Environmental Drivers of Cyanobacterial Abundance and Cyanotoxin Production in the Upper Mississippi River

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It’s Important to know what conditions are driving cyanobacteria blooms and the production of cyanotoxins

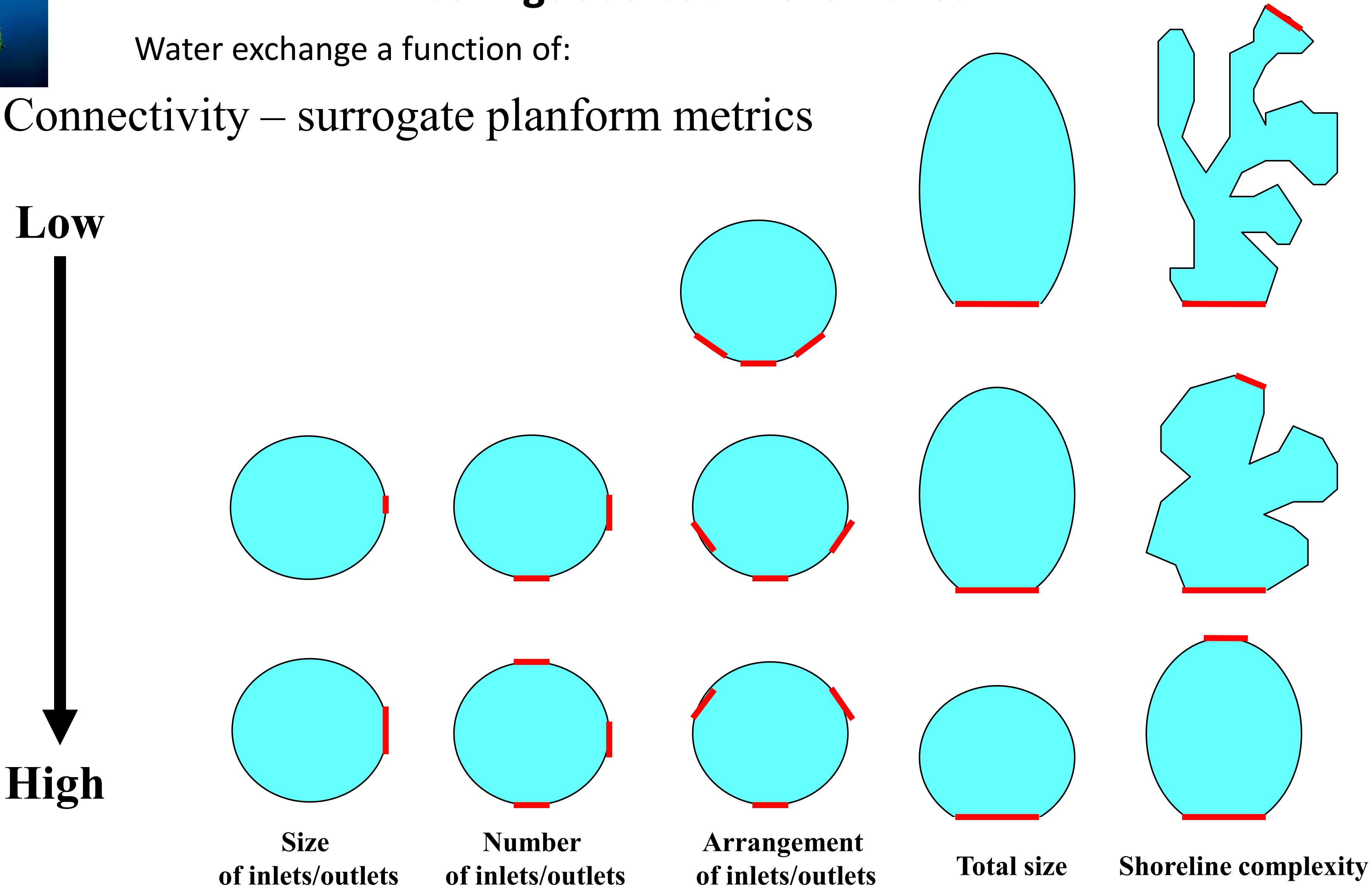

Main
Channel
Backwaters

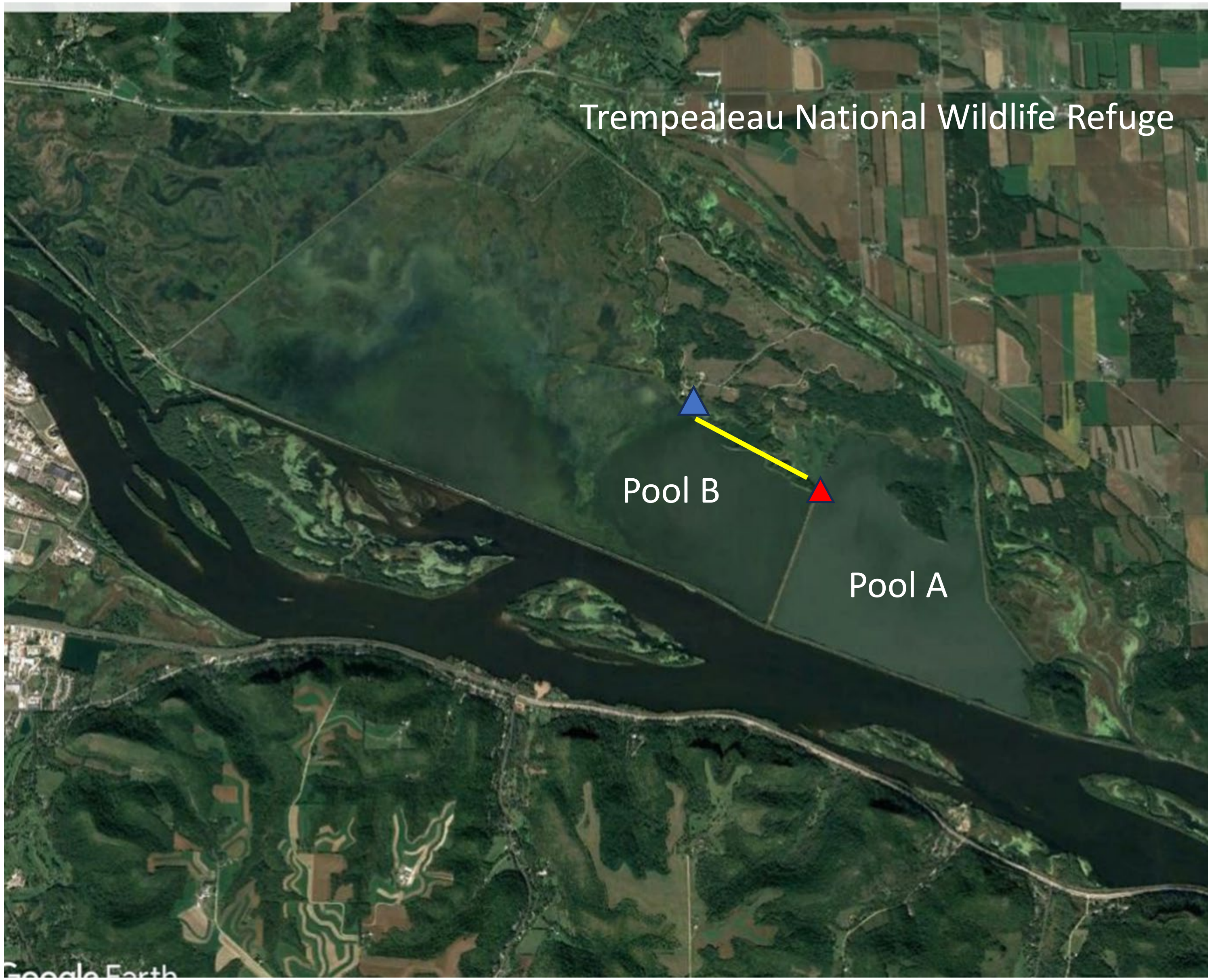
Backwater connectivity - types

contiguous backwater lakes

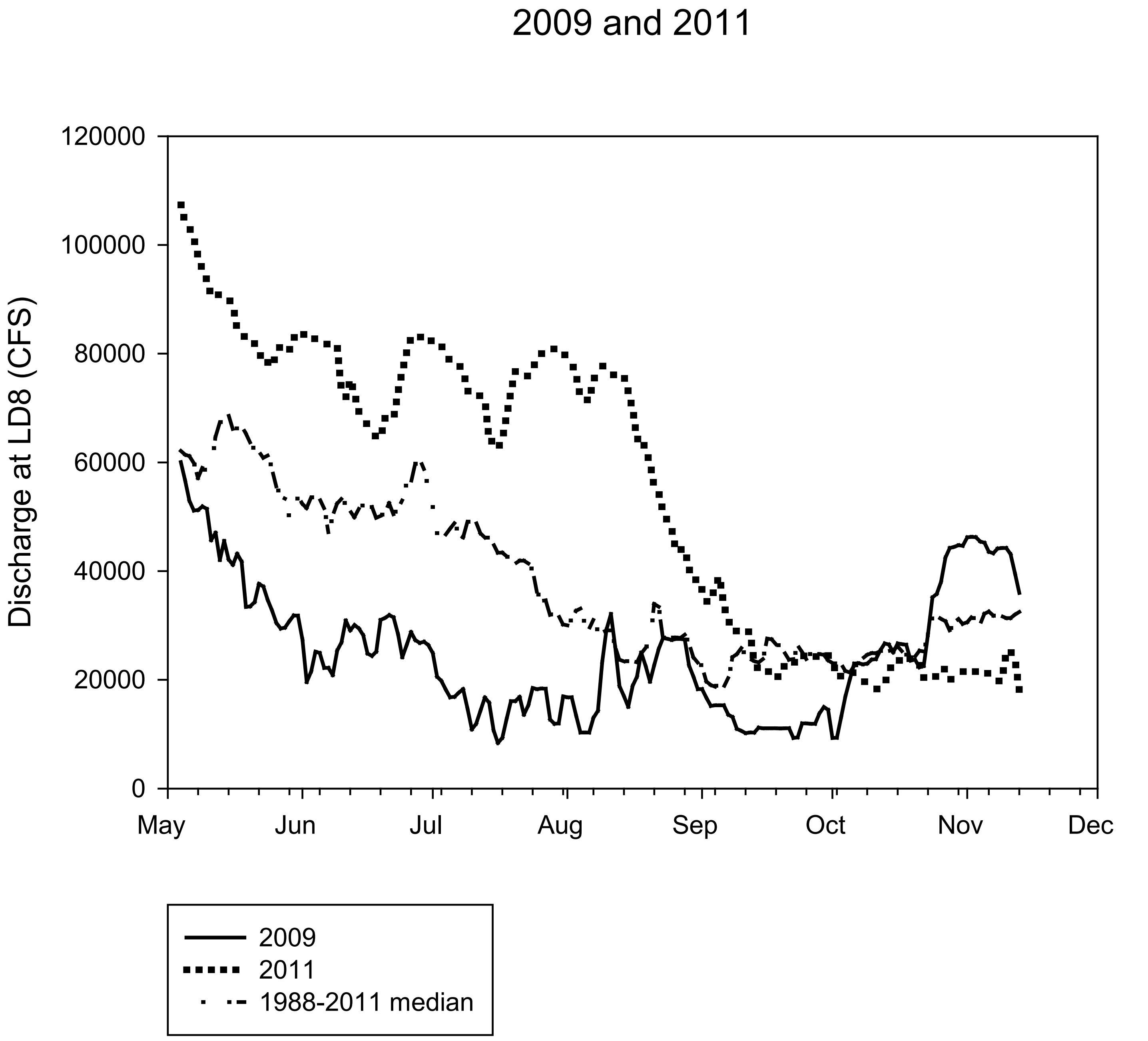
Water exchange a function of:

Connectivity – surrogate planform metrics




Trempealeau National Wildlife Refuge
Pool B
Pool A

Baseline Cyanobacteria Drivers Study



Between the high flow and low flow years- plus the wide range of connectivity to the MC of the seven sites (3 MC sites, 4 BW sites)

Nearly the full range of expected environmental conditions (water temp, nutrients, water velocity, water depth) within the UMR were sampled

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RESEARCH ARTICLE

WILEY

Environmental factors controlling phytoplankton dynamics in a large floodplain river with emphasis on cyanobacteria

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Abstract

Harmful algal blooms are occurring in large river ecosystems and at the mouth of large rivers with increasing frequency. In lentic systems, the chemical and physical conditions that promote harmful algal blooms are somewhat predictable but tracking prevalence and conditions that promote harmful algal blooms in lotic systems is much more difficult. We captured two of the most extreme discharge years within the last 20 years occurring in the Upper Mississippi River, allowing a natural experiment that evaluated how major shifts in discharge drive environmental variation and associated shifts in phytoplankton. Statistical models describing significant environmental covariates for phytoplankton assemblages and specific taxa were developed and used to identify management-relevant numeric breakpoints at which environmental variables may promote the growth of specific phytoplankton and/or cyanobacteria. Our analyses supported that potentially toxin-producing cyanobacteria dominate under high phosphorus concentration, low nitrogen concentration, low nitrogen-to-phosphorus ratio, low turbulence, low flushing, adequate light and warm temperatures. Cyanobacteria dominated in 2009 when low discharge and low flushing likely led to optimal growth environments for *Dolichospermum*, *Aphanizomenon* and *Microcystis*. Rarely will a single factor lead to the dominance, but multiple positive factors working in concert can lead to cyanobacteria proliferation in large rivers. Certain isolated backwaters with high phosphorus, low nitrogen, warm water temperatures and low potential for flushing could benefit from increased connection to channel inputs to reduce cyanobacterial dominance. Numerous examples of this type of habitat currently exist in the Upper Mississippi River and could benefit from reconnection to channel habitats.

KEYWORDS
algal blooms, connectivity, cyanobacteria, eutrophication, phosphorus, phytoplankton, Upper Mississippi River

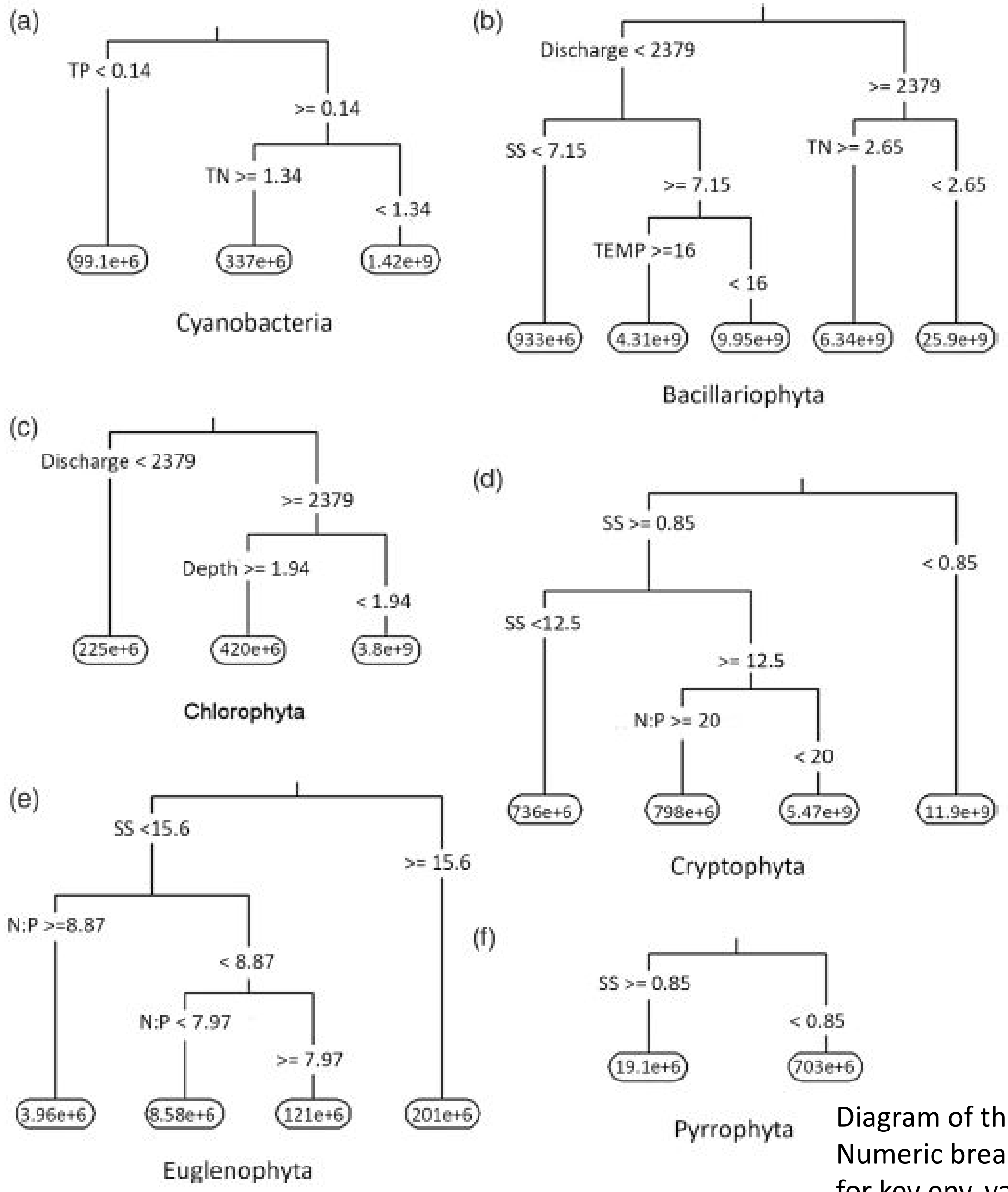
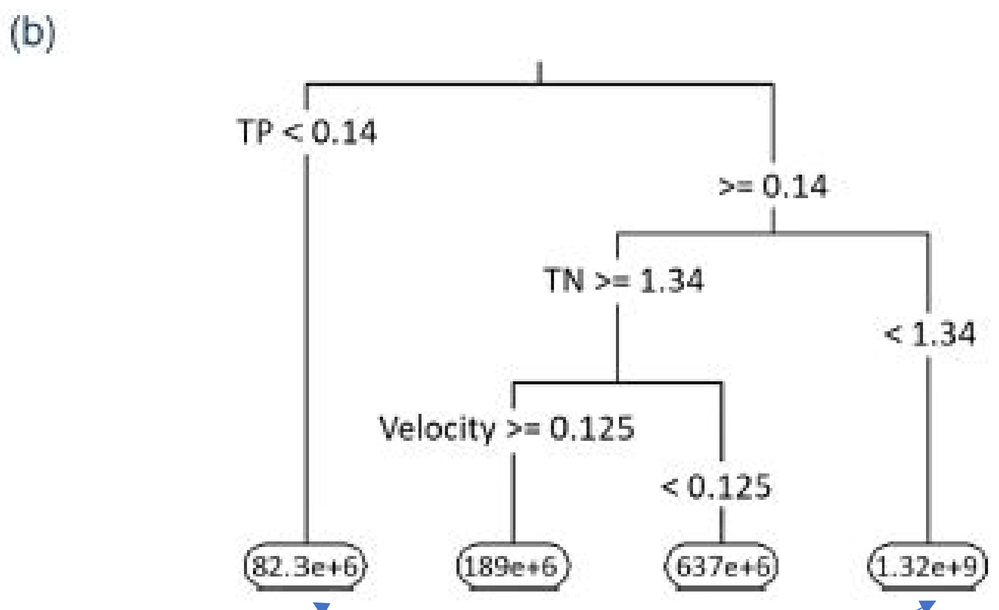


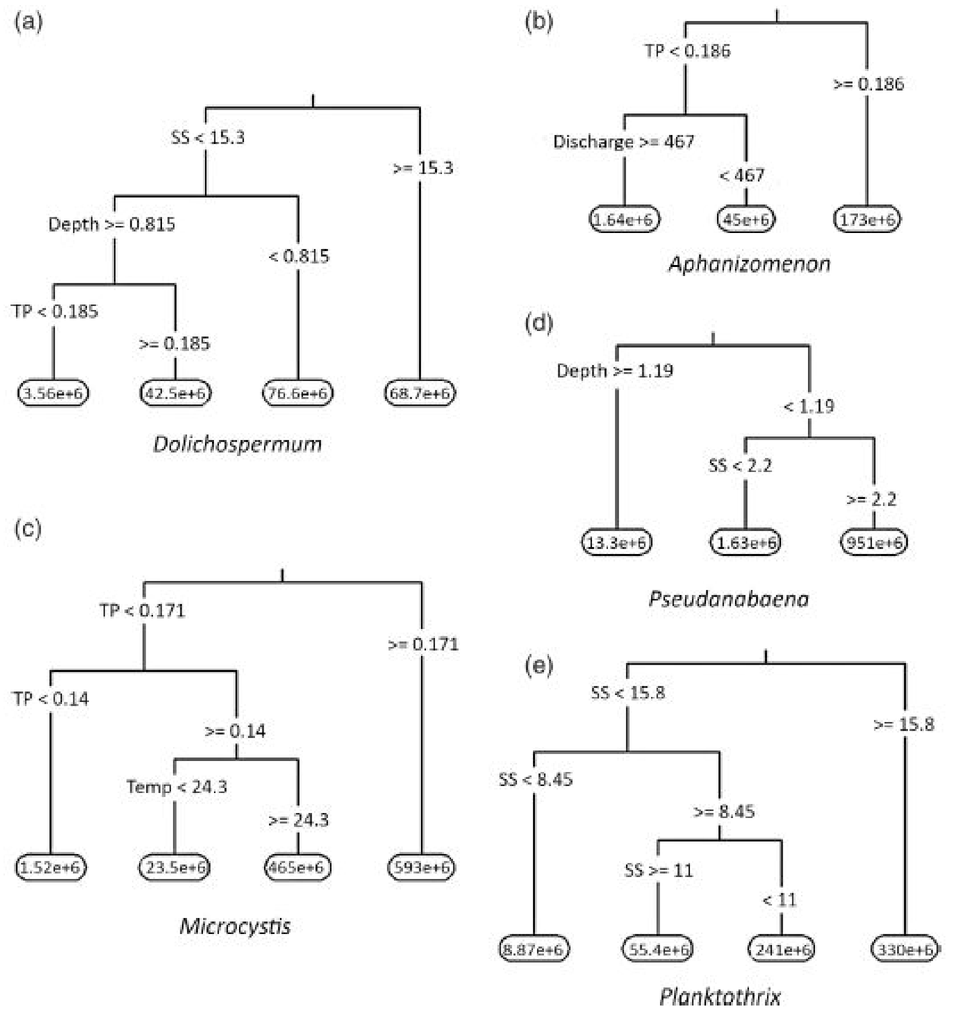
Diagram of thresholds
Numeric breakpoints
for key env. variables

FIGURE 5 Regression tree models predicting specific phytoplankton "phyla" biovolume (in $\mu m^3\ L^{-1}$) using uniform environmental covariates: (a) Cyanobacteria, (b) Bacillariophyta, (c) Chlorophyta, (d) Cryptophyta, (e) Euglenophyta, (f) Pyrrophyta. Predicted biovolume for each branch of the tree is in the lower ovals. The numeric breakpoint for each parameter defining a branch is presented on each split



16x difference in toxin-producing cyanobacteria biovolume

(b) Regression tree model. Predicted total toxin-producing cyanobacteria genera biovolume for each branch of the tree is in the lower ovals



Microcystin is produced by members of the genera *Aphanizomenon*, *Dolichospermum* (previously *Anabaena*), *Microcystis*, *Planktothrix,* and *Pseudanabaena*.

