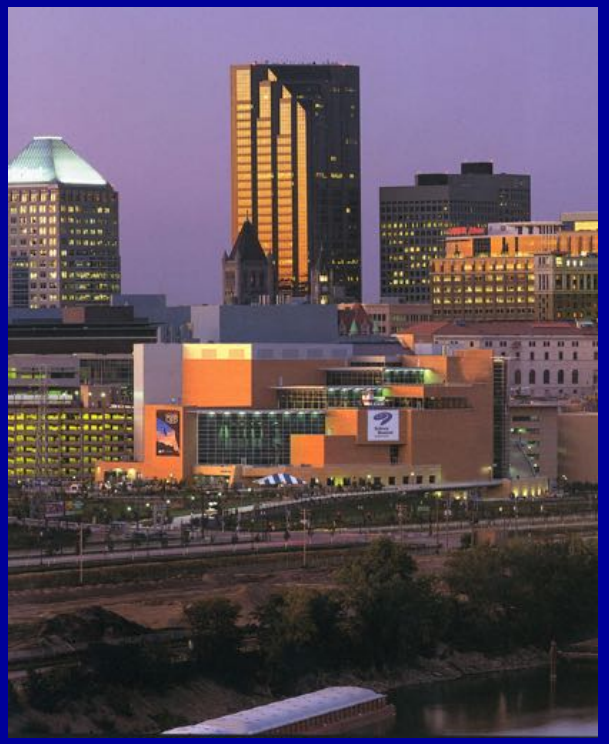
PALEOLIMNOLOGY IN THE NORTH COUNTRY

Mark Edlund
St. Croix Watershed Research Station

St. Croix Watershed Research Station

The Environmental Research Center of the Science Museum of Minnesota



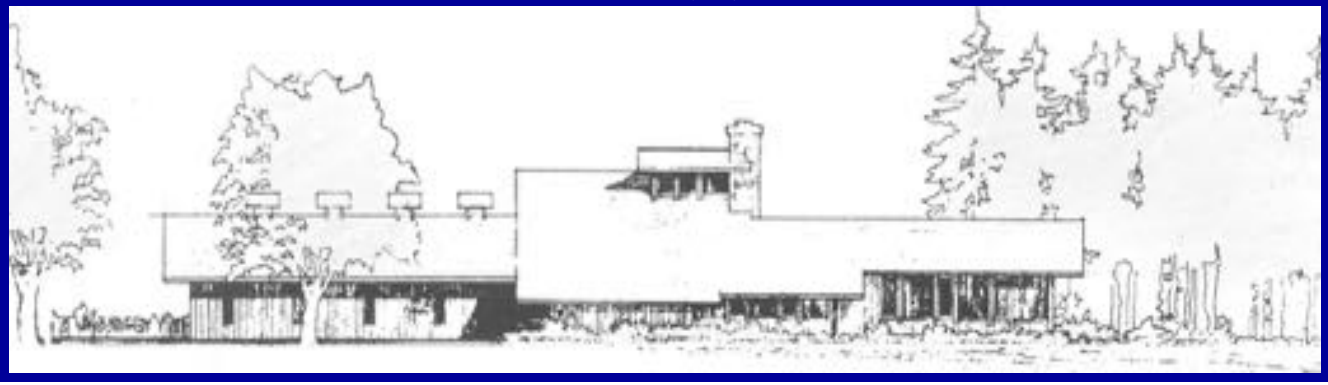
SCWRS: When, where, & why?

- Established in 1989
- 12 staff, 6 research scientists, support staff, plus graduate students, visiting scientists, and interns
- not-for-profit research institute
- Mission: "We do the science that helps make our rivers and lakes clean."

Science Museum of Minnesota

Inspire learning, Inform policy, Improve lives

How can our research help everyone make wise and science-based policy decisions?



Partnerships

Training

WDs and Lake groups

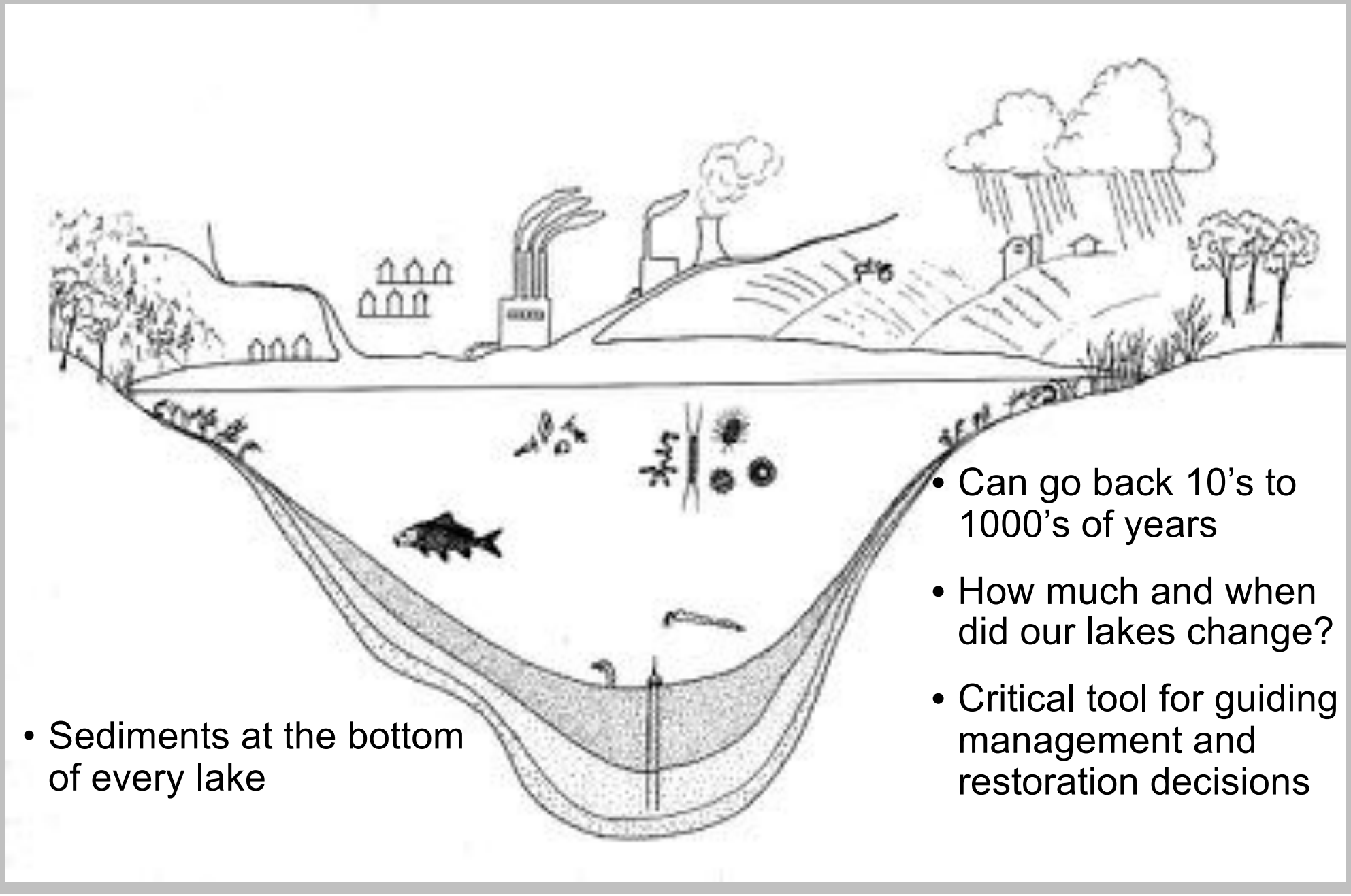
Colleges and Universities

Agencies, tribal, .com

Sediment Cores: a window on the past

- Establish Baseline Water Quality
- Critical for Lake Management and Restoration
- Numerous ongoing studies
- Funded by:
  - National Park Service
  - MPCA
  - NSF
  - LCCMR
  - Local watershed districts

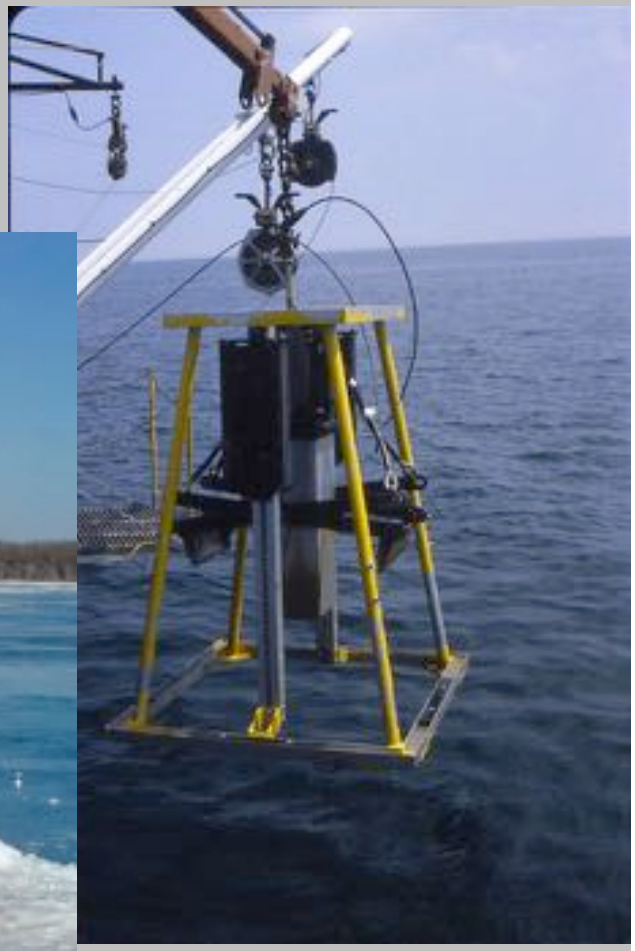
Paleolimnology-the study of lake sediments to reconstruct environmental history



- Sediments at the bottom of every lake

- Can go back 10's to 1000's of years
- How much and when did our lakes change?
- Critical tool for guiding management and restoration decisions

Coring Techniques



Dating Models - We use the predictable decay of radioisotopes to figure out when sediments were deposited on the lake bottom

Element	Source	Analysis location	
^{210}Pb	From natural radium minerals	SCWRS lab	150-200 yrs
^{137}Cs	Atmospheric tests of nuclear bombs	SCWRS lab	40-50 yrs
^{14}C	Cosmic rays hitting earth's atmosphere	Arizona lab	500-50,000 yrs

Dating Models

dictable decay of radioisotopes

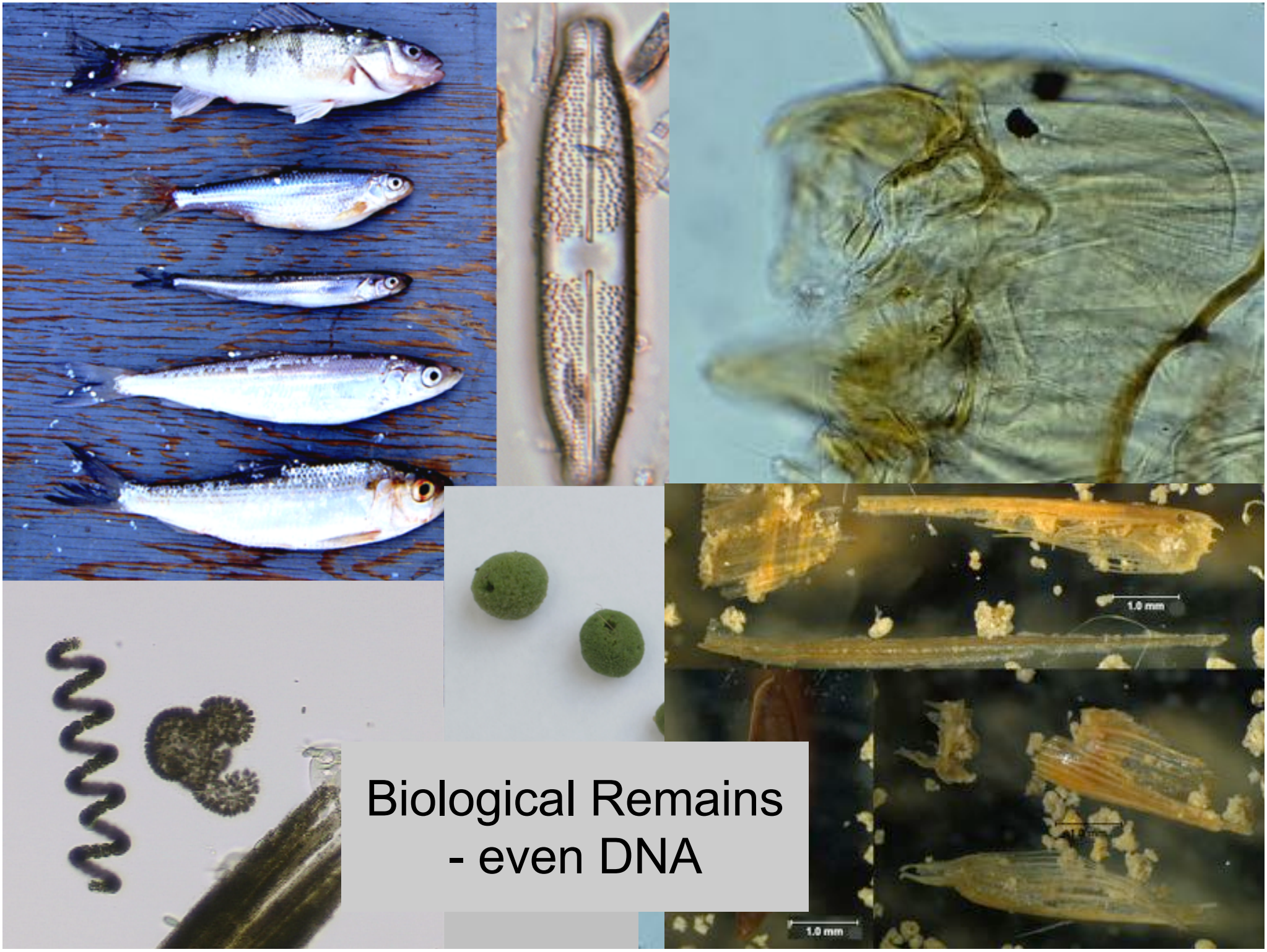
sediments were depo

bottom

Element		alysis location	
^{210}Pb	Fro rad	CWRS b	150-200 yrs
^{137}Cs	Atr tes bor	CWRS b	40-50 yrs
^{14}C	Co hitt atm	rizona lab	500-50,000 yrs

Sediment biogeochemistry

- Loss-on-ignition
  - organic
  - carbonates
  - mineral
- Phosphorus fractions
- biogenic silica
- algal pigments



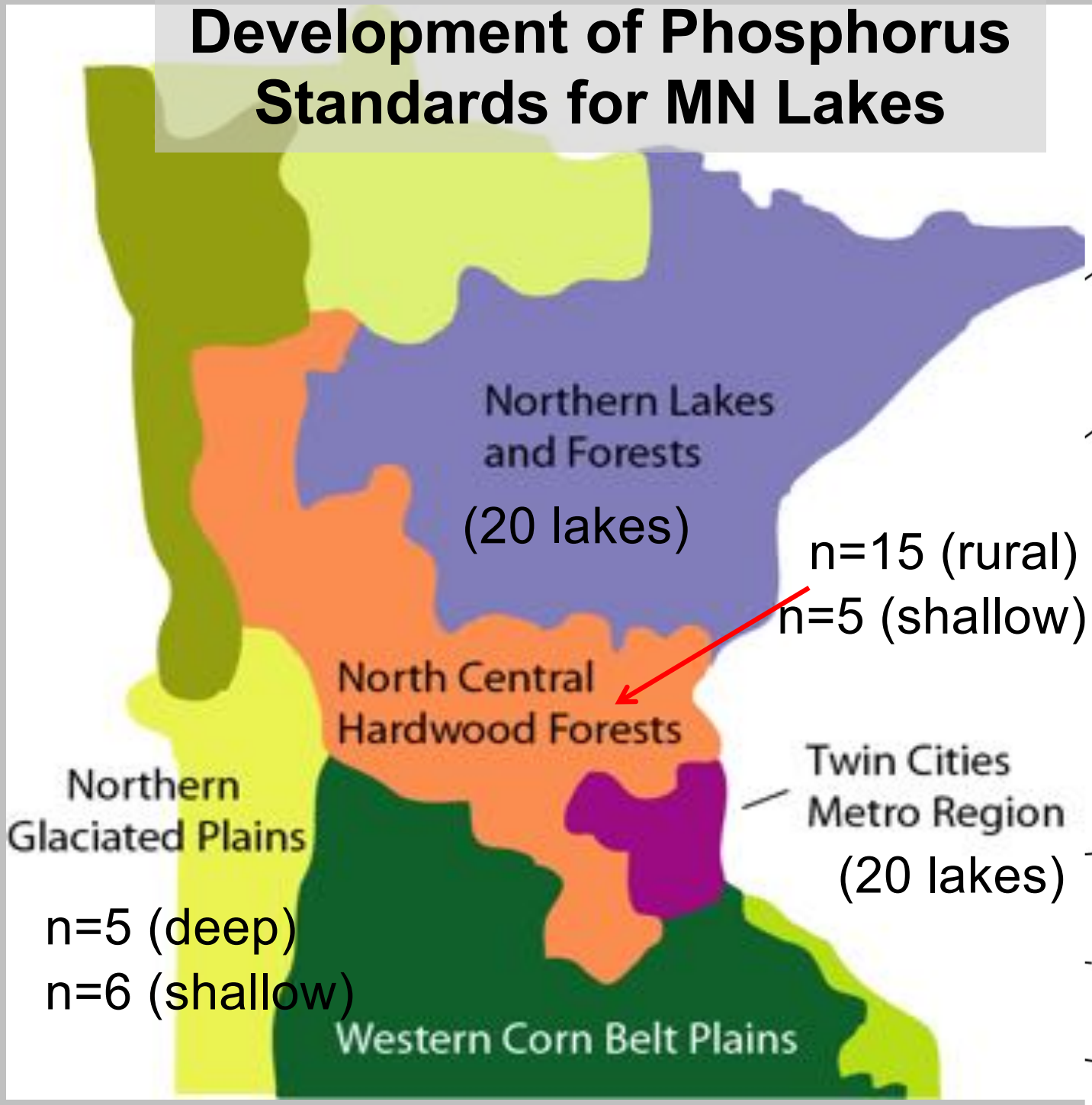
Biological Remains - even DNA


…under the scope, 1880s
Bartlett Lake, 69 cm, core 1, ca. 1885

…under the scope, 2015

- abundant
- sensitive to change
- identifiable to species
- well preserved fossils
- quantitative models
  total phosphorus (TP)

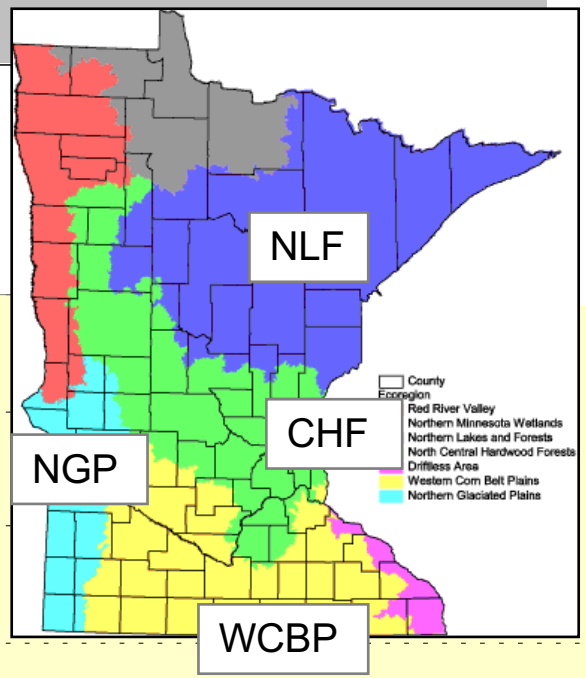
Development of Phosphorus Standards for MN Lakes



Top-Bottom Analysis

- Core top to assess modern conditions
- Samples taken from below settlement horizon to assess natural or background nutrient levels in lakes

Diatom-inferred Phosphorus: Pre-European vs. Modern, and MPCA TP Standards for MN lakes



TP ppb

0
20
40
60
80
100
120
140

<30 TP
<40 TP
<40 TP
<60 TP
<65 TP
<90 TP

NLF (n=20)
CHF-Metro (n=20)
CHF-Rural (n=15)
CHF-Shallow (n=5)
WCP - Deep (n=5)
WCP/NGP - Shallow (n=6)

Pre-E
Modern

Ramstack et al. 2003, 2004
Heiskary et al. 2004 Enviro. Bull.
Heiskary & Wilson 2008 Lk Res Mgmt

So what's happening to MN lakes?

