

# Impacts of Nutrients on the Biological Integrity of Wadeable Streams in Wisconsin

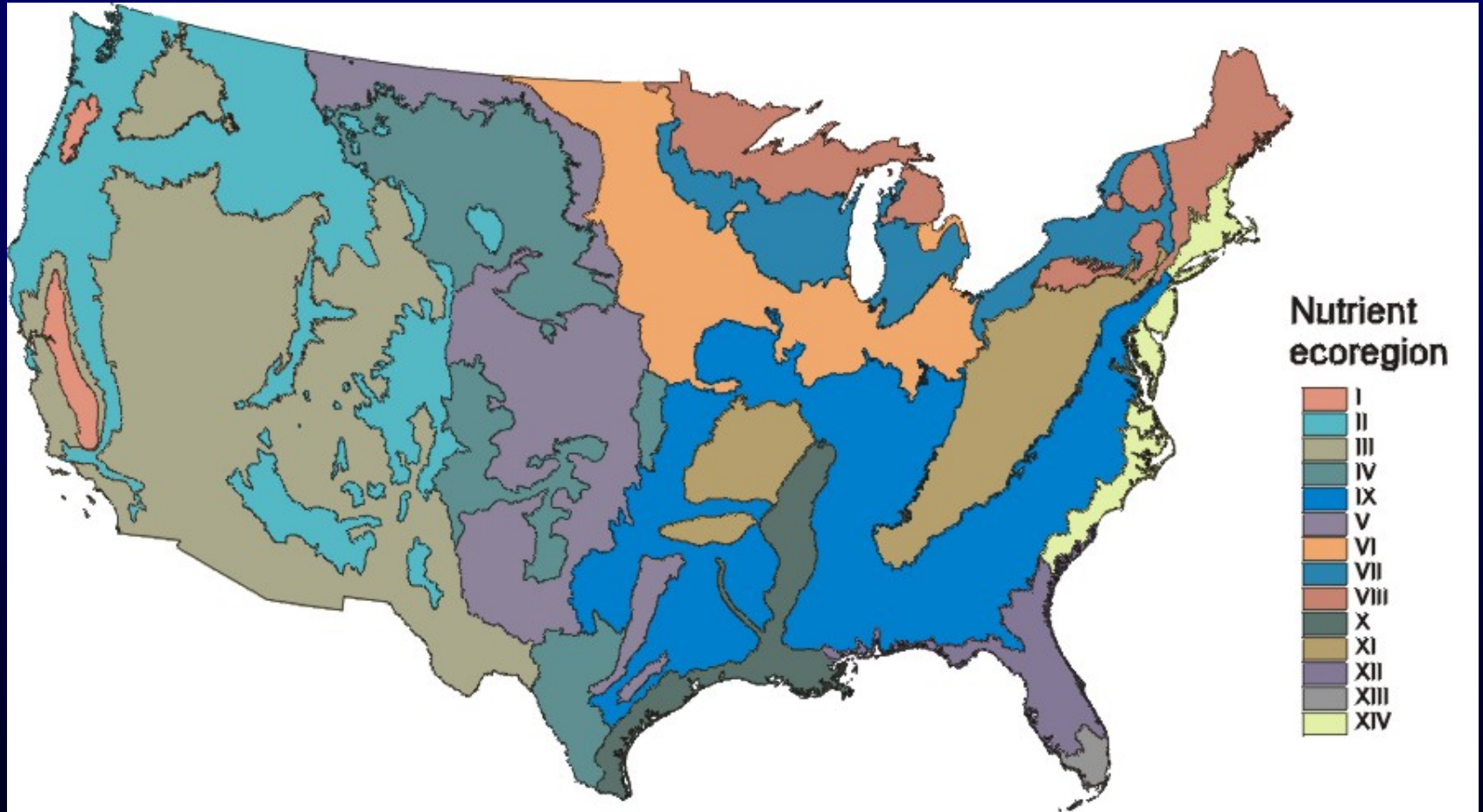
Dale Robertson  
David Graczyk



Lizhu Wang  
Paul Garrison  
Roger Bannerman

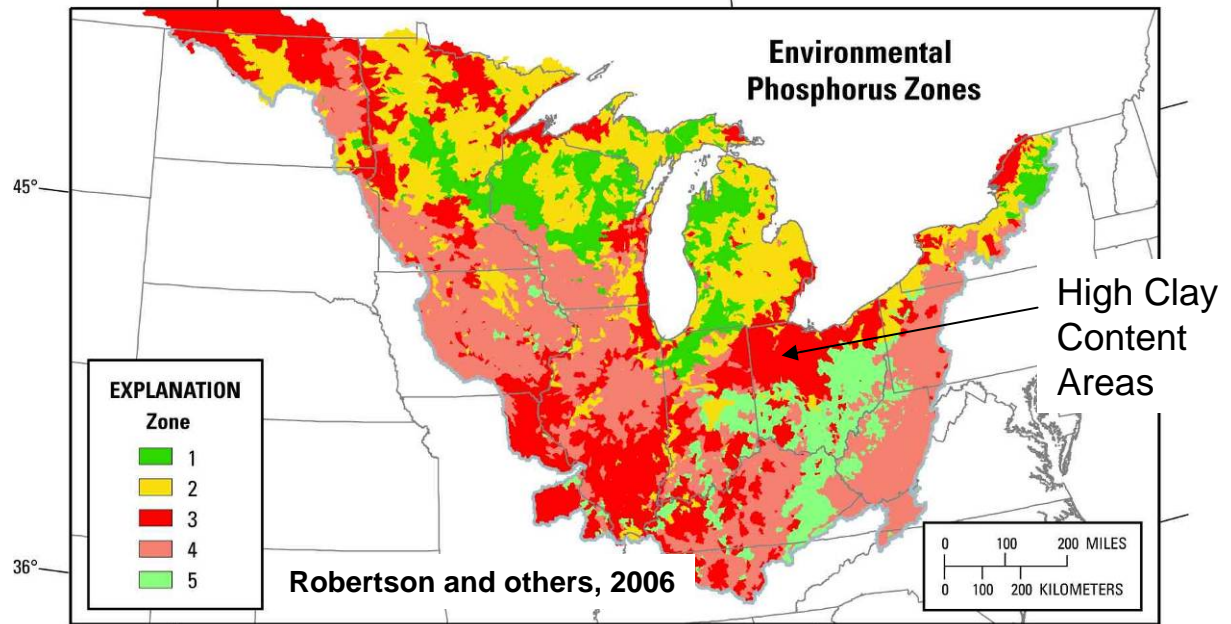
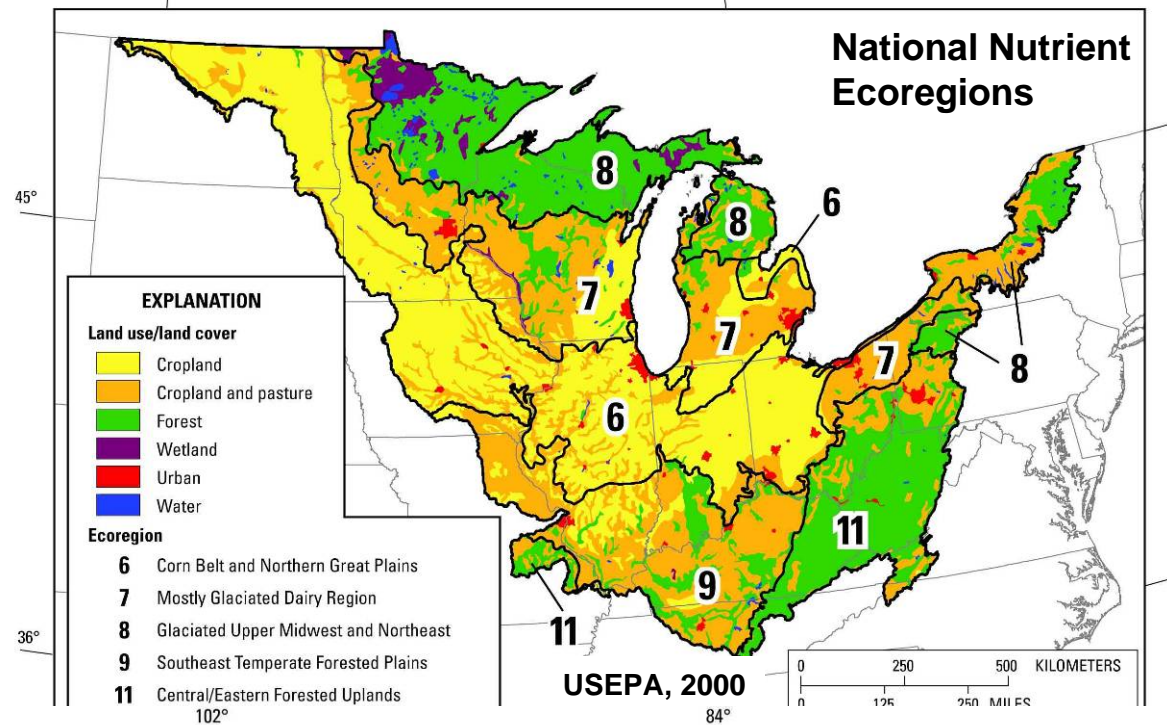


# Initial Classification Scheme for the National Nutrient Strategy – Based on Omernik Ecoregions



Criteria set based on reference/percentile approach (25th percentile of all data or 75th percentile of minimally impacted sites) or based on a threshold to biological response – with possible refinements by individual states

