Is climate warming altering nutrient-oxygen dynamics in Canadian Lake Trout lakes?

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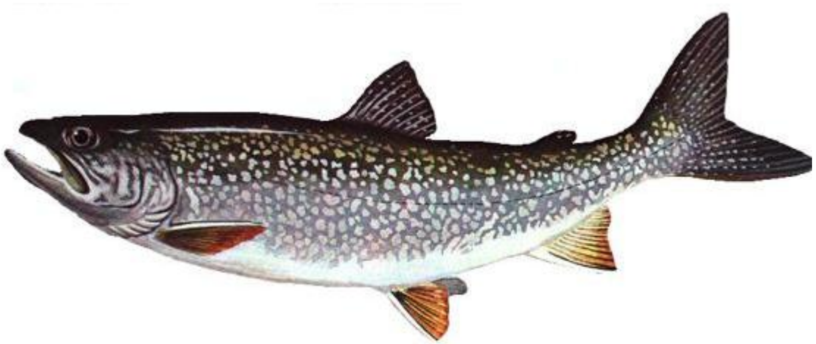
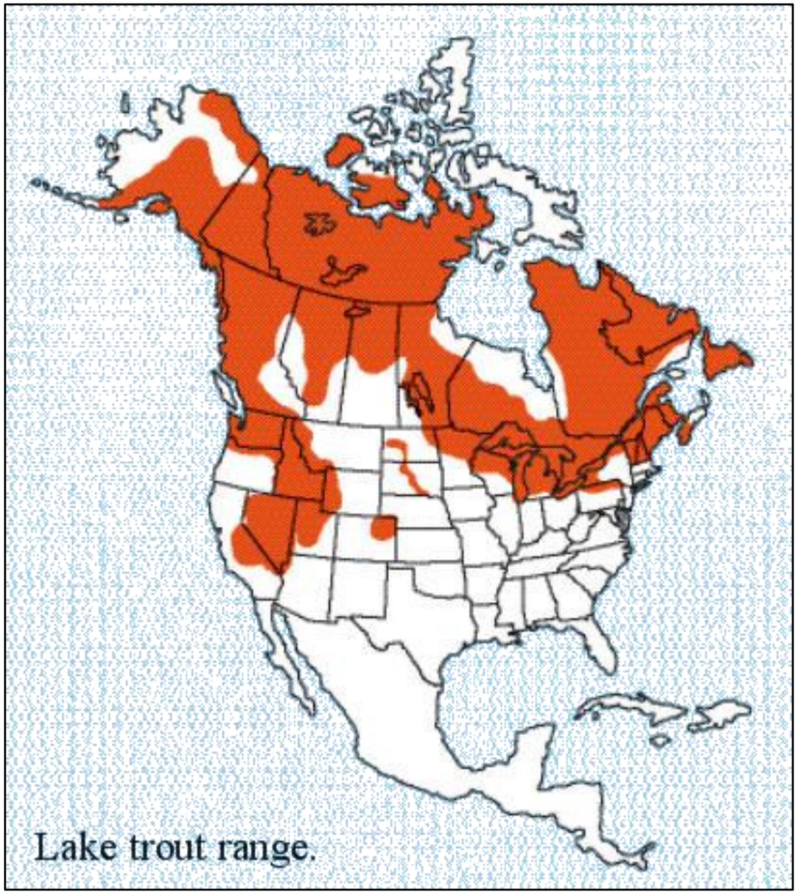
Queen's University

Lake Trout in Canada

- Widely distributed cold-water taxa
- Large bodied (30-80 cm in length) & late maturing (5-10 yrs)
- Valuable natural resource that is important to Canada's recreational fisheries



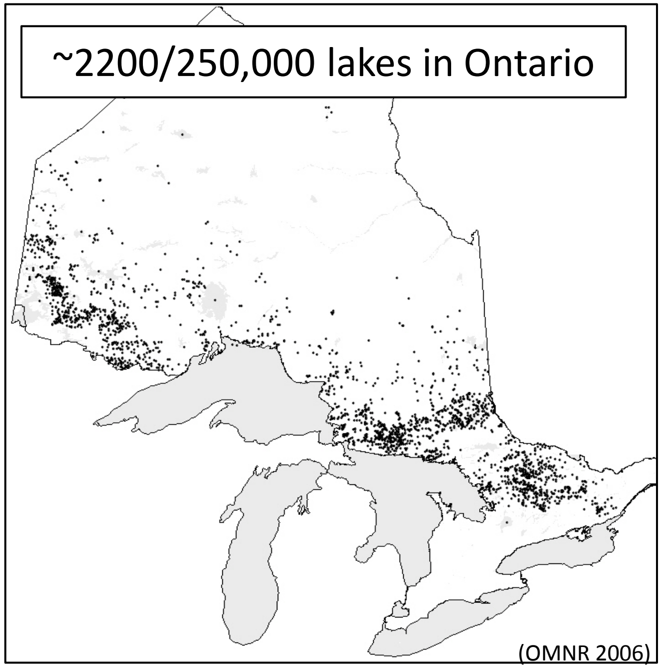
Lake Trout *(Salvelinus namaycush)*



Lake trout range.

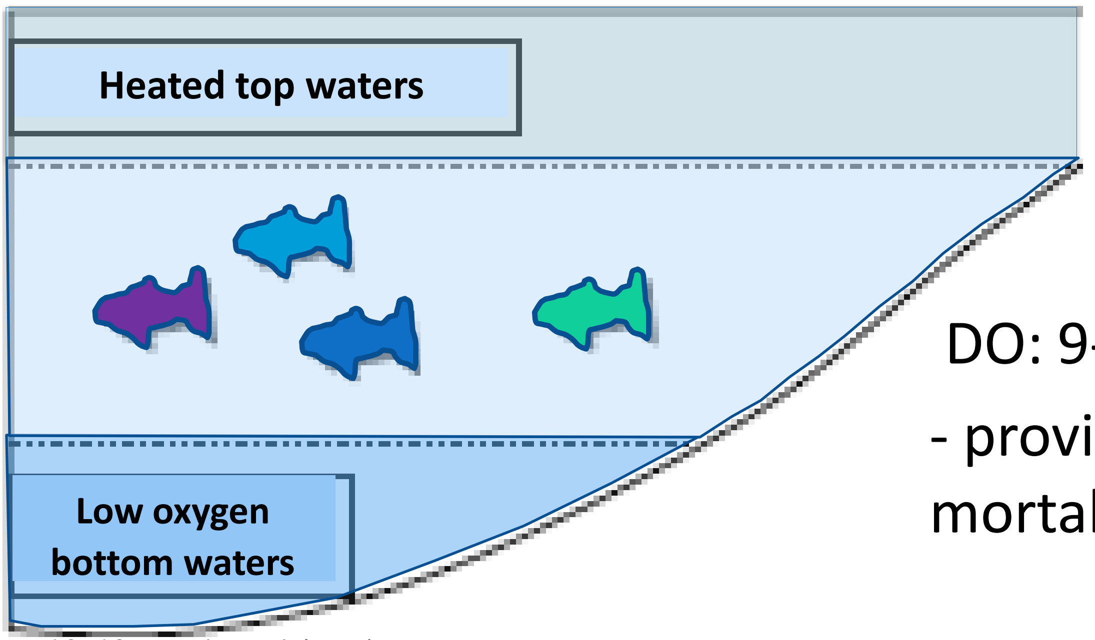
Ontario

- Relatively rare – only 1% of Ontario lakes contain Lake Trout
  (This represents 20-25% of all Lake Trout lakes worldwide)
- General decline in both sport fishery and habitat (OMNR 2006)



Habitat Requirements

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



Modified from Ficke et al. (2007).

Temperature: 6-15°C

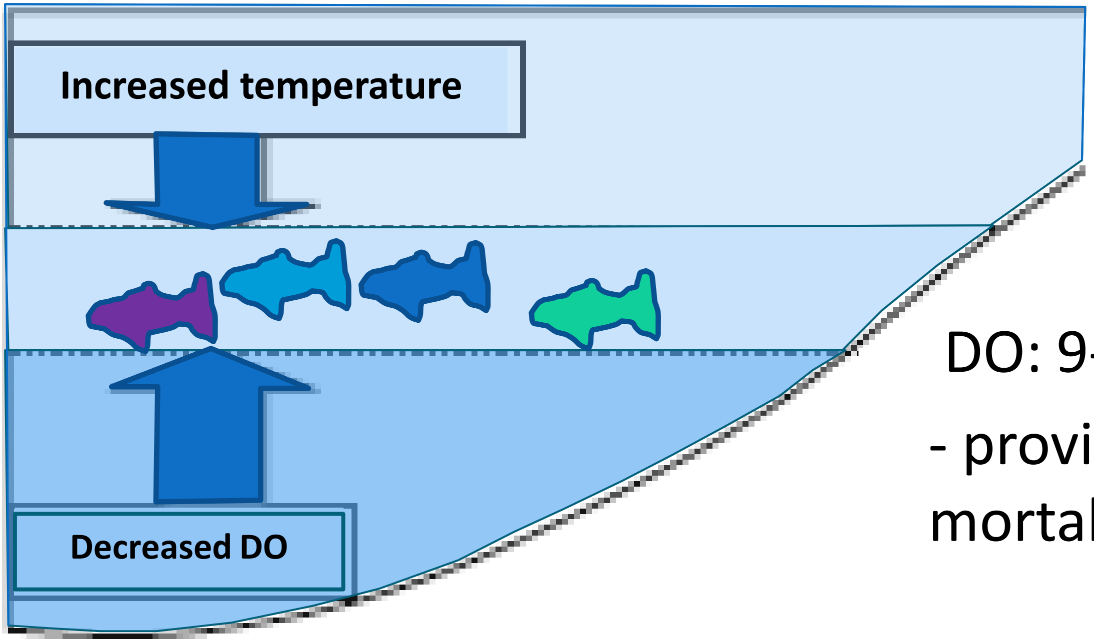
DO: 9-12 mg/L

- 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)



