Spatiotemporal Variation of Algal Nutrient Limitation in Grand Lake, Oklahoma and the Effect of Internal Nutrient Load

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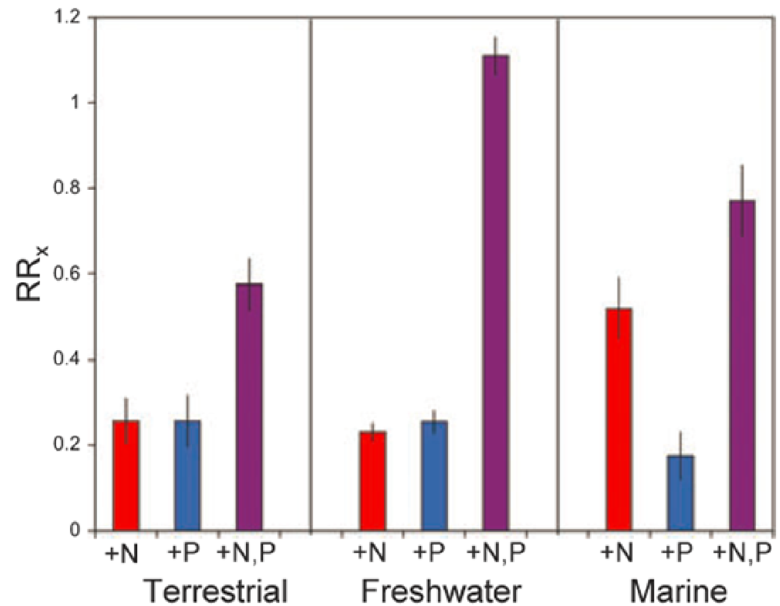
Introduction

- Nutrient Limitation
  - Phosphorus Limitation Paradigm
    - Phosphorus Limitation Paradigm [2]
      - Classical Experimental Lakes Enrichment (Lake 226)[3]
      - Premise: atmospheric inputs of N and N fixation offsets the imbalance of N and P [4]
  - Co-Limitation Paradigm
    - Greater response to simultaneous enrichment by both nutrients than single addition of N or P [5]
    - Synergy
      - Two or more nutrients added together creating a greater response than they do individually.

Introduction

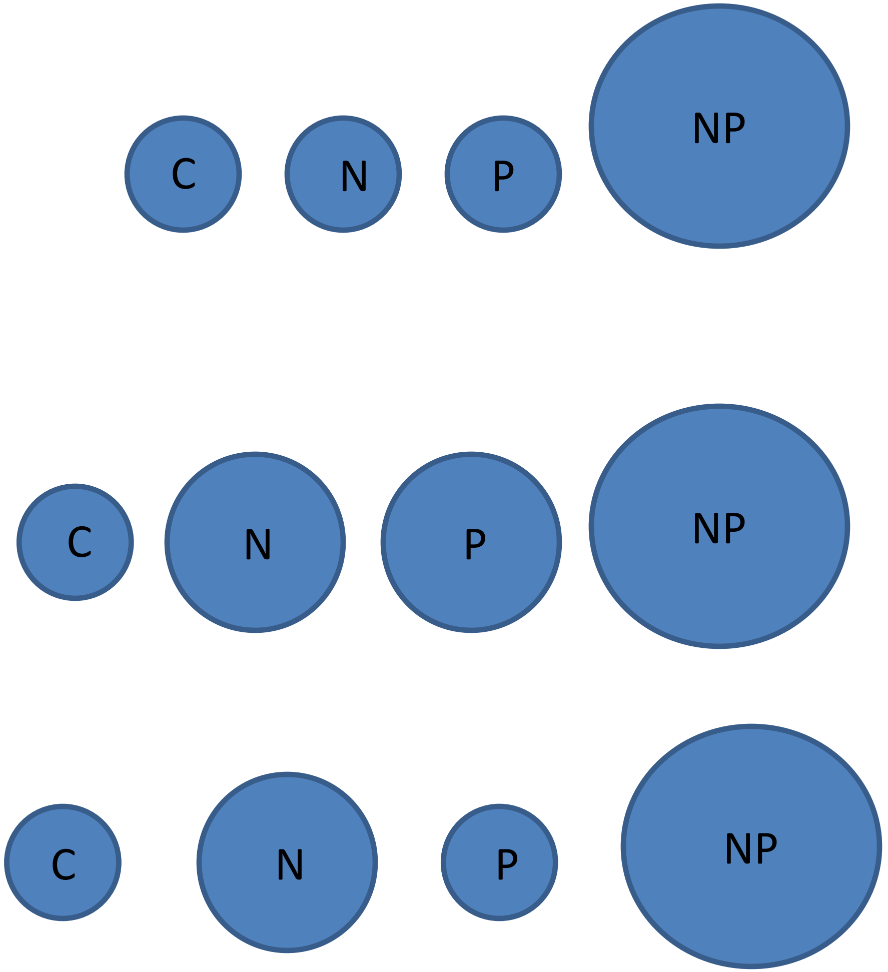
- Review of Nutrient enrichment data.
  - Co-Limitation
    - Greater response to simultaneous enrichment by both nutrients than single addition of N or P [5]
  - Synergy
    - Two or more nutrients added together creating a greater response than they do individually.



Elser et al. 2007[6]

Introduction

- Co limitation Types
  - Simultaneous
    - Both +NP required for a response
  - Independent
    - N and P alone induce response.
    - +NP > N or P alone
  - Serial Limitation
    - Order dependent
    - Not Strict Co-Limitation



Introduction

- N:P ratios
  - Used to predict N or P limitation of algal growth[7][2]
    - N:P>22 (P limited)
    - N:P<9 (N Limited)
  - Seen in OWRB BUMP reports

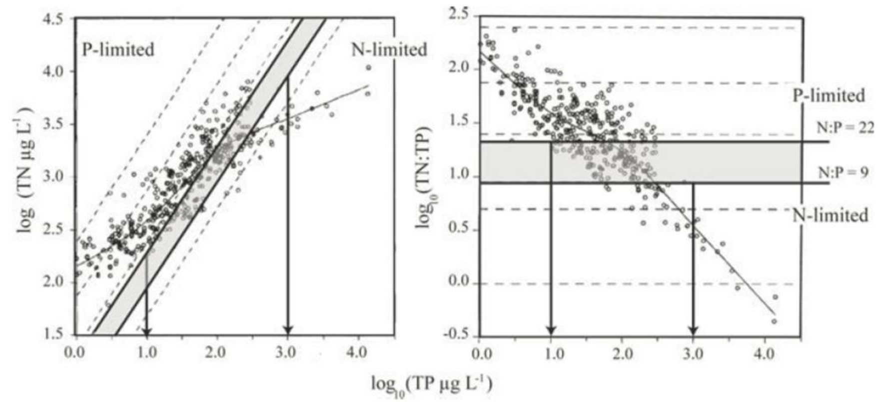


Figure 1. Stoichiometric linkages between TN and TP (log-transformed) for 221 lakes in 14 countries, plotted both as TN *vs.* TP (left) and as their ratio *vs.* TP. The shaded regions indicate the regions "inside" the TN:TP ratios proposed by Guildford and Hecky (2000) that are associated with N- or P-limitation. The vertical arrows indicate the TP levels above or below which one must extend in order to move outside of the range of variability in the data. Figure modified from Downing and McCauley (1992). Following the original publication, mass units are used.

