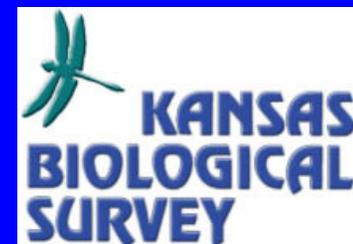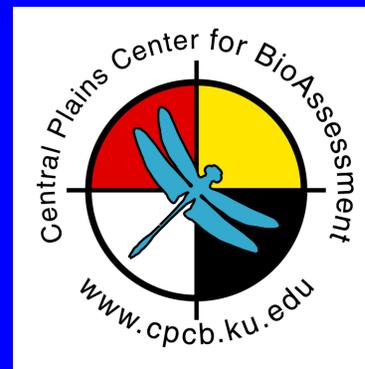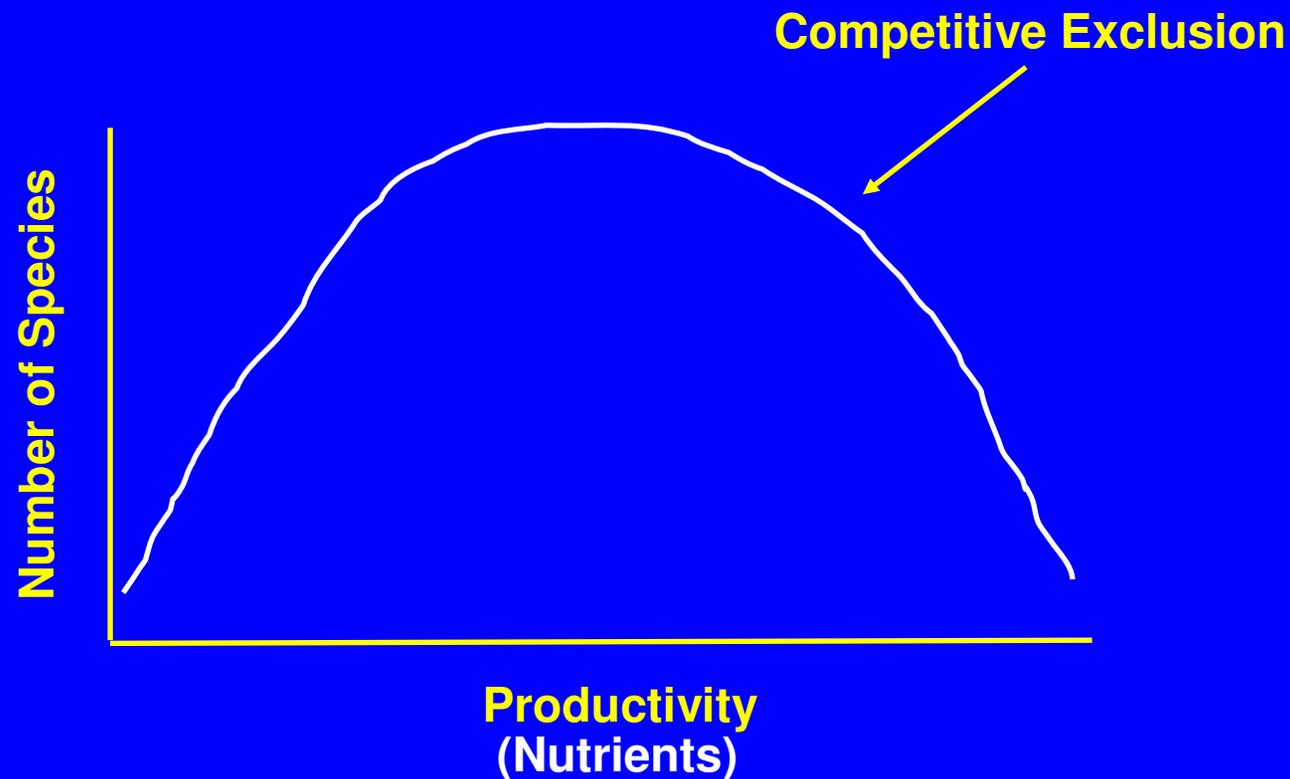# Thresholds in macroinvertebrate biodiversity and stoichiometry across water quality gradients in Central Plain's lotic ecosystems

