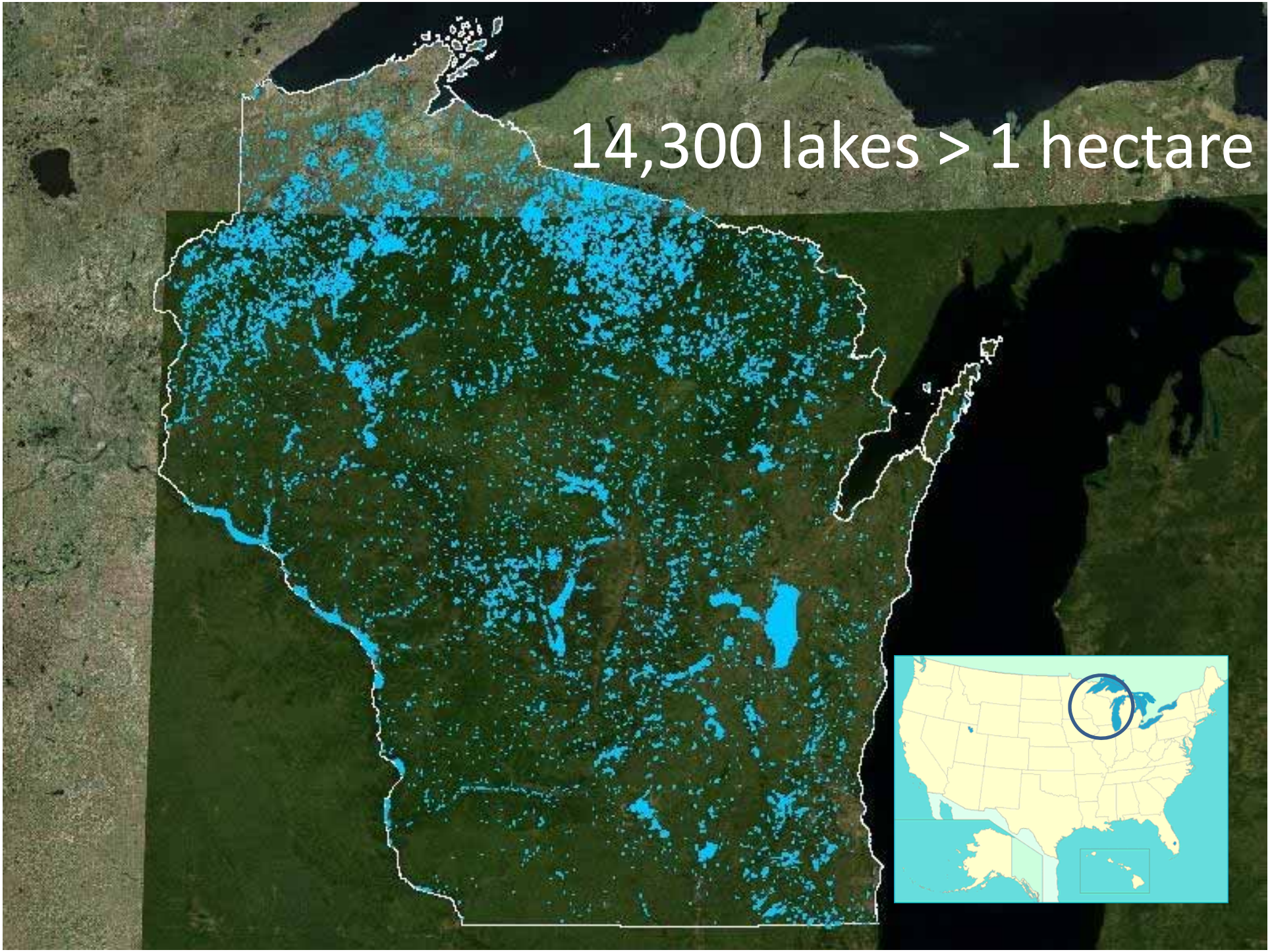
Long-Term Water Quality Trends in Wisconsin Lakes

Katie Hein

Wisconsin Department of Natural Resources


14,300 lakes > 1 hectare


ALUMACRAFT


Photos: Buzz Sorge
HONDA

Phosphorus Reduction Actions in Wisconsin

1933 **Soil Conservation**

1972 **Clean Water Act**

Runoff program

1977 **Great Lakes Water Quality Agreement**

1984 **Regulate Concentrated Animal Feeding Operations**

1992 **Discharge <1 mg/L phosphorus statewide**

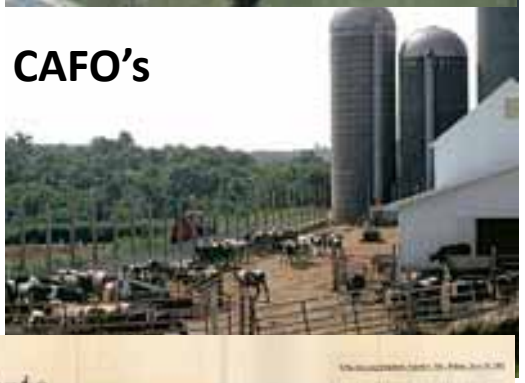
2002 **Runoff performance standards and prohibitions**

2007 **Tighten rules for large animal farms**

2010 **Fertilizer phosphorus ban**
Dish detergent < 0.5% phosphorus by weight
Phosphorus criteria for all surface waters
Phosphorus budgets for impaired watersheds

Wastewater Treatment

CAFO's

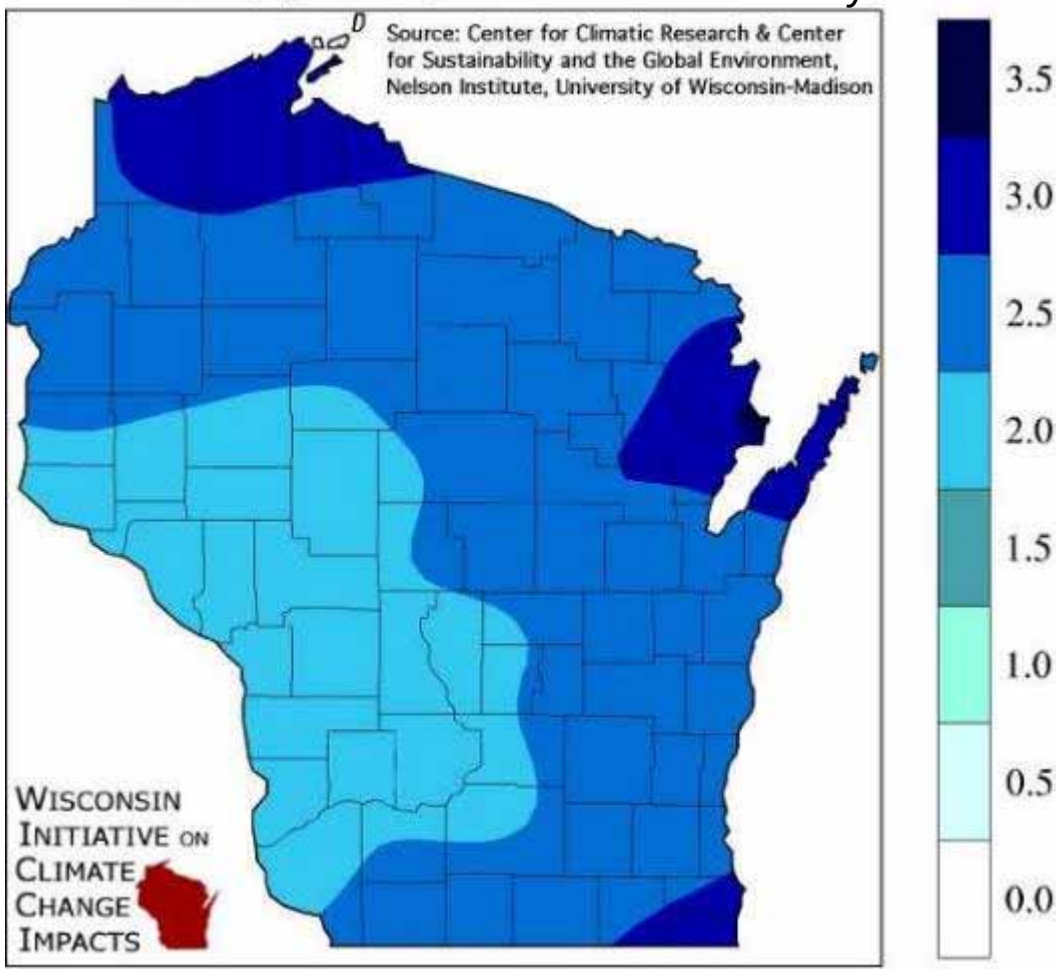



State
New phosphorus restrictions approved

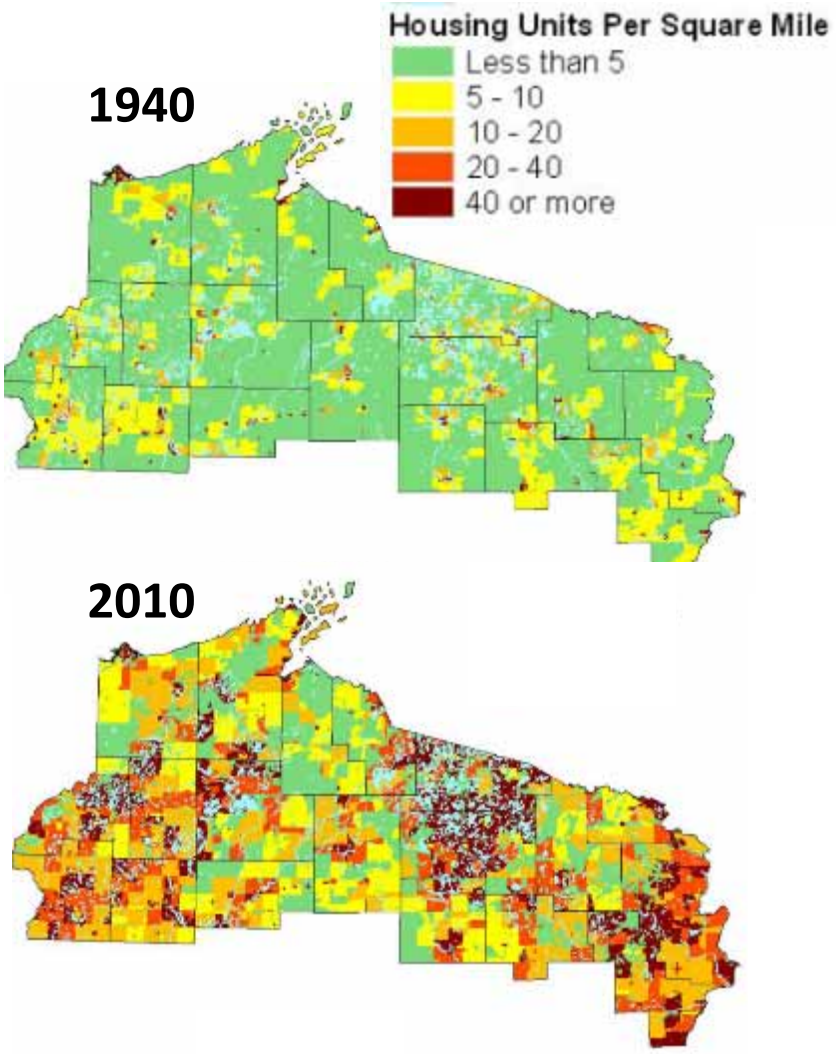
Phosphorus bans

Future Nutrient Loading Threats

Projected Change in Frequency of 2” Precipitation Events 1980 to 2055



Increase in Housing Density



Is lake water quality getting better, worse, or staying the same?

