exported from rivers to ocean



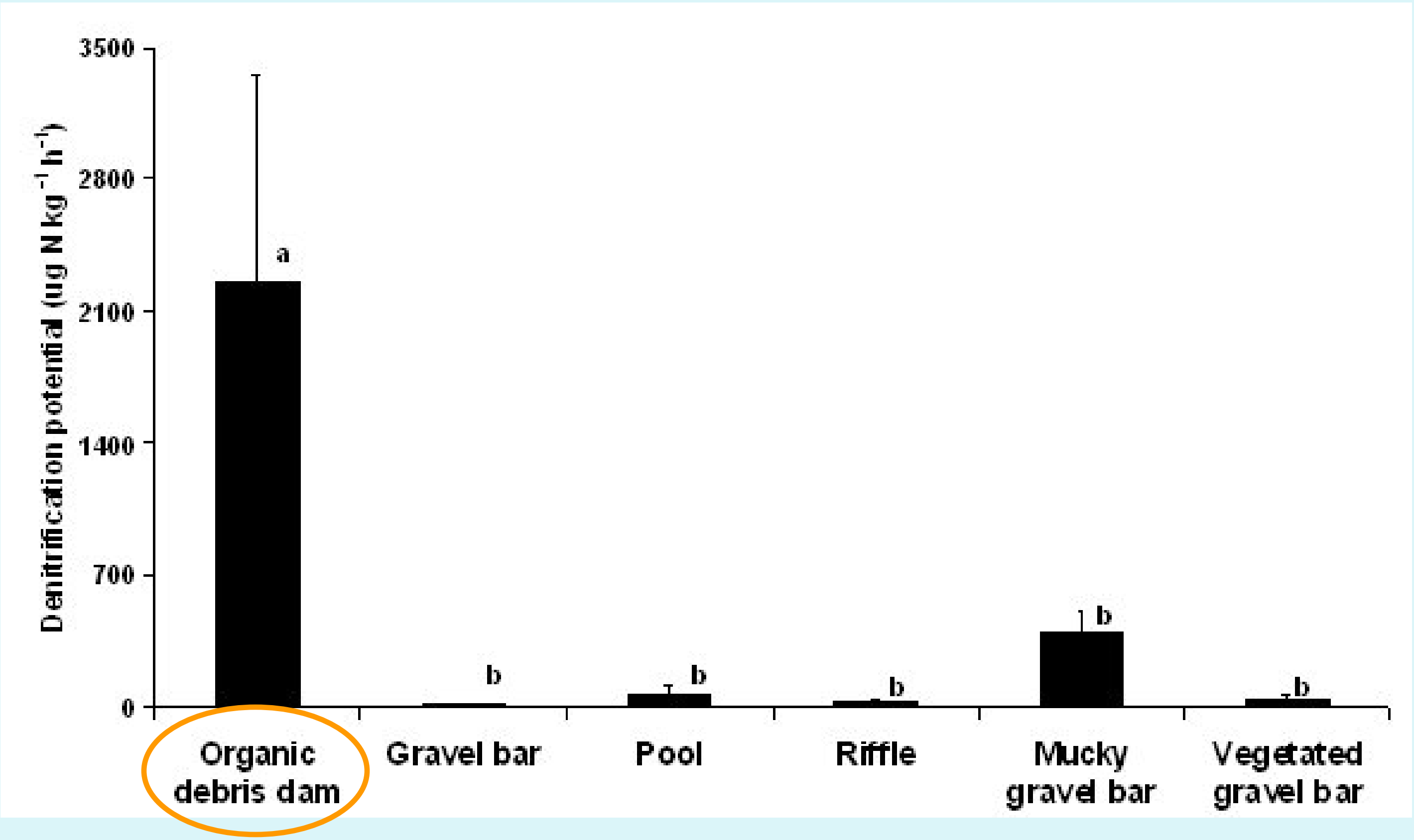
Howarth et al., 1996

Streams may be important N sinks

- Hydrological connectivity with terrestrial systems
- Biological activity
- Streambed sediments

