Tracking temporal trends in total phosphorus and hypolimnetic dissolved oxygen in an Ontario Lake Trout lake

SCL - CCFFR

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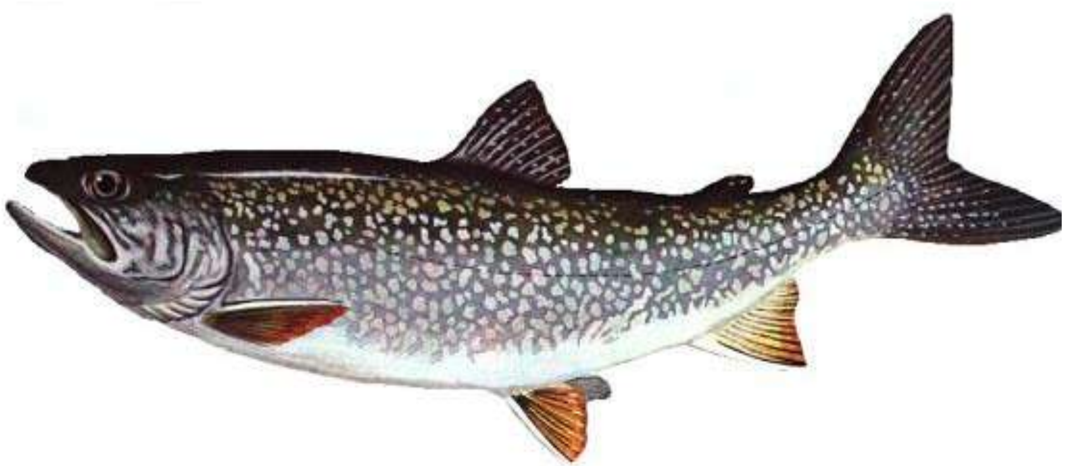
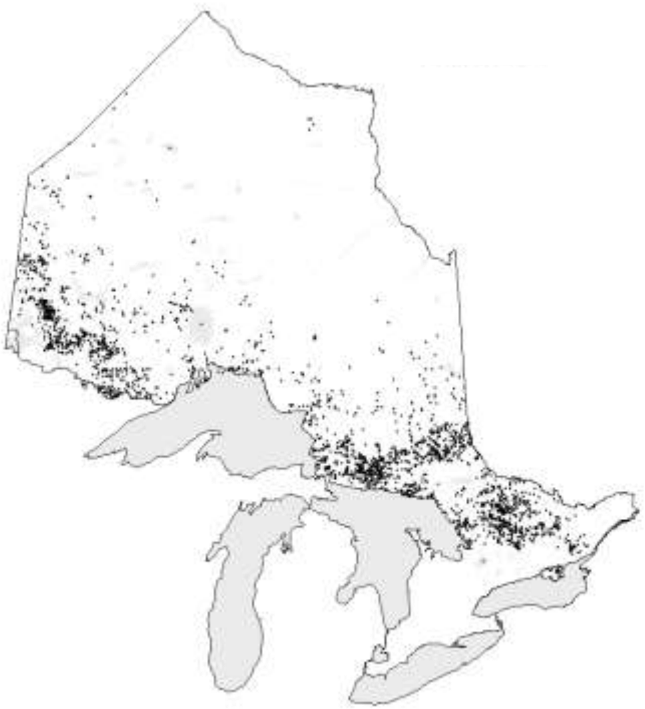
(Lake Manitou, June 2015)

Lake Trout

- Lake Trout lakes are relatively rare – only 1% of Ontario lakes
  - This represents 20-25% of all Lake Trout lakes worldwide
- Good ecological indicator
  - Large bodied (30-80 cm in length) and late maturing (5-10 yrs)
  - Specific habitat requirements for temperature and oxygen



Lake Trout *(Salvelinus namaycush*)



(OMNRF 2006)

(Photo http://www.hookhack.com/html/fom020113_laketrout.html)

Habitat Requirements

Warm Epilimnion

Usable: < 15 °C, Lethal: > 23.5 °C

Cold Hypolimnion

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

Provincial Standard for Volume-weighted Hypolimnetic O_2 > 7 mg/L

(Evans et al. 2007)

Habitat Requirements

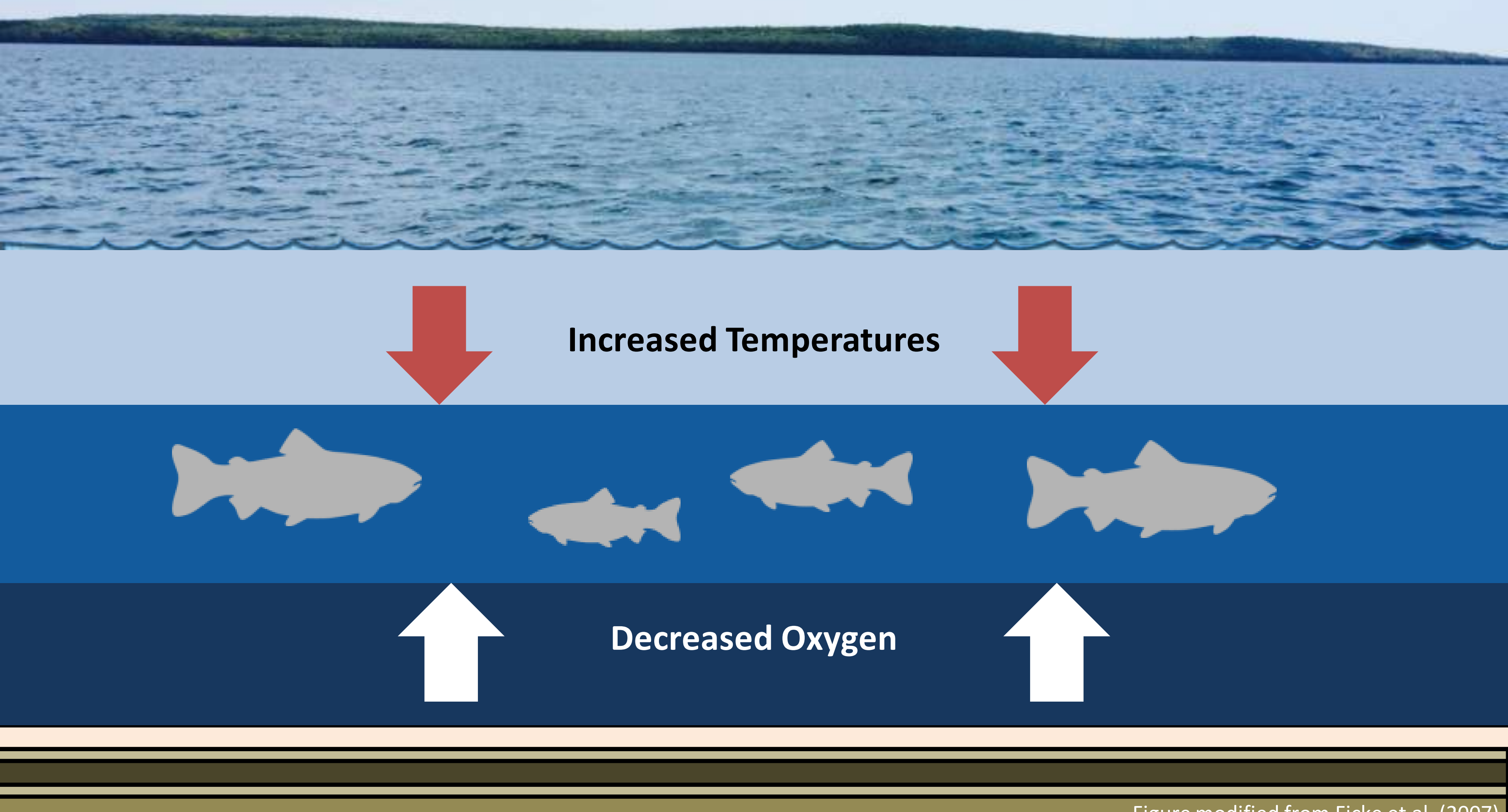
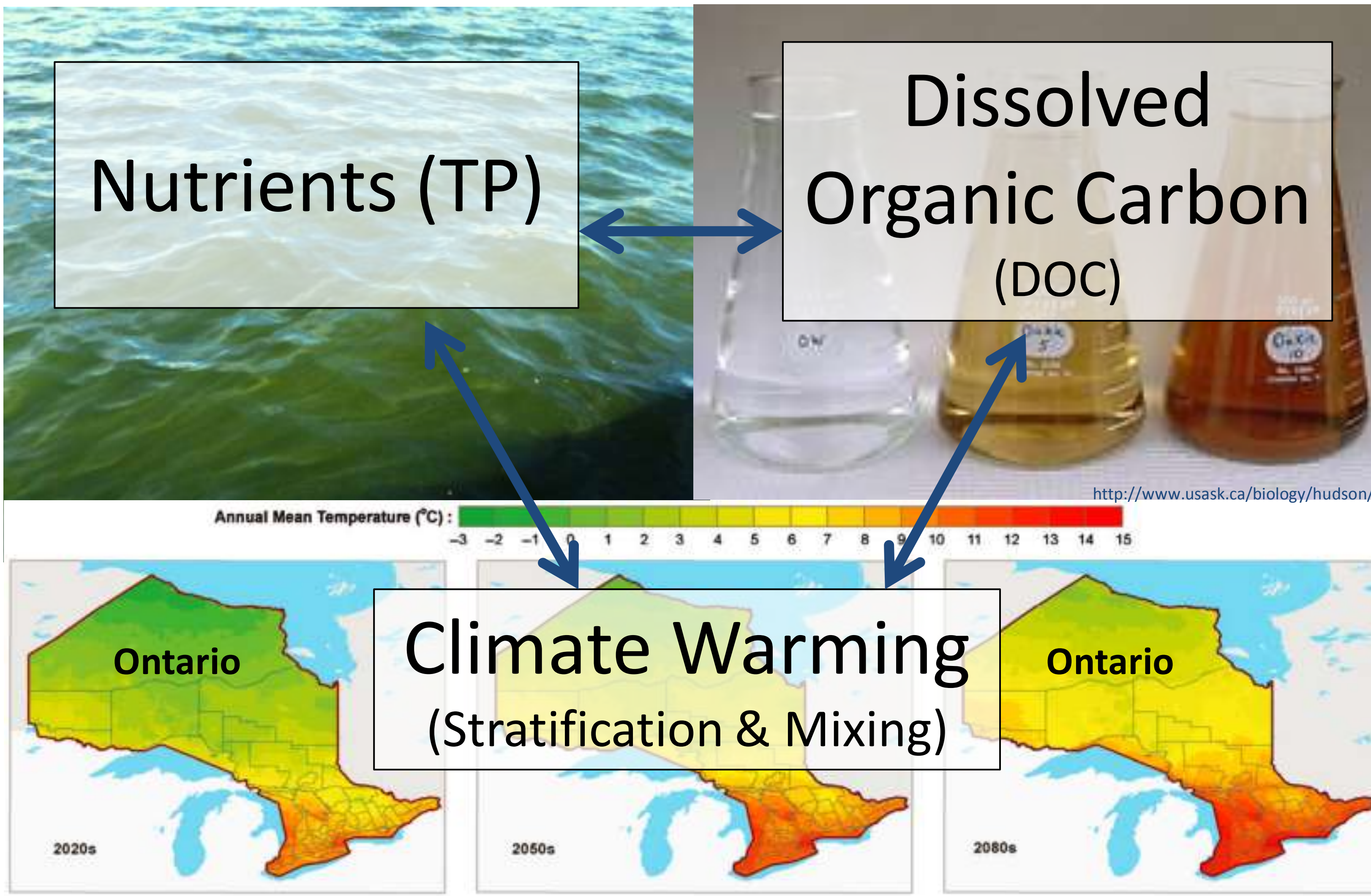
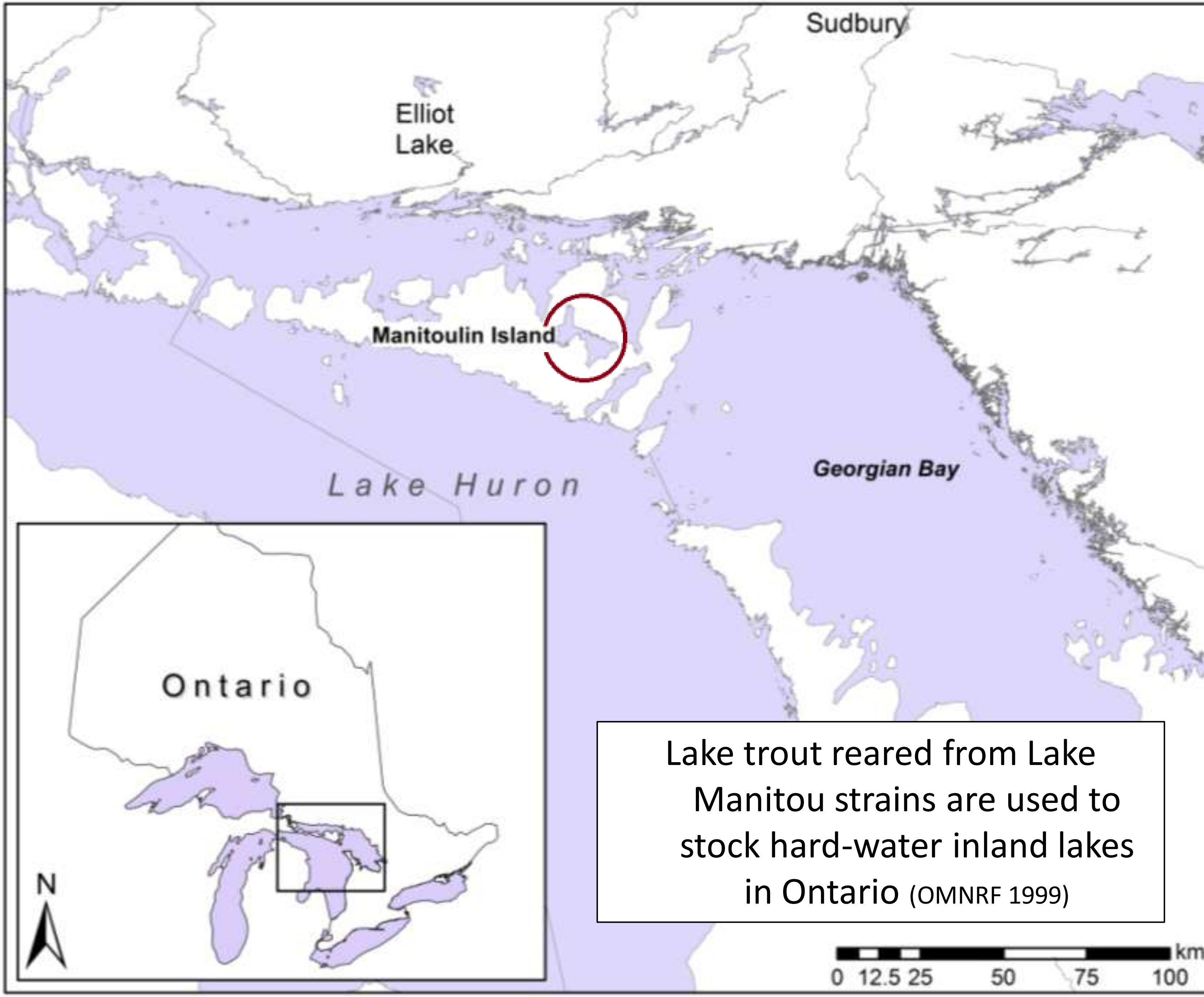