Eutrophication

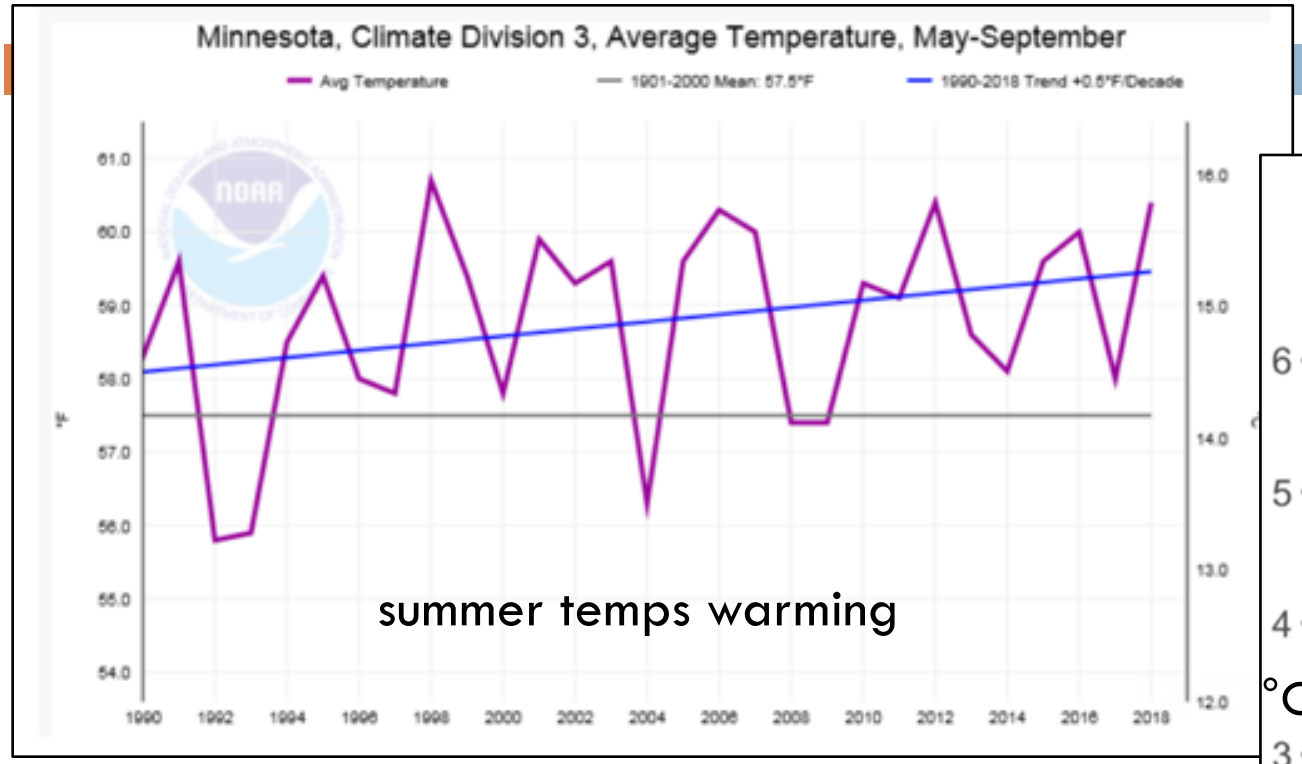
Development

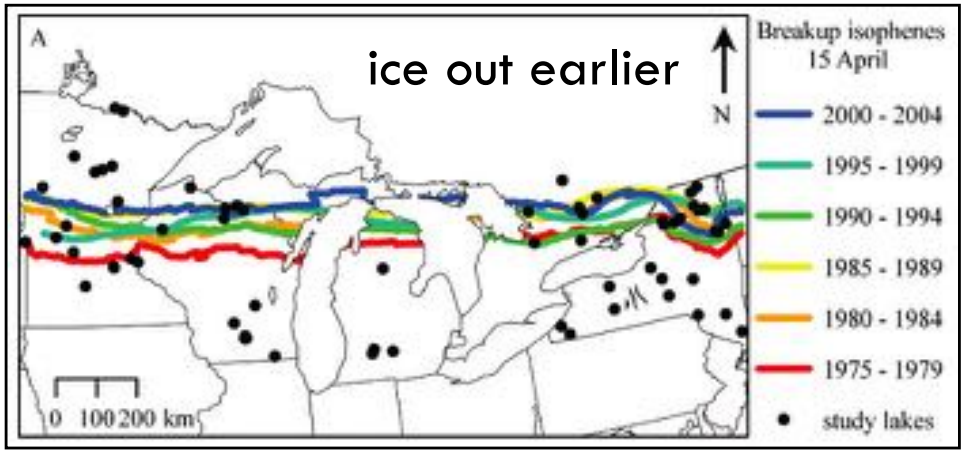
Landuse

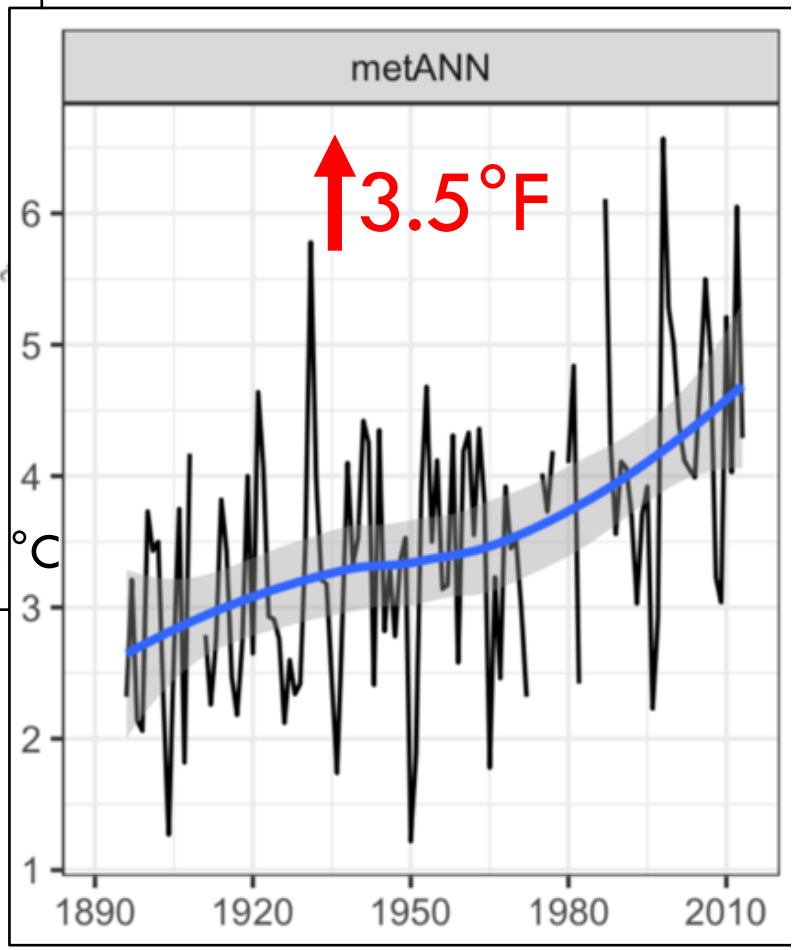
Recreation

Exotics AIS

Climate & Weather







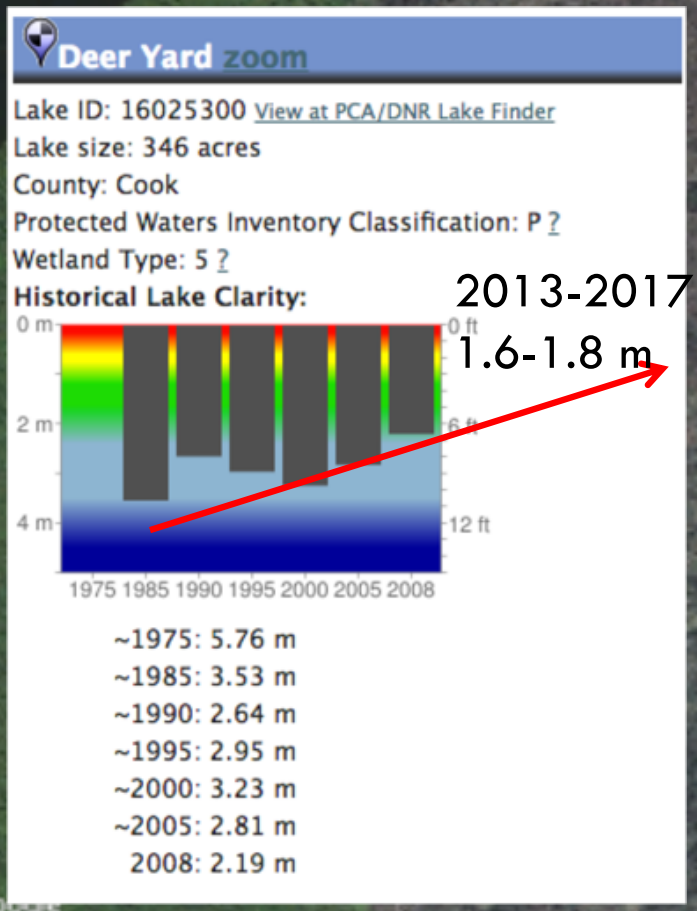
Eveleth MN Annual Temperature 1890-2014

Northern Lakes

- The aim of these projects was to use dated sediment cores to reconstruct the ecological and sedimentation history of lakes.
- Some lakes do not meet nutrient goals, or there has been a decreasing trend in Secchi depth – the lake is getting less clear.
- What is changing? Has the productivity of the lake changed over time? What was the historical condition of the lake? Why the current trajectory? What should we do with this info?

- Max Depth = 6 m (20 feet)
- One core collected from a deep, flat area of the main basin (core recovery – 1.02 m/40 inches)
- Currently meets nutrient goals – measured TP 10-22 ppb
- Decreasing trends in Secchi Depth

Deer Yard Lake



- Max Depth = 21 m (70 feet); marginal bays are commonly 9 m (30 feet) deep
- Core 1, Shallow Bay (core recovery – 1.03 m/40 inches)
- Core 2, Deep Central Basin (core recovery – 1.40 m/55 inches)
- Currently meets nutrient goals – measured TP 8-15 ppb
- Decreasing trends in Secchi Depth

Core 1

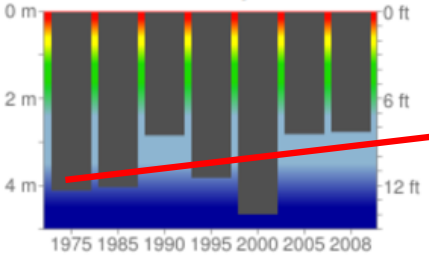
Core 2

Poplar Lake

Google

Poplar zoom

Lake ID: 16023900 View at PCA/DNR Lake Finder
Lake size: 802 acres
County: Cook
Protected Waters Inventory Classification: P ?
Wetland Type: 5 ?
Historical Lake Clarity:



2007-2010
2.7-3.5 m

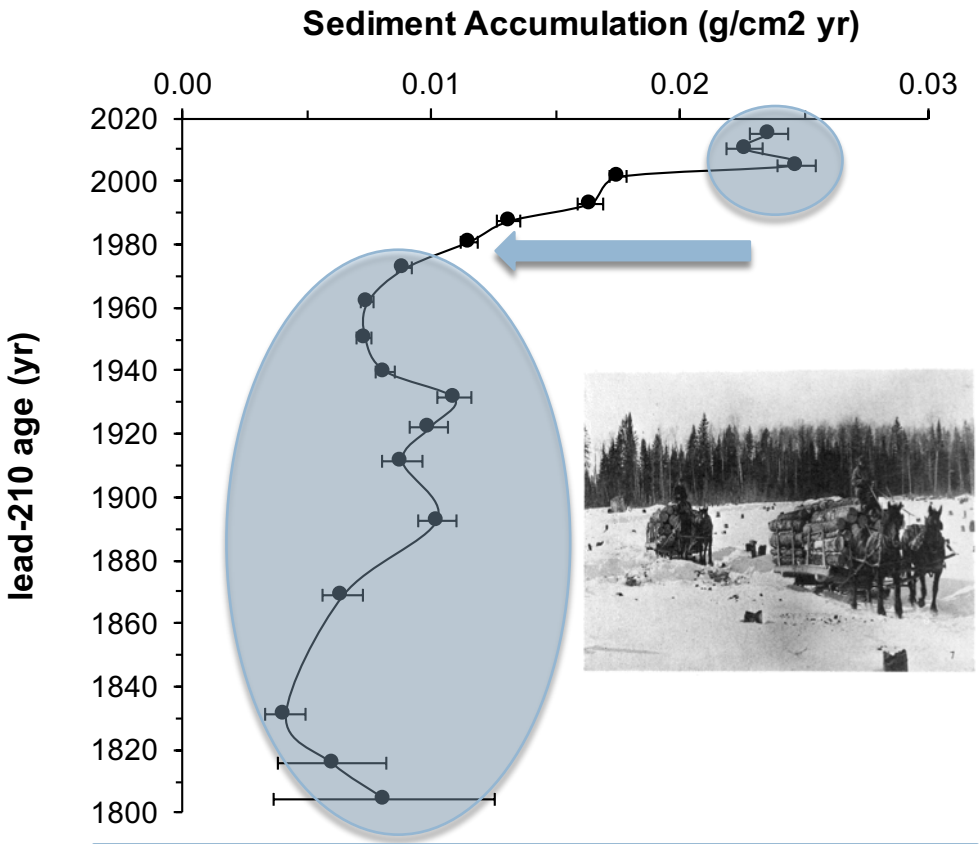
~1975: 4.1 m
~1985: 4.02 m
~1990: 2.83 m
~1995: 3.8 m
~2000: 4.64 m
~2005: 2.8 m
2008: 2.75 m

Sediment Coring

- Piston cores collected in 2016
- Dated with lead-210
- Analyzed biological and geochemical markers in the sediments
- Interested in condition before Euro-settlement, changes since Euro-settlement, and current trends

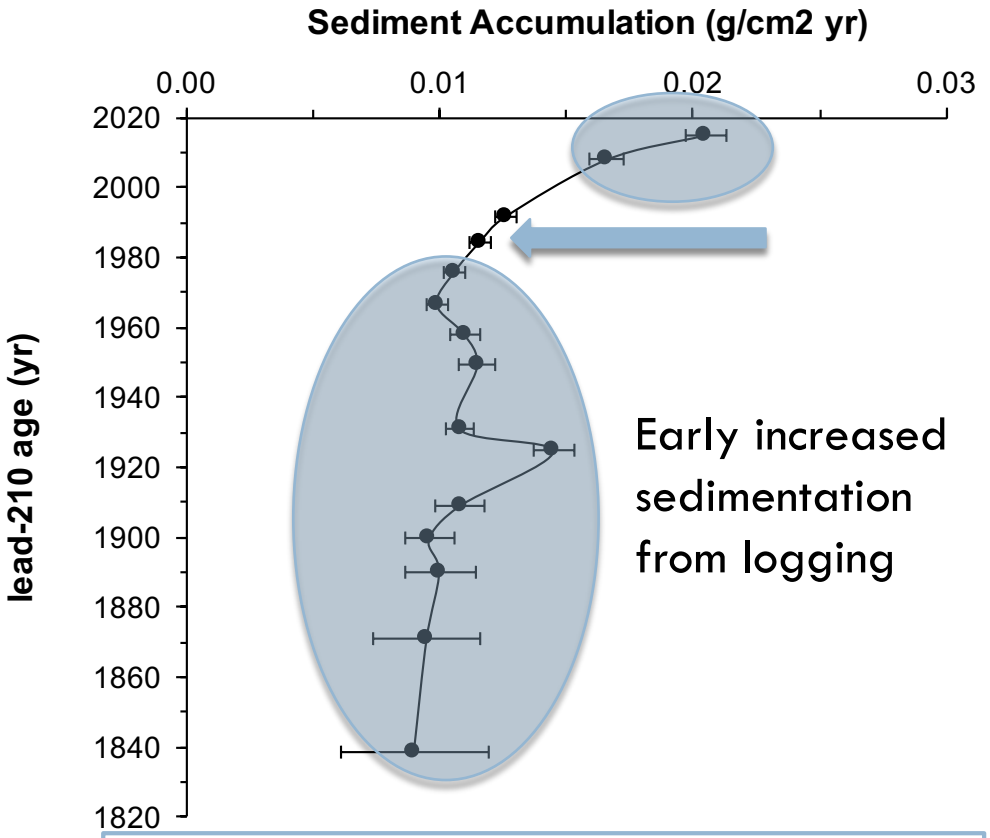
Sedimentation in Poplar Lake

Core 1 – Shallow Bay



Sedimentation rate in the recent decade nearly 3 times higher than the average rate from early 1800s through the 1970s

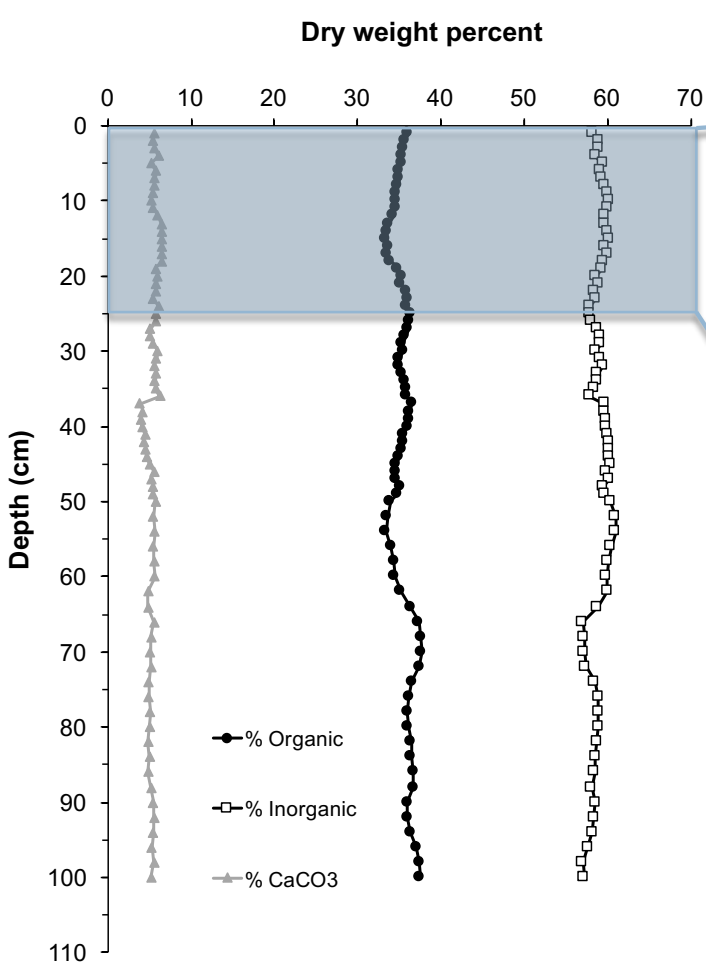
Core 2 – Deep Basin

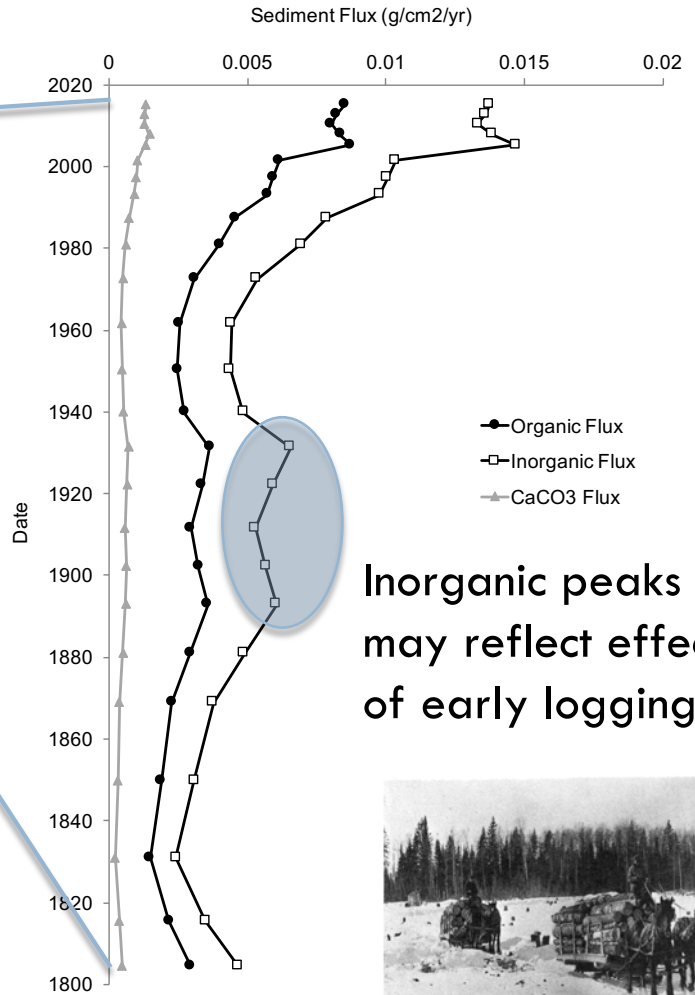


Sedimentation rate at the core top 2 times higher than the average rate from early 1800s through the 1970s