Long-Term Water Quality Monitoring

Spring and 3 X's in summer:

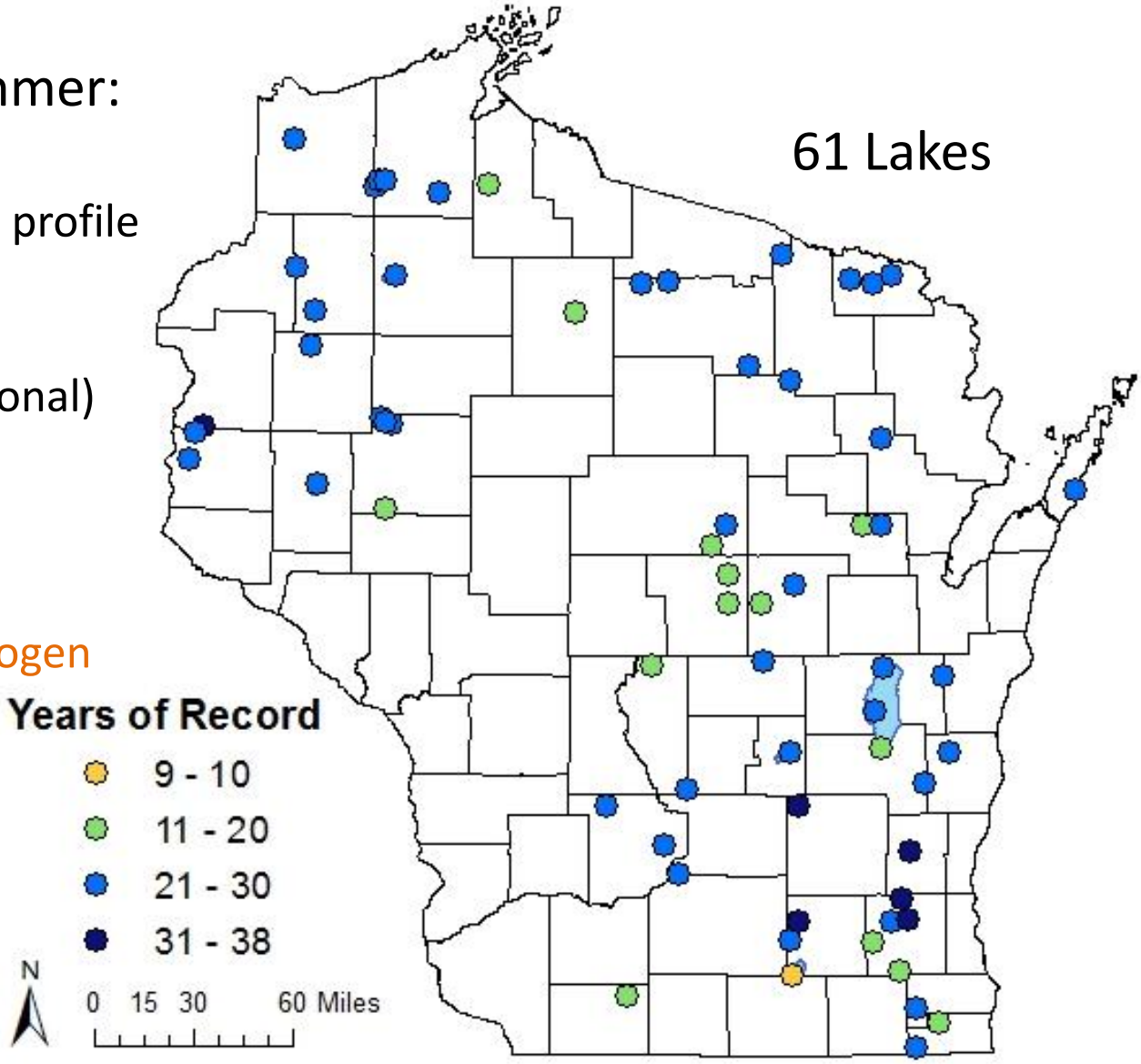
- Secchi depth
- Temperature/D.O. profile
- Total Phosphorus
- Chlorophyll *a*
- Conductivity (optional)
- pH (optional)

1 X in summer:

- Color
- Total Kjeldahl Nitrogen
- NO2+NO3
- Alkalinity

5 year cycle:

