Lake Manitou Area Association Meeting

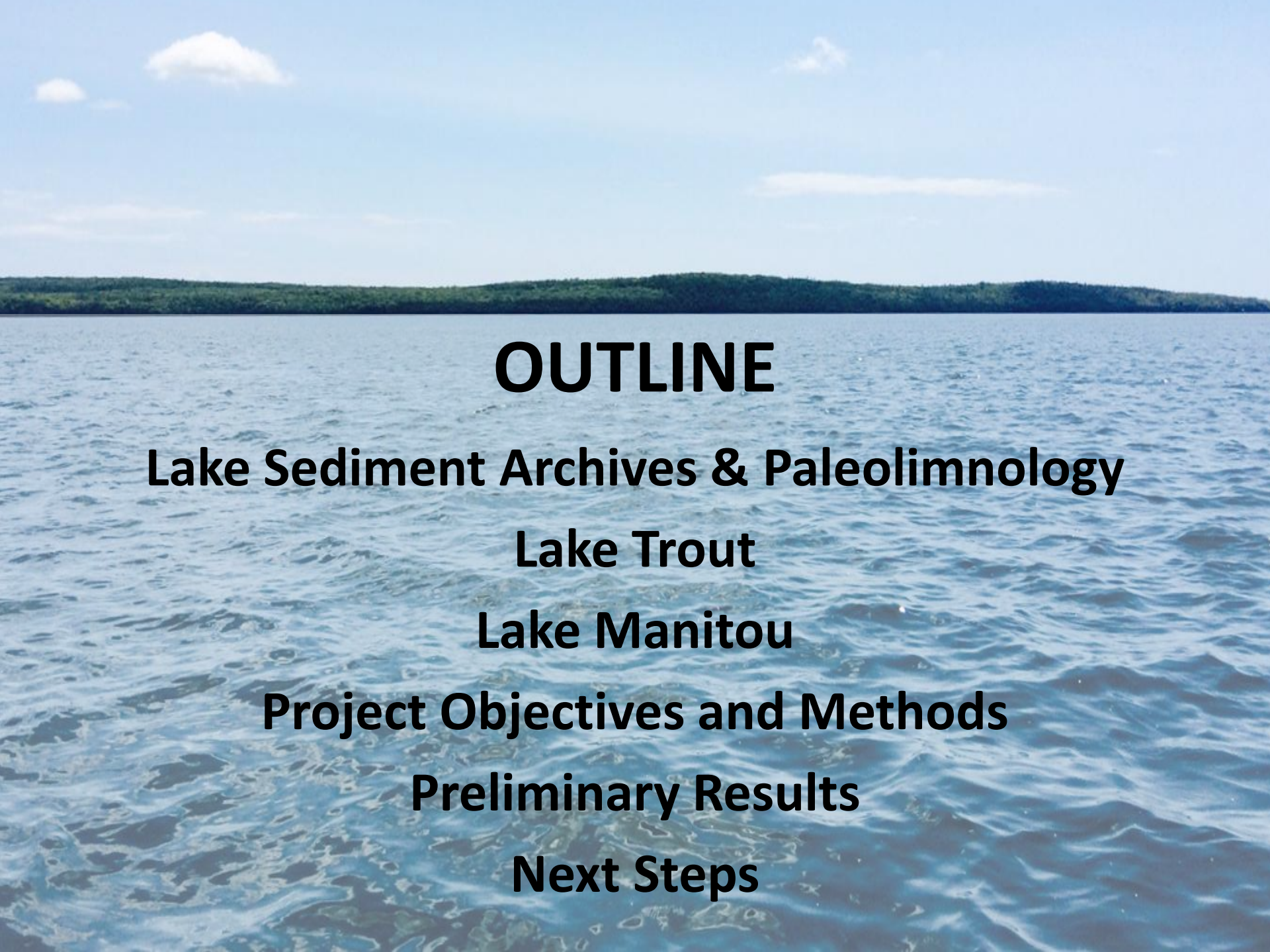
Understanding historic nutrient and oxygen conditions in Lake Manitou

Clare Nelligan, Adam Jeziorski, Kathleen M. Rühland,
Andrew M. Paterson, and John P. Smol

PEARL

August 8th, 2017

Queen's University



OUTLINE

Lake Sediment Archives & Paleolimnology

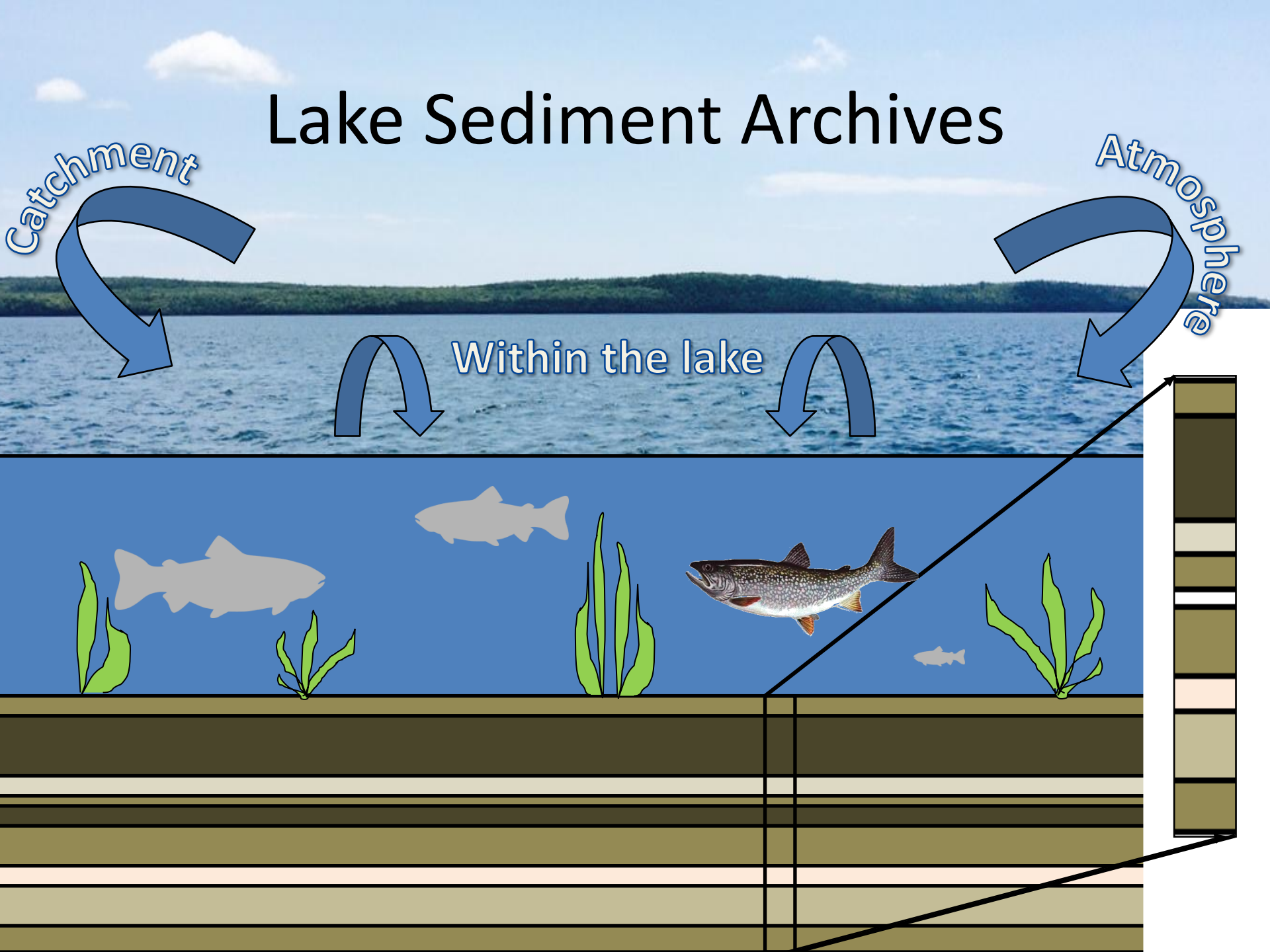
Lake Trout

Lake Manitou

Project Objectives and Methods

Preliminary Results

Next Steps


Lake Sediment Archives
Catchment
Atmosphere
Within the lake

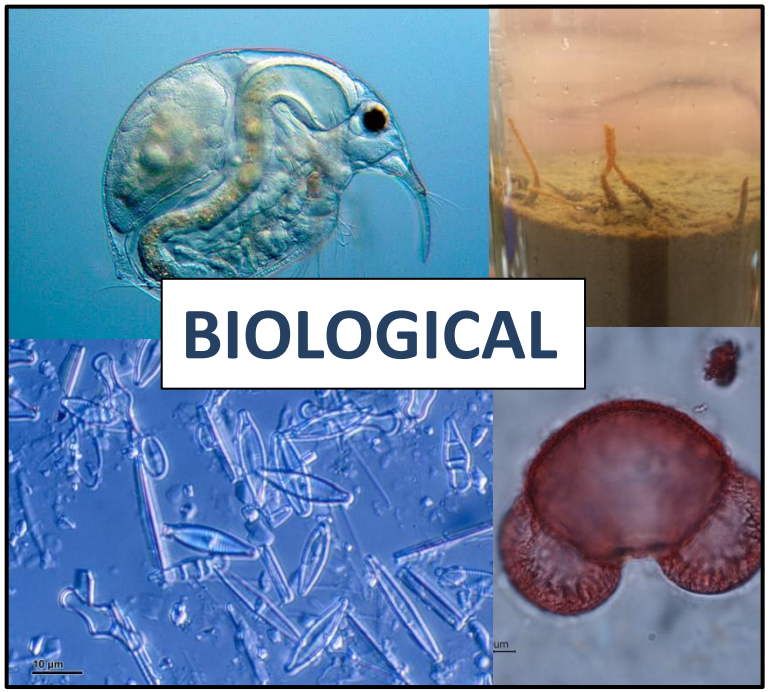
Paleolimnology

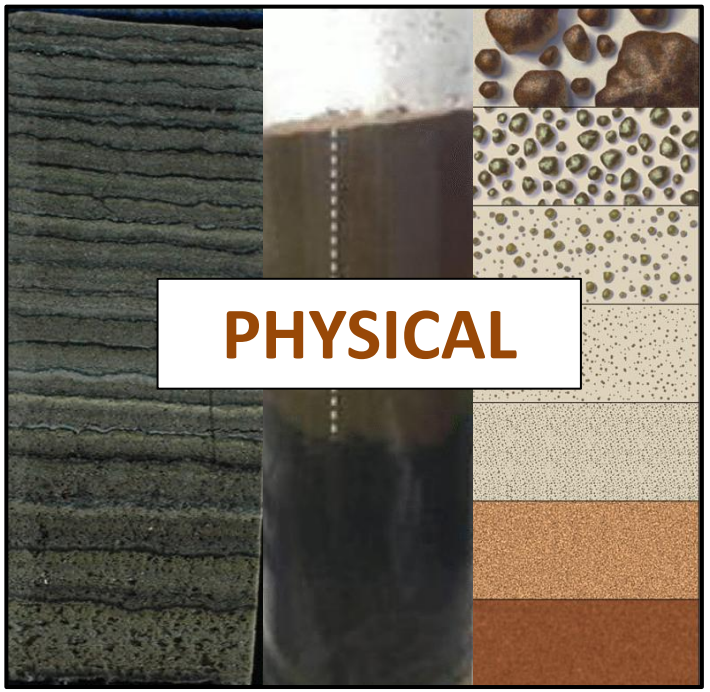
Greek: paleon=old, limne=lake, logos=study

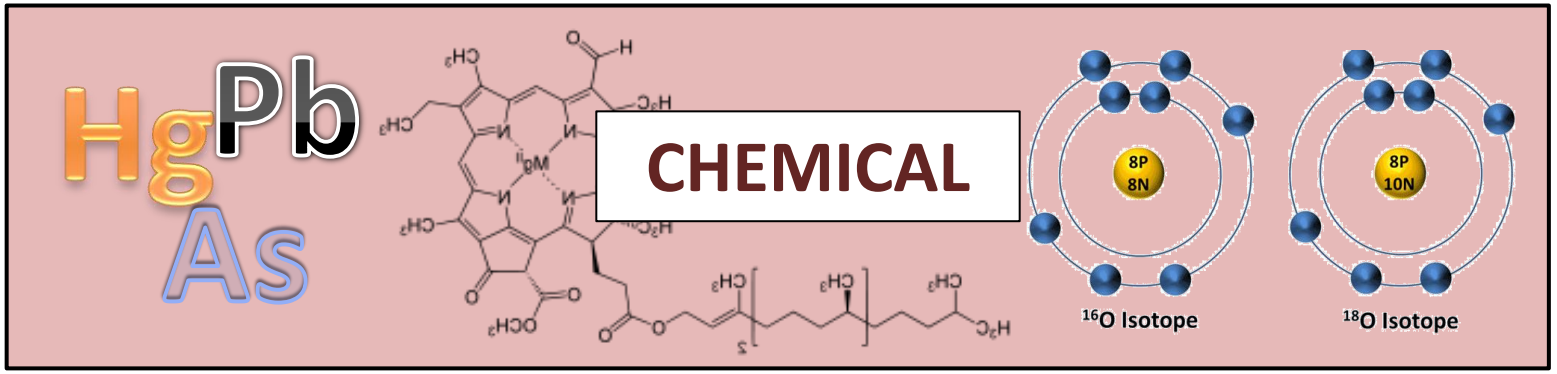
Study of the **BIOLOGICAL**, **CHEMICAL** and **PHYSICAL** indicators preserved in sediments

(Photo: K. Hargan)

Indicators in Lake Sediment

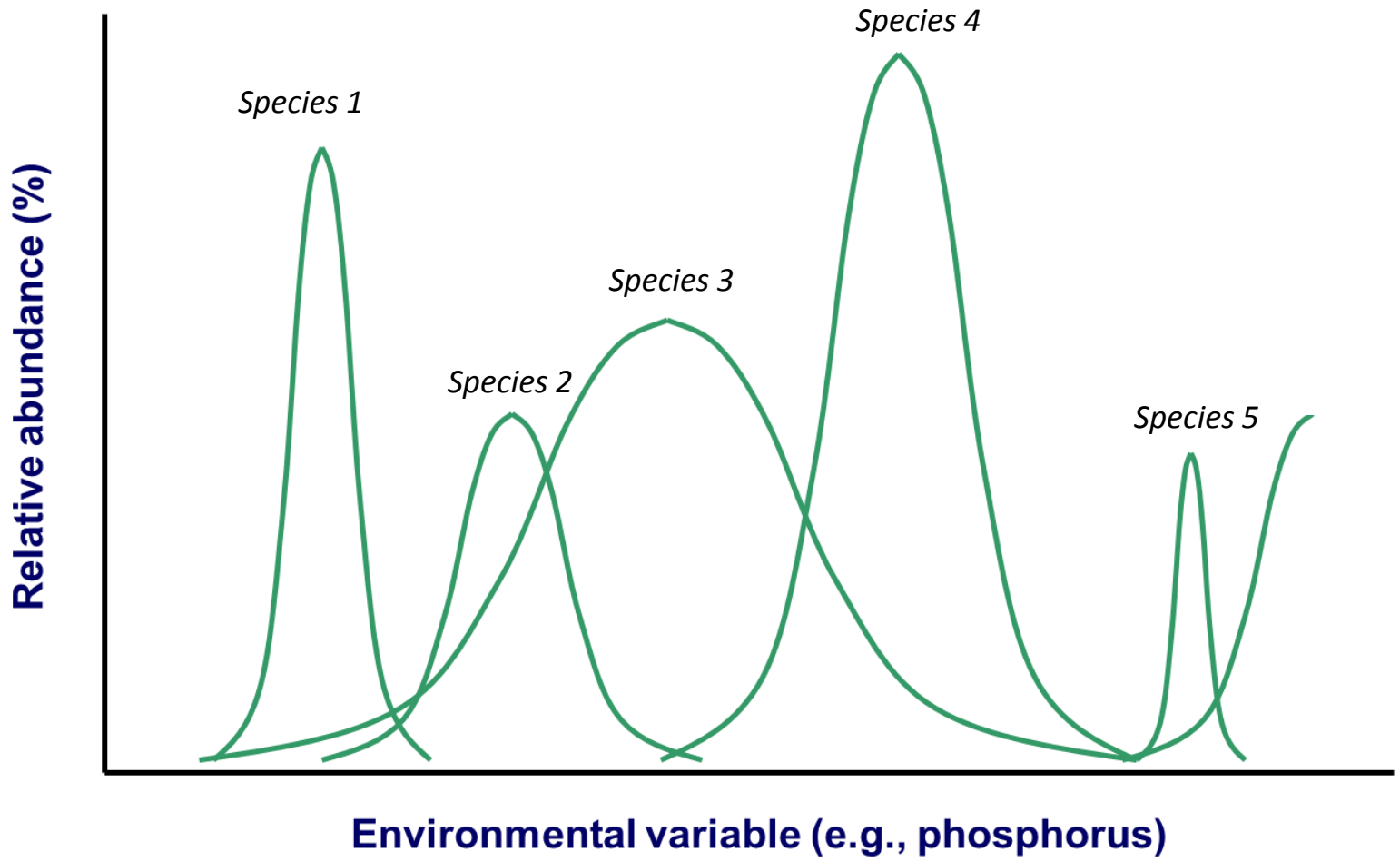






Indicators in Lake Sediments

We can infer past environments by understanding the conditions in which indicator species thrive

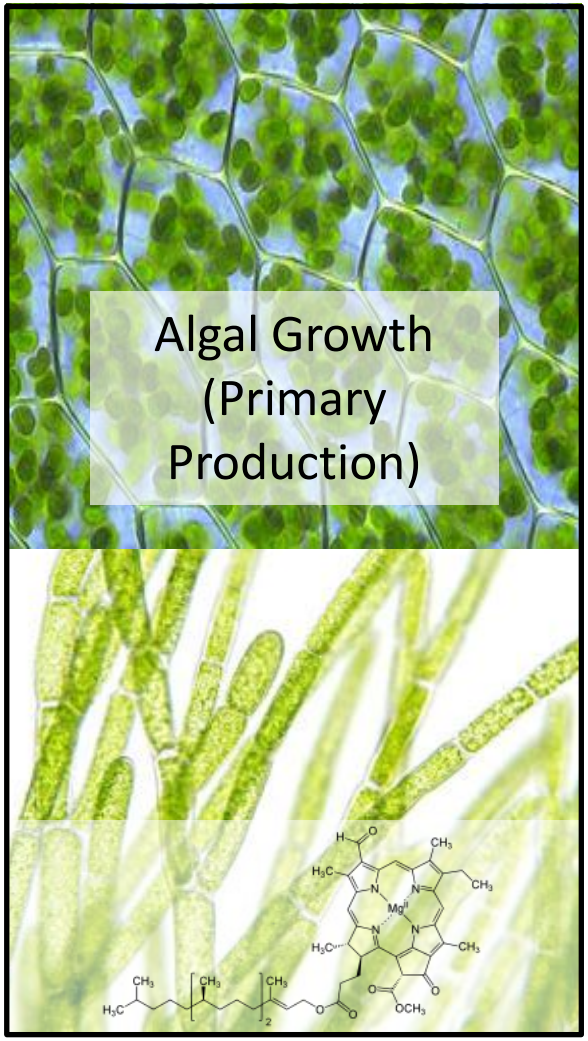


Indicators in Lake Sediments

Chironomids

Diatoms

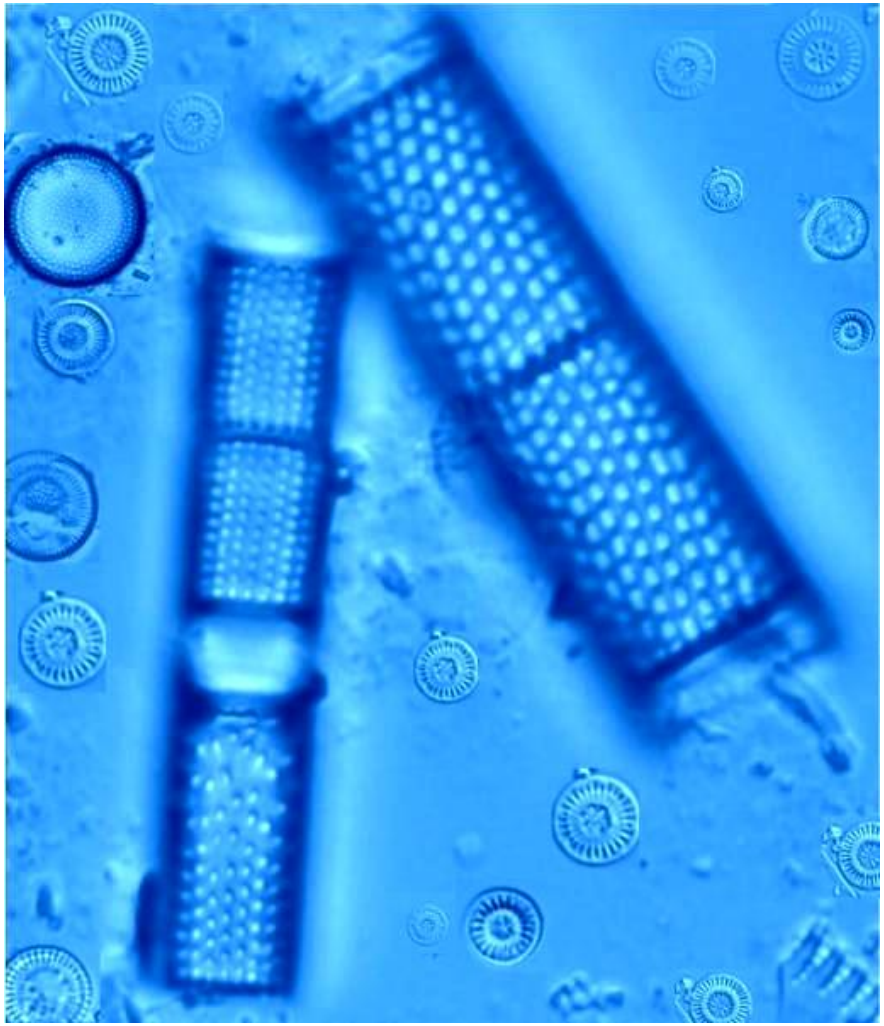
Chlorophyll-*a*



Indicators in Lake Sediments

DIATOMS

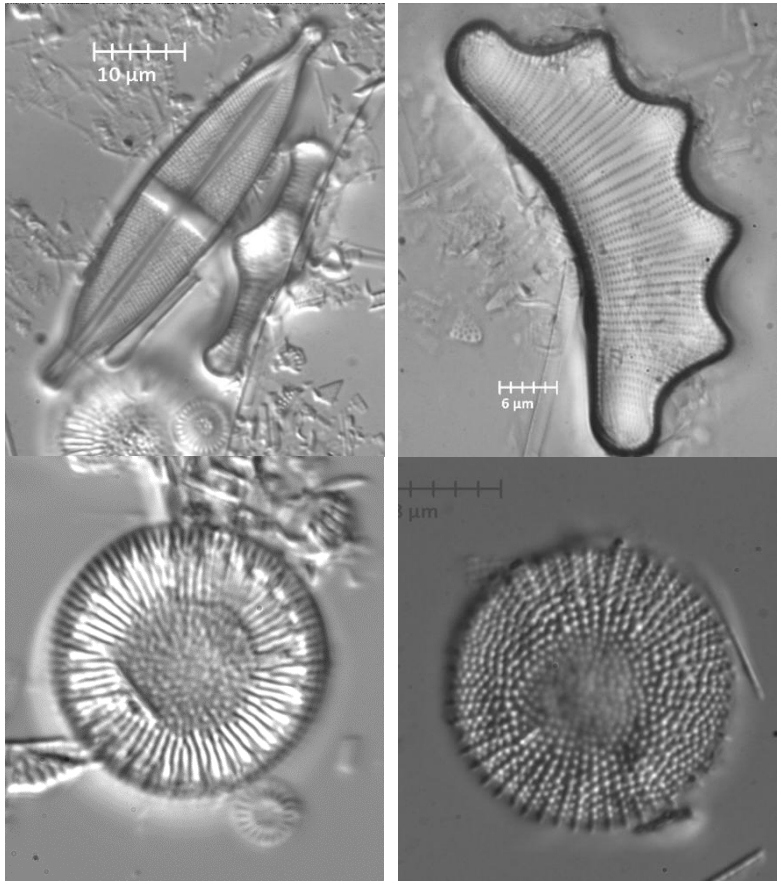
- Class of algae that leave “glass” valves preserved in sediments
- Sensitive to changes in their environment and live in well-defined conditions
- Can be used to investigate trends in climate and nutrients

