Long-term changes in lake nutrient concentrations across the Midwest and Northeast U.S.: How does WI stack up?

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Mississippi River Delta. Photo Credit: Landsat365

PRIMARY RESEARCH ARTICLE

WILEY Global Change Biology

Unexpected stasis in a changing world: Lake nutrient and chlorophyll trends since 1990

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Outline

1. Using lakes as indicators of change

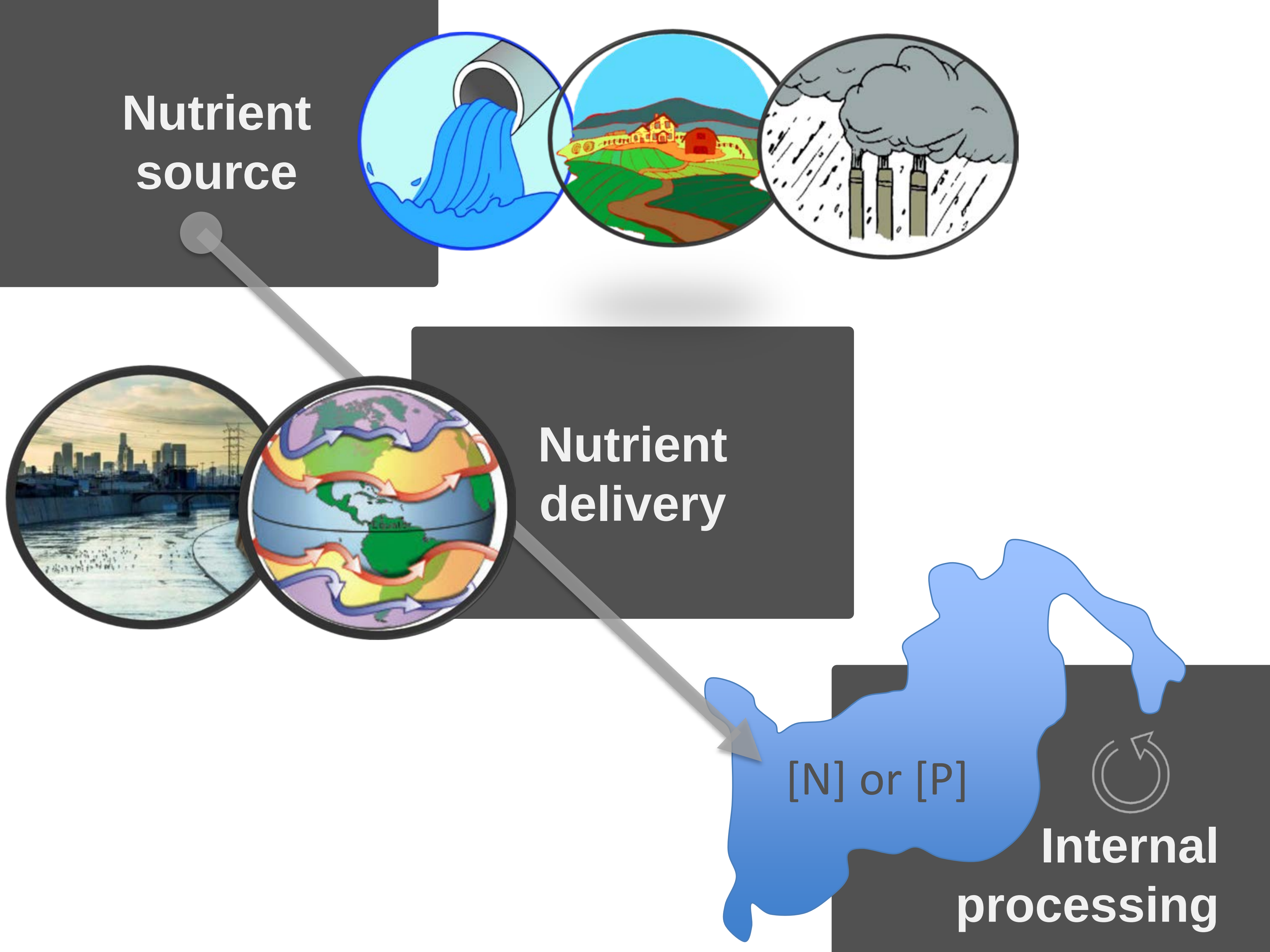
    We need big data to study big problems

2. Data solution – LAGOS

3. Who cares what's happening in other lakes?

4. Are lakes changing?

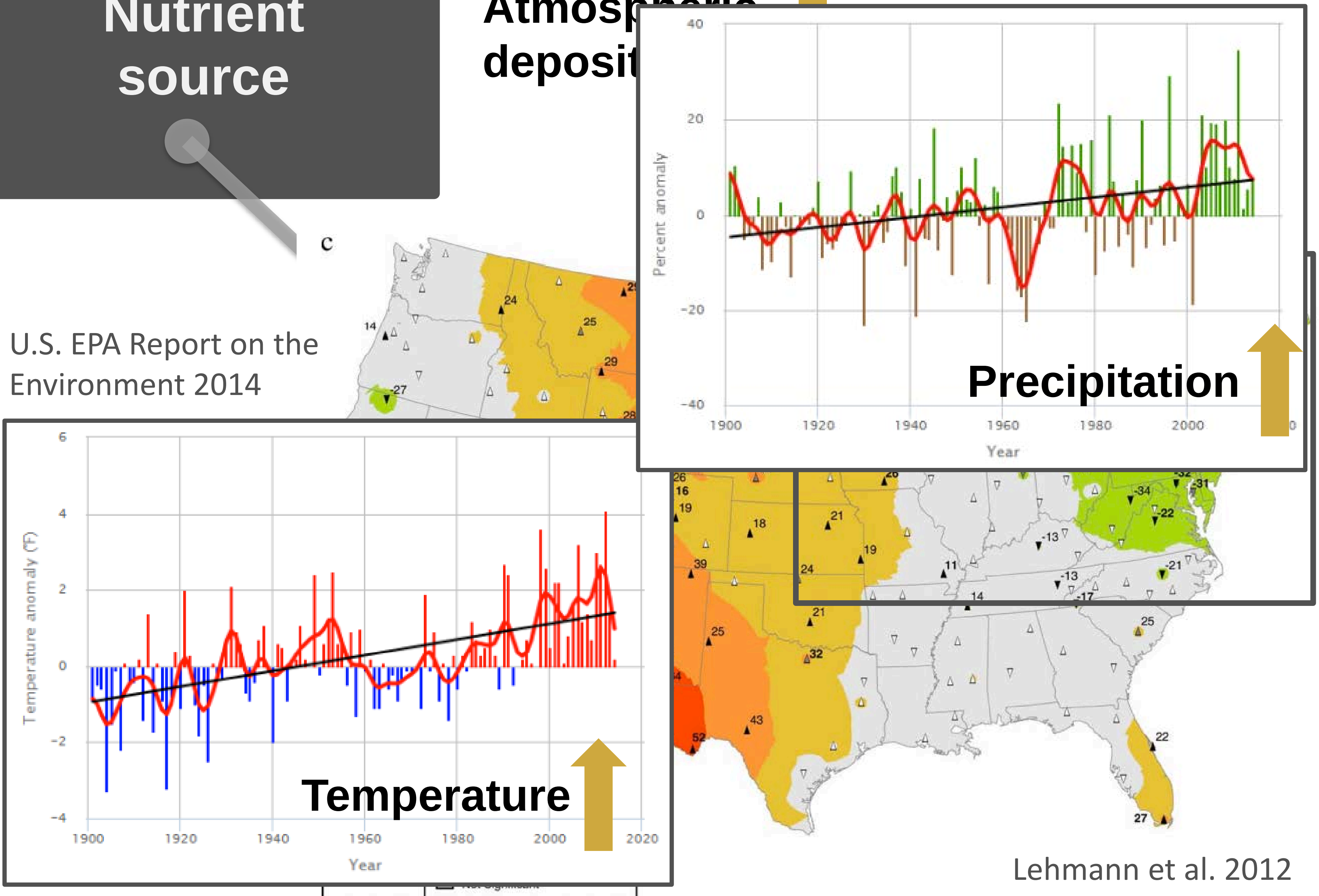
5. How are lakes in WI changing?


Nutrient source
Nutrient delivery
[N] or [P]
Internal processing

Nutrient source

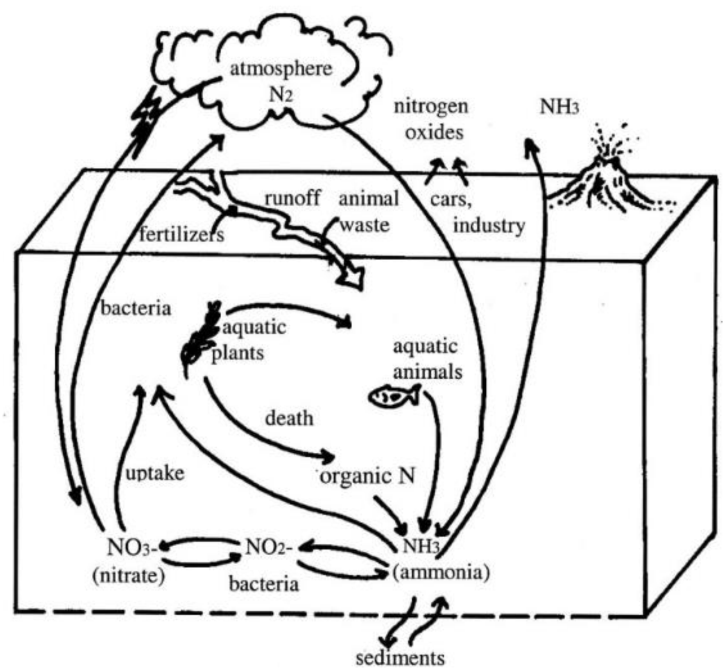
Atmospheric deposit

U.S. EPA Report on the Environment 2014

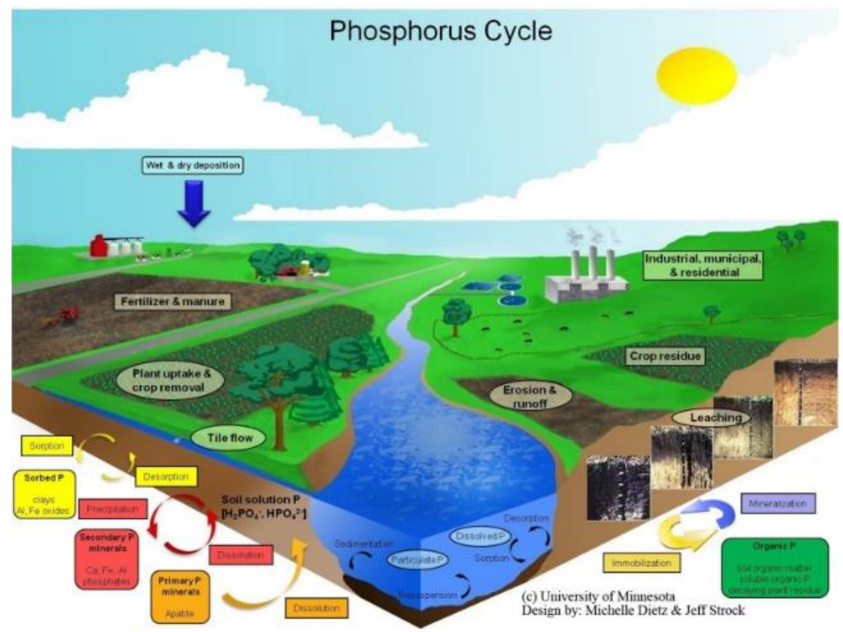


Lehmann et al. 2012

NITROGEN	PHOSPHORUS
Abundant, globally distributed	Scarce, localized geologic sources
Dissolved, easily transported by surface and subsurface water	“Sticky” and often in particulate form, primarily transported by surface water
Gas phase – N can fixed or removed by organisms, atmospheric transport	No gas phase



Utah State Extension

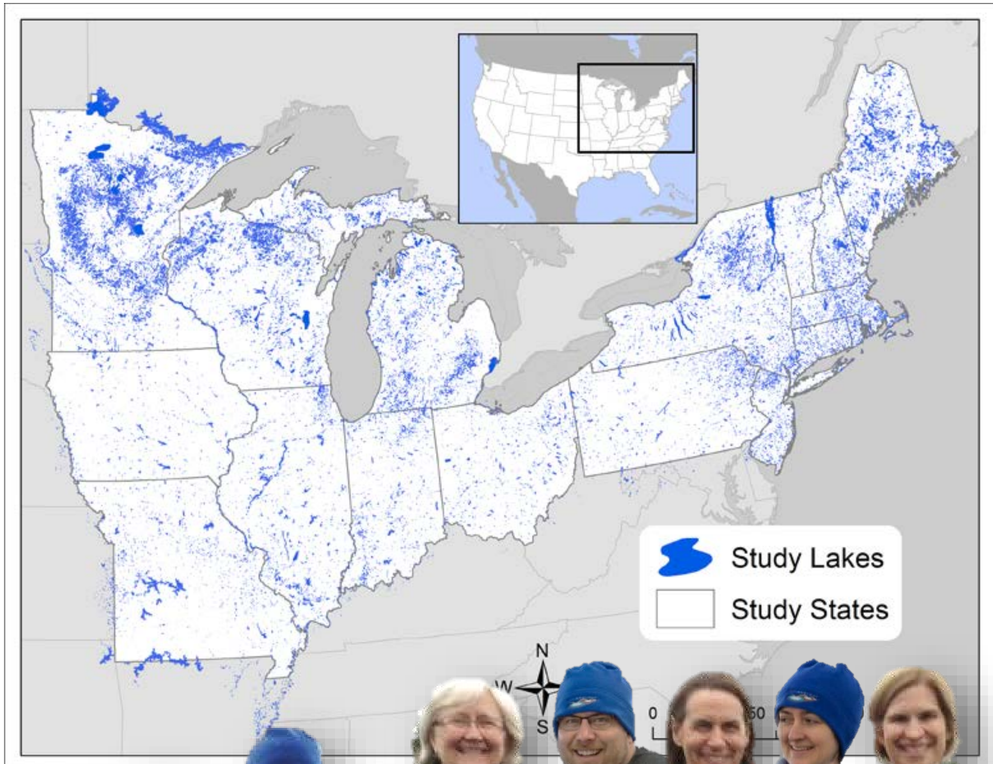


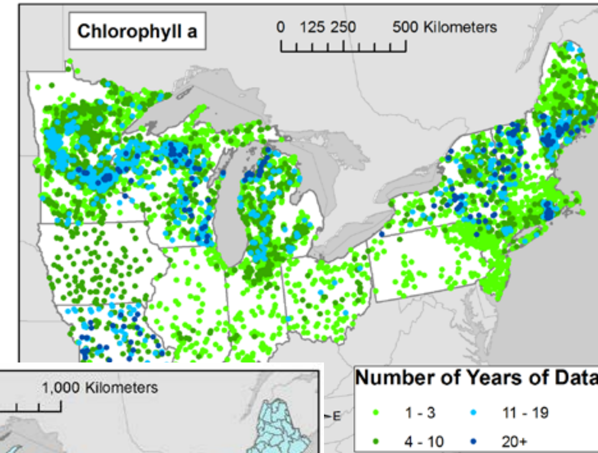
How do we study these “big problems”?