# Potential Regionalization Schemes



# Goals of Study

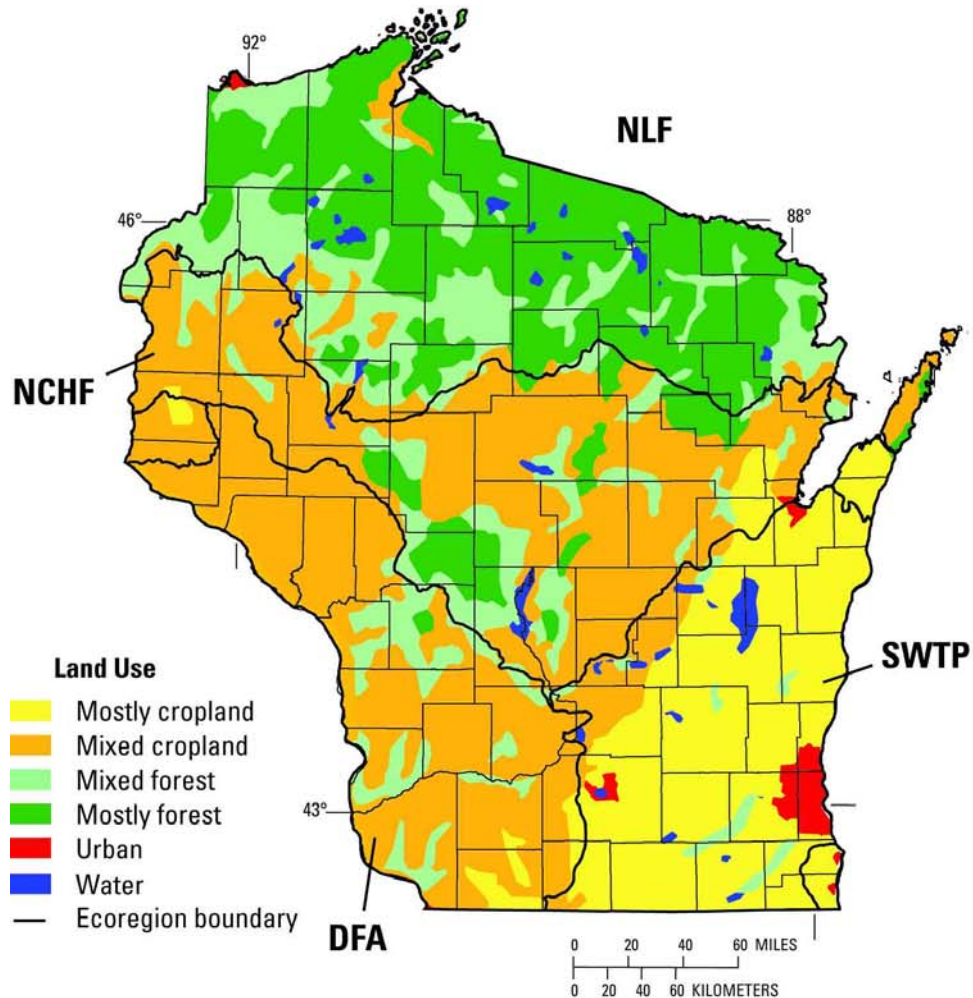
1. Describe the distribution of water quality and biology communities in Wisconsin's streams
2. Describe the importance of nutrients to biological community composition
3. Estimate reference conditions for the State on a "best" regional basis
4. Estimate thresholds in biological response
5. Develop refined Nutrient Criteria for Wisconsin



# Proposed Regionalization Schemes

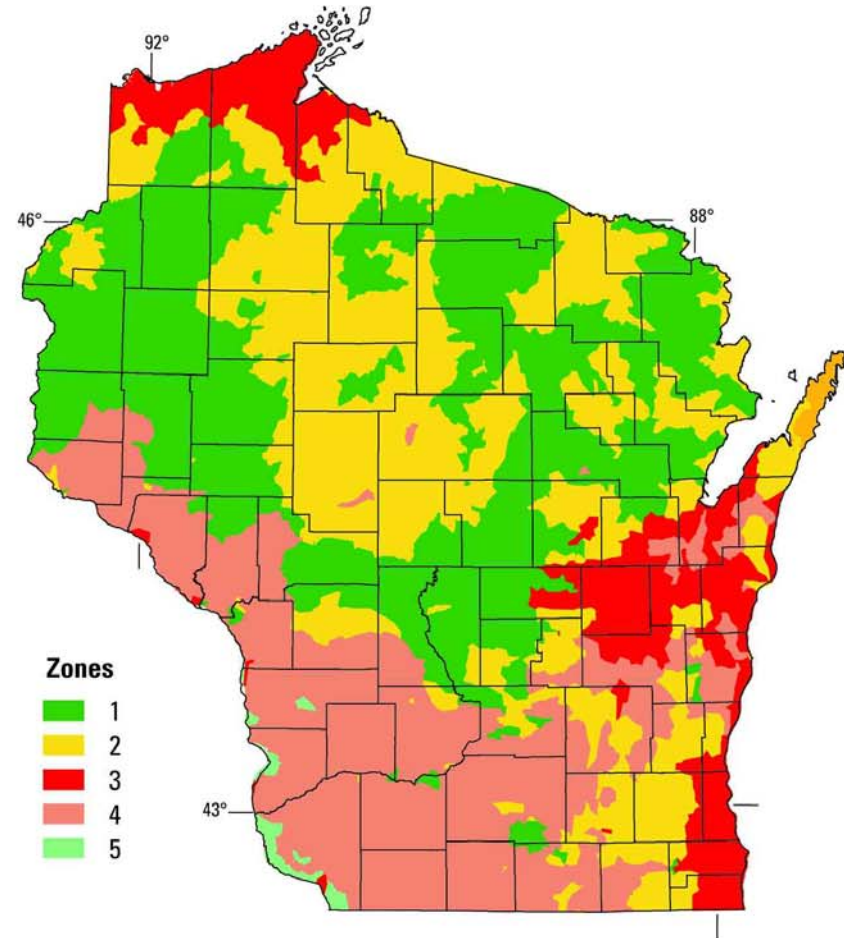
**A.**

**Level III Ecoregions**

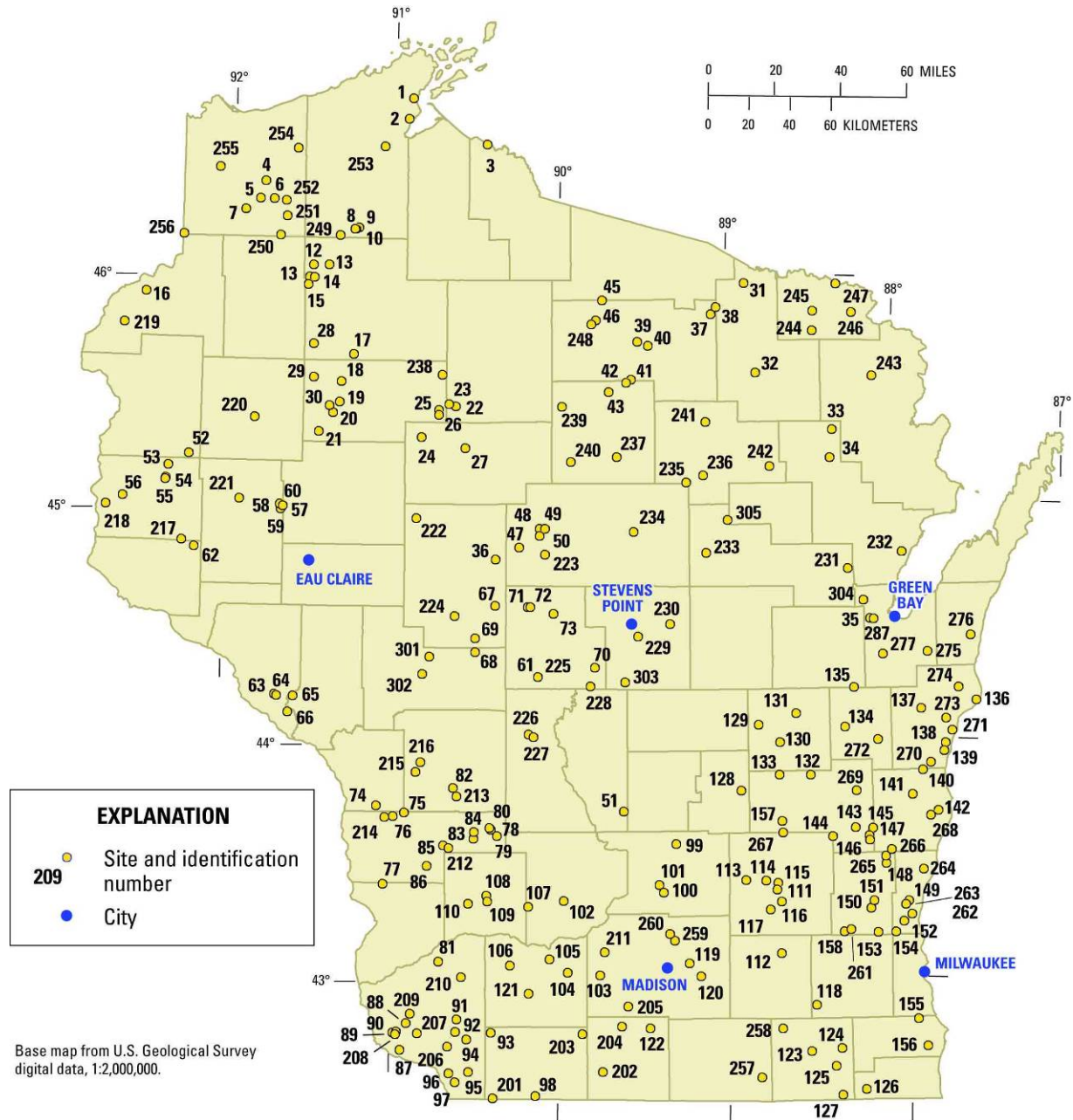


**B.**

**Environmental Phosphorus Zones**



# Locations of 240 wadeable sites sampled in the study

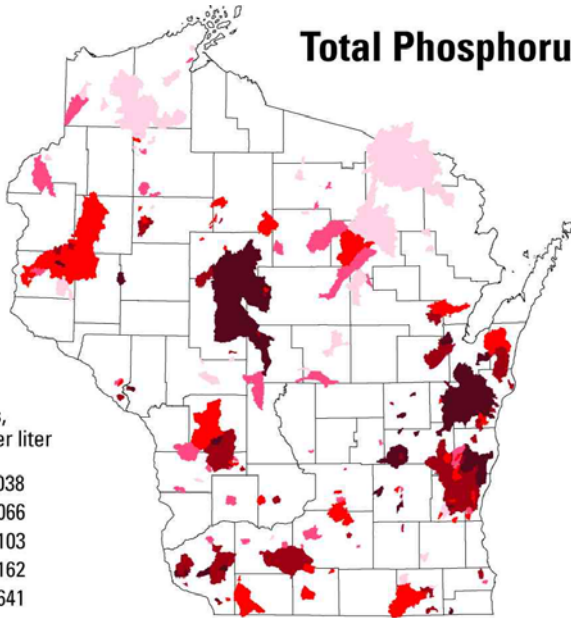


# Water Quality Measured Monthly at 240 Sites From May - October

## Total Phosphorus (P)

Concentrations,  
in milligrams per liter

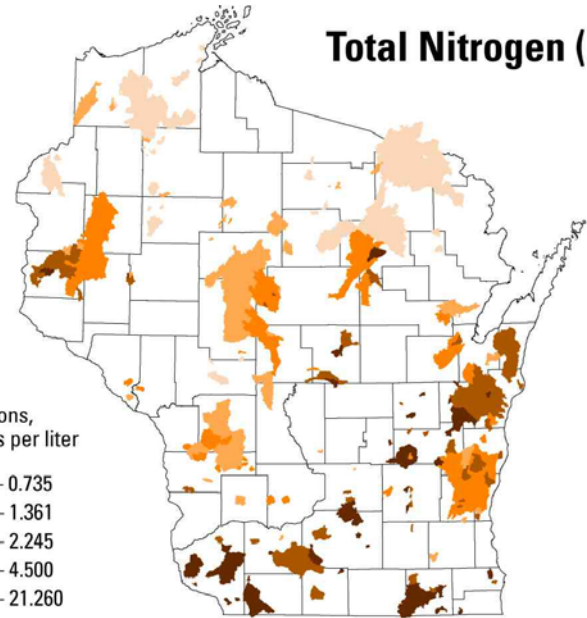
- 0.012 – 0.038
- 0.039 – 0.066
- 0.067 – 0.103
- 0.104 – 0.162
- 0.163 – 1.641



