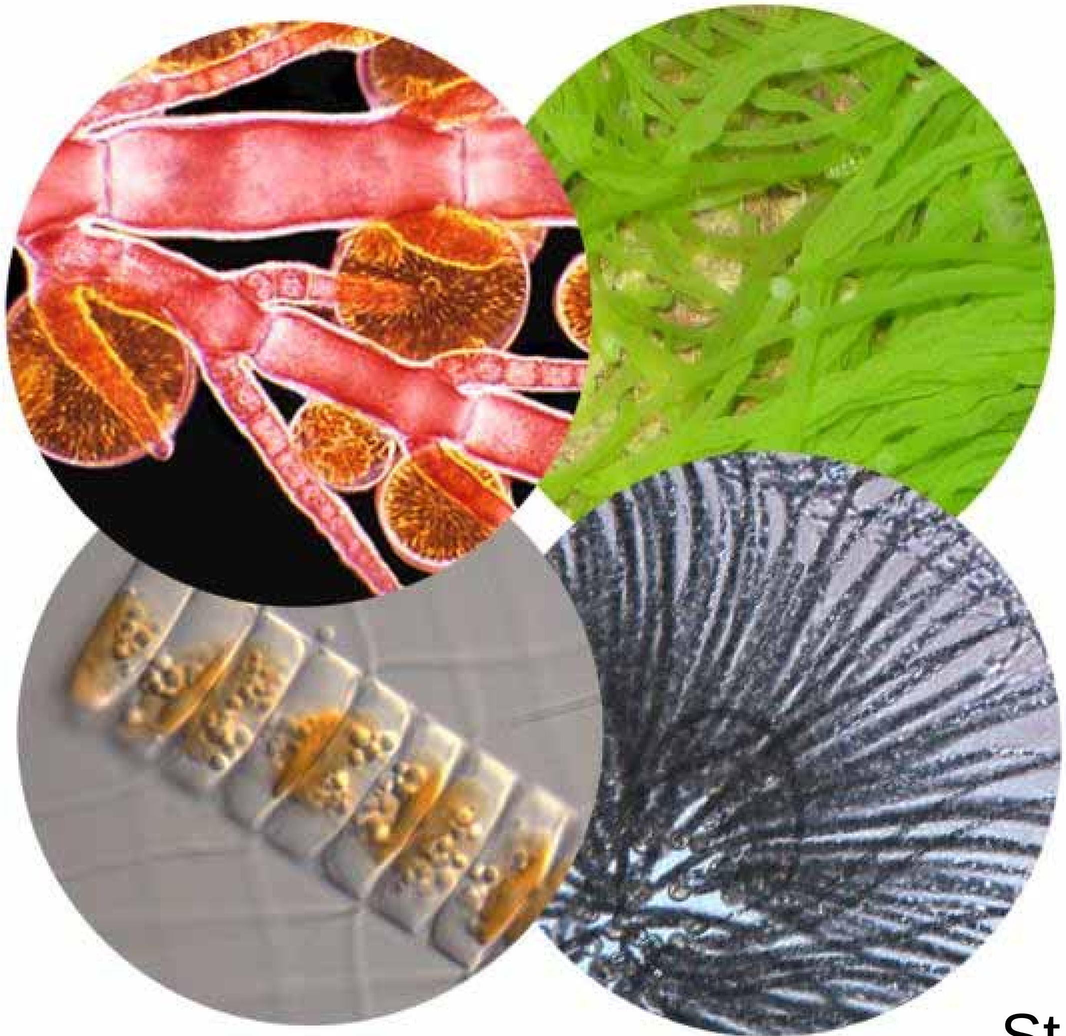


Eutrophication and Algae 101: The good, the bad, and the slimy

Mark Edlund

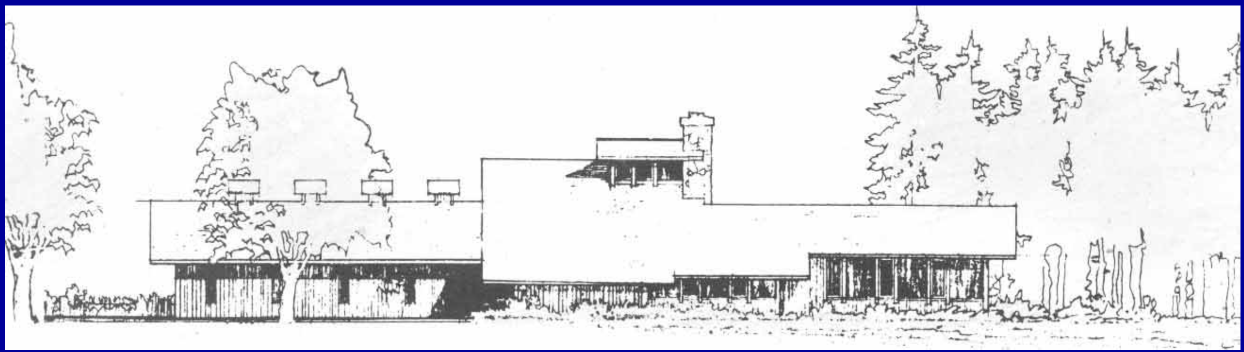
St. Croix Watershed Research Station, Science Museum of Minnesota

St. Croix Watershed Research Station:

SCWRS: When, where, & why?

- Established in 1989
- Located ¼ mile from Wisconsin and 10 miles N of Stillwater
- A department in the Science Division of the Science Museum of Minnesota
- Mission:

  Finding answers to important environmental questions impacting the St.Croix basin and watersheds worldwide



Let’s talk:

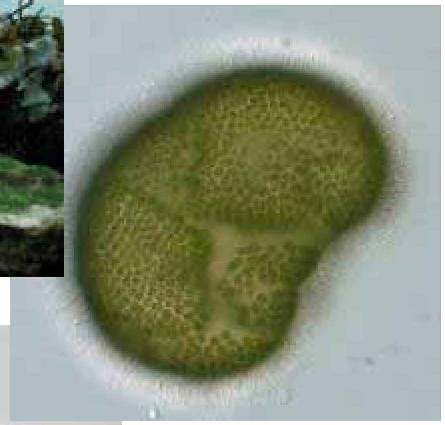
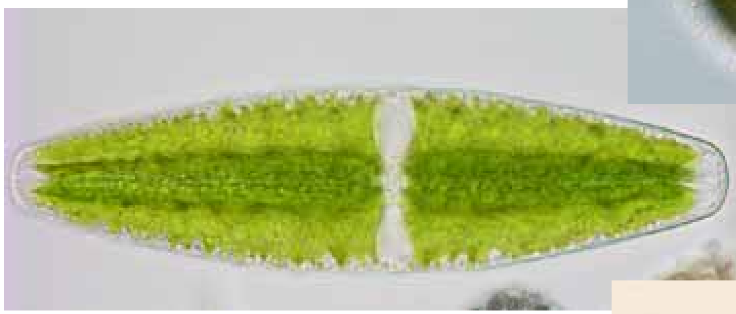
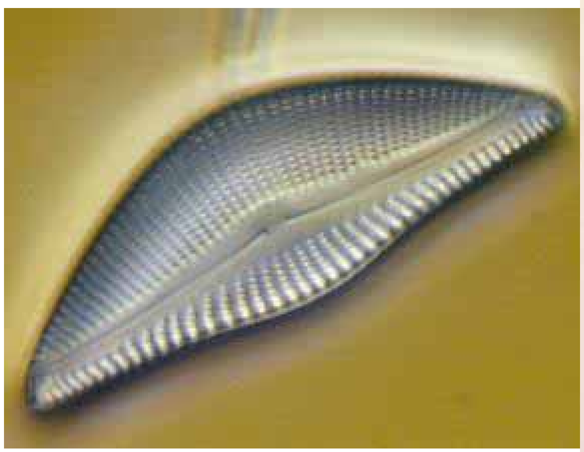
1. What are these algae?
2. When are they good?
3. When are they bad?
4. How is our research helping understand and manage lakes?

(caveats of today’s talk)

Algae?

- non-natural group (like “bugs”)
- mostly aquatic/marine, ubiquitous
- photosynthetic
- non-vascular
- repro w/o sterile layer of cells
- 1 µm to 50 m

- importance - ecological, global, geochemical, economic, toxic HABs


Algae are Everywhere

- Habitats and Algae
  - oceans, lakes, rivers
  - backwaters, estuary
  - floodplains
  - reservoirs
  - springs
  - soil, lichens
- most are native
- Lots of places for algae and lots of diversity (e.g., >350 spp of diatoms in St. Croix River)

What are algae?

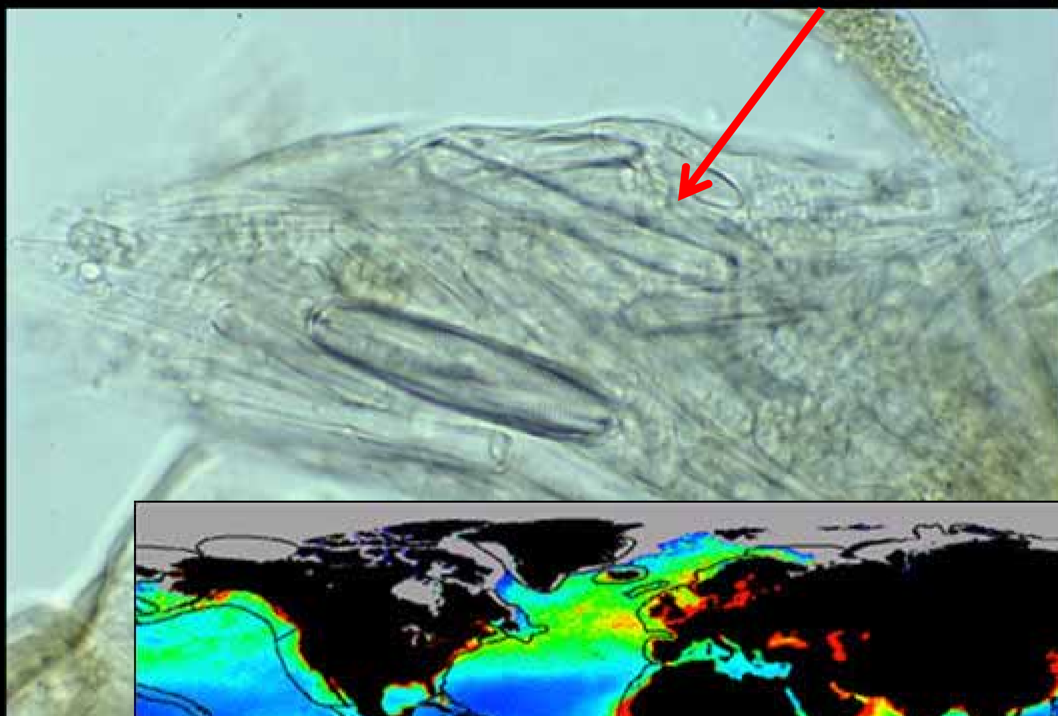
- many major groups
  - cyanobacteria (blue-greens)
  - chlorophytes (greens)
  - charophytes (stoneworts)
  - euglenoids
  - dinoflagellates (dinos)
  - xanthophytes (yellow-greens)
  - chrysophytes (golden-brown)
  - synurophytes (golden-brown)
  - diatoms
  - red algae
  - brown algae (kelps)

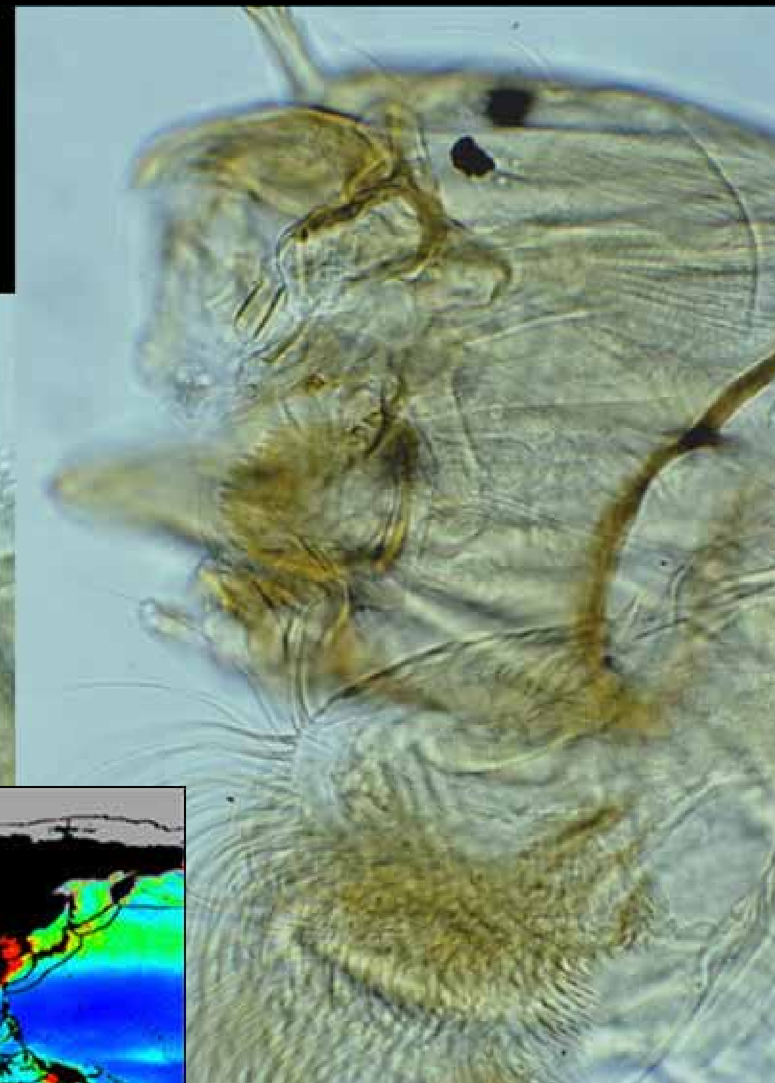
- - smaller groups include haptophytes, cryptomonads, glaucophytes, prymnesiophytes, bolidophytes, prasinophytes, …

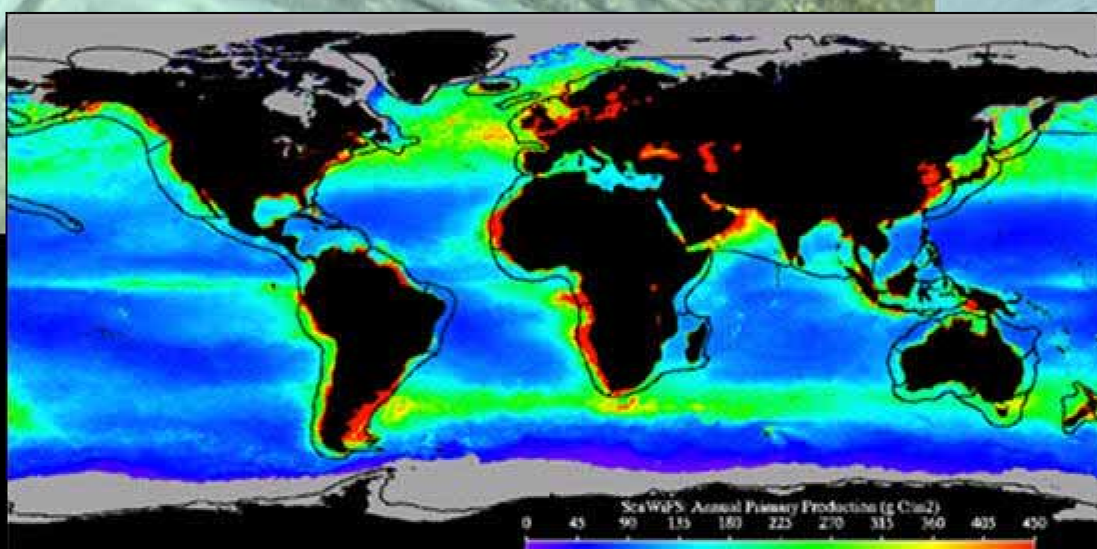
The GOOD: Algae are important!

they are the base of the aquatic food web …

diatoms in chironomid guts





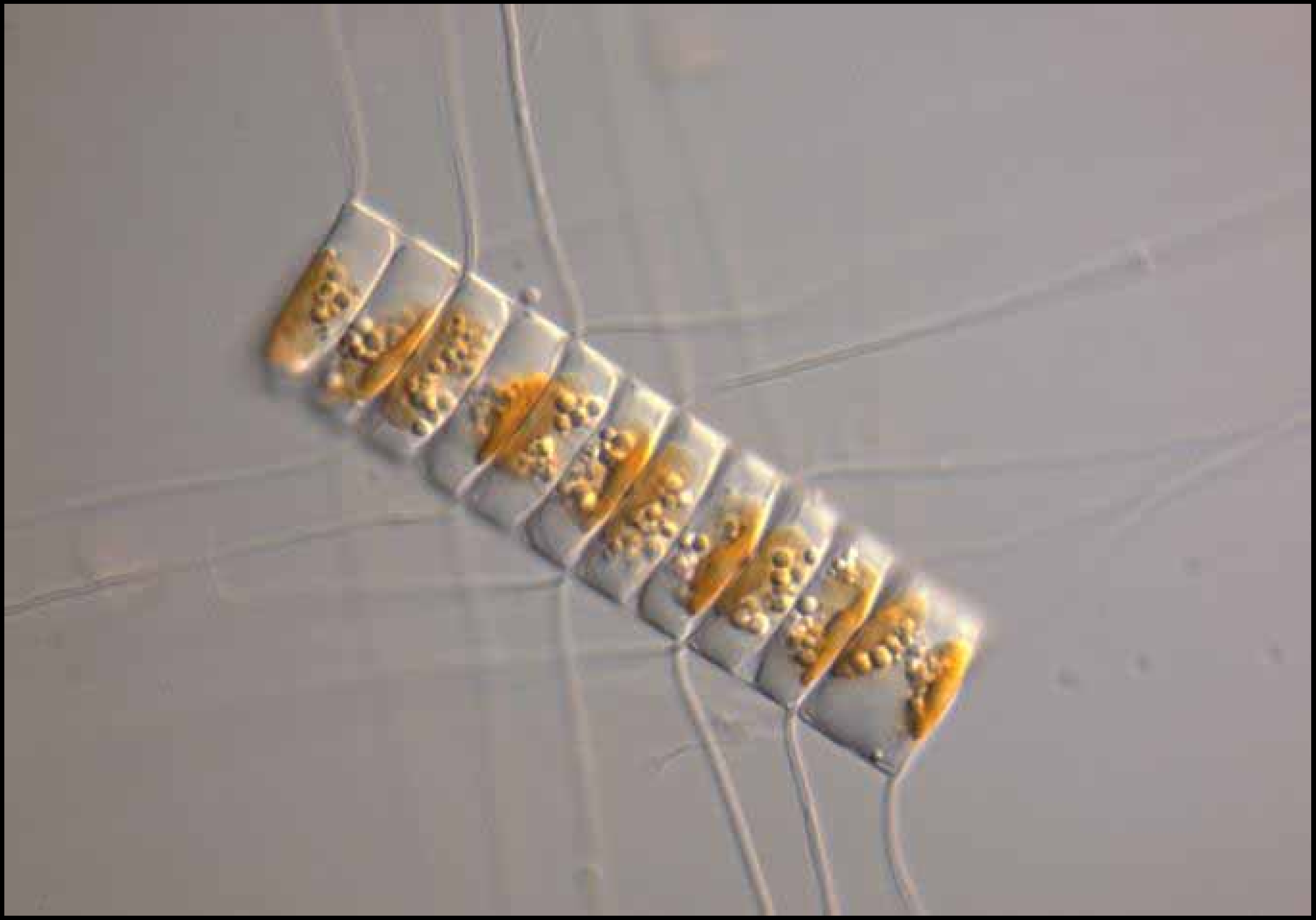


and 50% global primary production

Algae and the food chain

GOOD: My kid loves Algae!

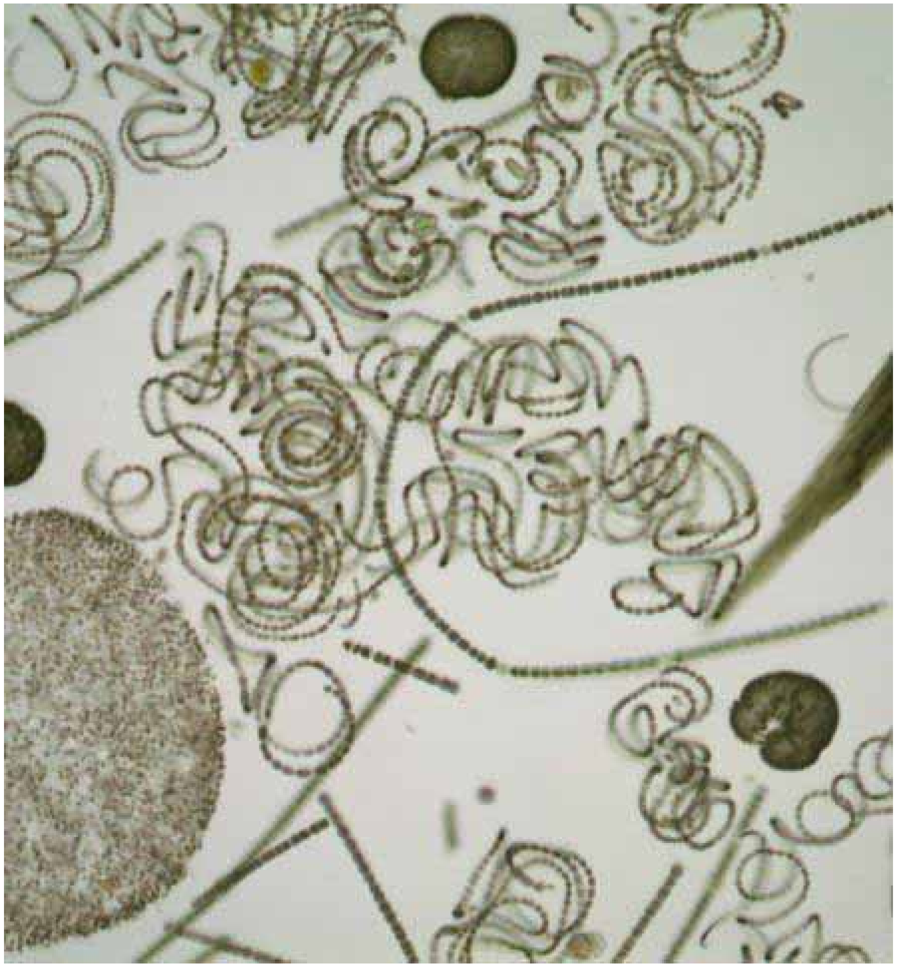
More GOOD - biofuel sources, secondary metabolites, food, feed - Chaetoceros sp.