Anatoxin a is produced by members of the genera *Aphanizomenon*, *Dolichospermum* (previously *Anabaena*), and *Planktothrix*, and *Pseudanabaena*.

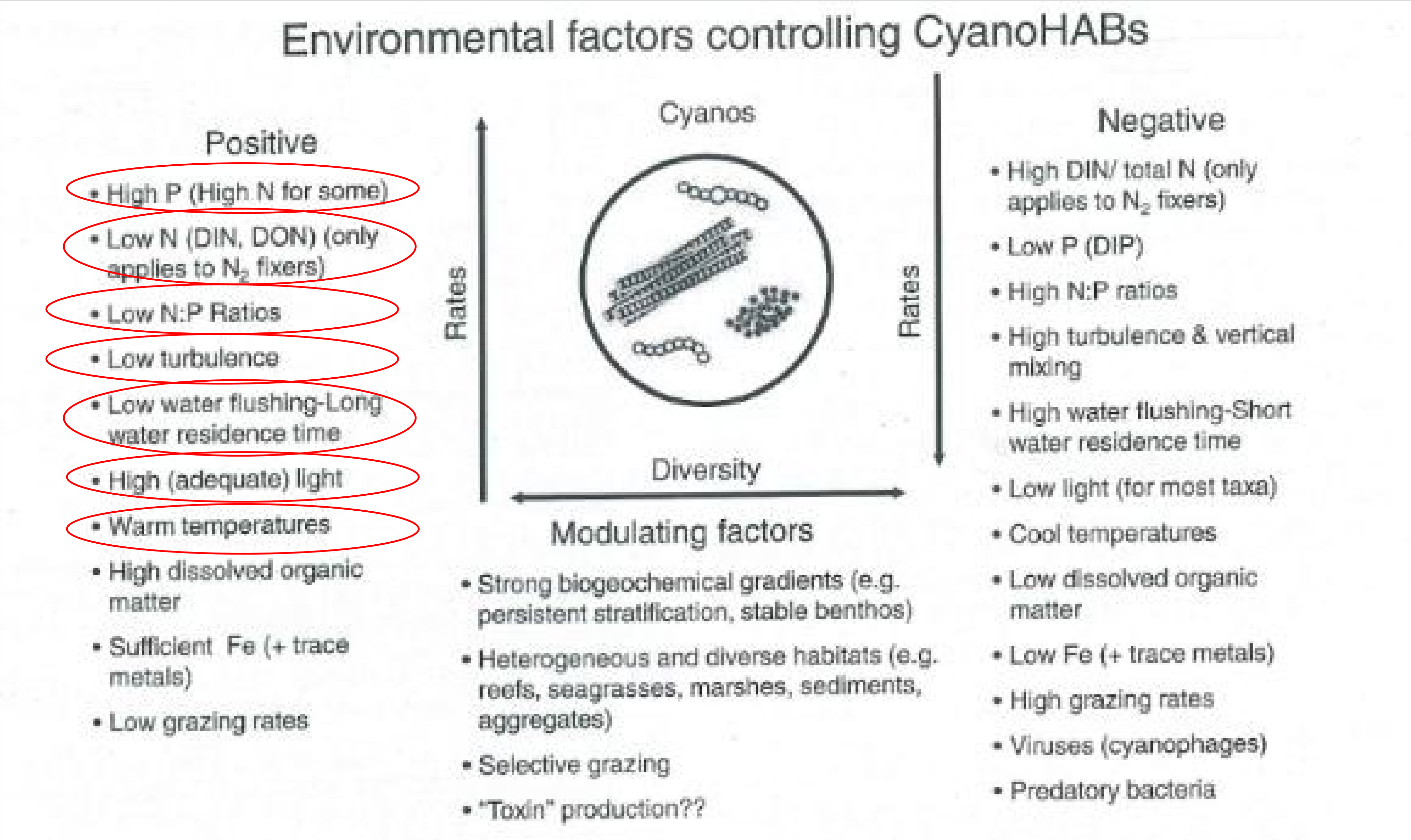
Plaas, H. E., & Paerl, H. W. (2020)

Table 2. Phytoplankton taxa related to explanatory environmental covariates based on general regression tree models.

	Higher Discharge	Warmer Water Temperature	Higher TP	Higher TN
General Regression Tree Trends	Higher total biovolume Higher Bacillariophyta biovolume Higher Chlorophyta biovolume Lower *Aphanizomenon* biovolume	Lower Bacillariophyta biovolume Higher *Microcystis* biovolume	Higher Cyanobacteria biovolume Higher potentially toxic Cyanobacteria biovolume Higher *Dolichospermum* biovolume Higher *Aphanizomenon* biovolume Higher *Microcystis* biovolume	Lower total biovolume Lower Bacillariophyta biovolume Lower Cyanobacteria biovolume Lower potentially toxic Cyanobacteria biovolume
	Higher N:P Ratio	**Higher SS***	**Greater Water Depth**	**Higher Water Velocity**
General Regression Tree Trends	Lower total biovolume Lower Cryptophyta biovolume Higher Euglenophyta biovolume	Higher total biovolume Higher Bacillariophyta biovolume Higher *Dolichospermum* biovolume Higher *Pseudanabaena* biovolume Higher *Planktothrix* biovolume	Lower total biovolume Lower Chlorophyta biovolume Lower *Dolichospermum* biovolume Lower *Psuedanabaena* biovolume	Lower potentially toxic Cyanobacteria biovolume

*Higher within study sites; maximum SS = 21.9 mg L^{-1}

- Giblin, S. M., & Gerrish, G. A. (2020). Environmental factors controlling phytoplankton dynamics in a large floodplain river with emphasis on cyanobacteria. *River Research and Applications*, *36*(7), 1137-1150.



Paerl and Otten 2013

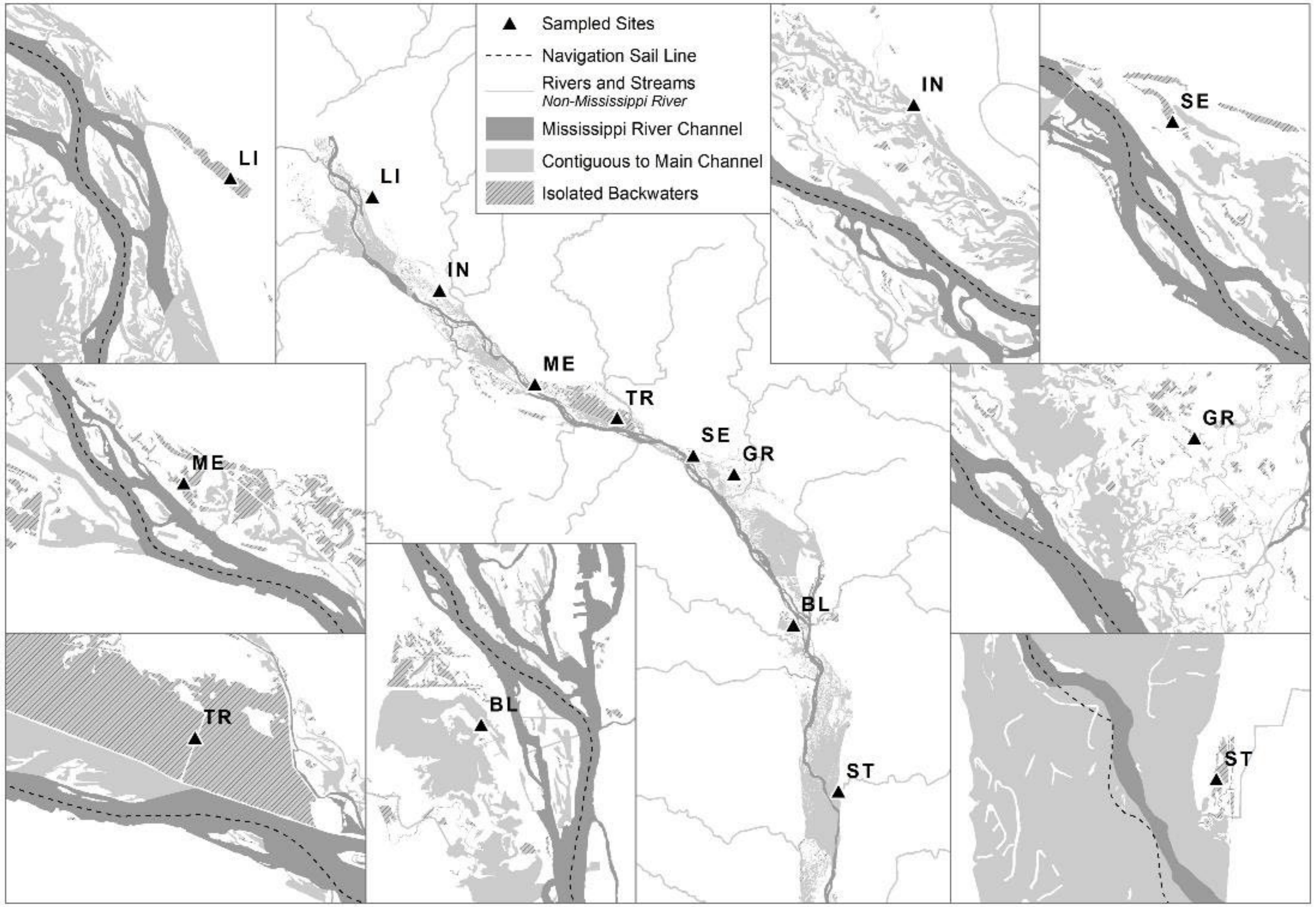
Environmental drivers of cyanobacterial abundance and cyanotoxin production in backwaters of the Upper Mississippi River

Shawn M. Giblin[1], James H. Larson[2] and Jeremy D. King[1]

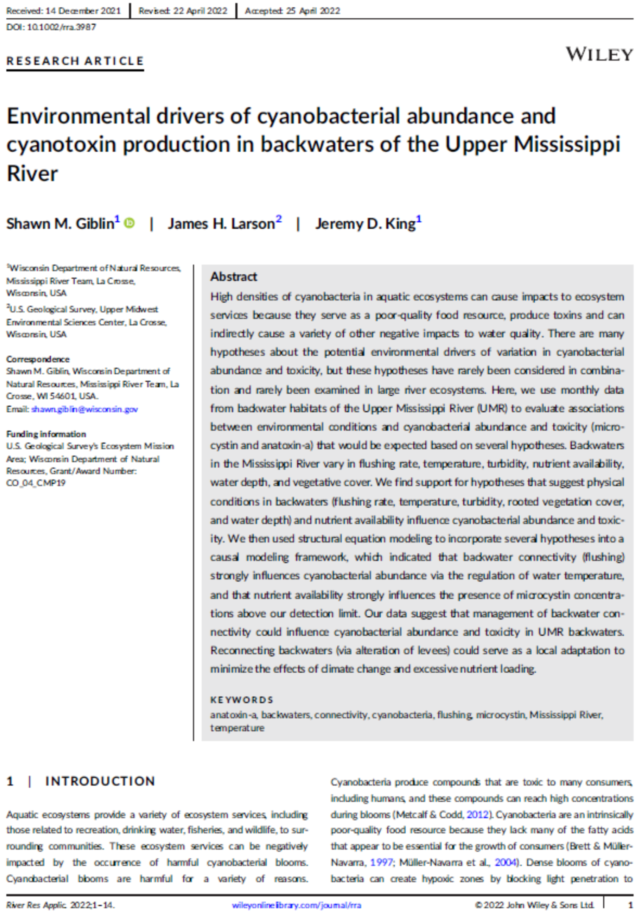
Pools 5-8 (63 river miles)

April-Oct 2019

Microcystin
Anatoxin a



8 Backwaters: Range of water residence time, N & P, temp, turbidity, water depth and rooted vegetation cover



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RESEARCH ARTICLE

WILEY

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Funding information
U.S. Geological Survey's Ecosystem Mission Area; Wisconsin Department of Natural Resources, Grant/Award Number: CO_04_CMP19

Abstract

High densities of cyanobacteria in aquatic ecosystems can cause impacts to ecosystem services because they serve as a poor-quality food resource, produce toxins and can indirectly cause a variety of other negative impacts to water quality. There are many hypotheses about the potential environmental drivers of variation in cyanobacterial abundance and toxicity, but these hypotheses have rarely been considered in combination and rarely been examined in large river ecosystems. Here, we use monthly data from backwater habitats of the Upper Mississippi River (UMR) to evaluate associations between environmental conditions and cyanobacterial abundance and toxicity (microcystin and anatoxin-a) that would be expected based on several hypotheses. Backwaters in the Mississippi River vary in flushing rate, temperature, turbidity, nutrient availability, water depth, and vegetative cover. We find support for hypotheses that suggest physical conditions in backwaters (flushing rate, temperature, turbidity, rooted vegetation cover, and water depth) and nutrient availability influence cyanobacterial abundance and toxicity. We then used structural equation modeling to incorporate several hypotheses into a causal modeling framework, which indicated that backwater connectivity (flushing) strongly influences cyanobacterial abundance via the regulation of water temperature, and that nutrient availability strongly influences the presence of microcystin concentrations above our detection limit. Our data suggest that management of backwater connectivity could influence cyanobacterial abundance and toxicity in UMR backwaters. Reconnecting backwaters (via alteration of levees) could serve as a local adaptation to minimize the effects of climate change and excessive nutrient loading.

KEYWORDS
anatoxin-a, backwaters, connectivity, cyanobacteria, flushing, microcystin, Mississippi River, temperature

1 | INTRODUCTION

Aquatic ecosystems provide a variety of ecosystem services, including those related to recreation, drinking water, fisheries, and wildlife, to surrounding communities. These ecosystem services can be negatively impacted by the occurrence of harmful cyanobacterial blooms. Cyanobacterial blooms are harmful for a variety of reasons. Cyanobacteria produce compounds that are toxic to many consumers, including humans, and these compounds can reach high concentrations during blooms (Metcalf & Codd, 2012). Cyanobacteria are an intrinsically poor-quality food resource because they lack many of the fatty acids that appear to be essential for the growth of consumers (Brett & Müller-Navarra, 1997; Müller-Navarra et al., 2004). Dense blooms of cyanobacteria can create hypoxic zones by blocking light penetration to

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Freshwater Biology

Freshwater Biology (2016) 61, 444–456 doi:10.1111/fwb.12718

Lake-type-specific seasonal patterns of nutrient limitation in German lakes, with target nitrogen and phosphorus concentrations for good ecological status

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a). Likely N limited: (DIN < 100 μg L^{-1} AND DIN : TP < 1.6).

b). Likely P limited: (DIP < 10 μg L^{-1} AND DIN : TP ≥ 1.6).

c). Neither N nor P limited: Everything else

i. (DIN > 100 μg L^{-1} AND DIP > 10 μg L^{-1}) OR

ii. (DIN < 100 μg L^{-1} AND DIN : TP ≥ 1.6 AND DIP > 10 μg L^{-1}) OR

iii. (DIP < 10 μg L^{-1} AND DIN > 100 μg L^{-1} AND DIN : TP < 1.6)

SUMMARY

1. Eutrophication is a global environmental problem that leaves many lakes with impaired ecological status. Human activity has increased the total concentrations of both nitrogen and phosphorus in aquatic systems, but their relative influence on phytoplankton biomass is uncertain. Their action as alternative limiting resources complicates assessment of their relative influence and disagreement may be in part due to seasonal shifts and lake-type-specific differences in the prevalence of limitation by nitrogen versus phosphorus. Debate continues as to whether measures to reduce nitrogen would be beneficial in addition to controls placed on phosphorus.

2. We used a piecewise model to test whether total nitrogen (TN) concentrations, in addition to total phosphorus (TP), influence phytoplankton biomass in 369 lowland German lakes. The piecewise model predicts biomass from TN for low N : P ratio lakes, and from TP for high N : P ratio lakes. We tested three N : P mass ratios to divide lakes: dissolved inorganic nitrogen to TP (DIN : TP), DIN to dissolved reactive phosphorus (DIN : DIP) and TN : TP. TN was a better predictor of biomass than TP when either the DIN : TP ratio was below 1.6, DIN : DIP was below 8.4, or TN : TP below 29; predictions were most accurate when using the DIN : TP ratio.

3. To investigate seasonal and lake-type-specific patterns of N and P limitation, we used the DIN : TP ratio, together with absolute concentrations of DIN and DIP, to predict the limiting

month of the vegetation period. N limitation was much more common

lakes. While a high proportion of both stratified and polymictic lakes

g (60–70%), for polymictic lakes, we found a strong shift from P

summer: more than 50% of polymictic lakes were N limited between

y 15–30% were P limited.

c nutrient targets we estimated the average TN and TP concentrations at

s achieved good ecological status according to EU water framework

kes achieved good ecological status at concentrations of 400–500 μg L^{-1}

e for polymictic lakes values of 500–1000 μg L^{-1} TN, or 35–75 μg L^{-1}

has an important influence on phytoplankton biovolume, and thus

olymictic lakes in Germany. While there is some uncertainty in the

chieve good ecological status, this uncertainty is small compared with

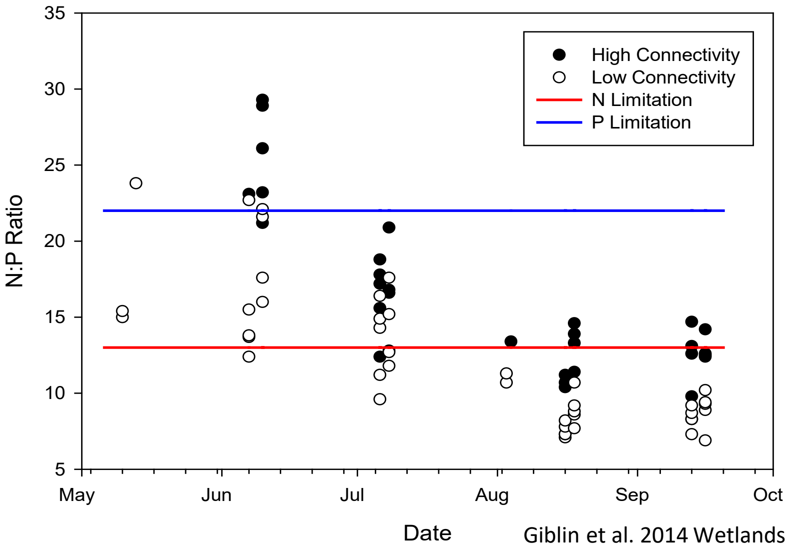
urrently observed, and lakes with moderate or worse status have

d TP that are far above these current target estimates.

