Eutrophication, water clarity, and divergent responses to variation in lake level

Peter Lisi

post-doctoral scientist

UW Center for Limnology

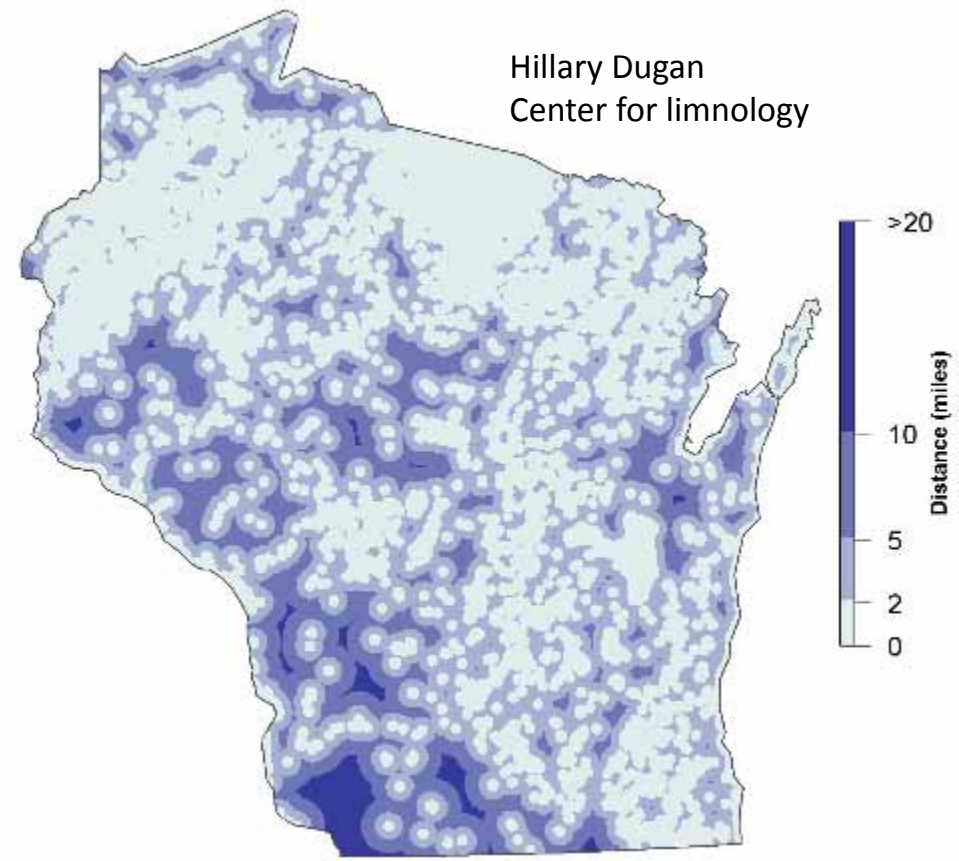
pjlisi@uw.edu

Catherine Hein

Wisconsin-DNR

PJL6
PJL7

Distance to a lake in Wisconsin



You are never further than 20 miles from a lake in Wisconsin

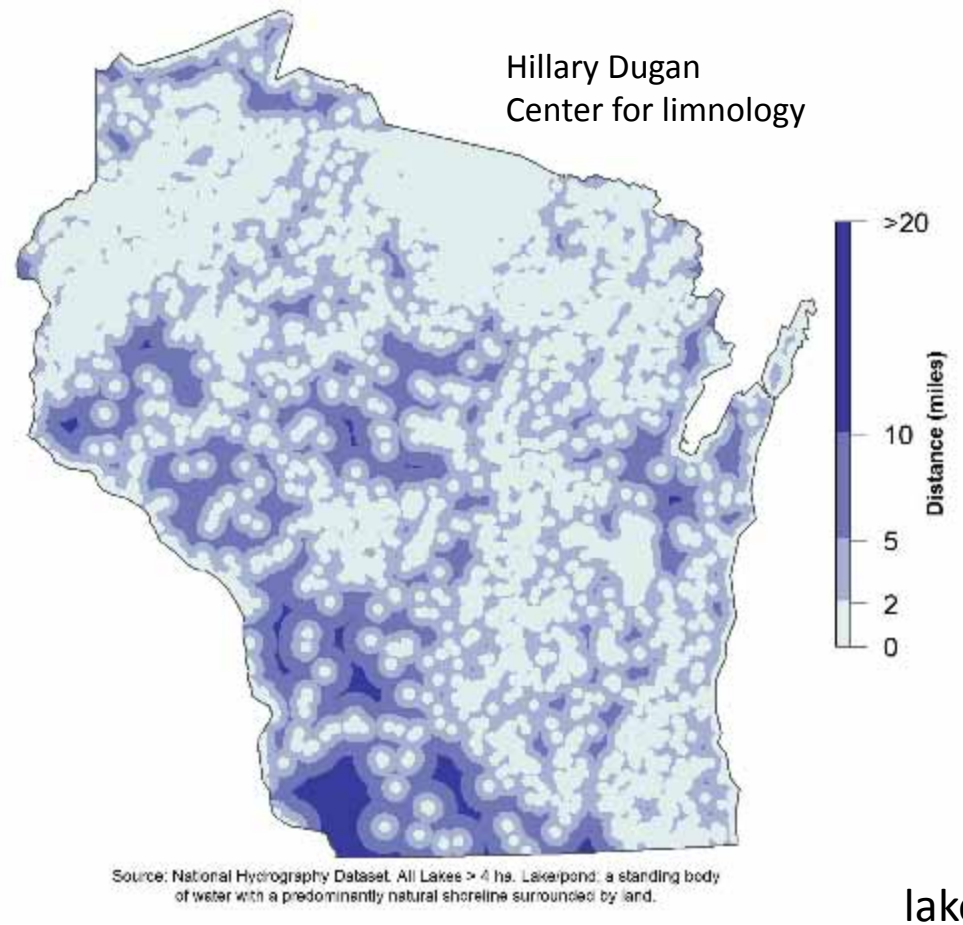
Slide 2

PJL6	LISI, PETER, 4/3/2017
PJL7	LISI, PETER, 4/3/2017

PJL6
PJL8

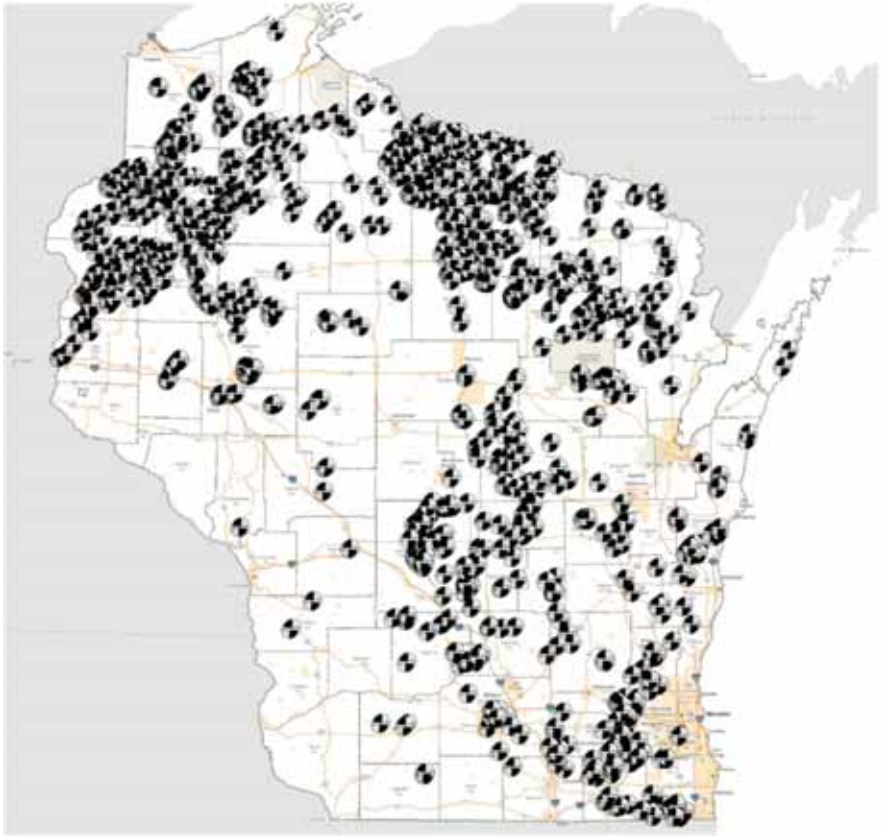
Distance to a lake in Wisconsin

Hillary Dugan
Center for limnology



Source: National Hydrography Dataset. All Lakes > 4 ha. Lake/pond: a standing body of water with a predominantly natural shoreline surrounded by land.

Distance to a lake association?



lake clarity sites measured by volunteer scientists

Slide 3

PJL6	LISI, PETER, 4/3/2017
PJL8	LISI, PETER, 4/3/2017



RED CEDAR RIVER WATERSHED

Photos Rod Olsen

Managing watershed inputs

Cleaning up old farms

Bank stabilization

retention ponds,
rain gardens,
rock gabion

Photos Rod Olsen

10 miles to a cleaner lake

No swimming for several years during high water

Land-use and changing climate hinders water quality

Changing precipitation

Loss of wetlands

Urban expansion

Dairy farms

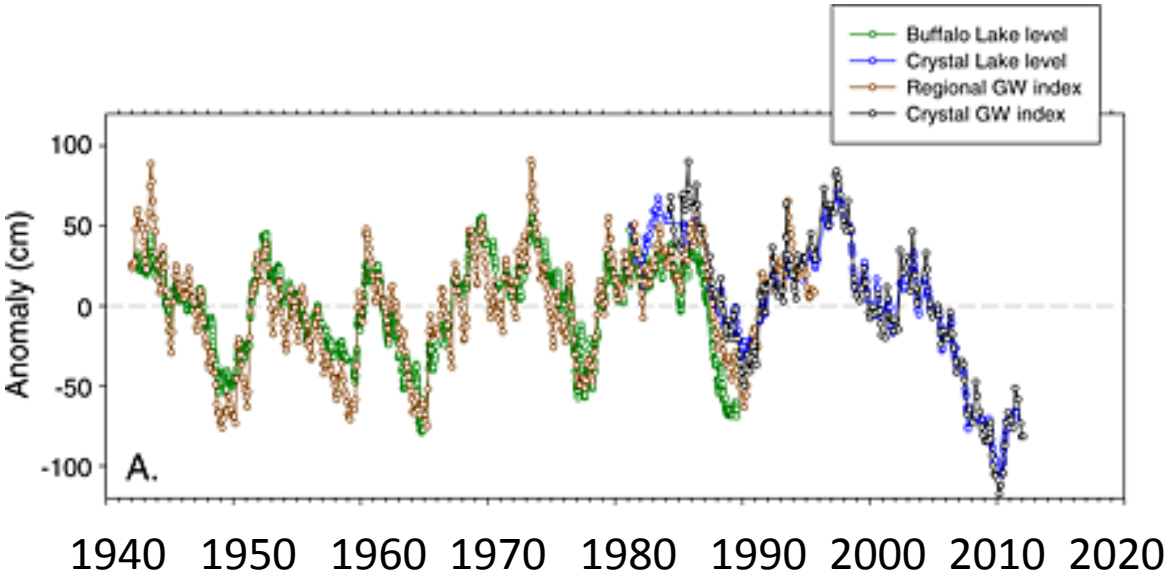
Row crops

Phosphorus legacy

(Yahara 2070)

How will a changing hydrology impact water clarity in WI?