The BAD and SLIMY: too much algae

- too many nutrients
- light and temp
- enviro impacts

Who you calling a "nuisance"?



Tabor Lake, Danbury, WI

- Nuisance Algae
  - visible growths/blooms
  - accumulations
  - late summer, fall
  - impact recreation & enjoyment & $$$
  - affect ecosystem services
  - becoming more common?
  - toxins!

1.The BAD: Cyanobacterial blooms

Kinni Beach, WI
Aug 2013
Brenda Lafrancois

Polk Co. WI, Jeremy Williamson

- Blue-greens
  - summer, fall
  - meso- & eutrophic lakes
  - shallow lakes
  - N-fixers
  - toxins (sometimes!)
  - regulate buoyancy
  - unpalatable

The BAD: Annie, Fannie & Mike

The BAD: Cyanobacterial blooms are more common than ever

- even in wilderness lakes
  - Isle Royale
  - 2 mile portage
  - climate? nitrogen?

2. The BAD: B-G Benthic mats

- Accumulations of blue-green gunk on leeward shores and quiet areas
- floating and suspended
- linked to backwater areas, boating?
- reports from Lake St. Croix, 2011-2013

Glen Brae, Somerset WI
Aug 4, 2013

photos: Jean Hoffman

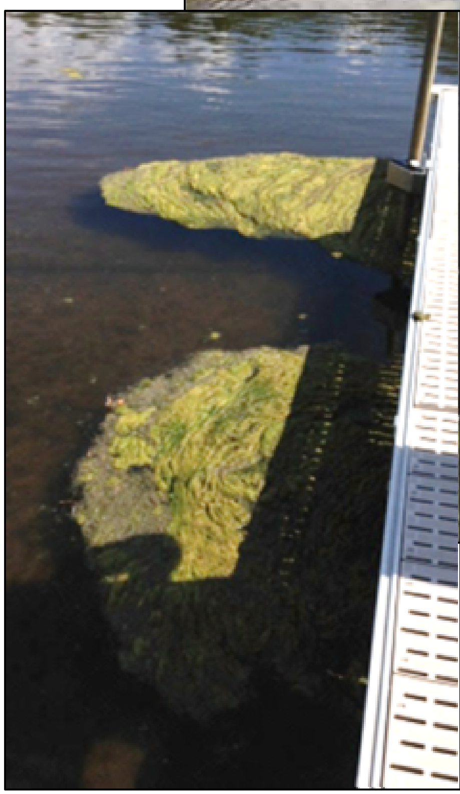
2. The BAD: B-G Benthic mats

Oscillatoria limosa

- common alga, mat former, not a toxin producer

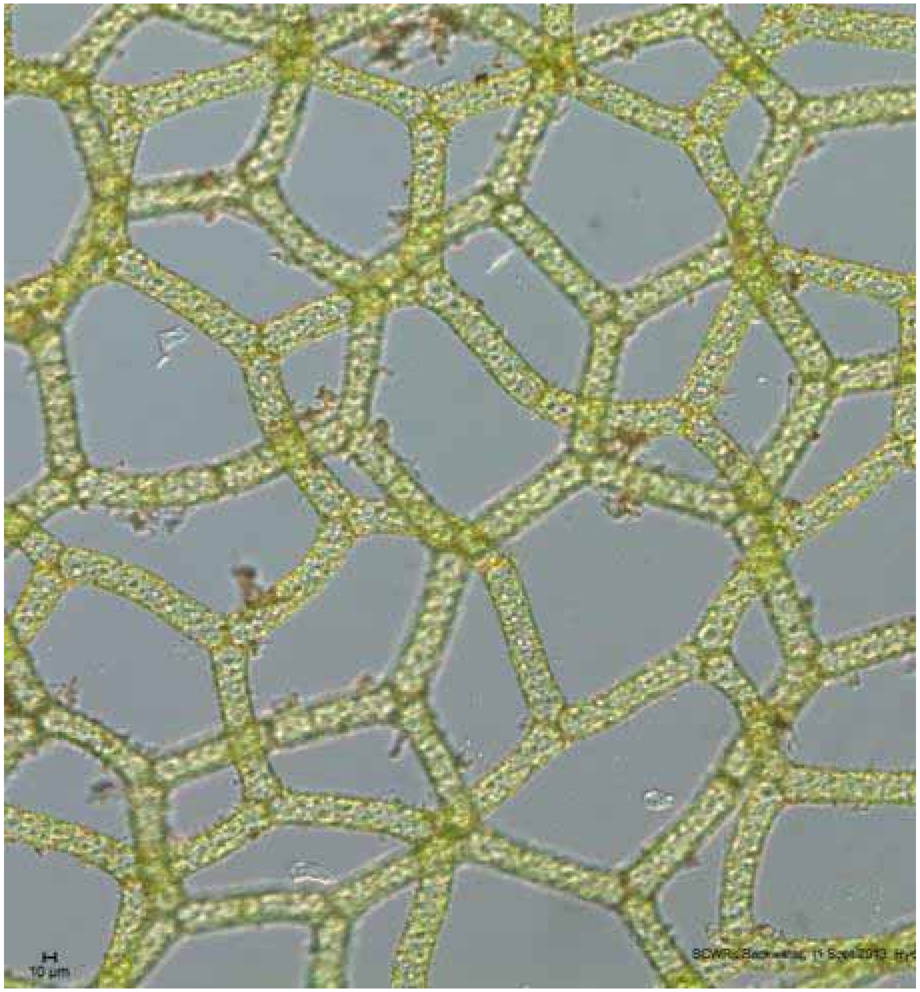
3. The BAD? Green algae


Cladophora

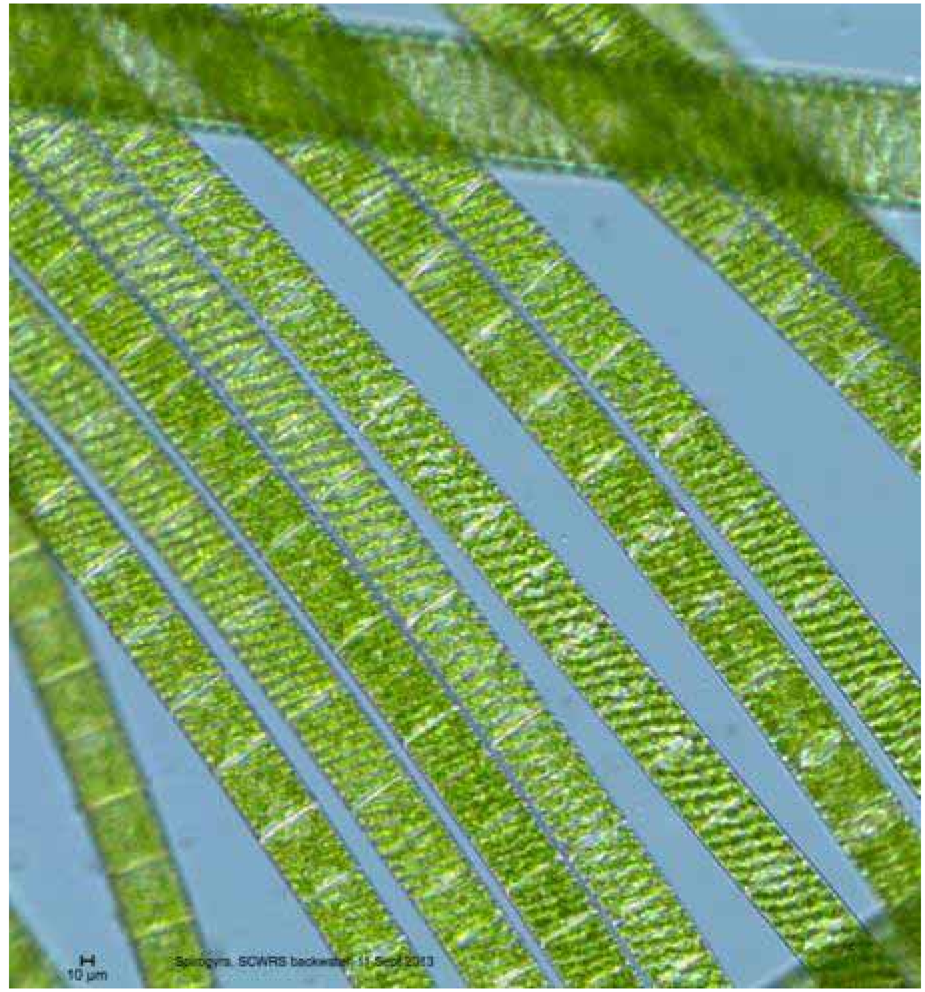


- common in backwater, shoreline, and littoral areas
- produce noxious accumulations
- several culprits
- early and late season species
- macroscopic
- Great Lakes *Cladophora* – botulism connection

3. The BAD? Green algal mats



Hydrodictyon reticulatum
(water net)



Spirogyra sp.

4. The SLIMY: Diatom mats

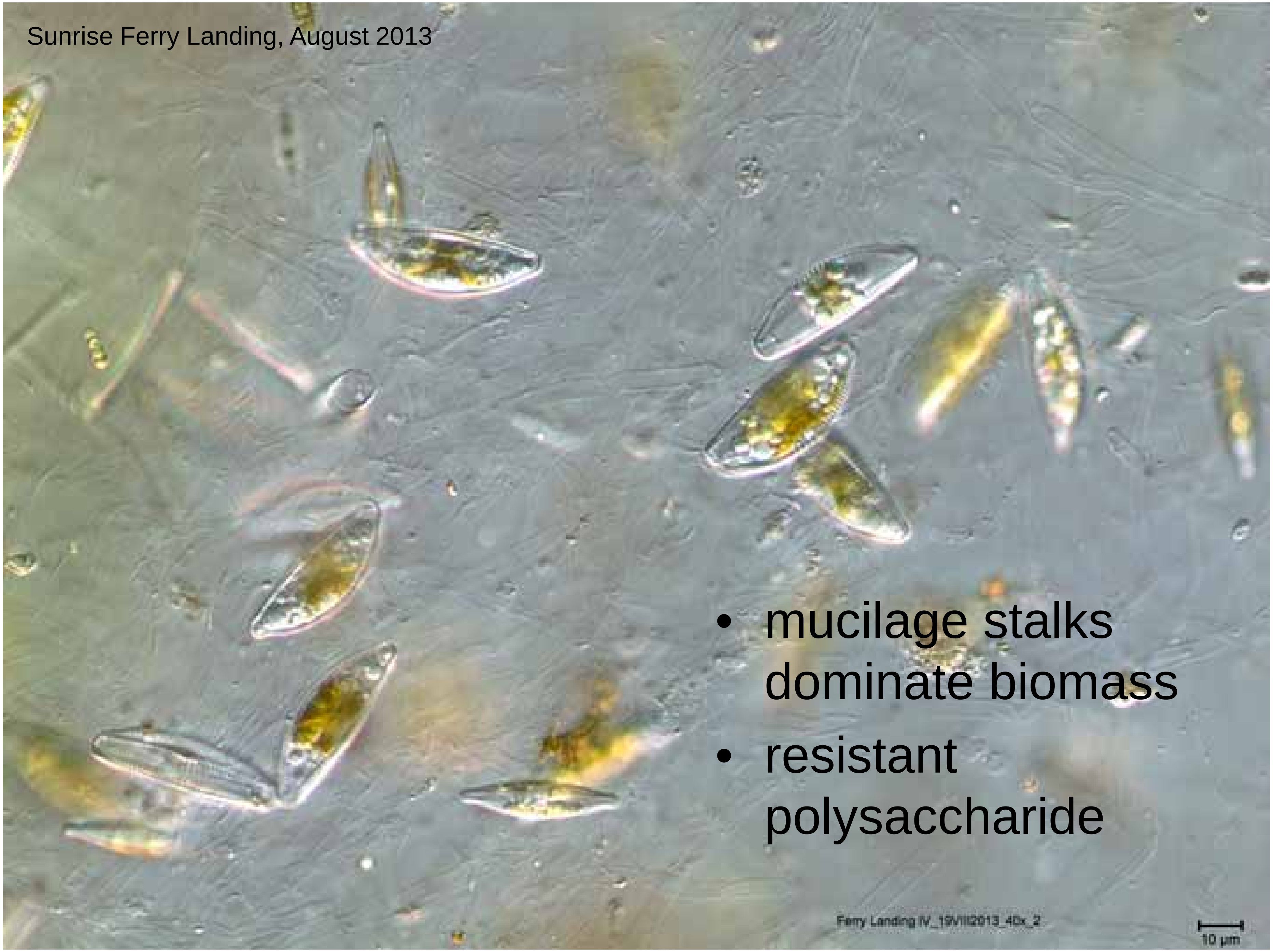

Nevers Dam, WI, Nov 2012


Interstate Park, MN-WI, Sept 2008

- golden-brown gelatinous gunk
- attached to rocks or free-floating
- cover everything
- can see spring, summer, & fall growths

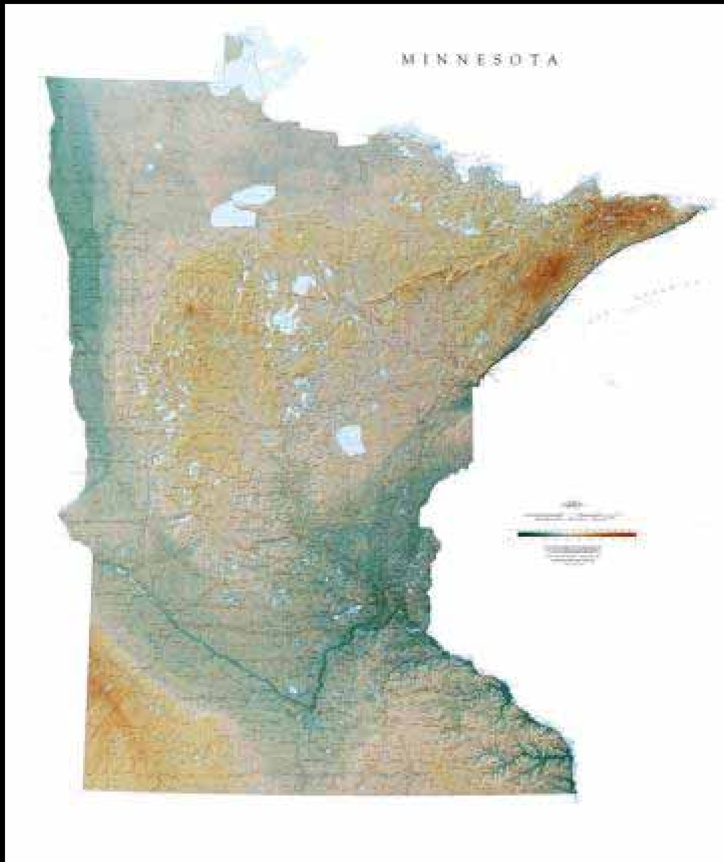
photos: Jeremy Williamson, Nick Rowse

Sunrise Ferry Landing, August 2013



- mucilage stalks dominate biomass
- resistant polysaccharide

Research in the Midwest

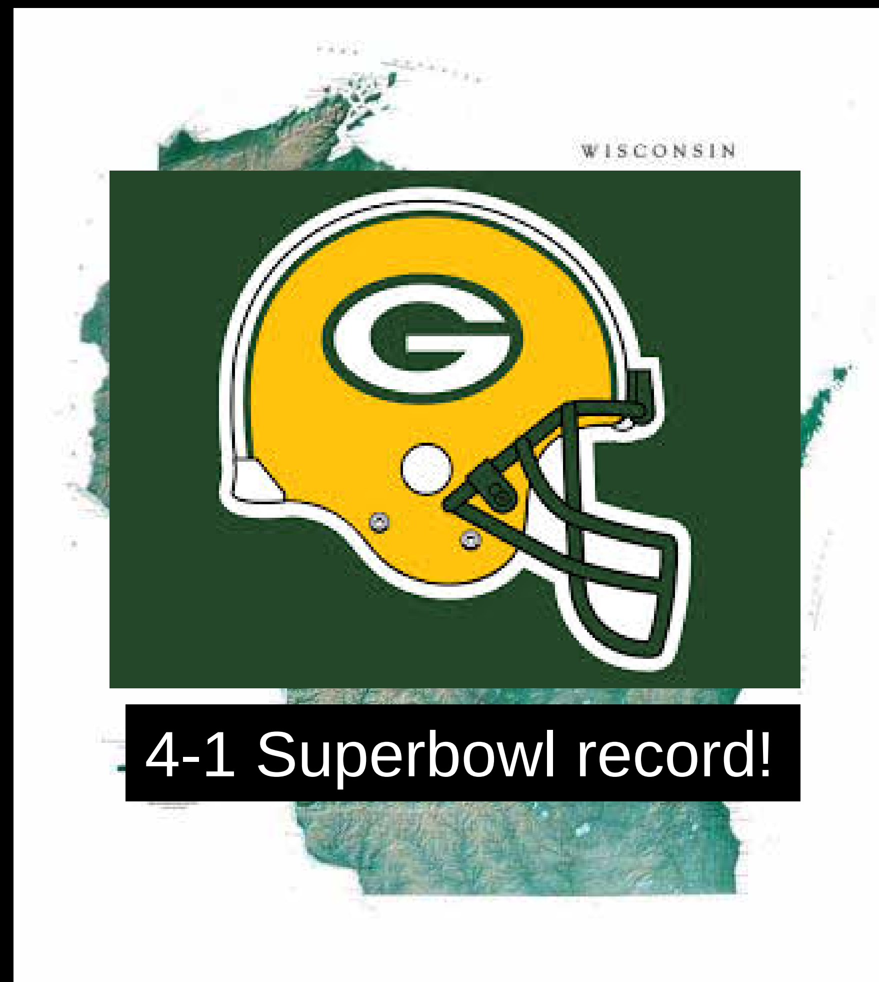


geology.com

- blessed with water
- MN 12th largest , 8th in water area
- WI 23rd largest, 4th in water area
- mostly covered during Wisconsin glaciation
- MN "Land of 10,000 Lakes"
- WI "Birthplace of Limnology"

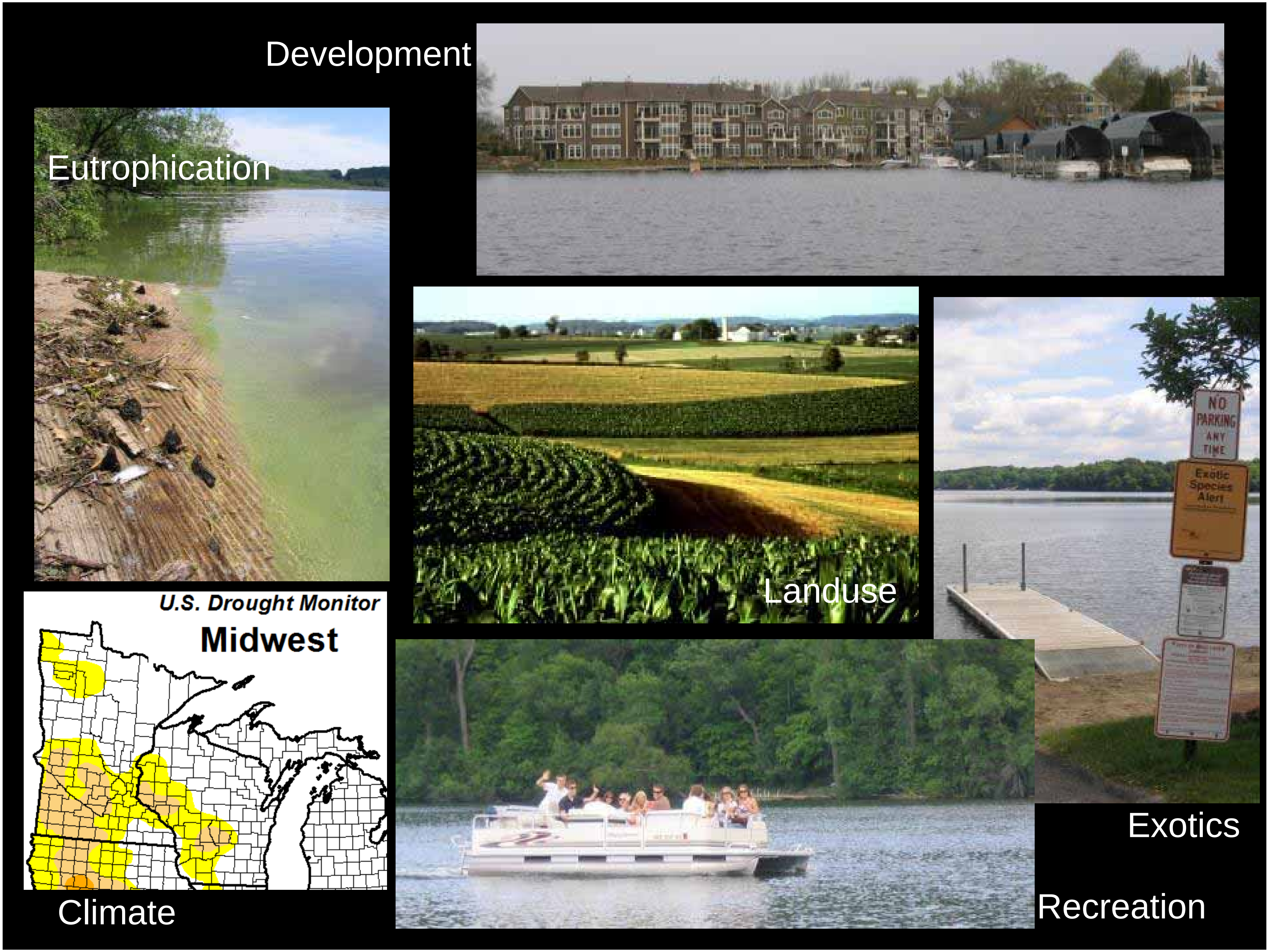
Lake Research in the Midwest

0-4 Superbowl record
Ouch!

