Nitrogen Dynamics and Metabolism

Work Order #3

Cohen Lab

September 9, 2016

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Our Charge

- Address the question: **Will nitrate reduction alone restore primary producer community structure?**

- Corrollary: **Is primary production nutrient limited?**
  - N but also P and Fe

Outline

- Task 2A: River Metabolism and Nutrient Uptake (Lily Kirk's poster)
- Task 2B: **Nutrient Enrichment and Depletion Assays**
- Task 2C: *In Situ* SAV Growth (Jenny McBride's poster)

Our Motivating Questions

(Task 2B)

- How does nutrient (N, P, Fe) enrichment affect system metabolism?
  - [overall growth response]
- How does nutrient enrichment (N, P, Fe) affect algal accumulation?
  - [algal growth response]
- How does nutrient depletion (N) affect growth and uptake?
  - [plant uptake kinetics]

How does nutrient (N, P, Fe) enrichment affect system metabolism?

[benthic boxes, act I]

Nutrient Enrichment/Depletion Assays

The Benthos Box

CONTROL BOX	TREATMENT BOX 1	TREATMENT BOX 2	TREATMENT BOX 3

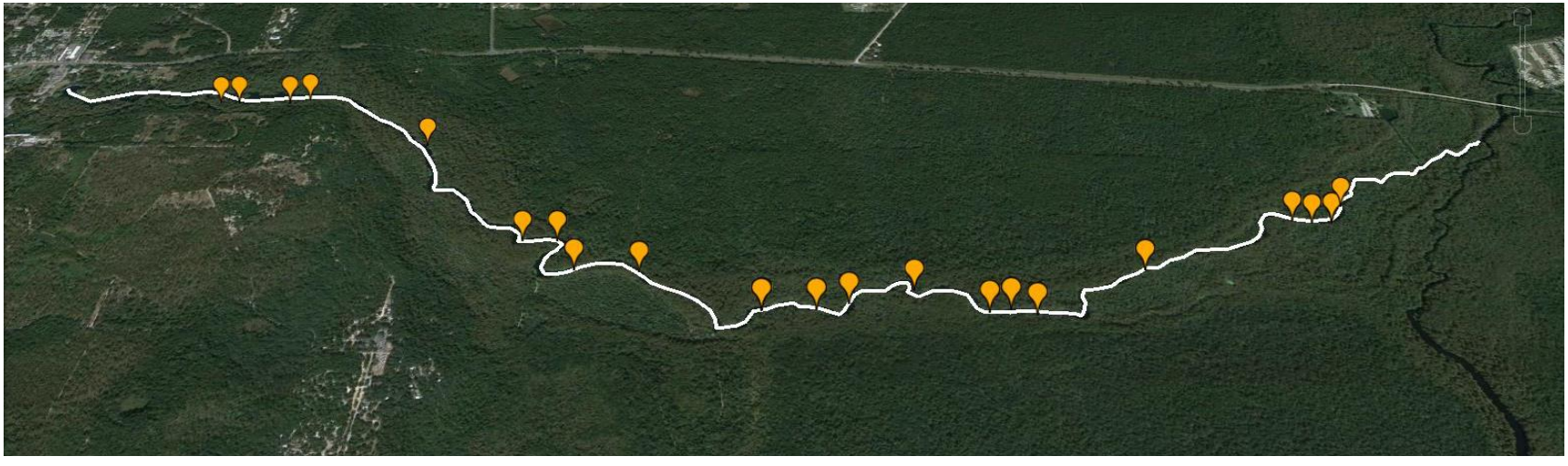
Conservative Tracer and Nutrient Additions

Ambient concentrations raised by:

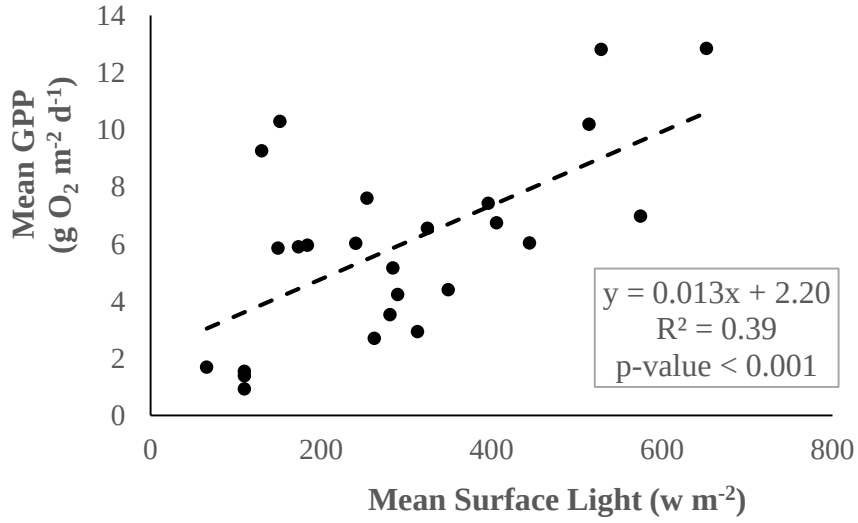
20 mg/L for Cl (in all boxes)
2 mg/L for N
0.05 mg/L for P
0.05 mg/L for Fe