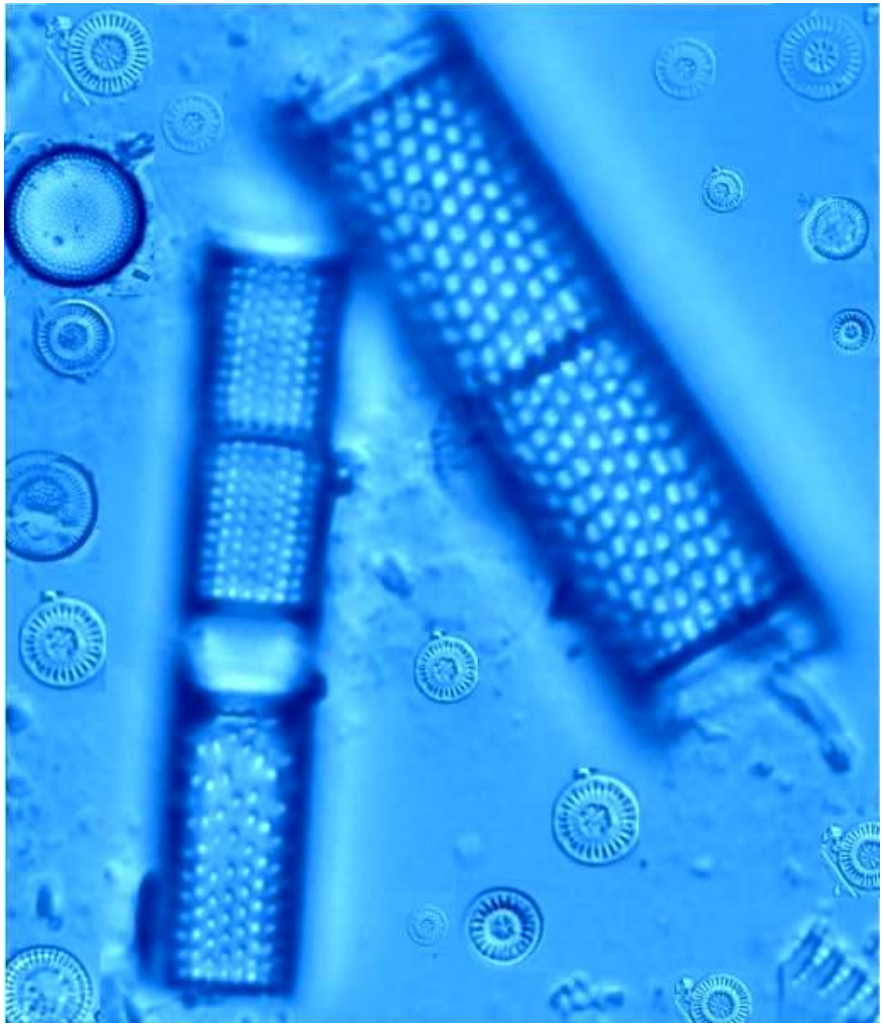


(Photo: K. Rühland)

Indicators in Lake Sediments

DIATOMS





(Photo: K. Rühland)

Indicators in Lake Sediments

CHIRONOMIDS

- Non-biting midges
- Aquatic larval stage
- Head capsules preserve well in sediments
- Good indicator of lake oxygen conditions


1

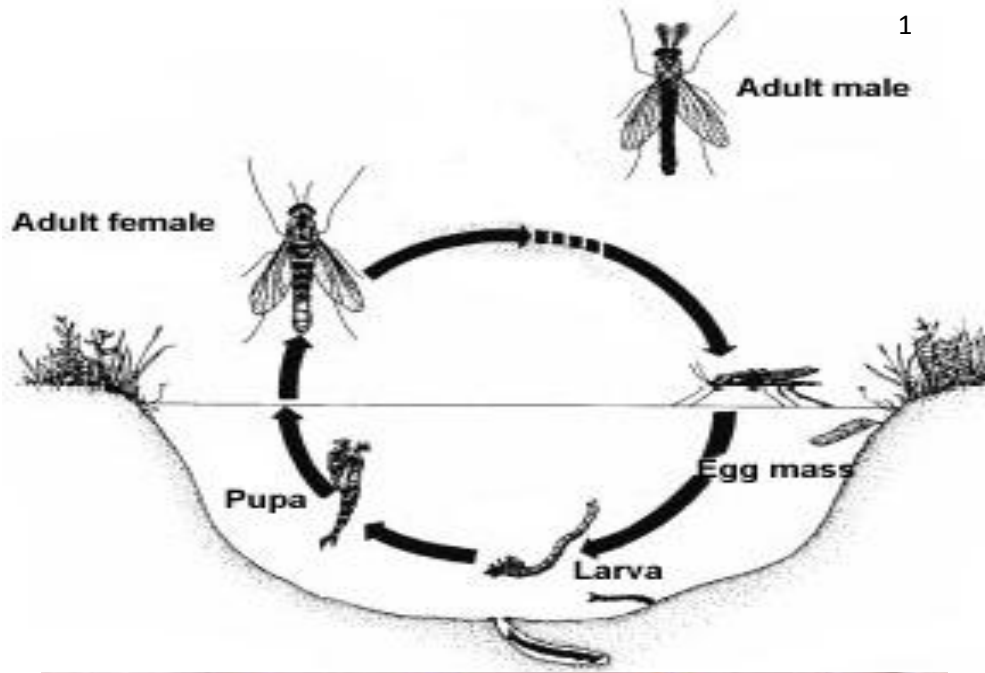

2

1) http://somethingscrawlinginmyhair.com/2011/08/13/swarming-midge/ 2) http://www.flyfishersrepublic.com/tactics/chironomid-tactics/

Indicators in Lake Sediments

CHIRONOMIDS

- Non-biting midges
- Aquatic larval stage
- Head capsules preserve well in sediments
- Good indicator of lake oxygen conditions

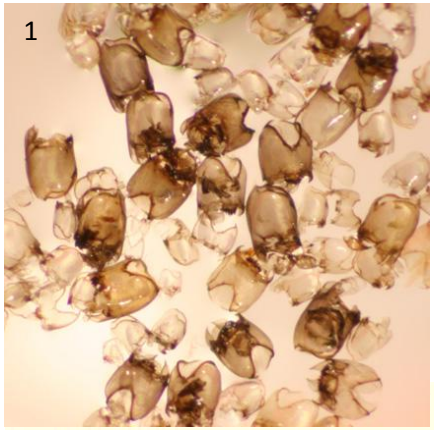


1) https://www.ces.ncsu.edu/depts/ent/notes/Urban/midges.htm 2) http://www.flyfishersrepublic.com/tactics/chironomid-tactics/

Indicators in Lake Sediments

CHIRONOMIDS

- Non-biting midges
- Aquatic larval stage
- Head capsules preserve well in sediments
- Good indicator of lake oxygen conditions



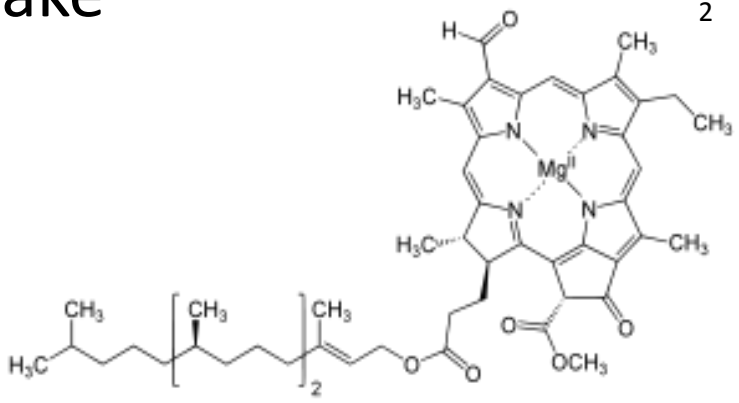
1)https://ecologyofthepast.info/2012/05/11/the-mighty-midge/ 2) http://www.earth.northwestern.edu/~yarrow/research.html 3) http://post.queensu.ca/~pearl/PNAS2005.htm
4) http://www.flyfishersrepublic.com/tactics/chironomid-tactics/

Indicators in Lake Sediments

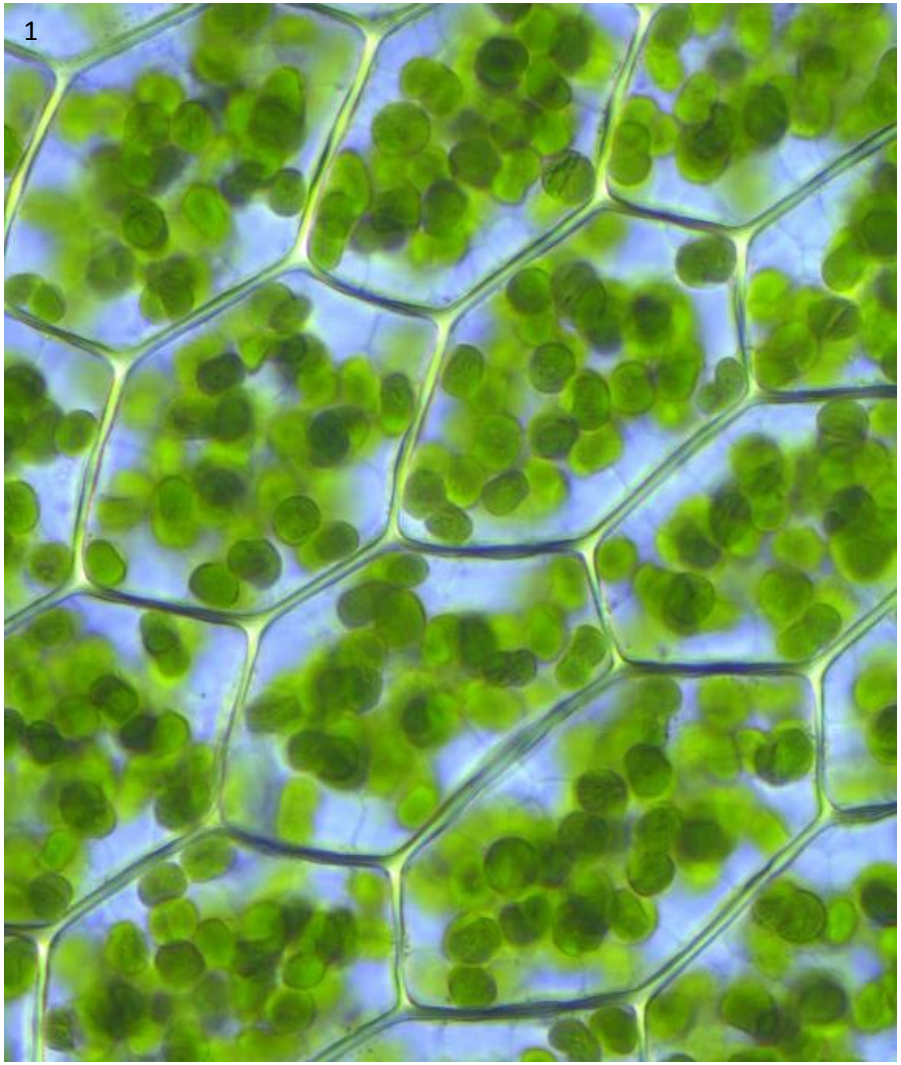
CHOROPHYLL-*a*

- Pigment found in all plants and algae
- Indicates how much algal matter is growing in the lake

2



1



1) https://en.wikipedia.org/wiki/Chlorophyll, 2) http://katieclare.co.uk/2013/05/omega-3-vegans-eating-fish/

Lake Trout in Ontario

- Rare and valuable resource
  - Present in ~1% of Ontario's 250,000 lakes
  - Ontario contains 20-25% of all Lake Trout lakes worldwide
- Important to recreational fisheries

http://www.hookhack.com/html/fom020113_laketrout.html

Habitat Requirements

Warm Surface Waters

Usable: < 15 °C, Lethal: > 23.5 °C

Cold Bottom Water

Usable: > 4 mg O_2 /L, Lethal: < 3 mg O_2 /L

Evans et al. (1991)

Habitat Requirements

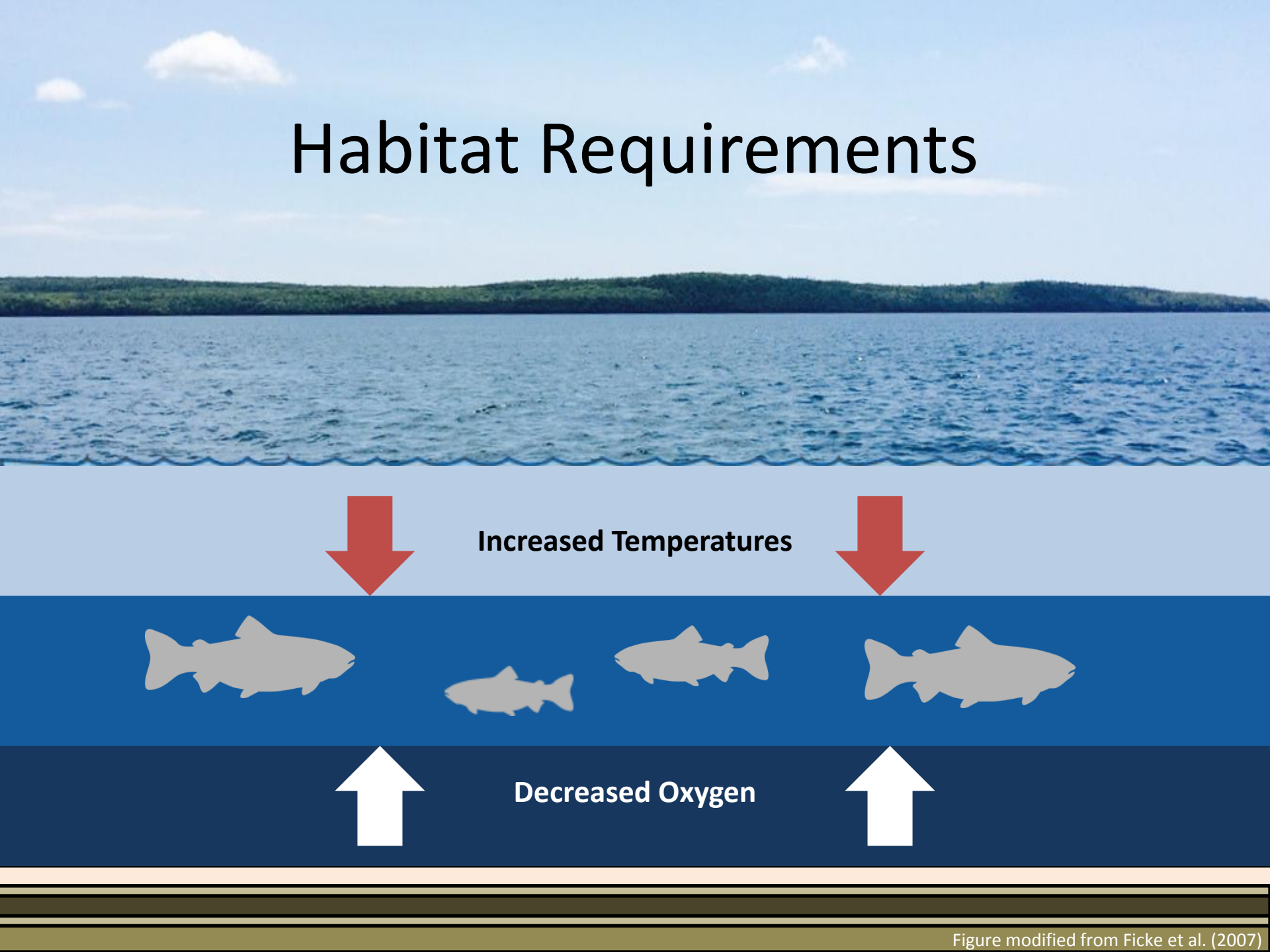
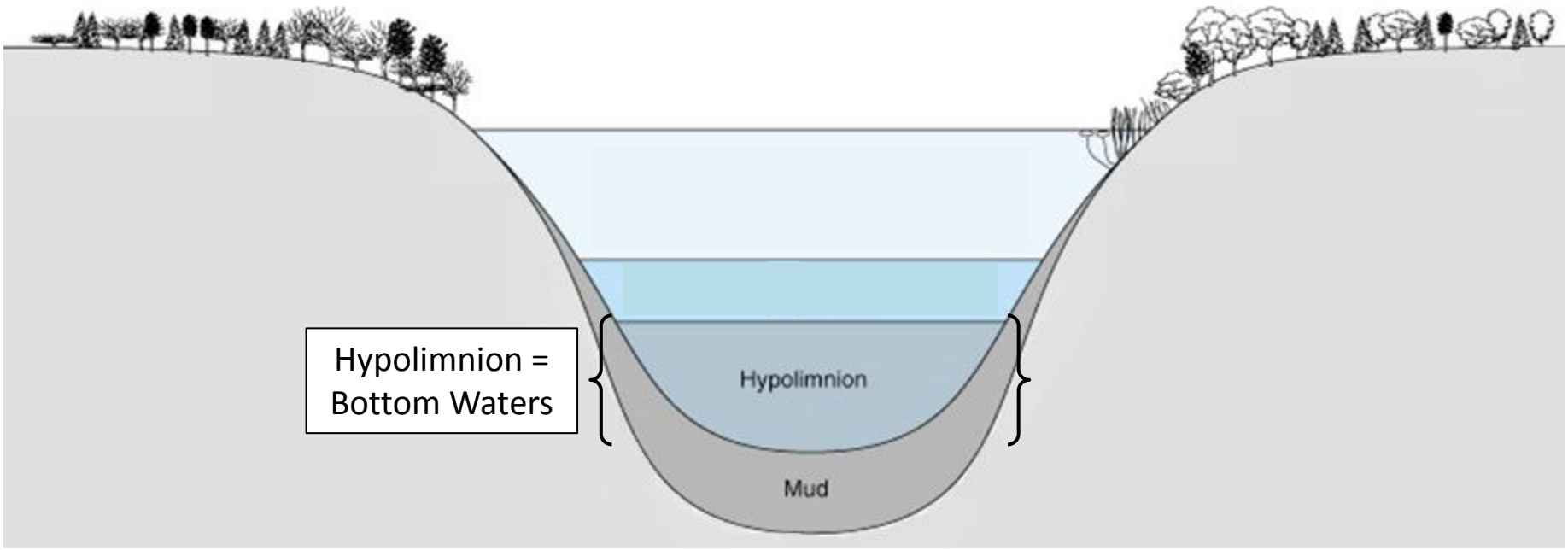


Figure modified from Ficke et al. (2007)

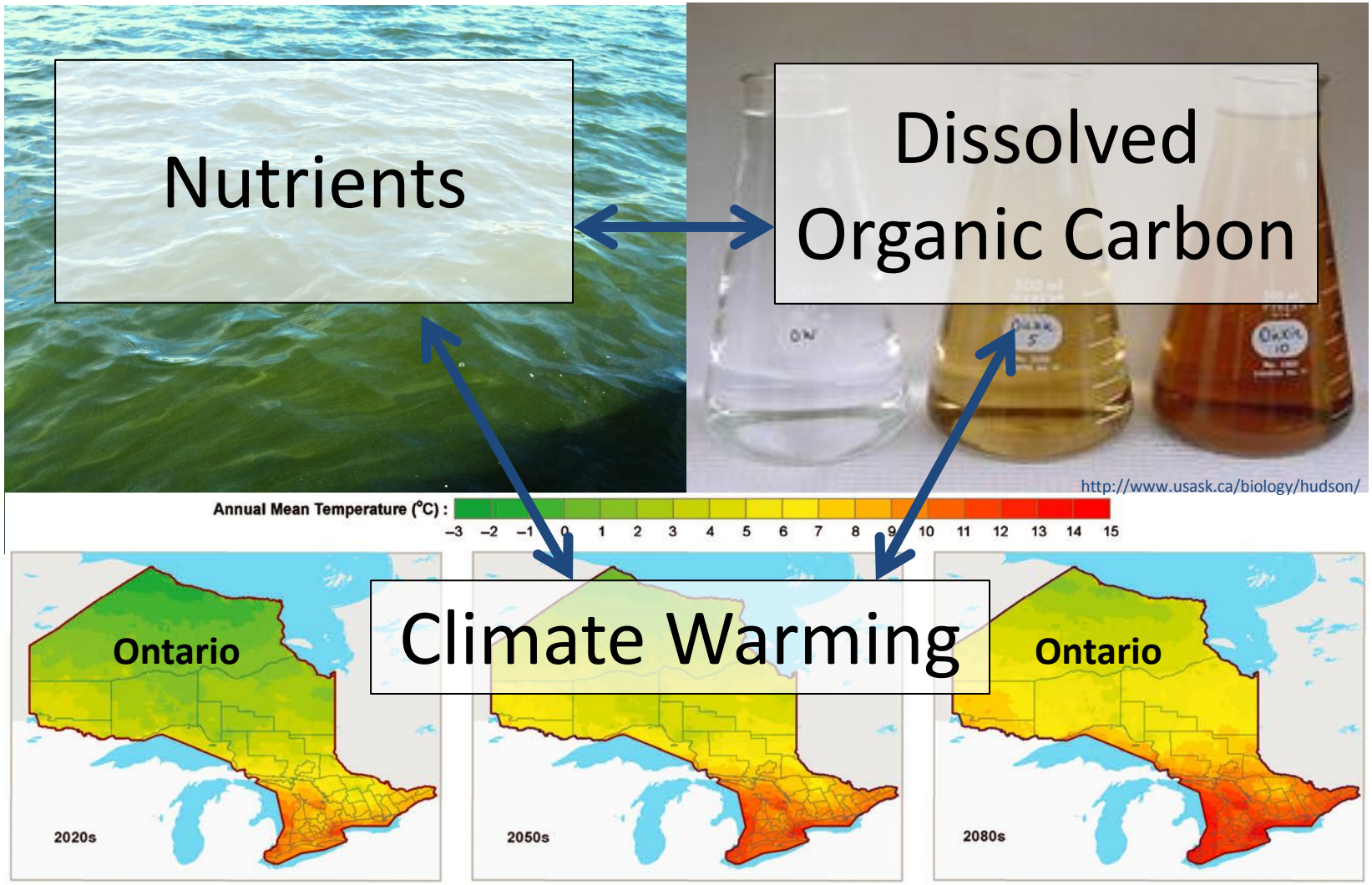
Volume Weighted Hypolimnetic Oxygen



Provincial standard for end-of-summer VWHO in a lake that sustains Lake Trout: > 7 mg/L (Evans et al. 2007)

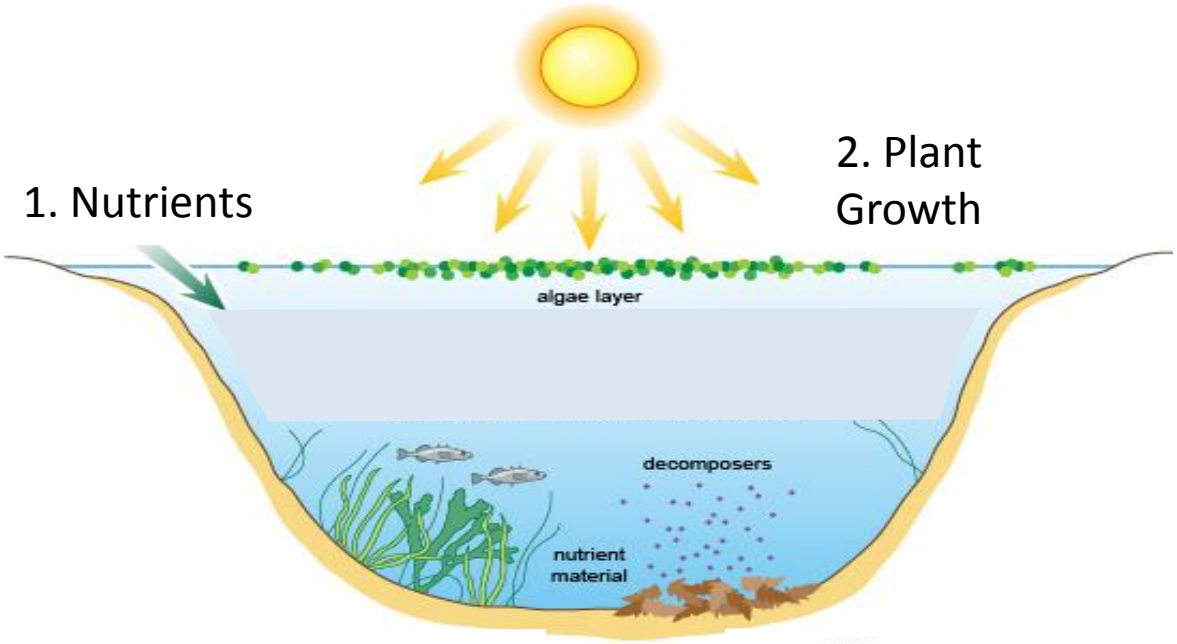
http://alexturner01.weebly.com/aquatic-ecosystem.html