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Temperature: 6-15°C

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(Plumb and Blanchfield 2009)

The Role of Total Phosphorus (TP) in Hypolimnetic Anoxia

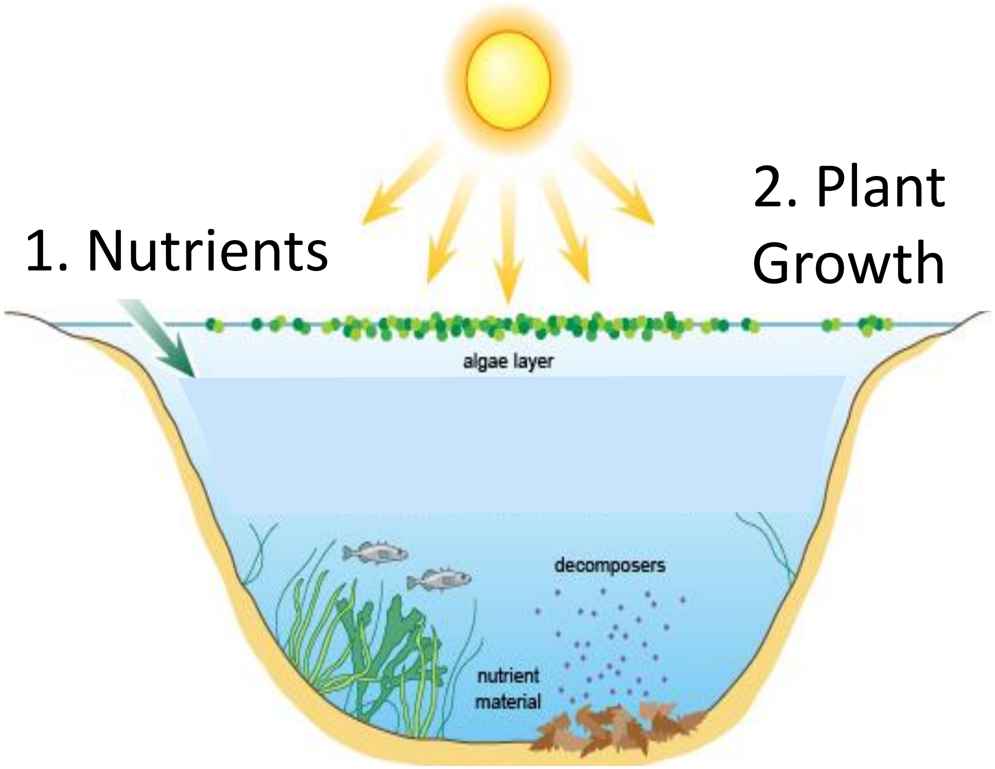
Management efforts currently centered on controlling TP

However, depleted DO has been observed in lakes with stable *or* declining TP (Summers et al. 2012)

