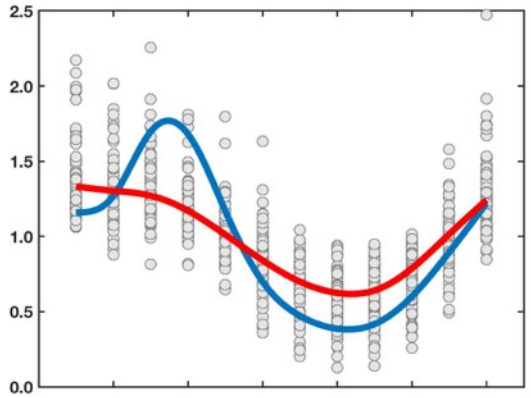
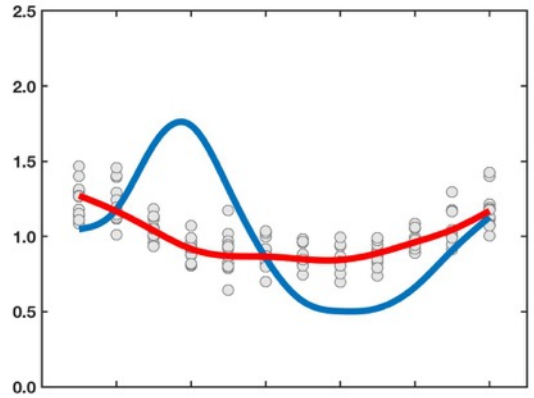
Biogeochemical Asynchrony

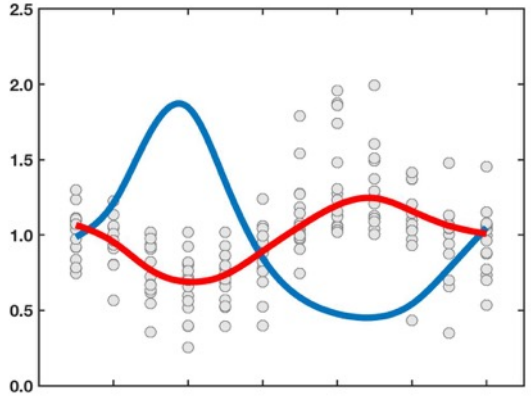
Ecosystem Drivers of Concentration-Discharge Dynamics Across Temporal Scales

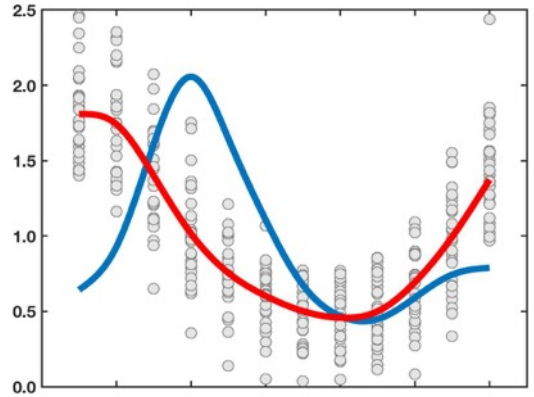
Kim Van Meter, Shadman Chowdry,
Danyka Byrnes, Nandita Basu

June 5, 2018







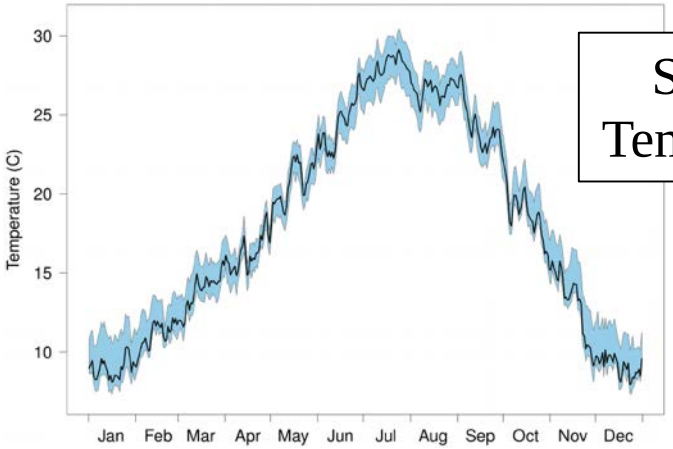


UNIVERSITY OF WATERLOO

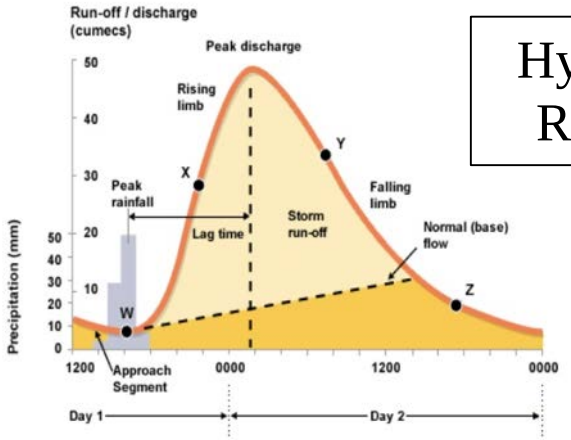
ecohydrology research group

the water INSTITUTE University of Waterloo

“Each stream is characterized by its own ‘heartbeat.’
-von Schiller et al. 2008.



Seasonal Temperatures



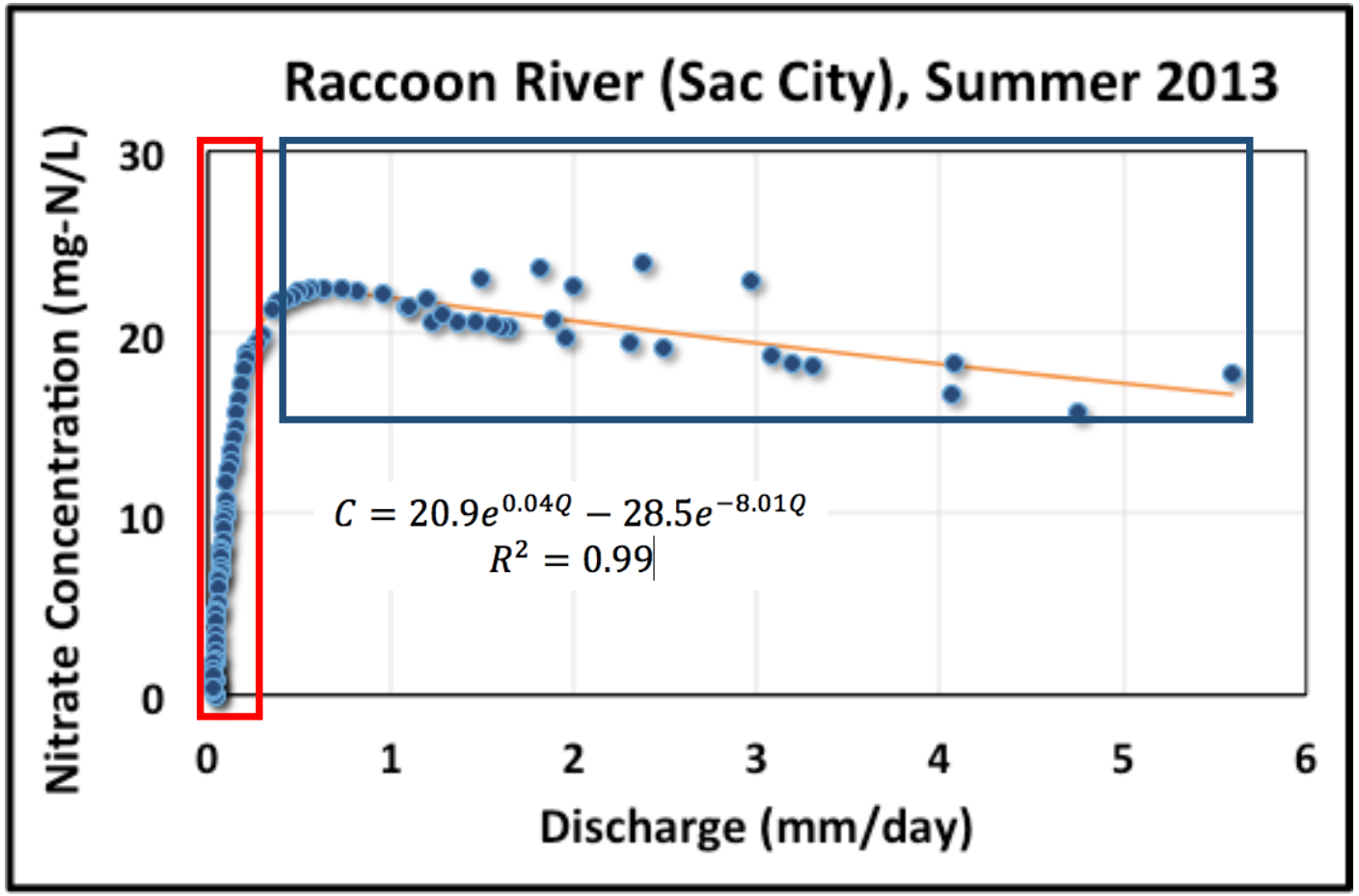
Hydrologic Response

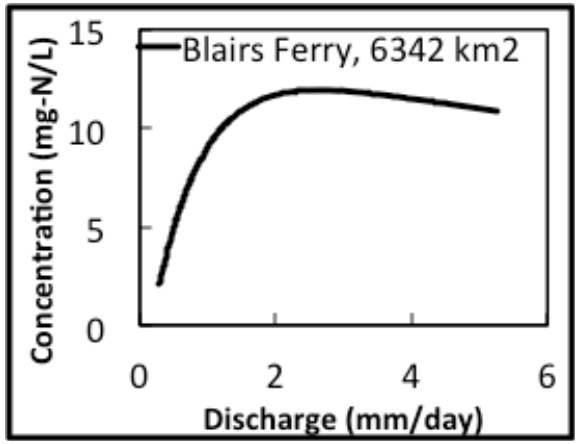
Landscape/Watershed Drivers

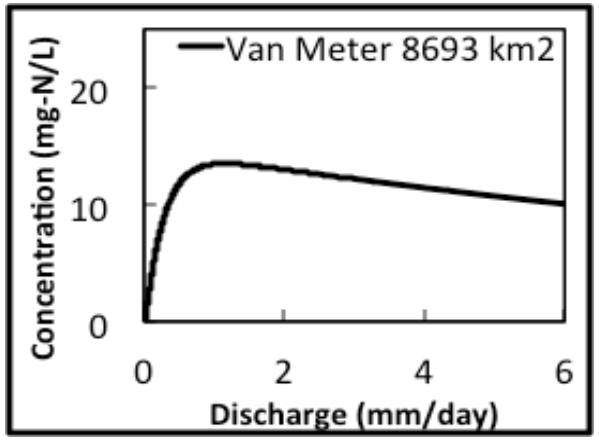
Rainfall Regime

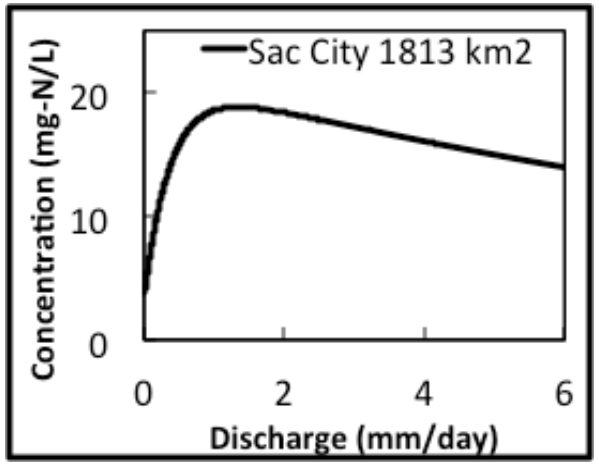
Threshold Effects

Chemodynamic under low flows while chemostatic under high flows?









$$C = aQ^b$$

Overall: b = 0.25, R^2 = 0.7

Red Zone (Regime 1): b = 0.9

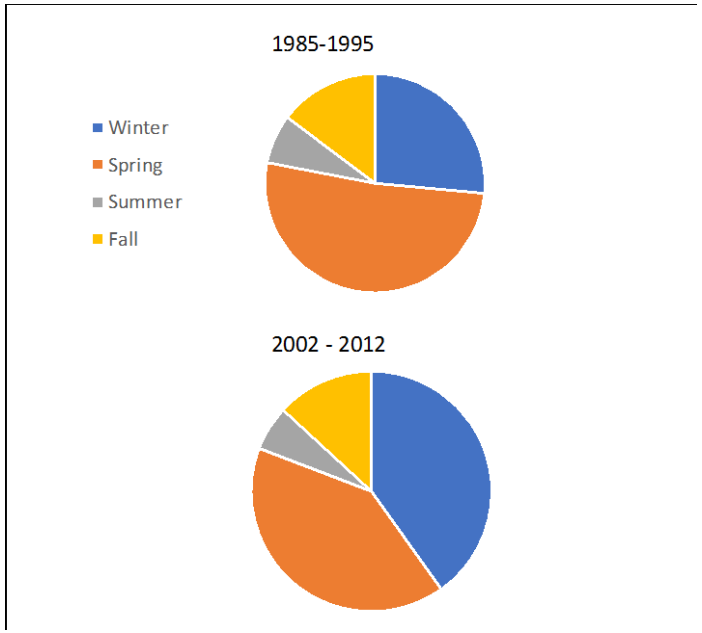
Blue Zone (Regime 2): b = -0.07

Lake Erie

Re-eutrophication

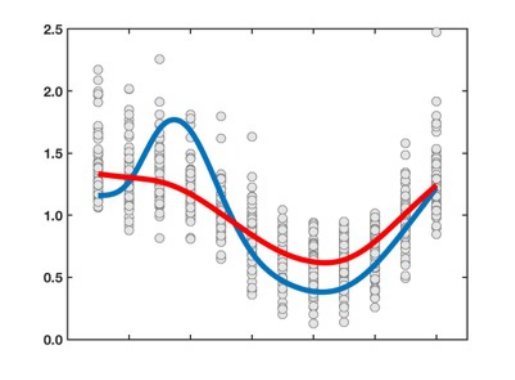
1985-1995
25% of the SRP
transported in winter

2002-2012
more than 40%
transported in winter

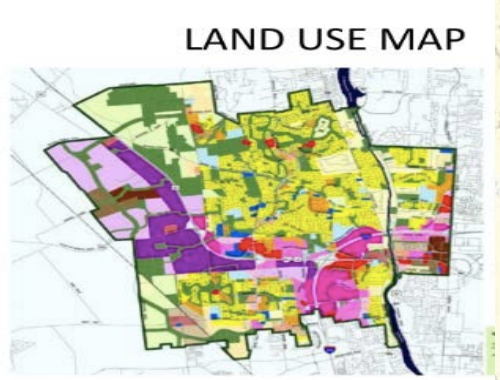


Van Meter & Basu, in prep

Research Questions



How do seasonal nutrient dynamics vary across the Great Lakes Basin?