Sediment Composition and Flux – Poplar Lake Core 1

The lead-210 record (1804-2016) was contained in the top 25 cm

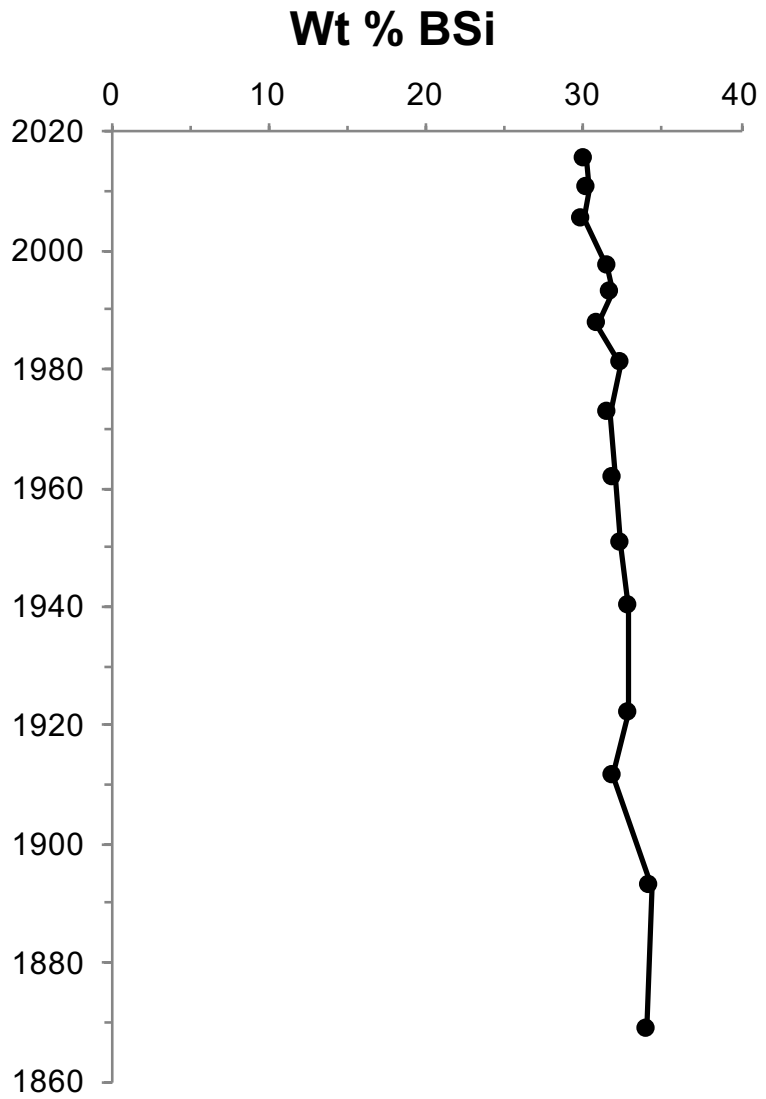


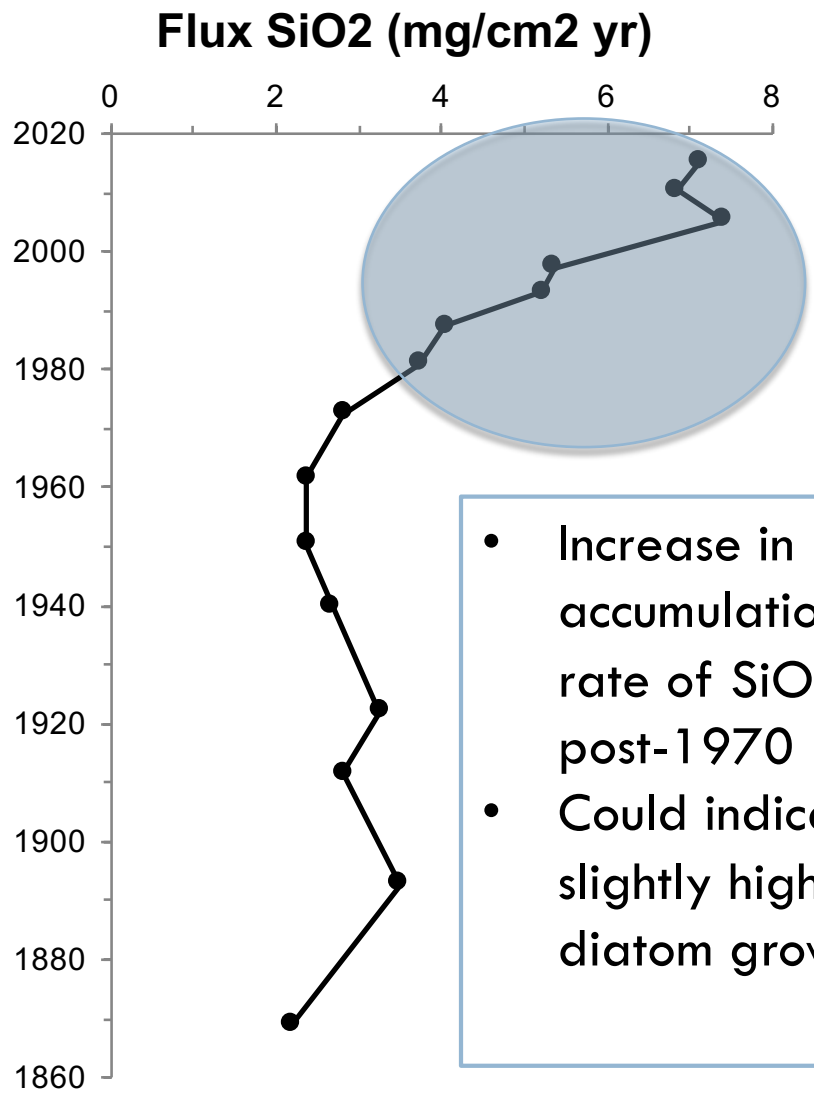


Inorganic peaks may reflect effects of early logging

Very little difference between Shallow Core 1 and Deep Core 2!

Biogenic Silica – Poplar Lake Core 1

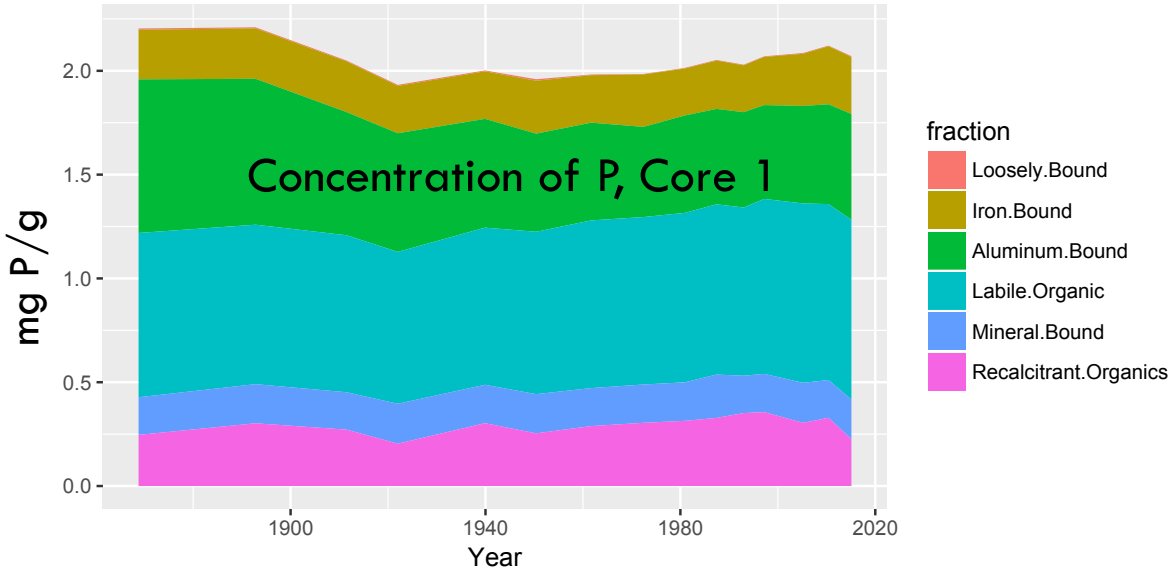


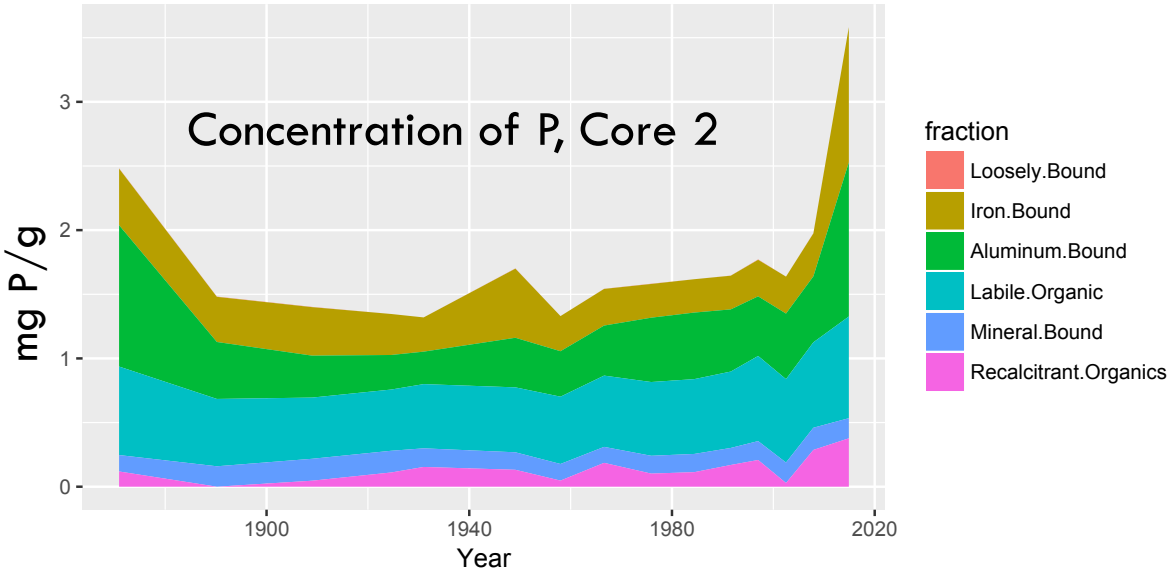


- Increase in accumulation rate of SiO2 post-1970
- Could indicate slightly higher diatom growth

Similar BSi record in Deep core

Phosphorus Fractions – Poplar Lake Cores 1,2



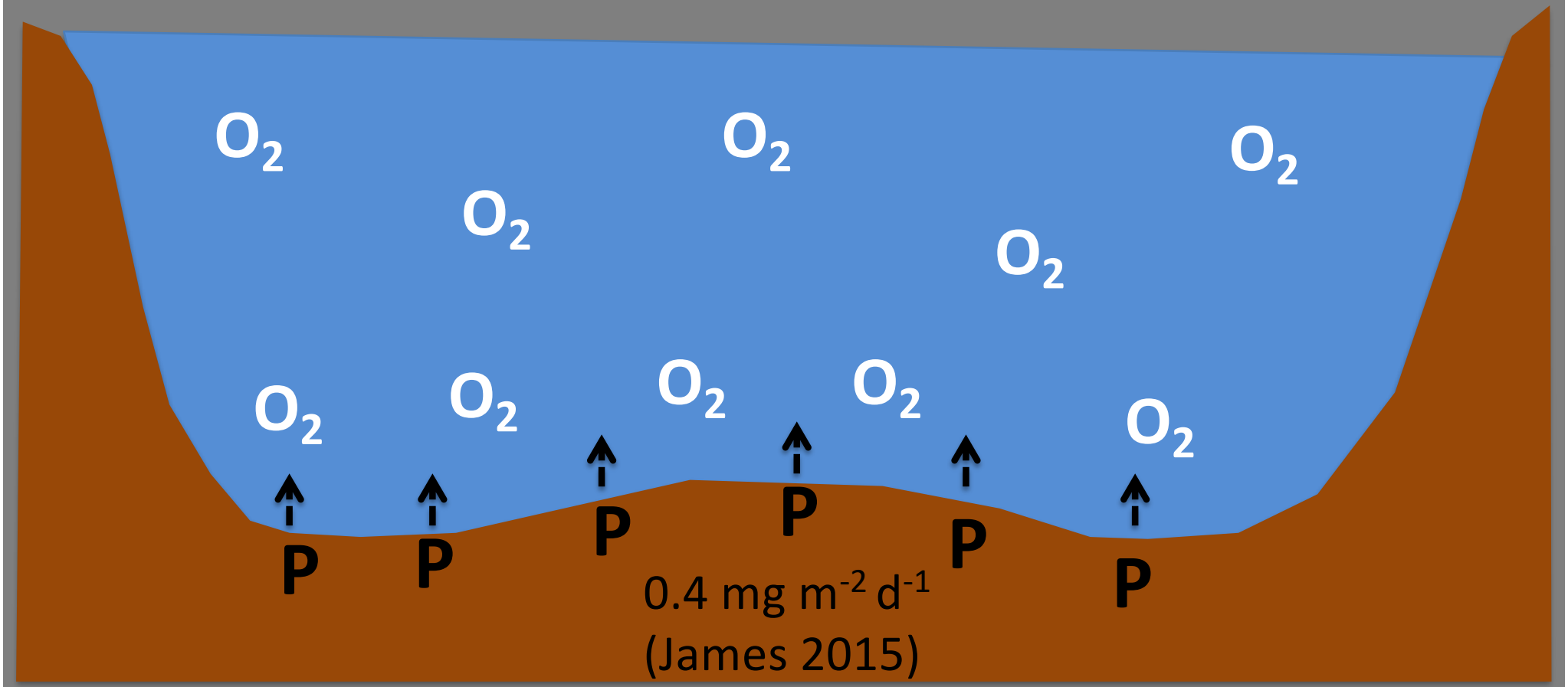


- Little overall change in the concentration of TP; Labile Organic P is the largest fraction
- Consistent concentration of Iron Bound P
  - Suggests minimal threat of enhanced internal loading in this shallow bay of Poplar Lake

- Spike in TP concentration and flux at the core top
  - May indicate greater potential for internal loading, due to upcore mobility of P, in the deep basin

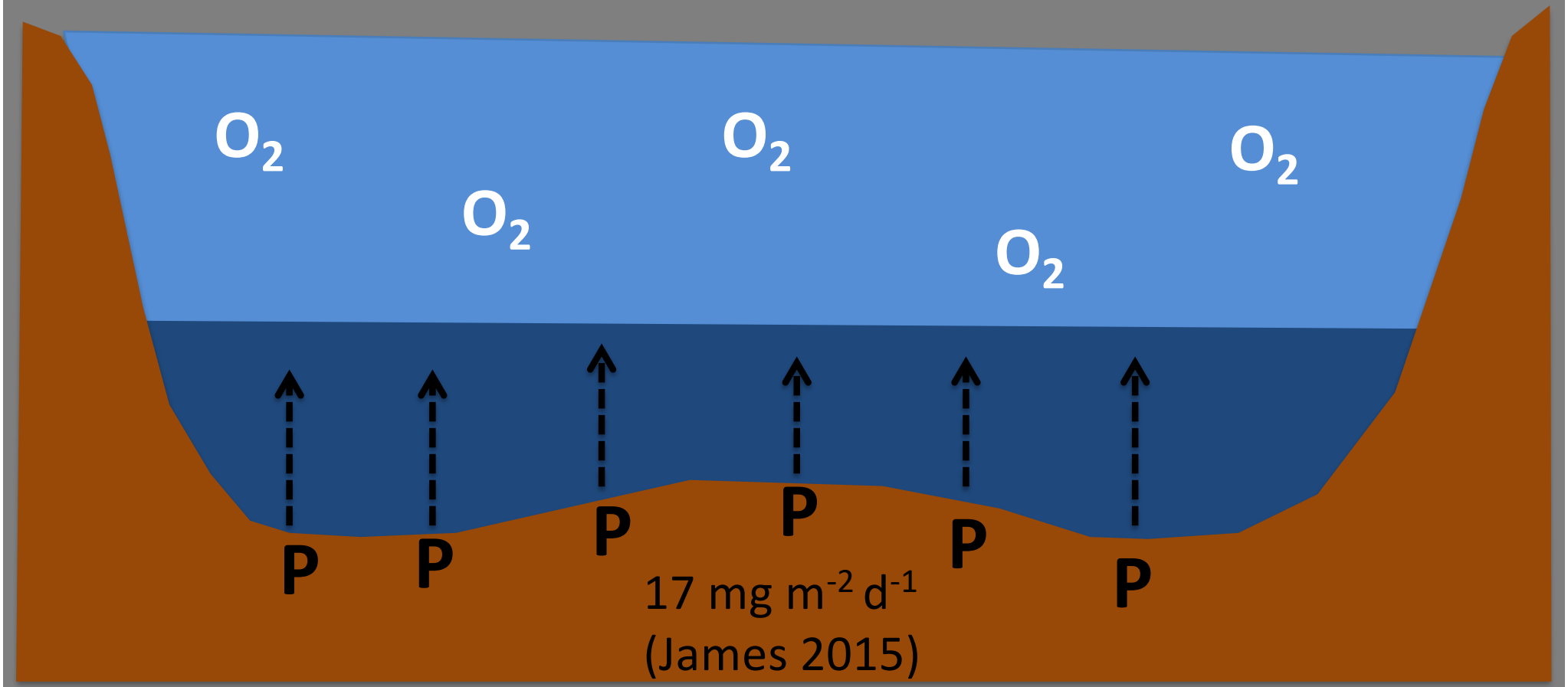
The roles of sediments in recycling P

Slow diffusion from sediments when lake is mixed with plenty of oxygen



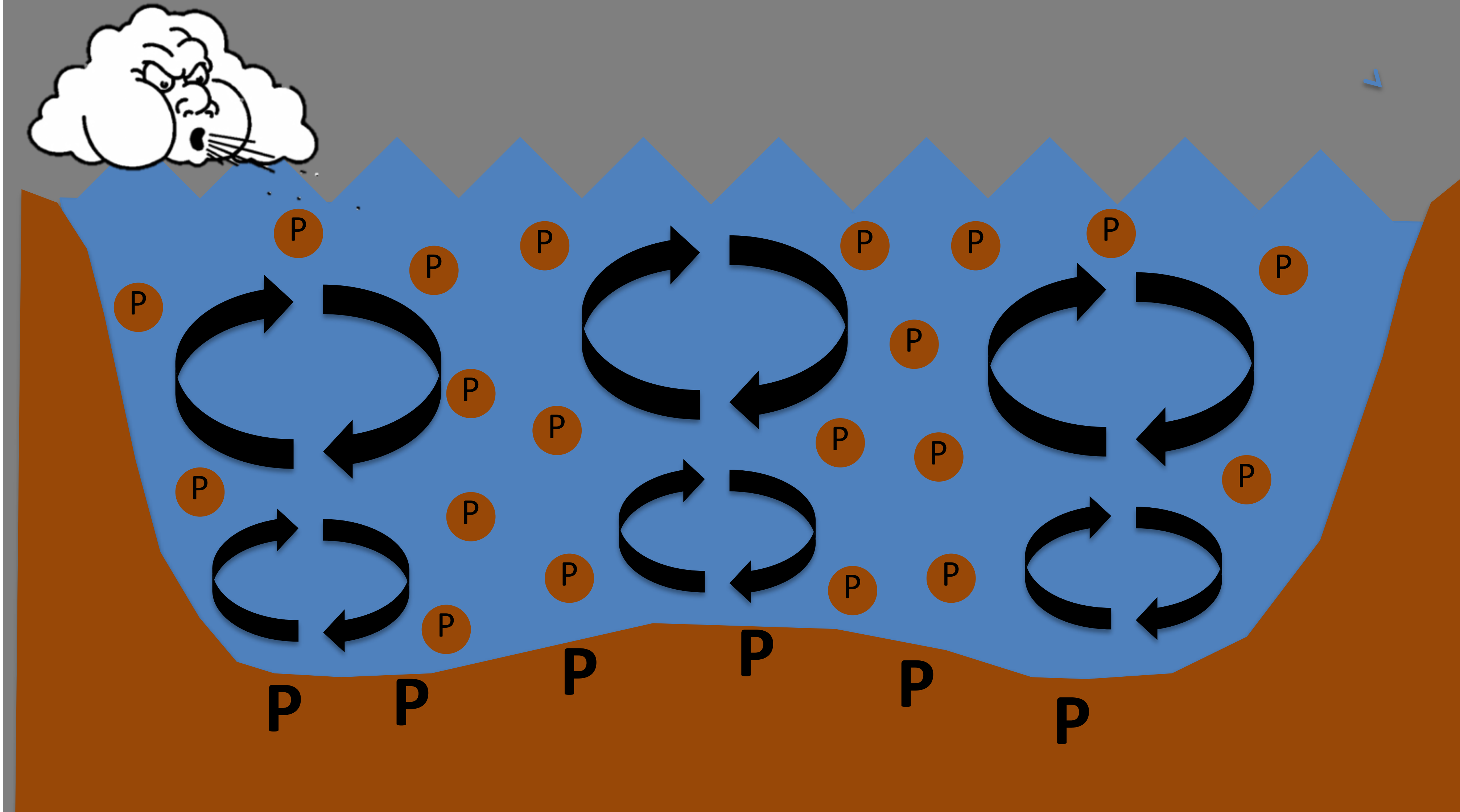
The roles of sediments in recycling P

Increased rate of diffusion if bottom waters become anoxic (8-43x faster!)