Suggests the influence of other factors

1. Nutrients

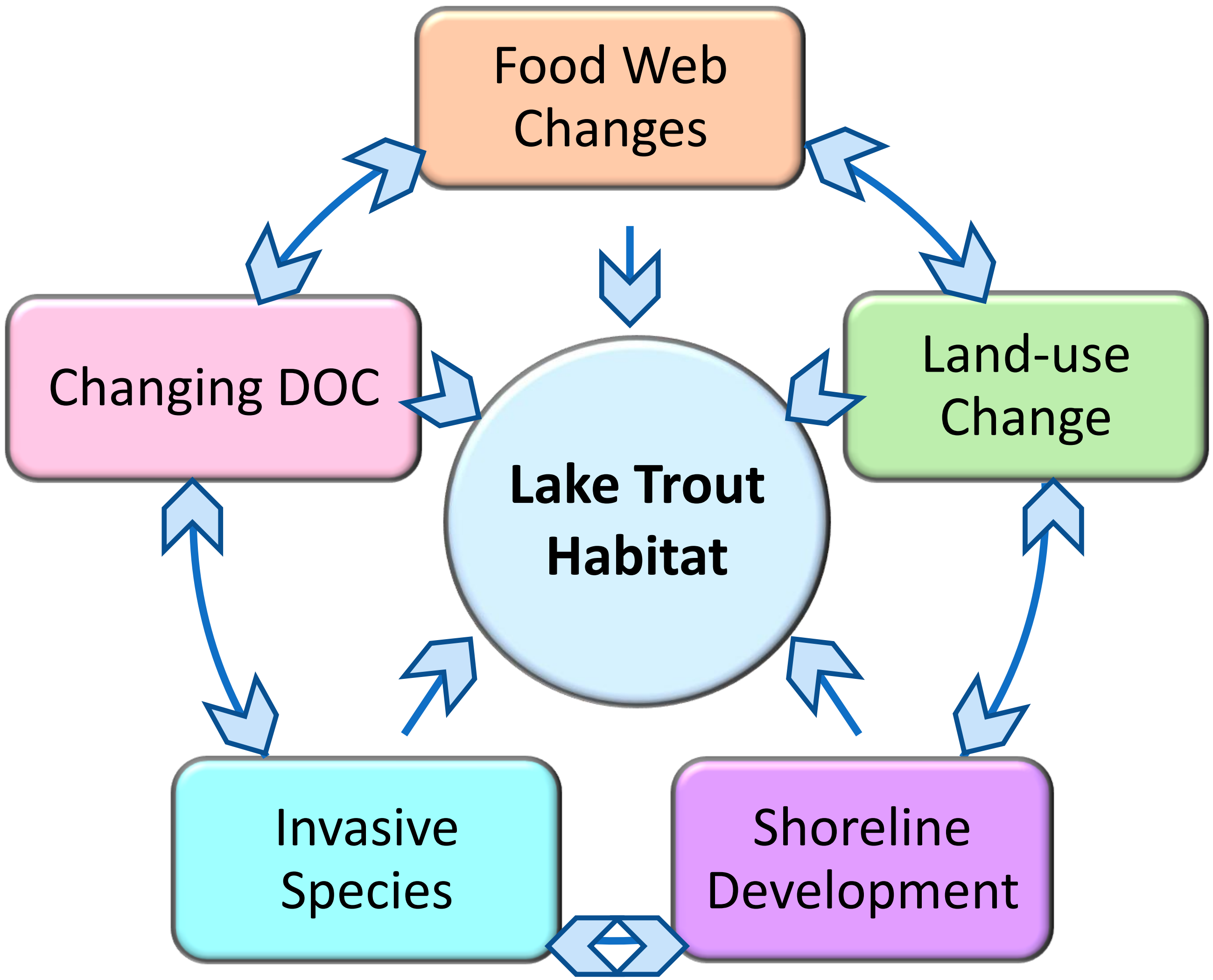
2. Plant Growth



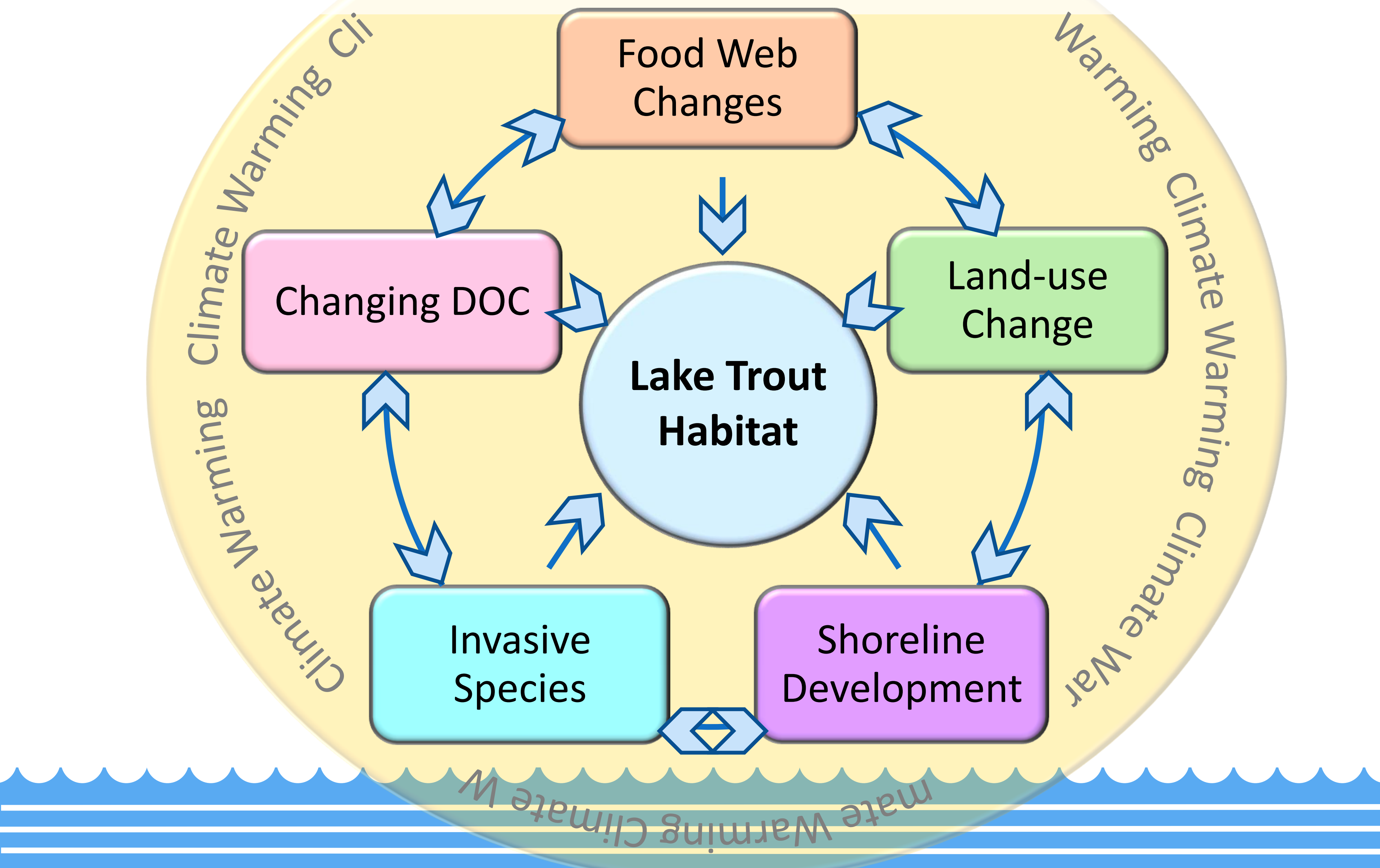
3. Decomposition depletes O_2

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

Multiple Stressors



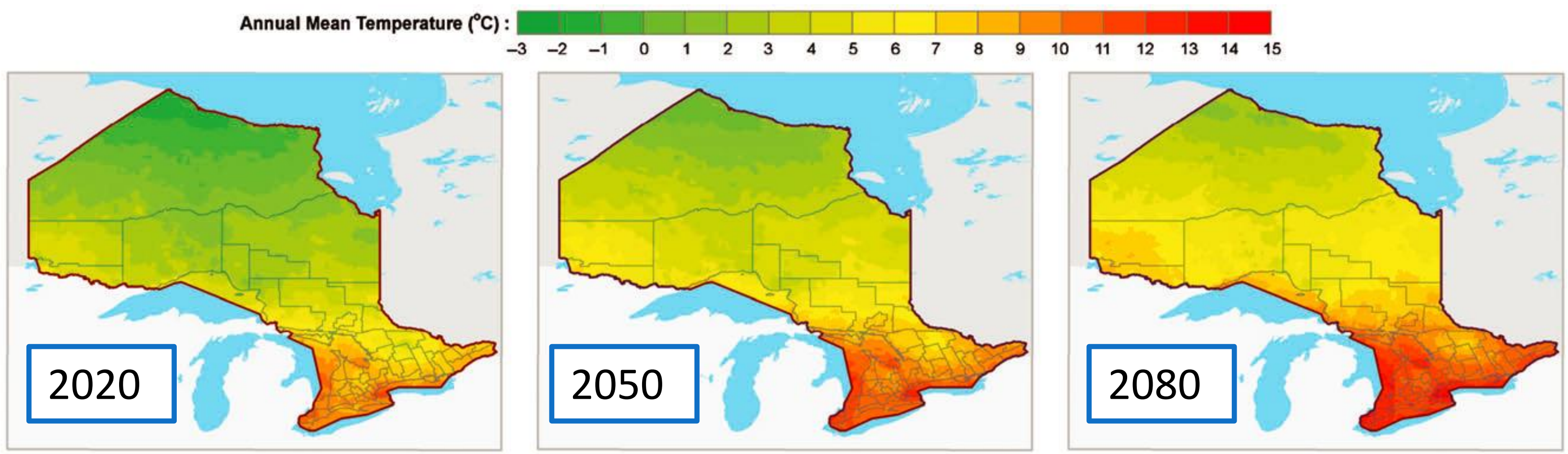
Multiple Stressors



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

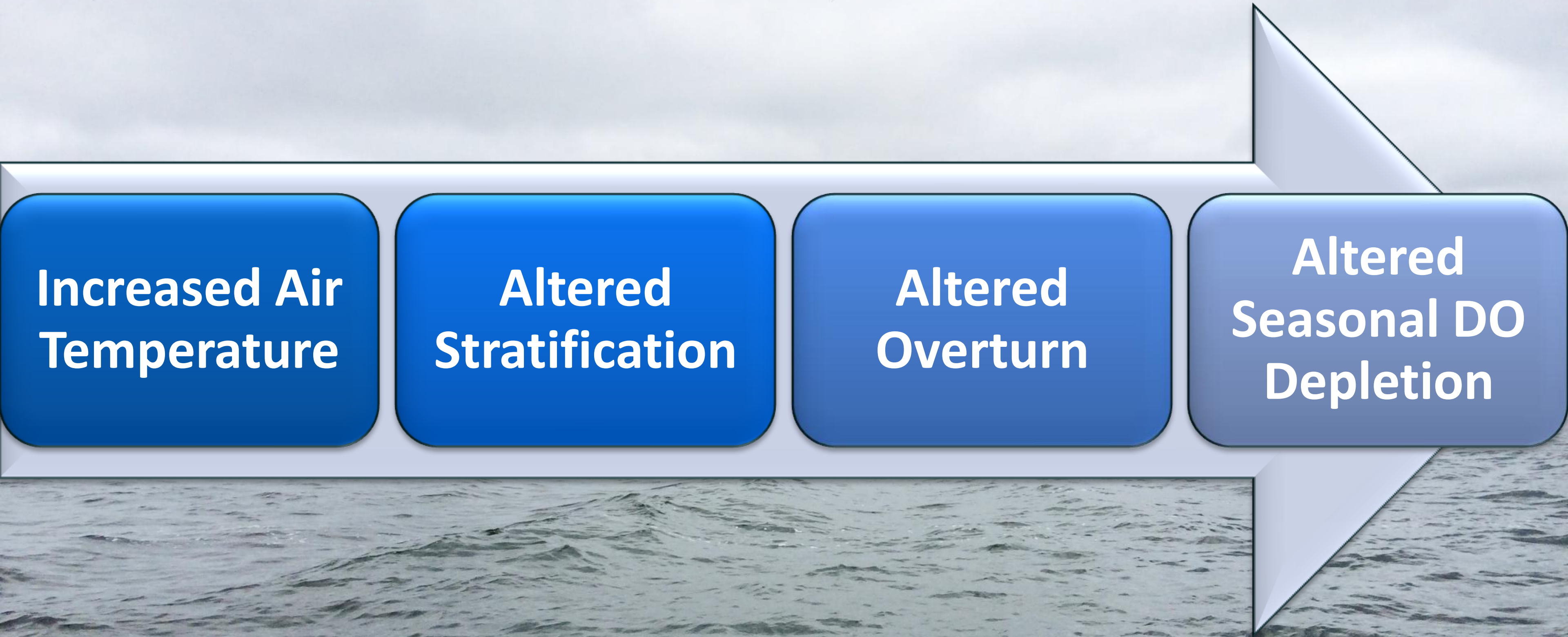
(Chiotti and Lavender 2008, McKenney et al. 2010)



(Wang et al. 2014)

Impacts of warming are clearly observed across Ontario

Climate Change



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

Project Objective

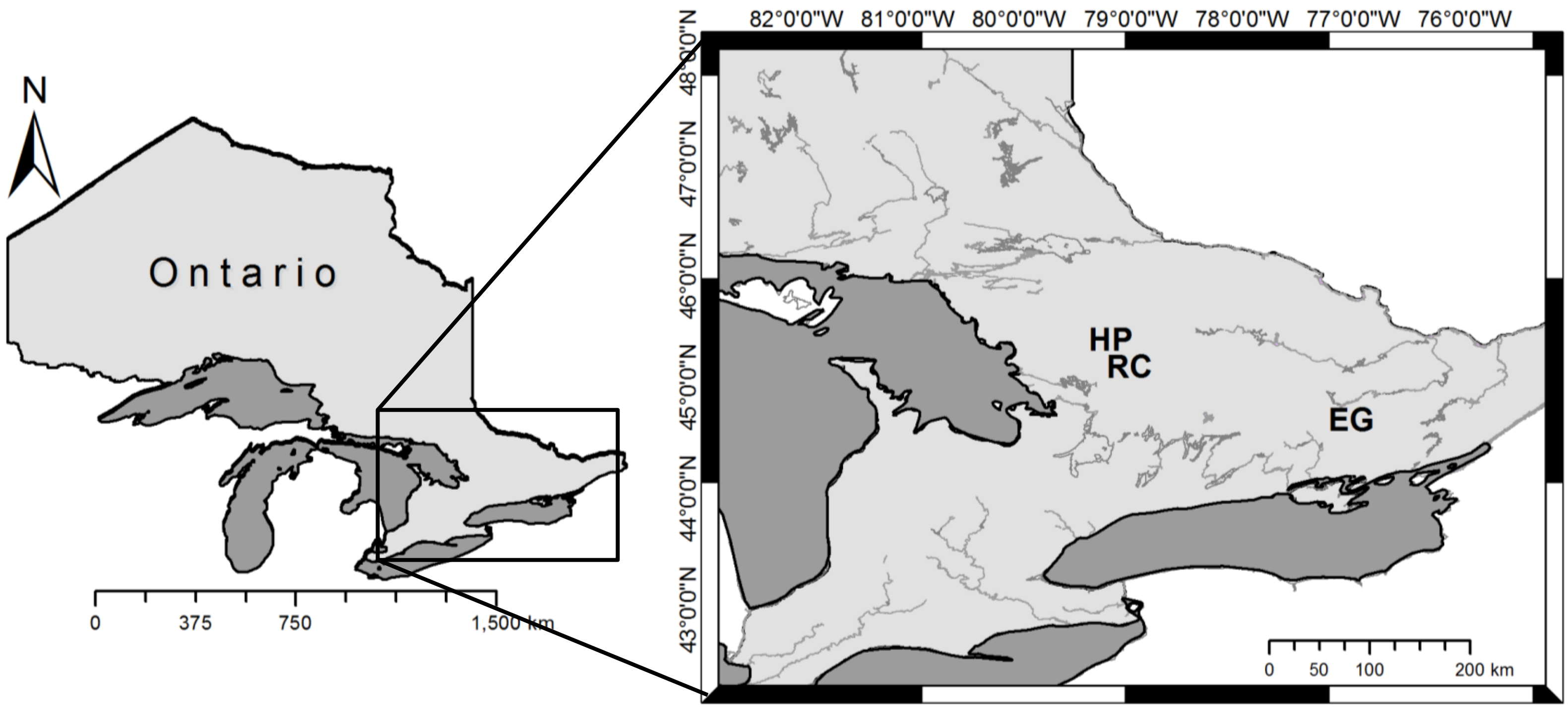
Investigate past TP-DO dynamics in 3 Ontario Lake Trout lakes with differing levels of shoreline development

(2 control lakes and 1 impacted lake)

Research Questions

1. How have diatom and chironomid assemblages changed over the past ~200 years in 3 Ontario Lake Trout lakes?
2. How have TP and DO changed?
3. How do control and impacted lakes differ?
4. Are the nature and timing of changes consistent?