## Total Nitrogen (N)

Concentrations,  
in milligrams per liter

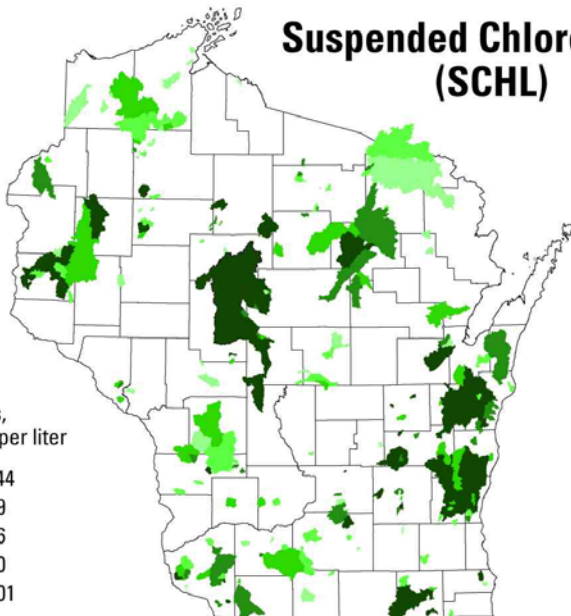
- 0.131 – 0.735
- 0.736 – 1.361
- 1.362 – 2.245
- 2.246 – 4.500
- 4.501 – 21.260



## Suspended Chlorophyll *a* (SCHL)

Concentrations,  
in micrograms per liter

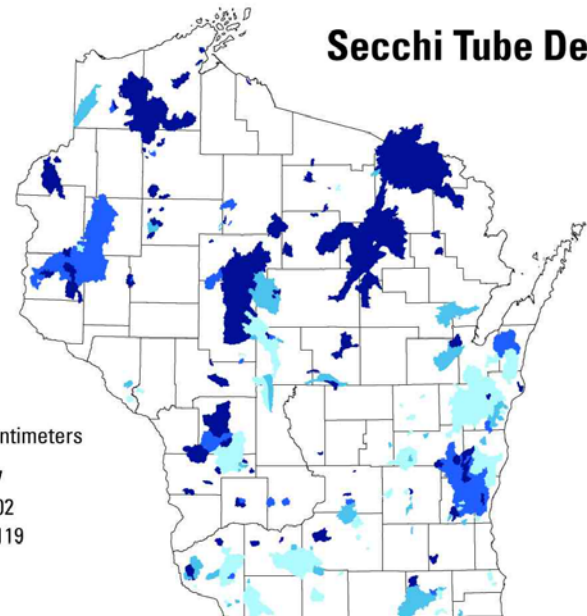
- 0.404 – 1.44
- 1.45 – 1.99
- 2.00 – 2.56
- 2.57 – 3.80
- 3.81 – 38.01



## Secchi Tube Depth (SD)

Depth, in centimeters

- 24 – 67
- 68 – 102
- 103 – 119
- ≥ 120

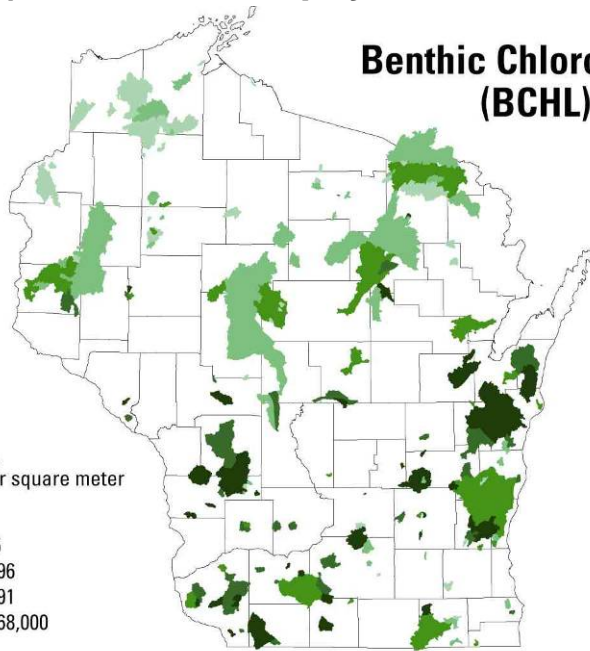




# Biology (Benthic Chlorophyll, Diatoms, Macroinvertebrate, and Fish) Measured Once at 240 Sites

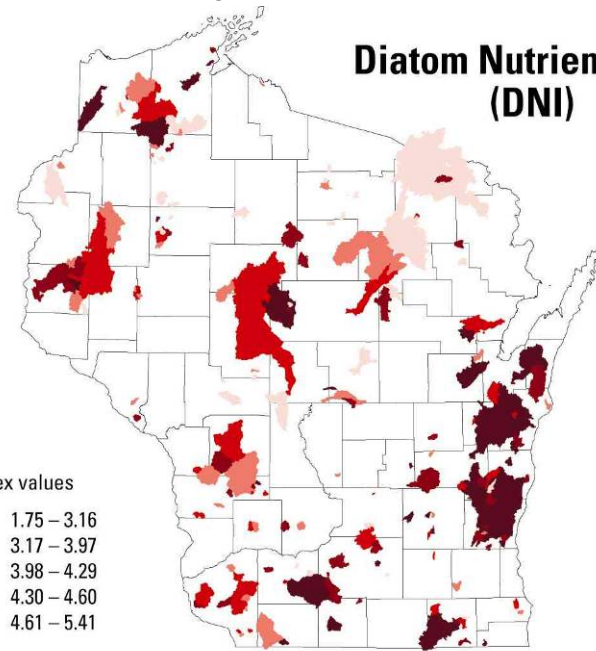
## Benthic Chlorophyll *a* (BCHL)

Concentrations,  
in milligrams per square meter



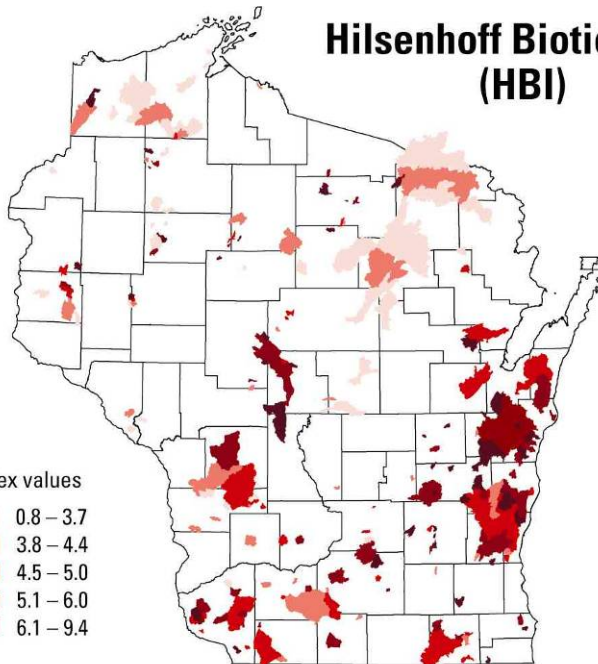
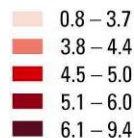
## Diatom Nutrient Index (DNI)

Index values



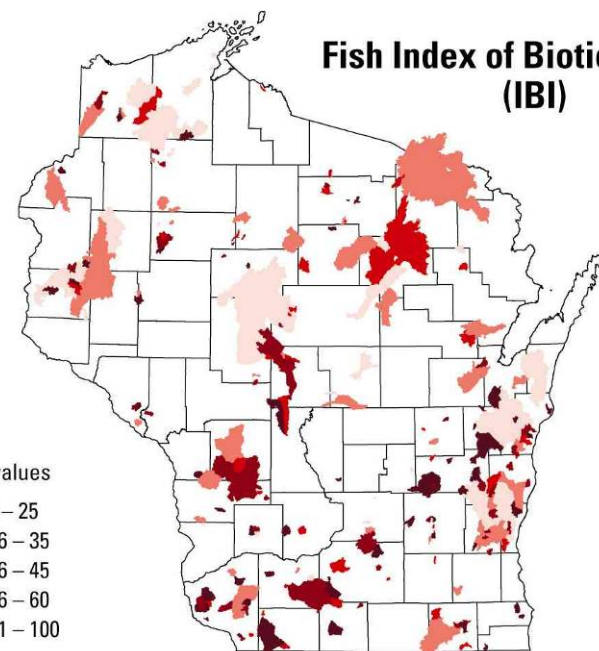
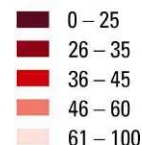
## Hilsenhoff Biotic Index (HBI)

Index values



## Fish Index of Biotic Integrity (IBI)

Index values





# Background Nutrient Concentrations (By Zone)

1.  $\text{Ln}(\text{TP}_p) = a + b (\text{Total Ag}) + c (\text{Total Urban}) + d (\text{PtS})$

2.  $\text{Ln}(\text{TP}_p) = -3.215 + 1.728 (0) + 2.926 (0) + 1.424 (0)$

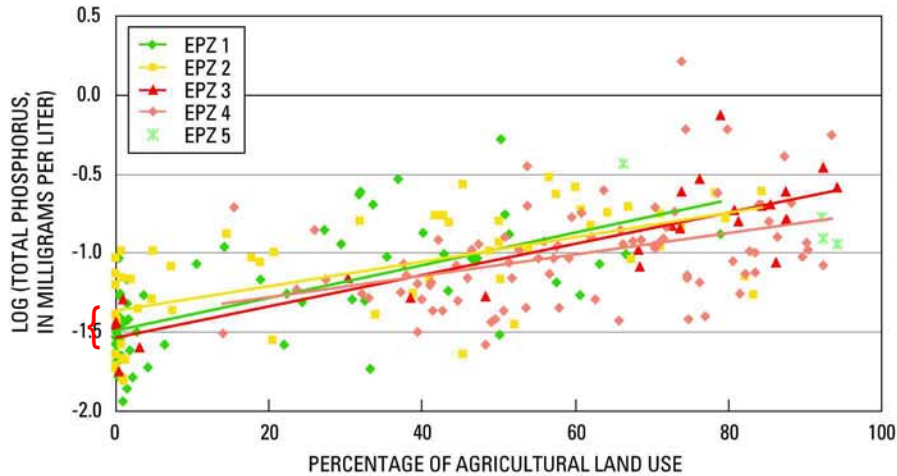
3.  $\text{Ln}(\text{TP}_B) = -3.215 \quad \text{SE} = 0.142$

