The influences of nutrients and climate change in Ontario lakes with a Lake Trout population

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PEARL

PALS 2015

Queen's University

Outline

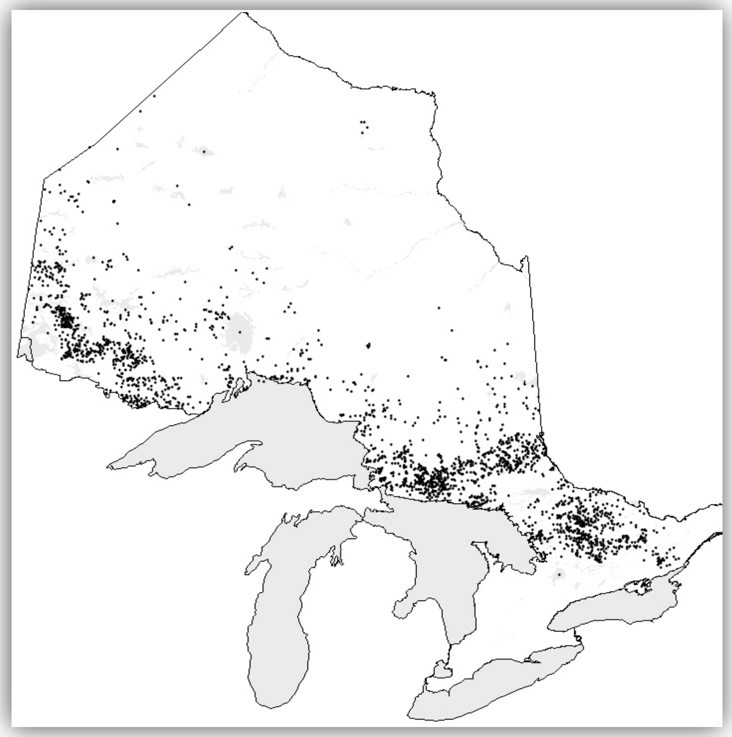
- Background
- Research Questions
- Preliminary Results
- Conclusions
- Next Steps

Lake Trout in Ontario

- Rare and valuable resource
  - Ontario contains 20-25% of all Lake Trout lakes worldwide
  - ~2200/250,000 lakes in Ontario
- Important to recreational fisheries
- General decline in both sport fishery and habitat

(OMNR 2006)

Lake Trout *(Salvelinus namaycush)*

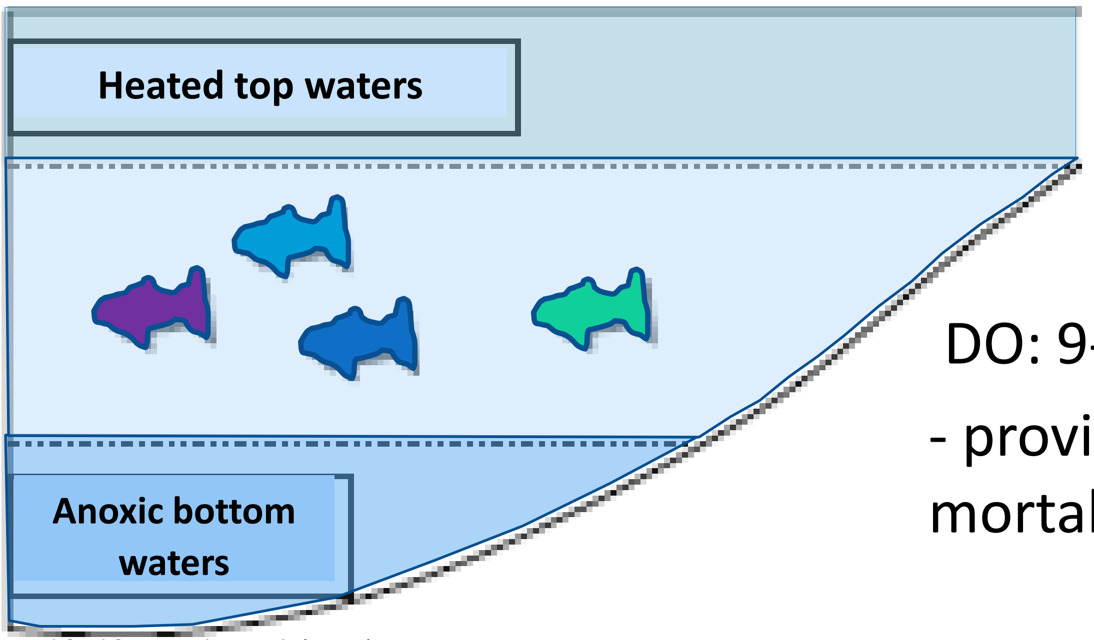


Lake Trout lakes across Ontario (OMNR 2006)

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

Habitat Requirements

Lake Trout have narrow physiological tolerances for temperature and dissolved oxygen (DO)



Modified from Ficke et al. (2007).

Temperature: 6-15°C

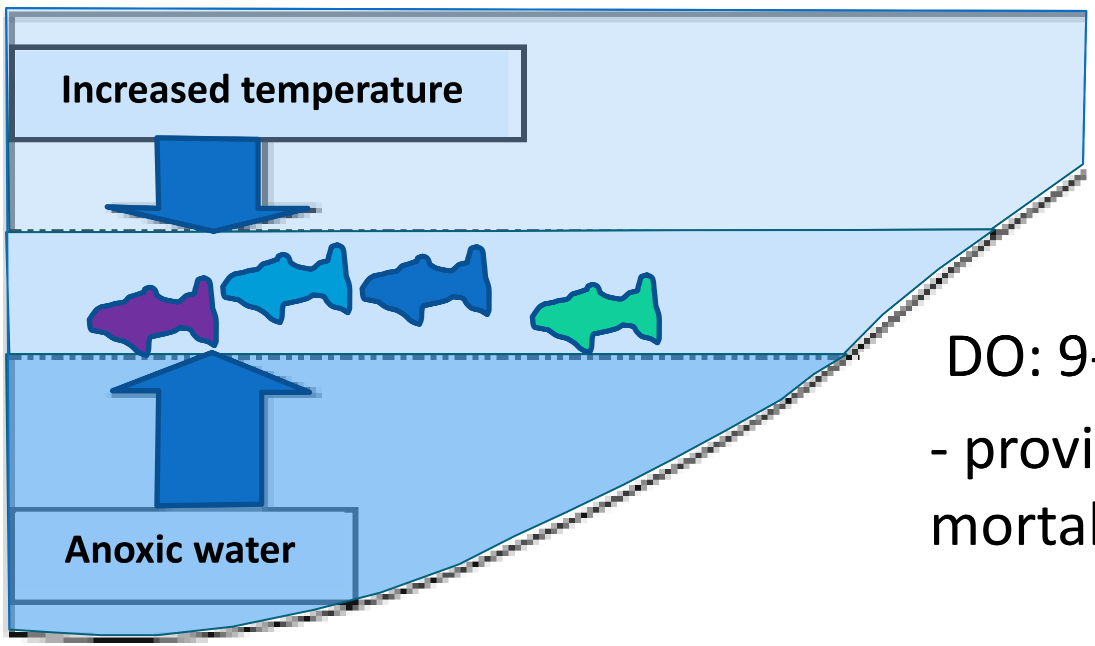
DO: 9-12 mg/L

- provincial standard: 7mg/L, mortality below 3 mg/L

(Plumb and Blanchfield 2009)

Habitat degradation within lakes

Lake Trout have narrow physiological tolerances for temperature and dissolved oxygen (DO)



Modified from Ficke et al. (2007).