Figure modified from Ficke et al. (2007)

Variables that Influence Hypolimnetic Dissolved Oxygen (DO)

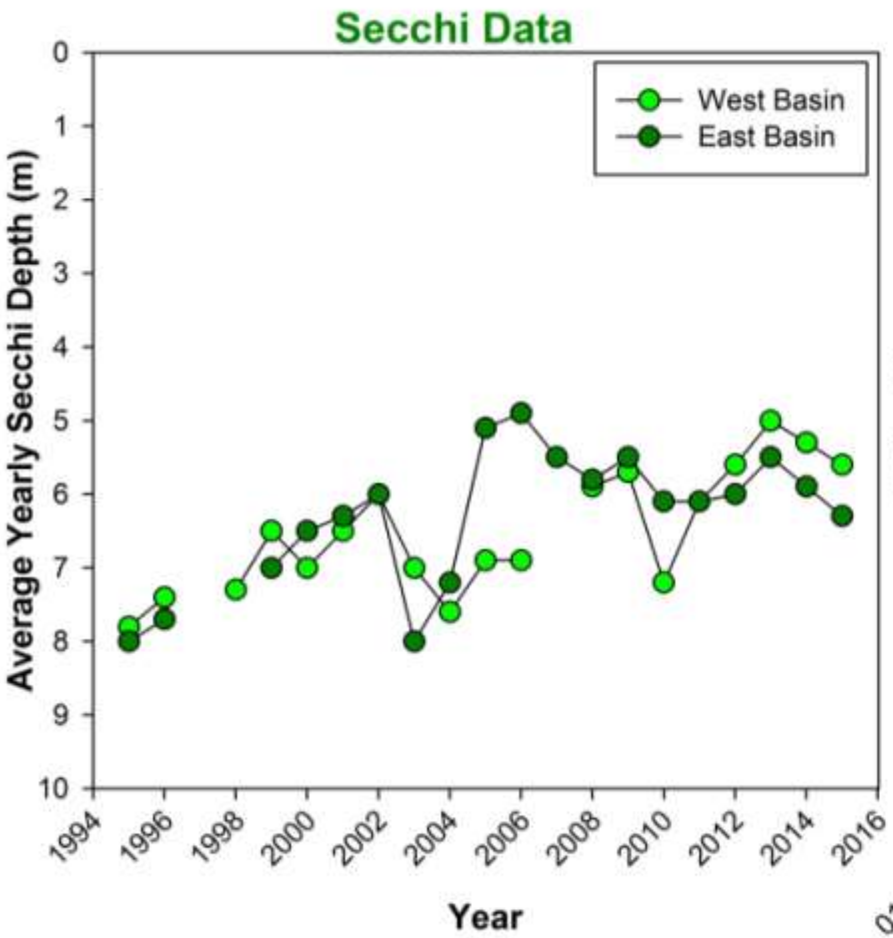


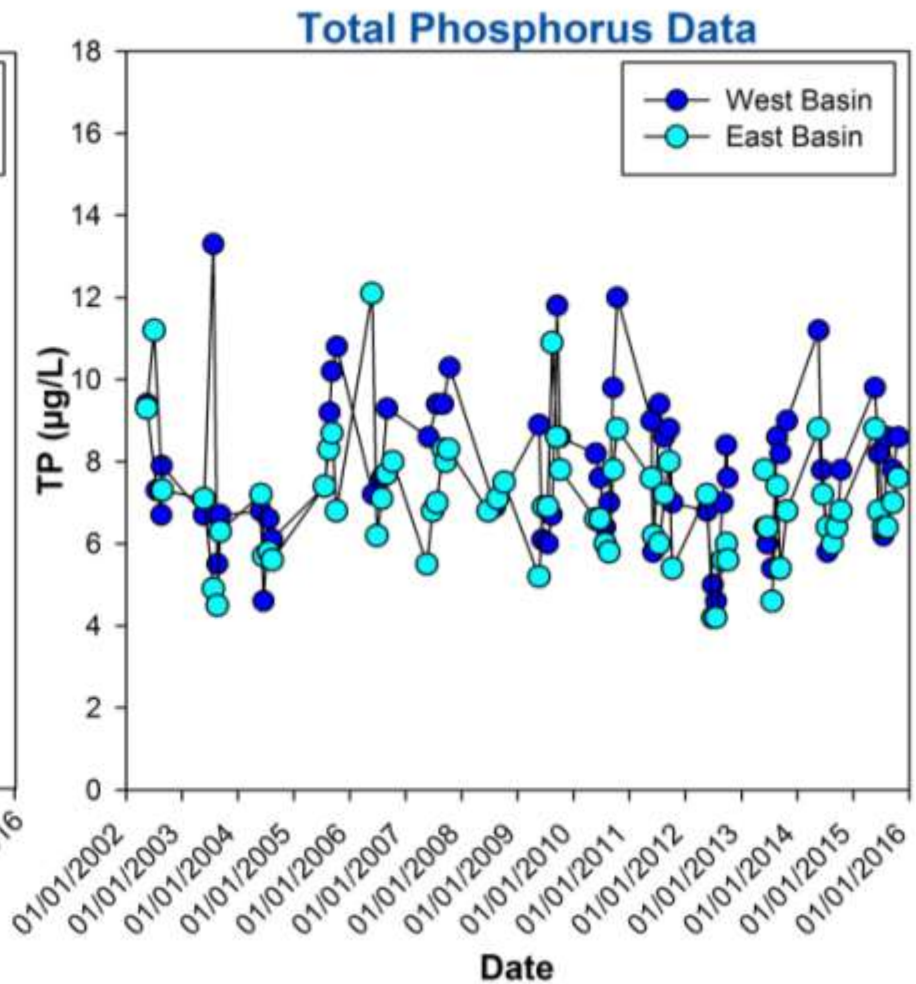
(Figure: Wang et al. 2014)



Lake trout reared from Lake Manitou strains are used to stock hard-water inland lakes in Ontario (OMNRF 1999)

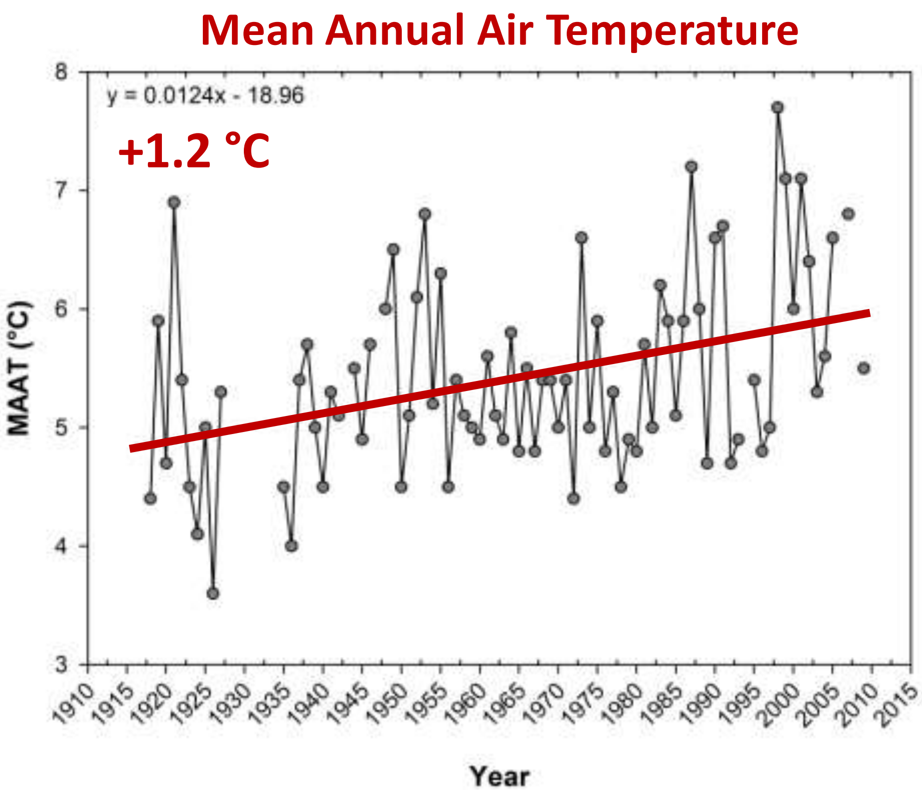
Lake Partner Program Data

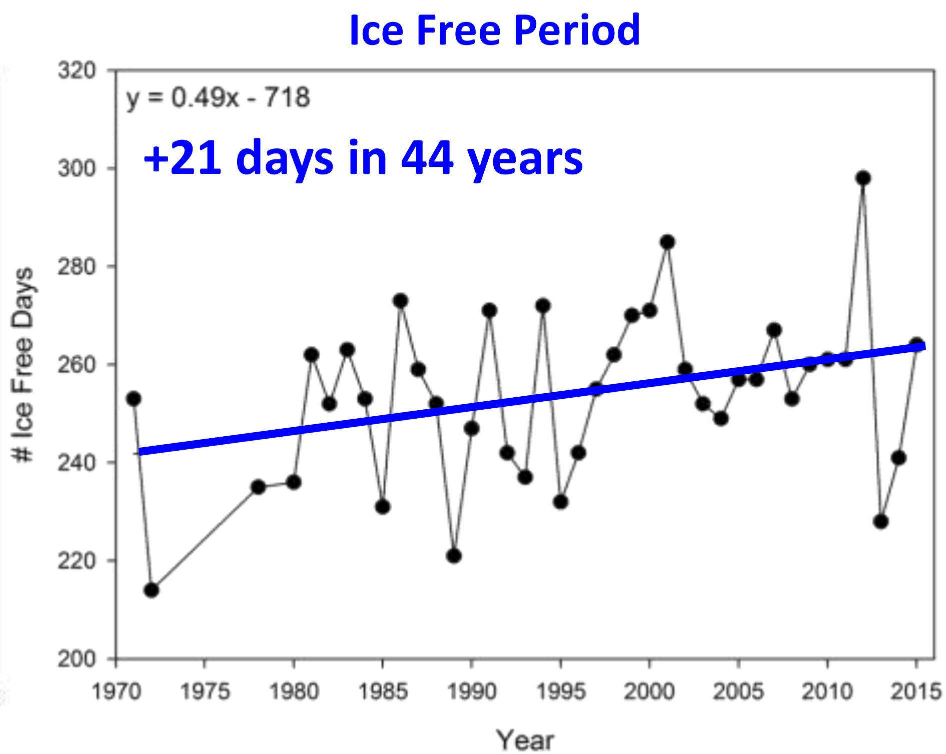




- ~2 m decrease in water clarity over 20 years
- Large seasonal variability in monitored TP, no clear trend since 2002
- TP often higher in the West Basin

