Assessing long-term nutrient and primary production trends in embayments containing Lake Trout in Lake of the Woods, Ontario

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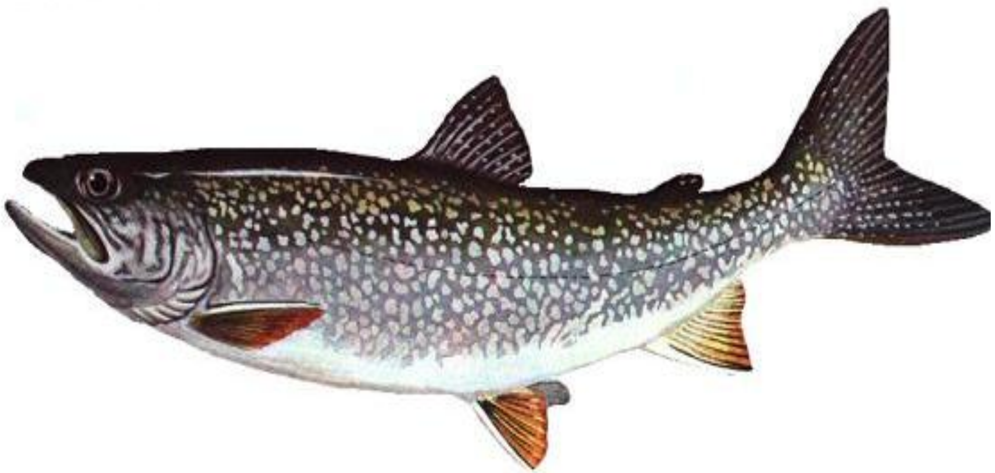
(Photo: Hilary Dugan)

Outline

- Background – Lake Trout & Lake of the Woods
- Study Design
- Methods
- Research Questions
- Results
- Conclusions
- Future Work

Lake Trout

- Widely distributed cold-water taxa
- Good ecological indicator
  - Large bodied (30-80 cm in length) & late maturing (5-10 yrs)
  - Narrow physiological thresholds for temperature and oxygen
- Valuable natural resource that is important to Canada's recreational fisheries