- Ca
- Mg

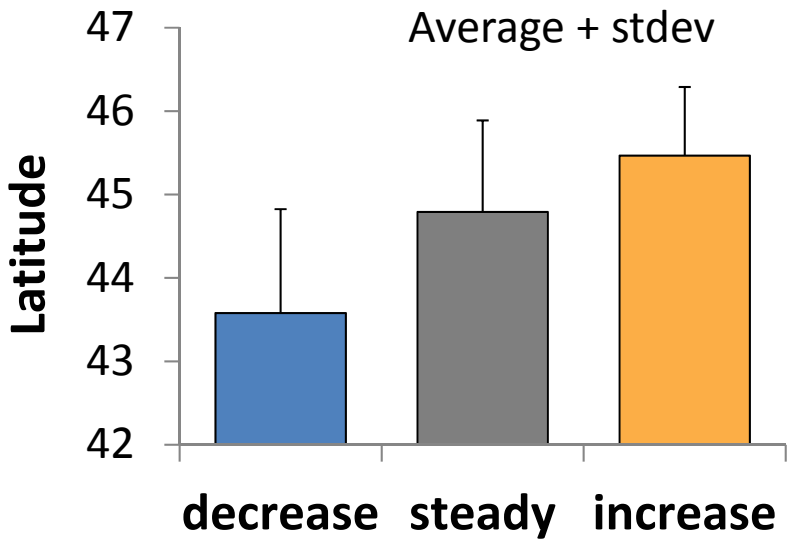


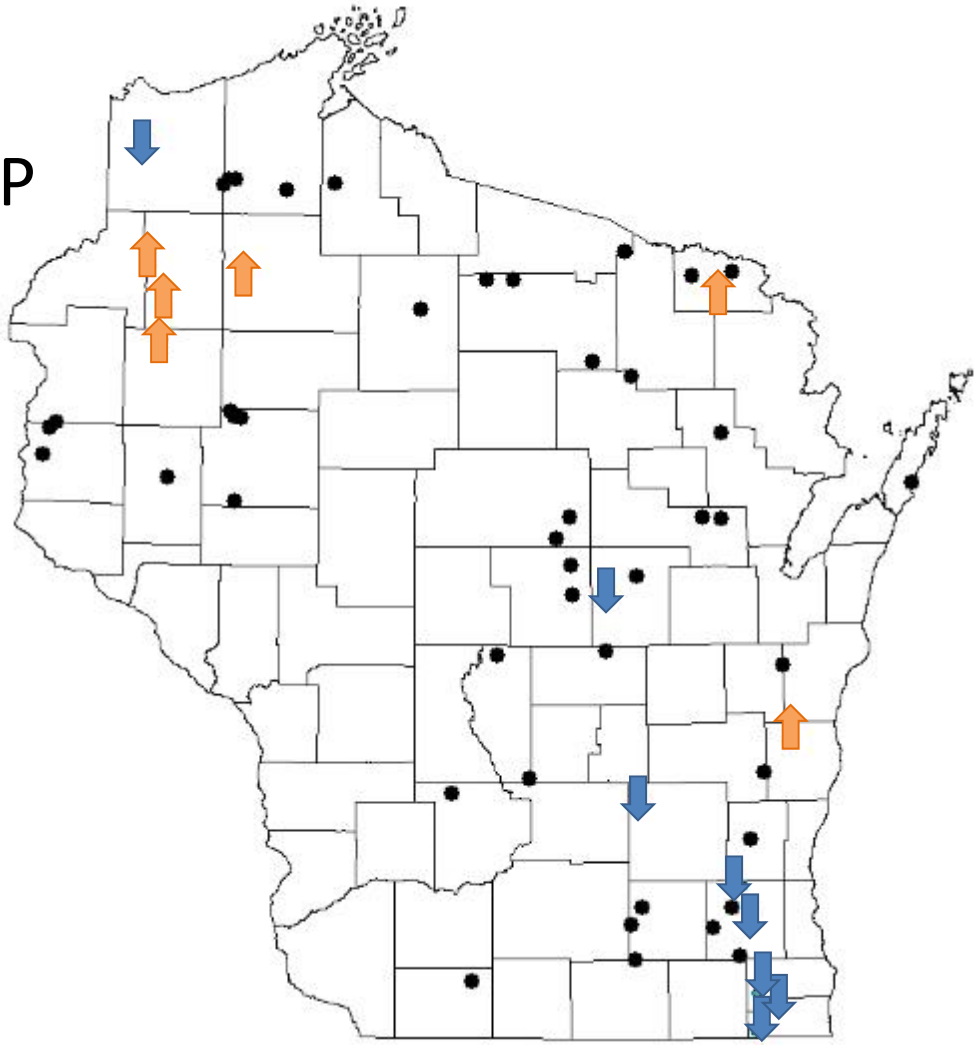
Trends in Total Phosphorus Over Time

8 lakes decreasing TP

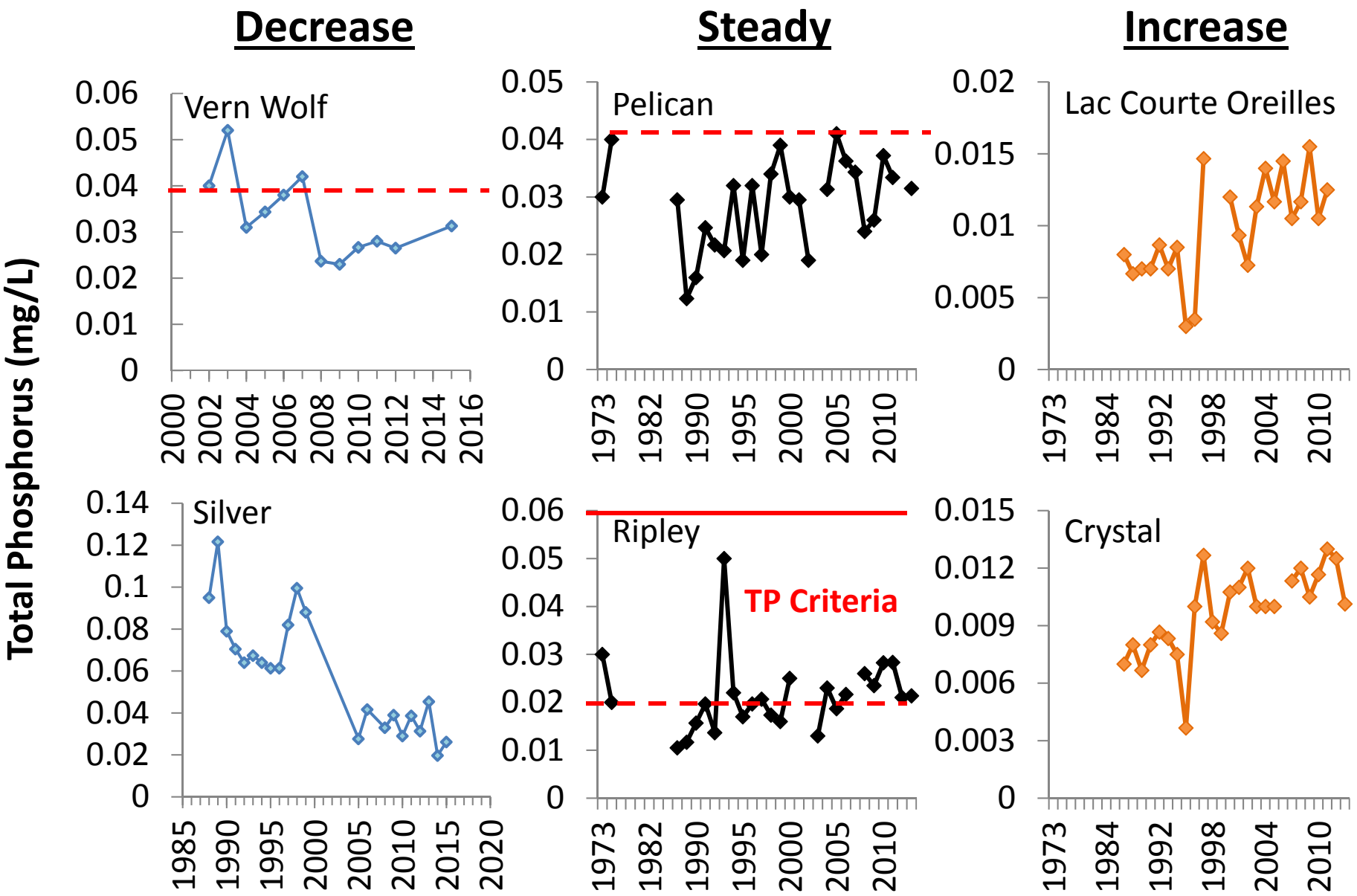
46 lakes no change in TP

6 lakes increasing TP

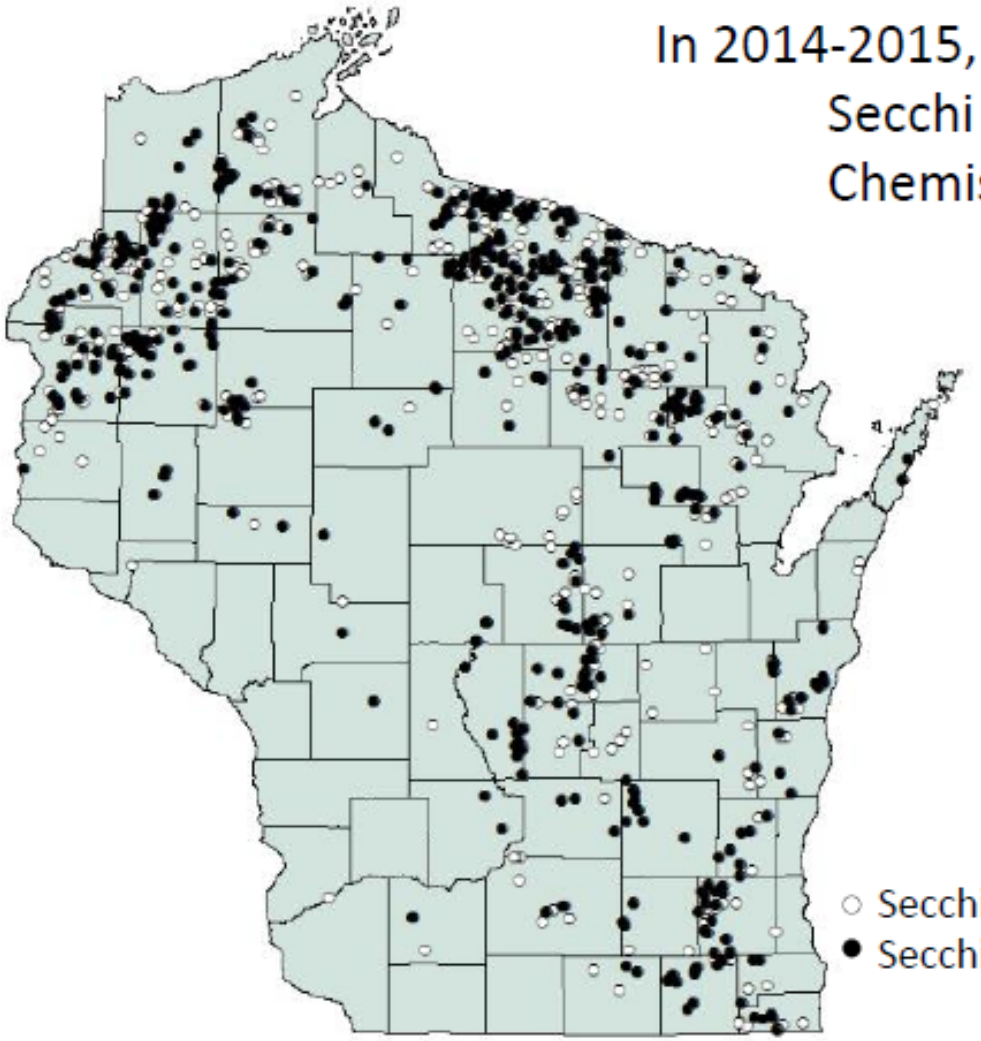




Trends in Total Phosphorus Over Time



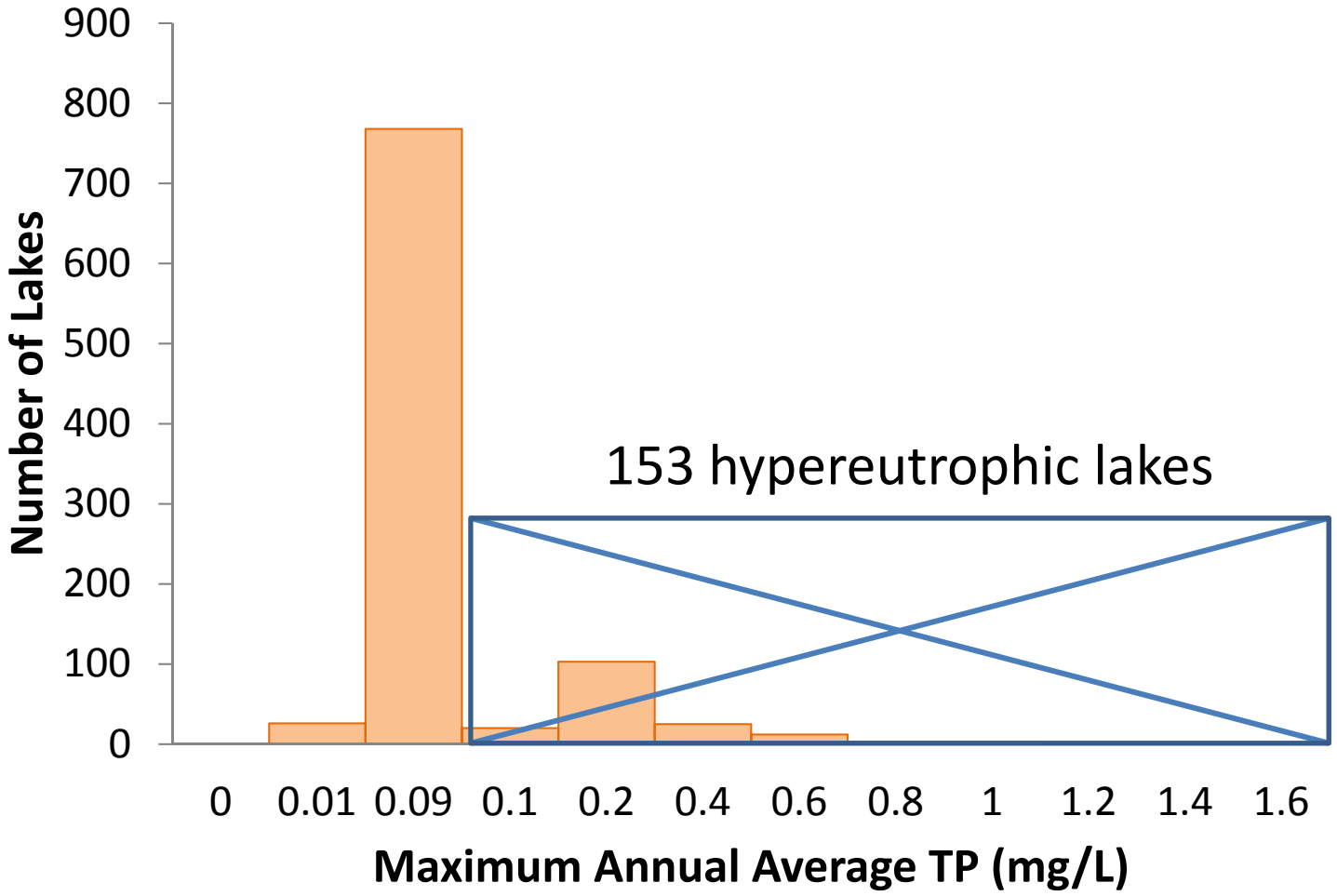
Expand analysis to all WDNR data



WDNR Data Download:

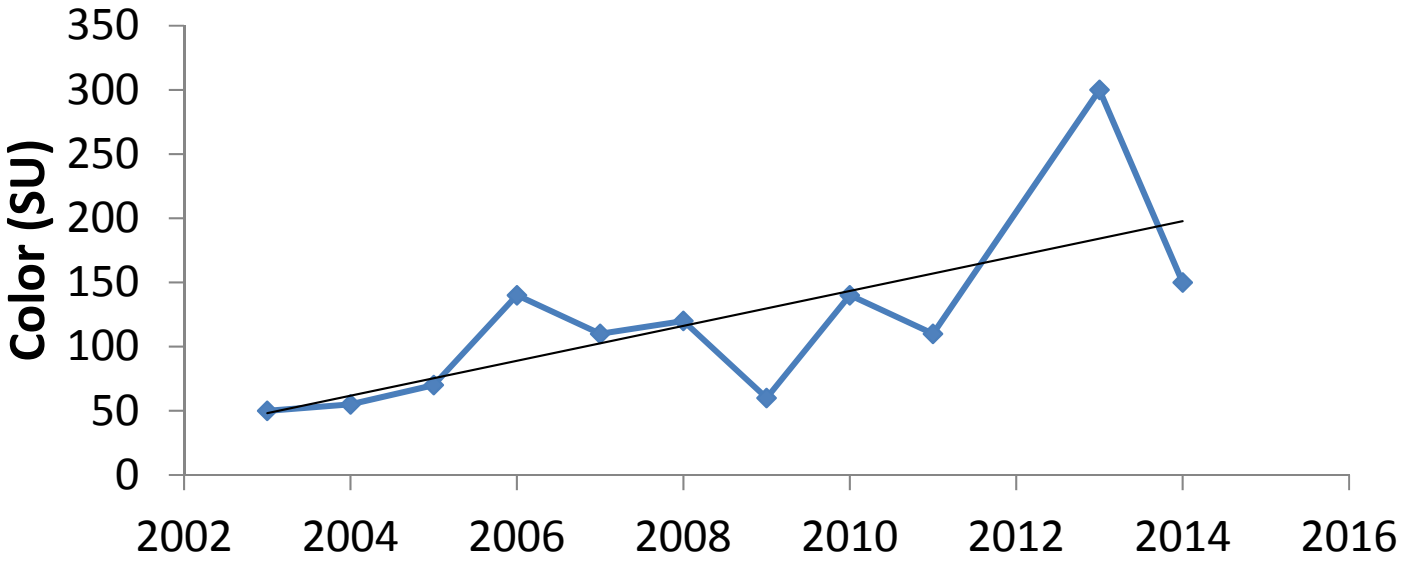
- 218,300 records
- 1501 lakes
- Data from 1968 - 2015
- Up to 34 years of data on a single lake