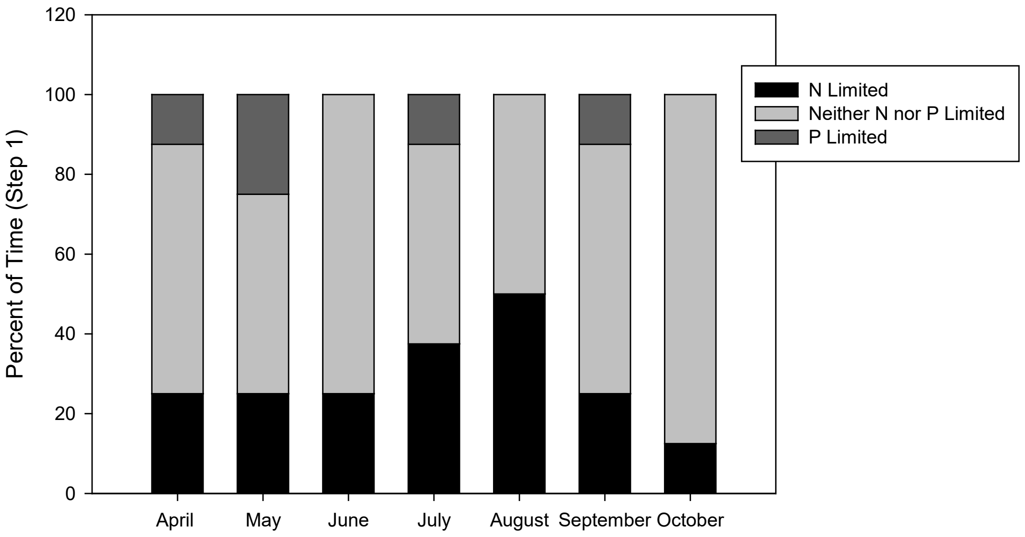
nutrient targets, phosphorus, phytoplankton

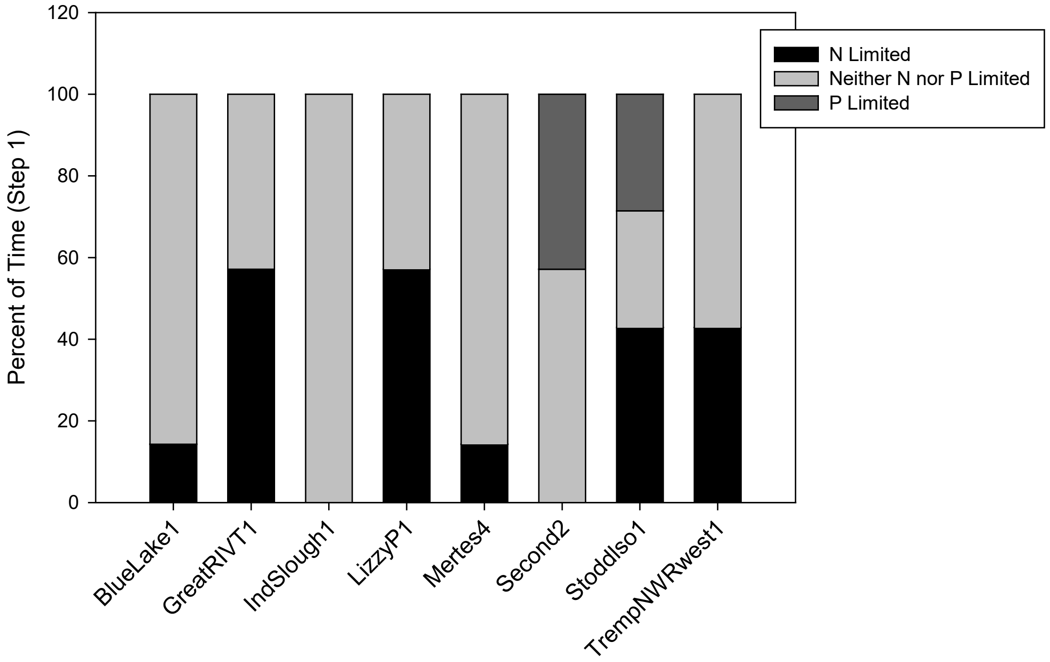
Freshwater Conservation, Brandenburg University of Technology Cottbus – Senften-

E-mail: andrew.dolman@b-tu.de

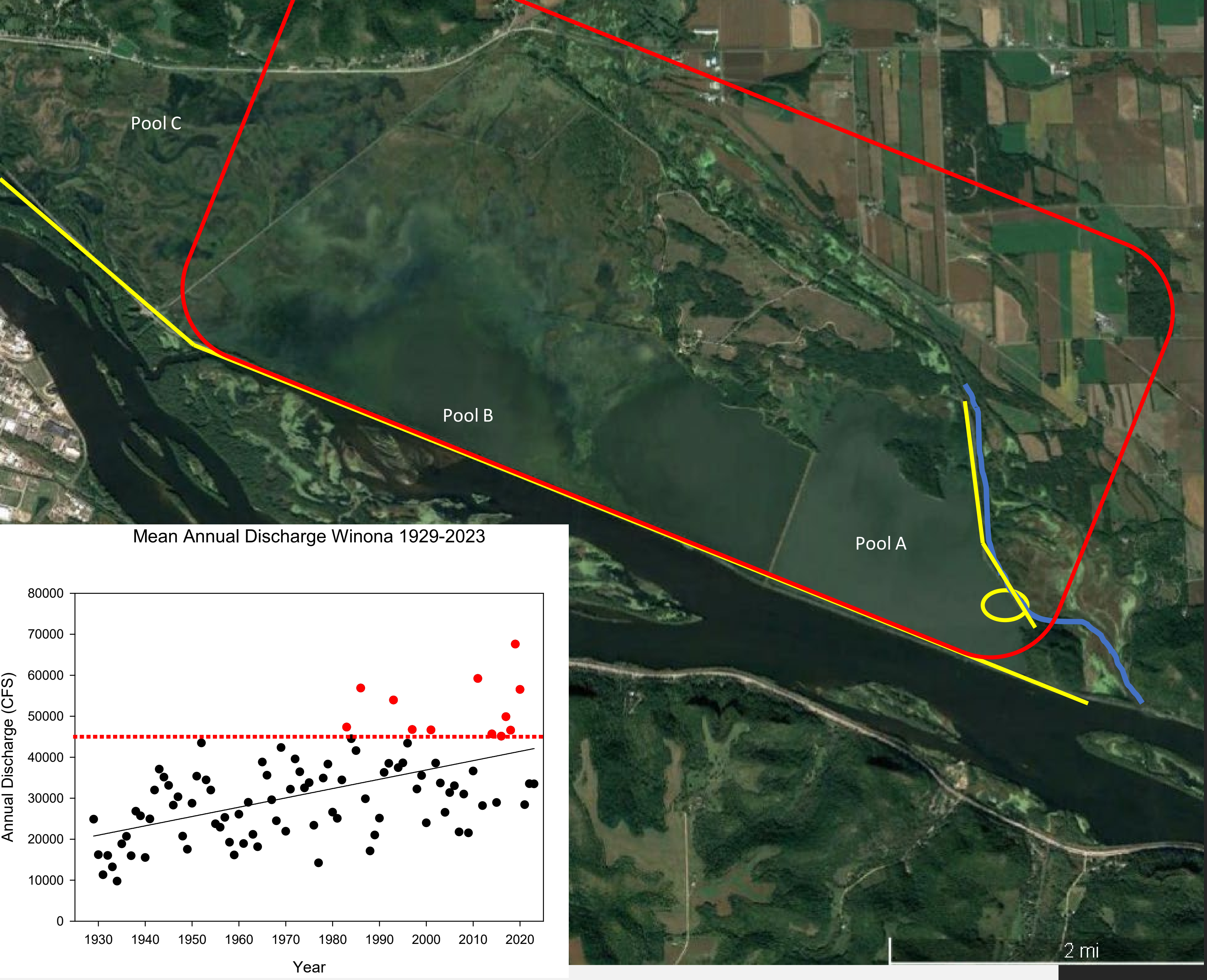


Giblin et al. 2014 Wetlands





We can't address Miss R. eutrophication issues without reducing both N & P loading.

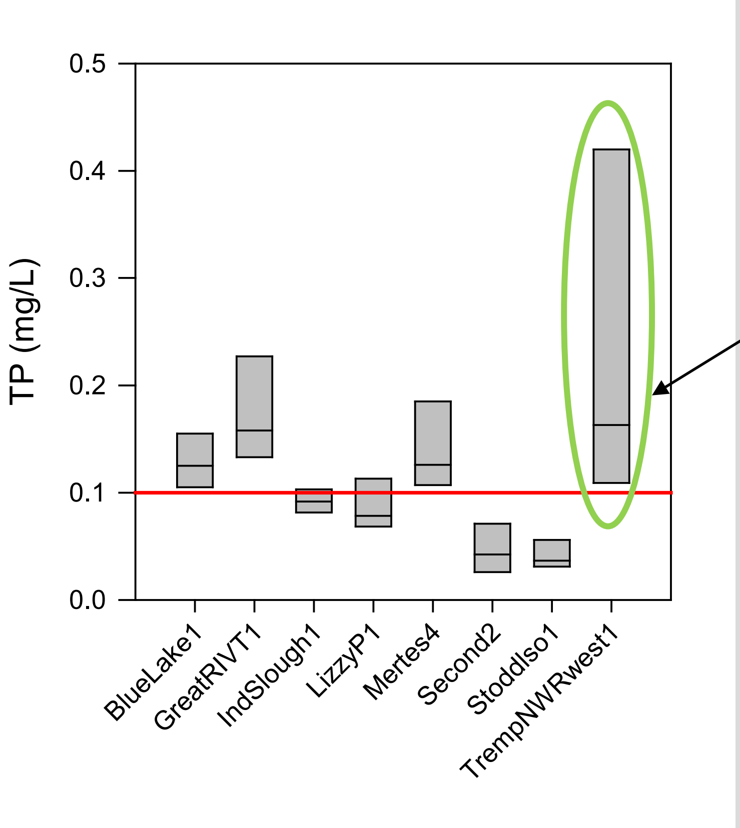


Trempealeau National Wildlife Refuge: Current Status and Opportunities for Restoration

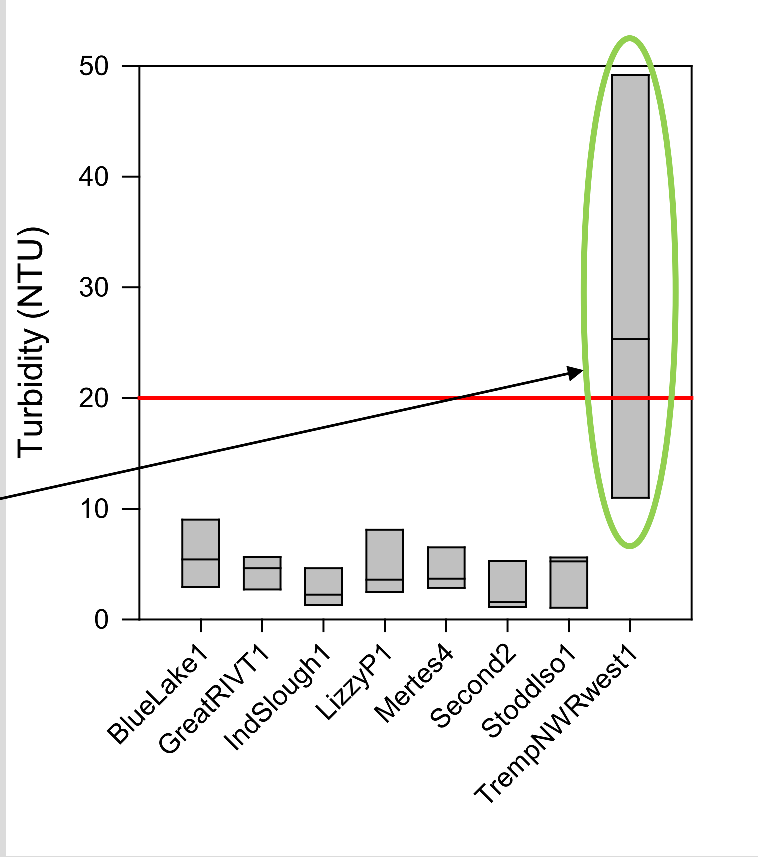
- Locked in an undesirable, turbid ecological state, making the establishment of desirable rooted vegetation difficult to impossible.
- High water conditions on the Mississippi and Trempealeau Rivers prevent growing season drawdowns that are effective to stimulate submergent and emergent plant growth.
- Habitat for migratory birds and marsh wildlife is diminished as a result of the turbid, unvegetated conditions.

Trempealeau NWR
Summer Conditions

2019 Cyanotoxin Study Data
April-October



TP continues to build up



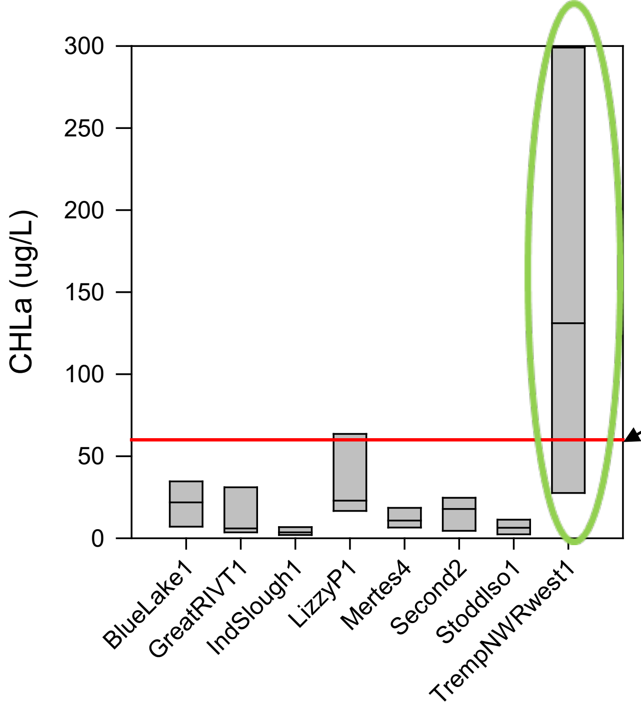
Turbidity goal < 20 NTU to promote rooted submersed vegetation

Also:

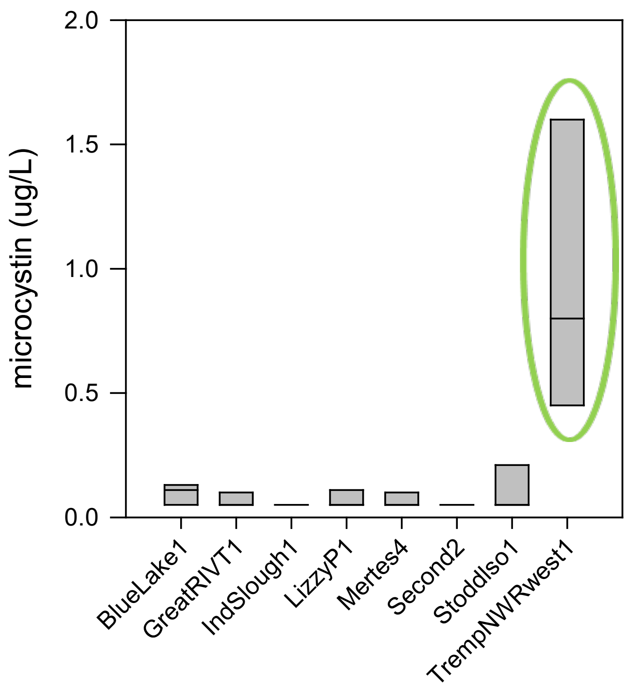
- shallow depth

And due to isolation (leveed):

- warmer water
- less flushing



Severe nuisance bloom >60 ug/L



Good opportunity for habitat restoration

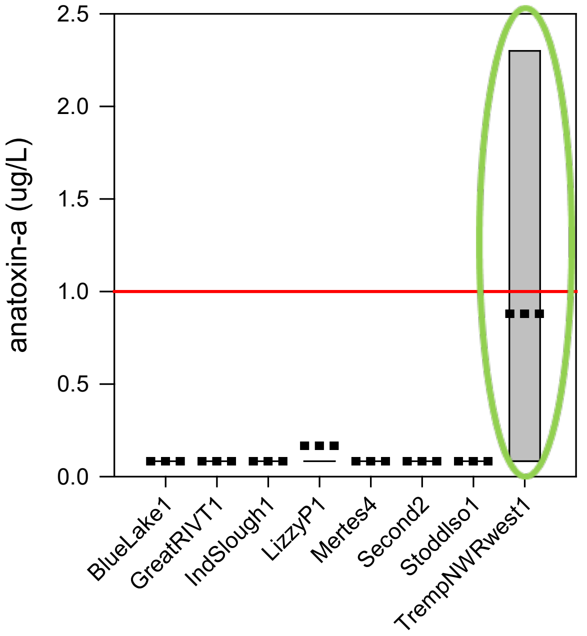
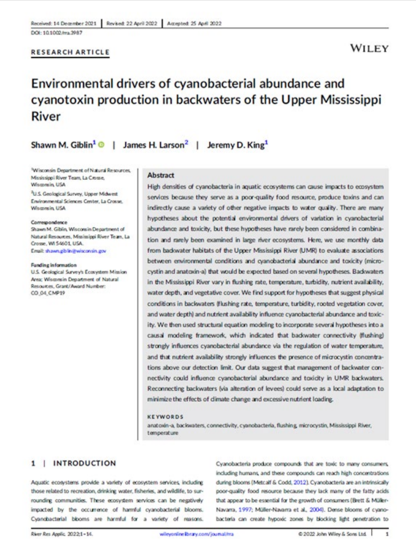


Table 2: Correlation coefficients (with bootstrapped 95% confidence intervals) between hypothesized drivers of cyanobacterial abundance and toxicity. Correlation coefficients are estimated using Kendall′s tau (recommended for samples with many non-detects).