Climate and Ice Data

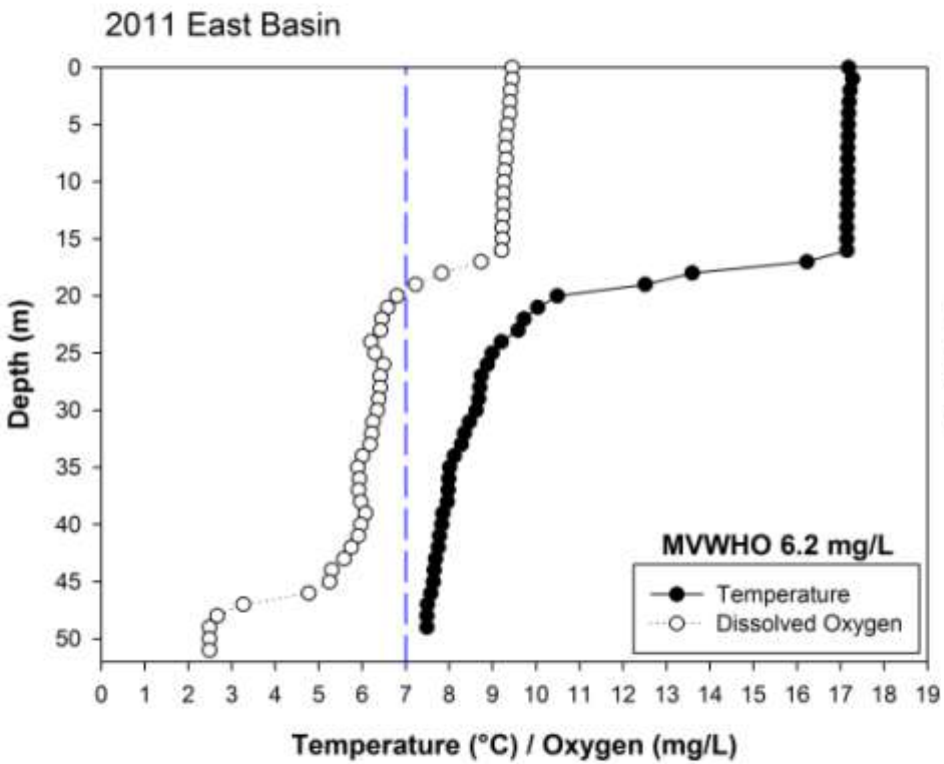


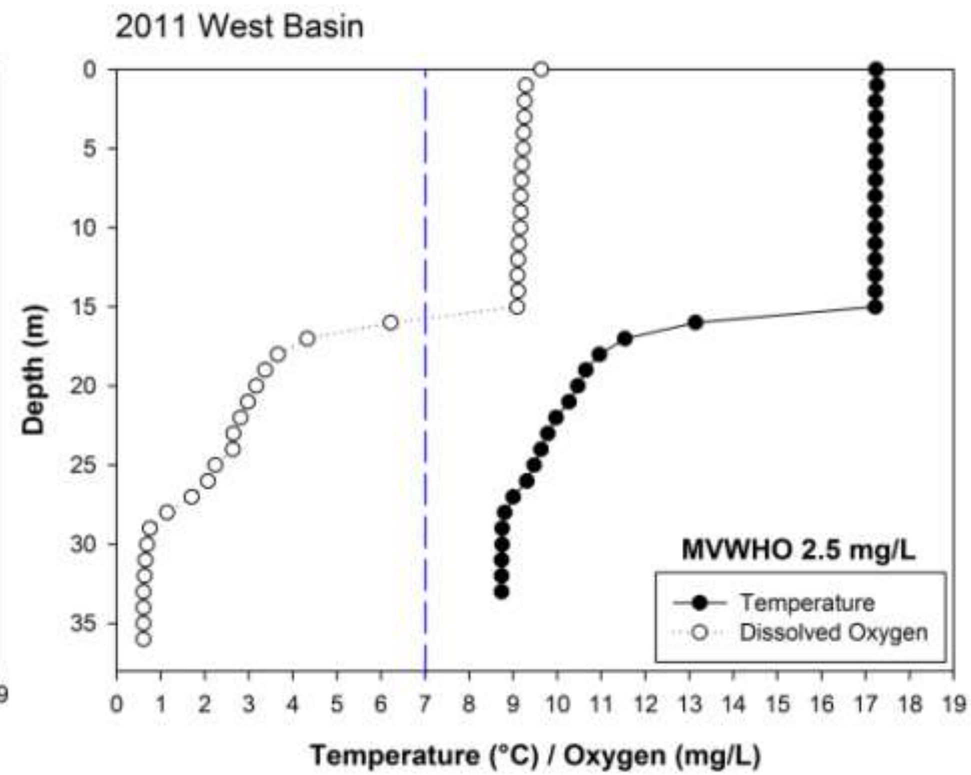


- Increases in air temperature not equal across seasons
- Greatest increases during the spring (~2 °C warmer since the early-1900s)
- Ice free period ~half a day longer/year

(Climate records from Environment Canada and Climate Change: Adjusted and Homogenized Canadian Climate Data. Ice records from Betty and Doug Heis)

End-of-Summer DO 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

- Are low end-of-summer DO values in Lake Manitou a recent development, or has this been a long-term feature of the lake?
- Are the low DO concentrations the result of a particular environmental stressor (climate/nutrients)?
- Have biota responded to these stressors, and if so, when?

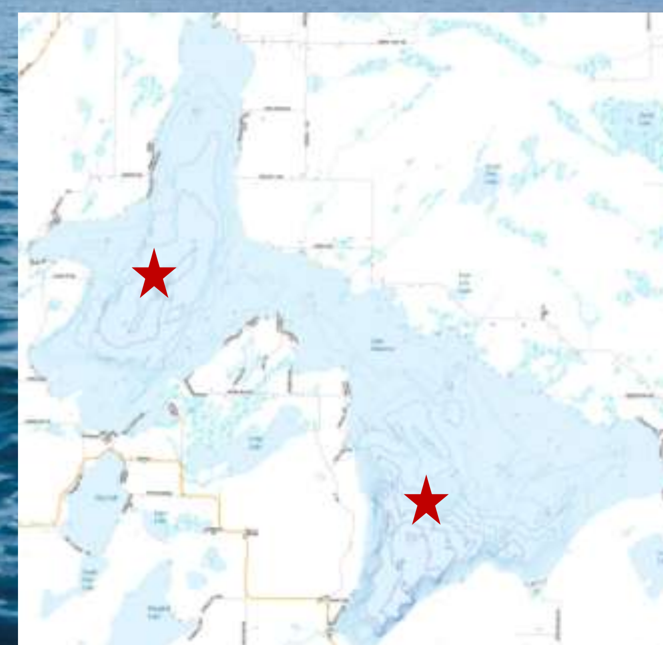
What can be done?

Fieldwork

June 2015: 24 cm long sediment core was collected from the East Basin

August 2016: 40 cm long core was collected from the West Basin

Cores were sectioned into 0.5 cm intervals



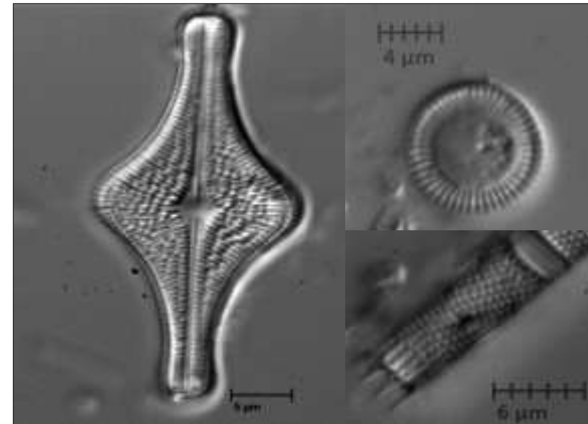
(Lake Manitou East Basin June 2015)

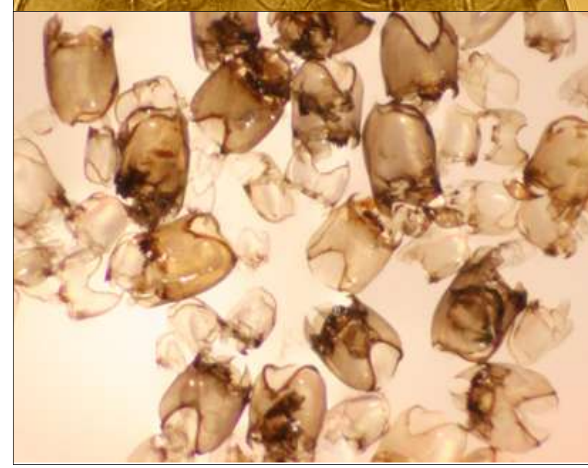
Methods

Sediment cores were dated using ^{210}Pb

Indicators to be analyzed:

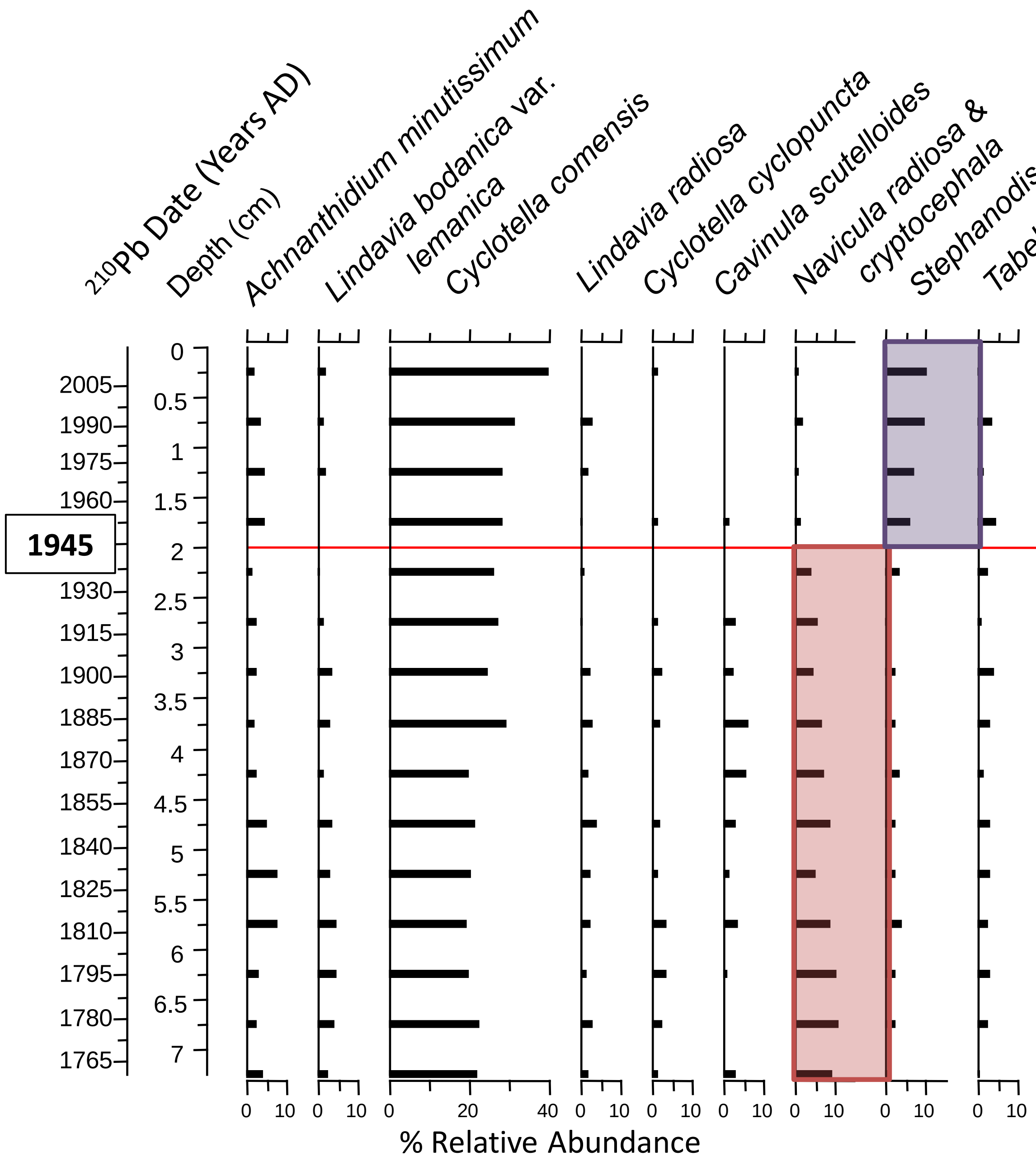
- **Diatoms:**
  - Common siliceous algae
  - Readily preserved and identifiable valves
  - Used to reconstruct the influence of nutrients and climate warming
- **Chironomids:**
  - Larval remains of non-biting midges
  - Identifiable head capsules preserve in sediments
  - Used to reconstruct end-of-summer hypolimnetic $[O_2]$





(Photo: http://post.queensu.ca/~pearl/cf8/cf8pics.html, http://www.earth.northwestern.edu/~yarrow/projects.html)

Manitou East Basin Diatom Results



- Increase in *Stephanodiscus* taxa – nutrient loading signal
- Decrease in epiphytic and epilithic taxa - *Navicula radiosa* and *N. cryptocephala*

(Douglas and Smol 1995, Winter and Duthie 2000)

