Using diatom assemblages to assess the influence of nutrient loading and climate warming on lakes that sustain Lake Trout populations in Ontario, Canada

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Lake Trout

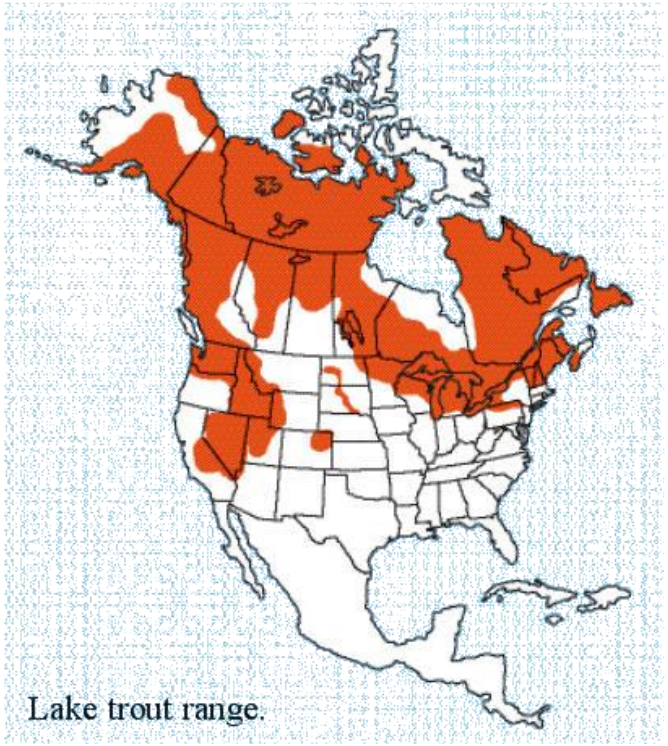
- Widely distributed cold-water taxon
- Good ecological indicator
  - Large bodied (30-80 cm in length) & late maturing (5-10 yrs)
  - Specific habitat requirements for temperature and oxygen

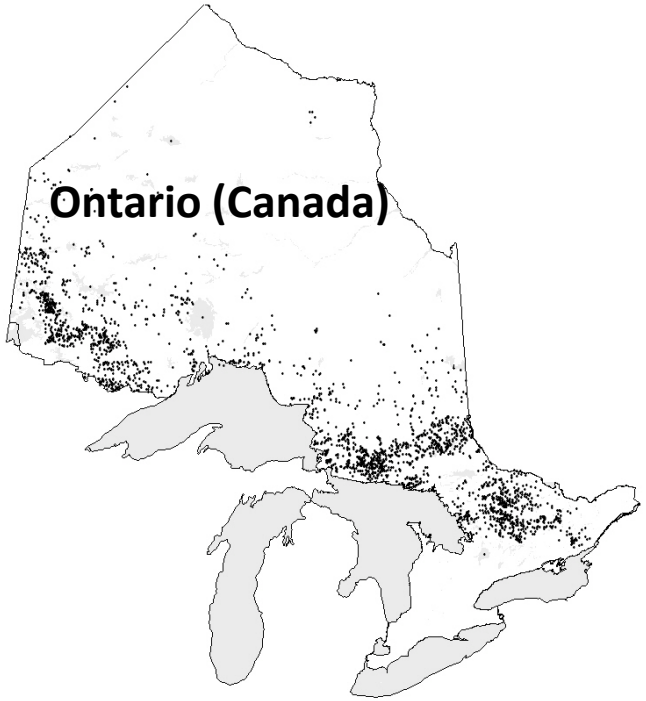
Lake Trout *(Salvelinus namaycush)*

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

Distribution

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





(OMNRF 2006)

(Photo: http://carnivoraforum.com/topic/9885166/1/)

Habitat Requirements

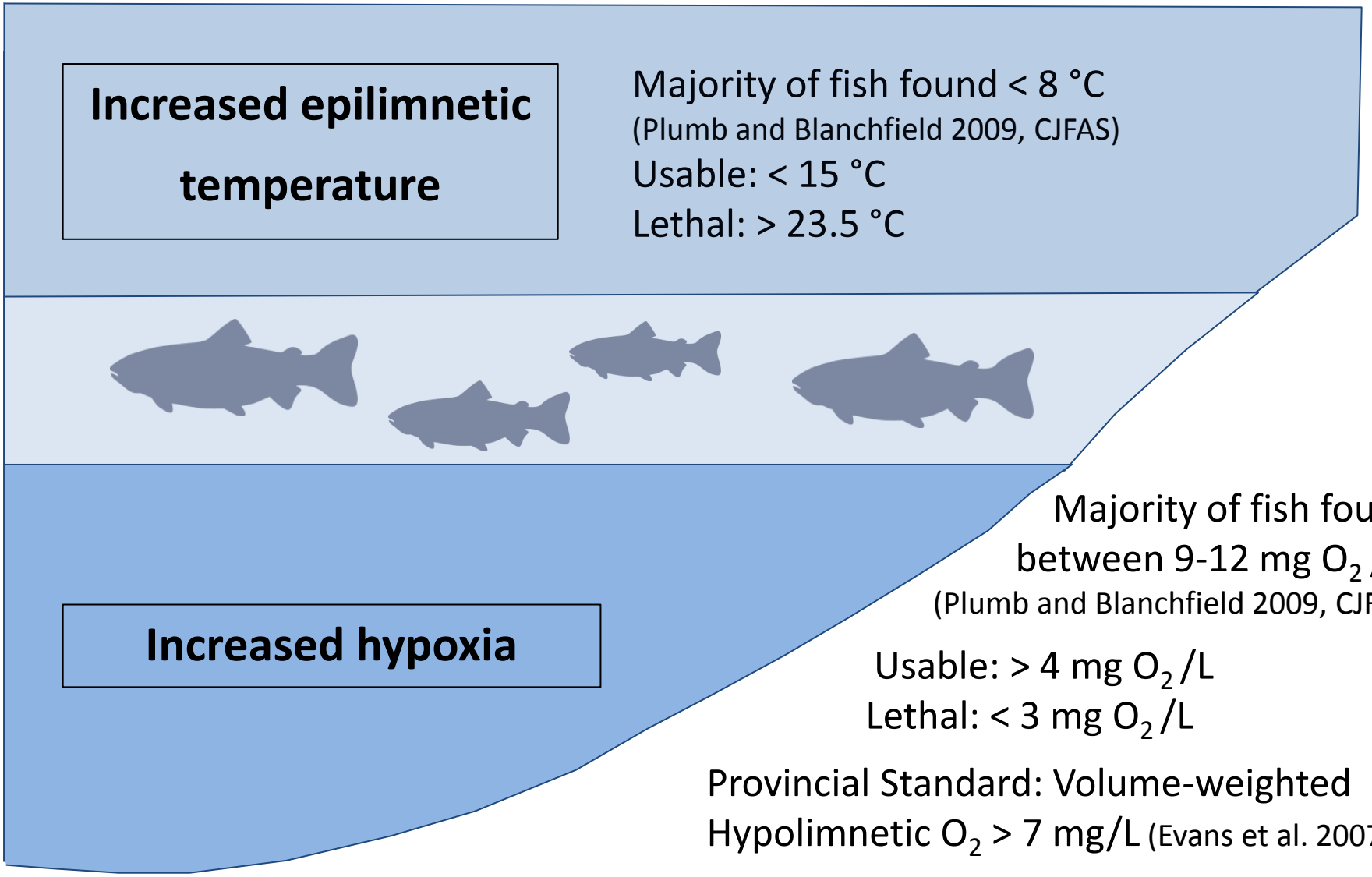
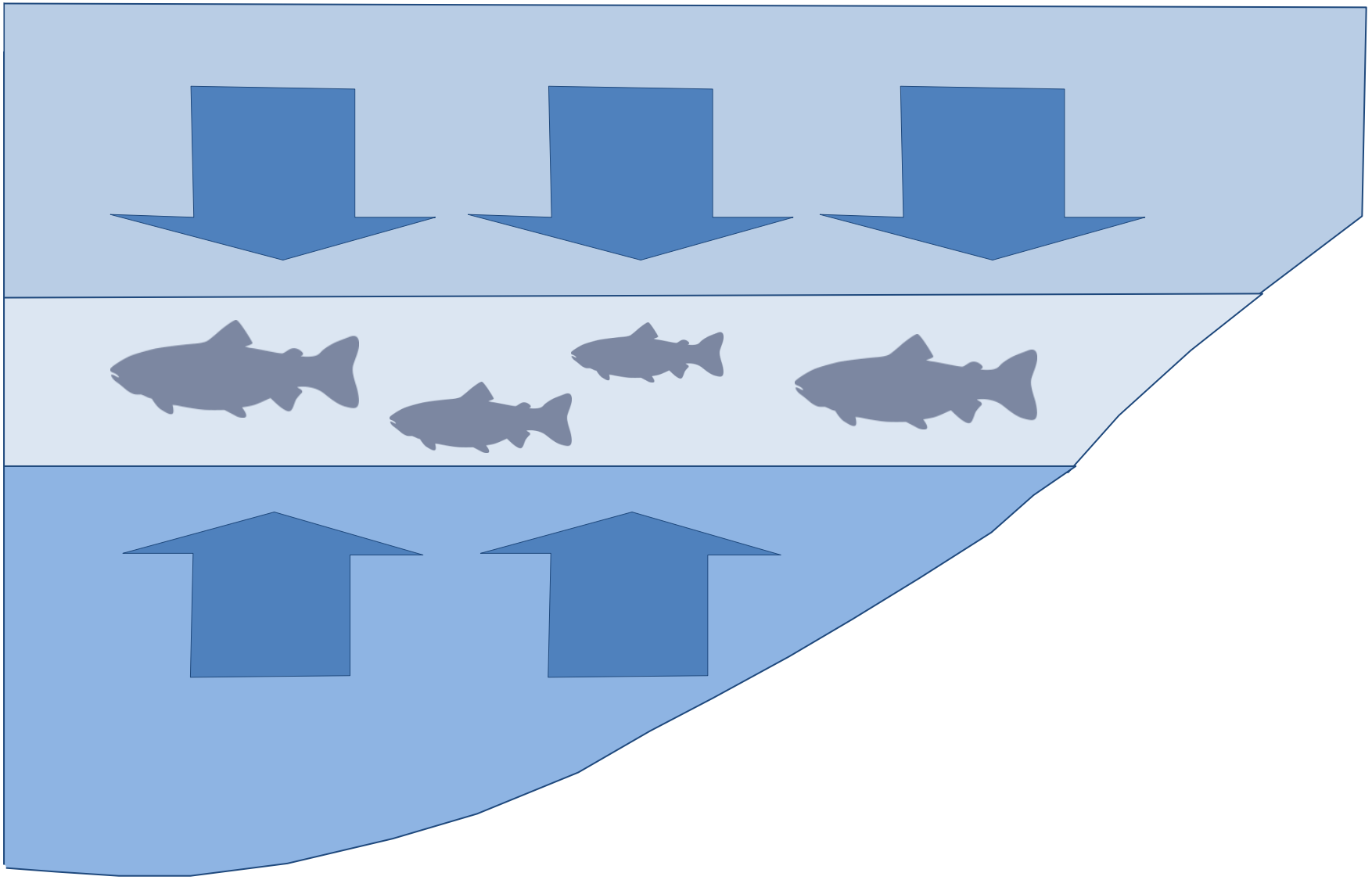