Variables that Influence Hypolimnetic Dissolved Oxygen



(Figure: Wang et al. 2014)

Increased Nutrients = Decreased Oxygen

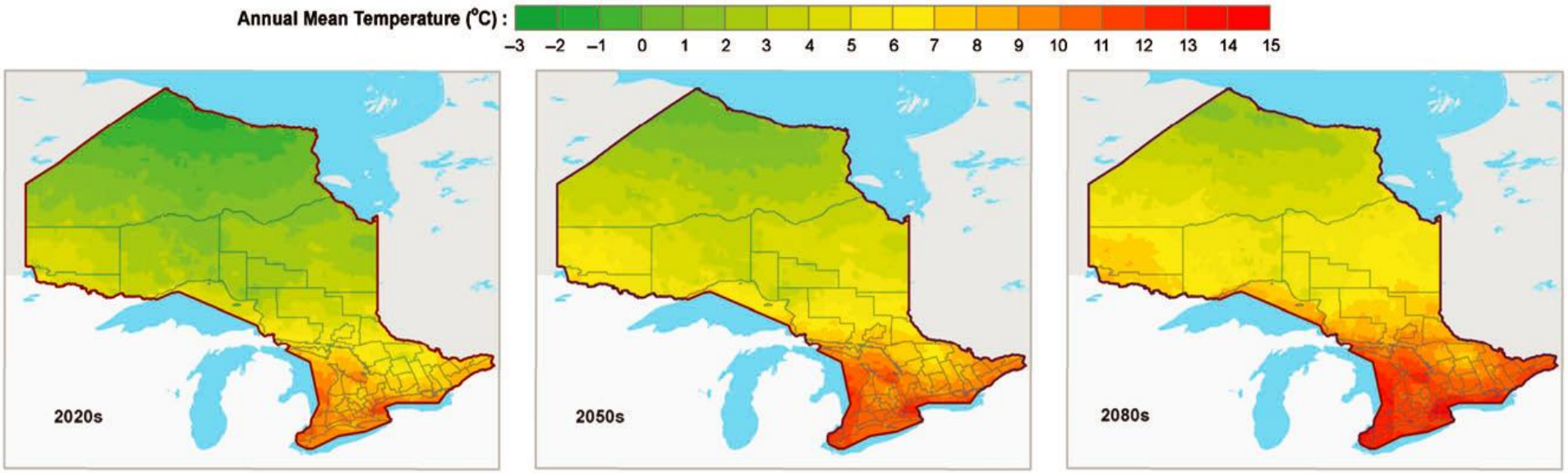


3. Decomposition depletes O_2

Sources: Runoff from agricultural and urban areas, atmospheric deposition, septic systems, decaying organic matter, soil erosion

http://www.bbc.co.uk/schools/gcsebitesize/science/edexcel/problems_in_environment/pollutionrev4.shtml

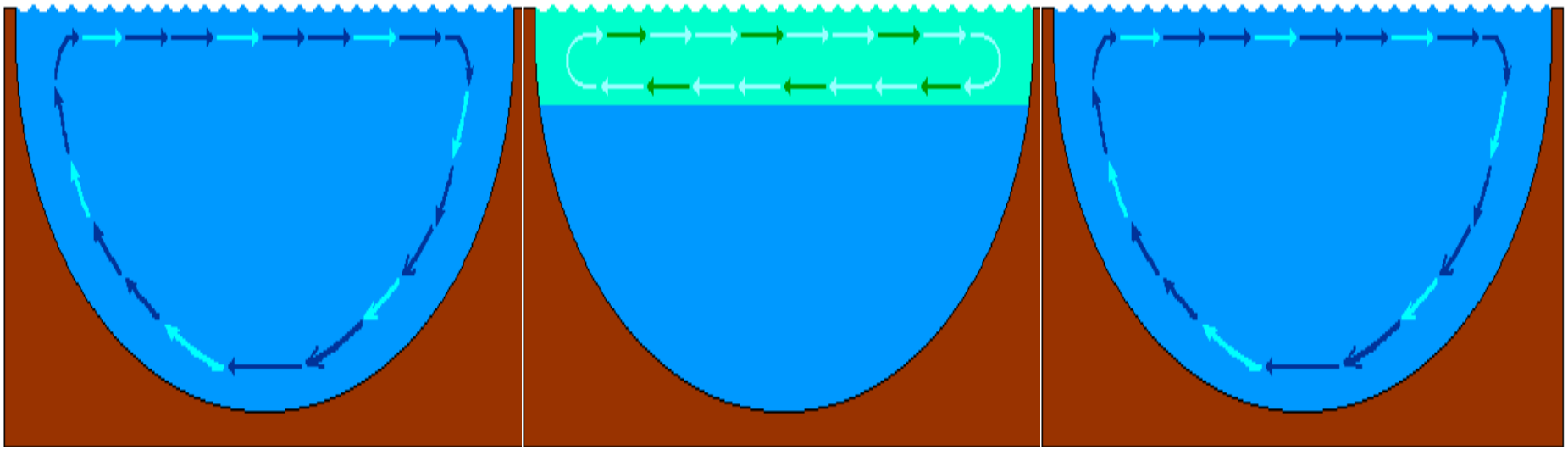
Increased Warming = Decreased Oxygen



(Figure: Wang et al. 2014)

Climate warming can indirectly influence bottom water oxygen by altering the thermal structure within a lake

Increased Warming = Decreased Oxygen

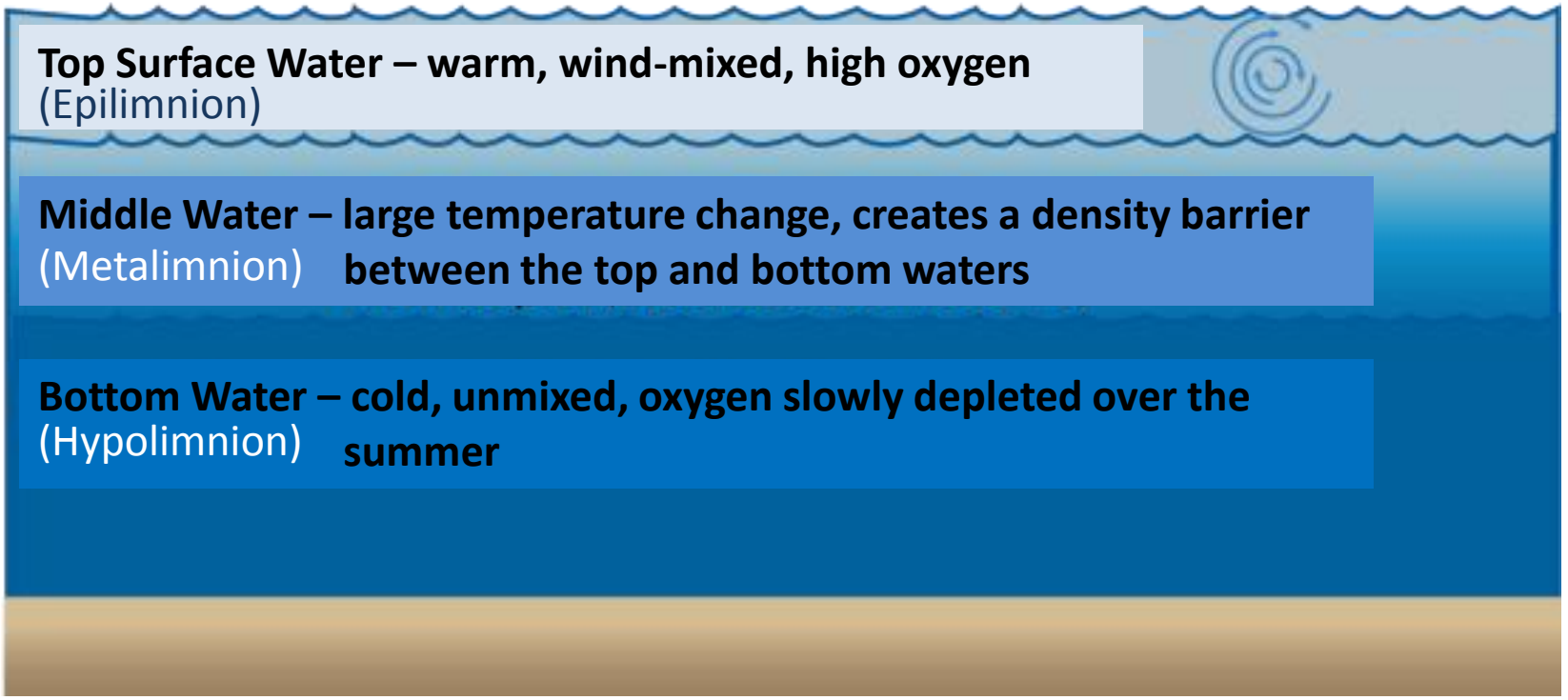


Spring **Summer** **Fall**

Climate warming can indirectly influence bottom water oxygen by altering the thermal structure within a lake

http://faculty.gvsu.edu/videticp/stratification.htm

Increased Warming = Decreased Oxygen

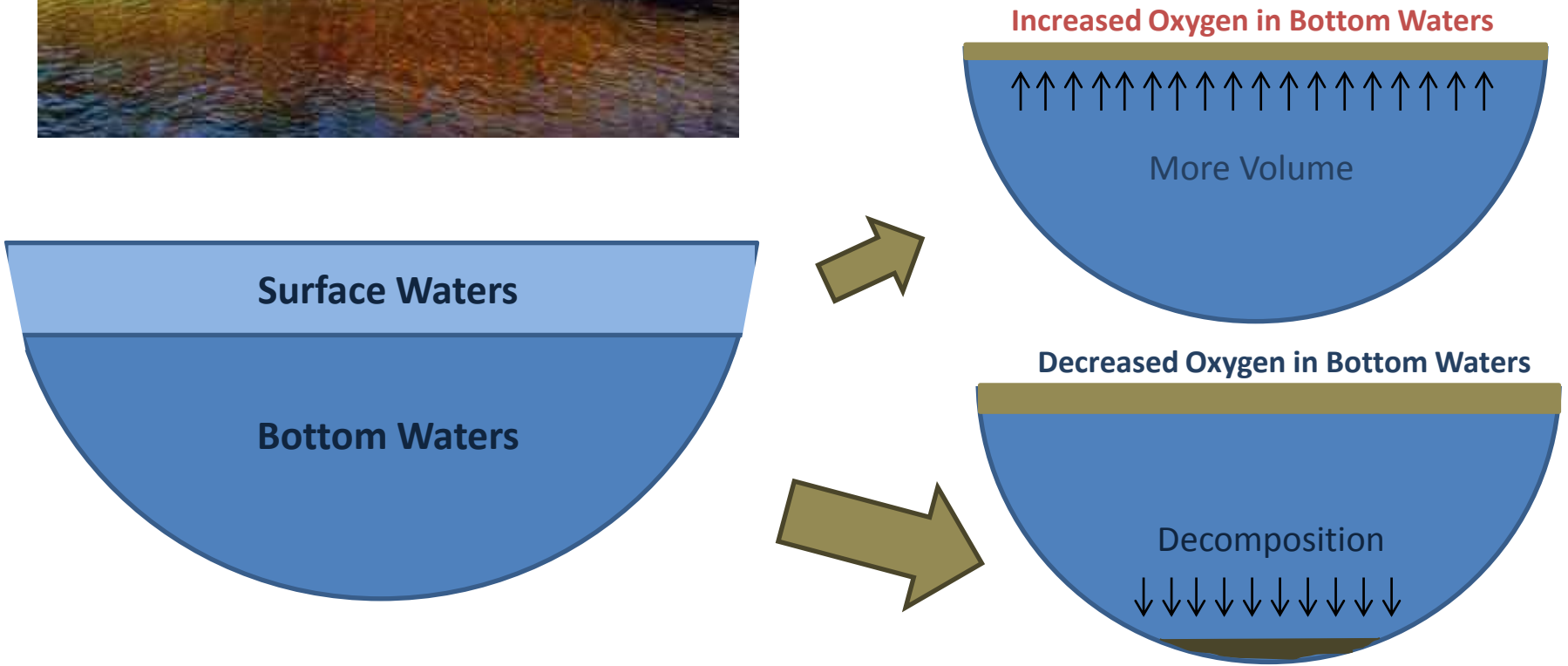


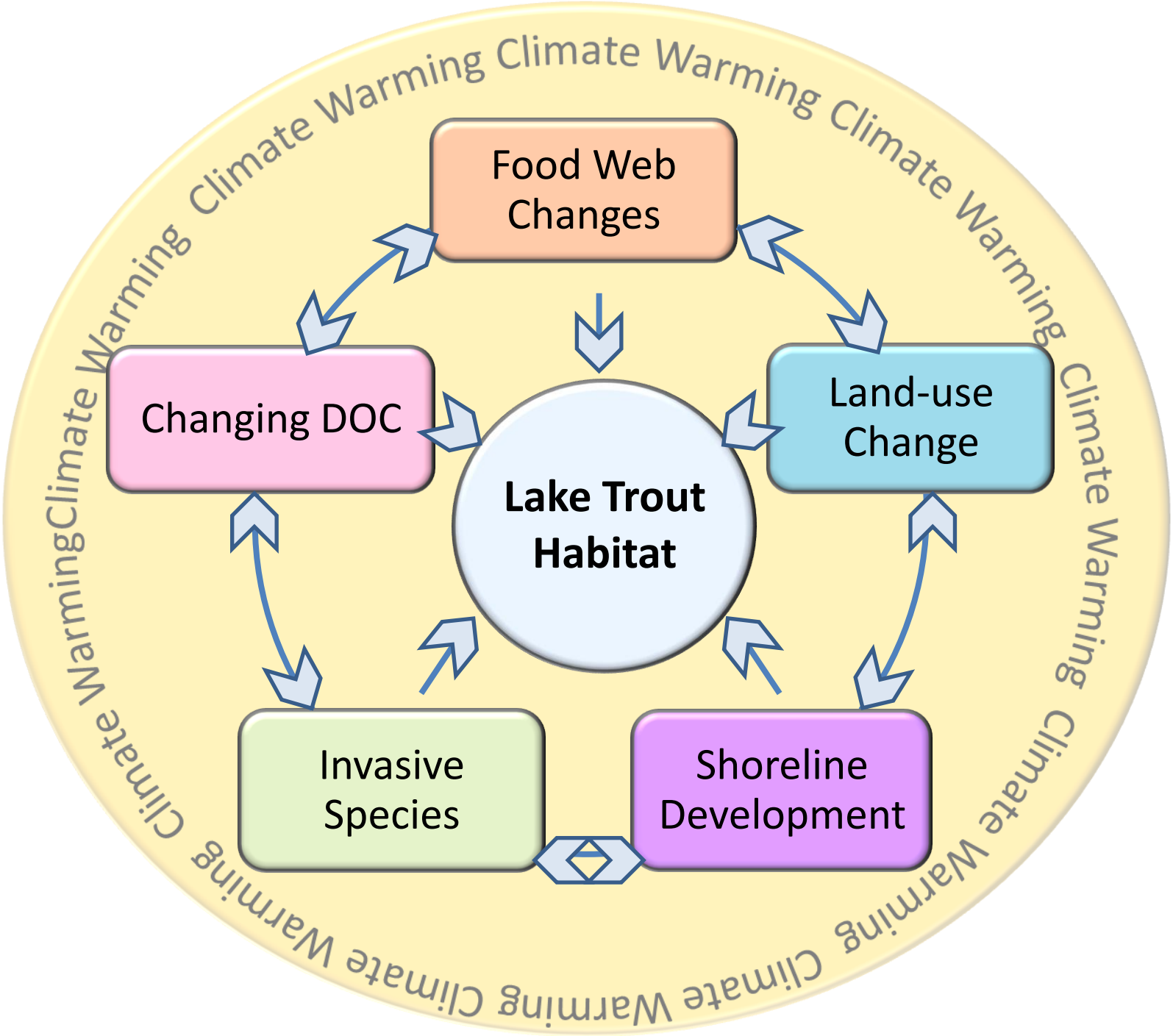
Climate warming can lead to longer and stronger periods of stratification = greater oxygen depletion

Modified from: http://nchsapes.pbworks.com/w/page/6971044/Freshwater%20Zone%204

Increased Dissolved Organic Carbon = Increased or Decreased Oxygen

- Dissolved organic carbon (DOC) gives water brown colouring
- From the terrestrial environment, wetlands, groundwater, and living organisms in the lake

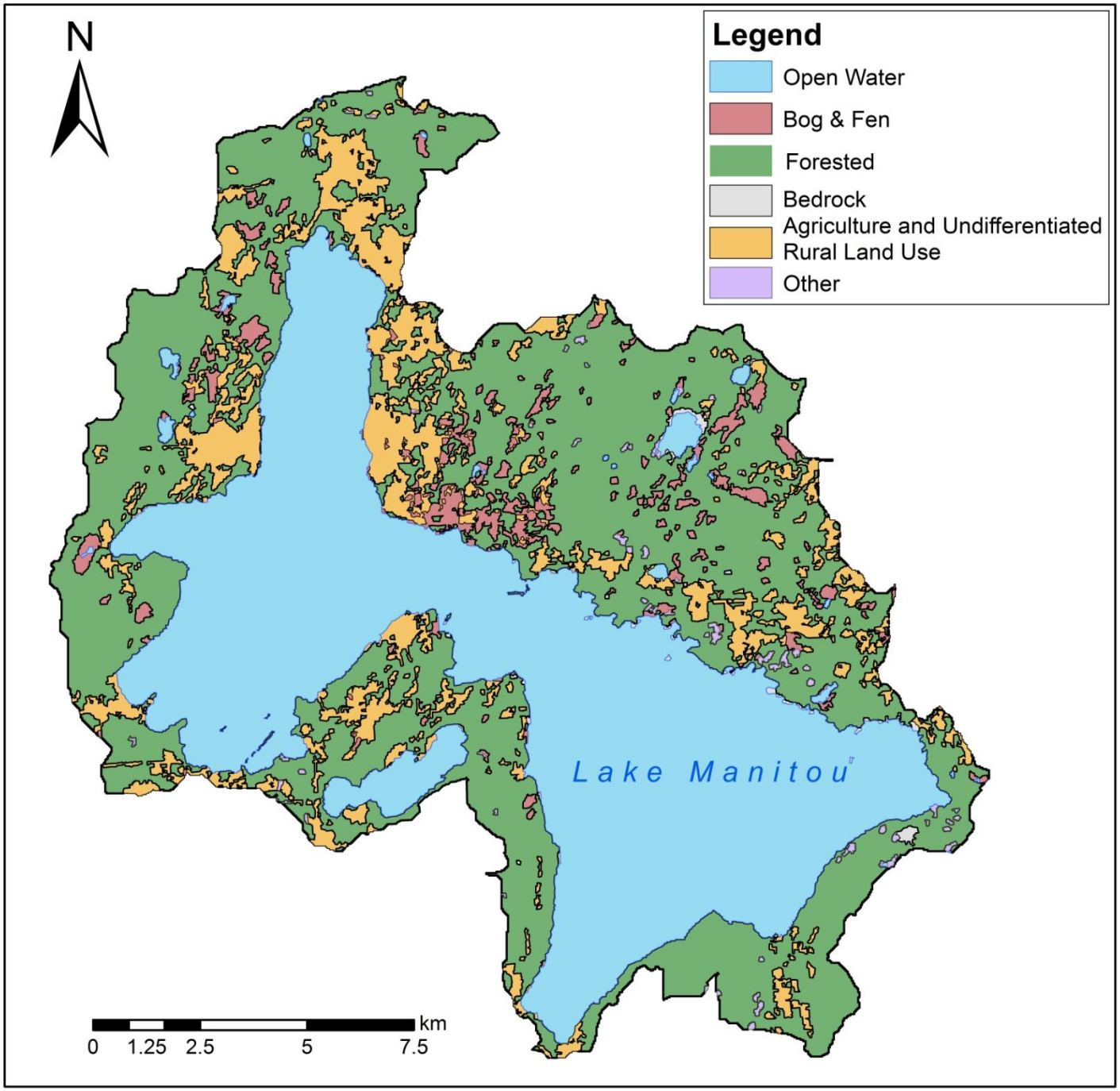



Climate Warming Climate Warming Climate Warming Climate Warming Climate Warming Climate Warming Climate Warming Climate Warming
Food Web Changes
Changing DOC
Land-use Change
Lake Trout Habitat
Invasive Species
Shoreline Development

Lake Manitou

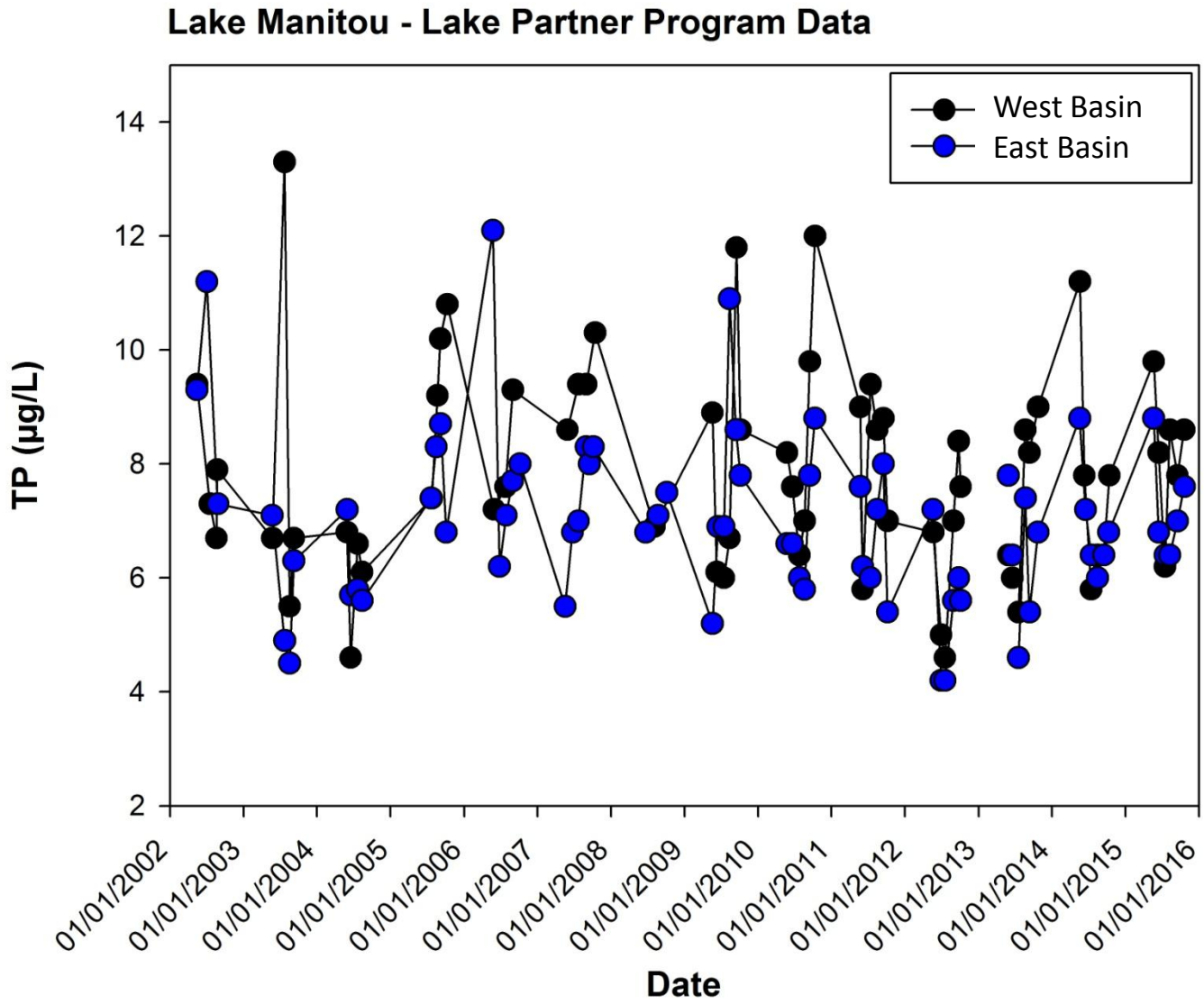
- Lake trout population and hatchery – stocked since the 1950s (Henderson 1982)
- Lake trout reared from Lake Manitou strains are used to stock hard-water inland lakes in Ontario (OMNRF 1999)