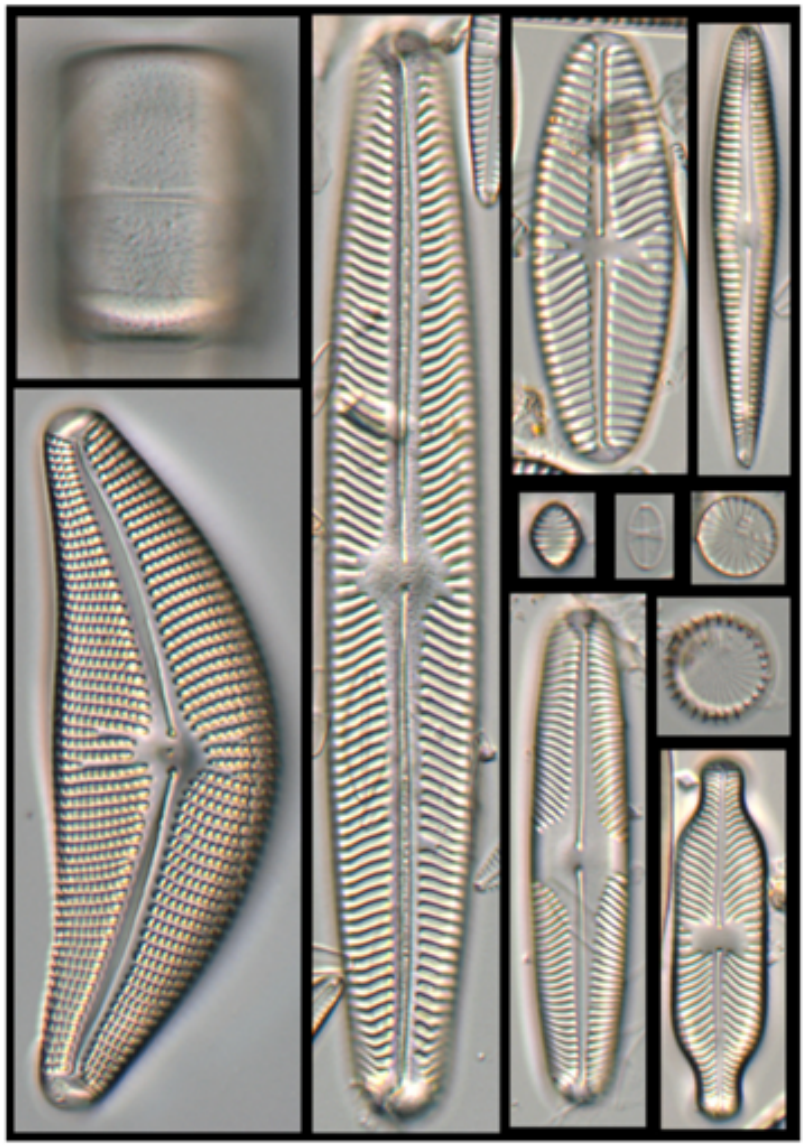


The roles of sediments in recycling P

Physical mixing from wind and wave action



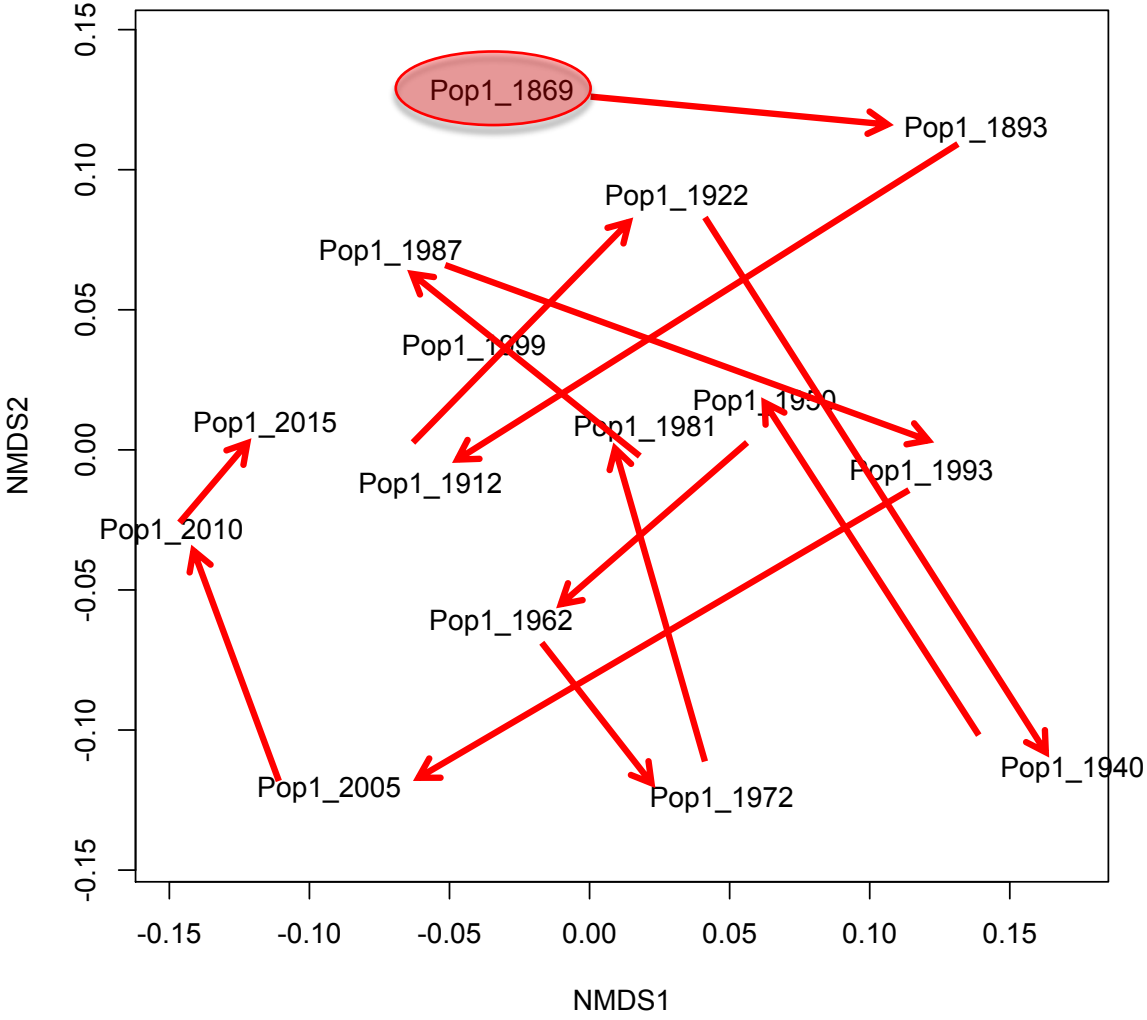
DIATOMS



- Generally abundant and well preserved in lake sediments
- Respond rapidly to changes in their aquatic environment
- Multivariate statistical techniques
- Use relationships to determine past lake conditions from fossil assemblages

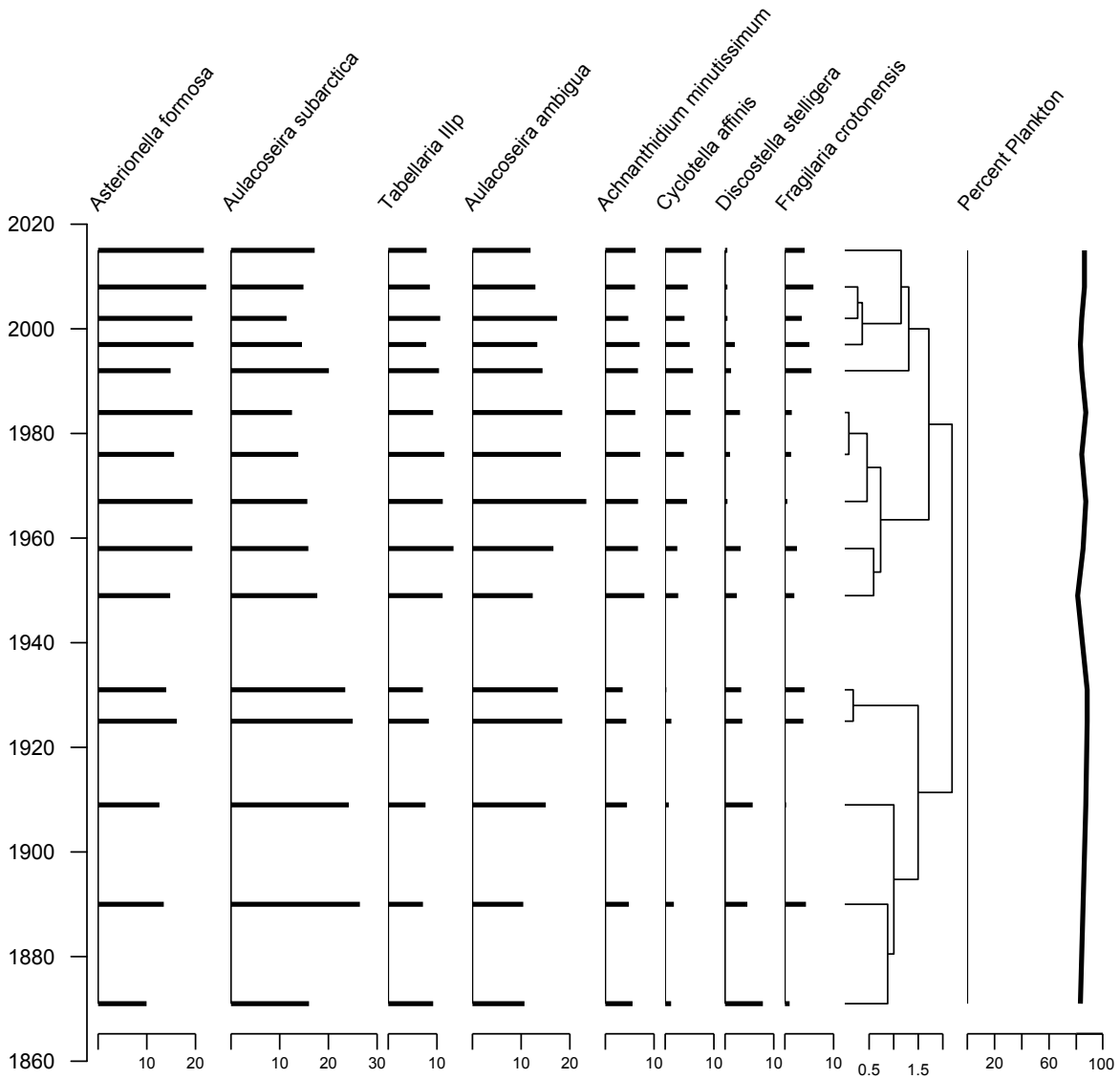
NMDS Biplot – Shallow Core 1

Poplar Lake core 1 NMDS



- Shows how the core samples cluster based on similarity of diatom assemblage
- No clear trajectory through time (with exception of three most recent samples clustering near each other)
- Very short gradients – very little change in the diatom community throughout the core from the shallow bay

Diatoms – Poplar Lake Core 2



- Diatom community in the deep basin was similar to that of the shallow bay
- Dominated by plankton (81 to 88% throughout the core)
- No statistically significant shifts in the diatom community – largest shift was between 1931 and 1949

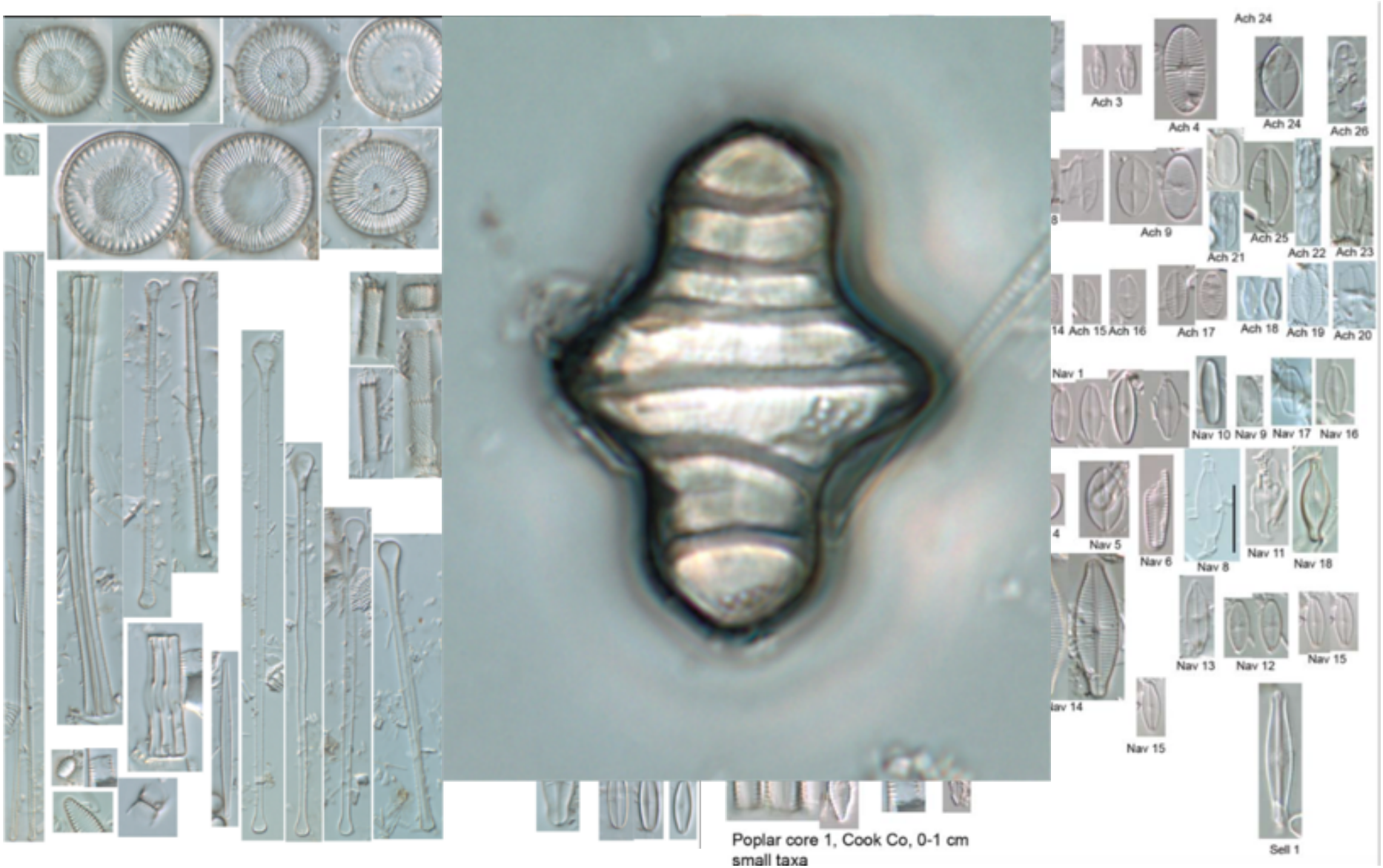
Poplar Diatoms

1800s Poplar

2000s Poplar

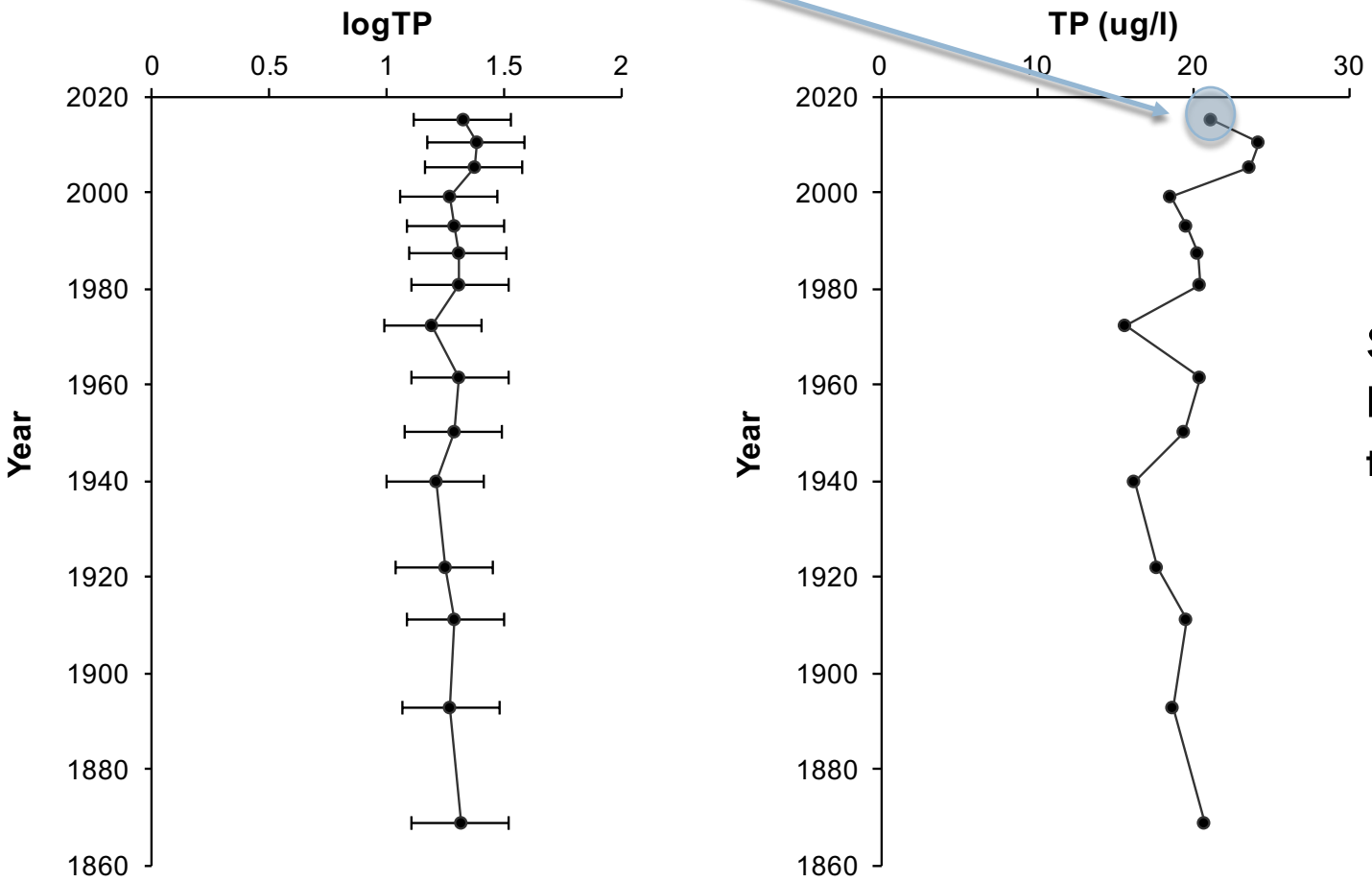
Diatoms – over 280 species

Diatoms *Tetracyclus glans* – first report in Minnesota – ever!



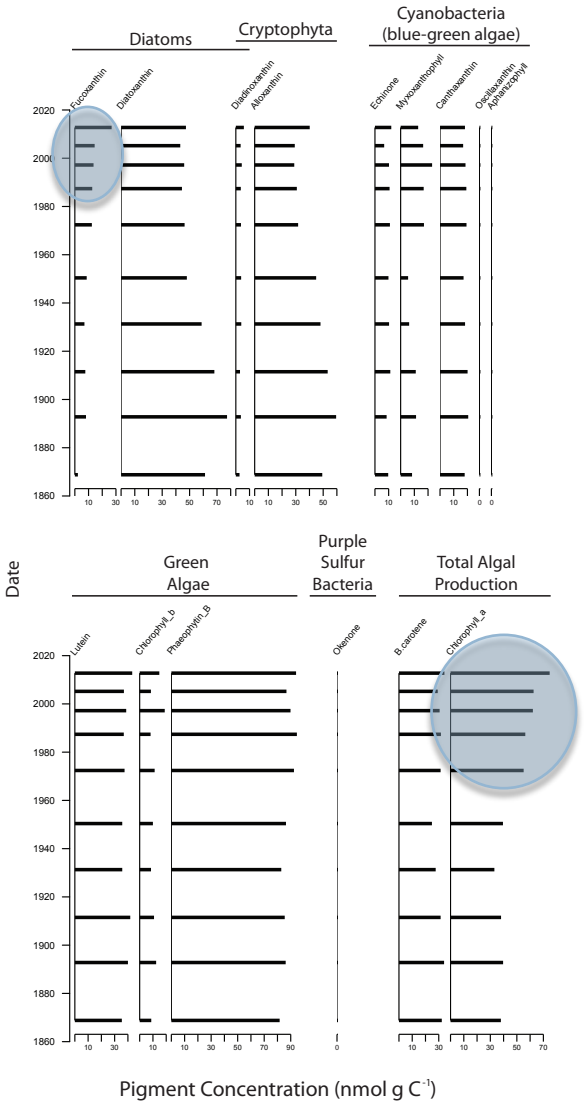
Diatom-Inferred TP – Poplar Lake Core 1

Core top DI-TP of 21 µg/l slightly higher than measured range of 8-15 µg/l); although both in the mesotrophic range



Suggests the lake has been mesotrophic since the mid-1800s

Algal Pigments – Poplar Lake Core 1

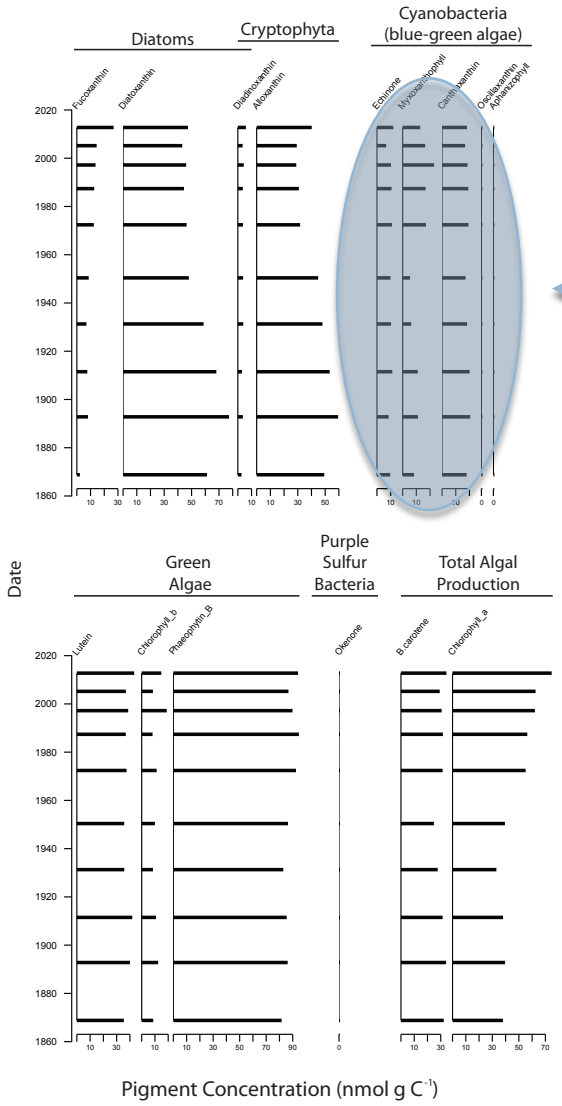


Slight rise in total algal production beginning in 1970s, continues through 2013.

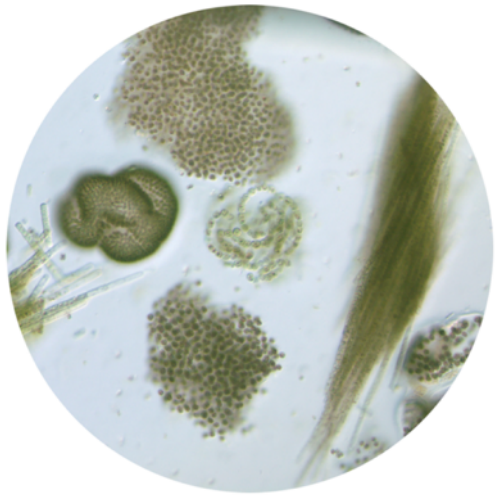
Driven primarily by increase in diatoms.

