Defining the Balance Between N_2 Fixation and Denitrification in Falls Lake

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UNRBA MRSW
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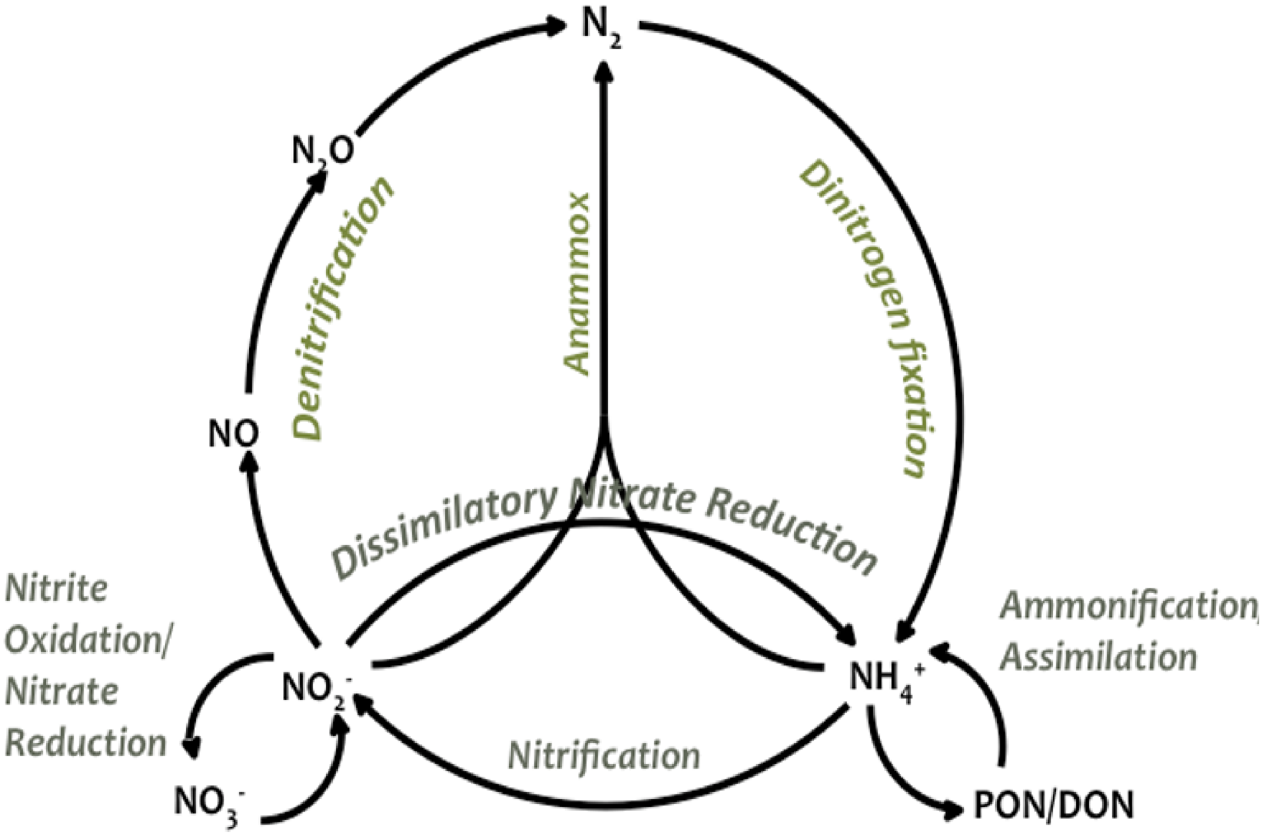
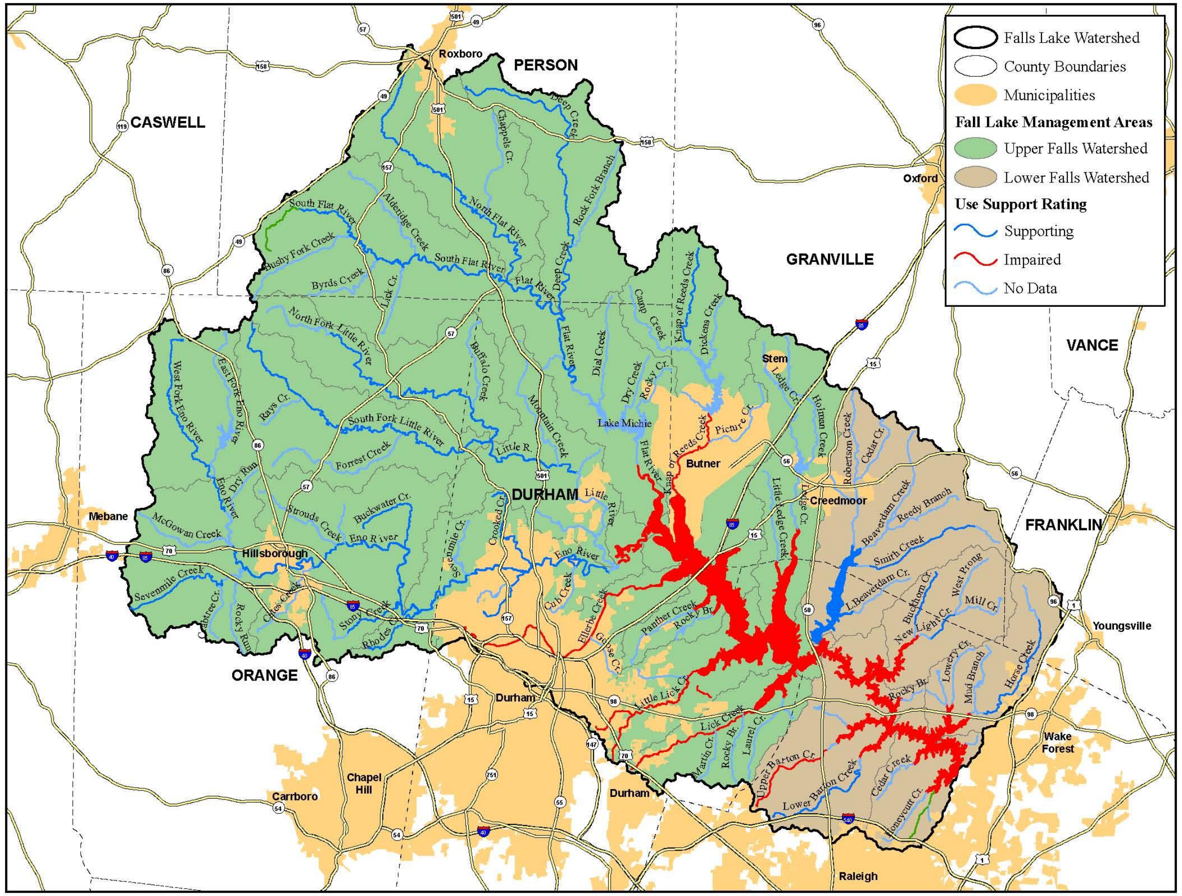
The nitrogen cycle – an overview and its importance to management and policy



FALLS LAKE WATERSHED



Understanding N_2 fixation of Falls Lake is a good idea

1) N_2 fixation can represent an important pathway of new N inputs-enhanced fertility and associated problems of eutrophication

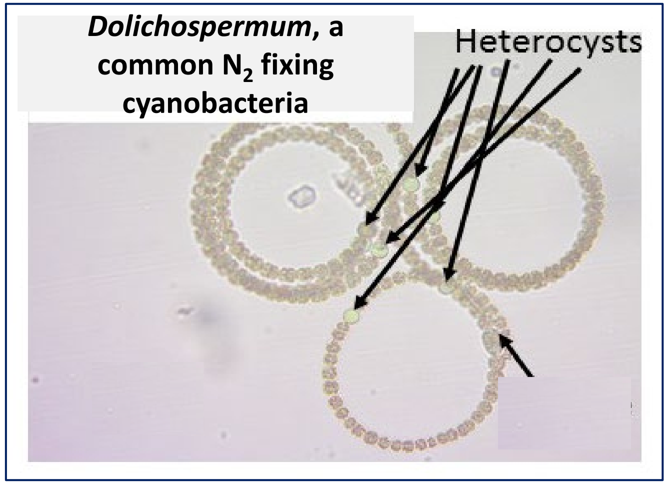
2) Many N_2 fixing cyanobacteria are scum and/ or toxin producers

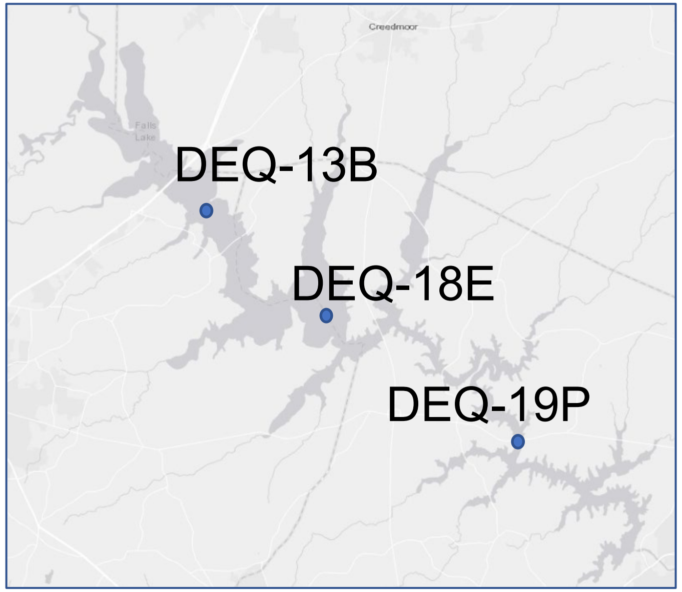
3) Balance of N_2 fixation and denitrification often determines nutrient limitation-can inform more effective nutrient control strategies