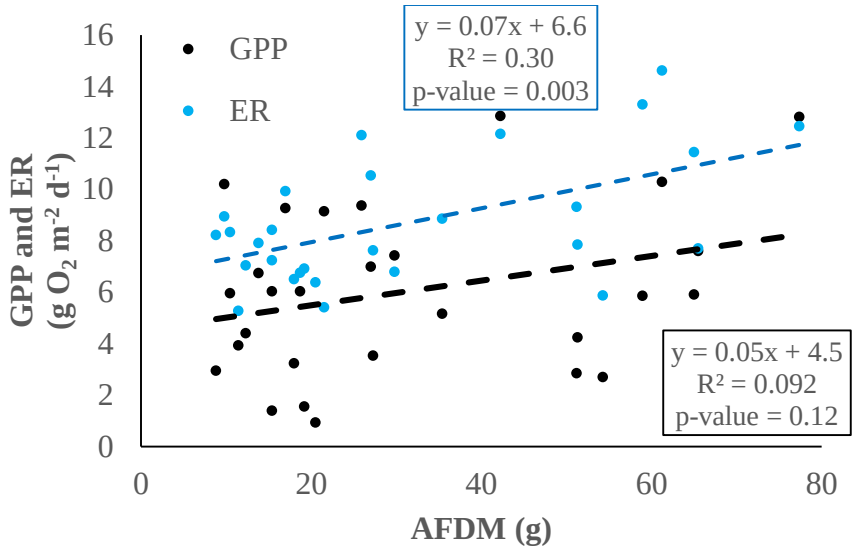
Treatments

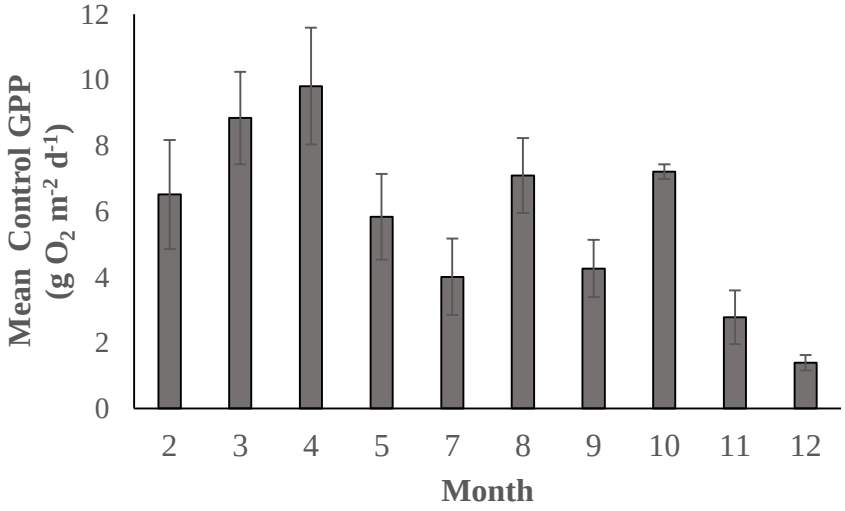
N
P
Fe
N + P
N + Fe
P + Fe
N + P + Fe

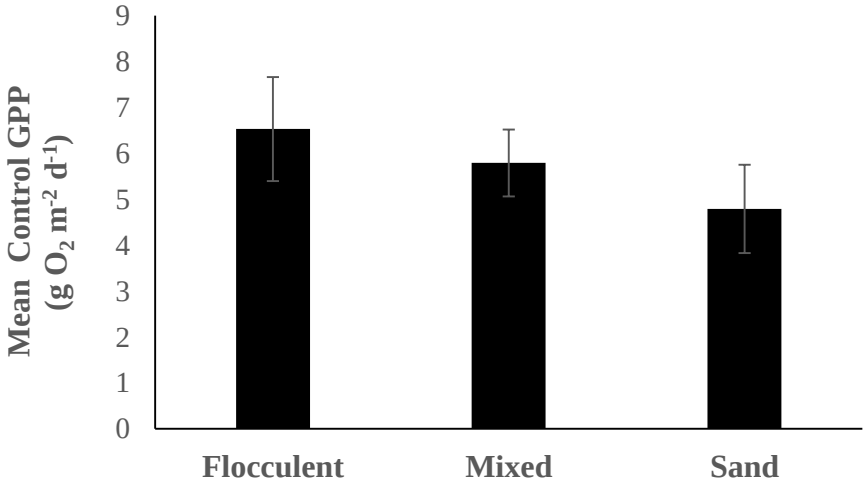


Environmental GPP Controls









Integrative Models of GPP and ER

- Effective for GPP (pseudo R^2 ~ 0.83) and ER (pseudo R^2 ~ 0.62)
- Informs interpretation of enrichment dosing

A: GPP	Est.	SE	t-value	p-value
Intercept (Fall)	-7.83	2.37	-3.30	0.004
Light	0.01	0.00	4.38	0.000
Depth	10.83	3.09	3.51	0.003
AFDM	0.04	0.02	2.19	0.044
Spring	3.08	0.90	3.43	0.003
Summer	-0.66	1.28	-0.52	0.611
Winter	1.69	1.06	1.59	0.132
Null Deviance	245.40			
Resid. Deviance	45.60			

B: ER	Est.	SE	t-value	p-value
Intercept	3.34	2.30	1.45	0.164
MeanGPP	0.40	0.17	2.38	0.029
Light	0.00	0.00	-1.13	0.273
Depth	4.15	3.18	1.31	0.208
AFDM	0.03	0.02	1.75	0.098
Null Deviance	126.60			
Resid. Deviance	48.20			

Nutrient Enrichment Effects

Significant temporal and spatial variation implies testing treatments using **relative response** (RR):

- Ratio of GPP in treatment vs. control

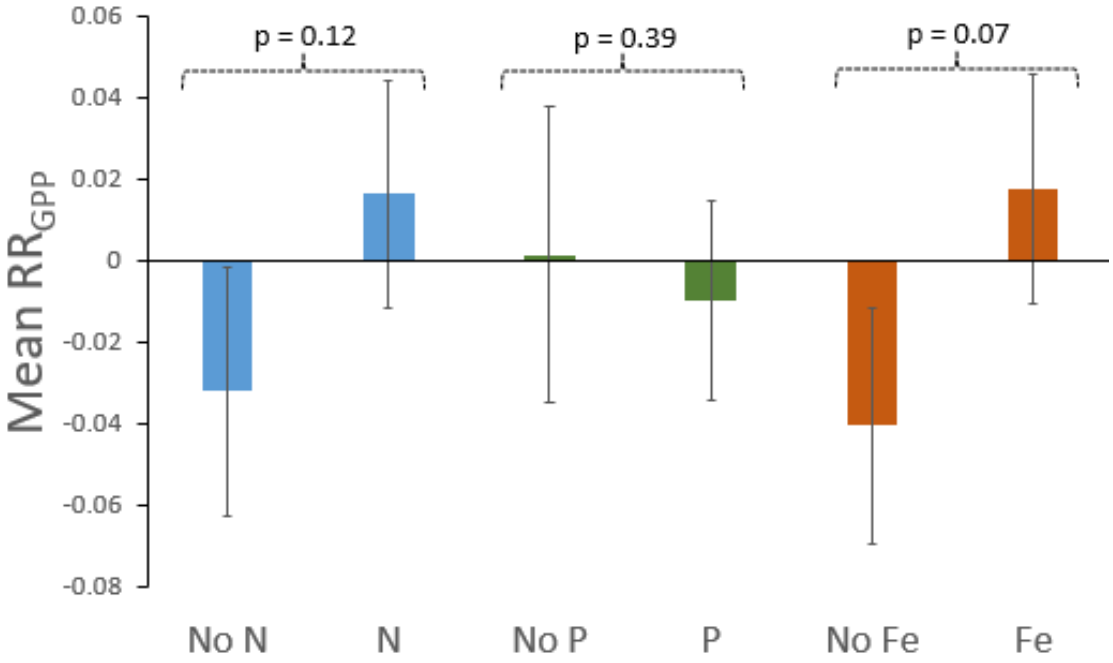
$$\mathbf{RR_{GPP} = \log (GPP_t : GPP_c)}$$