Diatoms

Algal Pigments – Shallow Core 1



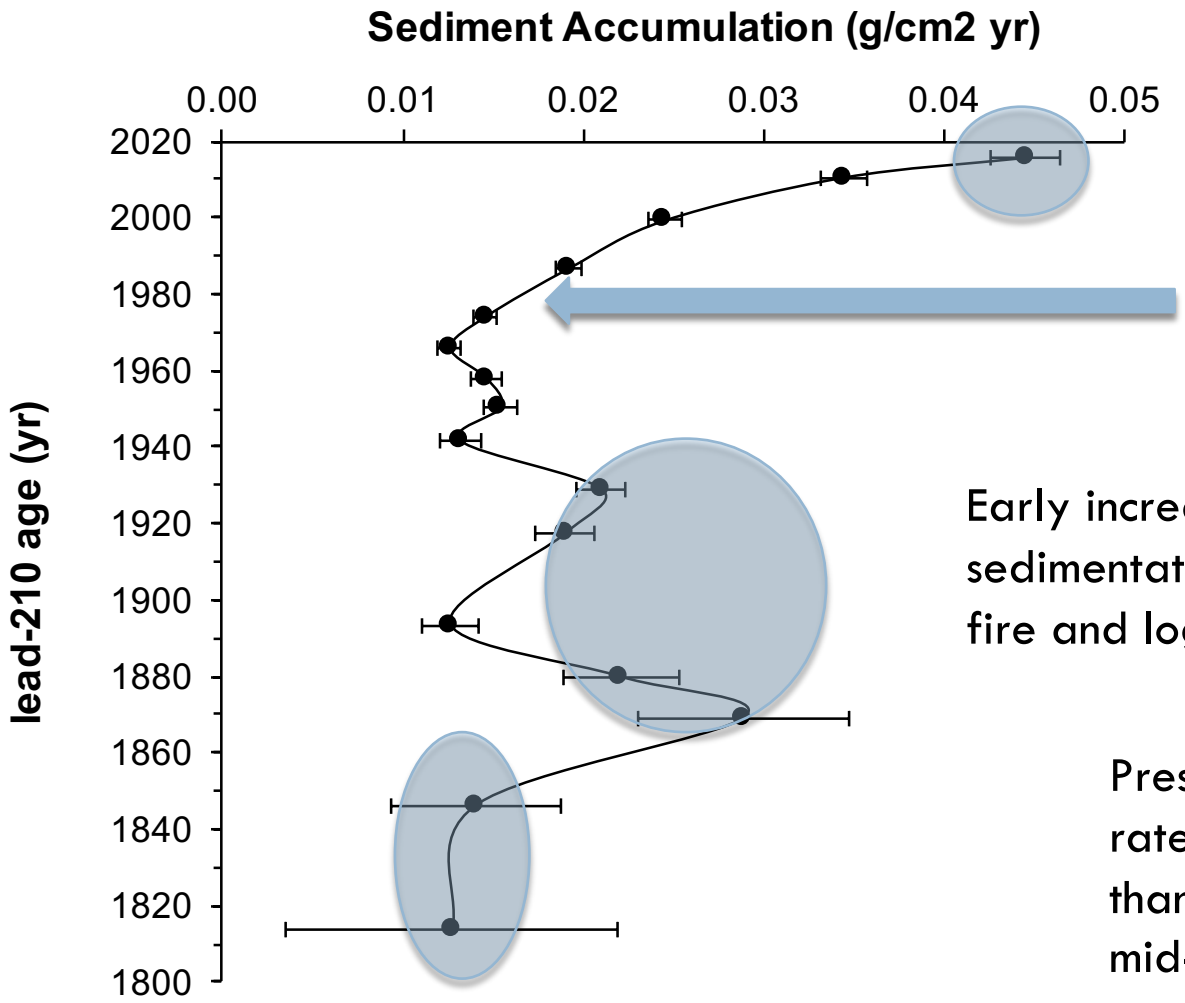
- Pigments of cyanobacteria (blue-green algae) remained relatively constant over the record, and were lower in concentration than other algal groups.
- Pigments from potentially toxic forms (myxoxanthophyll), and nitrogen-fixing forms (canthaxanthin) present throughout the record.
- No indication of blooms!
- Deep Core 2 showed overall similar patterns



Cyanobacteria

How about shallow Deer Yard Lake?

Sedimentation in Deer Yard Lake



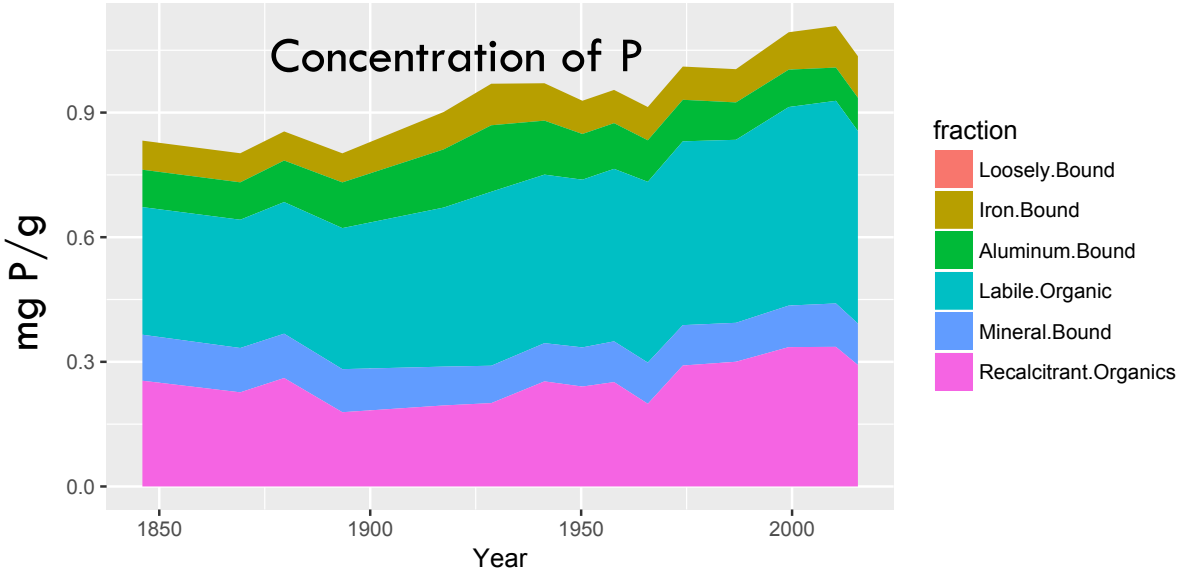
1800-2016 in top 34 cm!

Rise in sedimentation rate beginning in the 1980s

Early increased sedimentation from fire and logging

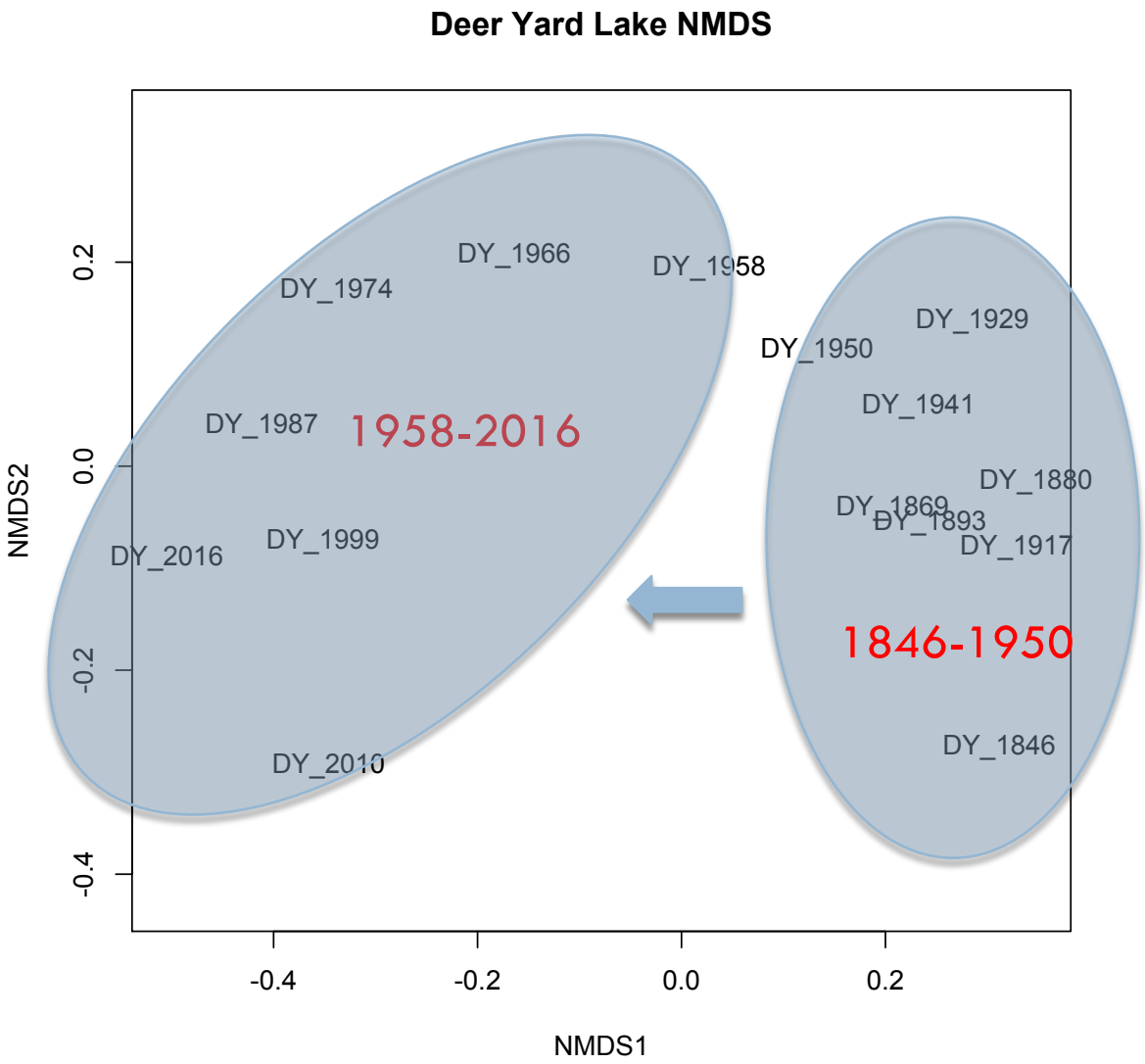
Present day sedimentation rate about 3 times higher than rate in the early to mid-1800s

Phosphorus Fractions – Deer Yard Lake



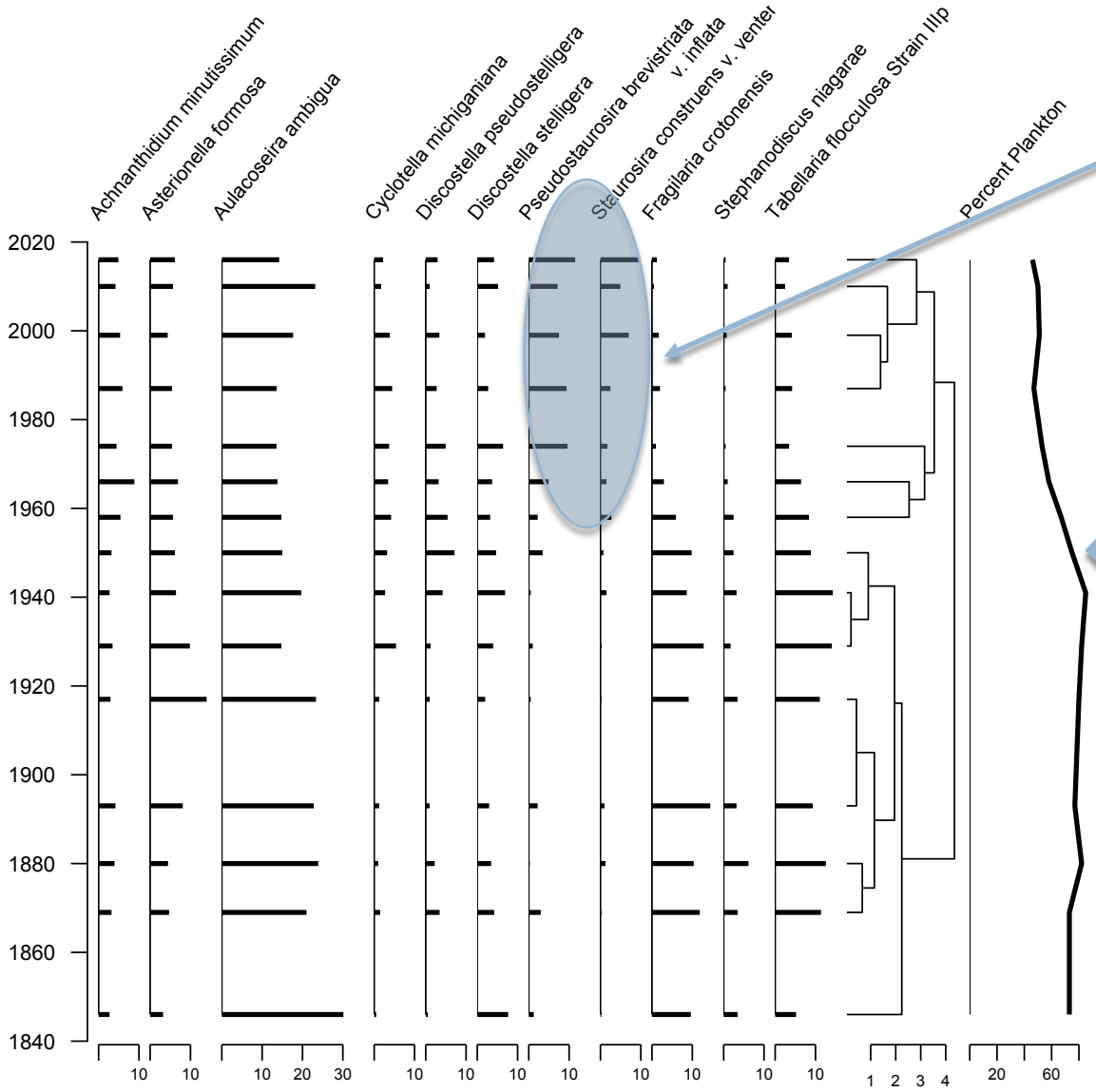
- Proportion of fractions did not change drastically – slight rise in Labile Organic P and Recalcitrant Organics
- Low and unchanging concentration of Iron Bound P
  - Little evidence to suggest increased or enhanced effects of internal loading

NMDS Biplot – Deer Yard Lake



- Shows how the core samples cluster based on similarity of diatom assemblage
- Samples from 1846 to about 1950 cluster on one side of biplot – then gradual change through core top

Diatoms – Deer Yard Lake

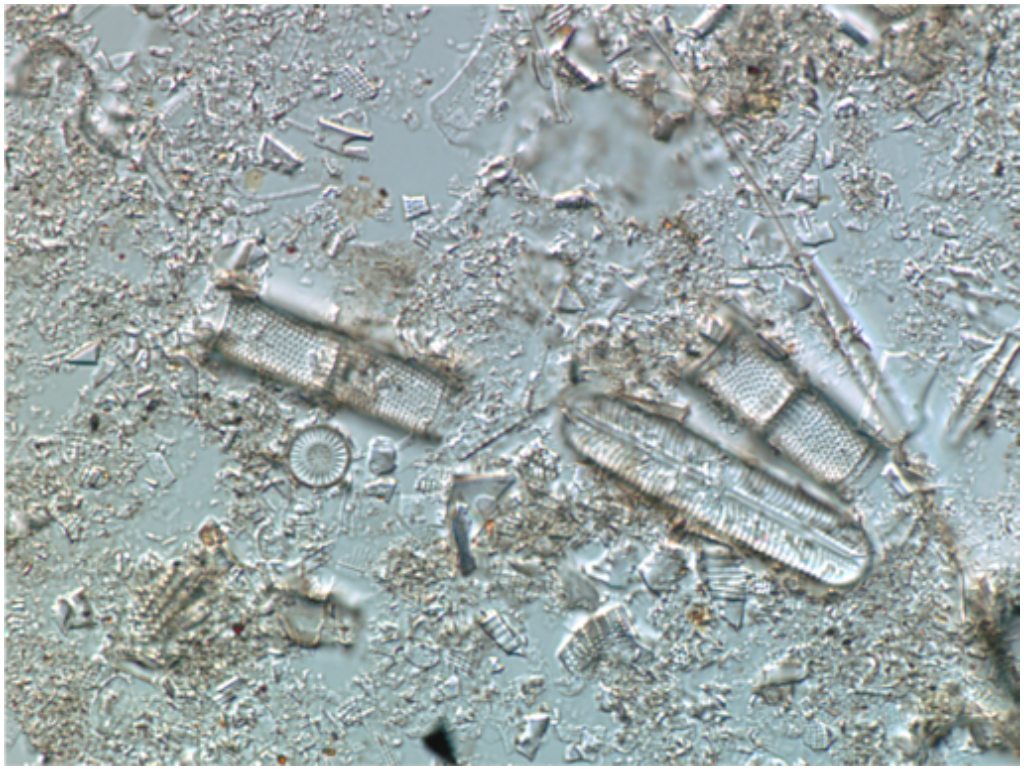


- Increase in tychoplanktonic species post-1950
- May be indicative of habitat change

- Largest shift in the diatom community (in the 1950s) corresponds to a decrease in percent plankton
- This shift is not statistically significant, indicating low overall change in the core

Deer Yard Diatoms

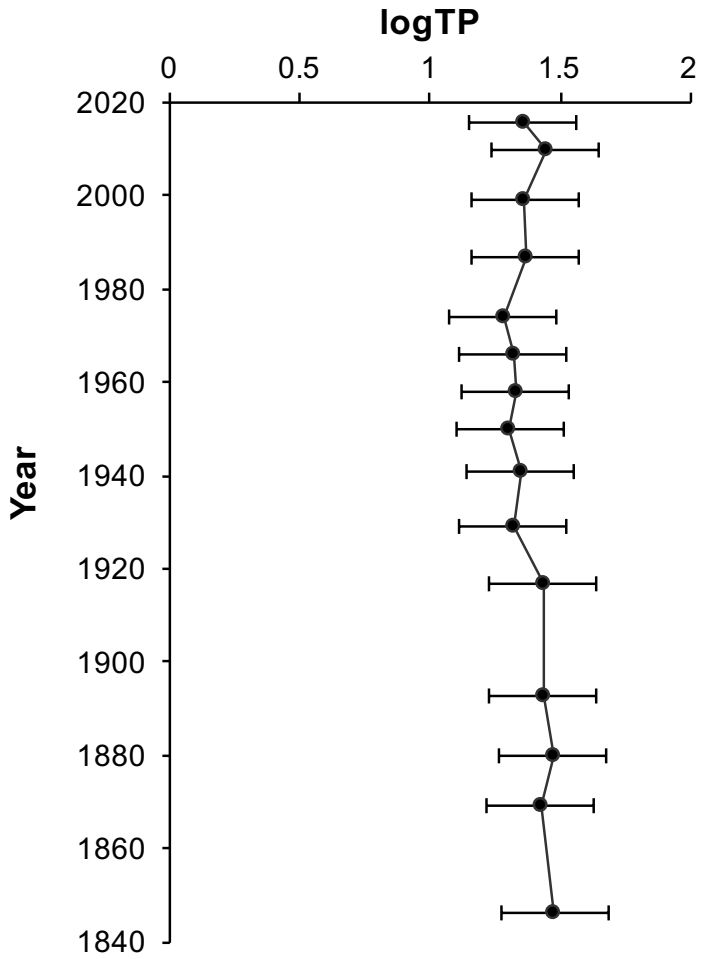
1800s Deer Yard

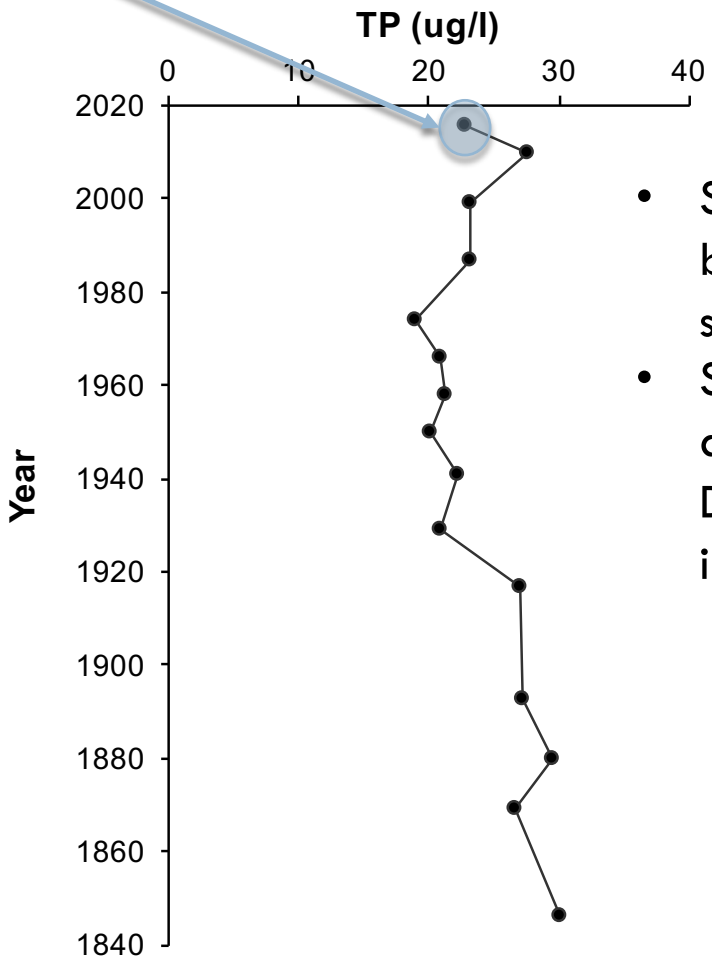


2000s Deer Yard

Diatom-Inferred TP - Deer Yard Lake

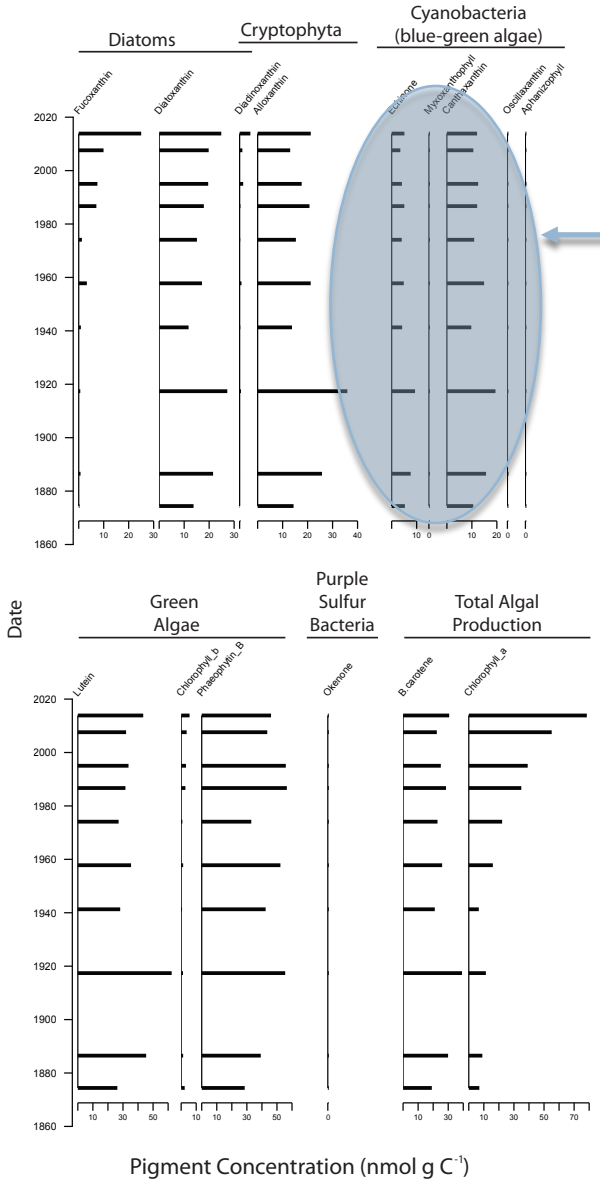
Core top DI-TP of 23 µg/l matches measured range of 10-22 µg/l)



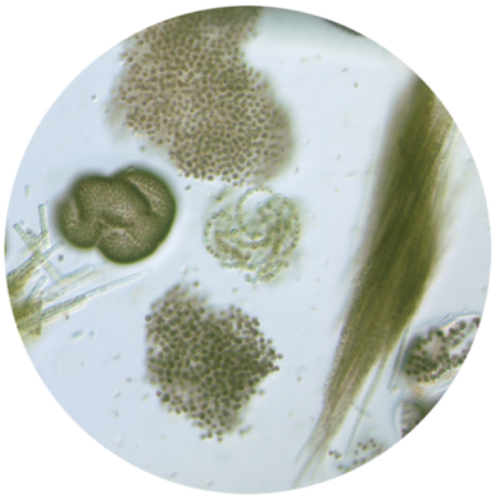


- Suggests the lake has been mesotrophic since the mid-1800s
- Suggests recent decreases in Secchi Depth not due to increases in TP

Algal Pigments – Deer Yard Lake



Pigments of cyanobacteria (blue-green algae) remained relatively constant over the record. Phew!