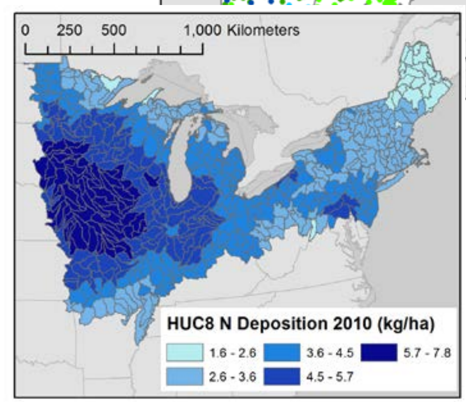
In other words, where can find lake data that spans the time, space, and ecological parameters we need?

Lake Multi-Scaled **Geos**patial & Temporal Database (LAGOS)

Database description: Soranno et al. 2015
Data release: Soranno et al., 2017







CSILIMNOLOGY

NSF

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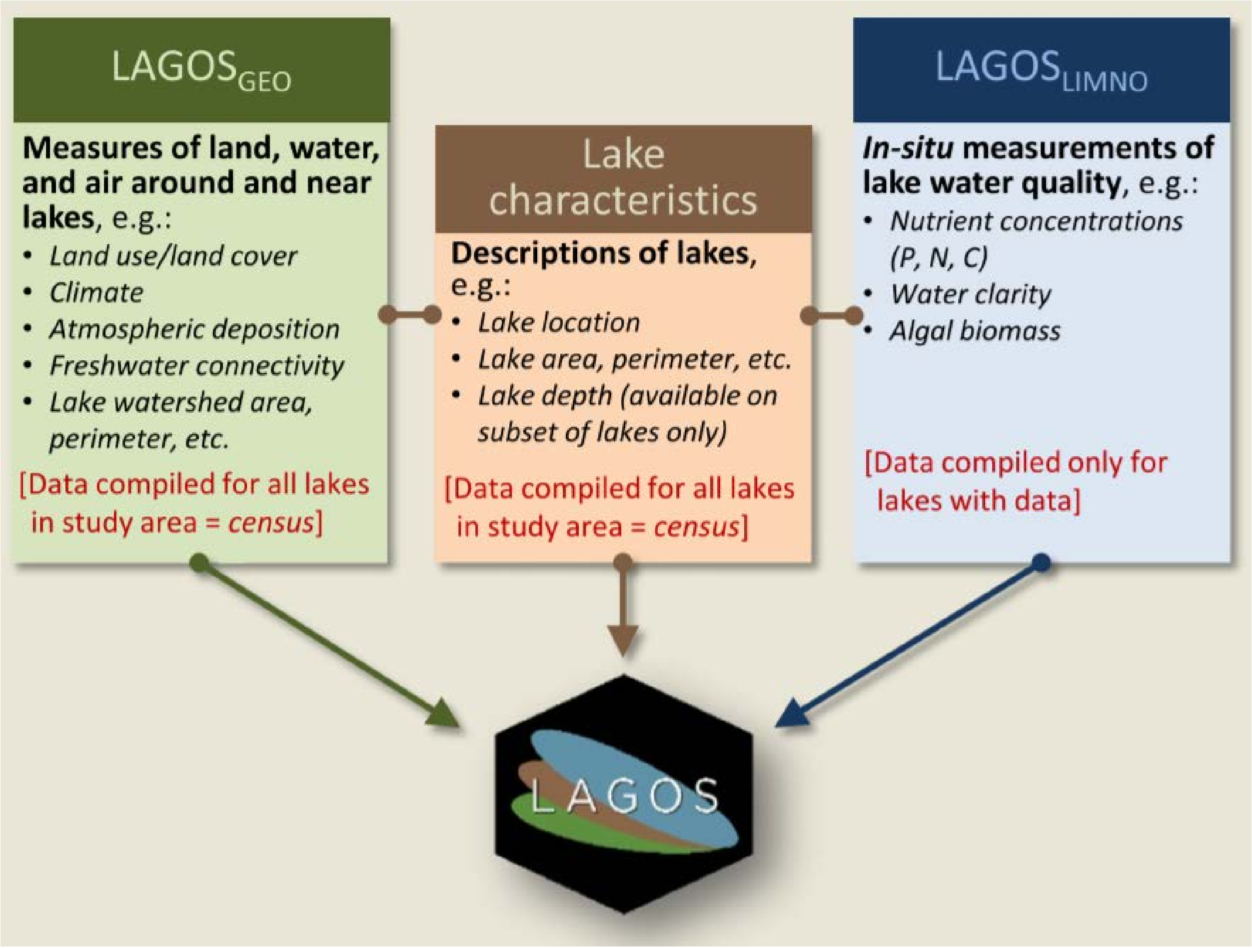

12,034 lakes with Secchi (2079 in WI)

9749 lakes with TP (1920 in WI)

All data publicly available + R package 'LAGOS' to access

CSILIMNOLOGY

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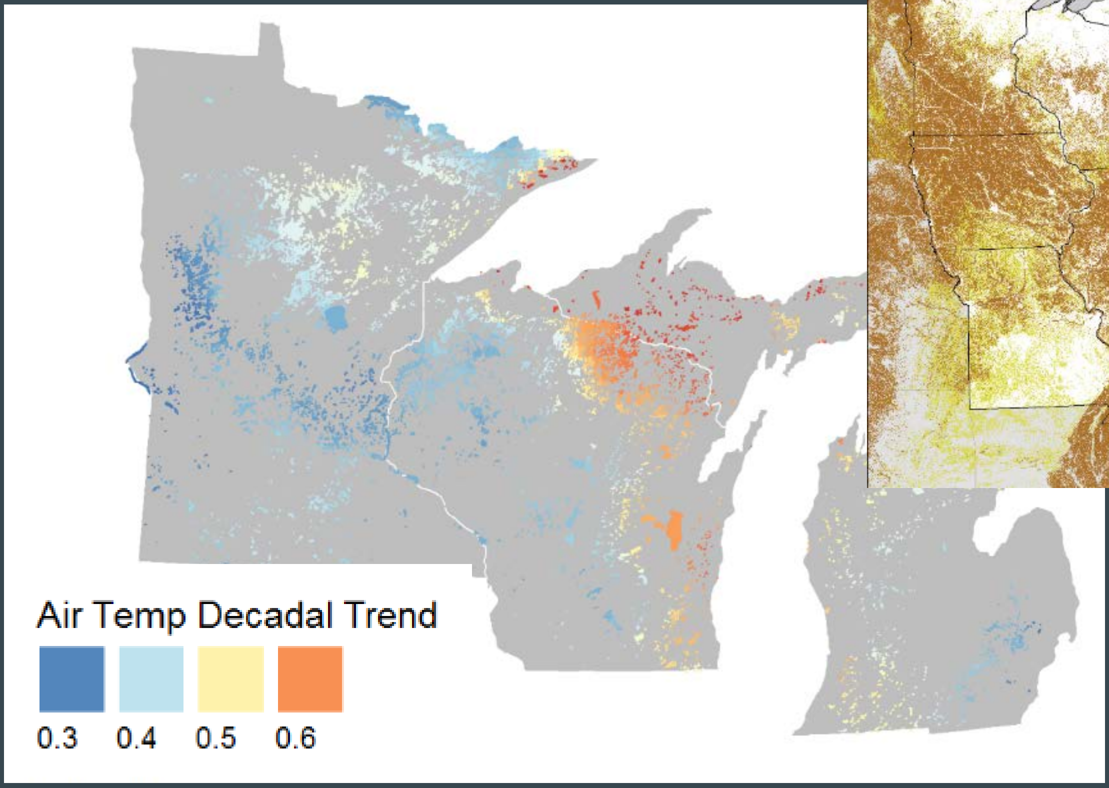
See https://lagoslakes.org/projects/continental-limnology/ for what's next

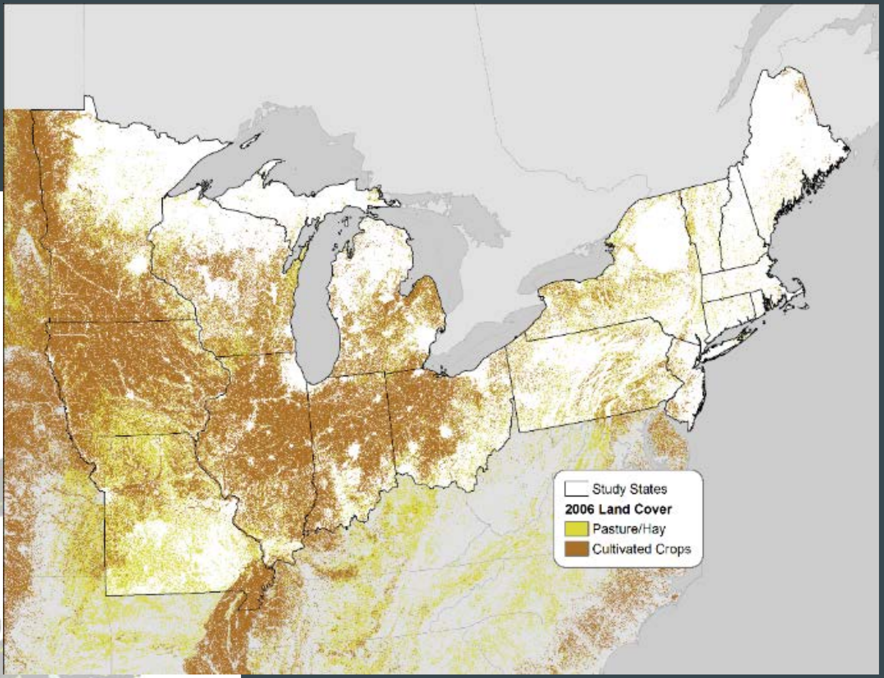
Now we have the data.

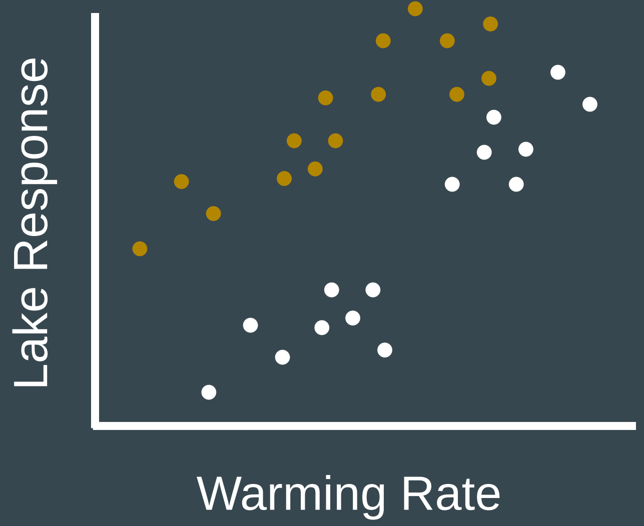
Case study: Why “we” depend on “you”.

Why large scale studies depend on lake-specific data.