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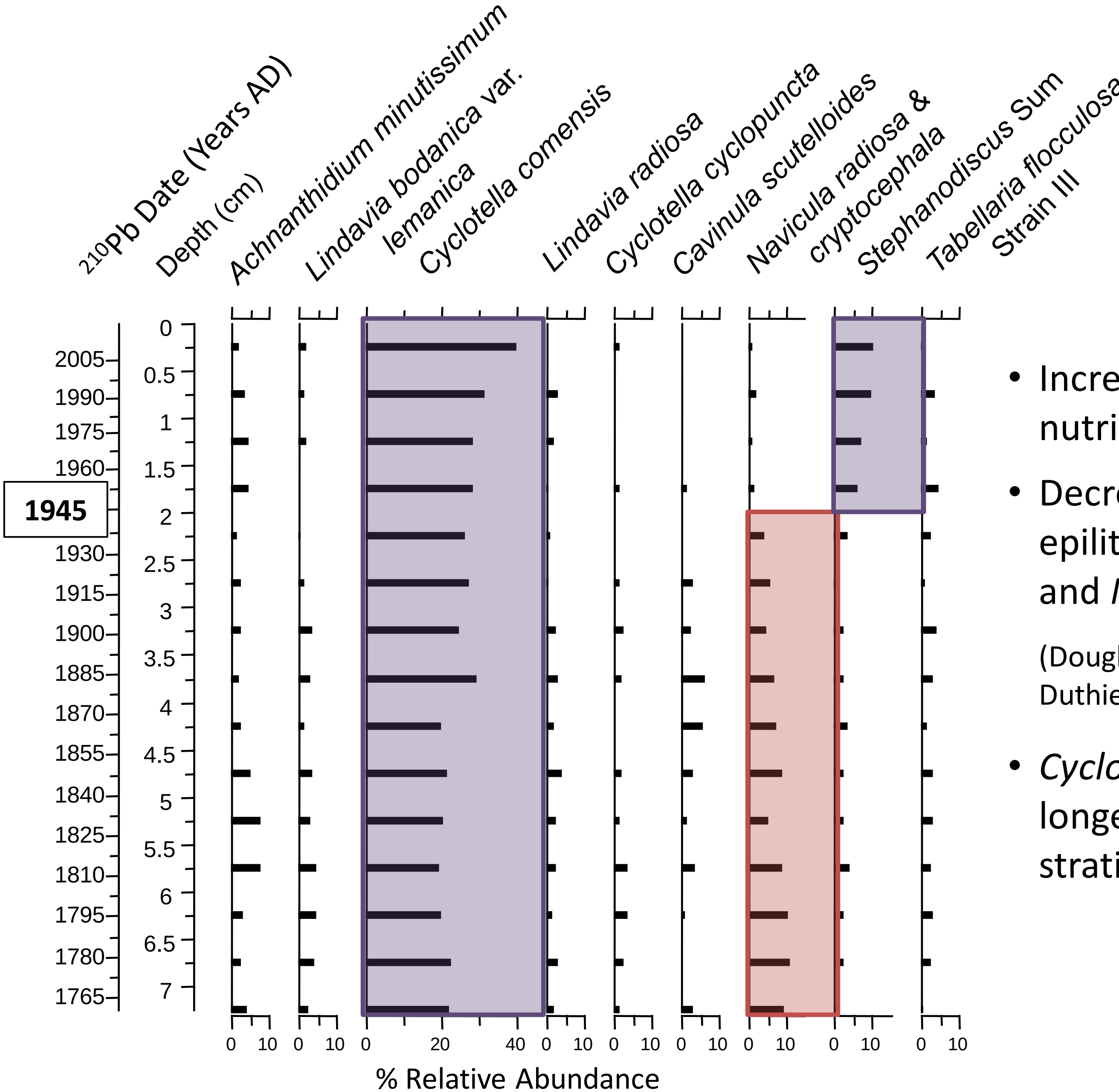

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- *Cyclotella comensis* increase – longer/stronger thermal stratification (Rühland et al. 2015)

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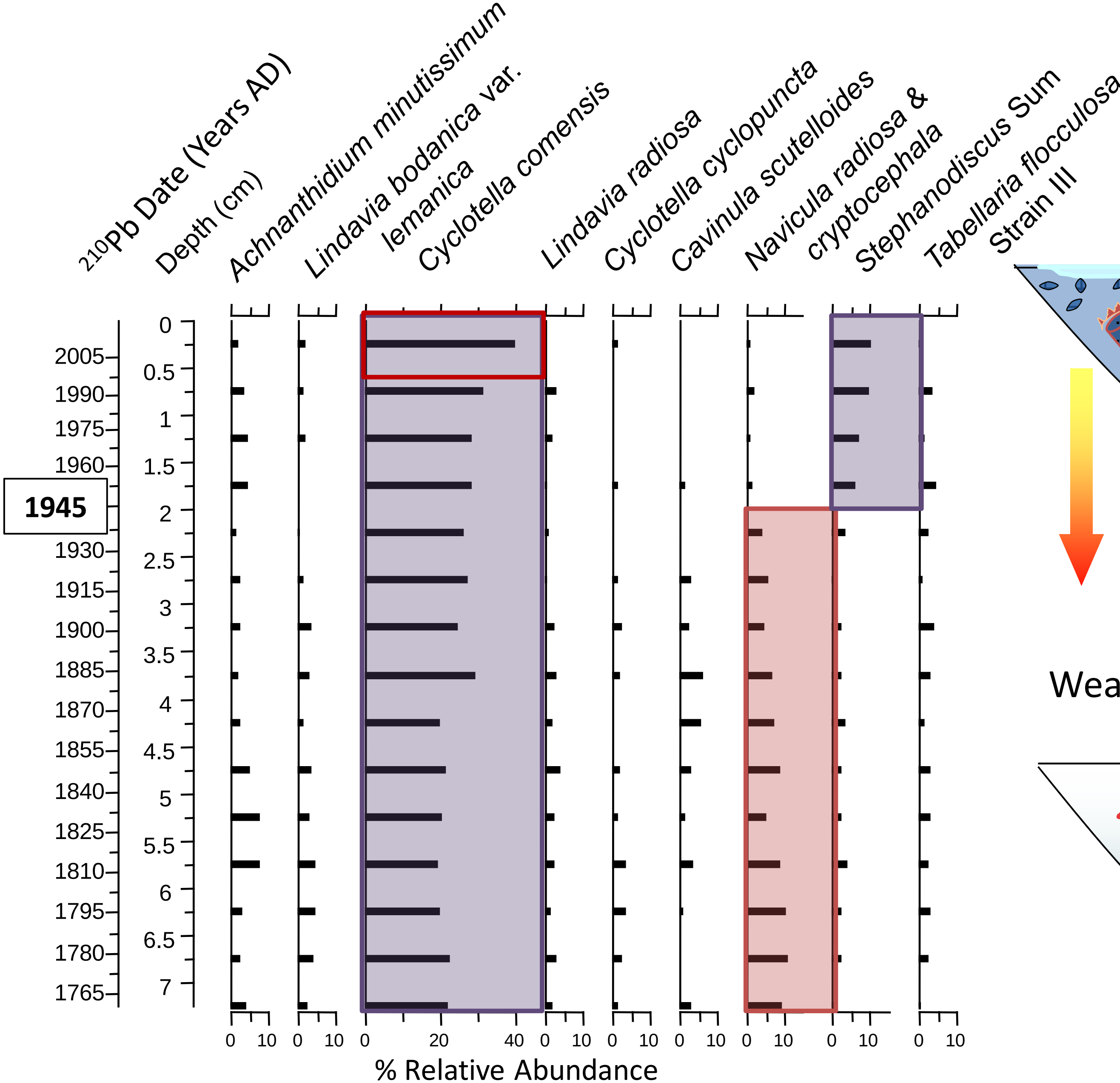
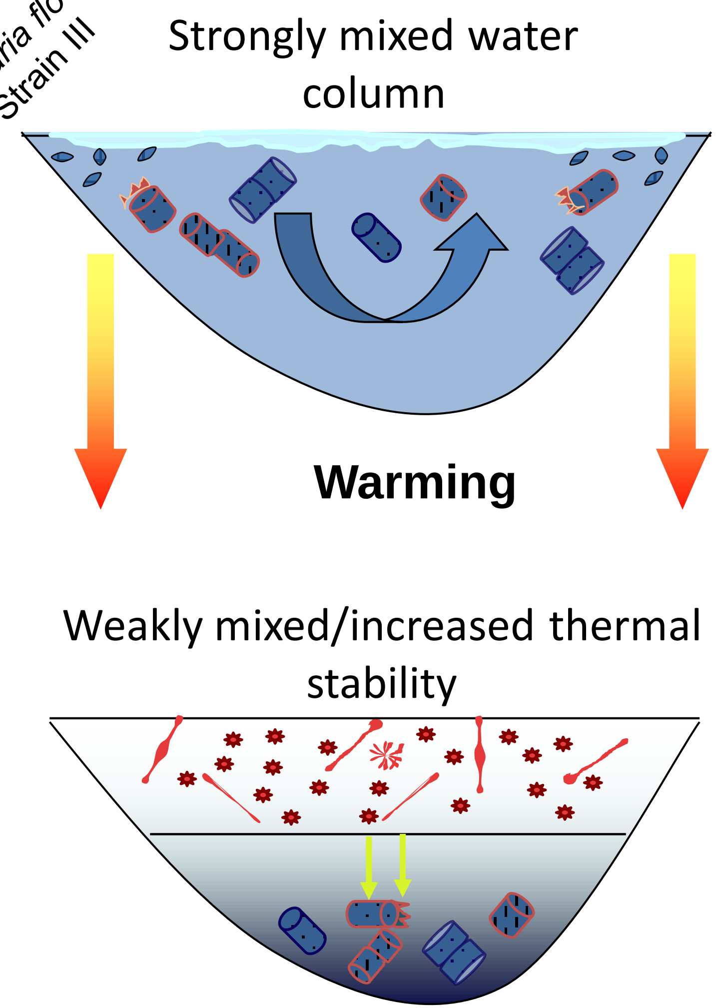
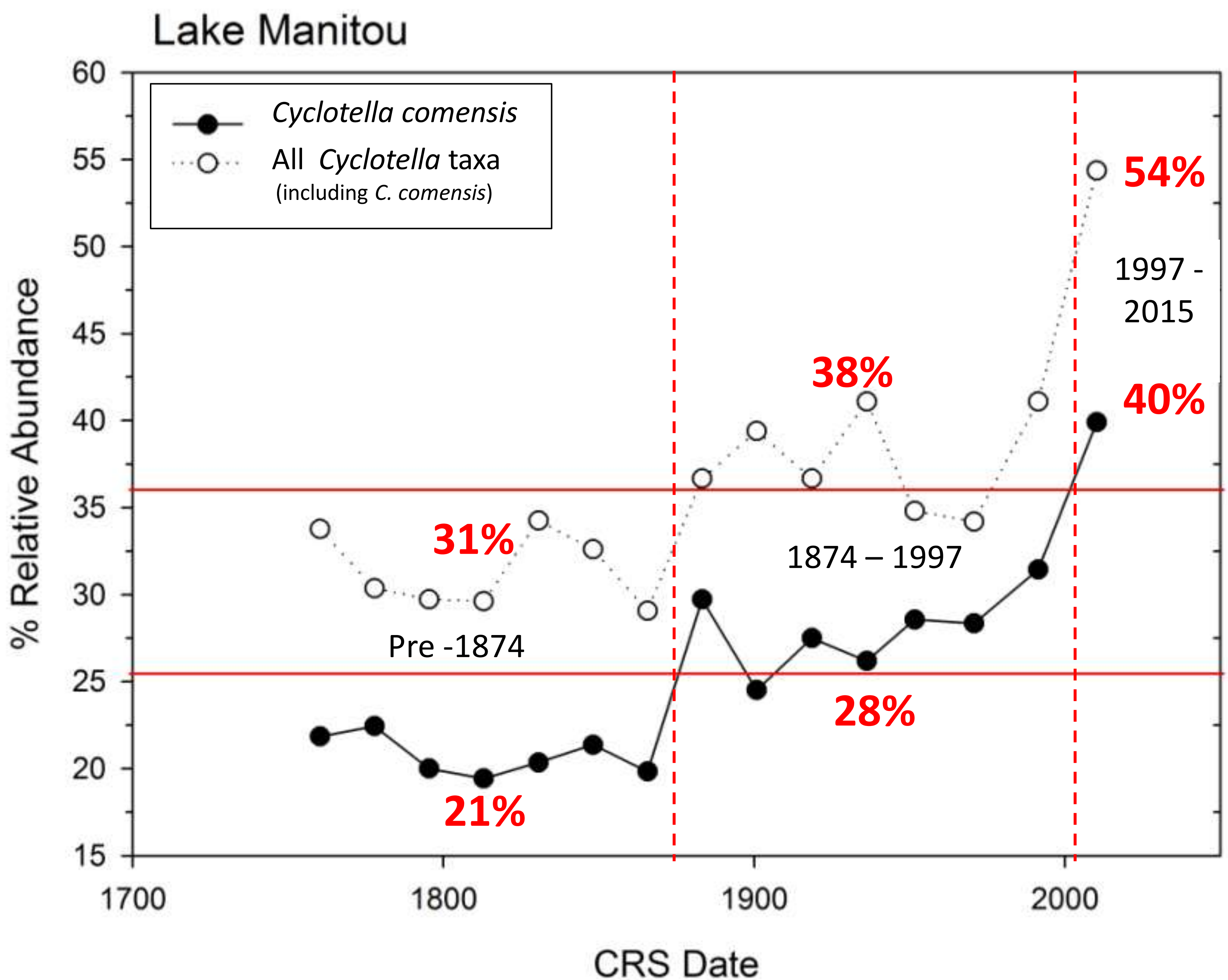