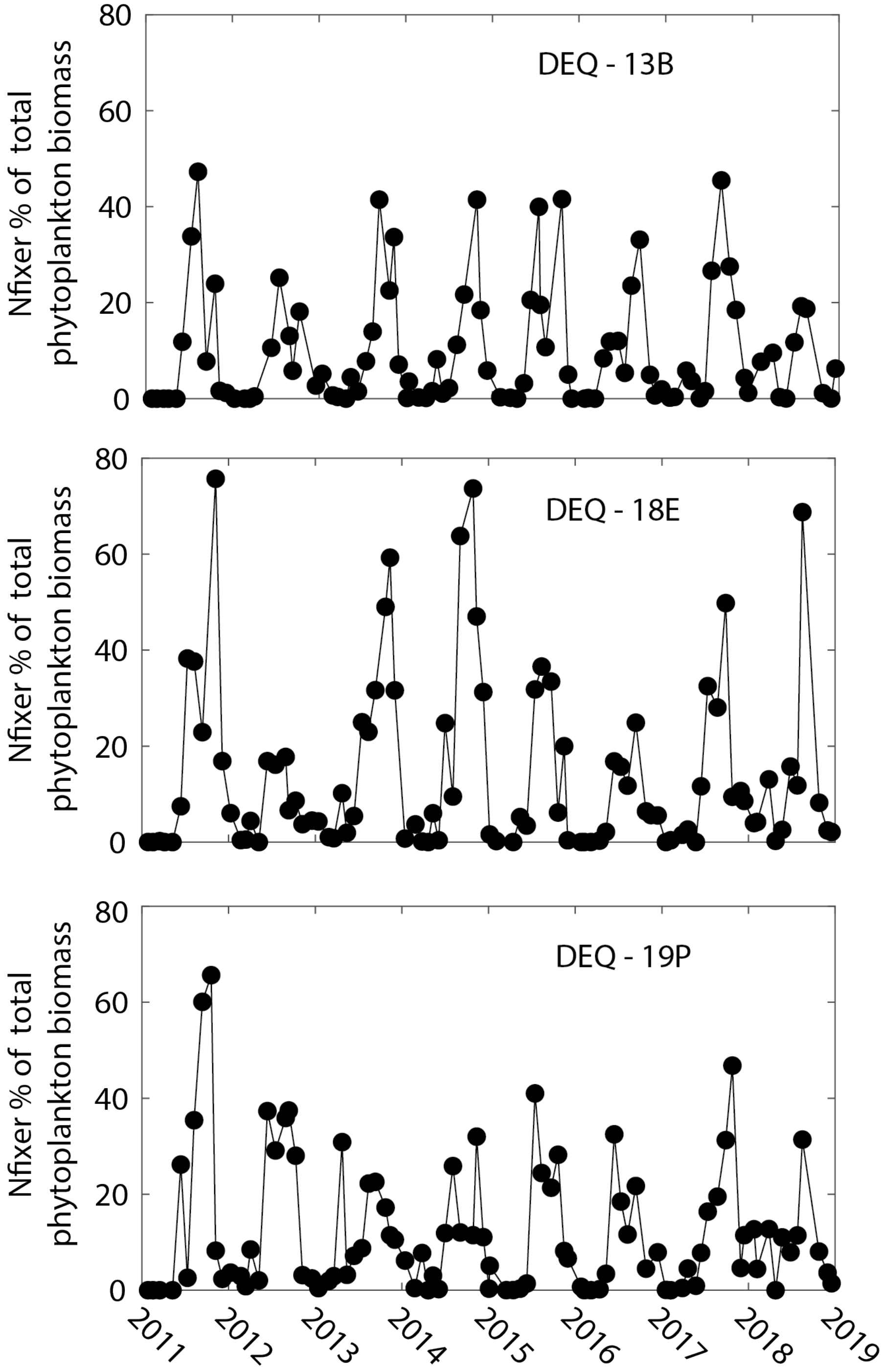
4) Can help constrain other parts of the N budget that are difficult to measure such as denitrification

Parking under the buzzard tree at the Barton Creek boat ramp is a BAD IDEA!

N_2 fixing cyanobacteria are important components of the Falls Lake phytoplankton community



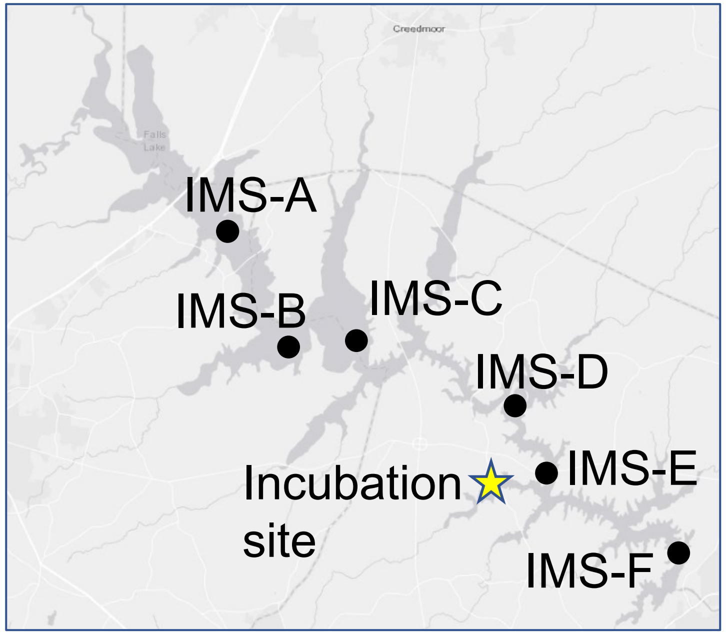




But N_2 fixing cyanobacteria are not currently represented in the latest DEQ or UNRBA models

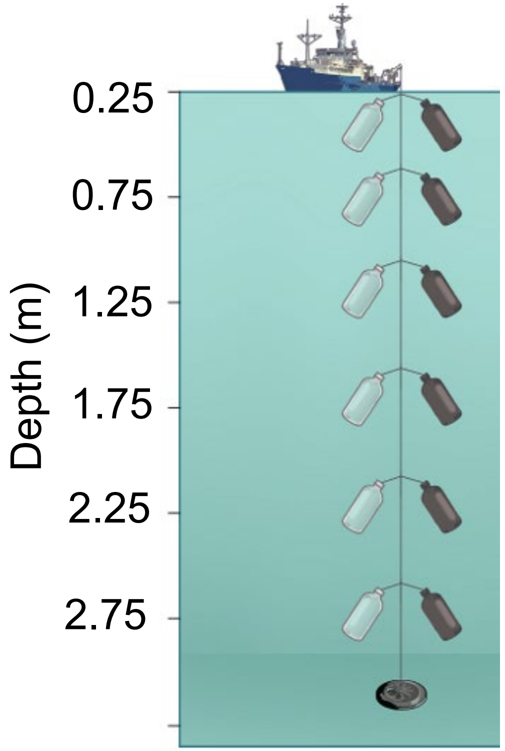
Study Objectives

1) Estimate lake-wide rates of N_2 fixation to determine its importance relative to other N sources
2) Explore correlates of N_2 fixation to constrain drivers
3) Experimentally determine N vs P limitation of phytoplankton growth
4) Construct a N mass balance for the lake that includes N_2 fixation to calculate a lake-wide estimate for denitrification

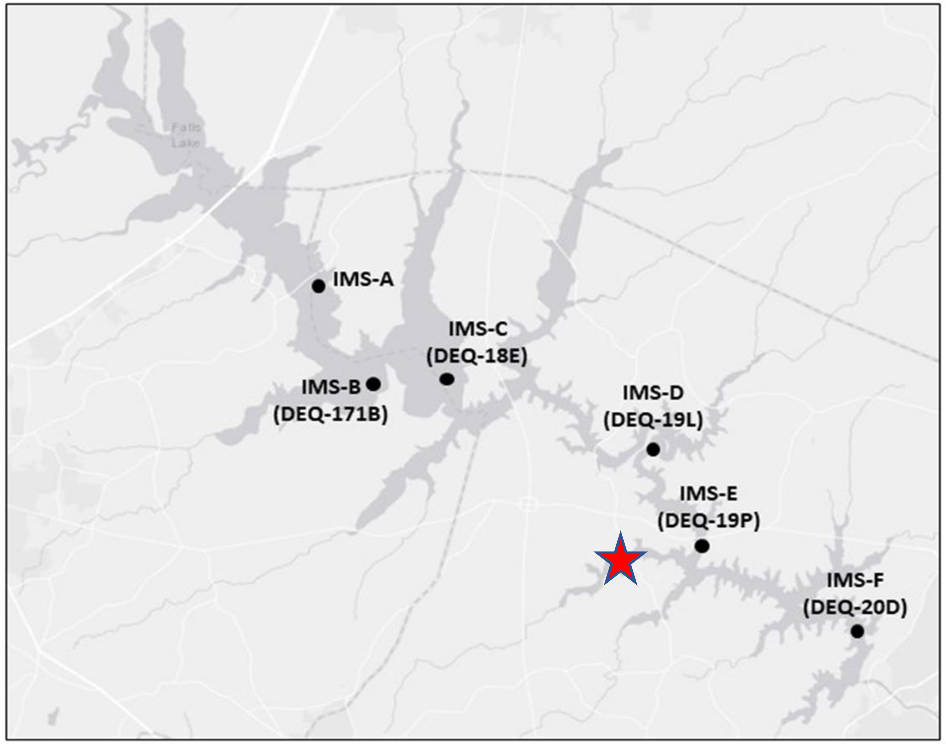


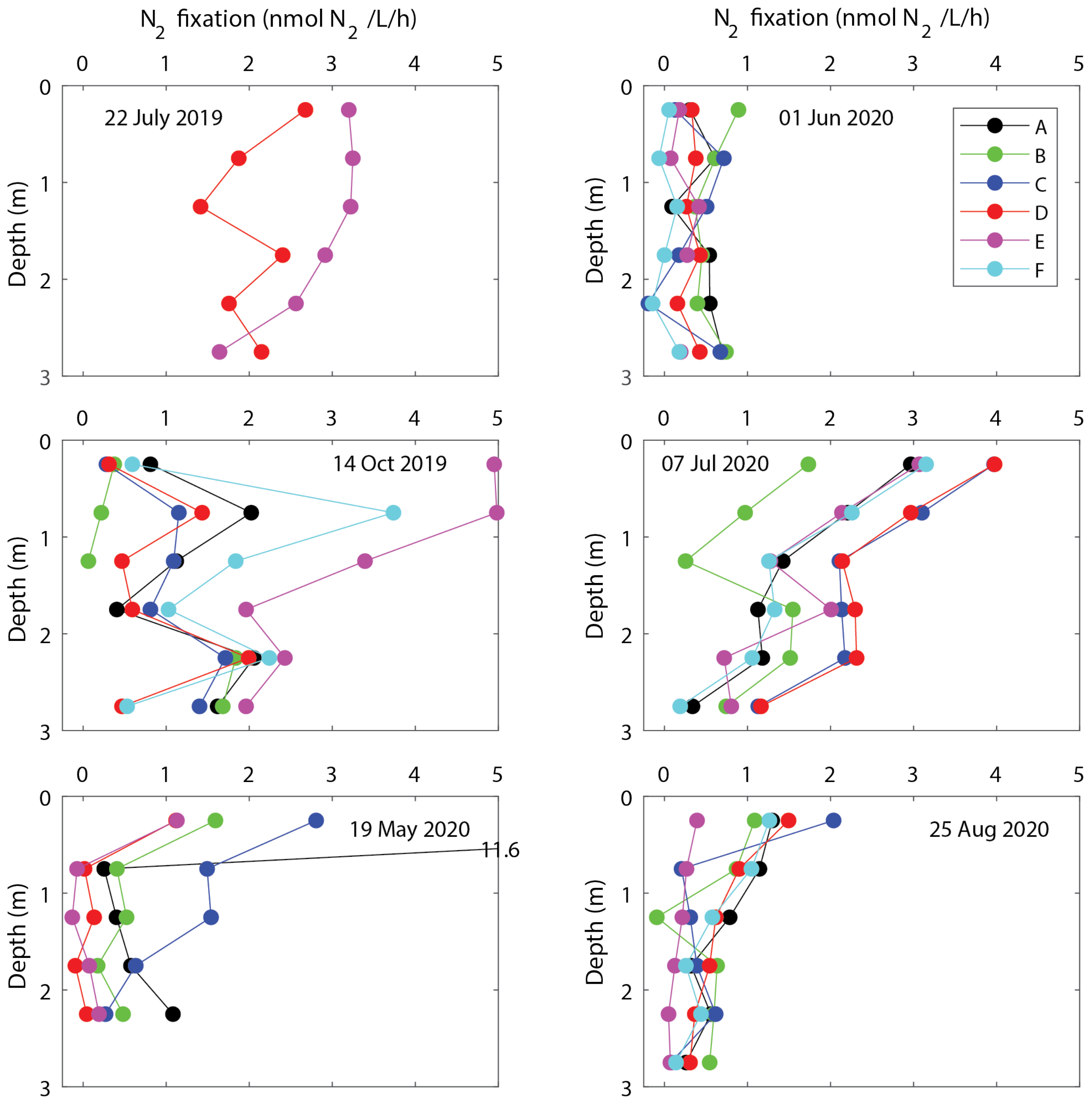
Main Channel Field Measurements 2019-2020