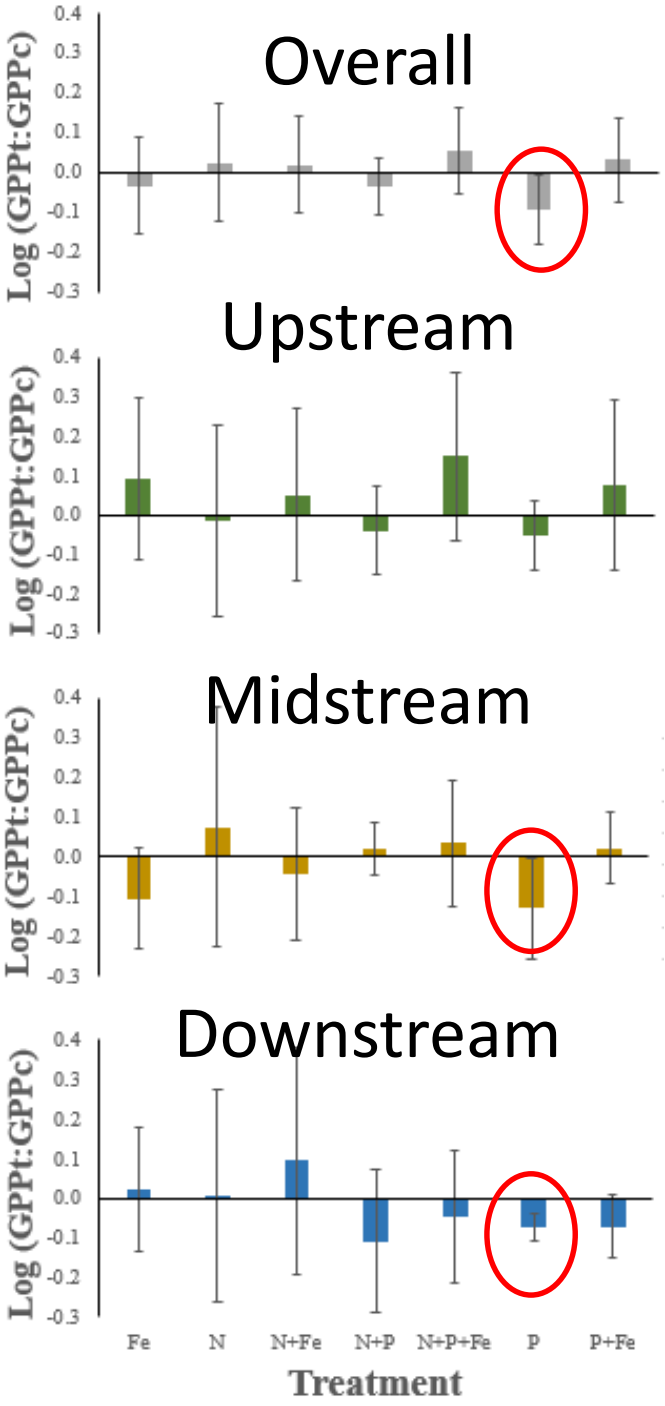
- Ratio of relative growth (GPP/B) in treatment vs. control

$$\mathbf{RR_{GPP:B} = \log (GPP_t/B_t : GPP_c/B_c)}$$

GPP Response

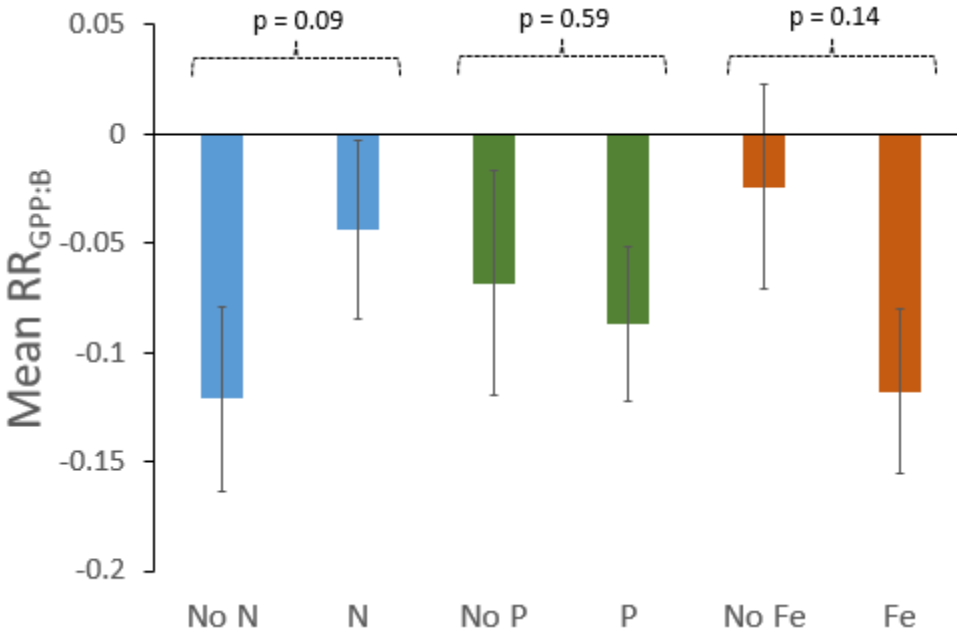
- Few significant effects
  - P inhibition
- Pairwise analysis (N, P, Fe main effects only)
  - Weak Fe stimulation