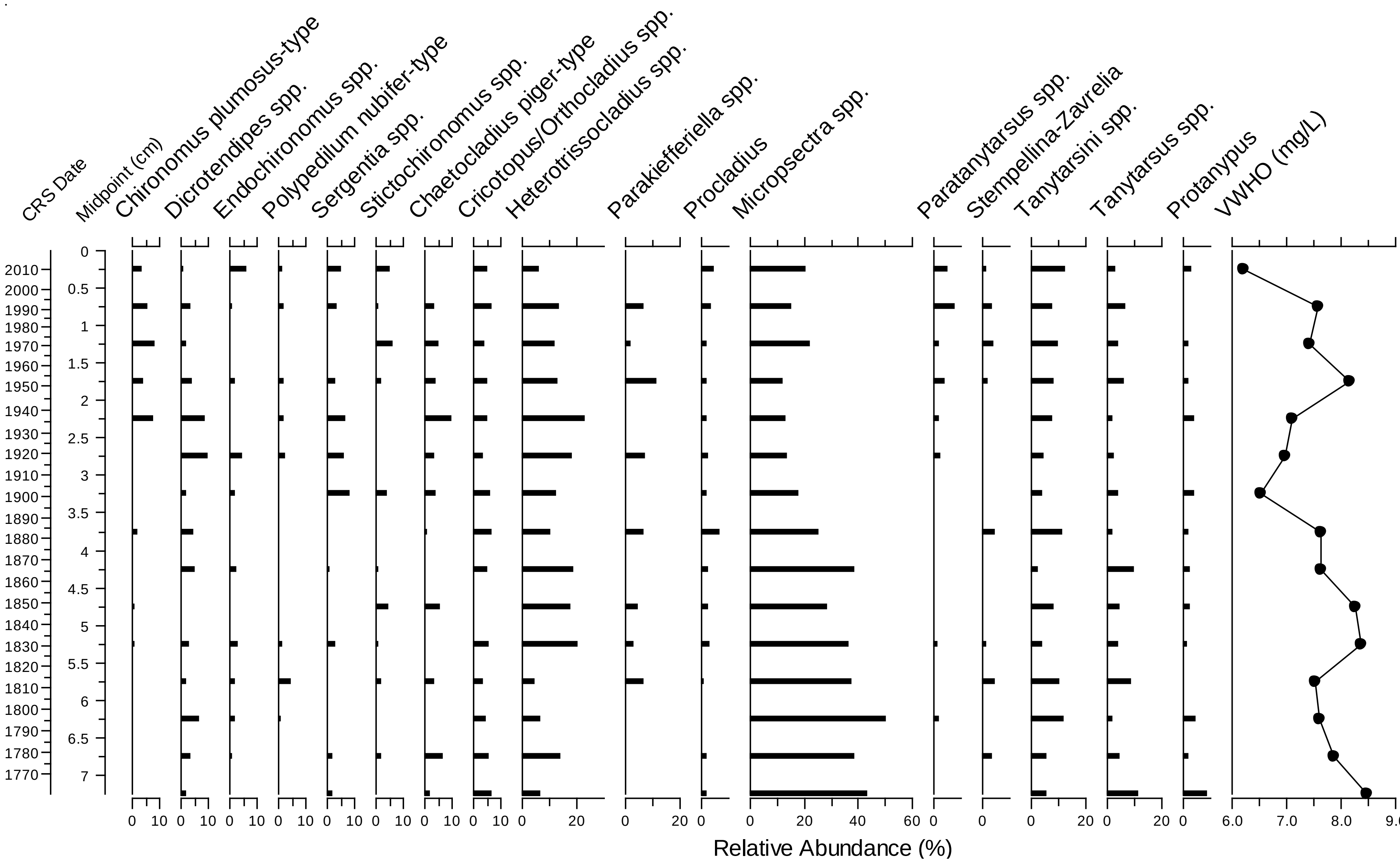


(Rühland et al. 2015)

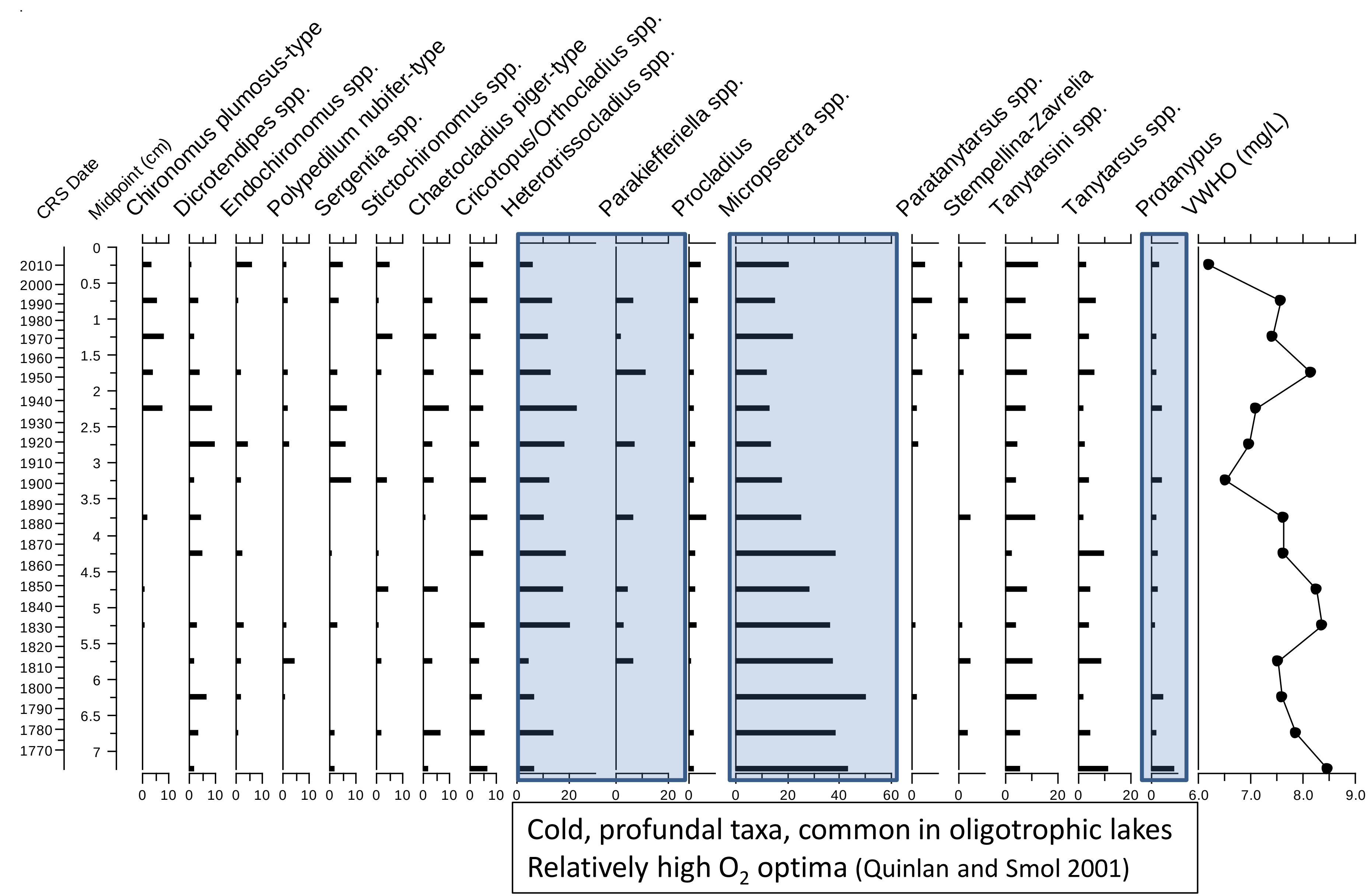


Lake Manitou
Cyclotella comensis
All Cyclotella taxa
(including C. comensis)
54%
1997 -
2015
38%
40%
31%
1874 – 1997
Pre -1874
28%
21%
60
55
50
45
40
35
30
25
20
15
% Relative Abundance
1700
1800
1900
2000
CRS Date