1) Collected photic zone composite sample from 6 sites
2) Light/ dark bottle, acetylene reduction assay
3) Incubated triplicated samples for 3-4 h at 6 depths (~50 to 1% PAR)
4) Deionized water blanks as a control for non-biological acetylene reduction
5) Calculated N_2 fixation based on 4:1 acetylene to N_2 fixation ratio
6) Ancillary measurements of nutrients, phytoplankton biomass/ composition, hydrographic profiles, and P.A.R.

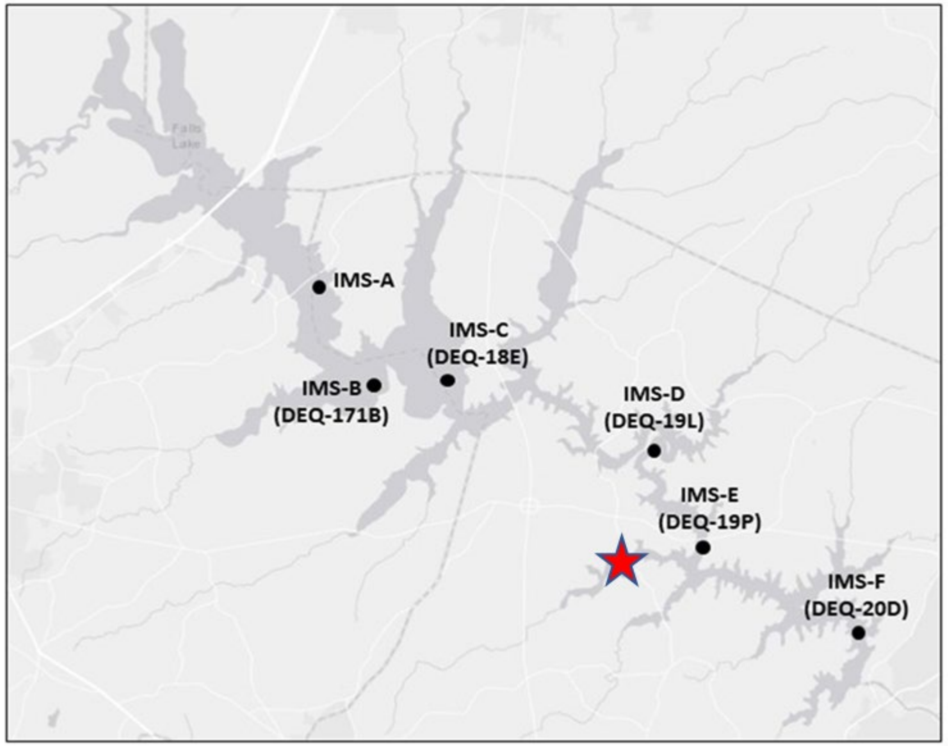


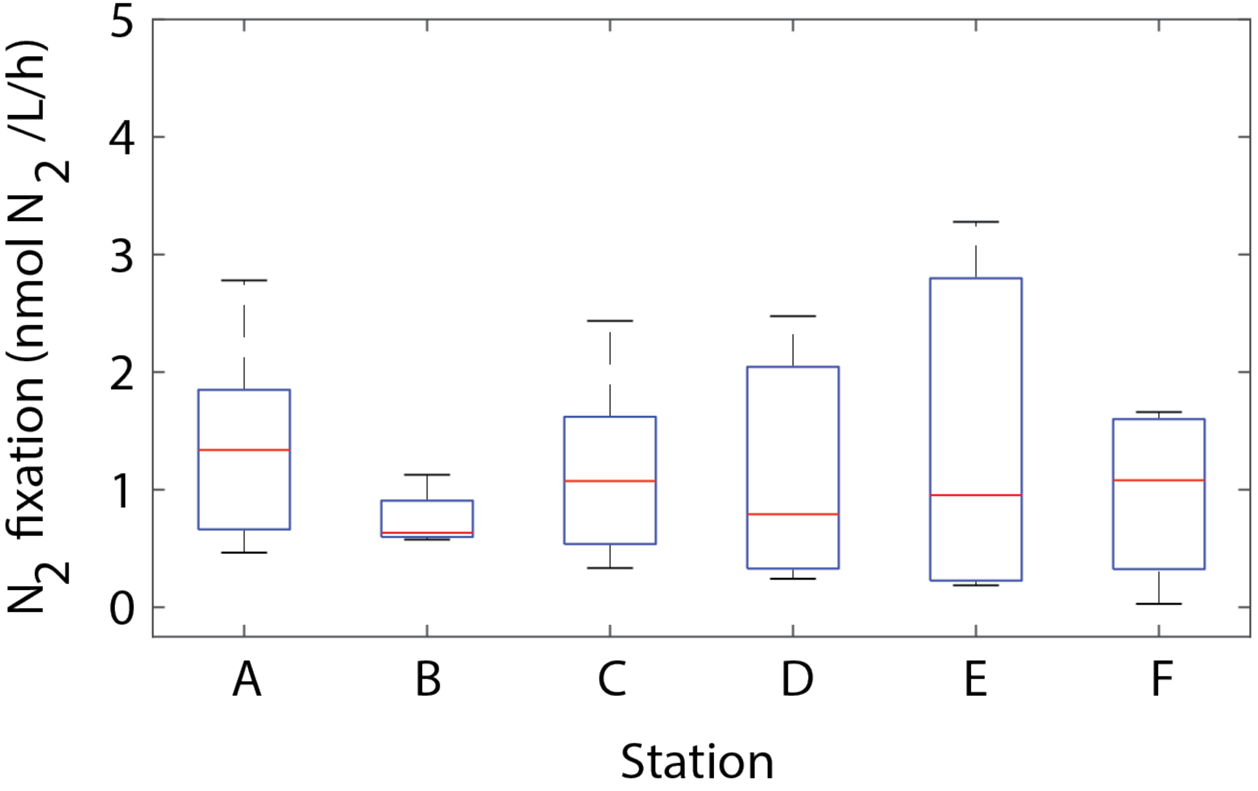
Depth profiles of N fixation
at 6 main channel stations on 6 dates