Lake Selection

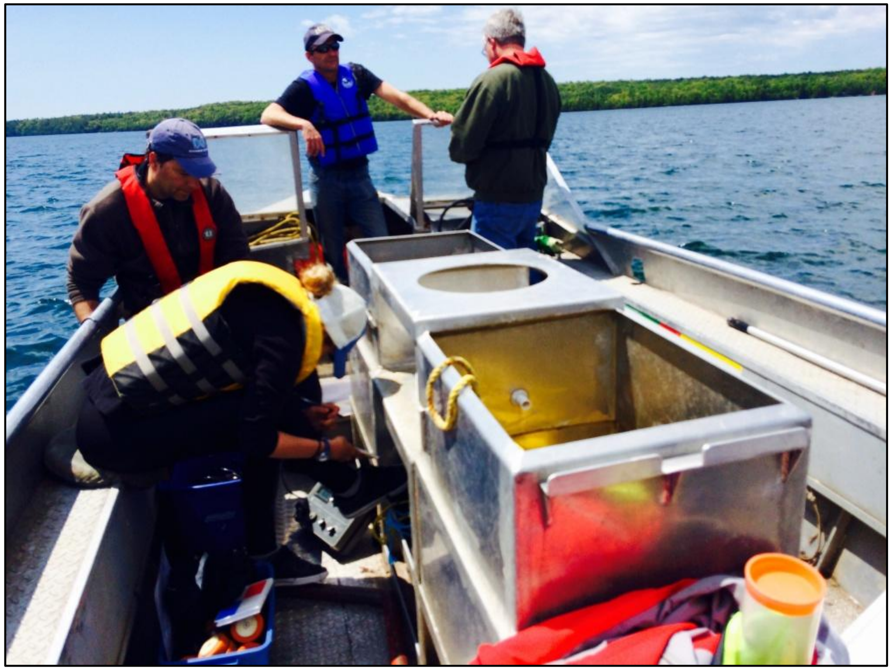


Three monitored lakes were selected:

- Two with minimal shoreline development - Harp (HP) and Red Chalk (RC) lakes
- One with moderate development pressure - Eagle (EG) lake

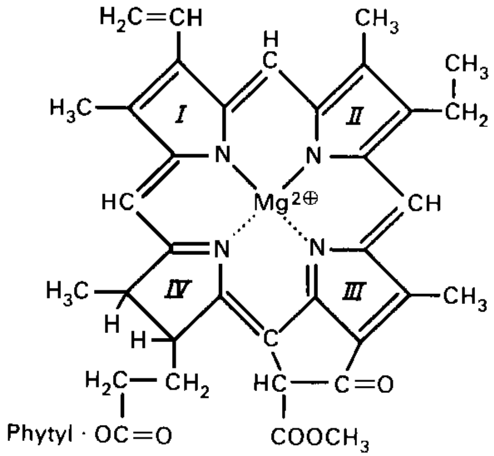
Methods

- Sediment cores collected from Harp, Red Chalk, and Eagle lakes

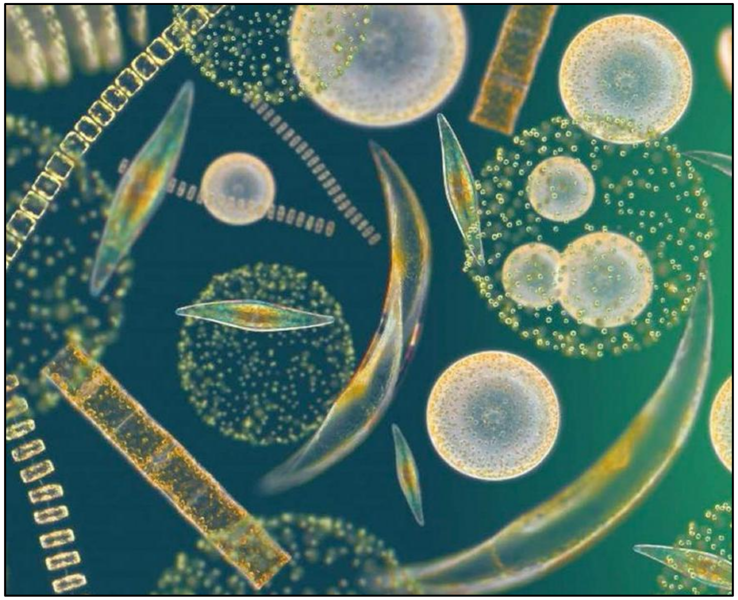


Methods

- Sediment cores collected from Harp, Red Chalk, and Eagle lakes
- VRS-inferred chlorophyll-*a* determined for each core

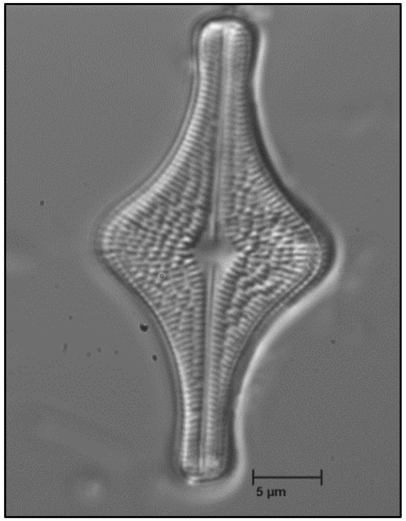


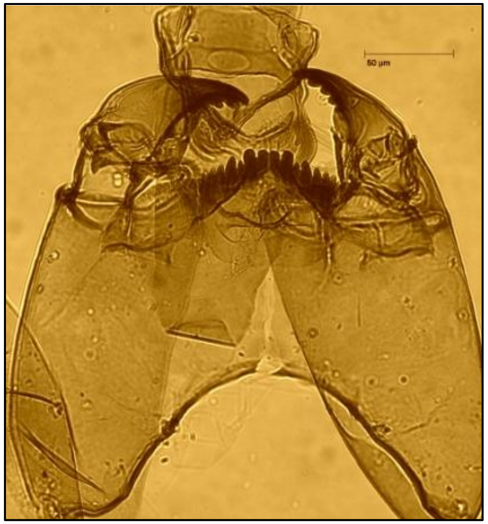
Chlorophyll *a*



Methods

- Sediment cores collected from Harp, Red Chalk, and Eagle lakes
- VRS-inferred chlorophyll-*a* determined for each core
- Downcore diatom assessment to reconstruct TP has been completed
- Downcore chironomid assessment to reconstruct DO has been completed for Harp Lake





http://www.shieldsgardens.com/info/Glossary.html
http://mic.com/articles/91037/these-hideously-ugly-creatures-are-actually-helping-us-fight-climate-change