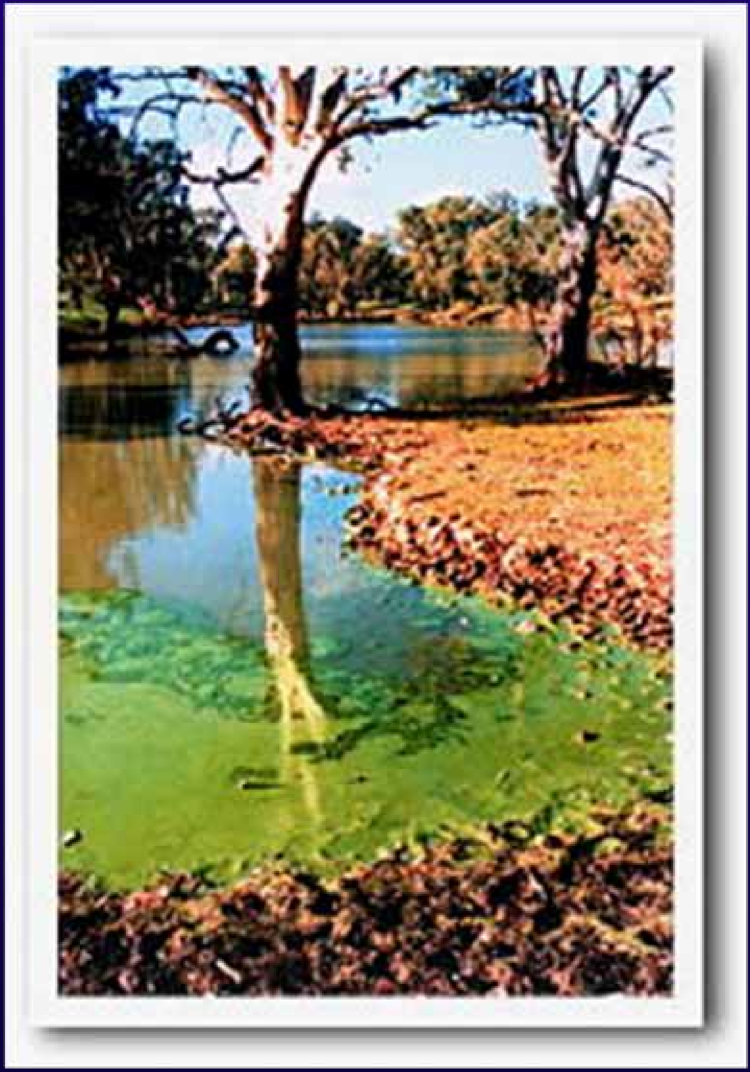


4-1 Superbowl record!

geology.com


Development
Eutrophication
Landuse
NO PARKING ANY TIME
Exotic Species Alert
U.S. Drought Monitor
Midwest
Exotics
Climate
Recreation

Nutrients and Trophic status of Lakes: Only the facts



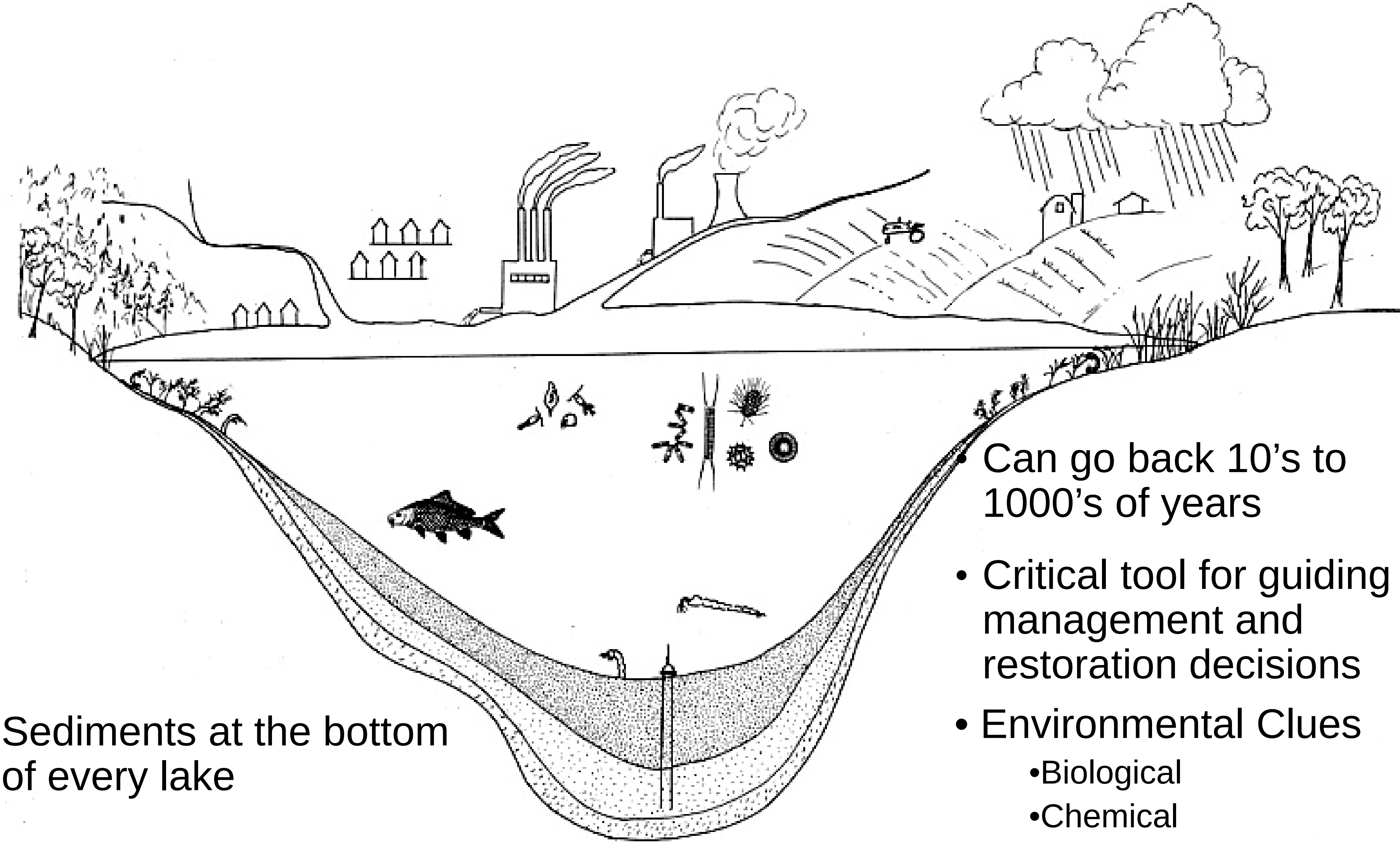
- Fresh waters are often phosphorus-limited
- Nutrients promote algae growth
- Changes species composition
- Impairs water for drinking, navigation, wildlife, and recreation
- Oligotrophic 0-10 ppb TP
  Mesotrophic 10-30 ppb
  Eutrophic 30-100 ppb
  Hypereutrophic >100 ppb

Strategy: Plan for the future, learn from the past

- Meld modern sampling with paleolimnology to better understand eutrophic lakes and algae
- Lake sediments are environmental archives, provide pre-monitoring
- Establish baseline water/habitat quality, identify timing and magnitude of environmental change

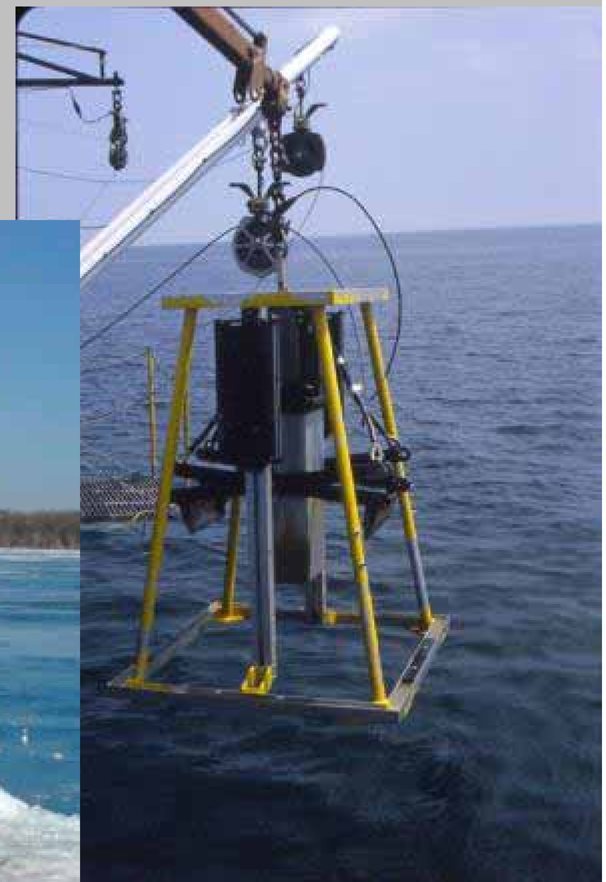
- 1. Lake Standards and prioritizing $$$
- 2. Lake St. Croix rehab
- 3. Paying for our sins – shallow lakes

Paleolimnology-the study of lake sediments to reconstruct environmental history



- Can go back 10's to 1000's of years
- Critical tool for guiding management and restoration decisions
- Environmental Clues
  - •Biological
  - •Chemical
  - •Physical
- Sediments at the bottom of every lake

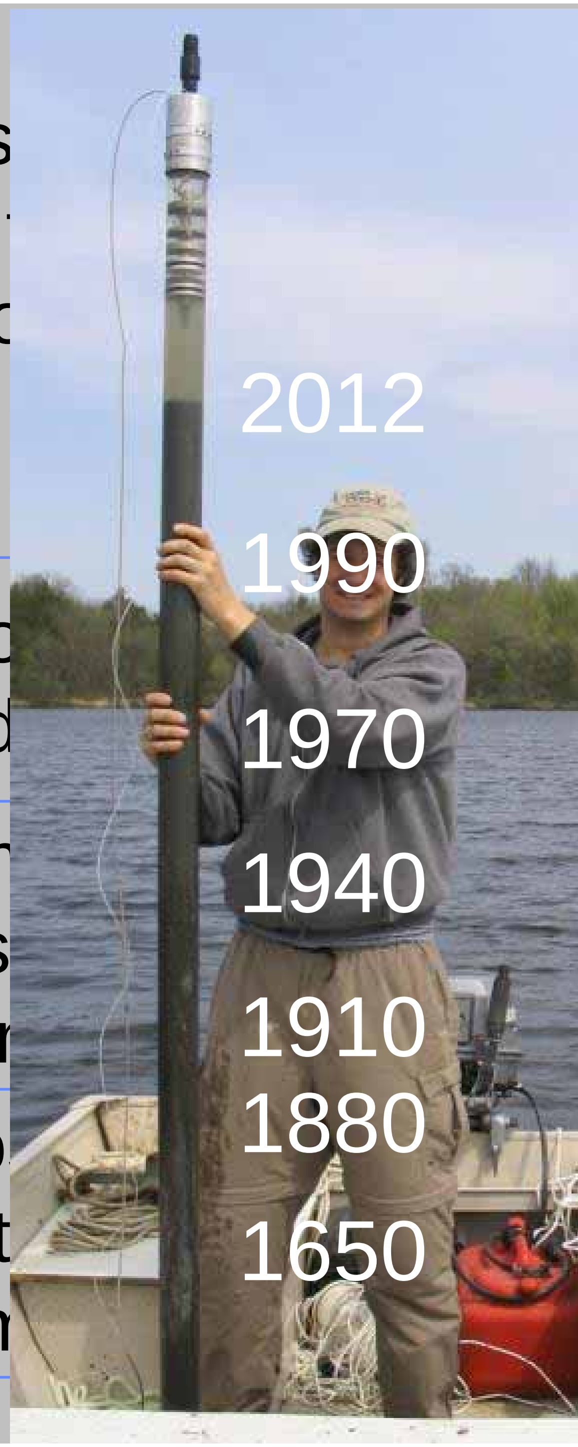
Coring Techniques



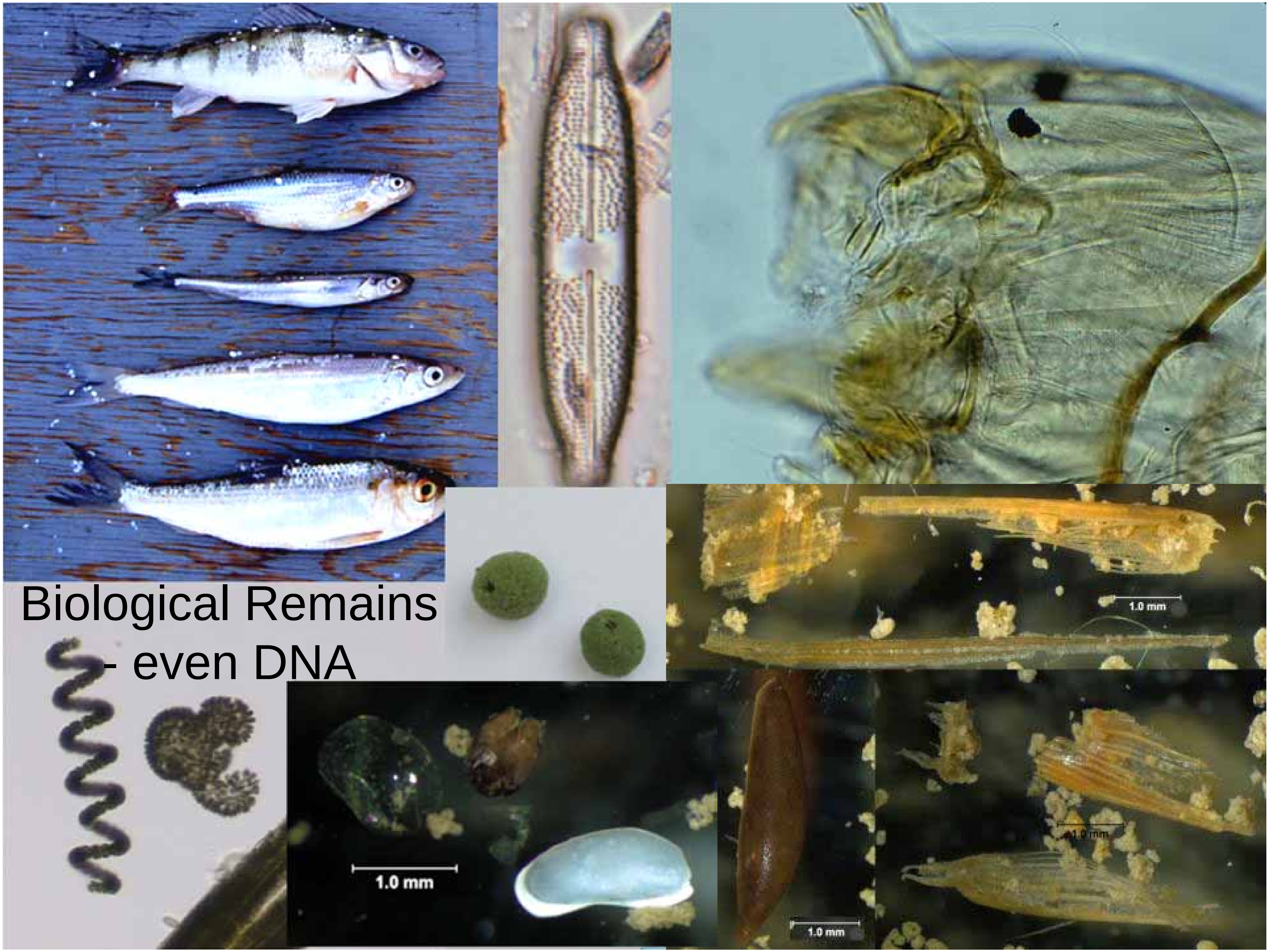
Dating Models - We use the predictable decay of radioisotopes to figure out when sediments were deposited on the lake bottom

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

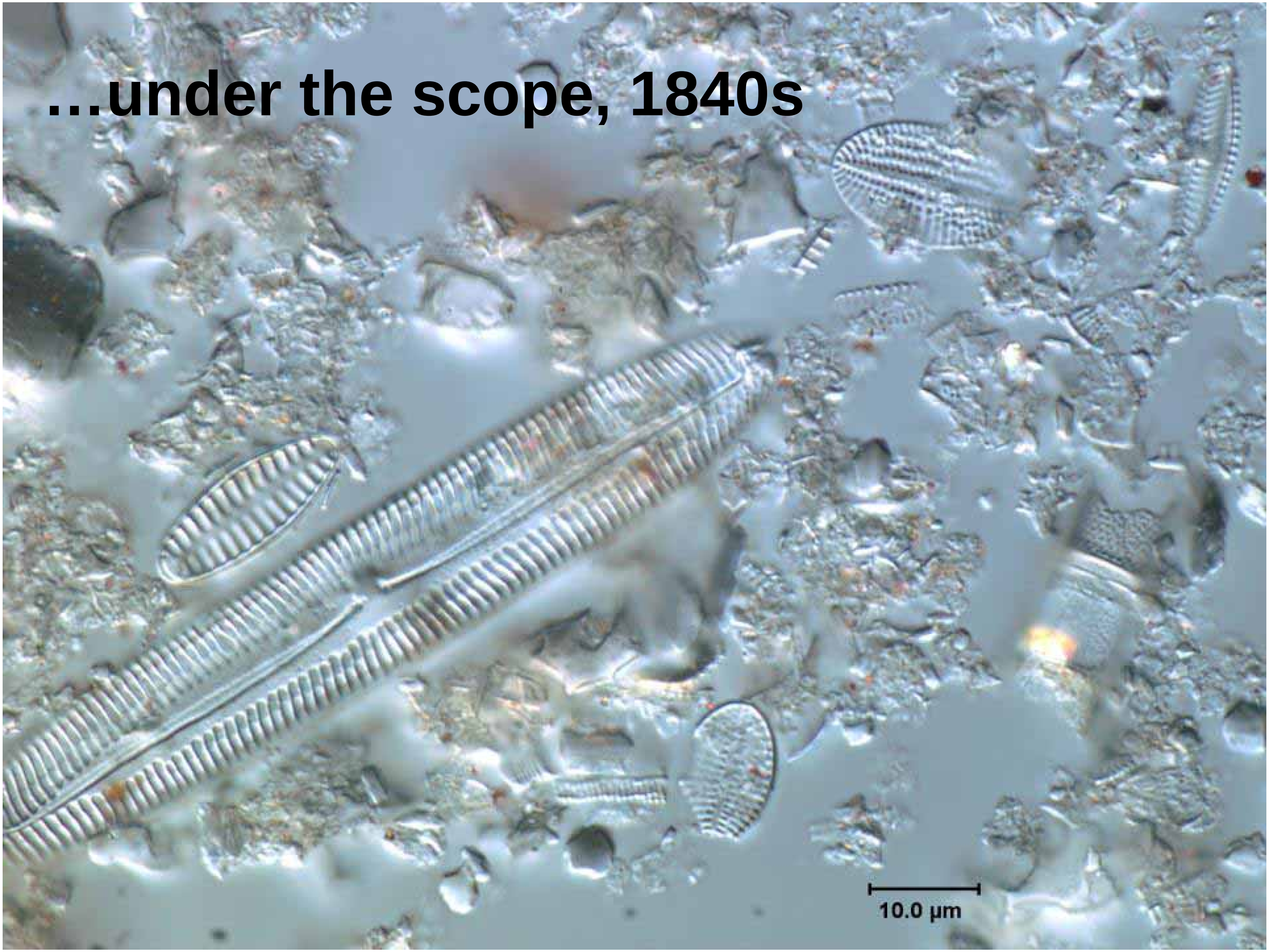


Element		...alysis location	
^{210}Pb	Fro... rad...	...CWRS ...b	150-200 yrs
^{137}Cs	Atr... tes... bor...	...CWRS ...b	40-50 yrs
^{14}C	Co... hitt... atm...	...rizona lab	500-50,000 yrs