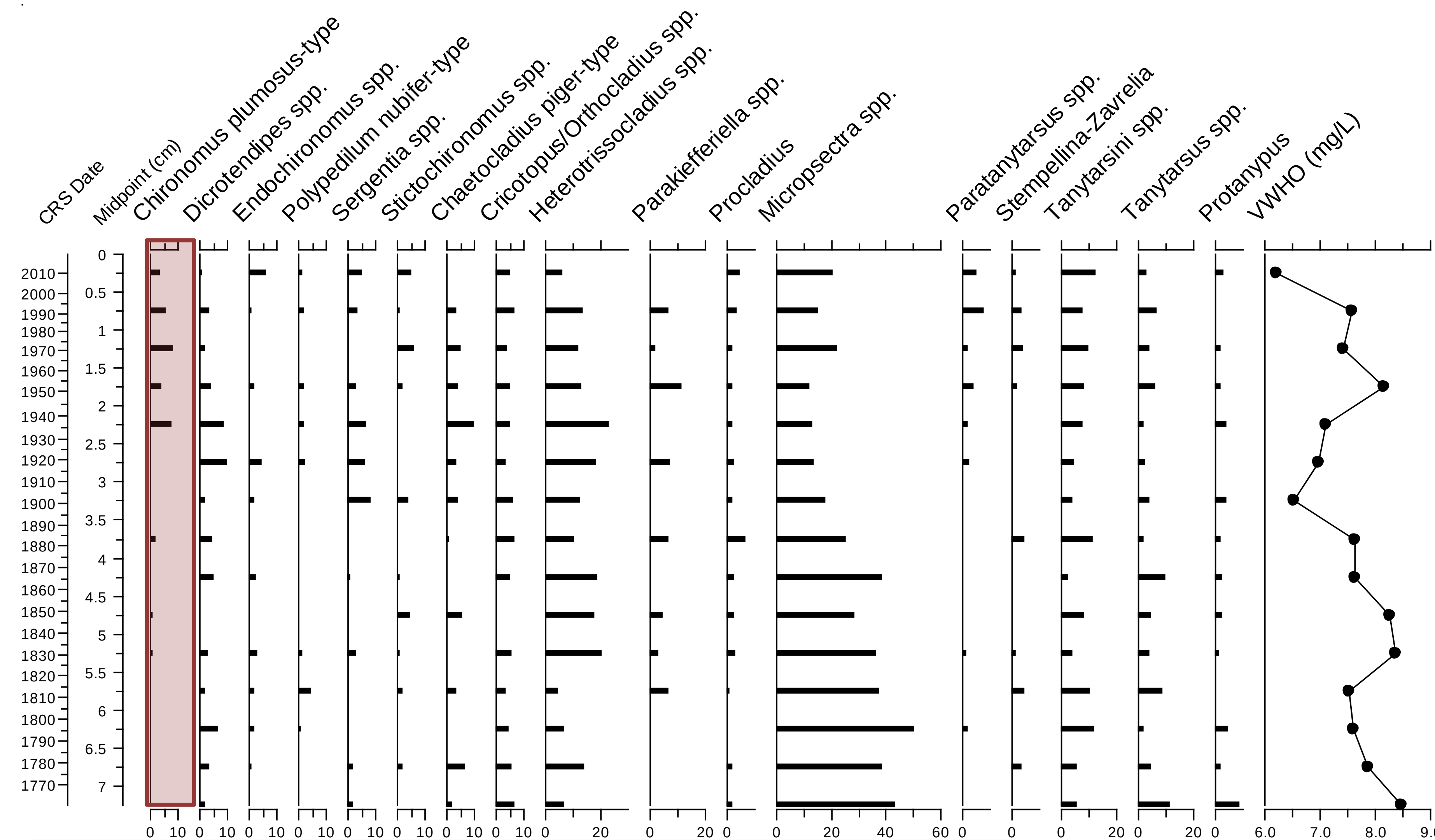
Manitou East Basin Chironomid Results



Manitou East Basin Chironomid Results

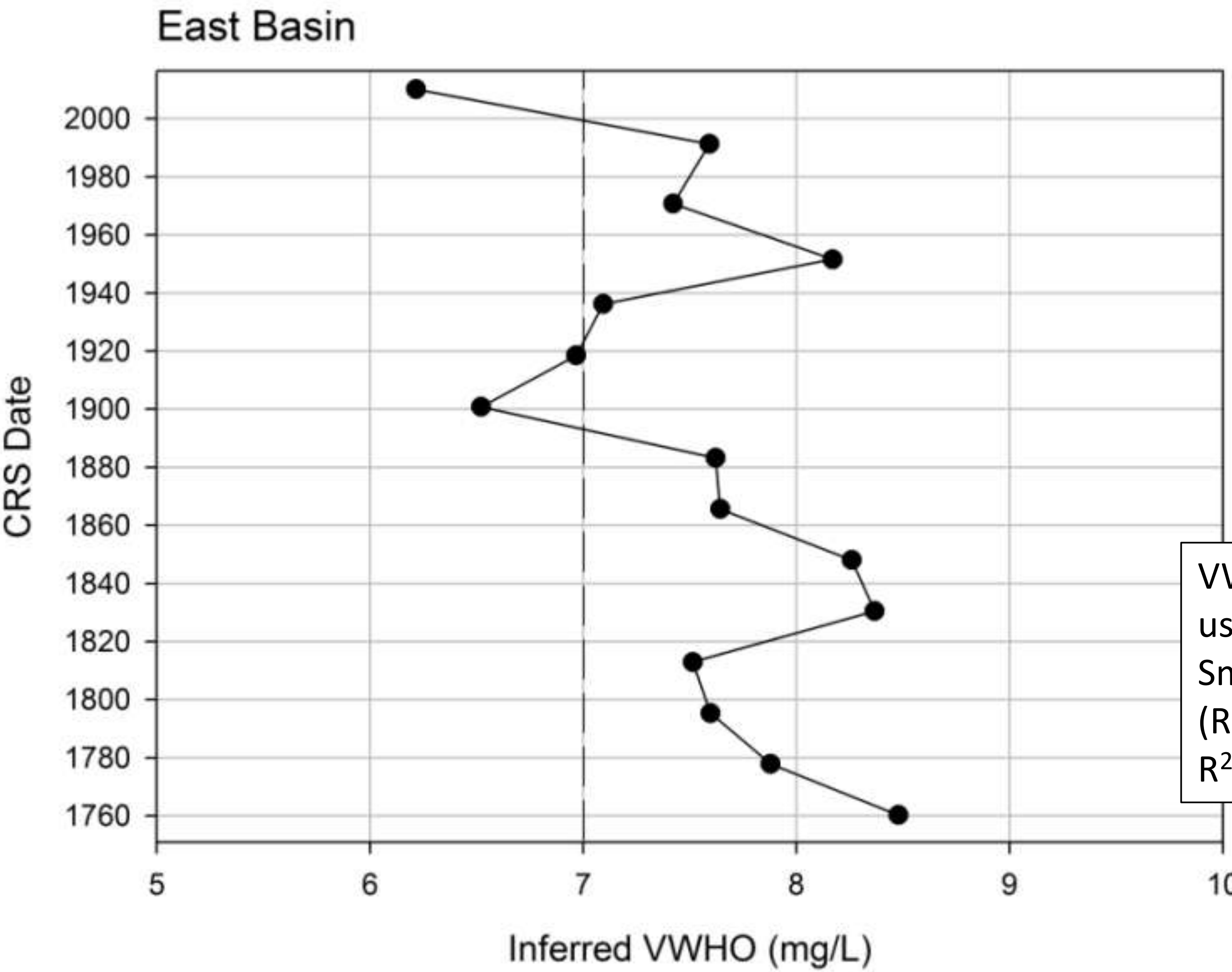


Manitou East Basin Chironomid Results



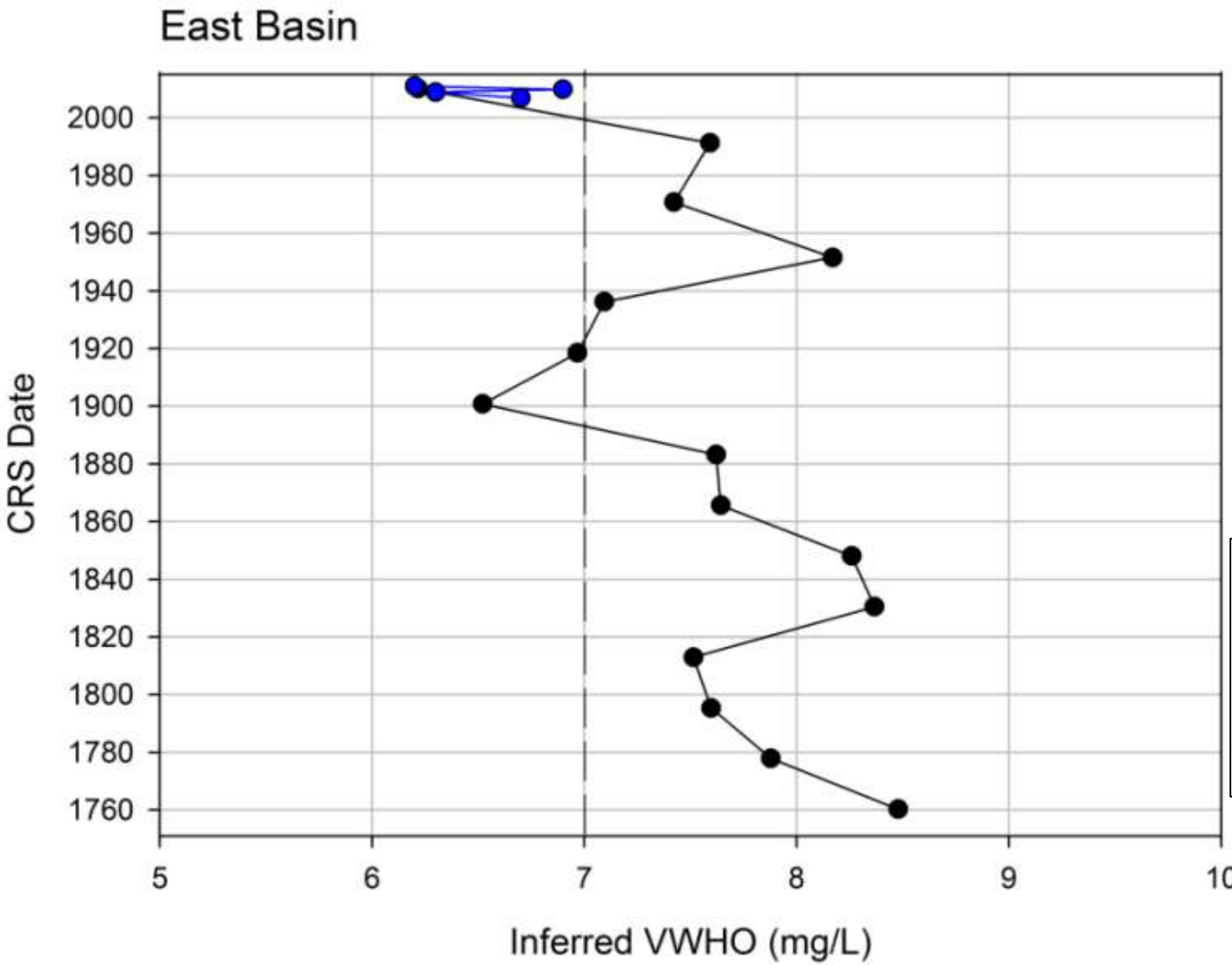
Chironomus plumosus: Profundal taxon tolerant of low oxygen conditions (Nagell and Landahl 1978)

VWHO Reconstruction Results



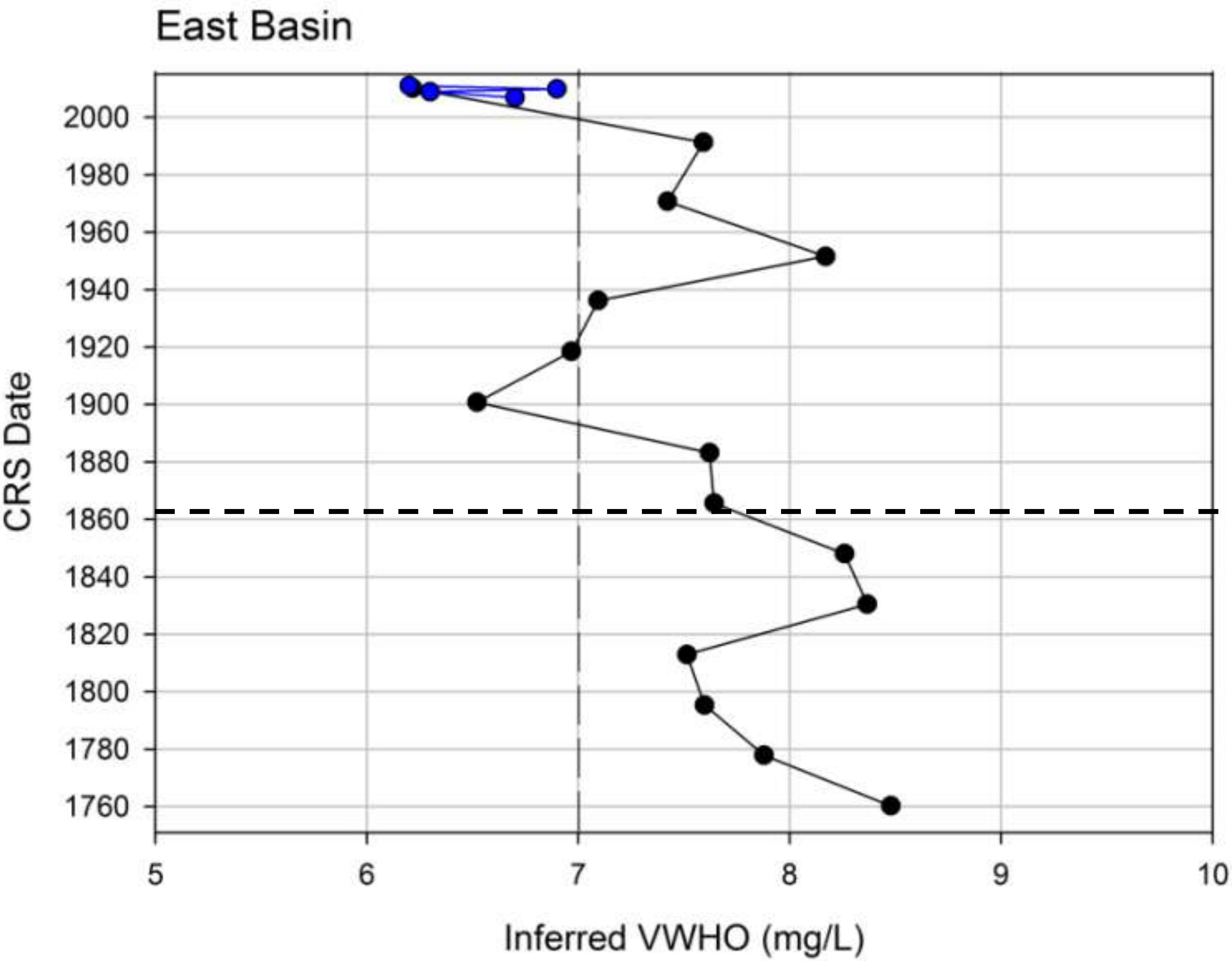
VWHO reconstructed using the Quinlan and Smol (2001) model (RMSE=1.98 mg/L, R^2=0.5998)

VWHO Reconstruction Results



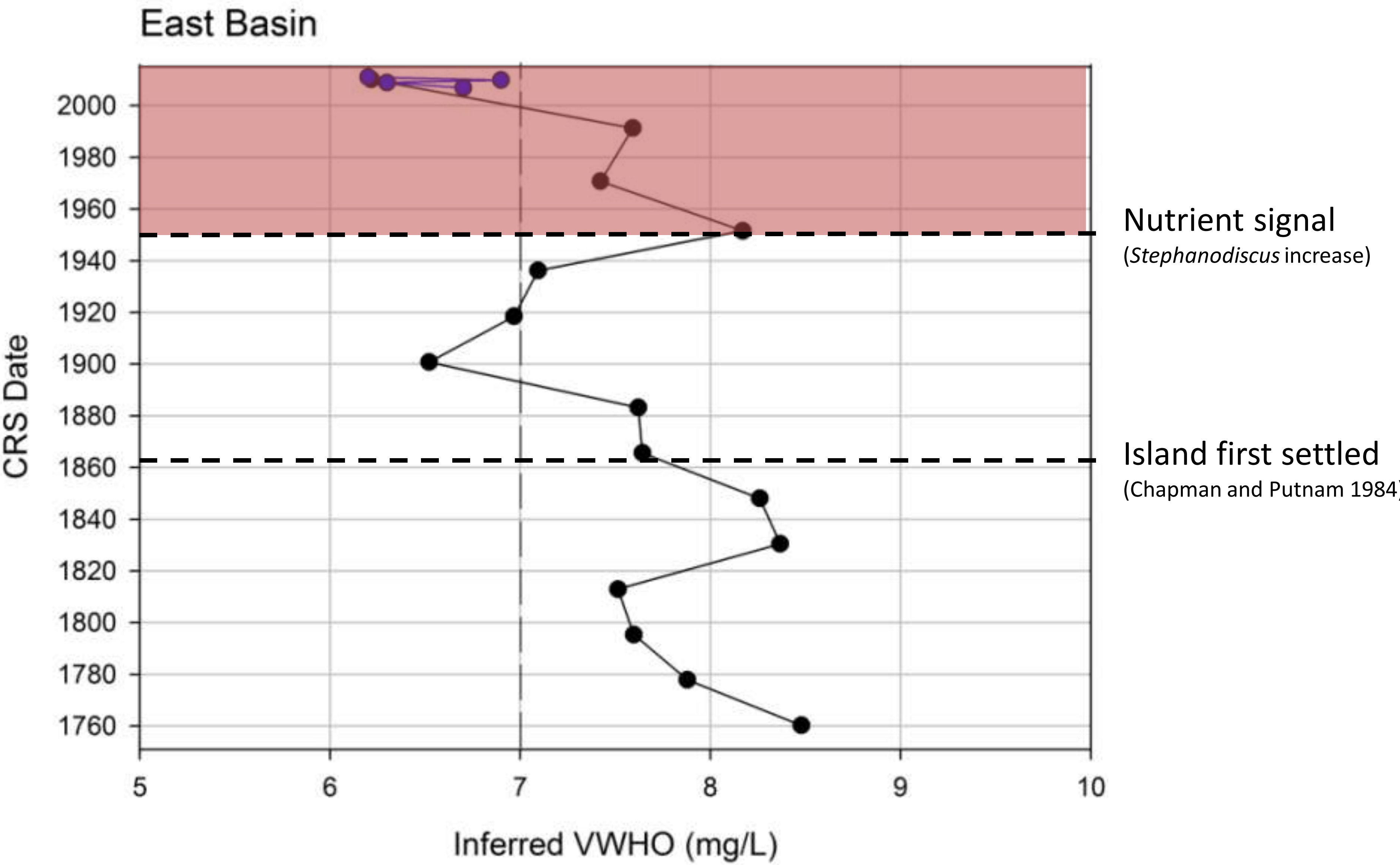
Monitored VWHO from 2007-2011 correspond well with chironomid-inferred VWHO

VWHO Reconstruction Results



Island first settled
(Chapman and Putnam 1984)