4.  $\text{TP}_B = 0.040 \text{ mg/L}$

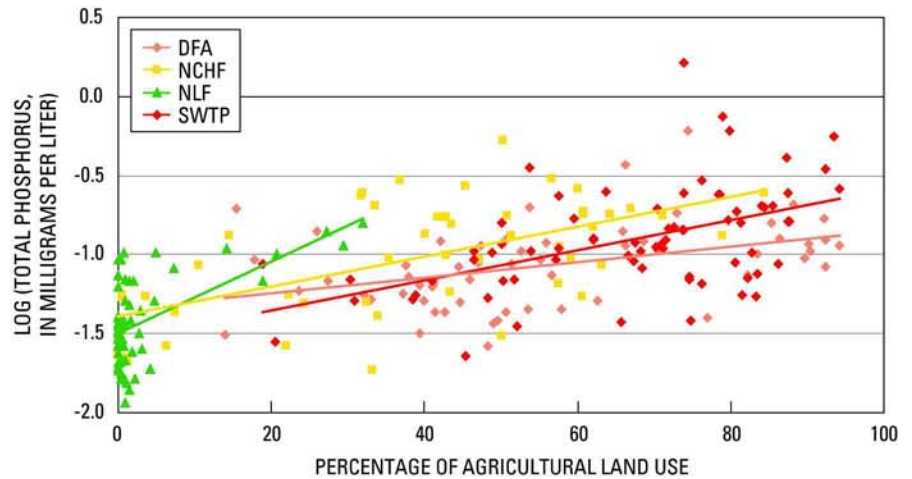
5.  $\text{TP}_B = 0.020 - 0.050 \text{ mg/L}$

# Reference Conditions and Response with the Regression Approach

A. Total Phosphorus By Environmental Phosphorus Zone



B. Total Phosphorus By Ecoregion



Problems with the traditional 25th percentile approach

{ **Reference Concentrations**

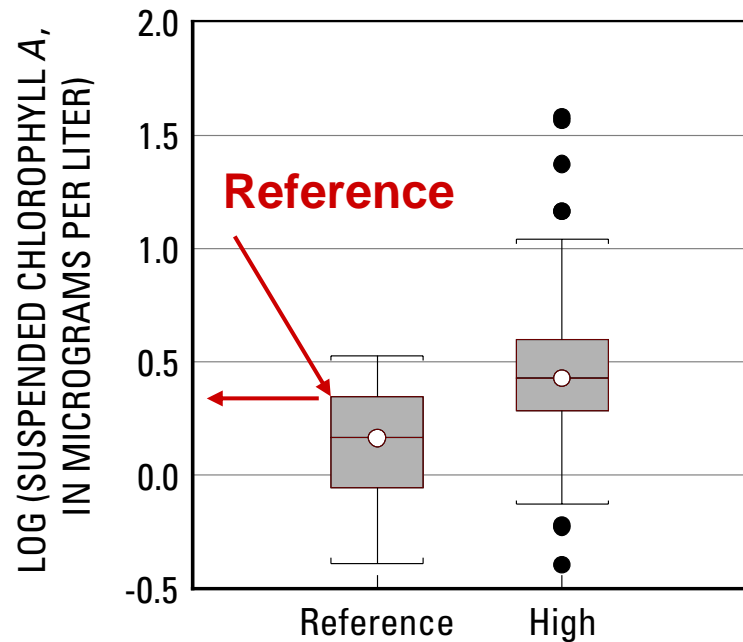
## Reference conditions

	Regression - This Study		This Study		USEPA Criteria
	Median Background	95 % Background	25th Percentile		
	Total Phosphorus (mg/L)				
EPZ 1	0.032	0.039	0.027	--	
EPZ 2	0.042	0.054	0.044	--	
EPZ 3	0.029	0.043	0.053	--	
EPZ 4	0.035	0.055	0.061	--	
DFA	0.040	0.057	0.053	0.070	
NCHF	0.041	0.060	0.054	0.029	
NLF	0.032	0.036	0.024	0.010	
SWTP	0.025	0.044	0.072	0.080	

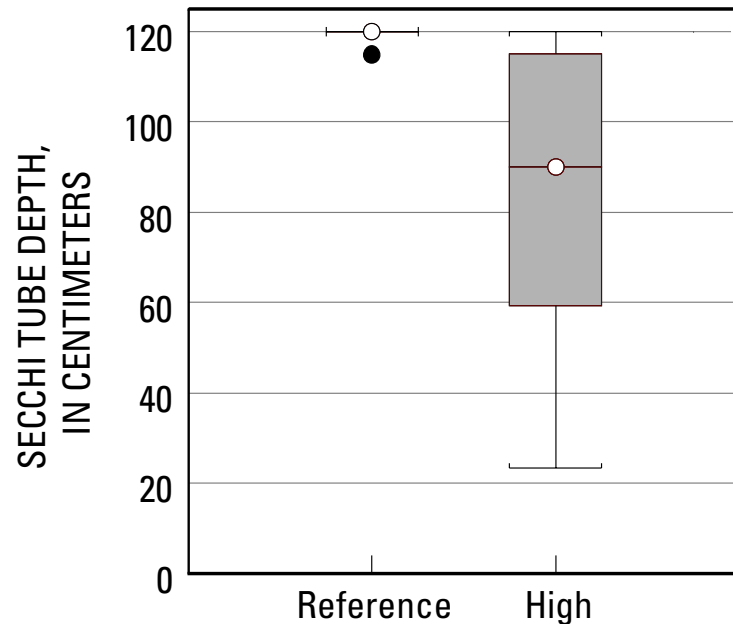
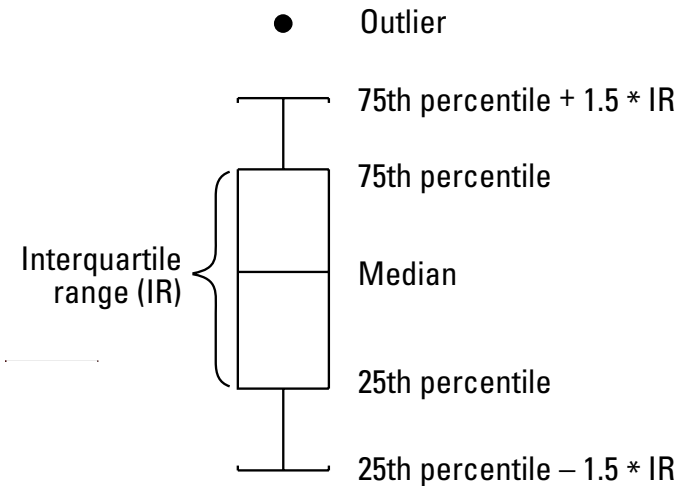


# Reference Conditions for Biotic Indices with the Percentile Approach

(75th percentile of Minimally Impacted Sites)



## EXPLANATION

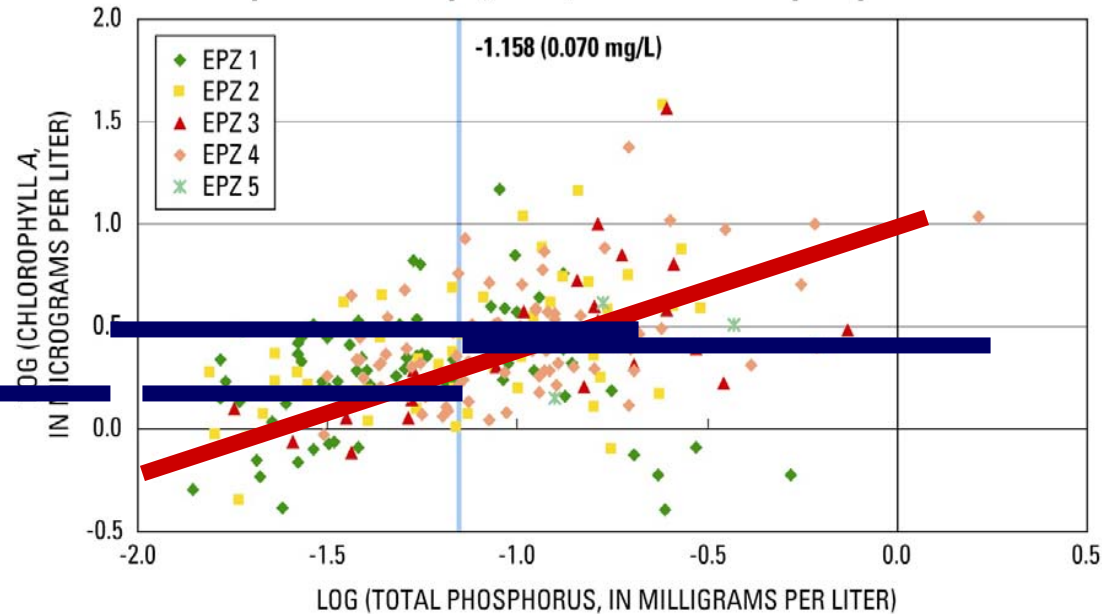


## Reference Conditions of Various Biotic Indices

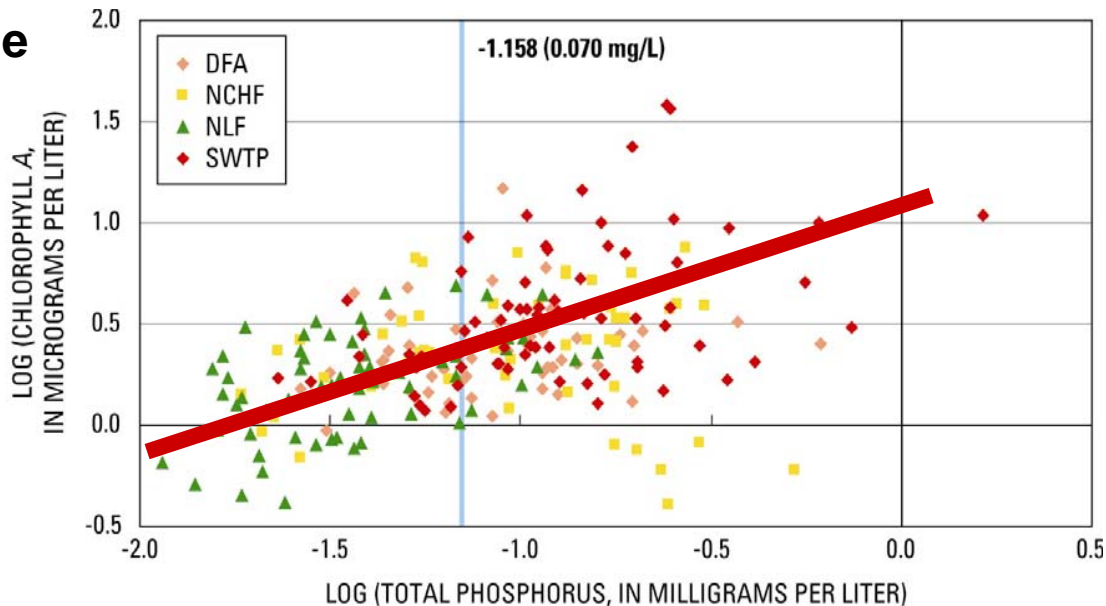
	Median Background	Worse 75th Percentile of Reference Sites
<b>Benthic Chlorophyll (mg/m<sup>2</sup>)</b>		
Benthic Chlorophyll a (mg/m <sup>2</sup> )	331	673
<b>Diatoms</b>		
Nutrient Index (DNI)	3.4	4.1
Siltation Index (DSI)	11.8	22.5
Biotic Index (DBI)	47.5	37.4
<b>Macroinvertebrates</b>		
Hilsenhoff Biotic Index (HBI)	3.1	4.4
Percent EPT individuals (EPTN%)	59.7	50.7
Percent EPT taxa (EPTTX%)	50.0	38.0
<b>Fish</b>		
Fish Index of Biotic Integrity (IBI)	50.0	40.0
Percent carnivorous fish (CARN%)	9.9	1.5
Percent intolerant fish (INTOL%)	14.7	2.0