Temperature: 6-15°C

DO: 9-12 mg/L

- provincial standard: 7mg/L, mortality below 3 mg/L

(Plumb and Blanchfield 2009)

The Role of Total Phosphorus (TP) in DO Depletion

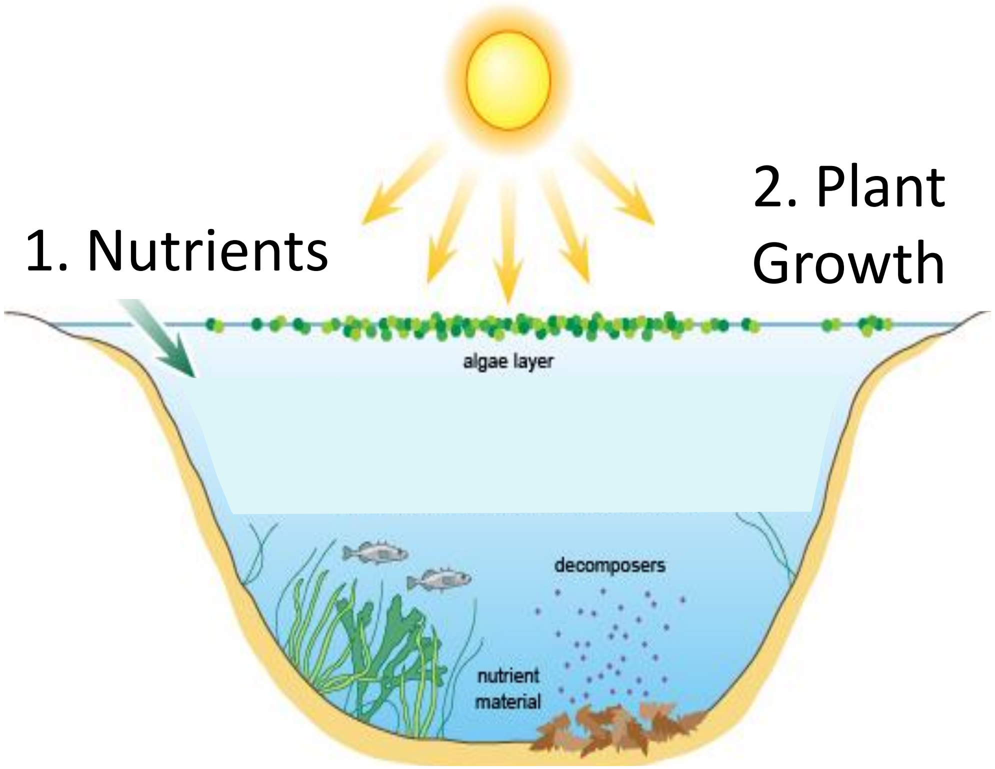
Management efforts currently centered on controlling TP

However, DO depletion has occurred in lakes with stable OR declining TP
(Summers et al. 2012)