Introduction

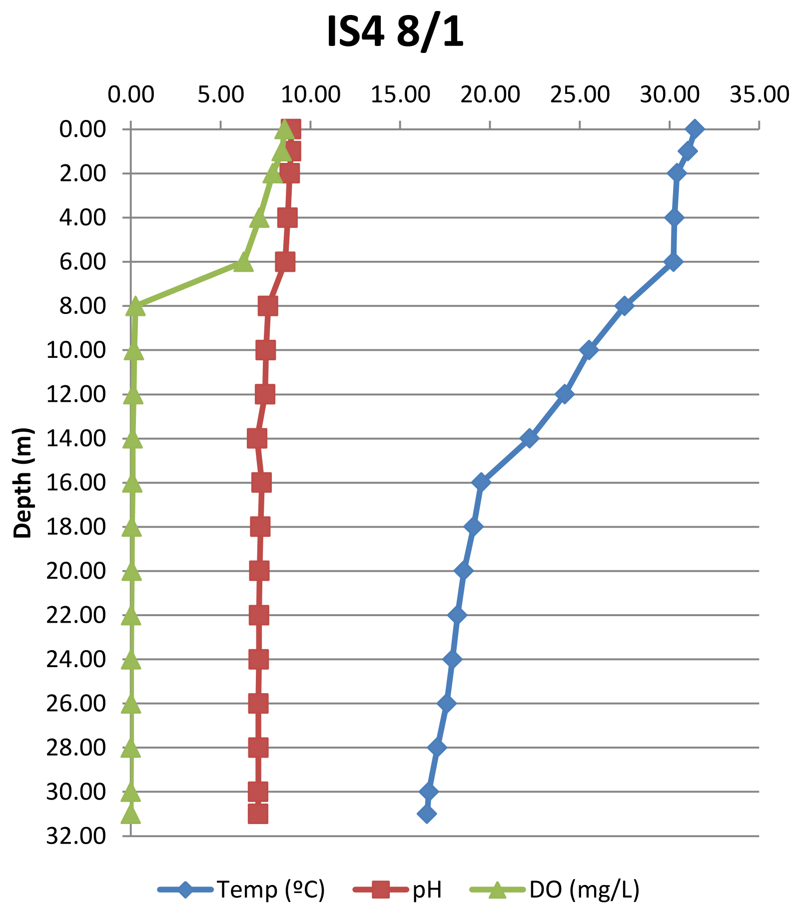
- Importance of determining the limiting nutrient
  - Guide management practices
    - Reducing inputs of the limiting nutrient improves water quality.

Introduction

- Internal nutrient loading
  - Re mineralization of N & P from anoxic sediments
  - Bacterial Mediated
    - Classic: Reduction of iron by bacteria

$FeOOH + 3H^{+} + e^{-} \rightarrow Fe^{2+} + H_2O$

  - Grand Lake Has an anoxia problem….

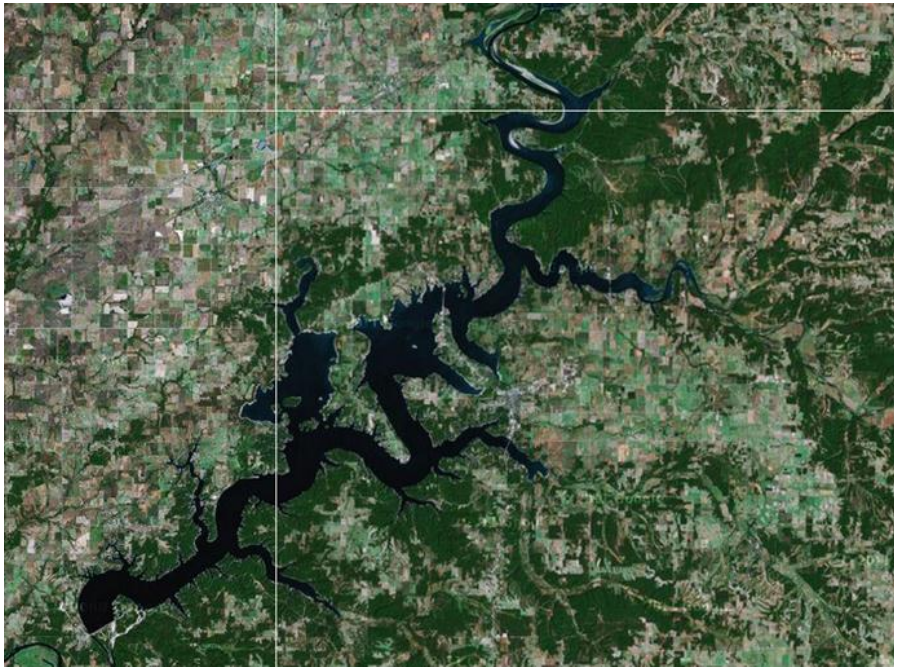


Objectives

- Monitor the nutrient limitation status Grand Lake.
  - Can nutrient limitation be accurately predicted from established N:P ratios?
- Examine how the internal load affects nutrient limitation.
  - Prediction
    - N:P ratios will drop as mixing begins in late summer.