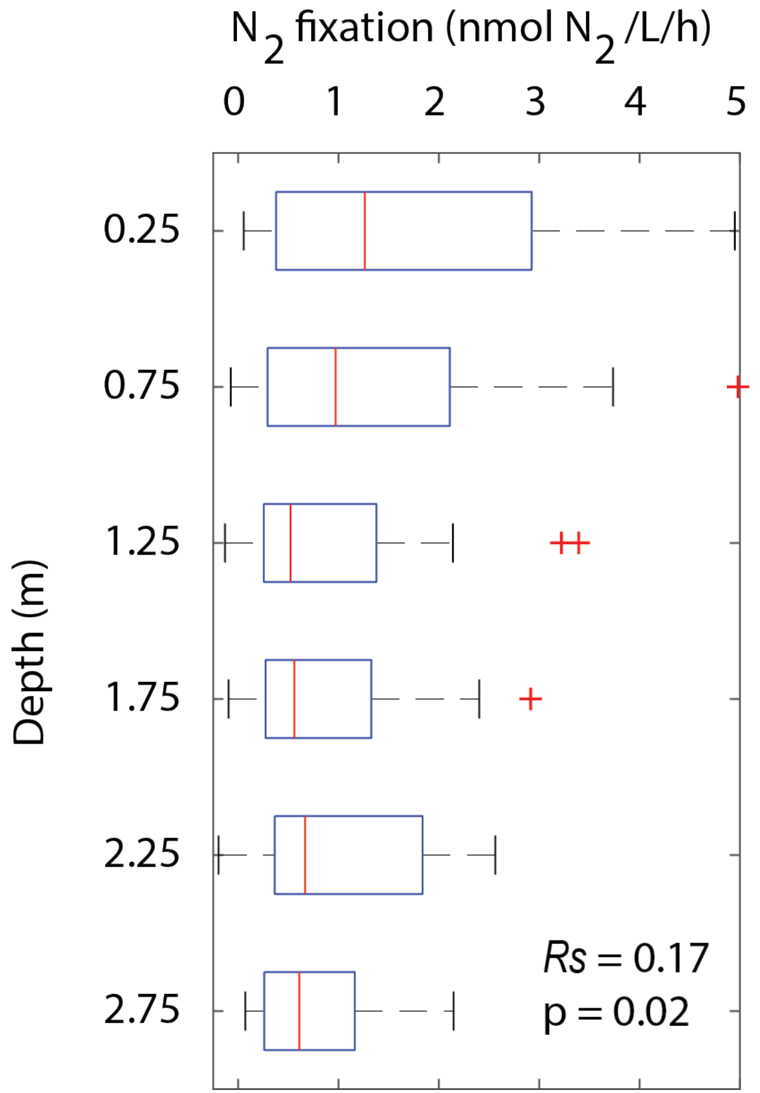


No strong downstream patterns were evident

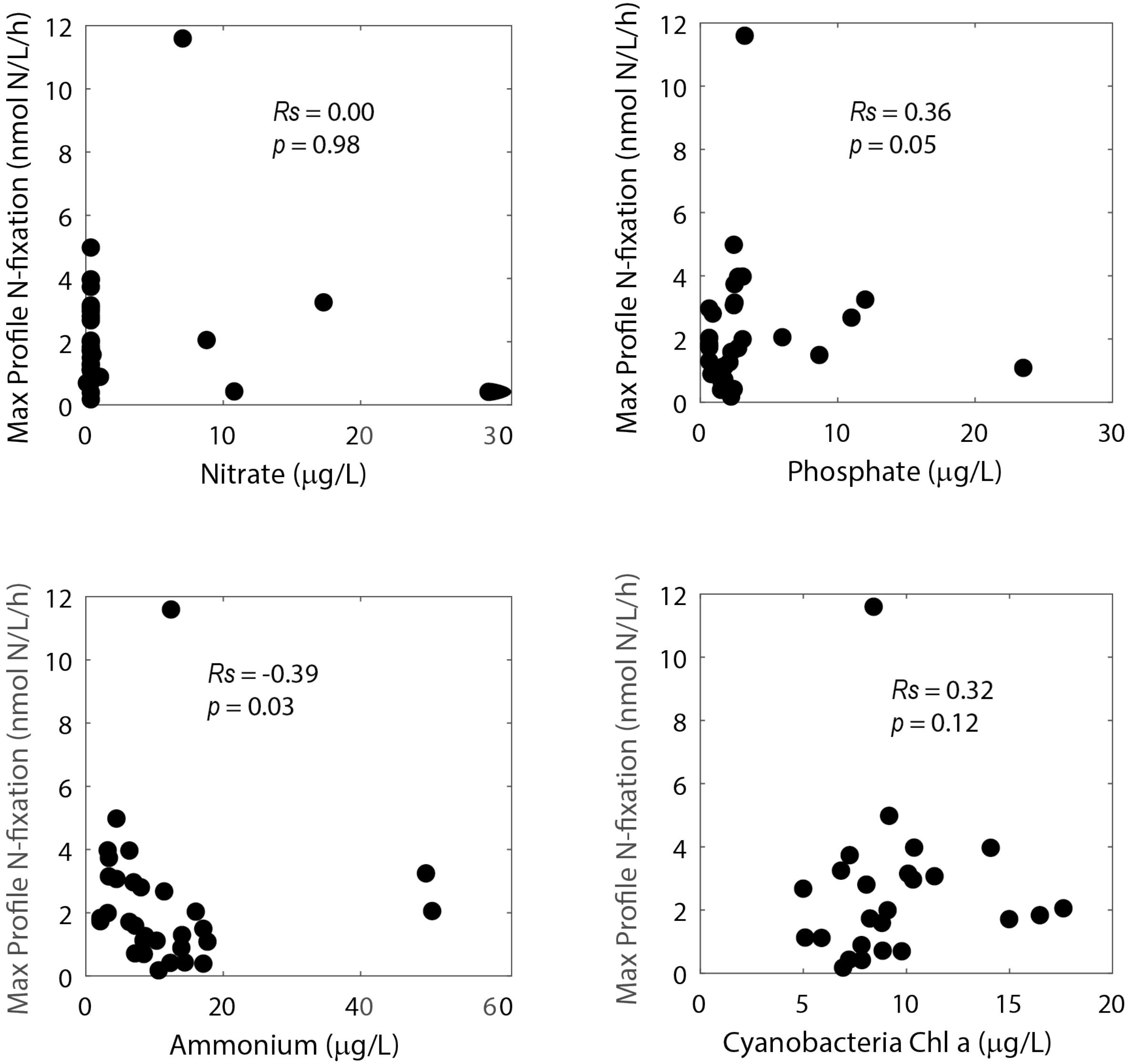


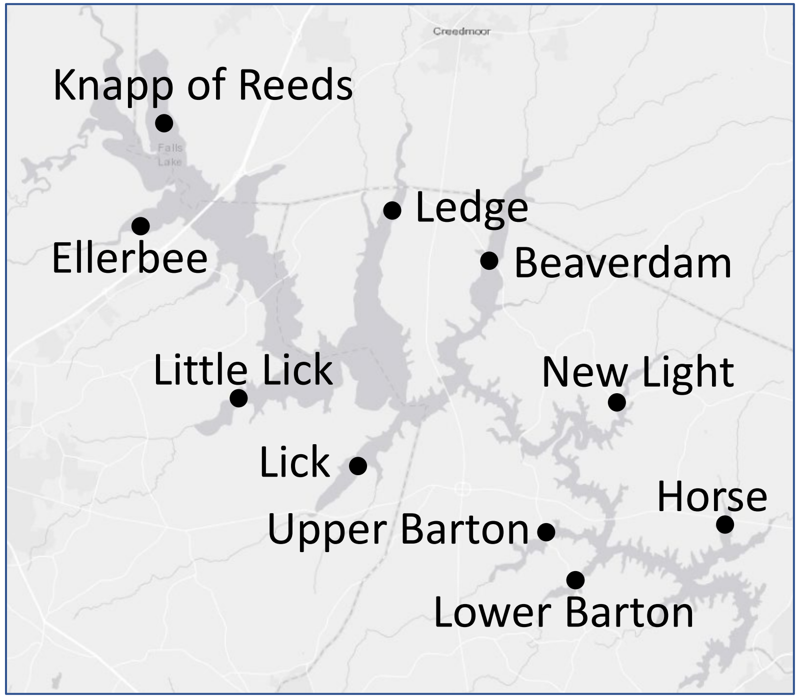


Response to the light gradient was weak but statistically significant



Negative relation to ammonium and positive relation to phosphate



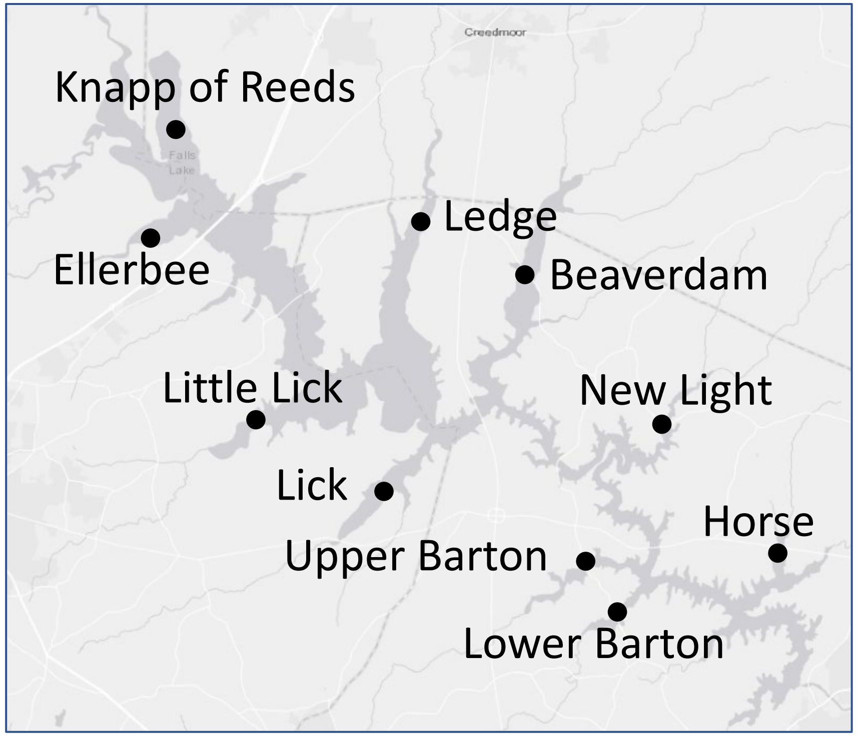


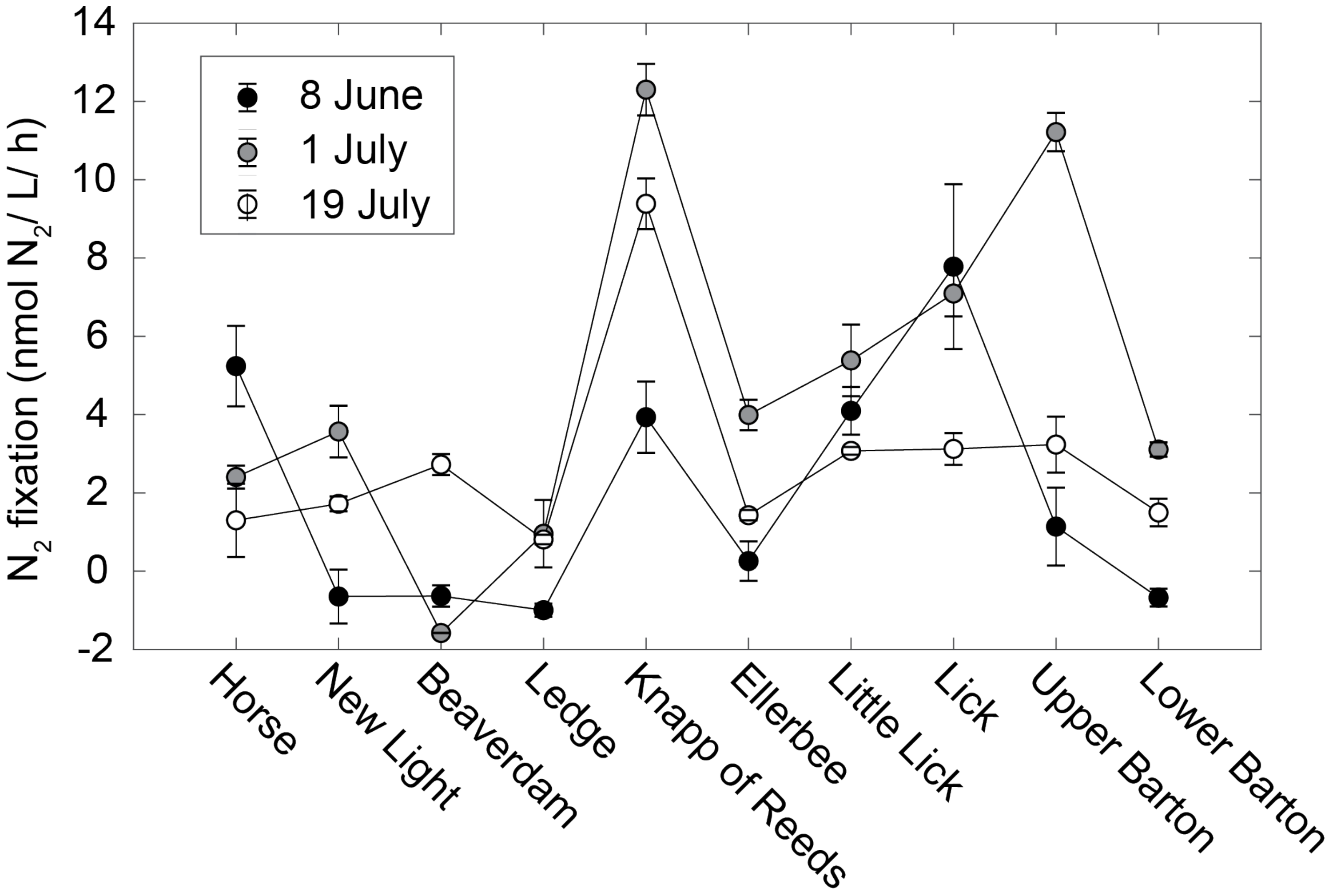
Creek Arm Field Measurements 2021

1) Surface grab from 10 creek arms, May, June, and July 2021
2) Light/ dark bottle, acetylene reduction assay, 20% PAR
3) Incubated triplicated samples for 3-4 h
4) Deionized water blanks
5) Assumed 4:1 acetylene: N_2 fixation ratio
6) Ancillary measurements of nutrients, phytoplankton biomass/ composition, hydrographic profiles, and PAR