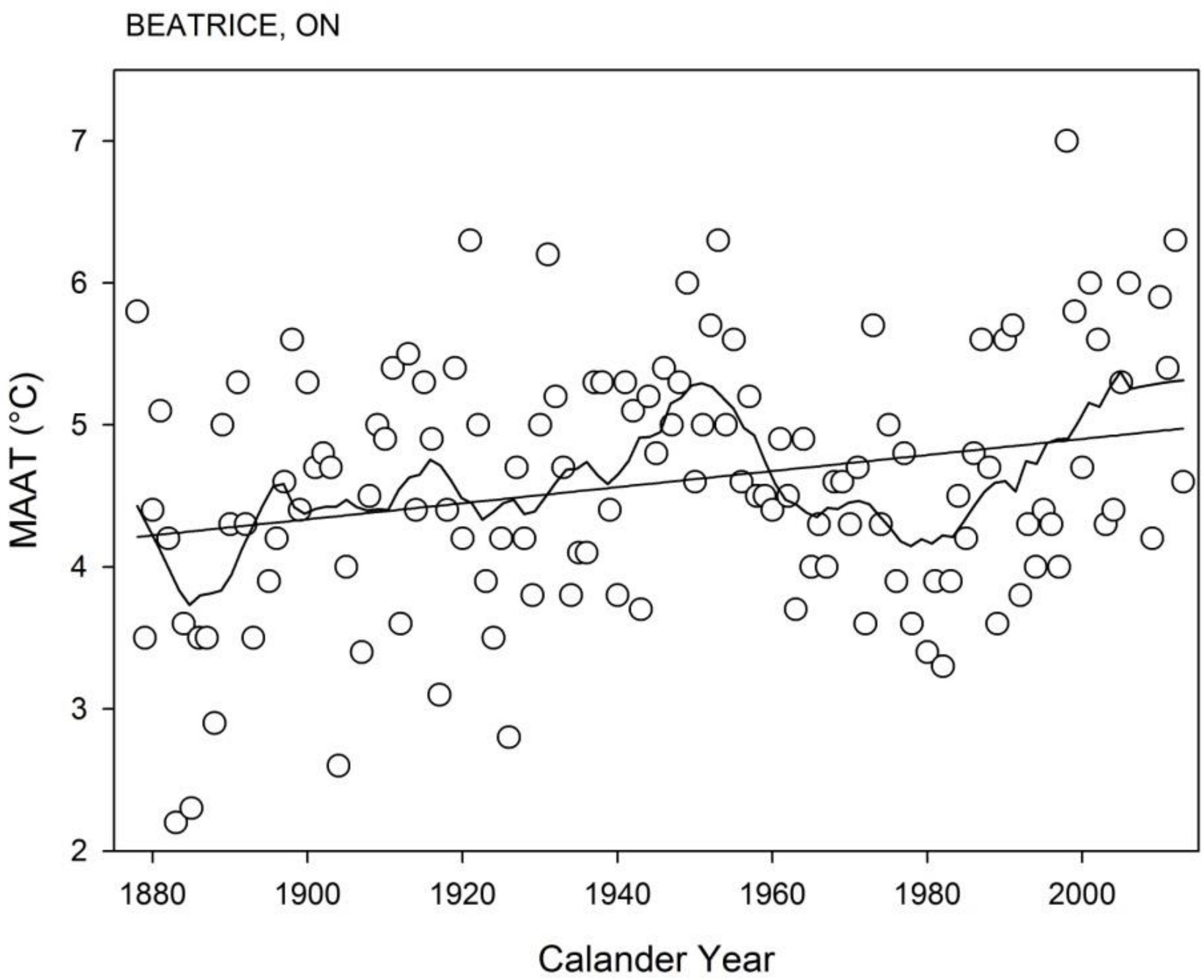
REFERENCE LAKES
Harp and Red Chalk

- Seven lakes in the south-central Ontario have been monitored continuously since the late-1970's
- Both lakes have minimal shoreline development
- Considered reference lakes for this investigation

Harp
Z_{max}: 37.5m, pH: 6.42, TP: 6.35 µg/L
Number of Cottages: under 100

Red Chalk
Z_{max}: 38 m, pH: 6.45, TP: 4.65 µg/L
Number of Cottages: 10

Regional Temperature Increases

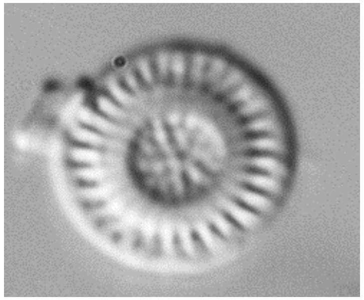


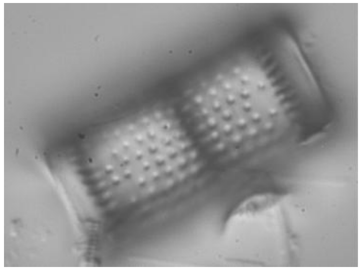
Climate station located ~35 km from Harp and Red Chalk lakes

MAAT increased by ~0.78°C since late-1880s

Reference Lakes 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

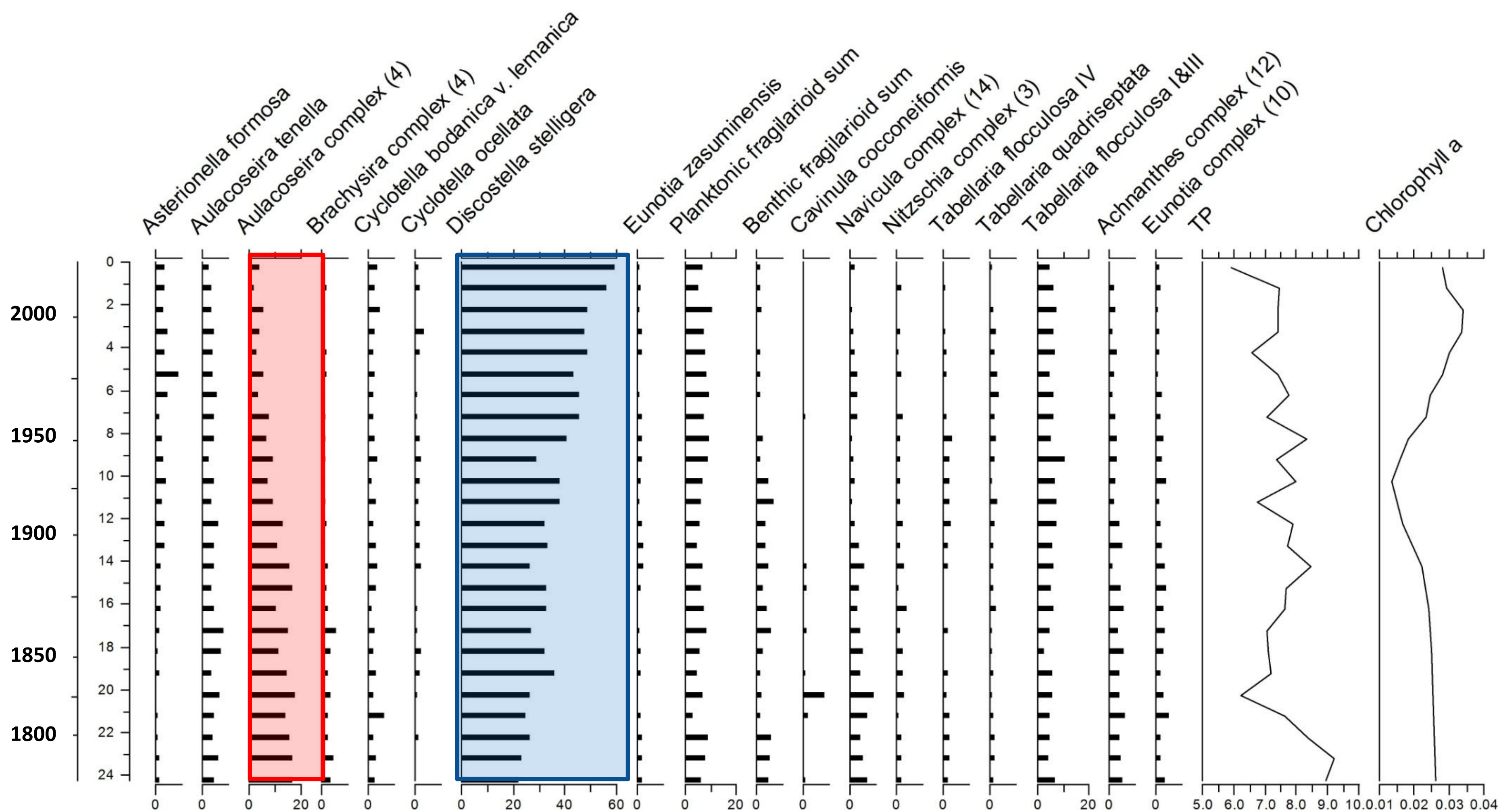




Indicative of a climate signal – longer ice free season and increased thermal stability (Rühland et al. 2015)