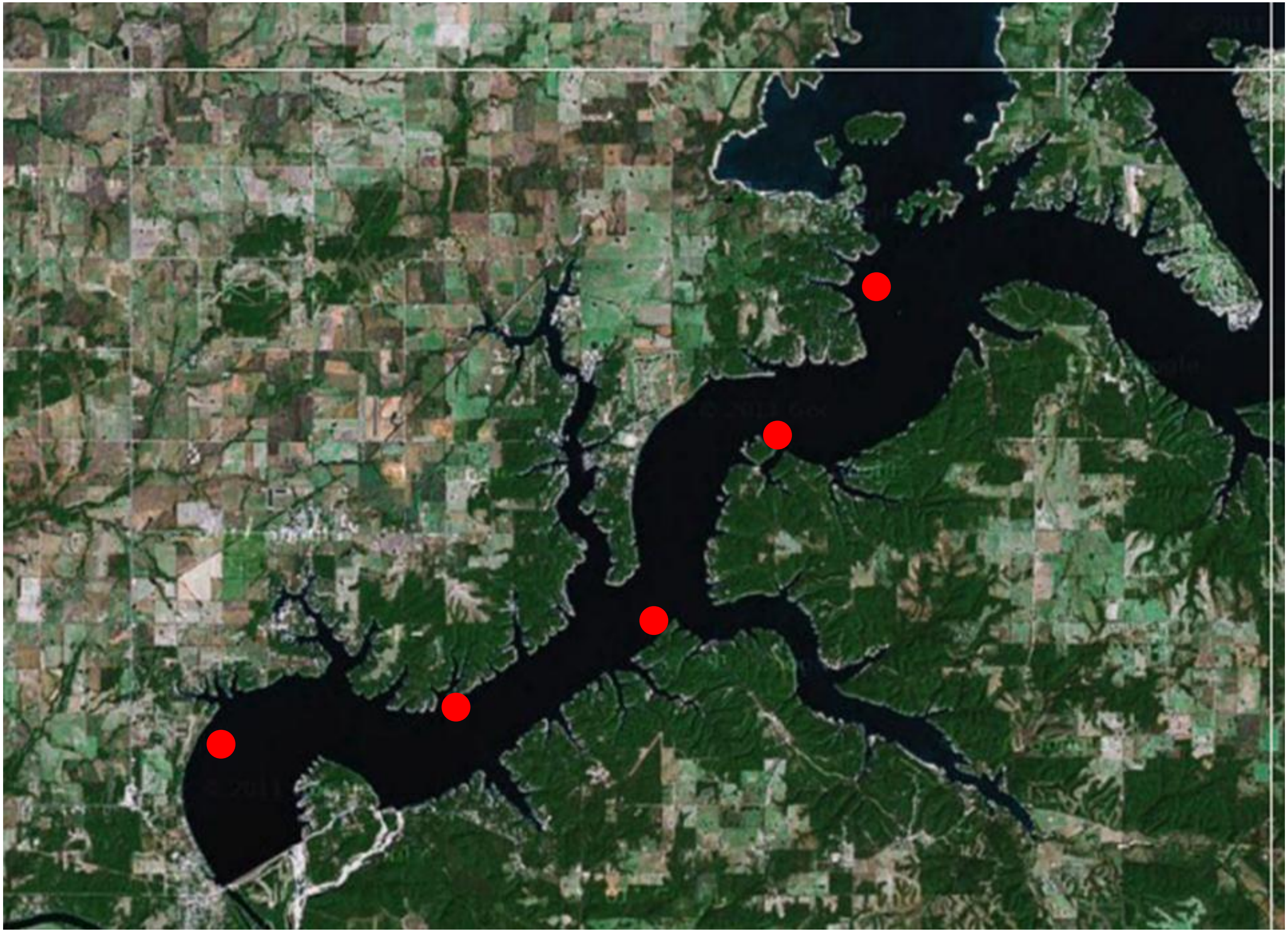
Methods

- Grand Lake
  - Stretches through Delaware, Ottawa and Mayes County in NE Oklahoma.
  - Surface area of +18,000 Ha
  - Z_{max} ~ 36 m
  - Agricultural Watershed.
  - Highly Developed shoreline.



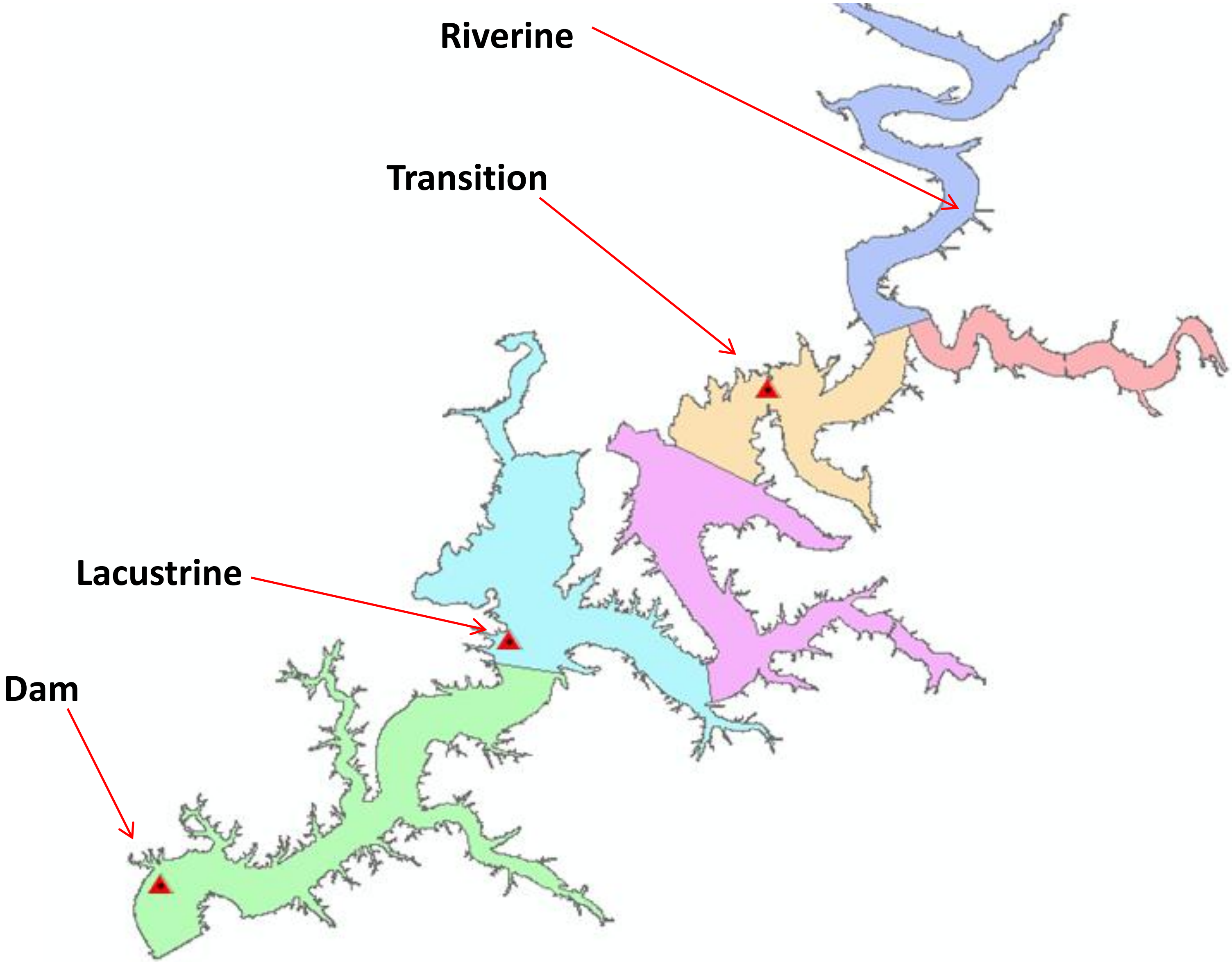
Methods (Sampling & Analysis)