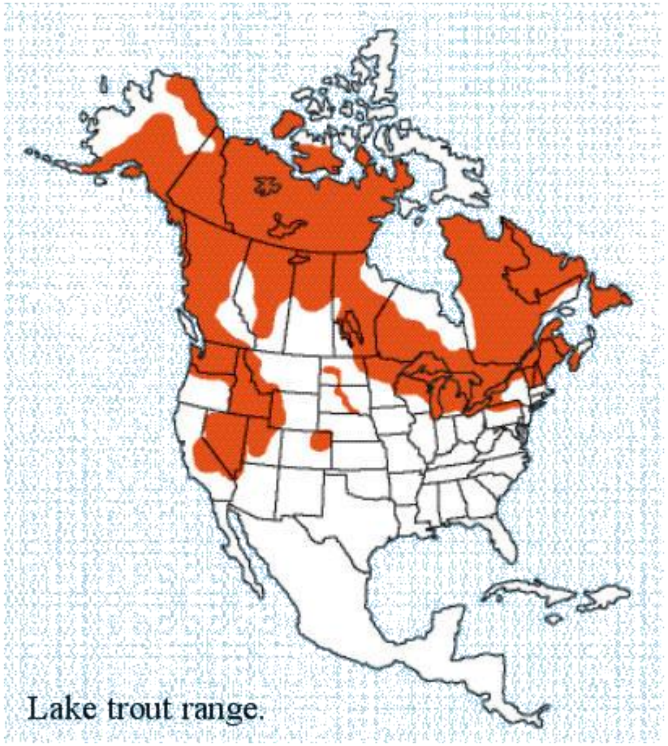


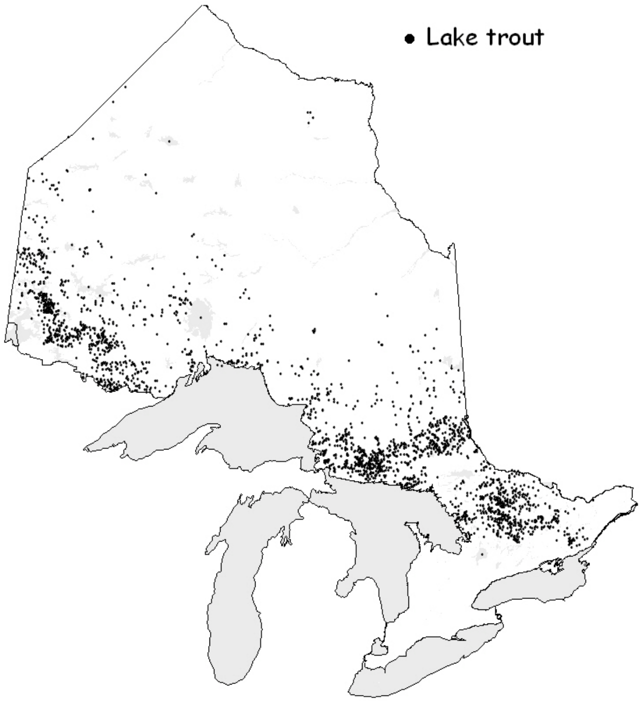
Lake Trout *(Salvelinus namaycush)*

(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 (OMNR 2006)

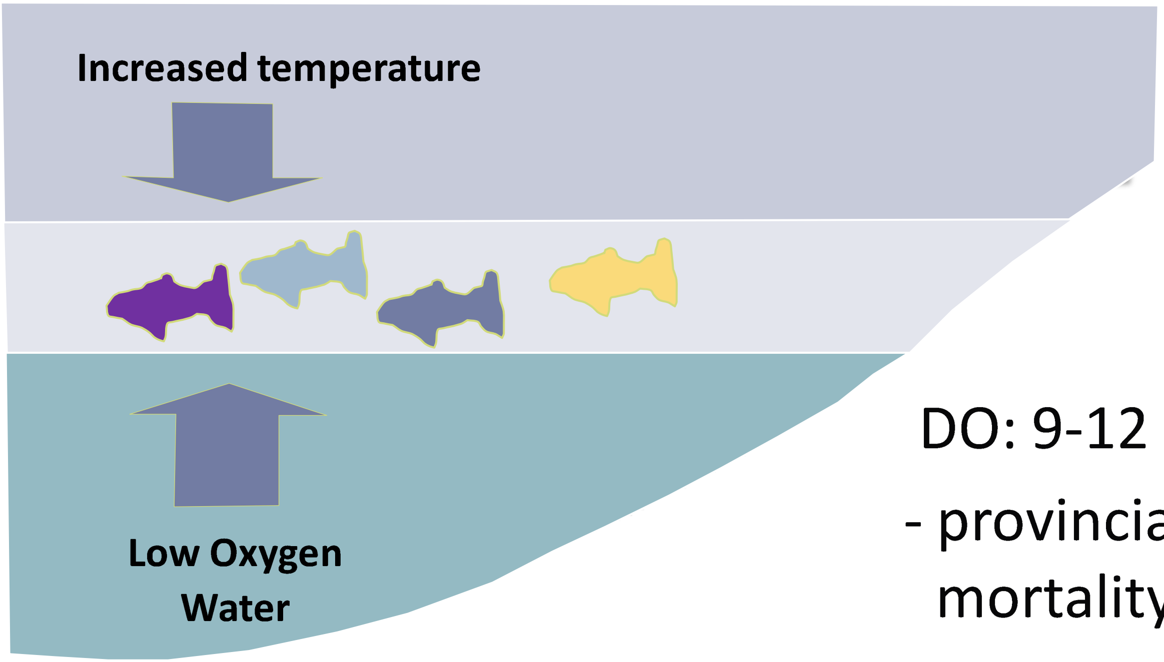




(OMNR 2006)
(Photo: http://carnivoraforum.com/topic/9885166/1/)