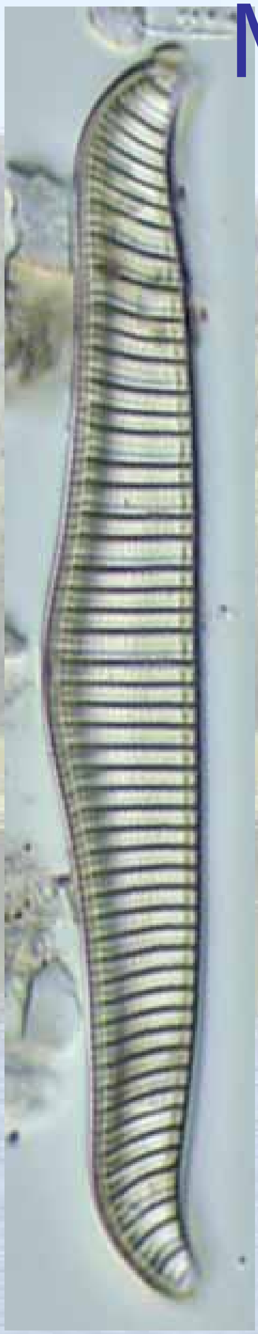
Biological Remains
- even DNA

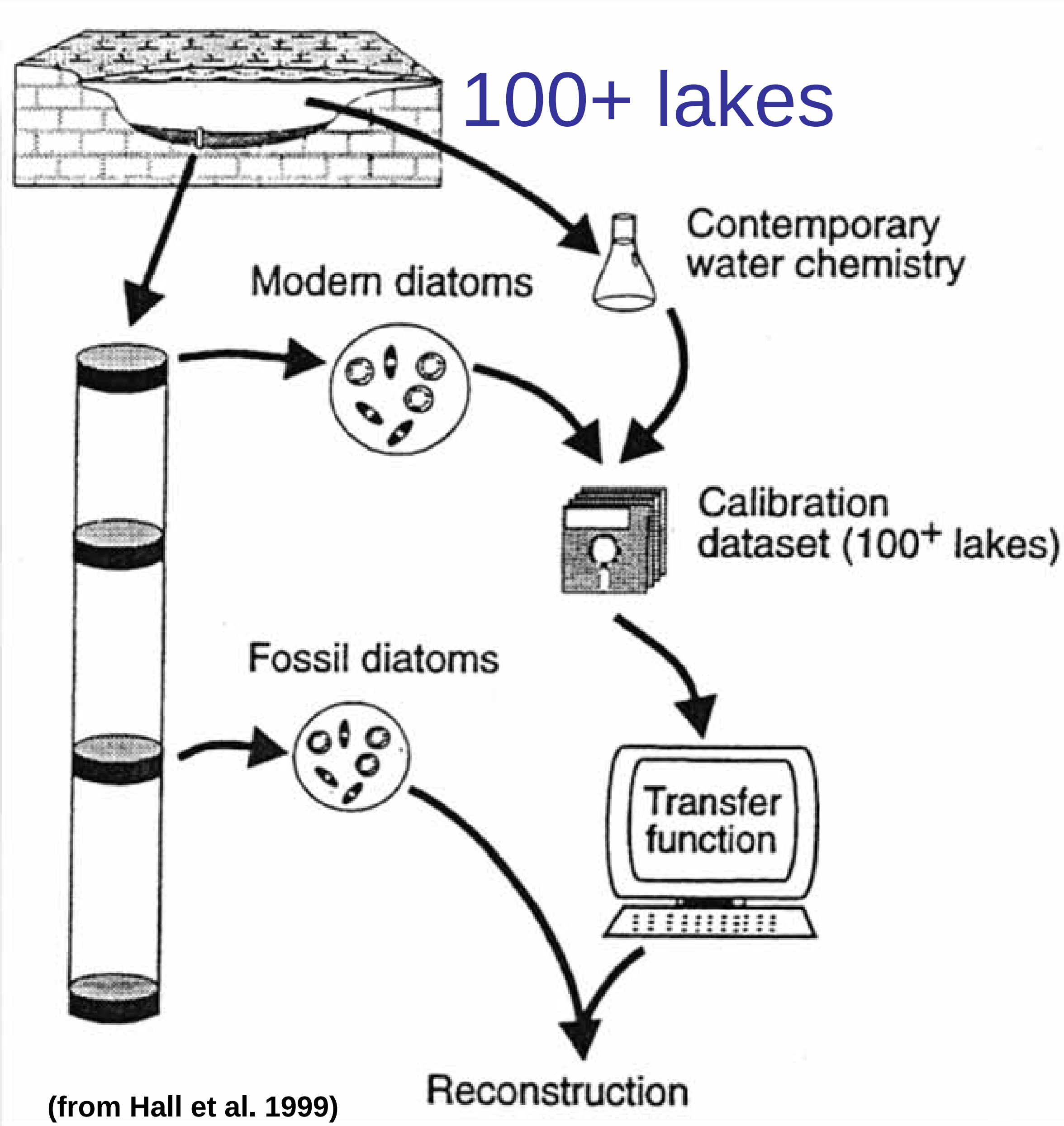
…under the scope, 1840s



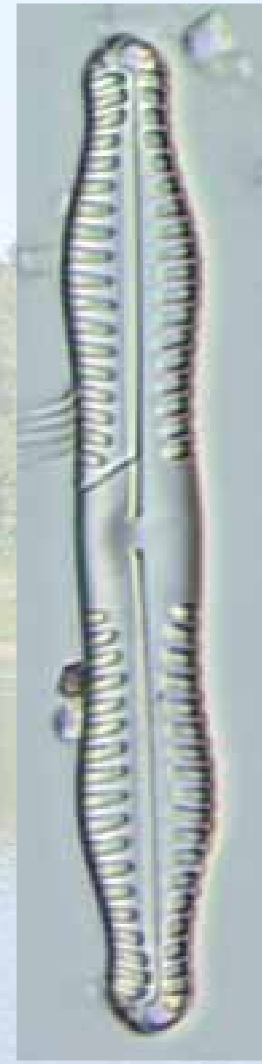

…under the scope, 2013
10.0 µm

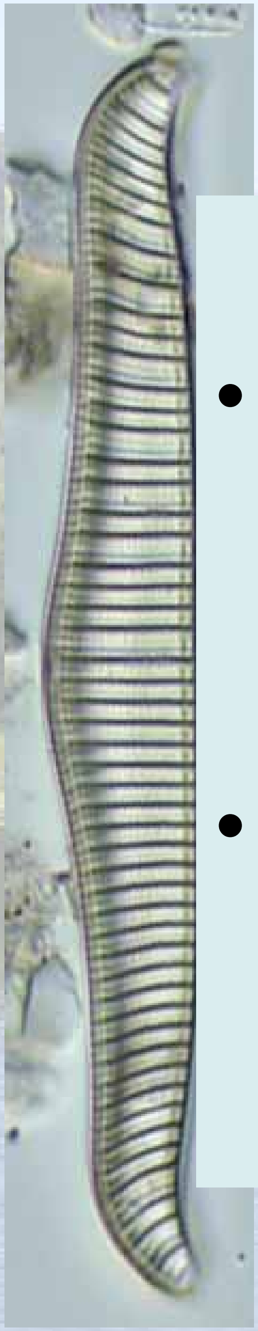
Models or Transfer Functions





(from Hall et al. 1999)

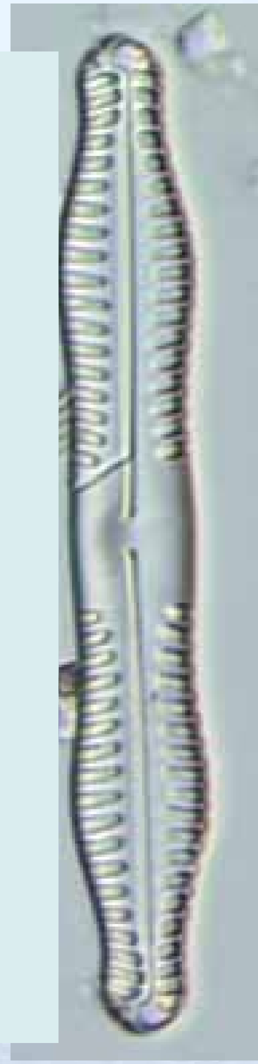




Quantitative models

- Goal: take a modern or fossil diatom community and use it to predict or reconstruct a water quality variable (like TP or pH)
- In MN, over 140 lakes have been studied to develop phosphorus models

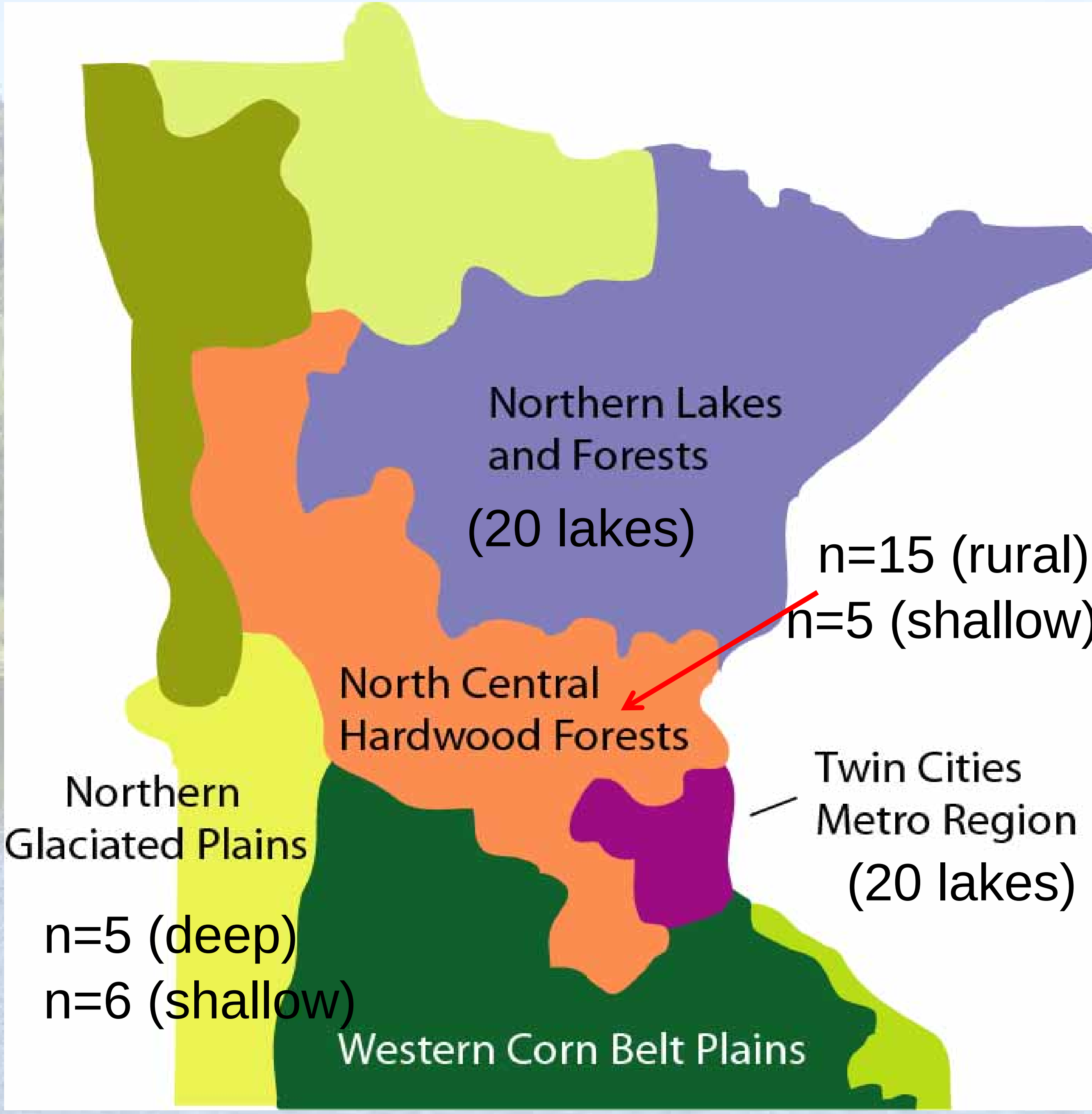
(from Hall et al. 1999)

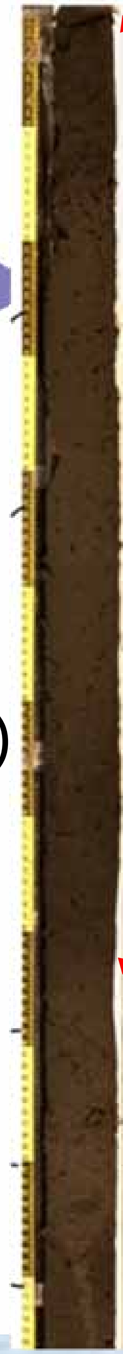


Development of Phosphorus Standards for MN Lakes

1. US Environmental Protection Agency wants states to develop phosphorus standards for lakes, wetlands, rivers & estuaries.
2. When waters exceed standards, that lake or river is officially "impaired."
3. Impaired waters must have a plan prepared to return them to compliance with standards.
4. Minnesota PCA has set phosphorus standards for different ecoregions of state and different lake types using paleolimnological evidence

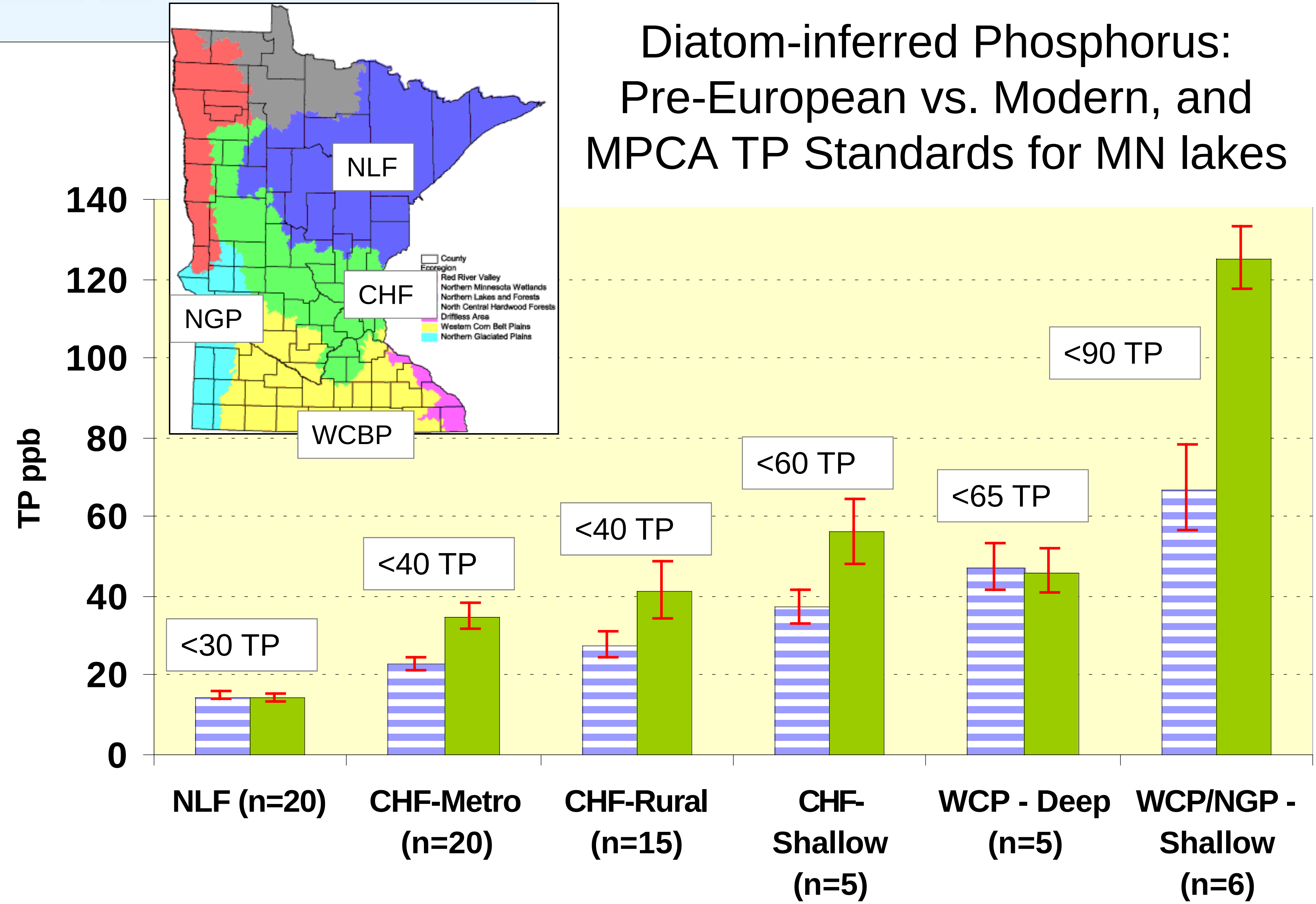
Top-Bottom Analysis





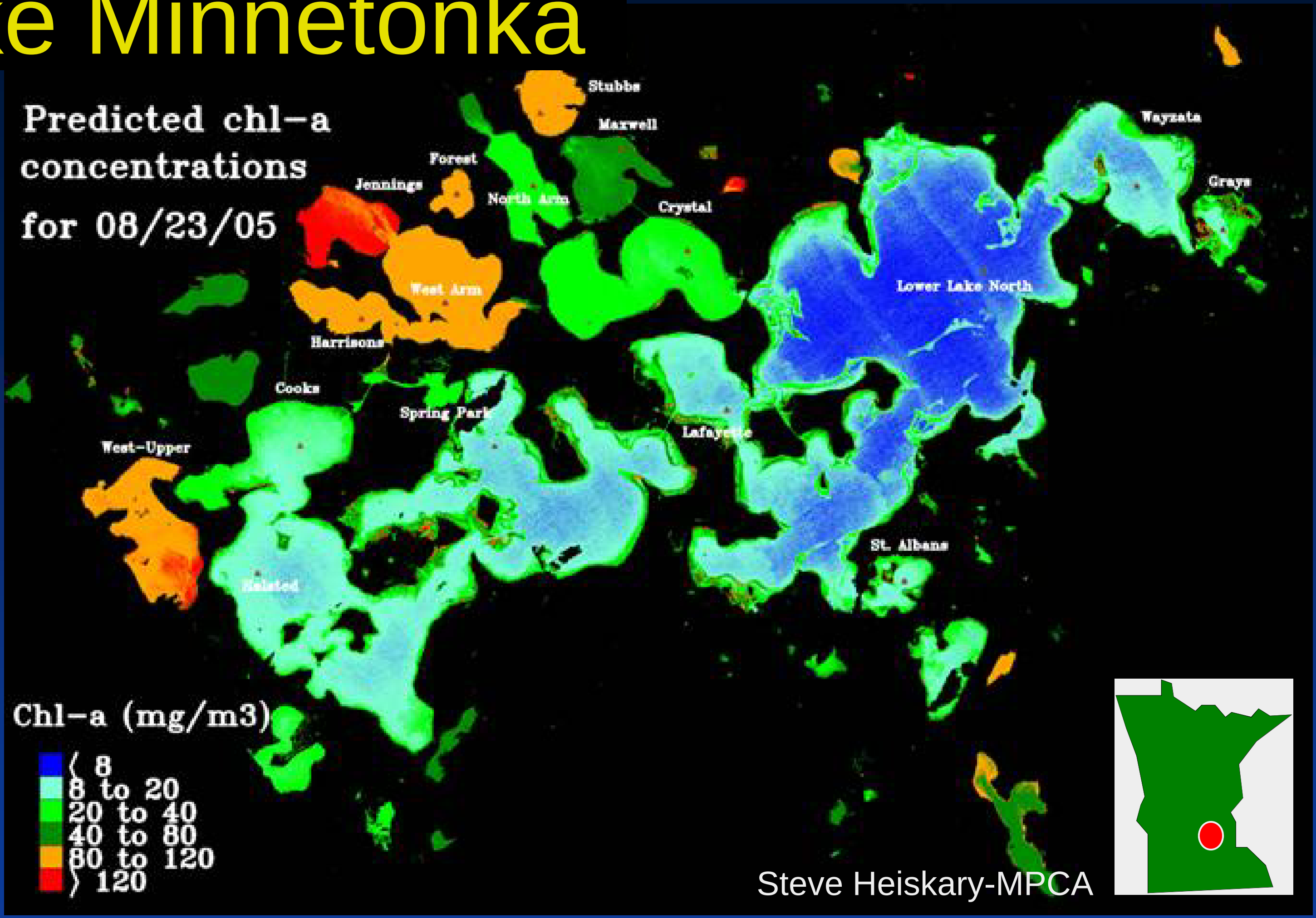
- Core top to assess modern conditions
- Samples taken from below settlement horizon to assess natural or background nutrient levels in lakes