- Sampling & Analysis
  - June-October 2011 (bimonthly)
  - Physiochemical Profiles
    - Temp, DO, ORP, pH, Cond.
  - 3 Epi & 3 Hypo samples
  - Samples Analyzed within 48 hours
    - TN, TP, NH_3-N, NO_3



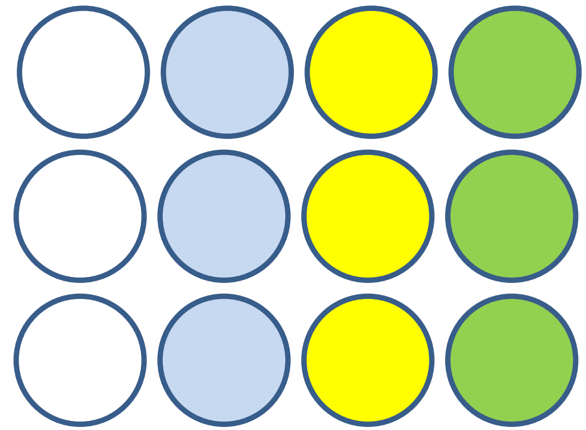
Methods (Nutrient Bioassays)

- 20 L collected from 3-4 sites.
  - May, June, August, September, October
- Collected volume filtered to remove macro-zooplankton
- Water placed into 12, 1 L glass bioassay jars
  - Initial Relative Florescence (RFU) measured.



Riverine
Transition
Lacustrine
Dam

Methods (Nutrient Bioassays)



- Control
- Treatments
  - Nitrogen (+N) (1600 μg L^{-1})
  - Phosphorus (+P) (100 μg L^{-1})
  - Nitrogen and Phosphorus (+NP)
- Placed into an environmental chamber at mean surface temperature and average day length
- Measured Every 24 hours after setup

Results (Epilimnion)

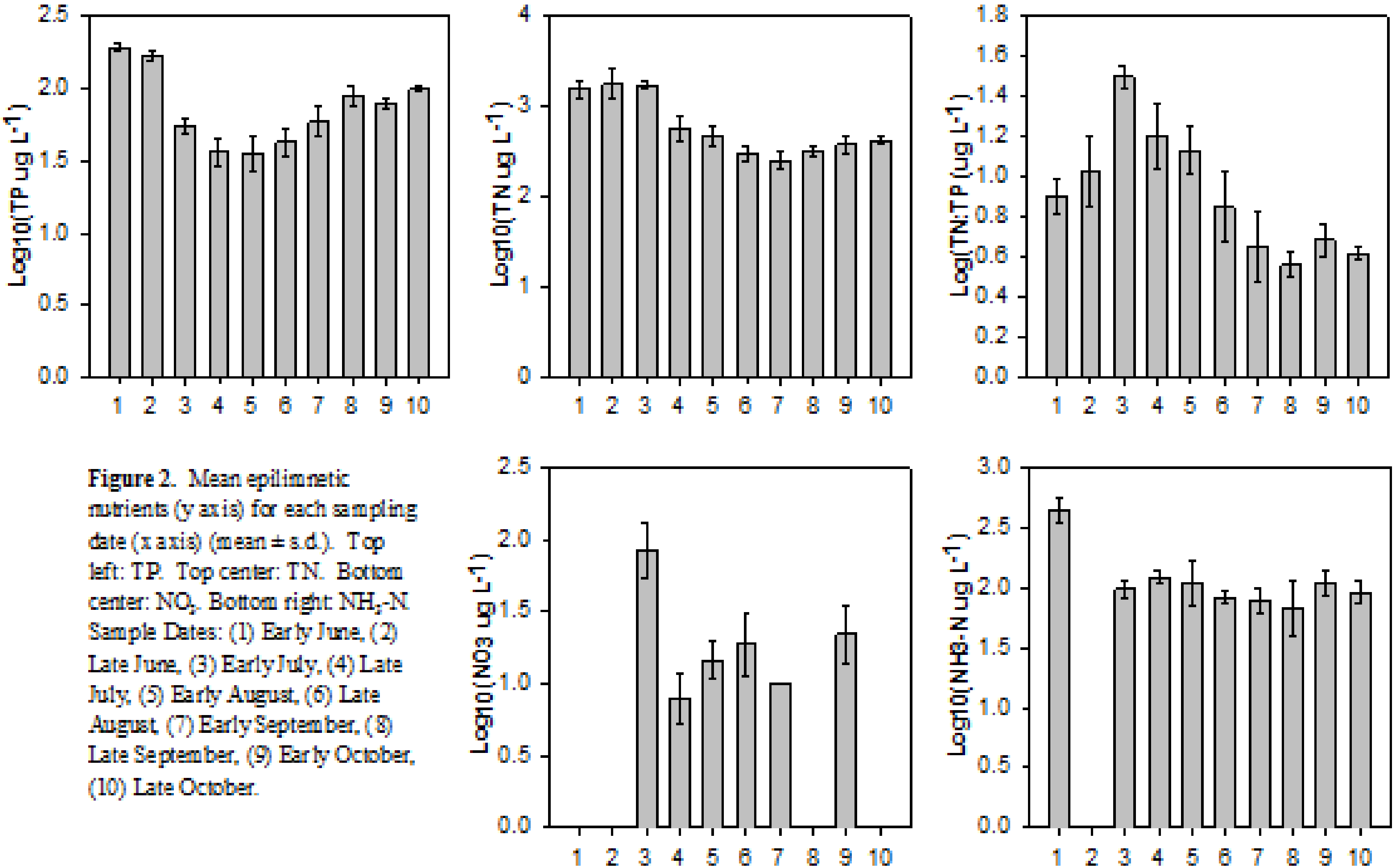


Figure 2. Mean epilimnetic nutrients (y axis) for each sampling date (x axis) (mean ± s.d.). Top left: TP. Top center: TN. Bottom center: NO_3. Bottom right: NH_3-N. Sample Dates: (1) Early June, (2) Late June, (3) Early July, (4) Late July, (5) Early August, (6) Late August, (7) Early September, (8) Late September, (9) Early October, (10) Late October.