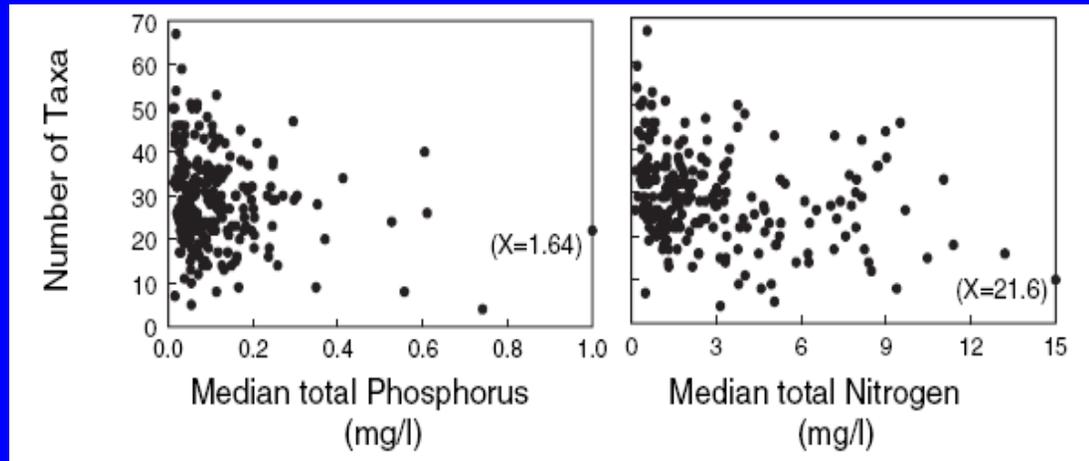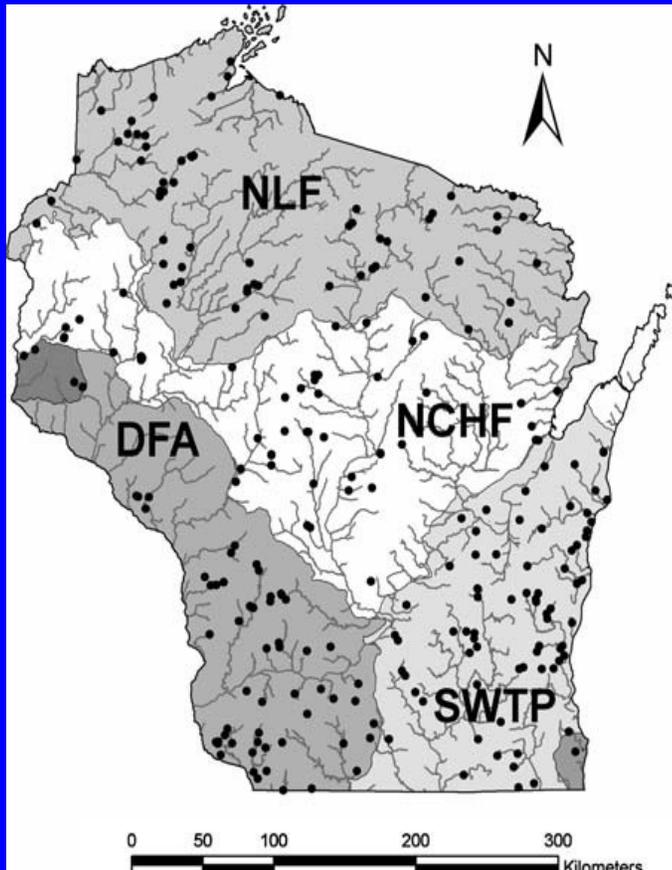Michelle A. Evans-White, Walter K. Dodds, Don G. Huggins, and Debra S. Baker

Animal Diversity Across Nutrient Gradients

Nutrients stimulate primary production

(e.g., Grime 1973; Huston1979; Tilman 1982)

Threshold Patterns Appear Across Large-Scale Nutrient Gradients

- **Mean and variance in richness decreases as nutrient concentrations increase**
- **Changepoint or threshold point for this can be used to establish water quality criteria**

What causes this threshold reduction in richness as nutrient concentrations increase?

Wang et al., *Environmental Management*, 2007

Possible Causes of Reduced Diversity

- **Direct Toxicity**
  - NH_3 (>0.08mg/L) and NO_3 (>2mg/L) (Ball1967; Rice&Bailey 1980; Mummert et al. 2003; Alonso & Camargo 2003)

- **Indirect Toxicity**
  - Low dissolved oxygen due to stimulation of primary production

- **Correlation ≠ Causation**
  - Another stressor that correlates with nutrient concentrations is responsible

- **Alteration of resource quality or quantity**
  - High dissolved nutrient concentrations usually elevate algal and detrital nutrient content.
  - Enrichment may favor a few species with high nutrient demands and growth rates

Resource Hypothesis

- Many aquatic macroinvertebrates have evolved using low quality food resources (Cross et al. 2003; Frost et al. 2006)

- Shredding macroinvertebrates generally have higher body C:P and reduced demand for dietary phosphorus (Frost et al. 2006)

- Body P content is linked to growth rate and a trade-off for utilizing low quality food resources might be a reduced growth rate (Elser et al. 2000, Frost et al. 2006).

- As nutrients become replete, a few species with high nutrient demands and growth rates may outcompete those with lower nutrient demands and growth rates.

Resource Hypothesis

Evidence from Dissolved Nutrient Additions:

- Increased growth and production of shredder and collector taxa (Cross et al. 2005).

- Short-lived faster-growing species ($\downarrow$C:P) were more sensitive than longer-lived slower growing species ($\uparrow$C:P) to enrichment (Cross et al. 2005,2006).

- Shifted community towards dominance by chironomids that had low C:P (Gafner & Robinson 2007).