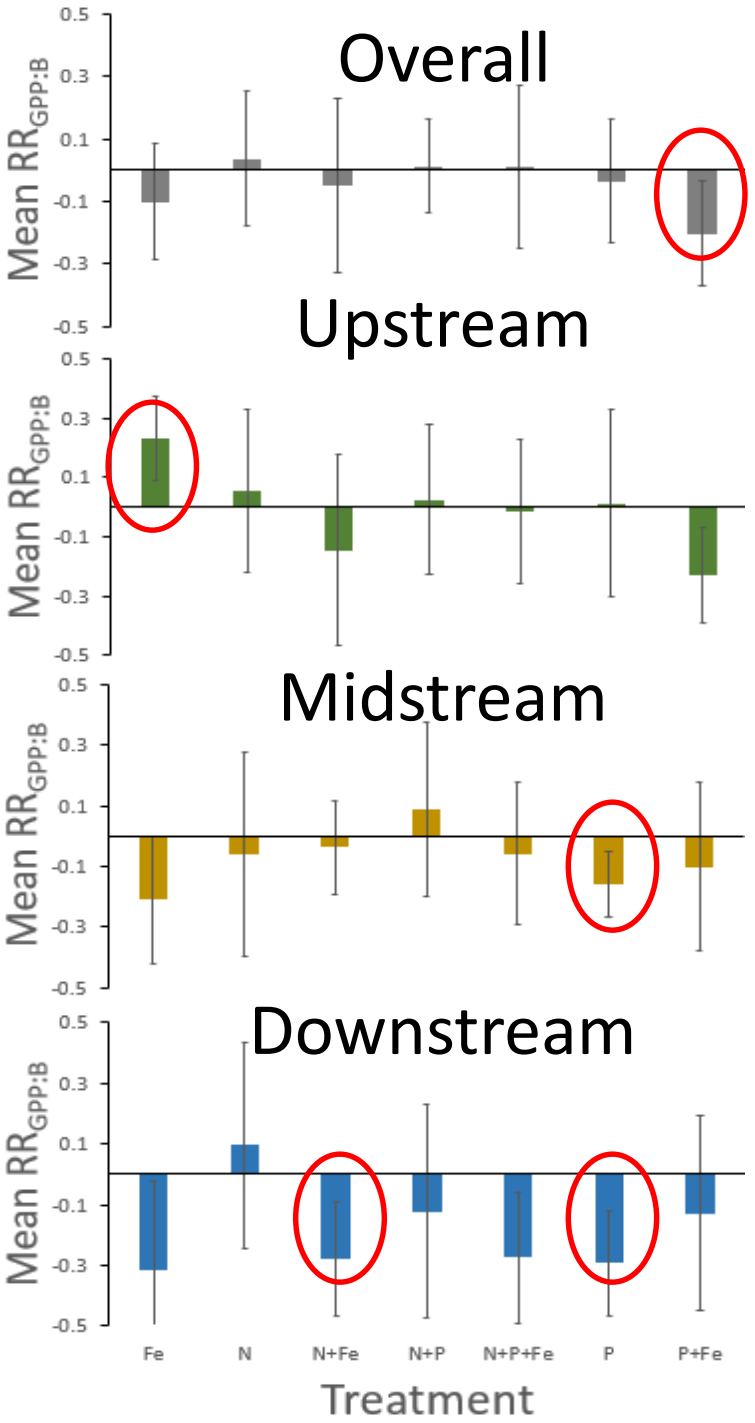




Relative Growth

- More significant effects
  - P inhibition, variable Fe
- Pairwise analysis (N, P, Fe main effects only)
  - Weak N stimulation





Summary of GPP Response

- GPP is highly predictable
  - Light, Biomass, Depth Season
- Nutrient enrichment treatments had **mostly no effect**
  - P inhibition
  - Weak pairwise Fe and N enrichment effects
  - Multivariate model with N, P, Fe x distance
    - R^2 ~ 0.14, with Fe the only significant predictor

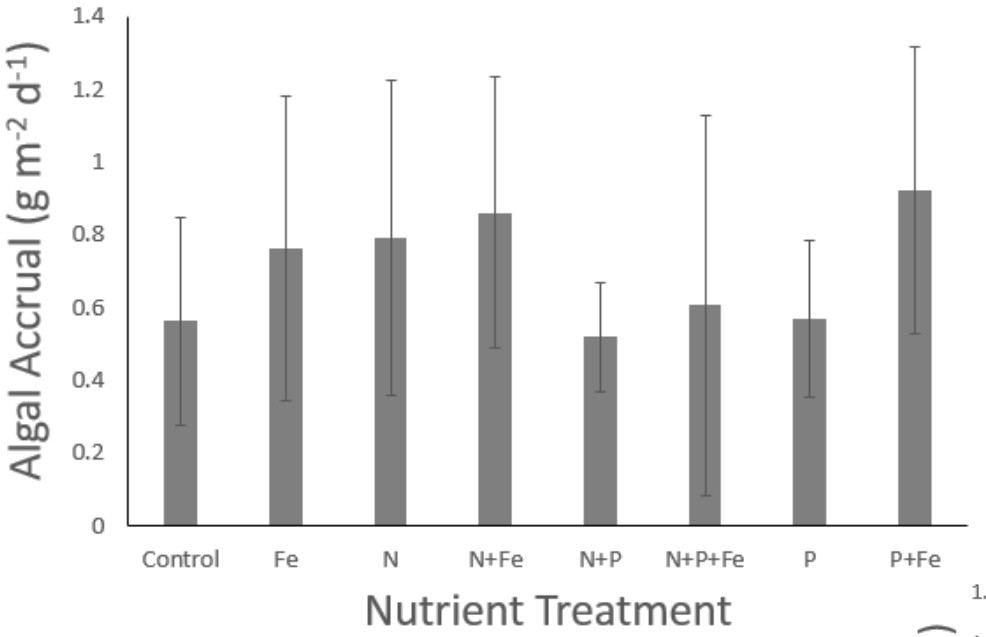
How does nutrient enrichment (N, P, Fe) affect algal accumulation?

[benthic boxes, act II]

Algal Tiles

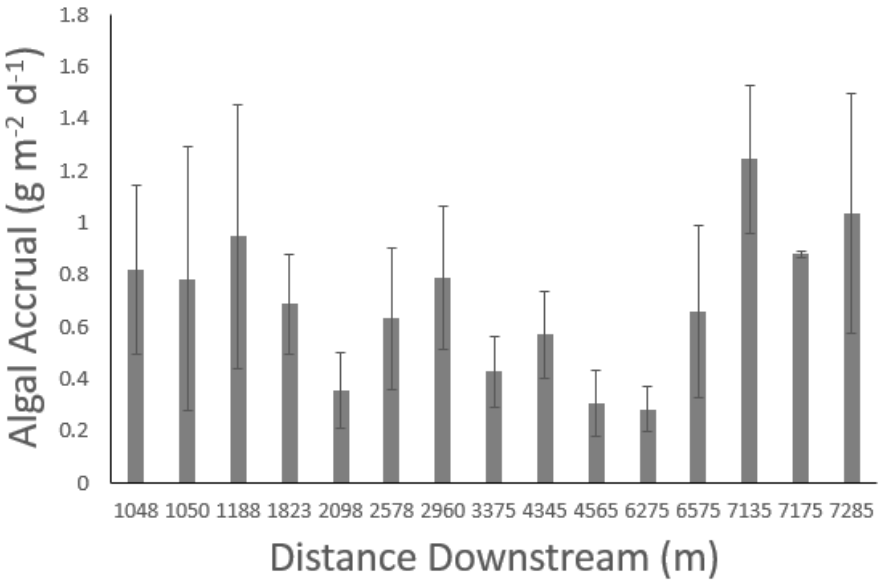
- Unglazed ceramic tiles (A = 144 cm^2)
- Hung in each box for week-long deployment
- Biomass accrual (dry weight)

Raw Algal Biomass Data



No clear enrichment effect without controlling for site variation (i.e., treatment relative to control)

No clear distance effect, possibly high near head spring and confluence, low in between