Results (Hypolimnion)

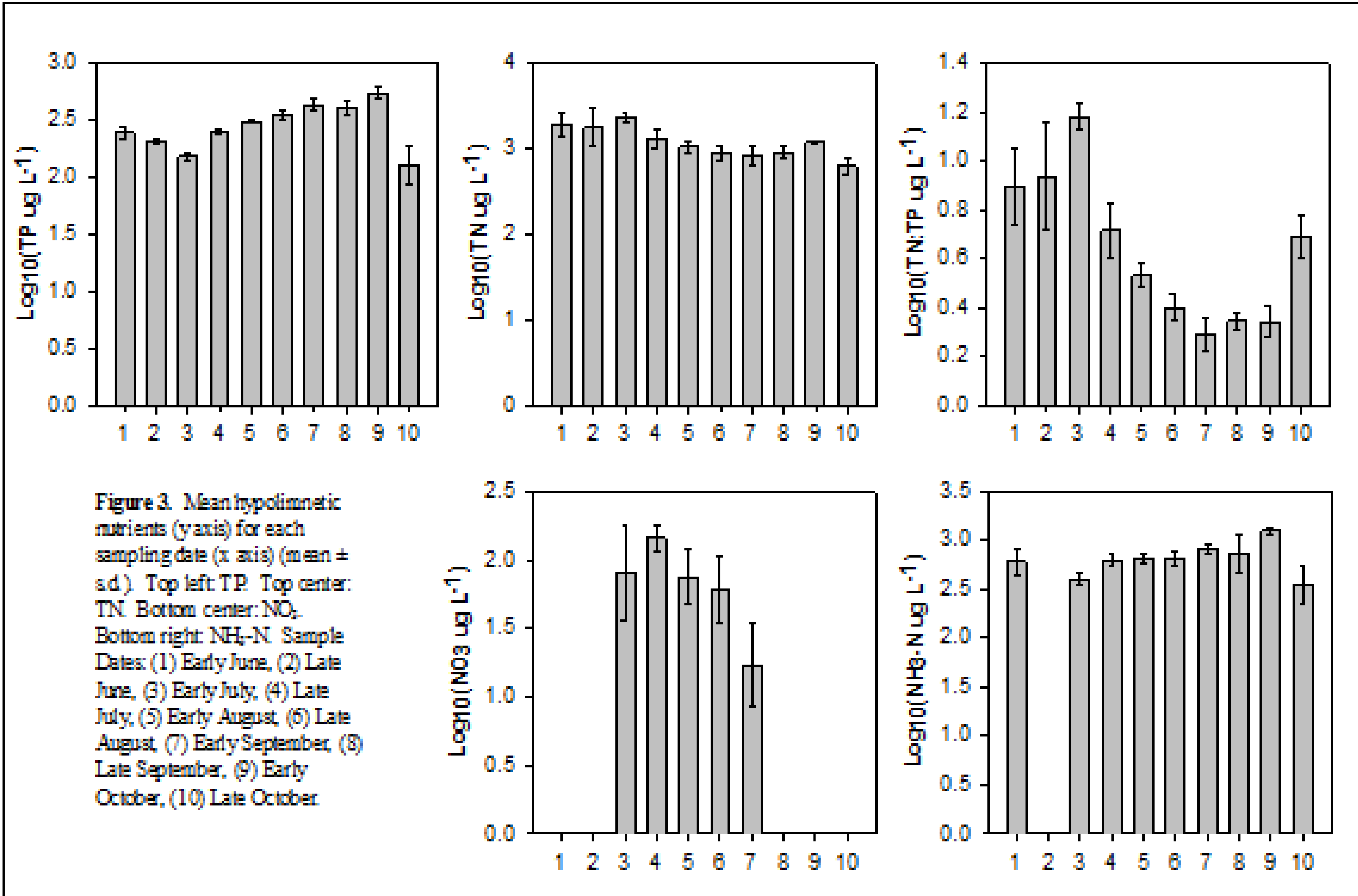


Figure 3. Mean hypolimnetic nutrients (y axis) for each sampling date (x axis) (mean ± s.d.). Top left: TP. Top center: TN. Bottom center: NO_3. Bottom right: NH_3-N. Sample Dates: (1) Early June, (2) Late June, (3) Early July, (4) Late July, (5) Early August, (6) Late August, (7) Early September, (8) Late September, (9) Early October, (10) Late October.