Evidence from Enriched Particle Additions

- Increased production of gathering taxa with high body P content (Singer and Battin 2007).

Questions

1. Do thresholds in macroinvertebrate richness occur across water quality gradients in Central Plains streams?

2. Could richness thresholds across nutrient gradients be driven by changes in resource quality or quantity?
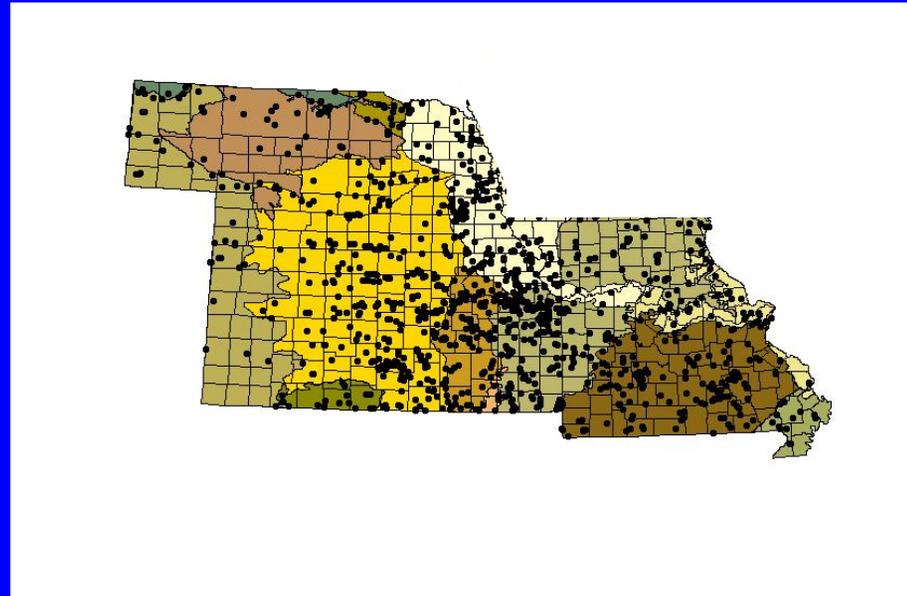
Methods

Water Chemistry

- Total Nitrogen (TN), Total Phosphorus (TP), Turbidity (NTU)

- 30-d median values

Macroinvertebrates

- 483 records taken Mar.-Nov. using D-nets in 13 ecoregions

- Central Great Plains, Central Irregular Plains, Flint Hills, and Ozark Highlands

- Assigned to functional feeding groups and body C:P based on literature values (Barbour et al. 1999; Cross et al. 2003; Evans-White et al. 2005; Singer & Battin 2007)

Threshold Analysis

1. Determine whether water chemistry (TN,TP, turbidity) correlate with richness (Spearman Rank Correlations)

2. Quantify statistical threshold points in richness variation across nutrients using nonparametric changepoint analysis (King & Richardson 2003)

   • Regression tree analysis

   • Bootstrap simulation (Efron &Tibshirani 1993)

   • Cumulative probability of changepoint (5, 50, 95%)

   5% = 5% of the bootstrap simulations resulted in a changepoints $\leq$ x.