Near decadal oscillation in NE Wisconsin lakes and aquifers



Watras et al. 2014 GRL

Slide 11

PJL3 LISI, PETER, 11/14/2016

PJL4
PJL5

Conventional wisdom:

Drought should result in a clearer water column.

- Reduced phosphorus loads
- Reduced shoreline erosion
- Ultraviolet bleaching

Wet years should result in a turbid lake

- Increased nutrient loads
- Increased sediments
- Increased shoreline erosion

L.M. Mosley 2015 earth science reviews

Slide 12

PJL4 LISI, PETER, 11/17/2016

PJL5 LISI, PETER, 11/17/2016

Conventional wisdom: opposite response can also be true.

Drought can increase severity of harmful algal blooms.

- warmer surface temps
- internal mixing, P recycling
- concentration of key nutrients

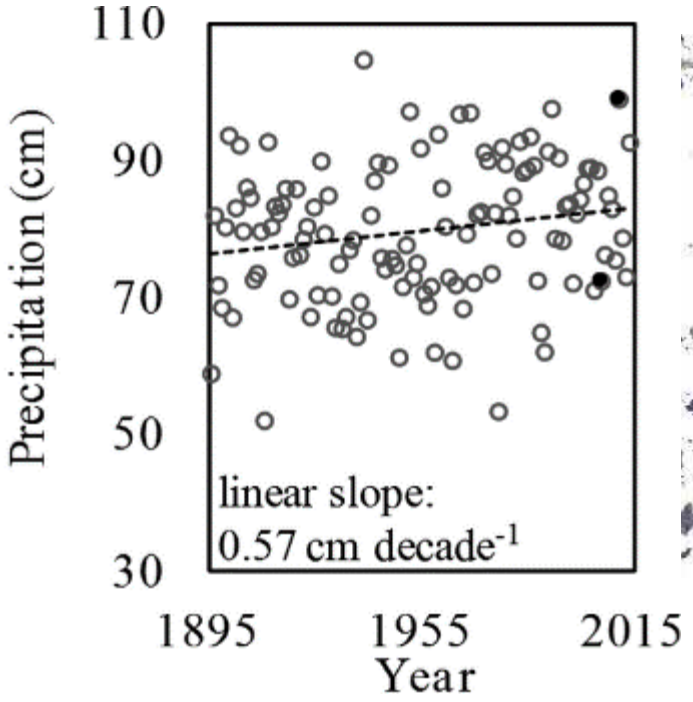
While higher lake levels result can in clearer lake!

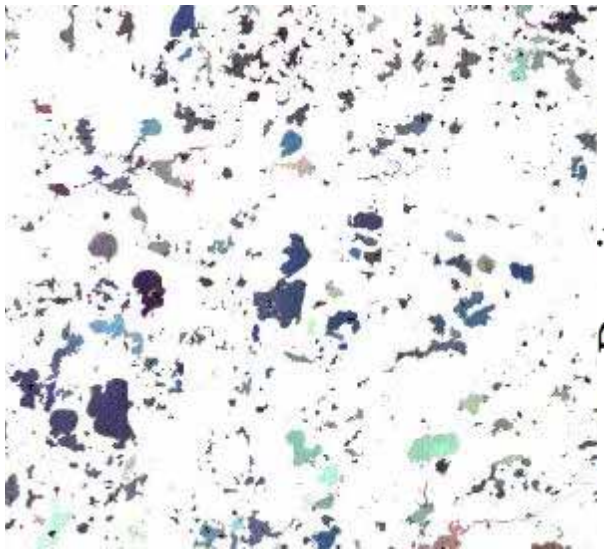
- Reduced water temperatures
- Deeper lake, increased stratification
- Flushing of nutrients

see L.M. Mosley 2015 earth science reviews

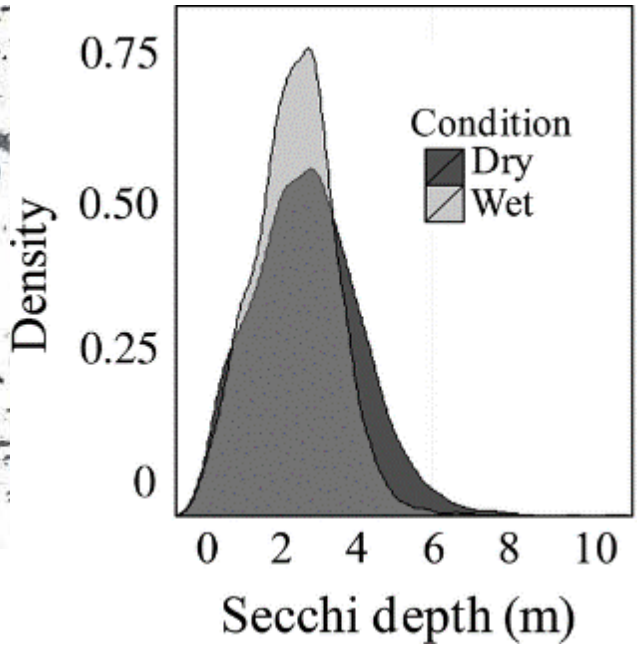
Wisconsin lakes are generally clearer during dry years.

- Clear water lakes are the most sensitive to precipitation
- ~3.5 feet clearer in a dry year versus a wet year