Nutrient Enrichment Effects

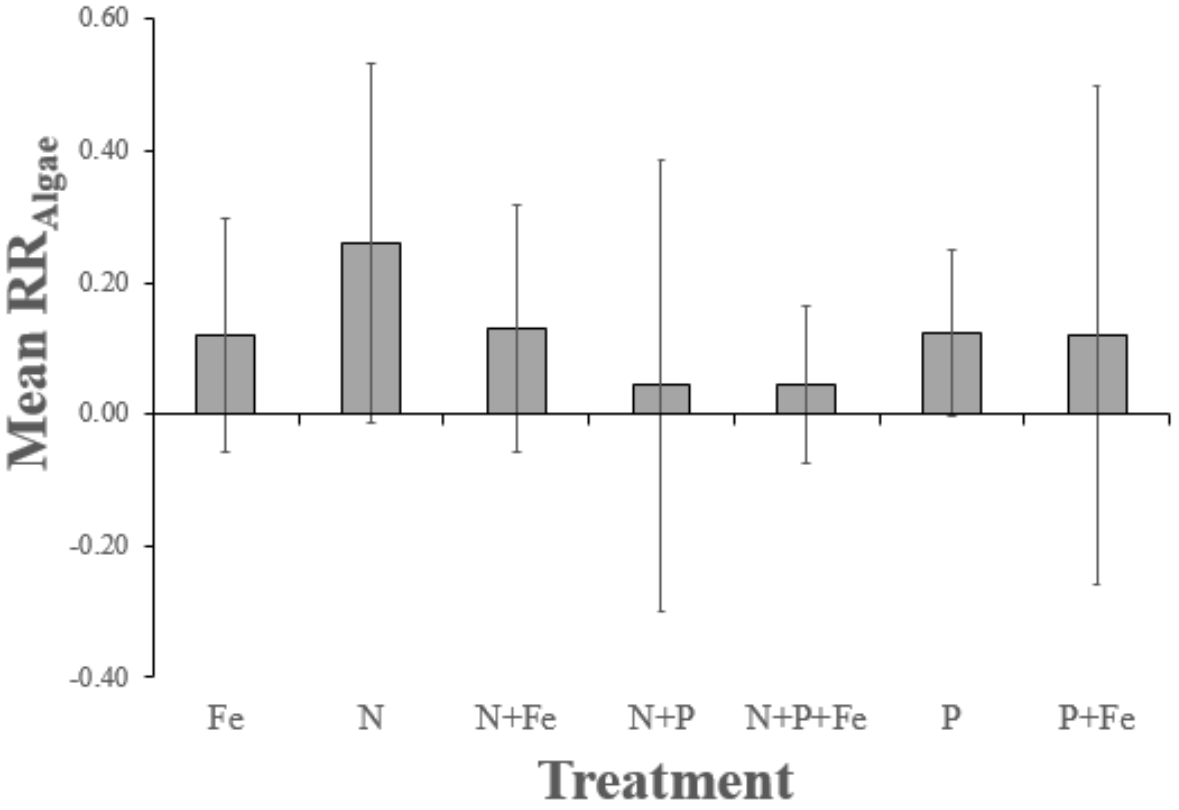
Significant temporal and spatial variation implies testing treatments using **relative response** (RR):

– Ratio of Algal Biomass in treatment vs. control

$$\mathbf{RR_{Algae} = \log (Algae_t : Algae_c)}$$

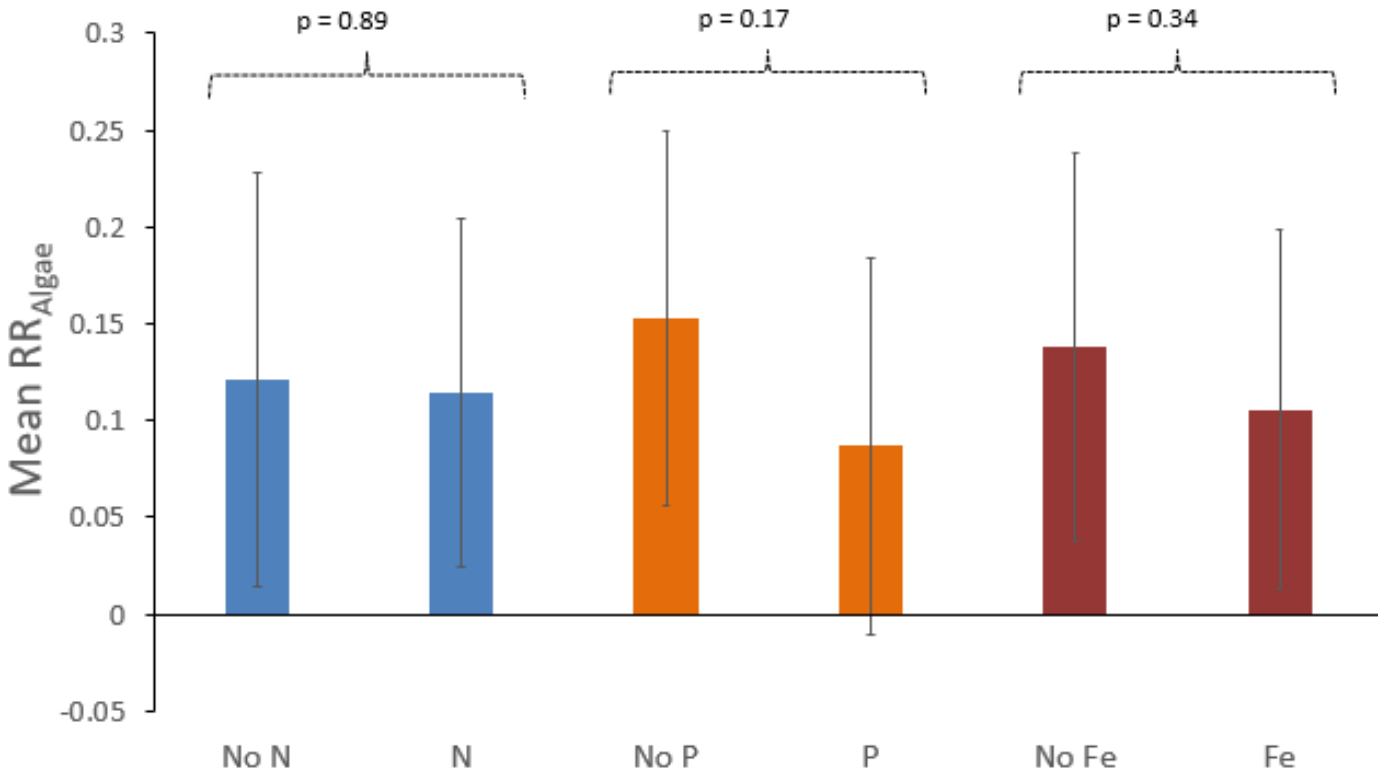
Treatment Effects - RR_{Algae}

- No statistically significant effects
- Weak N, P, and Fe enrichment effects



Pairwise Enrichment Effects

- Adding **ALL** nutrients weakly stimulates growth
- No clear pairwise N, P or Fe effect