Suggests the influence of other factors

1. Nutrients

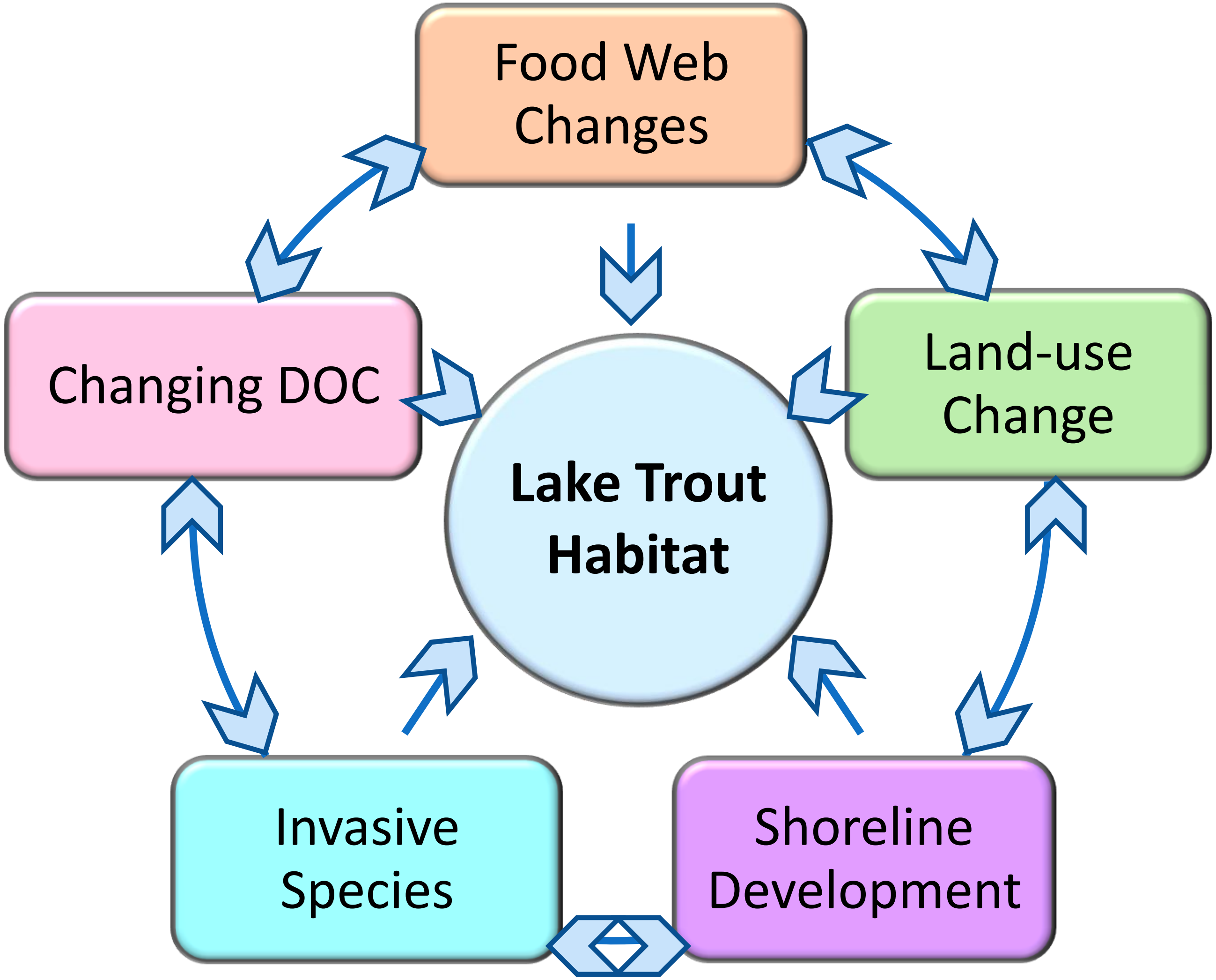
2. Plant Growth



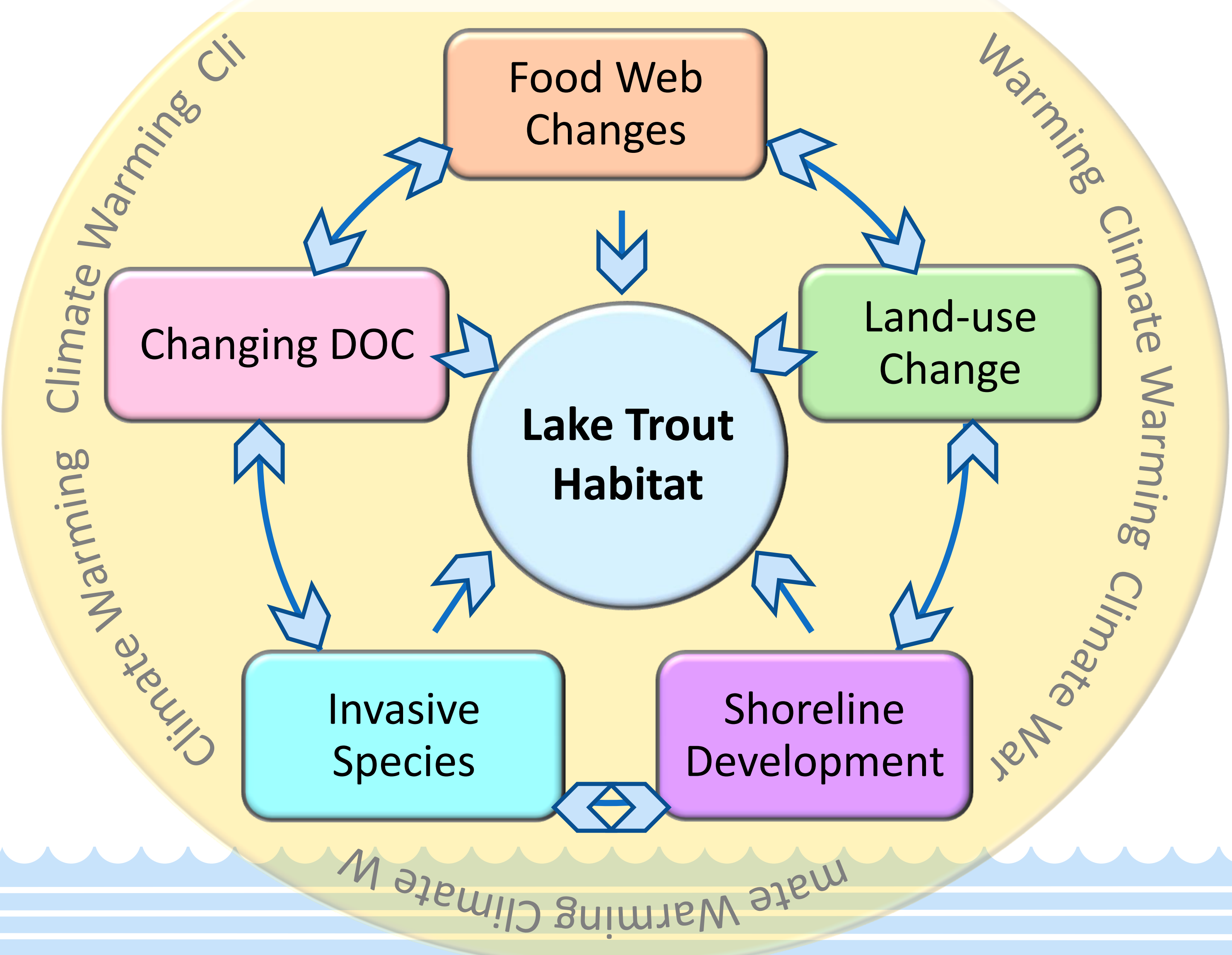
3. Decomposition depletes O_2

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

Multiple Stressors

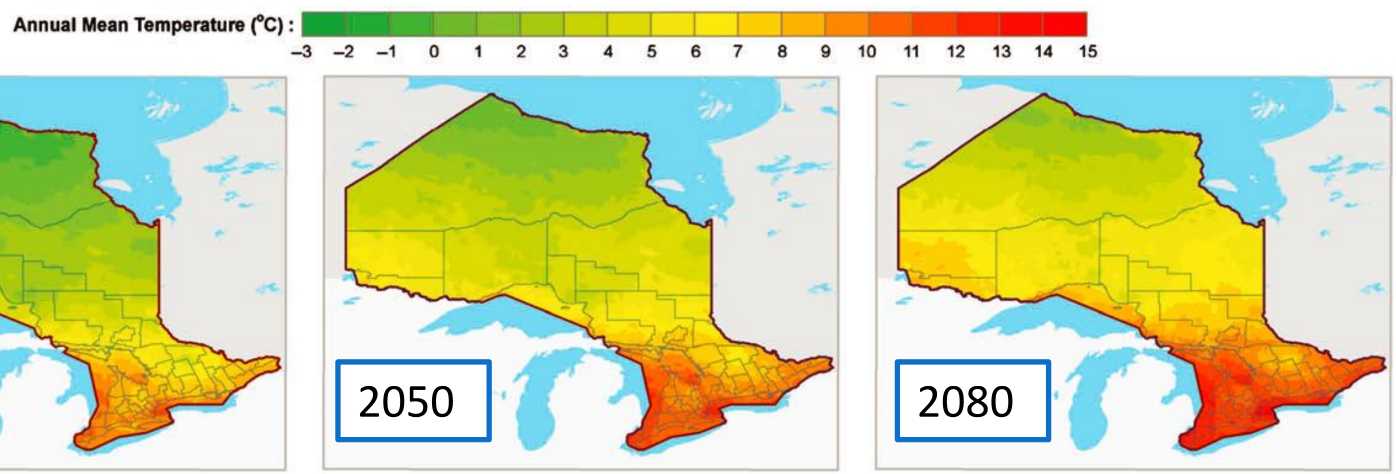


Multiple Stressors



Climate Change

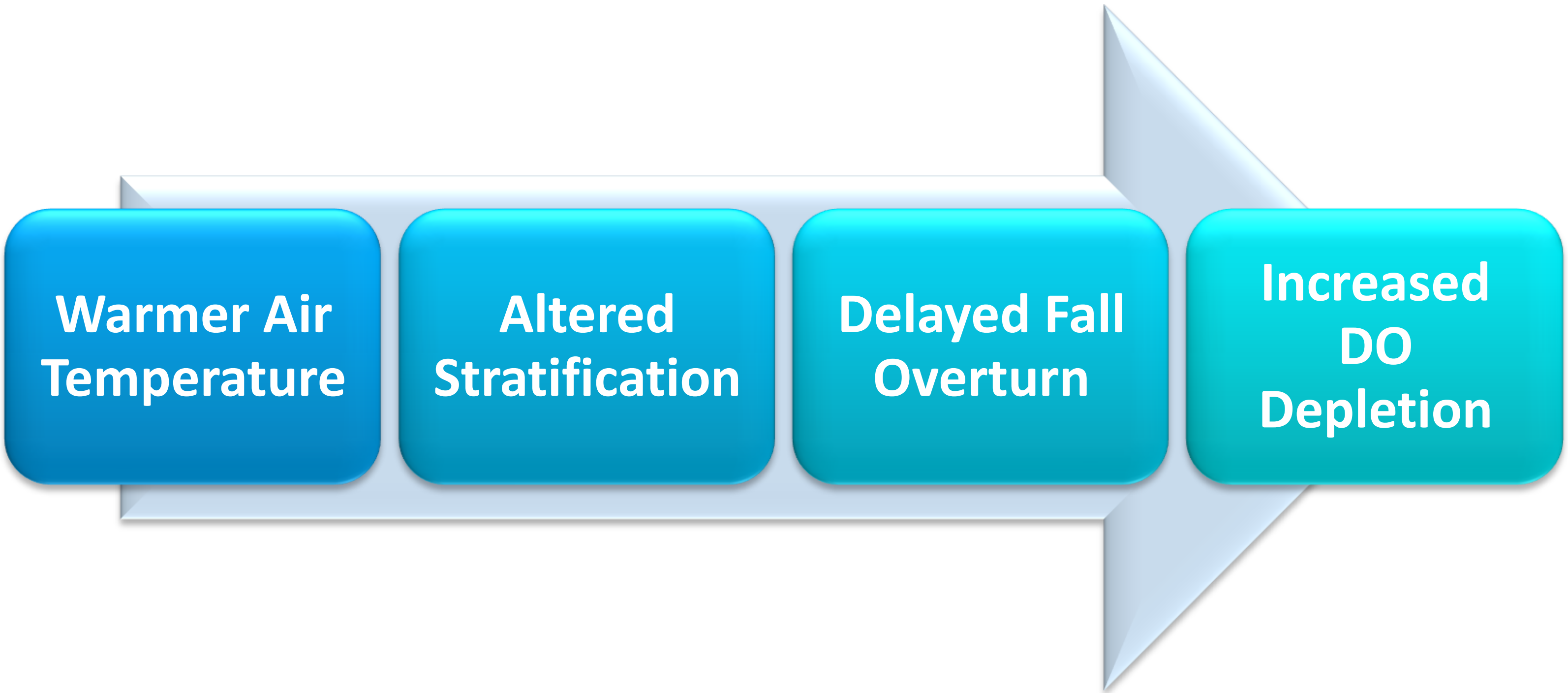
Mean annual air temperature in Ontario has increased by ~1.4°C since the mid 1900s with further increases predicted over the next century
(Chiotti and Lavender 2008, McKenney et al. 2010)



(Wang et al. 2014)

Regional impacts of warming already observed across Ontario

Climate Change



It is important to understand how climate change may be altering the relationship between TP & DO

Project Objective

Investigate past TP-DO dynamics in Lake Trout lakes across Ontario

Of interest due to:

- Inherent link between TP and DO depletion
- Steady or declining TP across Boreal lakes
- Compounded influence of modern stressors
- Implications for habitat management

Muskrat Lake (Oct, 2014)