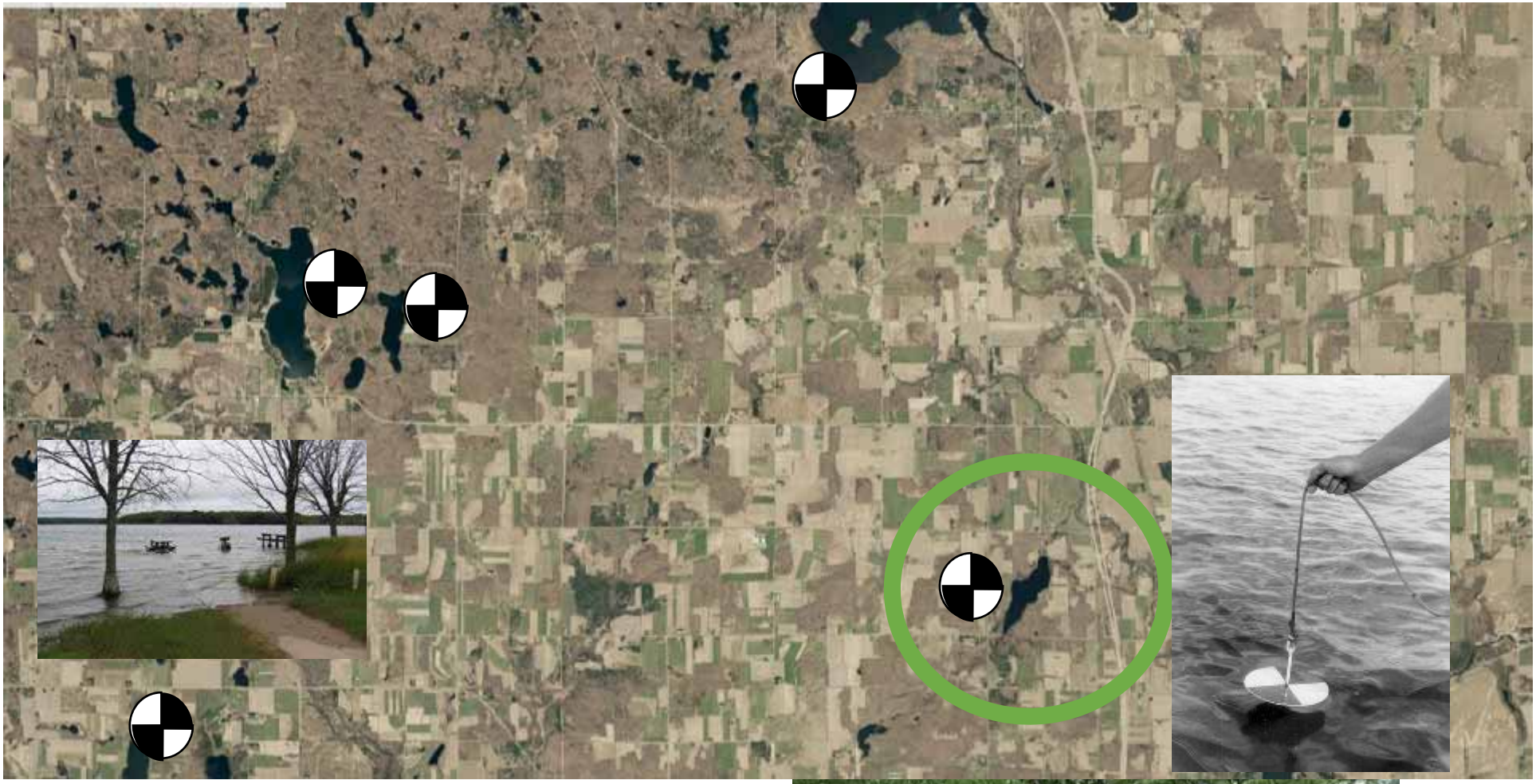




Remote sensing
5,000 WI lakes

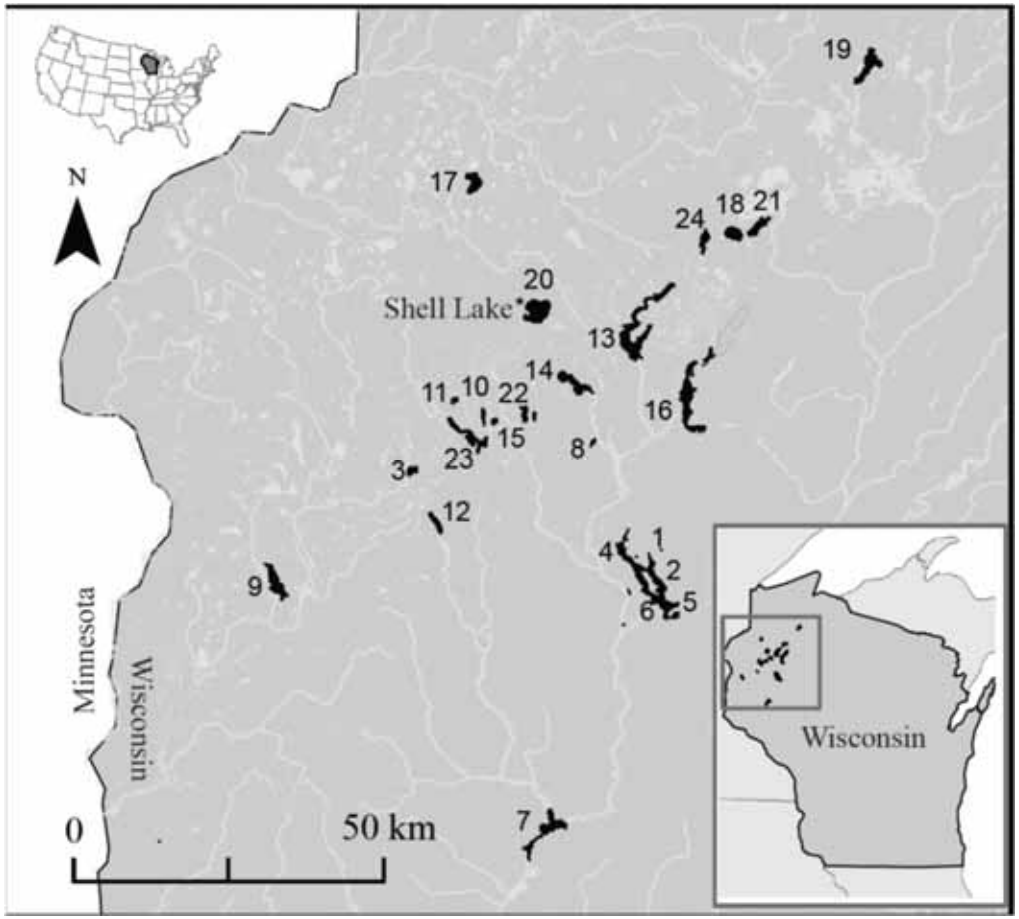


Rose et al. 2017 Ecological applications.



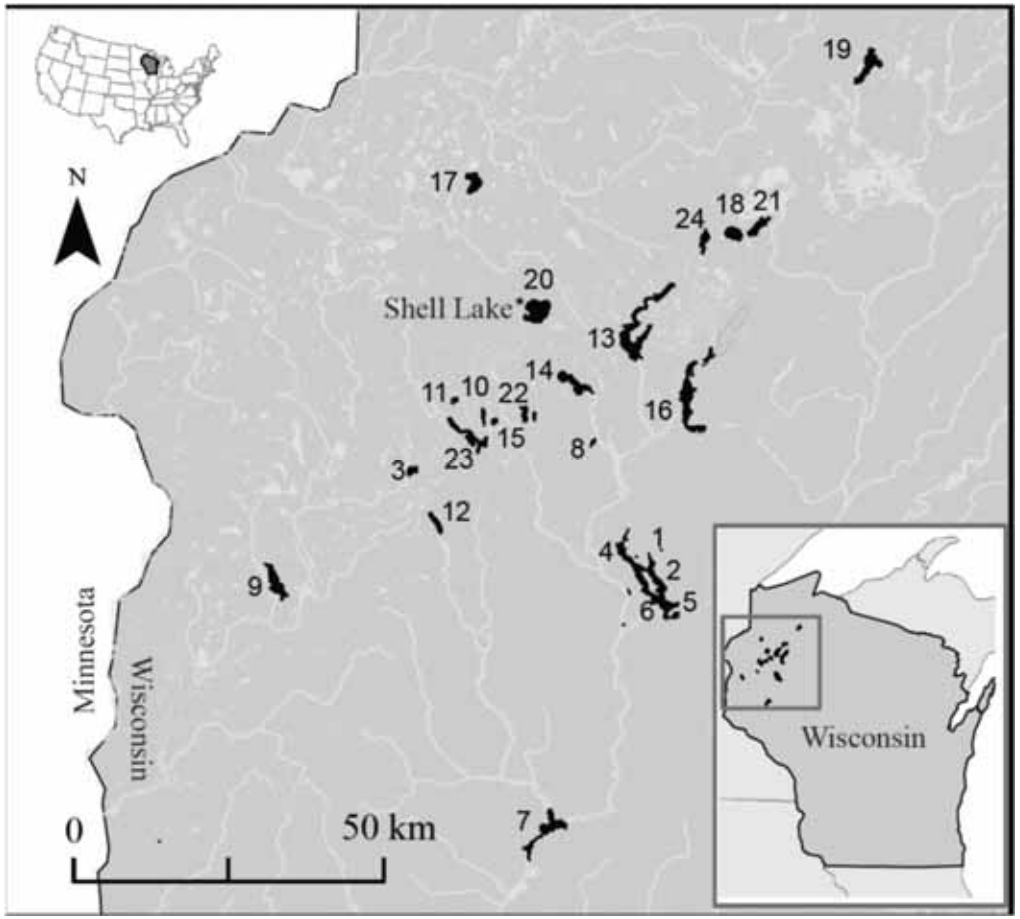
Does water clarity in “my lake” fluctuate like neighboring lakes when hydrology shifts?

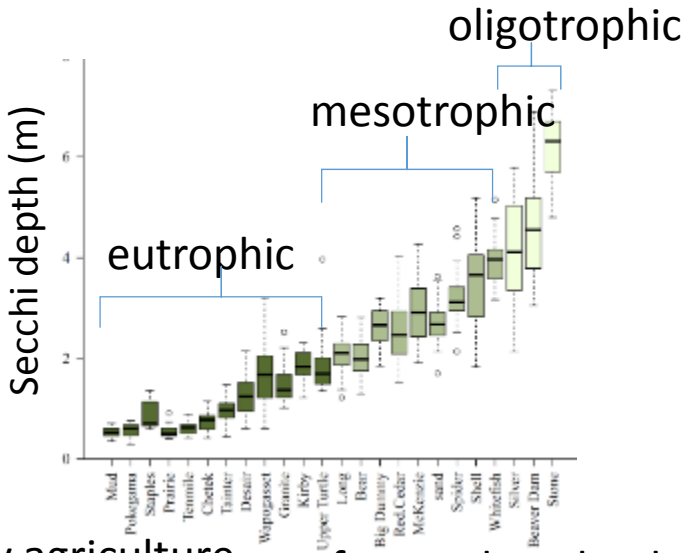
Case study in northwest Wisconsin. Citizen scientist Secchi depth time series