Figure modified from Ficke et al. (2007, Rev Fish Biol Fisher)

Habitat Requirements



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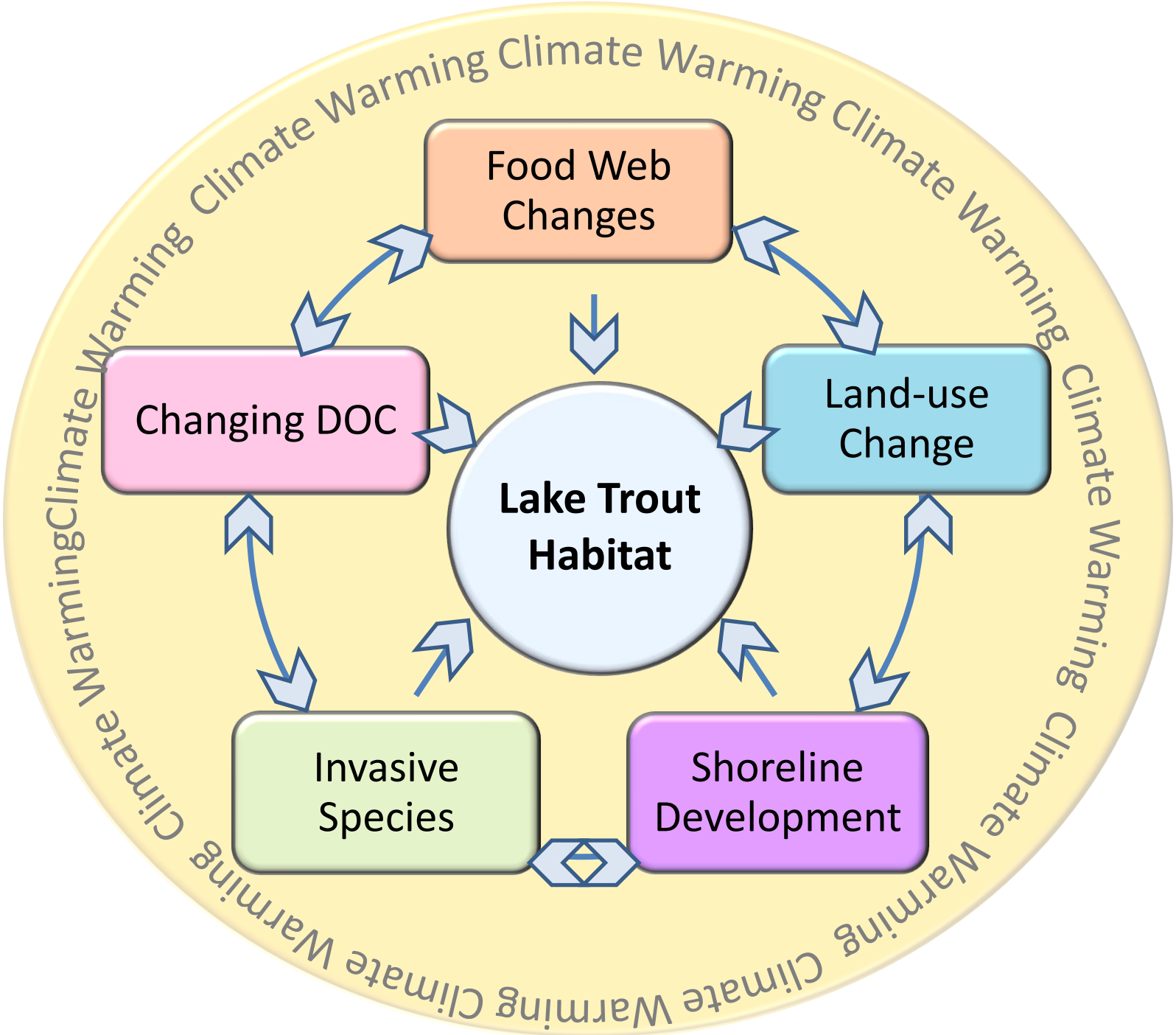
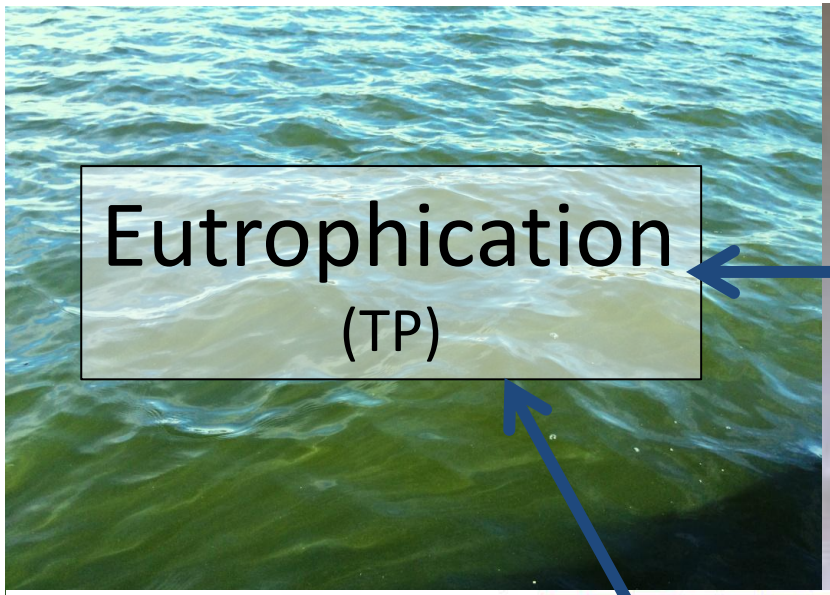

Climate Warming Climate Warming Climate Warming Climate Warming Climate Warming Climate Warming Climate Warming Climate Warming
Food Web Changes
Land-use Change
Shoreline Development
Invasive Species
Changing DOC
Lake Trout Habitat