Exclude hypereutrophic lakes (≥ 0.1 mg/L) from Total Phosphorus analysis

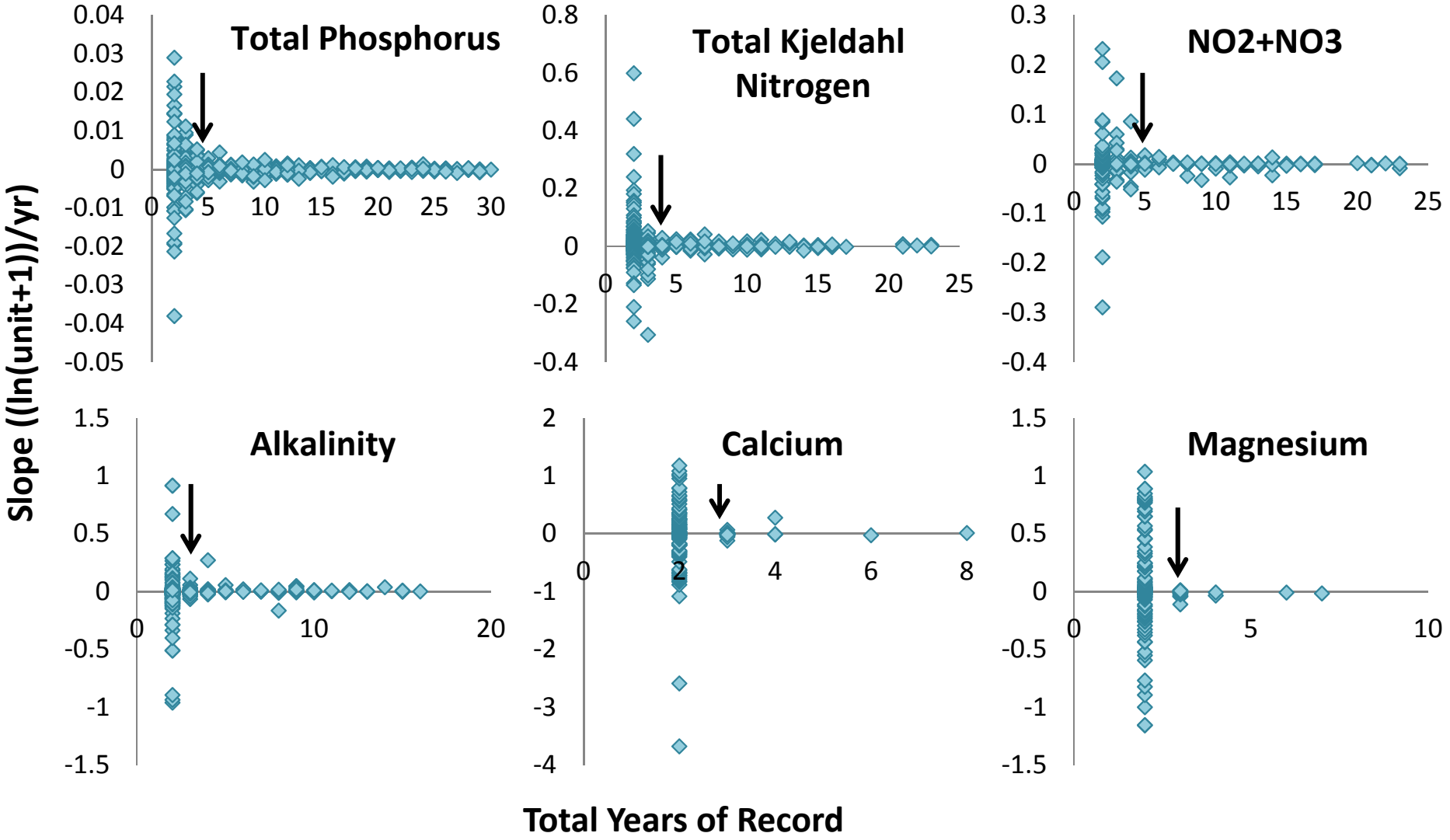


Simple linear regressions

- June 15 – September 15
- Annual Average
- Natural logarithm of concentration



Limit trend analysis to lakes with at least 3-5 years of data



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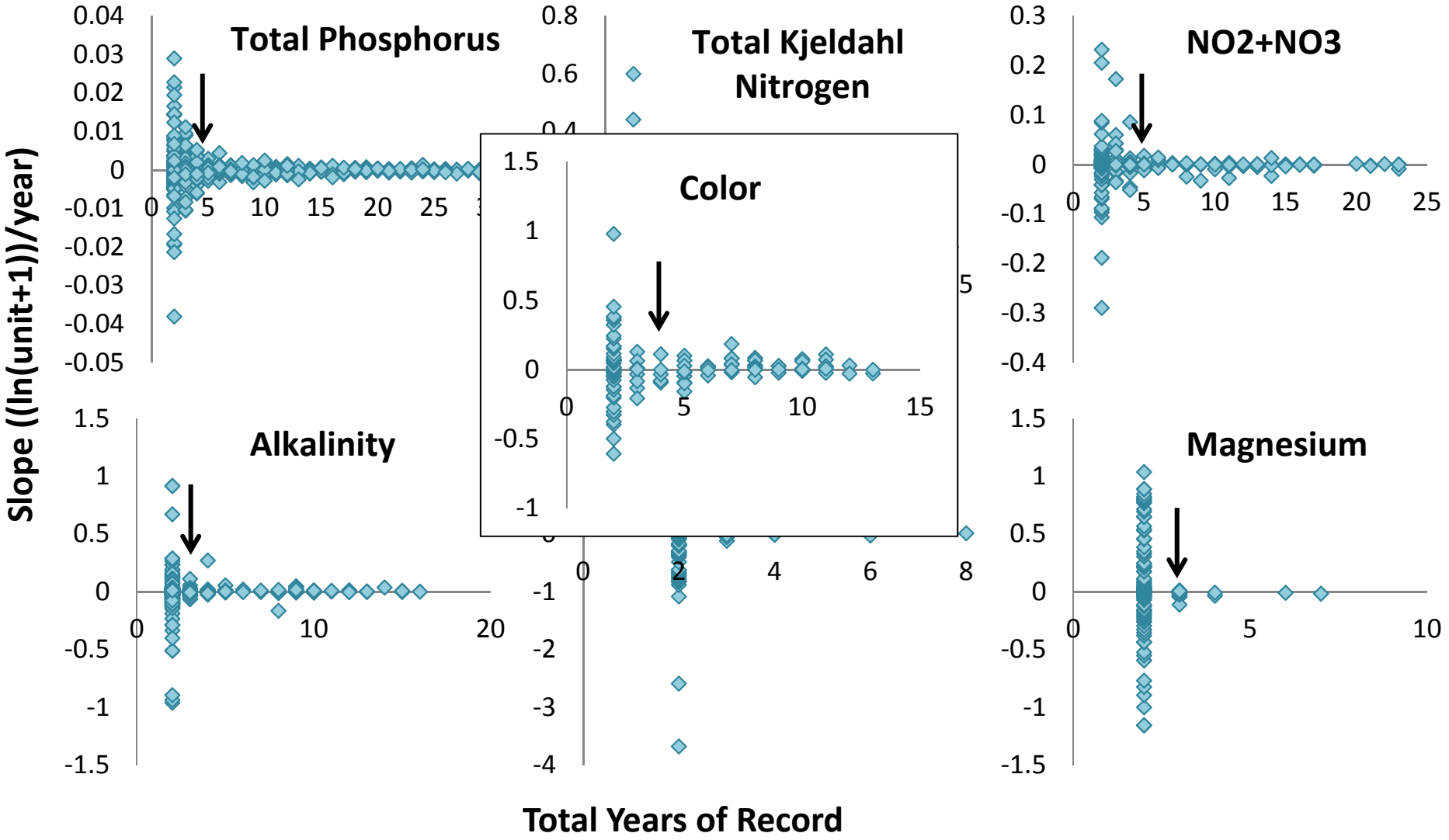
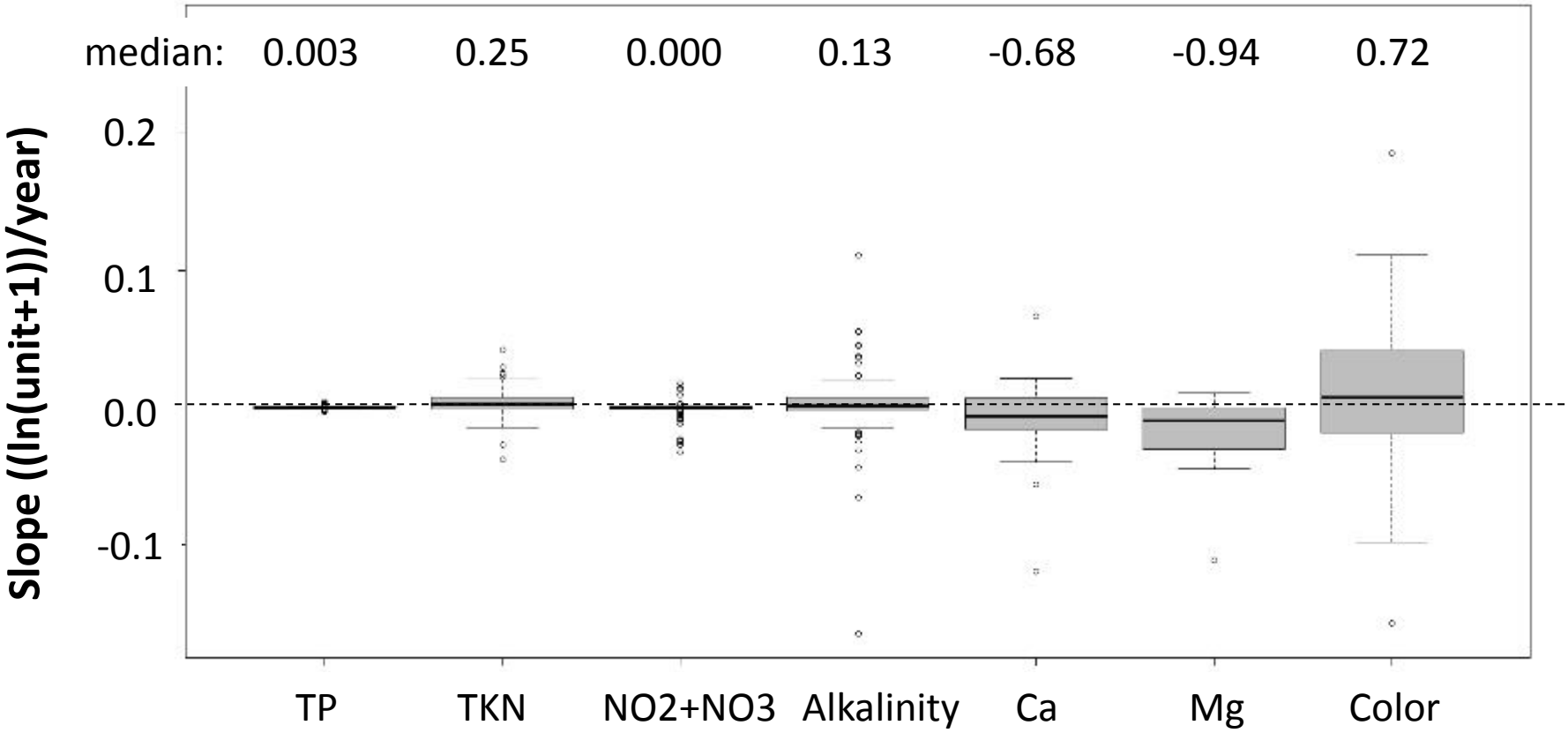
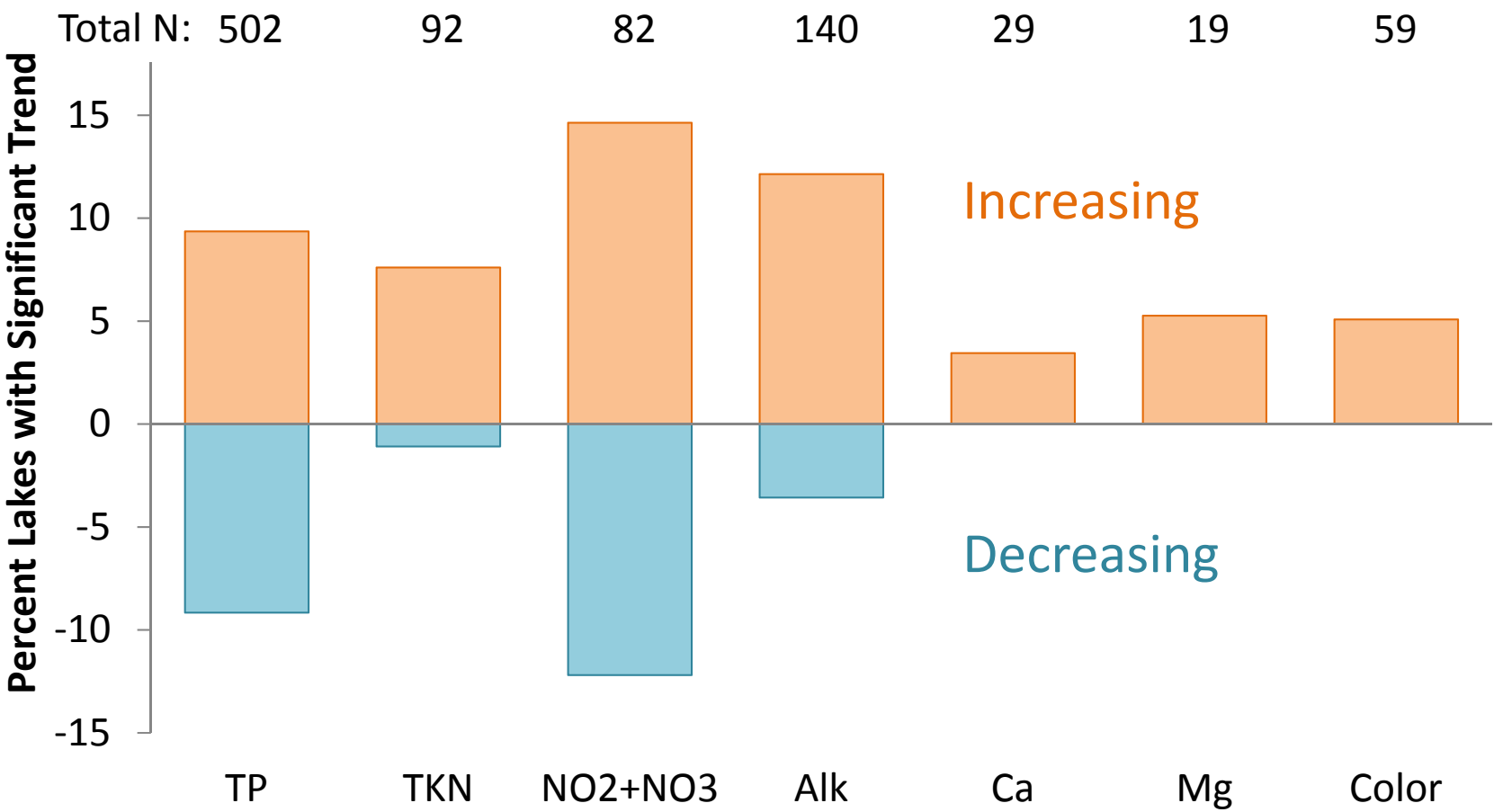


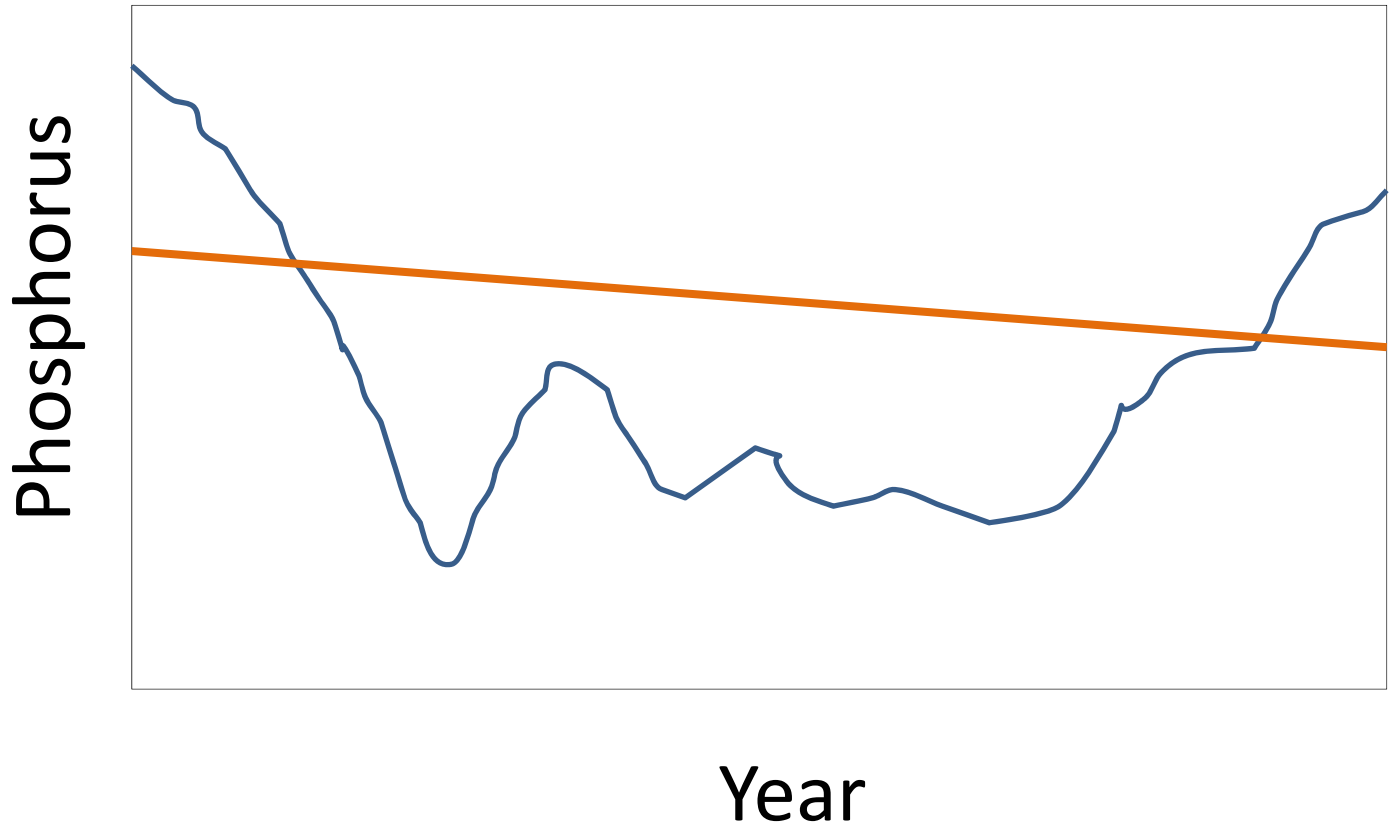
Trend Slopes Near 0 on Most Lakes



3%-27% of lakes had a significant trend



Does time period matter?