# Response in Suspended Chlorophyll Concentrations in Different Regions

Suspended chlorophyll *a* by environmental phosphorus zone



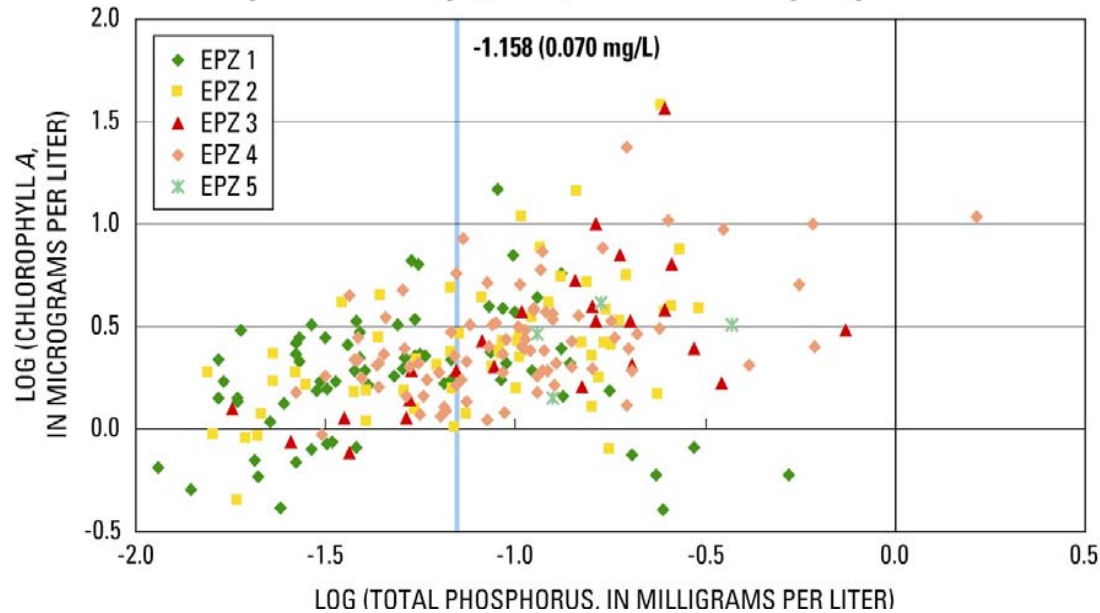
Differences in concentrations among regions but no real change in response





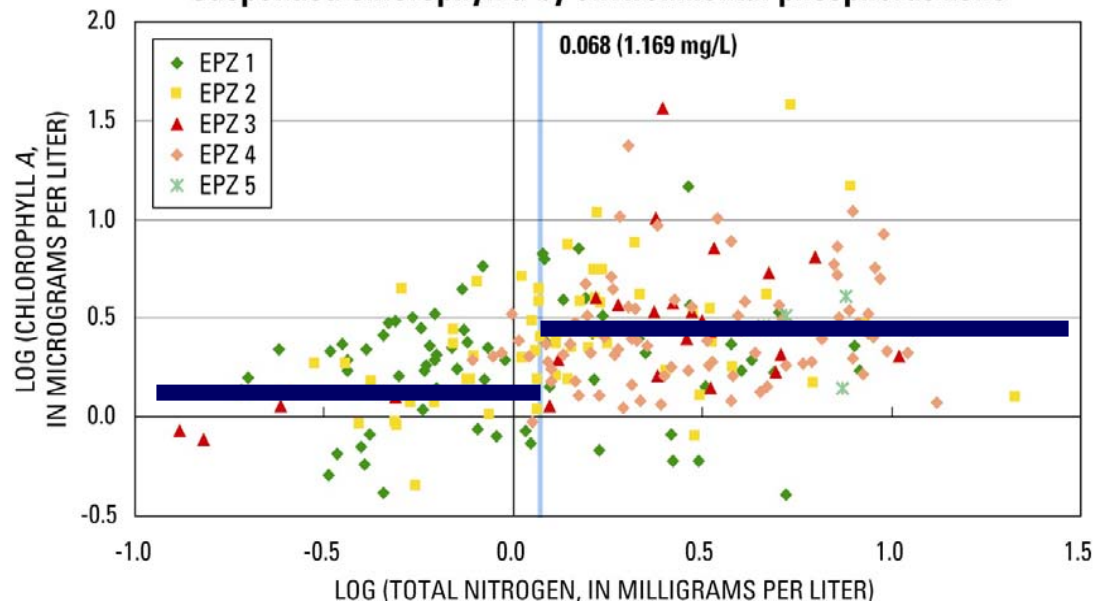
# Thresholds in the Response of Suspended Chlorophyll Concentrations

## Suspended chlorophyll *a* by environmental phosphorus zone



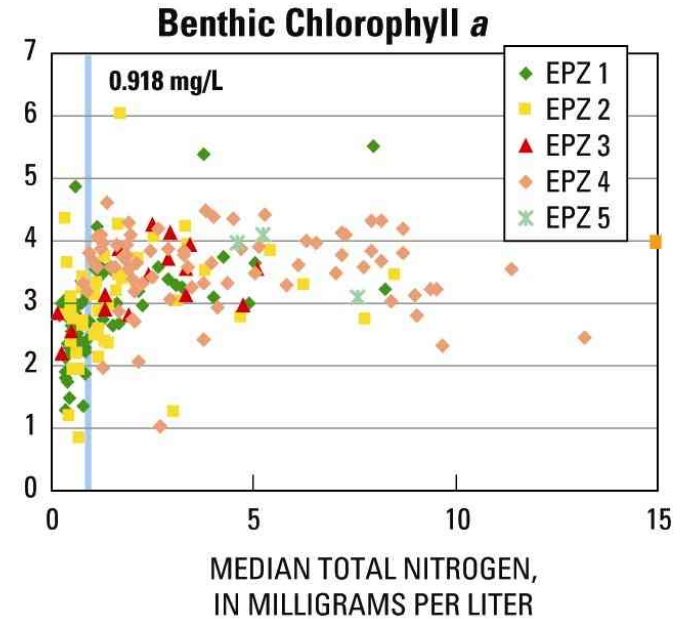
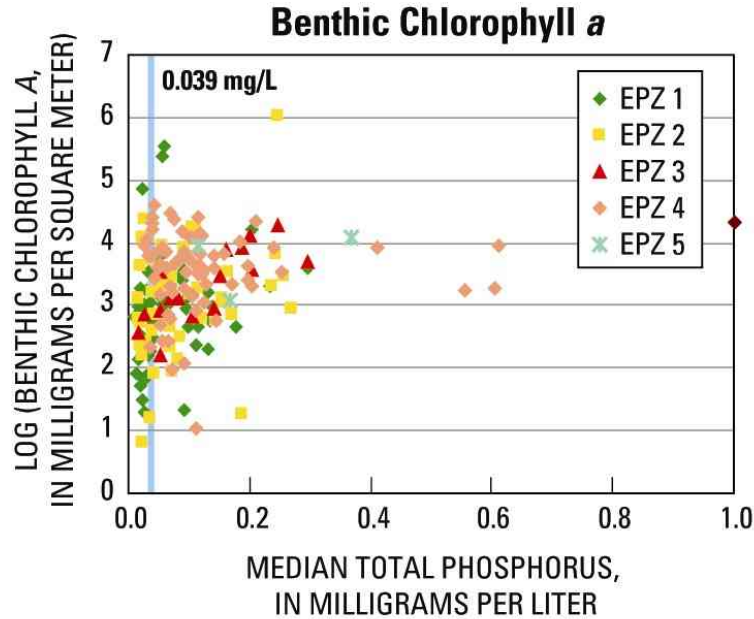
Suspended  
Chlorophyll

## Suspended chlorophyll *a* by environmental phosphorus zone

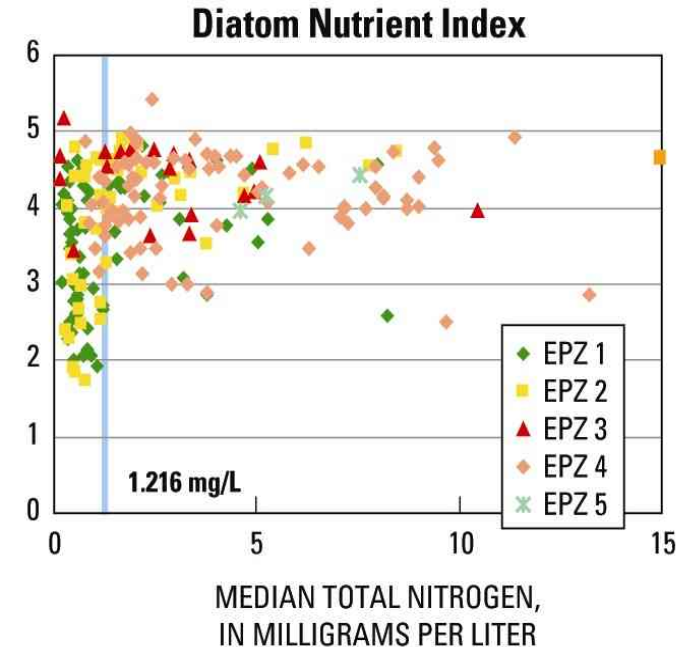
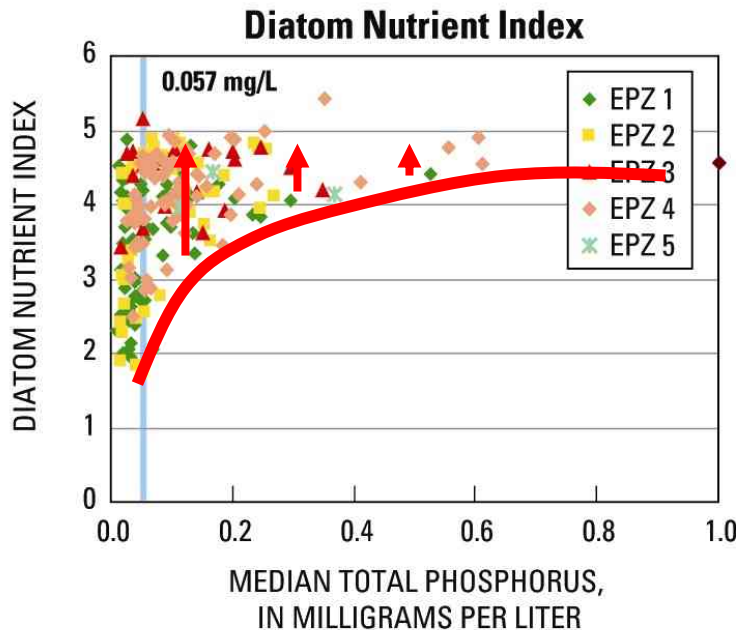