Potential Predictors	Cyanobacterial biovolume	N-fixing biovolume	Microcystin concentration	Anatoxin A concentration
Hypothesis: N-limitation/P-excess				
DIN:PO_4	0.03 (-0.19, 0.24)	-0.09 (-0.31, 0.12)	**-0.23 (-0.42, -0.05)**	-0.11 (-0.31, 0.09)
TN:TP	-0.01 (-0.20, 0.21)	-0.18 (-0.39, 0.03)	**-0.27 (-0.43, -0.11)**	**-0.21 (-0.36, -0.07)**
PO_4	-0.05 (-0.23, 0.13)	-0.17 (-0.35, 0.03)	-0.10 (-0.30, 0.10)	-0.19 (-0.37, -0.02)
TP	0.12 (-0.09, 0.35)	0.08 (-0.18, 0.33)	**0.25 (0.04, 0.46)**	**0.23 (0.02, 0.45)**
DIN	-0.03 (-0.22, 0.15)	**-0.22 (-0.41, -0.03)**	**-0.36 (-0.51, -0.20)**	**-0.29 (-0.44, -0.16)**
TN	0.17 (-0.02, 0.36)	-0.001 (-0.23, 0.23)	-0.08 (-0.31, 0.15)	0.10 (-0.11, 0.32)
Hypothesis: Temperature				
Water temperature (°C)	0.12 (-0.08, 0.33)	**0.40 (0.26, 0.55)**	**0.22 (0.02, 0.42)**	**0.17 (-0.02, 0.36)**
Hypothesis: Flushing				
Water velocity (m s^{-1})	-0.05 (-0.25, 0.14)	**-0.18 (-0.36, -0.004)**	**-0.43 (-0.52, -0.34)**	**-0.22 (-0.31, -0.13)**
Hypothesis: Turbidity				
TSS	0.15 (-0.07, 0.37)	0.06 (-0.21, 0.33)	**0.25 (0.02, 0.49)**	**0.39 (0.24, 0.55)**
Hypothesis: Vegetative shading/competition for nutrients/allelopathy				
Vegetative cover (percent)	-0.11 (-0.34, 0.11)	0.08 (-0.16, 0.33)	-0.12 (-0.38, 0.13)	**-0.34 (-0.51, -0.20)**
Hypothesis: Shallow depth results in more wind resuspension, increased N-limitation and higher water temperature				
Water depth	-0.14 (-0.33, 0.06)	**-0.35 (-0.53, -0.17)**	**-0.34 (-0.53, -0.15)**	**-0.26 (-0.42, -0.11)**



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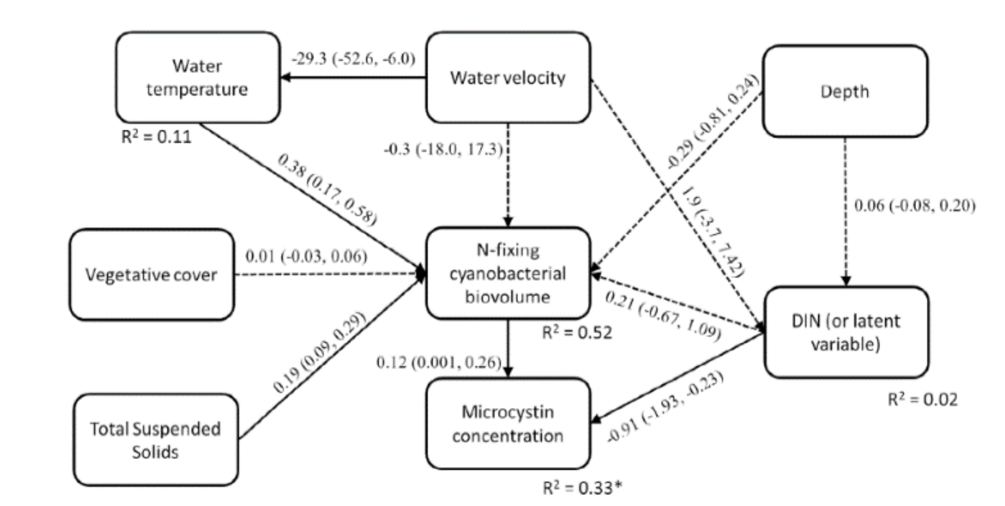
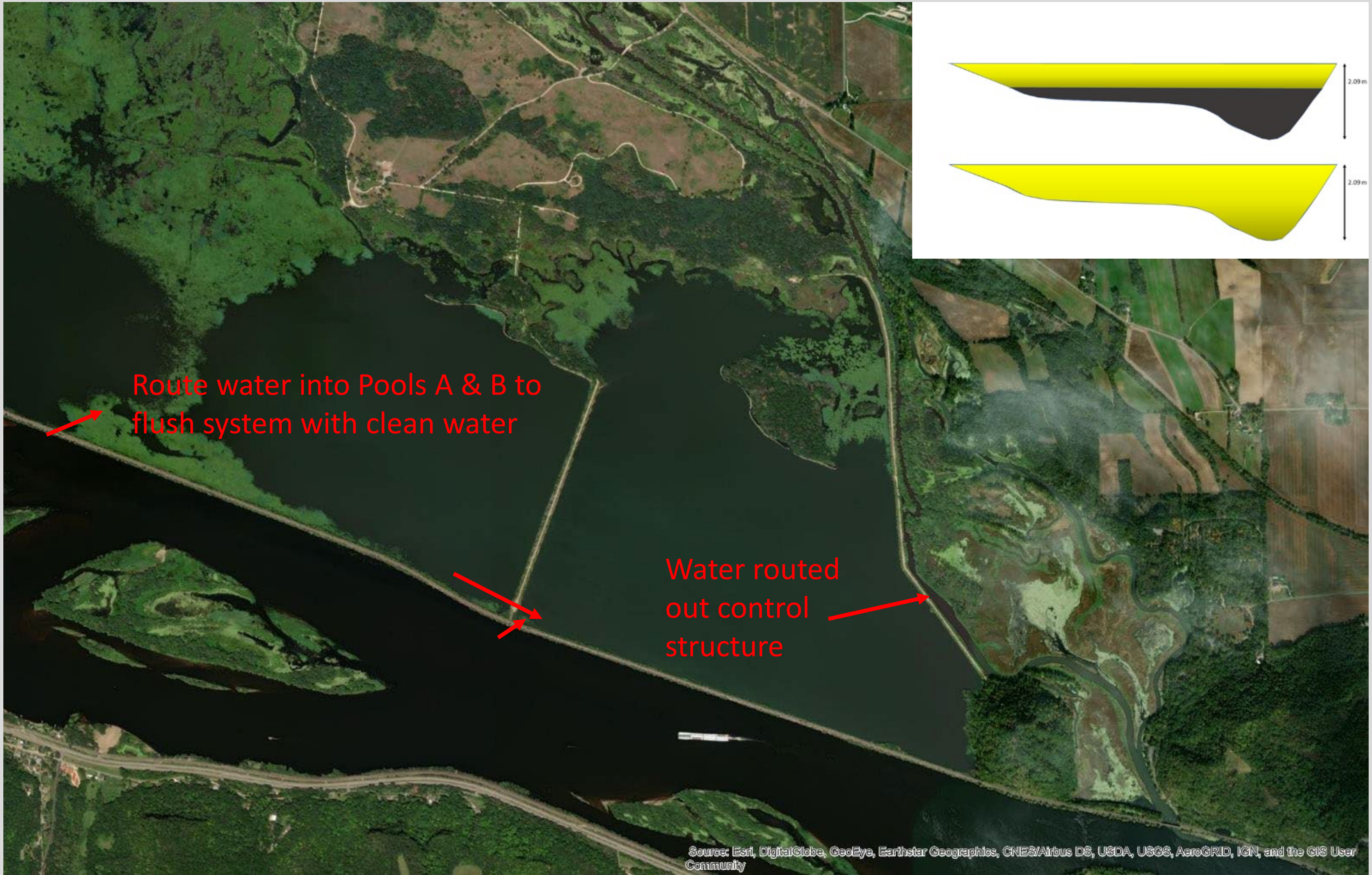
Seeing cyanobacteria and cyanotoxin problems in association with:

- High TP
- Low DIN
- High water temperature
- *Low water velocity (low flushing; long water residence time)*
- *High turbidity*
- Low rooted macrophyte cover
- Shallow water depth



A Simple solution that utilizes abundant, low P & TSS Mississippi River water to flush Pools A *and* B



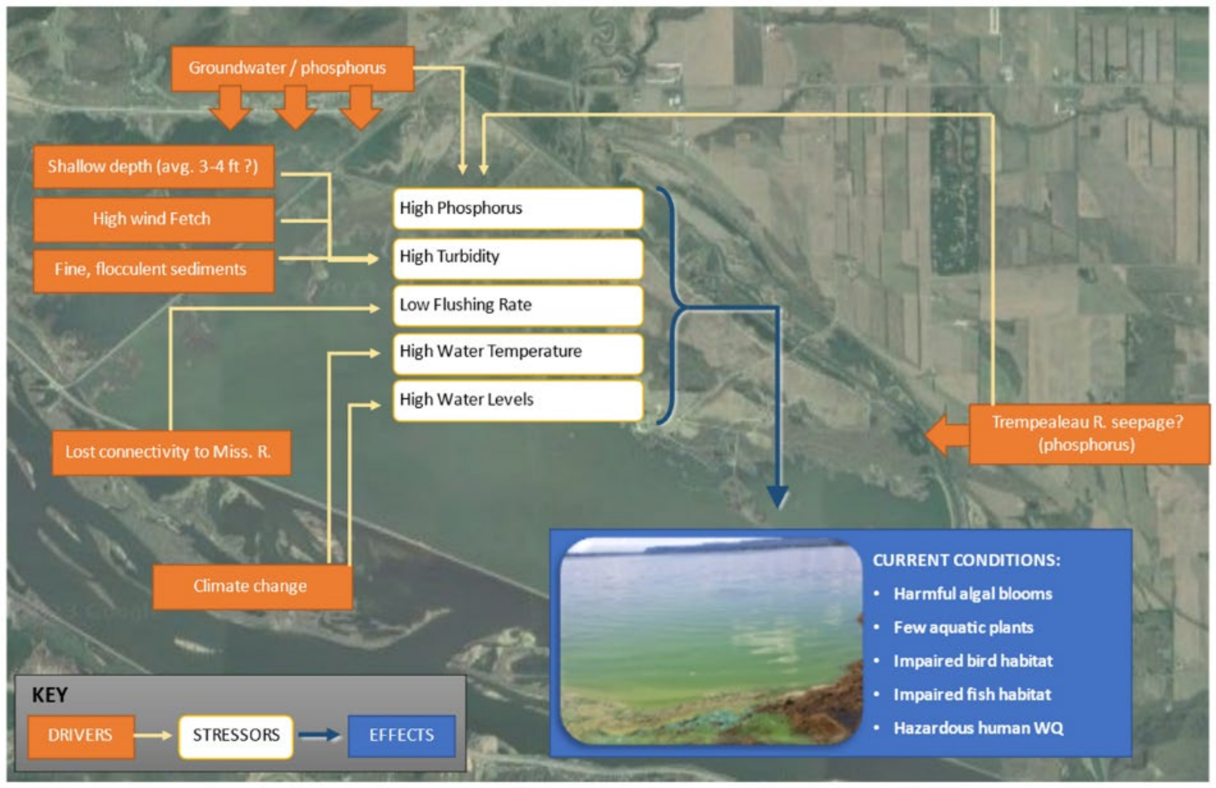
TP within main channel 1/3 that of Refuge Pools

Photic zone depth within main channel consistently 3x greater than the adjacent Refuge Pools

Typical year only getting sufficient light to bottom in about 10% of area in Refuge Pools

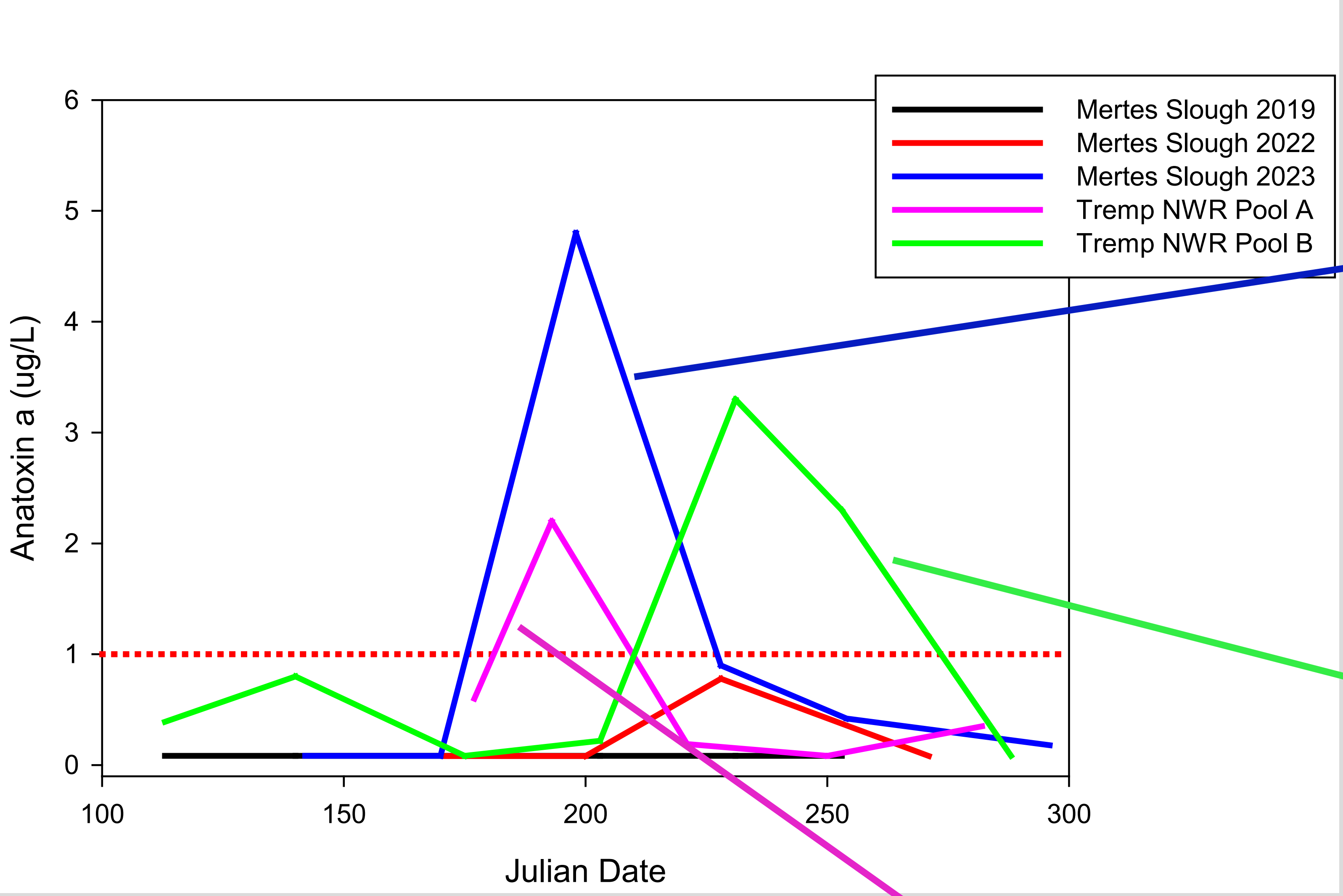
Flipping the Trempealeau NWR Ecosystem Back to a Clear/Vegetated Ecological State Will Likely Require:

- Flushing low phosphorus and low TSS Mississippi River main channel water through refuge pools to increase water clarity, reduce phosphorus and reduce water residence time.
- Building islands to break up wind fetch (as little as 5 mph wind can resuspend sediment & nutrients off bottom).
- Getting water levels as shallow as possible during the growing season so light can reach the bottom to establish submersed aquatic vegetation.



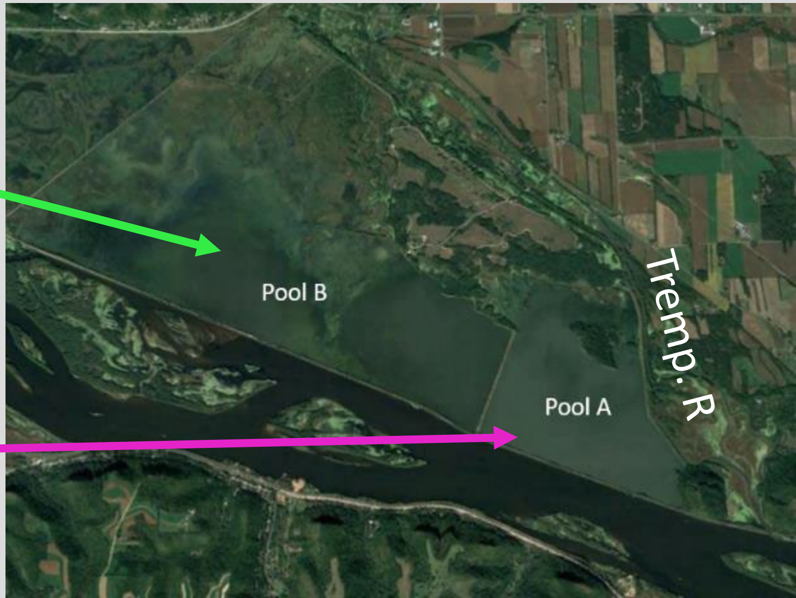
Conceptual Model from Tremp. NWR Letter Report

Trempealeau National Wildlife Refuge and Mertes Slough selected for next round of Upper Mississippi River Restoration habitat projects



Mertes Slough

Trempealeau National Wildlife Refuge



Day 100 = April 10
Day 300 = October 27

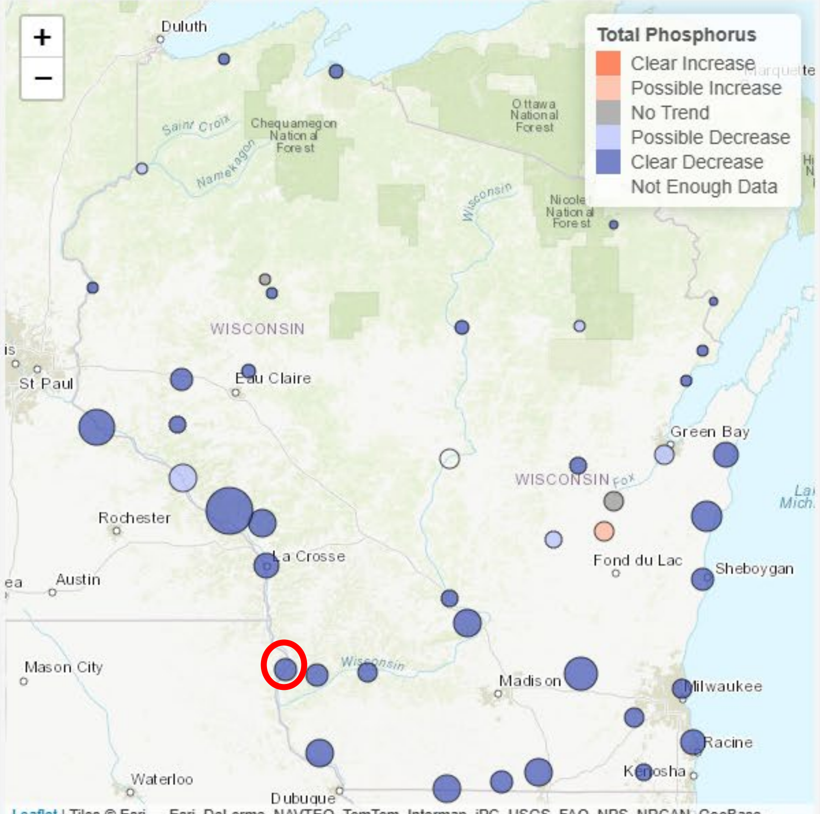
What's Eating the Trempealeau Lakes: The Case for Controlling Nitrogen Loading

Annual Phosphorus Concentration
Mississippi River
Lock and Dam 9 (Lynxville, WI)

~1% annual decrease

Select site from map

Circle size proportional to most recent concentration within selected time period



Select parameter

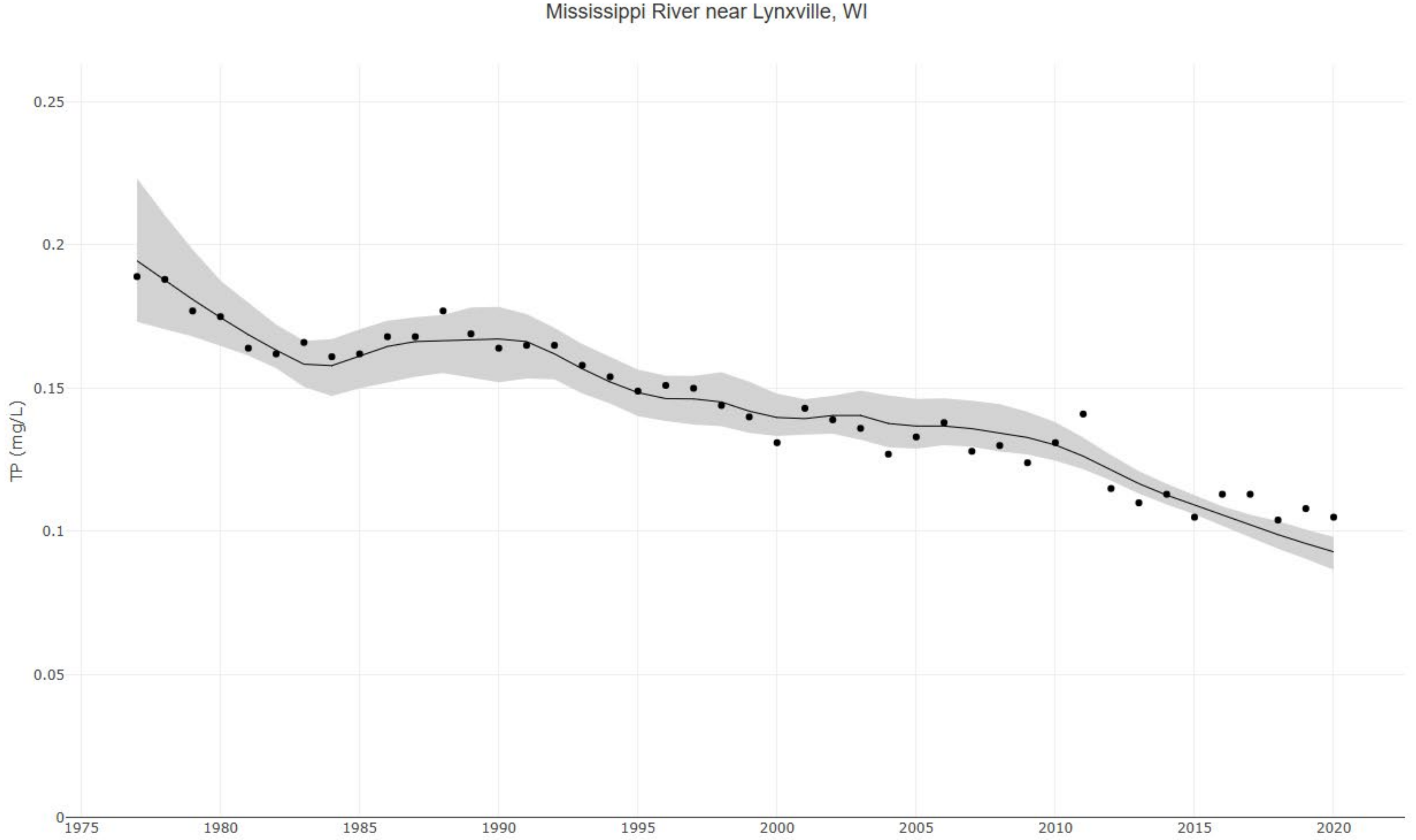
Total Phosphorus

Select time period

1961 — 2020

1961 1967 1973 1979 1985 1991 1997 2003 2009 2015 2020

Methods | Concentration Summary | Flux Summary | Parameter Comparison | Annual Concentration | Annual Flux | Season/Flow | Daily Concentration