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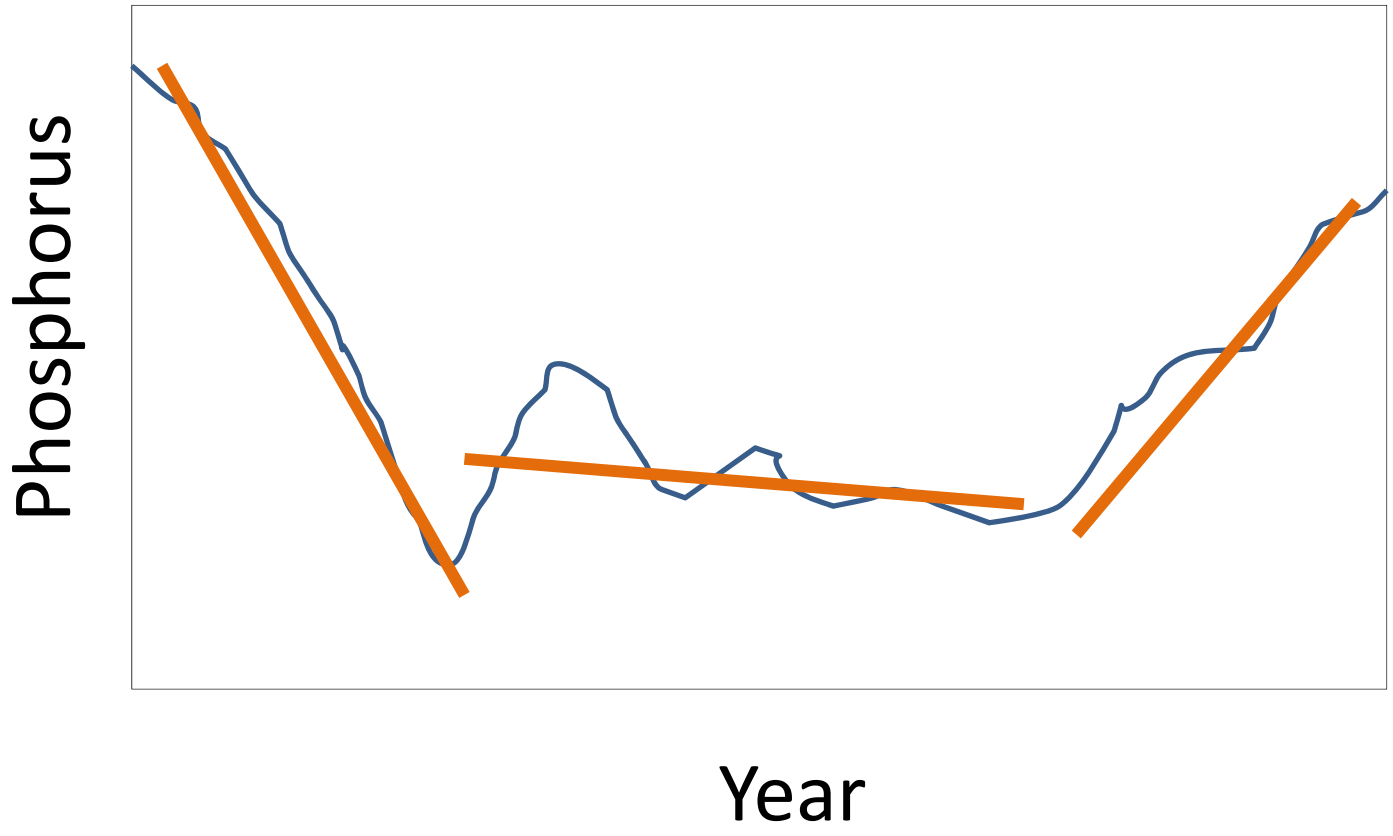
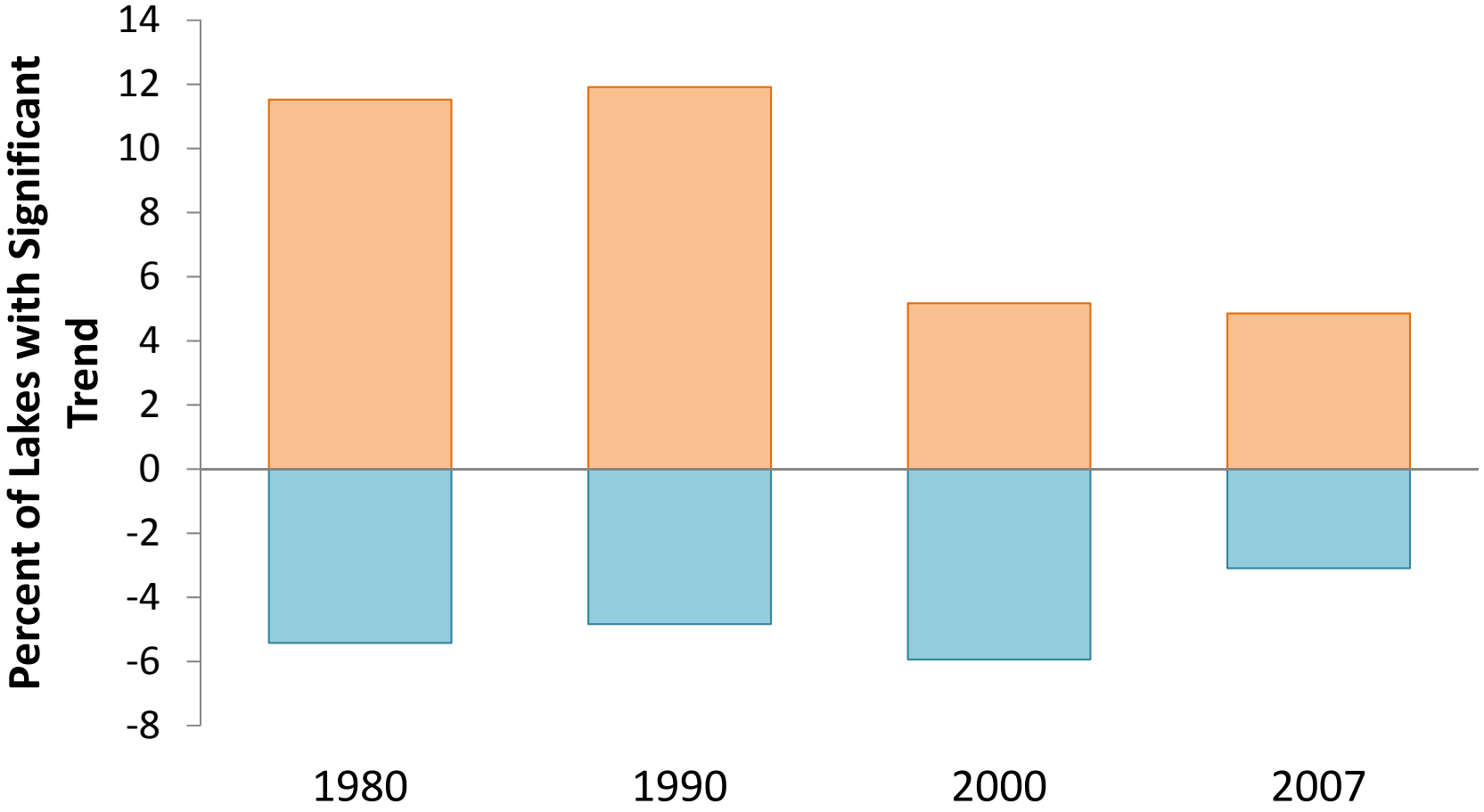
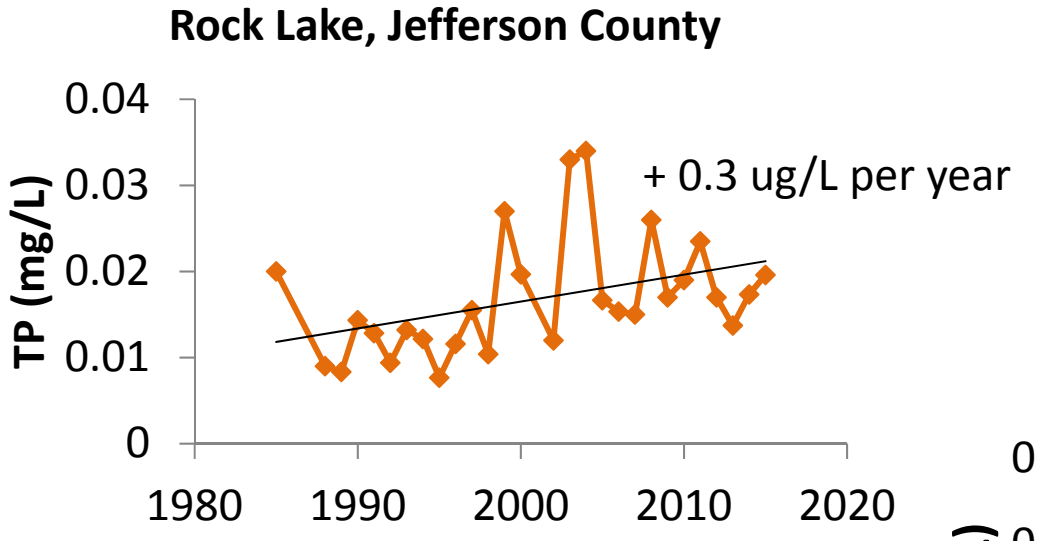
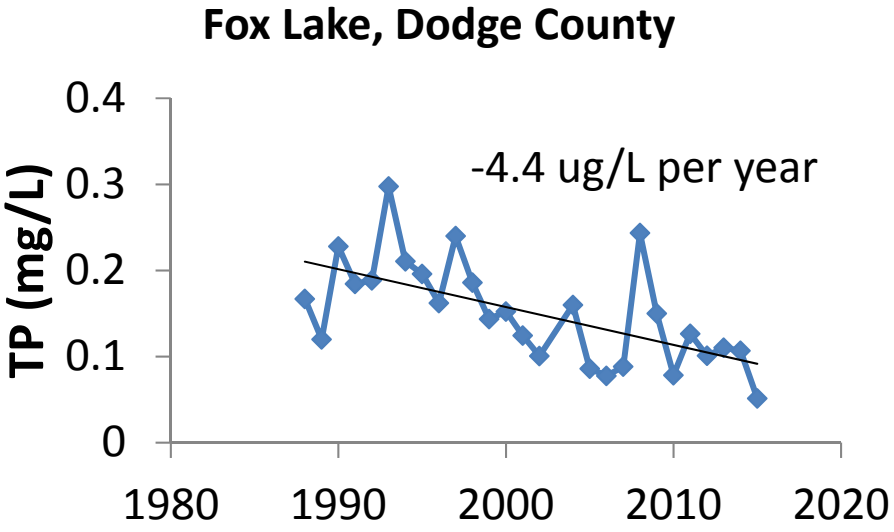
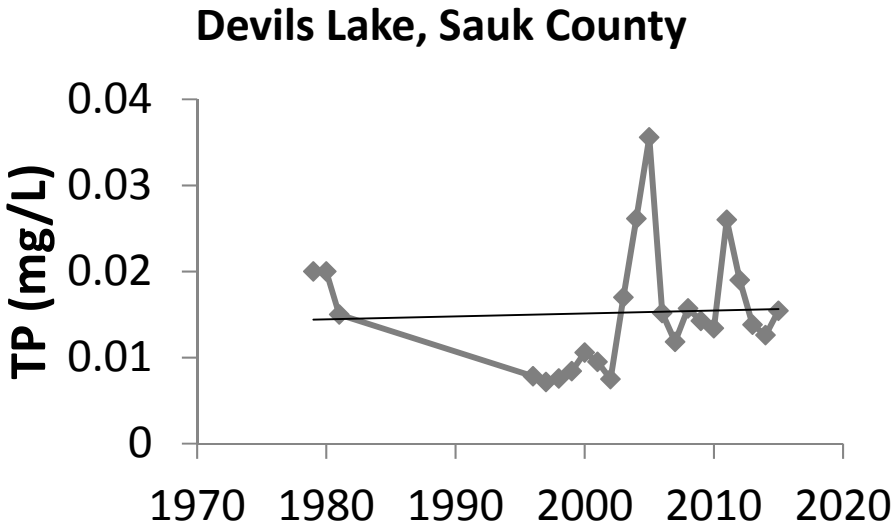