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



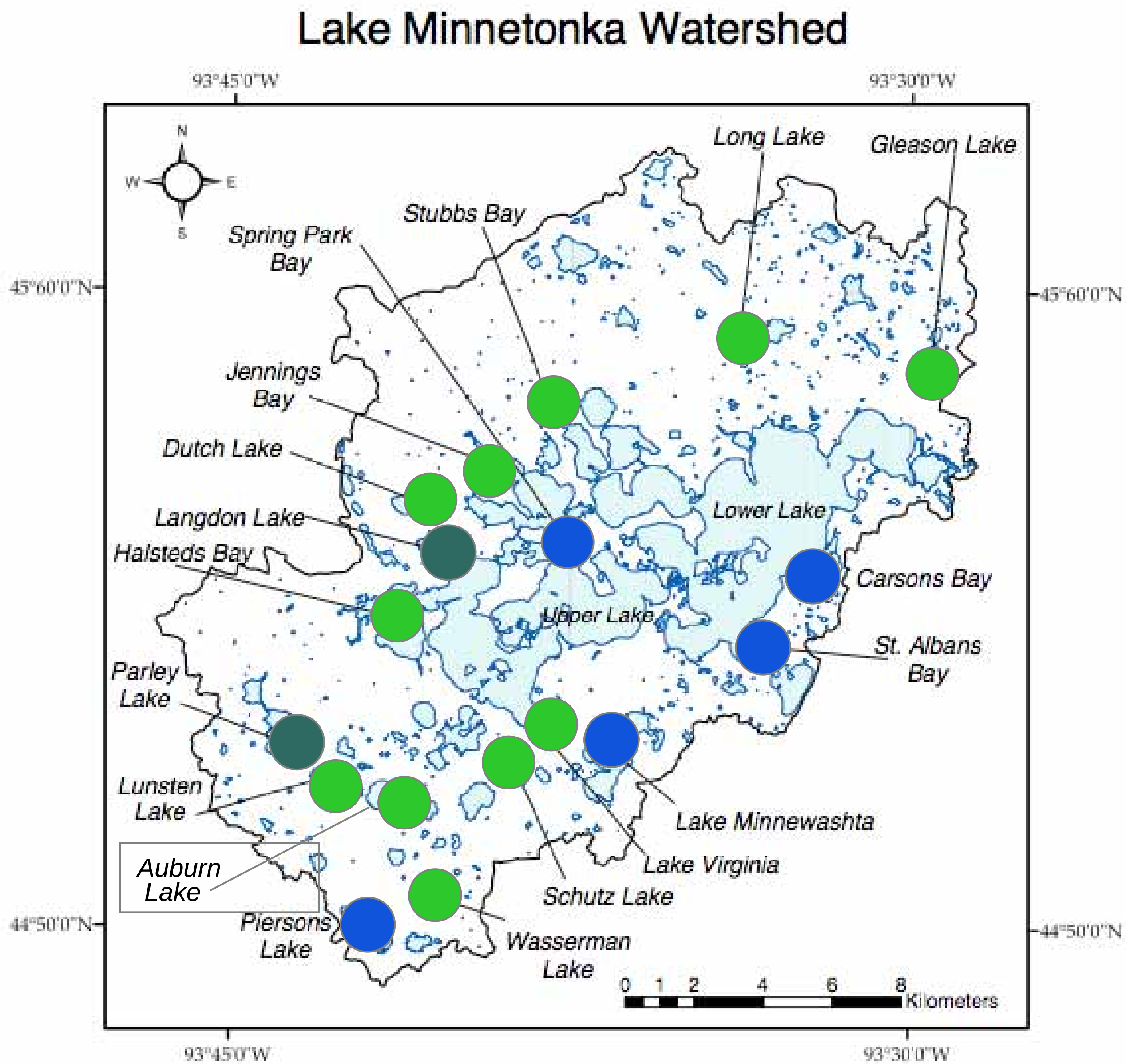
Heiskary et al. 2004 Enviro. Bull.
Heiskary & Wilson 2008 Lk Res Mgmt

Lake Minnetonka



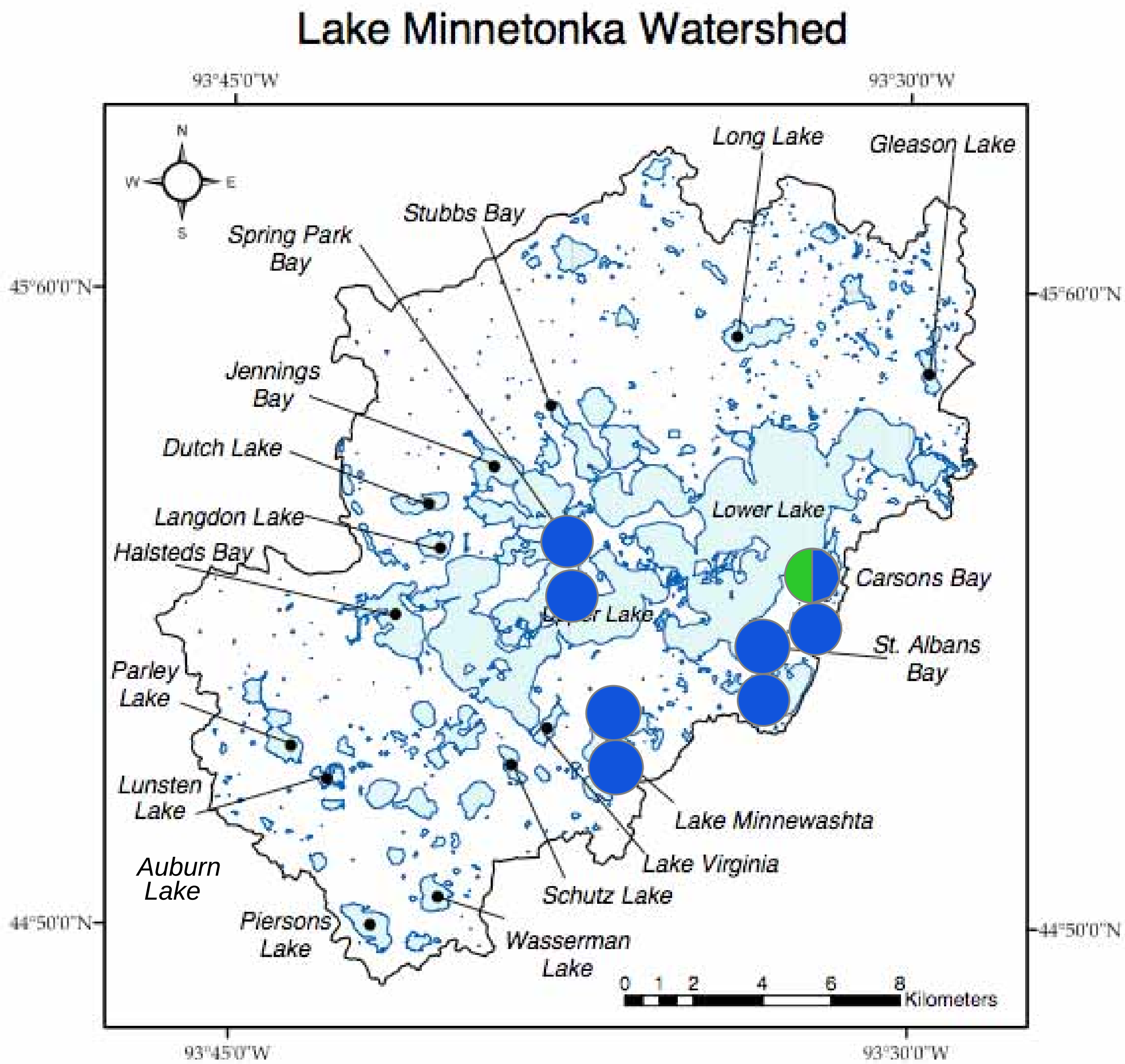
Dozens of basins, highly variable WQ throughout watershed, many basins have TP above proposed standards (40 ppb TP)

14 cities, 8 WWTP, high recreational use, urban development



Modern WQ

- Mean Annual TP from 18-139 μg/L
- Mesotrophic conditions (<40 μg/L TP) in 3 bays and 2 lakes
- All other sites eutrophic 40-100 μg/L TP) to hypertrophic (>100 μg/L)
- Nutrient standard for lakes of < 40 μg/L TP



Modern vs Historical WQ

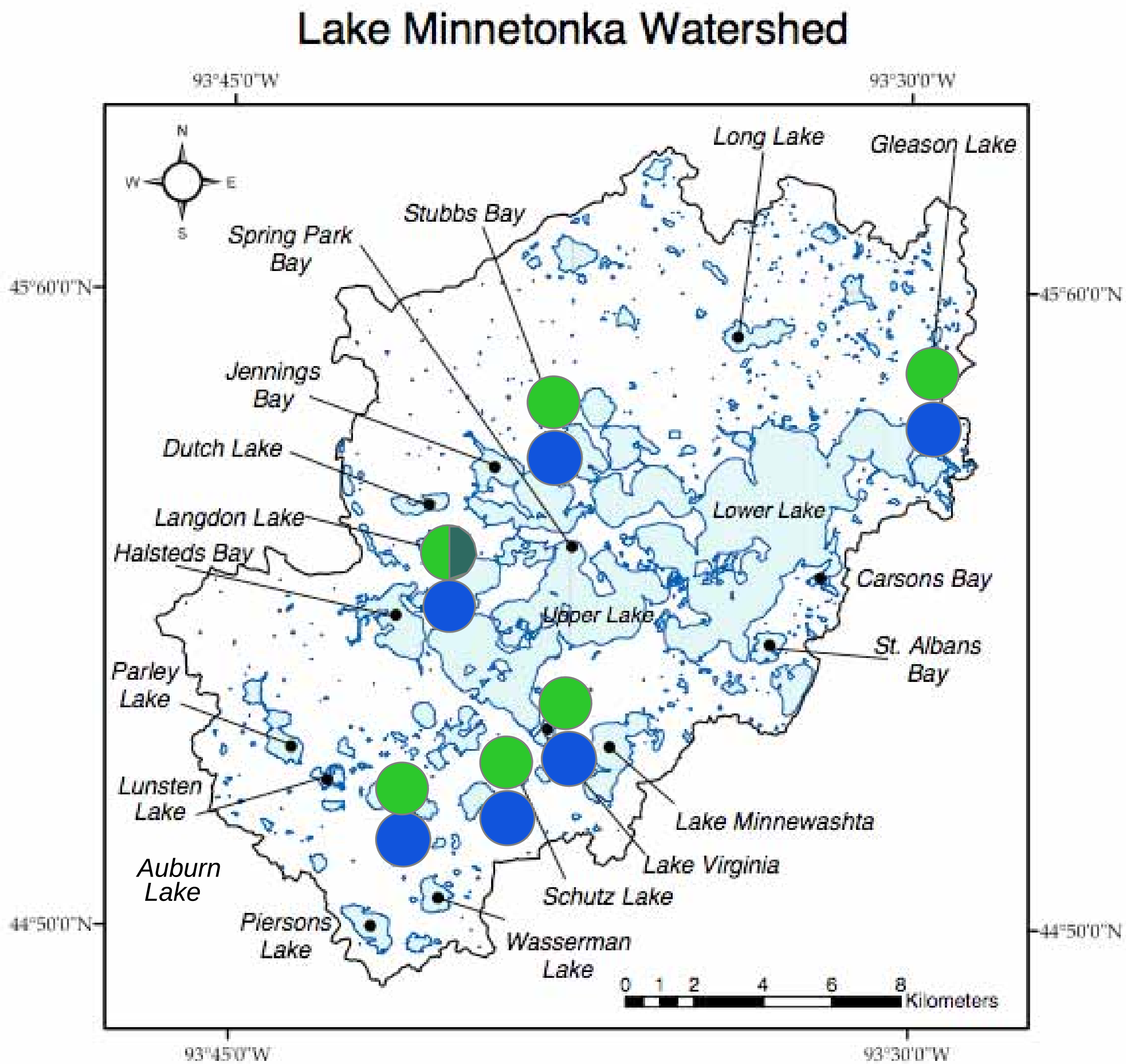
Three groups of lakes

<u>Group 1</u>. Mesotrophic in both pre-Euro and modern
- Carsons Bay
- St. Albans Bay
- Spring Park Bay
- Minnewashta

- <u>Group 1 lakes easily meet standards</u>

Top-modern DI-TP/WQ

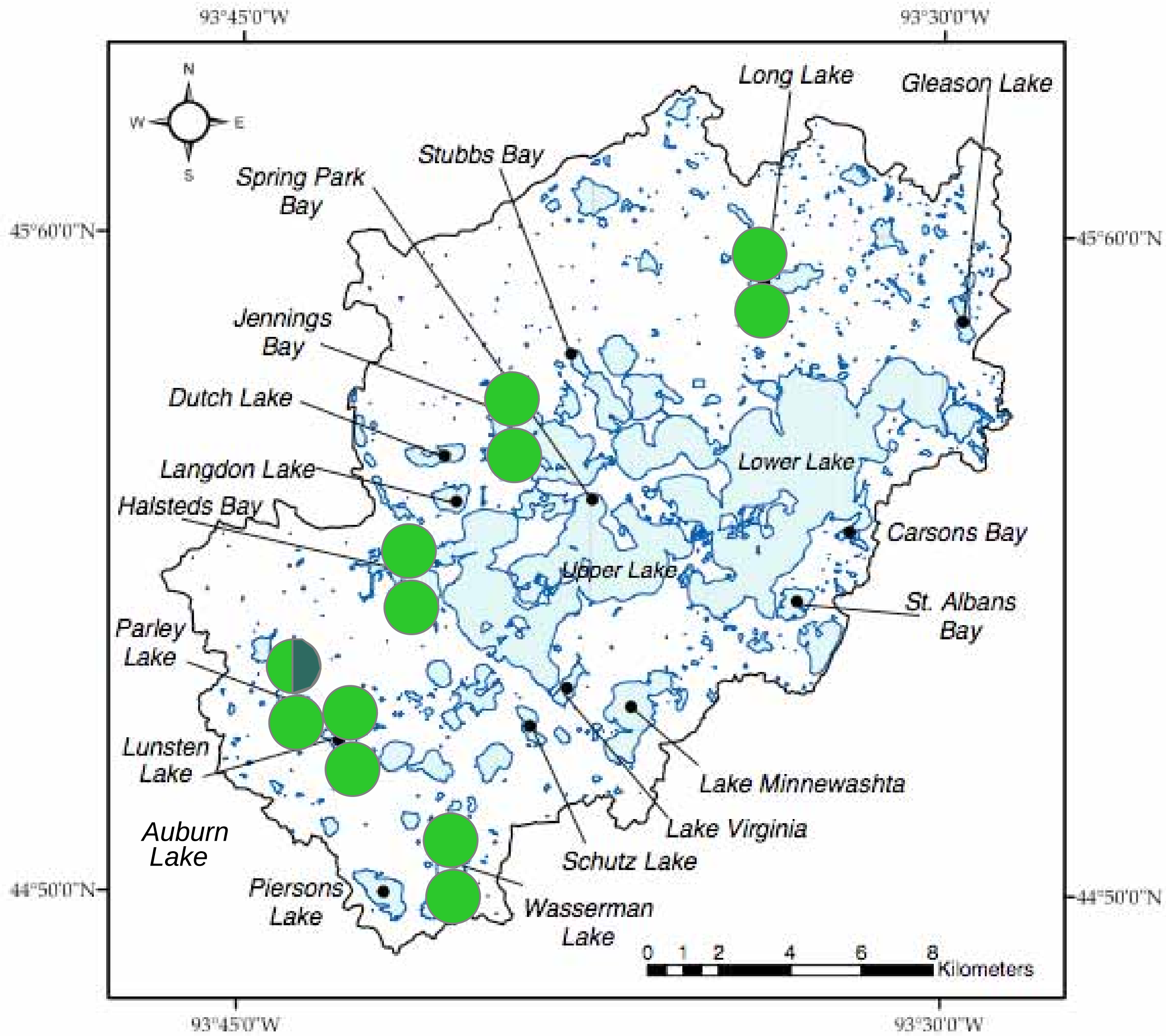
Bottom - historical DI-TP



Modern vs Historical WQ

- Group 2. Mesotrophic (blue) in pre-Euro, but eutrophic (green) to hypertrophic (dark green) in modern times
  - Gleason
  - Stubbs Bay
  - Langdon
  - Schutz
  - Auburn
  - Virginia
- Group 2 lakes do not meet standards, but are good targets for remediation

Lake Minnetonka Watershed



Edlund et al. 2009, MCWD

Modern vs Historical WQ

- <u>Group 3</u>. Eutrophic in pre-Euro, Eutrophic in modern times
  - Jennings Bay
  - Halsteds Bay
  - Wasserman
  - Long
  - Luntsen
  - Parley
- <u>Group 3 lakes do not meet standards, but have long been naturally productive systems</u>

Lake St. Croix

Lake St. Croix – it's nice, but has this river system changed?

St. Croix

A National Wild and Scenic River

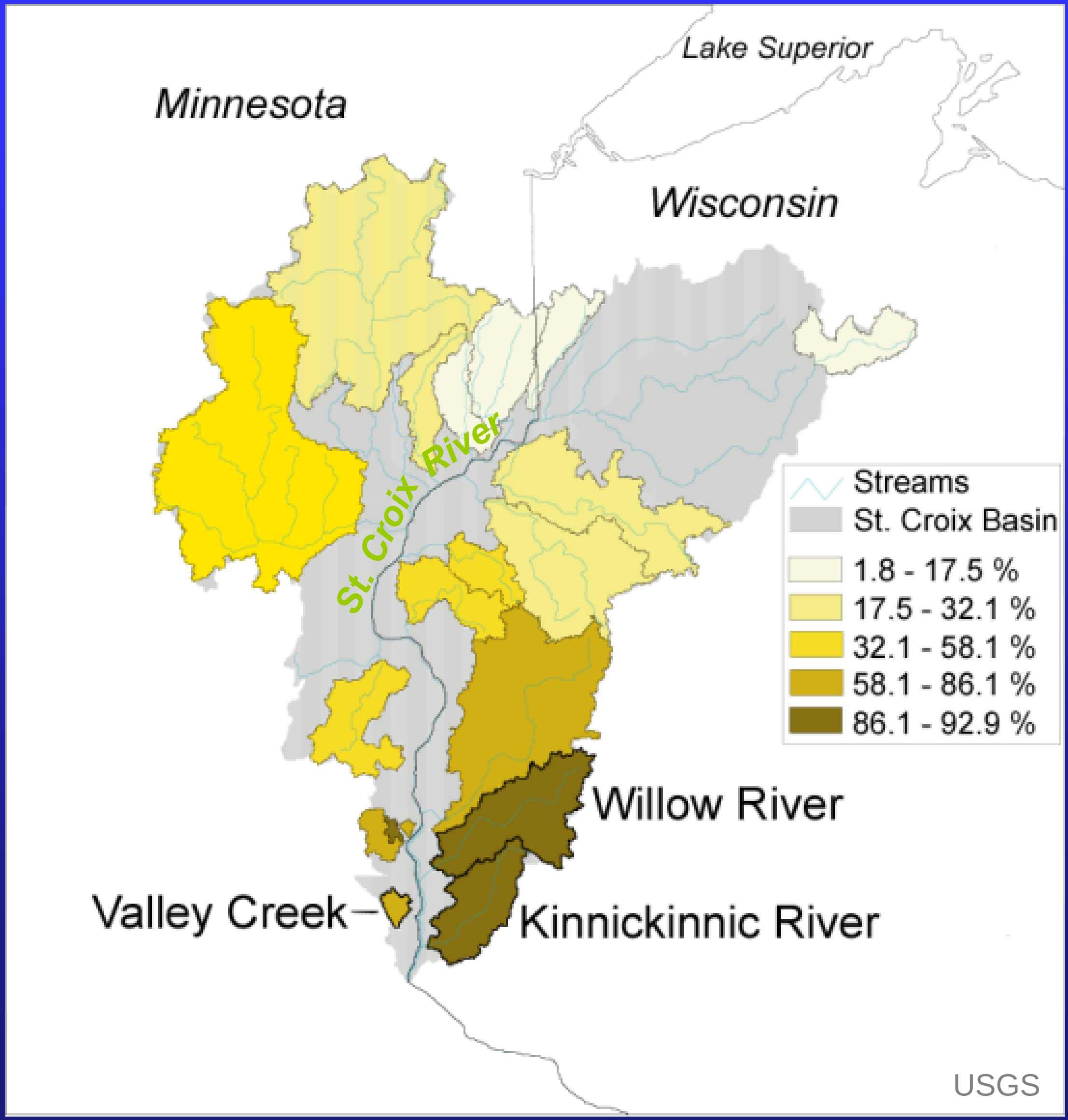
Mississippi

Urban and Agricultural

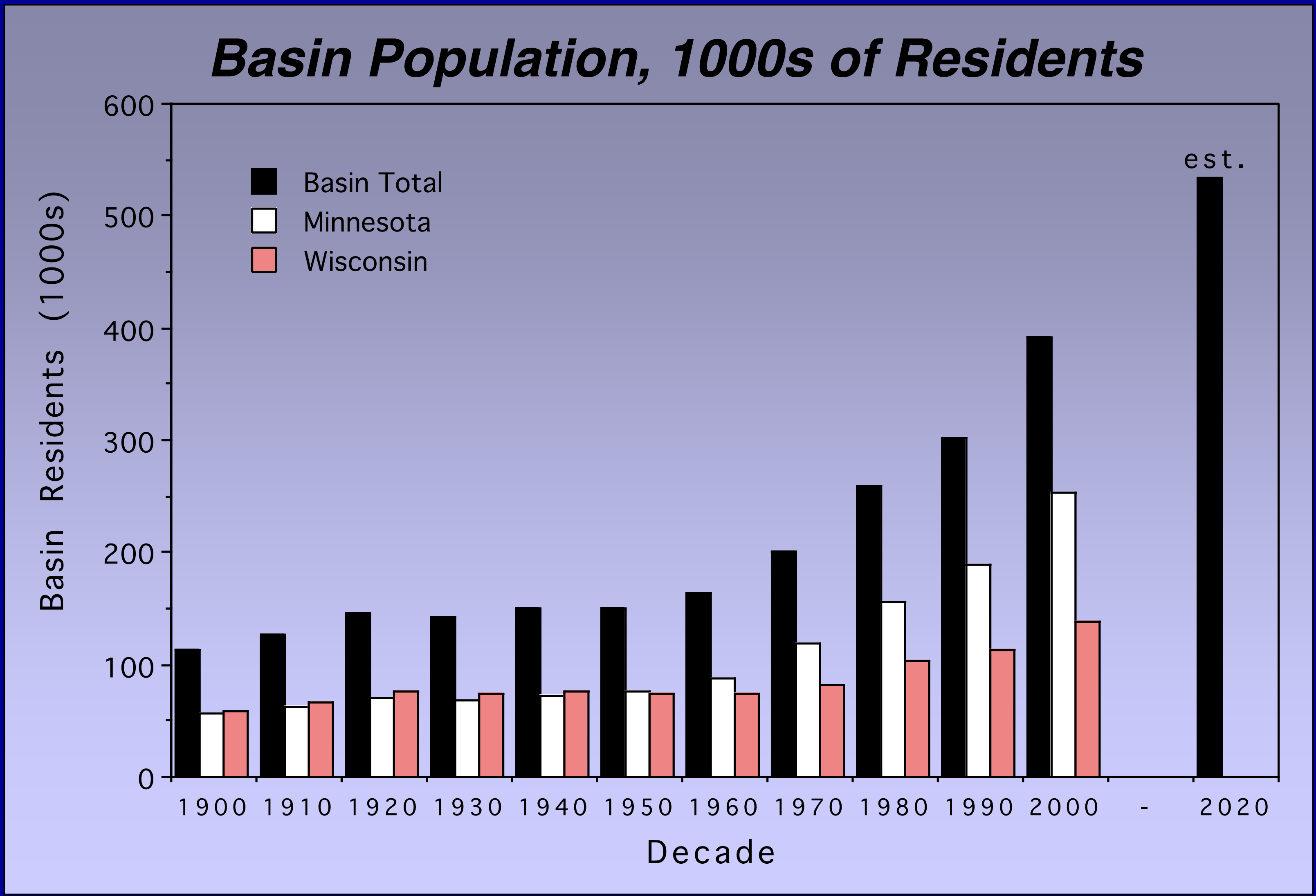
Historical land use: log jam on the St. Croix River, 1886