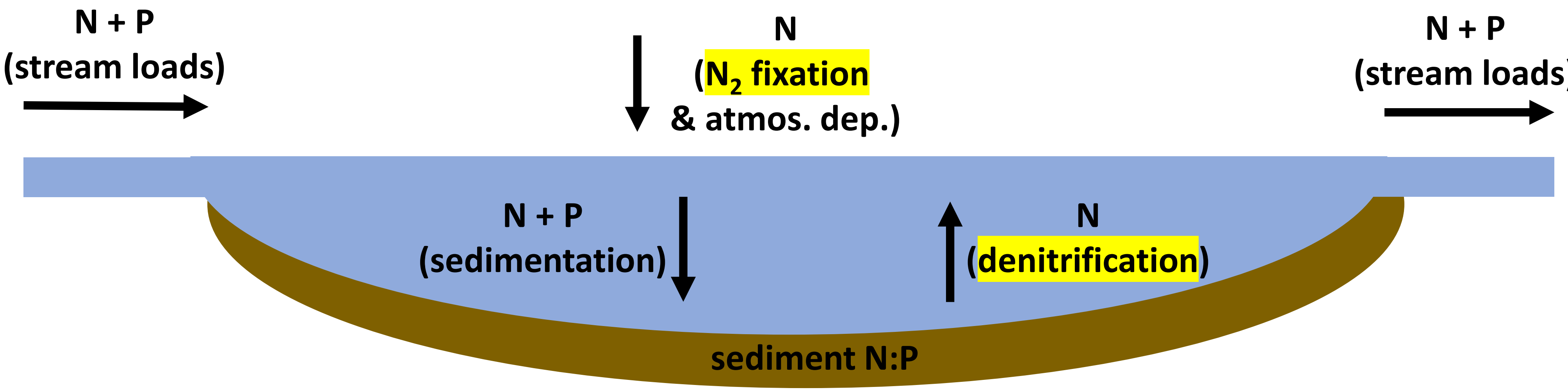
7) Spring and summer nutrient limitation experiments
   a) Control, N, P, N+P treatments- measured nutrients, biomass, and N_2 fixation

N_2 fixation in the creek arms





Estimating denitrification from a lake-wide mass balance of N and P

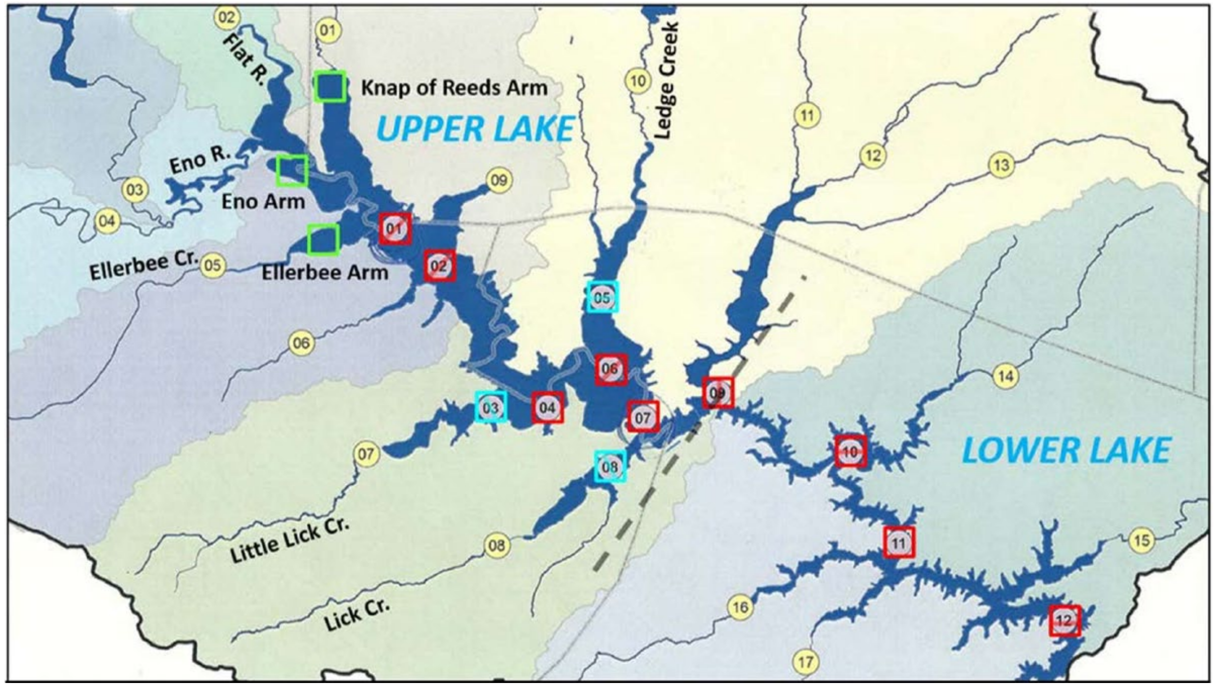


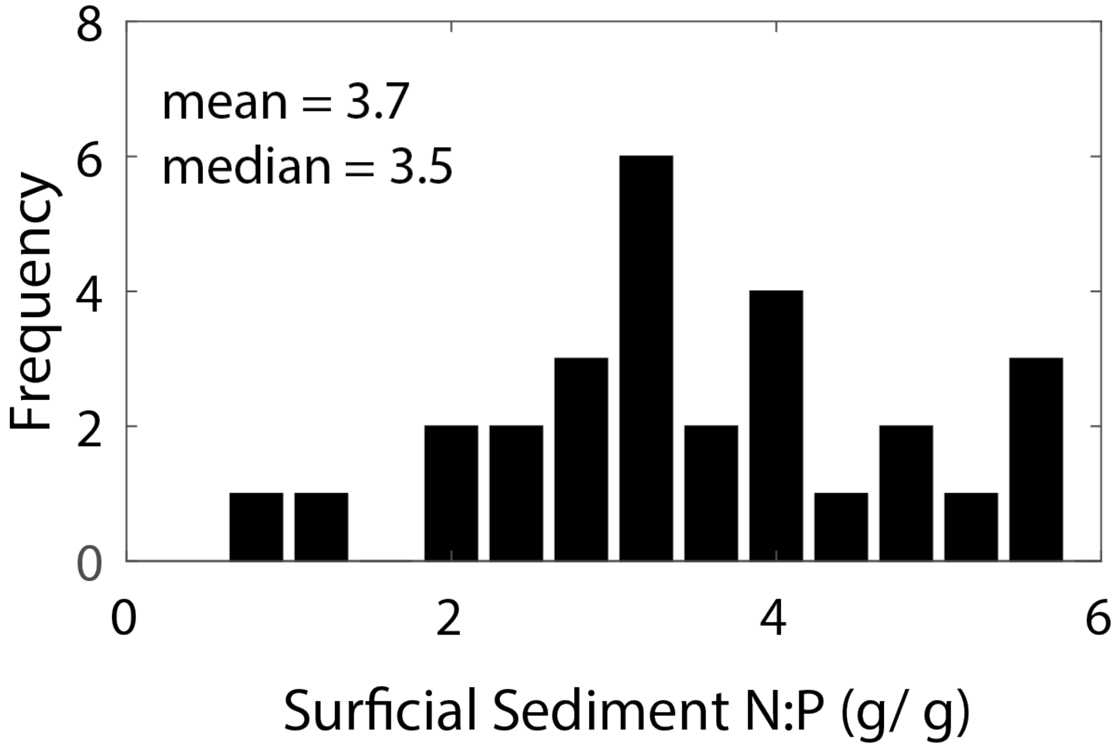
$$N_{ret} = N_{in} - N_{out}$$

$$P_{ret} = P_{in} - P_{out}$$

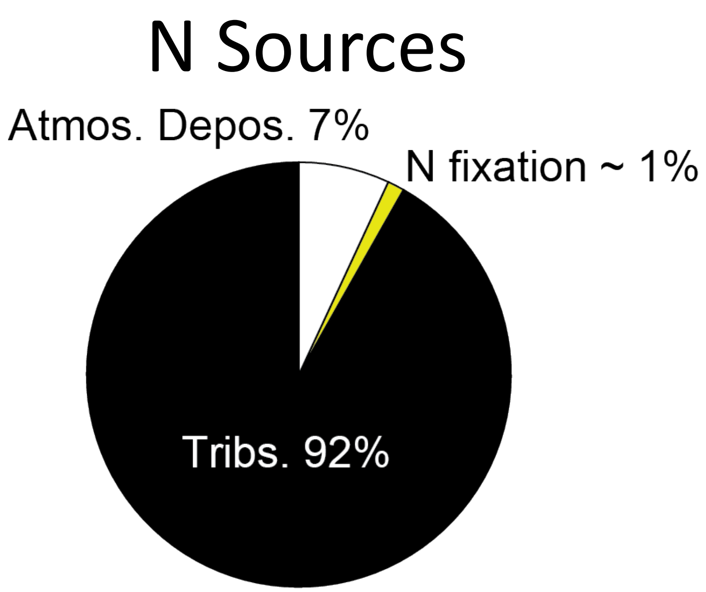
$$DNF = N_{ret}(N{:}P_{ret} - N{:}P_{sed})/(N{:}P_{ret})$$