Representation

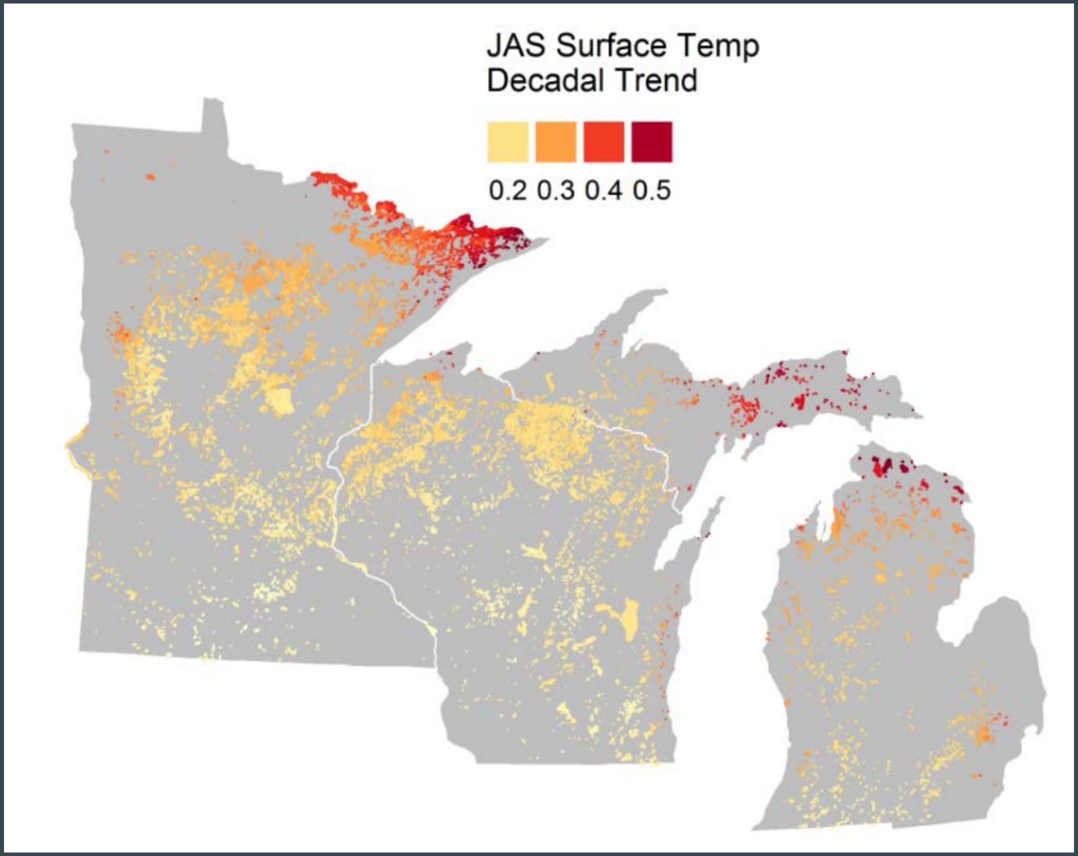


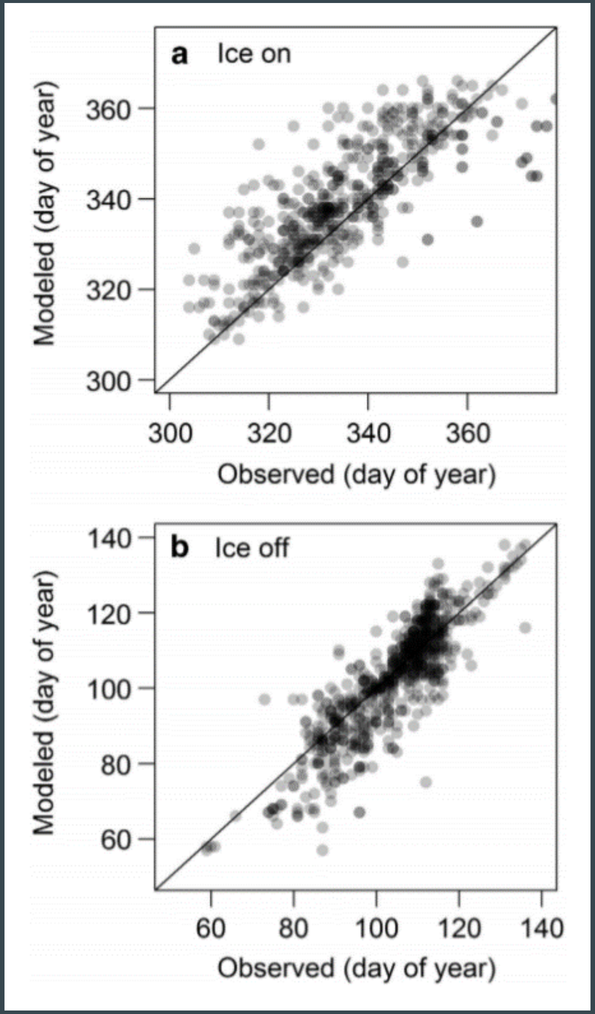




Winslow et al. 2017

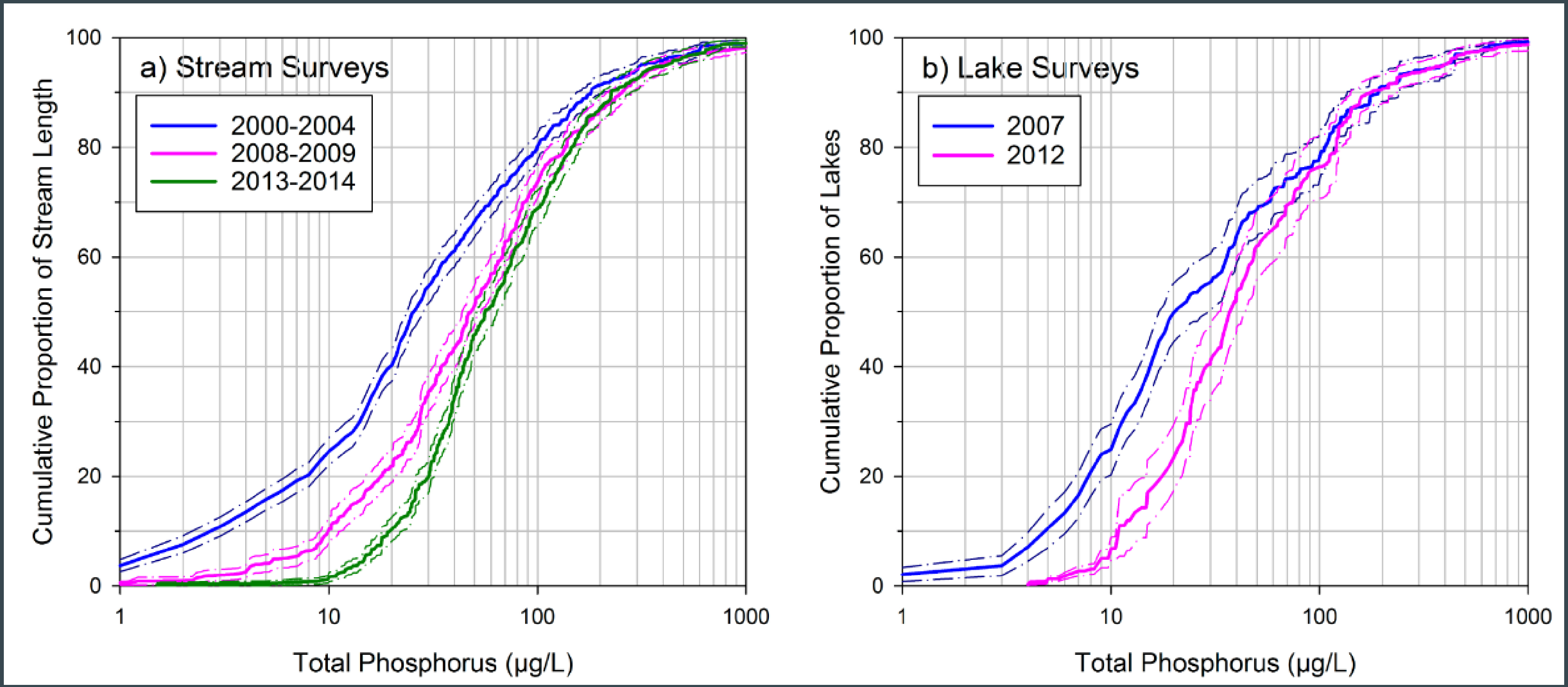
Prediction & Projection





“Models are never right, but sometimes they’re useful.” – we need real data to make them useful.

Scale of Problem & Solutions

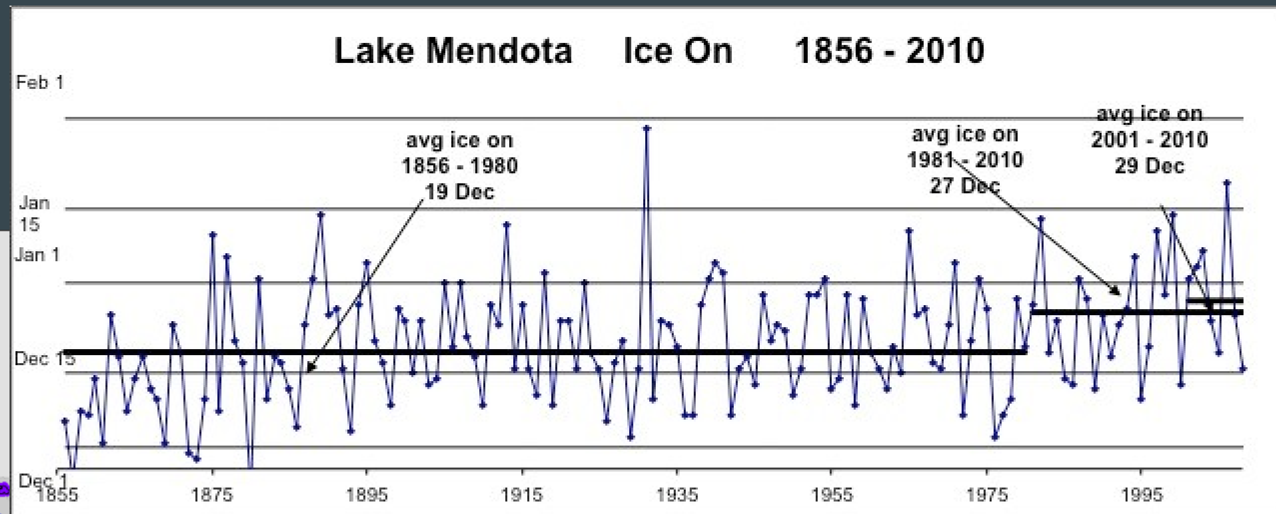


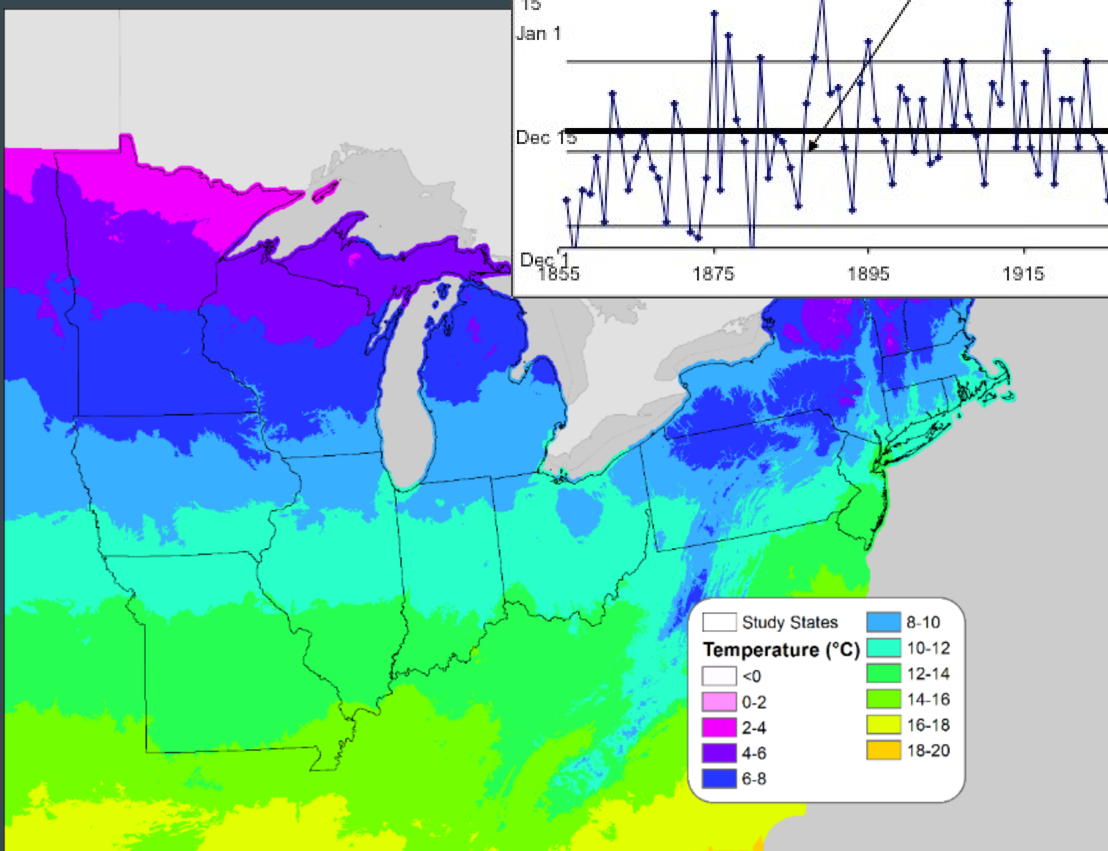
Stoddard et al. 2016

Why should you care about other lakes?

How individuals who are vested in individual lakes or regions can gain value from broad-scale studies.