Percent Land Used for Agriculture

Watersheds of the St. Croix River Basin

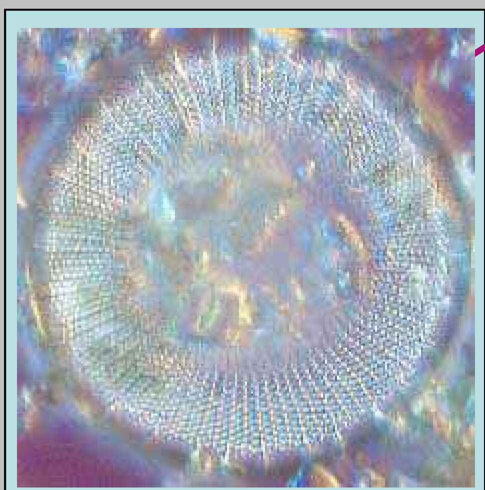


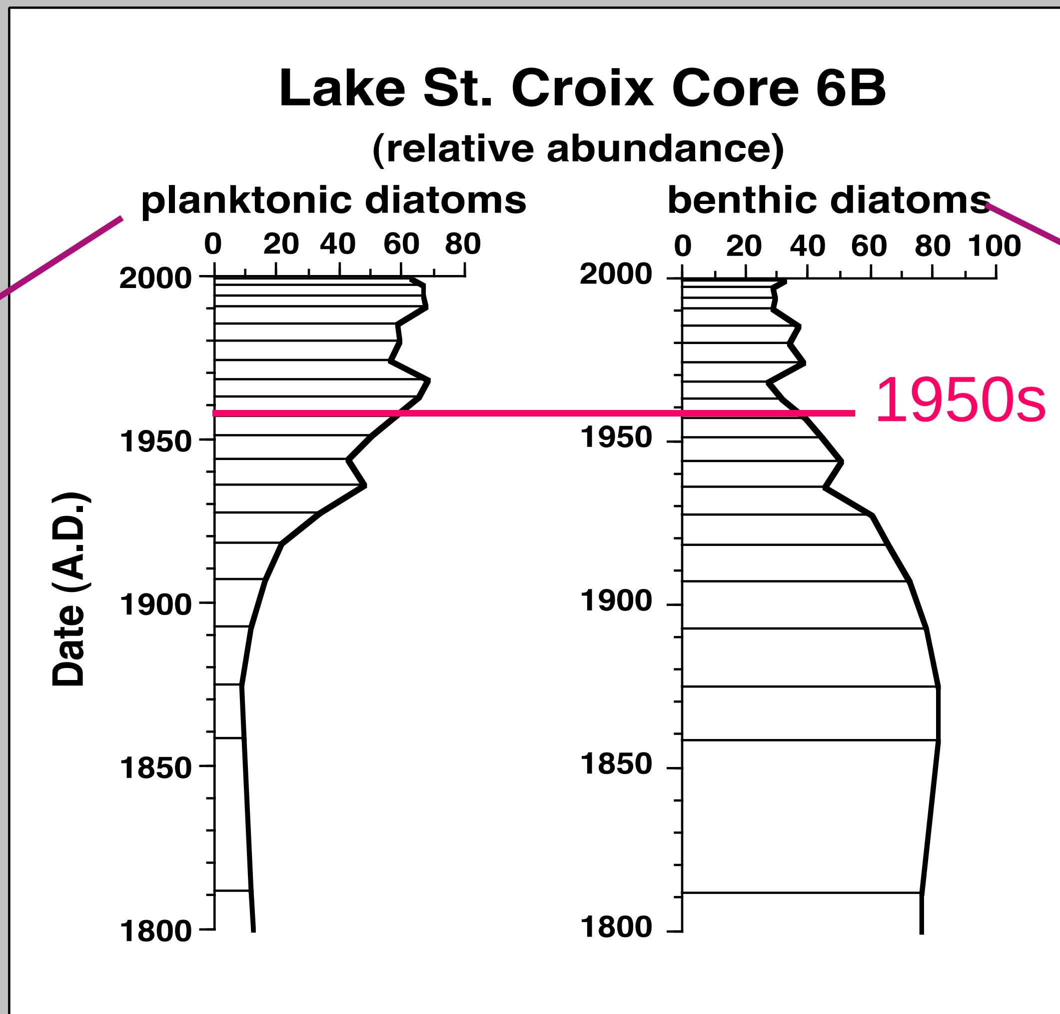
Living in the St. Croix Basin

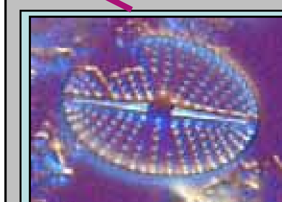


From US Census and Met Council

…the diatom community changes

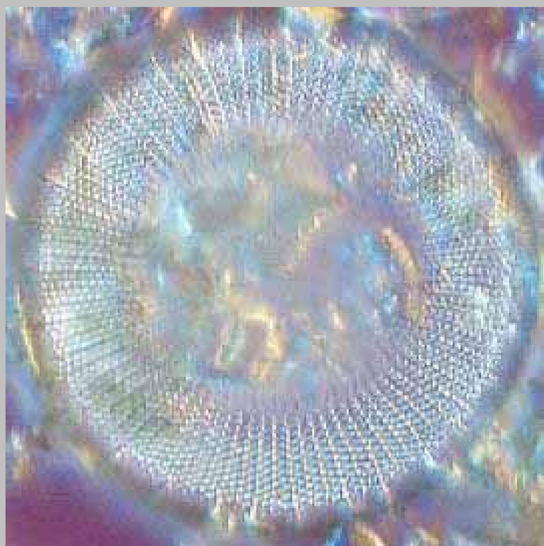


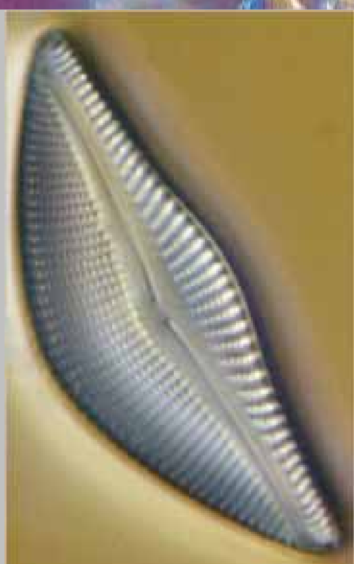




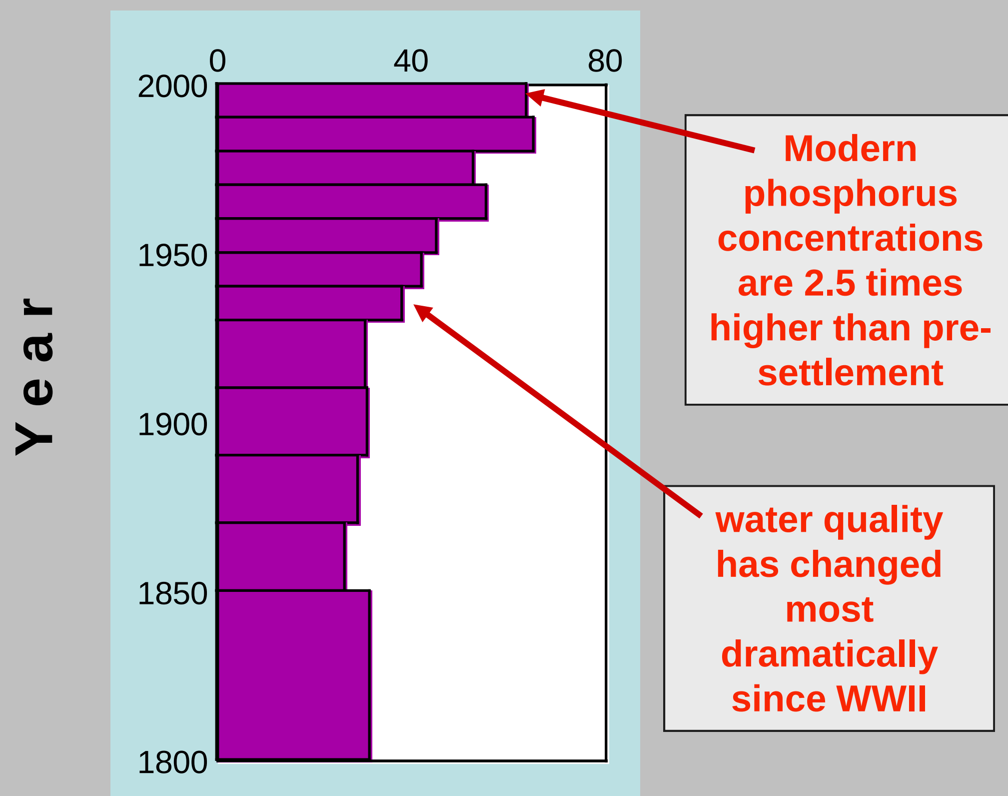
Edlund et al. 2009 JOPL

Historical Water Quality In Lake St. Croix



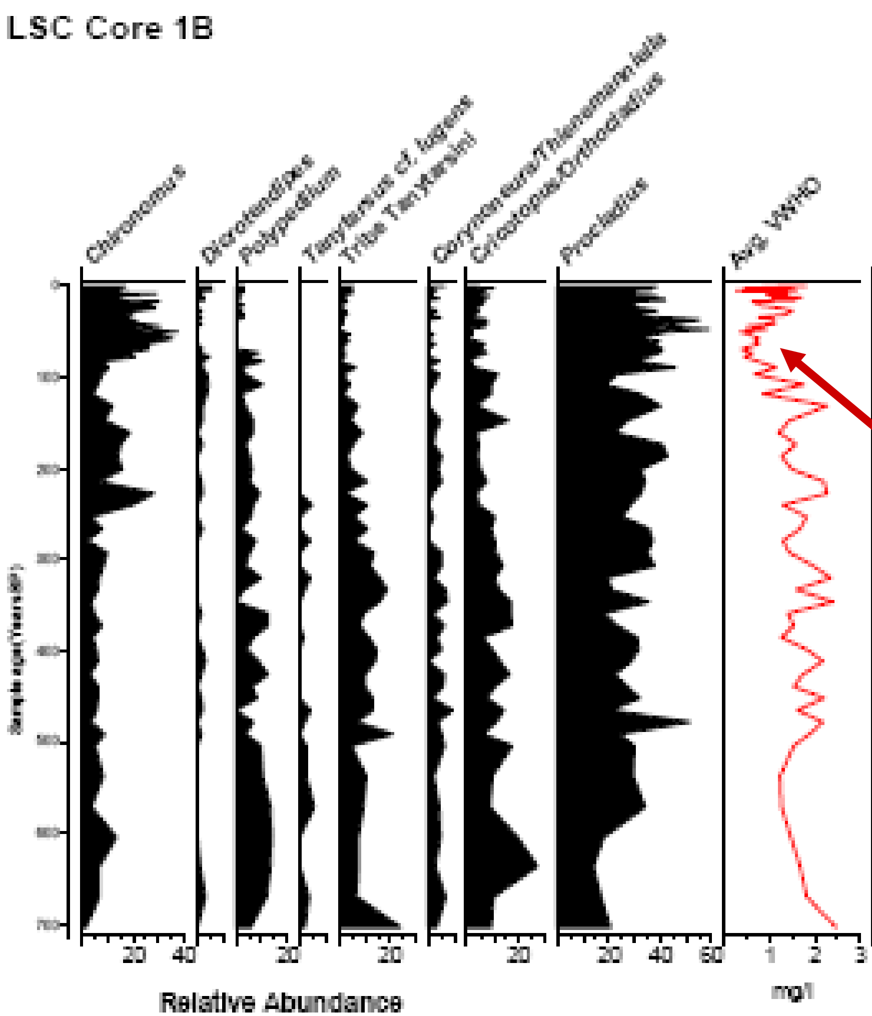


Total Phosphorus reconstructed from diatoms (ug/L)

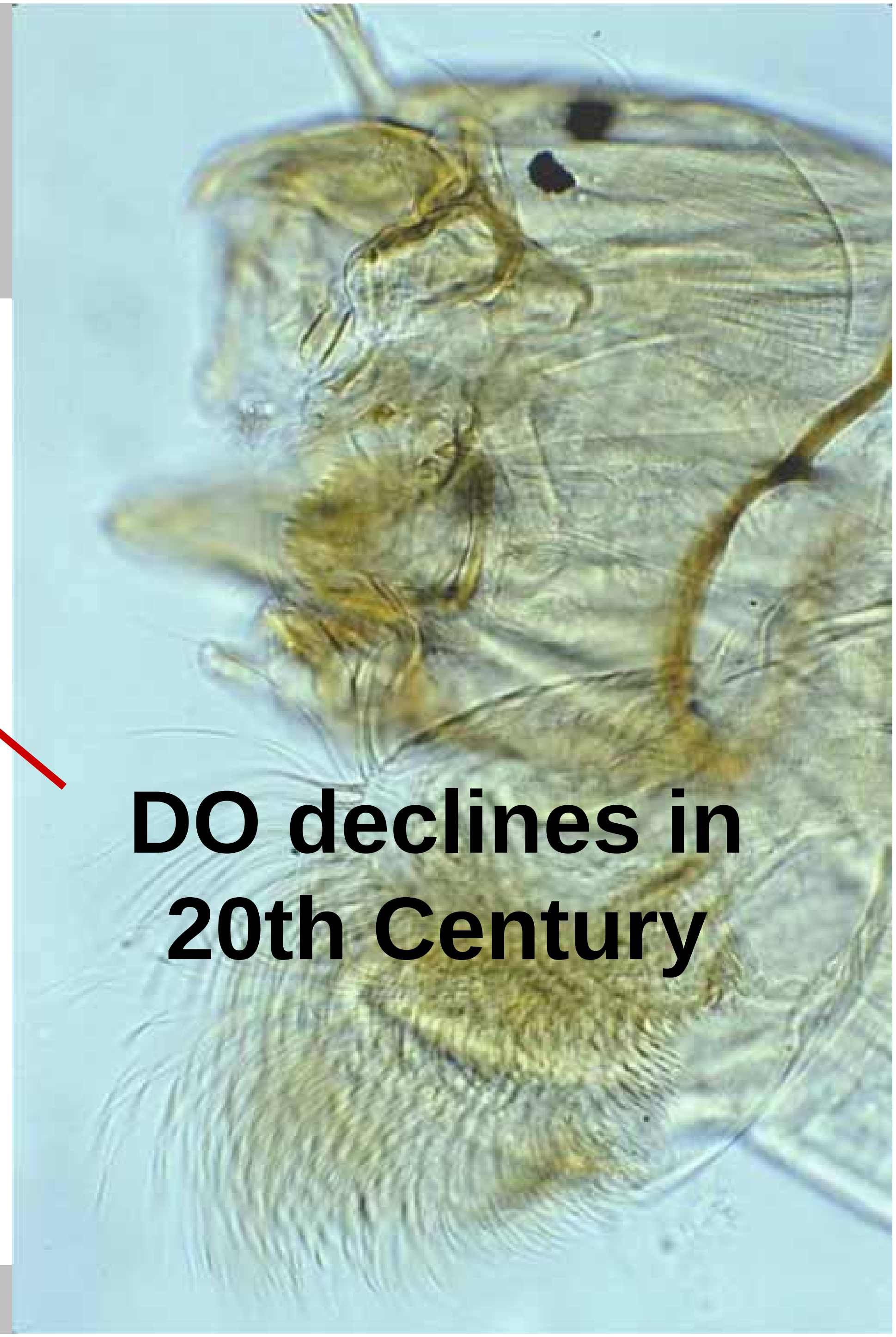


Edlund et al. 2009 JOPL

Reconstructing DO with chironomids

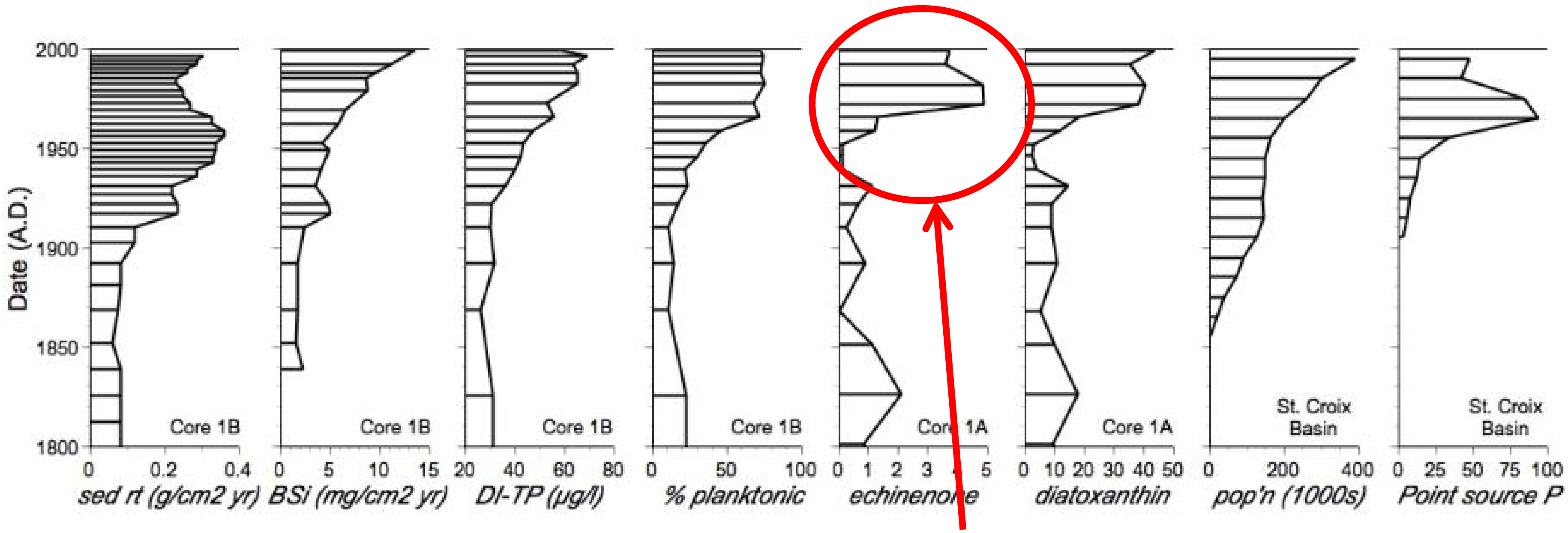


D. Francis (unpublished)

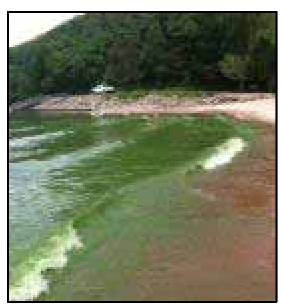


DO declines in 20th Century

Everything changed, even blue-greens



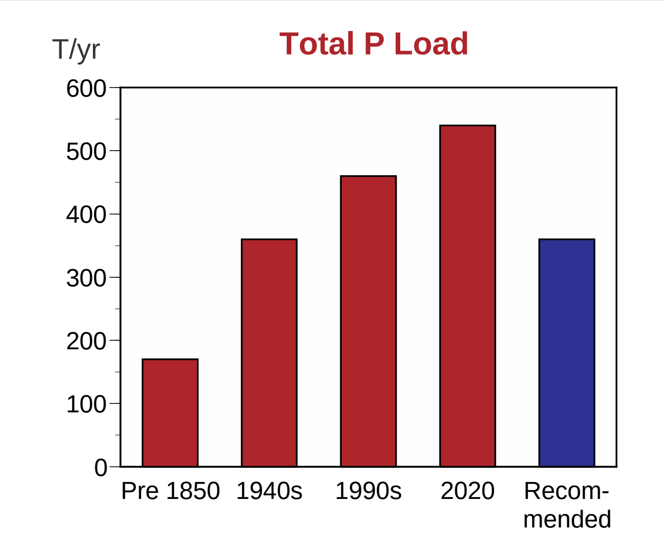
- blue-green blooms known from St. Croix since 1920s (Reinhard 1931)
- linked to nutrient loading, interannual differences