Award winning citizen scientists

Case study in northwest Wisconsin. Citizen scientist Secchi depth time series

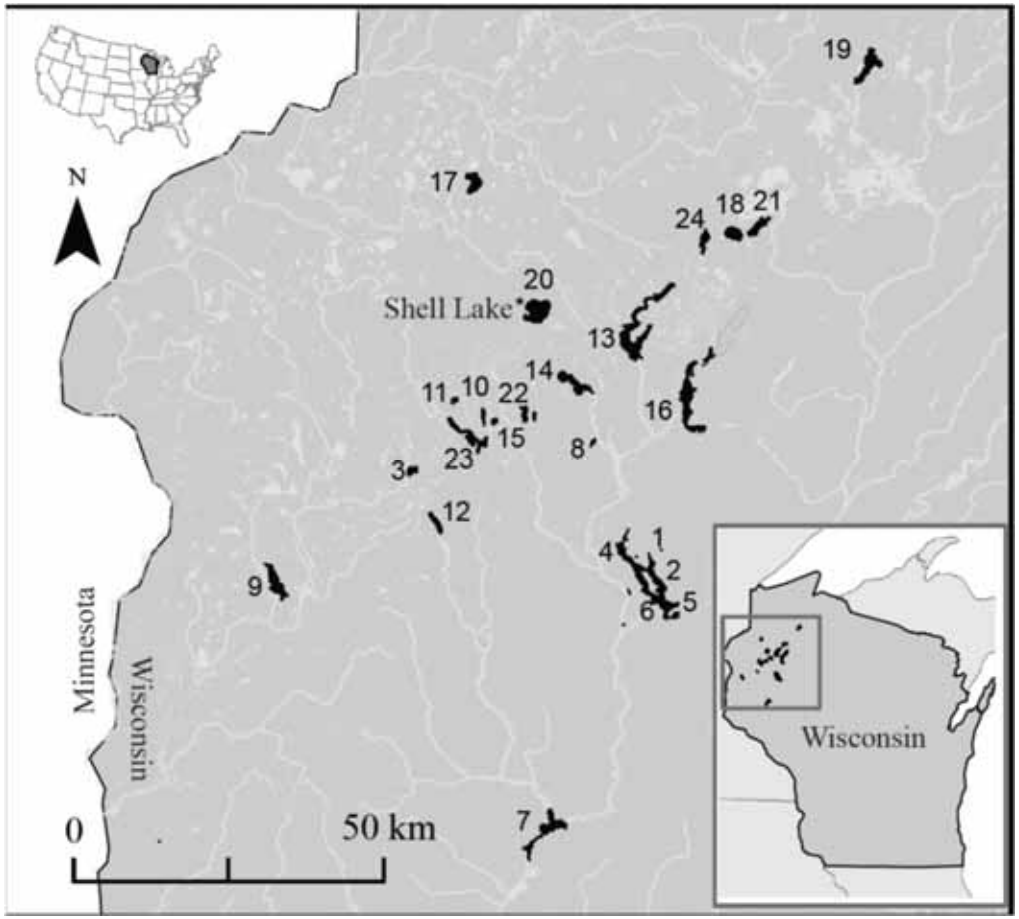


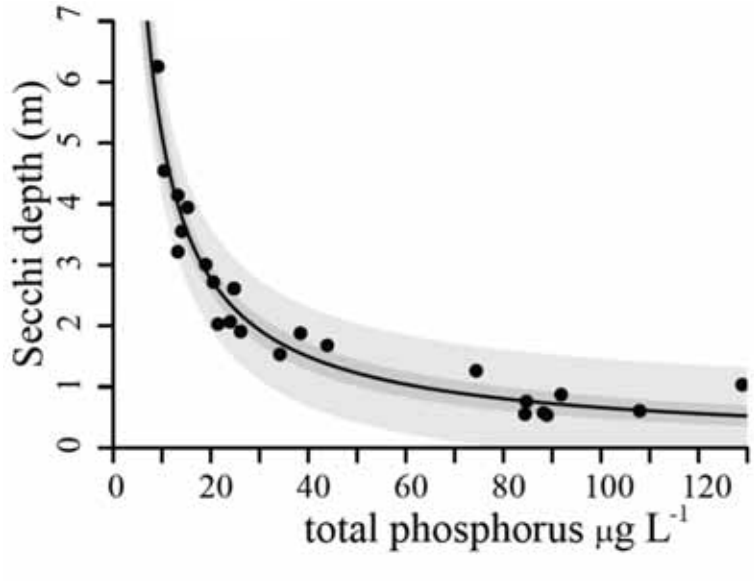


heavy agriculture

forested wetlands

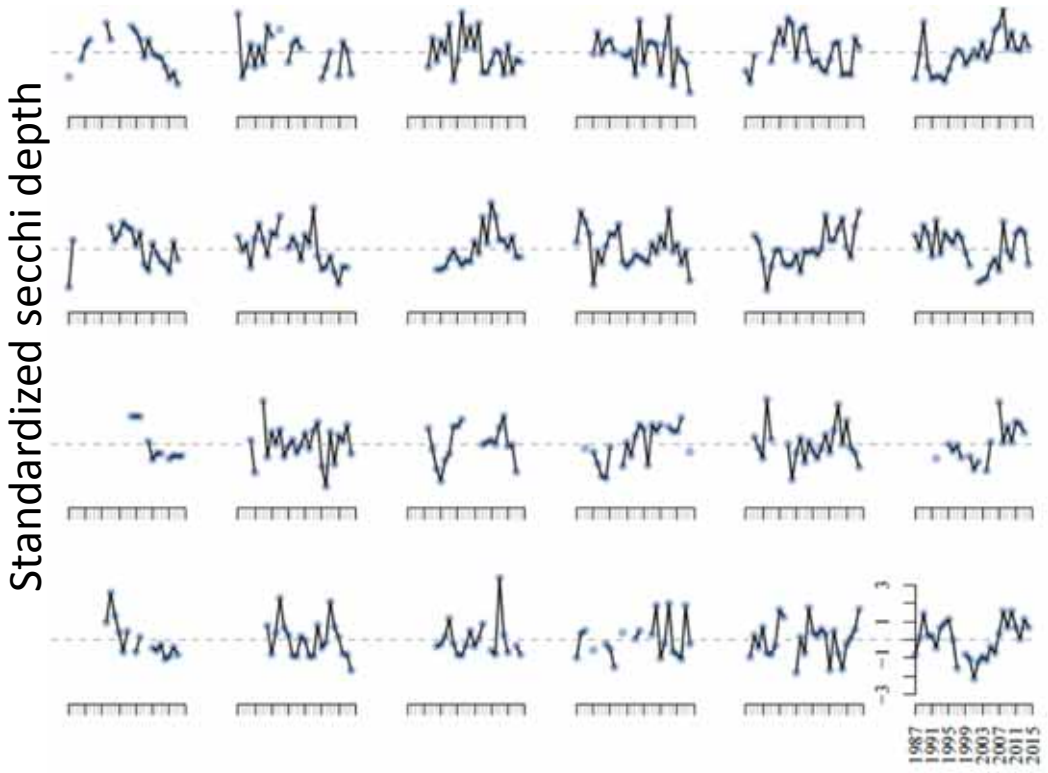
Case study in northwest Wisconsin. Citizen scientist Secchi depth time series





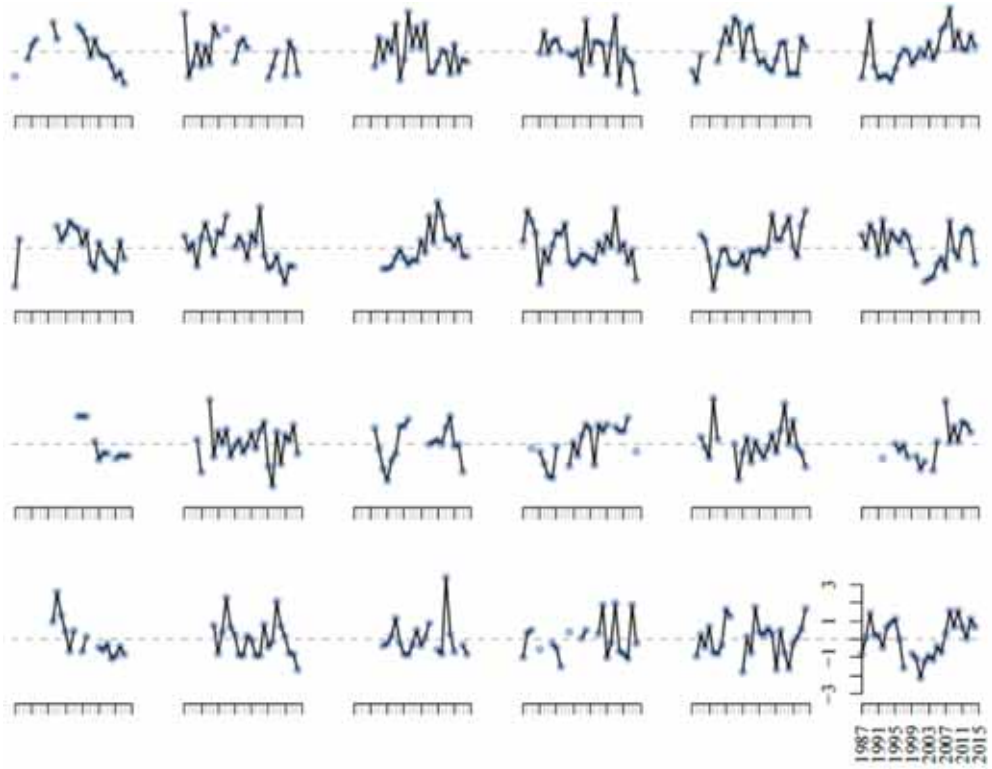
Secchi disk time-series

Citizen science data
July & August Secchi depth
Time period: 1987 to 2014

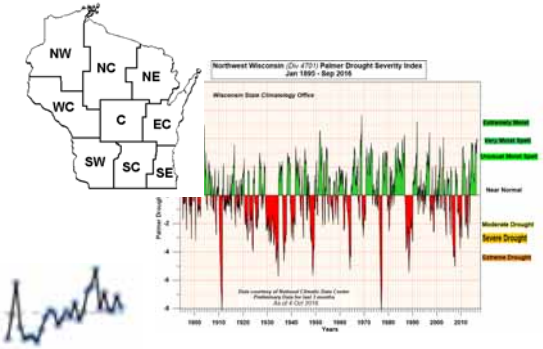


Secchi disk time-series

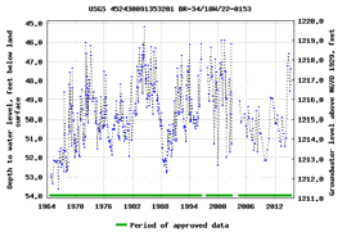
Citizen science data
July & August Secchi depth
Time period: 1987 to 2014