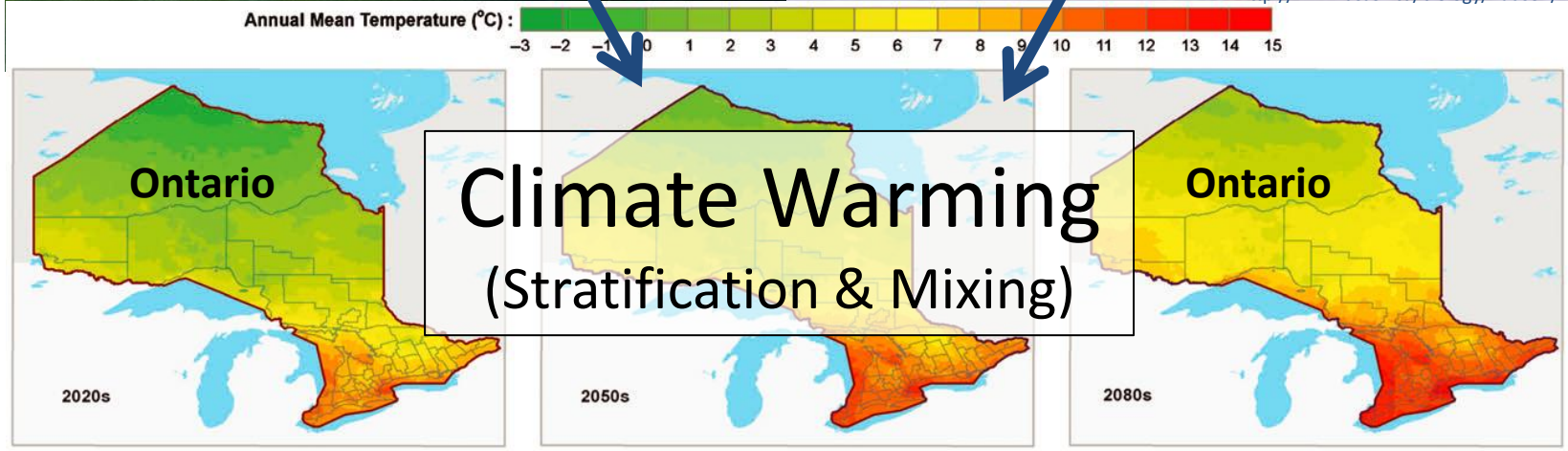
Variables that Influence Hypolimnetic Oxygen



Eutrophication
(TP)

Acidification
(DOC)

http://www.usask.ca/biology/hudson/



Climate Warming
(Stratification & Mixing)

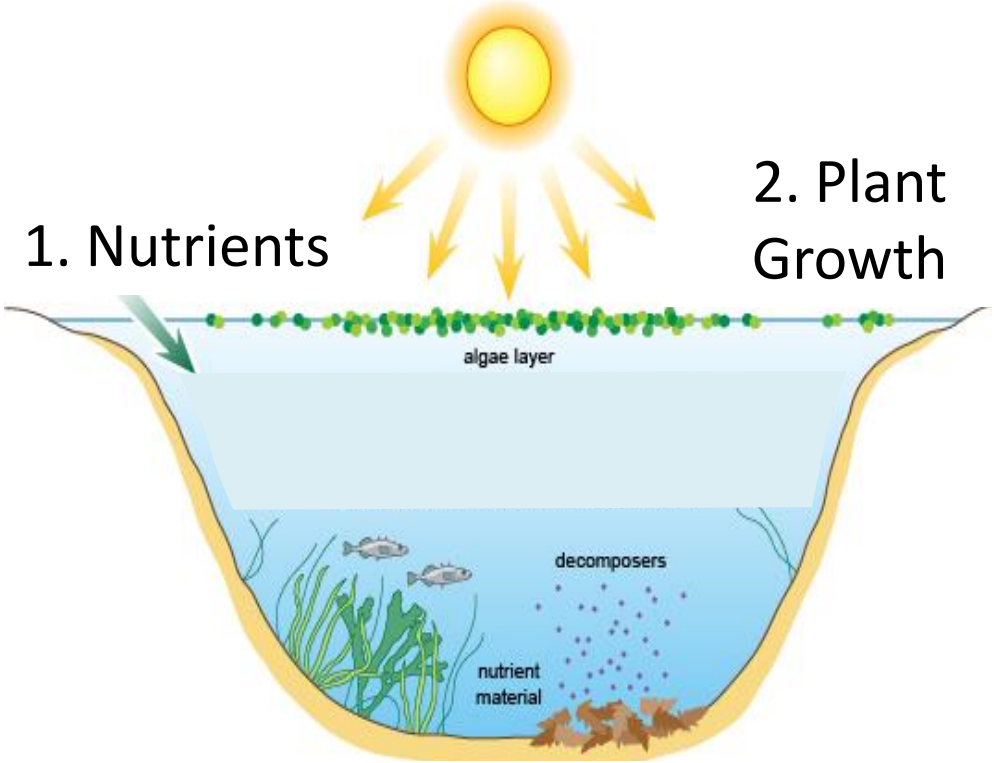
(Wang et al. 2014, Q J R Meteorol Soc)

The Role of Total Phosphorus (TP) in Hypolimnetic Anoxia

Management efforts currently centered on controlling TP

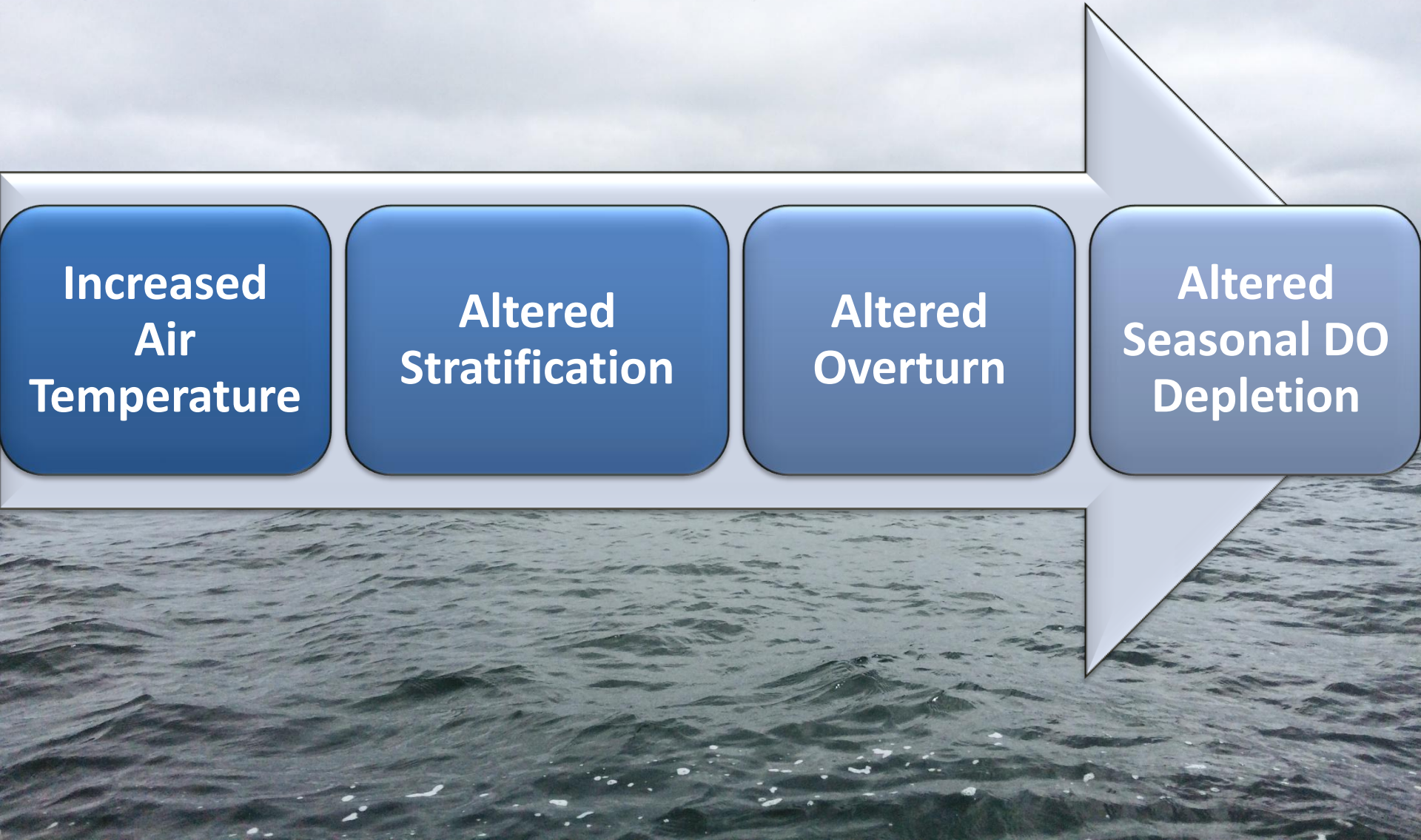
However, depleted DO has been observed in lakes with stable *or* declining TP
(Summers et al. 2012, J Limnol)