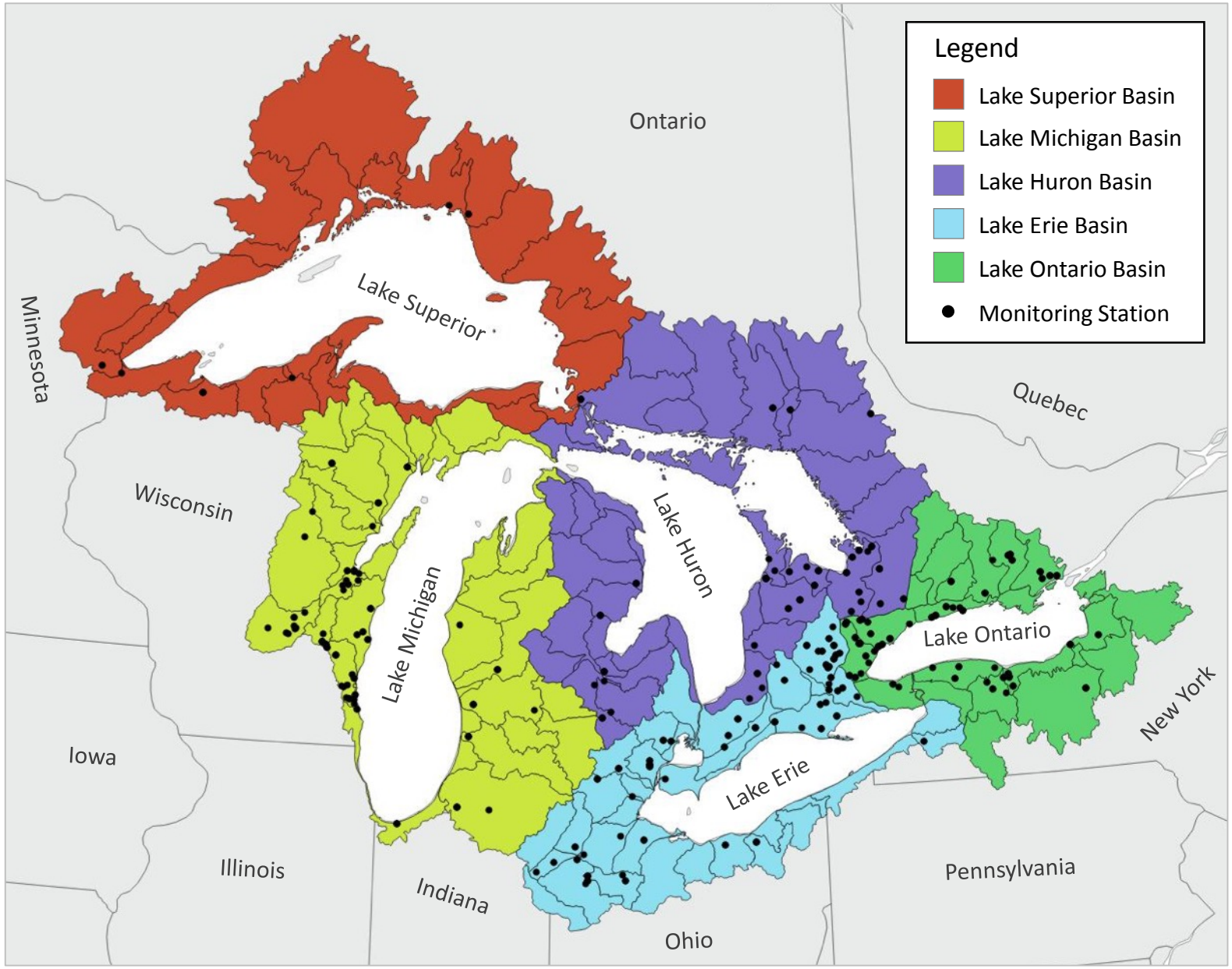
How does land use impact nutrient seasonality?

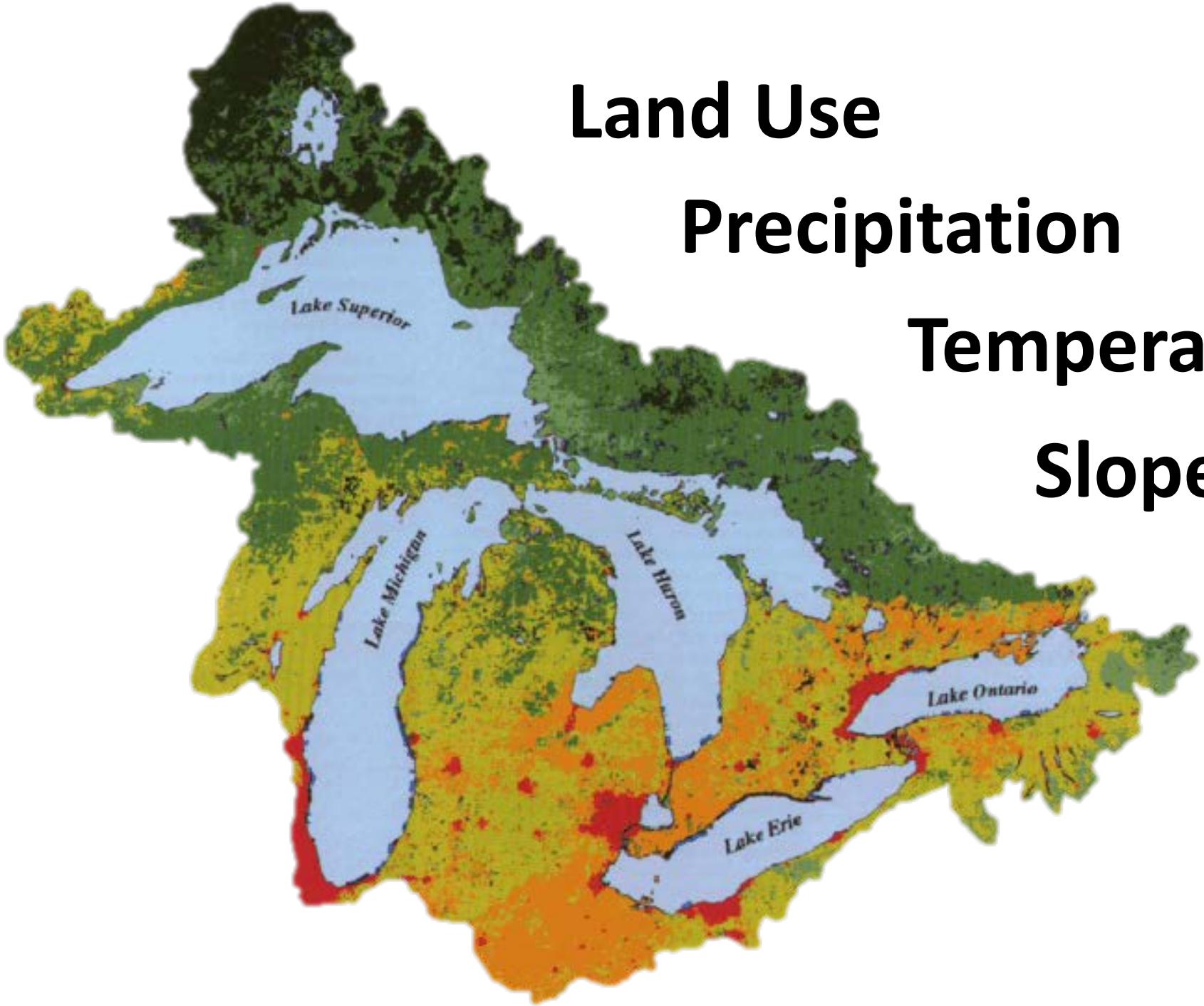
Can we characterize how human activity influences patterns of seasonality in stream nutrient concentrations?

Monitoring Stations across the Great Lakes Basin

185 nitrate
180 soluble reactive P
212 total P

available discharge and water quality data between 2000 and 2014





Land Use

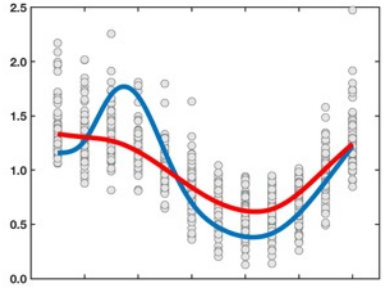
Precipitation

Temperature

Slope

Watershed Area

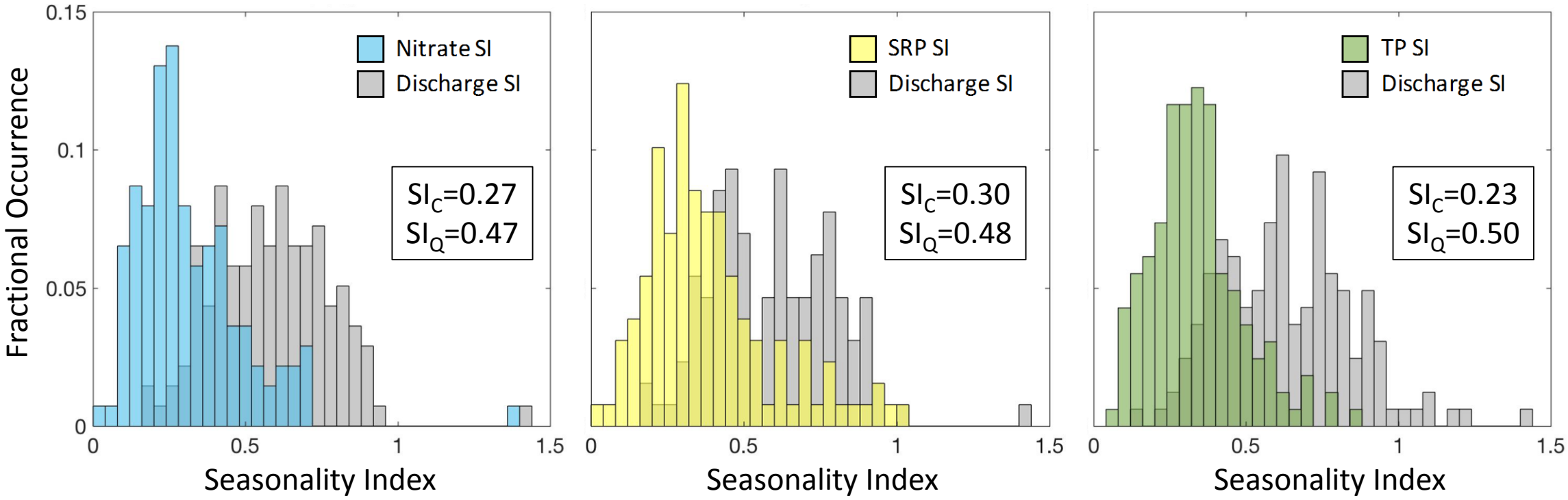
Baseflow Index

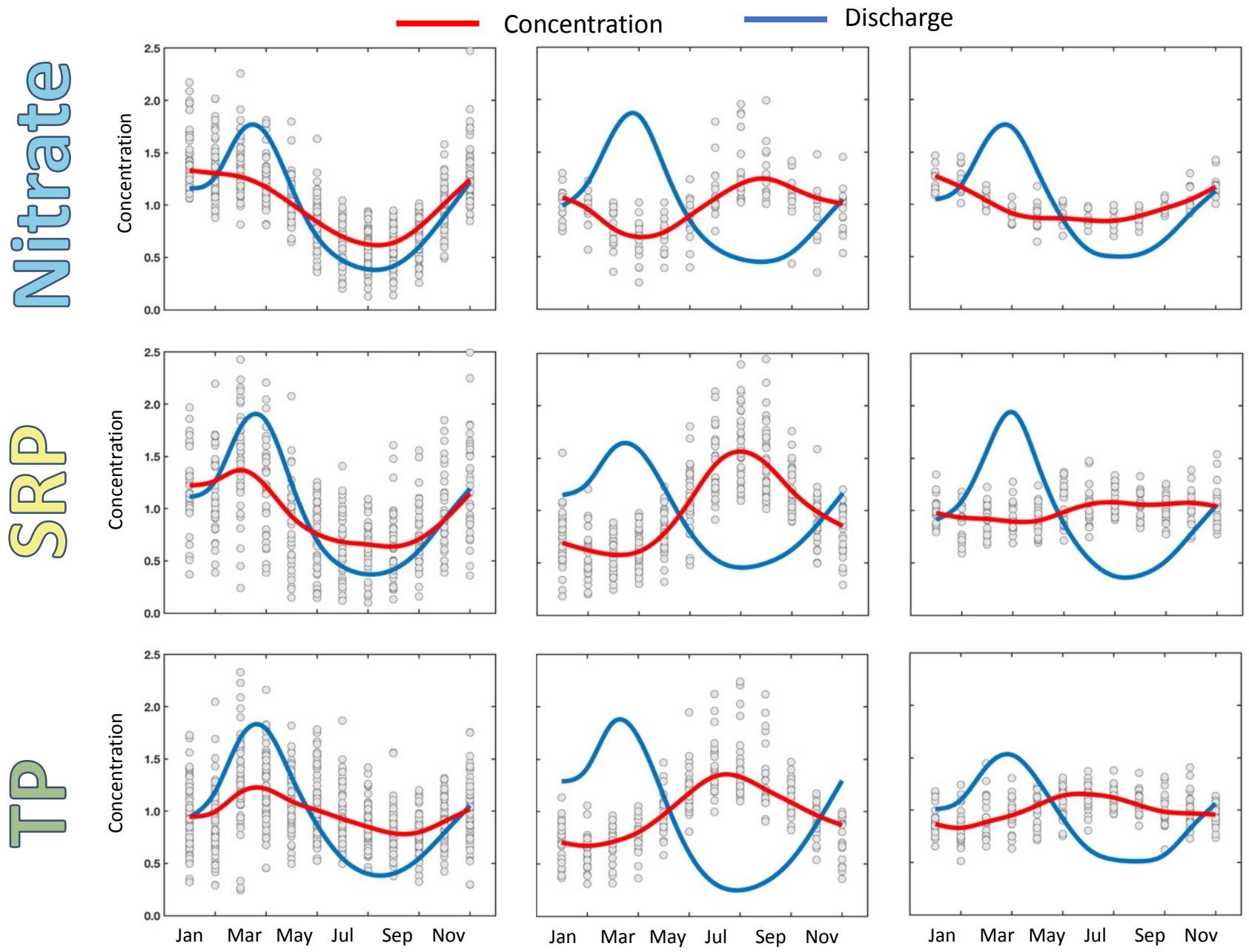


How do nutrient concentrations vary seasonally across the Great Lakes Basin?