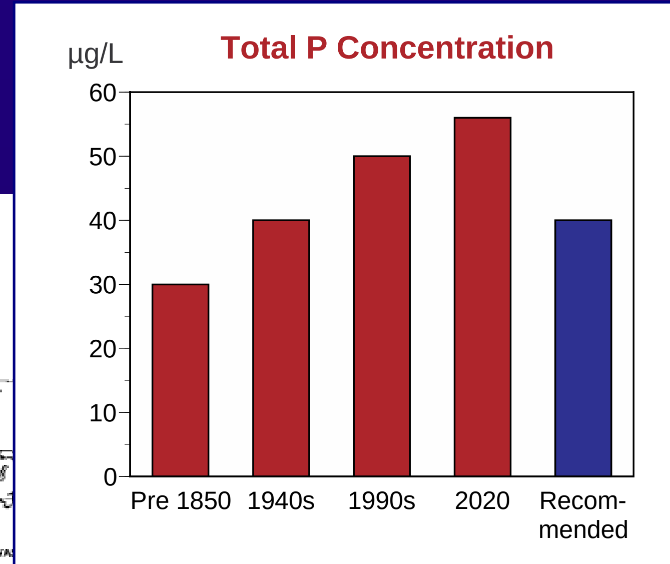


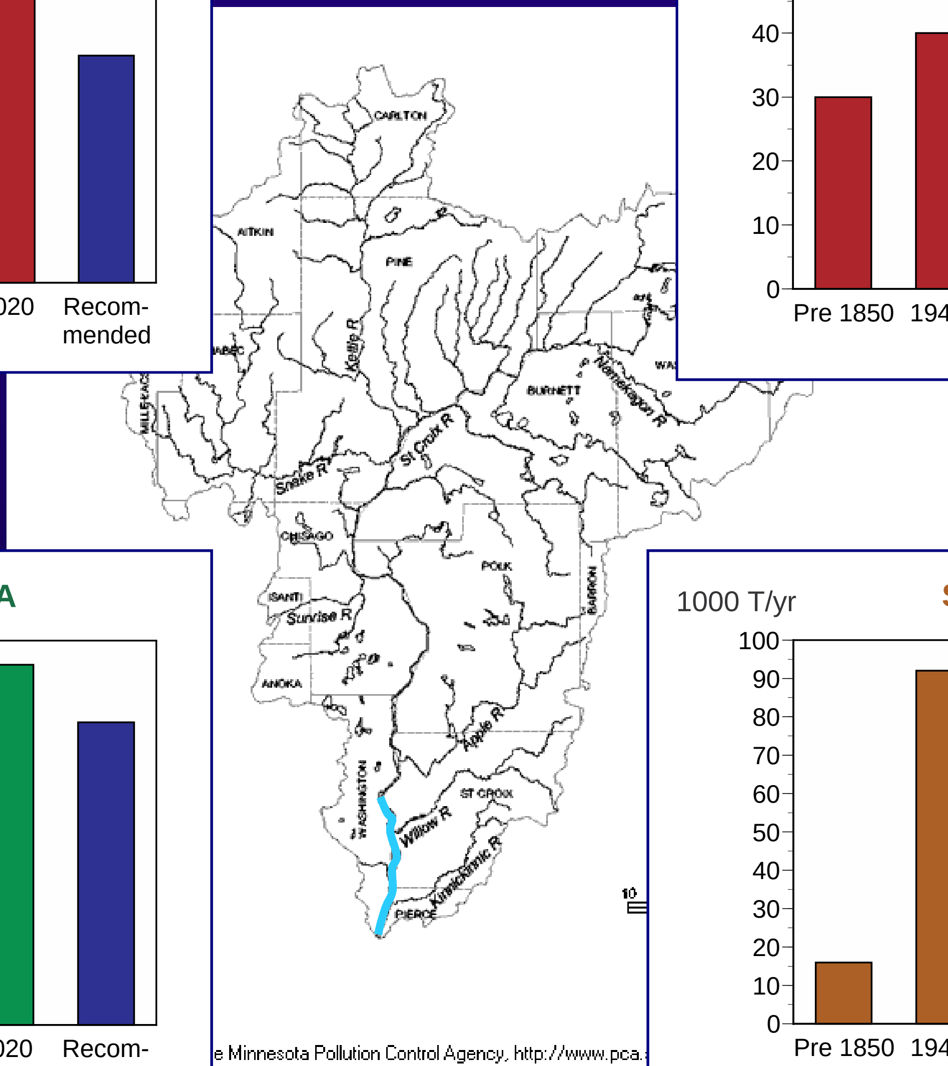
- but, increased abundance since 1960s (Edlund et al. 2009)
- modeled response to P loading & circulation (Robertson & Lenz 2004, Kiesling et al. in progress)

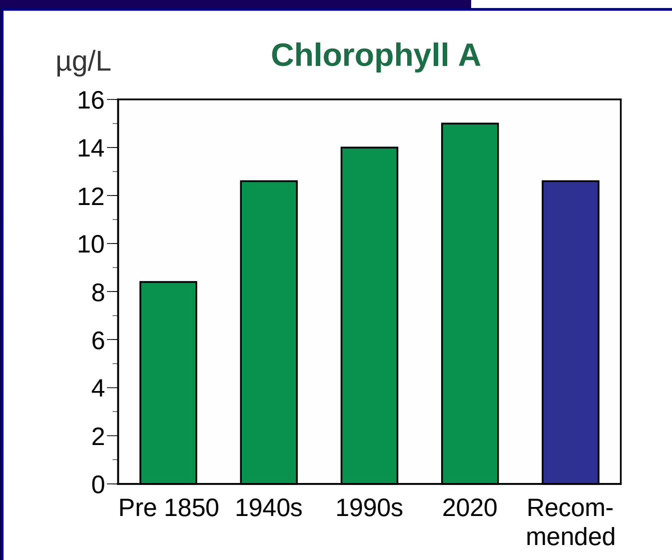
Edlund et al. 2009 JOPL

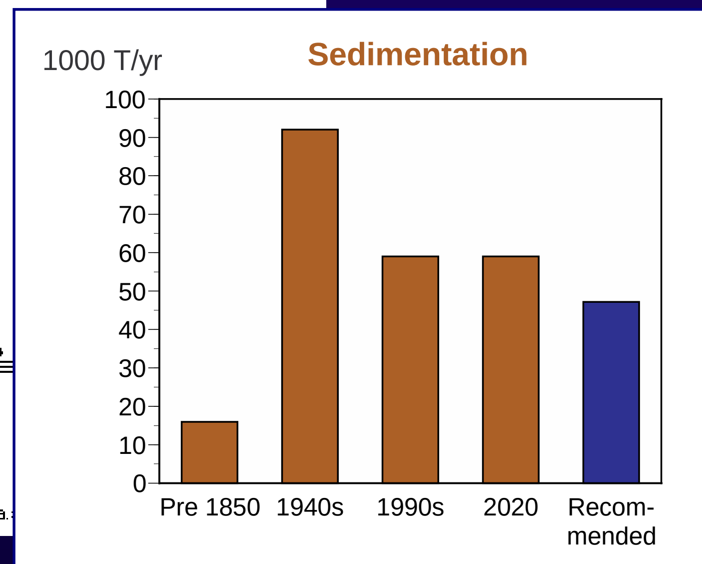
St. Croix Goals







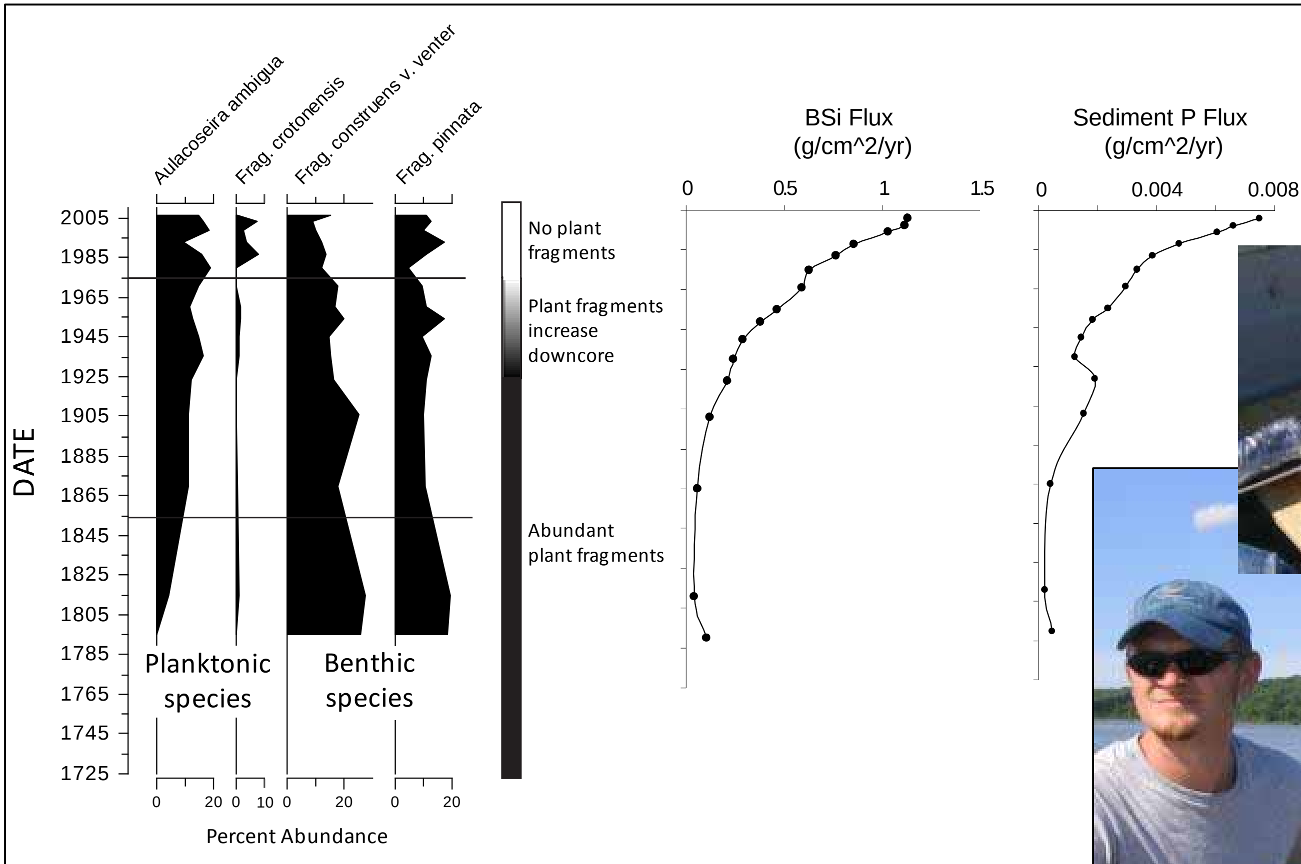




WDNR / MPCA Nutrient Reduction Agreement

Lake St. Croix declared impaired
20% Reduction in P inputs by 2020
modeling and monitoring

Does it work in other lakes?



- Horse Lake, Polk Co., Wisconsin
- turbid, shallow
- carp
- shows shift in algae, increase productivity
- loss of plants, ecological targets

Paying for out sins – Shallow lakes

Paleoecology of Lake Christina, MN: stable regimes and biomanipulations

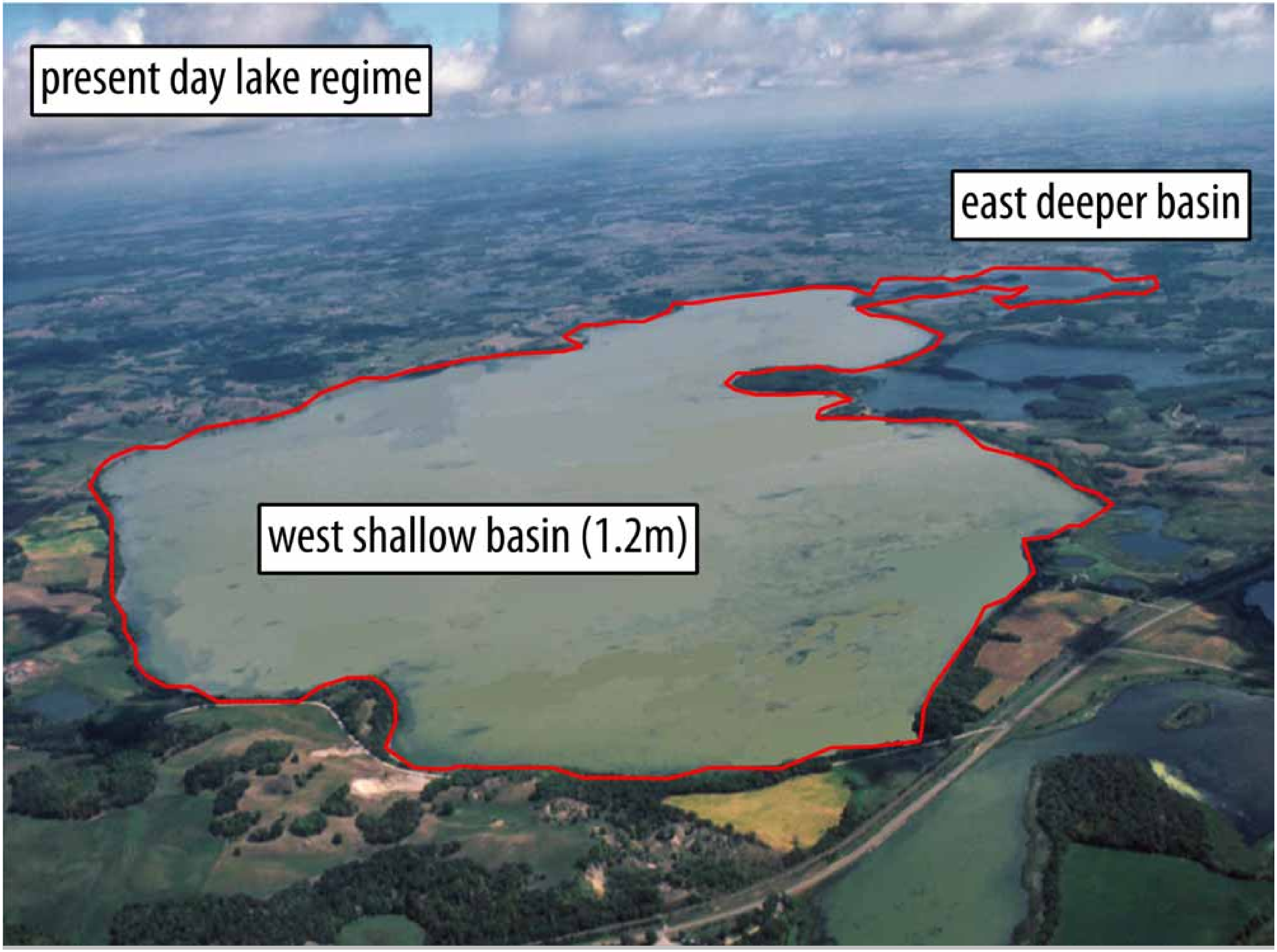
canvasback duck (Ducks Unlimited website)

Shallow Prairie Lake 'Stable Regimes'

Clear regime: macrophyte dominated; generally no or low abundance of planktivorous fish

often occupy 2 ecological extremes

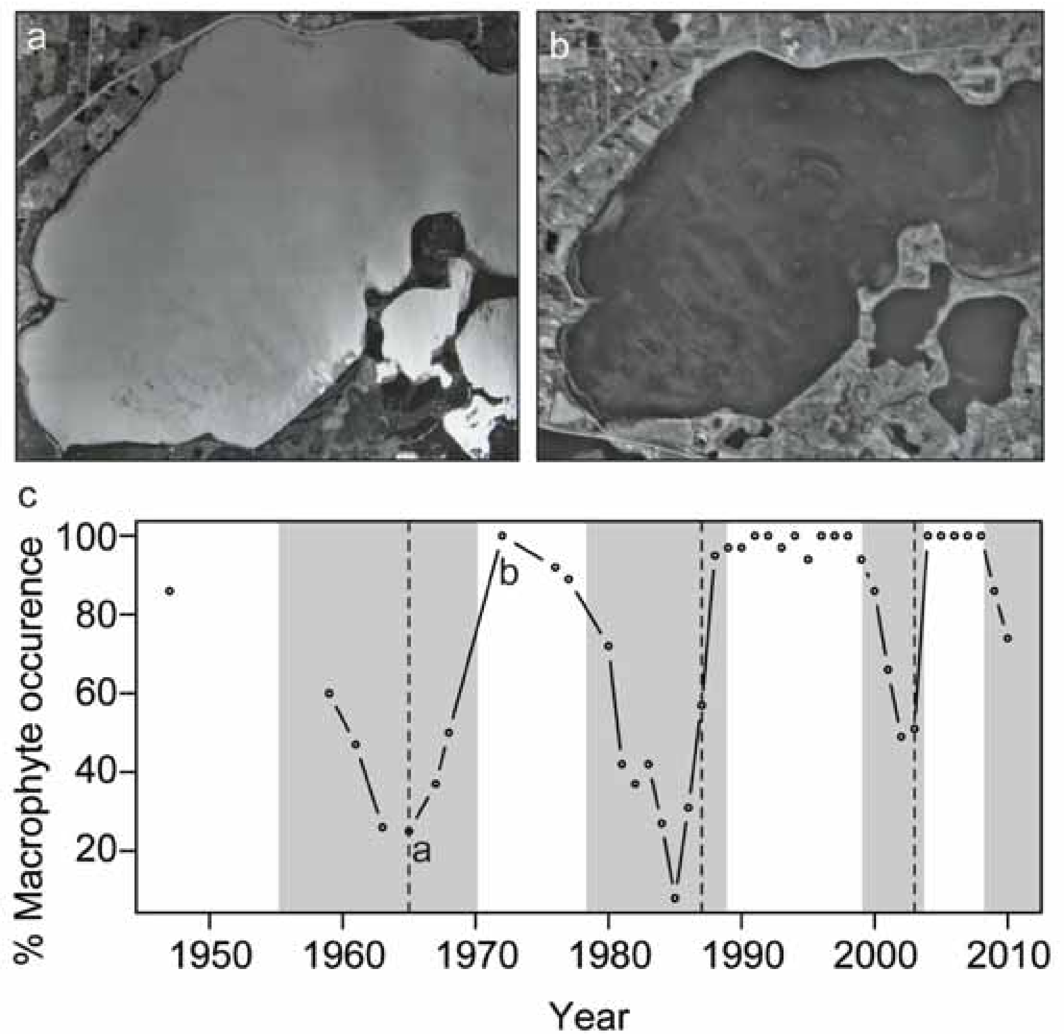
Turbid regime: algal dominated; eutrophic; possible high authigenic precipitation of minerals


present day lake regime
east deeper basin
west shallow basin (1.2m)

Lake manipulations during Anthropogenic period

Lake Christina has cycled between 'stable' regimes since the mid 1950s

Turbid versus clear water



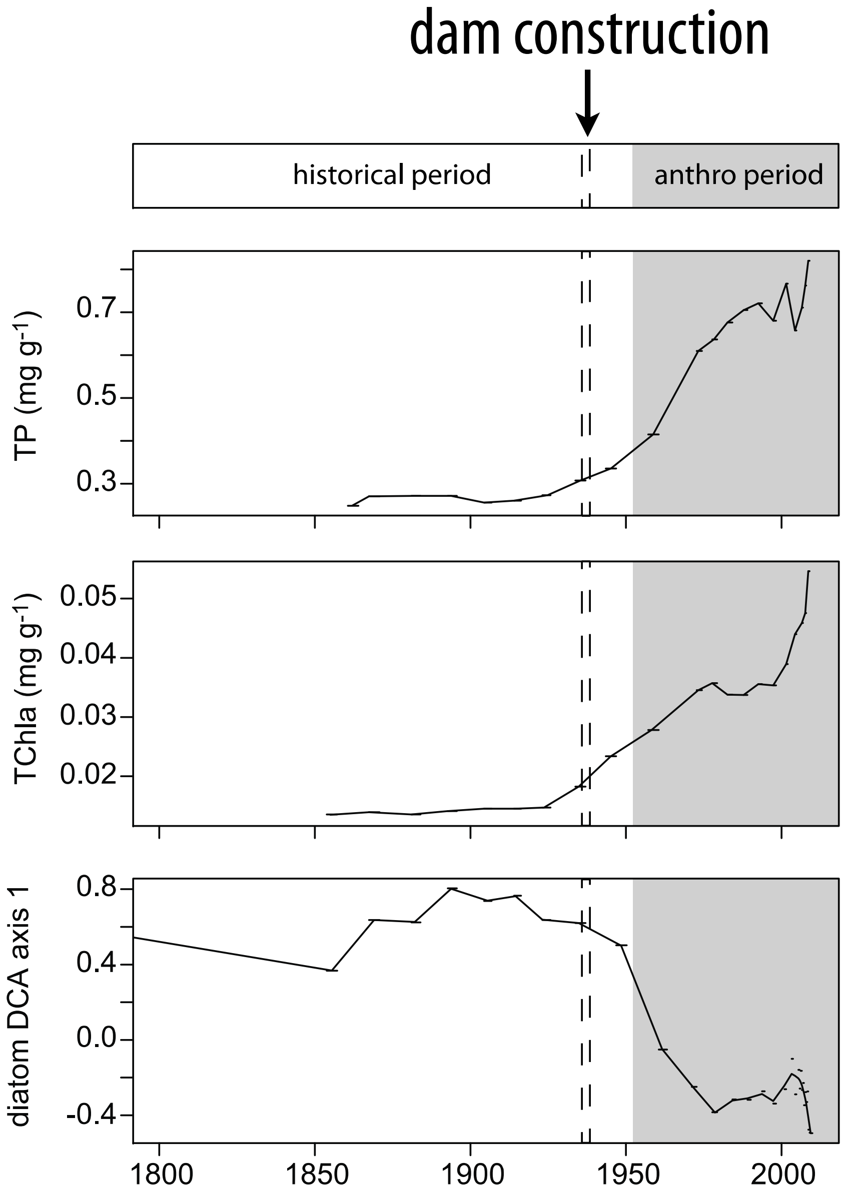
- unable to maintain stable clear regime
- continued eutrophication (possibly internal P-cycling) and persistence of planktivorous fish

- monitored macrophyte abundance shows periods of regime change

Q1: do the sediments record these changes?