Results

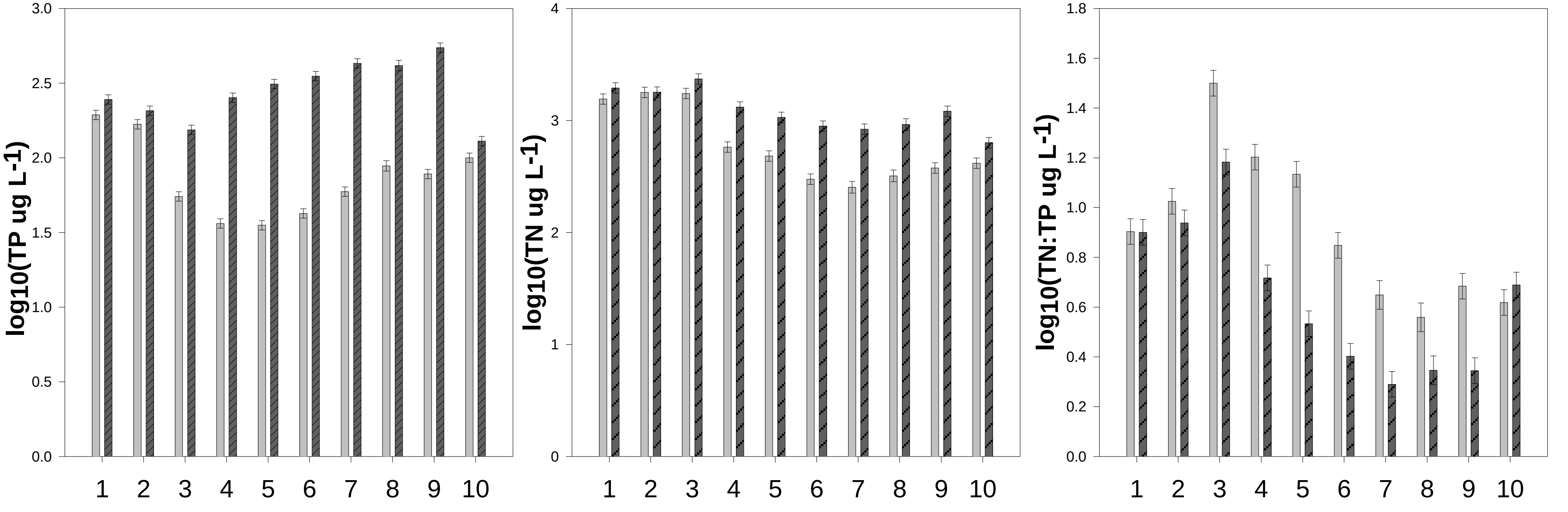
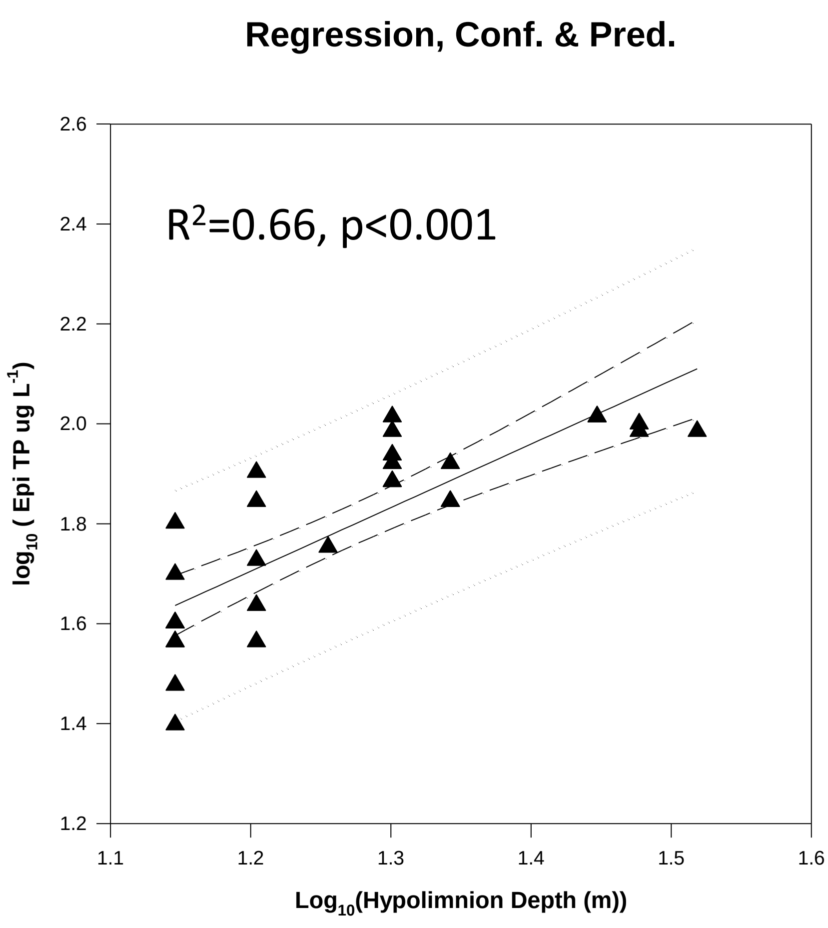
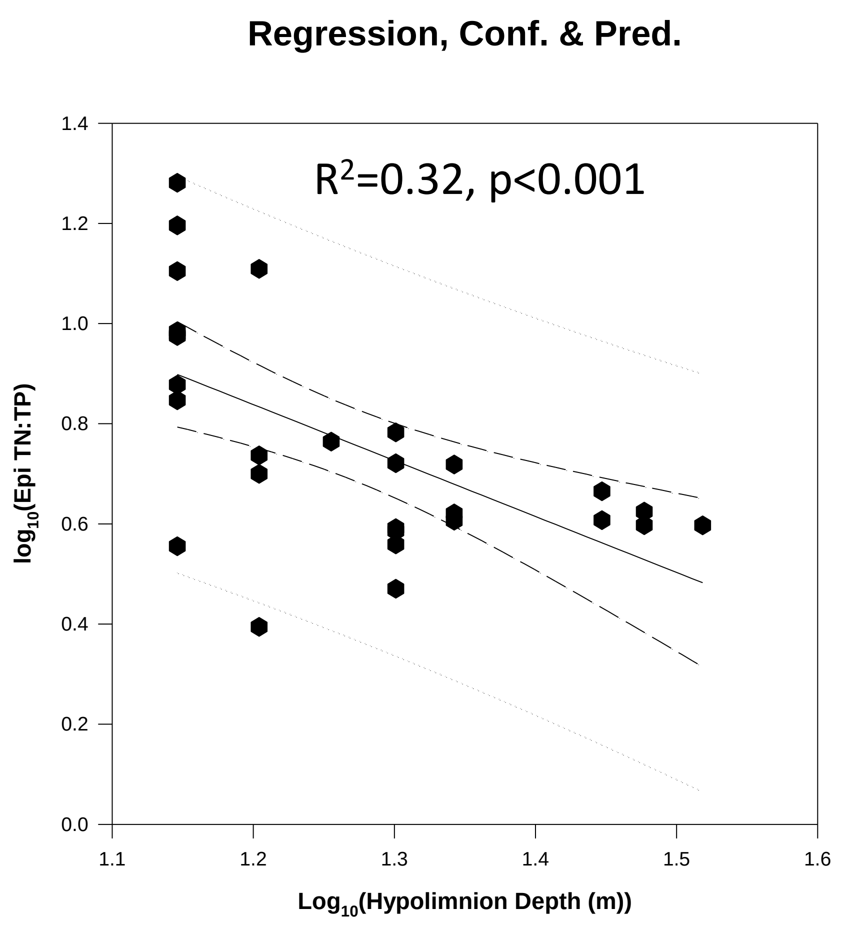


Figure 4. Mean epilimnetic and hypolimnetic nutrients (±s.d.) for each sampling date. Left: TP. Center: TN. Right: TN:TP. Sample Dates: (1) Early June, (2) Late June, (3) Early July, (4) Late July, (5) Early August, (6) Late August, (7) Early September, (8) Late September, (9) Early October, (10) Late October.