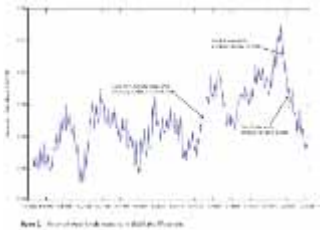
hydrologic explanatory time-series



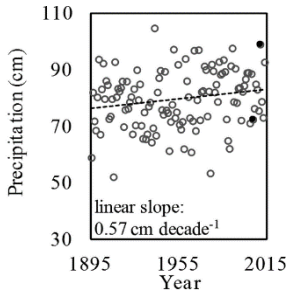
Palmer drought index



ground water height
Barron county

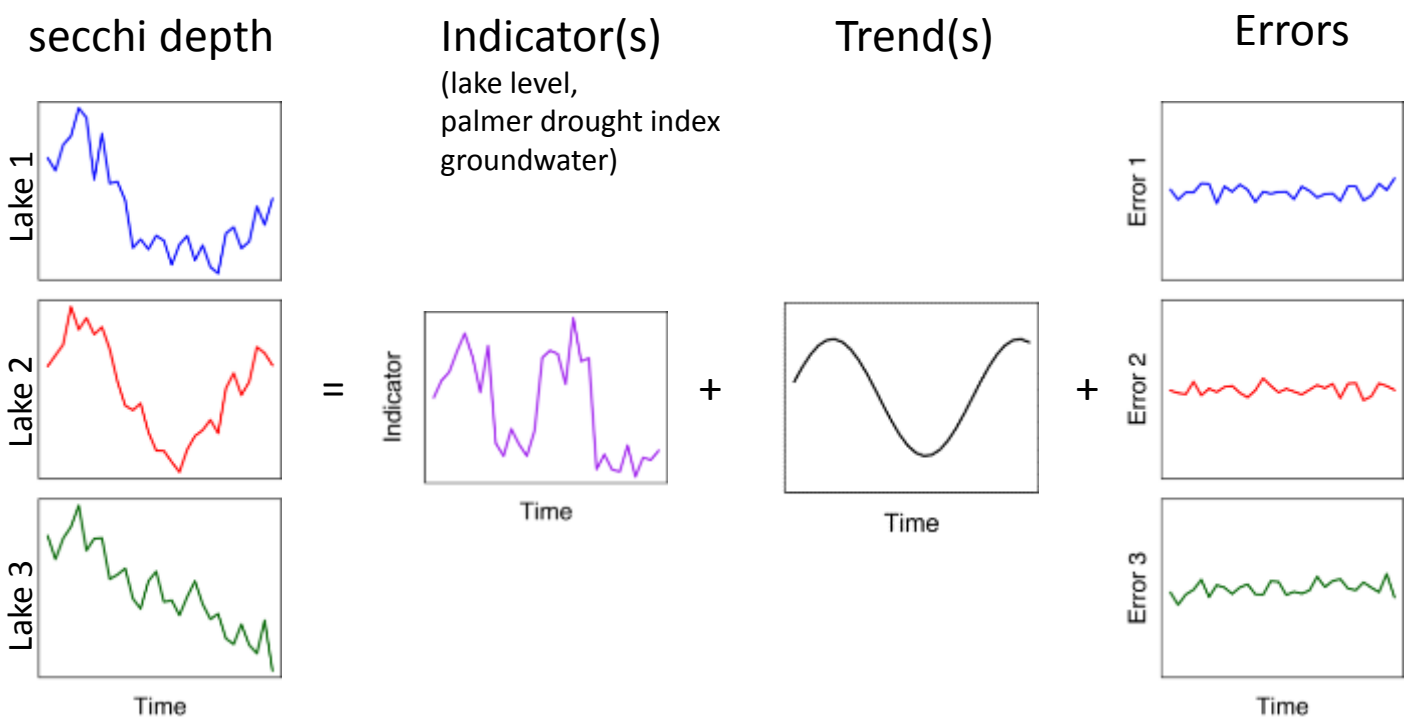


Shell Lake WI
Lake level



Previous year precipitation

“borrowing strength” from a collection of datasets



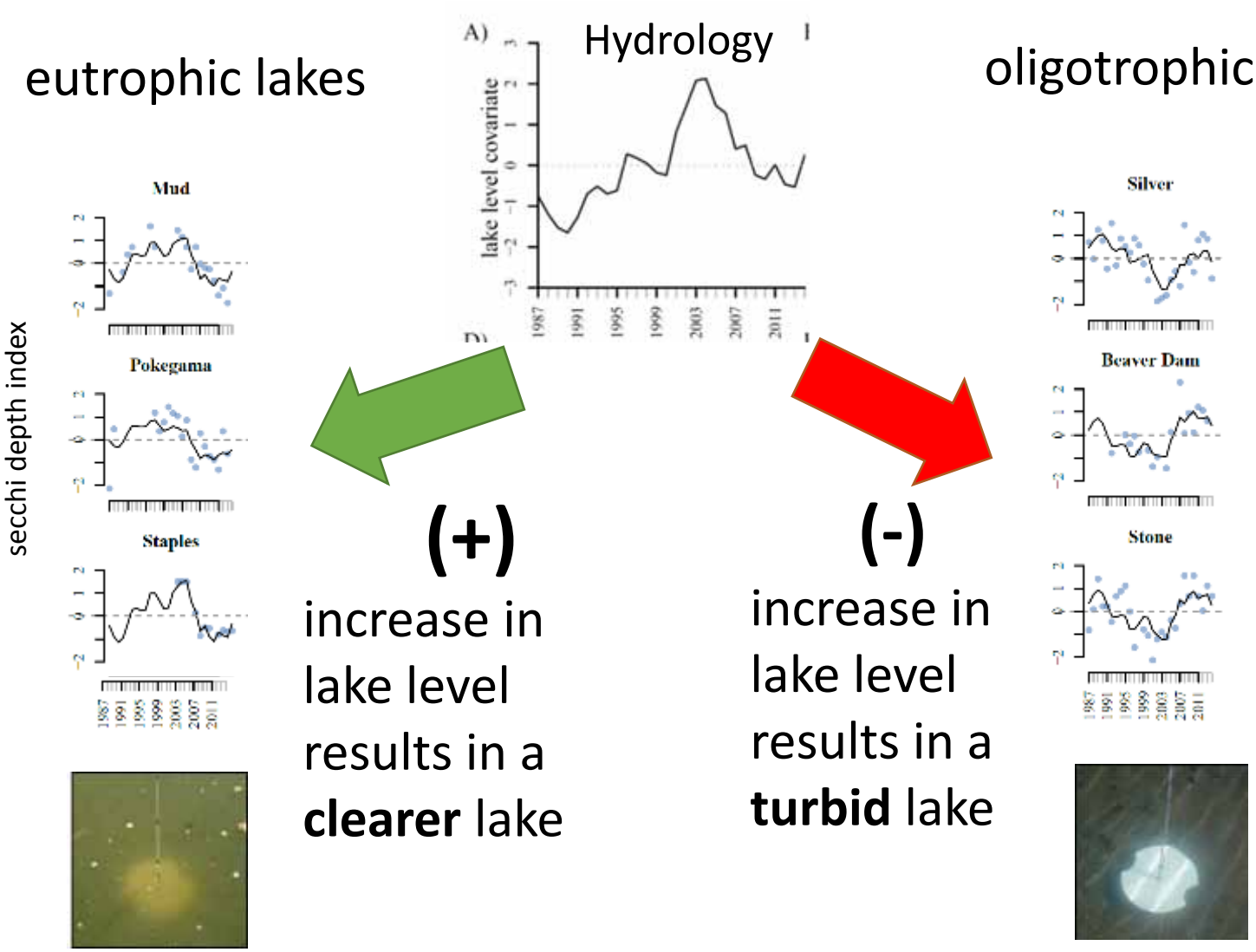
State space modeling, Dynamic factor analysis
“MARSS” package R. Holmes et al. 2013

Results: divergent response of water clarity to hydrology

eutrophic lakes

Hydrology

oligotrophic lakes



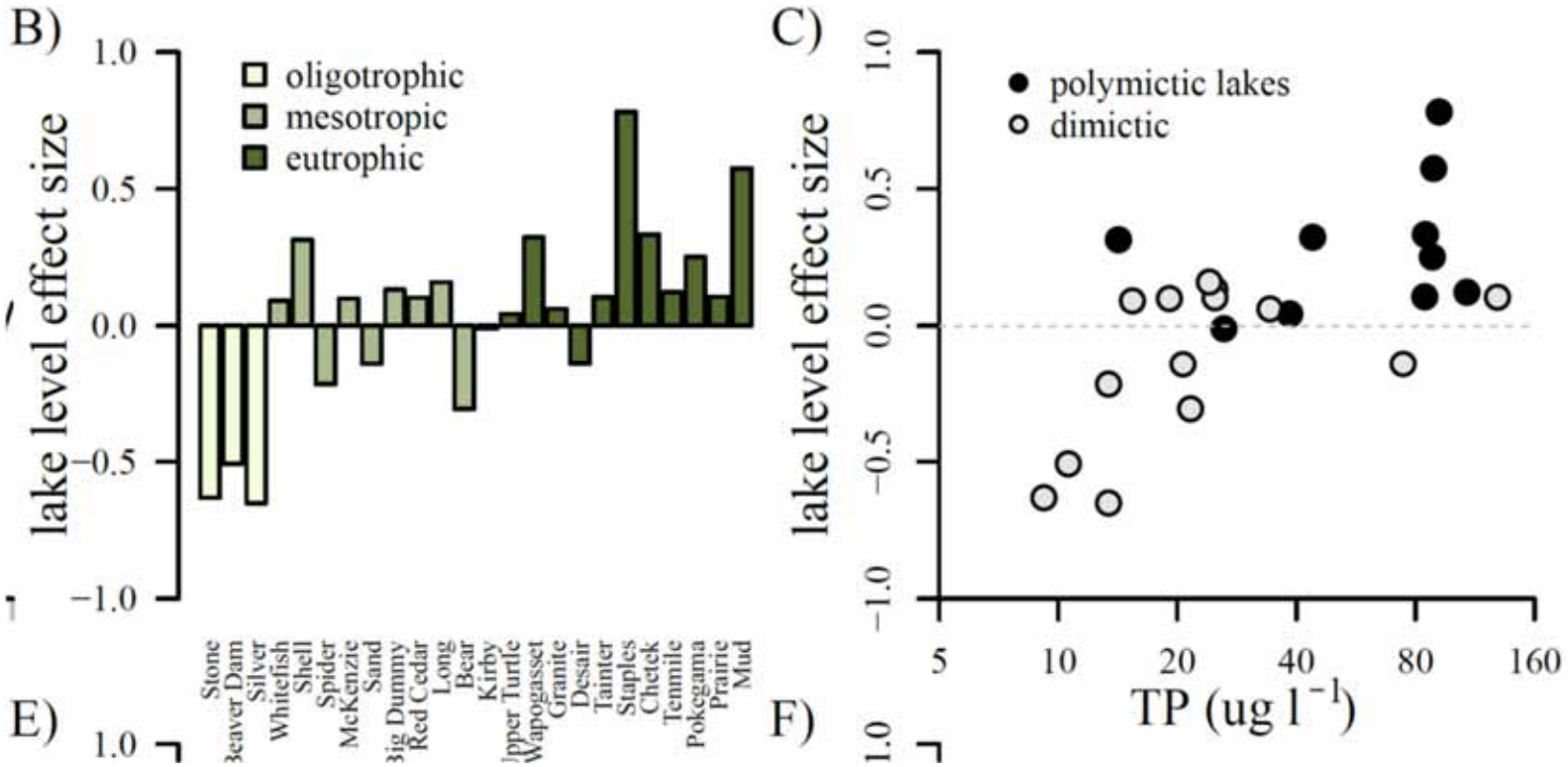
(+)

increase in lake level results in a **clearer** lake

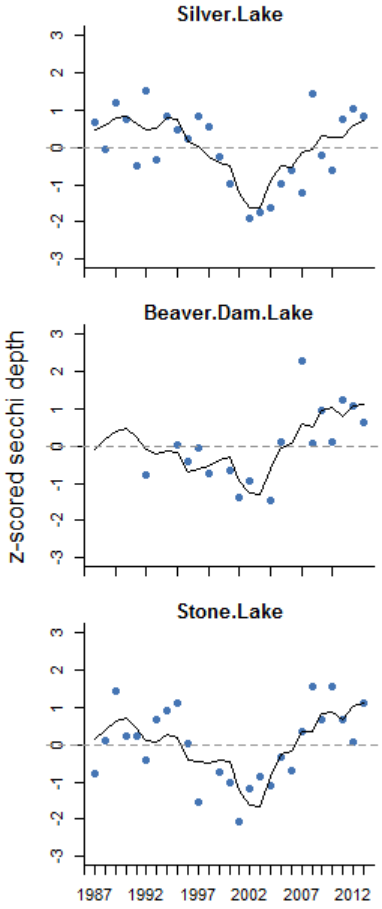
(-)