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

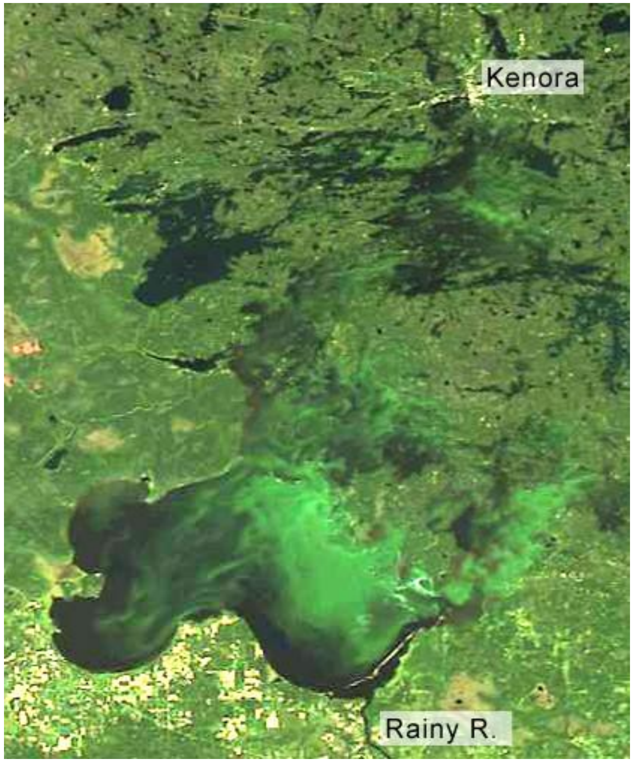
(Plumb and Blanchfield 2009)

Multiple Stressors

Lake Trout habitat can be influenced simultaneously by many stressors

Some of which can influence the dissolved oxygen (DO) concentrations available to Lake Trout, such as:

- **Eutrophication** – excess total phosphorus (TP) loading can deplete DO upon algal decomposition



(Photo: http://www.ijc.org/en_/blog/2015/12/01/dramatic_algal_blooms_lake_of_the_woods/)

Multiple Stressors

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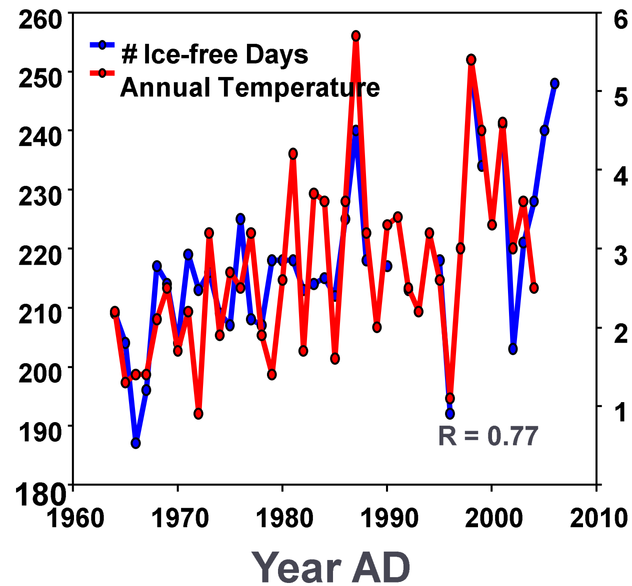
Some of which can influence the dissolved oxygen (DO) concentrations available to Lake Trout, such as:

- **Eutrophication** – excess total phosphorus (TP) loading can deplete DO upon algal decomposition
- **Climate Change** – enhanced thermal stability can increase the time between mixing events



•Greatest increase in air temperature during the winter months (2.29°C since 1890)
•Longer ice-free period (27.7 days since 1964)

(Rühland et al. 2008)

History of Lake Trout in Lake of the Woods

- Lake Trout are present in many northern bays (Whitefish, Clearwater, Echo, Cul de Sac, White Partridge)
- 1980s: Lake Trout in Echo and Clearwater bays impacted by overharvesting, reduced hypolimnetic O_2, and high TP and chlorophyll-*a*
- 1988: Winter fishery closed on Clearwater, Echo and Cul de Sac

(Clark and Sellers 2014)

(Photo: Jamie Summers)