Reference Lake

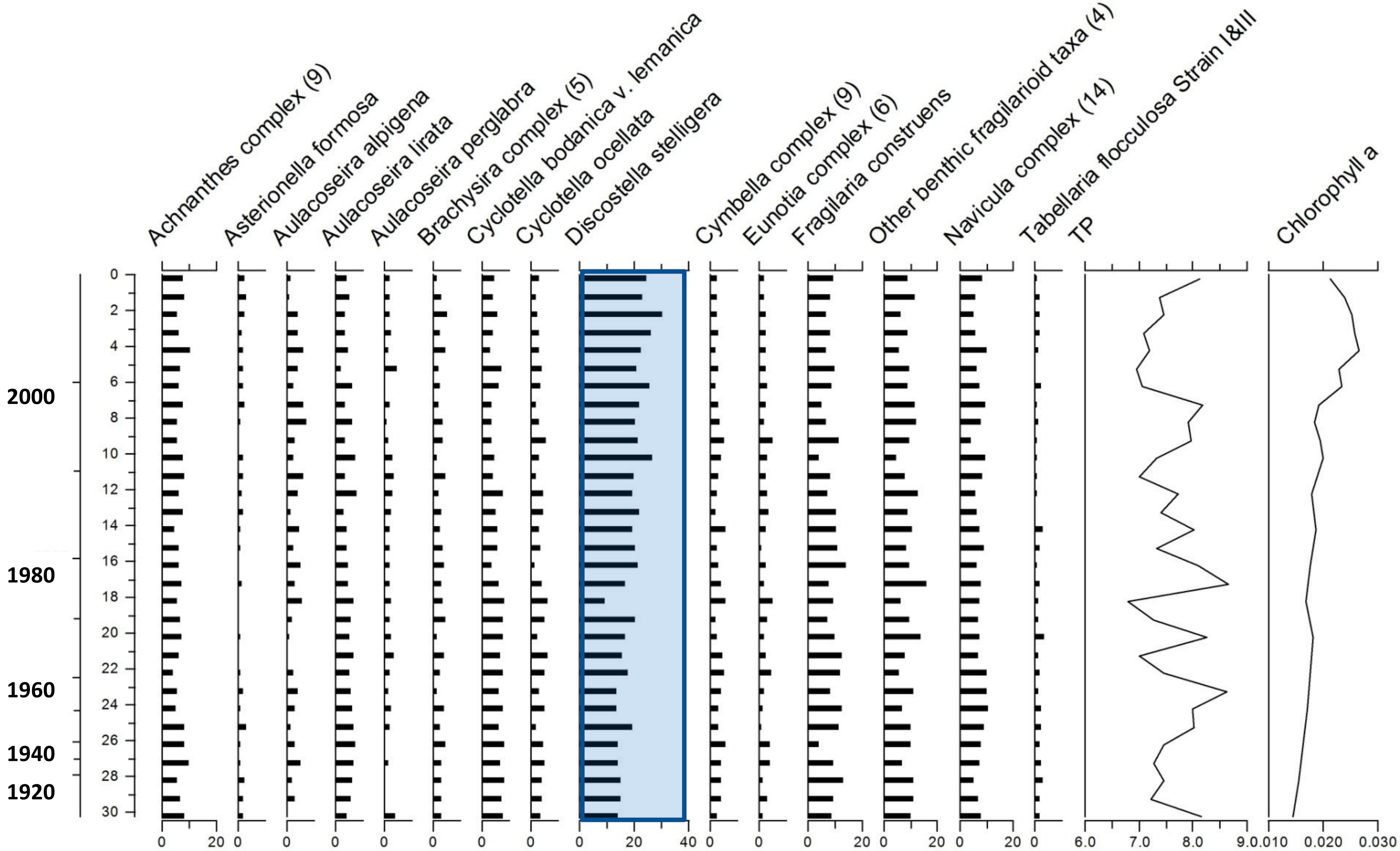
Harp Lake Diatom Results



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

Reference Lake

Red Chalk Diatom Results



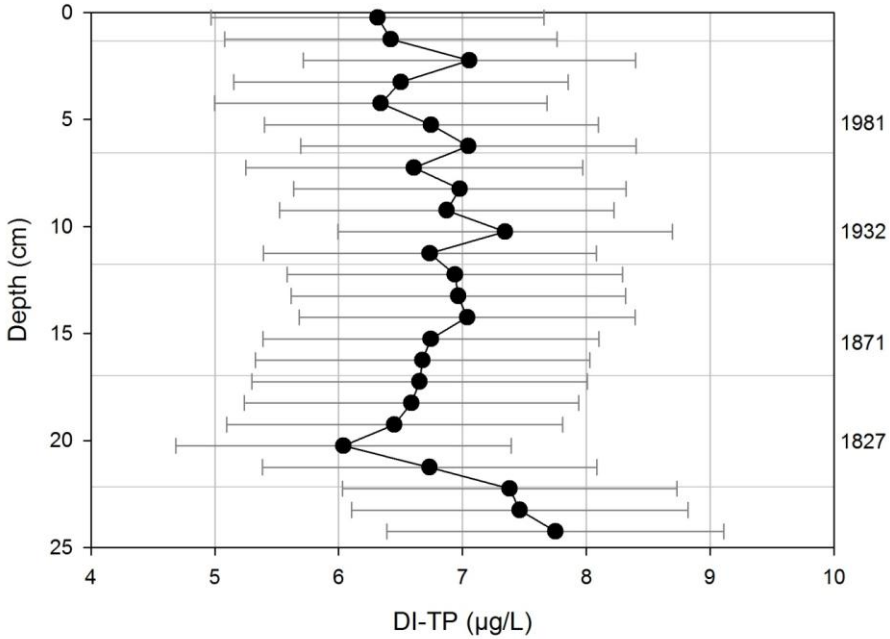
Max Depth: 38 m, pH: 6.45, TP: 4.65 µg/L

(Yan et al. 2008)