Suggests the influence of other factors



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

Climate Change



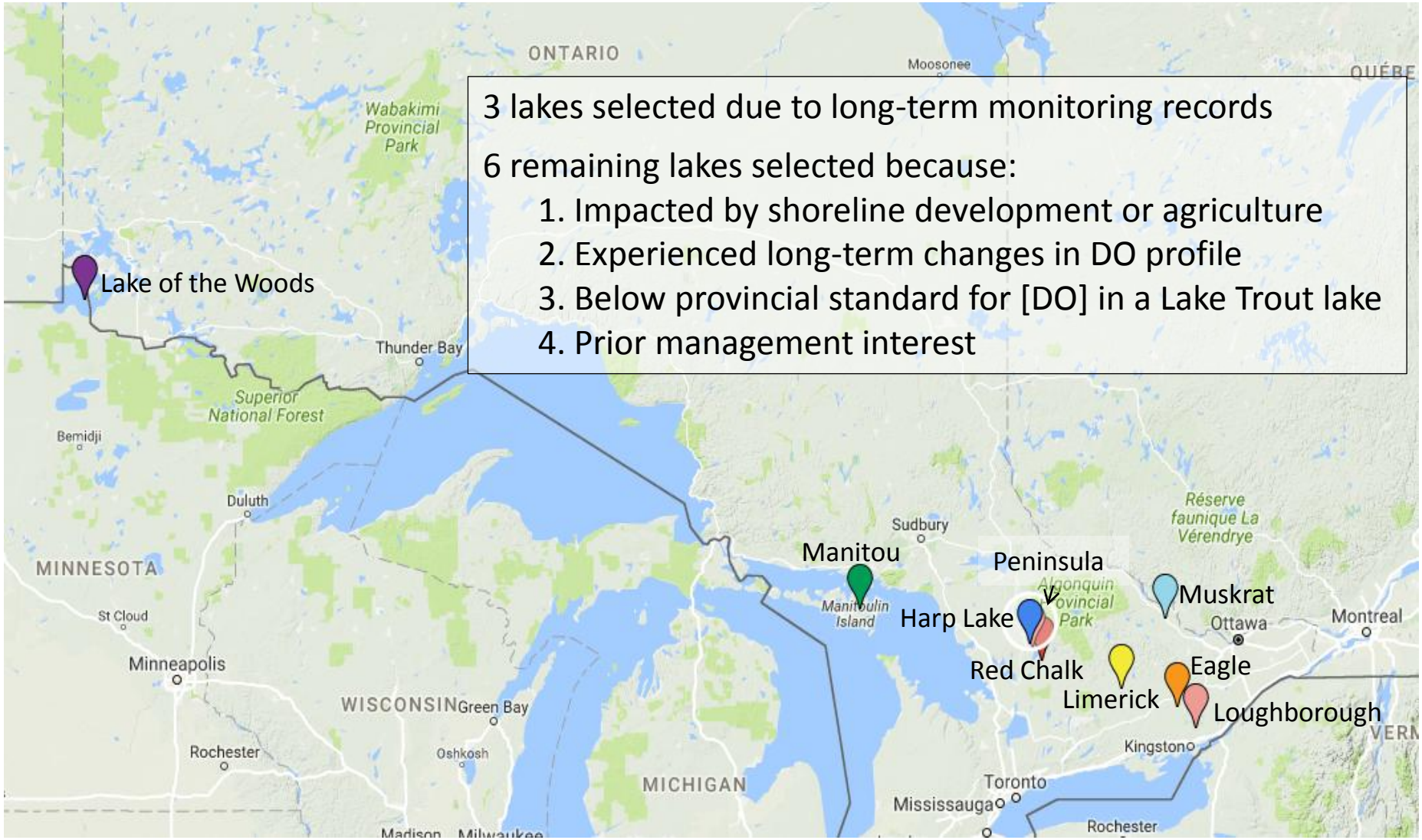
Project Objective

Use diatoms to understand the influence of nutrients and climate warming over the past ~ 200 years in lakes that sustain Lake Trout

Of interest because

- It provides an understanding of two stressors that influence hypolimnetic oxygen and how these stressors have changed through time
- Implications for habitat management

Strategy for Selection of Study Lakes



Research Questions

1. How have diatom assemblages changed over the past ~200 years in Lake Trout lakes across Ontario?

2. Is the nature of the assemblage changes indicative of a particular modern stressor (nutrients or climate)?

3. How do diatom changes compare across lakes?

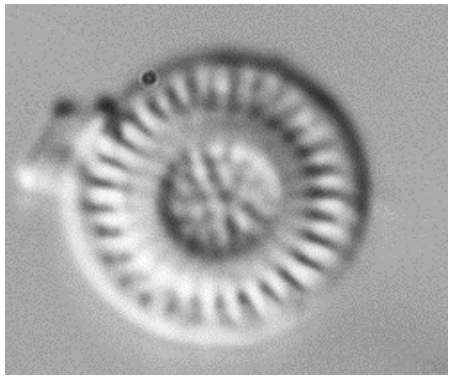
Progress to Date

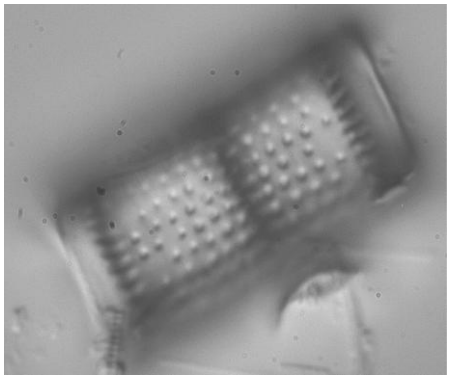
- 7 sediment cores have been dated and analyzed for diatoms to assess the influence of nutrients and climate warming
- These lakes vary in size, water chemistry, amount of shoreline development and degree of regional warming

Results

Diatom Results Summary

- All lakes have experienced an increase in the relative abundance of small, fast-growing cyclotelloid taxa
- Generally at the expense of benthic and heavily silicified tychoplanktonic taxa





- As expected, timing and magnitude of this assemblage shift differs among lakes

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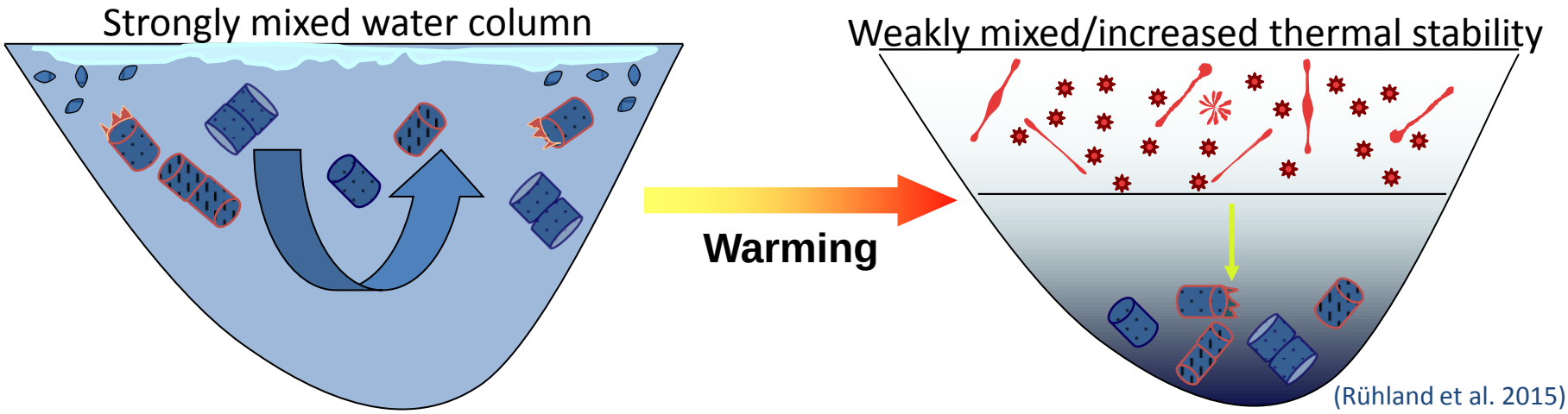
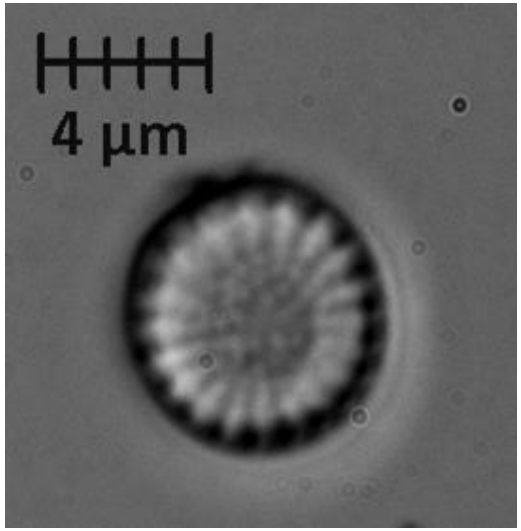
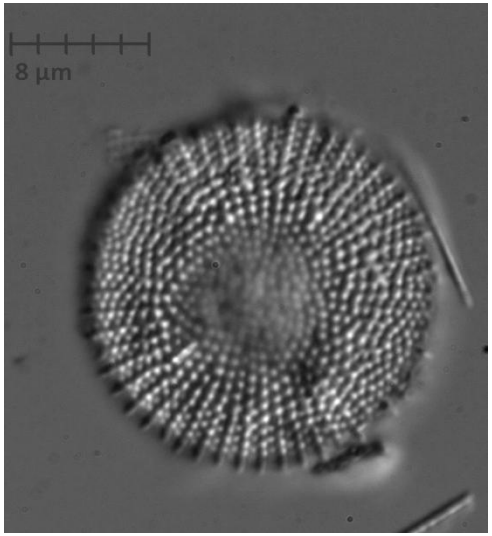