We have yet to invent a time machine

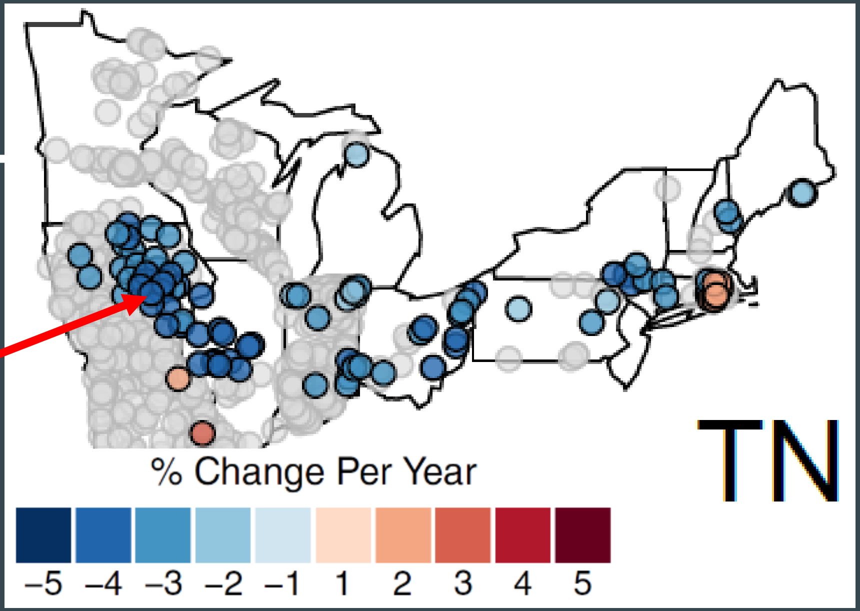




Scale of (your) problems & solutions

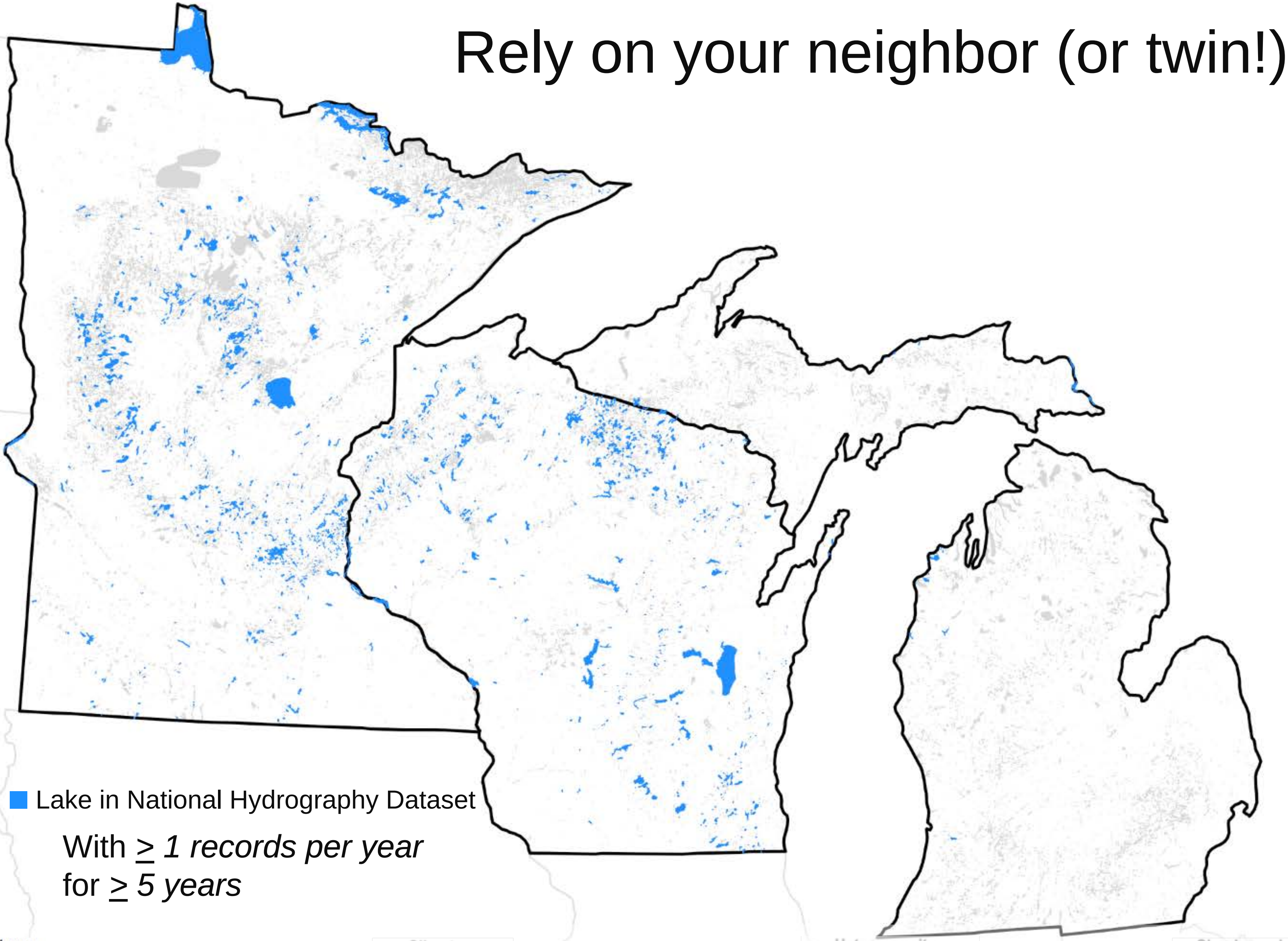
Your Lake

Conclusion: Our local intervention reduced nitrogen!



Conclusion: Some regional changes caused N declines in our lake.

Rely on your neighbor (or twin!)



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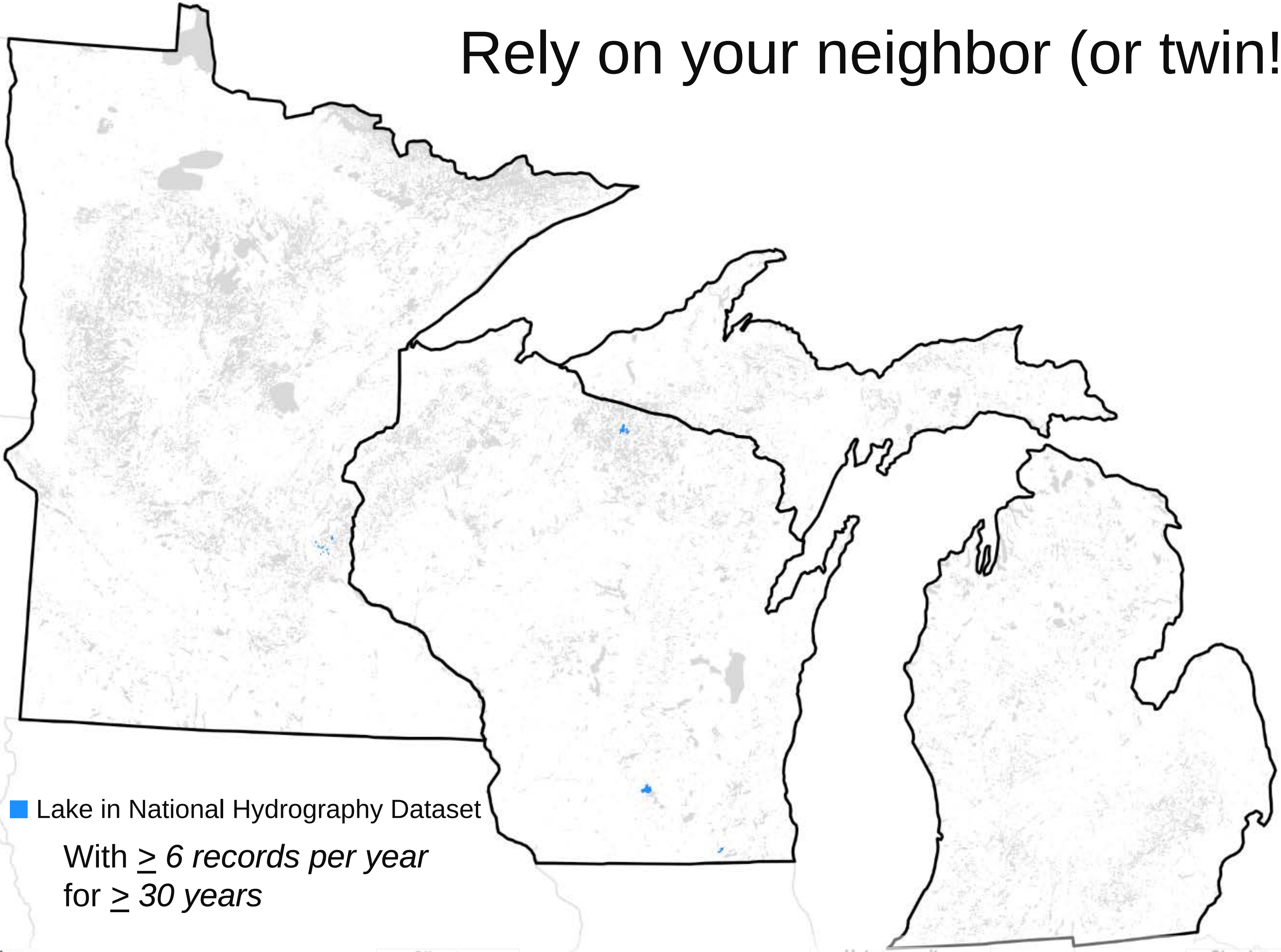
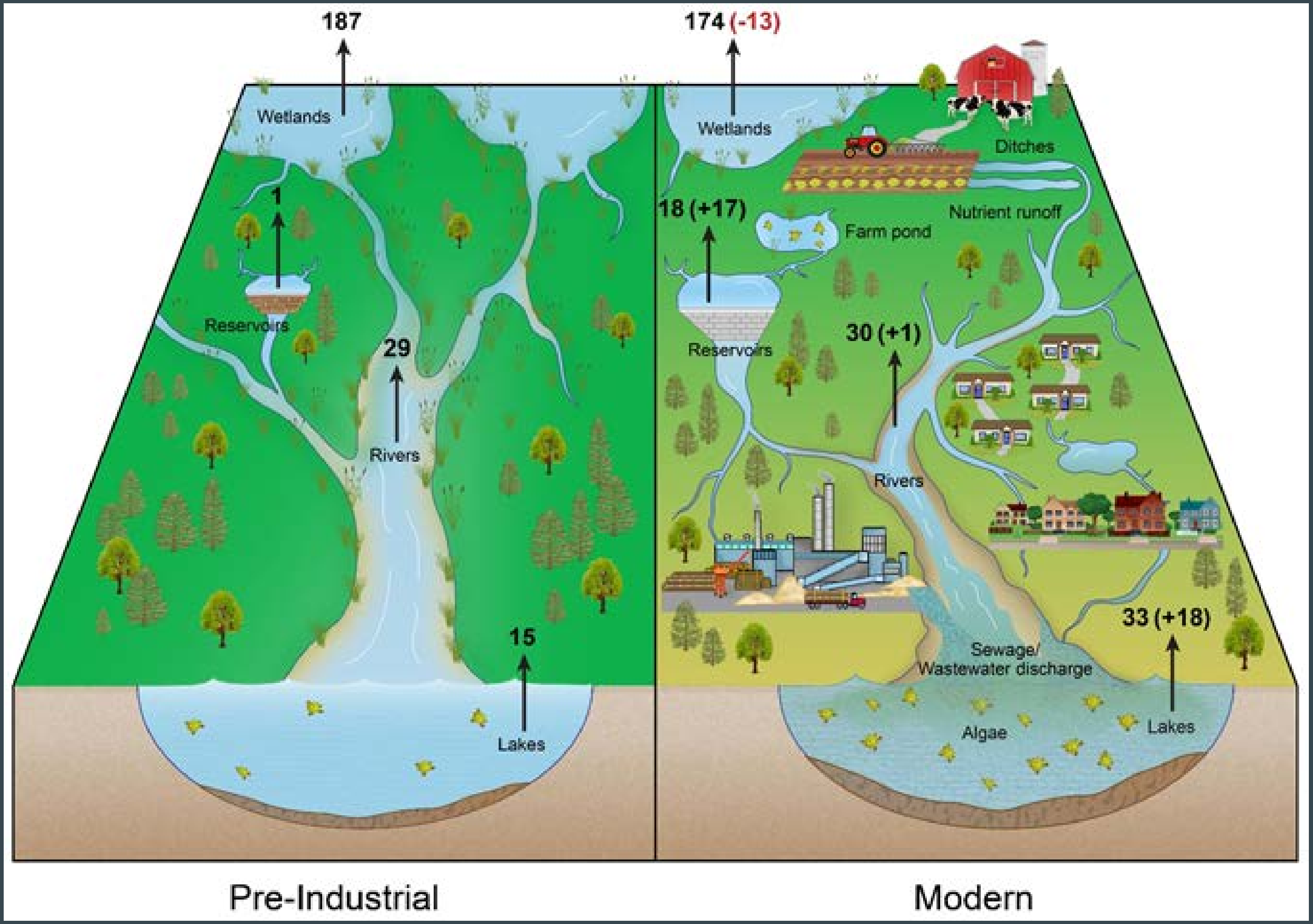


whole > ∑ parts

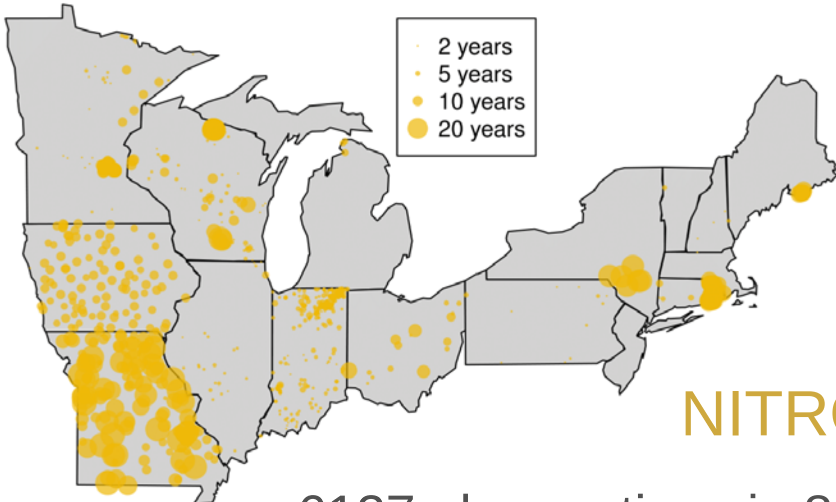


Stanley et al., in prep

Q1: Have lake nutrients or chlorophyll changed since 1990?