# Thresholds in the Response of Biotic Indices

Benthic Chlorophyll a

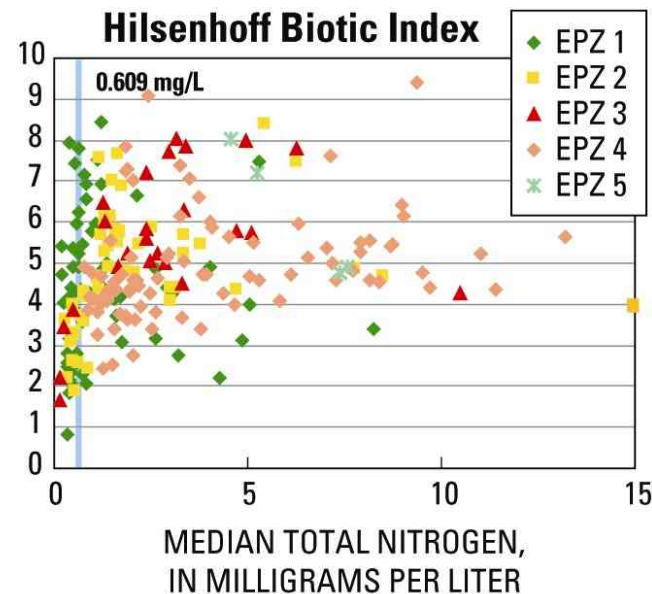
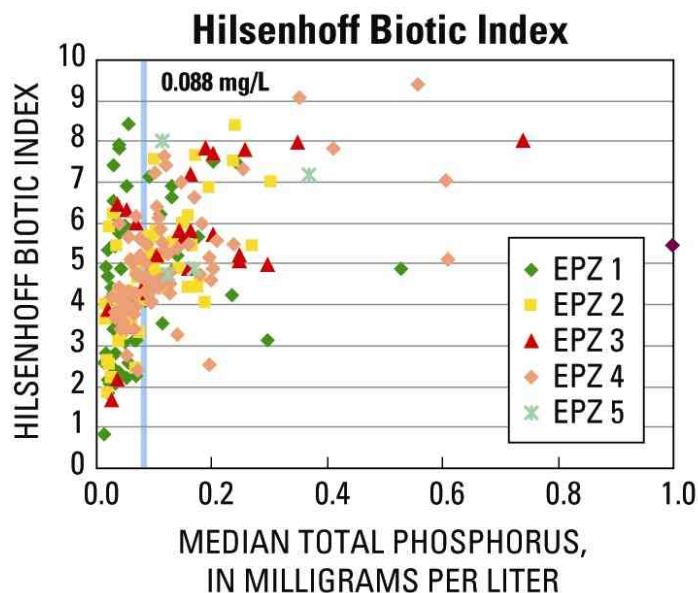


Diatoms

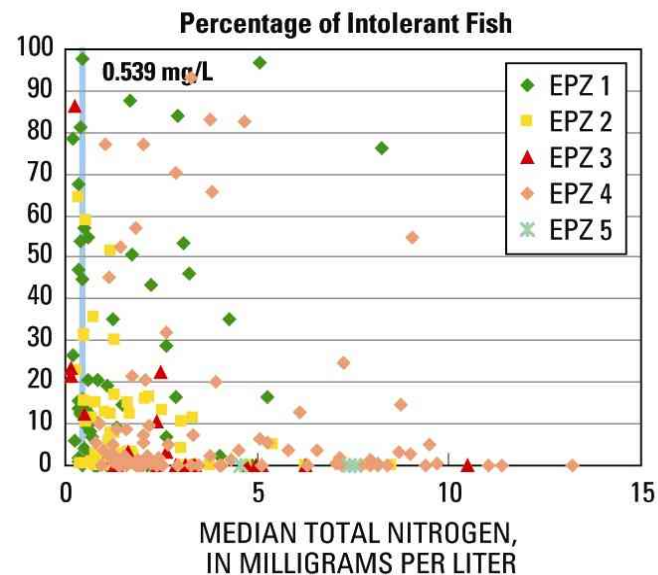
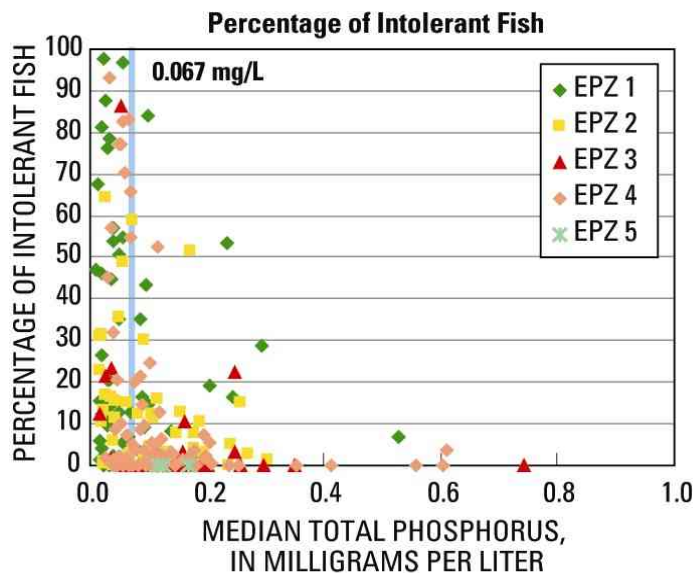


# Thresholds in the Response of Biotic Indices

Macro-  
invertebrates



Fish



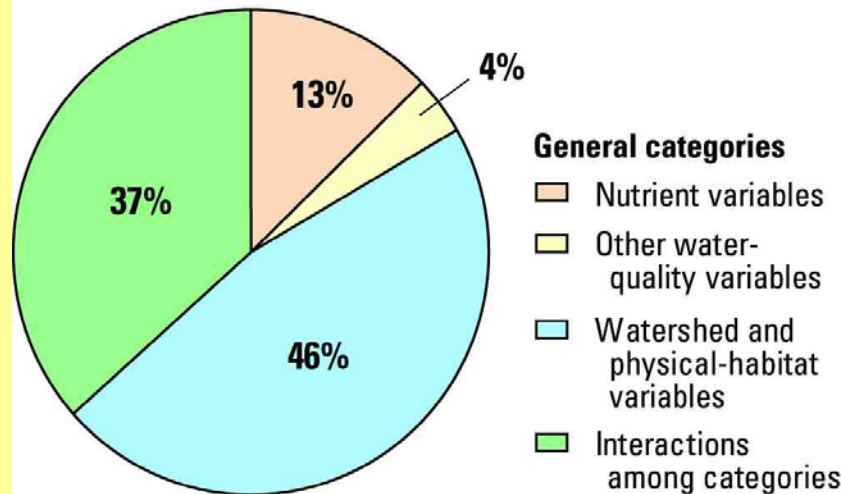


# Thresholds in the response in water quality and various biological indices

Biological Indices	Total Phosphorus	Total Nitrogen
<b>Water Quality</b>		
Secchi Depth (SD)	0.106	3.305
Suspended Chlorophyll (SCHL)	0.070	1.169
<b>Benthic Chlorophyll and Diatoms</b>		
Benthic Chlorophyll (BCHL)	0.039	0.918
Nutrient Index (DNI)	0.057	1.216
Siltation Index (DSI)	0.074	0.872
Biotic Index (DBI)	0.072	1.169
<b>Macroinvertebrates</b>		
Hilsenhoff Biotic Index (HBI)	0.088	0.609
Percent EPT individuals (EPTN%)	0.087	0.970
Percent EPT taxa (EPTTX%)	0.091	1.106
<b>Fish</b>		
Fish Index of Biotic Integrity (IBI)	0.055	0.539
Percent carnivorous fish (CARN%)	0.055	0.539
Percent intolerant fish (INTOL%)	0.067	0.539

# Percent of Variance explained by Nutrients and other Factors Based on Redundancy Analysis

**Percentages of Explained Variance in Benthic Chlorophyll *a* and Diatom Indices**



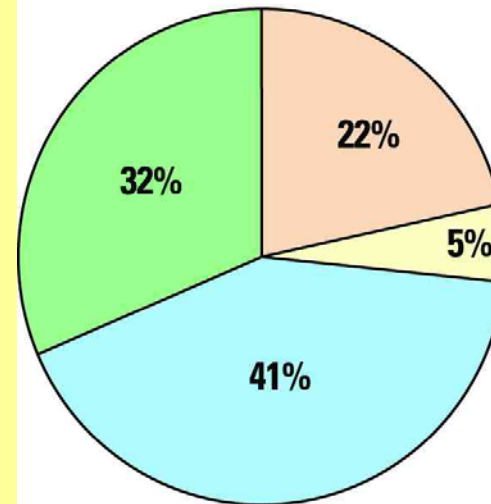
**Total Variance Explained = 54 %**

**Nutrient concentrations by themselves explain ~13 to 22% of the explained variation or 7 to 9% of the total variance**

basin

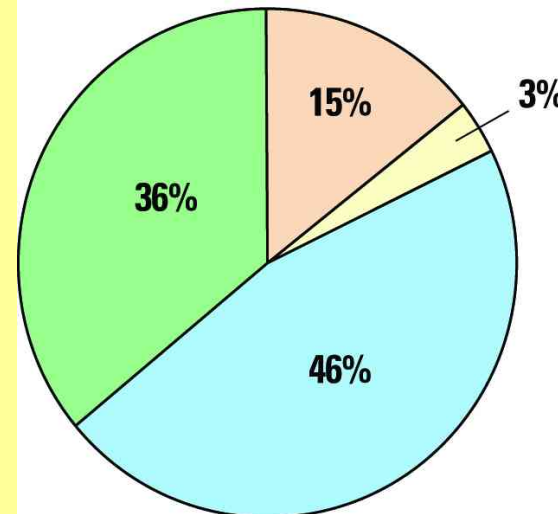
Physical habitat – 20 stream characteristics