Resource Hypothesis: Approach & Hypotheses

1. Are richness thresholds to TN, TP, and turbidity dependent upon feeding mode?

   - *Primary consumers should be more sensitive to TN and TP than predators.*

   - *TN and TP thresholds are more likely to depend on feeding groups than turbidity thresholds*
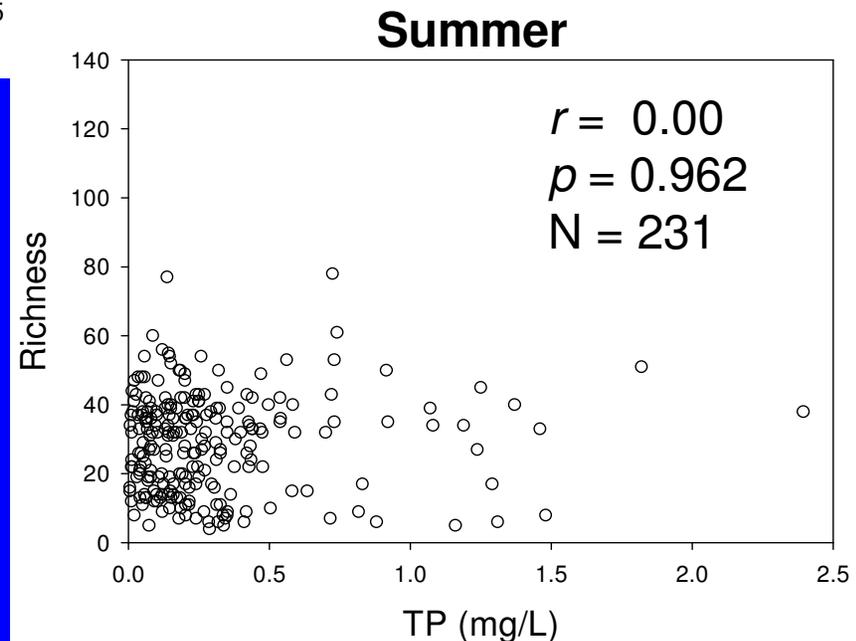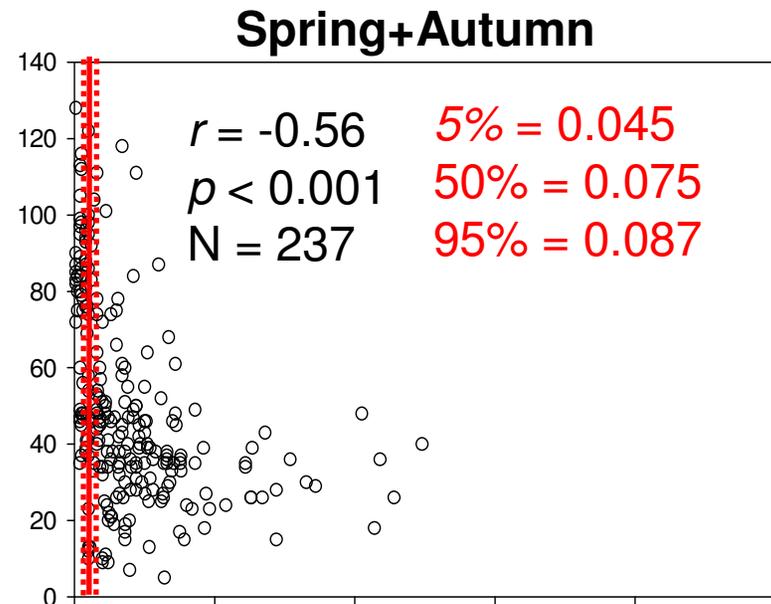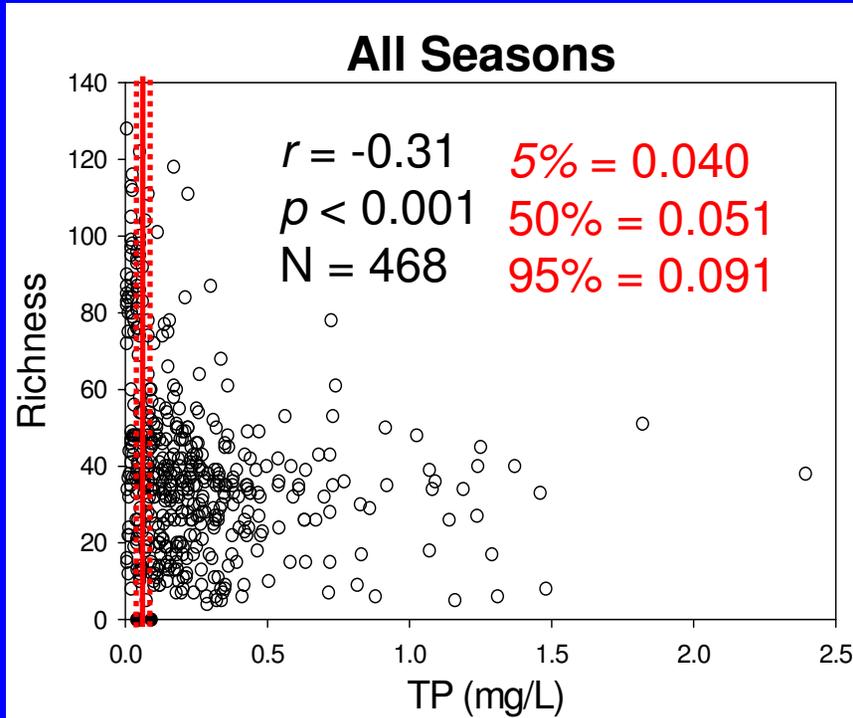
2. Do abrupt declines in diversity coincide with declines in mean taxa C:P?

   - *Primary consumer C:P should decrease as TP increases.*

Results

1. Seasonal Issues

2. *Primary consumers should be more sensitive to TN and TP than predators.*

3. *Primary consumers and predators should be equally sensitive to turbidity*

4. *Primary consumer C:P should decrease as TP increases.*

Seasonal Patterns: Summary

All Seasons

$r = -0.31$
$p < 0.001$
$N = 468$

5% = 0.040
50% = 0.051
95% = 0.091

Richness

TP (mg/L)

Spring+Autumn

$r = -0.56$
$p < 0.001$
$N = 237$

5% = 0.045
50% = 0.075
95% = 0.087

Summer

$r = 0.00$
$p = 0.962$
$N = 231$

Richness

TP (mg/L)

- **TN and TP thresholds were more sensitive to season than turbidity thresholds**