increase in lake level results in a **turbid** lake

Phosphorus (TP) and mixing tendency explain different responses



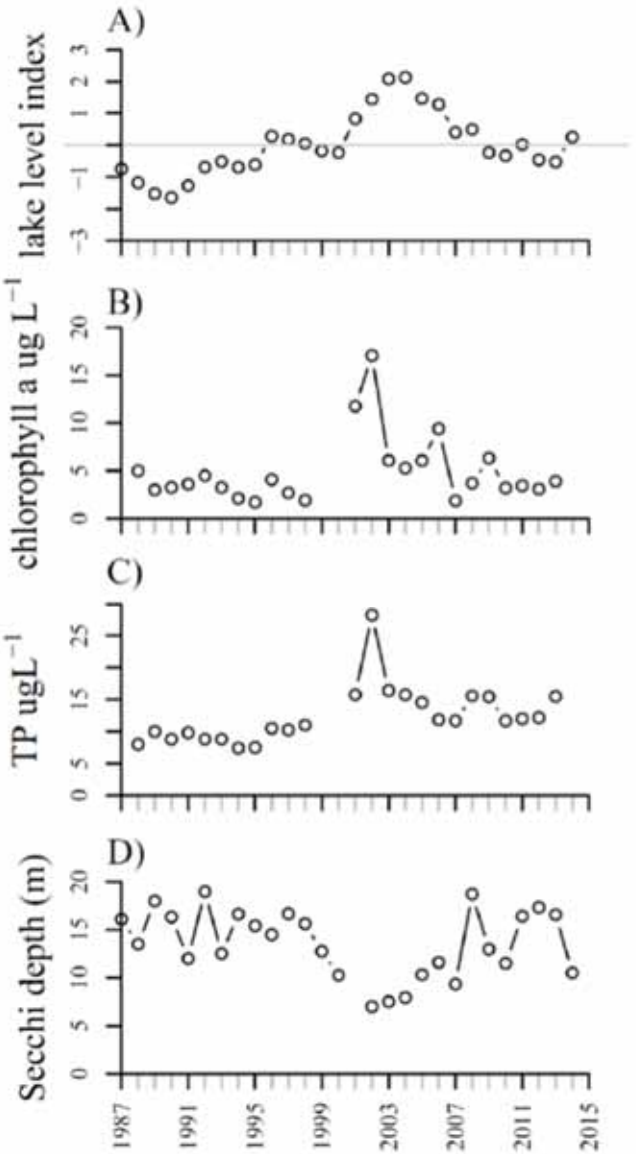
Similar regimes in oligotrophic lakes



Drought results in a clearer water column in oligotrophic lakes

Silver Lake shore after flooding
Robertson et al. 2009 USGS

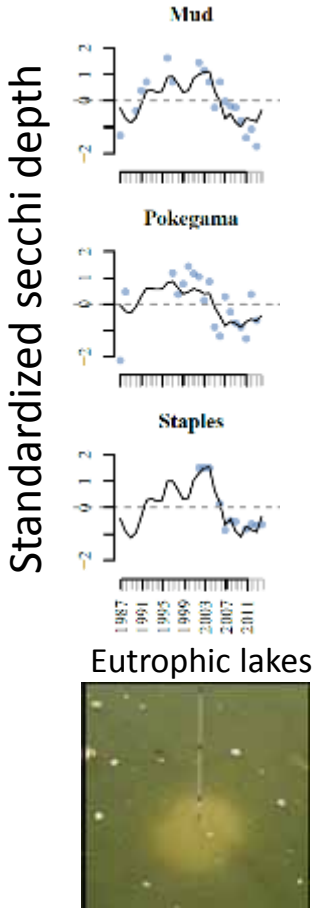
Example from Silver Lake WI



Drought results in a clearer water column in oligotrophic lakes

Silver Lake shore after flooding
Robertson et al. 2009 USGS

Potential explanation for opposite responses in eutrophic lakes



Eutrophic lakes

Drought years:

- sediment re-suspension in shallow lakes
- Increased nutrient concentration
- Increased surface temperature

Flood years:

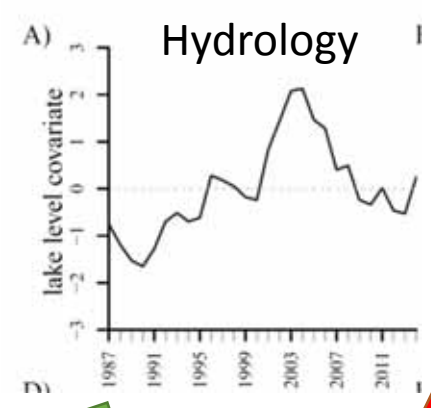
- Nutrient dilution and flushing
- Increased stratification and Fe stripping

What drives a divergent response in water clarity to changes in lake level?

eutrophic lakes

(+)

increase in lake level results in a **clearer** lake



oligotrophic lakes

(-)

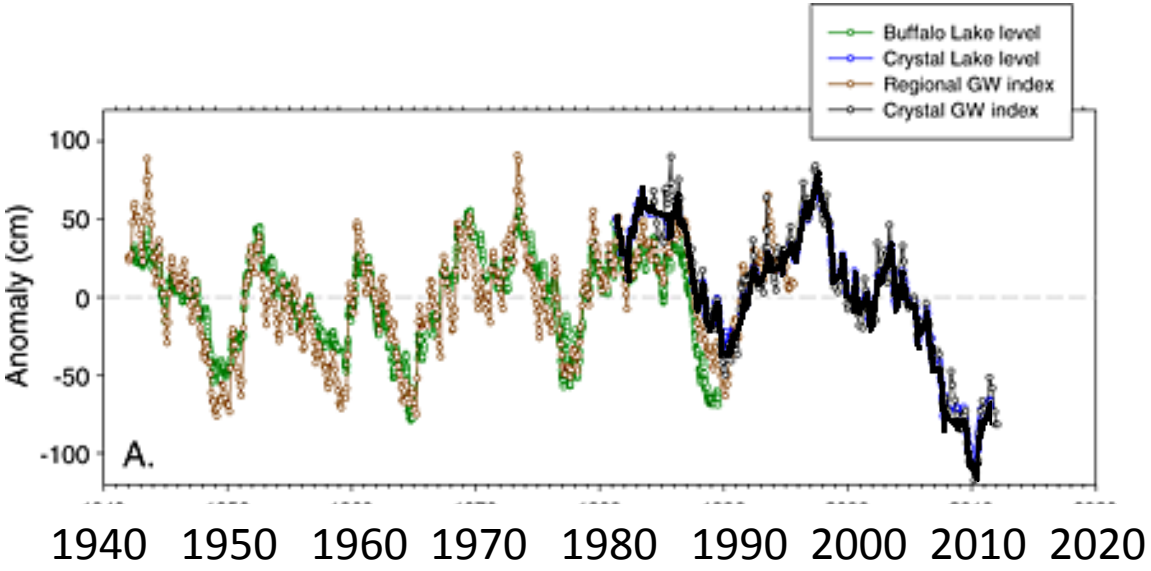
increase in lake level results in a **turbid** lake

stratification,
Fe stripping of P
dilution, flushing

Nutrient loading
DOC inputs

Hydrologic regimes will continue to change and impact water clarity

Phosphorus, land-use, and mixing tendency can help explain divergent trends.



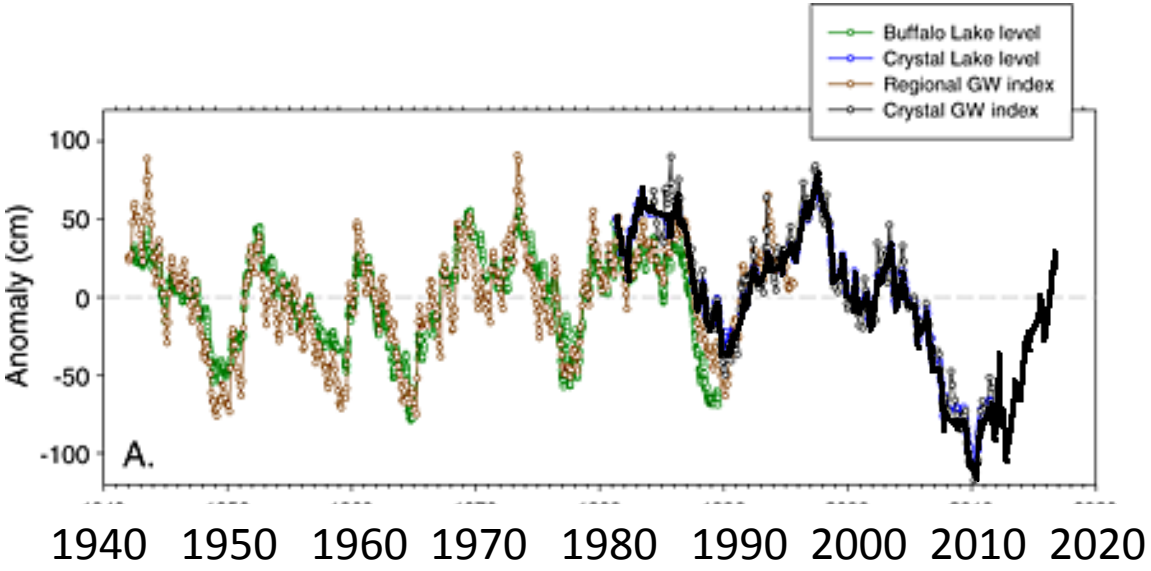
Watras et al. 2014 GRL

Slide 28

PJL10 LISI, PETER, 4/5/2017

Hydrologic regimes will continue to change and impact water clarity

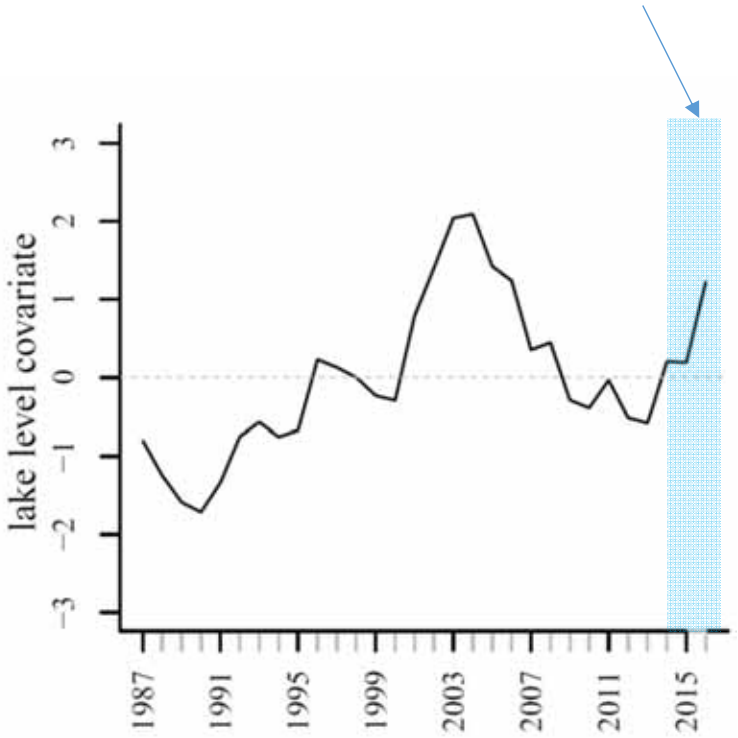
Phosphorus, land-use, and mixing tendency can help explain divergent trends.