Seasonality **I**ndex (SI)

$$SI_C = \frac{1}{C_A}\sum_{i=1}^{12}\left|C_i - \frac{C_A}{12}\right|$$



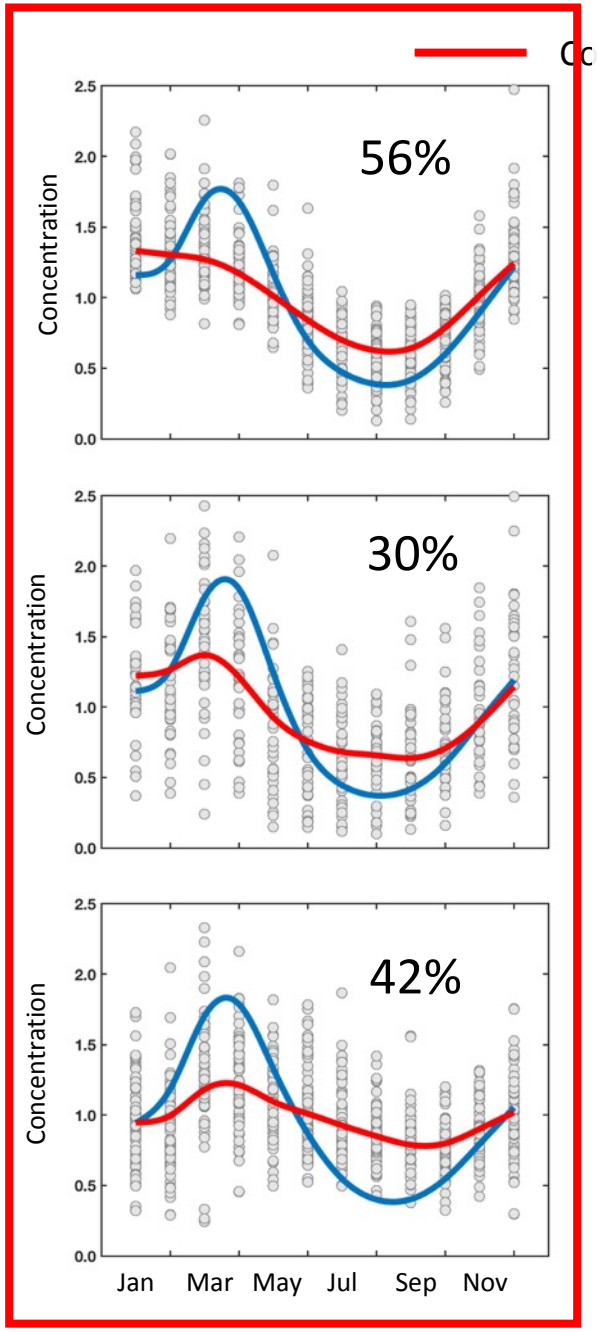


Three primary seasonal concentration regimes accounting for approximately 80% of watersheds

Nitrate

SRP

TP



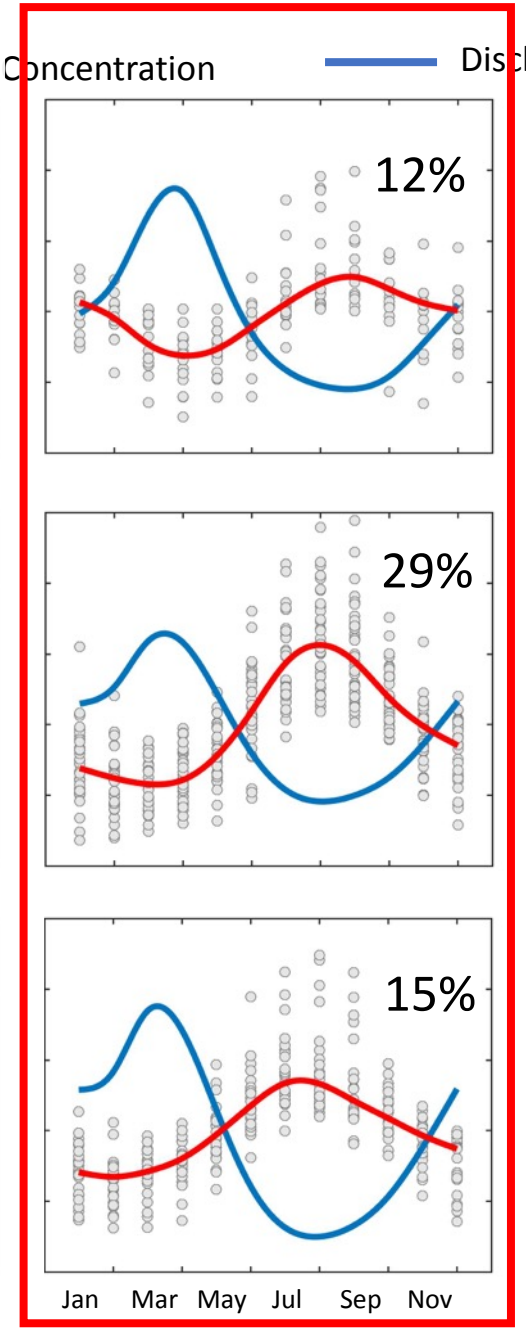
In Phase =

positive significant relationship between monthly concentrations and monthly discharge

Nitrate

SRP

TP



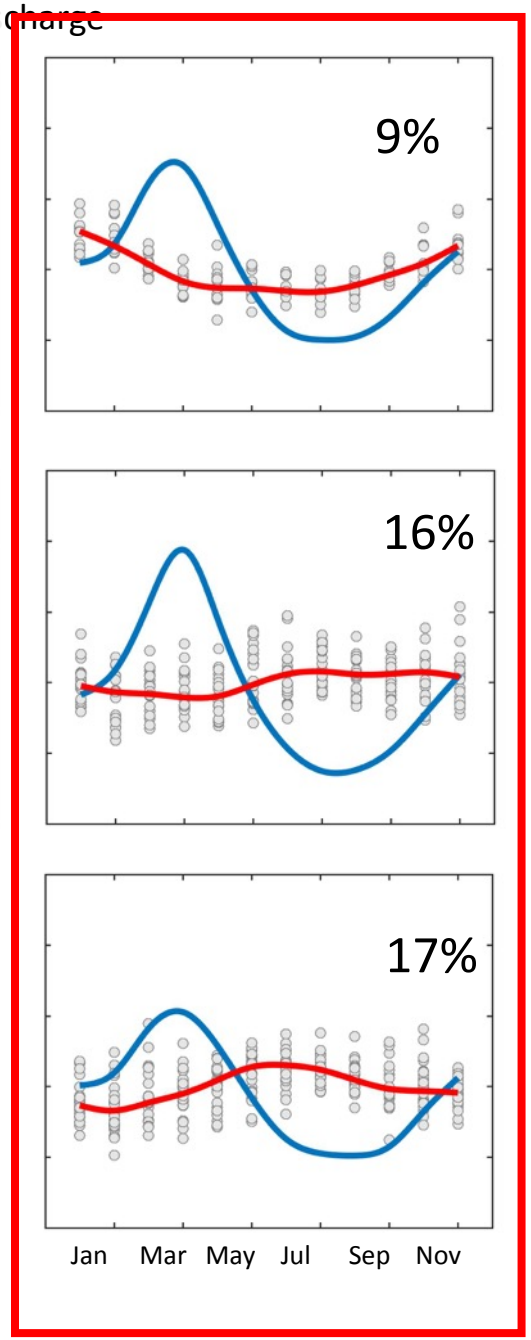
Out-of-Phase =

Negative significant relationship between monthly concentrations and monthly discharge

Nitrate

SRP

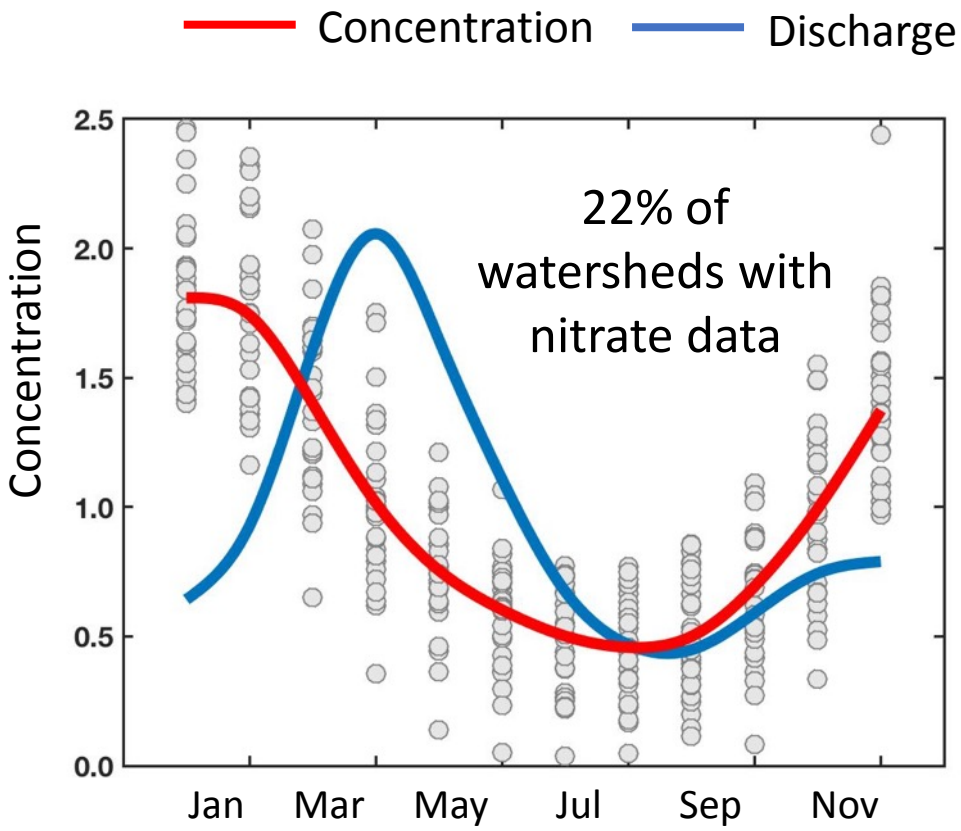
TP



Stationary =

NO significant relationship between monthly concentrations and monthly discharge, SI < 0.2