(August 2016)



(Ontario Flow Assessment Tools III, MNRF)

Lake Partner Program – Total Phosphorus (TP) Monitoring Data

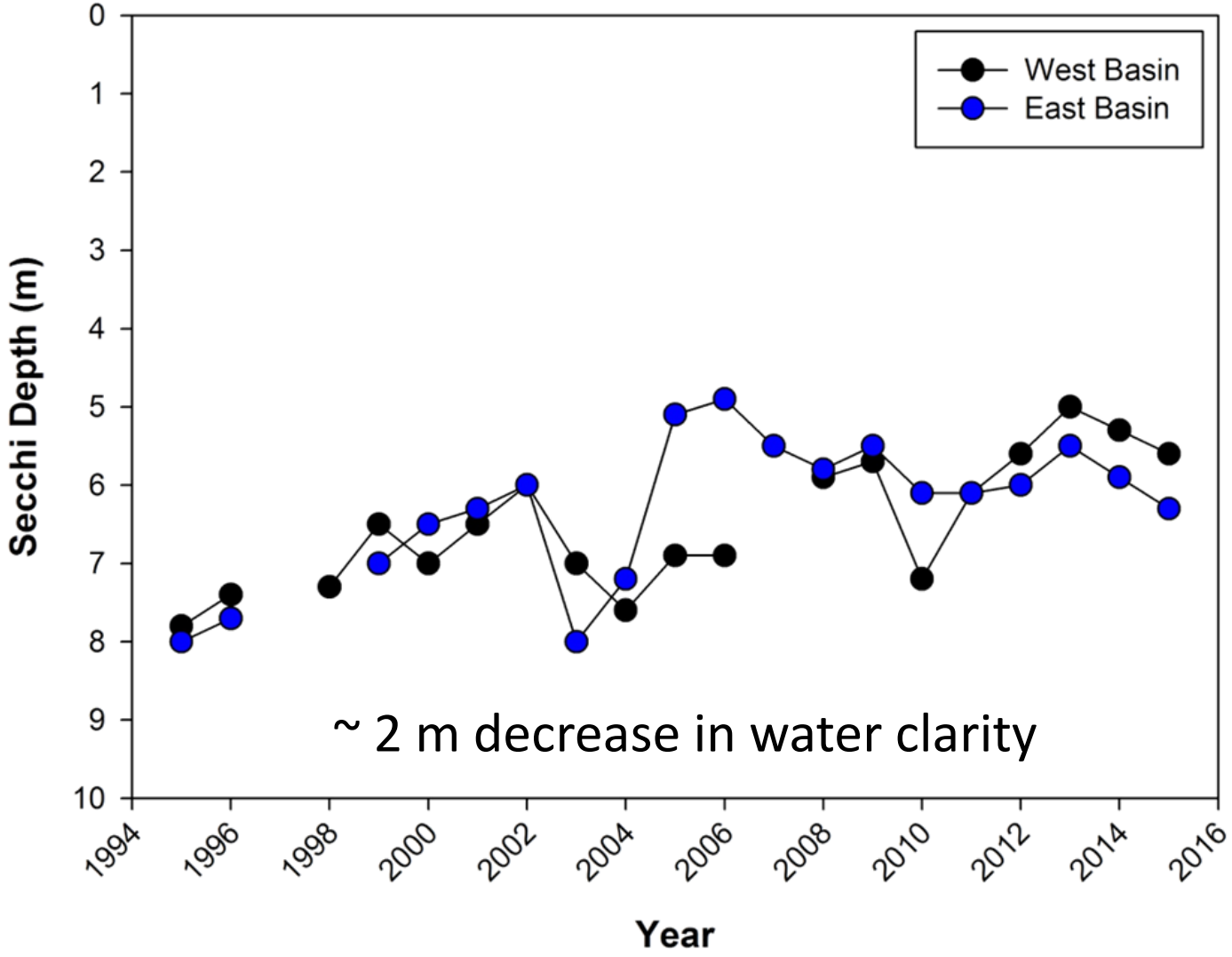


No clear trend in monitored TP since 2002

Large seasonal variability

TP often higher in the West Basin

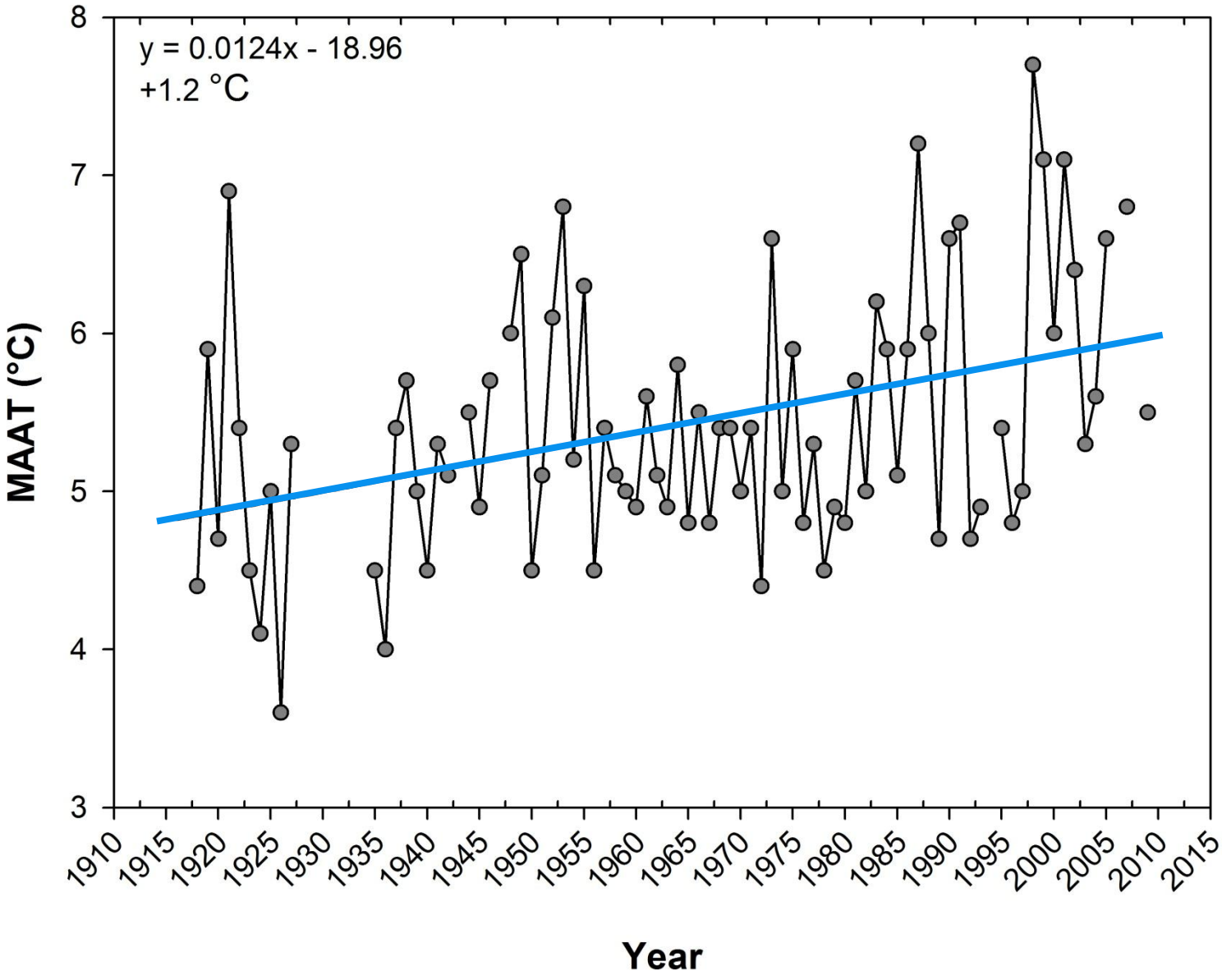
Lake Partner Program – Water Clarity Data



Variables that can influence water clarity:

- Amount of algae in the lake
- Dissolved organic carbon (DOC)
- Turbidity

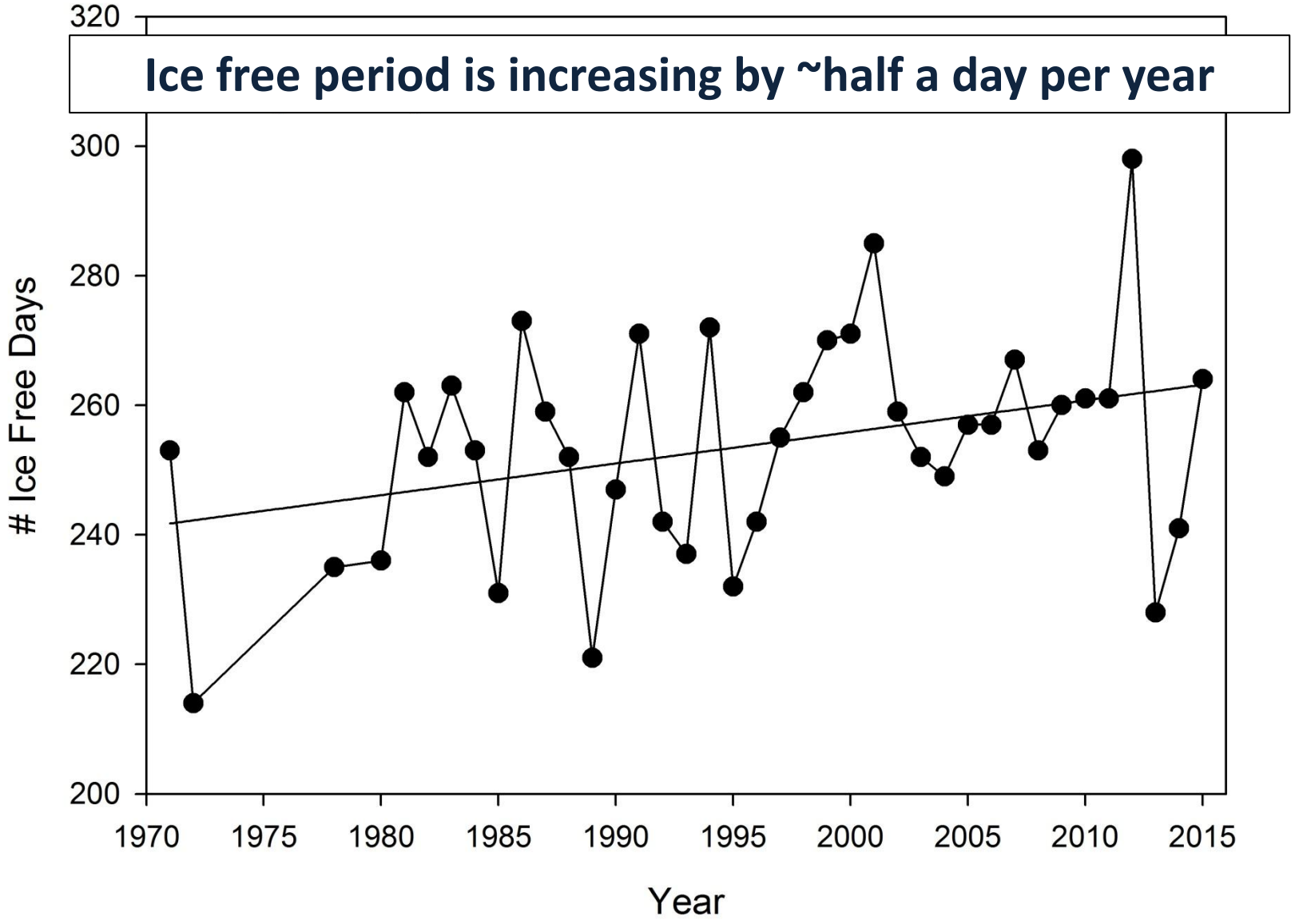
Gore Bay Climate Station



Seasonal temperatures increase at different rates

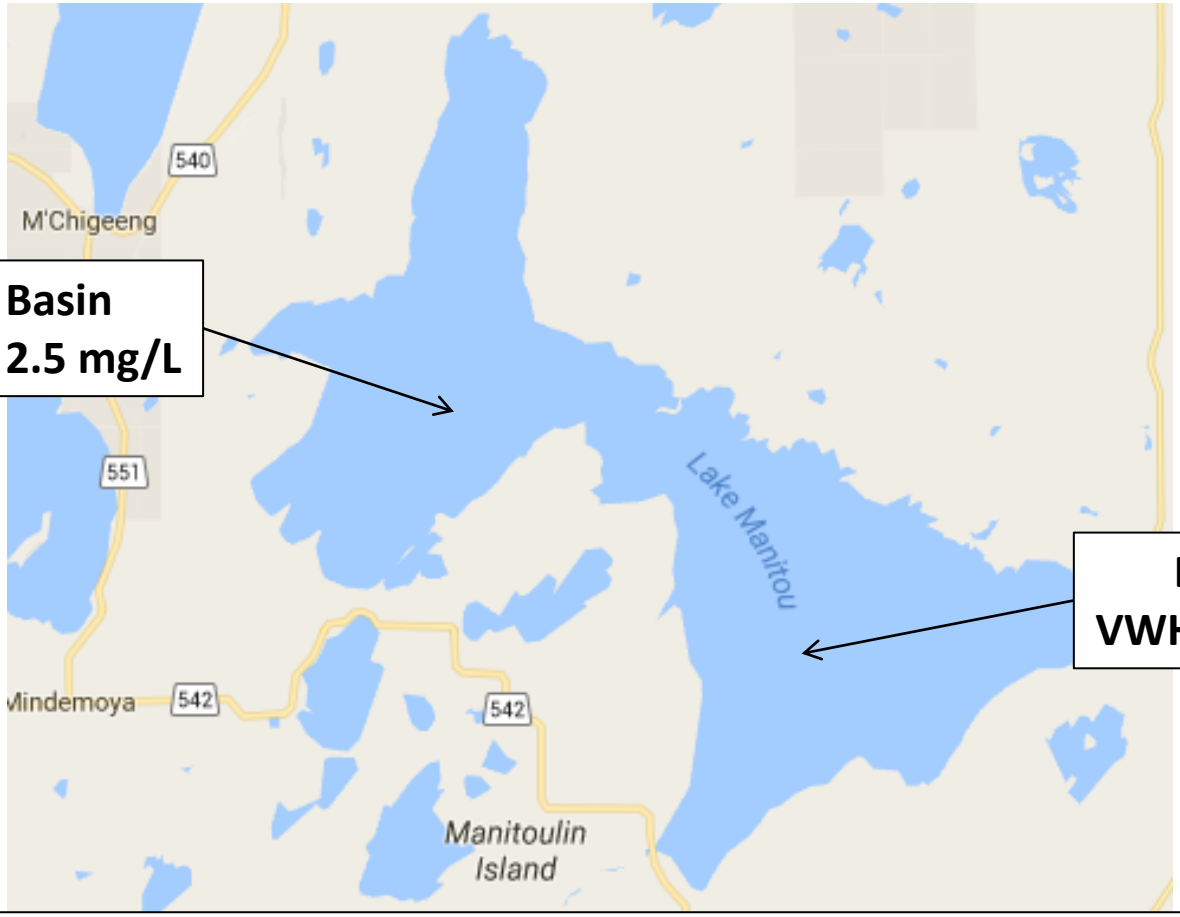
The largest increases have occurred during the winter and spring

Ice Free Period



(Ice records from Betty & Doug Heis)

End-of-Summer Oxygen in Lake Manitou



Both basins were below the provincial standard for end-of-summer oxygen concentration in a Lake Trout lake between 2007-2011

Lake was listed as “at capacity” in 2013 – development restricted within 300 m of shoreline

(Data collected by MNRF)

Research Questions

- Why are end-of-summer DO concentrations in Lake Manitou so low?
- Are the low end-of-summer DO values a recent development, or is this a persistent feature of Lake Manitou?
- Are the low DO concentrations the result of a particular event or environmental stressor (climate/nutrients)?
- What is the timing of the onset of these stressors?

What can be done?

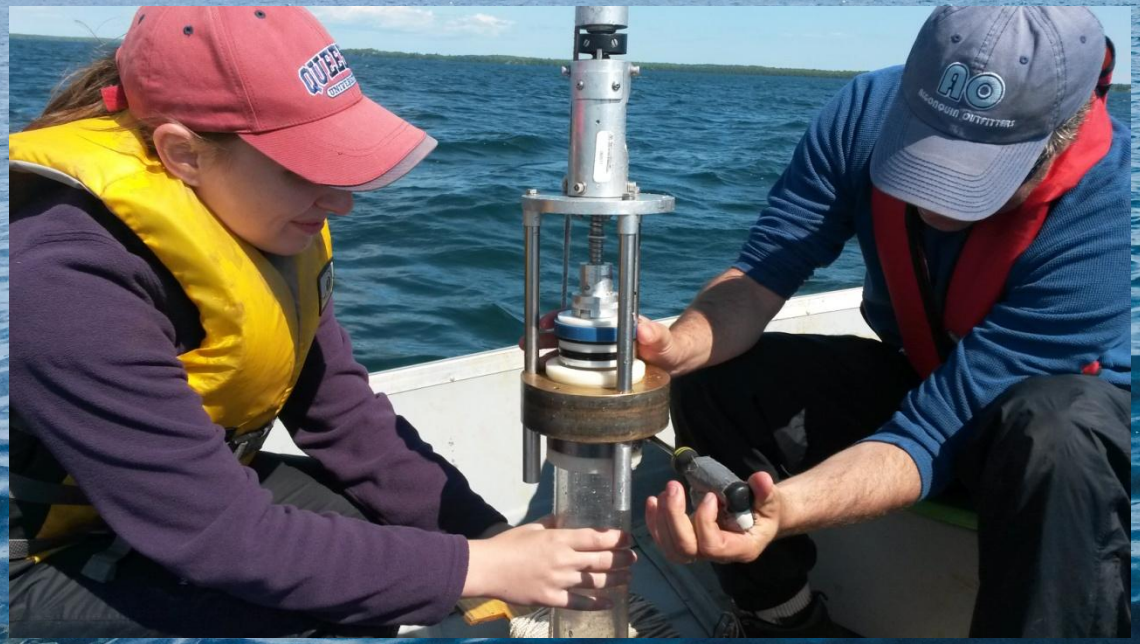
Objectives

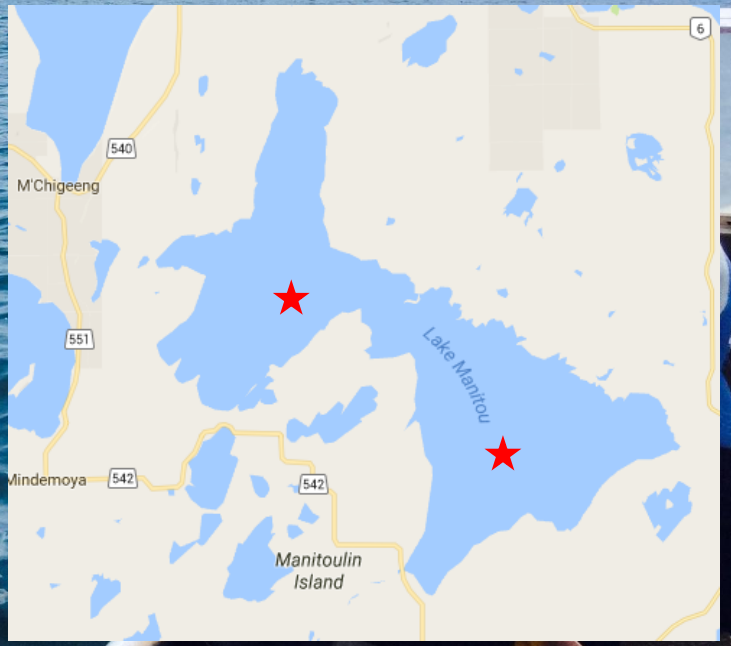
To understand past environmental conditions in Lake Manitou using lake sediments

1. Use fossil diatom assemblages to assess the influence of nutrients and climate warming
2. Use sedimentary chlorophyll-*a* to assess trends in primary production
3. Use chironomid remains to reconstruct past deep-water oxygen conditions

Fieldwork

Sediment cores were collected from both the East Basin (June 2015) and the West Basin (August 2016)