Reference Lake

DI-TP Results

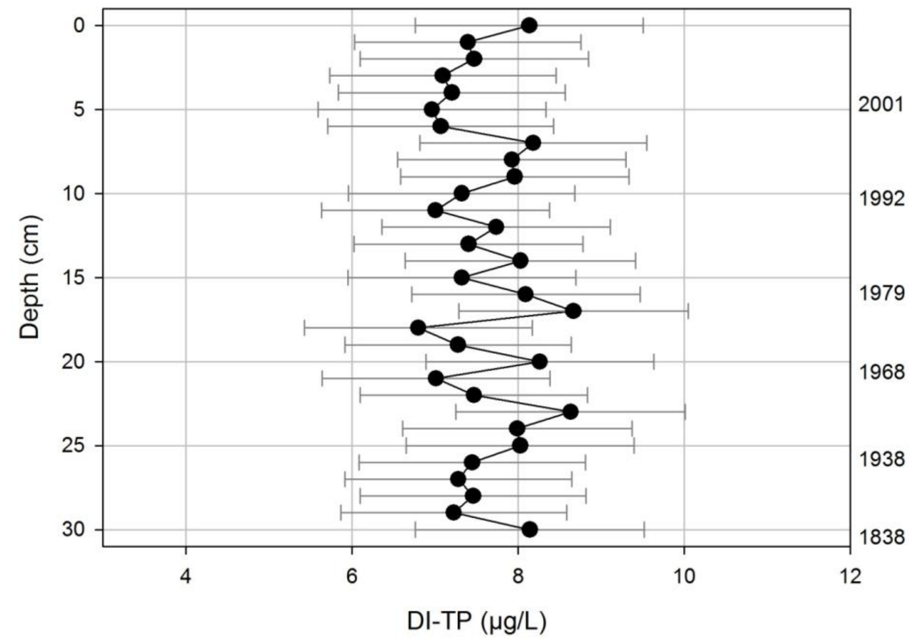
HARP



DI-TP shows a slight decreasing trend

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

RED CHALK

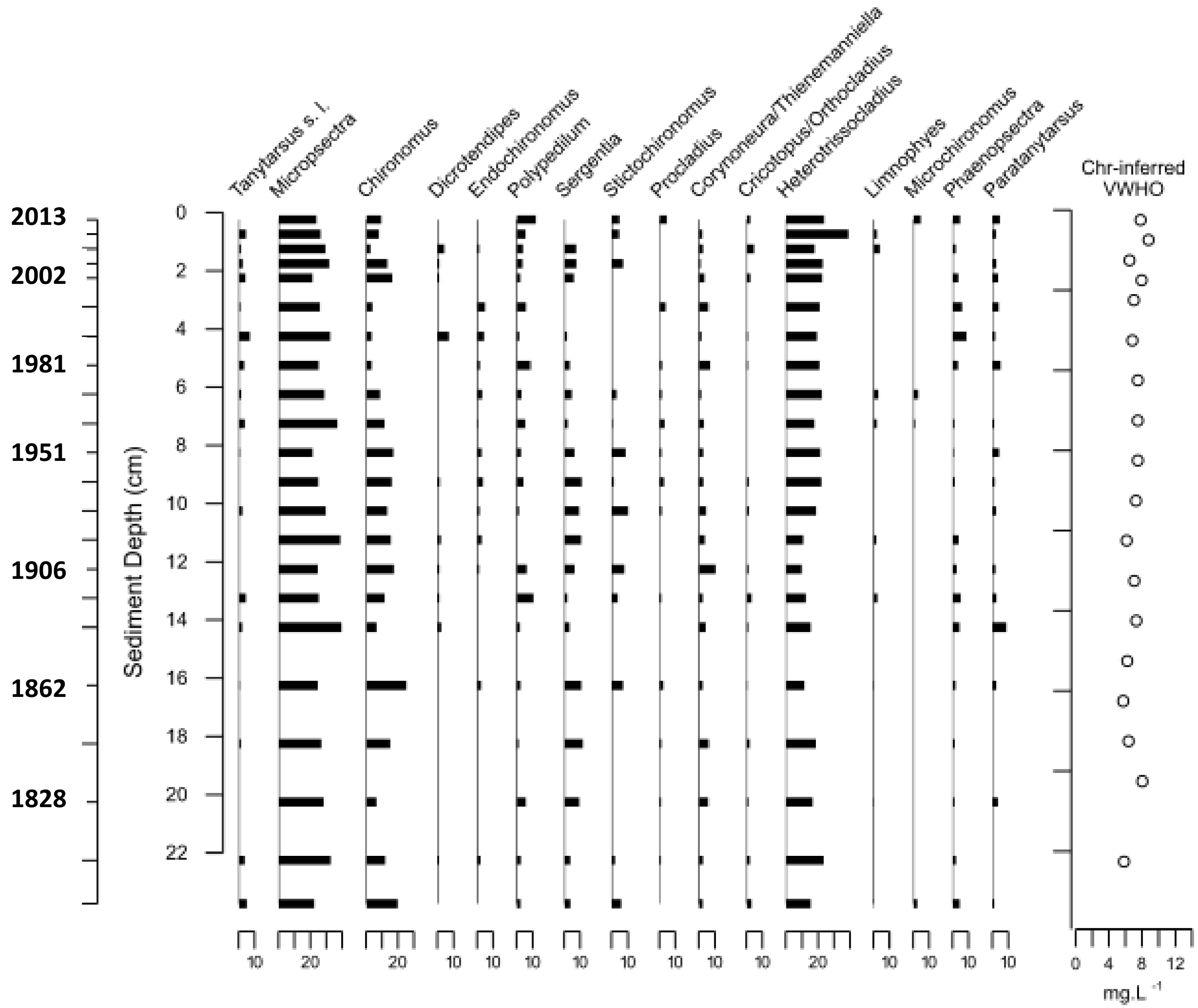


DI-TP shows no trend

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

Reference Lake

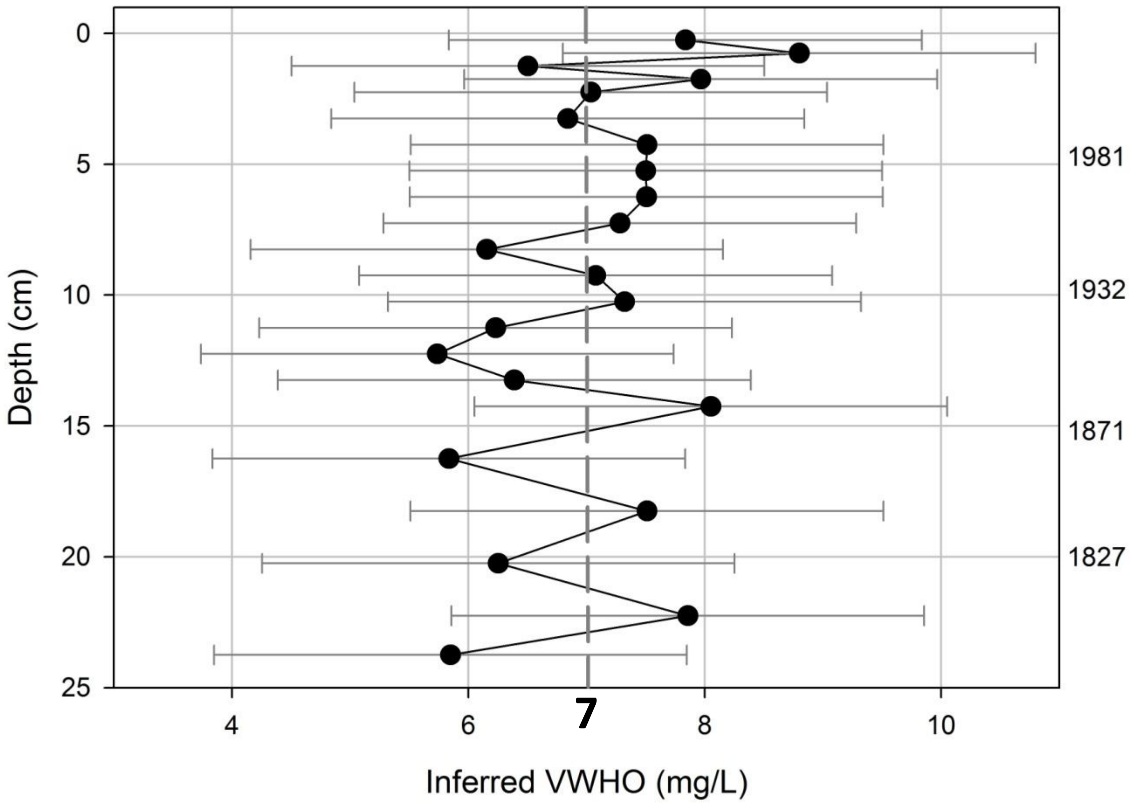
Harp Lake Chironomid Results



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

Reference Lake

Harp Lake VWHO Results



Predicted VWHO values indicate VWHO was historically variable around the provincial standard of 7mg/L

Note: Model is inferring end-of-summer VWHO concentrations

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

IMPACTED LAKE
Eagle Lake

- Moderate shoreline development since the late 1800's
- MVWHDO concentration below provincial standard of 7 mg/L
- Reclassified from a "threatened" to a "highly sensitive" Lake Trout lake in 2007
- Development subsequently restricted

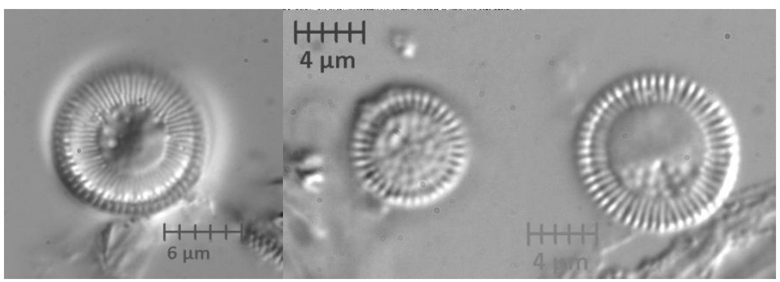
Z_{max}: 31.1m pH: 7.9 TP: 9 µg/L

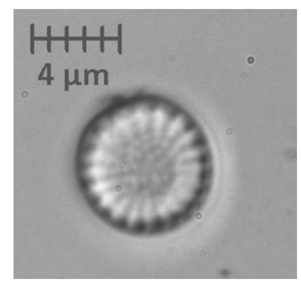
Shoreline development as of 2002:
-13 permanent residence
- 234 seasonal residences
-67 vacant lots
-2 camps (~ 545 campers)
-5% of shoreline is Crown land

Impacted Lake

Eagle Lake Diatom Results

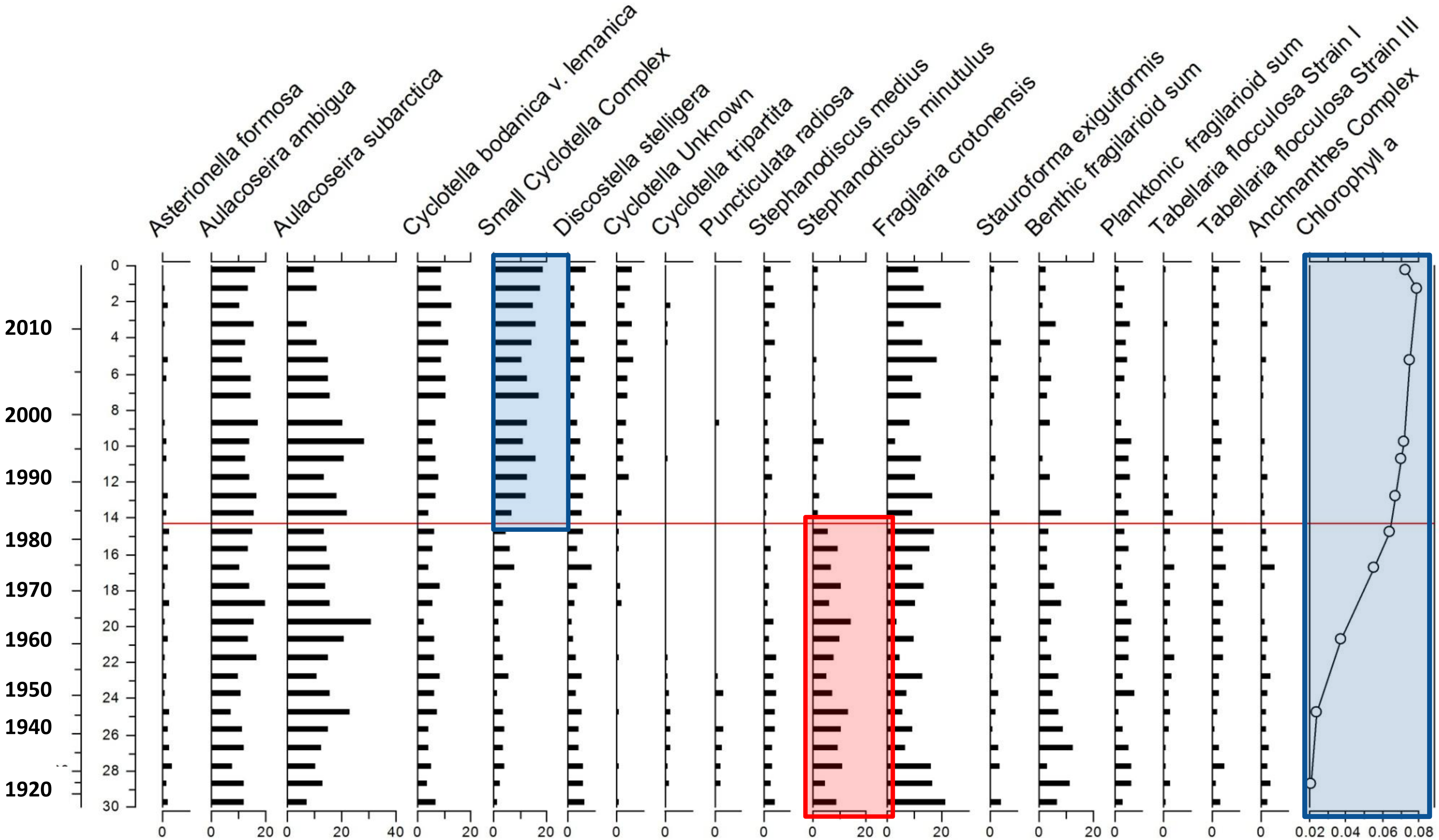
- Shift in diatom assemblage ~1985
  - Decrease in *Stephanodiscus minutulus*
  - Increase in small *Cyclotella* taxa (*C. comensis*, *C. gordonensis*, *C. michiganiana*)
- Increase in chlorophyll-*a*