Summary of Algal Response

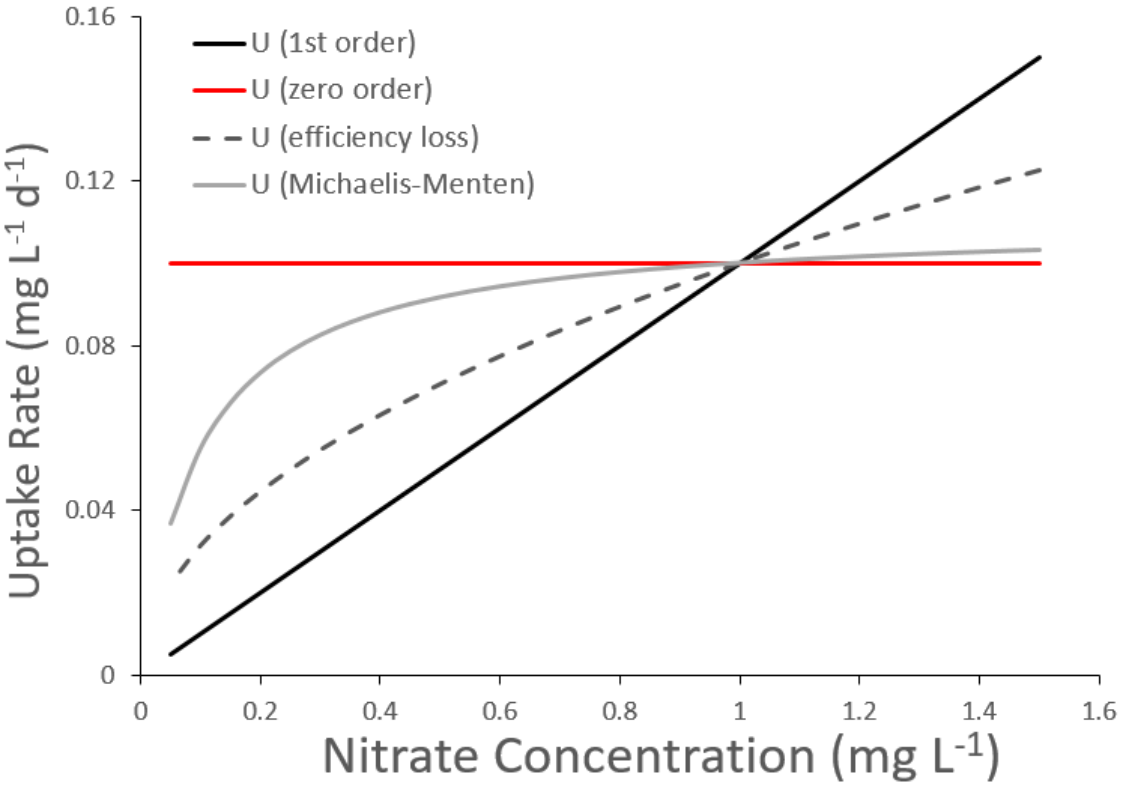
- Algal growth is not readily predictable
- No significant treatment effects
- Pairwise enrichment treatments had **weak stimulatory effects**
  - Any addition increased algal accumulation
  - No evidence of a specific N, P, or Fe effect

How does nutrient depletion (N) affect growth and uptake?

[benthic boxes, act III]

N Removal Kinetics

- Objective is to lower N concentrations
- What is the expected impact on N retention (including plant growth) of that?



Nitrate Depletion by Pathway

$$\frac{\partial C}{\partial t} = -Sol * k_A C^{n_A} - k_D C^{n_D}$$

U_a U_{den}

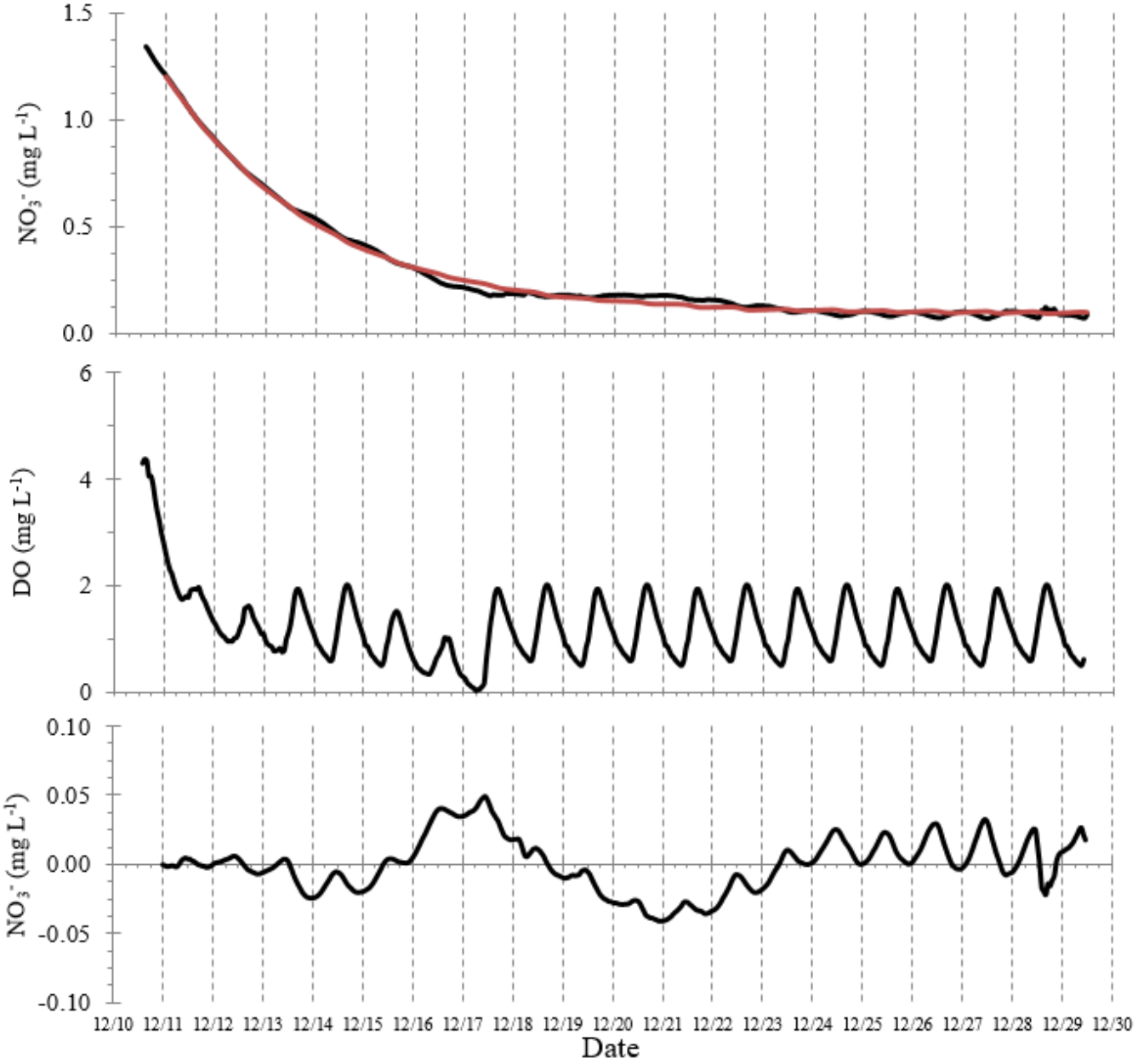
Nitrate (mg/L)