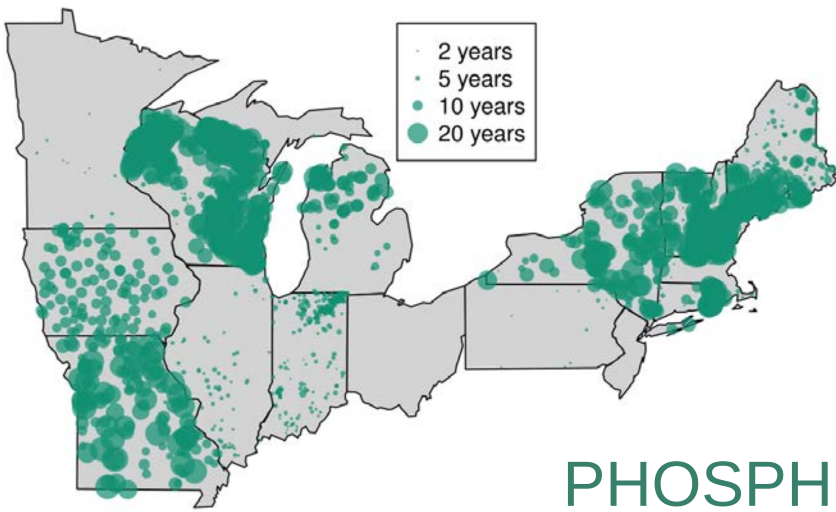
Q2: And if so, what local and regional factors are related to trends?

LAGOS v1.54



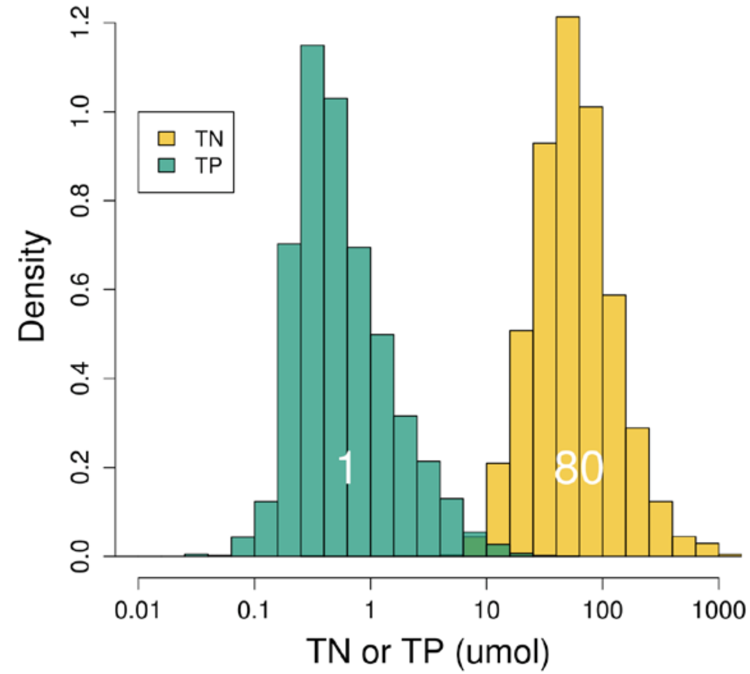
NITROGEN

6127 observations in 833 lakes
Mean record length: 7.4 years



PHOSPHORUS

20,872 observations in 2096 lakes
Mean record length: 10.0 years

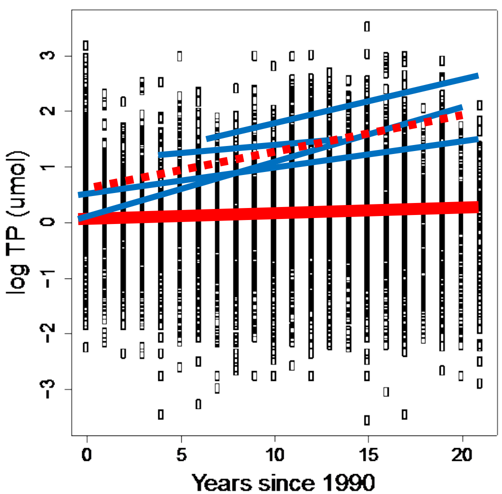


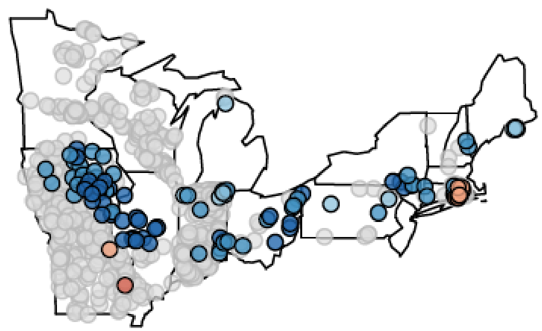
1) All observations > 1989
2) Obs in each half of timeframe (1990-2000, 2001-2011)
3) Data must span 5 years
4) Mean summer epilimnetic TN, TP, TN:TP (concurrent), Chl

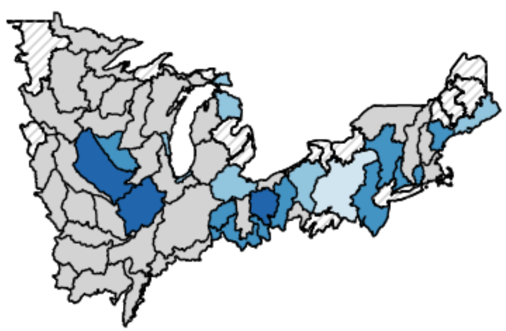
METHODS

Step 1: Hierarchical Linear Models (HLMs)

Starting concentration (intercept) and change through time (slope) allowed to vary by lake and region







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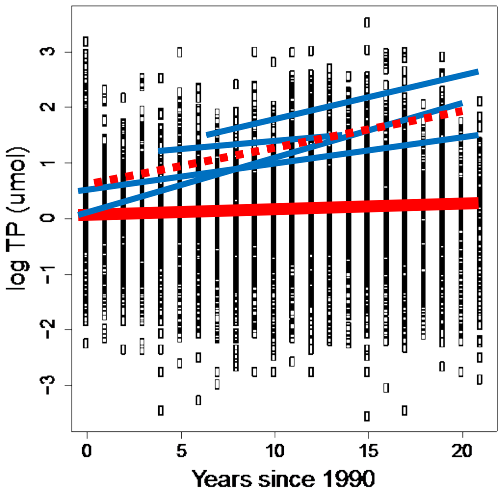
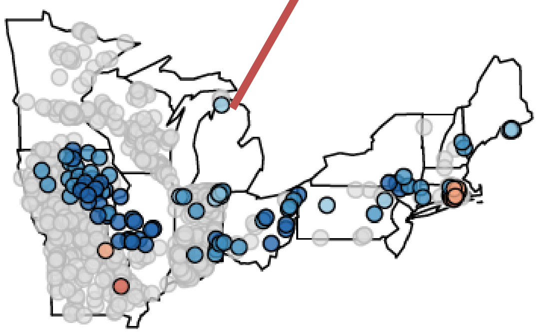