Mulholland et al., 2008

Watershed mass balance studies suggest considerable disappearance of N in landscape sinks



Groffman et al., 2005

Denitrification

$NO_3^- \rightarrow NO_2^- \rightarrow$ **$NO \rightarrow N_2O \rightarrow N_2$**

water soluble *gases*

- Anaerobic
- Heterotrophic (requires organic C)
- Microbes, C, and N must mix

Hot Spot Hypothesis

(Tiedje et al., 1984; McClain et al., 2004; Groffman et al., 2009)

- Denitrification focused in select, localized settings and thought to be a function of:
  - Pools of labile C
  - Extended residence time
  - Anoxia microsite

Research Interests

- What is the effect of fresh inputs of woody debris on nitrogen cycling in streams?
- What is the effect of biofilm on N cycling in streams of differing N enrichments?
- How do woody debris influence N cycling in zones of extended retention times (i.e. beaver ponds, river impoundments, natural pools)?

example of biofilm

Evaluated denitrification rates from 3 different substrates in two locations

- Fresh Red Maple wood blocks
- Woody debris naturally found in stream
- Ceramic blocks
- All in stream for 9 weeks; developing biofilms

Big Spring Run, Lancaster County, PA

Mawney Brook, East Greenwich, RI

Big Spring Run, PA	Mawney Brook, RI
NO_3^--N: 11.2 mg/L (agricultural)	NO_3^--N: 0.47 mg/L (suburban)
sun	shade
No riparian buffer	Forested riparian buffer
0.2-0.5 m depth	0.5-1.0 m depth