1.4
1.2
1
0.8
0.6
0.4
0.2
0

0 24 48 72 96 120 144 168

Deployment Time (hours)

Nutrient Depletion and Metabolism



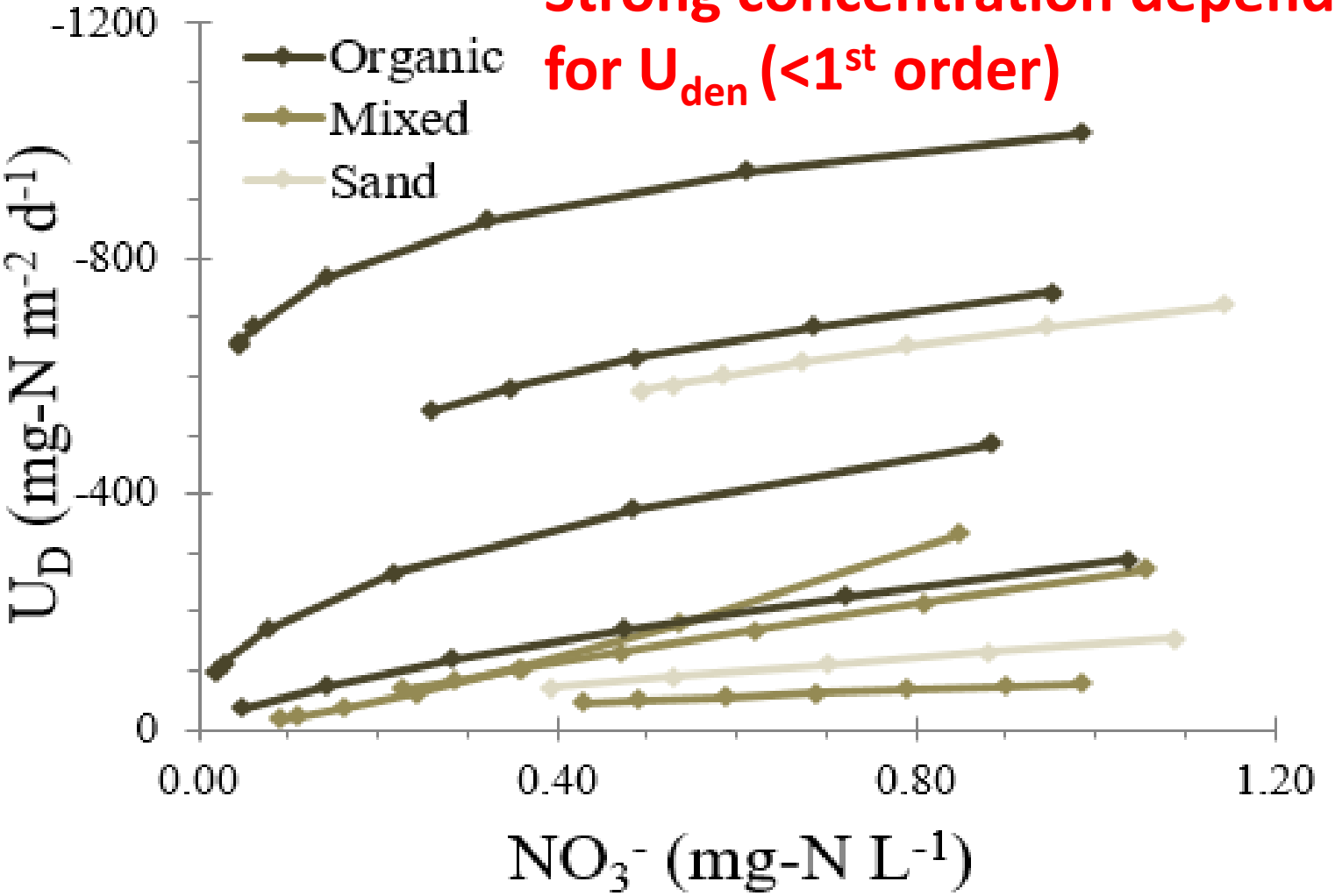
Diel variation at low [NO_3]
(new NO_3 balance includes nitrification)

No evidence of GPP decline
(zero order kinetics with respect to NO_3)

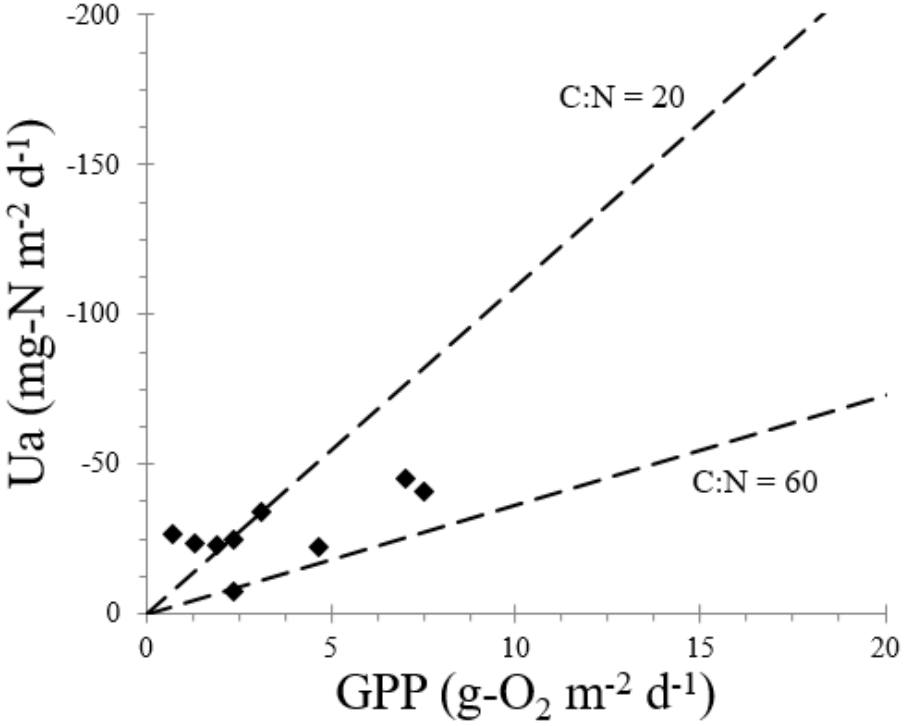
Diel model residuals
(out of phase with NO_3 uptake)