Fewer lakes with increasing phosphorus trend in recent years



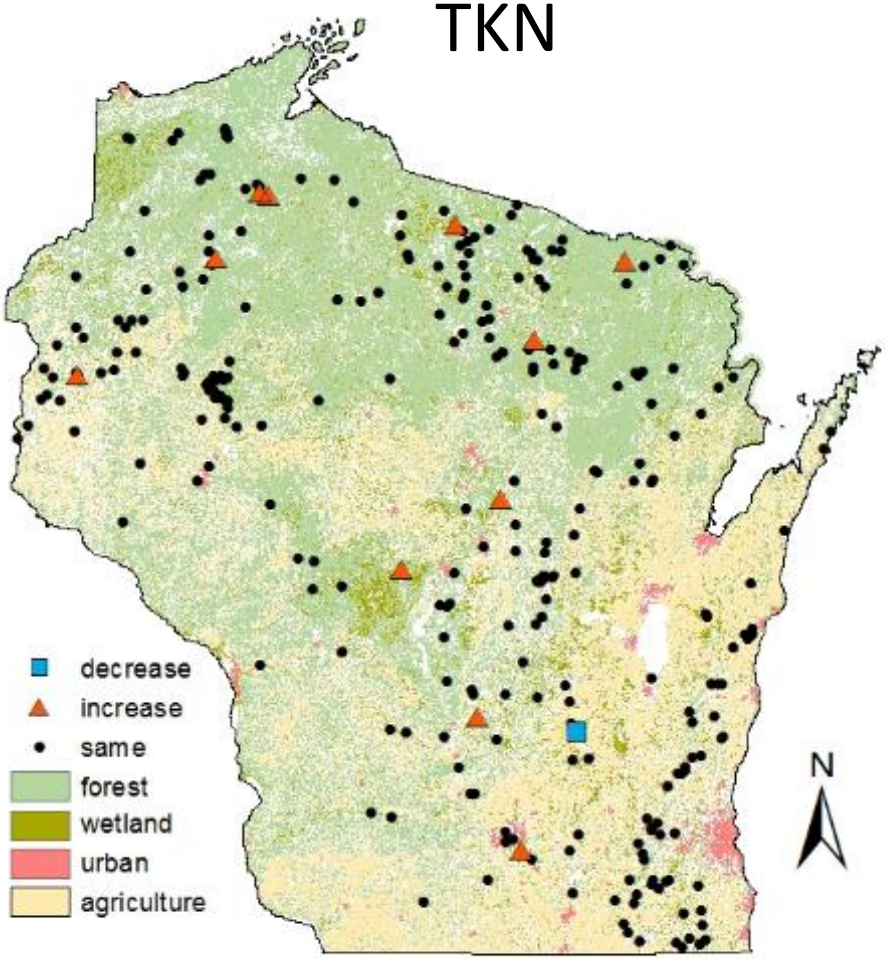

Rock Lake, Jefferson County
TP (mg/L)
0.04
0.03
0.02
0.01
0
+ 0.3 ug/L per year
1980
1990
2000
2010
2020


Fox Lake, Dodge County
TP (mg/L)
0.4
0.3
0.2
0.1
0
-4.4 ug/L per year
1980
1990
2000
2010
2020

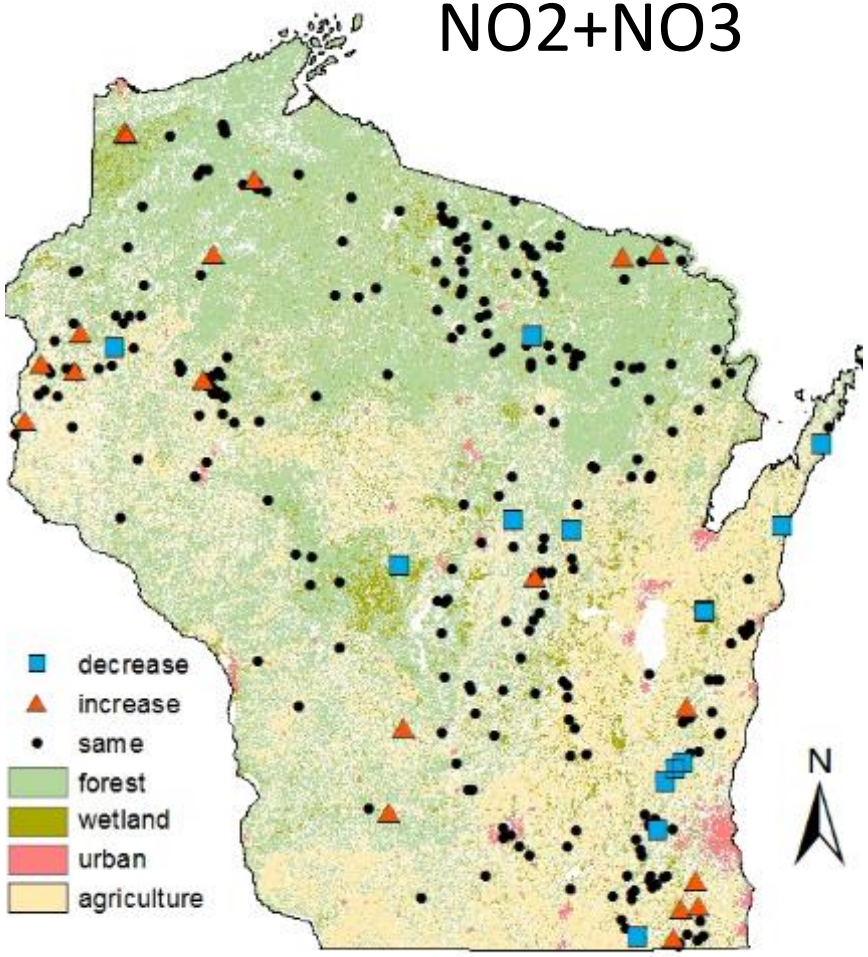

Devils Lake, Sauk County
TP (mg/L)
0.04
0.03
0.02
0.01
0
1970
1980
1990
2000
2010
2020