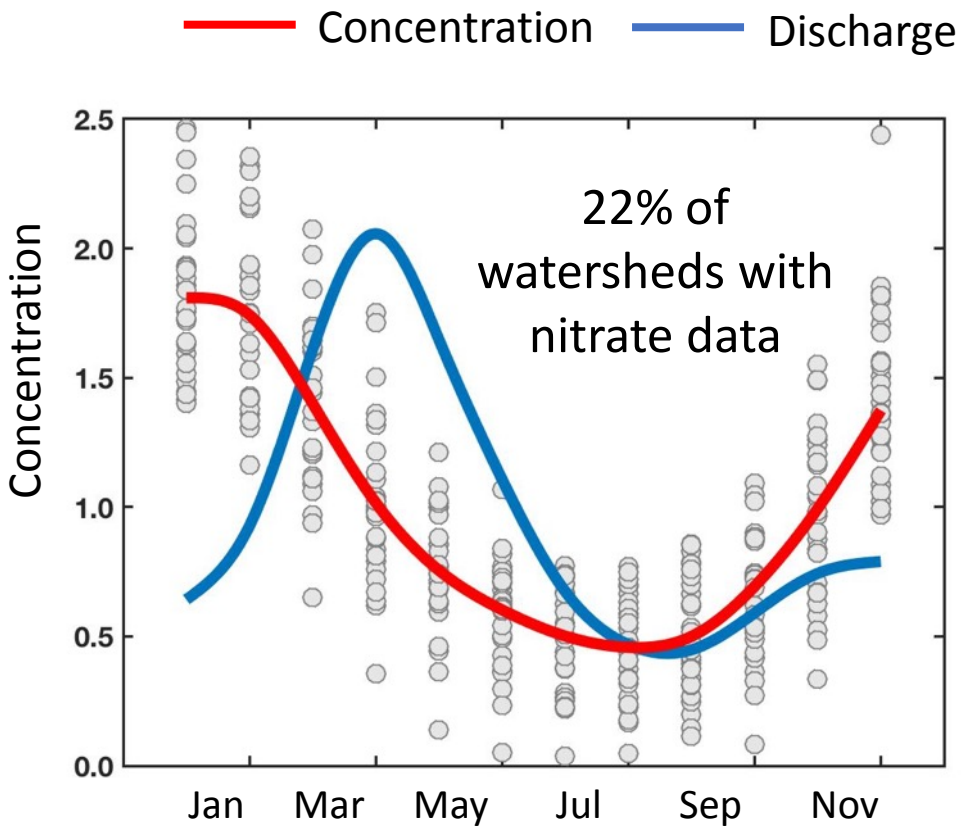
Nitrate



winter peaks

summer troughs

Nitrate

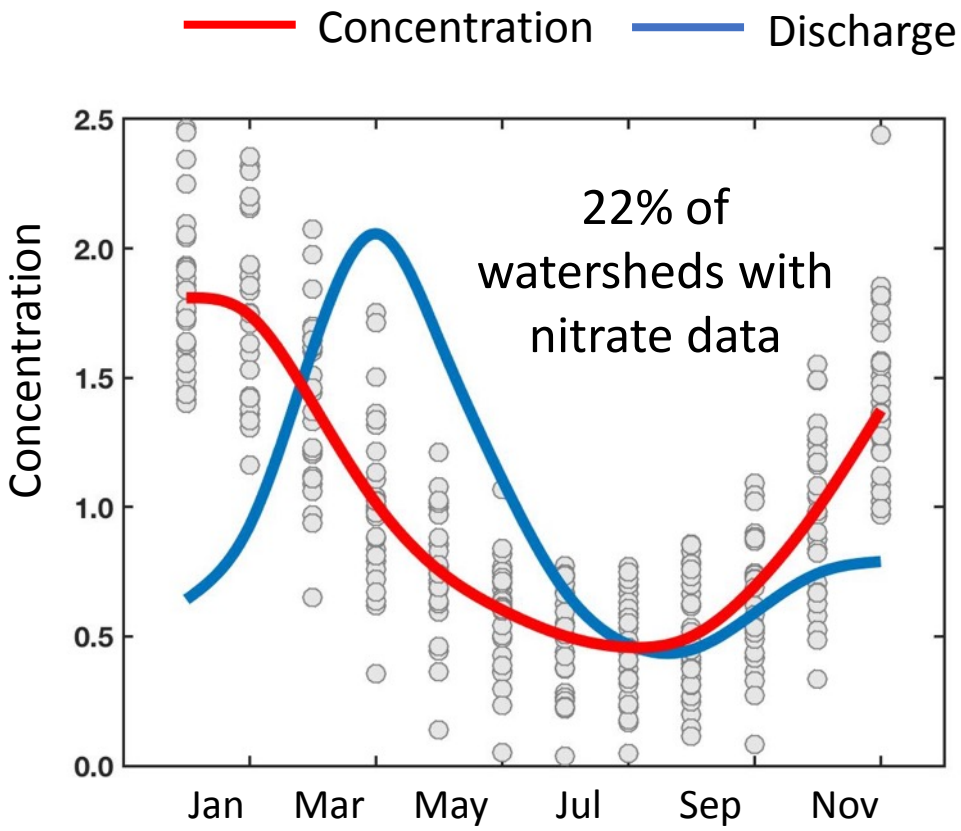


$SI_C = 0.44$

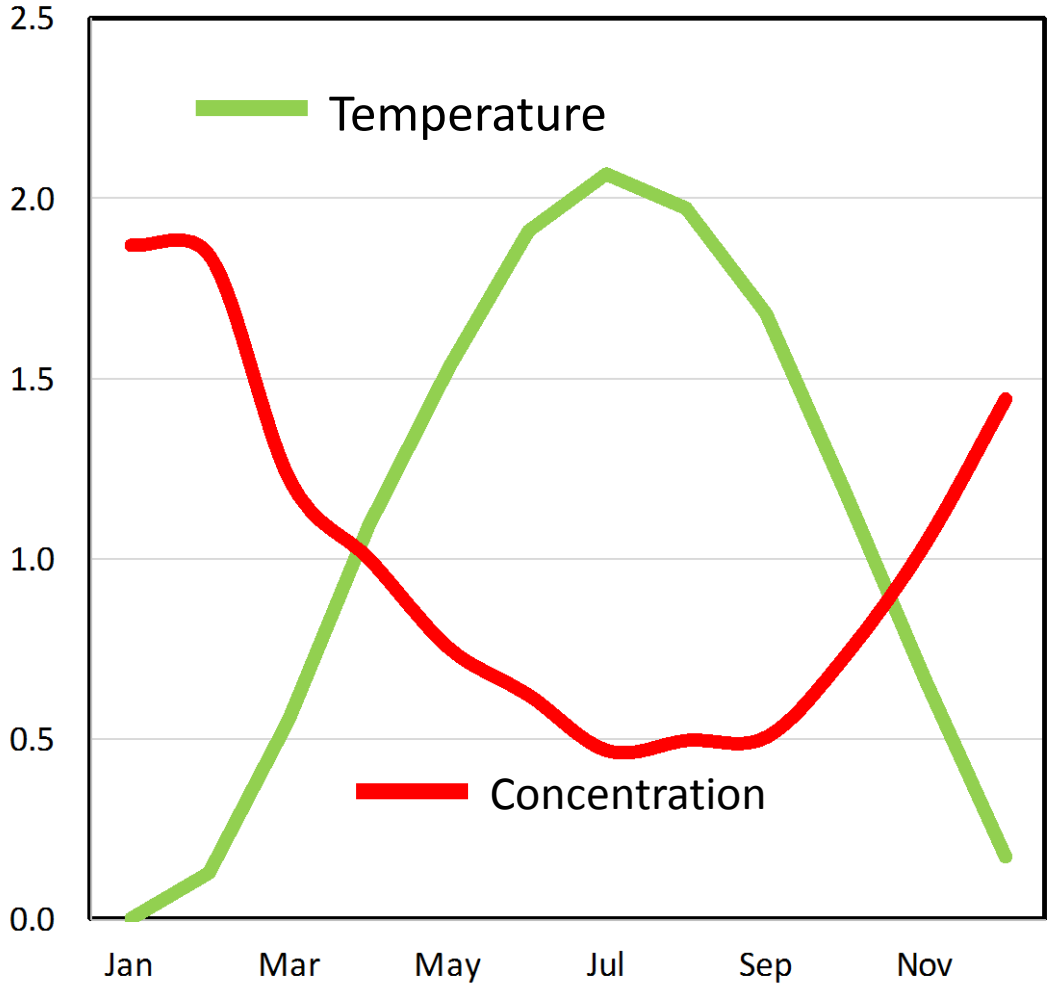
median $SI_C = 0.27$

high seasonality

Nitrate

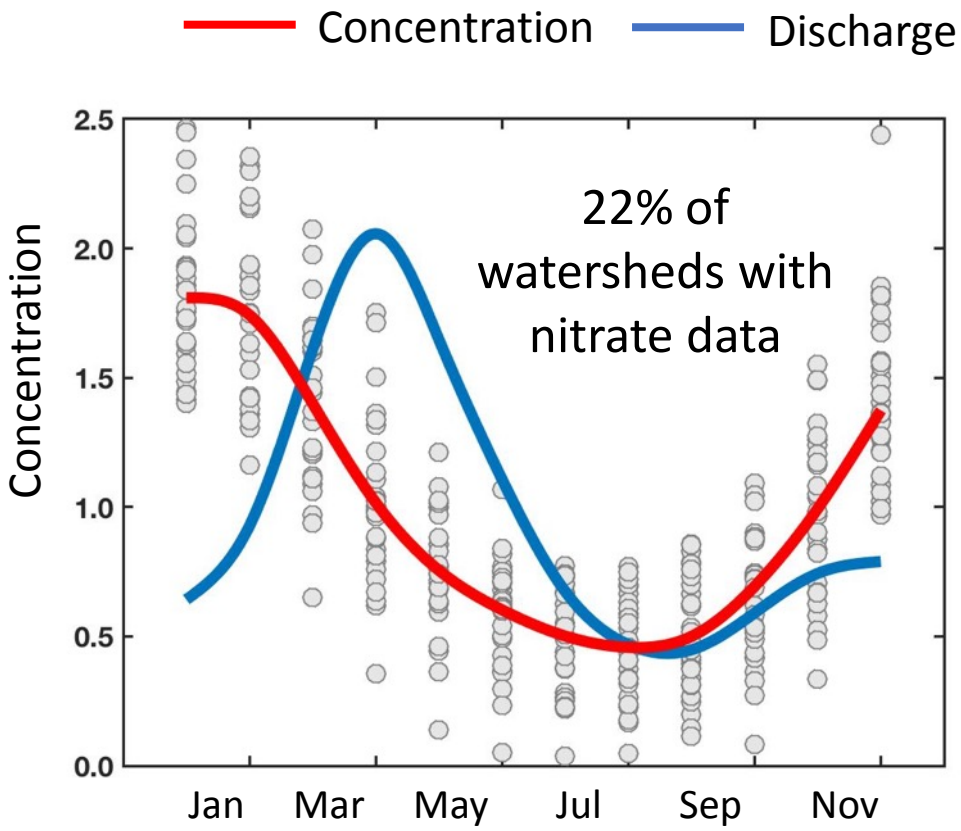


decoupled from seasonal discharge dynamics



strong coupling with seasonal temperature dynamics

Nitrate



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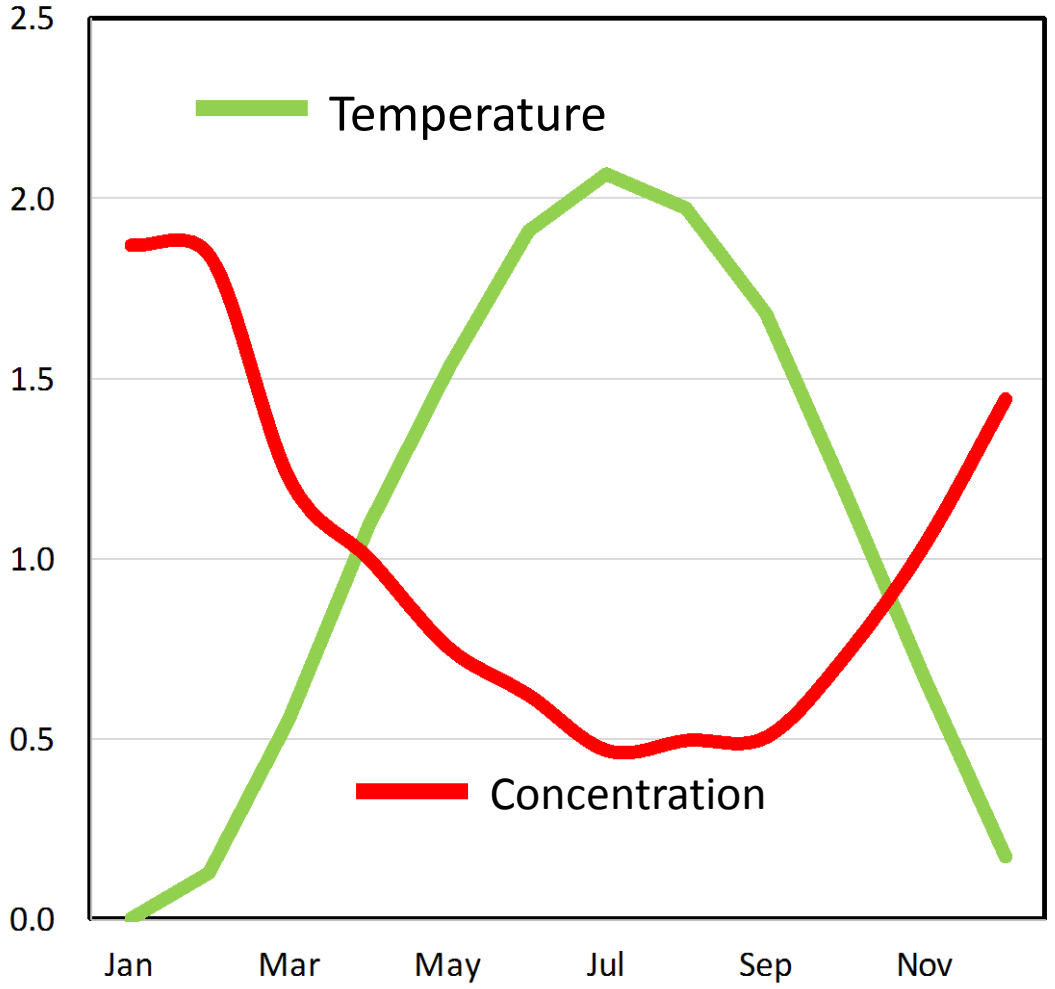
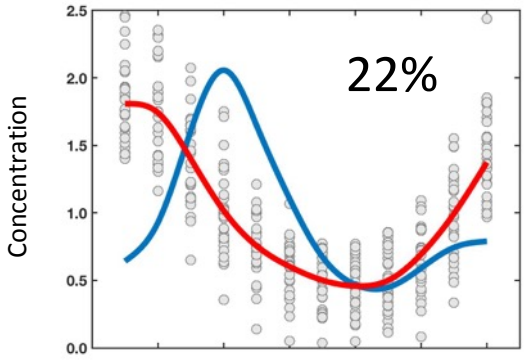


seasonal variations in **denitrification rate**

Concentration Discharge

Nitrate



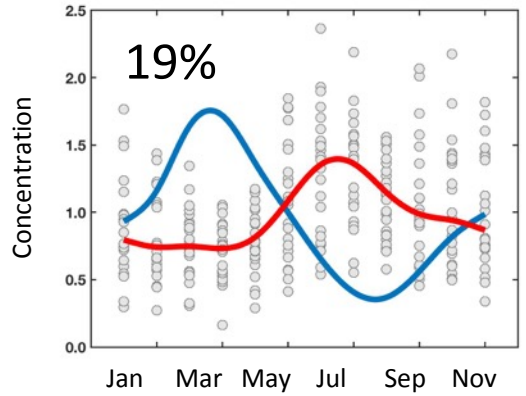
$SI_C = 0.44$

median nitrate $SI_C = 0.27$

~ higher seasonality

concentrations asynchronous with discharge

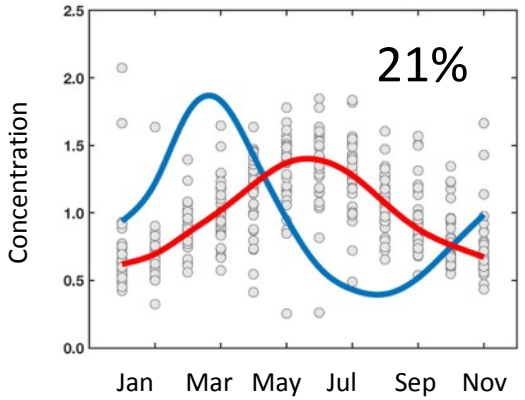
SRP



$SI_C = 0.32$

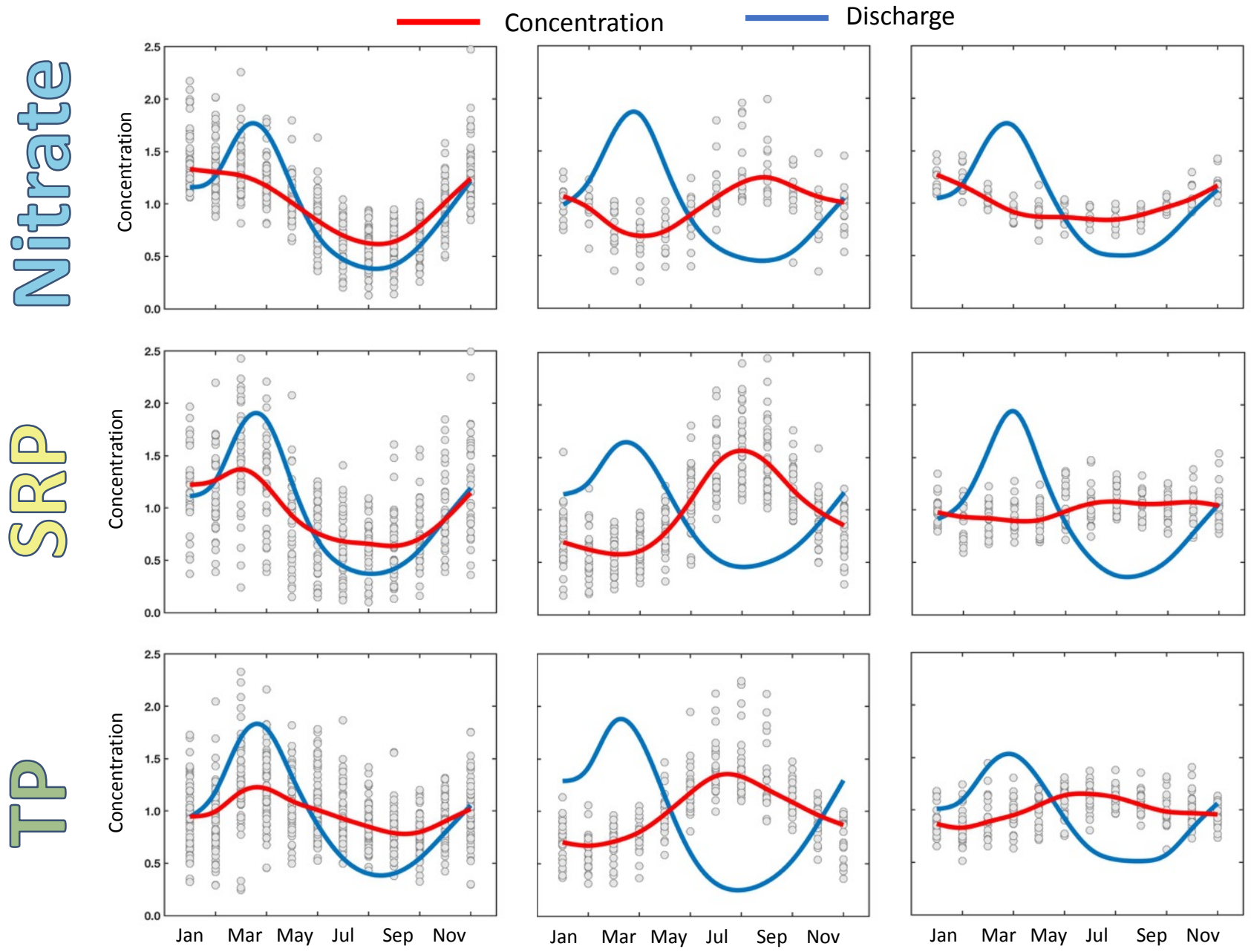
median SRP $SI_C = 0.30$

TP



$SI_C = 0.27$

median TP $SI_C = 0.23$



What is driving differences in seasonal concentration regimes?