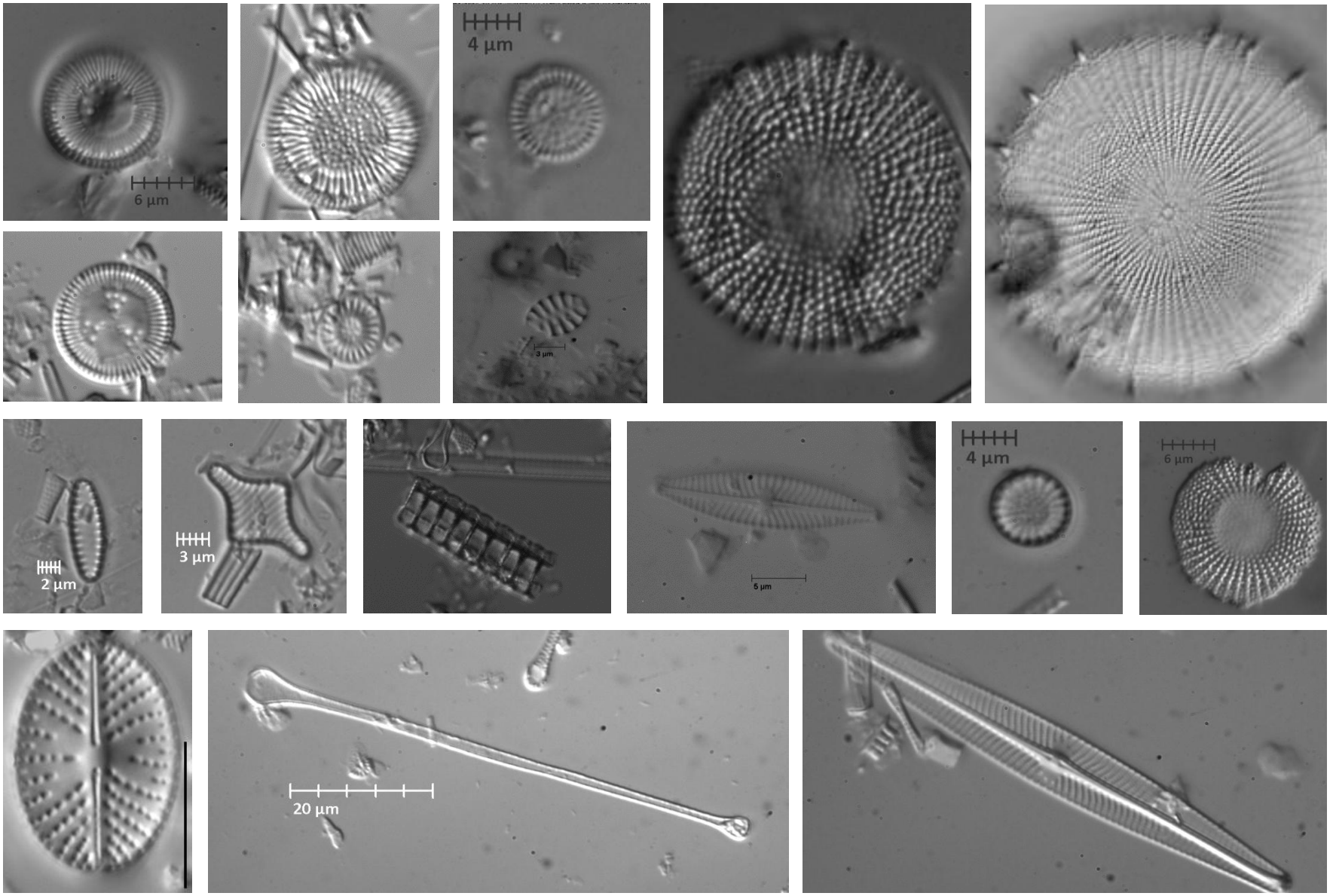


Fieldwork

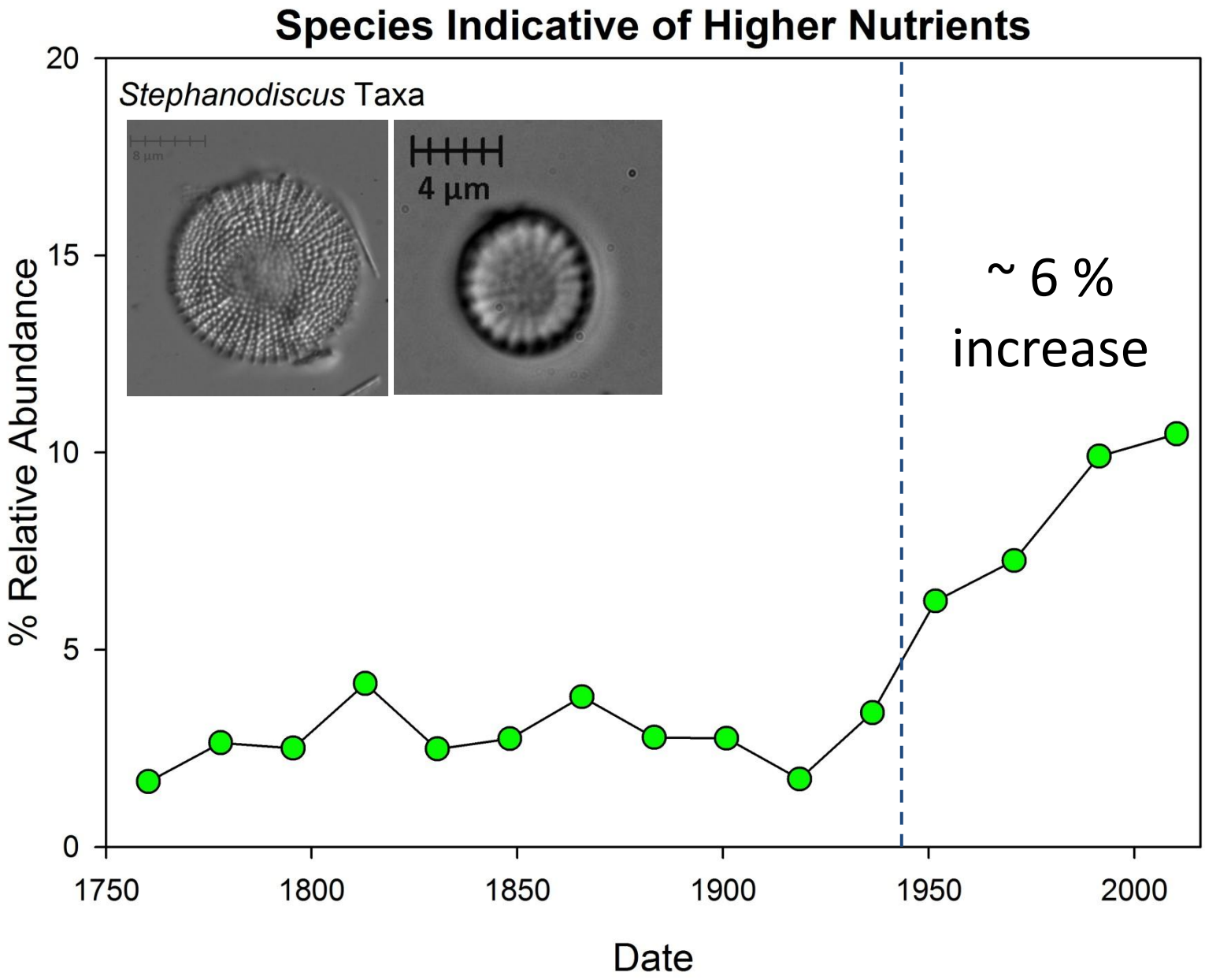
Sediment cores were collected from both the East Basin (June 2015) and the West Basin (August 2016)

Both cores were sectioned into 0.5 cm intervals and dated

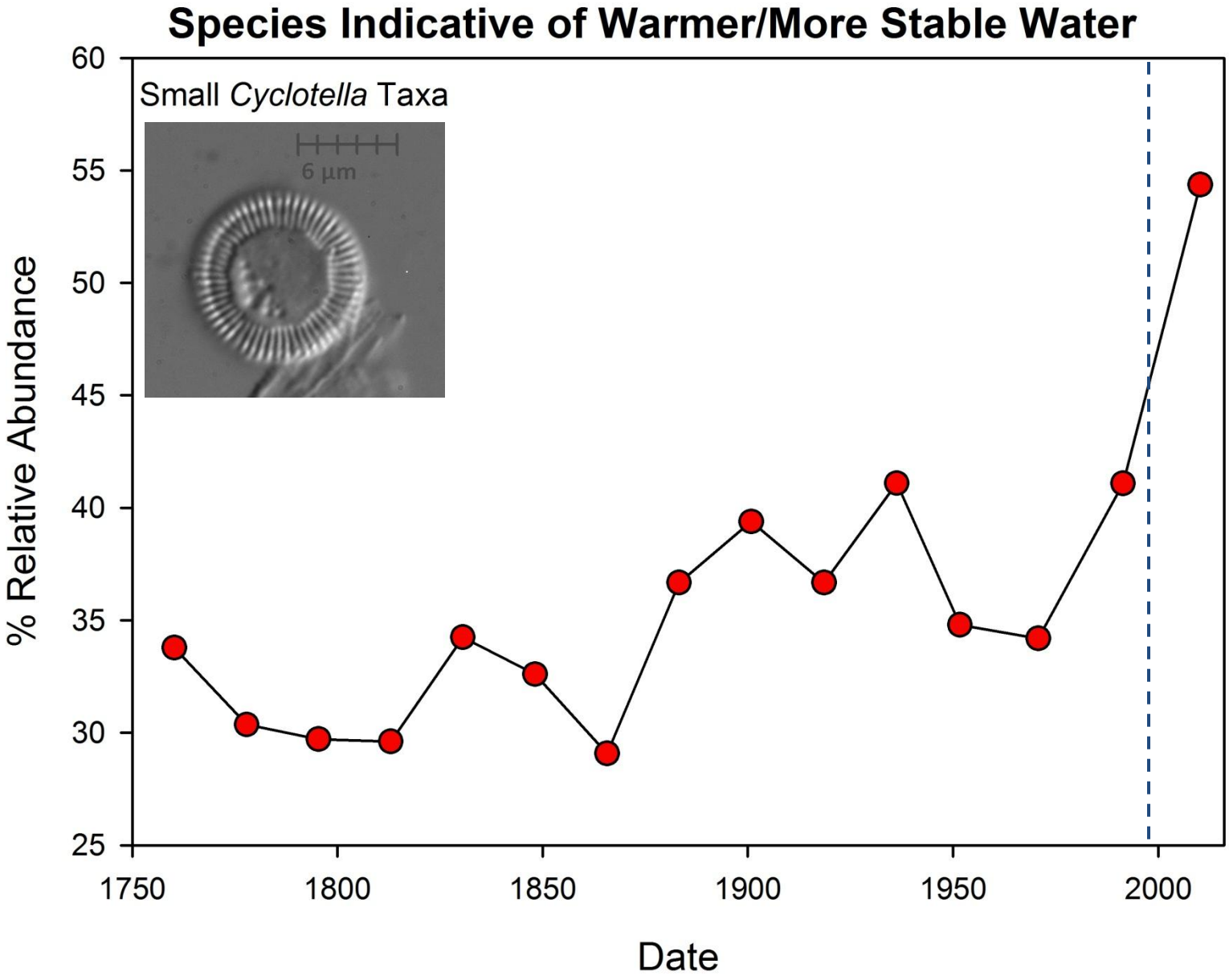
East Basin: Diatom Results



East Basin: Diatom Results



East Basin: Diatom Results

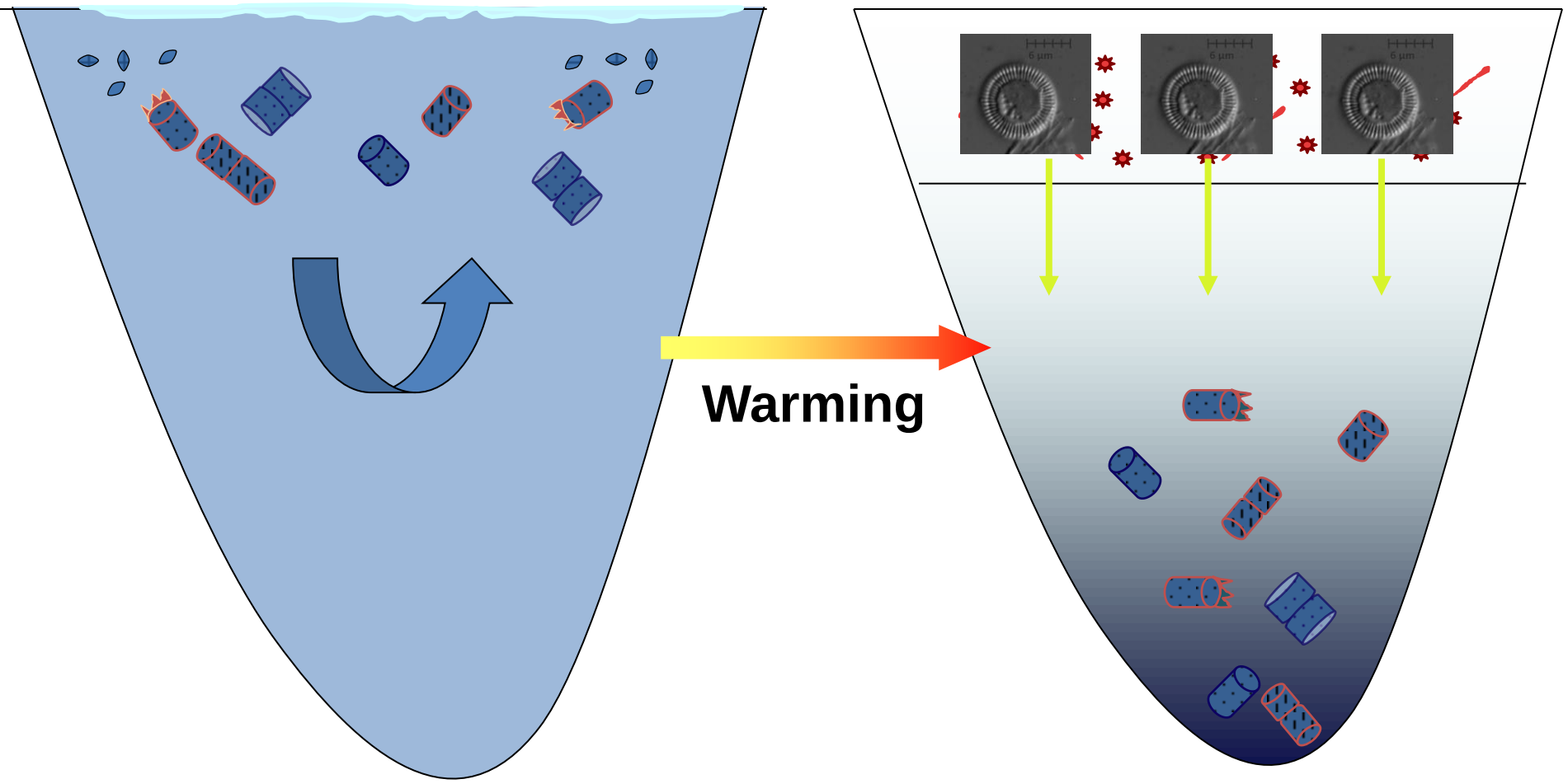


54%

East Basin: Diatom Results

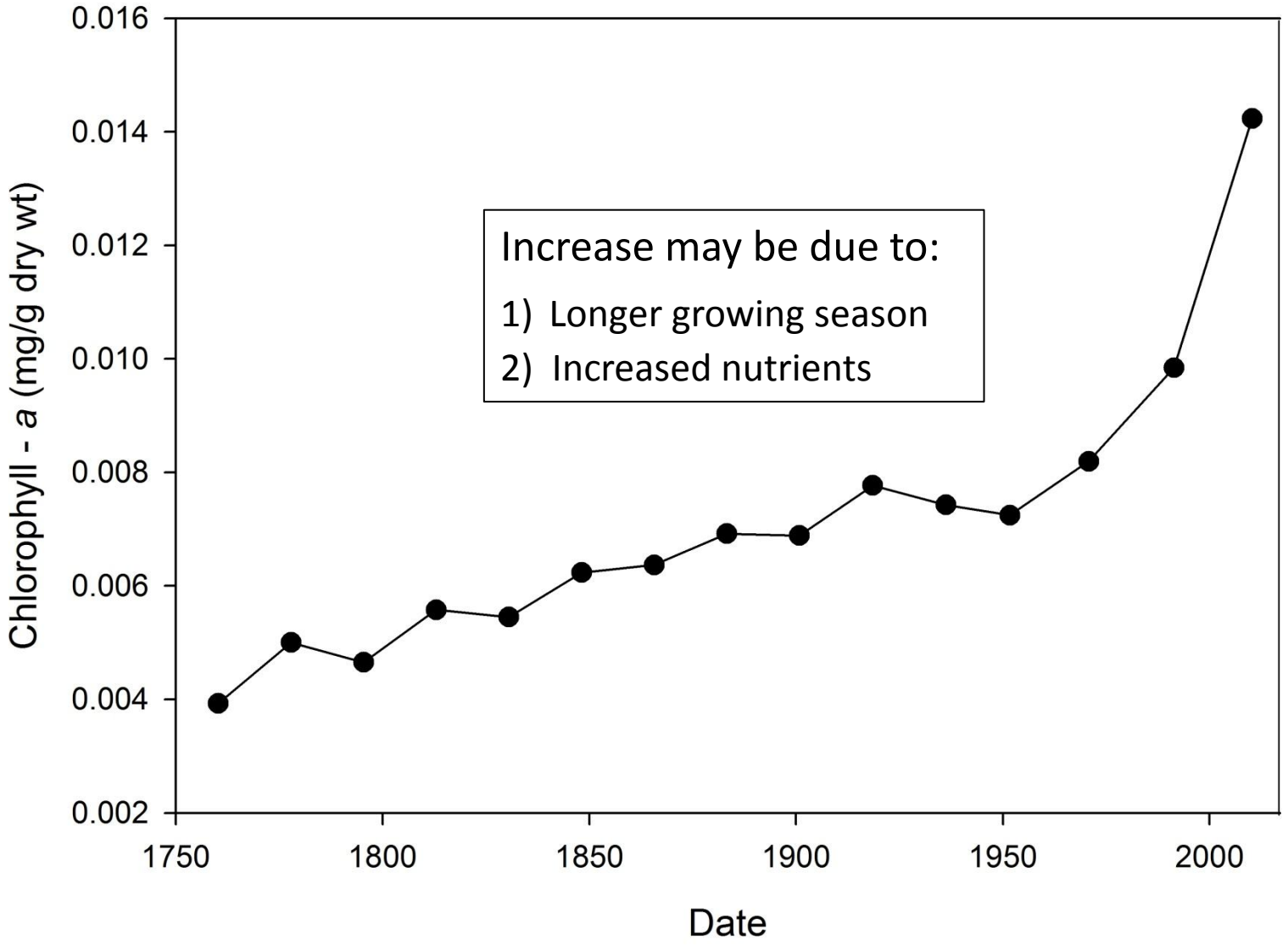
Strongly mixed water column

Weakly mixed/increased stability

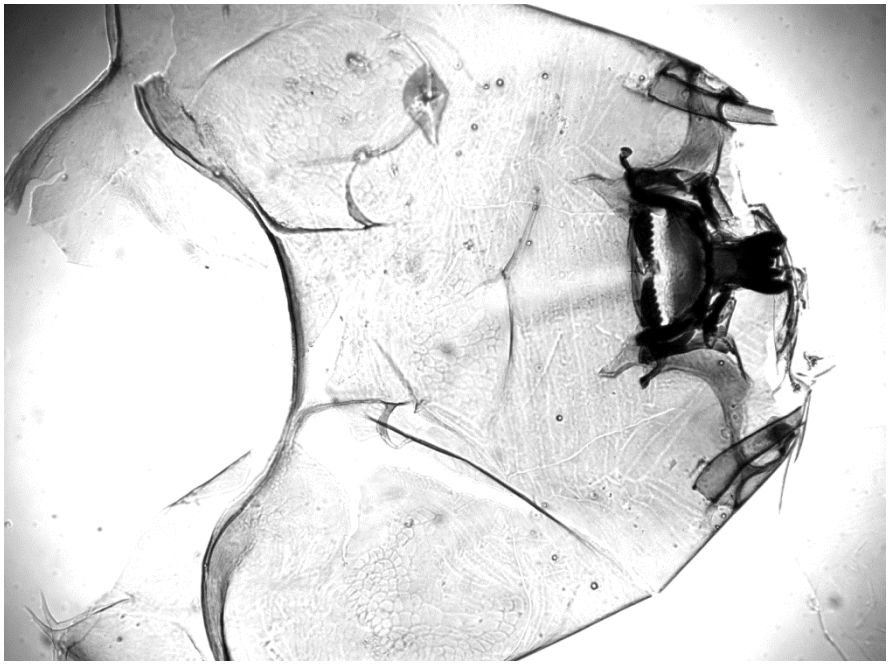


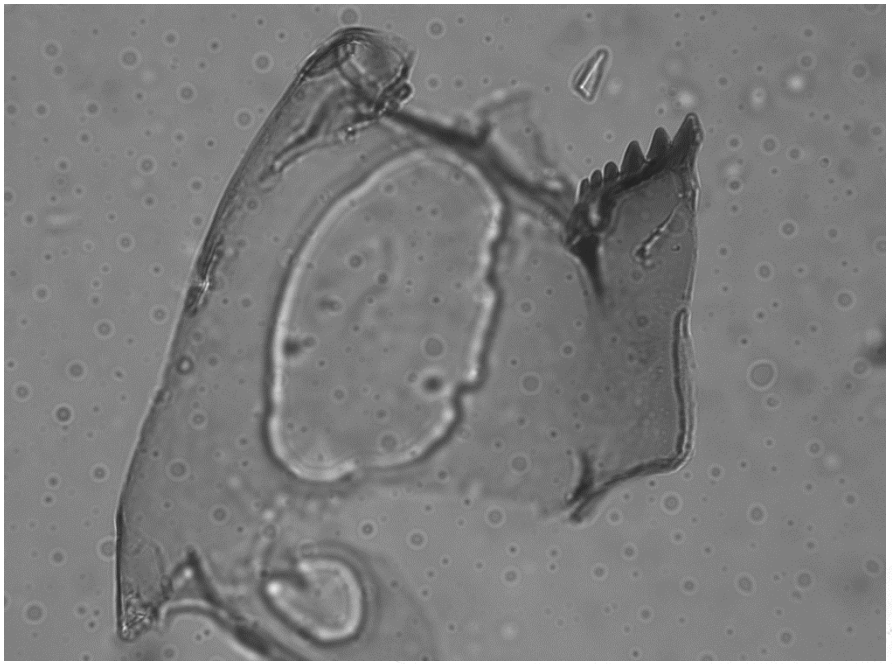
(Rühland et al. 2015)