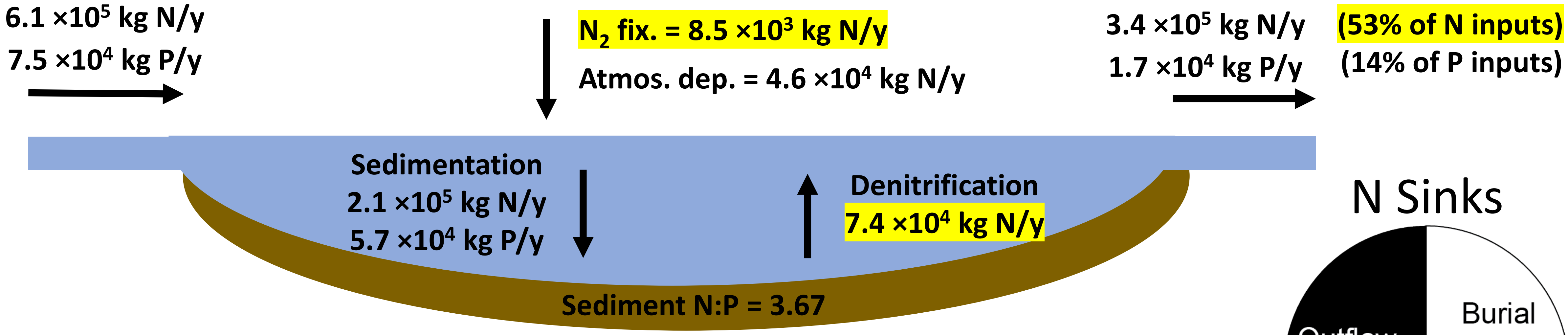
Sediment N:P ratios from UNRBA Study
Marc Alperin, UNC Chapel Hill

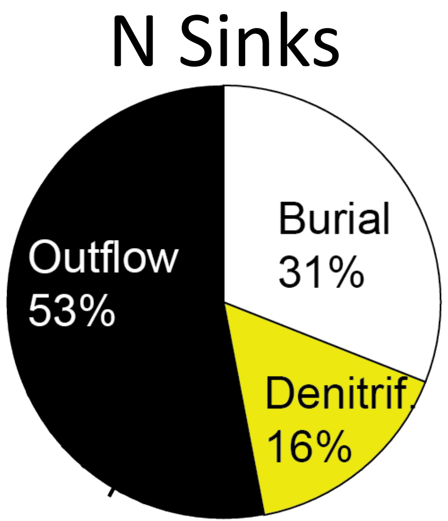




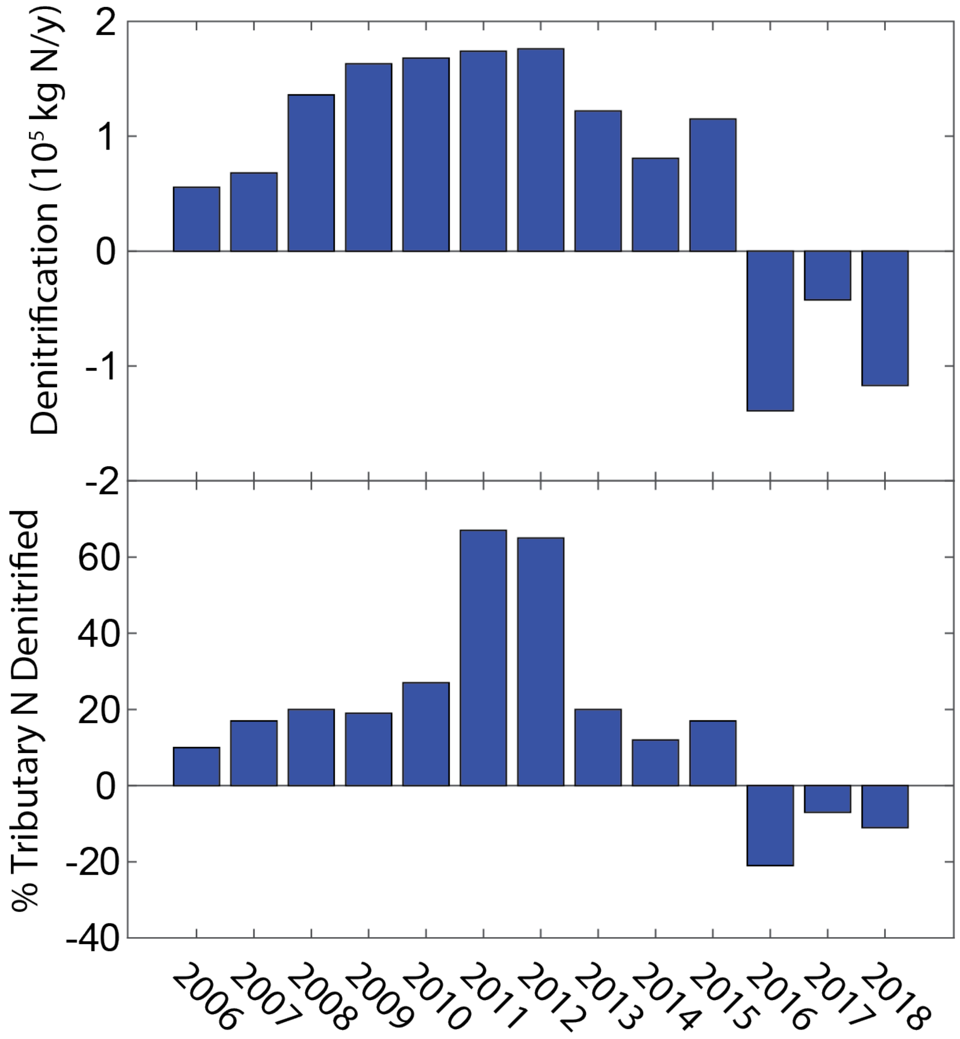
Budget for 2006-2018

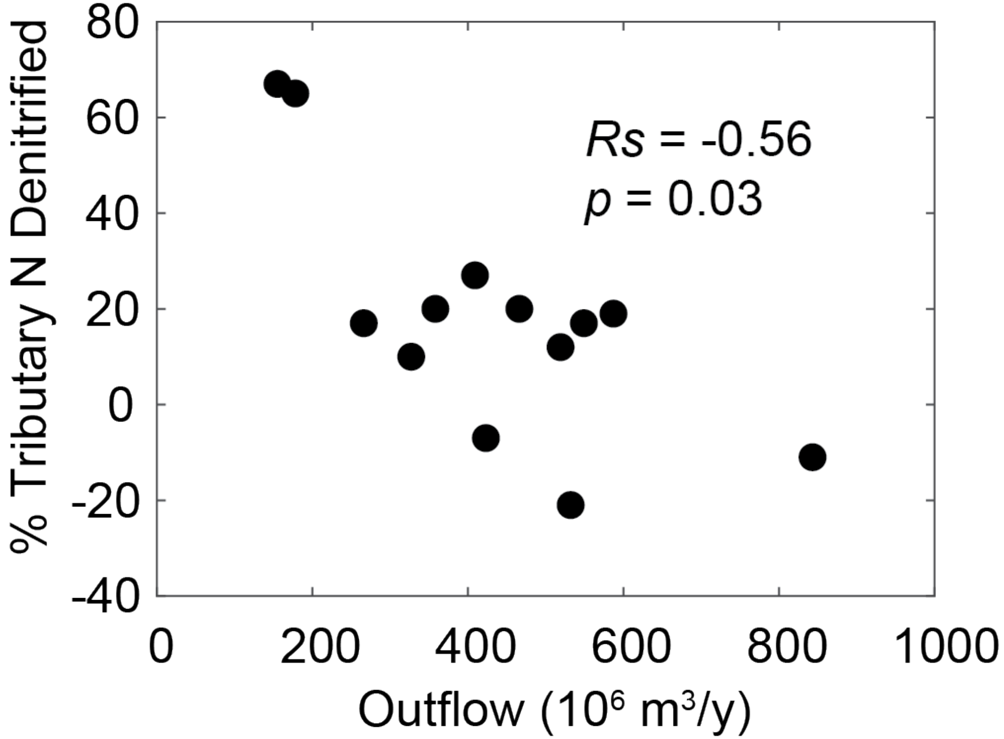






Annual Denitrification Rates by Mass Balance





Quantifying Sediment Nutrient Processing in Falls Lake

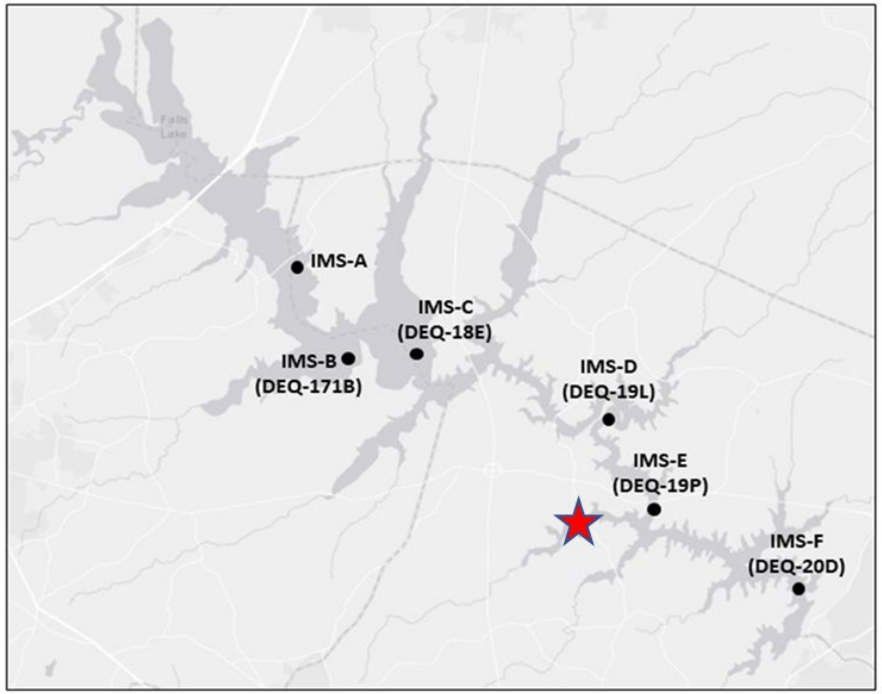
- Mike Piehler, Suzanne Thompson, Chelsea Brown, Anne Smiley
- UNC Chapel Institute of Marine Sciences

Questions

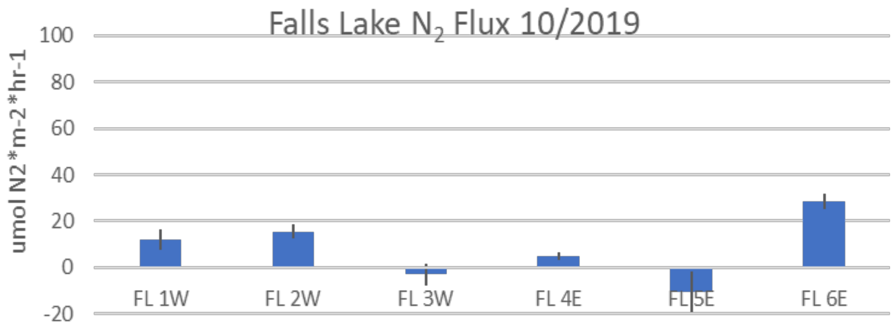
- What are the rates of sediment denitrification in Falls Lake
- How does denitrification vary in space and time?
- Is denitrification an important contributor to the fate of nitrogen in Falls Lake?