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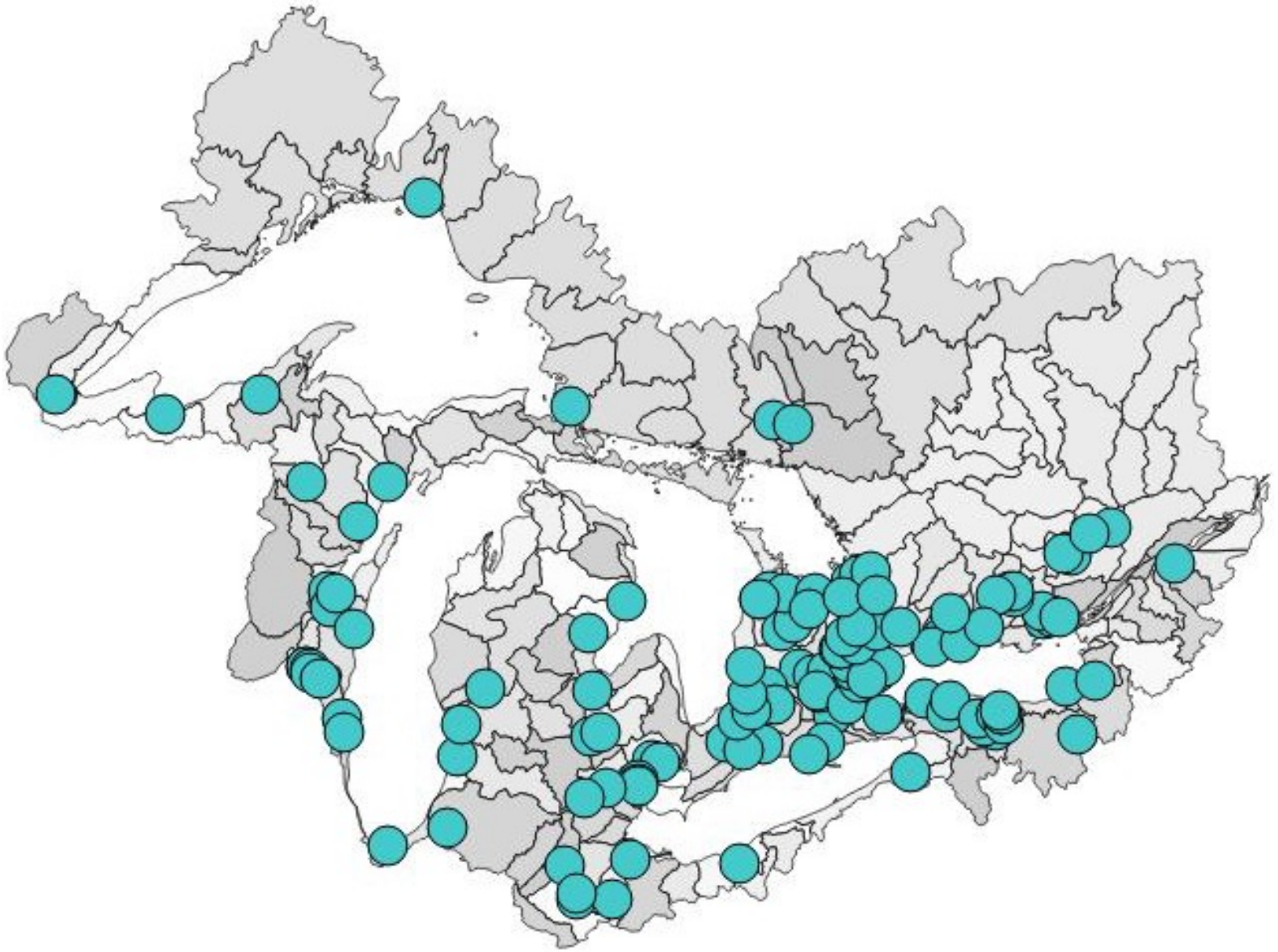

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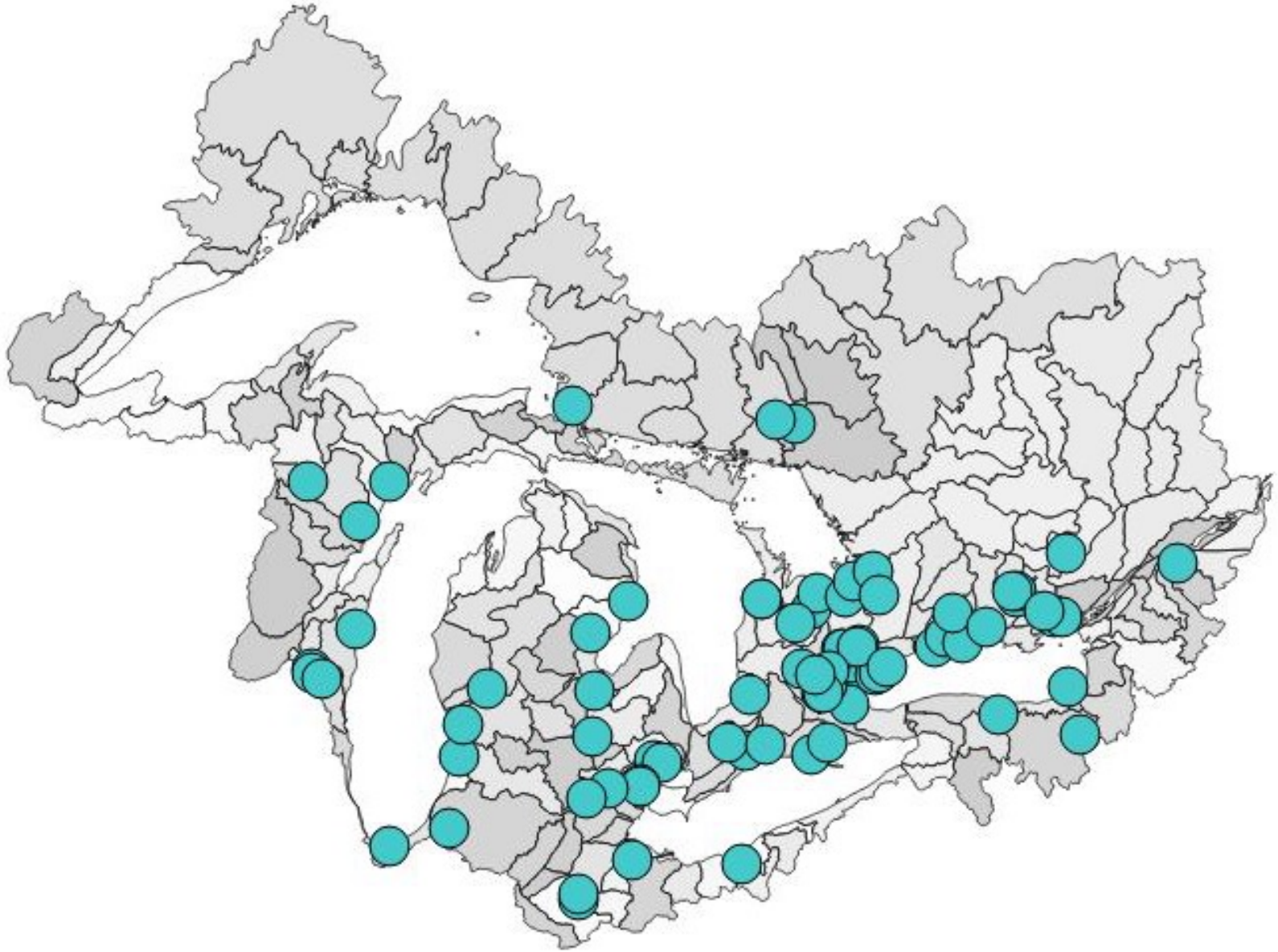
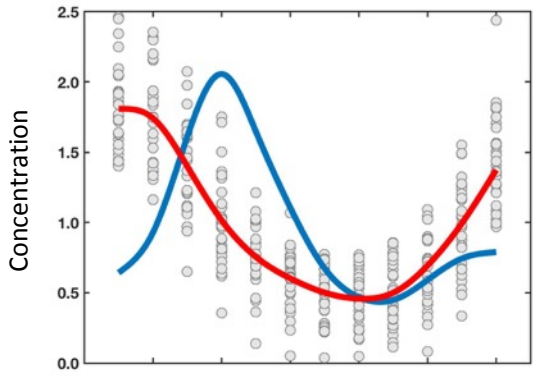
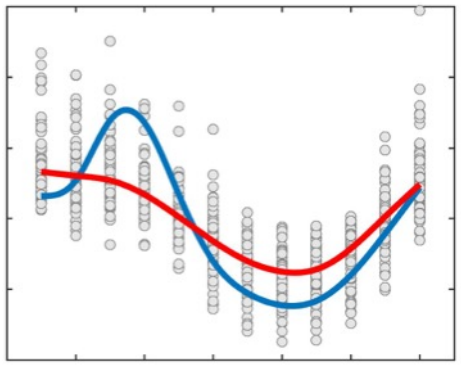


Nitrate

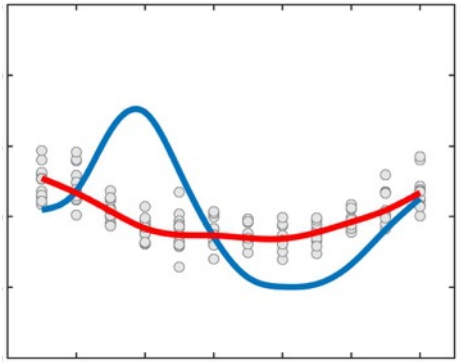
Temp-Driven



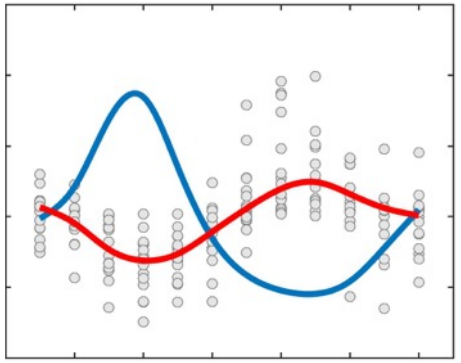
In-Phase

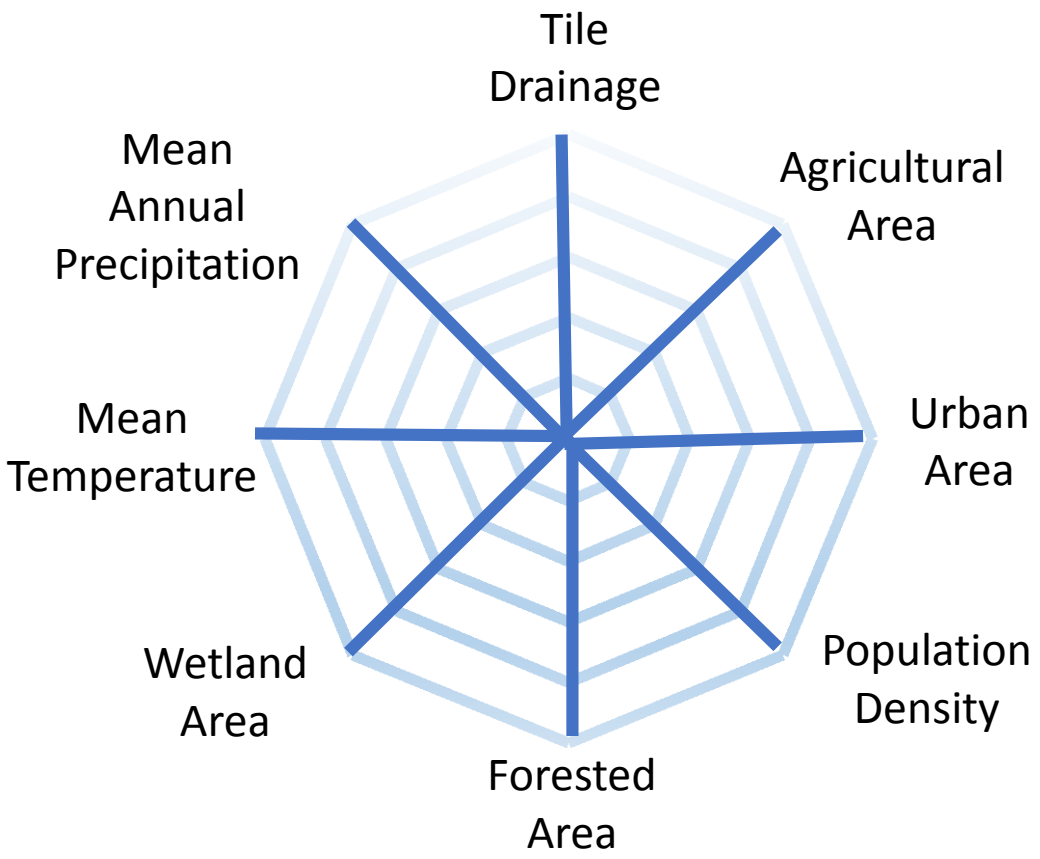


Stationary



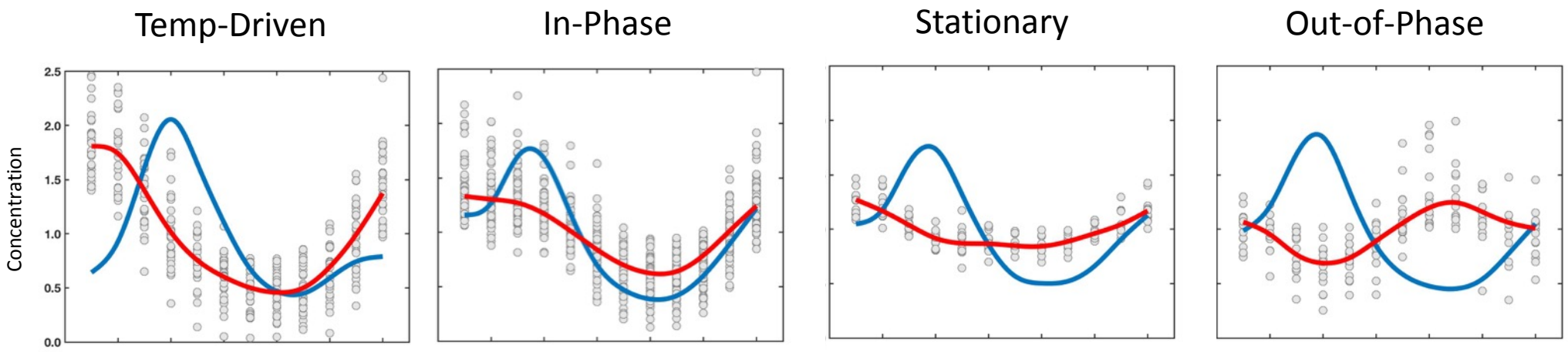
Out-of-Phase

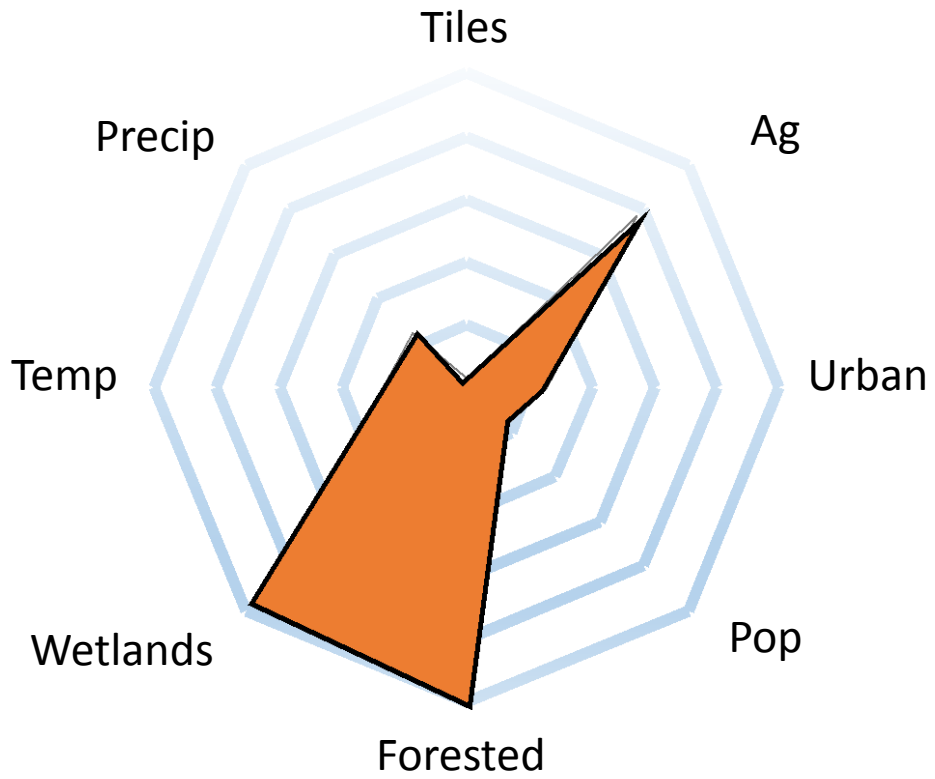




Watershed Characteristics	Range
(A) % Agriculture	18-56%
(Ti) Tile Drainage Density	0-7%
(U) % Urban	0-20%
(P) Population Density	0- >150 person/km^2
(F) % Forested	10-30%
(W) % Wetland	5-17%
(T) Mean Annual Temp	6-8 °C
(Pr) Mean Annual Precip	800-945 mm