**Percentage of Explained Variance in Macroinvertebrates Indices**



**Total Variance Explained = 43 %**

**Percentage of Explained Variance in Fish Indices**

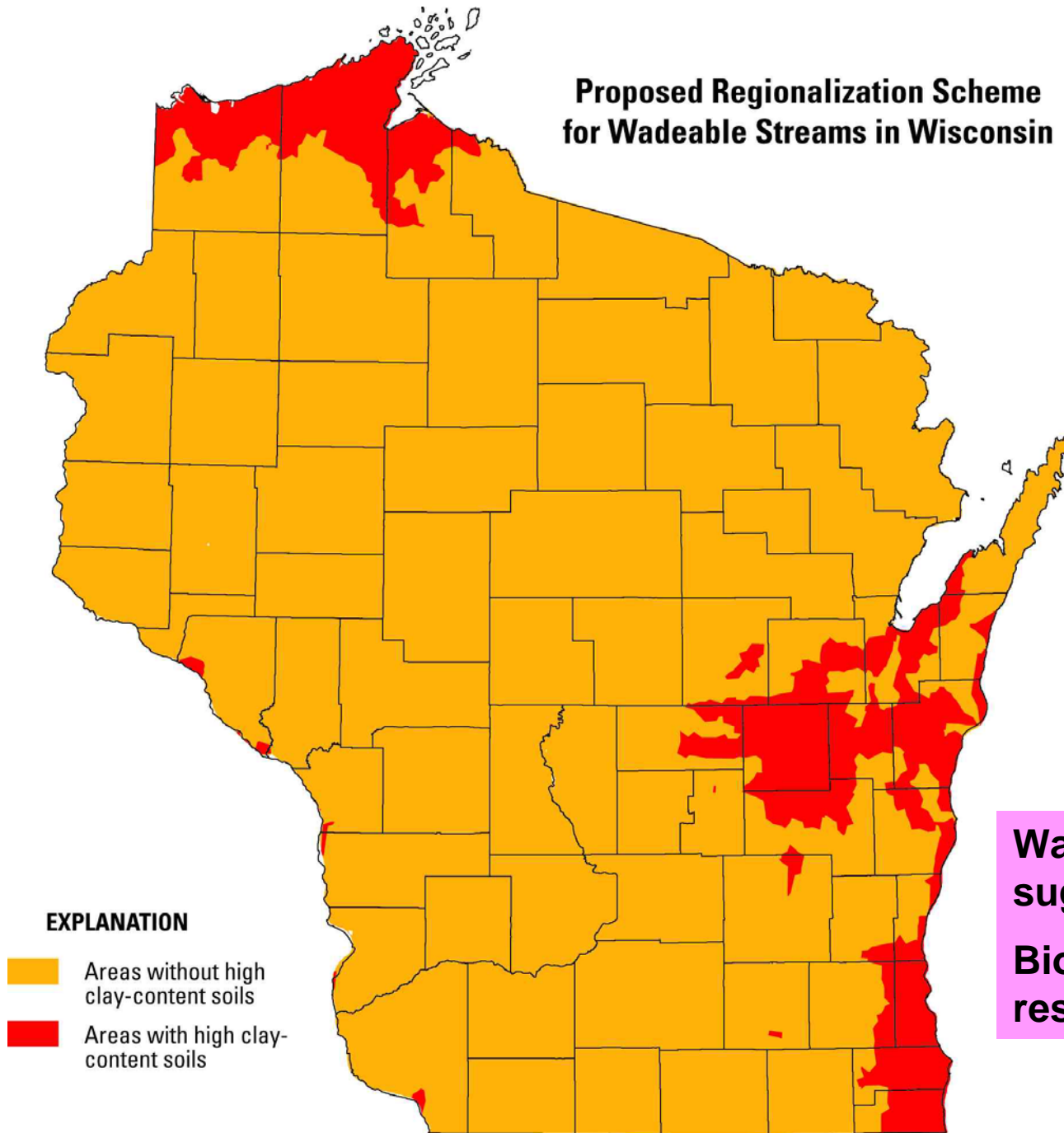


**Total Variance Explained = 44 %**

# Conclusions

1. Streams should be subdivided into two categories: those in clay areas and those in other areas

## Proposed Regionalization Scheme for Wadeable Streams in Wisconsin



**Water-quality data  
suggest two regions.**

**Biotic data suggests one  
response region.**

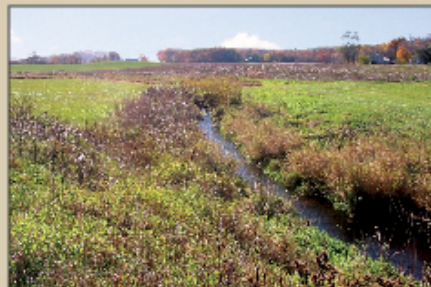
# Conclusions

1. Streams should be subdivided into two categories: those in clay areas and those in other areas
2. Background or reference conditions were determined: TP ~ 0.040–0.060 mg/L; TN ~ 0.700–1.000 mg/L
3. Biological response is similar across the state: thresholds defined and are close to reference concentrations
4. Nutrient concentrations by themselves only explain a small part of the variability in the biotic community (~10 % of the overall and 20% of the explained variance). Therefore, need to improve more than just nutrient concentrations to improve the biotic integrity of streams.



In cooperation with the Wisconsin Department of Natural Resources

## Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin



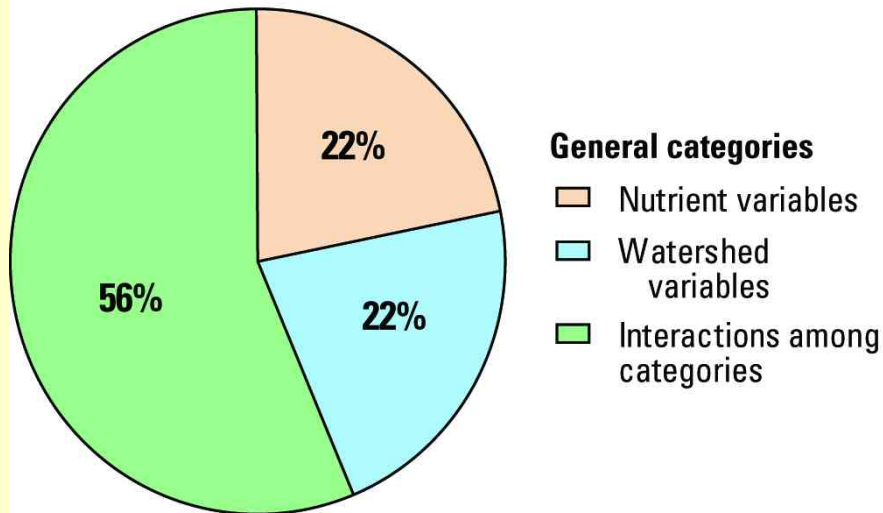
Professional Paper 1722

U.S. Department of the Interior  
U.S. Geological Survey

Dale Robertson  
[dzrobert@usgs.gov](mailto:dzrobert@usgs.gov)

# Percent of Variance explained by Nutrients and other Factors based on Multiple-Regression Approach

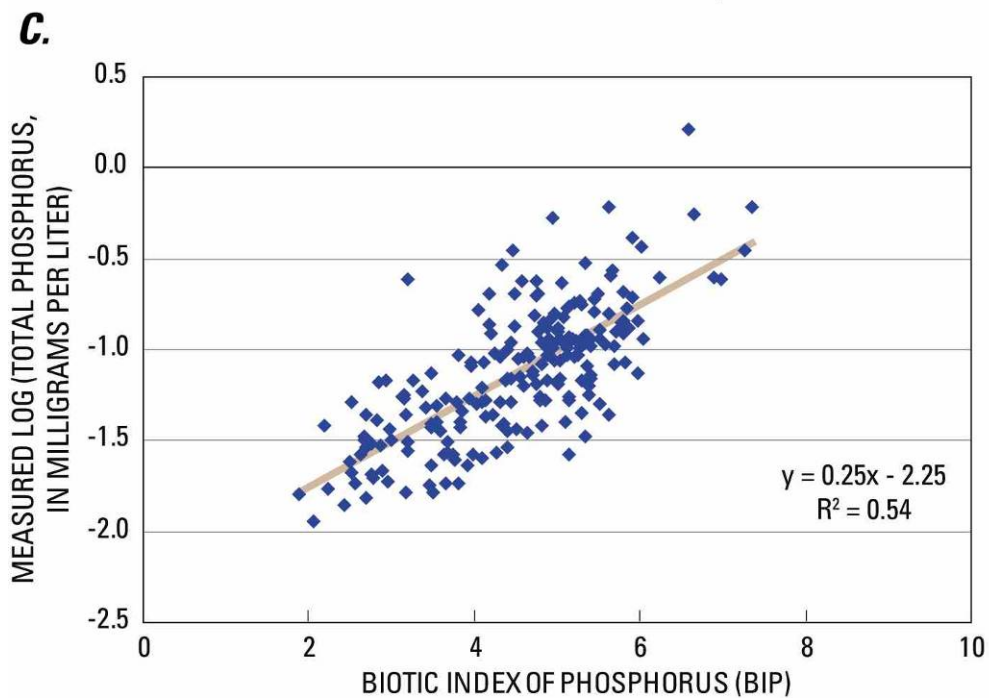
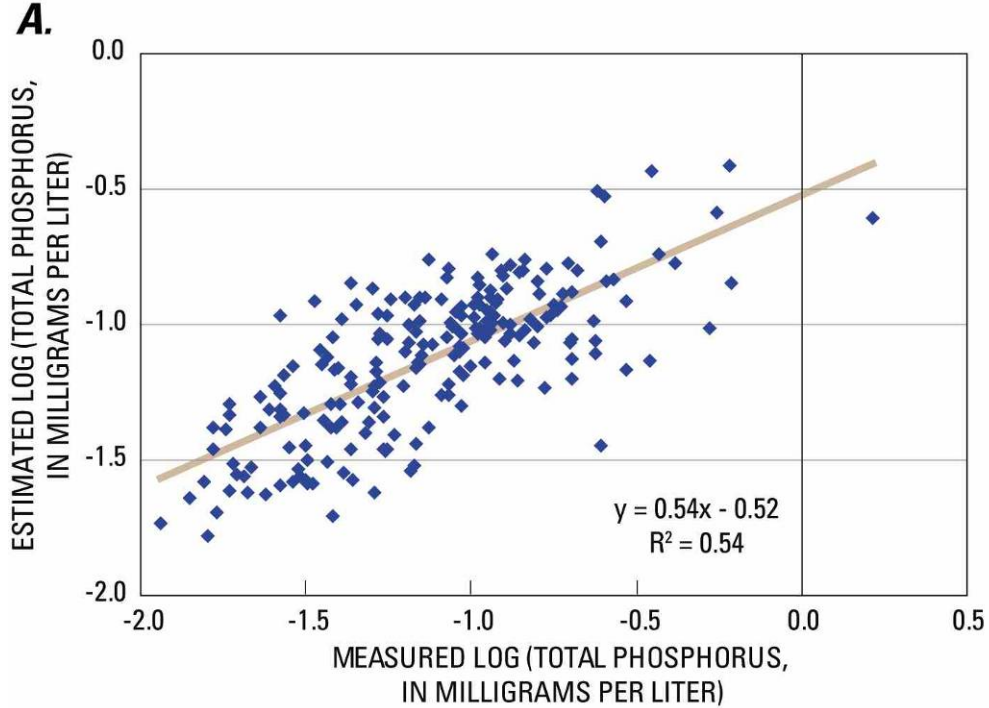
**A. Percentages of Explained Variance in Secchi Tube Depth**