Cyanobacteria

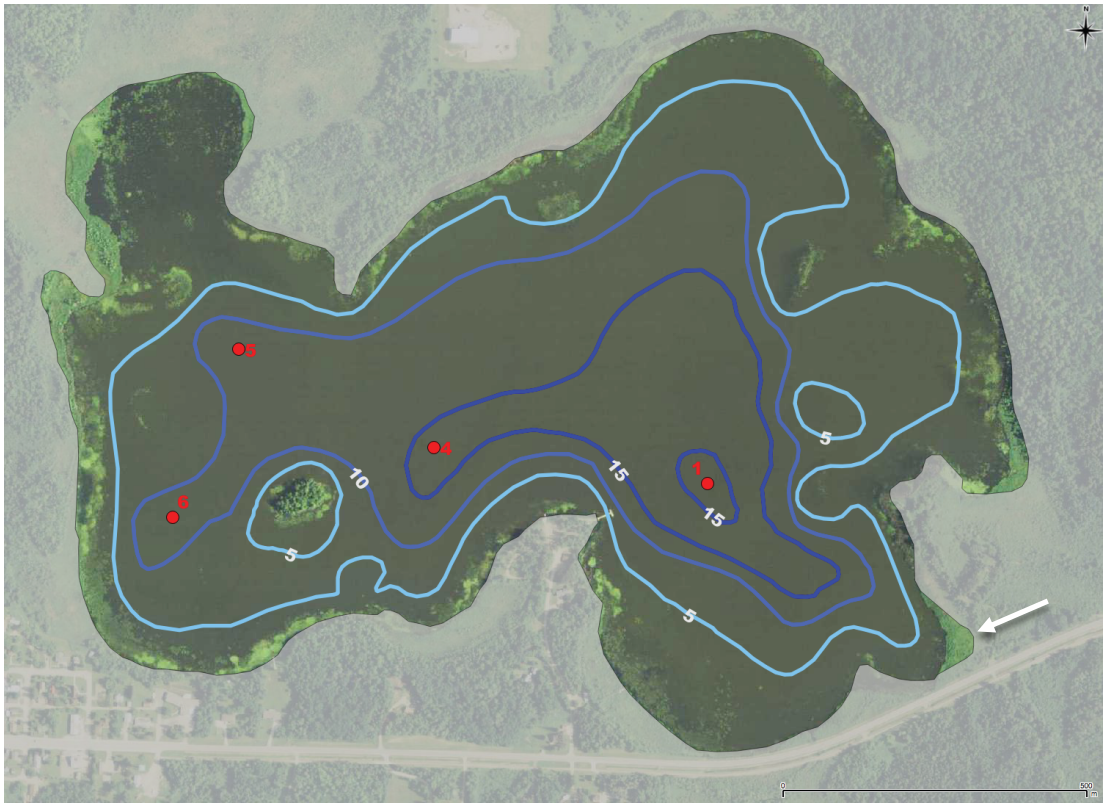
Conclusions – Poplar & Deer Yard

- Deer Yard and Poplar have a low sedimentation rates (140 years of lake history in top 8-10 inches).
  - Small increases in sedimentation rate from logging
  - Sedimentation rate increased again in the 1980s to levels that are currently about 2-3 times pre-settlement rate
- Little change in sediment composition – suggesting sediment sources to the lake have not changed.
- BSi (diatom algae) 35-40% of sediment weight – concentration changes little in the last 150 years.

Conclusions – Poplar & Deer Yard

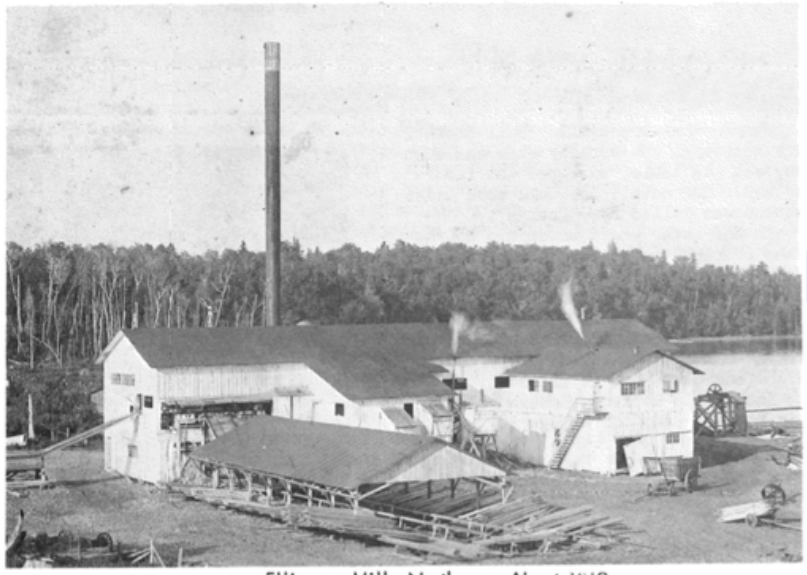
- Slight increase in P upcore (key fractions that drive internal loading do not change).
- Diatom community shows small shift in the 1950s to fewer planktonic species – suggests minor habitat change (forest maturation).
- DI-TP suggests the lakes have been mesotrophic since the mid-1800s.
- Algal pigments confirm the long-term stability of these – no major changes in communities and no evidence of increased cyanobacterial growth.
- Secchi trend? Sediment/Algae/DOC – browning of lakes

BARTLETT LAKE, NORTHOME, MN



- a typical MN lake?
- Shallow lake
- HABs
- excess TP, chl a, impaired
- long history of nutrient loading 1910s-1970s

BARTLETT LAKE



Ellingson Mill, Northome, About 1919

- Logging, early 1900s
- Creamery, 1916-1974
- Sewage, 1915-1979 (Imhoff tank, 1°)
- Clean Water Act
- But, it's not better

First Creamery

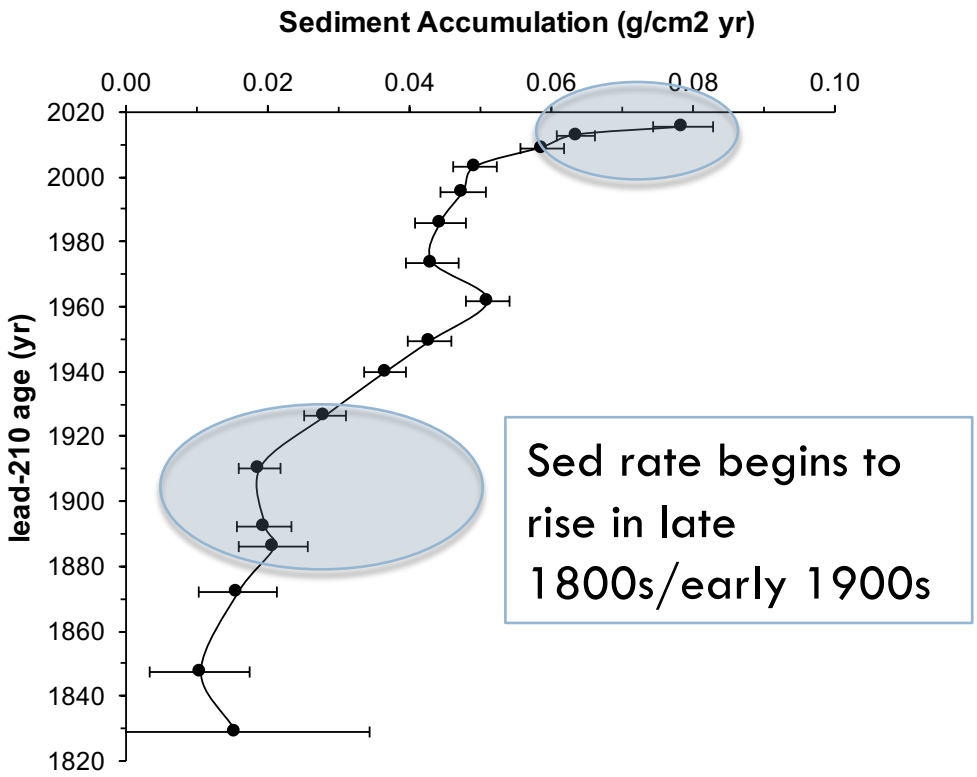
FRIDAY, APRIL 3, 1914. Number 13

THE NORTHOME CO-OPERATIVE CREAMERY

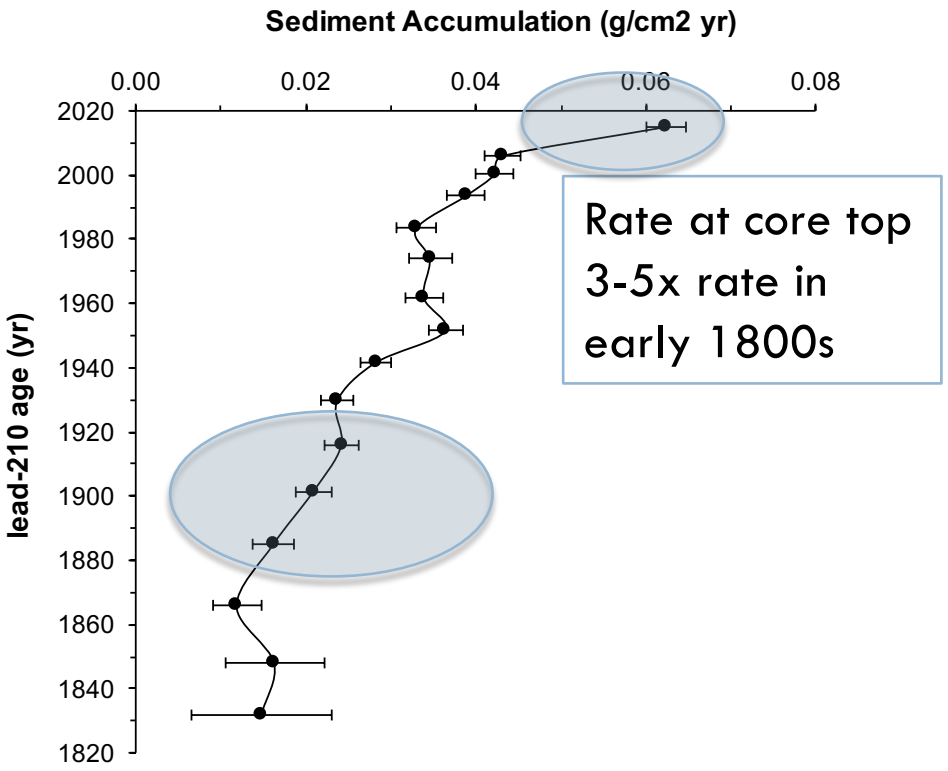
Mass Meeting of Citizens Get Together to Work For a Bigger and Better Northome and Improvement of Farming Conditions and a Co-operative Creamery Association is the Result

Sediment Accumulation Rate

Core 6 (West basin)



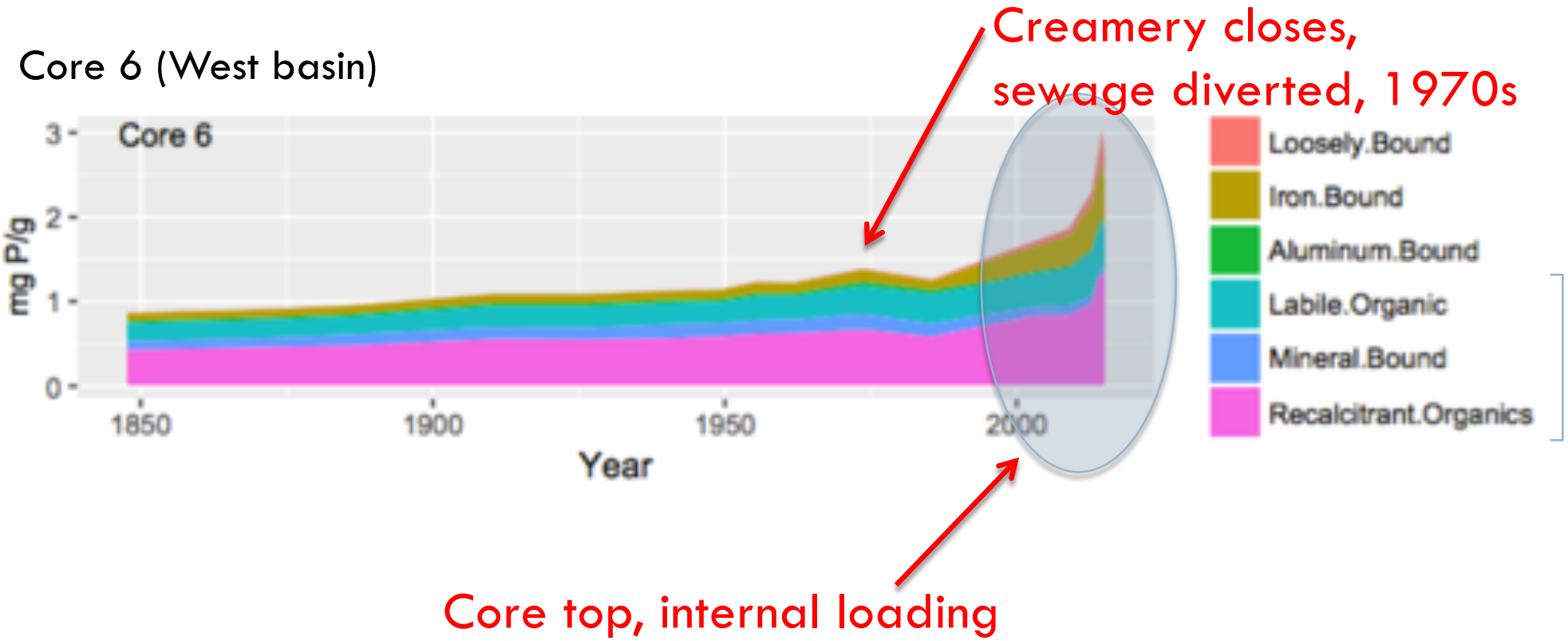
Core 1 (East basin)



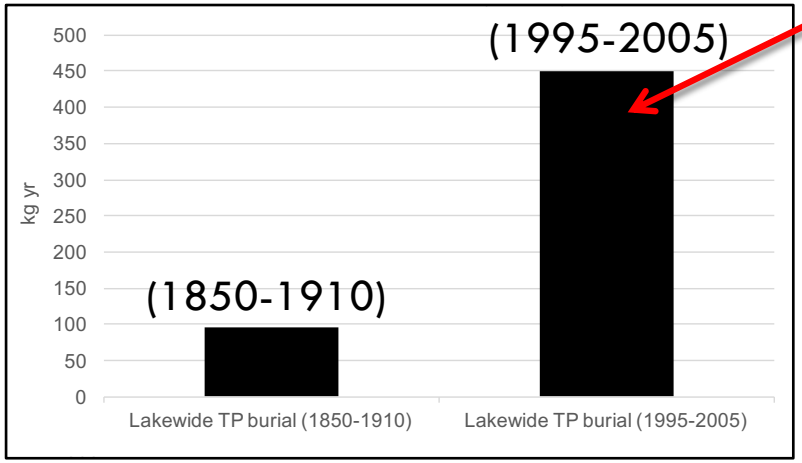
Sedimentation patterns similar in both east and west sides of the basin, slightly higher in West

Phosphorus in Cores

Core 6 (West basin)

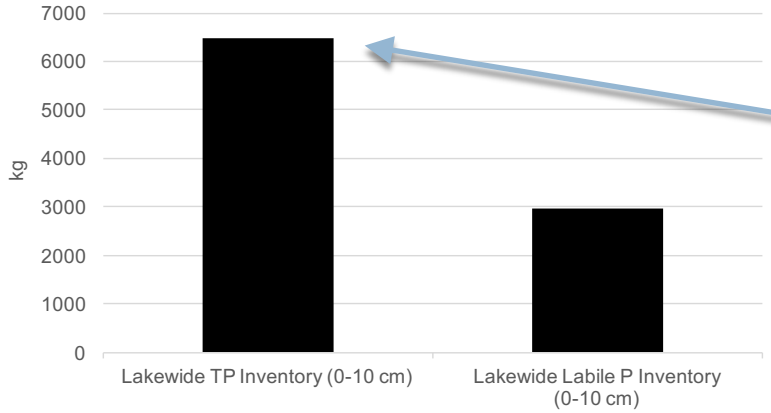


Phosphorus moves up the core and exchanges with the water through internal loading. “Fe-bound” and “labile-organic” P are the big players. HOW DO WE GET RID OF THAT “LEGACY” P?



up to 450 kg P buried per year

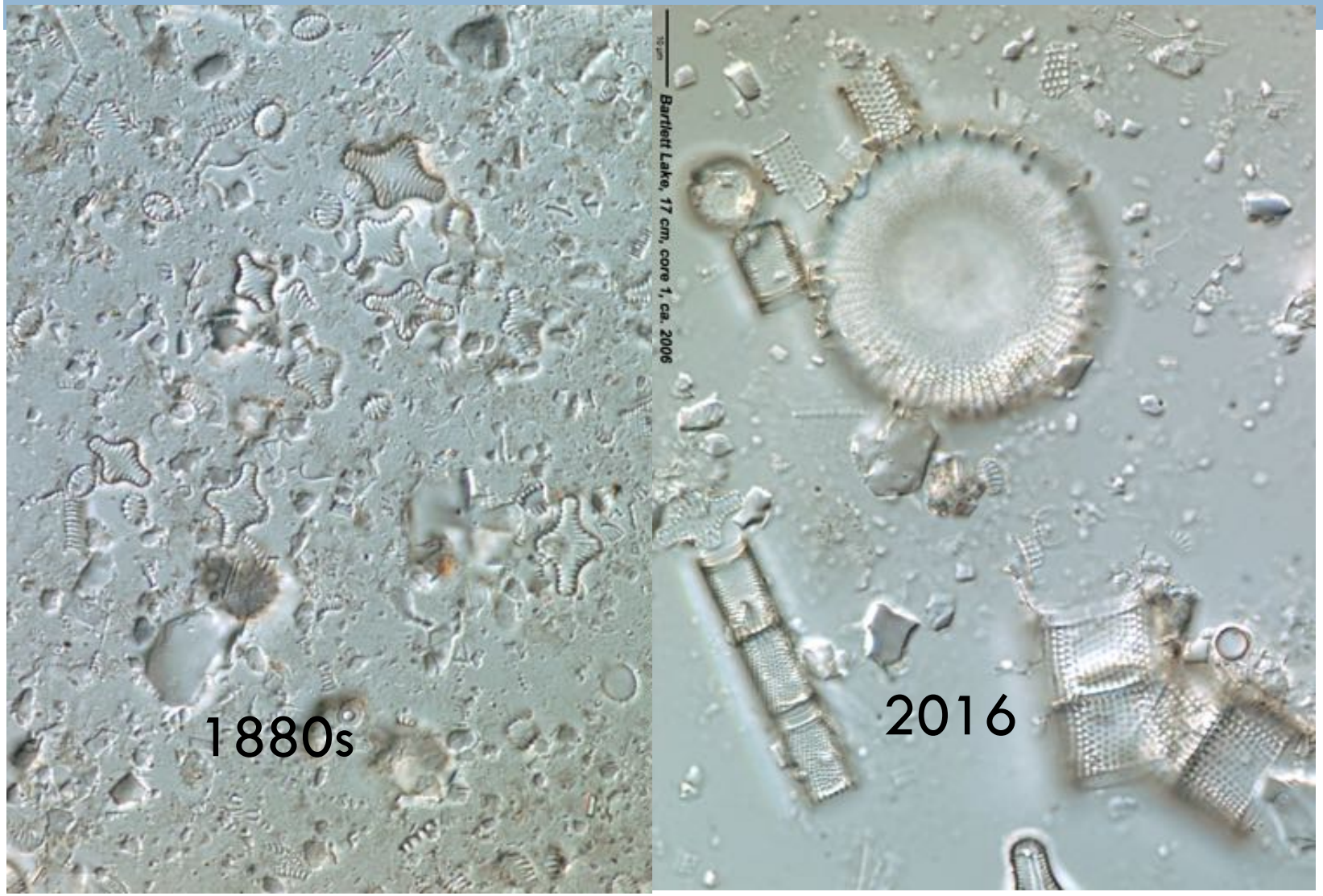
- Lakewide TP burial rate
  - About five times higher in recent times (1995-2005) than pre-settlement period (1850-1910)