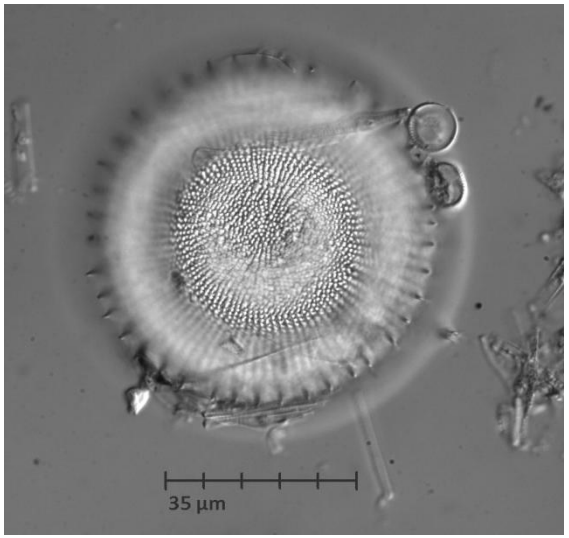
Shift characteristic of longer/stronger thermal stratification due to climate warming (Rühland et al. 2015, JOPL)

Diatom Results Summary

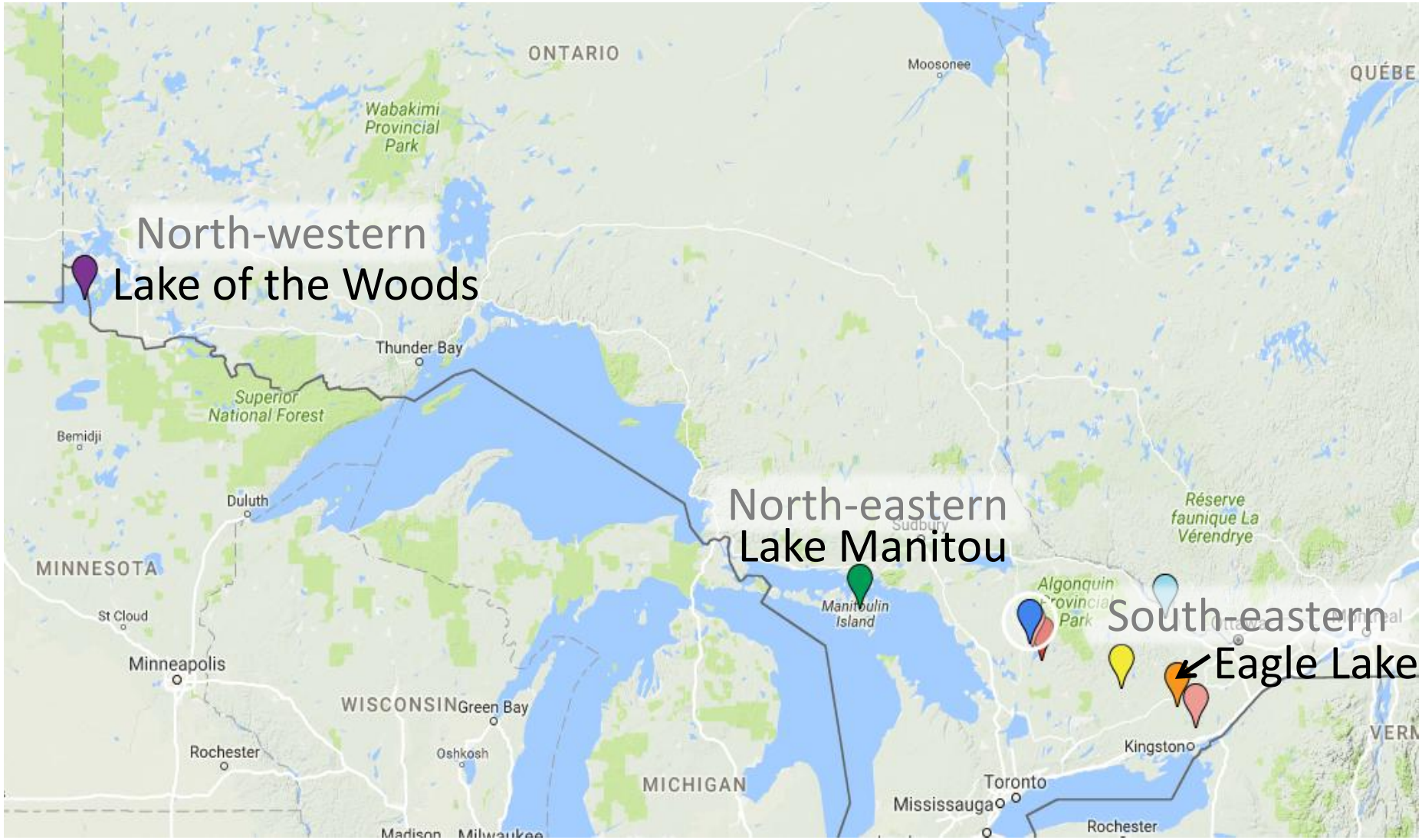
- Where present, diatom taxa indicative of higher nutrient environments decrease in all lakes (except for one)
- Changes suggest that in most study lakes, low oxygen is likely not a result of nutrient loading





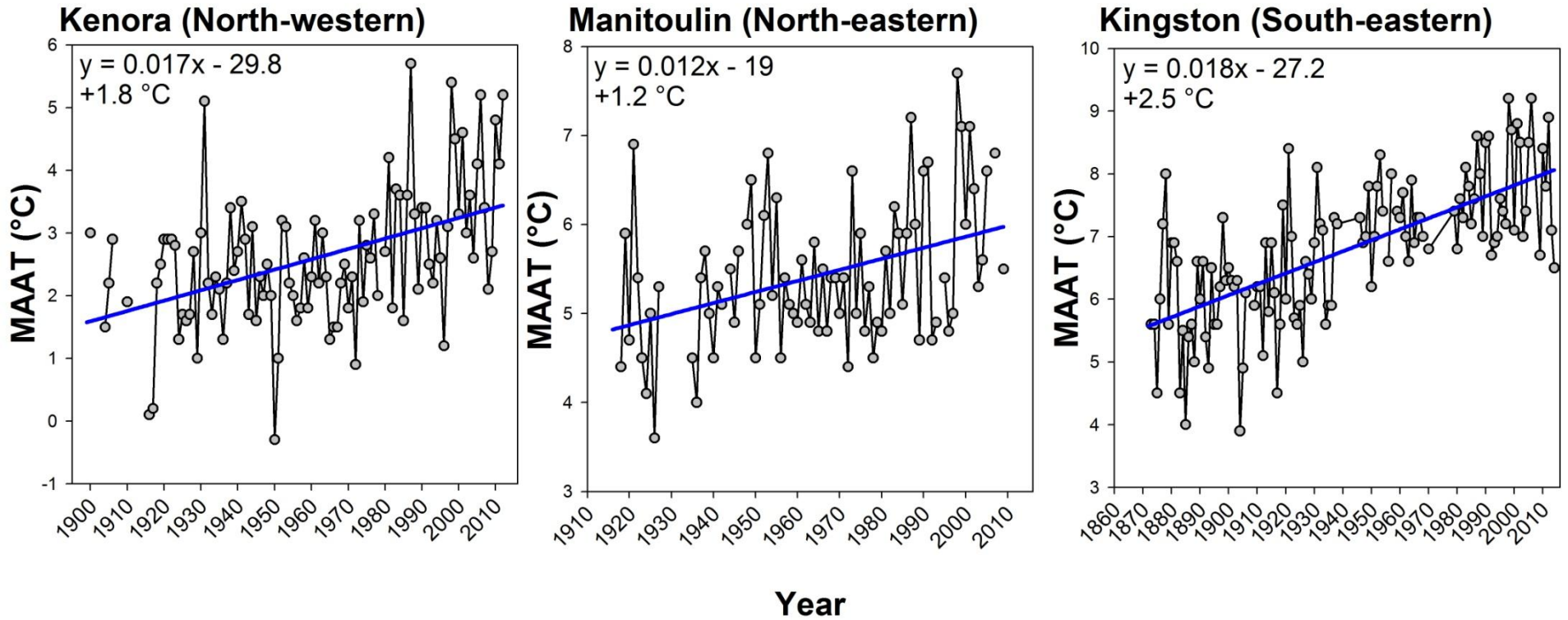


3 Case Studies



Climate Warming

- Warming not equal across the province
- All regions show increases in mean annual air temperature (MAAT), but different rates of warming
- Highest increases have occurred in spring and winter