Q2: does this mgmt strategy return the lake to “clear” state?

Paleoecological data define 'Anthropogenic' period



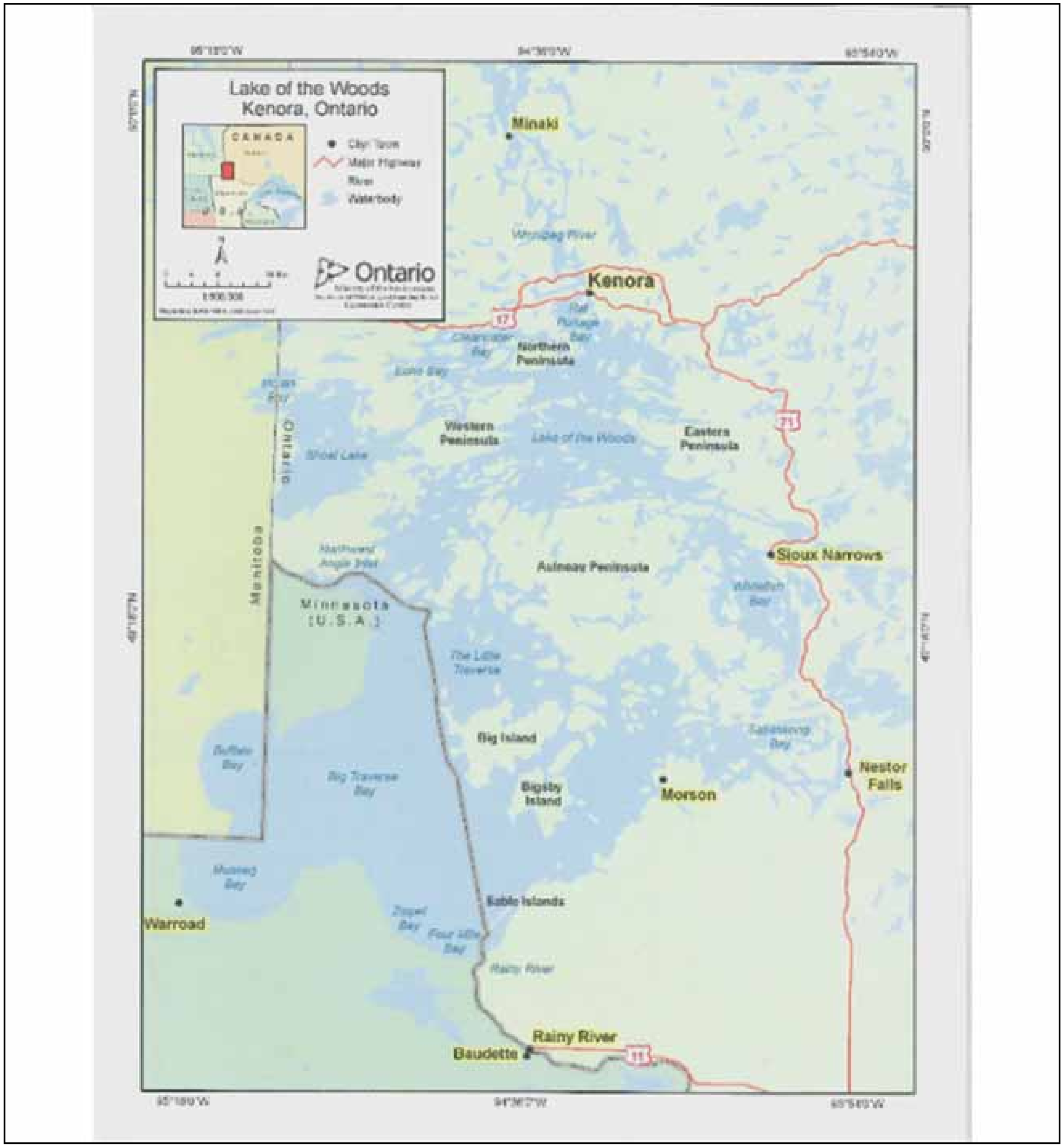
nutrients and primary production increase in Lake Christina prior to anthropogenic period and loss of stable clear water regime

only significant shift in the diatom communities

The trouble with shallow lakes

- single major shift in 1950s result of early eutrophication and land use, increase water level encouraged planktivorous fish, loss of macrophytes, loss of duck habitat
- short term $$$ manipulations that shift lake from turbid to clear do not influence the long term regime of the lake
- current management strategy includes continued development of wetlands in catchment and construction of a lake drawdown dam

Hobbs et al. 2012 Ecol Appl



Paying for our sins

Lake (not quite out) of the Woods

- it's huge!
- 65000 miles of shoreline
- 14500 islands
- 65 x 60 miles
- it's not all ours
- it's warming

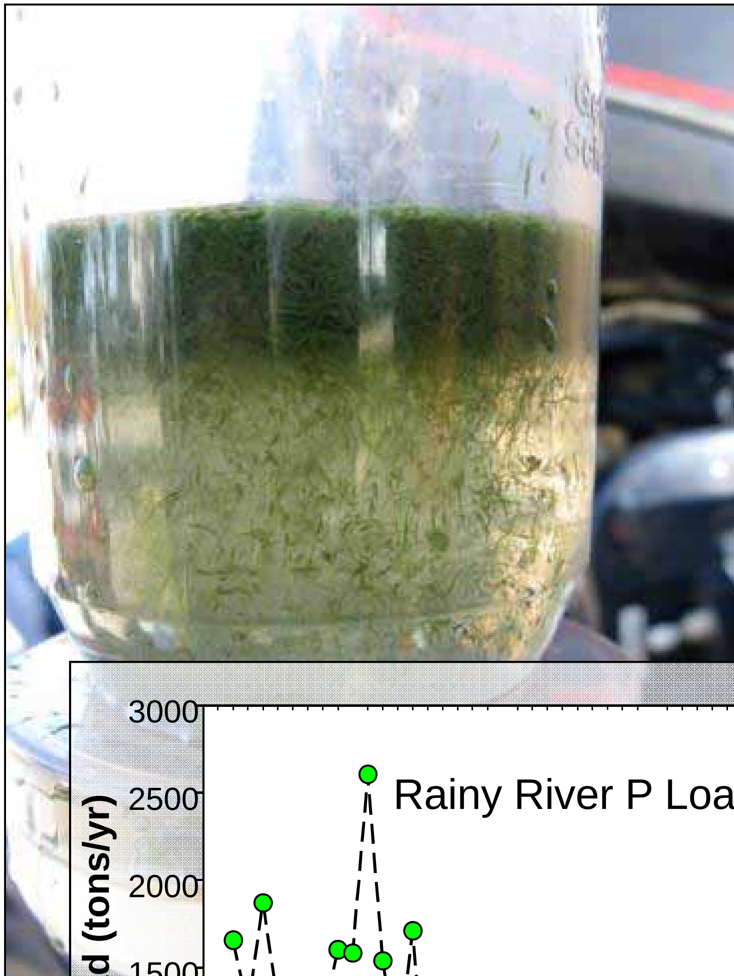
LoW

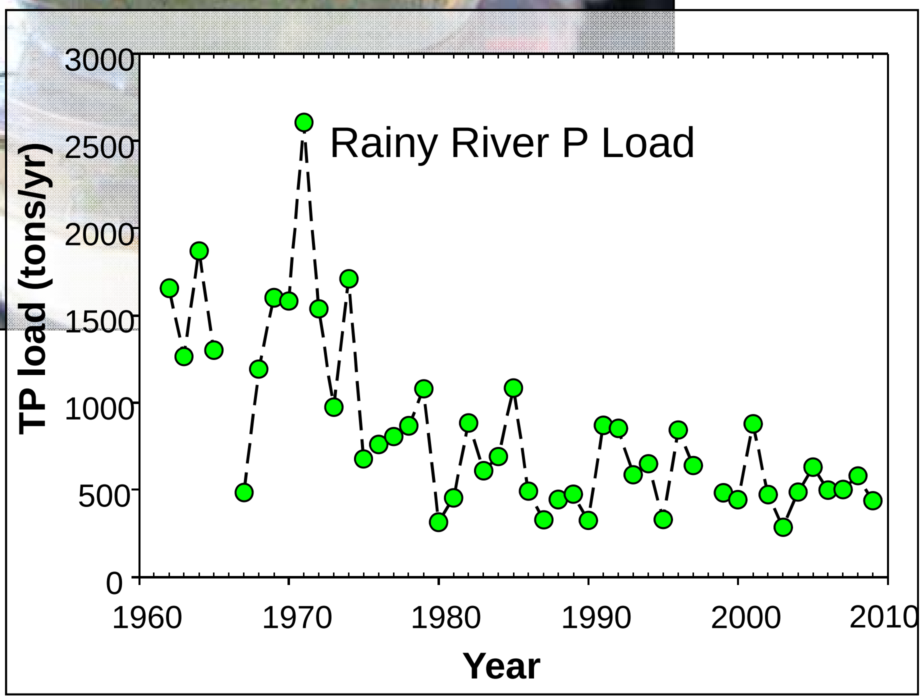
- it's a destination
- it's full of fish

- but…it's green?

Green?!

more blue-green than green





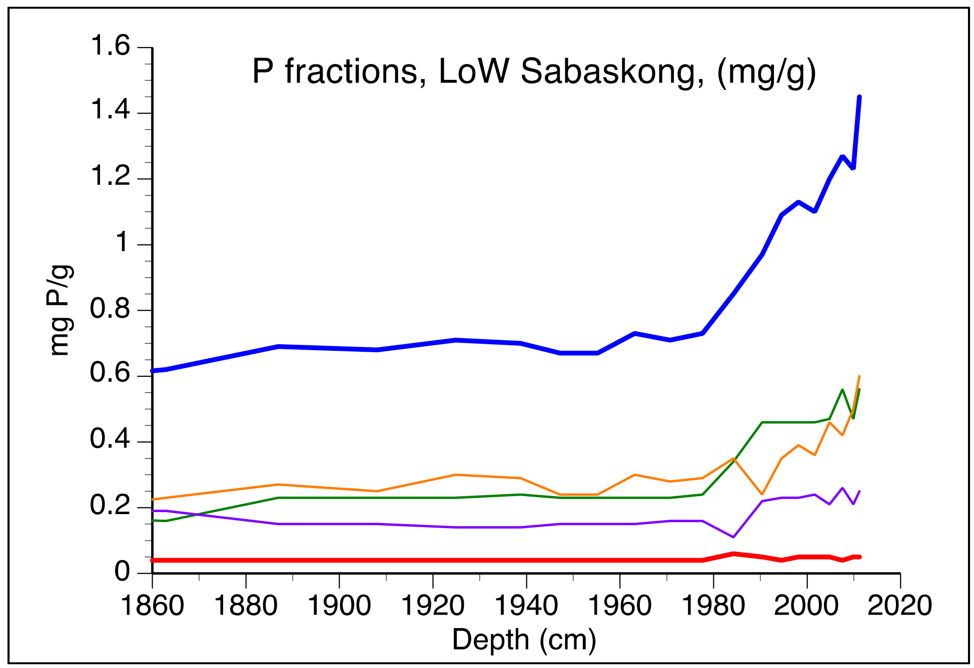
- cyanobacteria = nasty
- toxic at times
- monitoring data show reduced P loading
- increased frequency and extent of b-g blooms

- Why hasn't the lake responded?

from Hargan et al. 2011, JGLR

What have we learned about this lake?

- no evidence of decreased P load
- mobile P fractions dominate in cores
- profiles suggest P mobility upcore
- LoW poor at burying P
- still paying for our sins!



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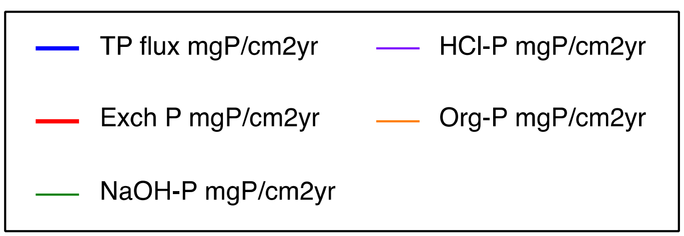
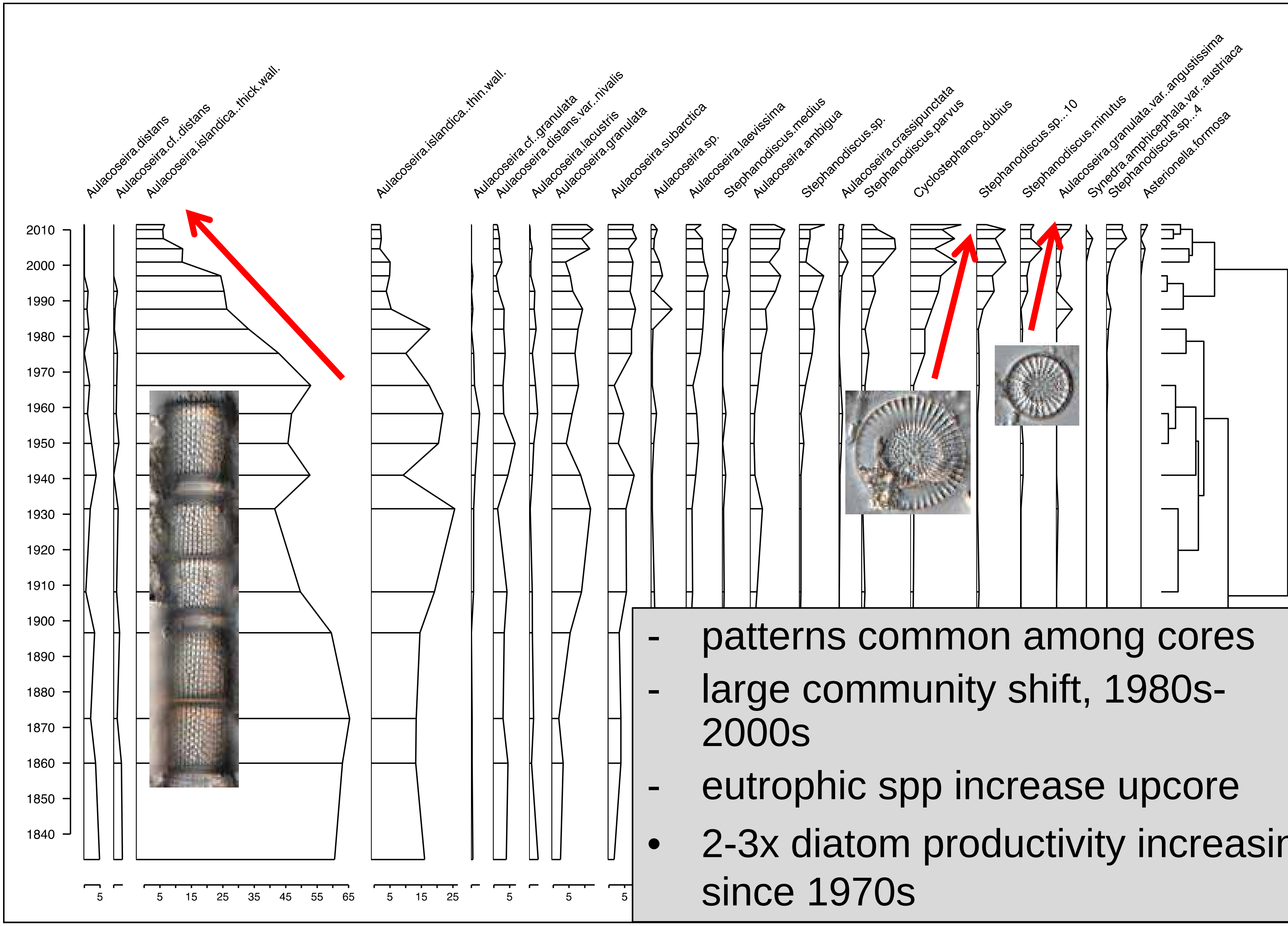


Diatom records, Little Traverse, % abundance

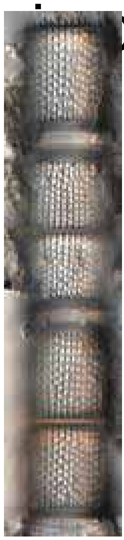
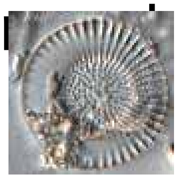
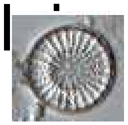
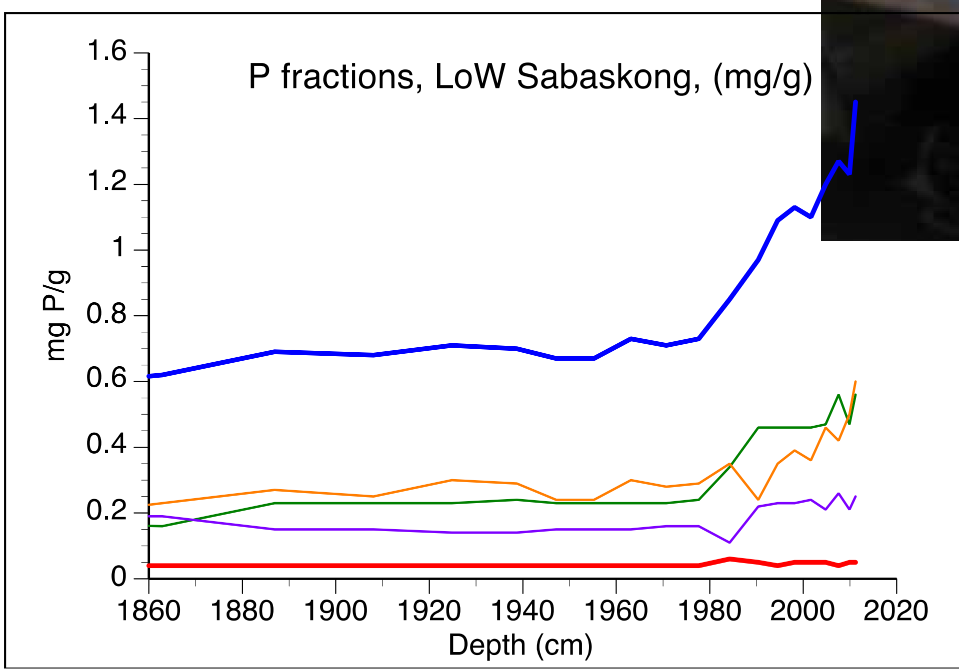


- patterns common among cores
- large community shift, 1980s-2000s
- eutrophic spp increase upcore
- 2-3x diatom productivity increasing since 1970s

An iconic lake in a death spiral?

- rare situation where we have good monitoring data on P loads
- no evidence that decreased loads have

- legacy P – climate interaction in southern Lake of the Woods?

What can we do about algae?

- protect our water (it’s easier than fixing it)
- algae can be a nuisance
- nutrients!
- solutions aren’t simple
- be a voice
- think like a scientist
- be smart
- citizen science

Thanks

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