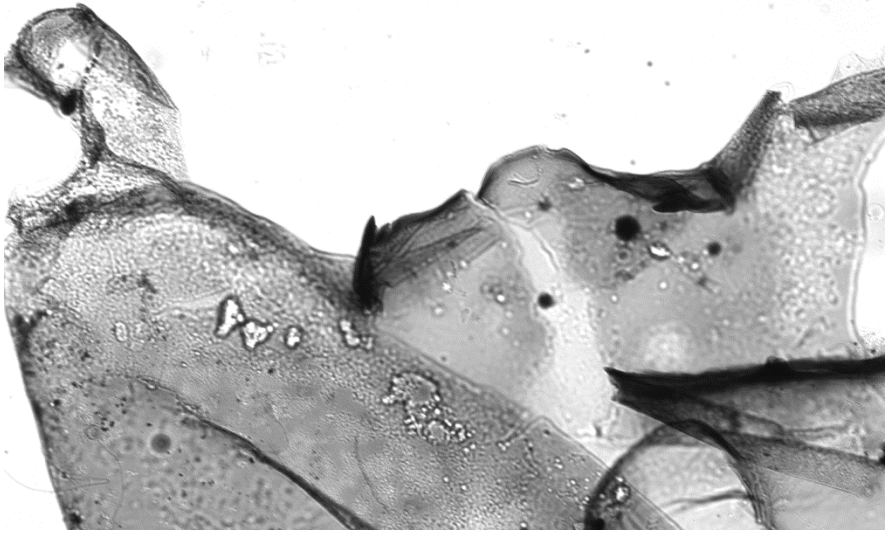
East Basin: Chlorophyll-*a*



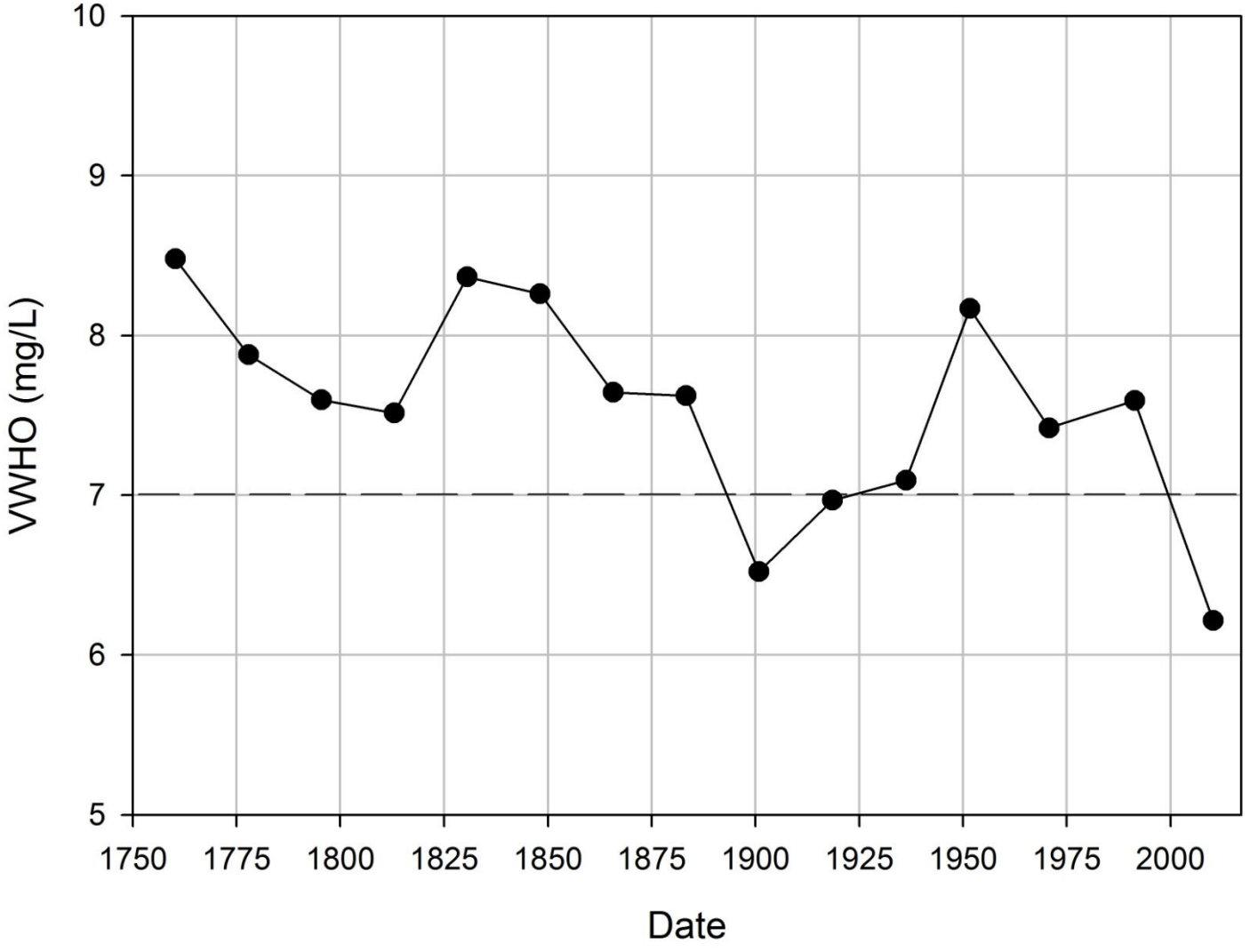
East Basin: Chironomid Results



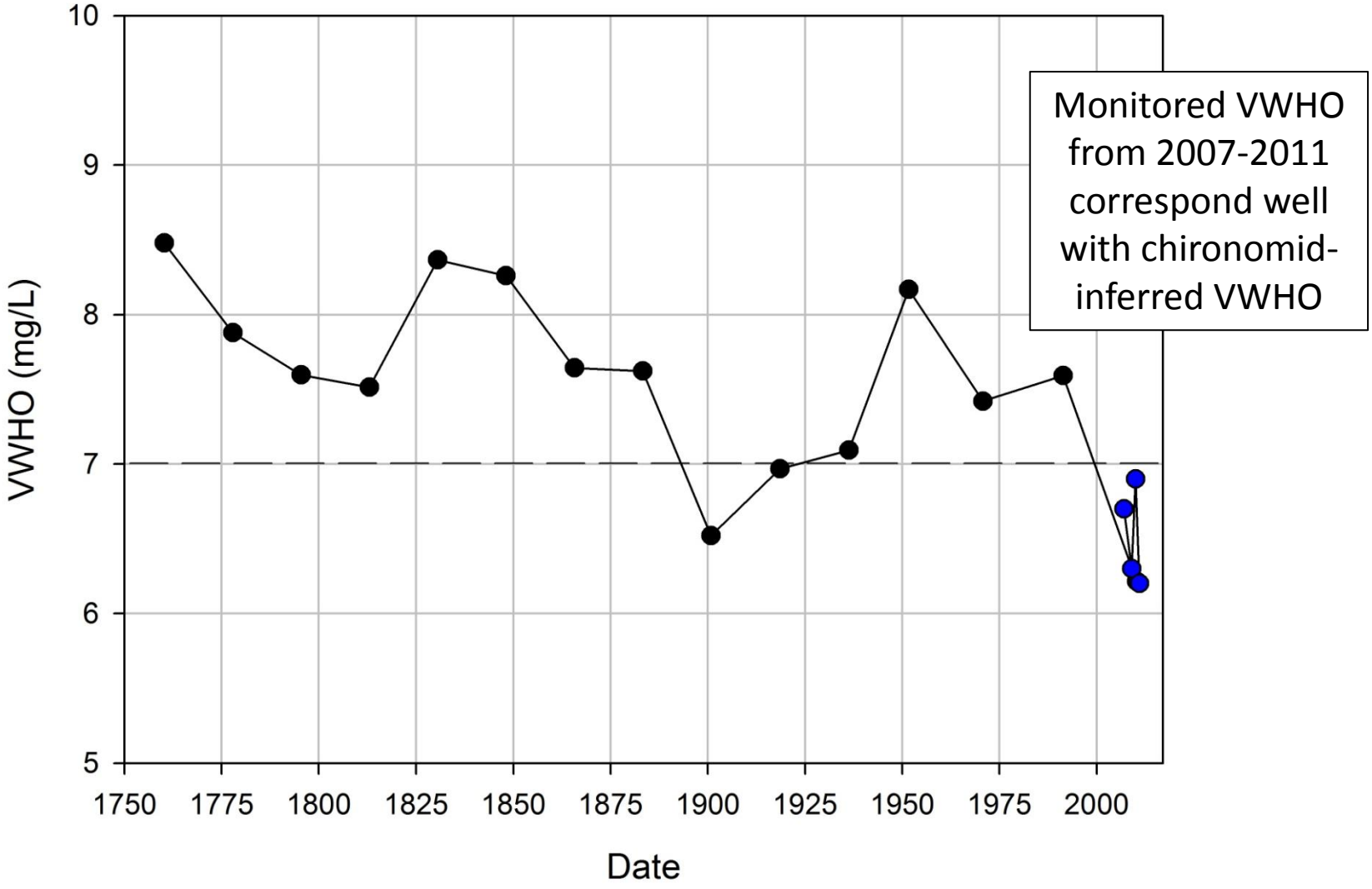




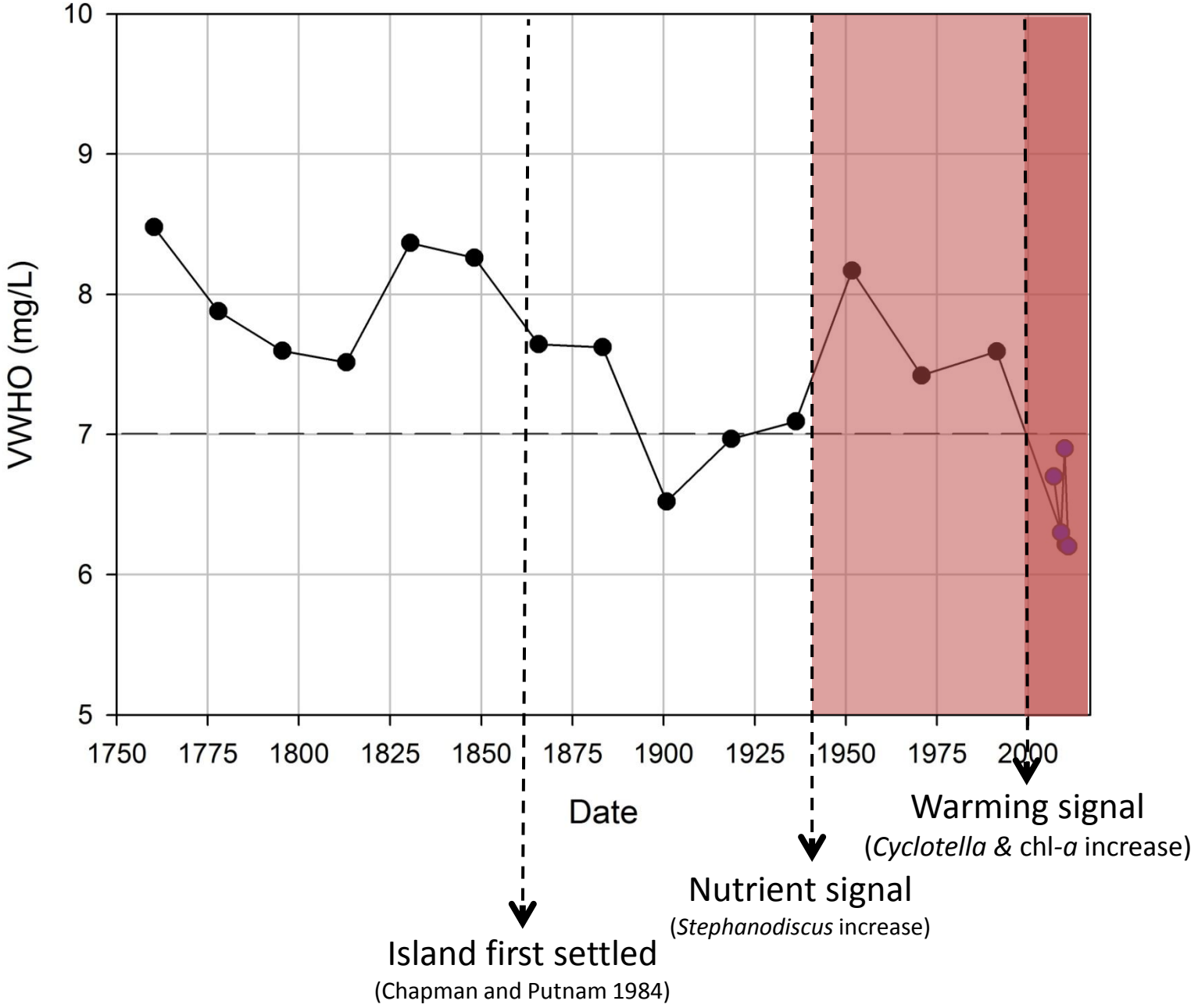
East Basin: VWHO Reconstruction



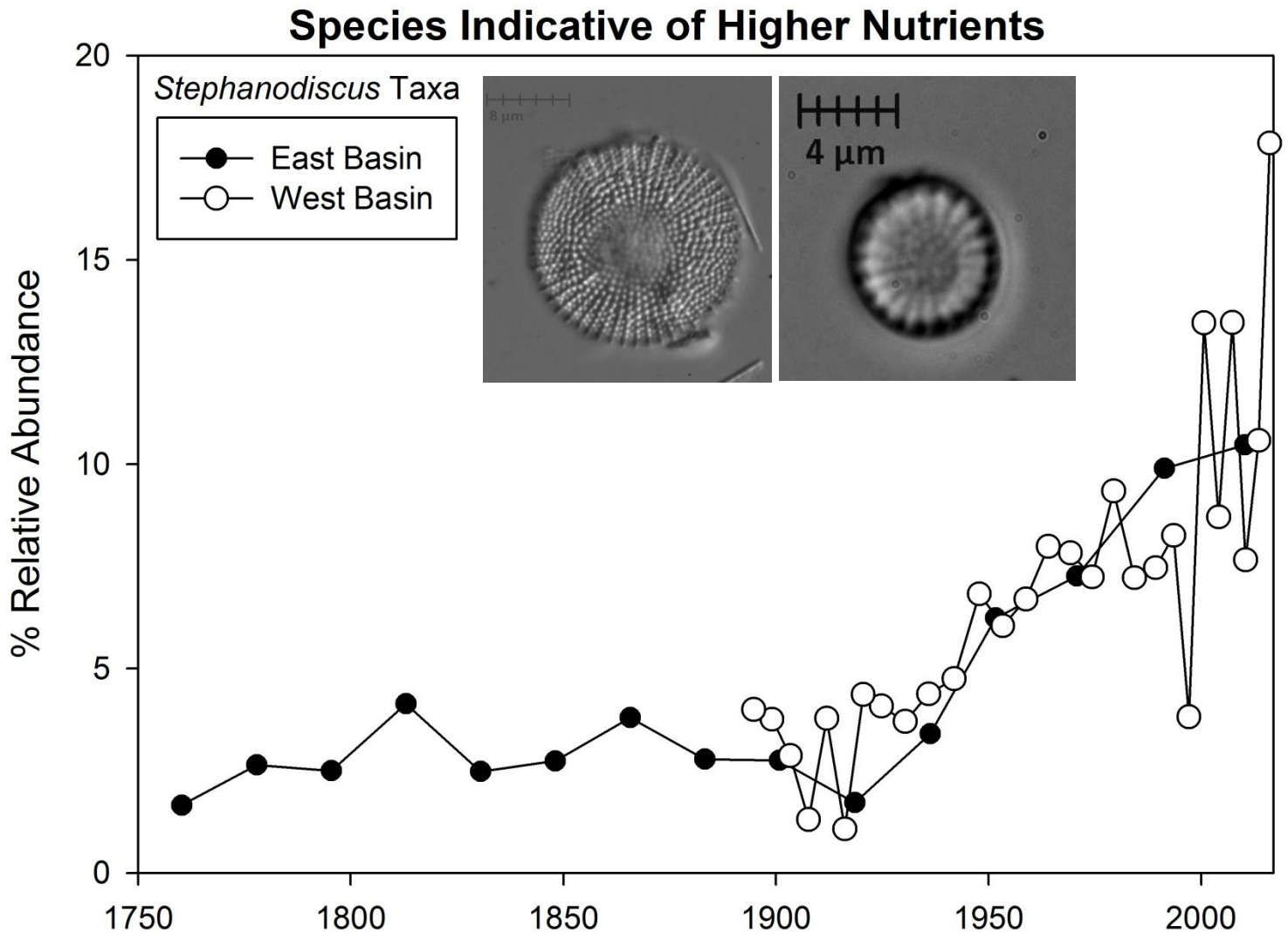
East Basin: VWHO Reconstruction



East Basin: VWHO Reconstruction

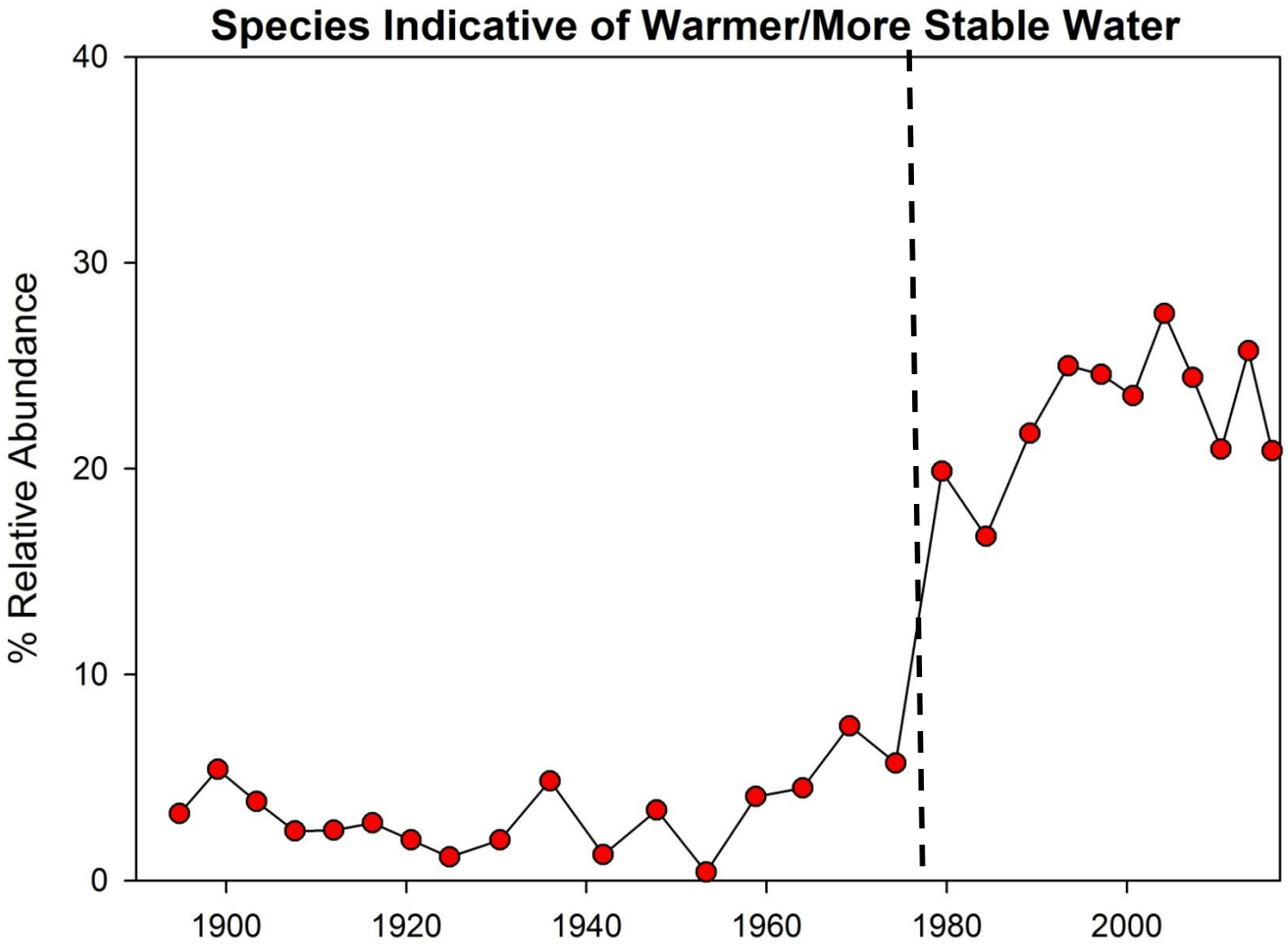


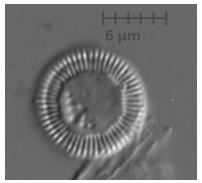
West Basin: Diatom Results



Increase in species indicative of higher nutrients occurring after ~1945 in both basins

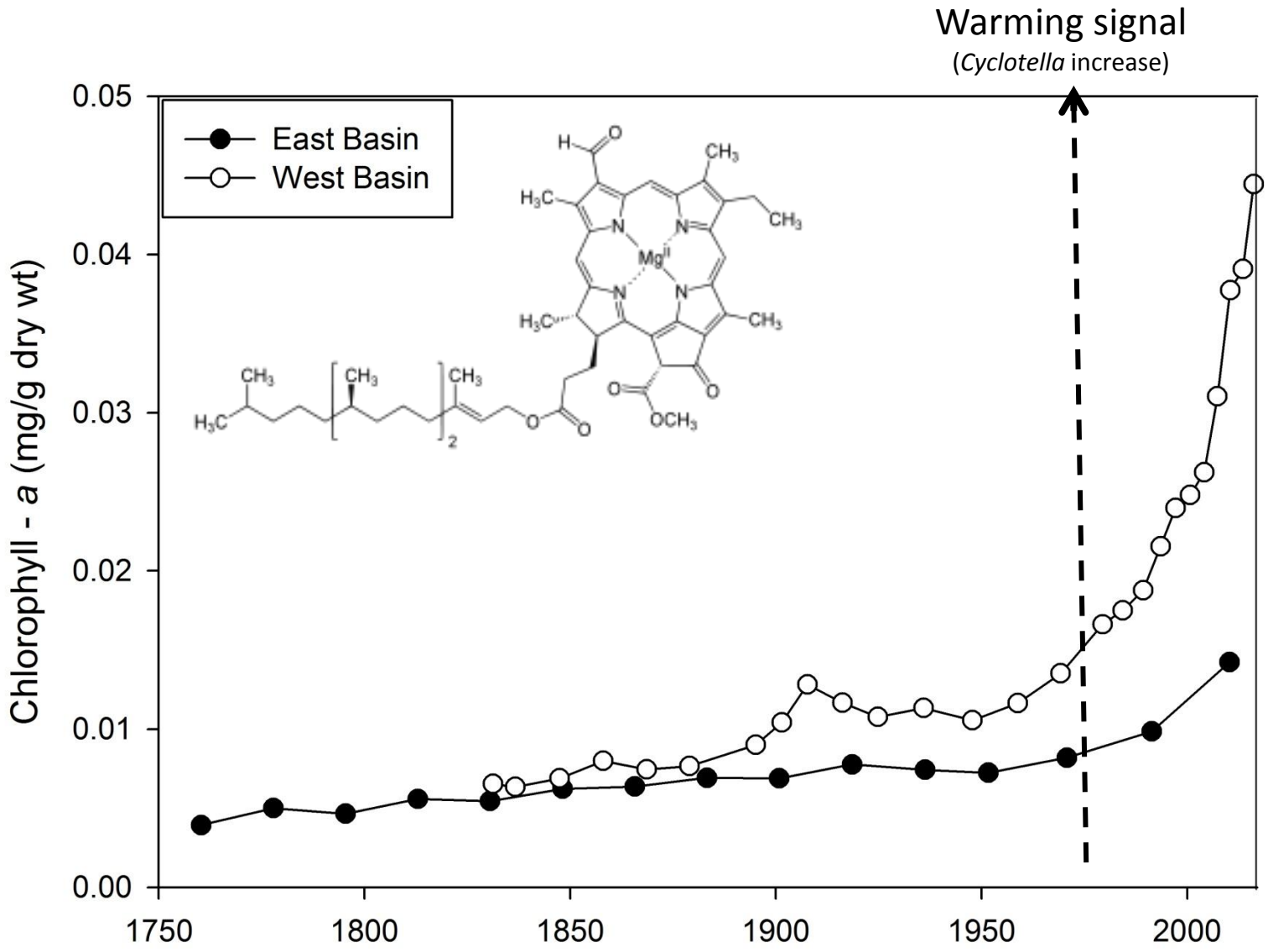
West Basin: Diatom Results





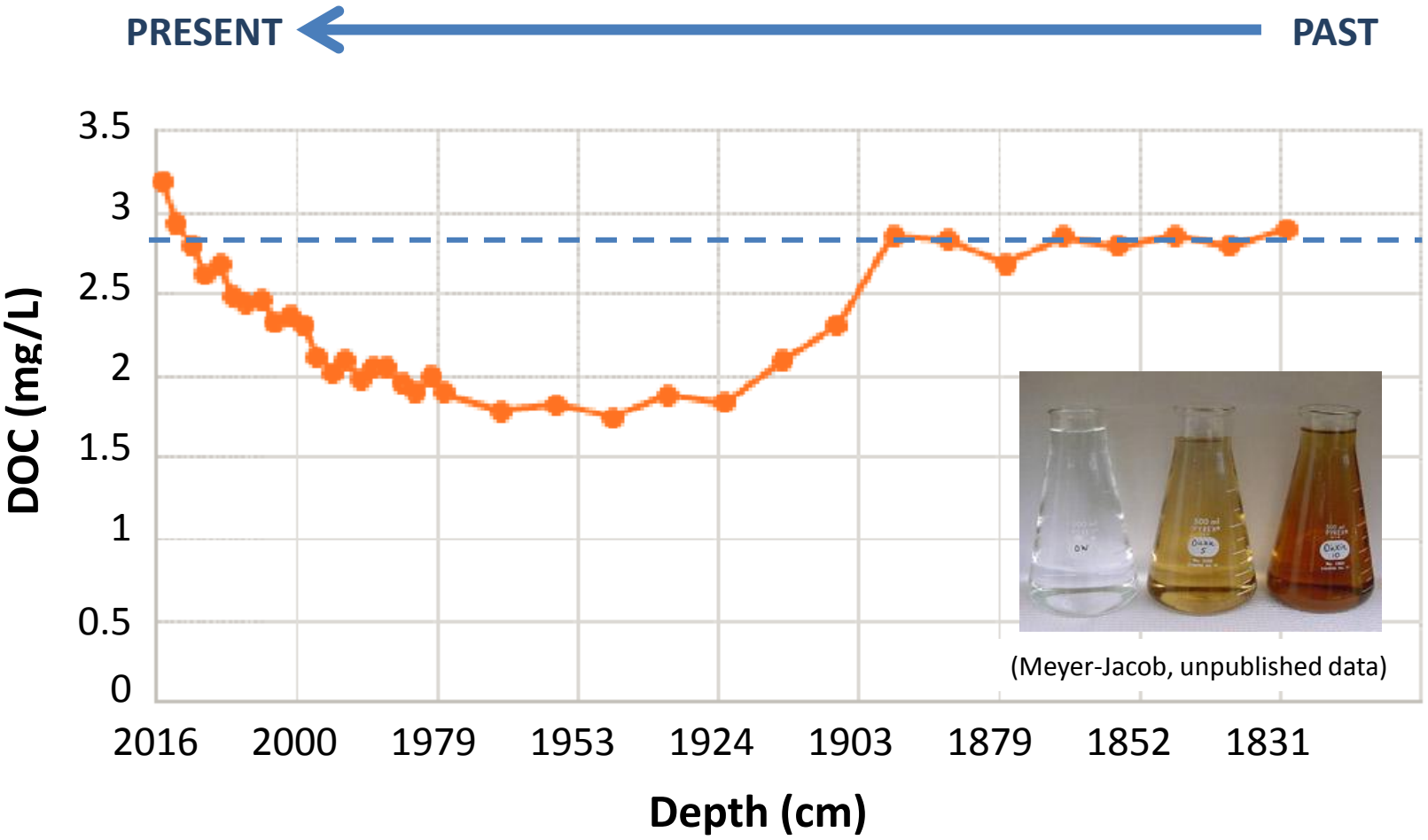
Warming signal occurs earlier in the West Basin
(1980s compared to late-1990s in the East Basin)

West Basin: Chlorophyll-*a* Results



West Basin is more productive than the East Basin and chlorophyll-*a* trend also follows warming signal