No Spatial Pattern in Temporal Trends

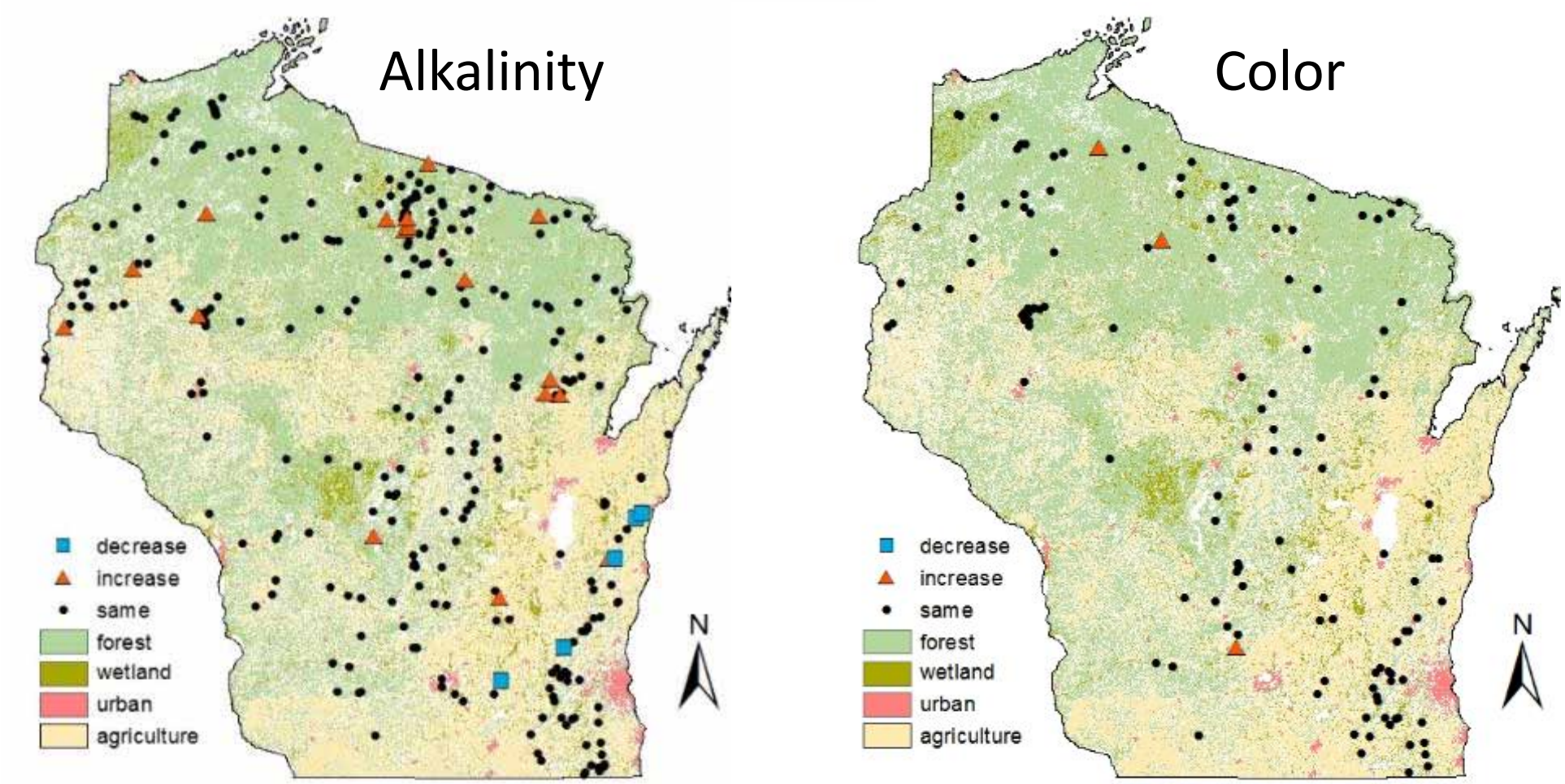
TKN



NO2+NO3

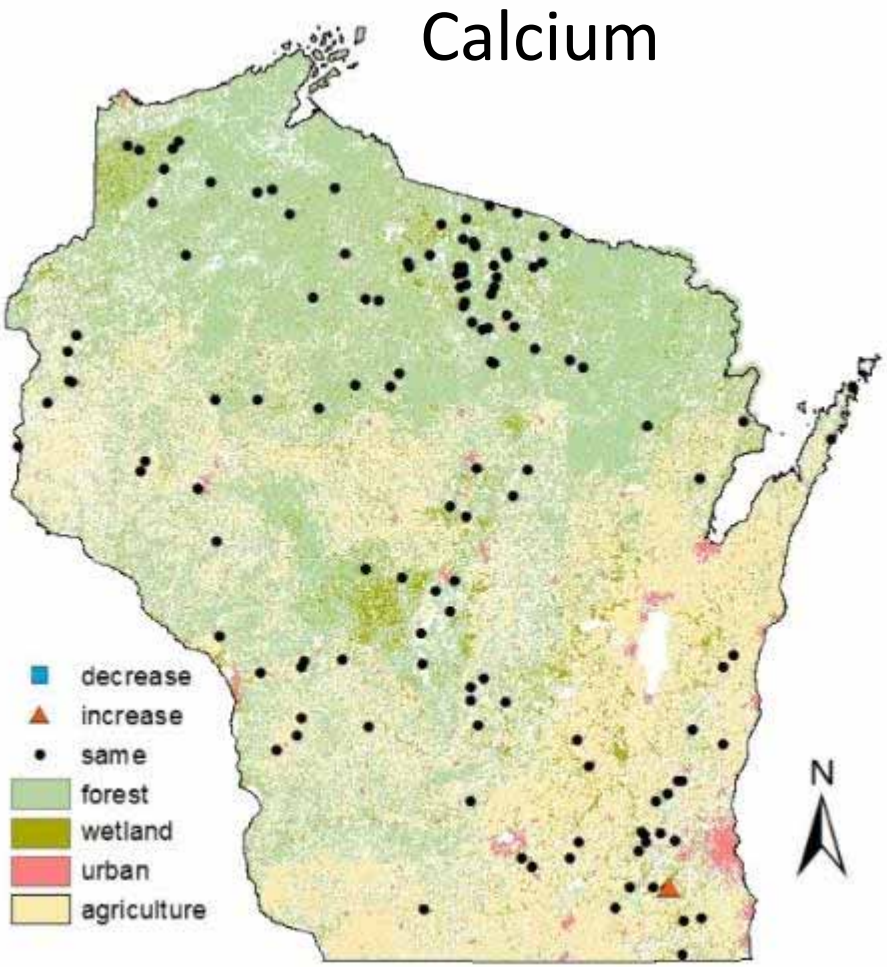


No Spatial Pattern in Temporal Trends

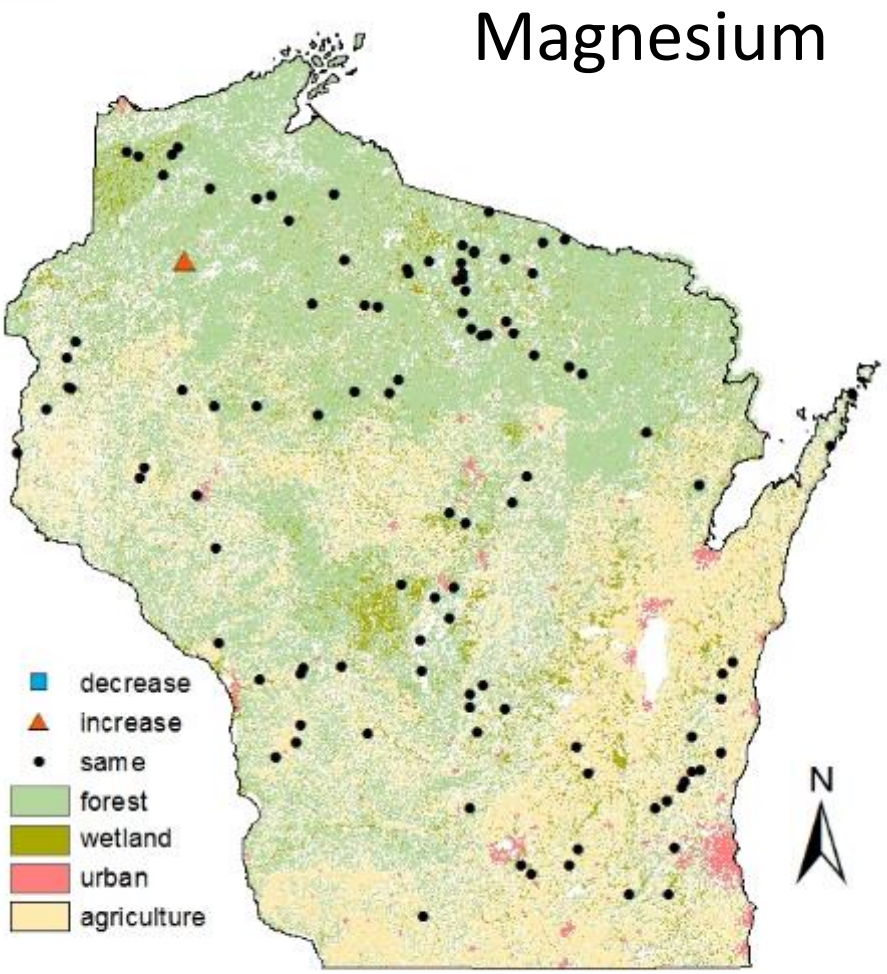


No Spatial Pattern in Temporal Trends

Calcium



Magnesium



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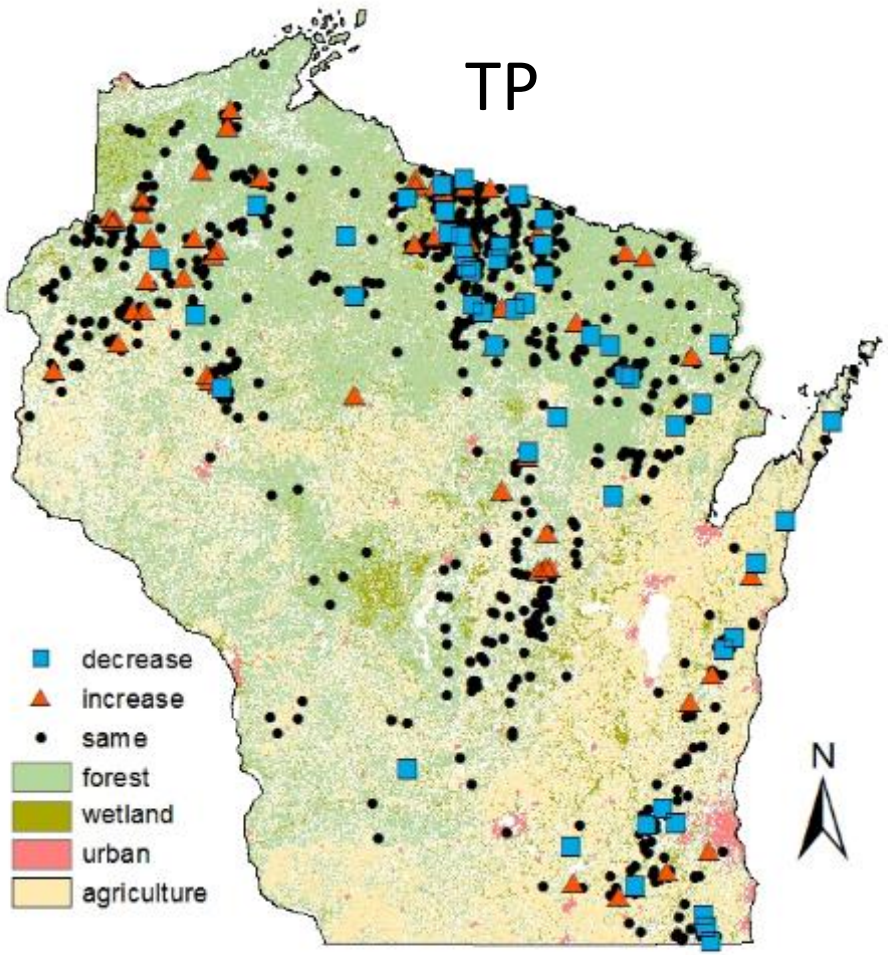
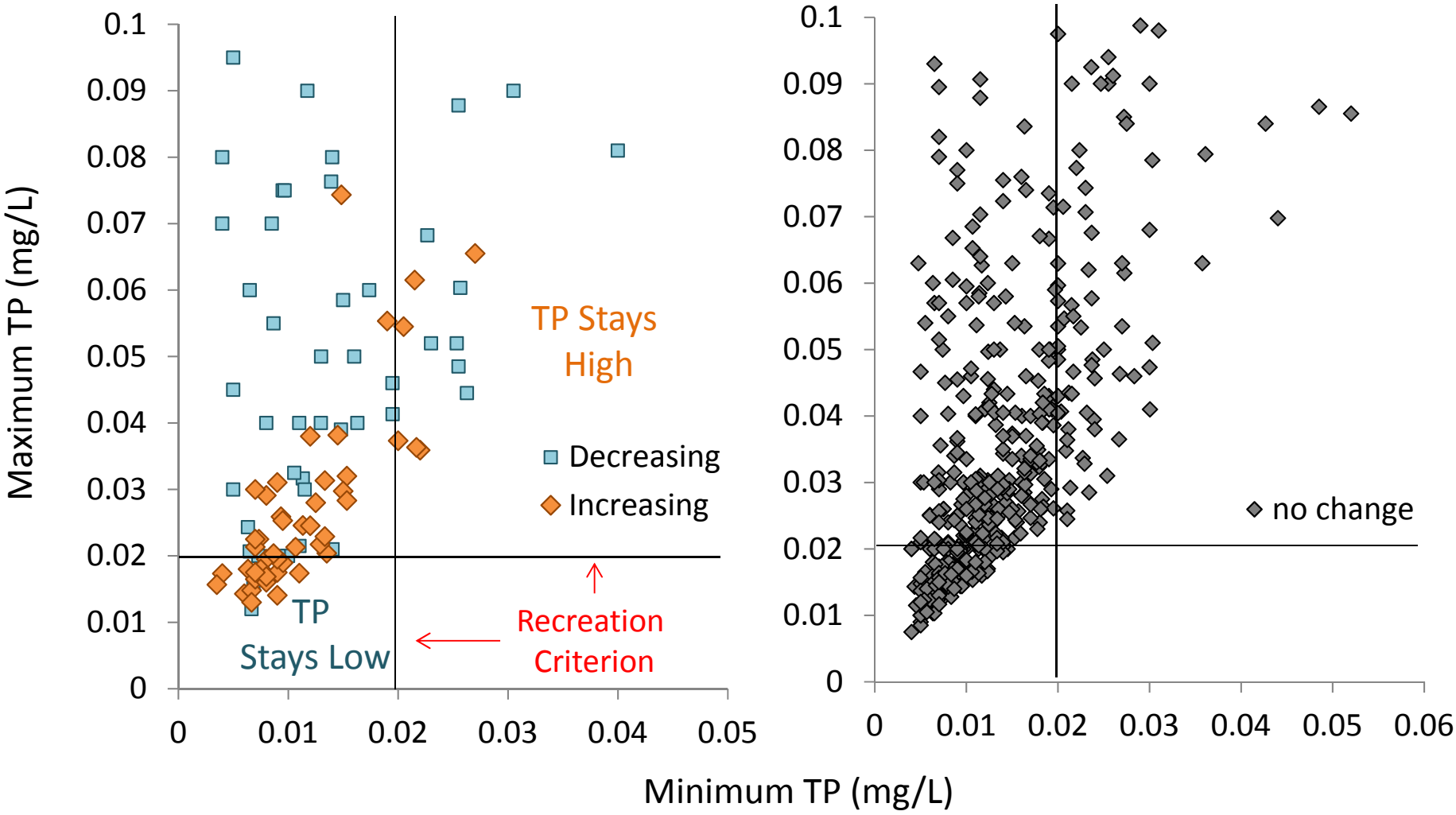


Are lakes getting better or worse?