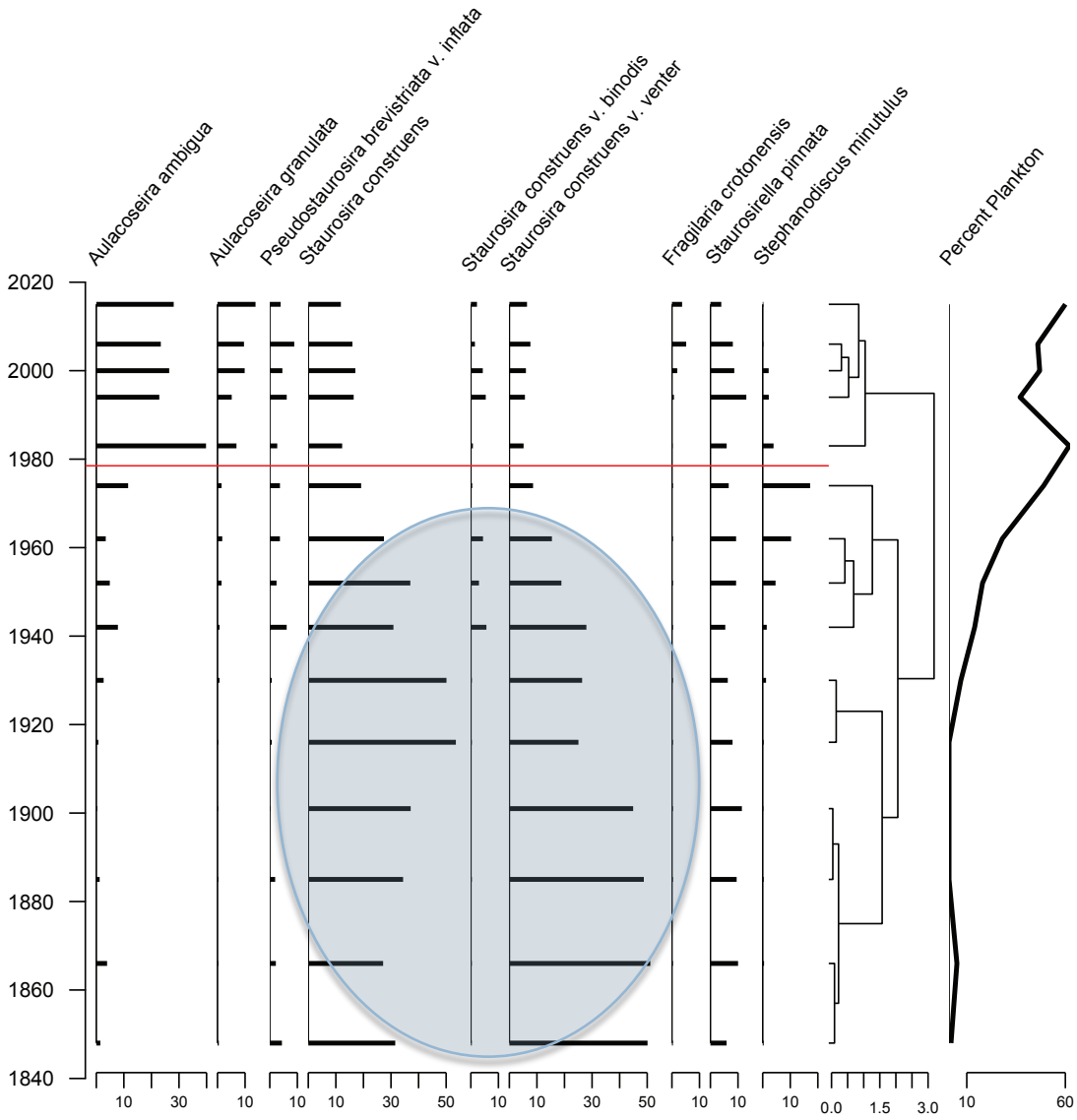
- Lakewide TP Inventory (top 10 cm)
  - ~6,500 kg of TP, including ~3,000 kg of labile P available to contribute to internal loading

6500 kg P = 7.3 tons, 1/3 of a dump truck load of fertilizer

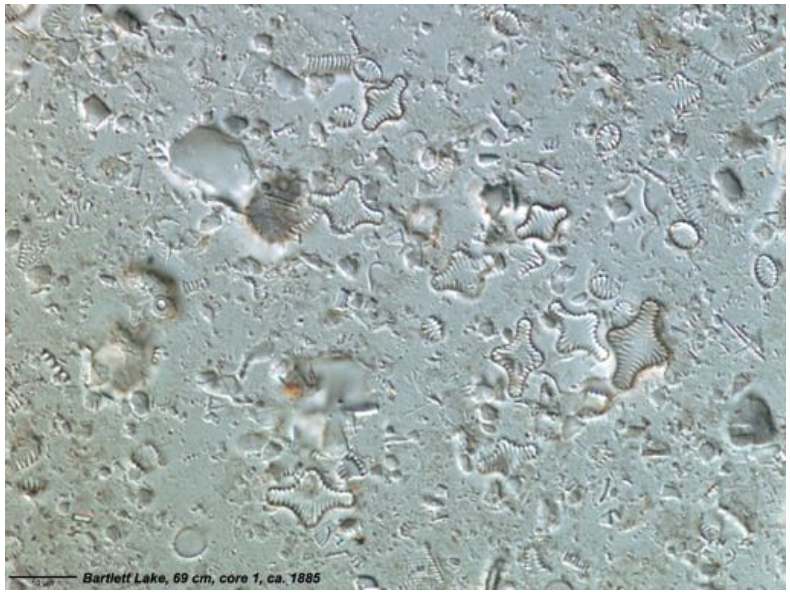
Bartlett - Diatoms



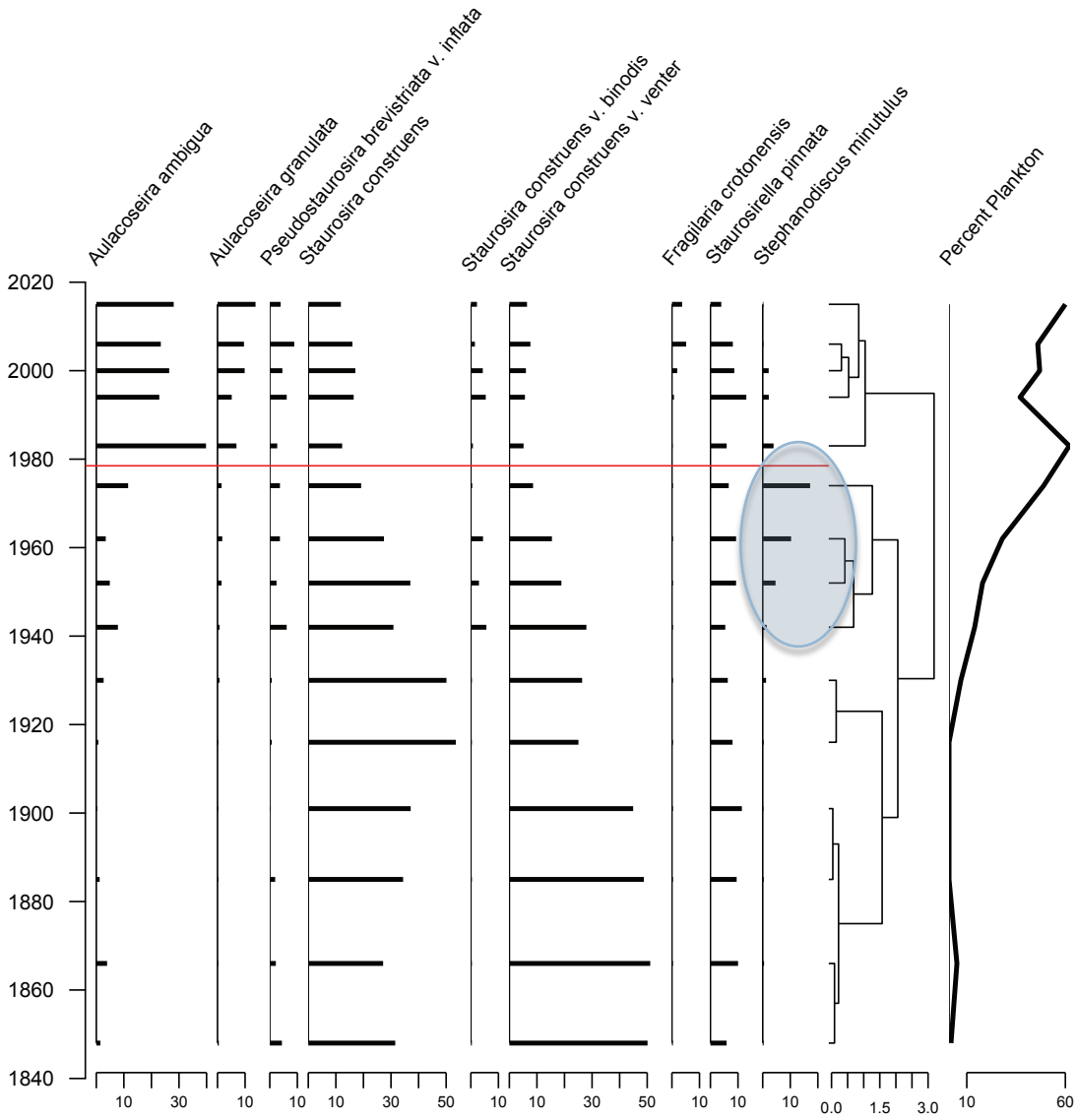
Diatom Stratigraphy



Bottom-living species dominate from the mid-1800s until the 1970s



Diatom Stratigraphy



Northome Creamery Ha Biggest Month In Its History

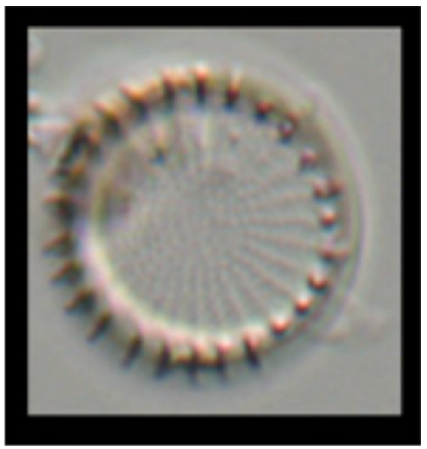
The Farmers' Coop Creamery of Northome enjoyed the biggest month of June in the history of the cooperative, Erick Berg, manager of the creamery announced this week.

Manager Berg disclosed that 47,229 pounds of butter were manufactured during June. The creamery paid out for Butter Fat $23,562.30, during the month and purchased 38,103.1 pounds of butter fat.

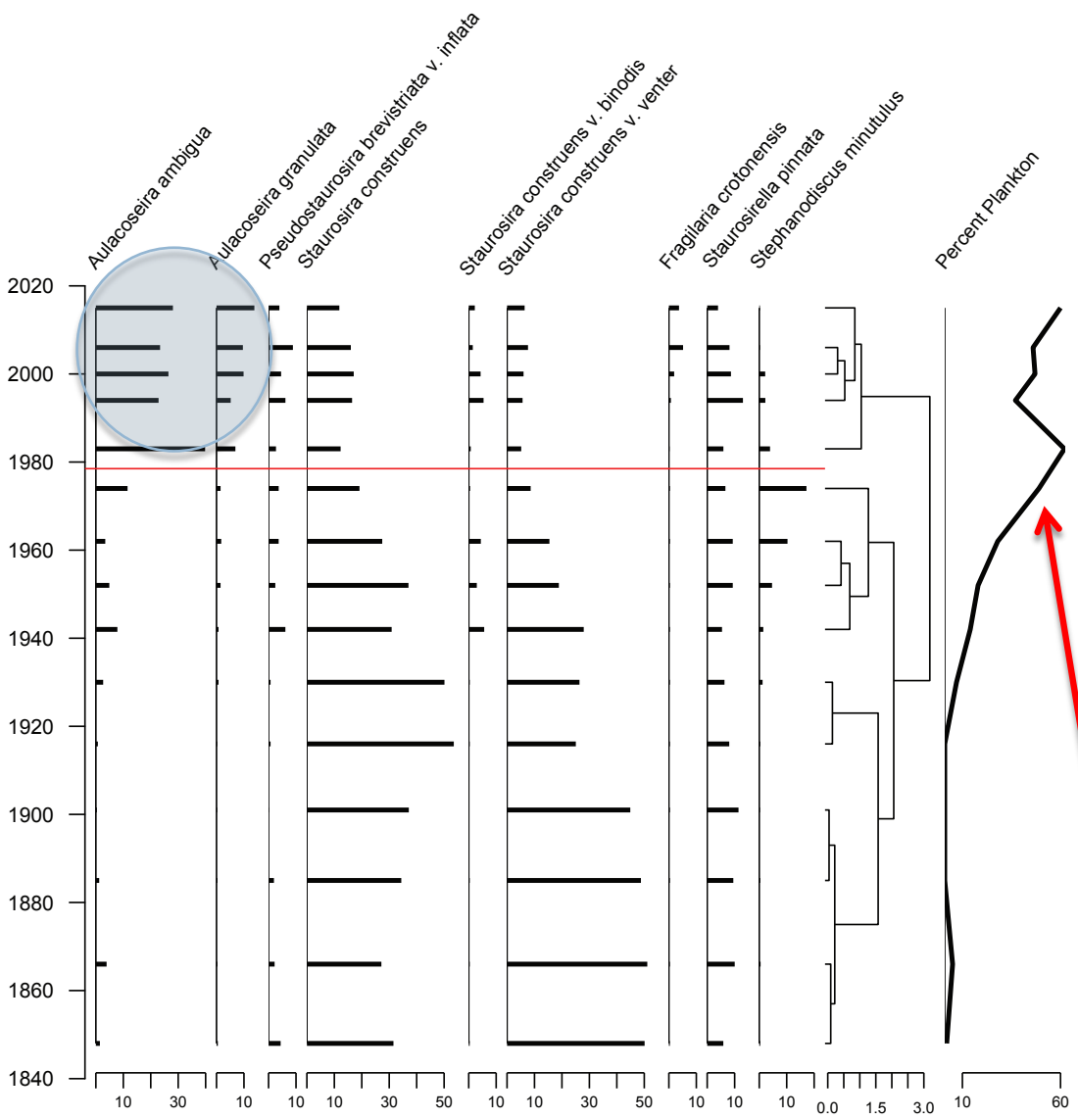
So far in July the receiving of cream is about that of July 1962. 1963

1940s/60s – slow rise in *Stephanodiscus minutulus*, with peak in 1970s.

Indicative of nutrient enrichment



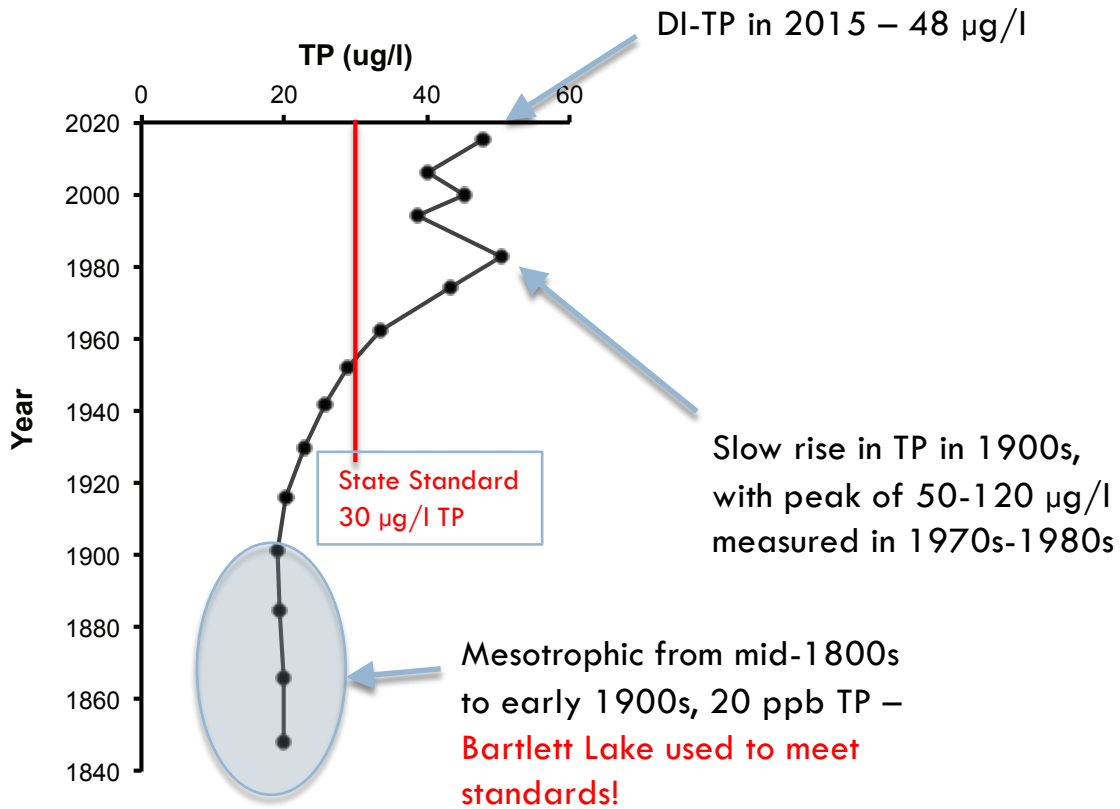
Diatom Stratigraphy



Late 1970s/early 1980s – rise in *Aulacoseira* species. Indicative of nutrient-rich, turbid, wind-swept conditions.

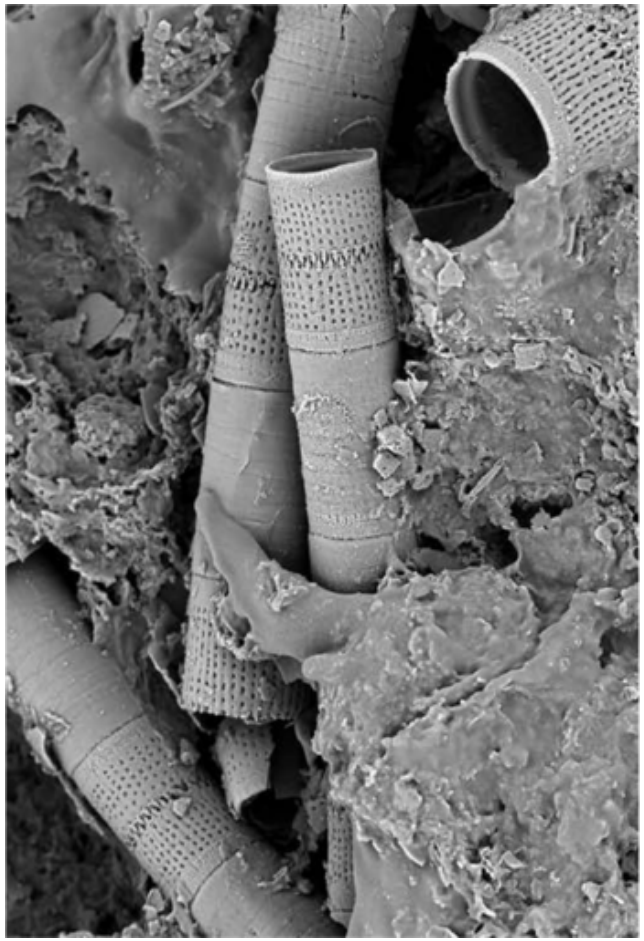
Continued increase in plankton forms

Bartlett Lake, history



- used to meet P standard
- complete bio shift
- slowly getting better
  1970s (> 100 ppb TP)
  2010s (38-48 ppb TP)
- loosing P to burial
- 40-plus years to "recover"
- What's the plan?

The Plan for Bartlett Lake



- Lake is slowly burying legacy P, that's good!
- New steady state (legacy load of P depleted) by **2025-2035**

- Recommendations made to MPCA, to SWCD, and Northome community
- <u>Recommended Plan</u>
  - patience, recovery is ongoing
  - fishery management
  - ~50 yrs later…

Management Recommendations – N MN lakes

- Participation in citizen monitoring programs to help detect any trends
- Continued sound management of lakeshore properties and watershed
- Wilderness users should follow backcountry guidelines
- Prevent the introduction of aquatic invasives
- Measure full water quality every 4-6 years
- Many lakes are currently high value resources and show minimal change in water quality, sedimentation, and algal communities over the past 150 years. Keep it that way!
- Don't screw up lakes! 40-50 yrs to fix!
- Caution and vigilance, lake associations, stay in touch with agencies
- Secchi trend? Sediment/Algae/DOC – browning of lakes

- but…

Some “pristine” lakes are turning green…

…and we don’t know why

Some “pristine” lakes are turning green…

…and we don’t know why

What is causing our lakes to change?