History of Lake Trout in Lake of the Woods

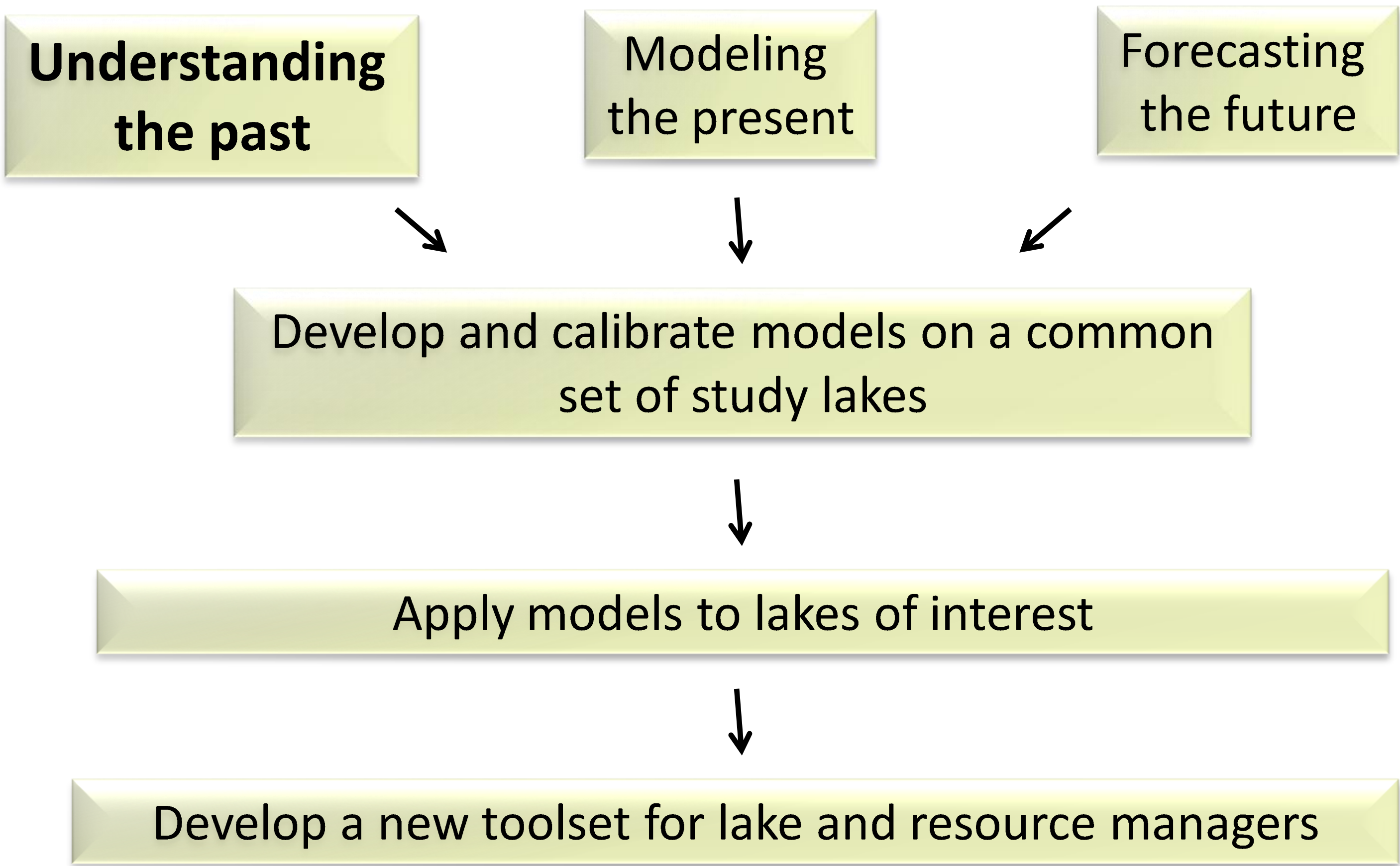
- 2010: Angling for Lake Trout outside of Clearwater and Whitefish bays catch and release only
- Improvements observed in Clearwater and Cul de Sac

  (increase in population, spawning and recruitment, declines in mortality)
- **Health of Lake Trout population still a concern due to low abundances of large-sized individuals in Echo and Clearwater**