Nitrate





Temp-Driven

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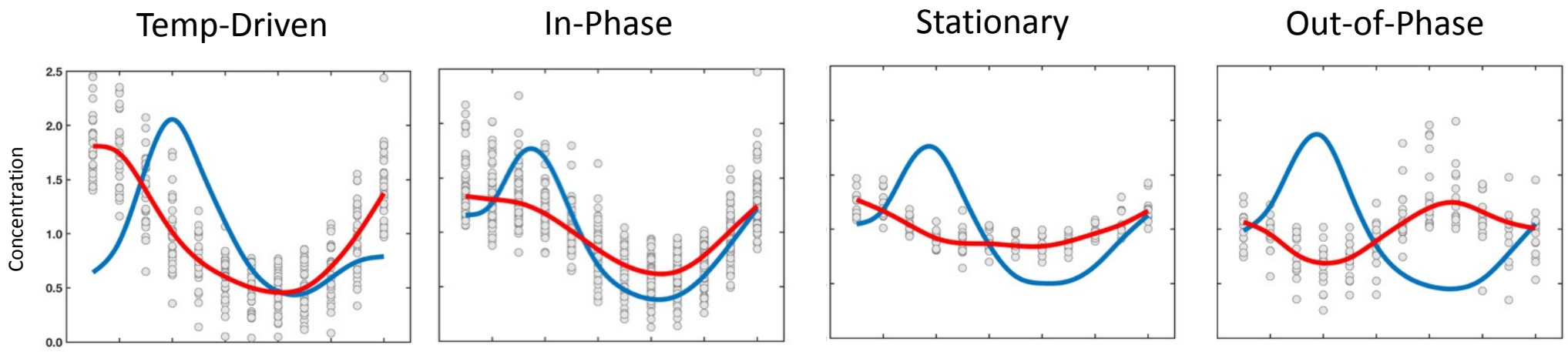
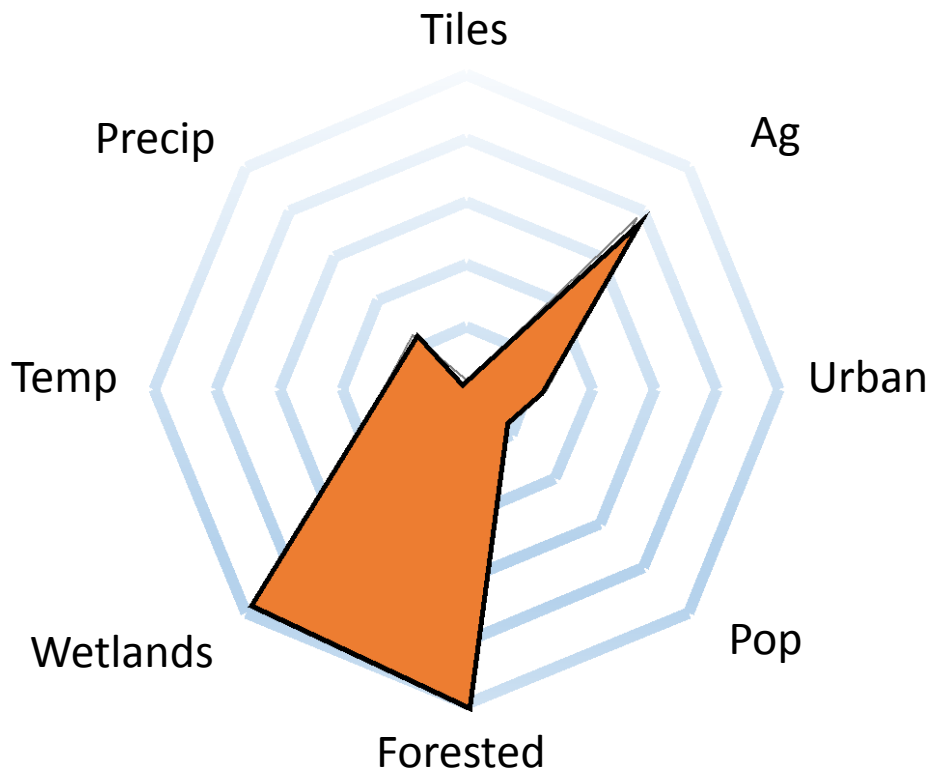
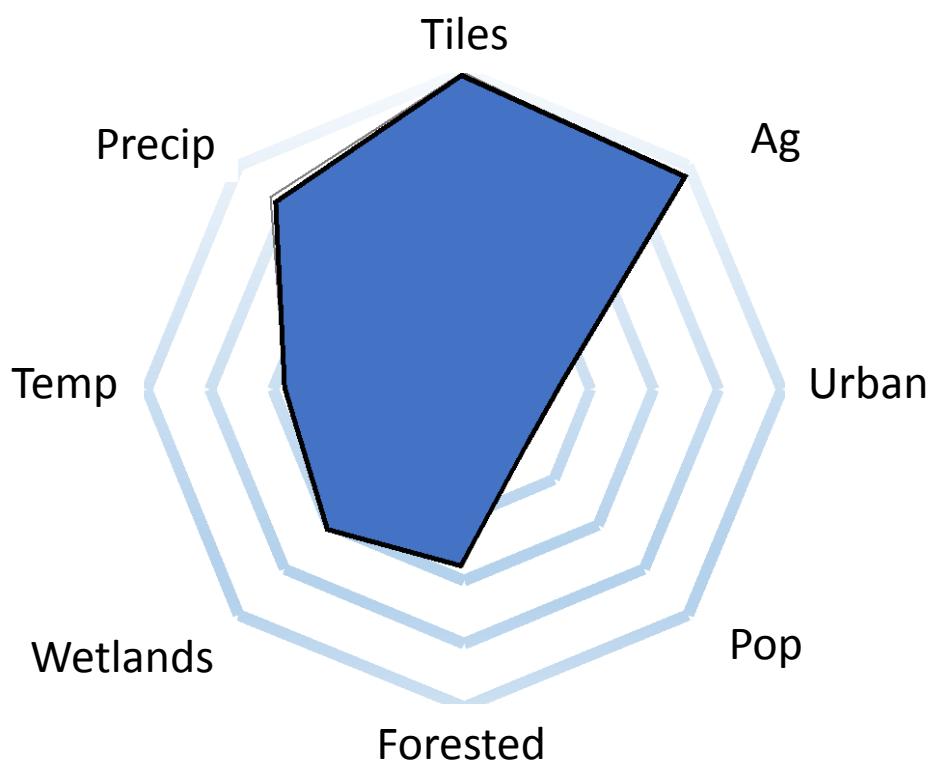




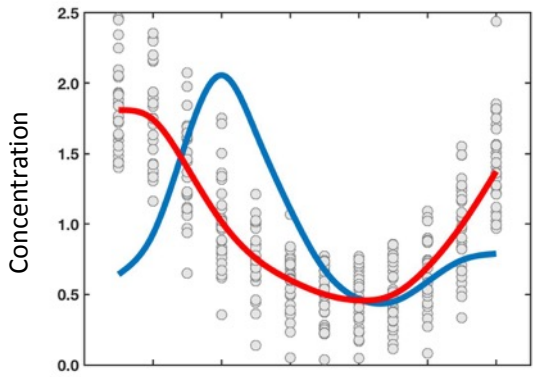
Temp-Driven

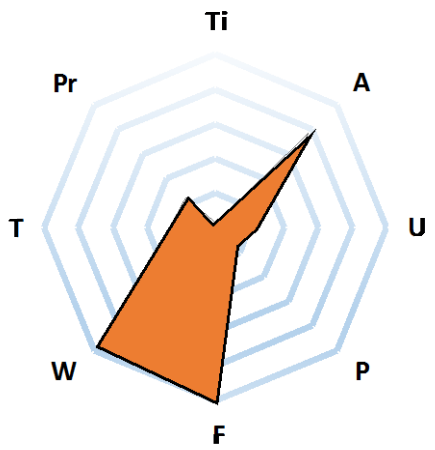


In-Phase, Discharge-Driven

Nitrate

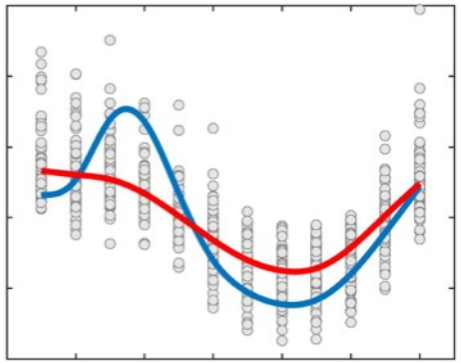
Temp-Driven

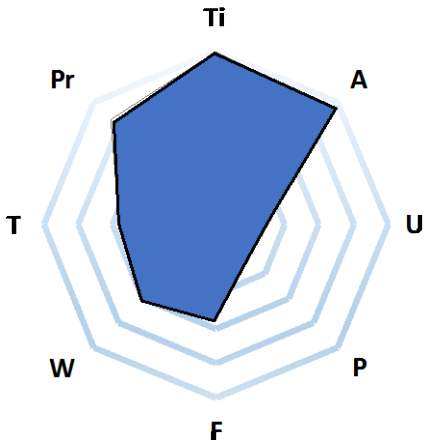




Temp-Driven

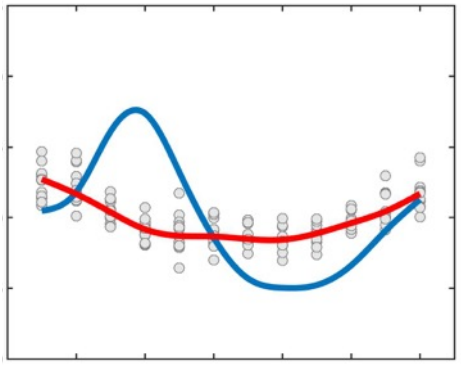
In-Phase

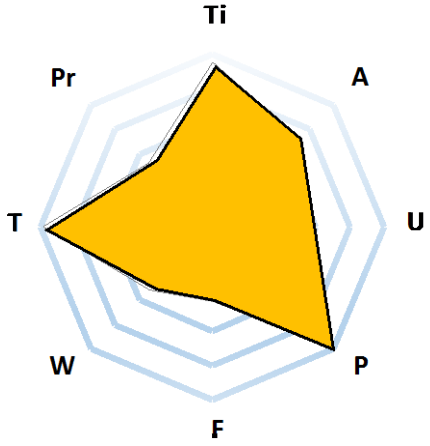




Discharge Driven

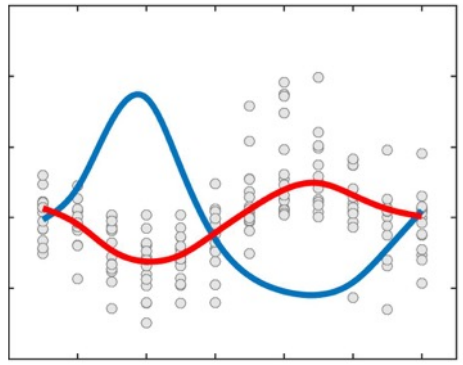
Stationary

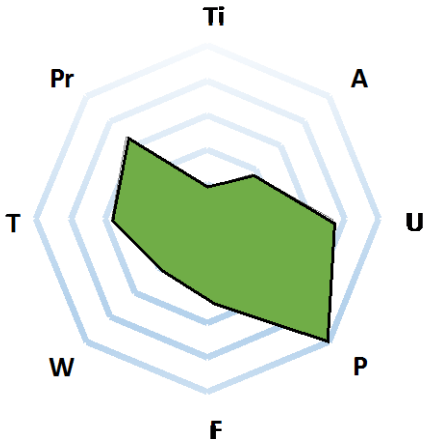




Mixed Sources

Out-of-Phase





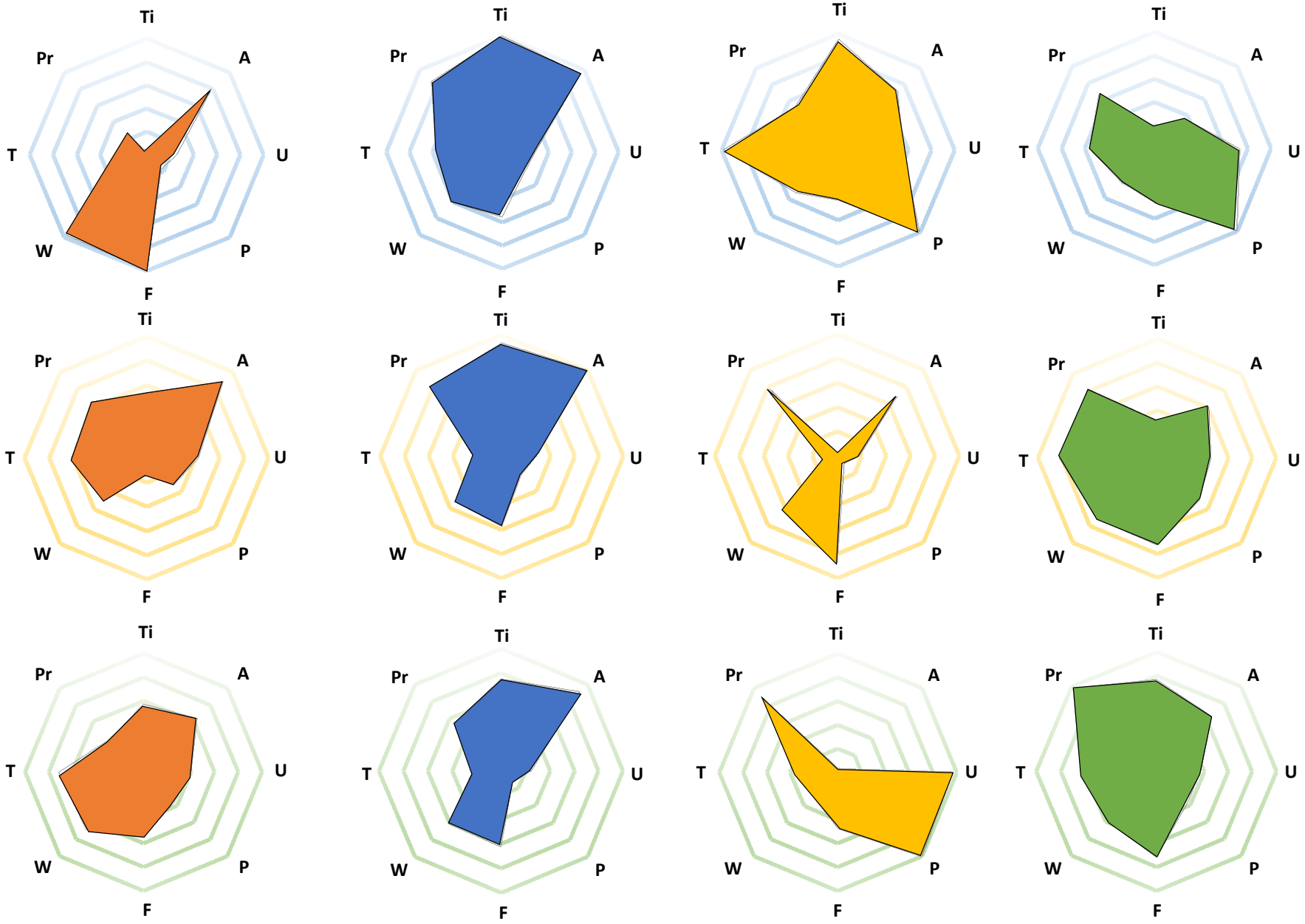
Point Sources

Temp-Driven

Q-Driven

Mixed Sources

Point Sources??