Study Design

Understanding the past

Modeling the present

Forecasting the future

↘ ↓ ↙

Develop and calibrate models on a common set of study lakes

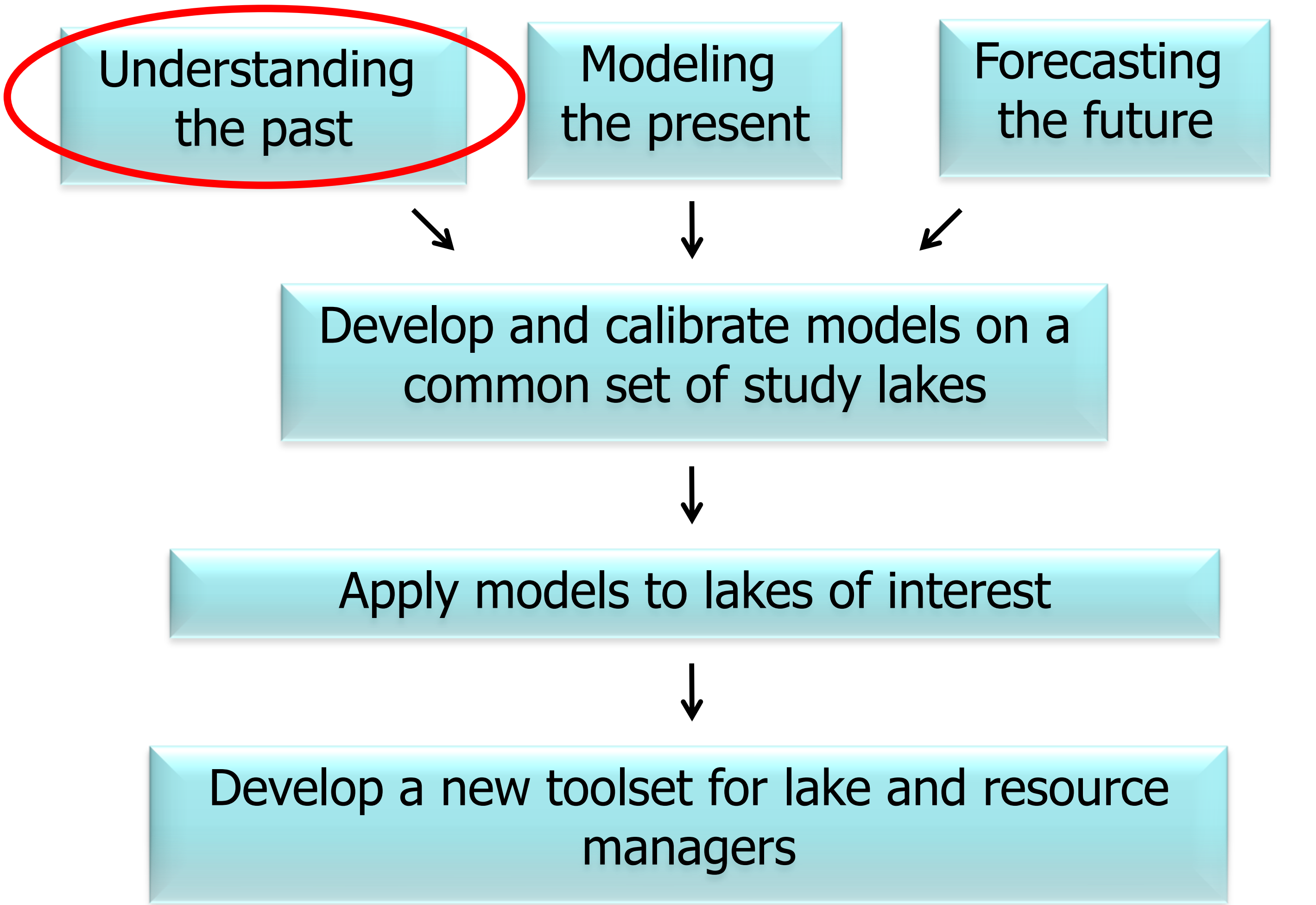
↓

Apply models to lakes of interest

↓

Develop a new toolset for lake and resource managers

Study Design



Understanding the Past: Paleolimnology

- Detailed information of past conditions is needed to assess the effects of modern stressors

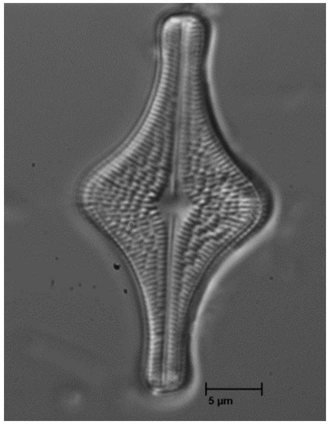
Goal is to reconstruct background conditions, trajectories of change and evaluate models

http://post.queensu.ca/~pearl/extruding.htm

Understanding the Past: Paleolimnology

Indicators proposed to be analyzed:

- **Diatoms:**
  - Used to reconstruct past spring [TP]
    (Hall and Smol 1996)



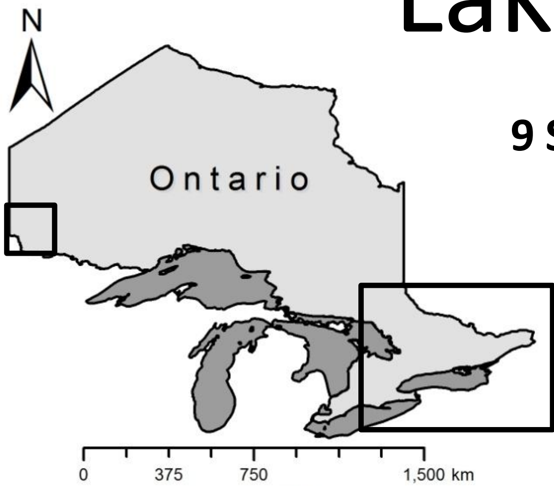
- **Chironomids:**
  - Used to reconstruct end-of-summer hypolimnetic [O_2]
    (Little and Smol 2010, Quinlan et al. 1998)

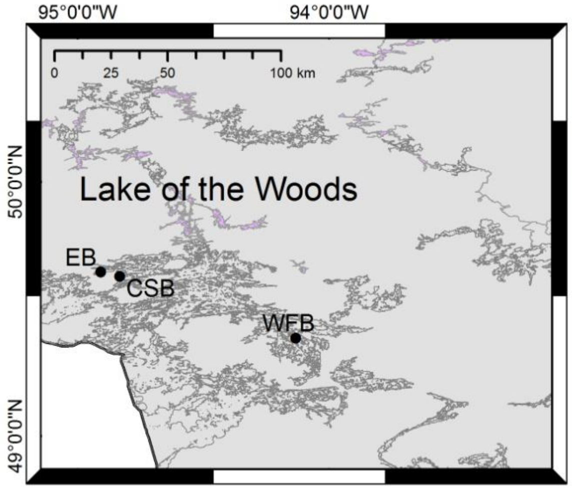
Research Questions

1. How have diatom and chironomid assemblages changed over the past ~200 years in Lake Trout lakes across Ontario?
2. How have TP and DO changed?
3. Are the timing of changes consistent across lakes? (i.e. in the same direction and magnitude)

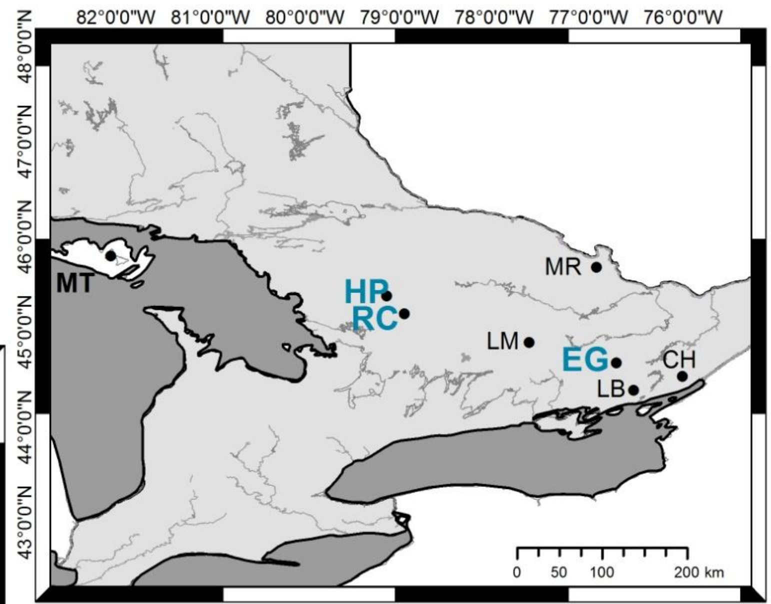
Eagle Lake (Sept, 2014)