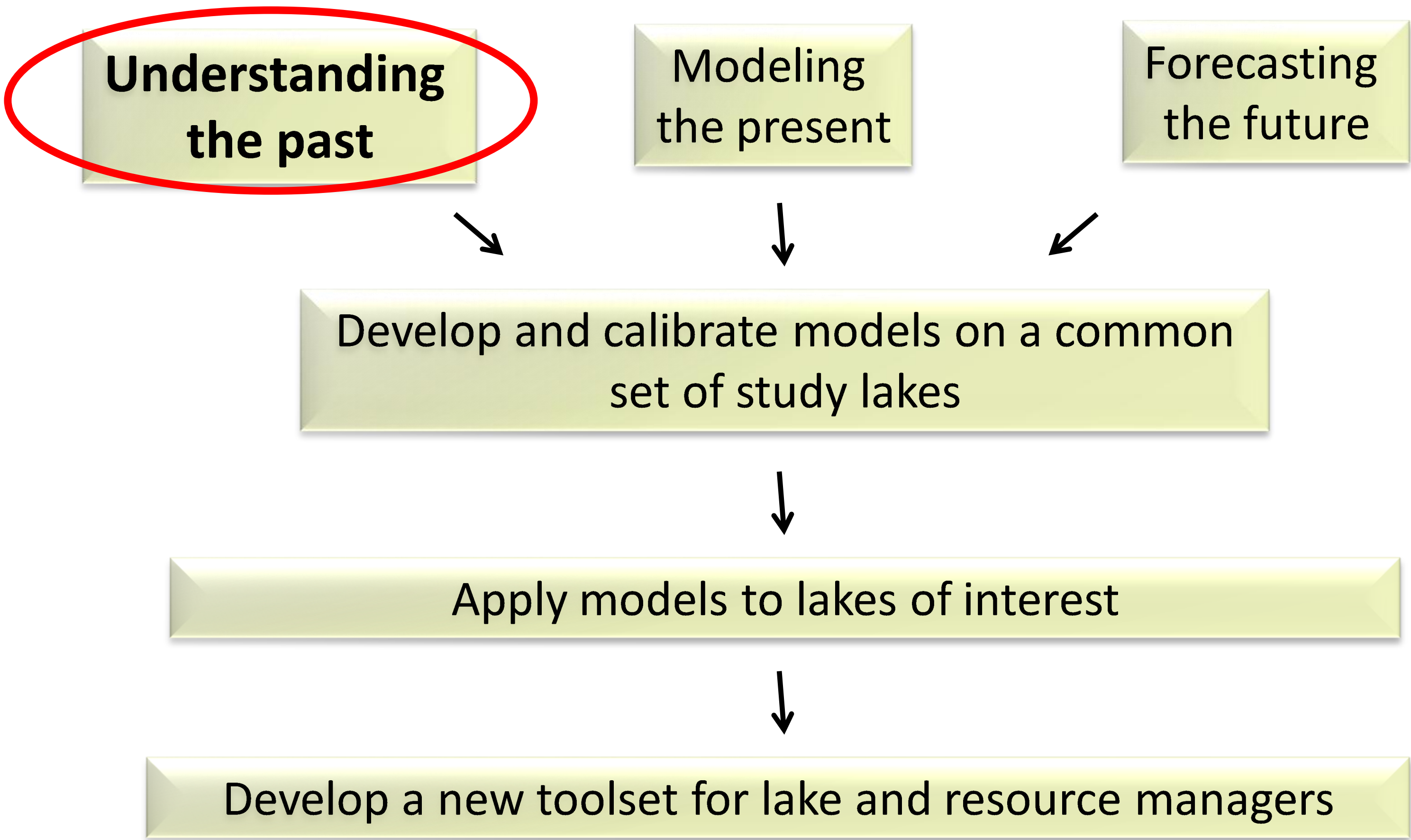
(Clark and Sellers 2014)

(Photo: Jamie Summers)