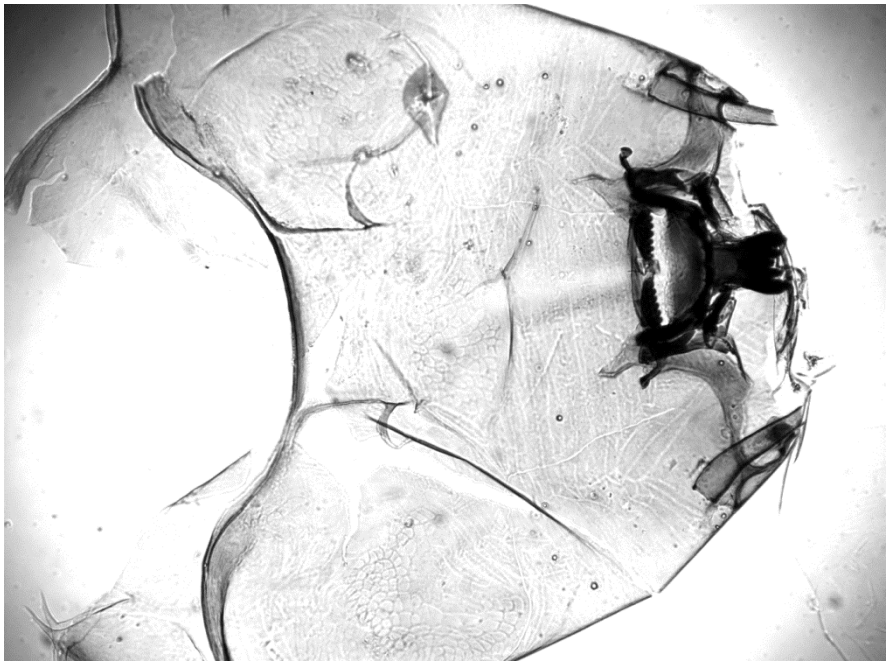
West Basin: Dissolved Organic Carbon Model

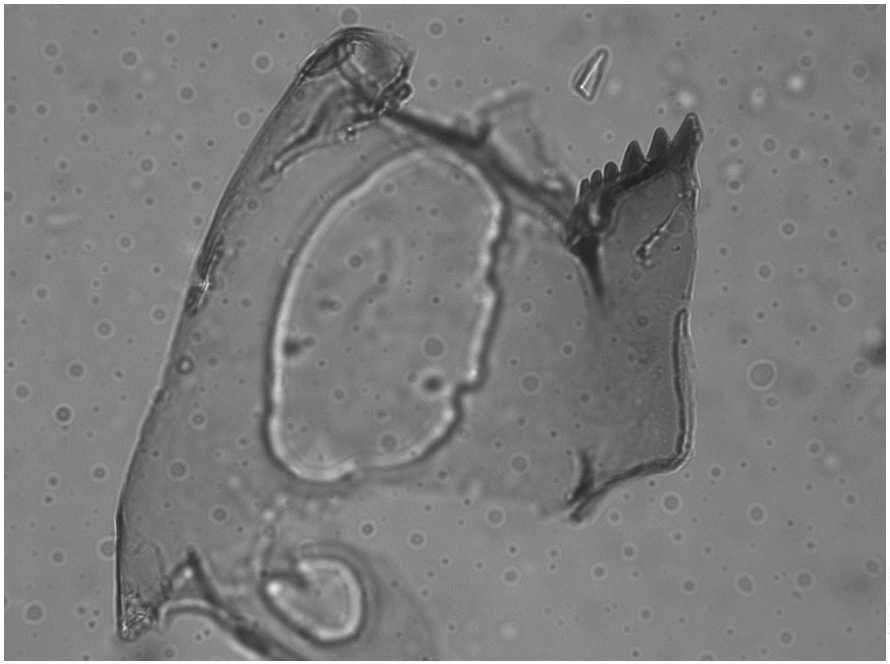


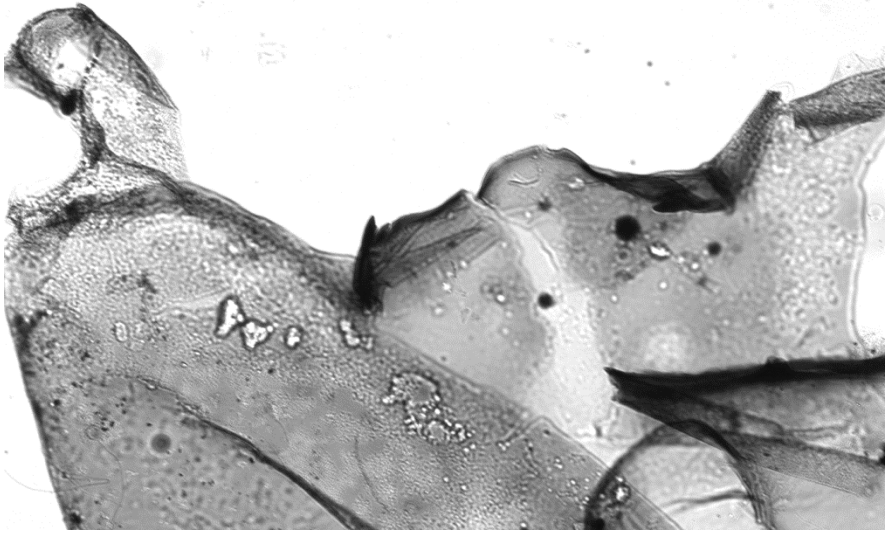
(Meyer-Jacob, unpublished data)

Both **increased** algae production and **increased** dissolved organic carbon likely contributing to **reduced water clarity**

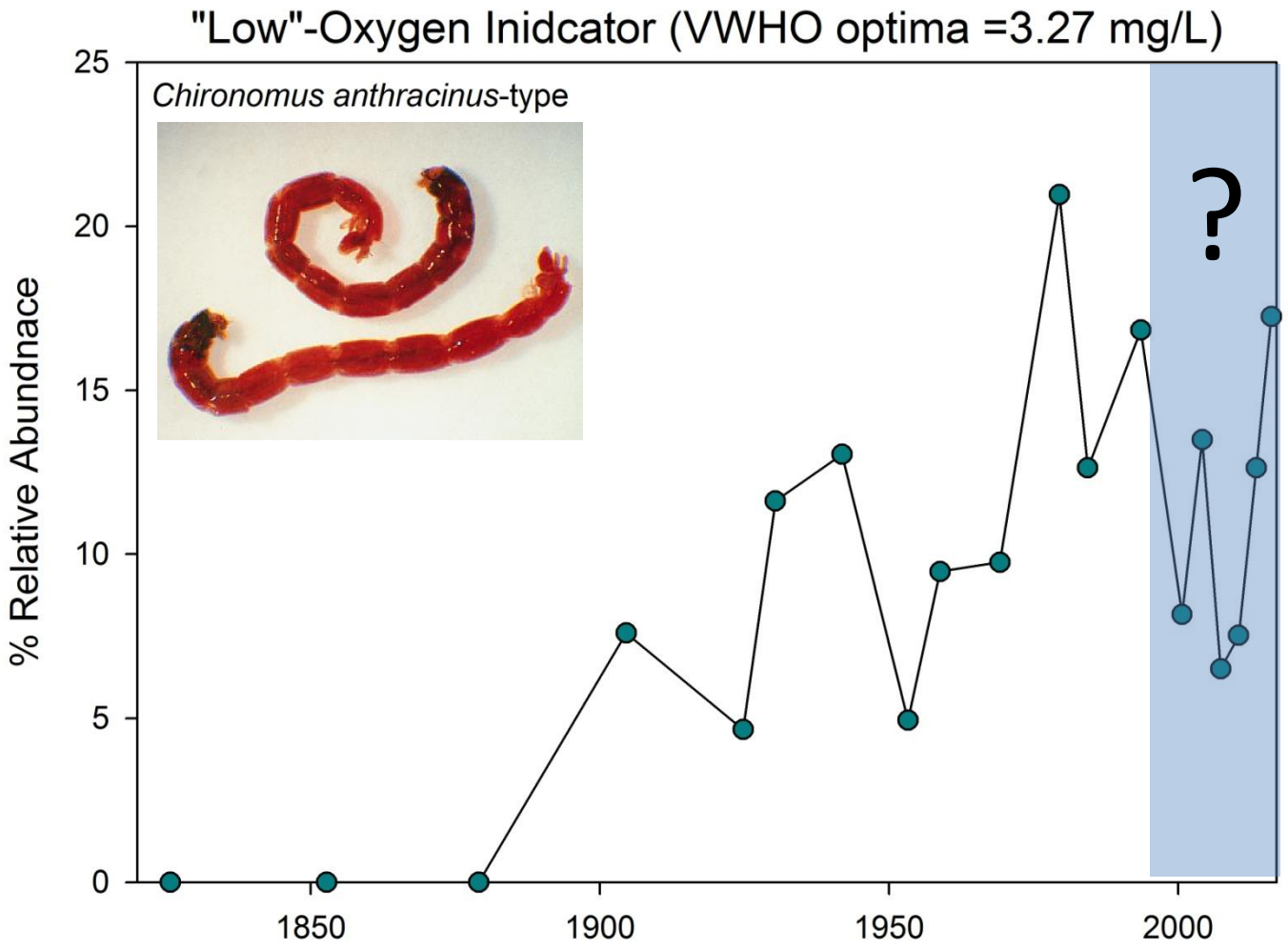
West Basin: Preliminary Chironomid Results





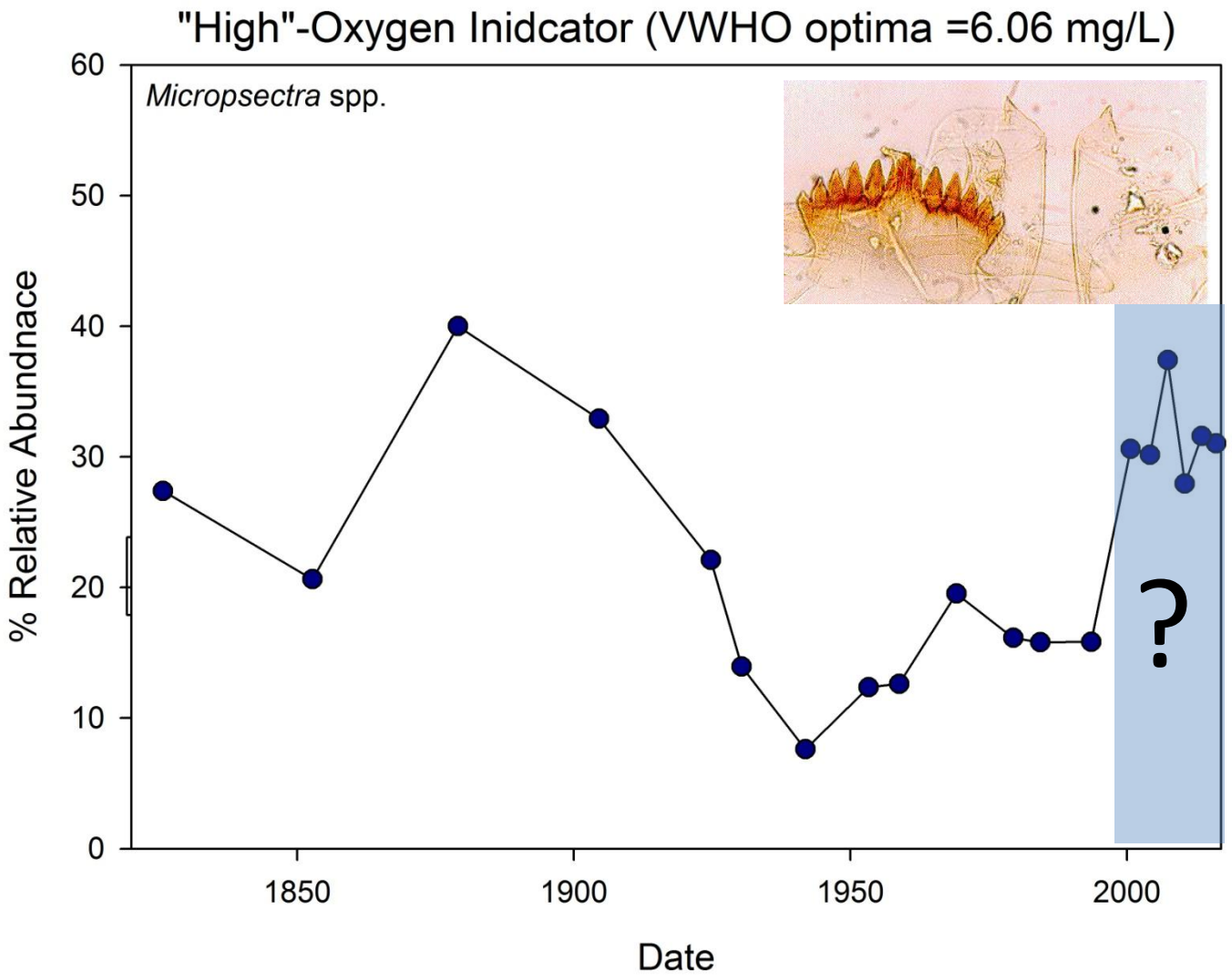


West Basin: Preliminary Chironomid Results



Decrease in low-oxygen indicator may suggest **increase** in West Basin VWHO in recent years

West Basin: Preliminary Chironomid Results



Preliminary Results Summary

Diatom Data:

Warming signal apparent in both basins but at different times – longer/stronger stratification and reduced mixing

- Occurs in the West Basin earlier (shallower and may be more sensitive to warming)

(June 2015)

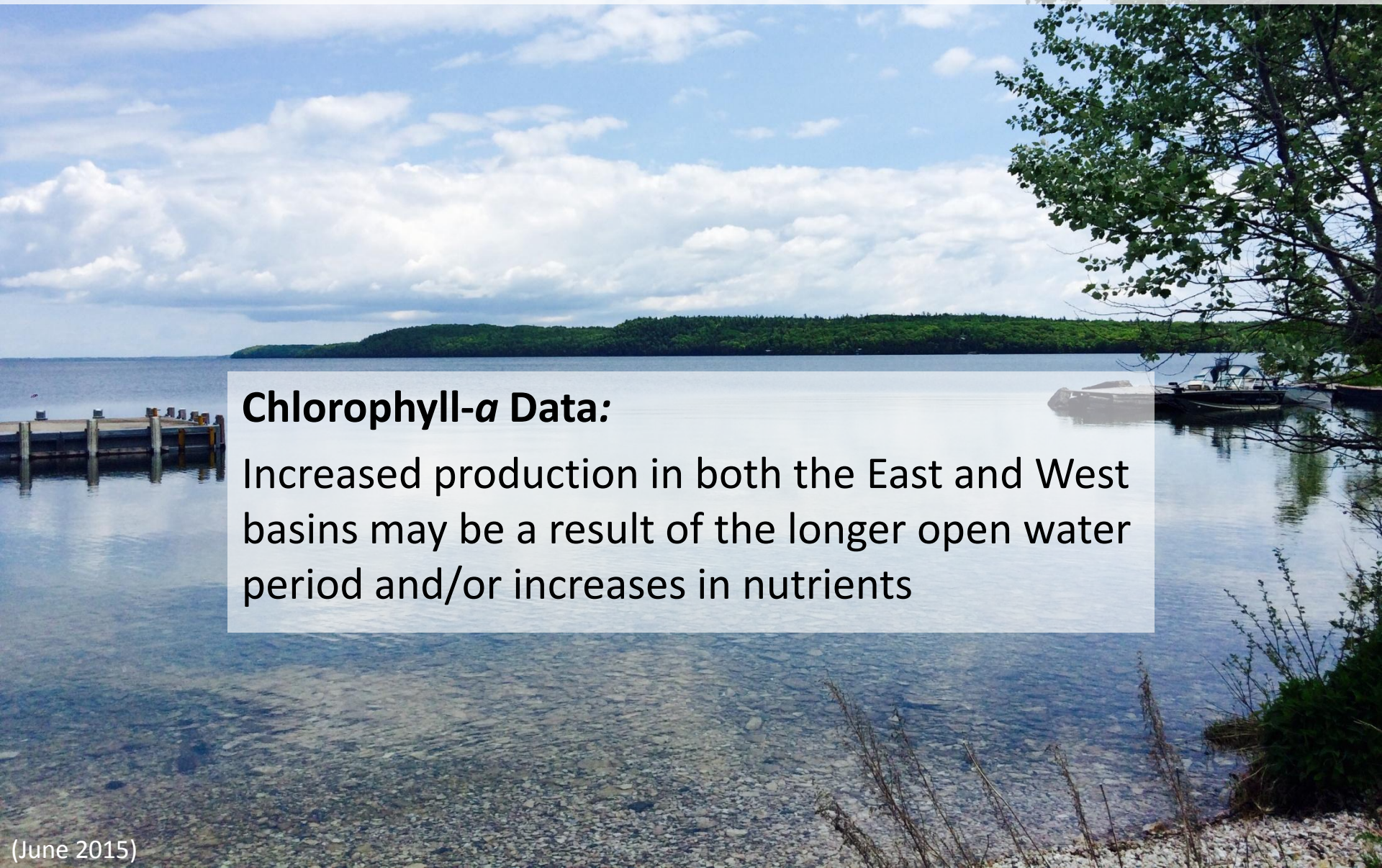
Preliminary Results Summary

Diatom Data:

Nutrient signal in both basins after ~1945

(June 2015)

Preliminary Results Summary

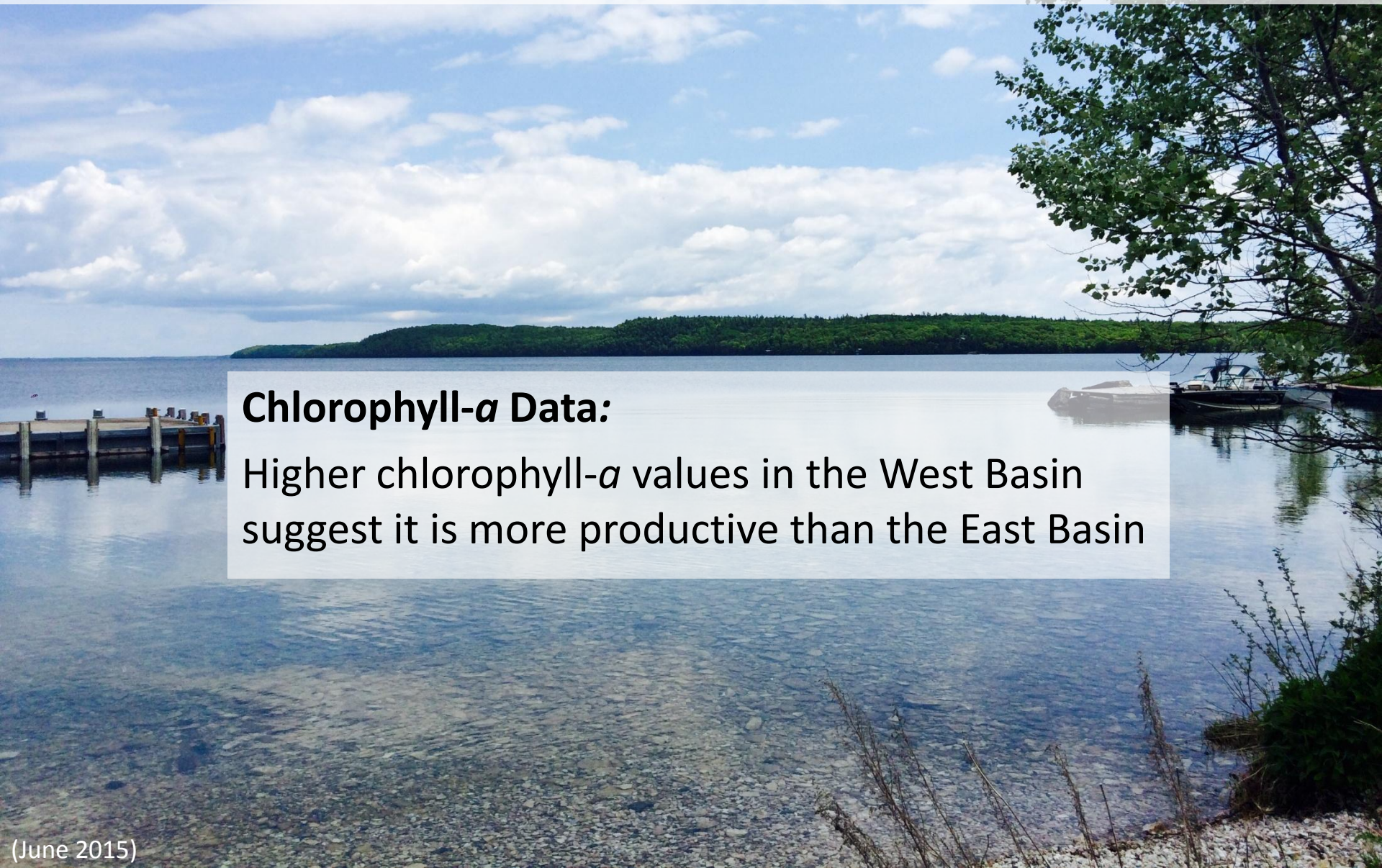


Chlorophyll-*a* Data*:*

Increased production in both the East and West basins may be a result of the longer open water period and/or increases in nutrients

(June 2015)

Preliminary Results Summary

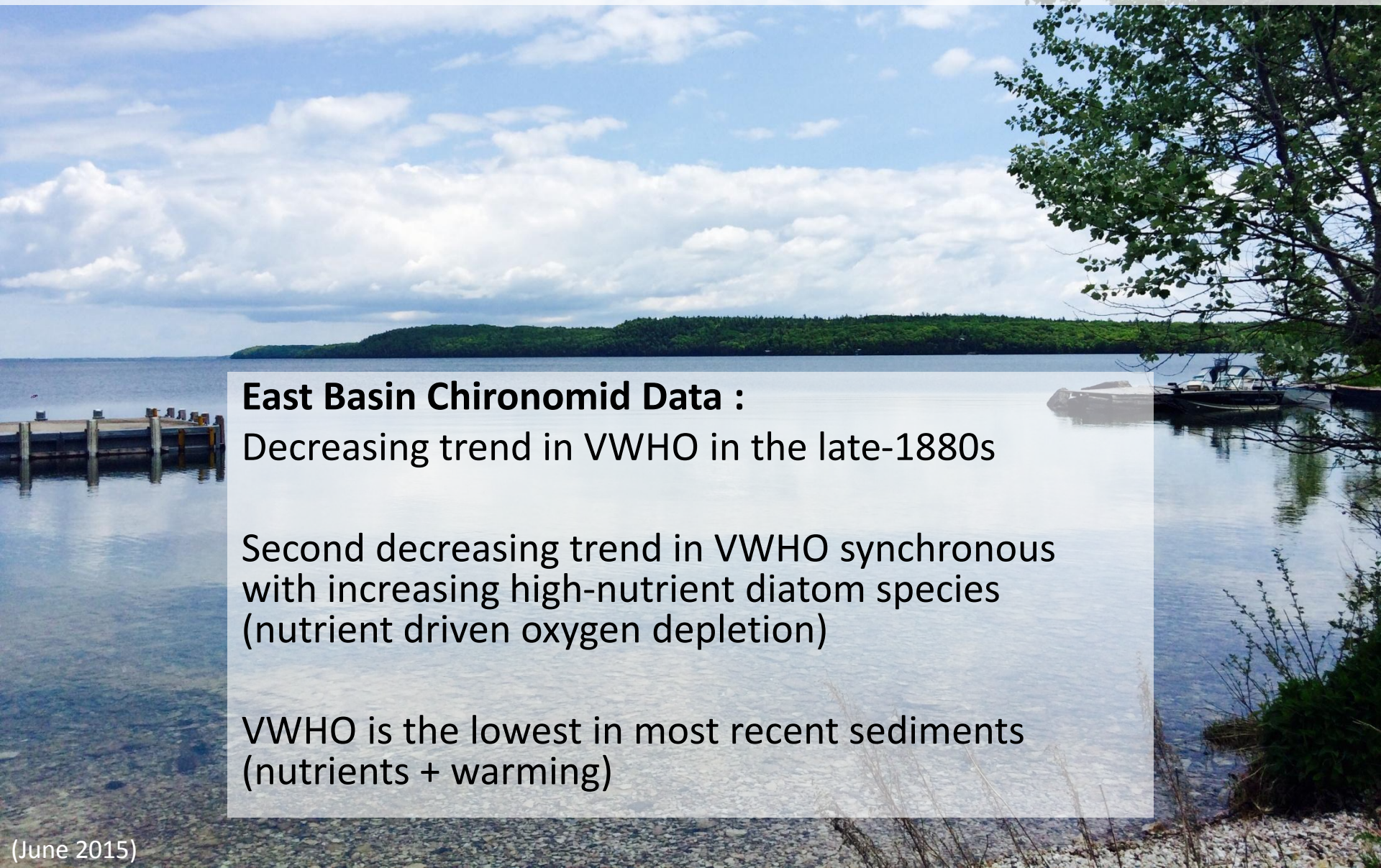


Chlorophyll-*a* Data*:*

Higher chlorophyll-*a* values in the West Basin suggest it is more productive than the East Basin