- **Nutrient thresholds may be sensitive to seasonality of food resource availability**
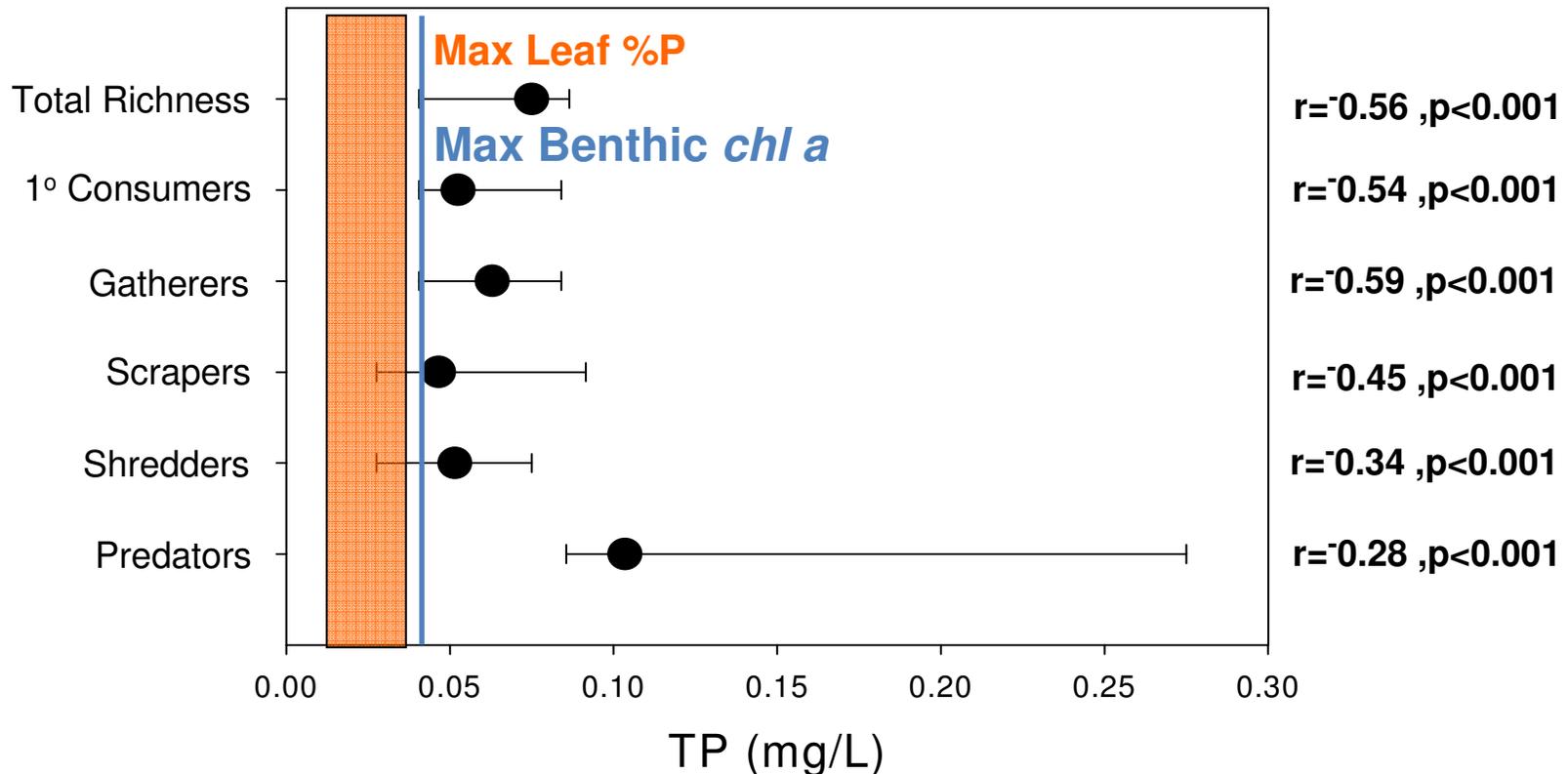
Results