Lake Selection





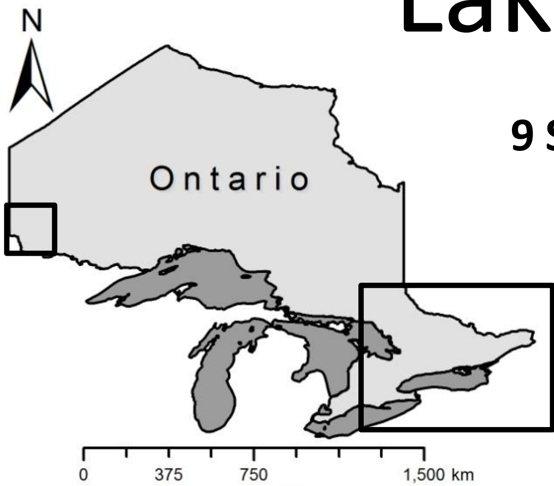
9 Study Lakes

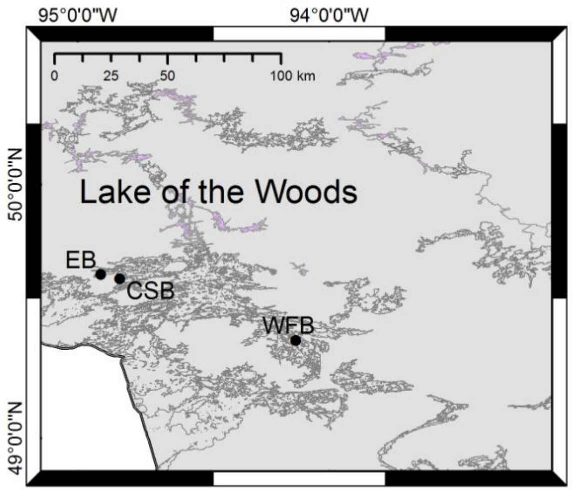


3 Monitored Lakes:

- Harp (HP), Red Chalk Main (RCM) and Eagle (EG)
- used to ground truth predictive models and paleo reconstructions

Lake Selection





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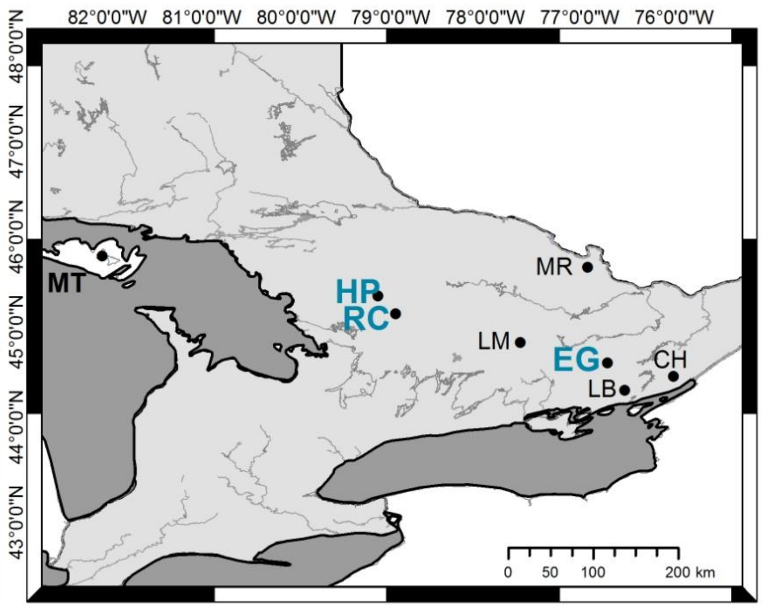


6 Lakes of Interest:

- Charleston (CH), Limerick (LM), Loughborough (LB), Muskrat (MR), Manitou (MT),
- 3 bays from Lake of the Woods (LoW): Whitefish (WFB), Cul de Sac (CSB), and Echo (EB)

Lake Selection

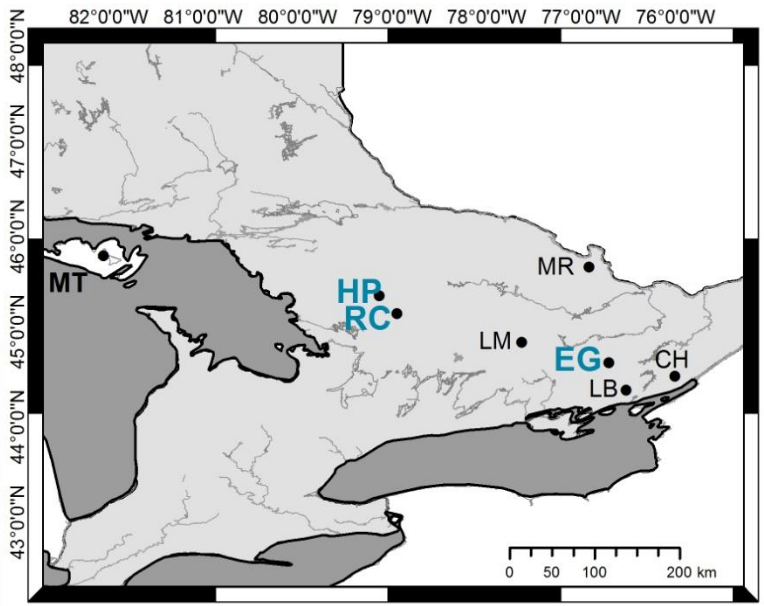
6 Lakes of Interest:

1. Impacted by shoreline development or agricultural stressors
2. Experienced long-term changes in DO profiles
3. Late summer hypolimnetic [DO] near or below 7 mg/L
4. Prior management interest

Progress to Date

- Sediment cores collected from Harp, Red Chalk Main, Eagle, and Limerick lakes, and the 3 LOW bays
- Chlorophyll-*a* analysis completed for all cores
- Downcore diatom assessment has been completed for the 3 lakes with continuous monitoring

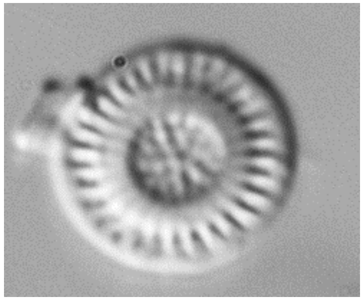
(Harp, Red Chalk Main and Eagle)