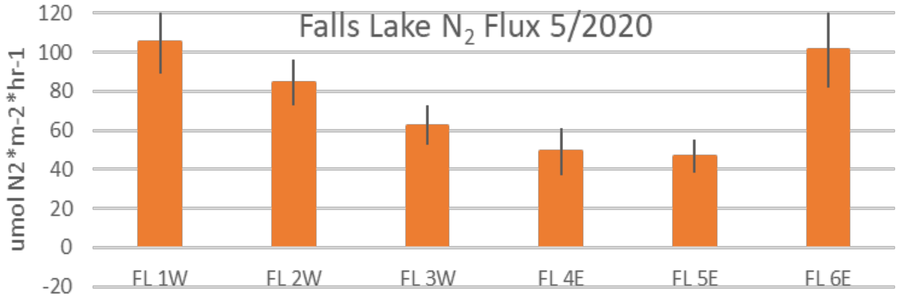
Methods

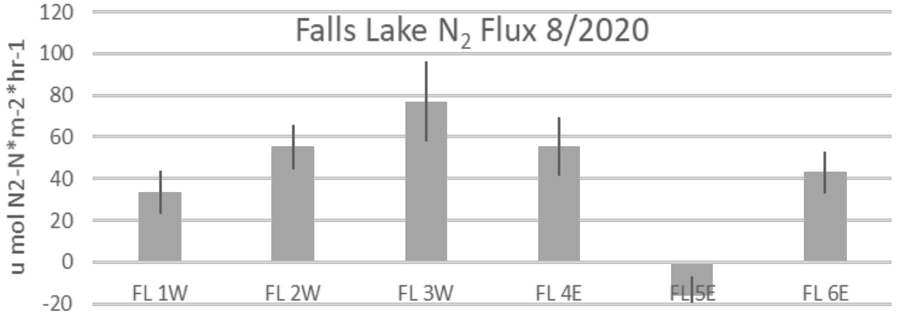
- Sediment cores and bottom water were collected in fall, spring, and summer along a transect of six sites
- Cores and water were transported to the Institute of Marine Sciences in Morehead City
- Continuous flow flux experiments were conducted
- Water samples were collected at 5-hour intervals from each core in gas tight vials for analysis of dissolved gases (N_2, O_2 and Ar)
- Analysis was conducted on a membrane inlet mass spectrometer (MIMS)
- Areal flux rates were calculated



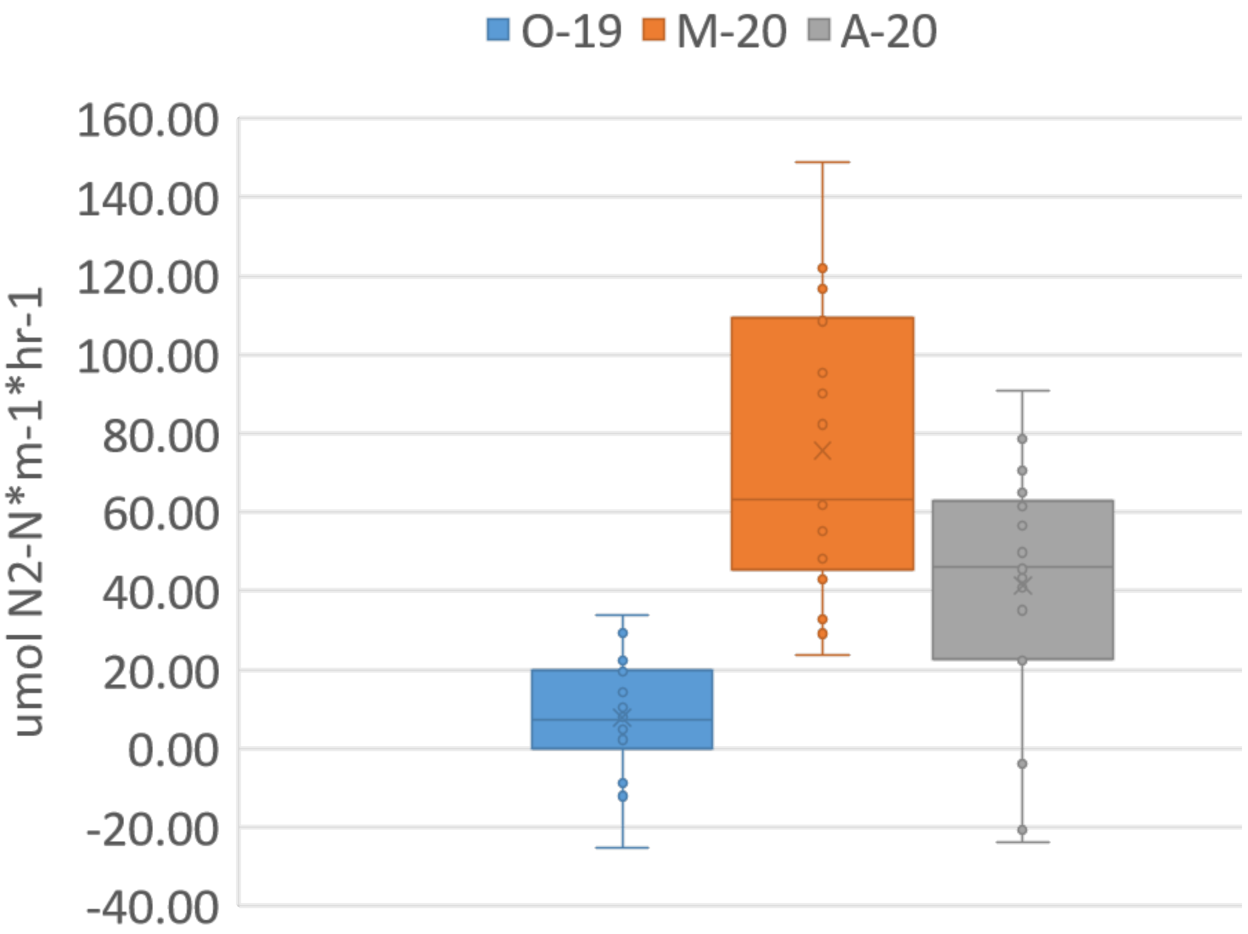
Direct Measurements of Denitrification by Sediment Core Incubations
Main Lake Sites





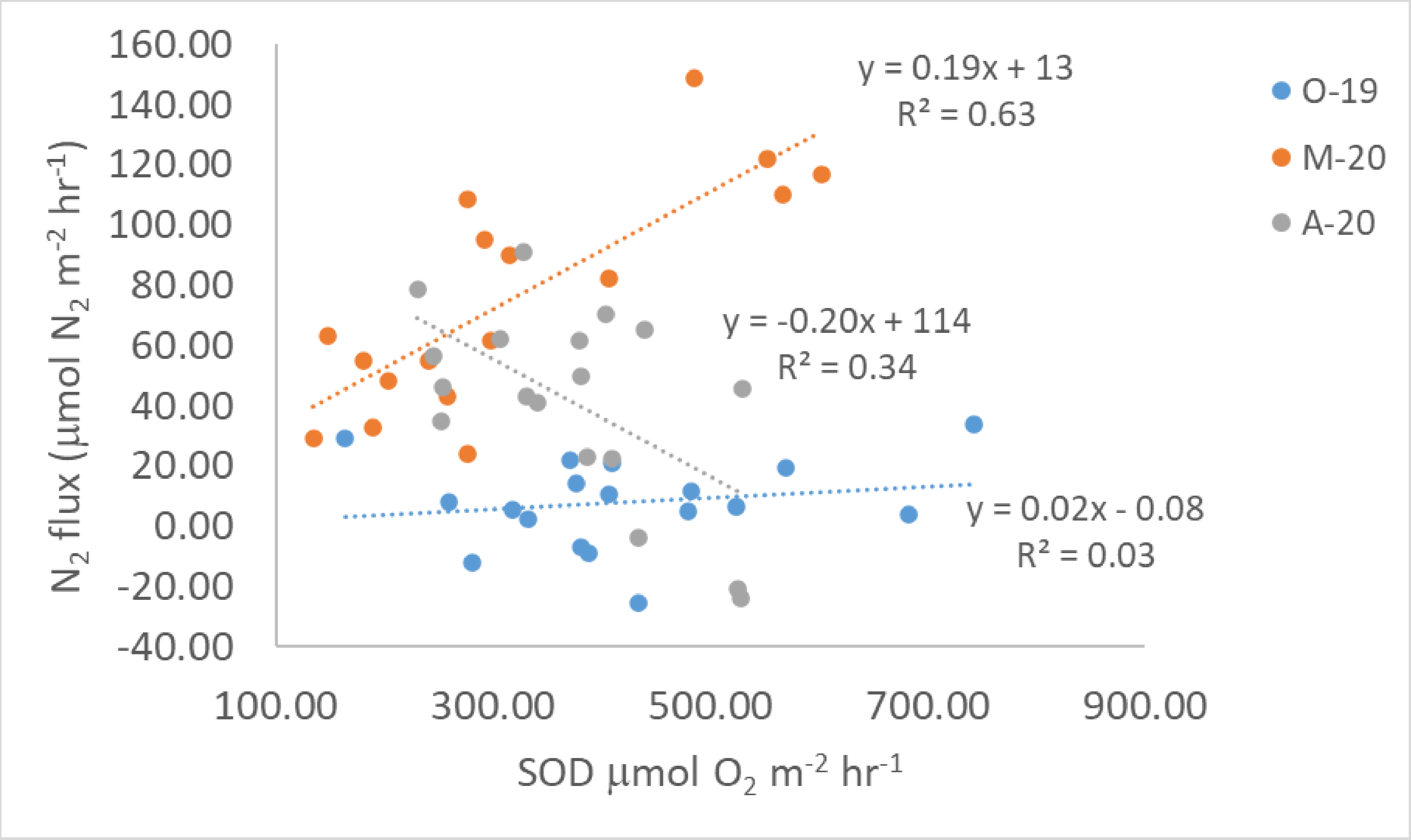


Average Denitrification Rates Scaled to Lake Sediment Surface



Denitrification as (% Stream Load)	
Oct 2019:	8%
May 2020:	75%
Aug 2020:	41%
Average	42%