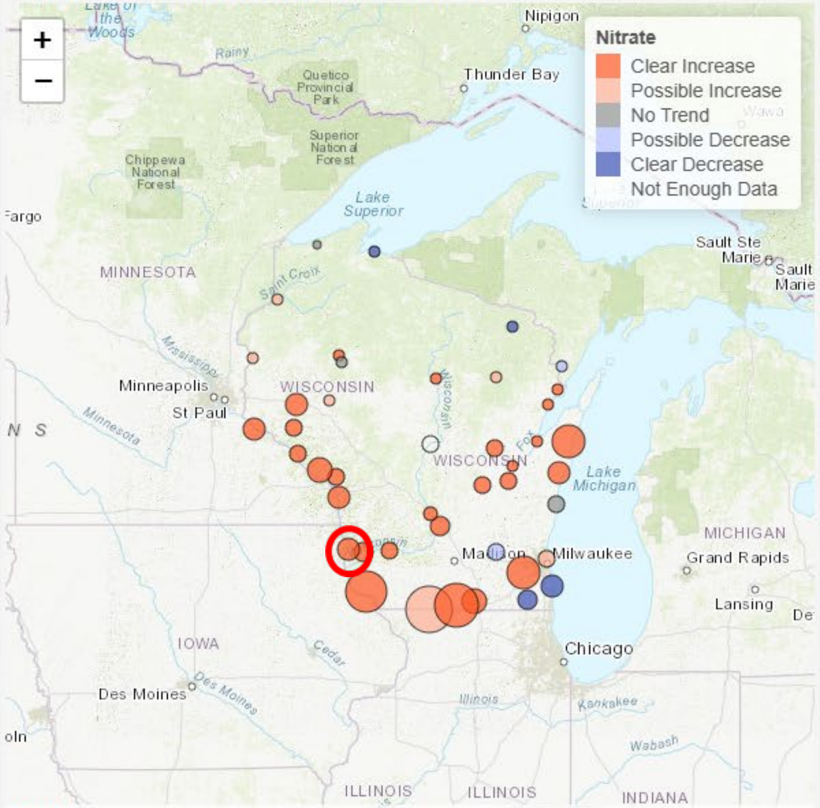
This plot shows WRTDS-estimated annual mean concentrations of the selected parameter. Points are annual estimates (not flow normalized), line is flow-normalized estimate, and gray band (if present) is the 90% confidence interval around the flow-normalized estimate (LCL and

Annual Nitrate Concentration
Mississippi River
Lock and Dam 9 (Lynxville, WI)

~2% annual increase

Select site from map

Circle size proportional to most recent concentration within selected time period



Leaflet | Tiles © Esri — Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

Select parameter

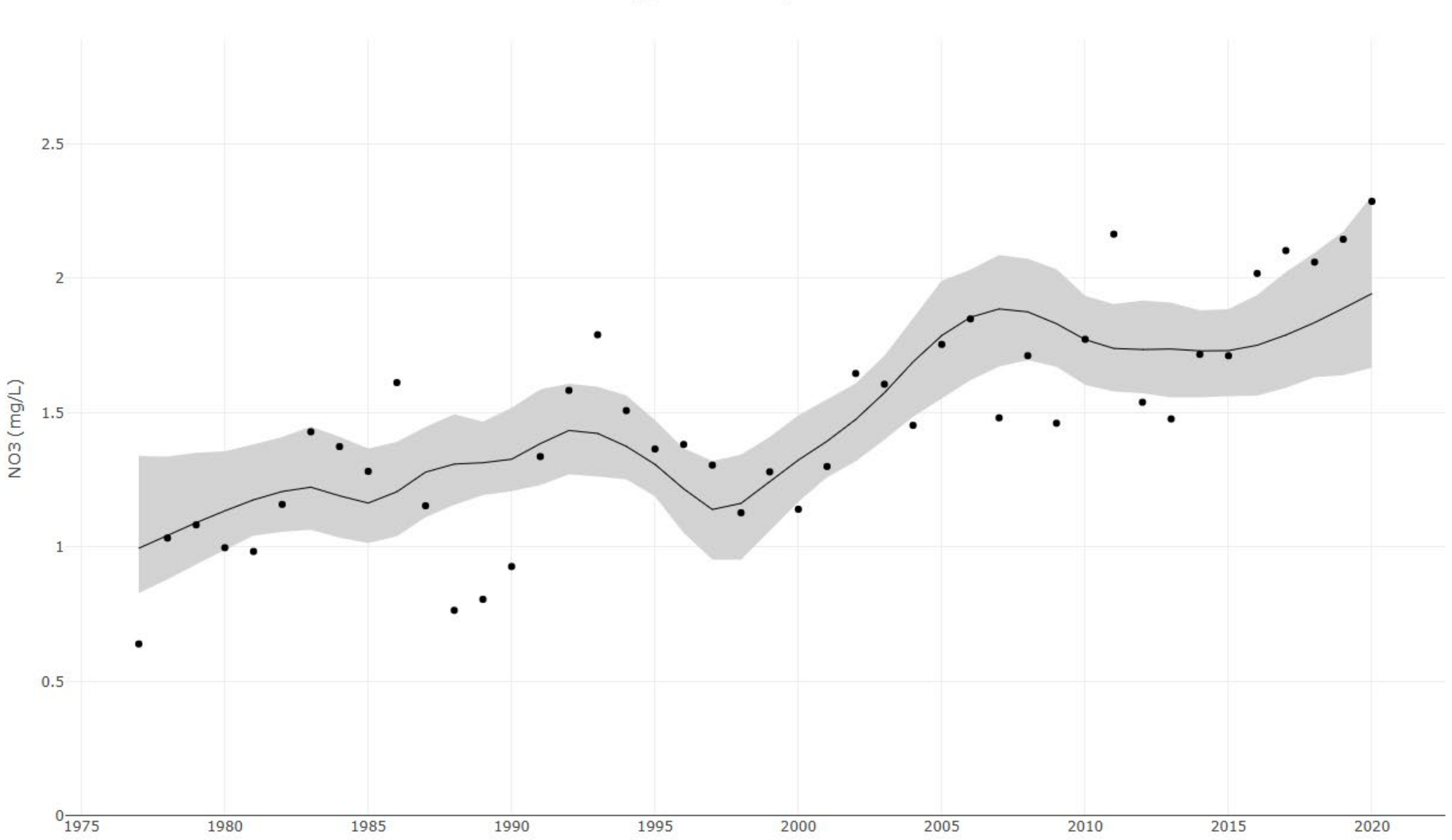
Nitrate

Select time period

1961 — 2020

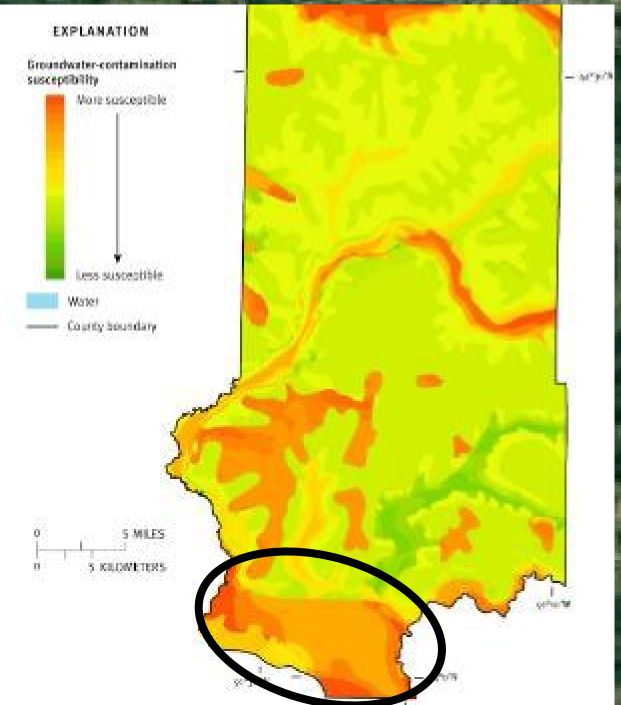
1961 1967 1973 1979 1985 1991 1997 2003 2009 2015 2020

Methods | Concentration Summary | Flux Summary | Parameter Comparison | Annual Concentration | Annual Flux | Season/Flow | Daily Concentration

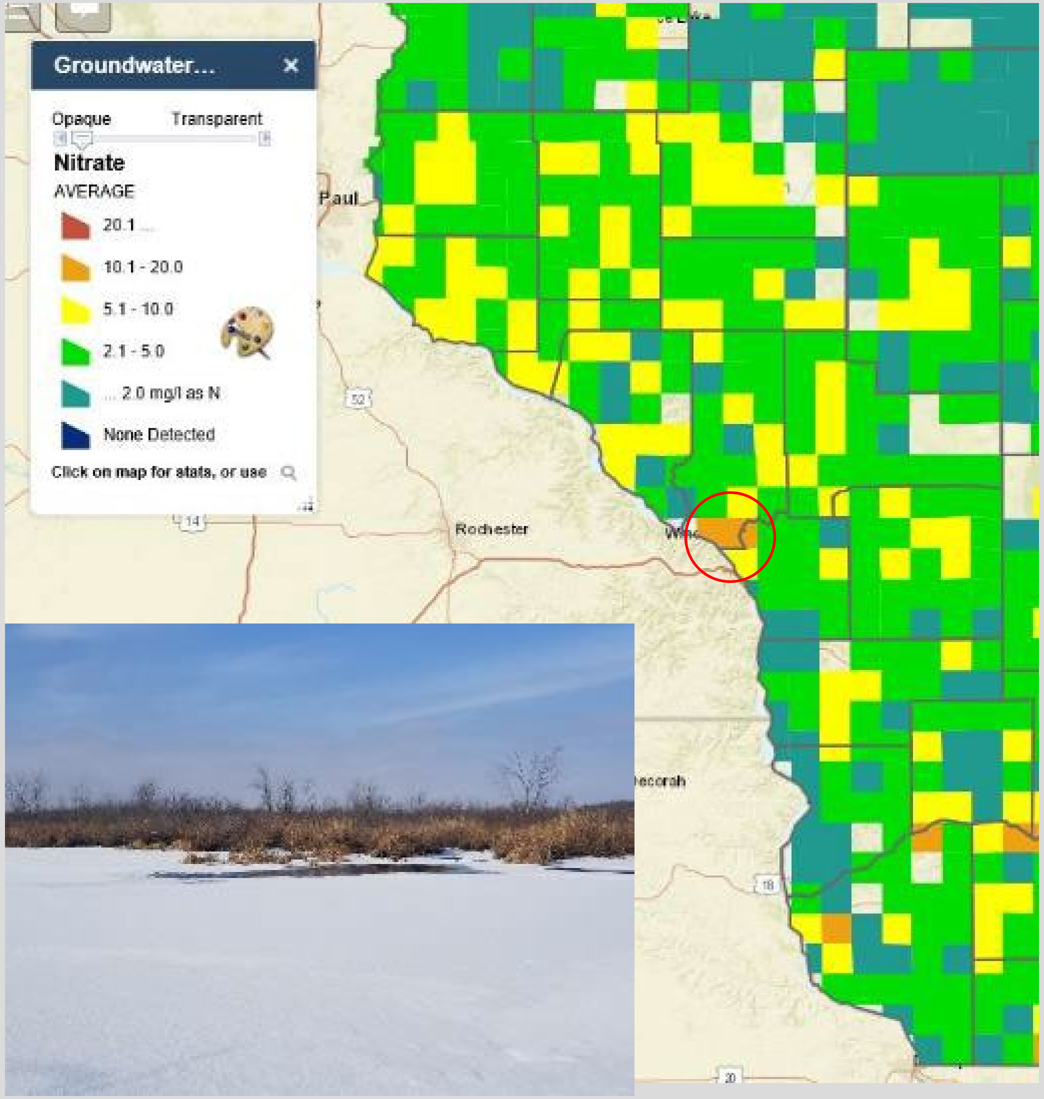


This plot shows WRTDS-estimated annual mean concentrations of the selected parameter. Points are annual estimates (not flow normalized), line is flow-normalized estimate, and gray band (if present) is the 90% confidence interval around the flow-normalized estimate (LCL and UCL are lower and upper confidence limits).

- ~30 square miles
- sand outwash terrace
- permeable sandy soils
- intensive cash cropping



WI Well Water Viewer



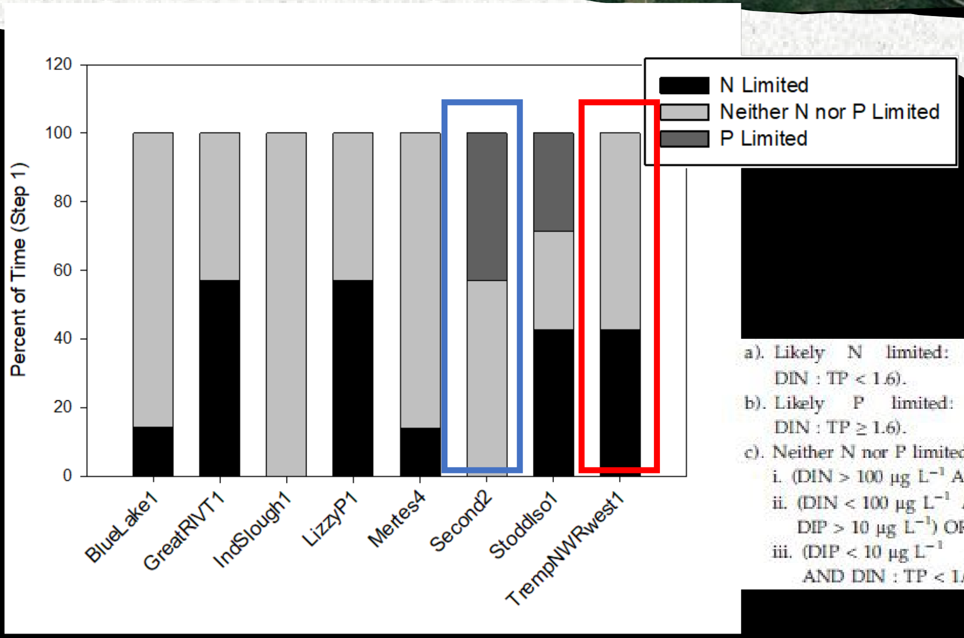
[WI Well Water Viewer - Center for Watershed Science and Education | UWSP]()

Groundwater Nitrate-Nitrogen Problem Areas

1. S. Trempealeau County- near Trempealeau

Highly permeable soil region

The Trempealeau NWR and Trempealeau Lakes: Two Water Problems With Different Solutions



a). Likely N limited: (DIN < 100 μg L^{-1} AND DIN : TP < 1.6).

b). Likely P limited: (DIP < 10 μg L^{-1} AND DIN : TP ≥ 1.6).

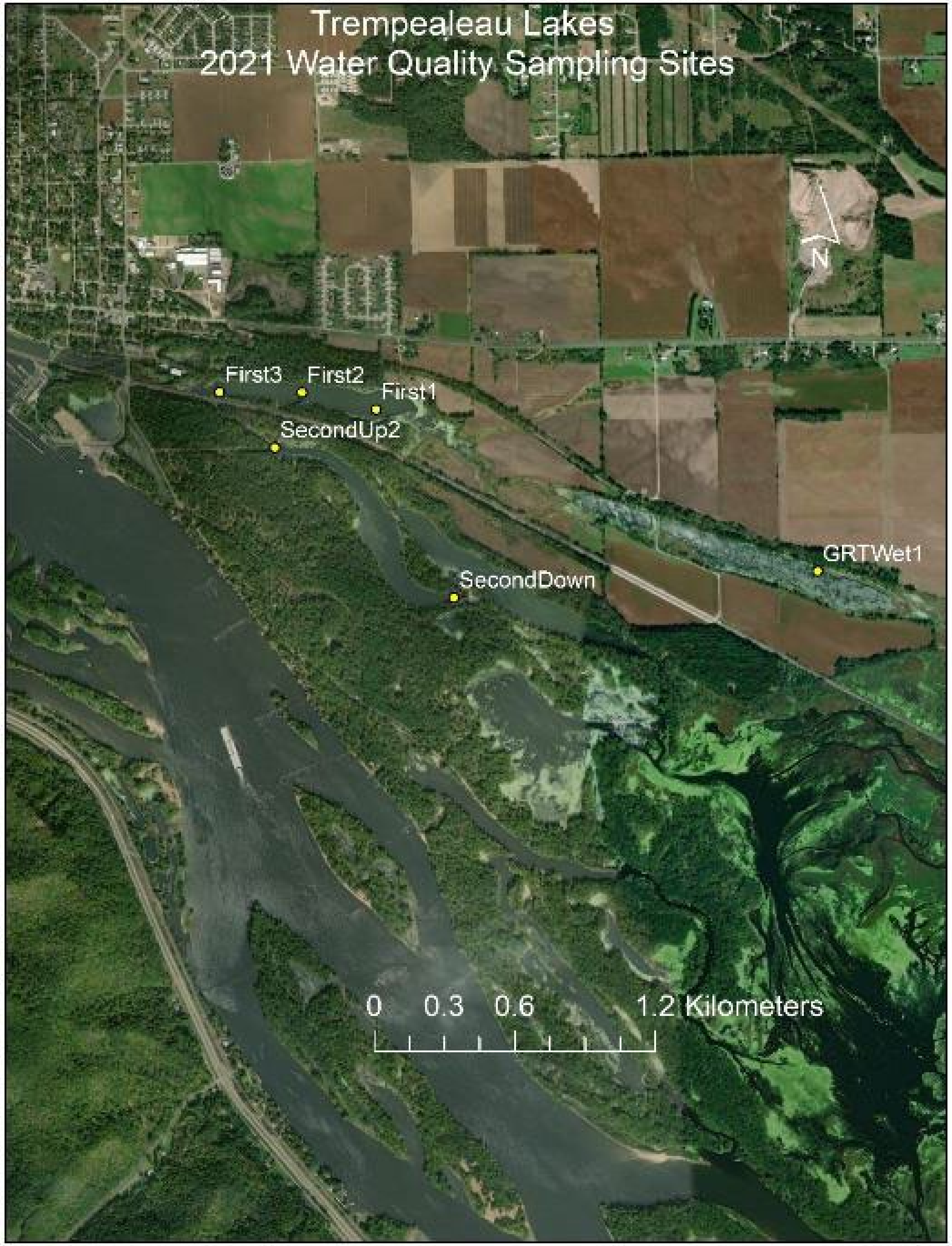
c). Neither N nor P limited: Everything else
   i. (DIN > 100 μg L^{-1} AND DIP > 10 μg L^{-1}) OR
   ii. (DIN < 100 μg L^{-1} AND DIN : TP ≥ 1.6 AND DIP > 10 μg L^{-1}) OR
   iii. (DIP < 10 μg L^{-1} AND DIN > 100 μg L^{-1} AND DIN : TP < 1.6)

Second Lake

Complaints from public- noticing changes

Not a lot of recreational, ecological value

Non-profit formed (Friends of Trempealeau Lakes) to address issues



2021 Trempealeau Lakes Study

- Six Sampling Sites
- Sampled Monthly (May-Sept)
- Parameters Sampled (n=17)
  - Dissolved Oxygen
  - Water Temp
  - Water Depth
  - Water Velocity
  - Specific Conductance
  - pH
  - Turbidity/TSS
  - Ammonia-N
  - Nitrate+Nitrite-N
  - Total Nitrogen
  - Total Phosphorus
  - Orthophosphate
  - Chlorophyll a (indicator of algal biomass)
  - Phycocyanin (meter measured)
  - Rooted veg cover
  - Filamentous algae cover
  - Duckweed cover

First Lake 7/22/21

First Lake 8/19/21

Second Lake

Calcium carbonate

“whiting event”