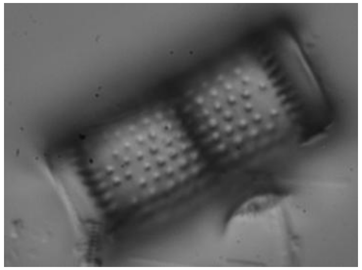


Preliminary Results

Diatom Results

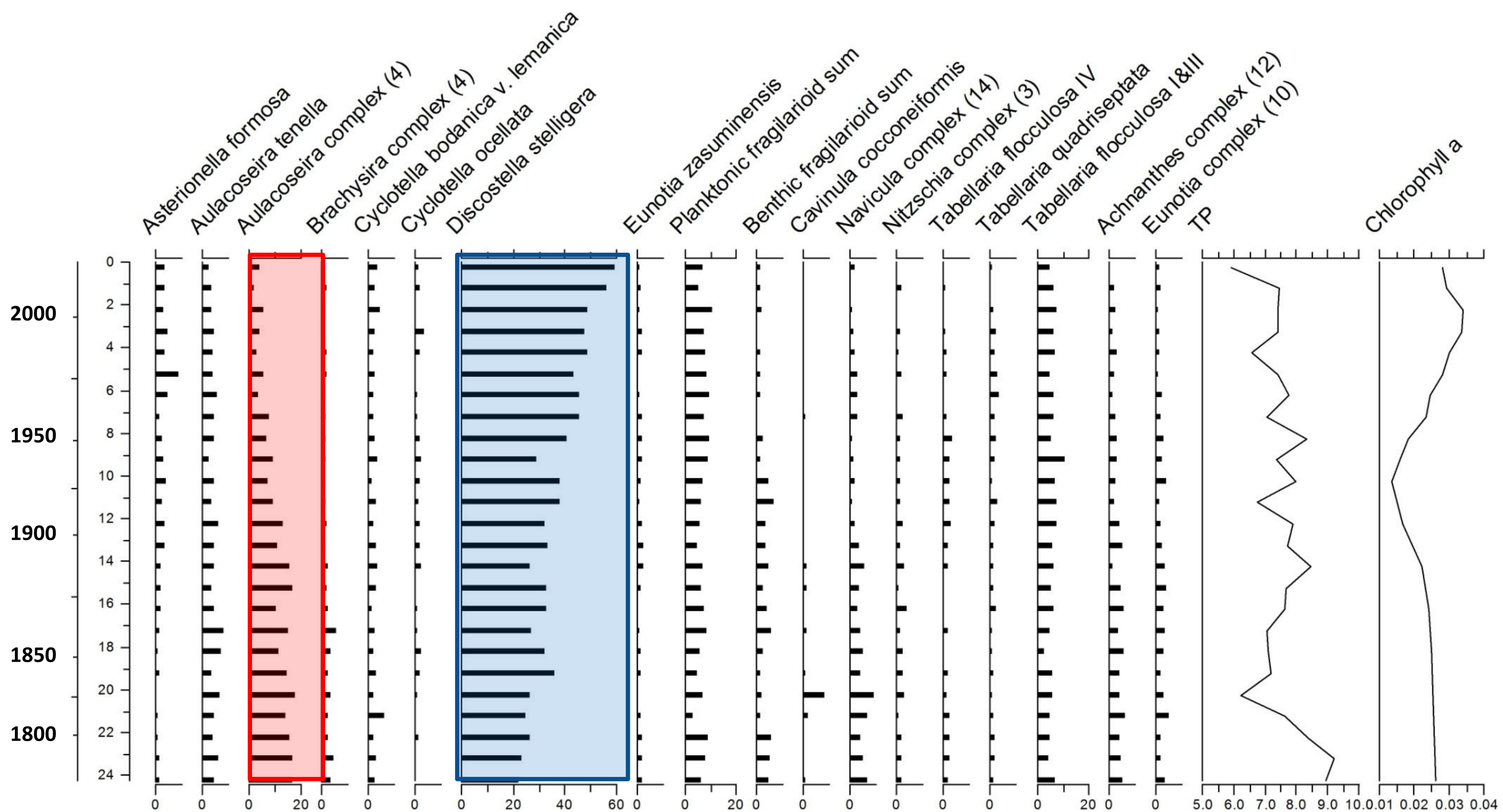
- Subtle changes are evident in both Harp and Red Chalk
  - Increases in small, fast-growing planktonic taxa
  - Decreases in benthic and heavily silicified tychoplanktonic taxa





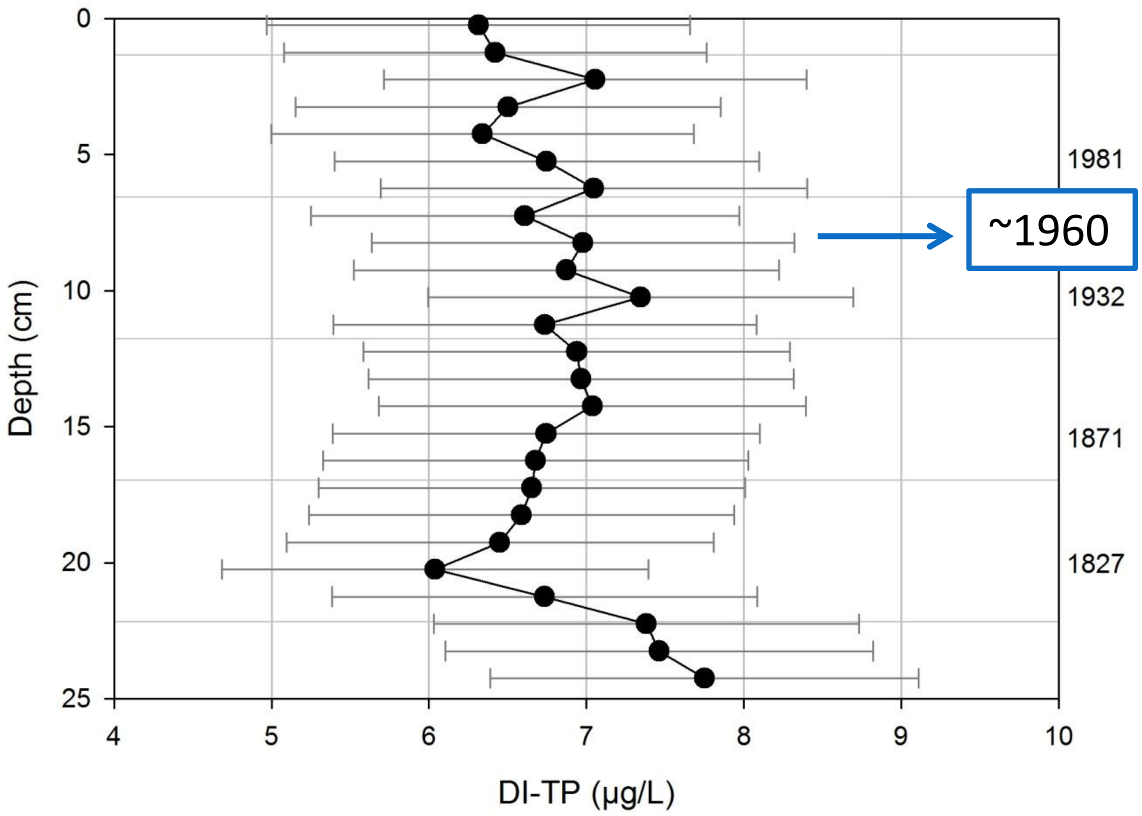
Indicative of a climate signal – longer ice free season and increased thermal stability (Rühland et al. 2015)

Harp Lake Results



Max Depth: 37.5 m, pH: 6.42 , TP: 6.35 µg/L
(Yan et al. 2008)