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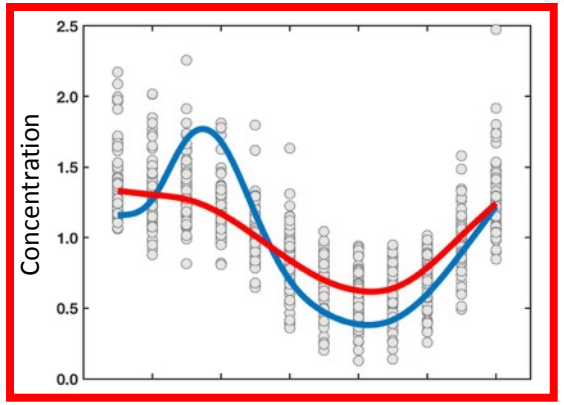
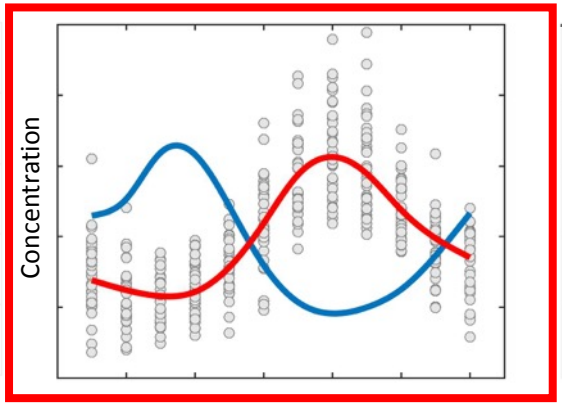
Temperature-Drive	(TD)
In-phase	(IP)
Stationary	(S)
Out-of-Phase	(OP)

Nitrate



In-Phase Nitrate

SRP



Out-of-Phase SRP

ASYNCHRONY

What is driving differences in seasonal concentration regimes?

Paired Watersheds

Muskegon River
Niles, Michigan

Rifle

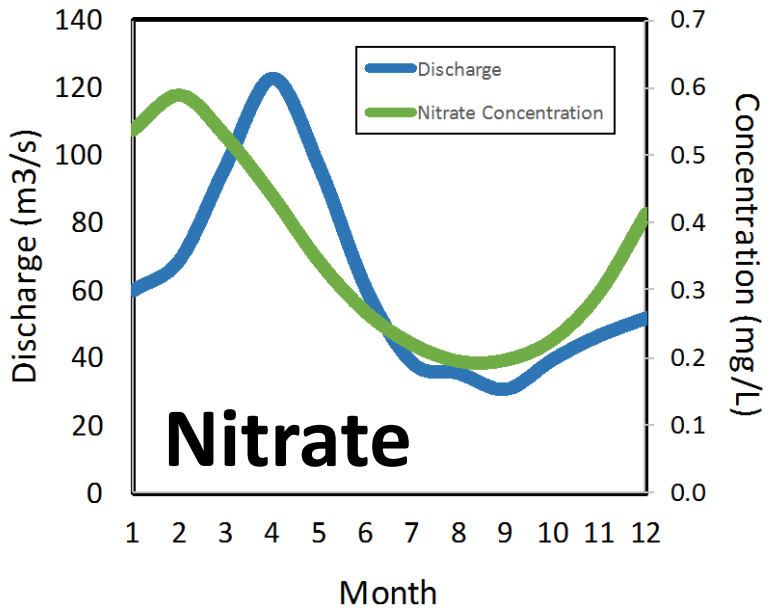
17% agricultural
9% urban
43% forested
23% wetland
2% tile-drained