May 2021

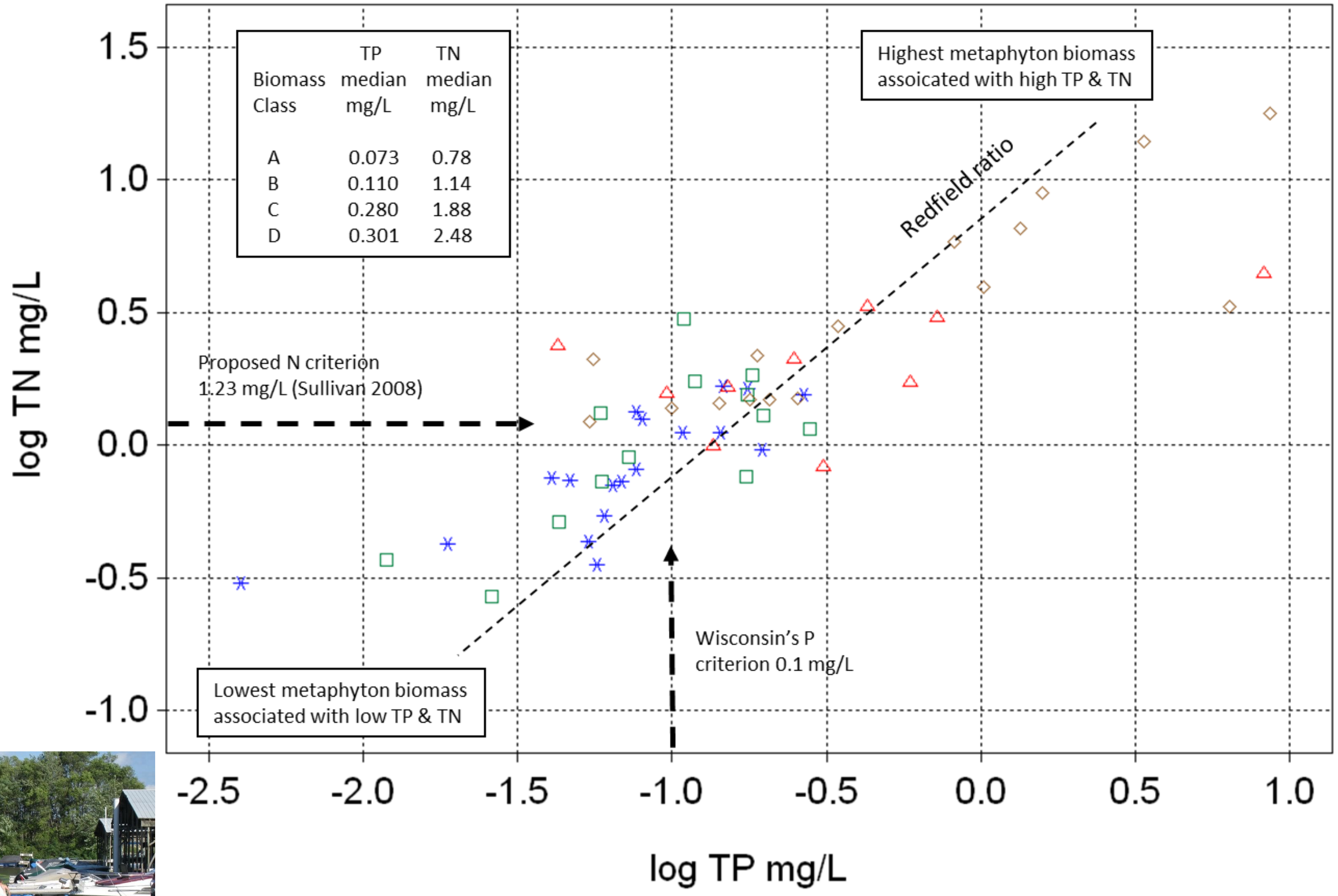
(pH values > 10)

The use of Metaphyton to Evaluate Nutrient Impairment and Proposed Nutrient Criteria for Wetlands and Backwaters in the Upper Mississippi River

John F. Sullivan
Mississippi River Team
Wisconsin Department of Natural Resources
La Crosse, Wisconsin DNR
October 2008

TN vs TP by Metaphyton Biomass

Mississippi River Backwaters



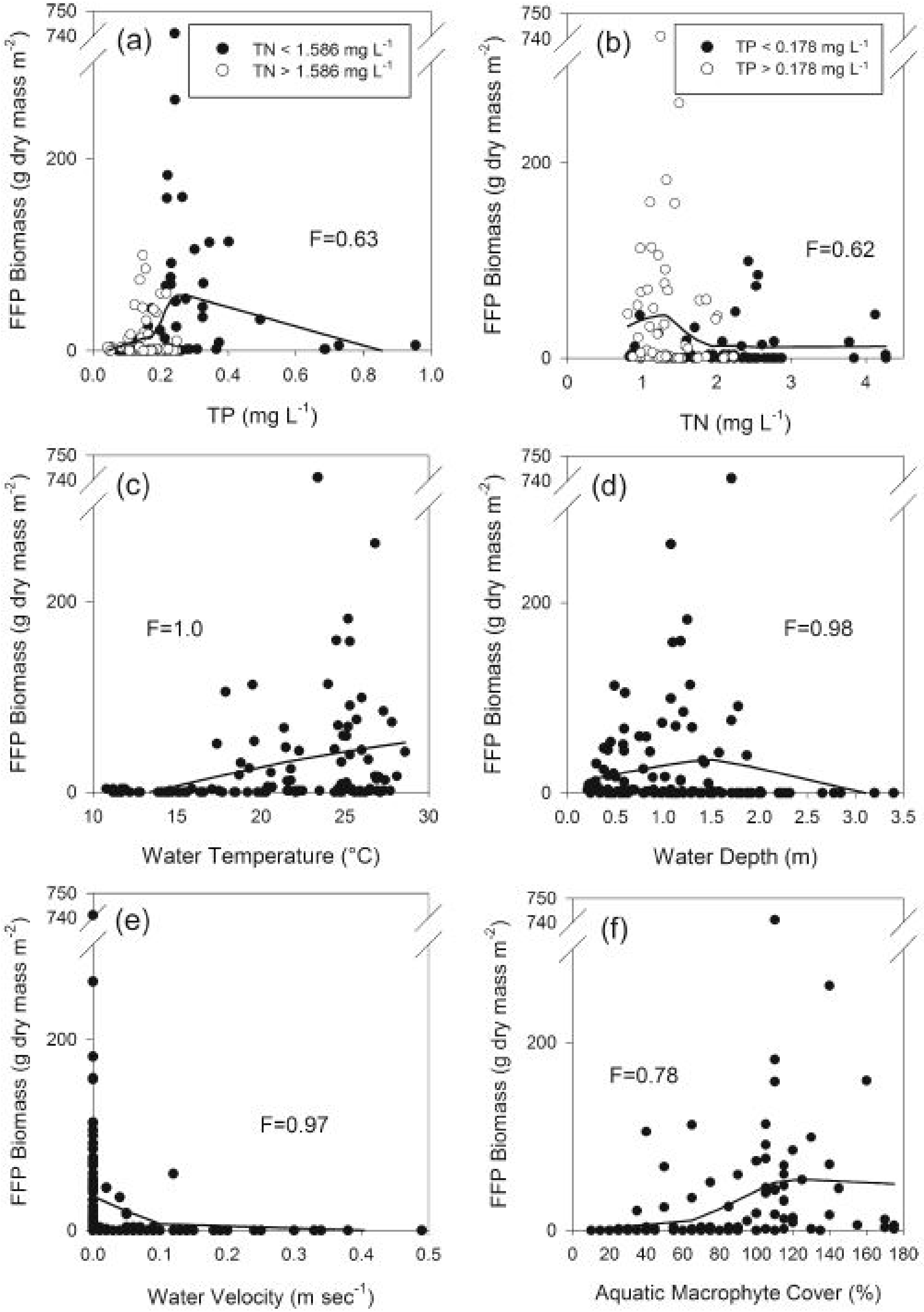
Meta. Biomass: A = 0, B = 1-25, C = 26-50, D = >50 gDW/sq m

Table 6. Proposed nutrient criteria for total phosphorus and total nitrogen for Mississippi River backwaters and wetlands.

Basis of Nutrient Criteria	Nutrient Criterion: Total Phosphorus mg/L	Nutrient Criterion: Total Nitrogen mg/L	Comment
Dissolved Oxygen			
5 mg/L	0.075	0.88	DO x TP Regression for TP < 0.16 mg/L DO = 9.012 - 53.34(TP) r^2 = 0.484
3 mg/L	0.113	1.37	
1 mg/L	0.150	1.86	DO x TN Regression for TN < 2 mg/L: DO = 8.564 - 4.056(TN) r^2 = 0.250
Metaphyton Cover			
≤ 20%	0.078 (0.069)	1.02 (1.11)	Average and (median)
≤ 60%	0.160 (0.081)	1.18 (1.11)	Average and (median)
Average	0.119 (0.075)	1.10 (1.11)	Estimate for ≤ 40% cover
Metaphyton Biomass			
0 g/m^2 dw	0.089 (0.079)	1.09 (1.11)	Average and (median)
< 10 g/m^2 dw	0.092 (0.077)	1.01 (0.90)	Average and (median)
< 25 g/m^2 dw	0.101 (0.079)	1.09 (1.11)	Average and (median). Substantial light attenuation occurs at biomass exceeding this value.

Avg TN = 1.23 mg/L

Even years later appears to be a very sensible target



Relationships Between FFP Biomass and Key Environmental Variables

Dependent variable	Independent variable	Range	Equation	Threshold	X-axis intercept
FFP biomass	TP ($mg\ L^{-1}$)	0.043–0.167 0.168–0.25	$y=-4.959+(116.459\times TP)$ $y=-90.233+(606.909\times TP)$	0.167- lower 0.25- upper	0.043
	TN ($mg\ L^{-1}$)	0.808–1.308	$y=(-40.656\times TN^2)+(108.84\times TN)-29.1$	0.808 - lower 1.308 - upper	<0.808
	Temperature (°C)	10.8–28.6	$y=-47.162+(3.590\times \text{Temperature})$	None	13.14
	Water depth (m)	0.21–1.52	$y=11.202+(17.059\times \text{Water Depth})$	1.52	3.12
	Water velocity ($m\ s^{-1}$)	<0.1 >0.1	$y=35.751-(302.420\times \text{Water Velocity})$ $y=9.031-(22.350\times \text{Water Velocity})$	0.095	0.405
	Aquatic macrophyte cover (%)[a]	10–65 70–110 115–125 130–175	$y=-0.852+(0.175\times \text{Macrophyte Cover})$ $y=-0.852+(0.175\times \text{Macrophyte Cover})$ $y=27.092+(0.216\times \text{Macrophyte Cover})$ $y=66.608-(0.0999\times \text{Macrophyte Cover})$	65- lower 130- upper	4.85

[a] Sum of percent submersed, rooted floating and emergent macrophyte cover at site

Wetlands (2014) 34:413–425
DOI 10.1007/s13157-013-0508-8

ARTICLE

Thresholds in the Response of Free-Floating Plant Abundance to Variation in Hydraulic Connectivity, Nutrients, and Macrophyte Abundance in a Large Floodplain River

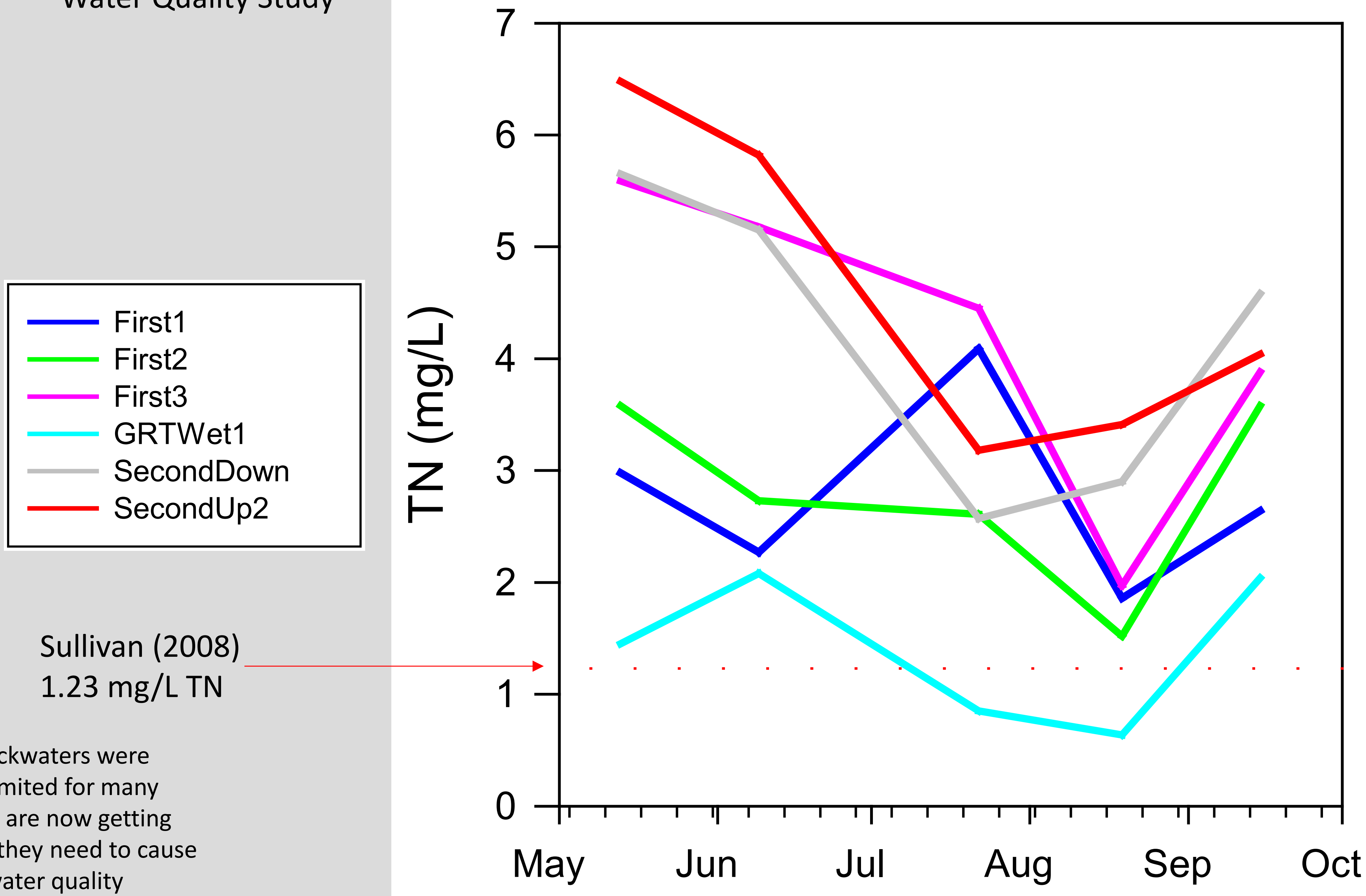
Shawn M. Giblin · Jeffrey N. Houser · John F. Sullivan · Heidi A. Langrehr · James T. Rogala · Benjamin D. Campbell

Received: 13 March 2013 / Accepted: 12 December 2013 / Published online: 28 December 2013

Abstract Duckweed and other free-floating plants (FFP) can form dense surface mats that affect ecosystem condition and

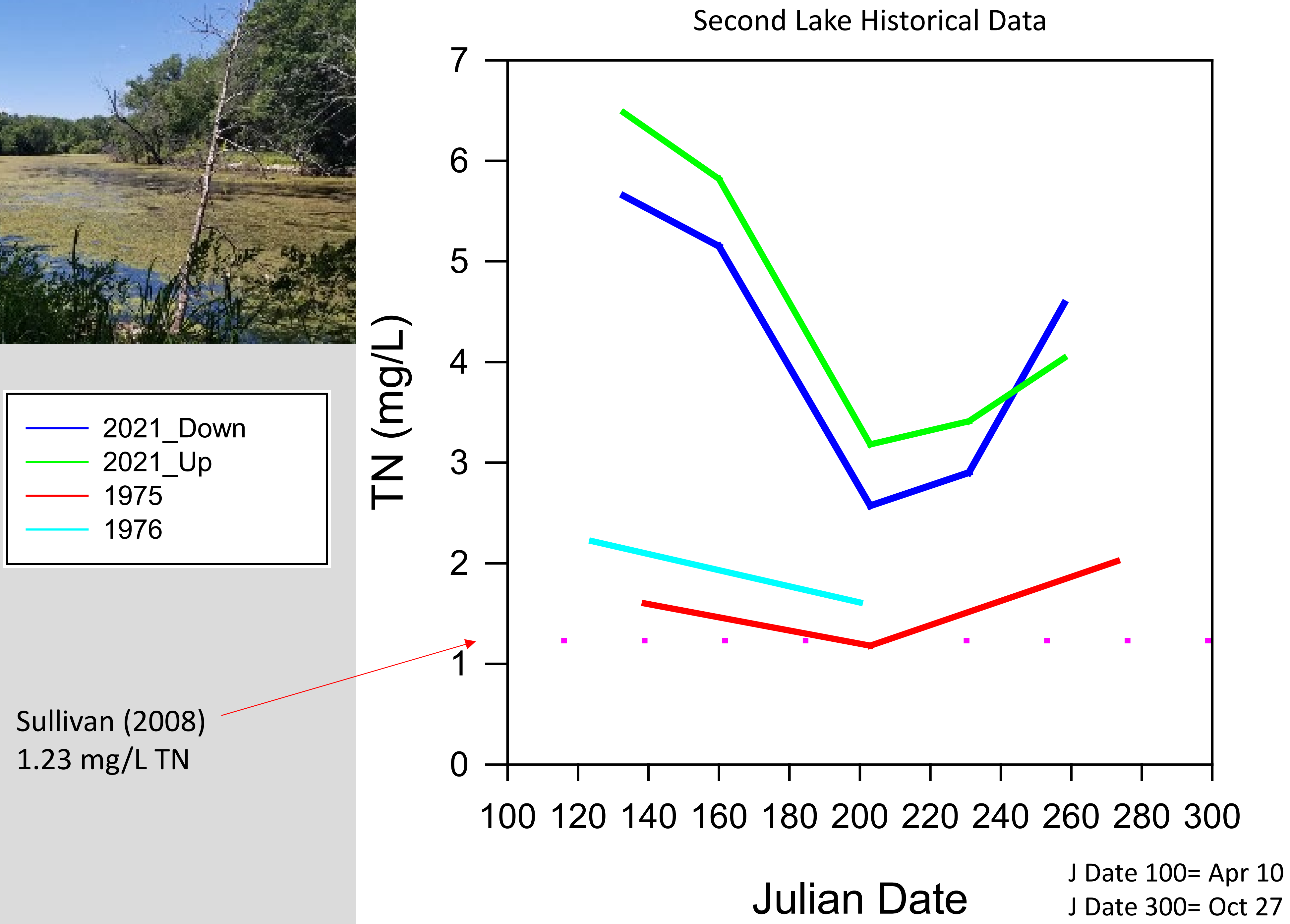
Keywords Mississippi River · Free-floating plants · Duckweed · Nitrogen · Phosphorus · Connectivity

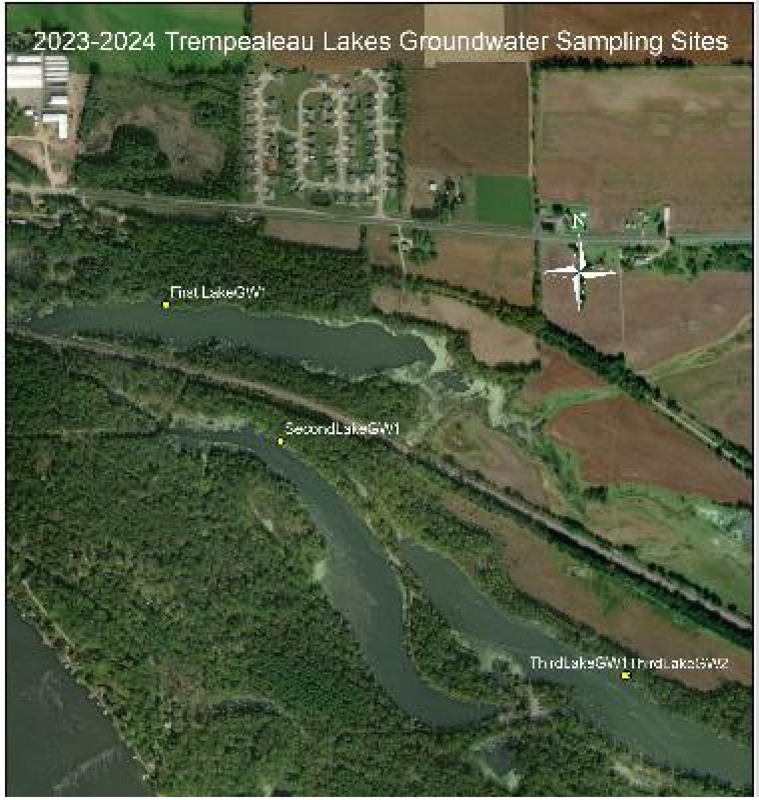
2021 Trempealeau Lakes Water Quality Study