VWHO Reconstruction Results



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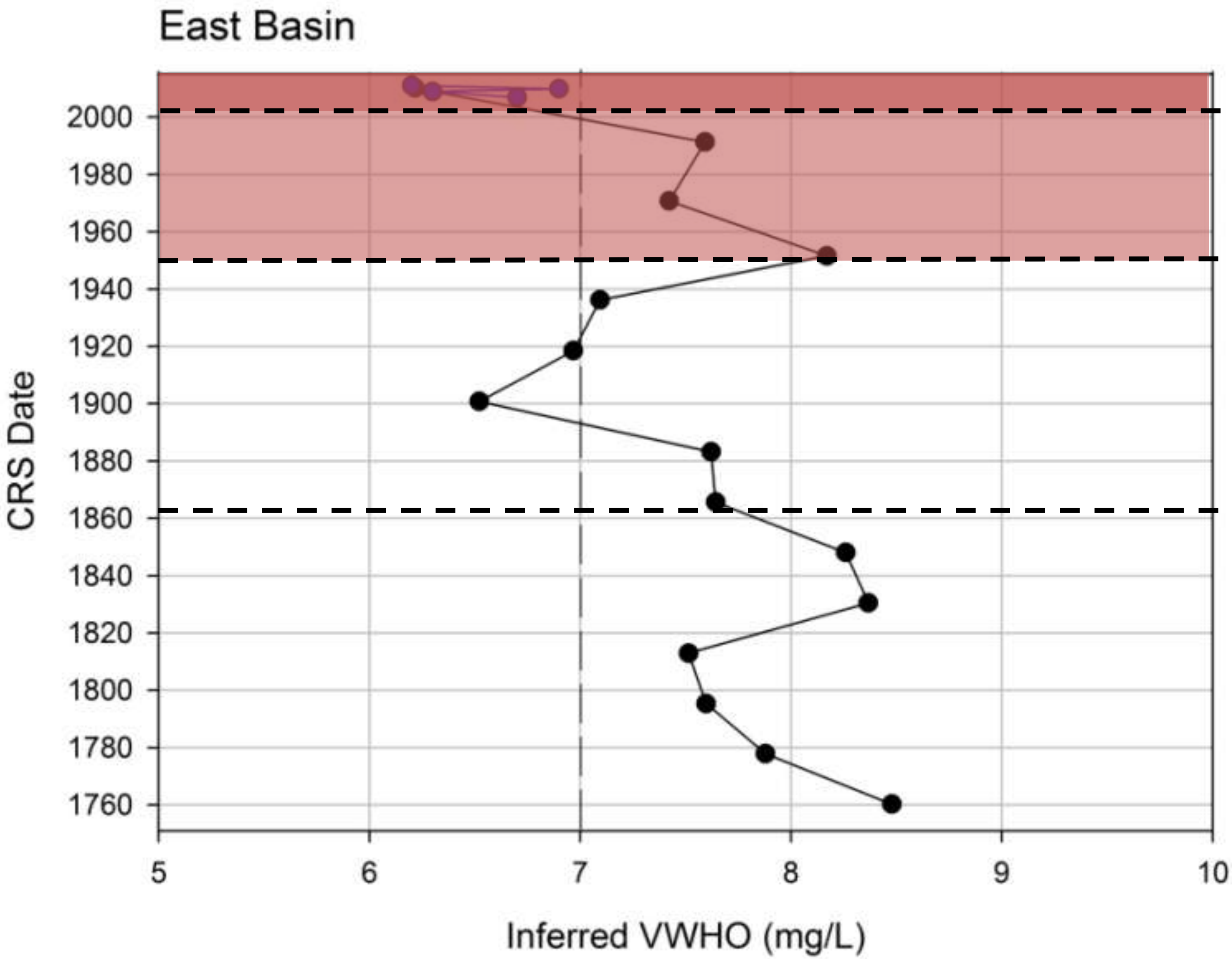


Warming signal
(*Cyclotella* & VRS-chl-*a* increase)

Nutrient signal
(*Stephanodiscus* increase)

Island first settled
(Chapman and Putnam 1984)

Preliminary Results Summary

Diatom Data:

- Shift in diatom assemblage ca. 1945 suggests increase in nutrients
- Increase in small *Cyclotella* taxa in the late-1990s indicative of longer/stronger thermal stratification

Chironomid Data:

- Decreasing trend in VWHO in the late-1880s
- Second decreasing trend in VWHO synchronous with increasing *Stephanodiscus* taxa
  - Suggests nutrient-driven oxygen depletion
- VWHO is lowest in most recent sediments
  - Nutrients + warming

Next Steps

- Compare diatom and chironomid trends between East and West Basin
- Major events that happened in the ~1950s ? (development, landscape changes, etc.)
- Compare changes in Lake Manitou with other lakes of interest across the province

Acknowledgements

- Liz Favot and the staff from the Blue Jay Creek Hatchery
- NSERC
- Environment Canada
- Ontario Ministry of the Environment and Climate Change
- Ontario Ministry of Natural Resources and Forestry
- Federation of Ontario Cottagers' Associations

Ontario

NSERC
CRSNG

FOCA
Federation of Ontario Cottagers' Associations

Environment
Canada

Thank you for your attention

Key Literature

Chapman, L. J., D.F. Putnam. 1984. The physiography of Southern Ontario (third edition). *In* Ontario Geological Survey Special Volume 2. Ontario Ministry of Natural Resources. 165-166 pp.

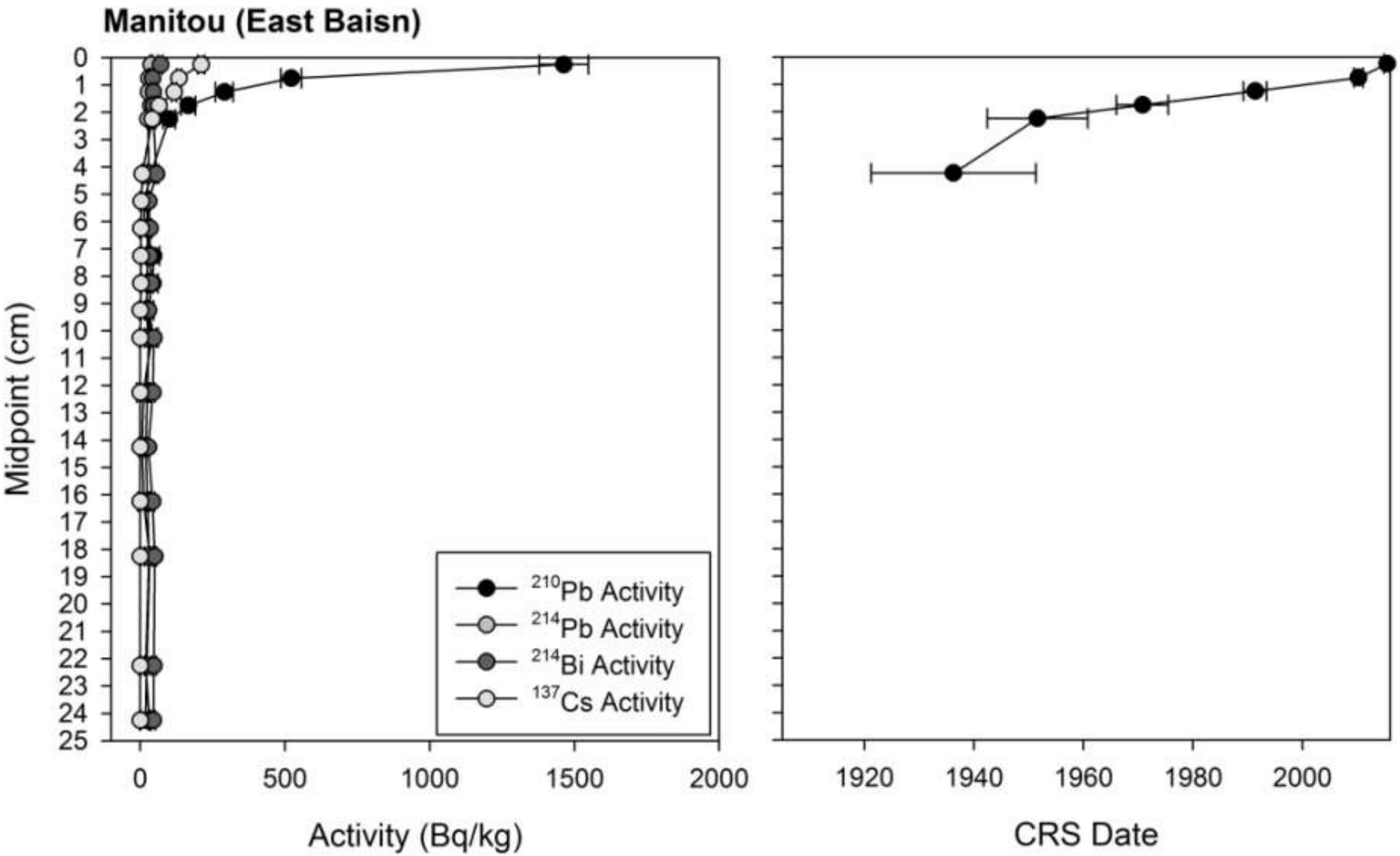
Douglas, M. S. V., J. P. Smol. 1995. Periphytic diatom assemblages from high arctic ponds. J Phycol 31:60-69.

Evans, D. O. 2007. Effects of hypoxia on scope-for-activity and power capacity of lake trout (*Salvelinus namaycush*). CJFAS 64:345-361.

OMNR. 2006. Inland Ontario Lakes Designated for Lake Trout Management. 58 pp.

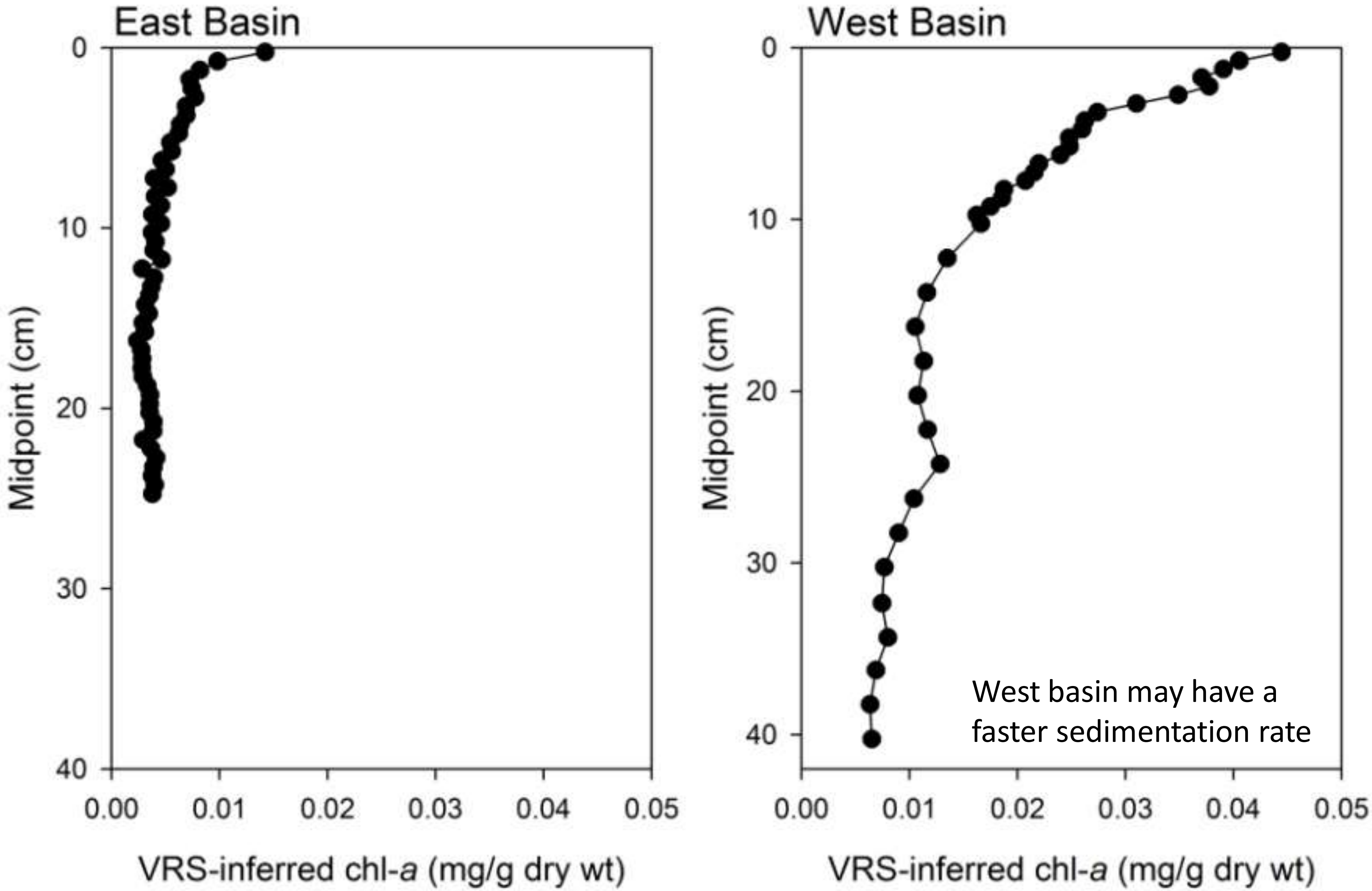
Quinlan, R., J. P. Smol. 2001. Chironomid-based inference models for estimating end-of-summer hypolimnetic oxygen from south-central Ontario shield lakes. Freshwater Biology 46:1529-1551.

Rühland, K., A. M. Paterson, and J. P. Smol. 2015. Lake diatom responses to warming: reviewing the evidence. JOPL 35:110-123.