**Total Variance Explained = 55 %**

Nutrient, TP, CP, TN, NO<sub>3</sub>-N, and NH<sub>4</sub>-N by themselves explain ~22% of the explained variation for all 26 of the total variance

Watershed land use, vegetation, and climate explain ~22% of the explained variation for all 26 of the total variance



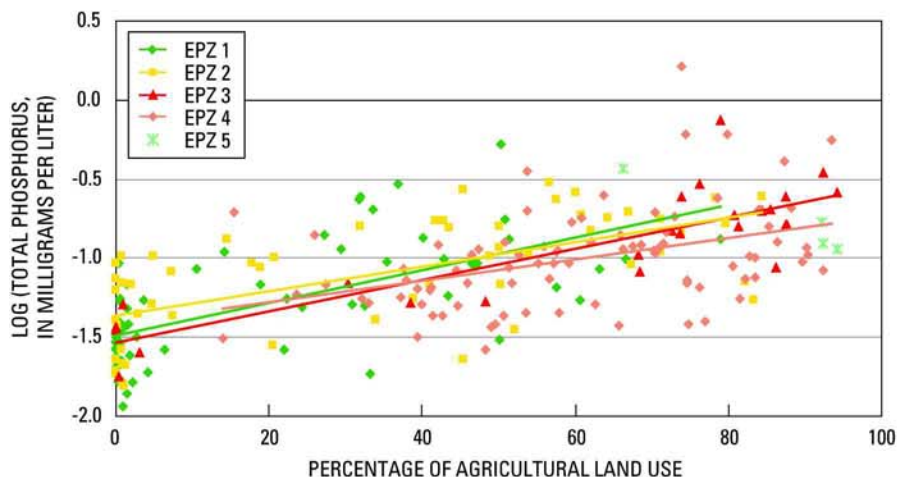
# How do Average Concentrations Change as a Function of Increased Land Use? (By Zone)

1.  $\text{Ln}(\text{TP}_p) = a + b (\text{Total Ag}) + c (\text{Total Urban}) + d (\text{PtS})$

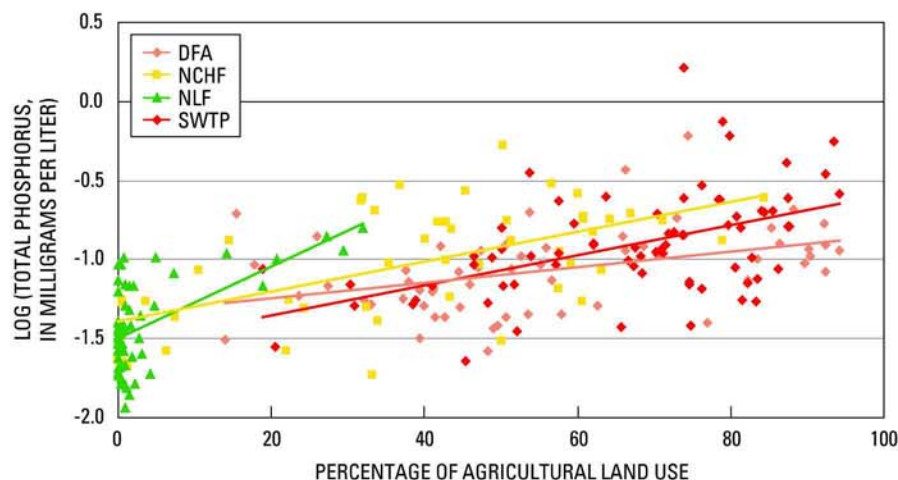
2.  $\text{Ln}(\text{TP}_p) = -3.215 + 1.728 (0 \rightarrow 100) + 2.926 (0) + 1.424 (0)$

# Reference Conditions and Response with the Regression Approach

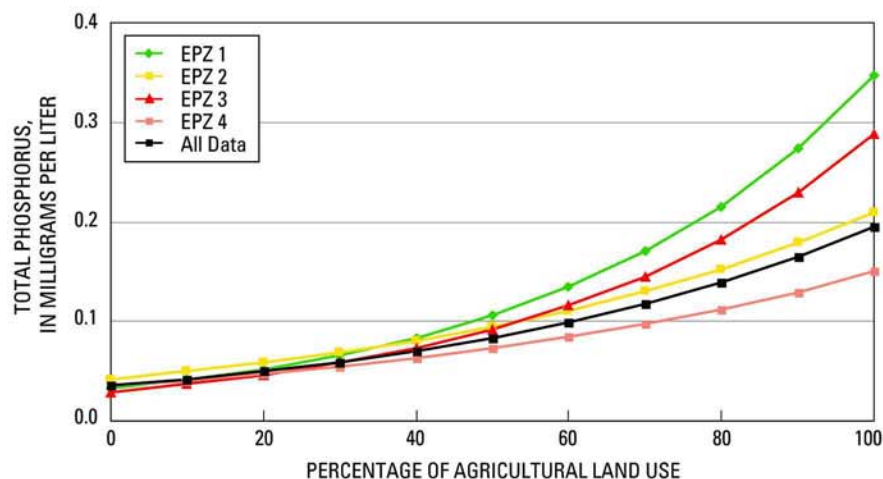
## A. Total Phosphorus By Environmental Phosphorus Zone



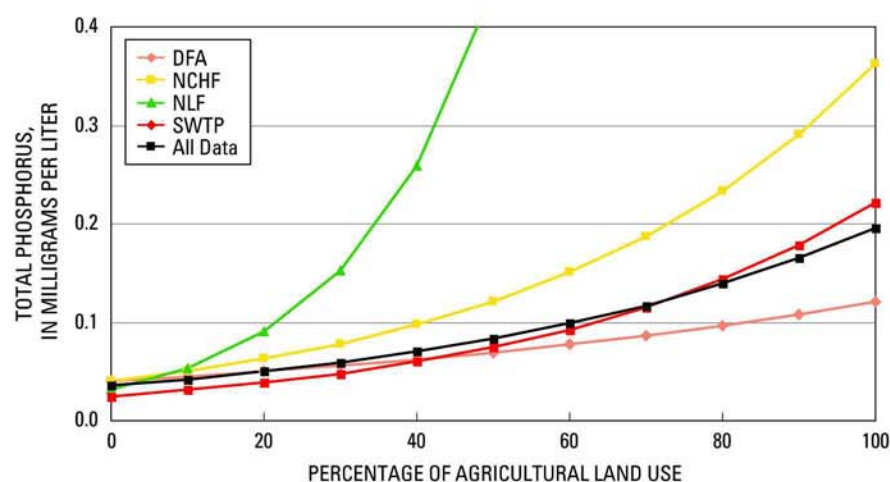
## B. Total Phosphorus By Ecoregion



## C. Response as a Function of the Percentage of Total Agriculture

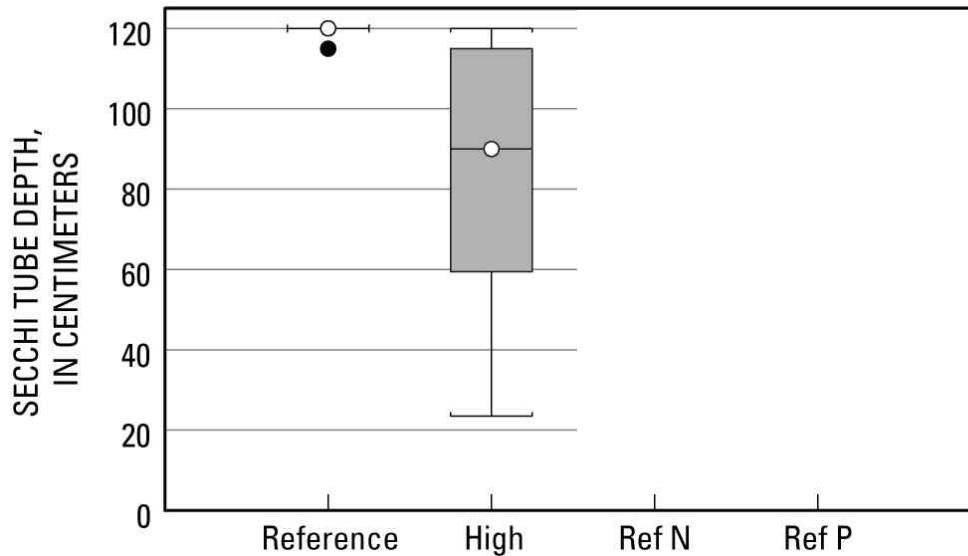
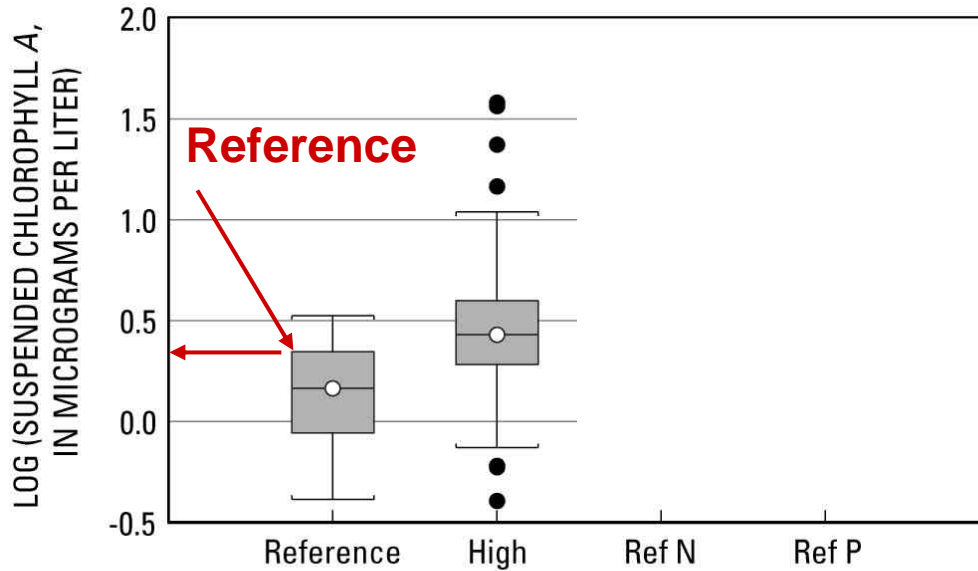


## D. Response as a Function of the Percentage of Total Agriculture





## Reference Conditions for Biotic Indices with the Percentile Approach



### EXPLANATION