Categorized as increasing, decreasing, not changing

RF 1: trends ~ lake predictors

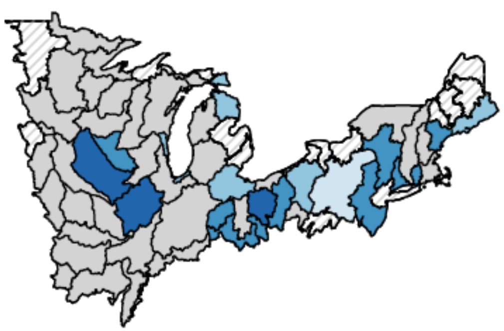
- WS LULC, lake depth, area

RF2: trends ~ regional predictors

- HUC 4 LULC, climate, atm. Dep

RF3: trends ~ regional + lake

- Model selection to find most important predictors

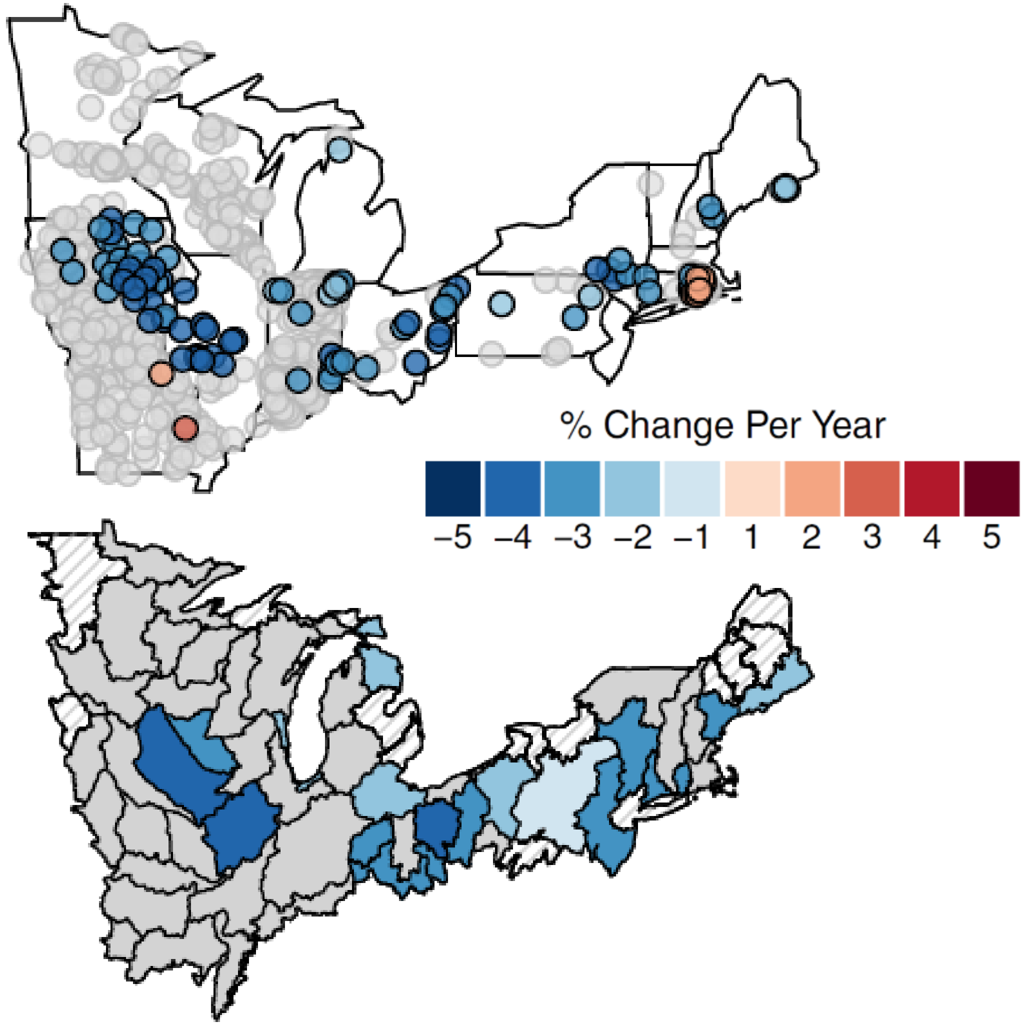


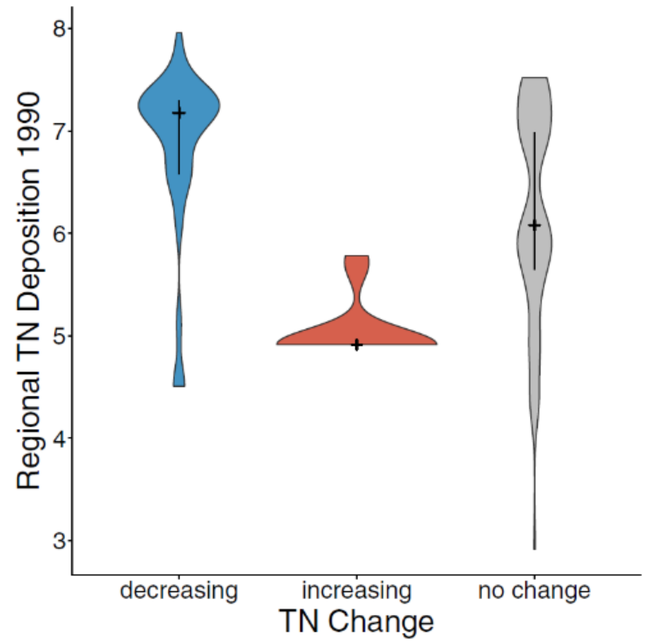
Step 2: Random Forests

Lake and region-level predictors used to predict lake-specific trends

NITROGEN

833 lakes



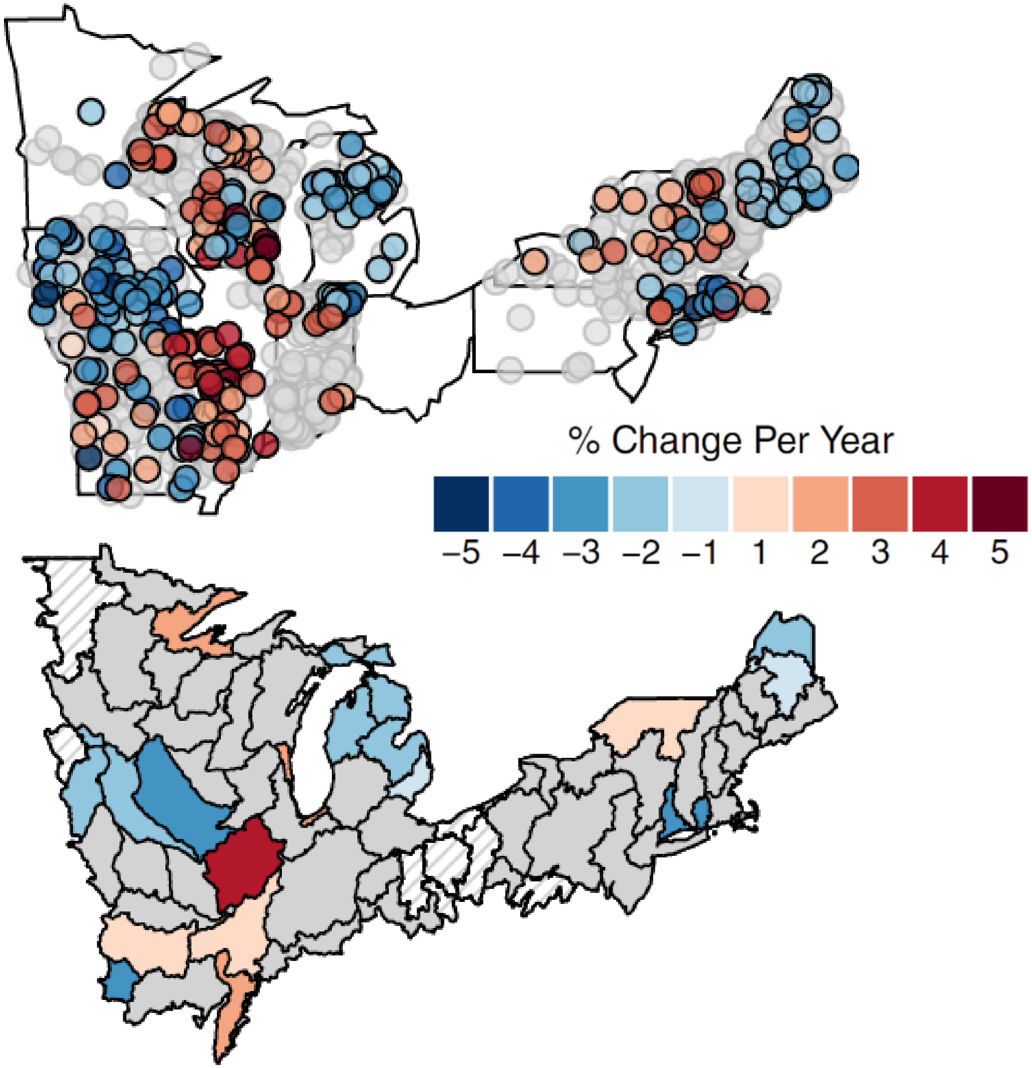


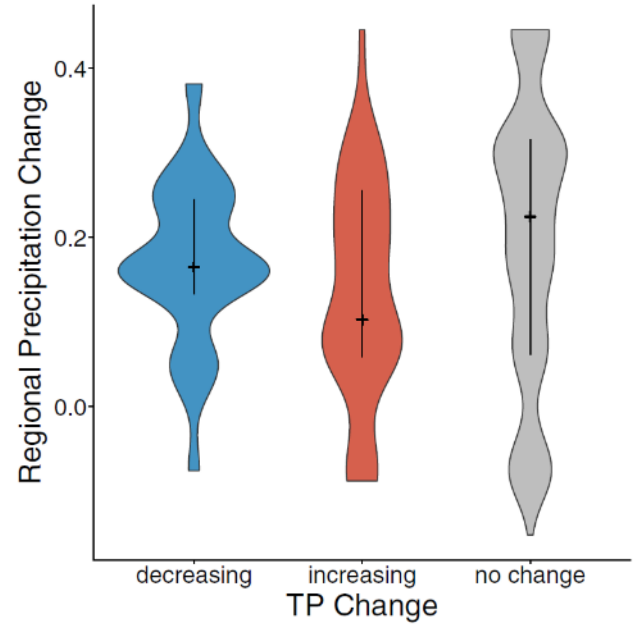
Regional predictors alone could correctly classified 82% of lakes

Across all lakes, TN **declined at a rate of -1.1% (-1.5 to -0.70)** per year. Only **13% of lakes** and **32% of regions** had significant trends in TN.

PHOSPHORUS

2096 lakes



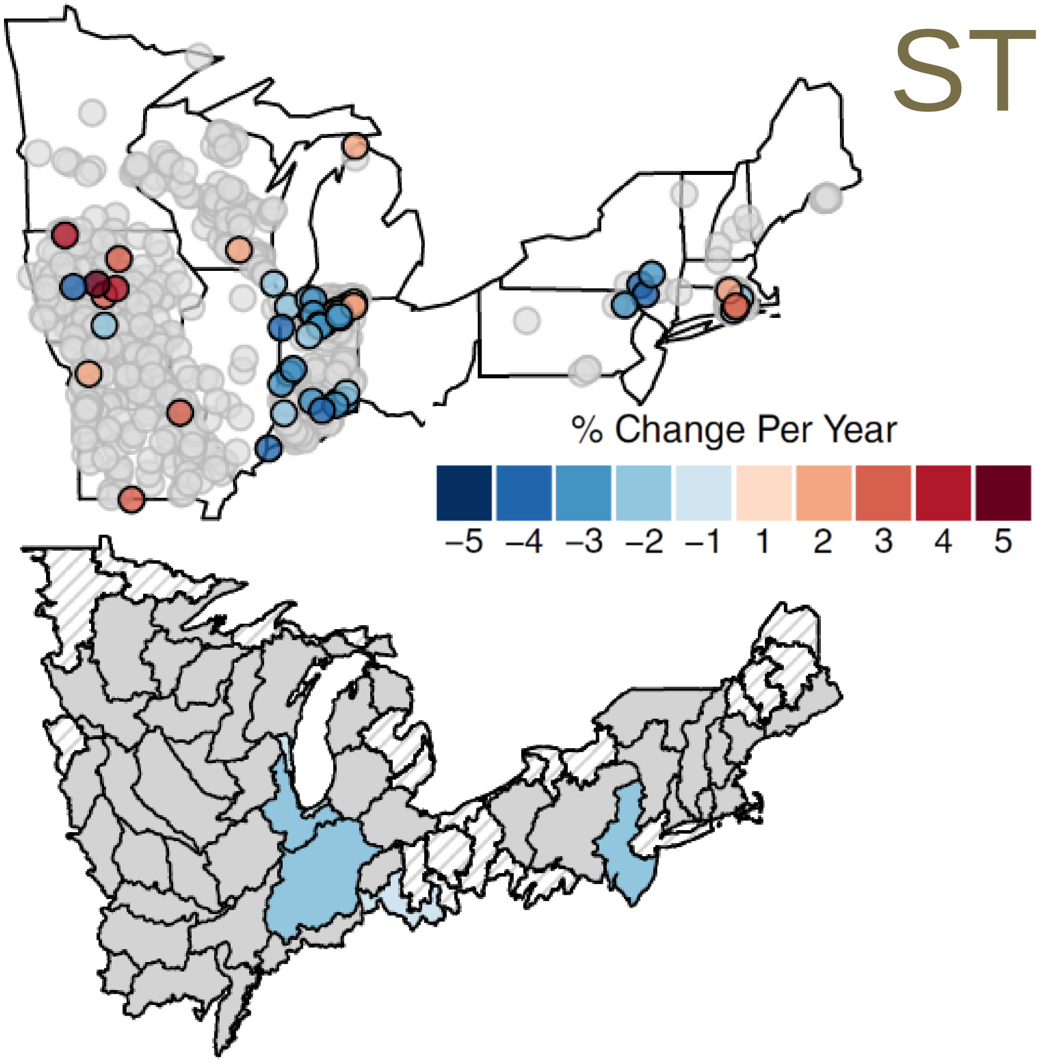


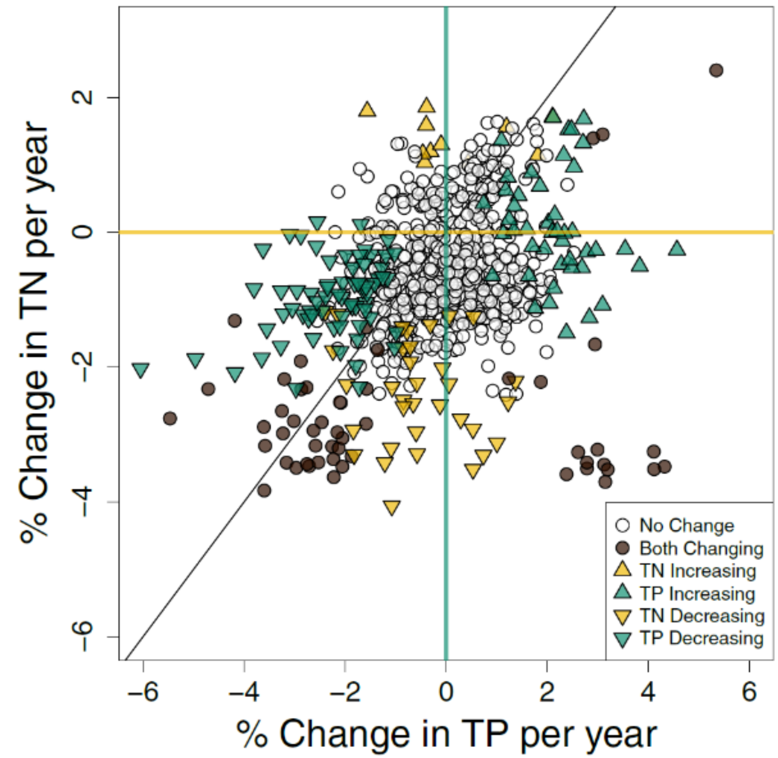
Lake and region-level predictors performed similarly at predicting TP change, RF models could accurately classify 68% of lakes.

Across all lakes, TP declined at a rate of -**0.2% (-0.5 to 0.1) per year.** 16% of lakes and 31% of regions had significant trends in TP.

STOICHIOMETRY

742 lakes

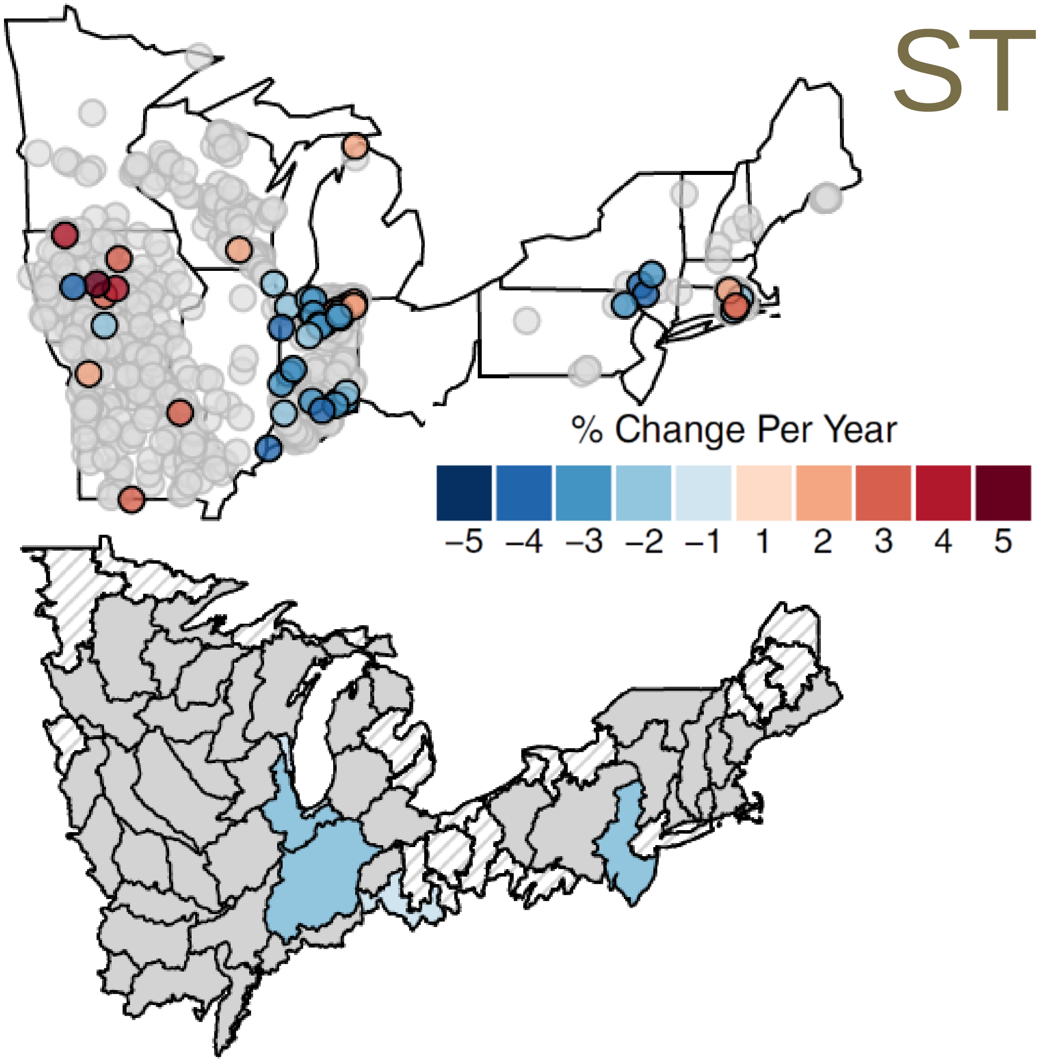


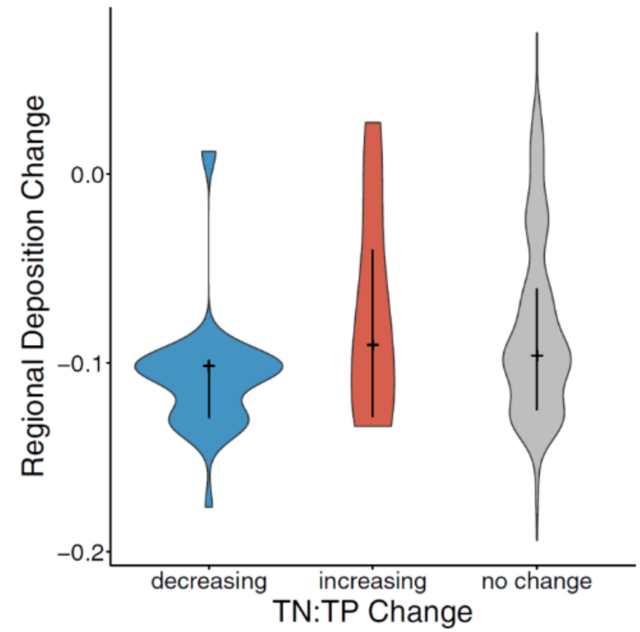


Across all lakes, TN:TP declined at a rate of **-0.2% (-0.6 to 0.1) per year.** 7% of lakes and 11% of regions had significant trends in TN:TP.