1. Seasonal Issues   **YES**

2. *Primary consumers should be more sensitive to TN and TP than predators.*

3. *Primary consumers and predators should be equally sensitive to turbidity*

4. *Primary consumer C:P should decrease as TP increases.*

Total Nitrogen and Richness
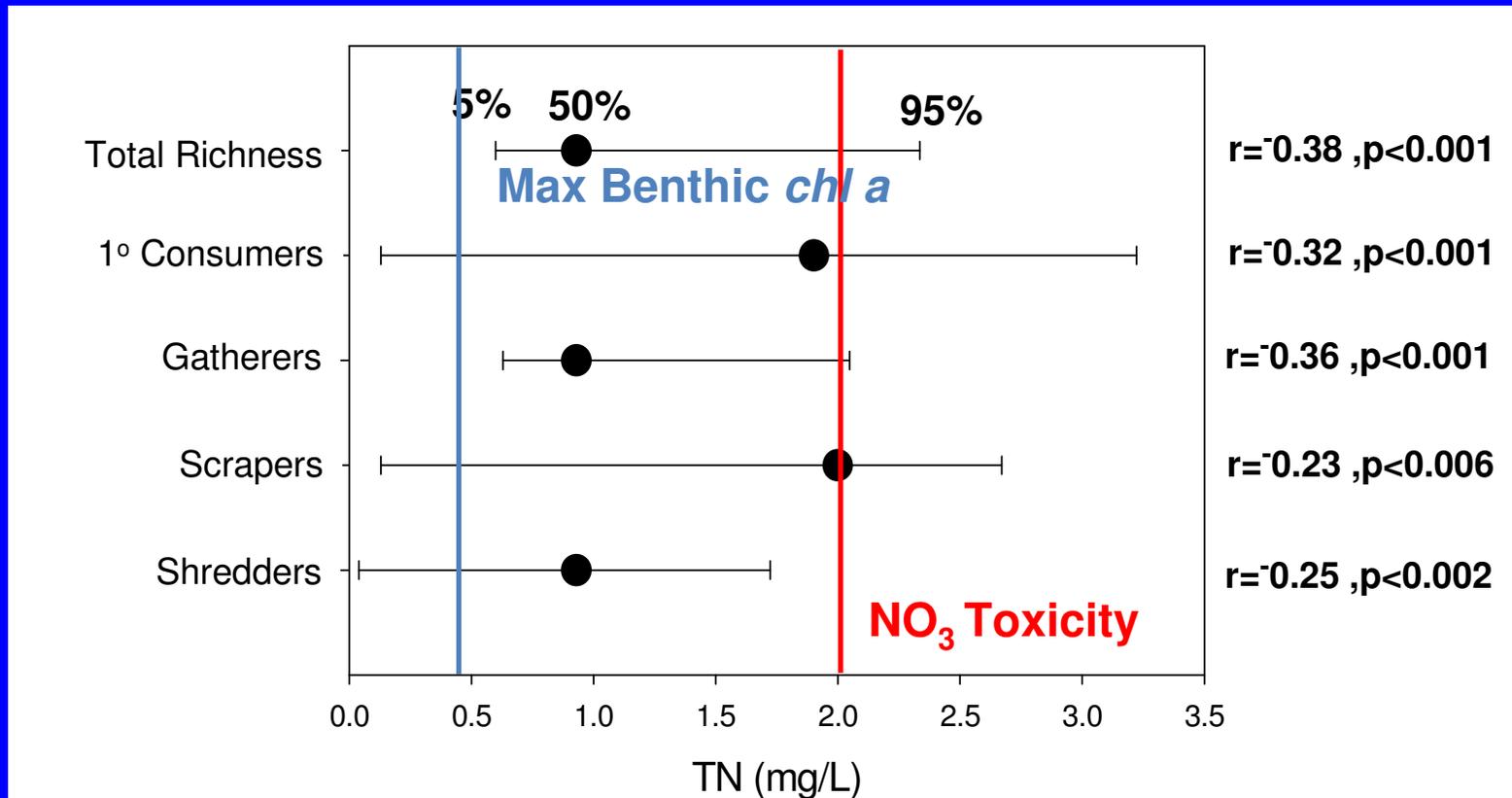
- Primary consumer species were most affected.
- Threshold medians above average maximum benthic chl a threshold (Dodds et al. 2002,2006)
- Threshold medians generally below NO_3 toxicity levels (Camargo et al. 2006)

# Total Phosphorus and Richness

- Primary consumers < predators
- Diversity thresholds > average maximum benthic chl a threshold (Dodds et al. 2002, 2006)
- Diversity thresholds > maximum %P in leaves (Baldy et al. 2006)

Results

1. Seasonal Issues **YES**

2. *Primary consumers should be more sensitive to TN and TP than predators.* **YES**