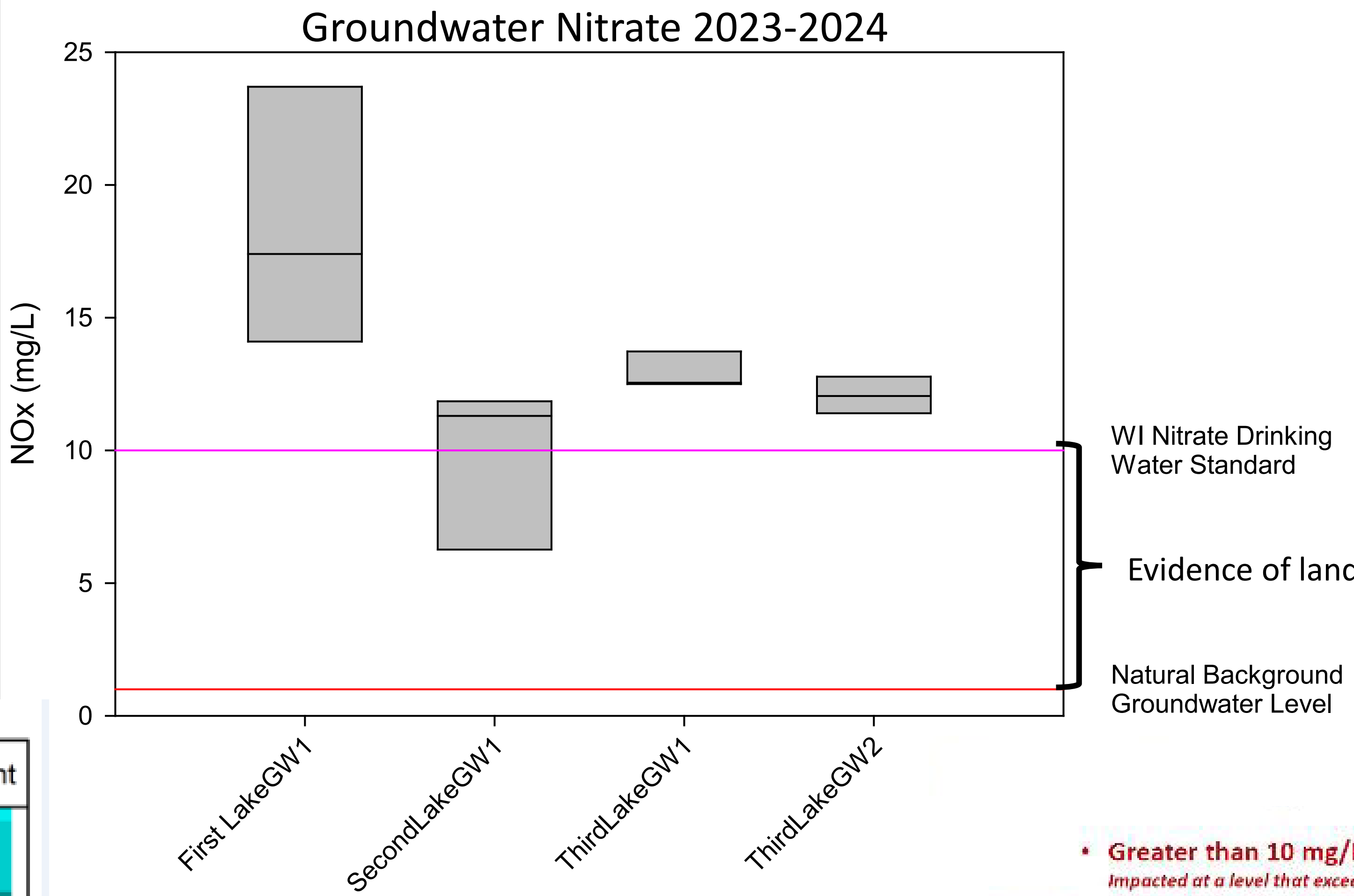


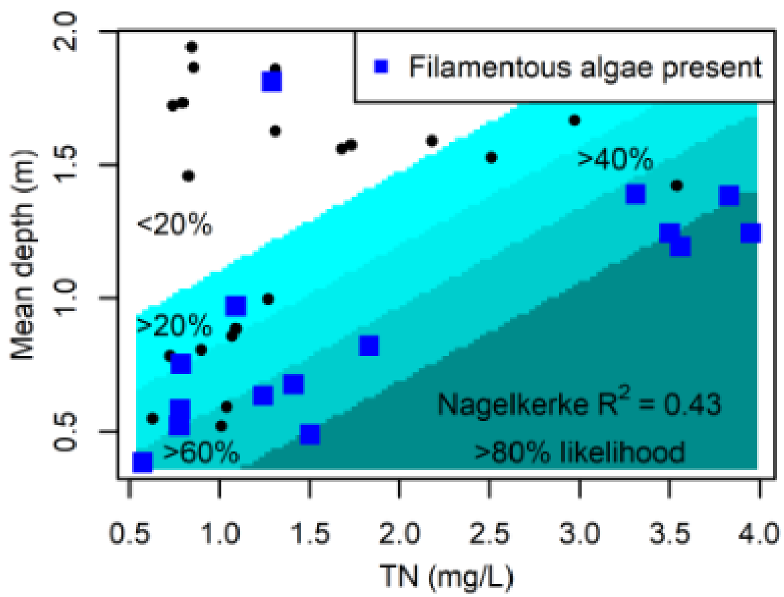
Sullivan (2008)
1.23 mg/L TN

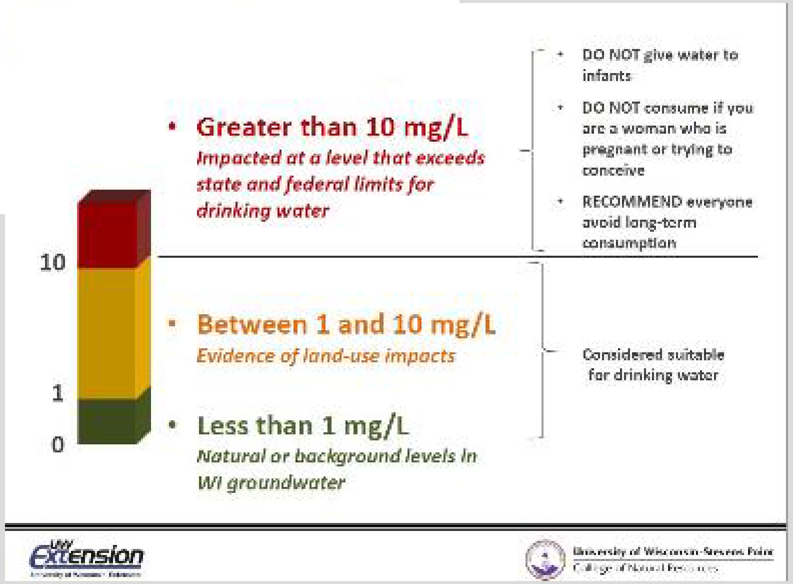
These backwaters were likely N limited for many years but are now getting all the N they need to cause serious water quality problems.


Second Lake Historical Data
2021_Down
2021_Up
1975
1976
TN (mg/L)
0
1
2
3
4
5
6
7
100
120
140
160
180
200
220
240
260
280
300
Julian Date
Sullivan (2008)
1.23 mg/L TN
J Date 100= Apr 10
J Date 300= Oct 27


2023-2024 Trempealeau Lakes Groundwater Sampling Sites
N
First LakeGW1
SecondLakeGW1
ThirdLakeGW1
ThirdLakeGW2


Groundwater Nitrate 2023-2024
NOx (mg/L)
0
5
10
15
20
25
First LakeGW1
SecondLakeGW1
ThirdLakeGW1
ThirdLakeGW2
WI Nitrate Drinking Water Standard
Evidence of land-use impacts
Natural Background Groundwater Level


Filamentous algae present
Mean depth (m)
TN (mg/L)
<20%
>20%
>40%
>60%
>80% likelihood
Nagelkerke R^2 = 0.43
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0


10
1
0
Greater than 10 mg/L
Impacted at a level that exceeds state and federal limits for drinking water
DO NOT give water to infants
DO NOT consume if you are a woman who is pregnant or trying to conceive
RECOMMEND everyone avoid long-term consumption
Between 1 and 10 mg/L
Evidence of land-use impacts
Considered suitable for drinking water
Less than 1 mg/L
Natural or background levels in WI groundwater
Extension
University of Wisconsin-Stevens Point

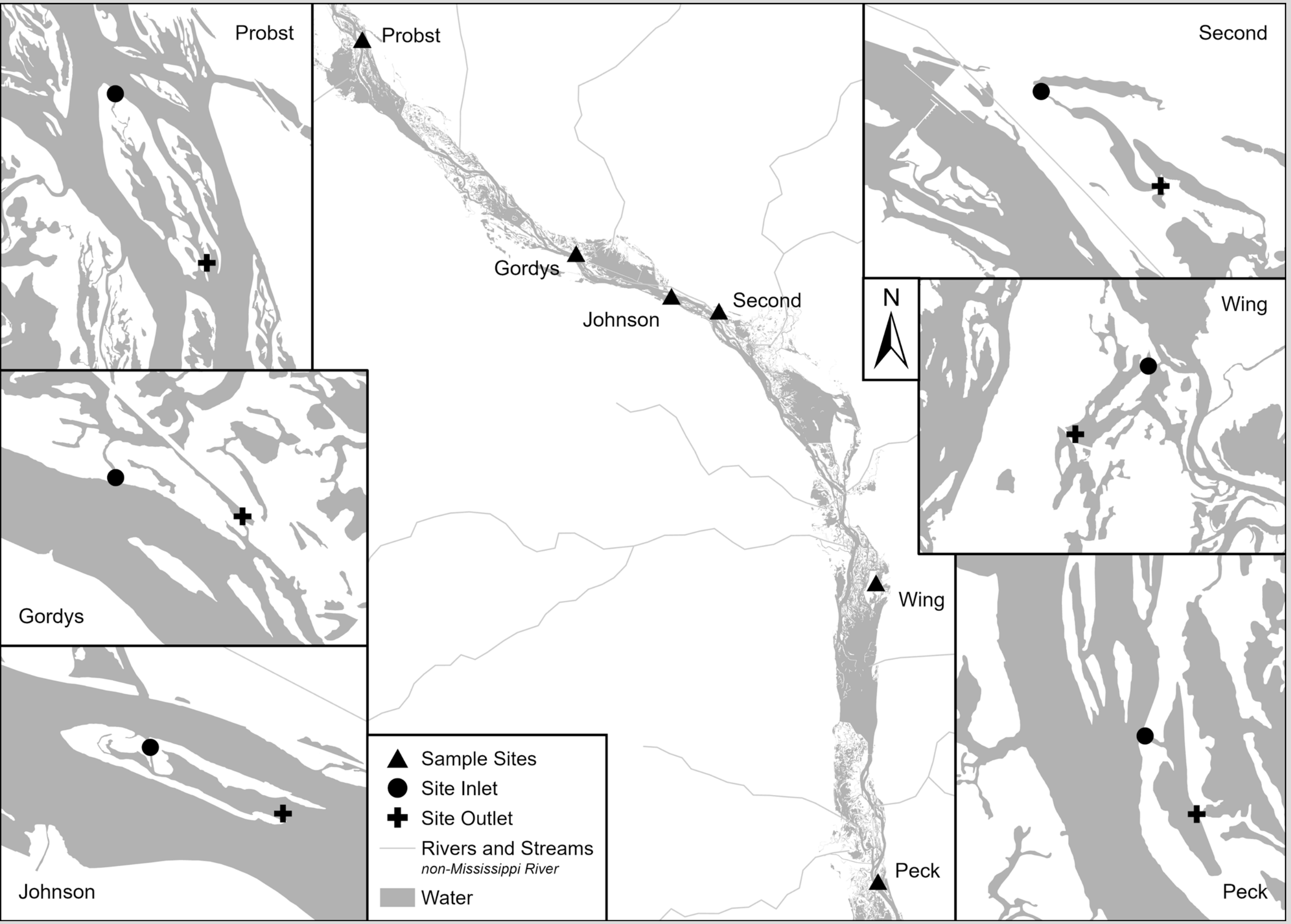
Backwater Residence Time Project: Inlet/Outlet Design

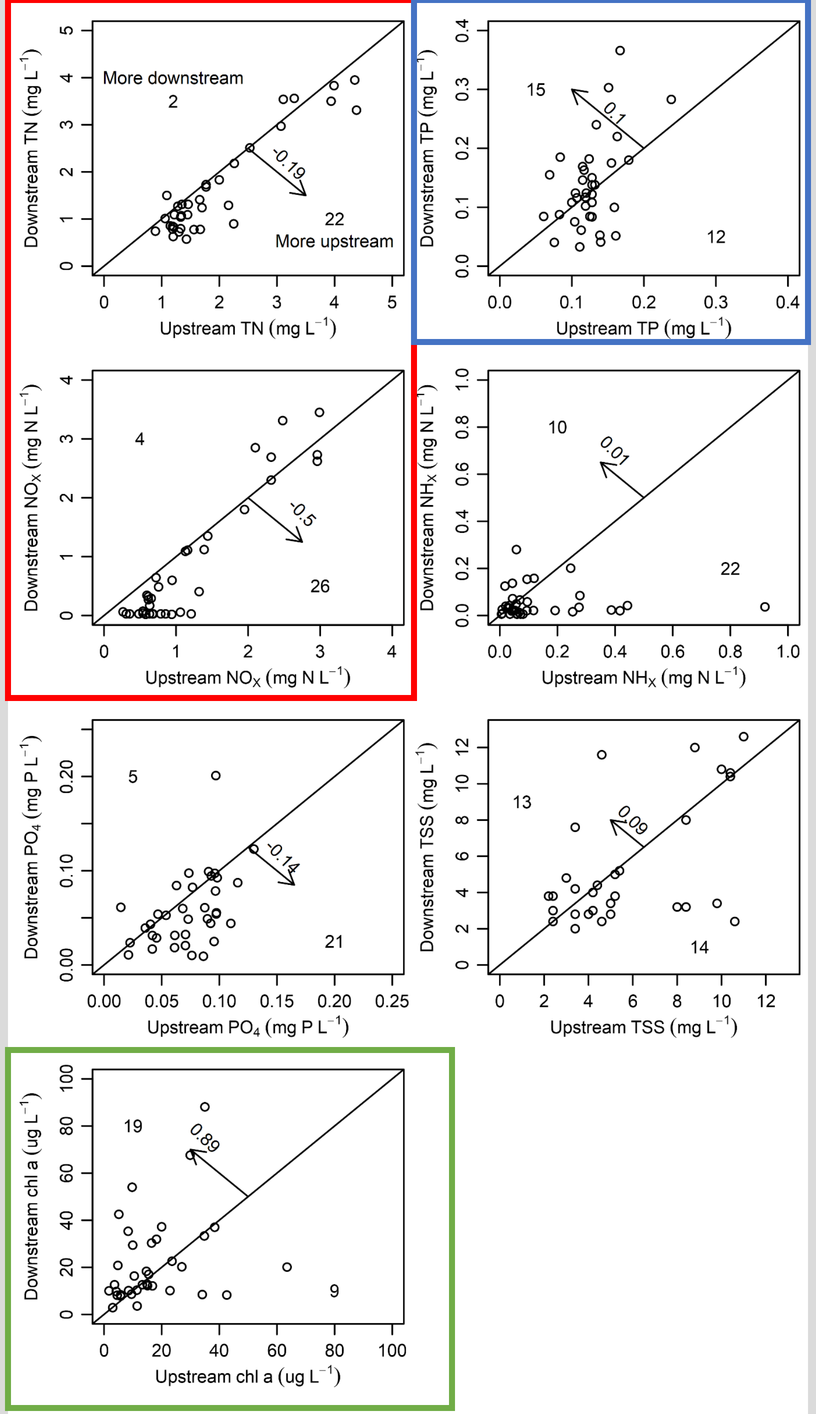
Objectives: Develop residence time and backwater depth targets to alleviate habitat problems (algae blooms & FFP mats) for habitat restoration projects on UMR.

- Examine how nutrients change as they move though backwaters

n=6; growing season
2 years (2020 & 2021) of differing discharge

6 backwaters sample 6x during growing season





General Themes:

- Lower N at outlet (backwaters hungry for DIN)
- Slightly higher P at outlet (backwaters source of P)
- Higher CHLa at outlet

a). Likely N limited: (DIN < 100 μg L^{-1} AND DIN : TP < 1.6).

b). Likely P limited: (DIP < 10 μg L^{-1} AND DIN : TP ≥ 1.6).

c). Neither N nor P limited: Everything else

i. (DIN > 100 μg L^{-1} AND DIP > 10 μg L^{-1}) OR

ii. (DIN < 100 μg L^{-1} AND DIN : TP ≥ 1.6 AND DIP > 10 μg L^{-1}) OR

iii. (DIP < 10 μg L^{-1} AND DIN > 100 μg L^{-1} AND DIN : TP < 1.6)

Very stringent nutrient limitation standard

Freshwater Biology

Freshwater Biology (2016) 61, 444–456 doi:10.1111/fwb.12718

Lake-type-specific seasonal patterns of nutrient limitation in German lakes, with target nitrogen and phosphorus concentrations for good ecological status

ANDREW M. DOLMAN*, UTE MISCHKE[†] AND CLAUDIA WIEDNER*

*Department of Freshwater Conservation, Brandenburg University of Technology Cottbus – Senftenberg, Bad Saarow, Germany

[†]Department of Ecohydrology, Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany

SUMMARY

1. Eutrophication is a global environmental problem that leaves many lakes with impaired ecological status. Human activity has increased the total concentrations of both nitrogen and phosphorus in aquatic systems, but their relative influence on phytoplankton biomass is uncertain. Their action as alternative limiting resources complicates assessment of their relative influence and disagreement may be in part due to seasonal shifts and lake-type-specific differences in the prevalence of limitation by nitrogen versus phosphorus. Debate continues as to whether measures to reduce nitrogen would be beneficial in addition to controls placed on phosphorus.

2. We used a piecewise model to test whether total nitrogen (TN) concentrations, in addition to total phosphorus (TP), influence phytoplankton biomass in 369 lowland German lakes. The piecewise model predicts biomass from TN for low N : P ratio lakes, and from TP for high N : P ratio lakes. We tested three N : P mass ratios to divide lakes: dissolved inorganic nitrogen to TP (DIN : TP), DIN to dissolved reactive phosphorus (DIN : DIP) and TN : TP. TN was a better predictor of biomass than TP when either the DIN : TP ratio was below 1.6, DIN : DIP was below 8.4, or TN : TP below 29; predictions were most accurate when using the DIN : TP ratio.

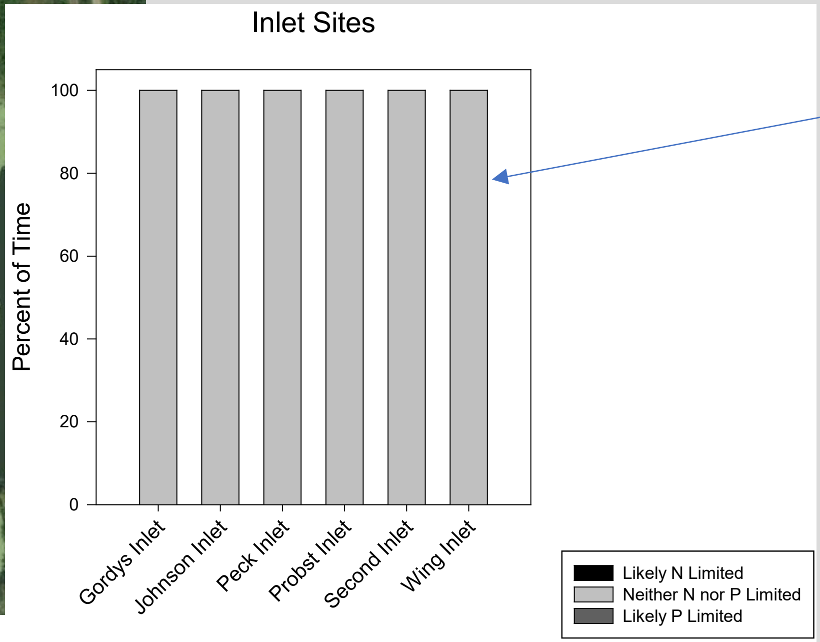
3. To investigate seasonal and lake-type-specific patterns of N and P limitation, we used the DIN : TP ratio, together with absolute concentrations of DIN and DIP, to predict the limiting nutrient at each lake in each month of the vegetation period. N limitation was much more common in polymictic than stratified lakes. While a high proportion of both stratified and polymictic lakes were P limited in early spring (60–70%), for polymictic lakes, we found a strong shift from P limitation to N limitation in summer: more than 50% of polymictic lakes were N limited between June and September and only 15–30% were P limited.