CVS
SPF
30
SUNBLOCK
SPORT
30

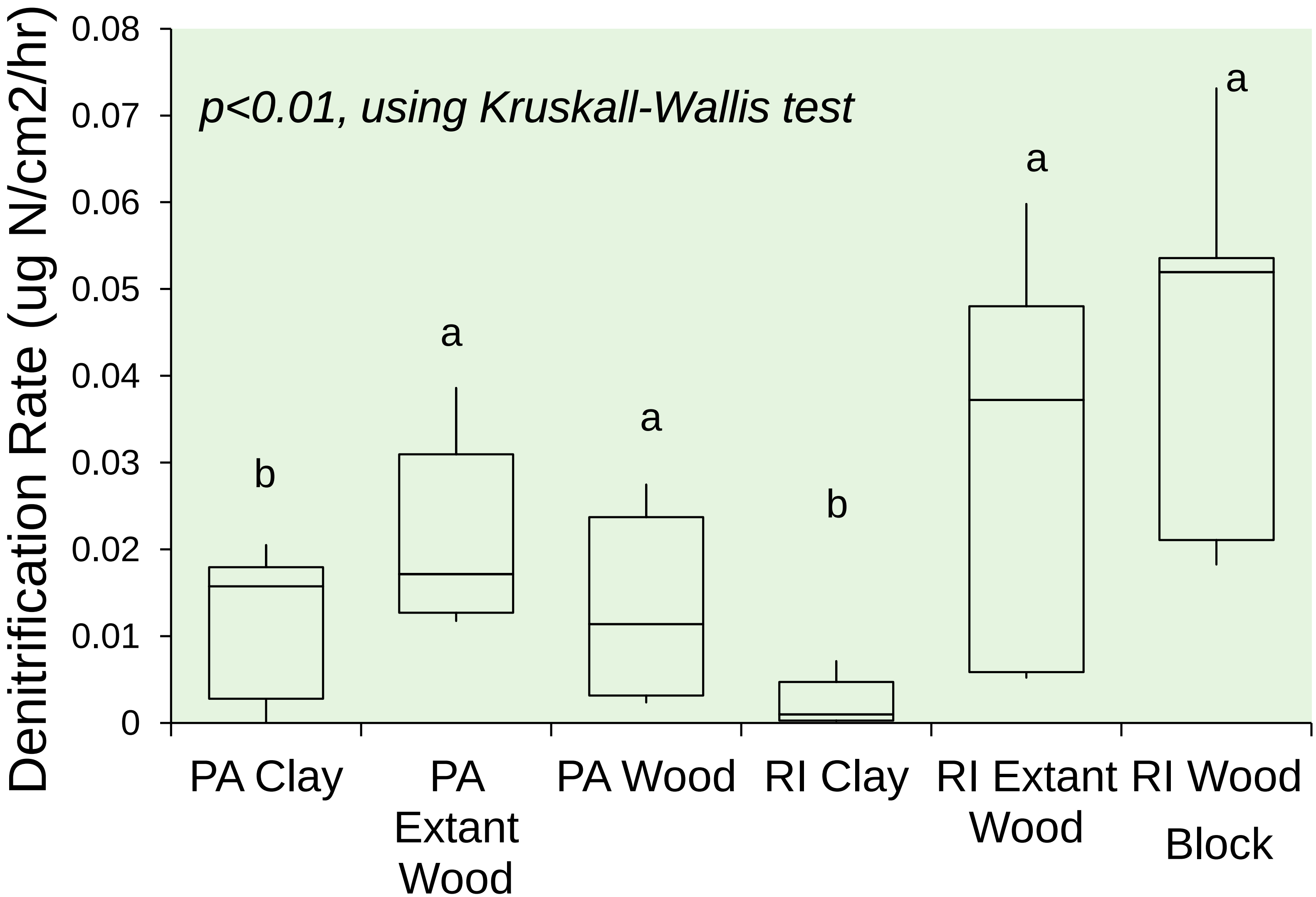

Methods

- NO_3^- ^{15}N tracer
  - Heavier isotope used to trace DeN that occurs in mesocosm
- Incubation samples at time 0, 1.5 hrs, 3 hrs, and 18 hrs
- Substrates in oxic and anoxic environments
- Rates expressed in ug N/cm^{-2} hr^{-1}
- Biofilm mass

Results

- **Woody substrates usually displayed the highest N transformation rates**
- **Biofilm development was most substantial on woody substrates in the forested, low-nitrate stream; mineral substrates had the lowest accumulation of biomass**
- **Nitrous oxide generation was negligible (< 0.1%) in both oxic and anoxic mesocosms for all substrates and across all rates of denitrification.**

Wood substrates had significantly higher denitrification rates than clay substrates.



Implications

- Wood substrates, whether new or extant, tend to generate higher denitrification and nitrate disappearance rates than mineral substrates, suggesting that fresh inputs of natural woody debris, like branches and tree trunks, may be an important nitrate sink in streams.
- This research further emphasizes the importance of restoring mature forest cover in riparian settings for nitrogen management.