Creek Arm Denitrification Vs. Sediment Oxygen Demand Indicates Coupled Nitrification-Denitrification When Water is Oxic



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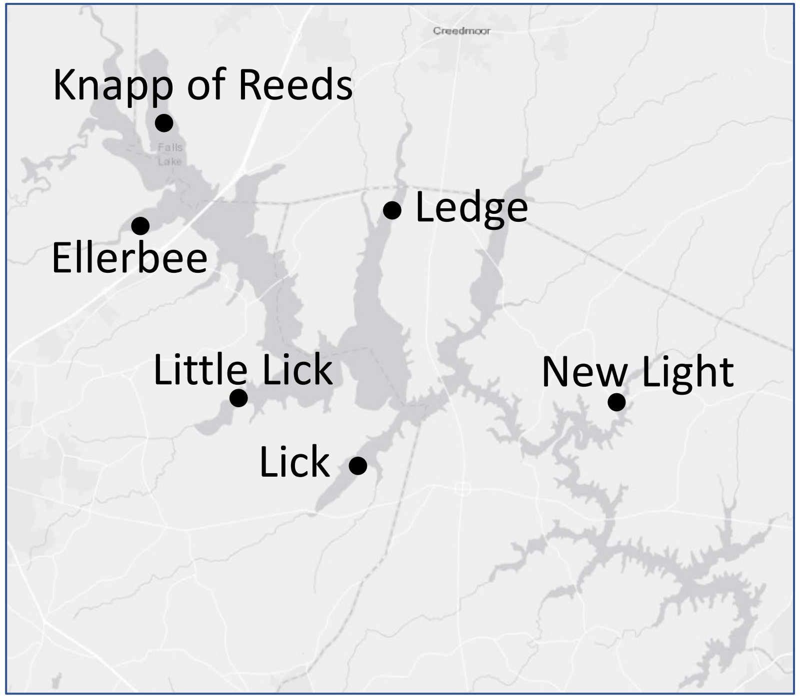
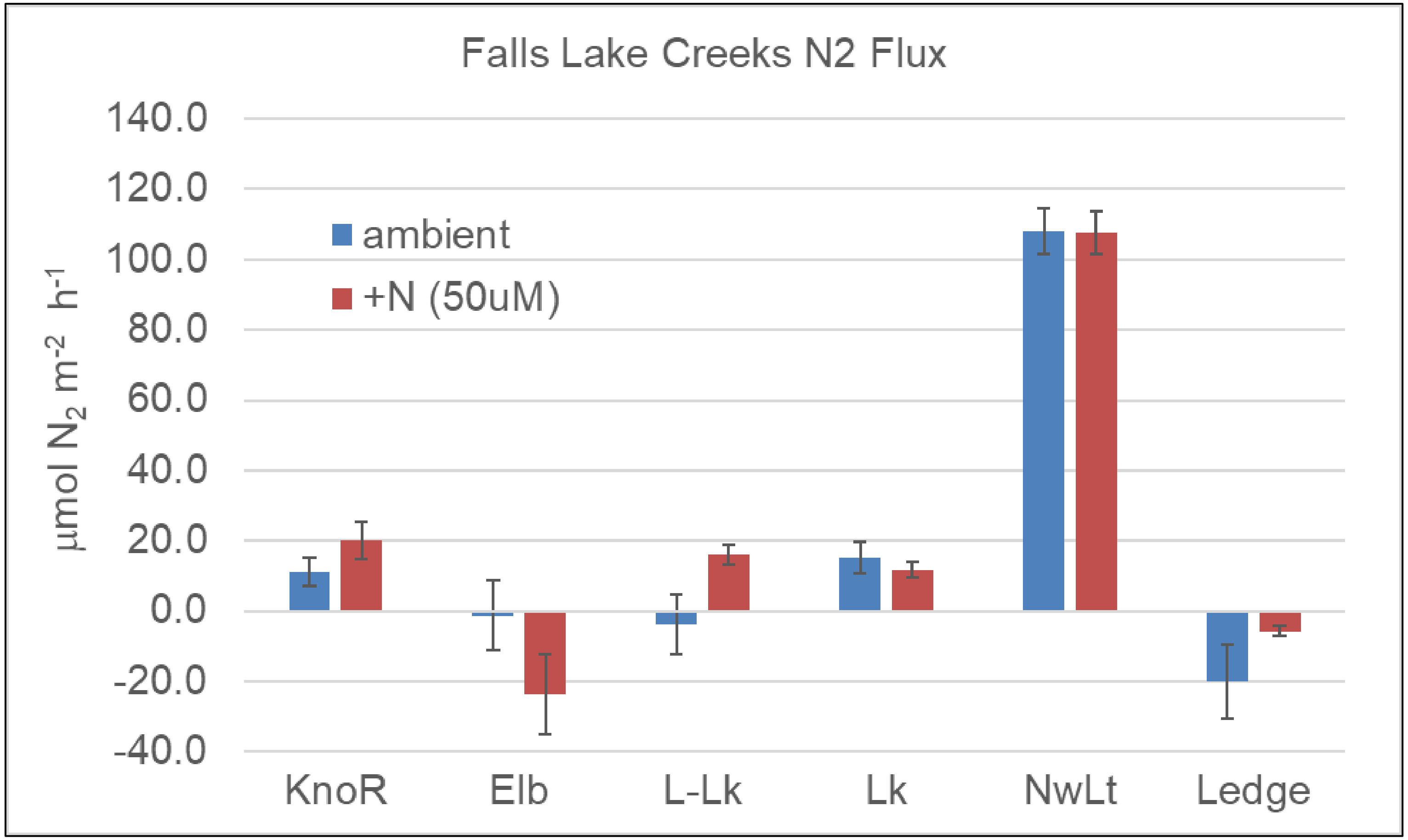


19 July 2021



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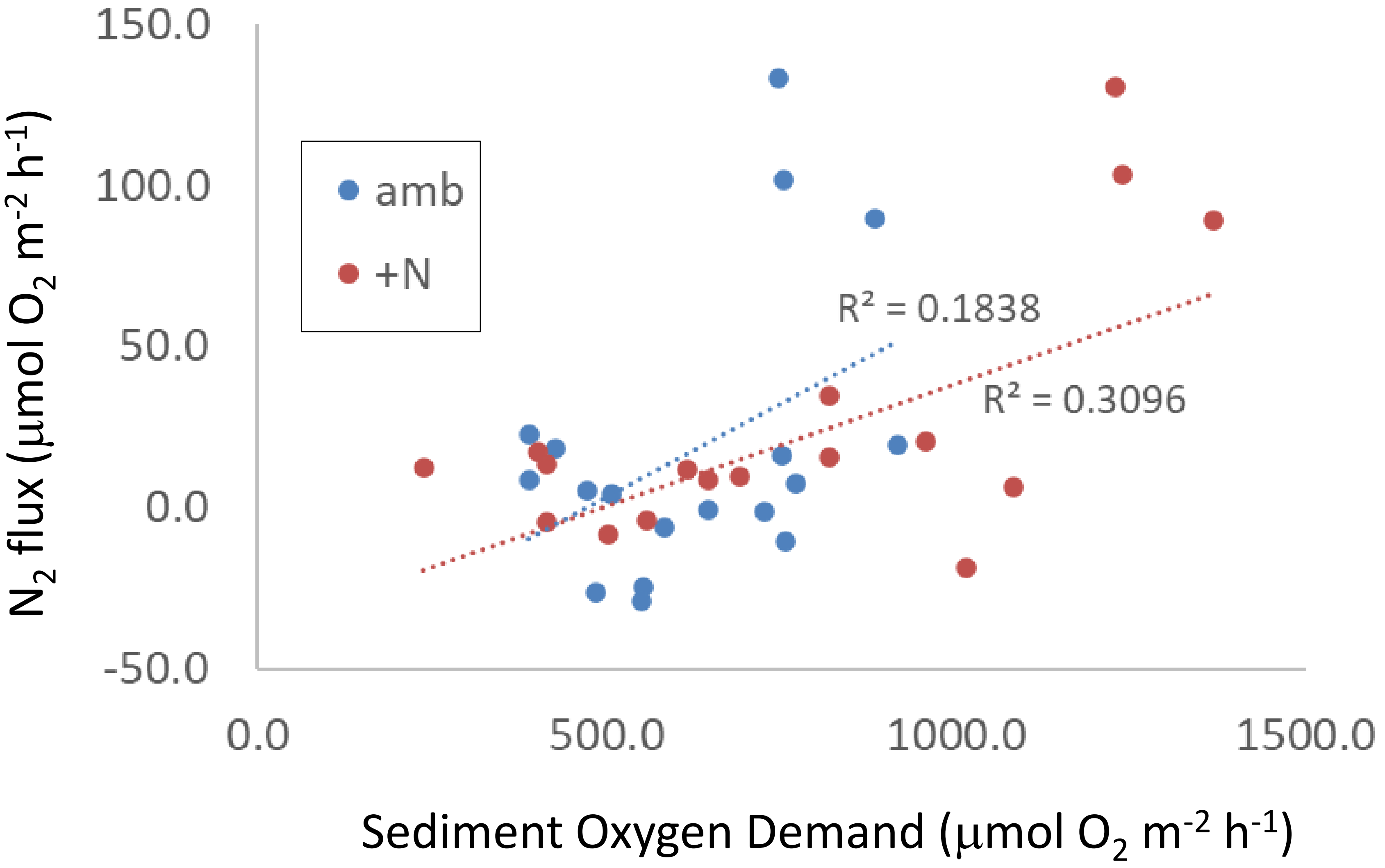

Findings to Date

1) N_2 fixation appears to be a small N source, ~1% of stream loads
2) Highest N_2 fixation rates in upper and western arms
3) Sediment denitrification is variable but significant, 15-40% of stream loads
4) Coupled nitrification/denitrification dominates when water column is oxic
5) Anoxia shuts down sediment denitrification

Applications

1) Models improved by measurements of N transformations
   a) Decisions on which processes to include
   b) Parameterizing drivers of rates (e.g. D.O. effects on denitrification, NH_4^+ effects on N_2 fixation)
2) Sediment quality measurements will inform EFDC sediment diagenesis modeling and initial conditions
3) Water quality measurements provide additional data for main channel and difficult to access areas in creek arms (e.g. PAR, nutrients, chl-a, phytoplankton community composition)
4) Better general understanding of fate of nutrients

Continuing Work

1) N_2 fixation measurements in creek arms and main channel-further constrain rates and drivers
2) Use nutrient addition experiments to test nutrient limitation status and ability to “turn on” N_2 fixation
3) Measure creek arm denitrification in spring 2022
4) Continue analysis of denitrification relative to other factors including residence time, and internal and external N loading