Study Design



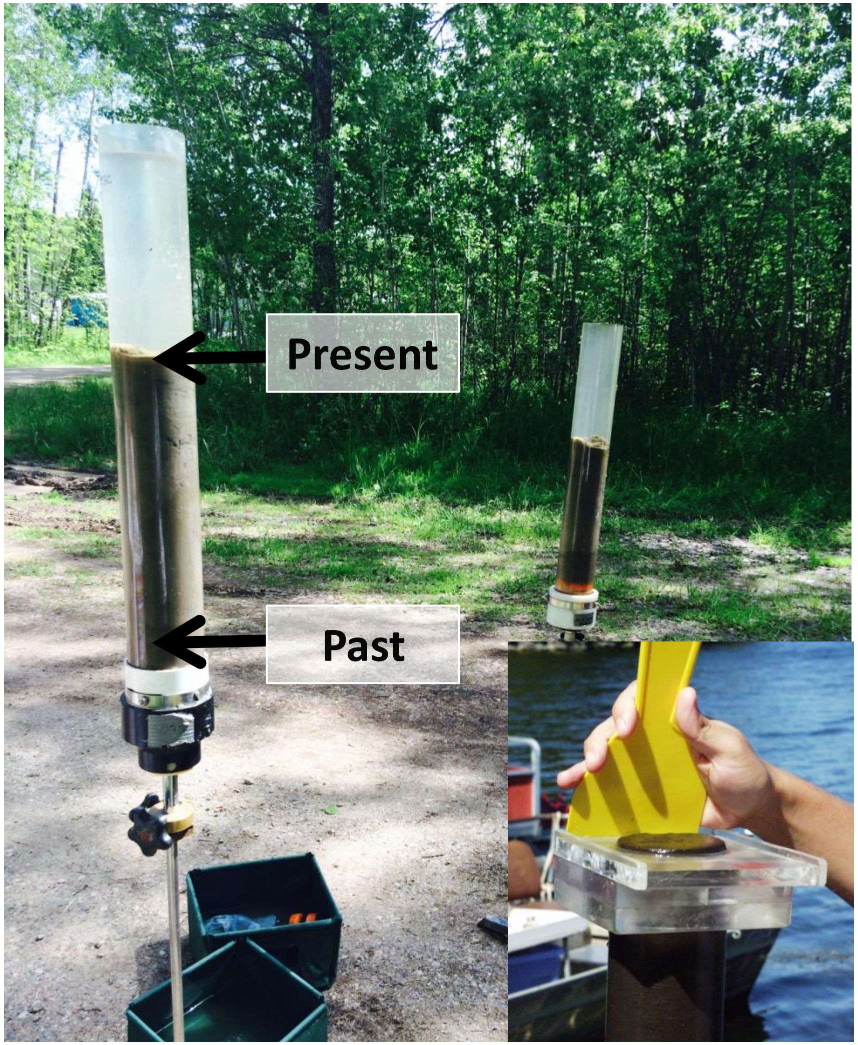
Study Design



Understanding the Past: Paleolimnology

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

Goal is to reconstruct background conditions and assess how lake water quality has changed

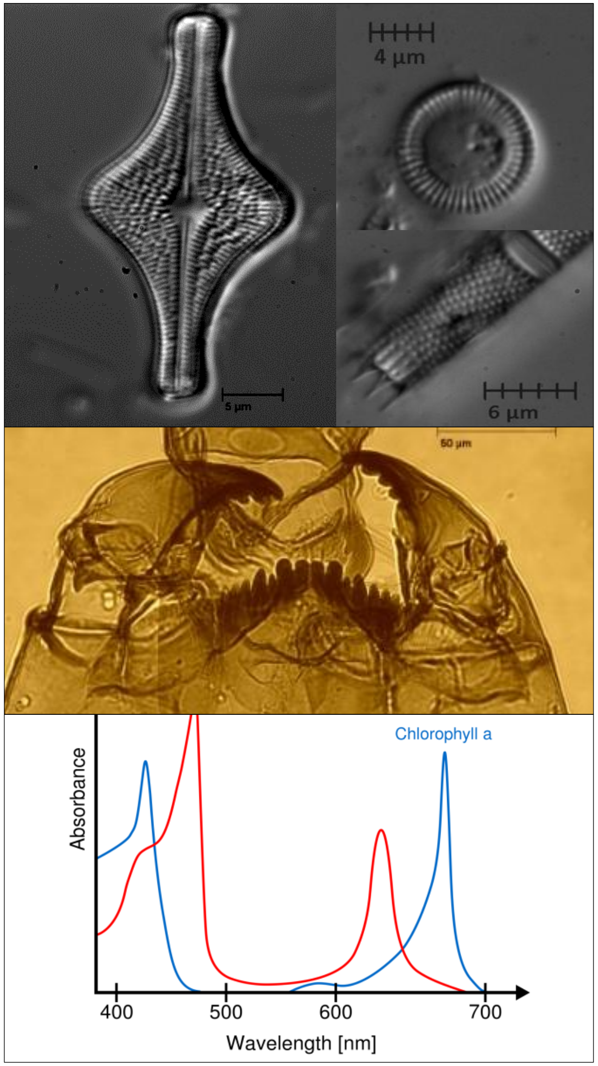


(Photo: http://post.queensu.ca/~pearl/extruding.htm)