Slow rate of sedimentation
Dates past 1936 were extrapolated

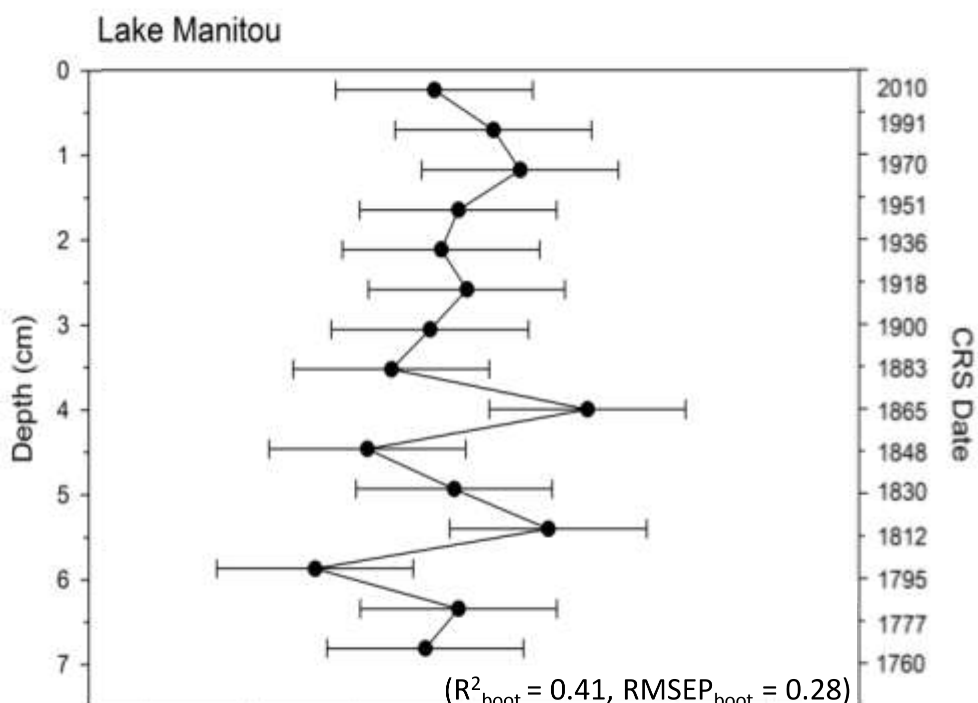
VRS-inferred chlorophyll-*a* Results



West basin may have a faster sedimentation rate

Is applying a TP model appropriate?

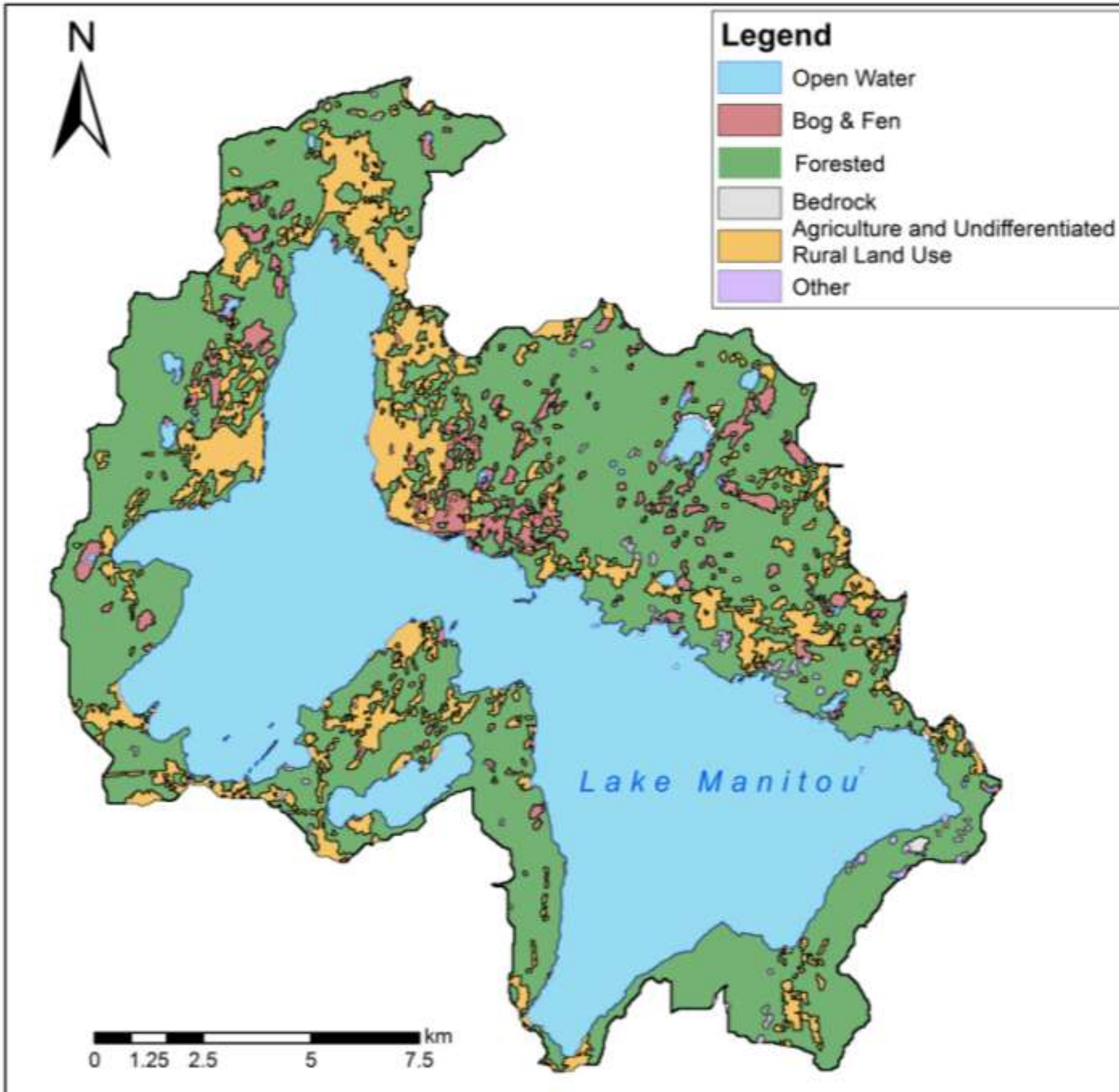
- Increase in both high-nutrient and low-nutrient taxa in recent sediment – the slight decrease in DI-TP at the surface of the core may not be realistic



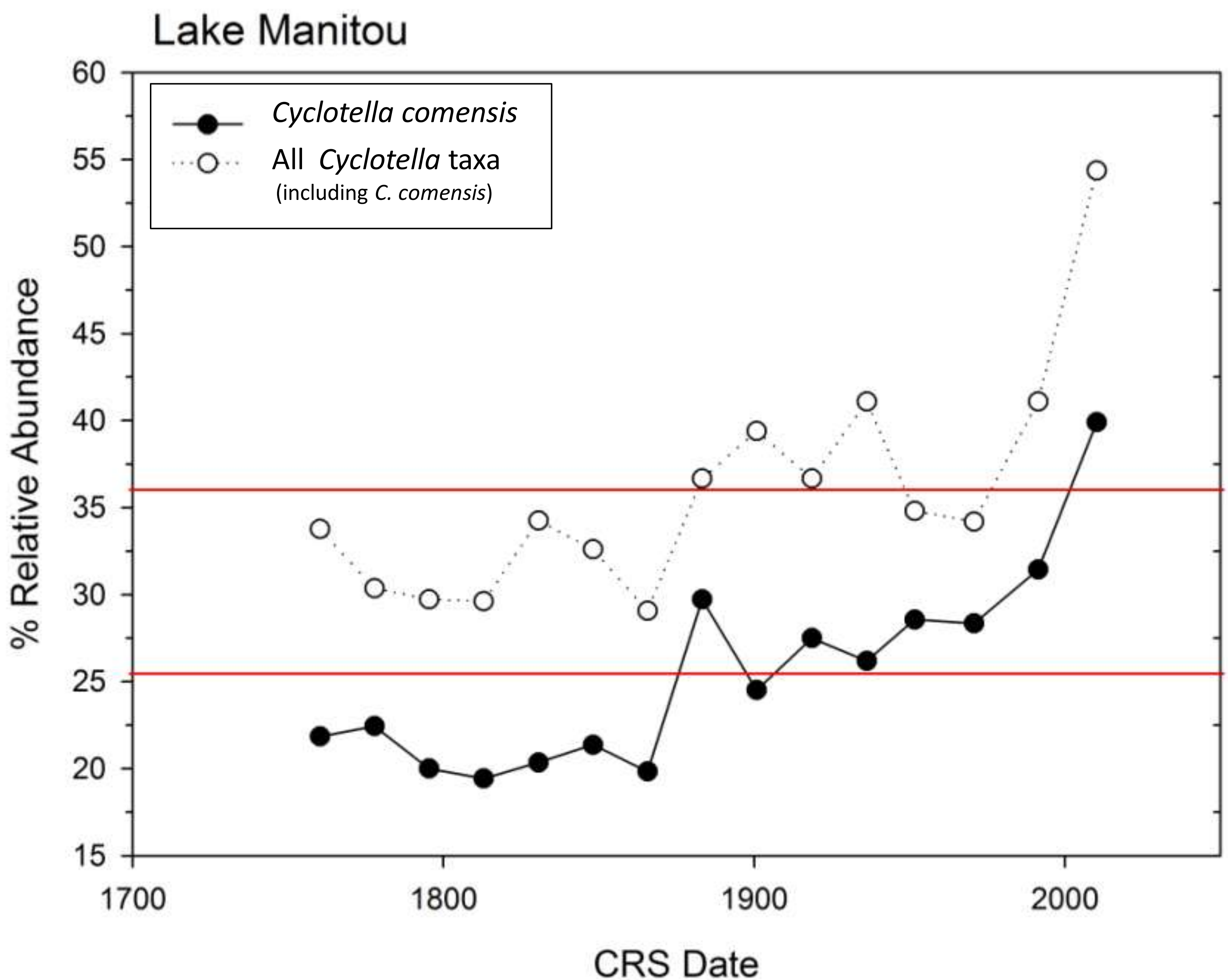
(R^2_{boot} = 0.41, $RMSEP_{boot}$ = 0.28)

DI-TP (µg/L)

- Suggests other environmental variables are driving changes in the diatom assemblages



(Ontario Flow Assessment Tools III, MNRF)



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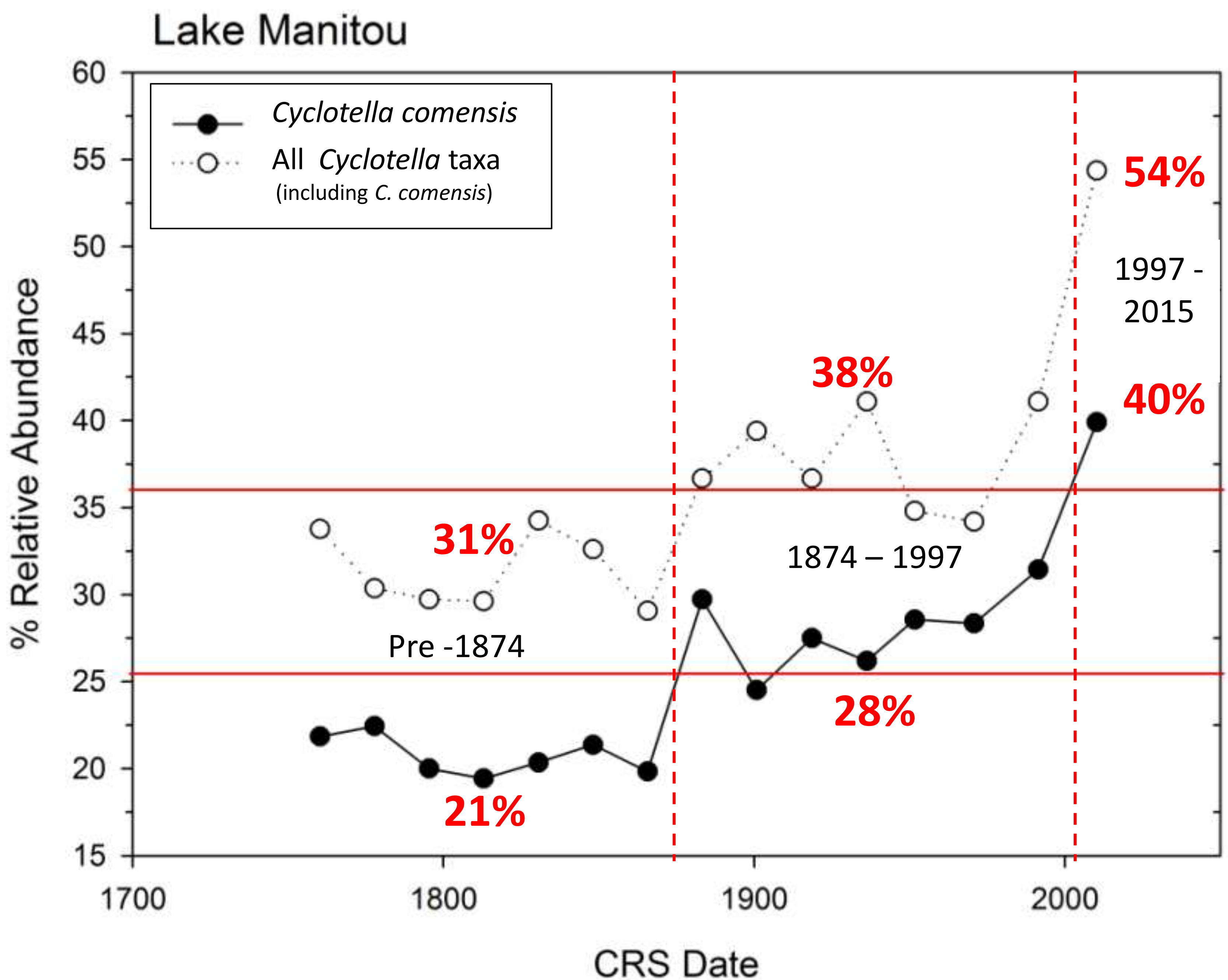

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