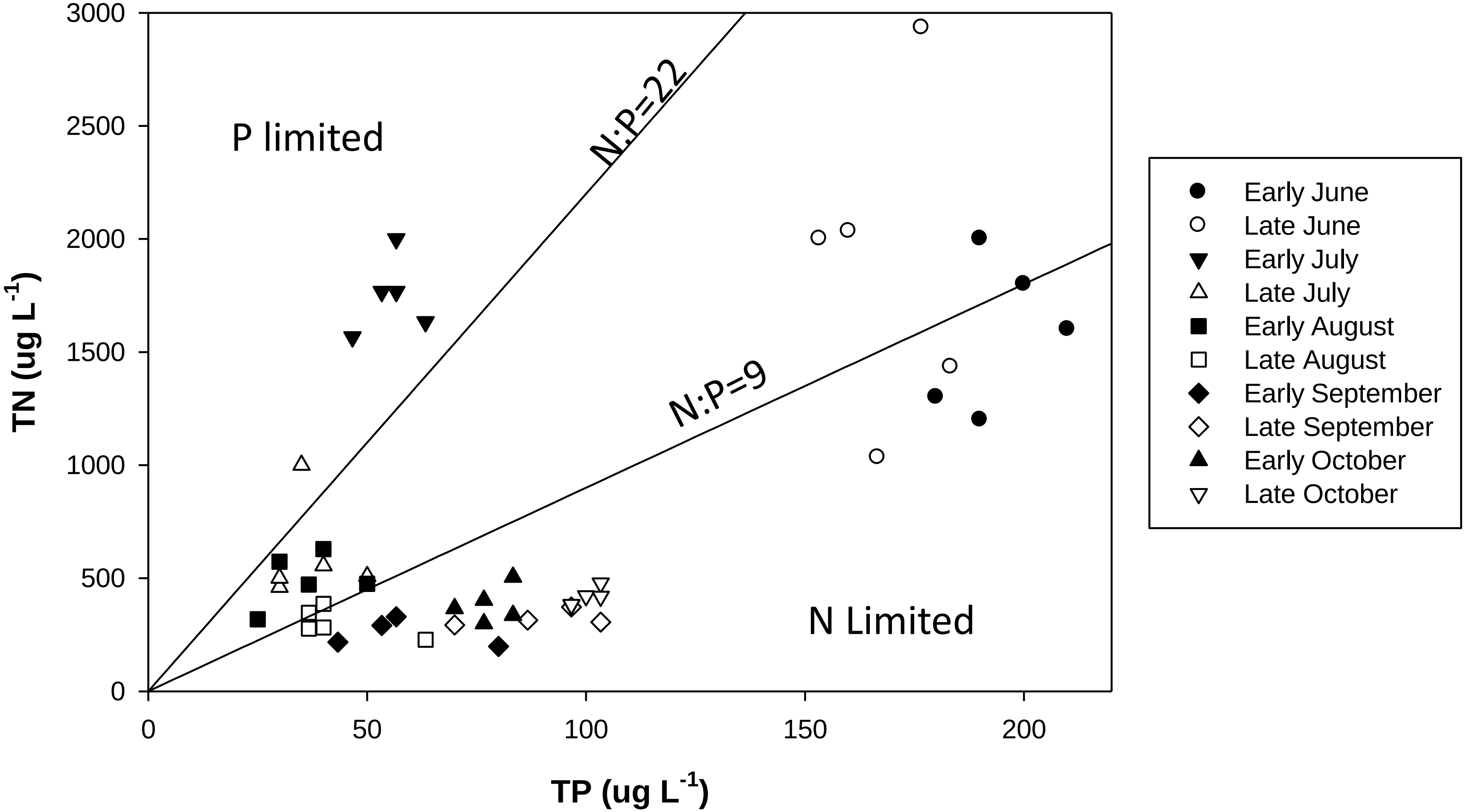
Results





TN: no significant relationship

Results



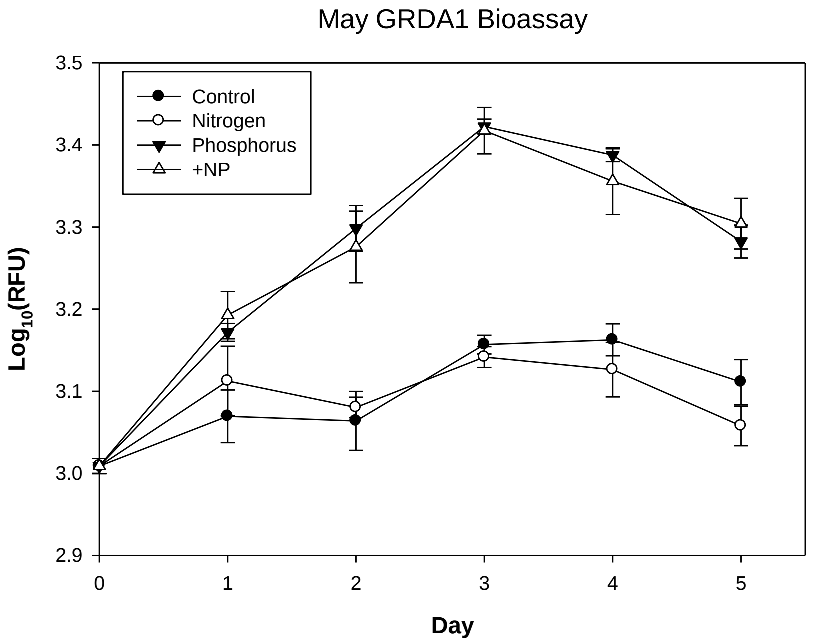
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
TN (ug L-1)
TP (ug L-1)
P limited
N Limited
N:P=22
N:P=9
Early June
Late June
Early July
Late July
Early August
Late August
Early September
Late September
Early October
Late October

Results (Bioassays)

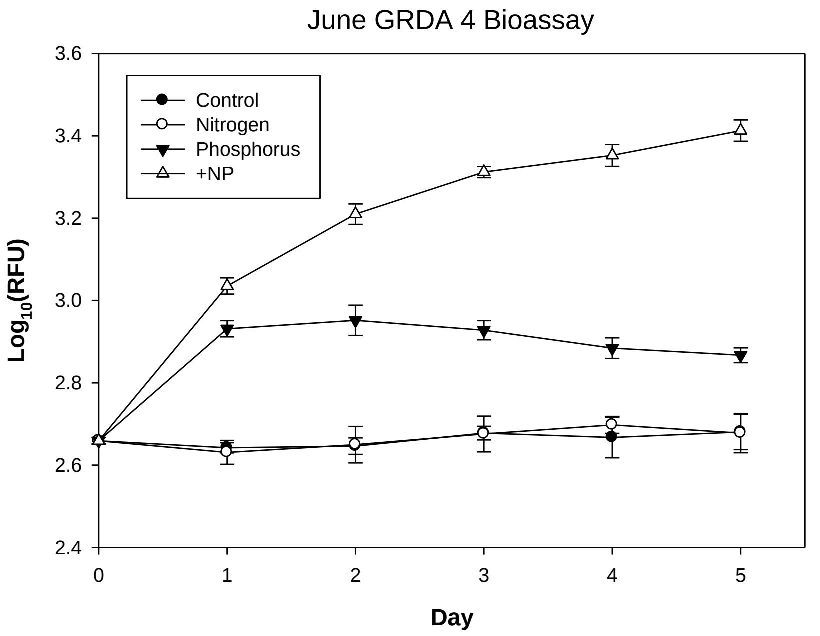
Month	Riverine	Transition	Lacustrine	Dam
May	P Limitation	P Limitation	No Response	No Response
June	P Serial Limitation	P Serial Limitation	P Serial Limitation	P Serial Limitation
August	----	Independent Co -Limitation	Independent Co -Limitation	P Serial Limitation
Sept	----	N Serial Limitation	N Serial Limitation	N Serial Limitation
October	No Response	No Response	No Response	No Response

Results (Bioassays)