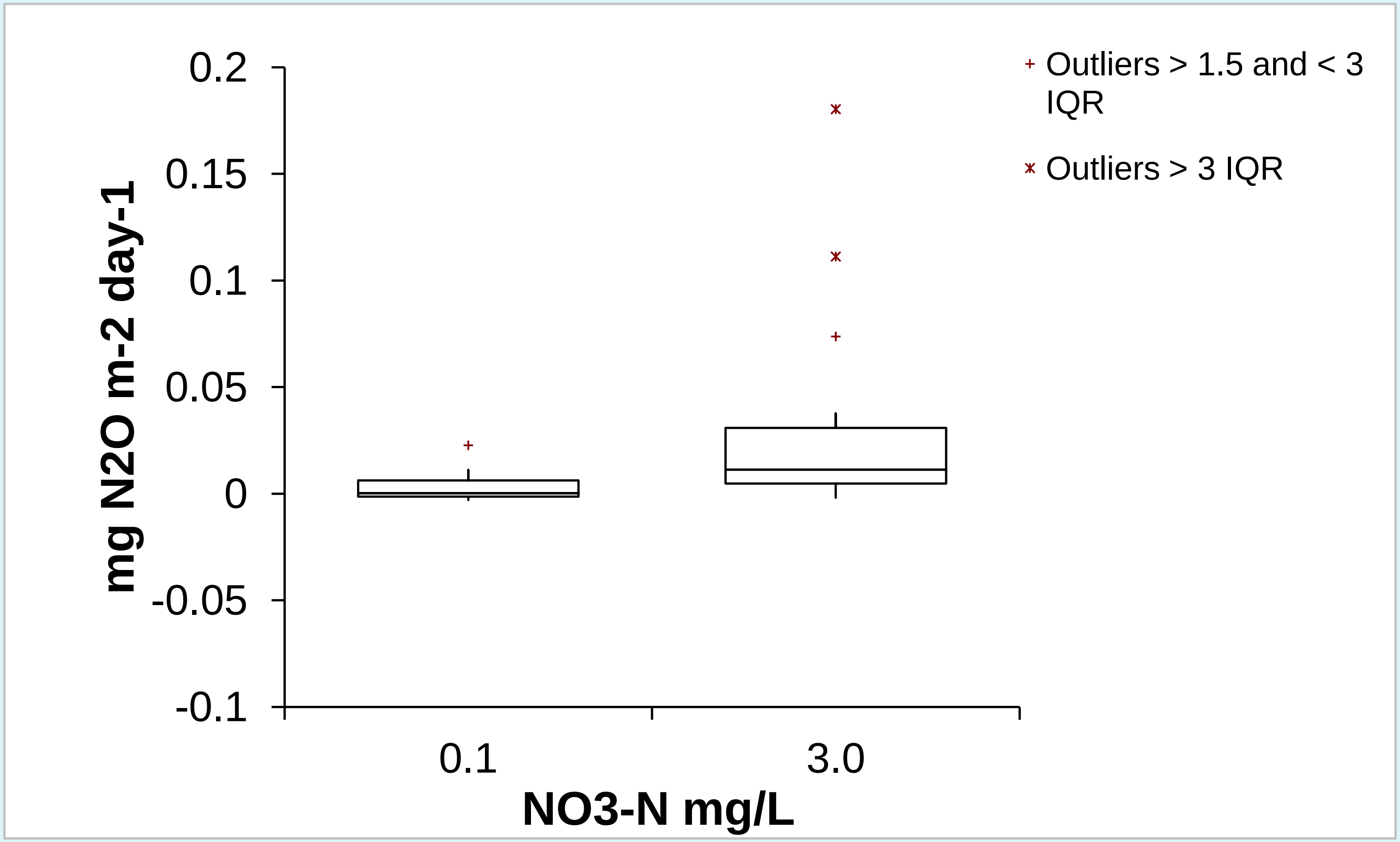
Current Work

- Examine role of beaver ponds in N attenuation and cycling
  - Routine supply of fresh wood
  - Accumulation of organic matter
  - Beaver populations increasing