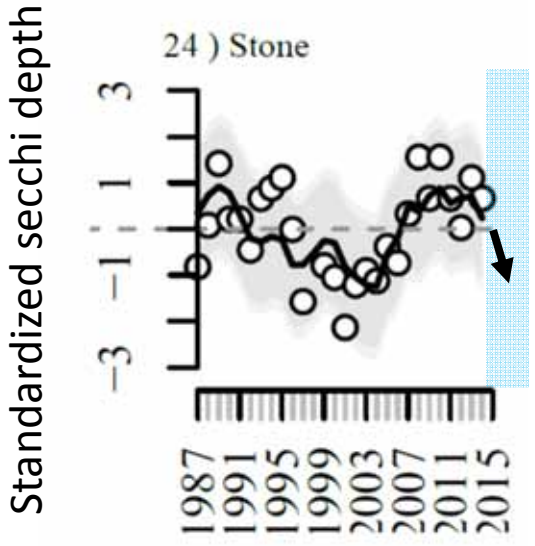
LTER Crystal Lake through 11/14/2016

Watras et al. 2014 GRL

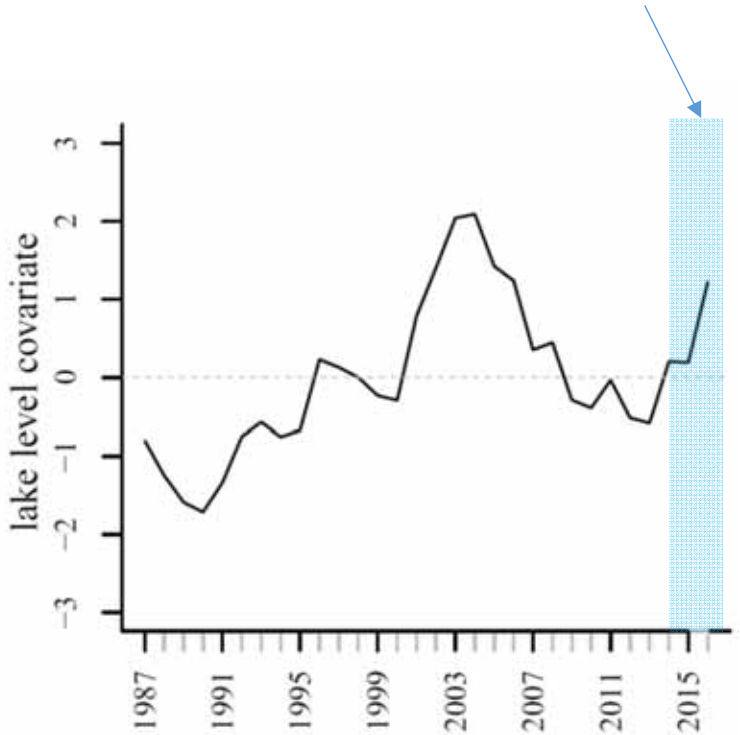
Recent lake level increase 2015-2016



Expected change

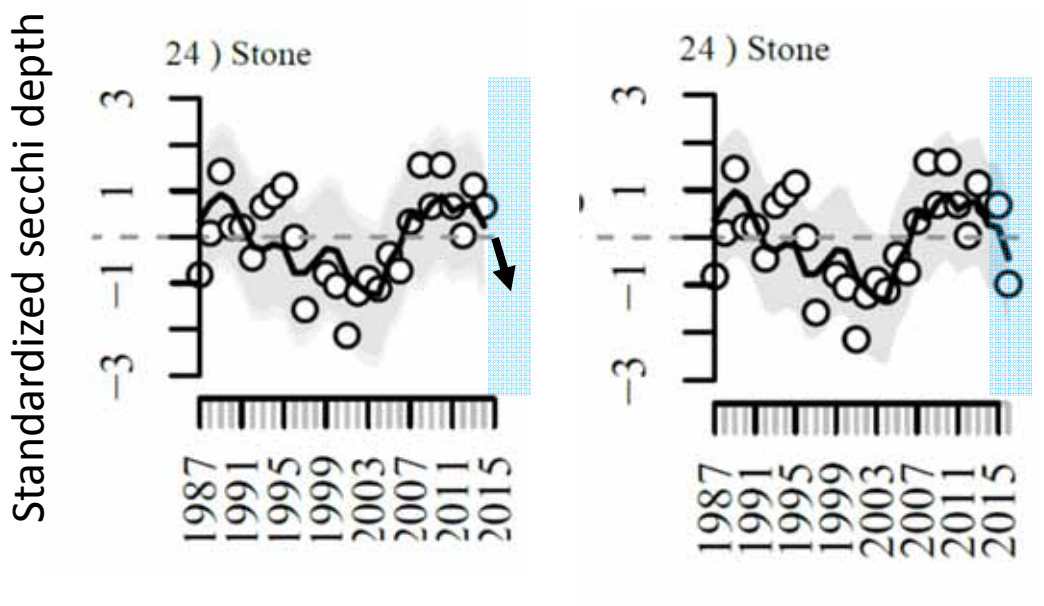


Recent lake level increase 2015-2016



Expected change

Updated result



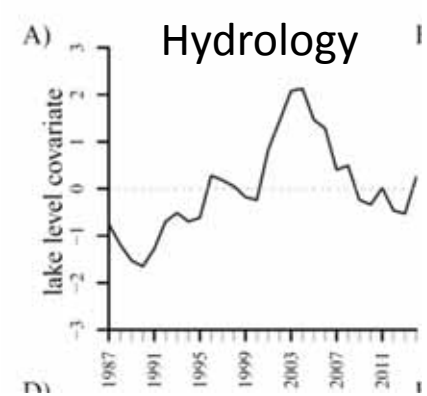
Divergent response of water clarity to hydrology

eutrophic lake

(+)

increase in lake level results in a **clearer** lake

shallow lakes
polymictic lakes
agricultural



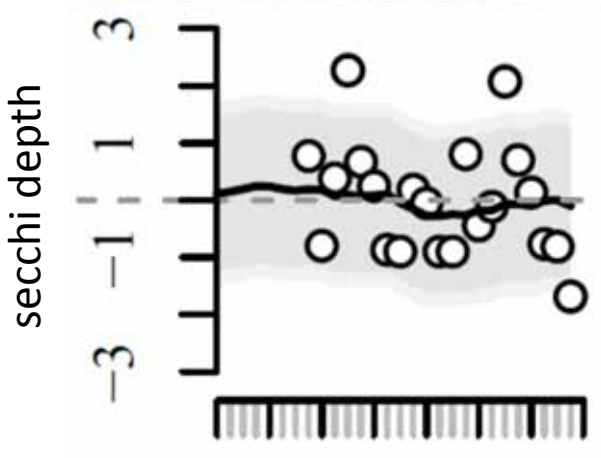
oligotrophic lakes

(-)

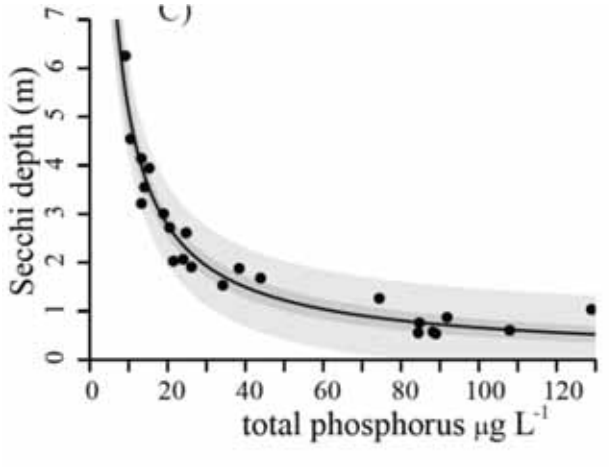
increase in lake level results in a **turbid** lake

deep
dimictic
forested

Does water clarity in “my lake” fluctuate like neighboring lakes when hydrology shifts?



Eutrophication not only
changes the mean secchi depth..



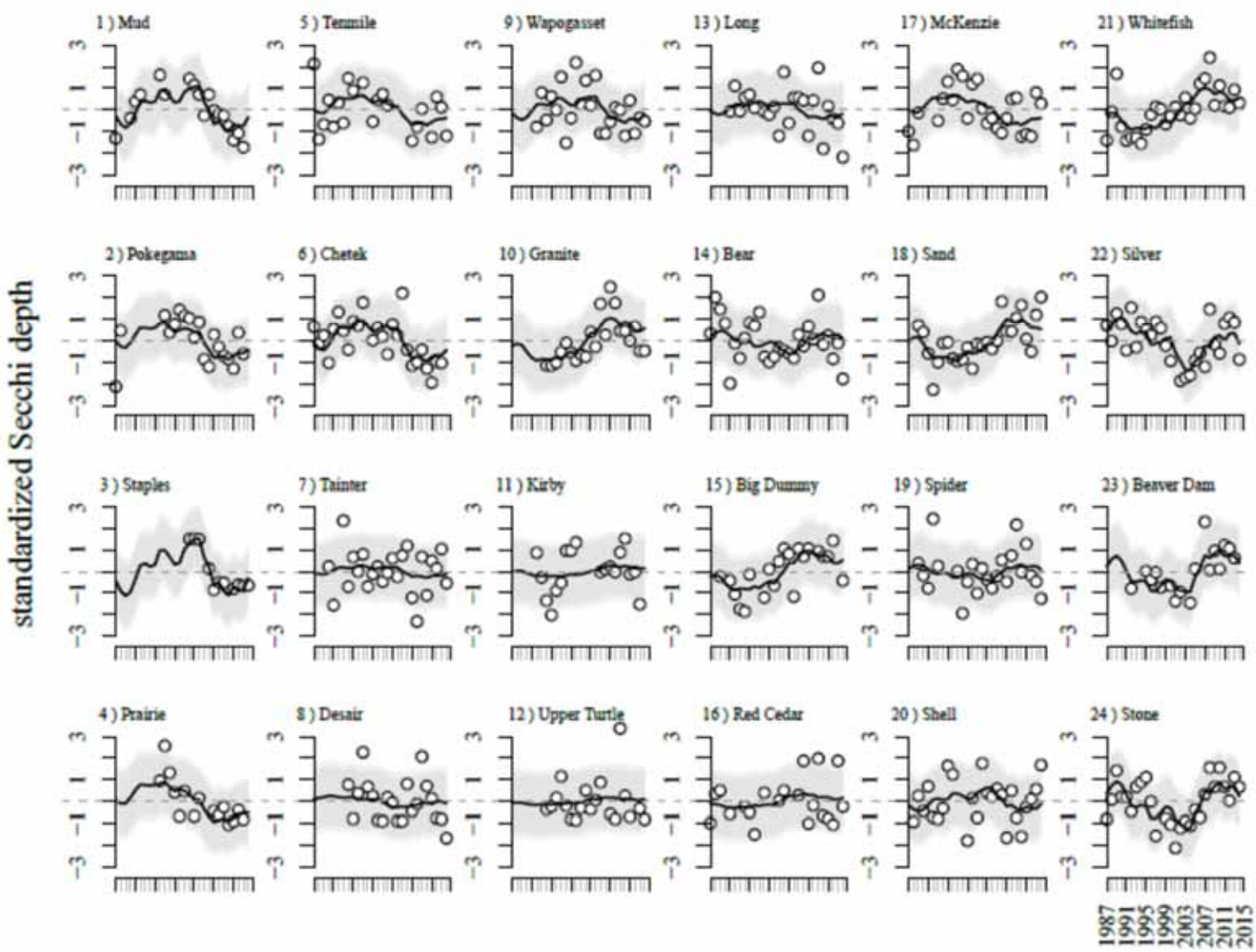
,but also the natural response of
water clarity to a changing hydrology.