(June 2015)

Preliminary Results Summary



East Basin Chironomid Data :

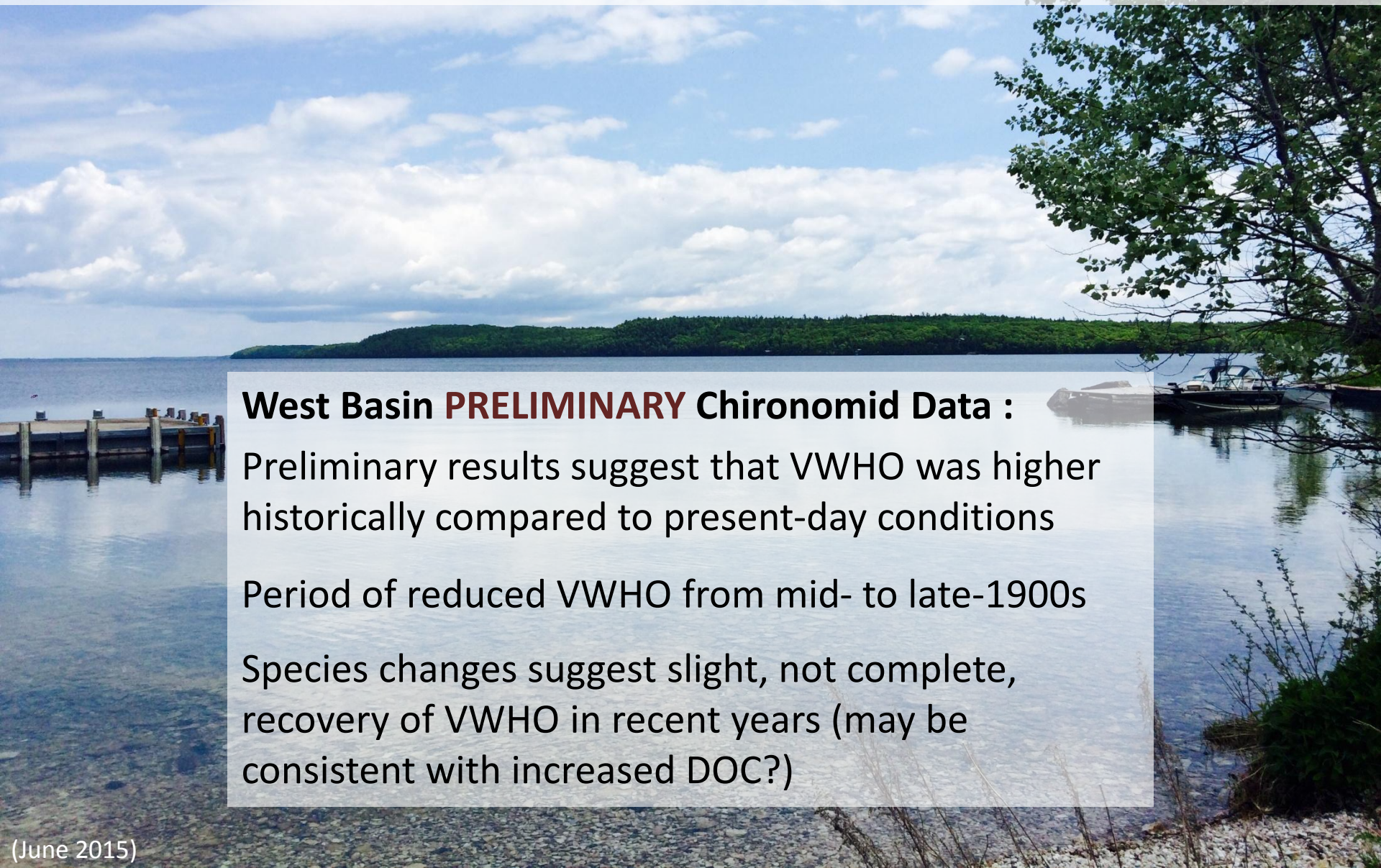
Decreasing trend in VWHO in the late-1880s

Second decreasing trend in VWHO synchronous with increasing high-nutrient diatom species (nutrient driven oxygen depletion)

VWHO is the lowest in most recent sediments (nutrients + warming)

(June 2015)

Preliminary Results Summary



West Basin PRELIMINARY Chironomid Data :

Preliminary results suggest that VWHO was higher historically compared to present-day conditions

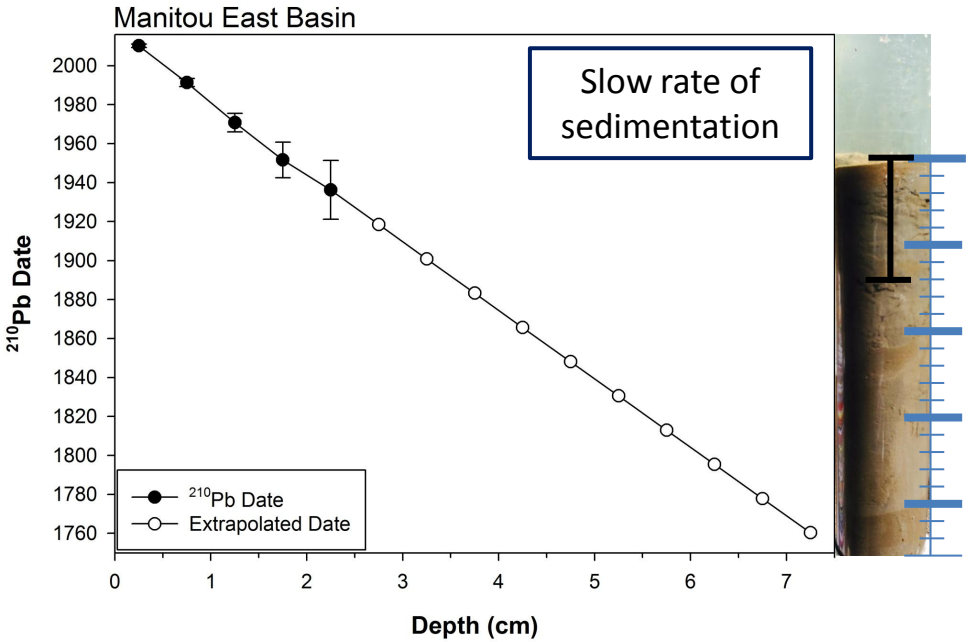
Period of reduced VWHO from mid- to late-1900s

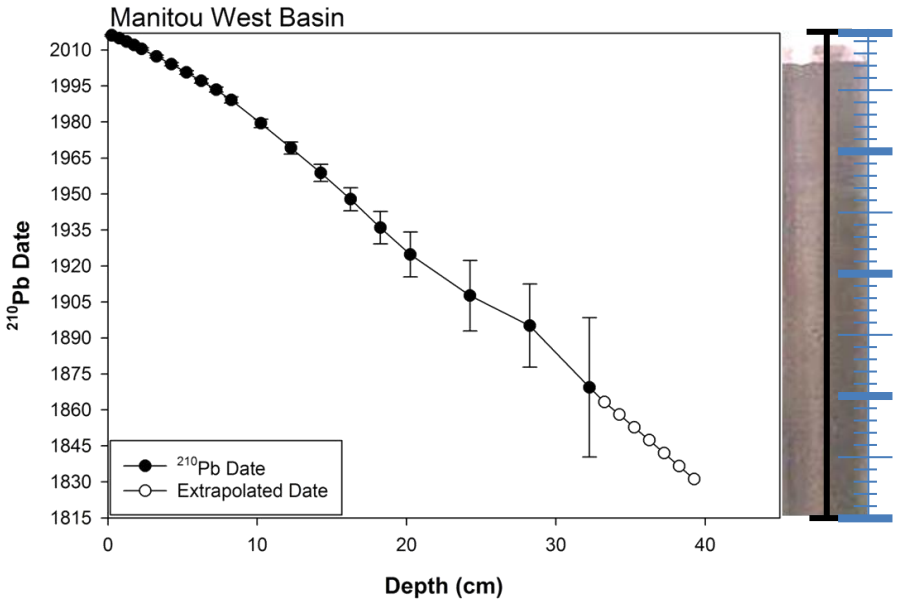
Species changes suggest slight, not complete, recovery of VWHO in recent years (may be consistent with increased DOC?)

(June 2015)

Preliminary Results Summary

NOTE: ~20 years represented in 1st interval in the East Basin core compared to 10 intervals in the West Basin core

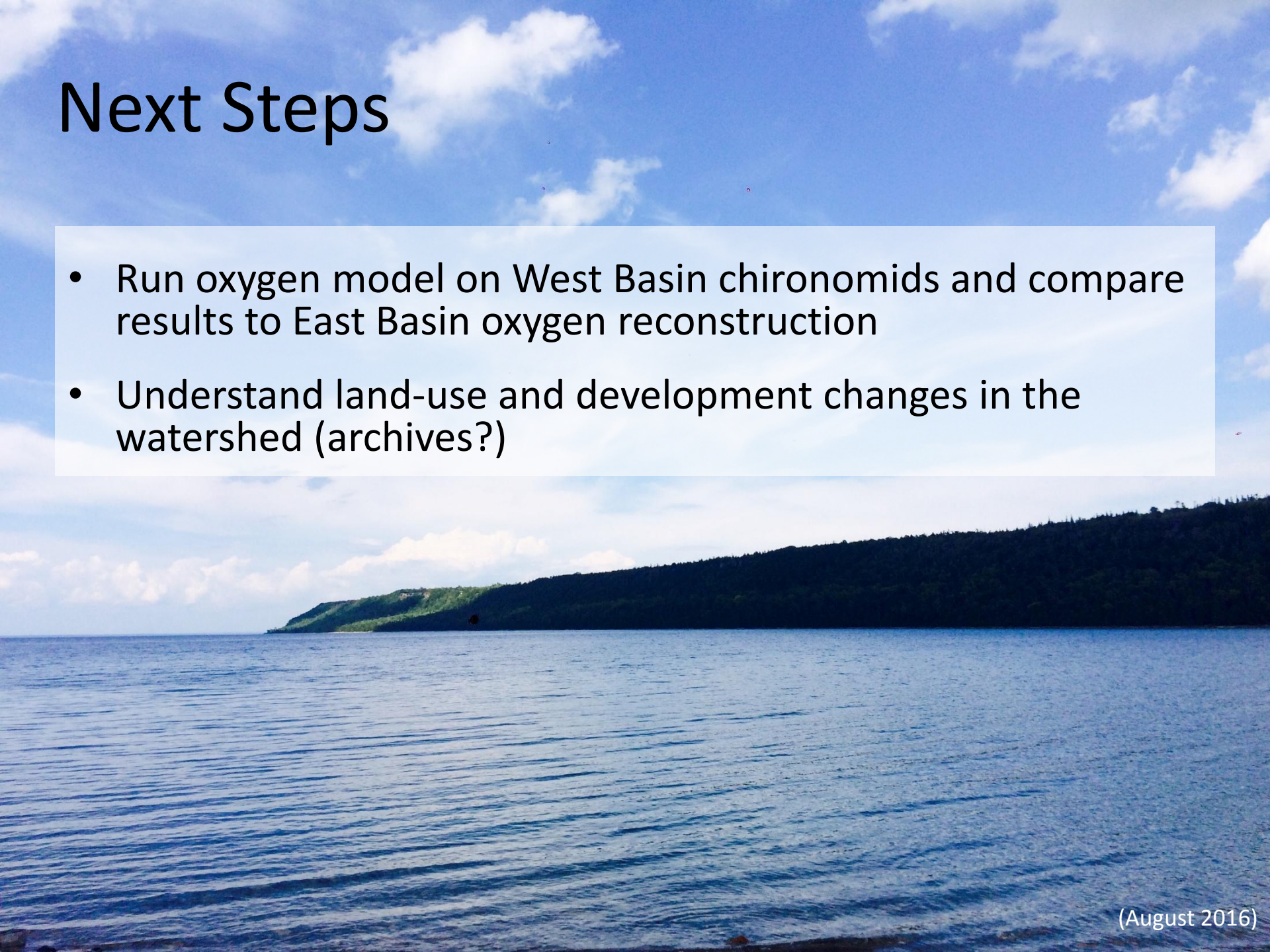




The faster sedimentation rate in the West Basin core improves our understanding of oxygen trends within that period

Next Steps

- Run oxygen model on West Basin chironomids and compare results to East Basin oxygen reconstruction
- Understand land-use and development changes in the watershed (archives?)



(August 2016)

Thank you for your attention

Diatom Data:

- Diatom assemblage shifts in both basins suggest that lake mixing is weaker and thermal stratification is stronger and longer
- Increase in high-nutrient species in both basins after ~1945

Increase in Chlorophyll-*a:*

- Suggests there has been an increase in the length of the open water period and/or increases in nutrients

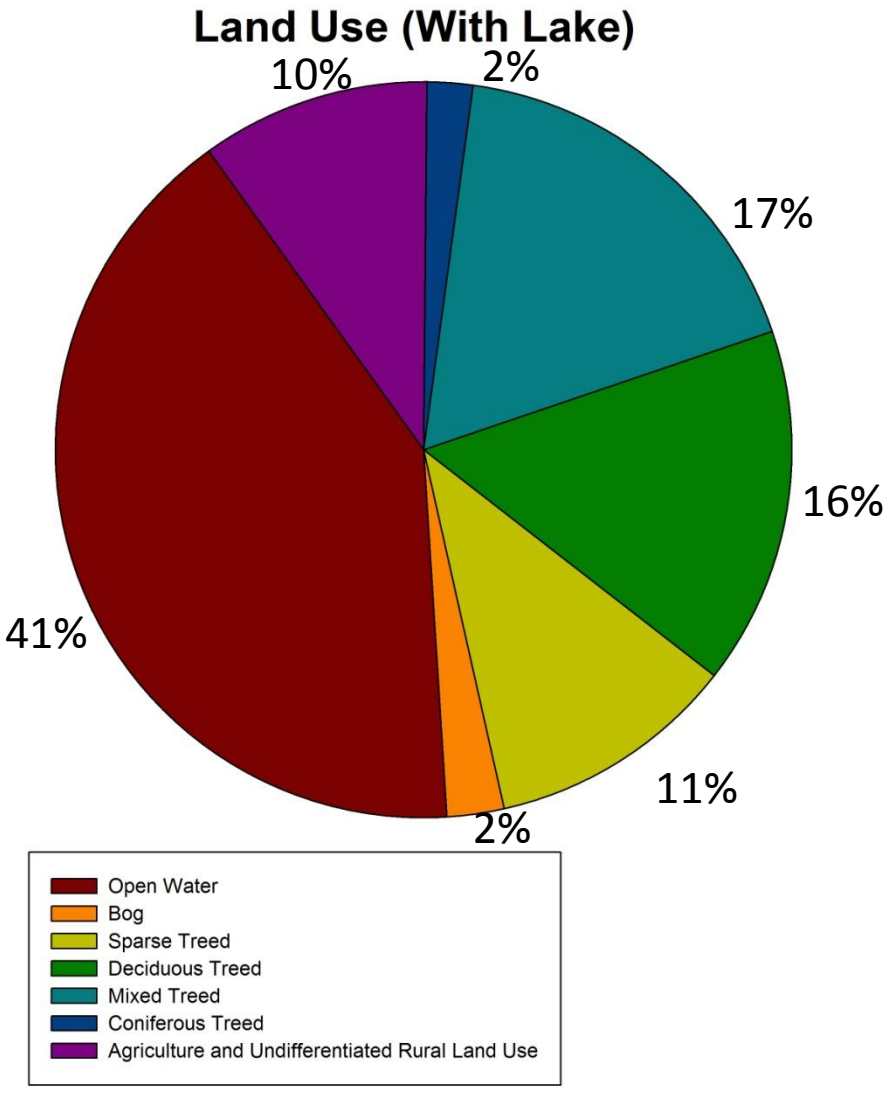
Chironomid Data:

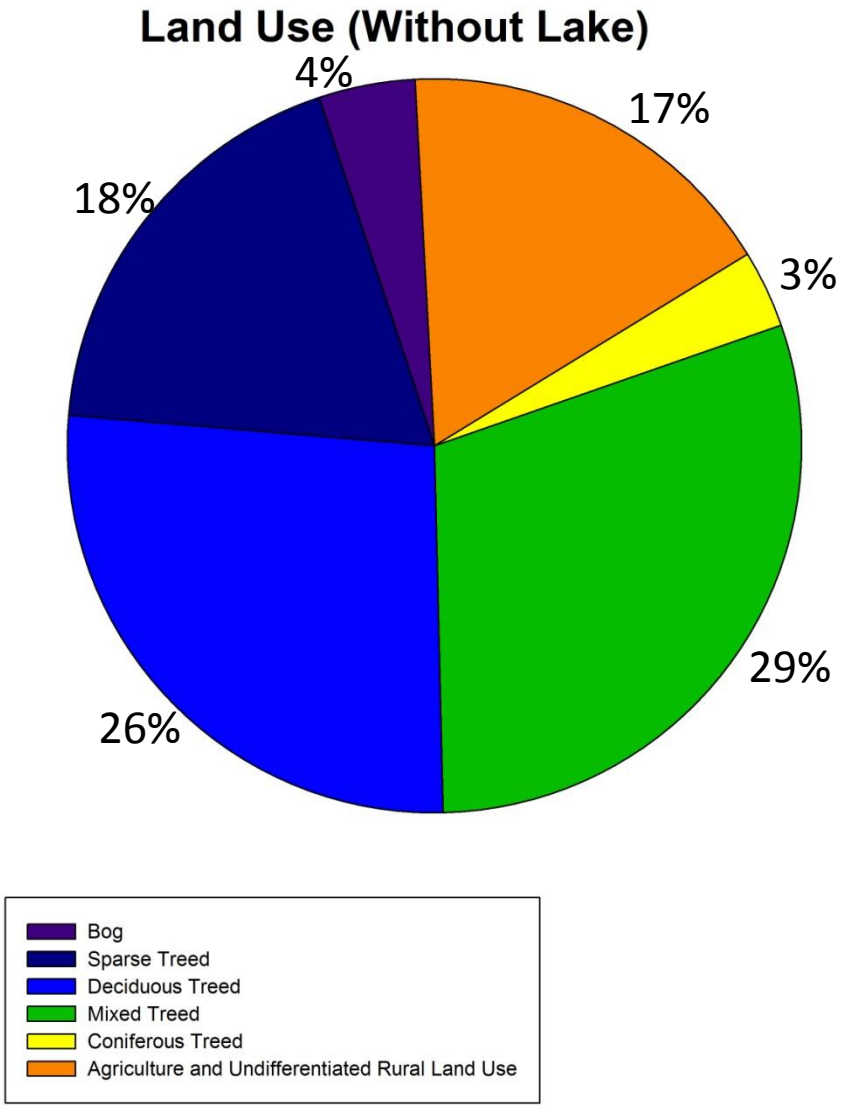
- East Basin: VWHO is lowest in most recent sediments (nutrients + warming)
- West Basin: Current oxygen conditions likely lower today than in the past and may have slightly improved in recent years (due to increased DOC?)

Recent Monitoring Data:

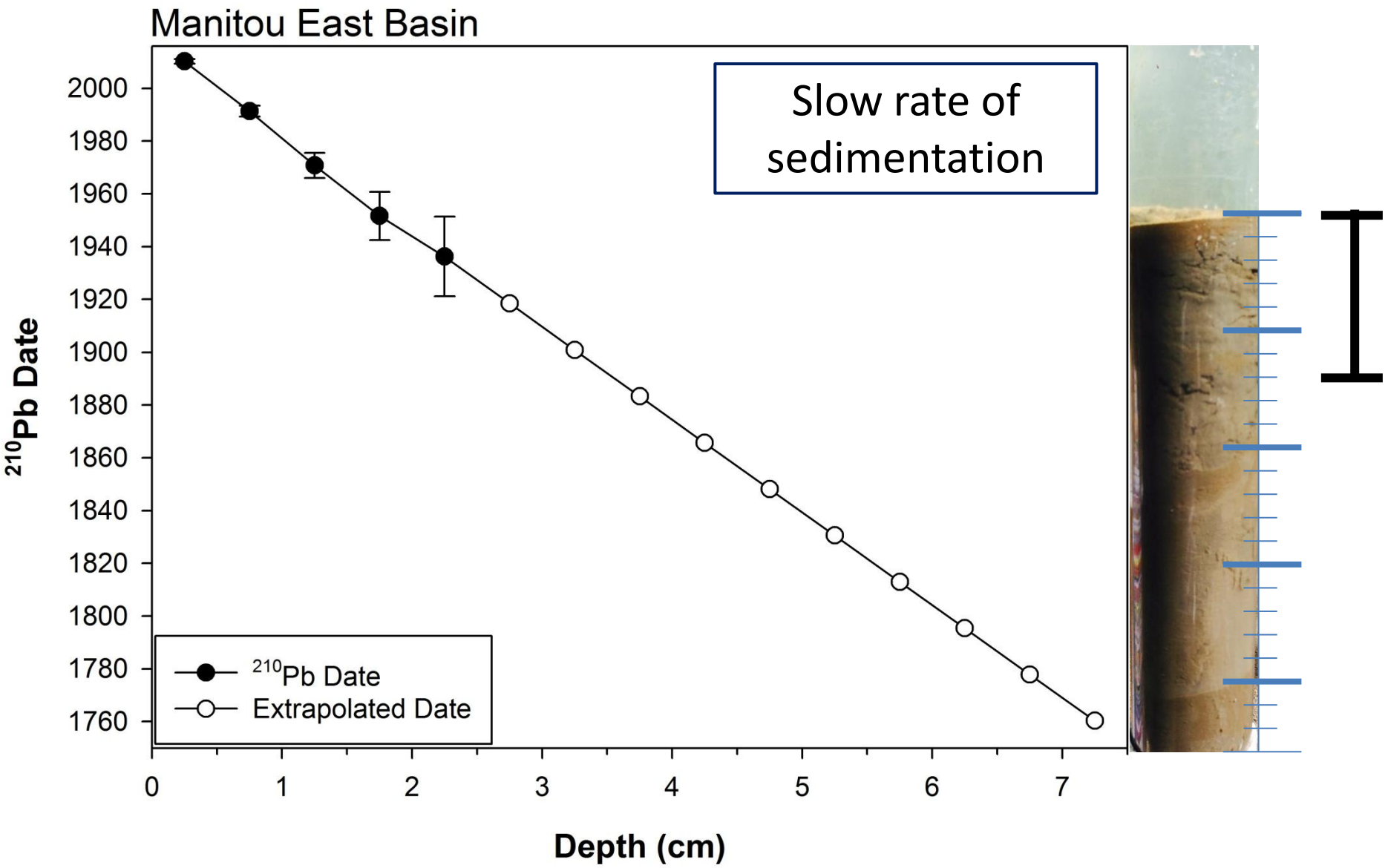
- Observed 2 m reduction in lake water clarity over ~ 20 years
- Consistent with increase in primary production and DOC

(August 2016)


Land Use (With Lake)
10%
2%
17%
16%
41%
11%
2%
Open Water
Bog
Sparse Treed
Deciduous Treed
Mixed Treed
Coniferous Treed
Agriculture and Undifferentiated Rural Land Use


Land Use (Without Lake)
4%
17%
18%
3%
29%
26%
Bog
Sparse Treed
Deciduous Treed
Mixed Treed
Coniferous Treed
Agriculture and Undifferentiated Rural Land Use

Sediment core was dated using radioisotopes of lead (Pb)



Sediment core was dated using radioisotopes of lead (Pb)