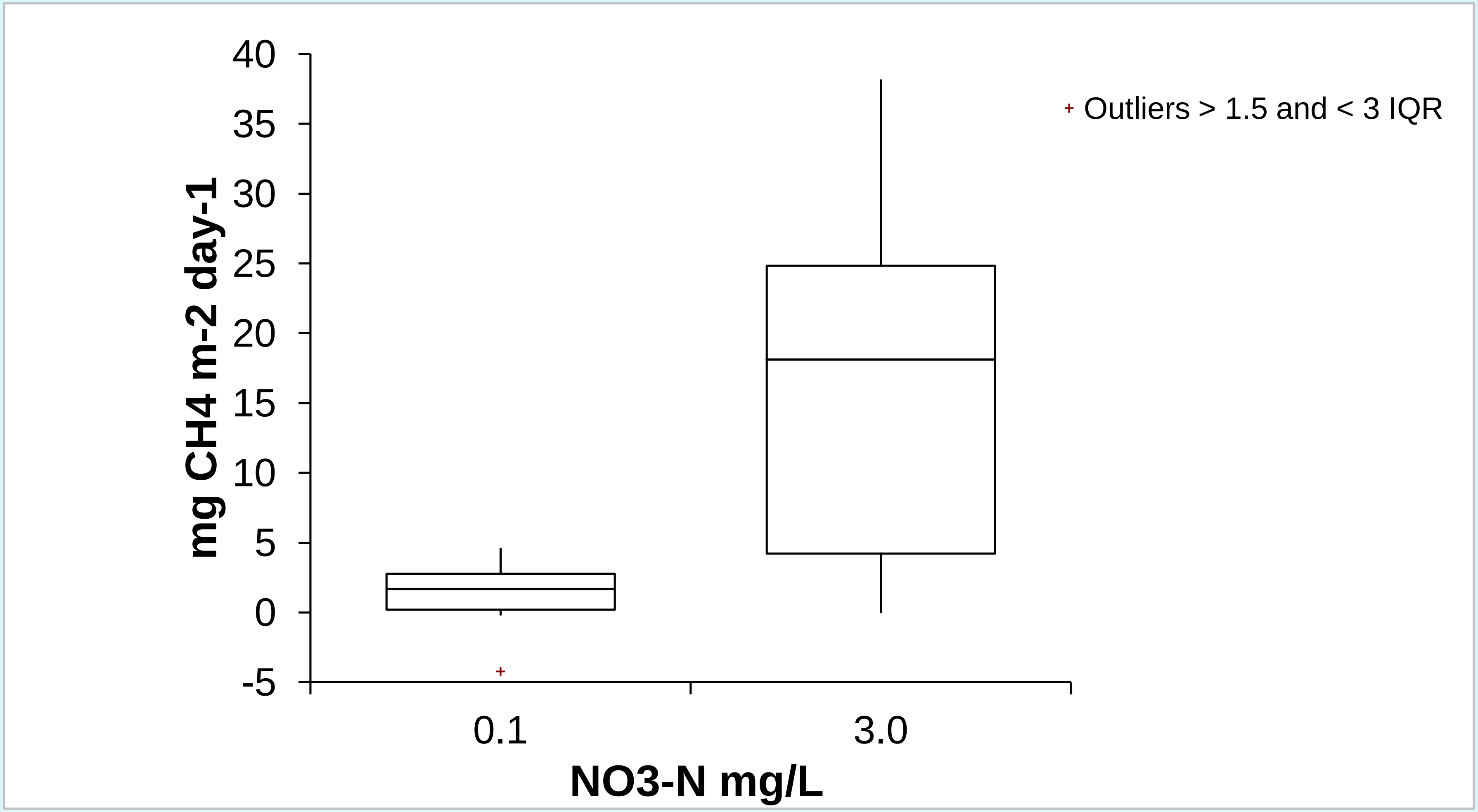
Current Work: Balancing Ecosystem Services with Greenhouse Gas “Disservices”

- Concerns have emerged about side effects of ecosystem “disservices,” especially greenhouse gas production, associated with landscape approaches to agricultural nutrient management
- Using N_2O, CO_2, and CH_4 production disservices associated with wetland nitrogen removal services as an example, we are trying to assess the greenhouse gas implications of landscape nitrogen management

Stimulation of denitrification is expected to increase N_2O flux, although a recent review suggests that stream N_2O fluxes are non-responsive to nitrate concentrations (Beaulie and others 2011). Further development of this work should allow for a complete accounting of the greenhouse gas disservices associated with the nitrogen removal services that take place in the pond sink area.



Increased CH_4 flux in the presence of higher NO_3^- contradicts expectations based on thermodynamic theory, wherein we would expect reduced CH_4 emissions because increased NO_3^- should stimulate denitrification, a more favorable form of anaerobic respiration than methanogenesis (Tiedje and others 1984).