Peter Lisi
post-doctoral scientist
UW Center for Limnology
pjlisi@uw.edu

Co- author with Katie Hein
Wisconsin DNR

Thanks to Wisconsin lake associations, numerous Citizen scientists, WDNR, UW extension-lakes

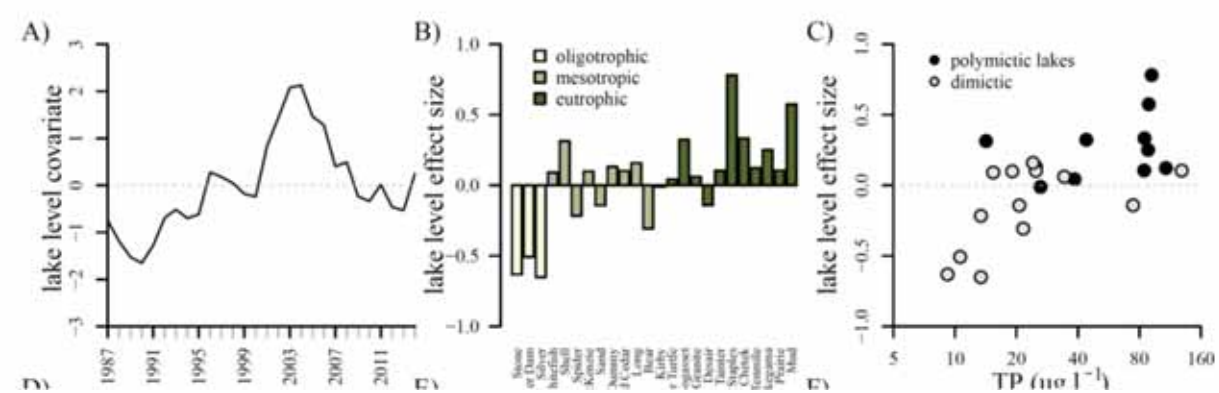
Daniel Schindler, Steve Carpenter, Pete McIntyre, Emily Stanley, Richard Lathrop for input.

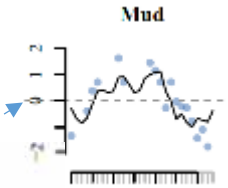

standardized Secchi depth
1) Mud
5) Tennile
9) Wapogasset
13) Long
17) McKenzie
21) Whitefish
2) Pokegama
6) Chetek
10) Granite
14) Bear
18) Sand
22) Silver
3) Staples
7) Tainter
11) Kirby
15) Big Dummy
19) Spider
23) Beaver Dam
4) Prairie
8) Desair
12) Upper Turtle
16) Red Cedar
20) Shell
24) Stone
3
1
−1
−3
1987
1991
1995
1999
2003
2007
2011
2015

Secchi disk time series

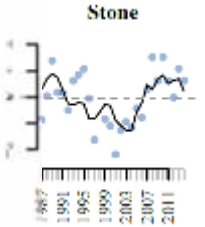
Lake level

Effect of lake level

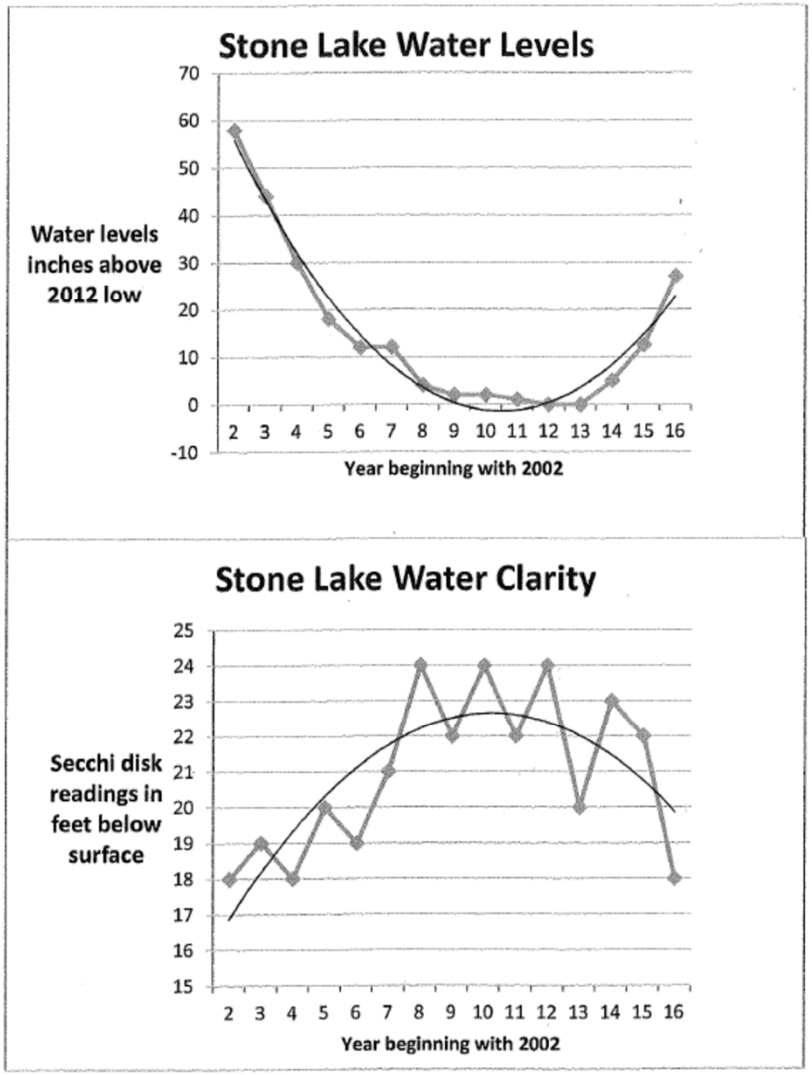




(+)
increase in lake level results in a **clearer** lake



(-)
increase in lake level results in a **turbid** lake



Relationship of Water Level and Clarity of Stone Lake

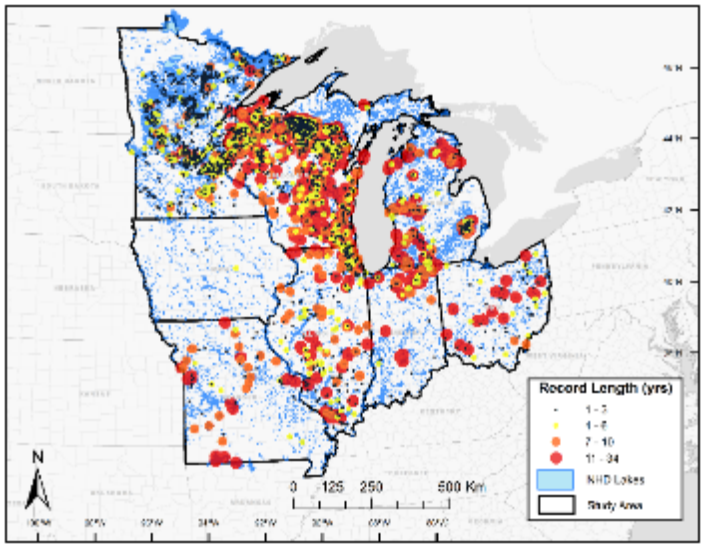
The graphs represent the relationship of water depth and the clarity of Stone Lake over the past 14 years. The graphs include "trend lines" that have been created mathematically to create a visual representation of the direction the data (water depth and clarity) is moving with time.

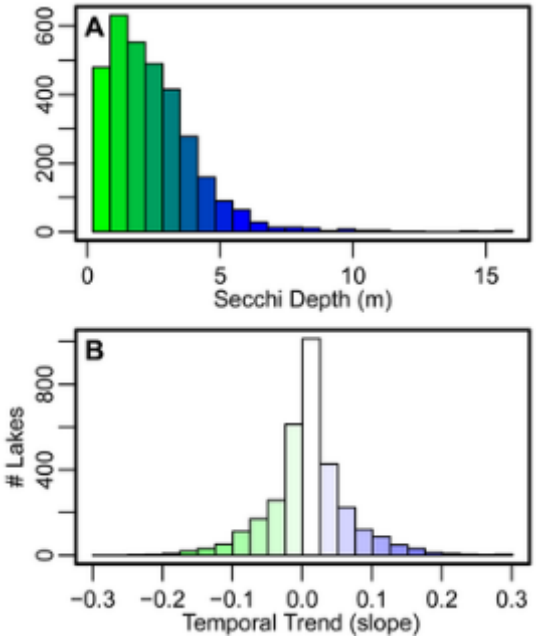
As the water elevation has increased due to higher rainfall, the clarity of the water has decreased. This is apparently due to the added particulates in the rain as well as increased particulates from the runoff reaching the lake from the adjacent land. As the weather cycle again reverts to a drier period, the trend should reverse - less particulate laden water will be entering the lake and the particulates accumulated during the rainy years will settle out.

This is a natural cycle. However, it indicates how sensitive the lake is to runoff from your property. Avoiding the runoff of nutrients and chemicals by maintaining a natural shoreline is essential to a healthy lake.

The preceding is an observation, not a scientific study. The lake level and clarity data is based on data recorded by Stone Lake shore owners and reported to the UW Stevens Point Citizen's Lake Monitoring program. It is provided for information only.

Macro- scale studies reveal high degree of heterogeneity in water clarity trends through time.





Lottig et al. 2014