Harp Lake Results



TP reconstruction shows a slight decreasing trend

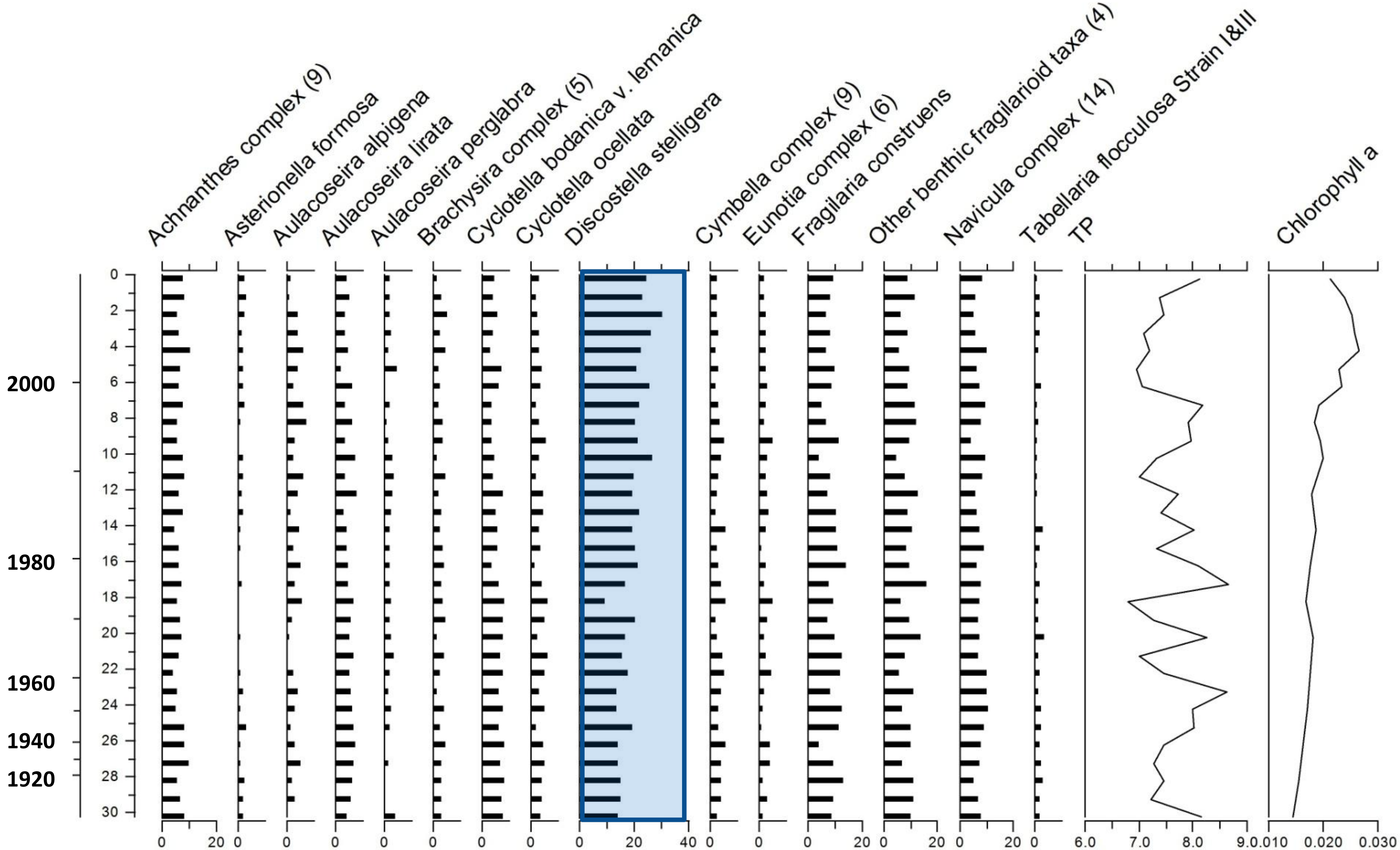
Predicted values consistent with recent MOECC sampling

1980: 9.02 µg/L
2003: 6.35 µg/L
2014: 5.74 µg/L

Note: Monitoring data is average TP over the ice-free period and DI-TP is diatom inferred TP at spring turnover

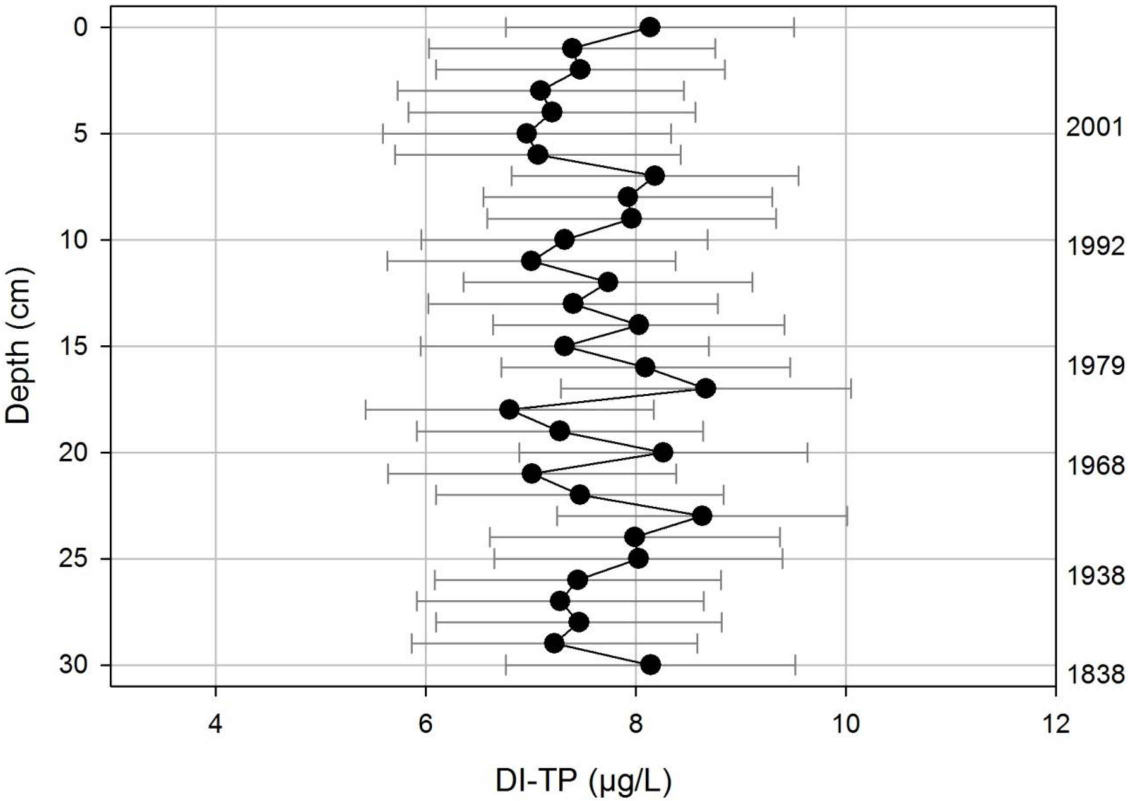
Max Depth: 37.5 m, pH: 6.42 , TP: 6.35 µg/L
(Yan et al. 2008)

Red Chalk Main Results



Max Depth: 38 m, pH: 6.45, TP: 4.65 µg/L
(Yan et al. 2008)

Red Chalk Main Results



TP reconstruction shows no trend

Only small changes detected through MOECC TP monitoring

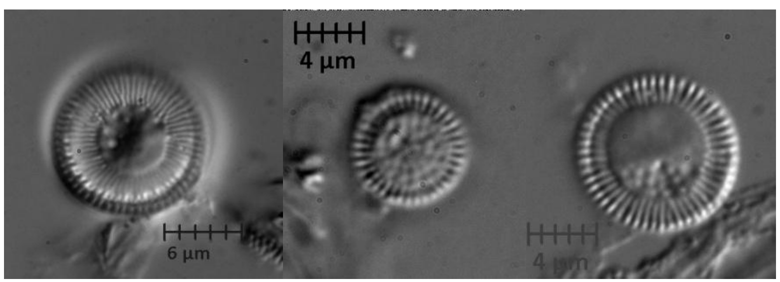
1980: 5.84 µg/L
2003: 4.65 µg/L
2014: 4.74 µg/L

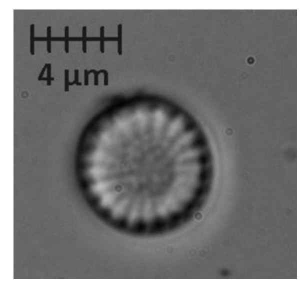
Max Depth: 38 m, pH: 6.45, TP: 4.65 µg/L
(Yan et al. 2008)