4. To obtain lake-type-specific nutrient targets we estimated the average TN and TP concentrations at which lakes of different types achieved good ecological status according to EU water framework directive criteria. Stratified lakes achieved good ecological status at concentrations of 400–500 μg L^{-1} TN or 20–35 μg L^{-1} TP, while for polymictic lakes values of 500–1000 μg L^{-1} TN, or 35–75 μg L^{-1} TP were required.

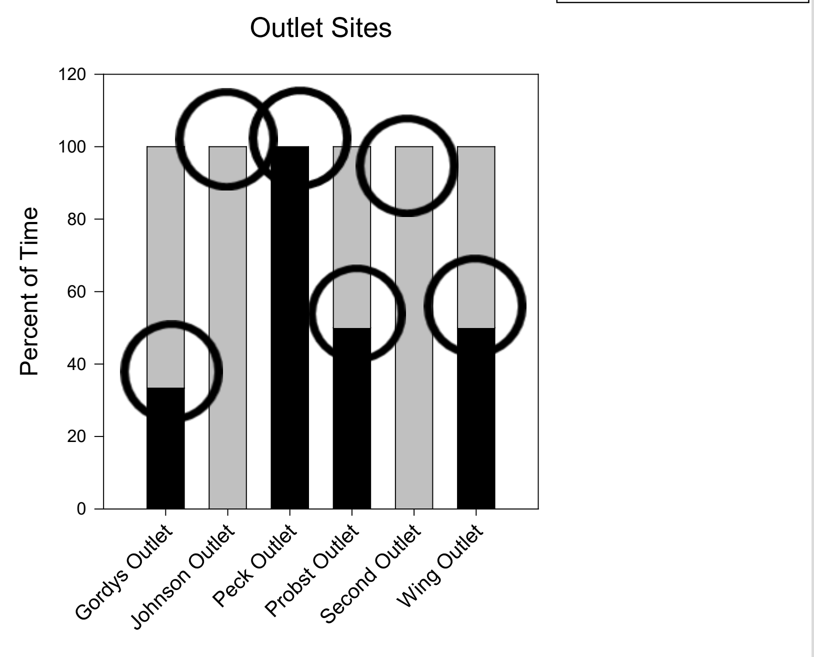
5. We estimate that nitrogen has an important influence on phytoplankton biovolume, and thus ecological status, for many polymictic lakes in Germany. While there is some uncertainty in the nutrient targets required to achieve good ecological status, this uncertainty is small compared with the range of concentrations currently observed, and lakes with moderate or worse status have concentrations of both TN and TP that are far above these current target estimates.

Keywords: limitation, nitrogen, nutrient targets, phosphorus, phytoplankton

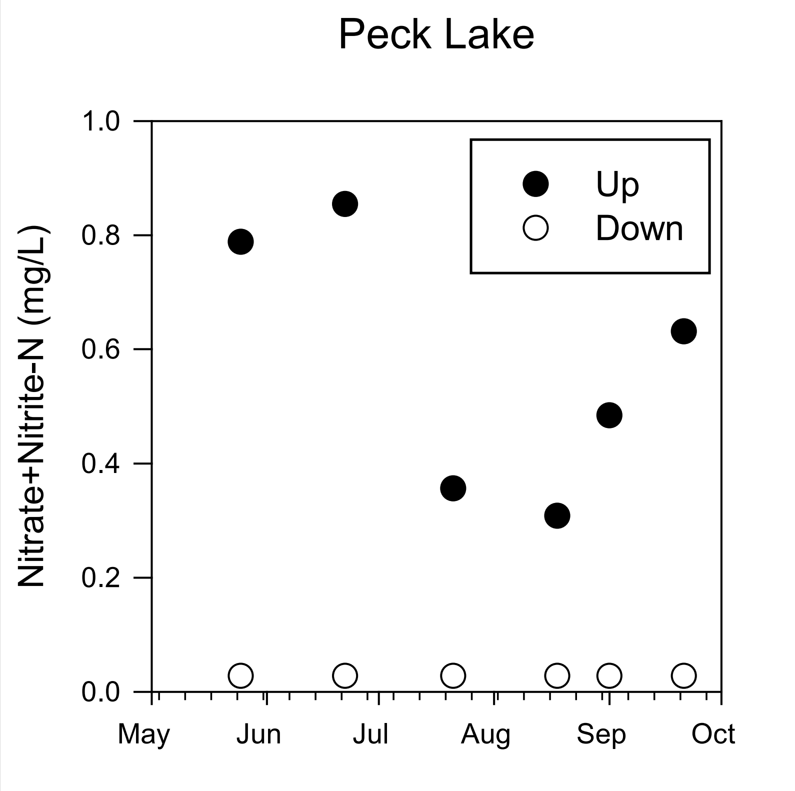
Correspondence: Andrew M. Dolman, Department of Freshwater Conservation, Brandenburg University of Technology Cottbus – Senftenberg, Seestraße 45, D - 15526, Bad Saarow, Germany. E-mail: andrew.dolman@b-tu.de

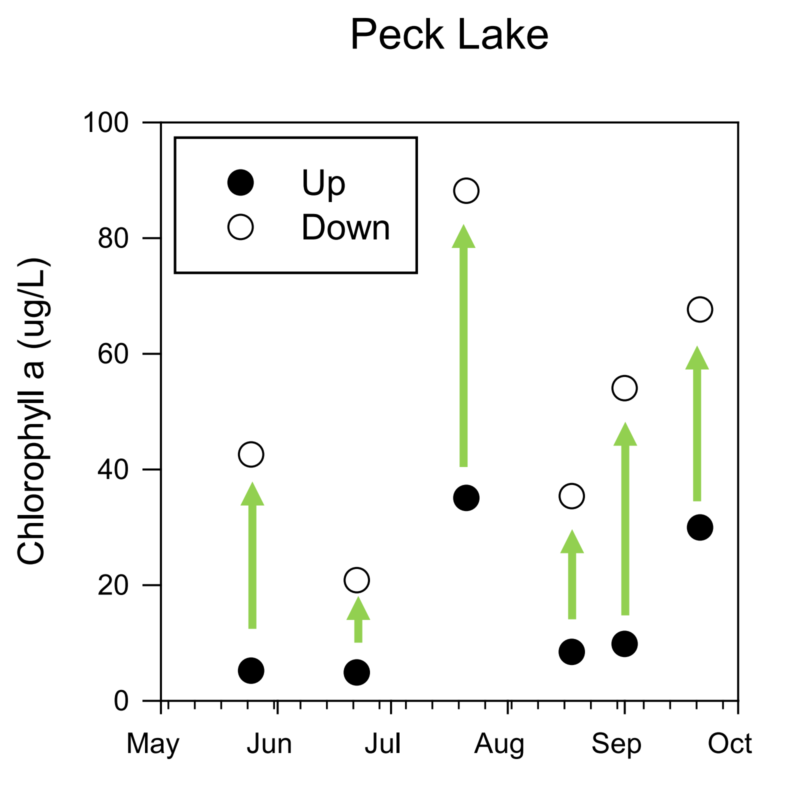


Sites at all 6 inlets on all 6 sampling days (n=36) Neither N nor P limited.



- Peck Lake Outlet N Limited 100% of time.
- Wing & Probst Lake Outlet N Limited ~50% of time.
- Sam Gordys Slough Outlet N Limited ~ 35% of the time.
- Johnson Island BW N Limited 0% of time- flushing very fast (RT <1.3 days)
- Second Lake N limited 0% of time. High GW nitrate loading off Tremp Sand Terrace.





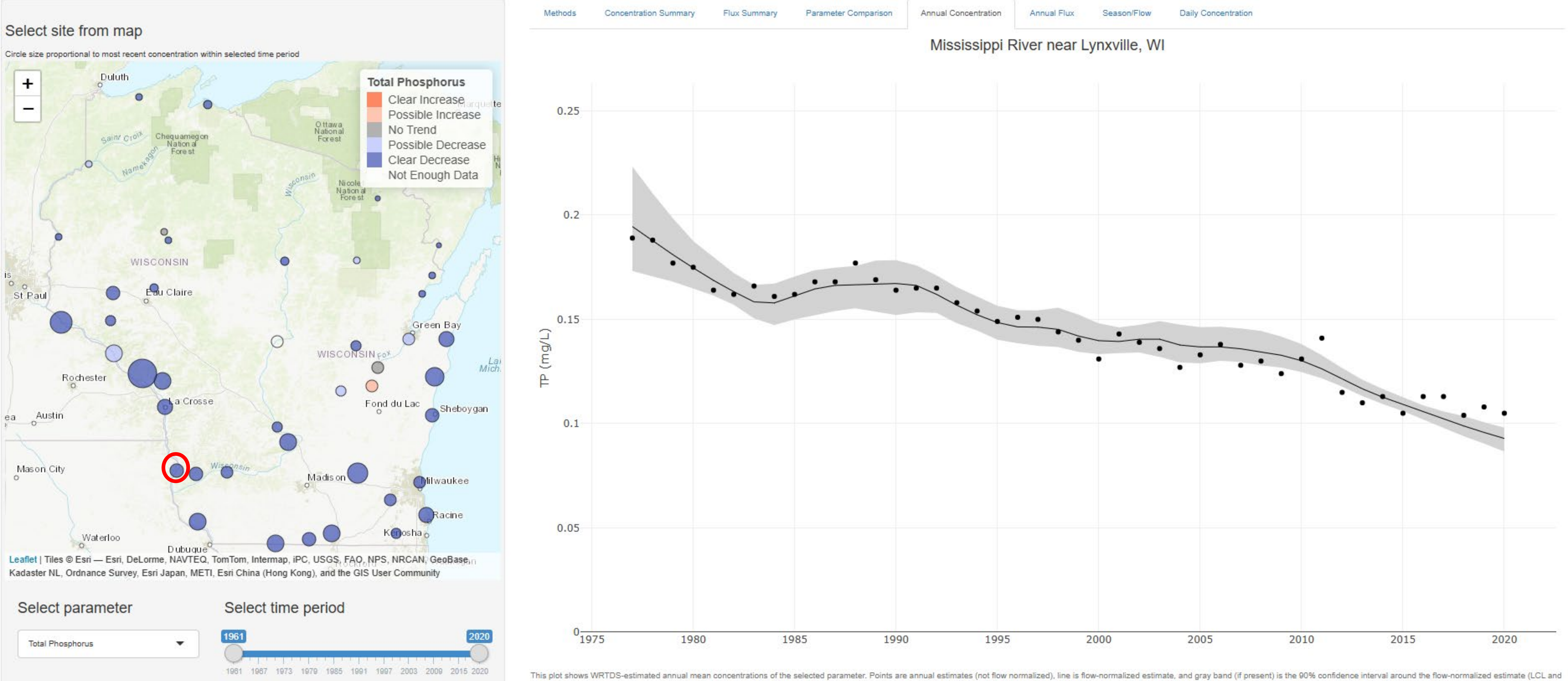
Chlorophyll a 15-55 ug/L higher at outlet

Algae blooms will develop proportional to the nitrogen loaded to the backwater

Nitrogen reductions are likely as important as phosphorus reductions

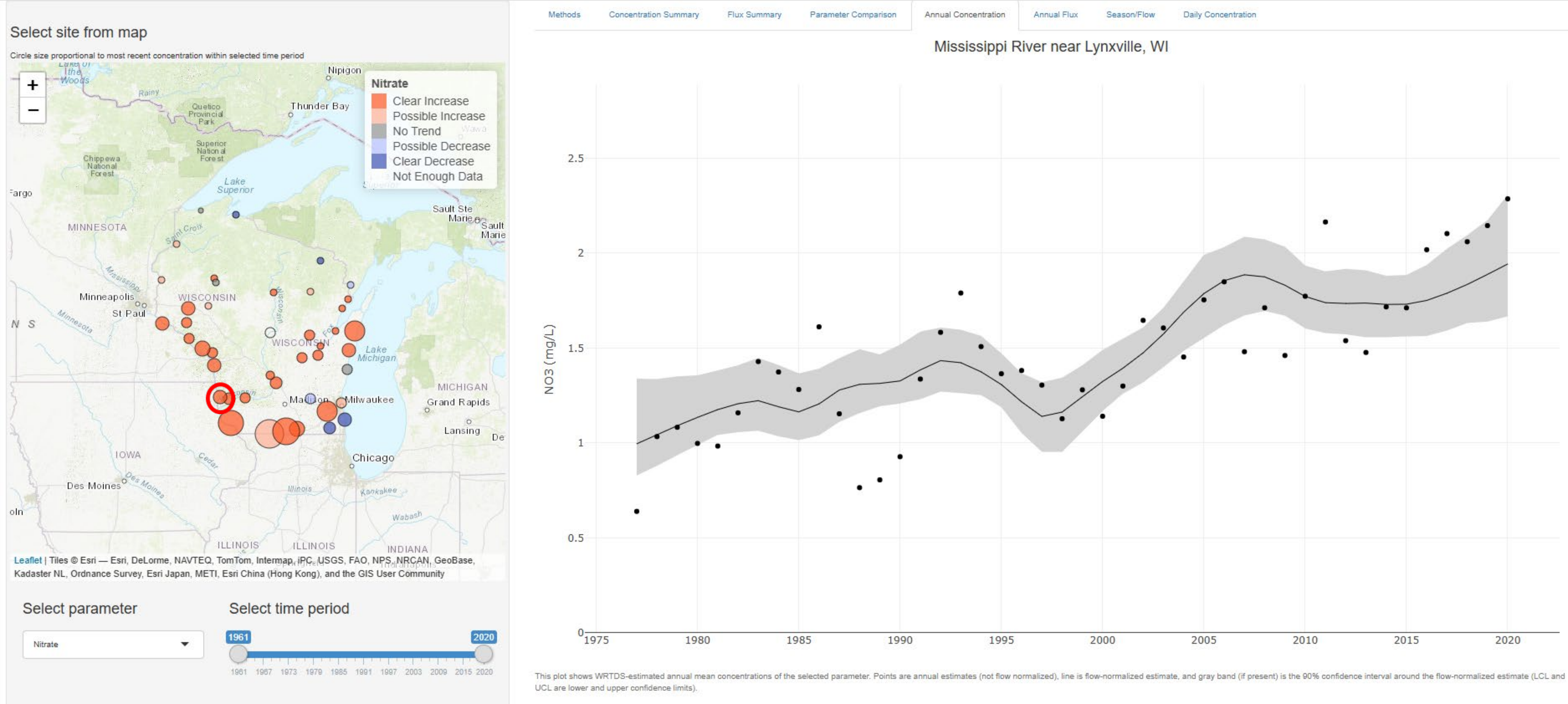
Annual Phosphorus Concentration
Mississippi River
Lock and Dam 9 (Lynxville, WI)

~1% annual decrease



Annual Nitrate Concentration
Mississippi River
Lock and Dam 9 (Lynxville, WI)

~2% annual increase



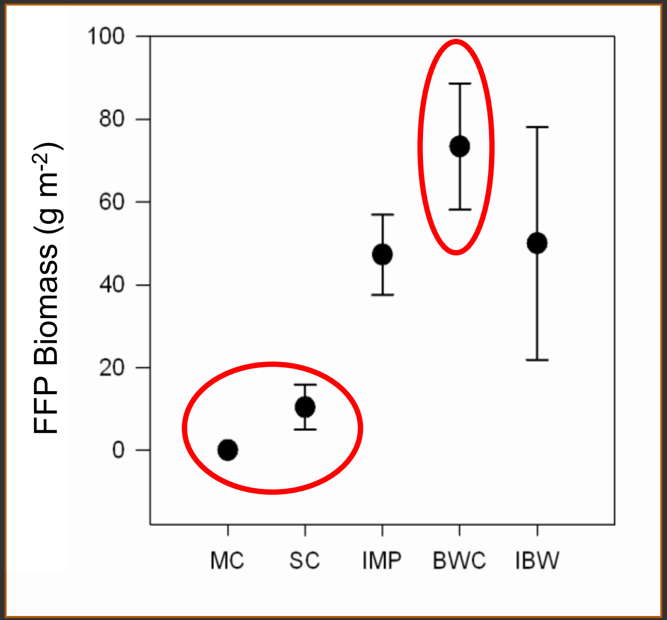
In Summary:

- Get focused on nitrogen reduction- need both nitrogen & phosphorus controls
- Doesn’t mean we don’t continue to reduce phosphorus

Questions?

Shawn.Giblin@wisconsin.gov

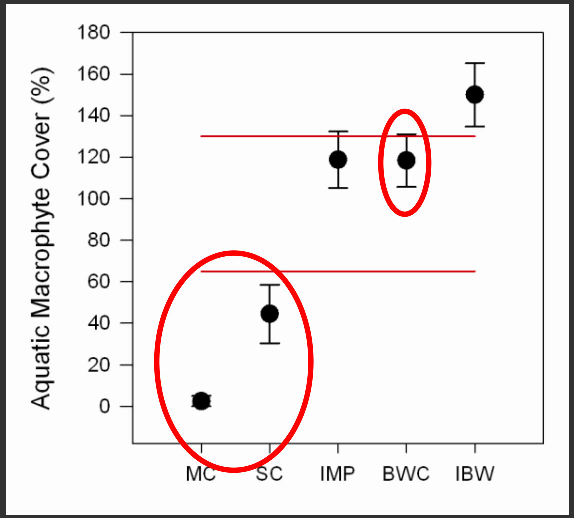
Testing Thresholds
(SRS Data)

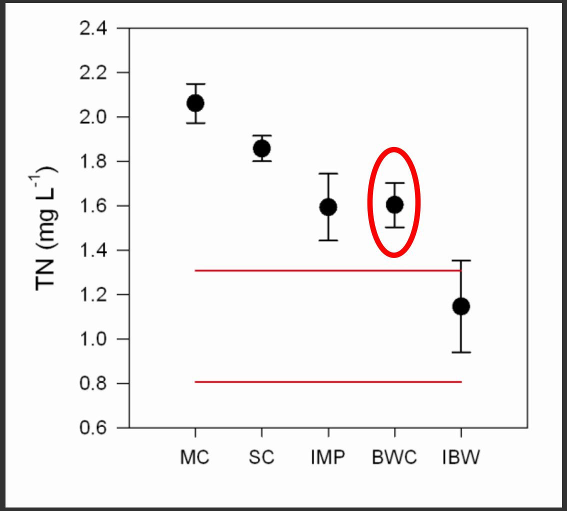


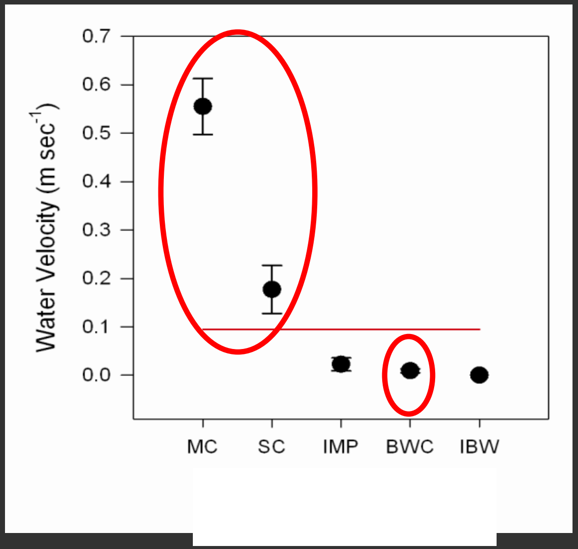
Most to Least Connected

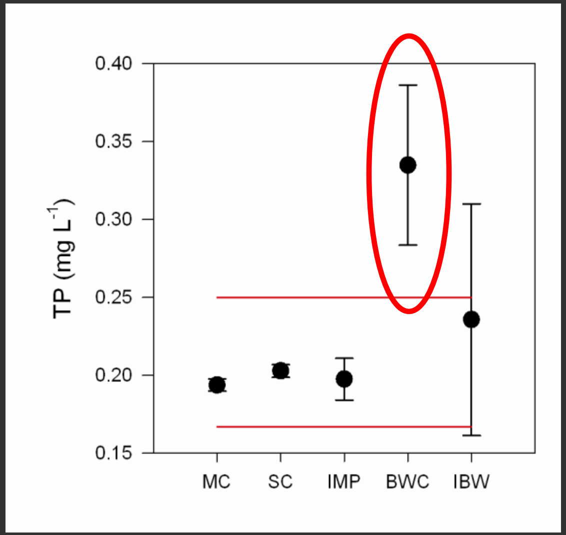
-Physical factors first

- Nutrients play a role only after physical factors are met.









Most to Least Connected

Most to Least Connected