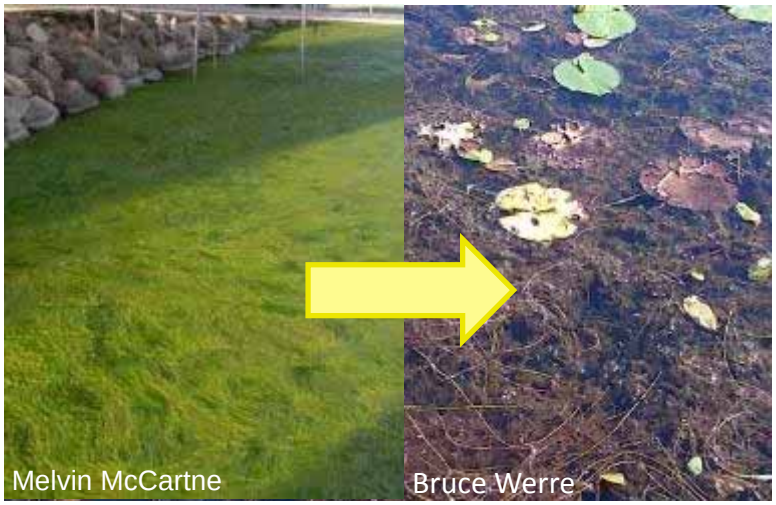


Reasons for Phosphorus Decline

Urbanization of Agricultural Land

Septic to Municipal Sewage

Algal to Plant-Dominated Lake



Best Management Practices

Reasons for Increasing Phosphorus

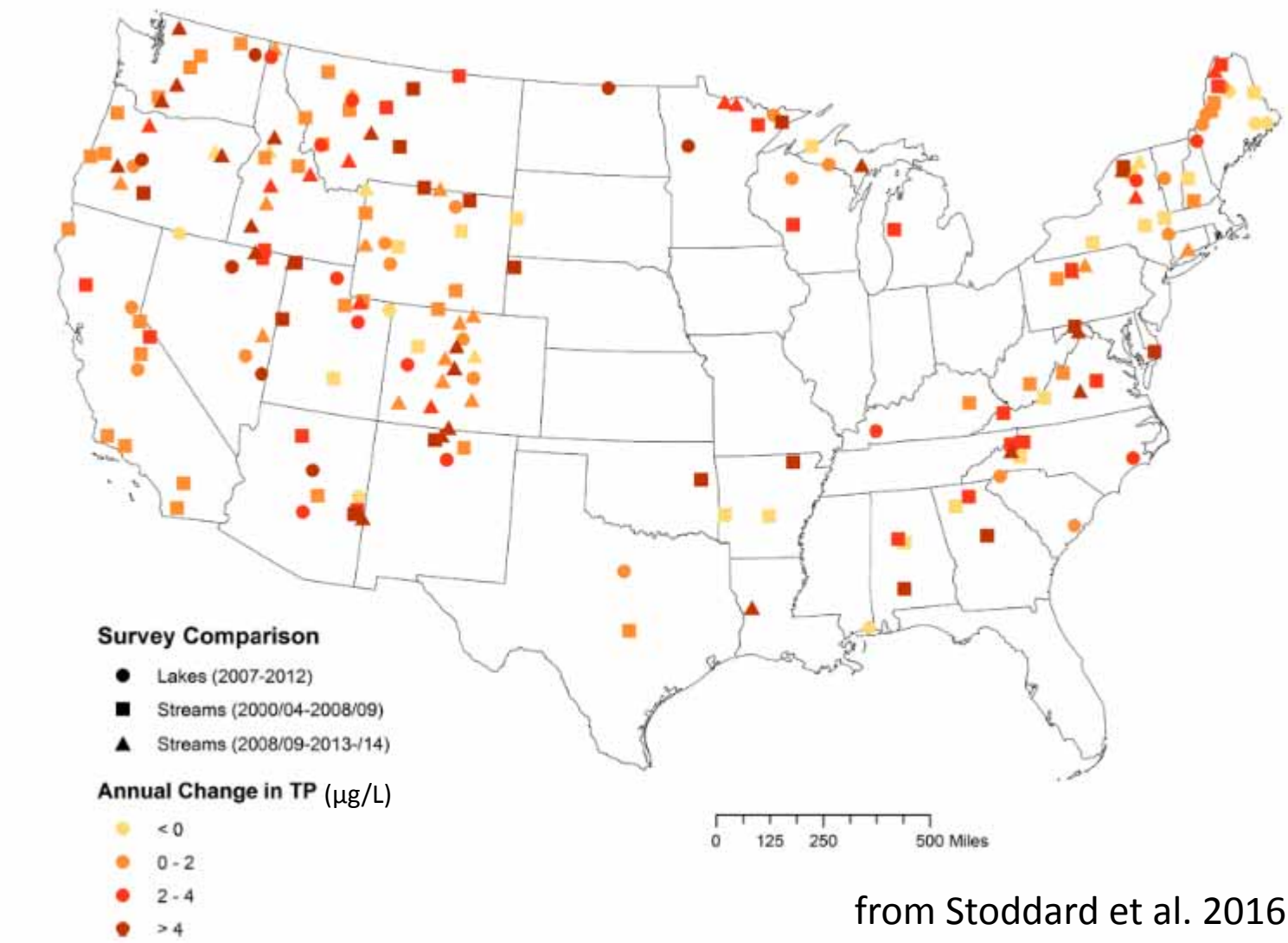
Agriculture

Lake Shore Development

Plant to Algal-Dominated Lake

Climate and Water Levels

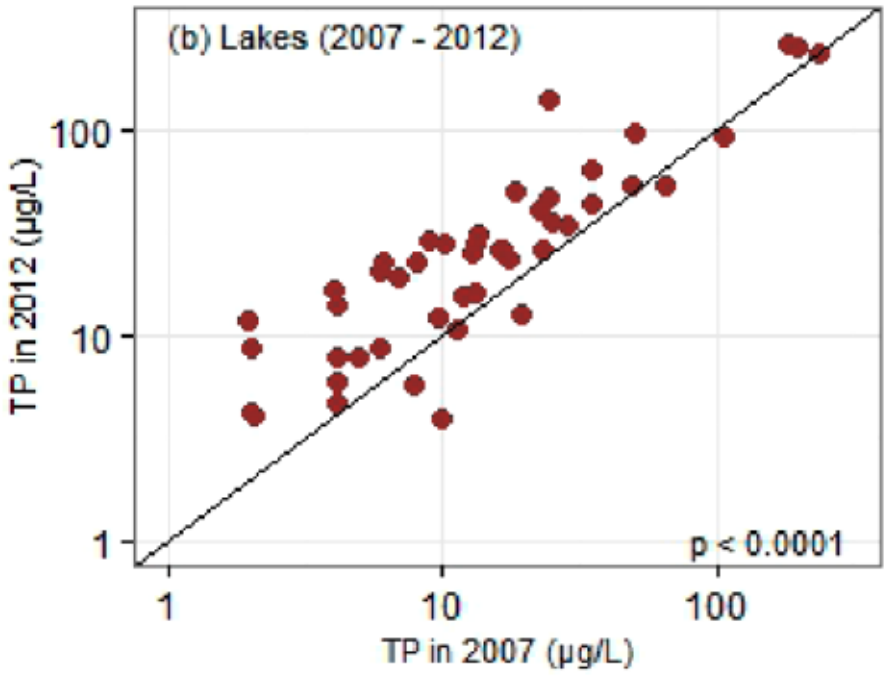
National Aquatic Resource Surveys: Minimally Disturbed Lakes and Streams are Getting Worse



from Stoddard et al. 2016 Env Sci & Tech

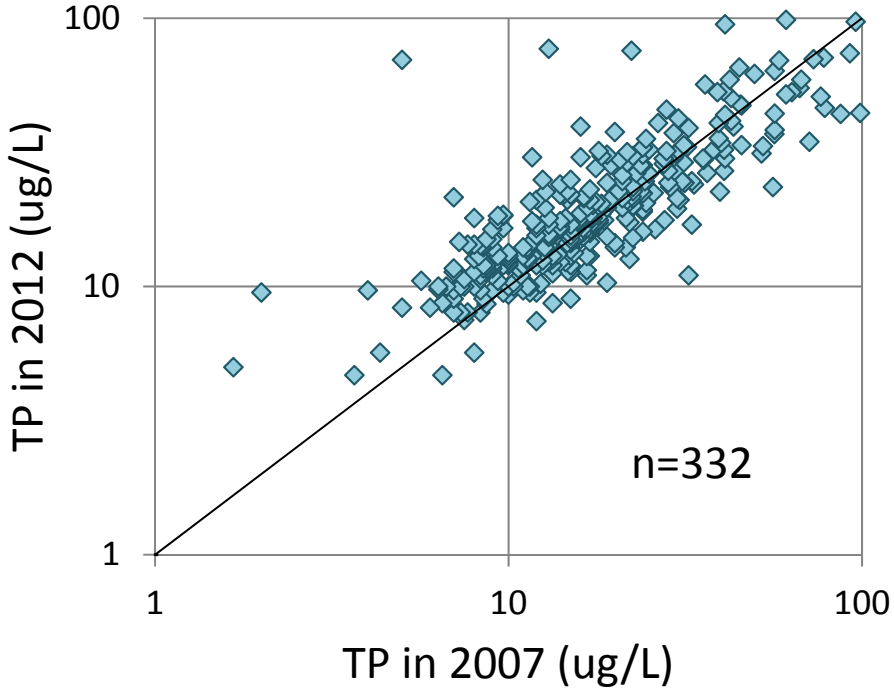
National vs. Wisconsin Trends

National Reference Lakes



Median annual TP increase: 1.6 ug/L/year

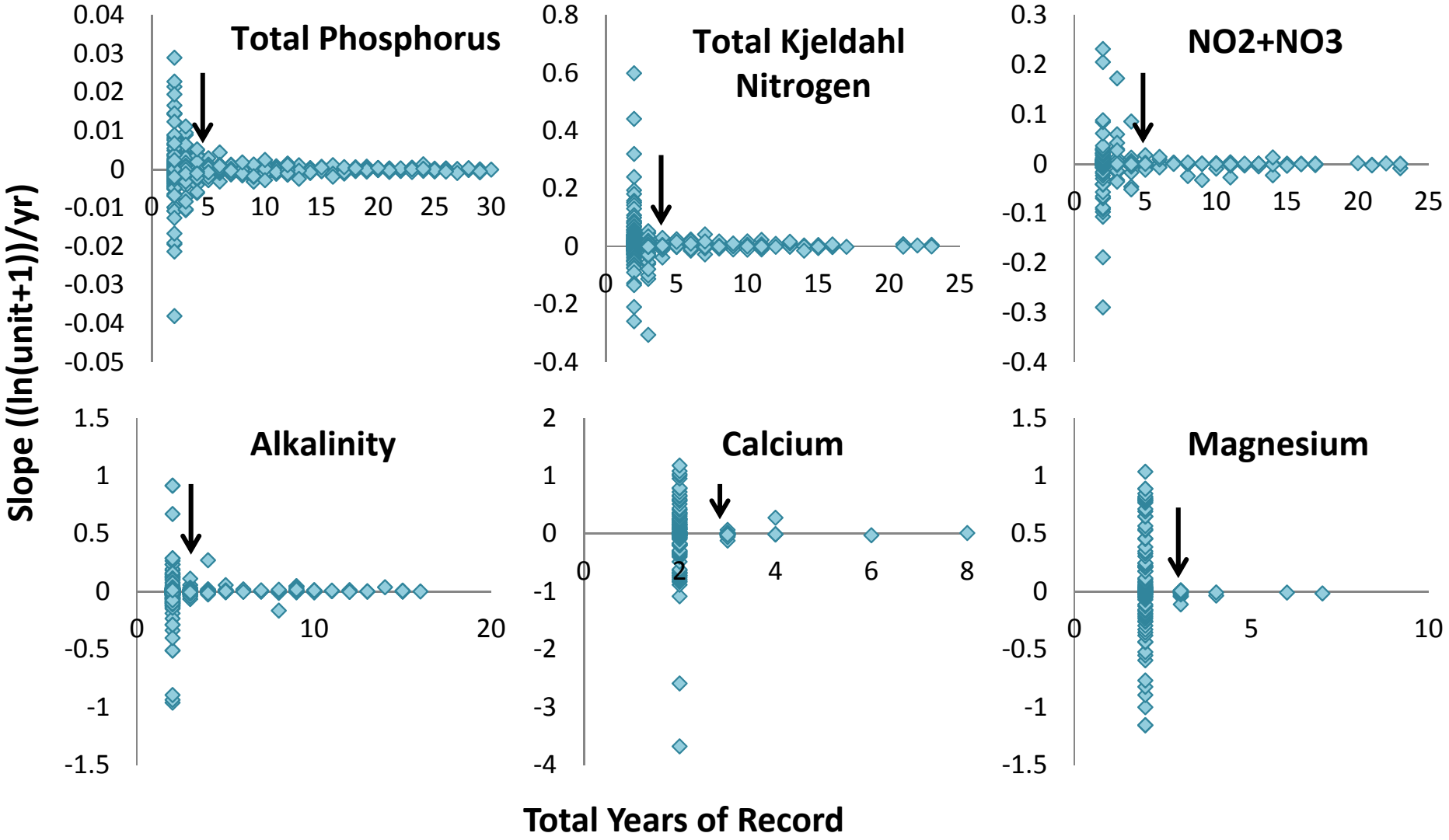
All Wisconsin Lakes



0.27 ug/L/year

from Stoddard et al. 2016 Env Sci & Tech

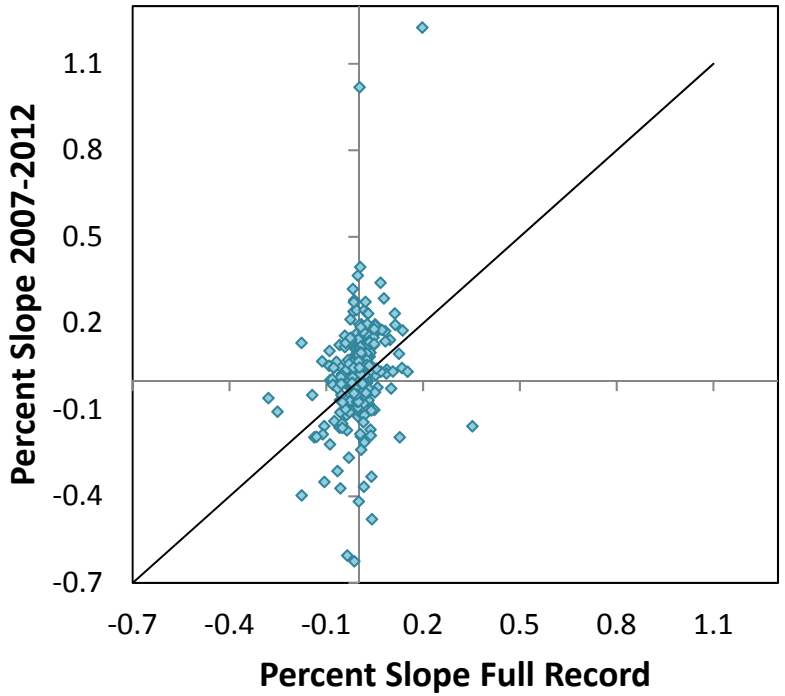
Trends more extreme with less than 3-5 years of data

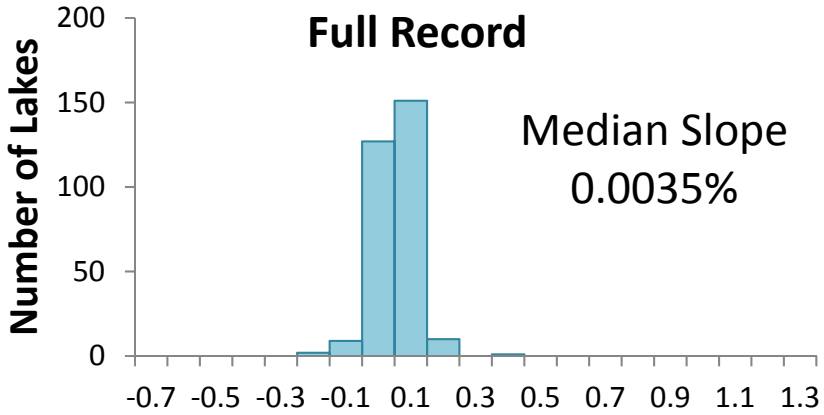


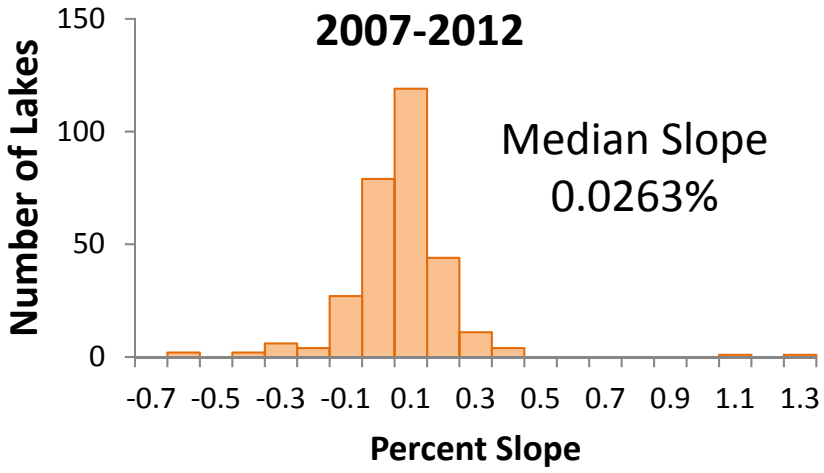
Trends in Total Phosphorus from 2007-2012 vs. Full Record

Full Record

Years of Data:	4 - 31
Start Year:	1973 - 2007
End Year:	2012 - 2015







Paired T-Test ($p<0.02$)

Analytical Approach

- Consider length of record when drawing conclusions about trends
- Slopes from 2 years of data much more extreme than those from longer records
- Simple linear regression over long period of record may mask recent trends
- Fewer lakes with increasing phosphorus trends in recent years

Summary of Trends

- Most lakes have not changed over time spans of 3 – 43 years, but a small percent of lakes have significantly increasing or decreasing trends.
- Lack of spatial pattern suggests local watershed processes are important drivers
- Median slope
  - Calcium, Magnesium

  0 NO_2+NO_3

  + TP, TKN, Alkalinity, Color

Future Work

- Analyze potential drivers of change: land cover, climate, policy & management actions
- Examine nonlinear trends over time

- Investigate lakes that are vulnerable to eutrophication
- Celebrate success stories


Thanks to Department of Natural Resources lake biologists, summer staff, and citizen volunteers!