Methods

Indicators to be analyzed:

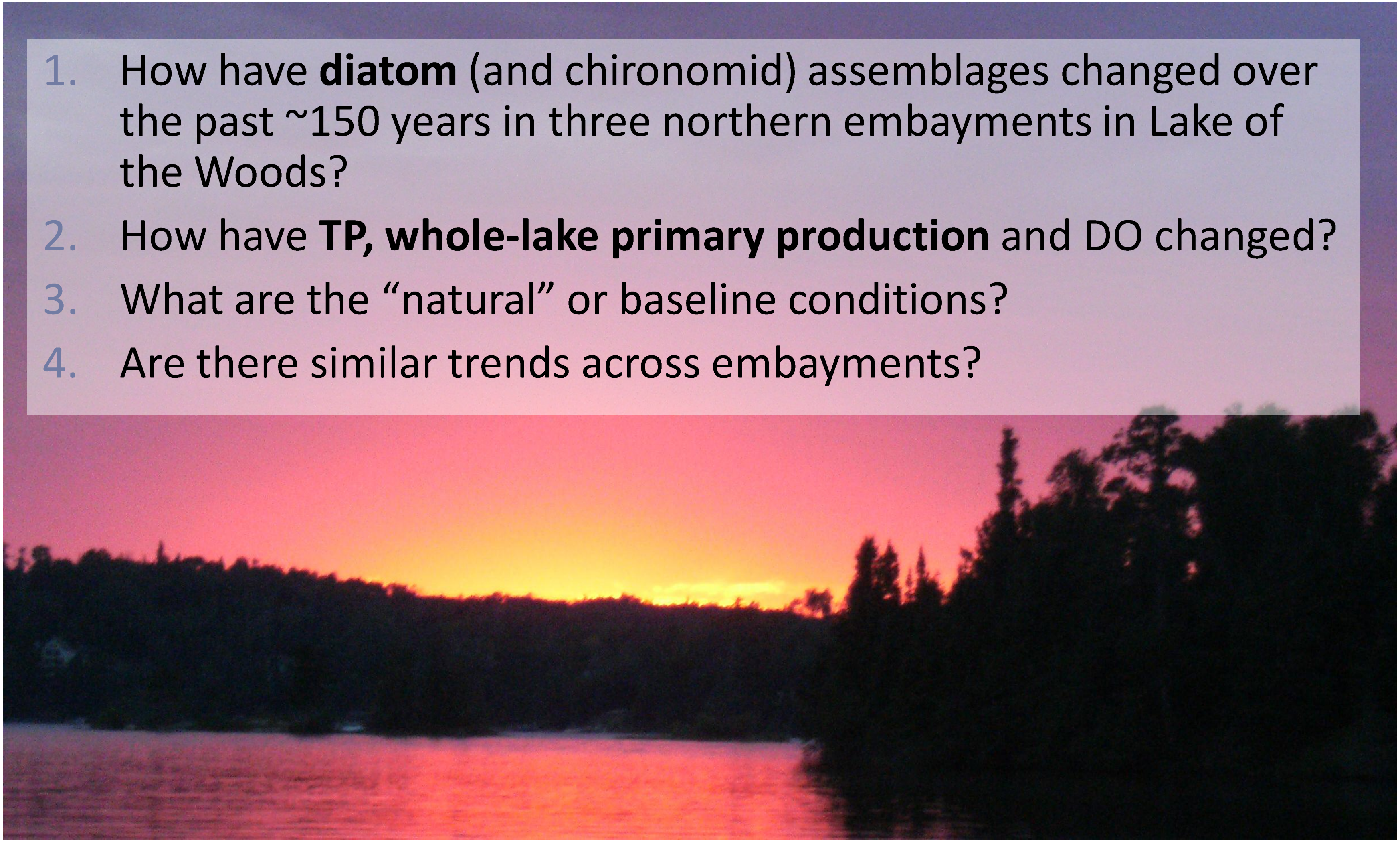
- **Diatoms:**
  - Common siliceous algae
  - Readily preserved and identifiable valves
  - Used to reconstruct past [TP]
- **Chironomids:**
  - Larval remains of non-biting midges
  - Identifiable head capsules preserve in sediments
  - Used to reconstruct end-of-summer hypolimnetic $[O_2]$
- **VRS-chlorophyll-*a***
  - To infer whole-lake primary production