3. *Primary consumers and predators should be equally sensitive to turbidity*

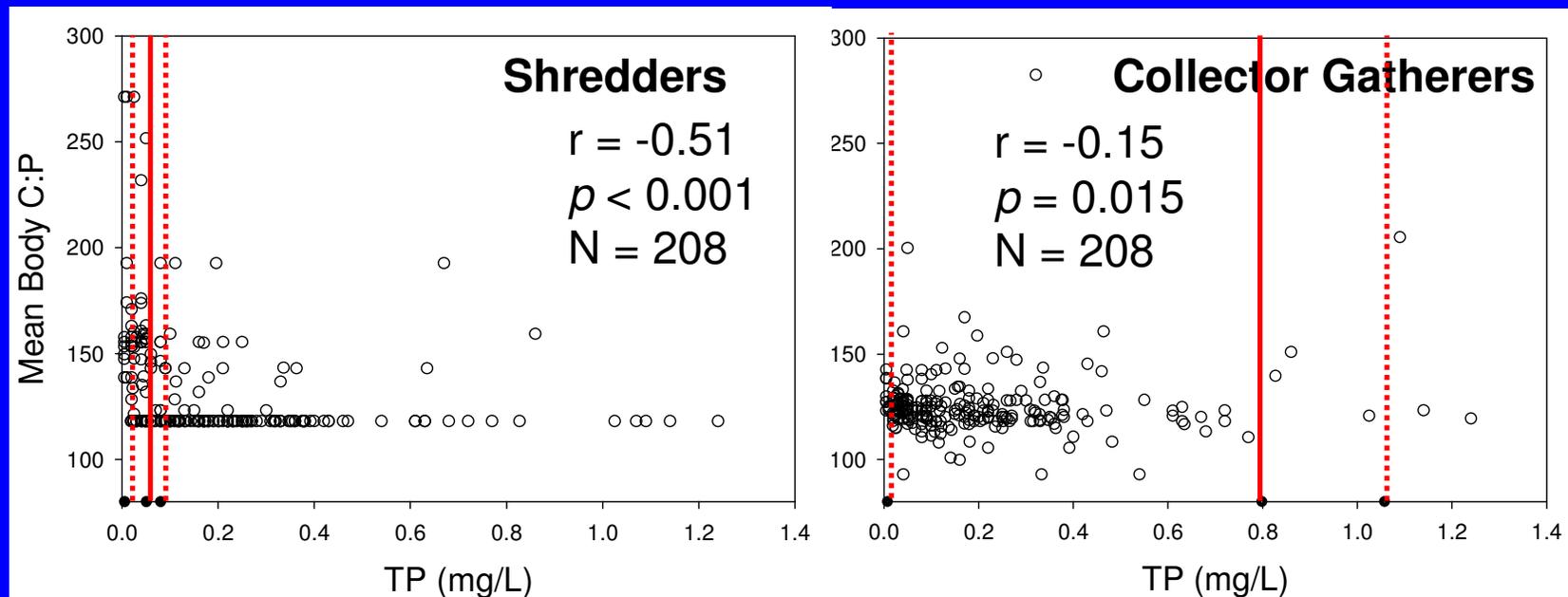4. *Primary consumer C:P should decrease as TP increases.*

Turbidity and Richness
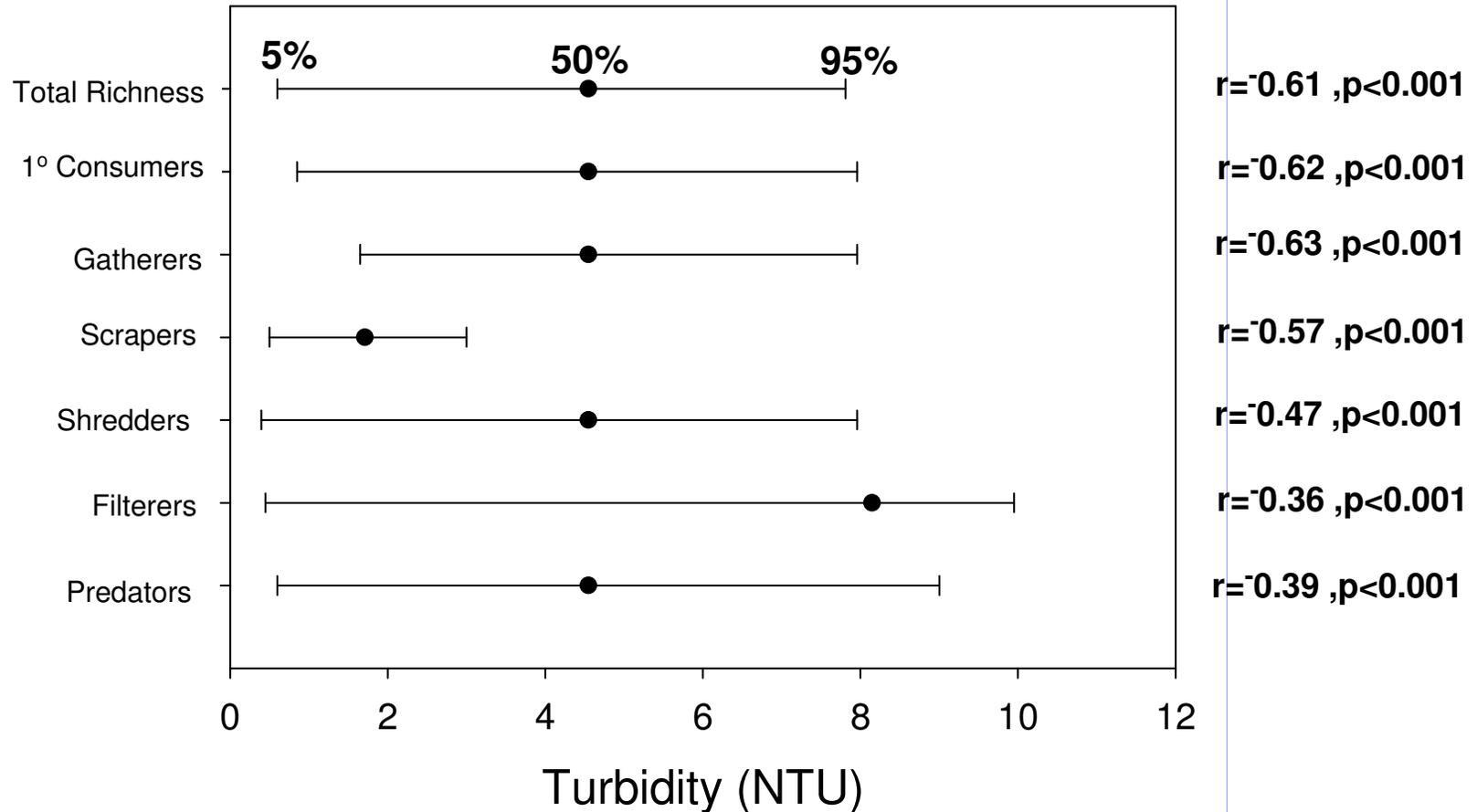
• Turbidity significantly reduced richness within all feeding groups