Results

Eagle lake

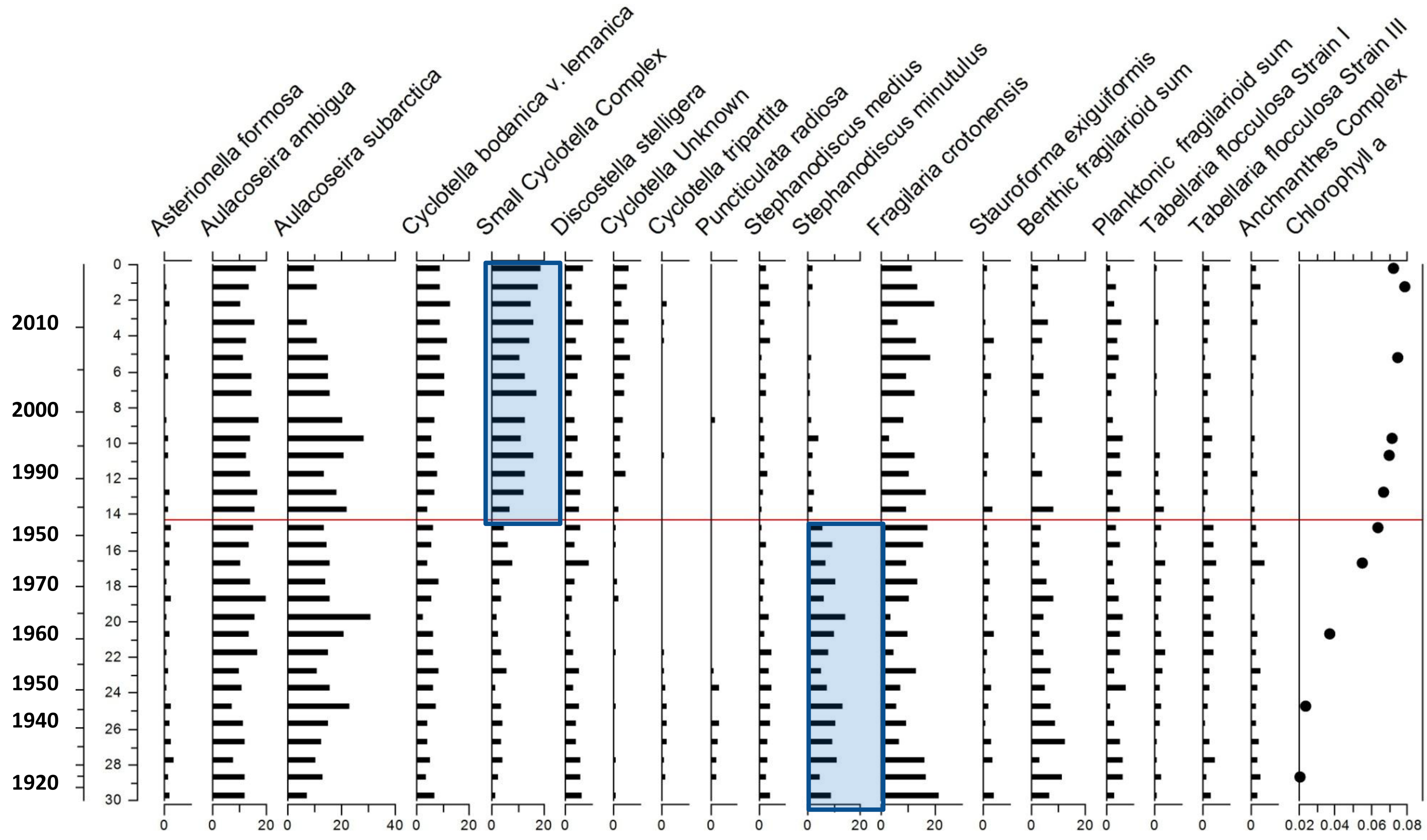
- Shift in diatom assemblage ~1985
  - Decrease in *Stephanodiscus minutulus*
  - Increase in small *Cyclotella* taxa (*C. comensis*, *C. gordonensis*, *C. michiganiana*)
- Increase in chlorophyll-*a*

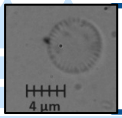




Suggests that production is increasing independent of nutrients

Eagle Lake Results



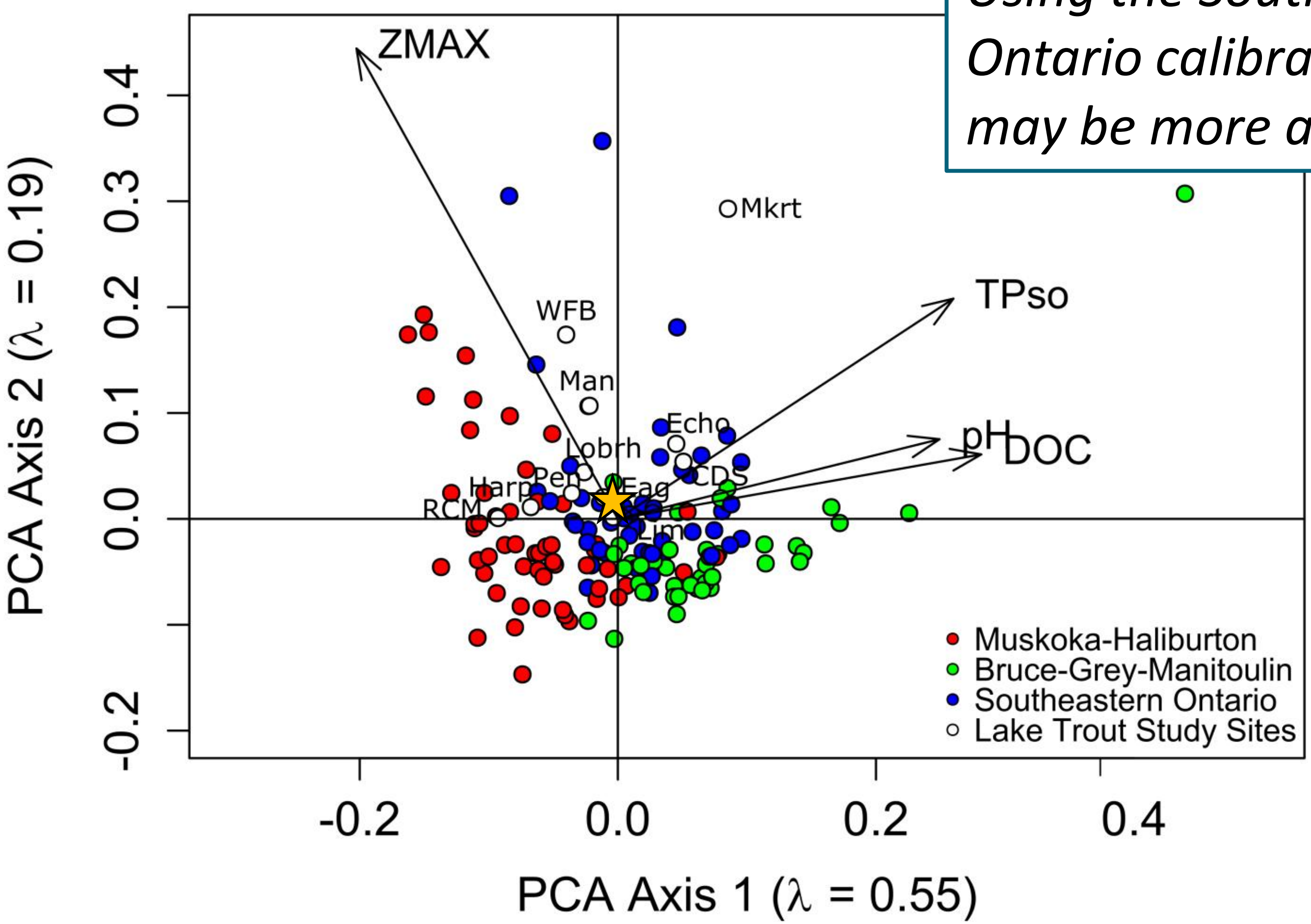


Unknown *Cyclotella* taxon

Max Depth: 31.1 m, pH: 8.09 , TP:12 µg/L
MOECC – May 2012 Monitoring

Eagle Lake Results

Using the Southeastern Ontario calibration set may be more appropriate



Preliminary Conclusions

Preliminary results for Harp and Red Chalk lakes show subtle changes in diatom assemblage over the last ~200 years

- **Consistent with monitoring data from the Dorset Environmental Science Centre**
- **DI-TP values for Harp Lake and Red Chalk are comparable to modern sampling**

Preliminary results for Eagle lake suggest decreasing TP and increasing overall production

- **Increase in production may be due to lengthened growing season**

Overall:

- **Results indicate a climate warming signal suggesting longer stratification**
- **Decreasing TP trend for Harp and Eagle lakes**

Next Steps

1. Test the DI-TP models – are diatom changes due to TP?
2. Compare DI-TP with chironomid-inferred DO
3. Collect the remaining sediment cores

   (Muskrat, Loughborough, Charleston, Manitou)
4. Broaden analyses to include the 6 lakes of interest
5. Incorporate paleolimnological reconstructions with predictive modelling

Acknowledgements

- NSERC
- Environment Canada
- Ontario Ministry of the Environment and Climate Change
- Ontario Ministry of Natural Resources and Forestry
- Federation of Ontario Cottagers' Associations
- Lake of the Woods Water Sustainability Foundation

Thank you, Questions?

Key Literature

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