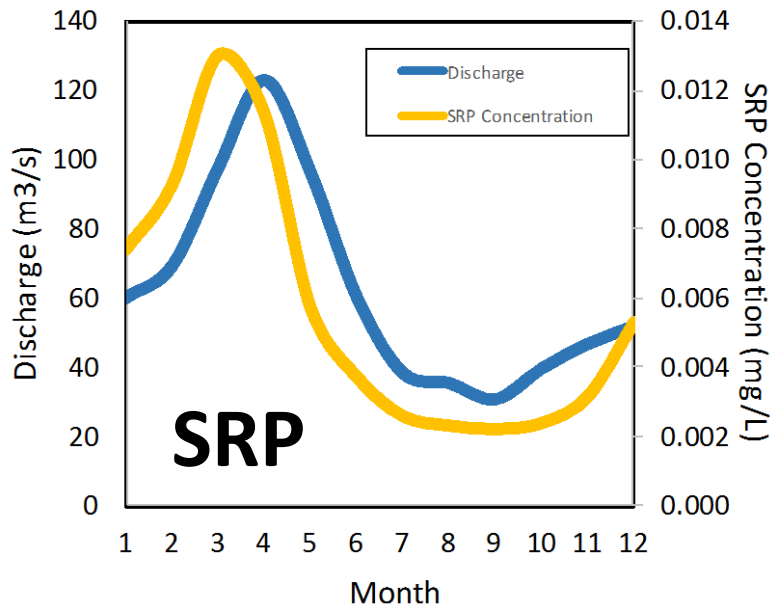
Muskegon

19% agricultural
7% urban
40% forested
23% wetland
6% tile-drained

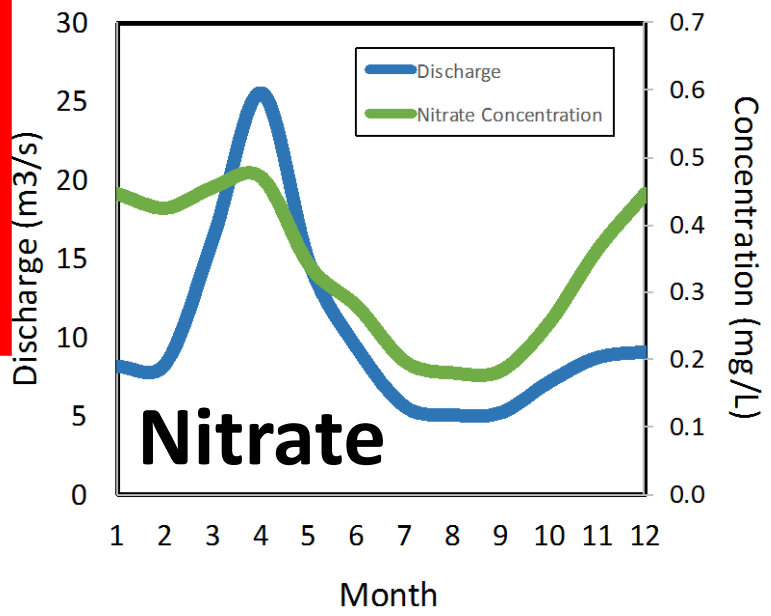
Paired Watersheds

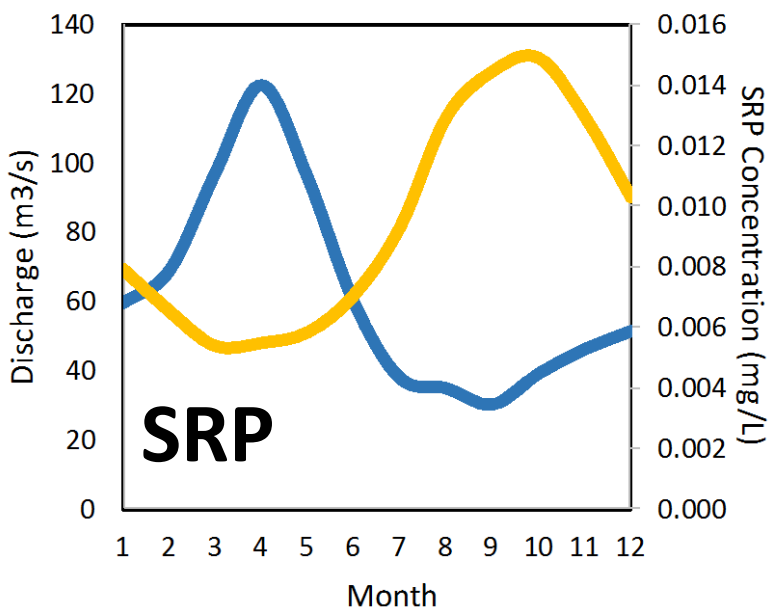
Muskegon River
Niles, Michigan

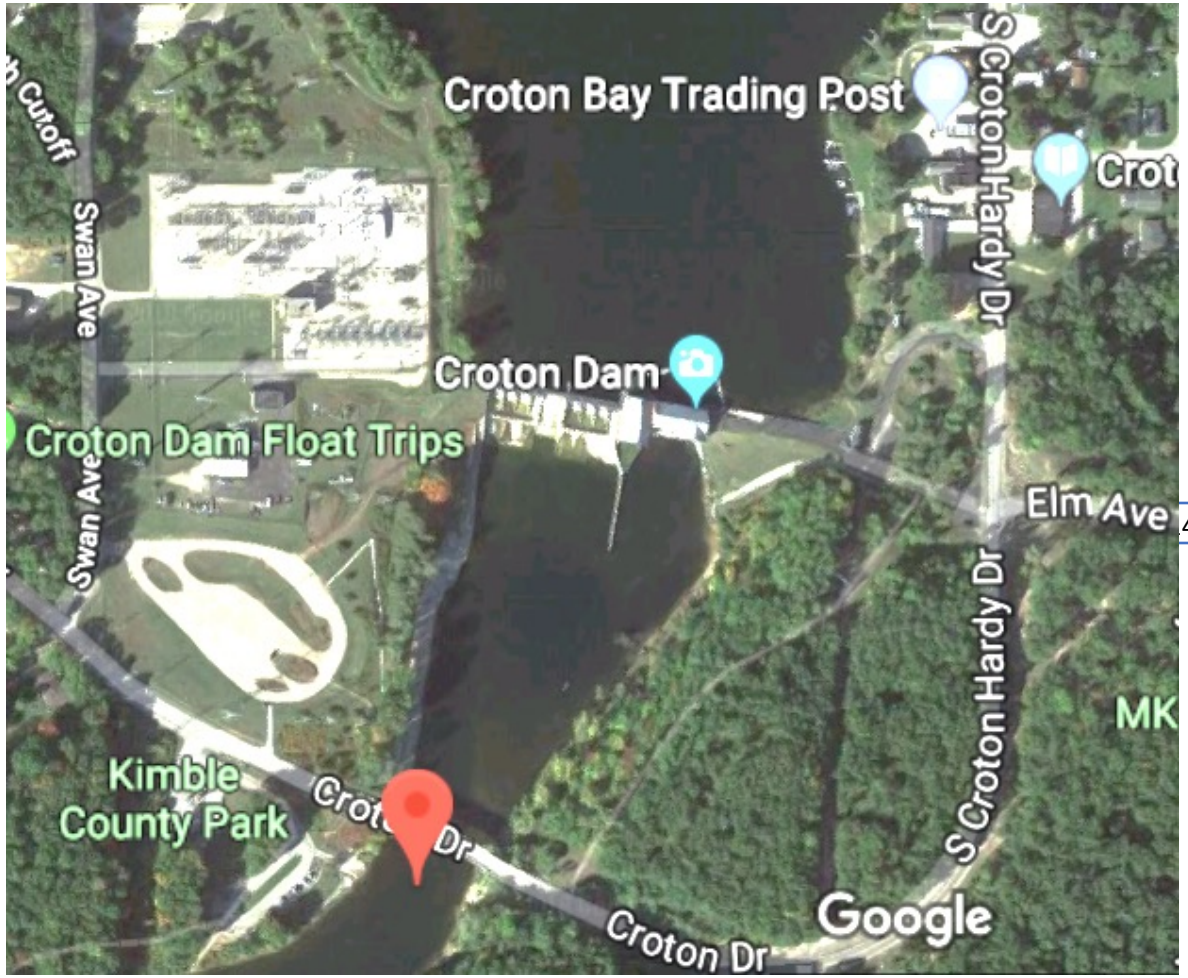




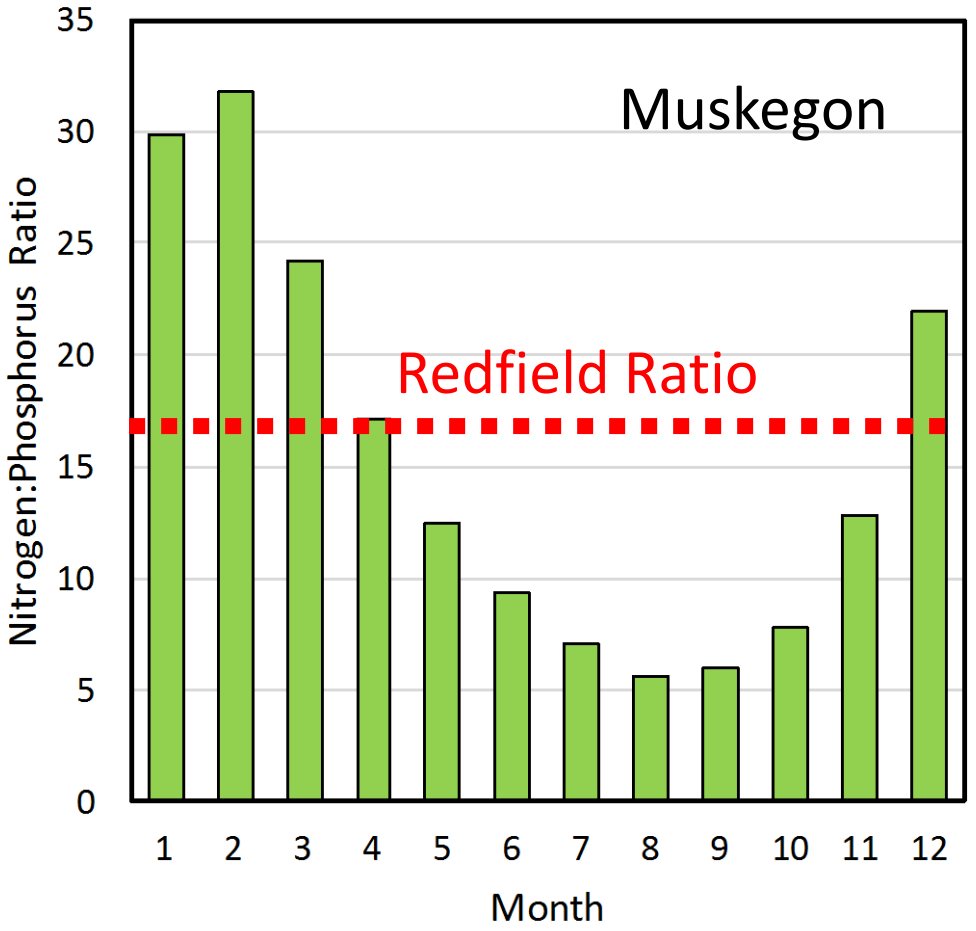
Reservoirs as Biogeochemical Hot Spots



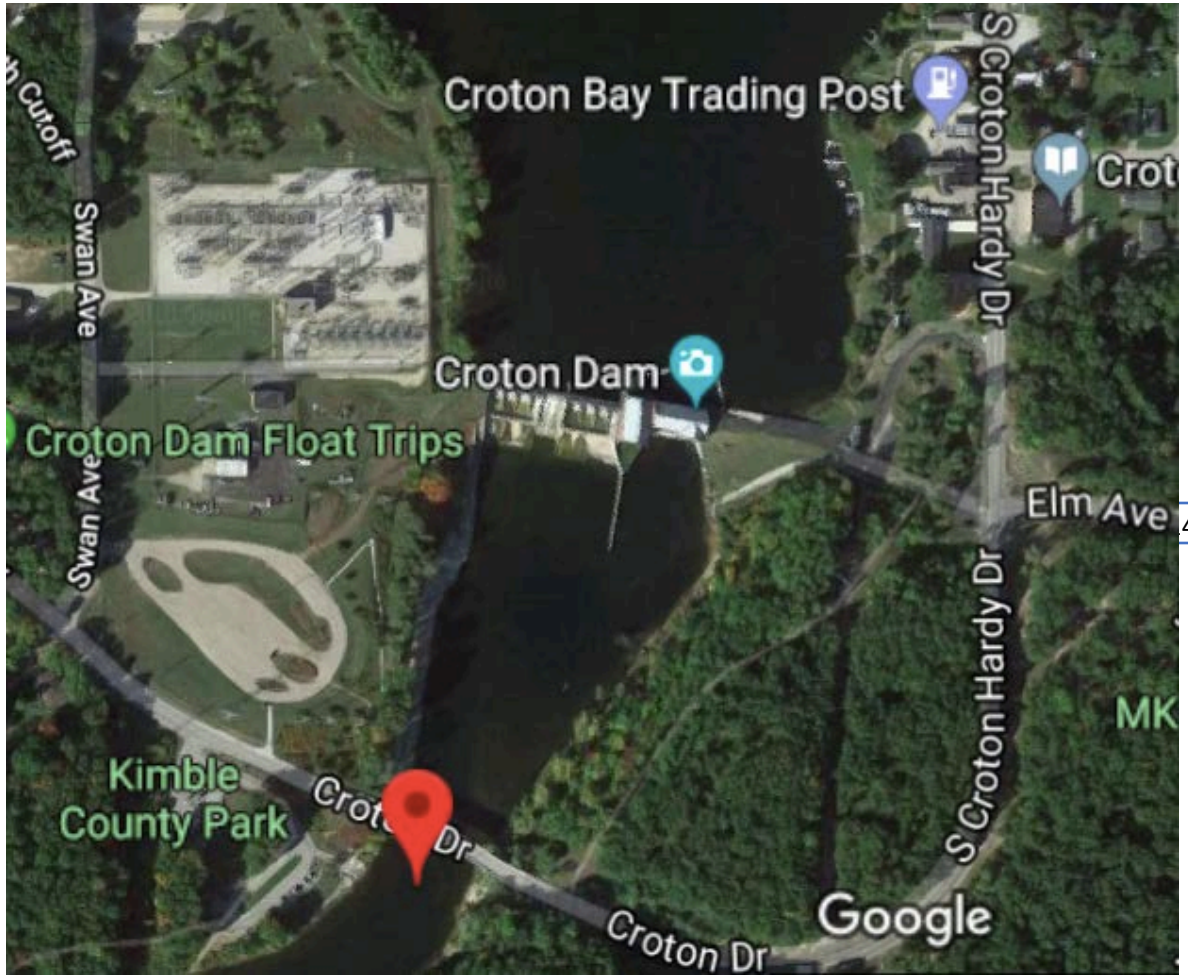




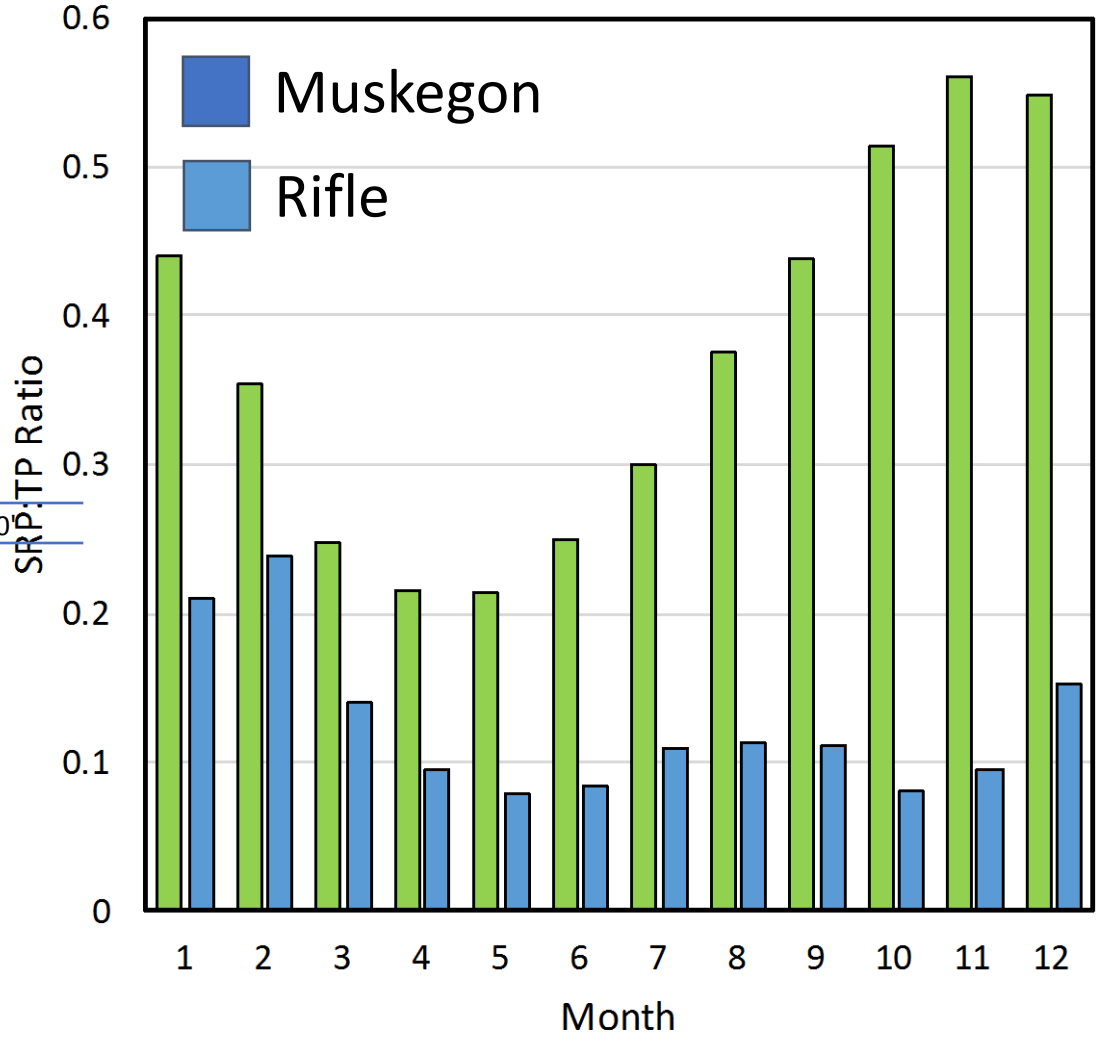
Muskegon River
Niles, Michigan



Seasonal N:P Ratios

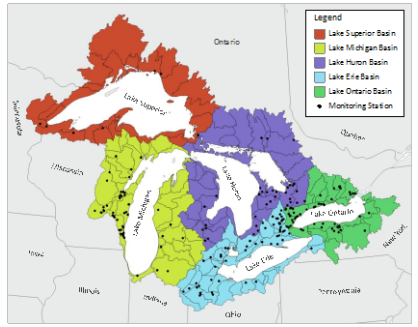


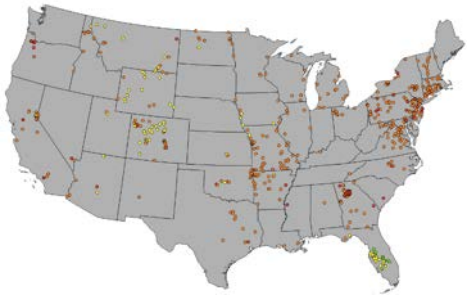
Muskegon River
Niles, Michigan

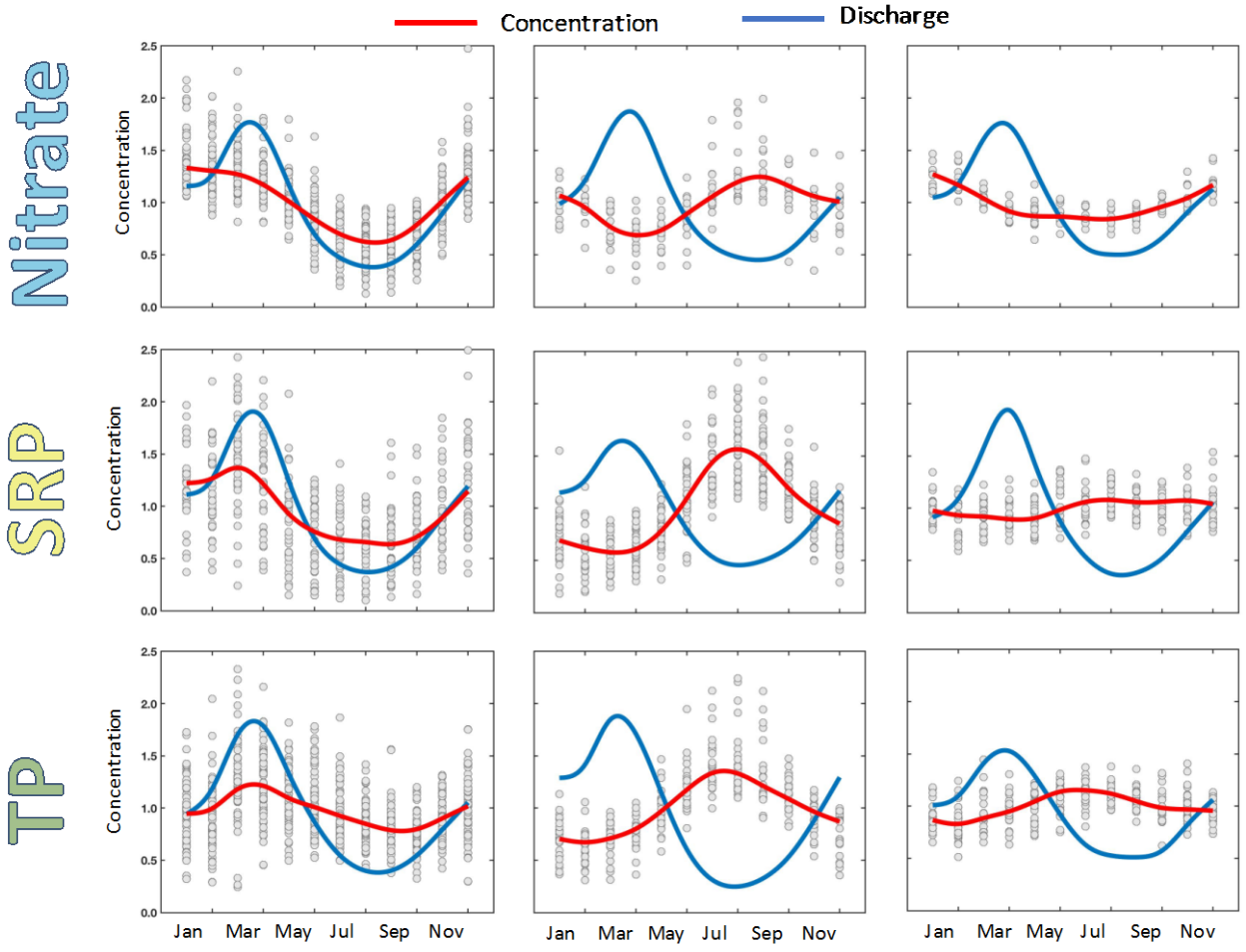


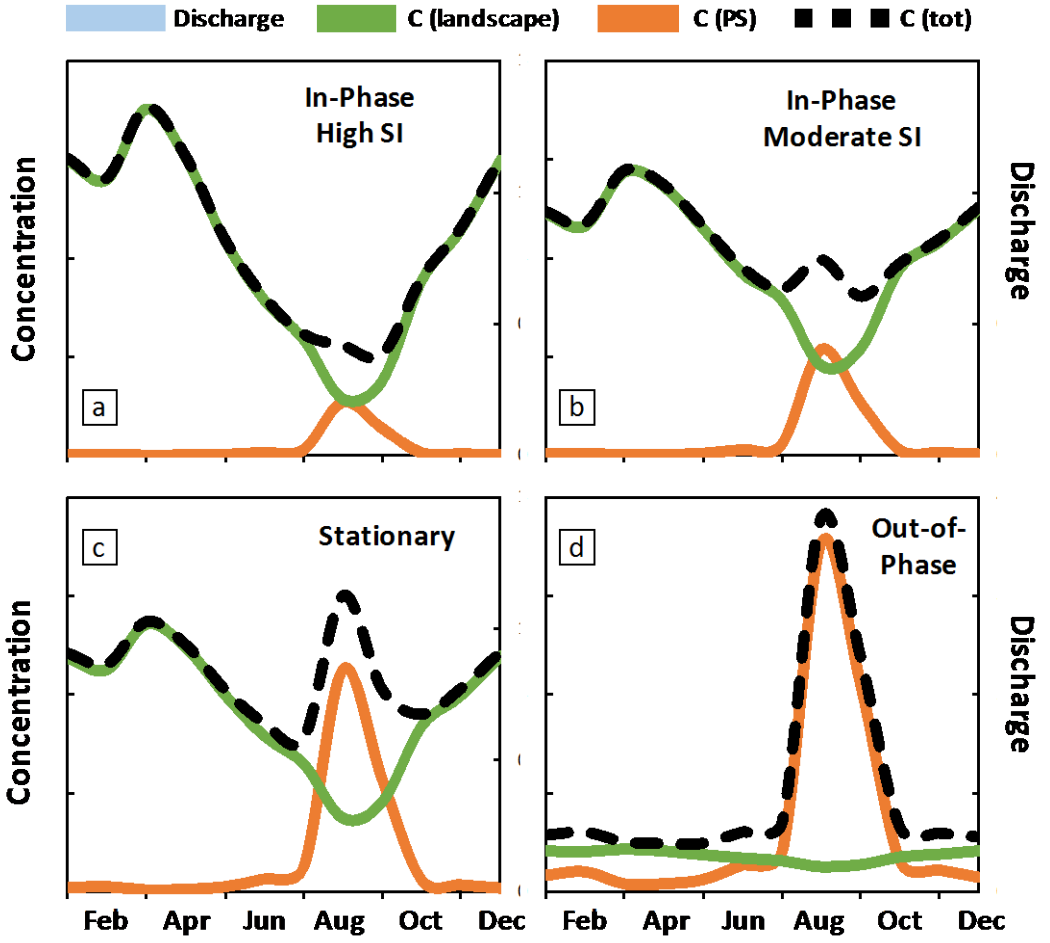
Seasonal SRP:TP Ratios

QUESTIONS?


Legend
Lake Superior Basin
Lake Michigan Basin
Lake Huron Basin
Lake Erie Basin
Lake Ontario Basin
Monitoring Station
Ontario
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
New York
Illinois
Ohio




Concentration
Discharge
Nitrate
SRP
TP
Concentration
0.0
0.5
1.0
1.5
2.0
2.5
Jan
Mar
May
Jul
Sep
Nov


Discharge
C (landscape)
C (PS)
C (tot)
In-Phase
High SI
In-Phase
Moderate SI
Stationary
Out-of-
Phase
a
b
c
d
Concentration
Discharge
Feb
Apr
Jun
Aug
Oct
Dec