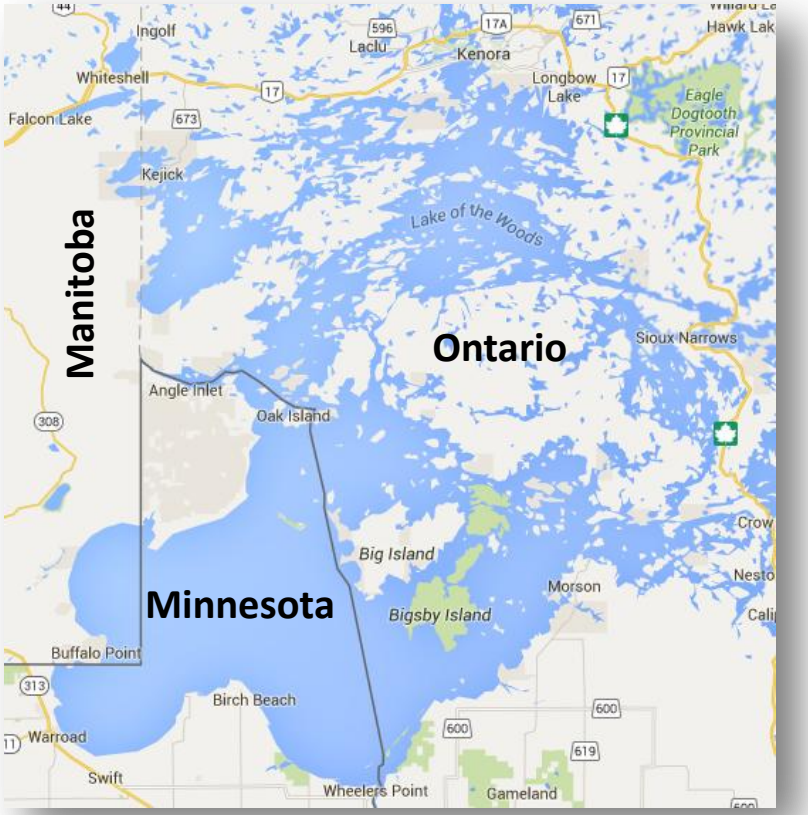


Management Interest

Lake of the Woods:

- International waterbody
- Reported increases in the severity and frequency of cyanobacterial blooms in northern regions
- Substantial decrease in annual TP load after the 1970s (still large internal load)

(Hargan et al. 2011, J Great Lakes Res)



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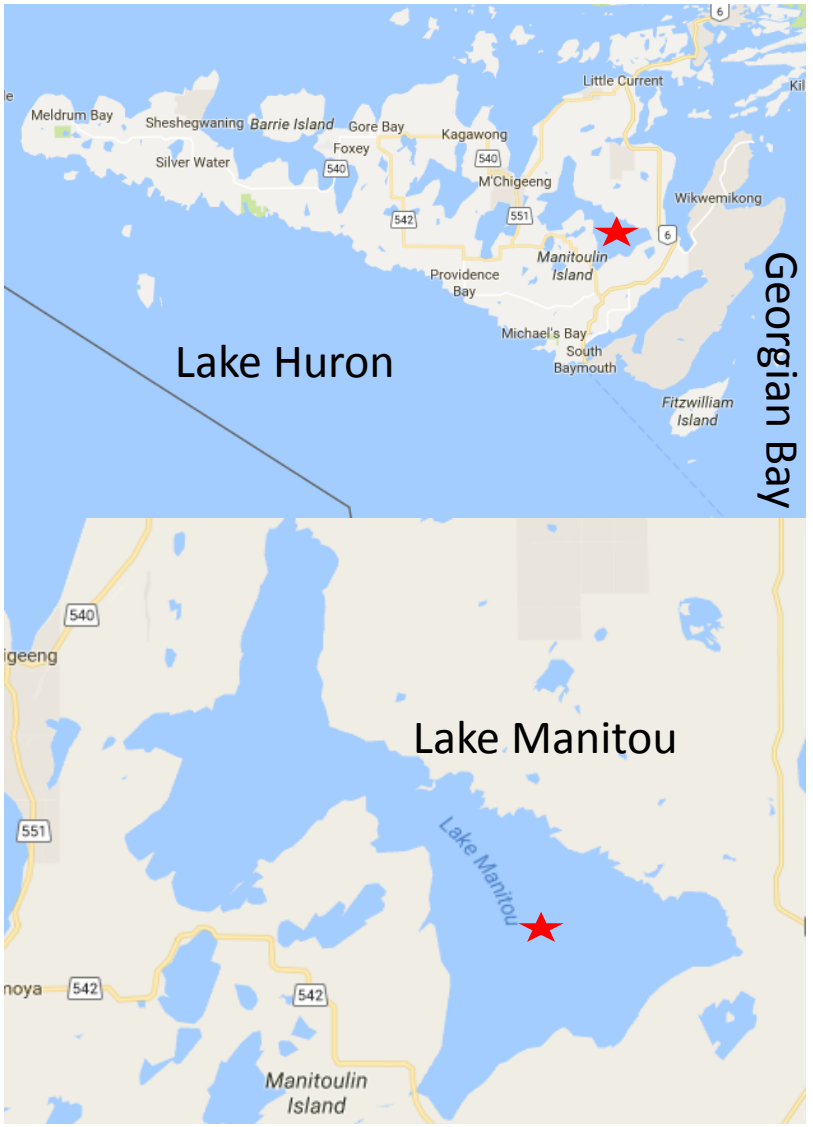
(Photo: Lake of the Woods Water Sustainability Foundation 2011)

Management Interest

Lake Manitou:

- World's largest freshwater lake on an island
- Lake trout reared from Lake Manitou strains are used to stock hard-water inland lakes in Ontario
- Low VWHO concentrations between 2007-2011
- Further development has been restricted within 300m of the shoreline



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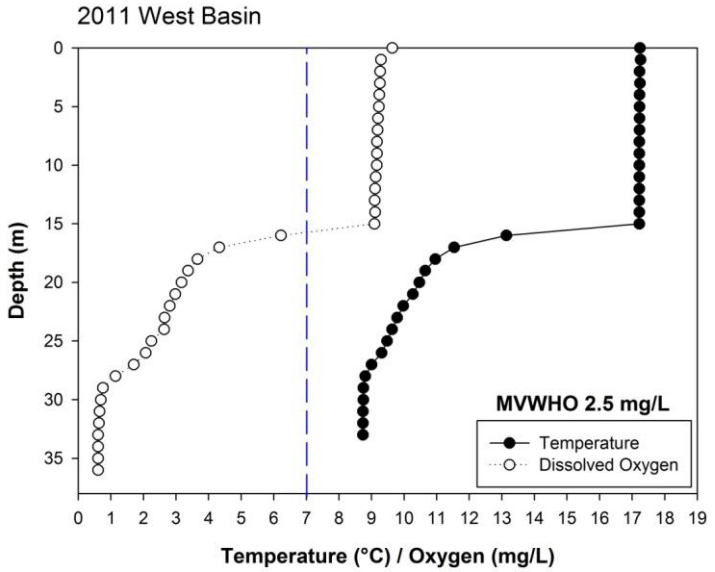
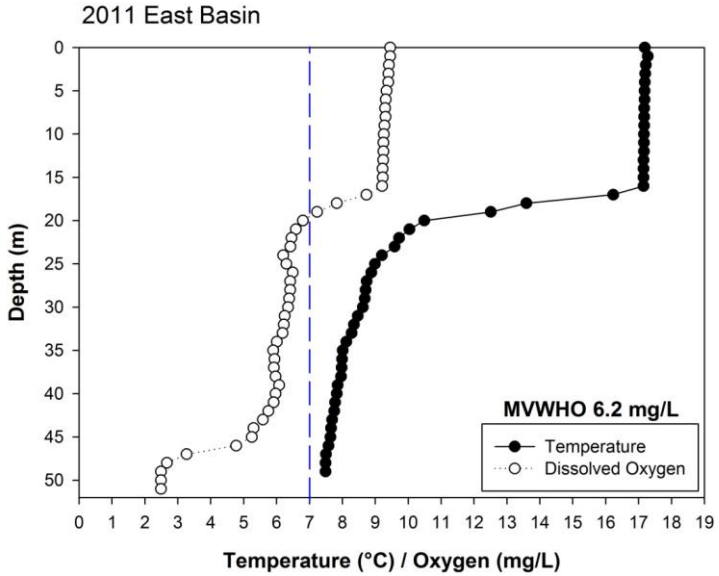




Management Interest

Eagle Lake:

- MVWHDO concentration below provincial standard of 7 mg/L since the early-2000s (OMOECC 2011)
- Reclassified from a “threatened” to a “highly sensitive” Lake Trout lake in 2007
- Development subsequently restricted within 300 m of shoreline