P Limitation

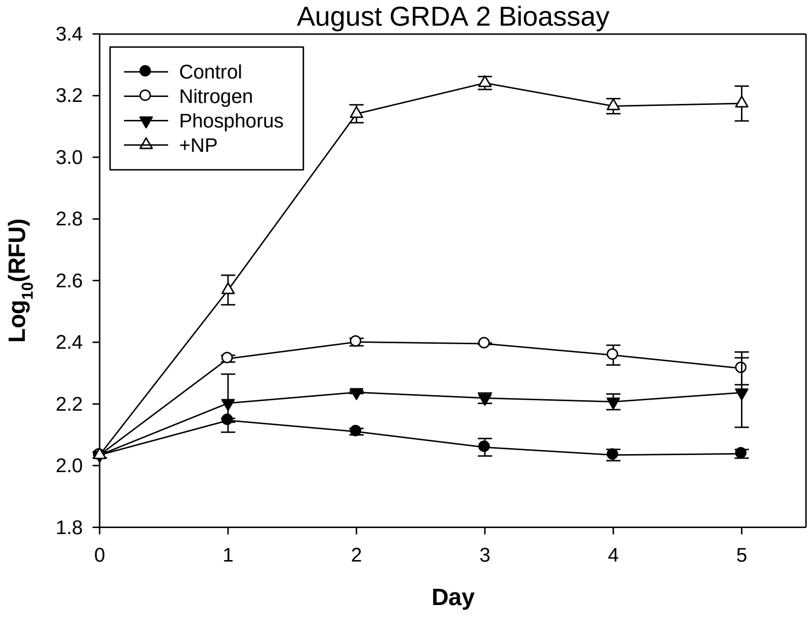


P Serial Limitation

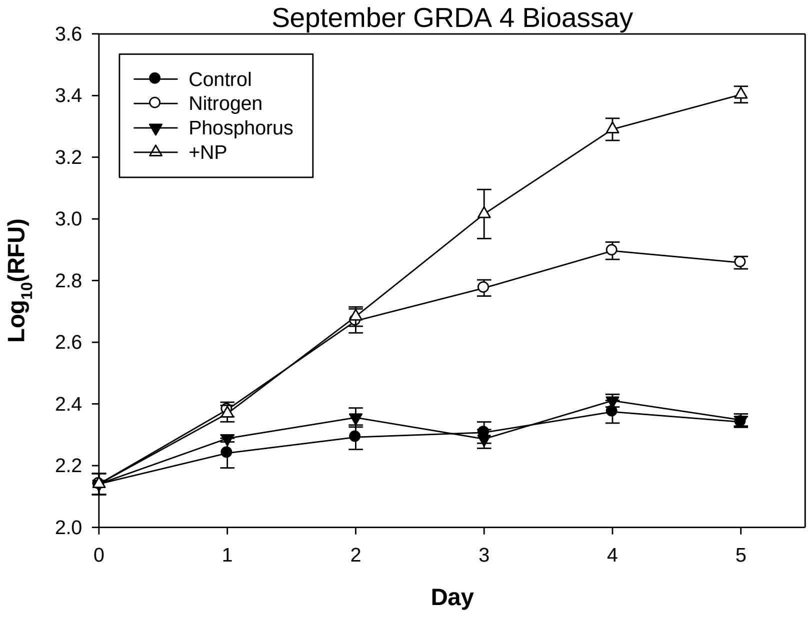


Results (Bioassays)

Independent Co-Limitation

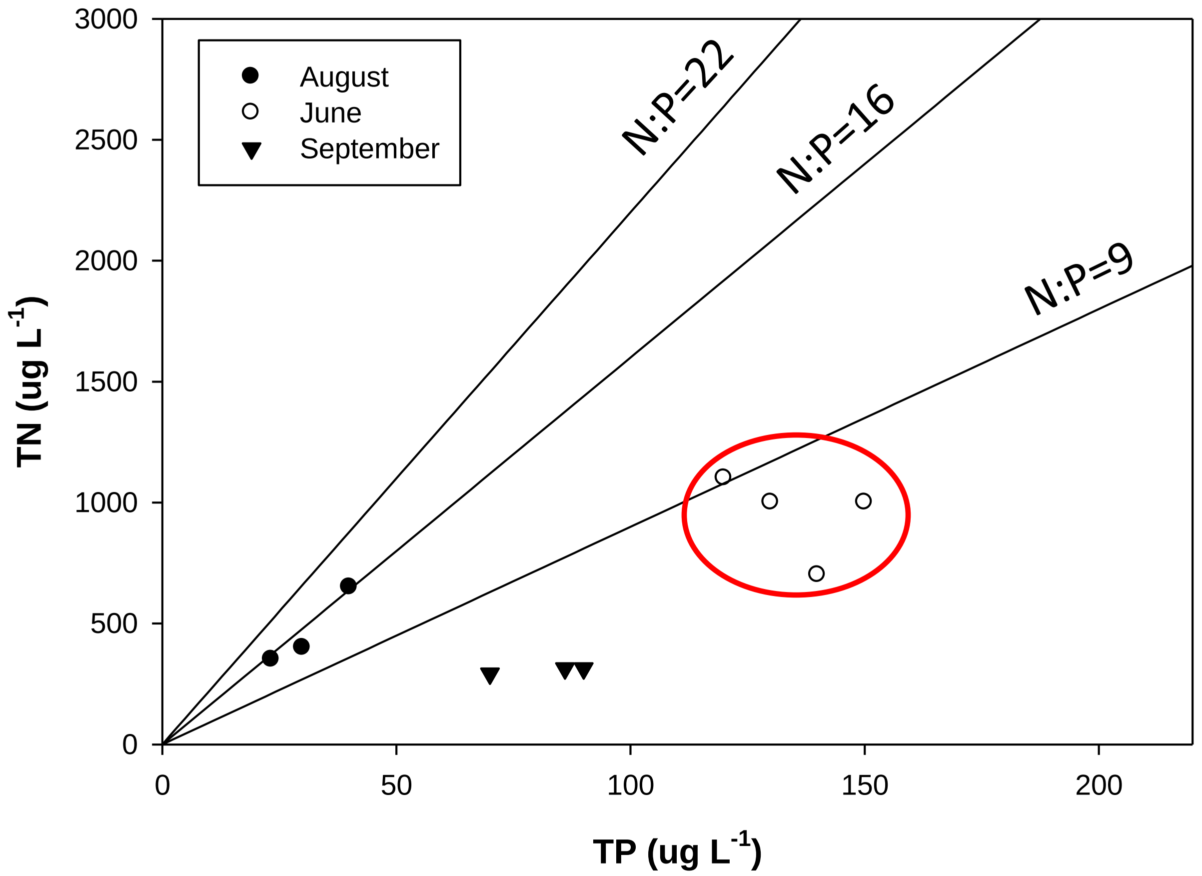


N Serial Limitation



See Harpole et al. (2011)

Results (Bioassays)



Conclusions

- Nutrient Limitation Varied Spatially and temporally in Grand Lake
- N:P ratios are generally good predictors of nutrient limitation, but could use further development.
- The internal phosphorus load drove N:P ratios low later in the year.

Comments/Questions?