STOICHIOMETRY

742 lakes



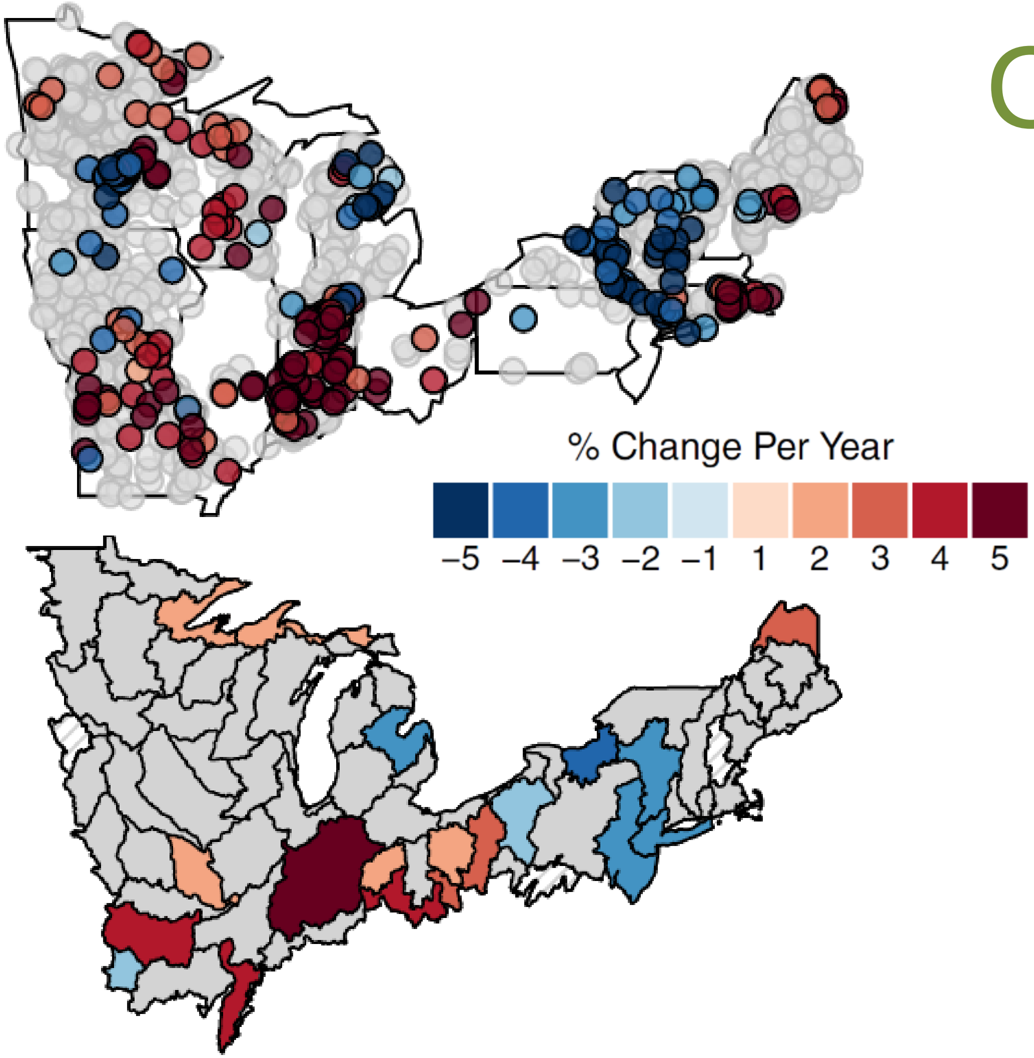


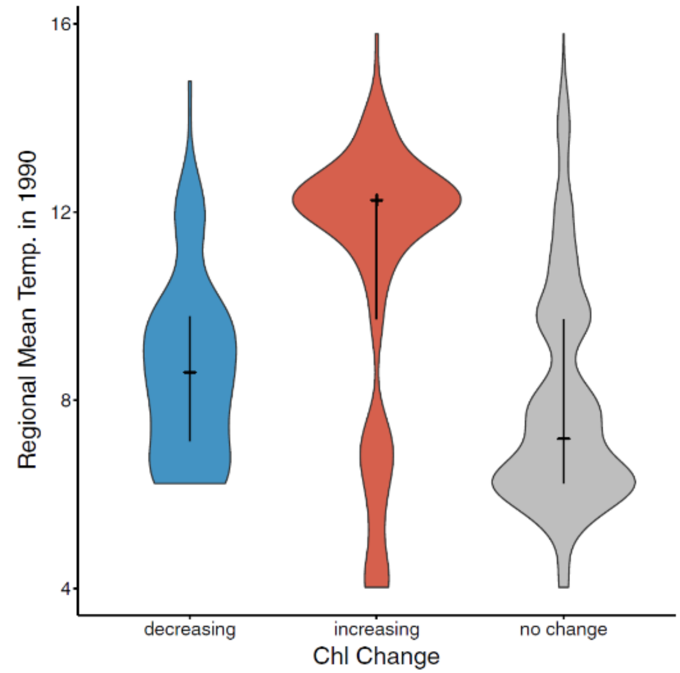
Region-level predictors performed worse than random, lake-level predictors accurately classified 59% of lakes.

Across all lakes, TN:TP declined at a rate of -**0.2% (-0.6 to 0.1) per year.** 7% of lakes and 11% of regions had significant trends in TN:TP.

CHLOROPHYLL

2239 lakes



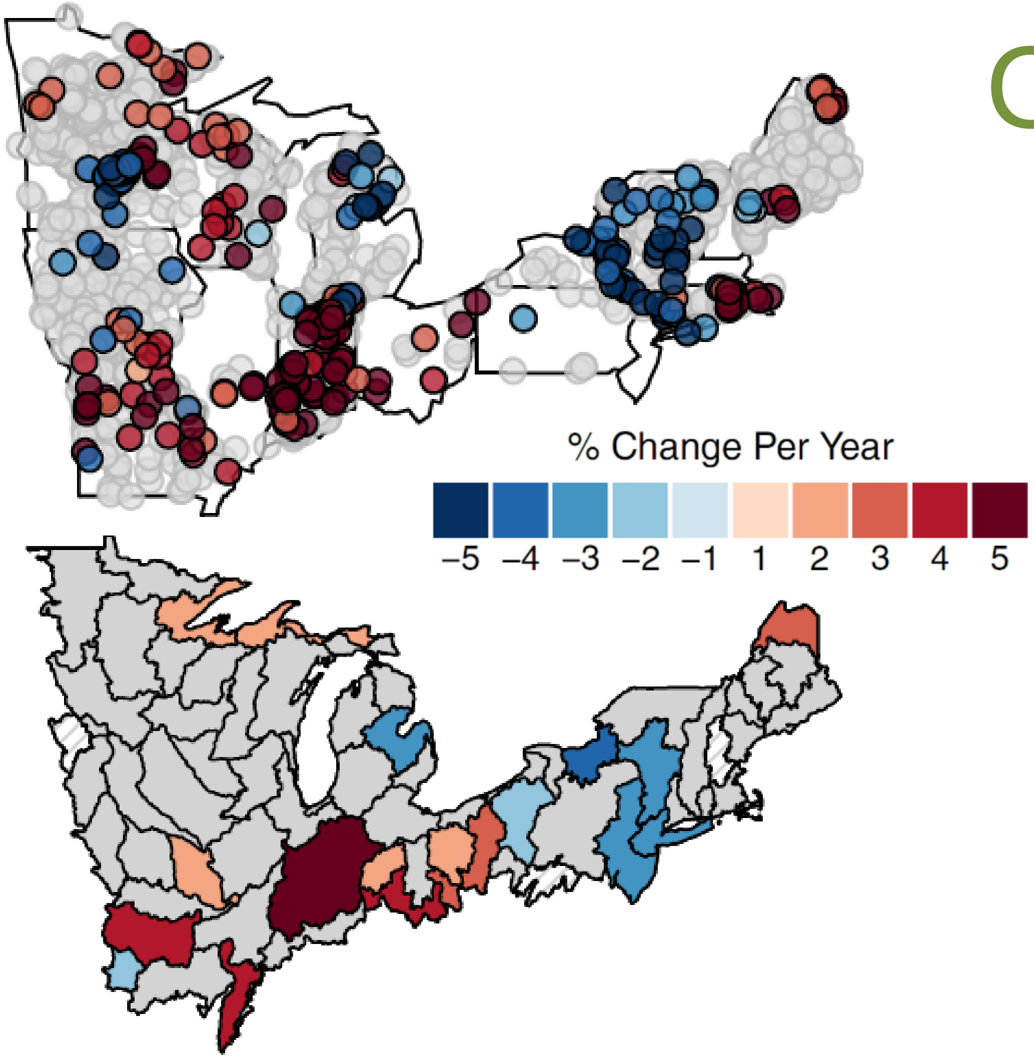


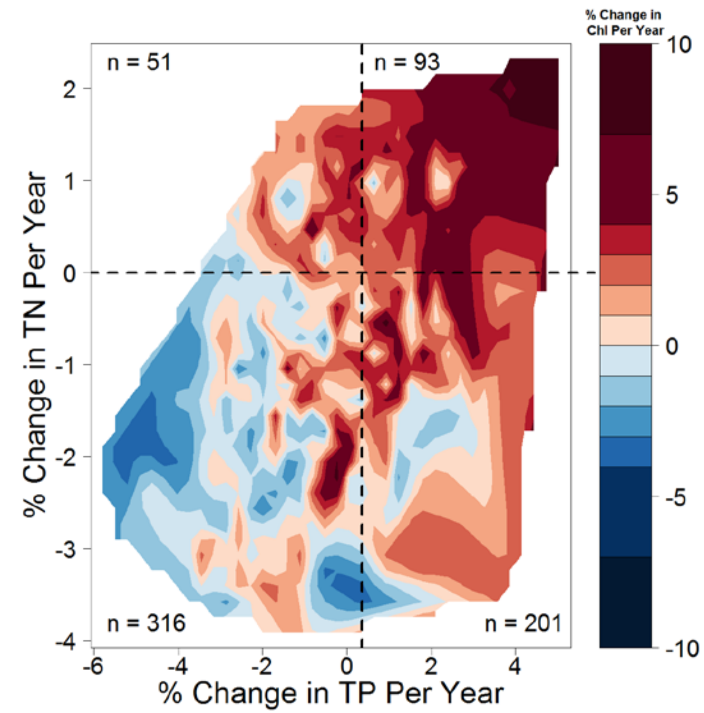
Lake and region-level predictors performed similarly at predicting Chl changes. RF models could accurately classify 72% of lakes.

Across all lakes, Chl increased at a rate of **0.3% (-0.2 to 0.8) per year.** 15% of lakes and 29% of regions had significant trends in Chl.

CHLOROPHYLL

2239 lakes





Across all lakes, Chl increased at a rate of **0.3% (-0.2 to 0.8) per year.** 15% of lakes and 29% of regions had significant trends in Chl.

Q1: Have lake nutrients or chlorophyll changed since 1990?

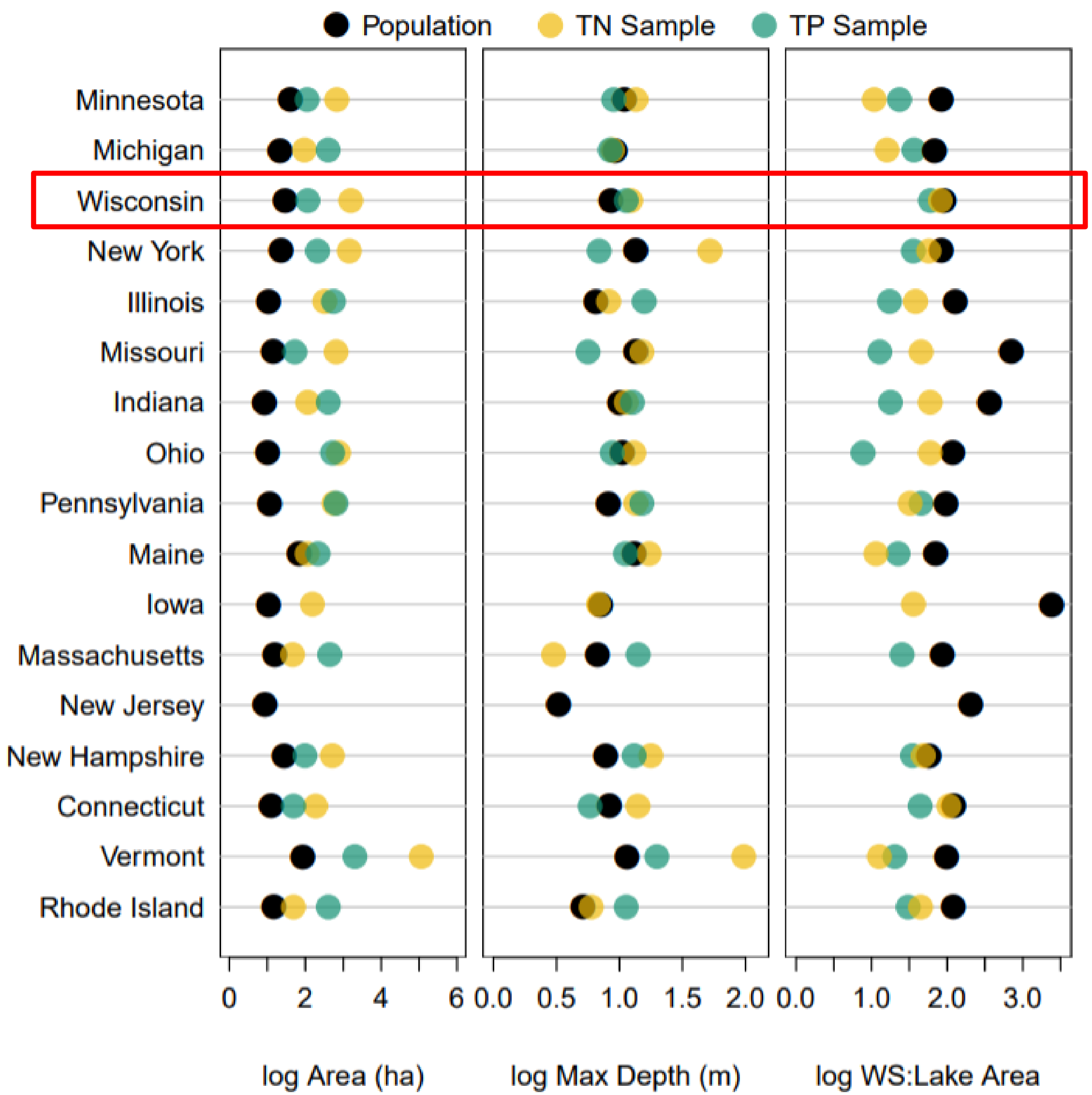
At the population scale, nitrogen is declining. However, most individual lakes have not changed in N, P, N:P or chlorophyll since 1990.