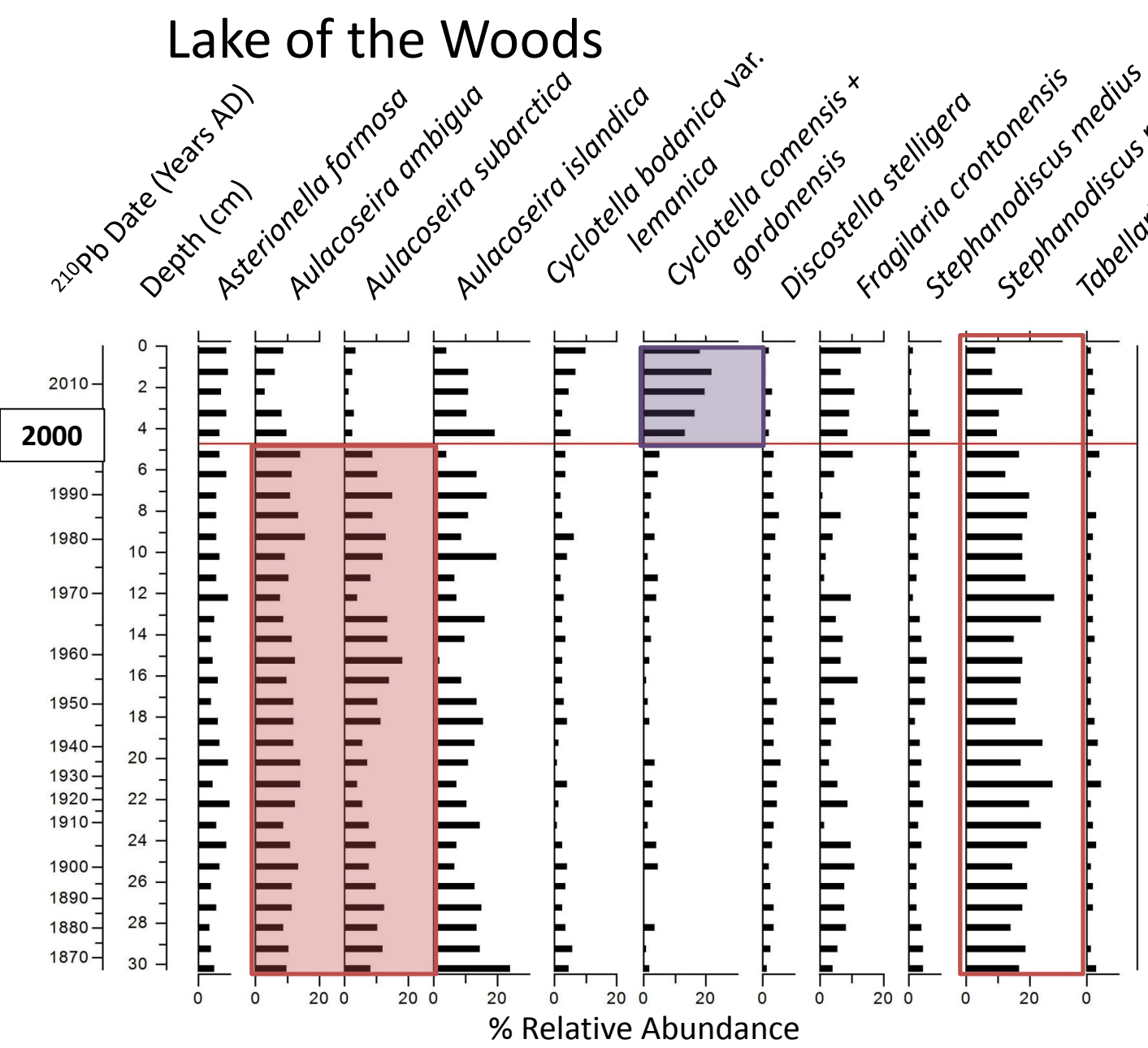
(Eagle Lake 2014)

Lake Characteristics

Characteristic	Lake of the Woods (Cul de Sac)	Lake Manitou (East Basin)	Eagle Lake
Max Depth (m)	32	54	31
Surface Area (ha)	132	10618	665
pH	7.98	8.43	8.00
TP(µg/L)	10.1	8.2	9.5
Ca (mg/L)	15.08	31.6	15.5
DOC (mg/L)	7.78	2.8	4.05
# of cottages/residents	2	850	247
End-of-summer VWHO (mg/L)	4.89 (2009)	6.2-2.5 (2011)	5.52 (2007)
Source	Hargan 2010, OMNRF & OMOECC 2014 data	TP- Lake Partner Program average 2015 data, Werner 2003	OMOECC average May-Sept 2012

Cul de Sac Bay Diatom Results

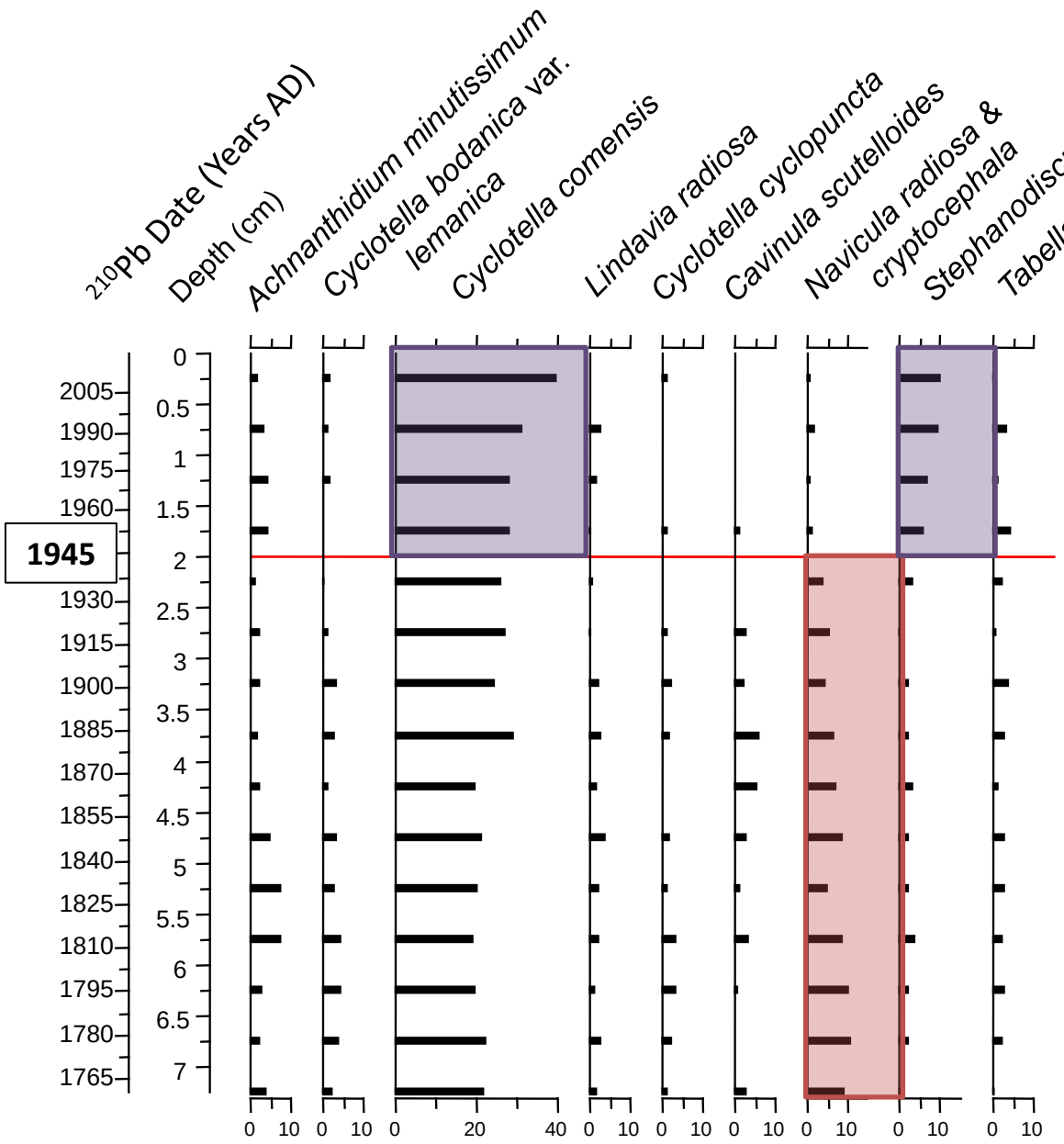
Lake of the Woods



- Increase in *Cyclotella comensis* and *C. gordonensis*
- Decrease in *Aulacoseira ambigua* and *A. subarctica*
- Decrease in *Stephanodiscus minutulus*