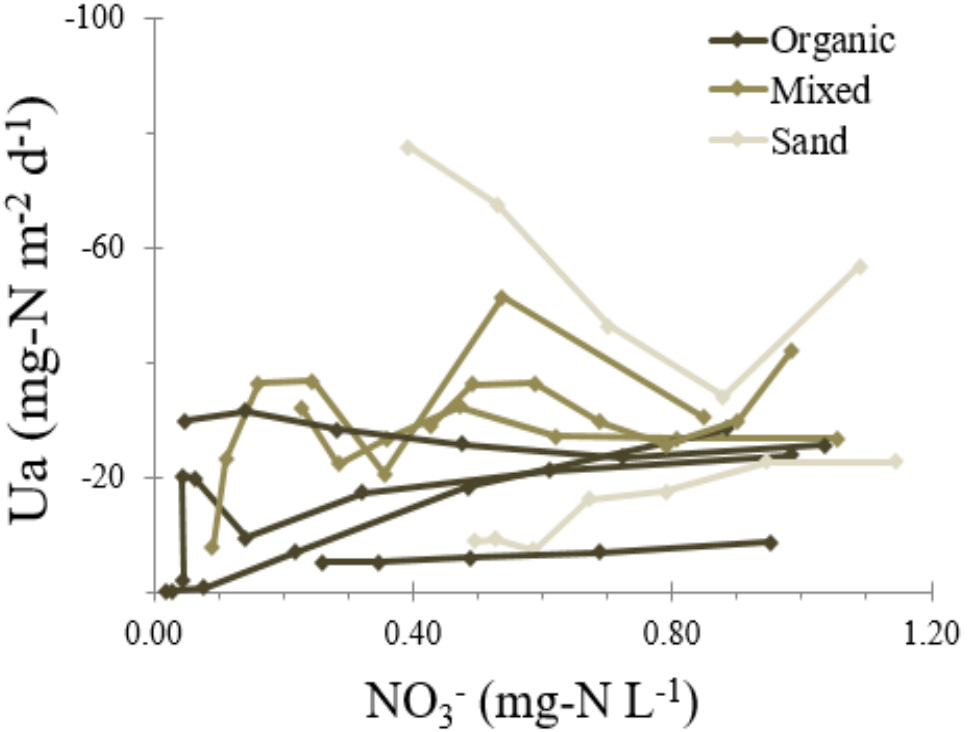
Kinetics from Depletion (U_D)

Strong concentration dependence for U_{den} (<1st order)



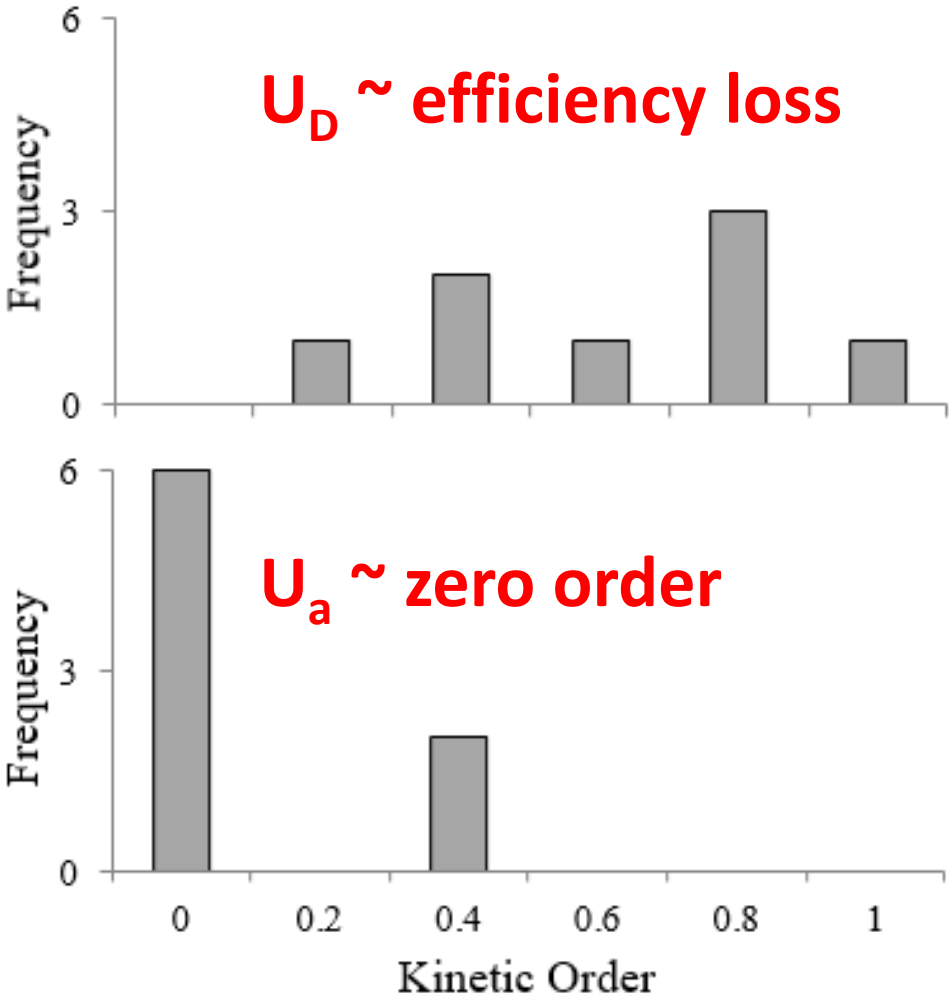
Kinetics from Depletion (U_a)





Concentration independence for U_a (~0^{th} order) and fixed C:N stoichiometry

Summary of Removal Kinetics



- Lowering NO_3 will **lower denitrification** rates but **not affect plant uptake** rates
- Caveats:
  - Time scales and nutrient storage
  - Switching N supply
  - Algae vs. SAV

Year 2 Conclusions – Task 2B
(post-preliminary, pre-final)

- Nutrient Impacts on Metabolism
  - Metabolism varies substantially, and predictably
  - Nutrient enrichment had mostly no effect
    - Evidence of **P inhibition**
    - Weak pairwise **Fe and N stimulatory effects**
    - **Fe stimulatory effects** in multivariate model
- Nutrient Impacts on Algal Growth
  - Low rates of biomass accrual (0.25 g C m^{-2} d^{-1})
  - No significant treatment effects
  - "Any nutrient will do" pairwise stimulatory effects
- Nutrient Depletion Effects
  - Removal dominated by U_{den} (~ 10 x U_a)
  - Denitrification is <1^{st} order (concentration **dependent**)
  - Assimilation is ~0^{th} order (concentration **independent**)

Ongoing Work

- Benthic box deployments in Alexander River
  - Nitrate dynamics in ambient and enriched boxes
- SAV growth
  - Alexander and Silver (Jenny McBride)
- Metabolism and Nutrient Cycling
  - Alexander and Silver (Lily Kirk)
- Parallel work in Rainbow River
  - Funded by SWFWMD