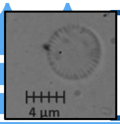




Suggests that production is increasing independent of nutrients

Eagle Lake Diatom Results



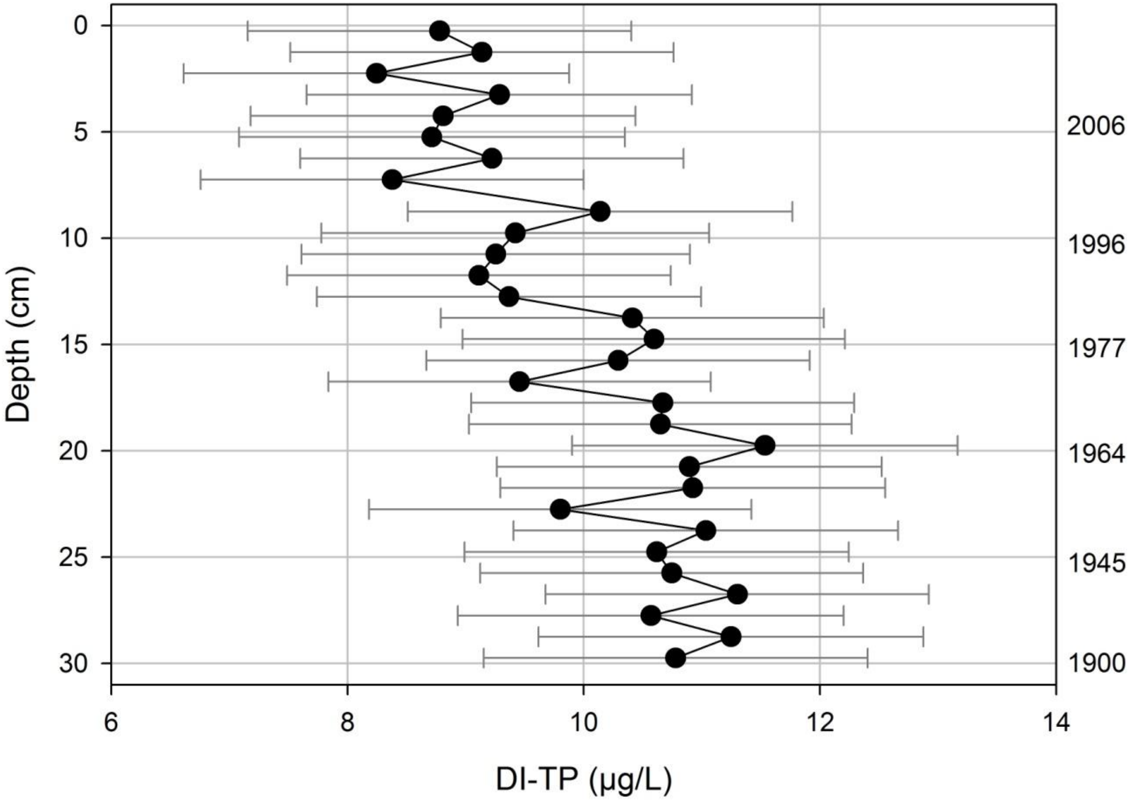


Unknown *Cyclotella* taxon

Max Depth: 31.1 m, pH: 8.09 , TP: 9 µg/L
MOECC –2012 Monitoring

Impacted Lake

Eagle Lake DI-TP Results



Decreasing DI-TP trend consistent with monitoring data

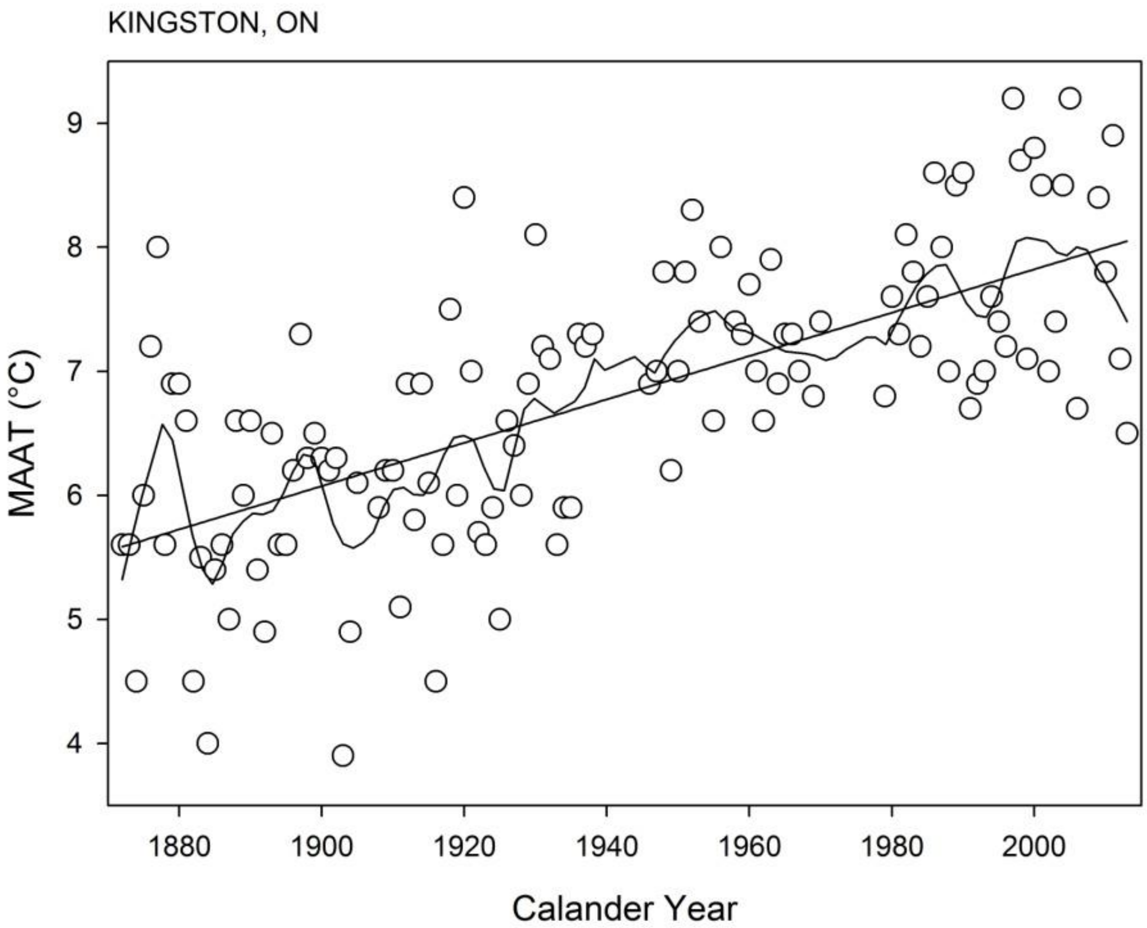
Model may be underestimating historical TP

1975: 17.3 µg/L
1981: 9.8 µg/L
2003: 7.4 µg/L
2012: 9 µg/L

Max Depth: 31.1 m, pH: 8.09 , TP:9 µg/L
MOECC – 2012 Monitoring

Impacted Lake

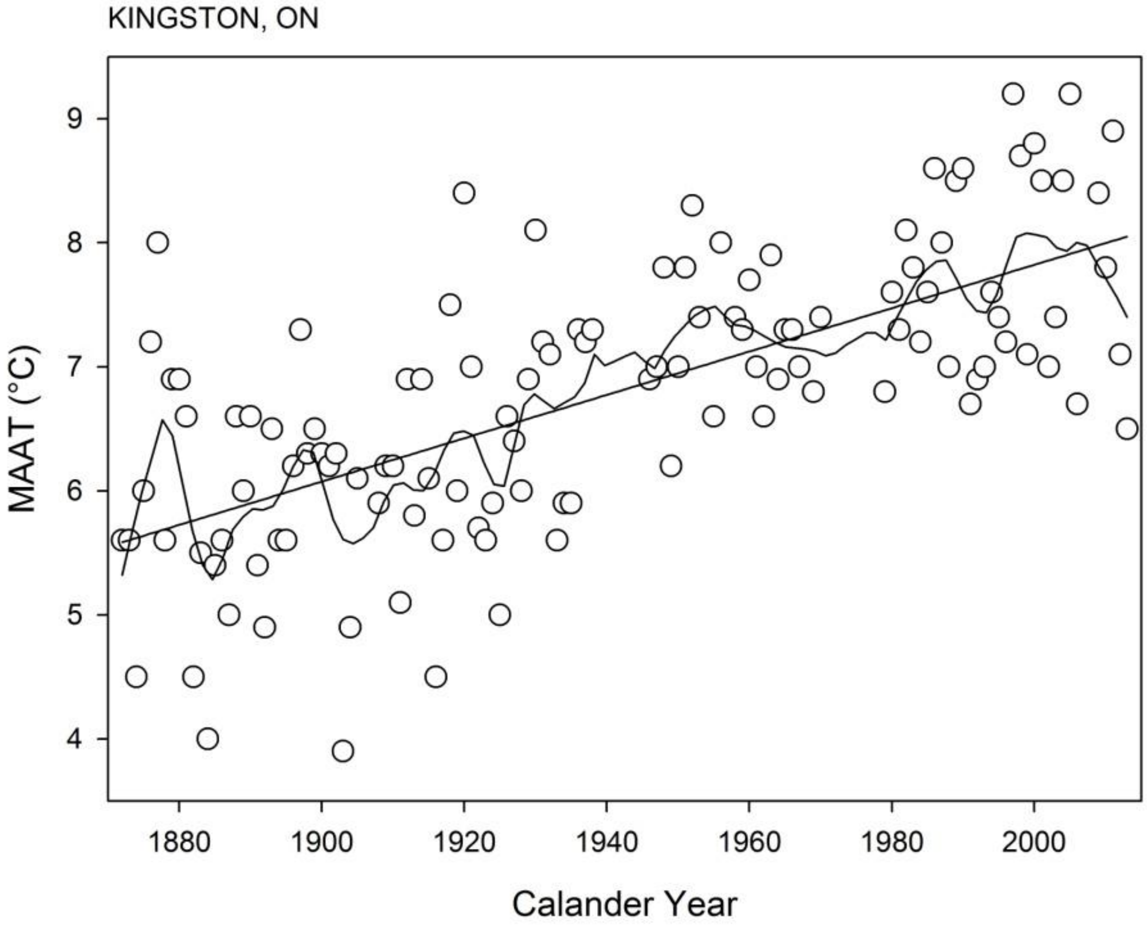
Regional Temperature Increases



Climate Station ~50 km from Eagle Lake

Warmed by ~2.5°C since the late-1880s

Regional Temperature Increases



Increase in VRS-chl*a* and *Cyclotella* taxa may be associated with warming

Recent DO declines more likely due to regional warming than shoreline development

Conclusions

- Results for Harp and Red Chalk lakes show subtle changes in diatom assemblages over the last ~200 years

- DI-TP shows minimal changes in both lakes

- Suggests that TP increases are not responsible for any oxygen depletion in these systems

Conclusions

-Results for Eagle Lake suggest decreasing TP and increasing overall production

-Increase in production may be due to lengthened growing season

- No evidence that TP is linked to the observed declines in hypolimentic oxygen

Next Steps

1. Compare DI-TP with chironomid-inferred DO for Red Chalk and Eagle lakes
2. Apply models to Lake Trout lakes of interest across Ontario

Acknowledgements

- Roberto Quinlan, Kelli Charbonneau and Joseph Vaitekunas
- 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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