Results

1. Seasonal Issues **YES**

2. *Primary consumers should be more sensitive to TN and TP than predators.* **YES**

3. *Primary consumers and predators should be equally sensitive to turbidity* **YES**

4. *Primary consumer C:P should decrease as TP increases.*

Mean Macroinvertebrate Body C:P

- Focused on groups that had significant declines in diversity as TP increased.

- Collector-gatherers, shredders, scrapers, and predators

- Both of these feeding groups have been shown to be sensitive to experimental food nutrient elevations (Cross et al. 2006; Singer & Battin 2007)

Mean Macroinvertebrate Body C:P
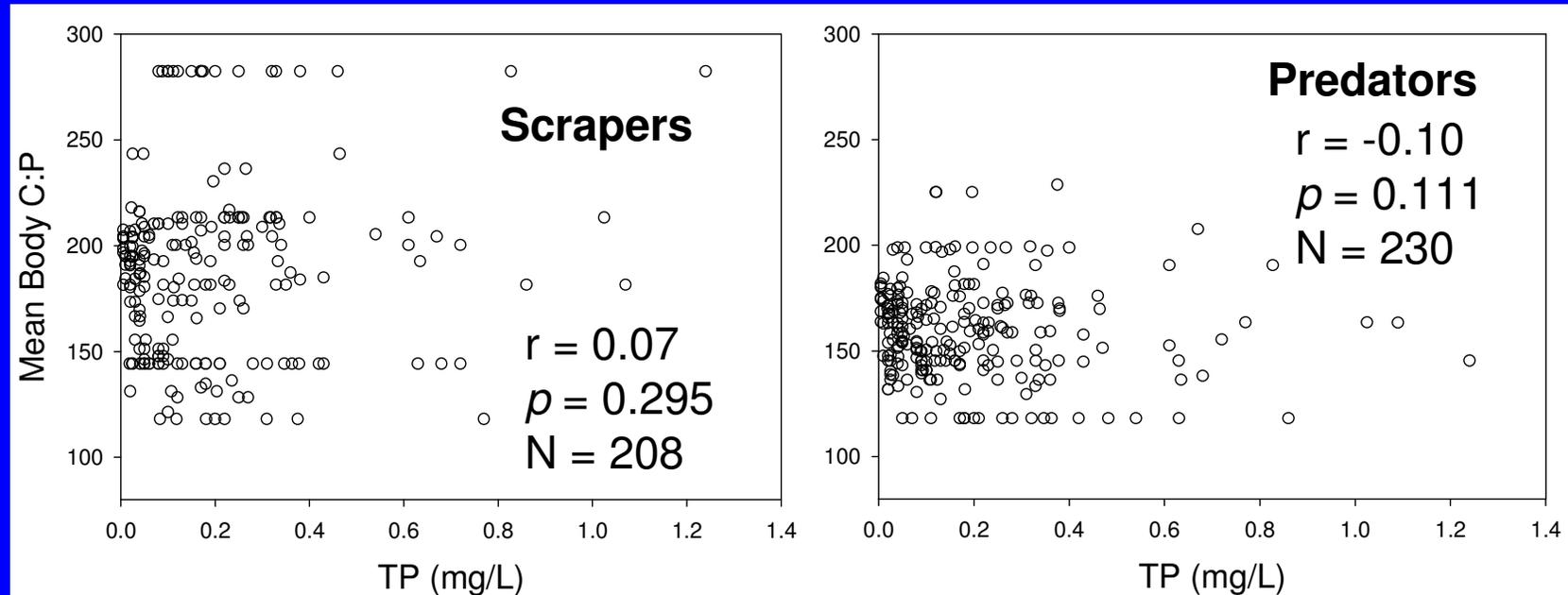
- No evidence that scraper communities are structured by resource quality.

- Predator C:P was not related to TP

Results

1. Seasonal Issues **YES**

2. *Primary consumers should be more sensitive to TN and TP than predators.* **YES**

3. *Primary consumers and predators should be equally sensitive to turbidity* **YES**

4. *Primary consumer C:P should decrease as TP increases.* **YES—Shredders & Gatherers**

Conclusions

- Shredder and collector-gatherer feeding groups richness and body C:P declined as nutrients increased

- Seasonality of nutrient thresholds may be driven by the timing of detrital inputs

- Greater than 90% of the streams in our dataset had nutrient concentrations above diversity and stoichiometry thresholds

The nutrient conditions under which most biota evolved could be exceeded in many streams lowering diversity and pushing the stream to a new state.

Acknowledgements

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