Future Prospects

- Advances in landscape science are a platform for addressing emerging concerns about ecosystem disservices associated with the water quality maintenance function/services of wetlands, riparian buffer zones, etc.
- A quantitative understanding of water and nitrogen sources and sinks provides a basis for quantifying greenhouse gas fluxes and establishing linkages to fertilizer dynamics and other human activities

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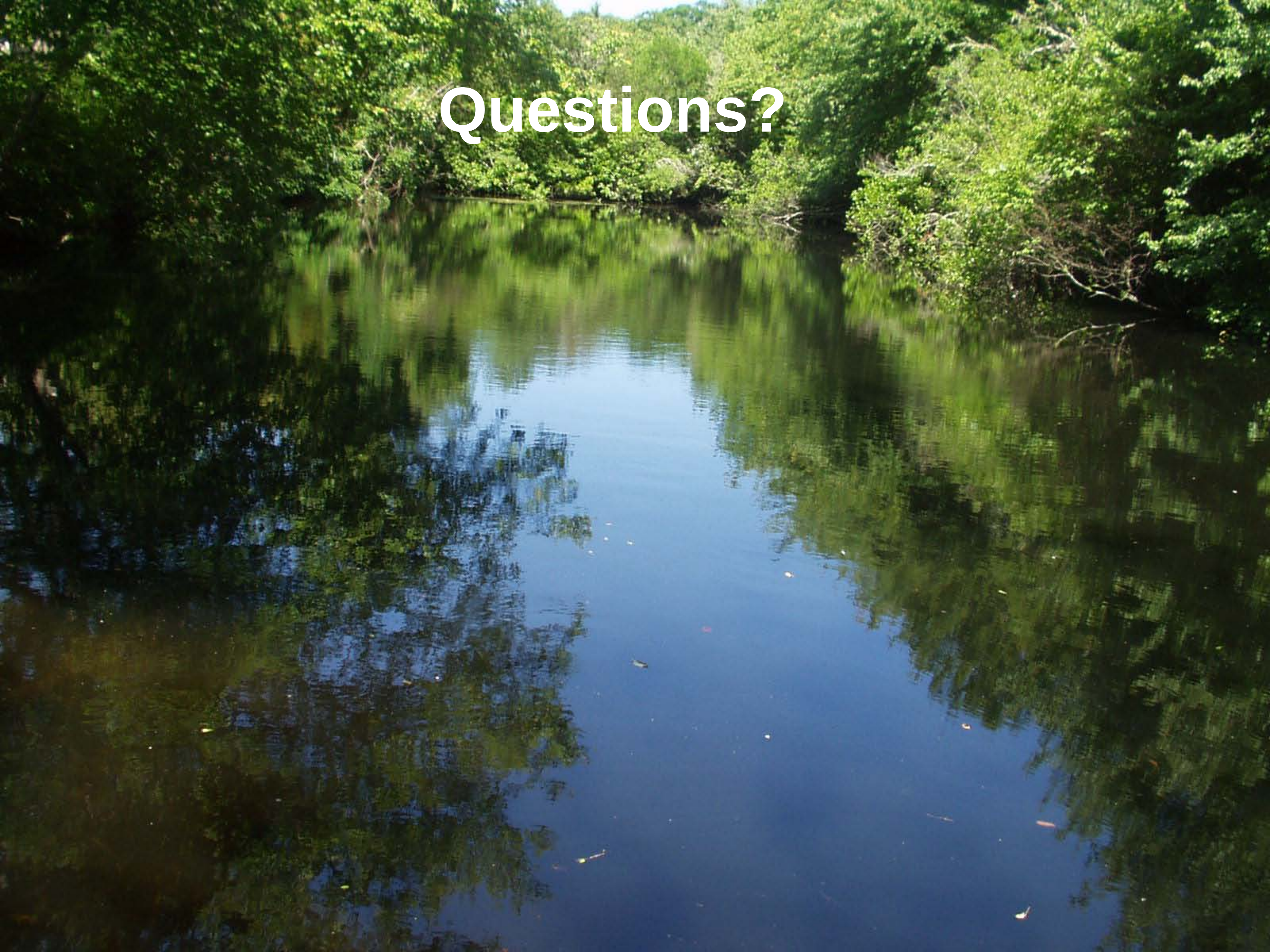
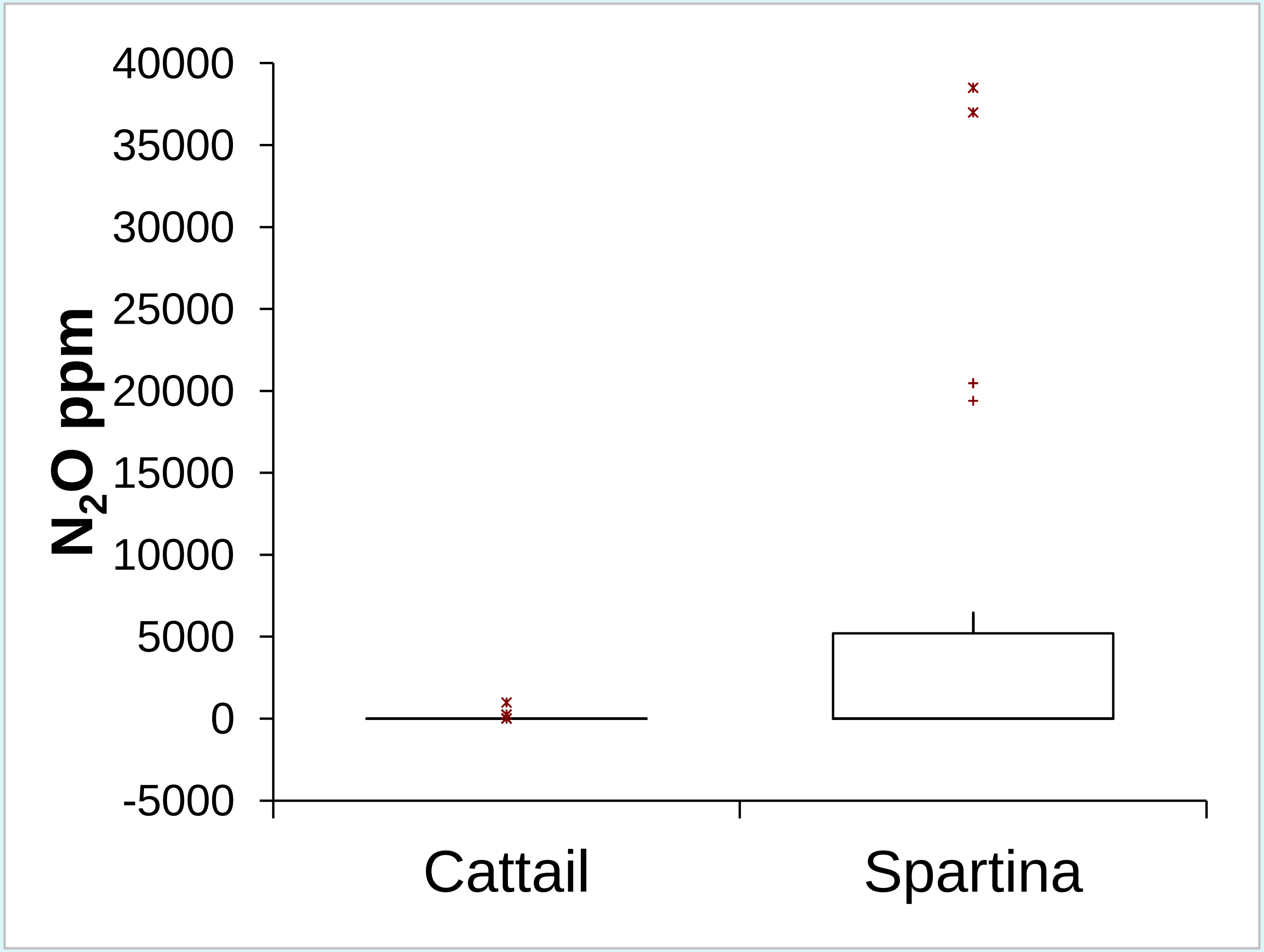

Questions?

Data from sampling on Feb. 3-4, 2011.
p value =0.01 using a t-test



Data from sampling on Feb. 3-4, 2011.
p value=0.0593 using a t-test.