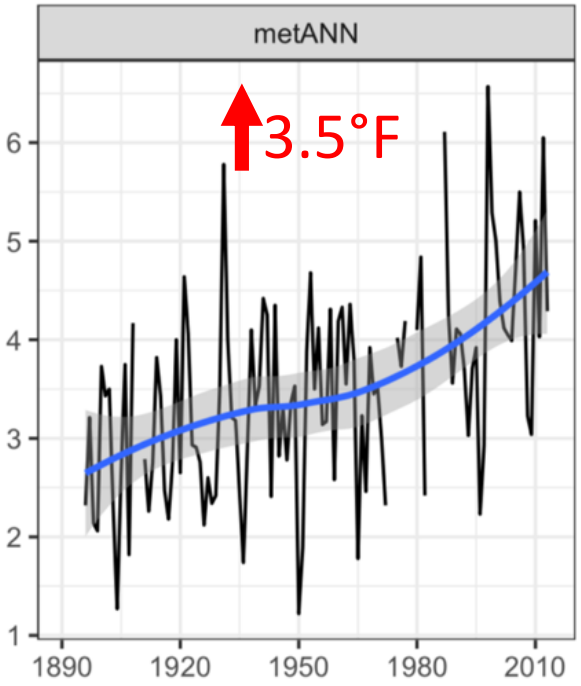
Atmospheric Deposition


April's Texas "snirt"


BC Wildfire Service

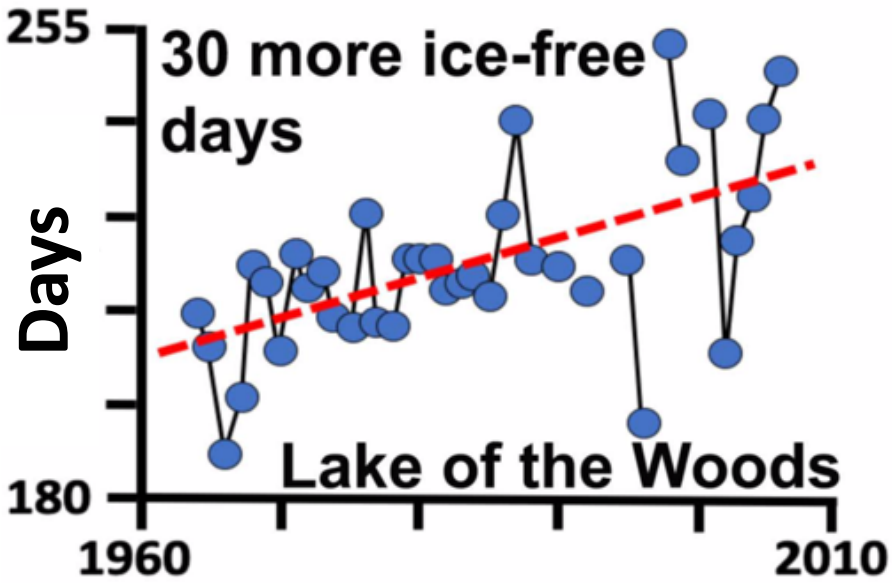
Weather

Climate

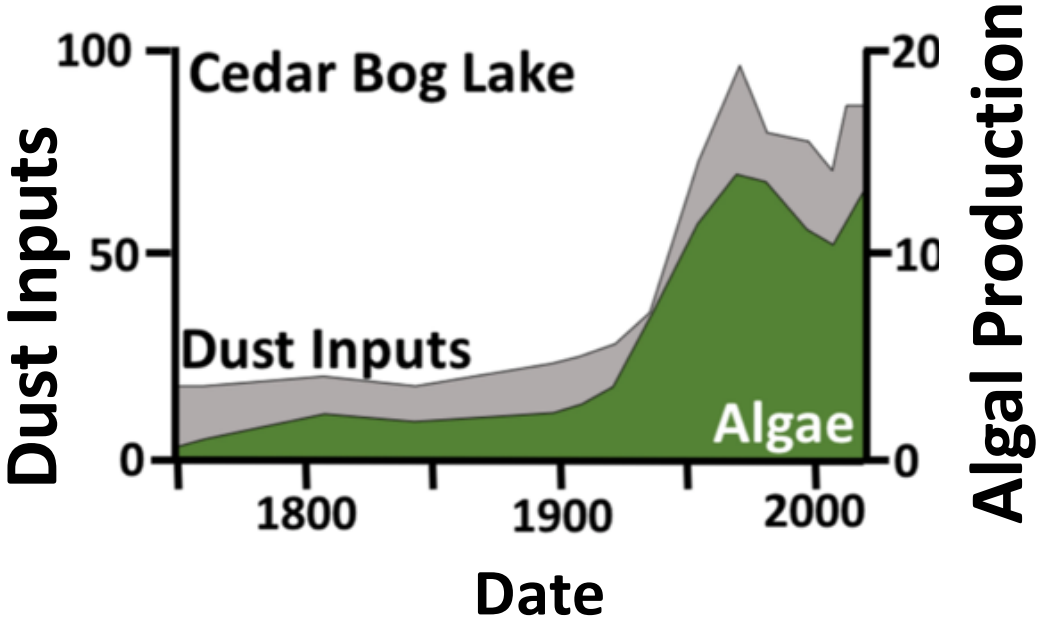


Eveleth MN Annual Temperature 1890-2014

…and it affects lakes

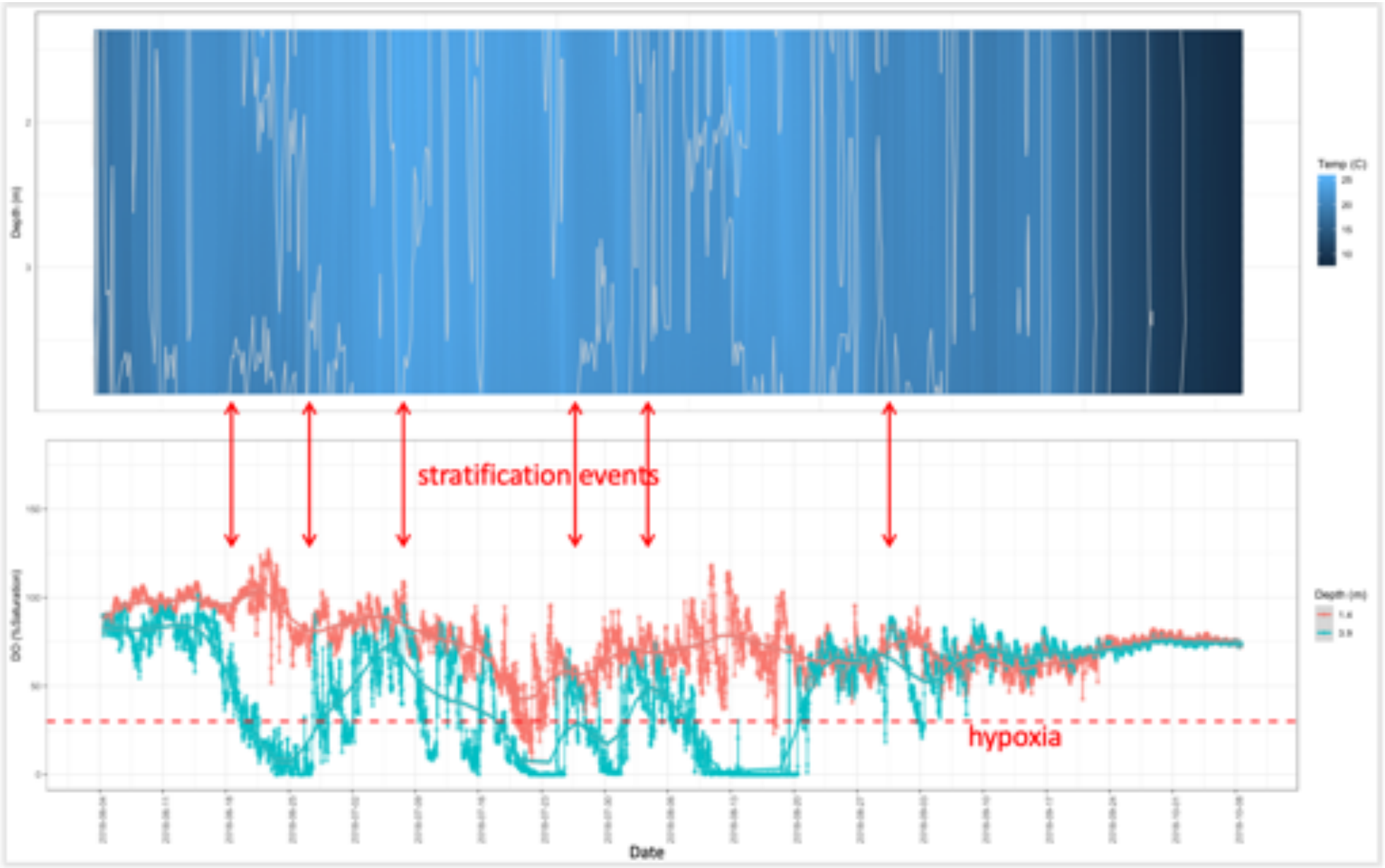


Lakes in MN have longer ice-free seasons

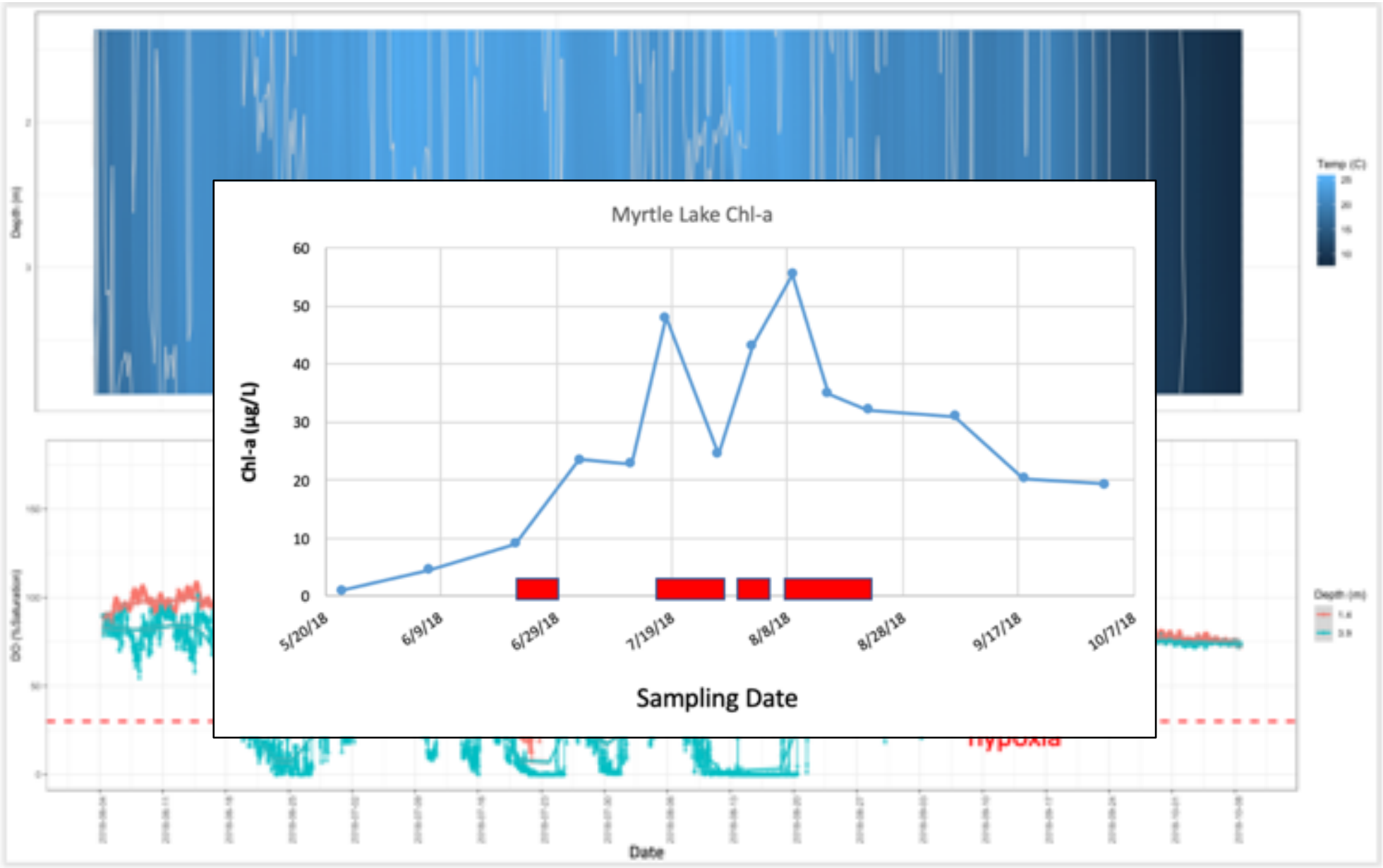


Atmospheric inputs since the 1940s have increased algae growth in MN

Let us know if you see lakes changing!



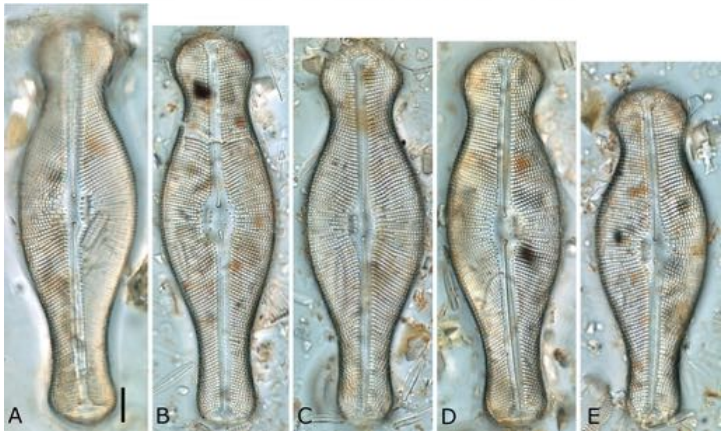
Let us know if you see lakes changing!



Let us know if you see lakes changing!

Didymo or “rock snot”

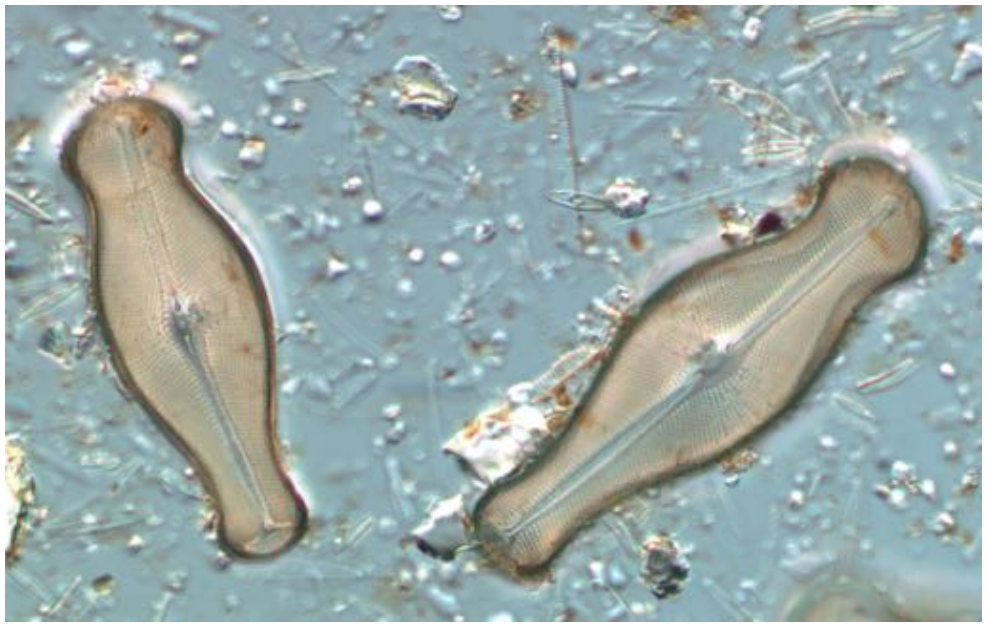
- Microscopic alga, a diatom
- Cold water, low nutrient, base flow
- appearing around US and world
- forms massive growths on everything



Aggressive Colonization Hypothesis
Changing Environment Hypothesis

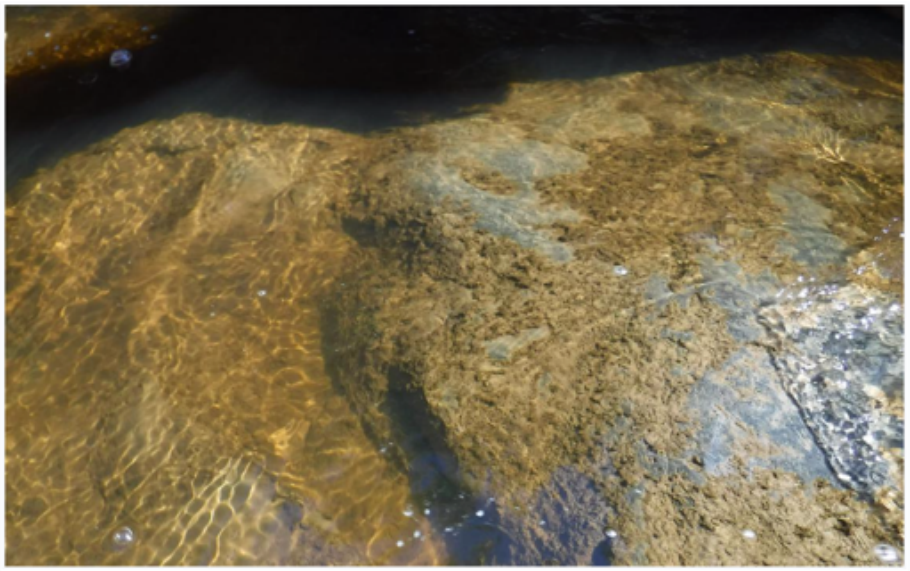
August 2018 – Poplar River invaded!

Didymo affects the “Triple Bottom Line”
Recreation – Ecology – Economics



Didymo affects recreation

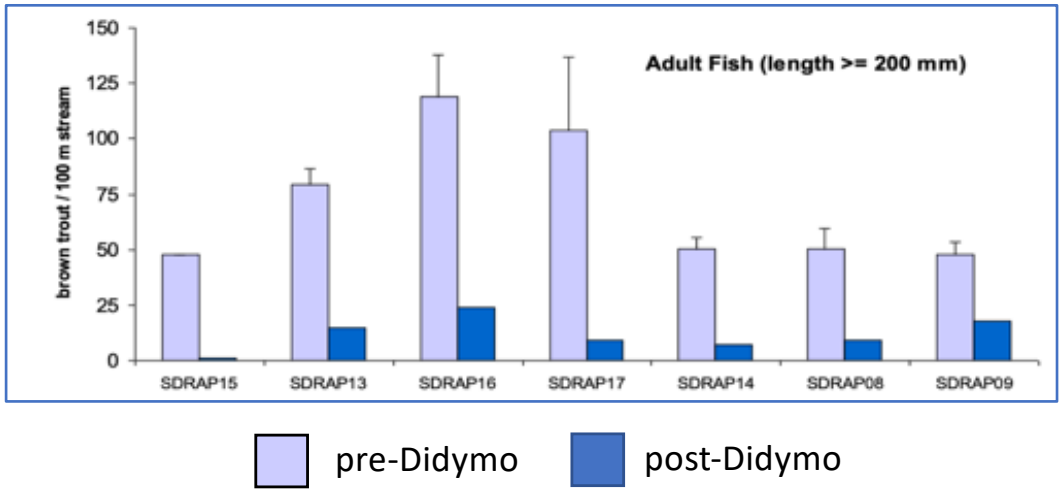
- it's NASTY!
- it screws up stream fishing
- it looks gross
- it covers everything in goo



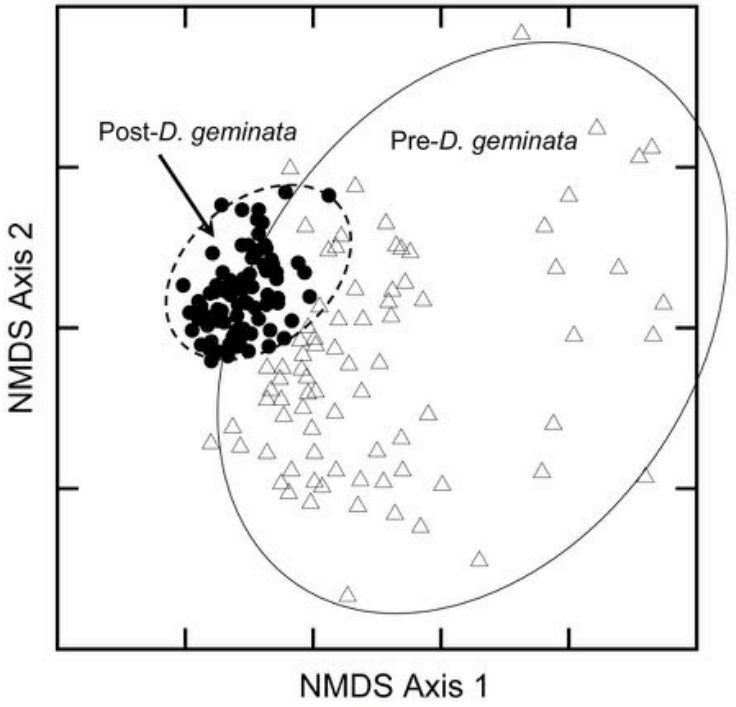
Didymo affects ecology

- changes the biology of streams
- affects the food
- affects the fish

Fewer adult trout post-invasion



Algae become uniform



(Spaulding, Kilroy, Edlund 2010)

Didymo affects the economy

- $20 million dollar annual impact (New Zealand)
- North Shore summer economy $250 million

Let us know if you see rock snot in N Shore streams!

Thank You

- Thanks to MPCA and MNDNR/LCCMR for funding various projects, coordinating project logistics, and working with lake residents and stakeholders.
- Special thanks to John Oberholzer, Rockwood Resort, Trout Lk Resort for arranging boats, lake access.
- SCWRS team performed lead-210 analysis, core geochemistry and diatom prep.
- Irene Mullen, CCCoLA

- Mark Edlund, medlund@smm.org, 651-433-5953

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