Indicative of warming and a decrease in nutrients

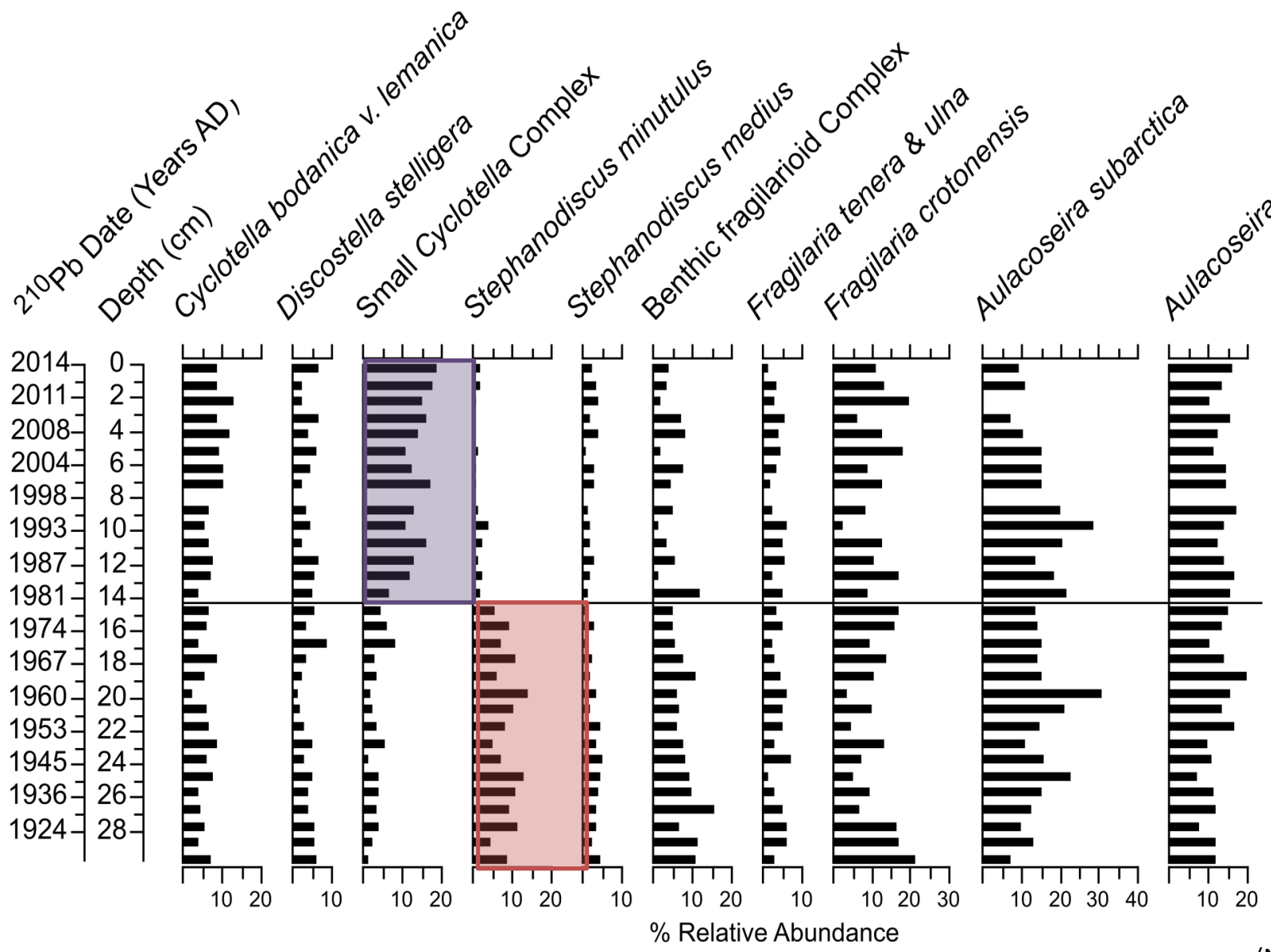
Lake Manitou Diatom Results



- ~10% increase in *Cyclotella comensis* – increased thermal stratification
- Increase in *Stephanodiscus* taxa – nutrients/internal loading signal
- Decrease in epiphytic and epilithic taxa - *Navicula radiosa* and *N. cryptocephala*

  (Douglas and Smol 1995, J Phycol; Winter and Duthie 2000, Aquat Ecol)

Eagle Lake Diatom Results



Indicative of warming and a decrease in nutrients

(Nelligan et al. 2016, LRM)

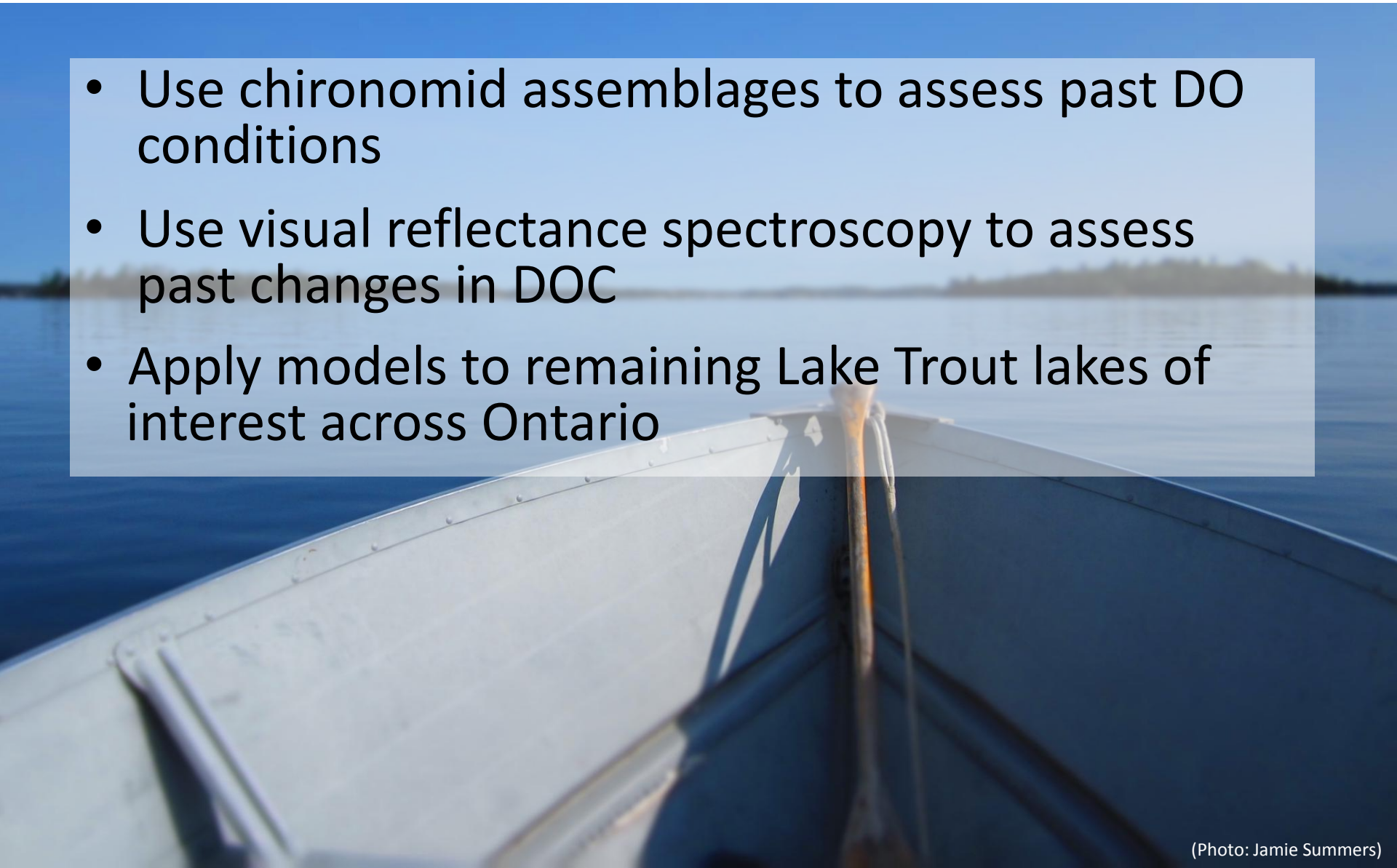
Summary

- All three lakes show increases in small cyclotelloid taxa – likely from enhanced or lengthened periods of stratification
- Influence of nutrients at each lake varies
  - Decreases in Eagle and Cul de Sac
  - Increases in Lake Manitou
- The three lakes change at different times likely due to different combinations of local stressors and the varying influence of regional warming

(Photo: Jamie Summers)

Next Steps

- Use chironomid assemblages to assess past DO conditions
- Use visual reflectance spectroscopy to assess past changes in DOC
- Apply models to remaining Lake Trout lakes of interest across Ontario



(Photo: Jamie Summers)

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

Lake of the Woods water sustainability foundation

Ontario

NSERC CRSNG

FOCA Federation of Ontario Cottagers' Associations

Environment Canada

Thank you!

Key Literature

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