Q2: And if so, what lake and regional factors are related to trends?

Direction of N changes similar within and across regions, and related to region-level drivers, compared to variable P trends, which were related to both lake and region drivers. Greatest Chl increases related to nutrient trends and climate.

So how does Wisconsin stack up?

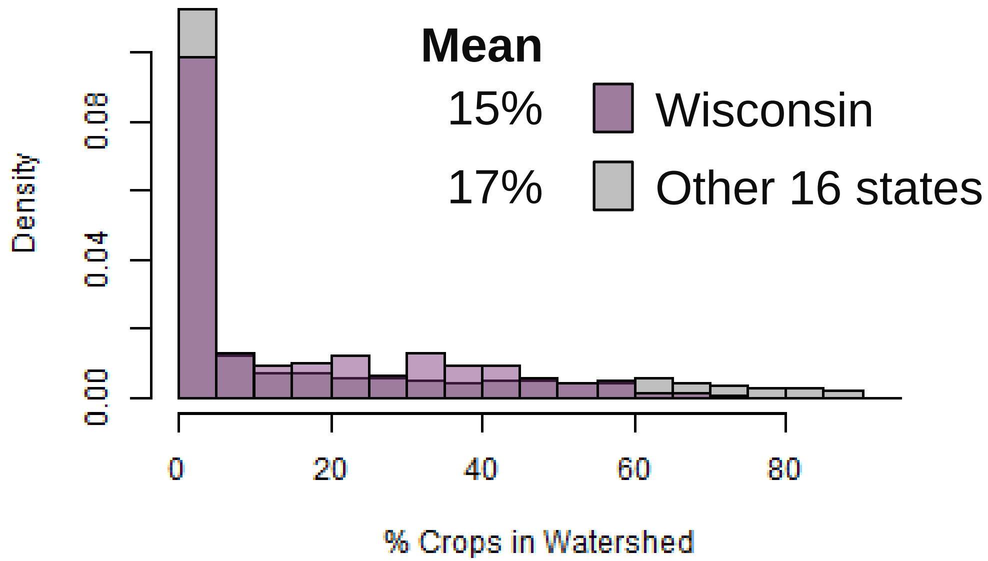
First, are we comparing apples to apples?

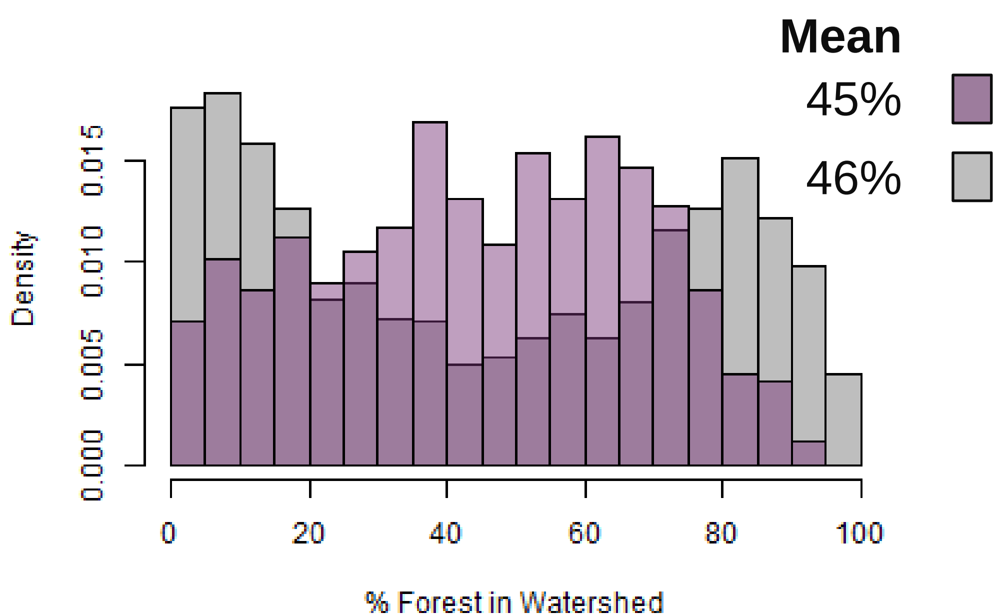


For example, we know we have data for a subset of lakes that are *larger, deeper,* and have *longer residence time* than the population of lakes on the landscape.

But Wisconsin is just as biased (or less!) than other states.

First, are we comparing apples to apples?

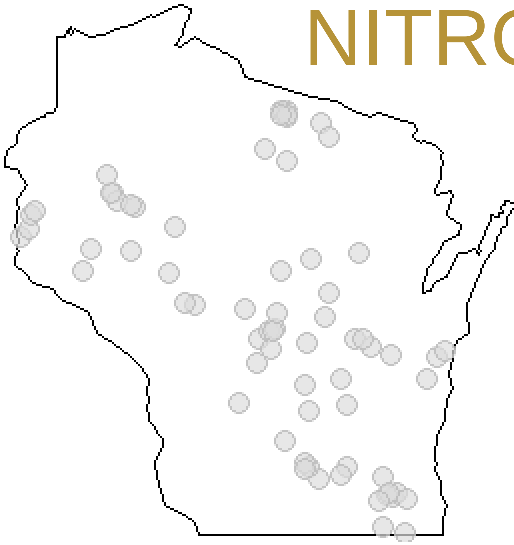




Overall, the types of lakes we sample in WI appear to be representative of the lakes we sample elsewhere.

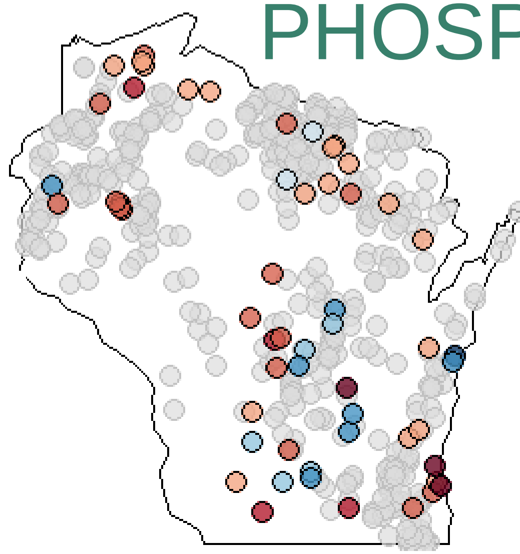
Water quality trends in Wisconsin

NITROGEN (69 lakes)



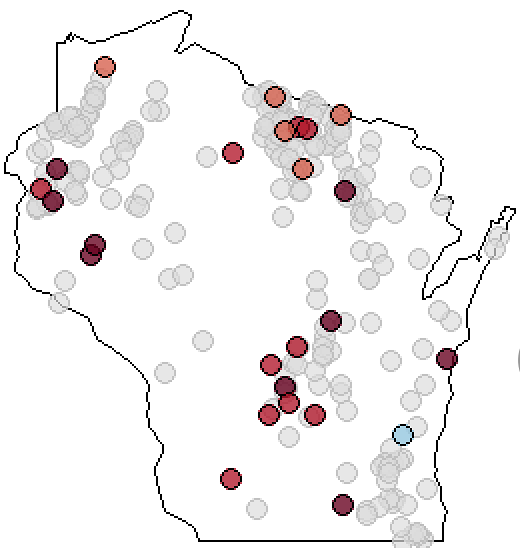
No change

PHOSPHORUS (536 lakes)

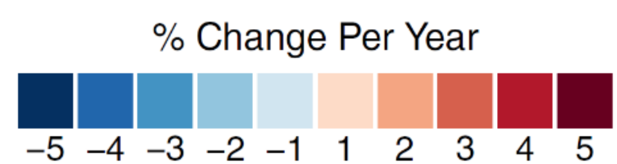


Fewer lakes changing, but increasing > decreasing
42 lakes increasing (8%)
15 lakes decreasing (3%)

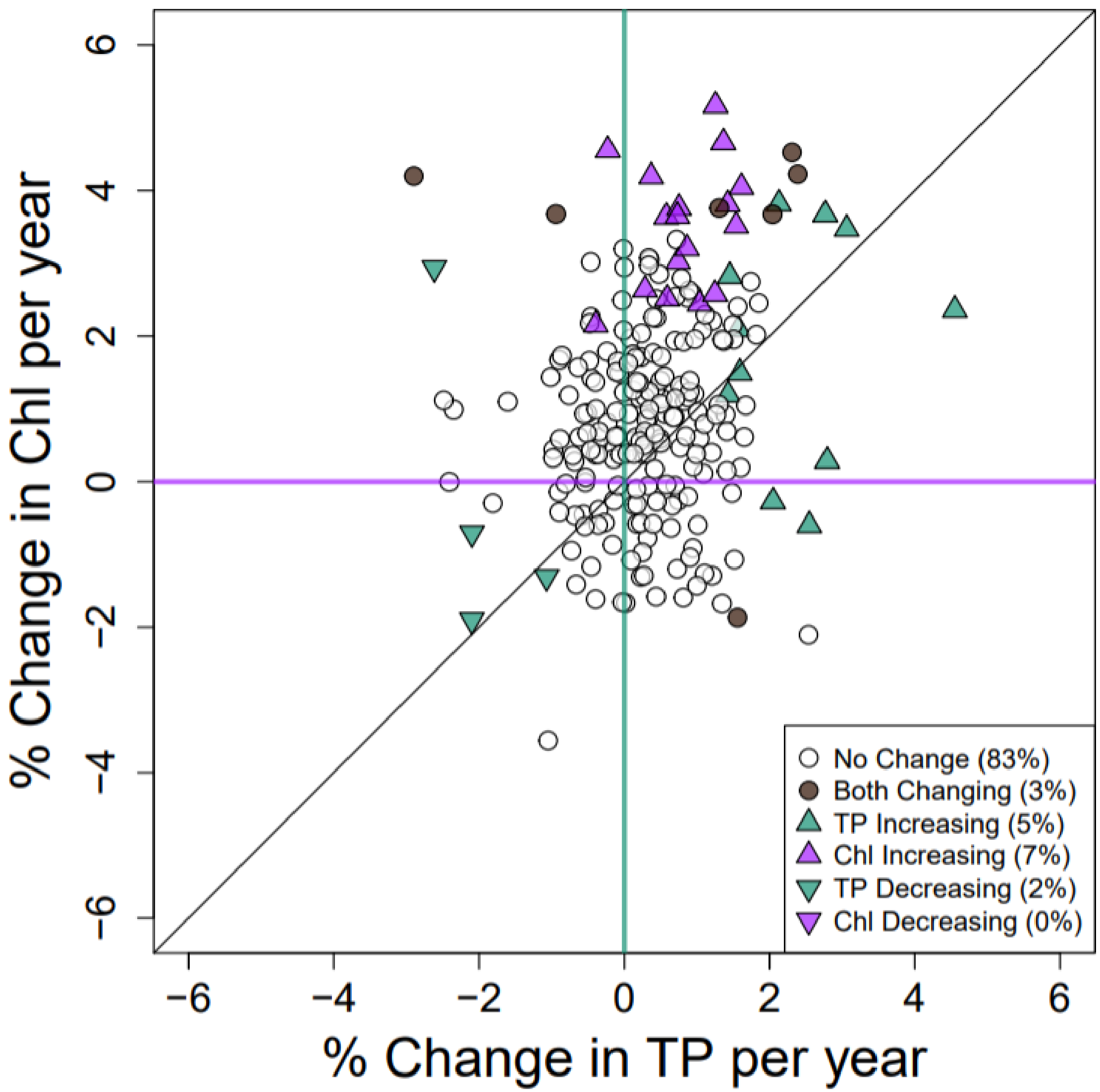
CHLOROPHYLL (233 lakes)



10% of lakes increasing
At mean rate of 4% per year



Water quality trends in Wisconsin



Changes in nutrients not necessarily a good predictor of changes in chlorophyll.

In summary

Hopefully I’ve convinced you…

- Water quality in the Midwest and Northeast US has neither degraded no improved in since 1990.
- WI largely follows this pattern – but maybe slightly worse off?
- Your data are important to these efforts – keep it up!
- Large-scale analyses/research are relevant to your lake.

Questions?

Funding

GLEON
global lake ecological observatory network

UNIVERSITY OF WISCONSIN–MADISON
Graduate School
Advancing Knowledge through Education and Research

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SOCIETY FOR FRESHWATER SCIENCE

USGS
science for a changing world

ASLO
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