(Photo: http://post.queensu.ca/~pearl/cf8/cf8pics.html, https://en.wikipedia.org/wiki/Chlorophyll_a)

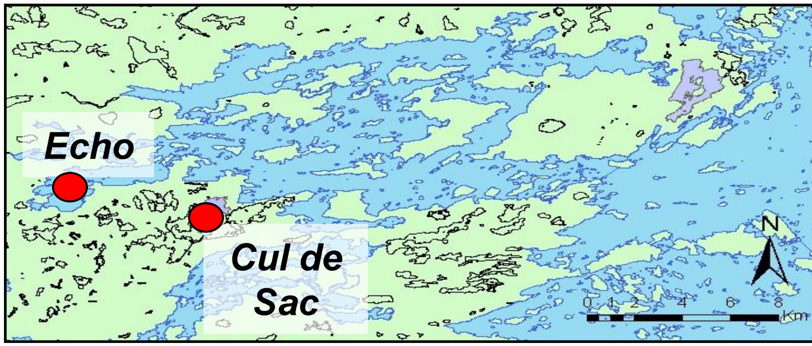
Research Questions

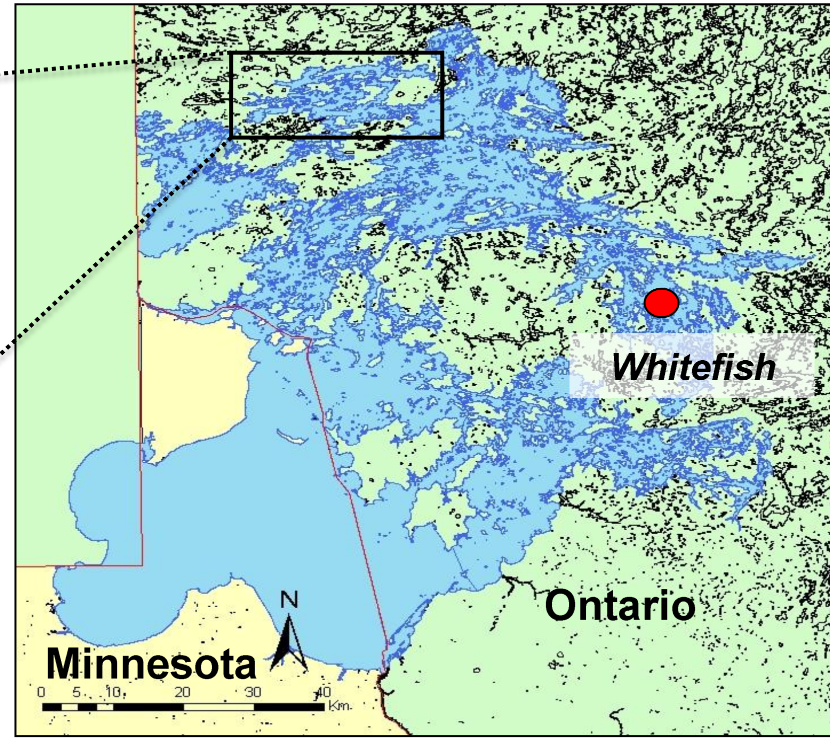
1. How have **diatom** (and chironomid) assemblages changed over the past ~150 years in three northern embayments in Lake of the Woods?
2. How have **TP, whole-lake primary production** and DO changed?
3. What are the “natural” or baseline conditions?
4. Are there similar trends across embayments?



(Photo: Jamie Summers)

Study Sites





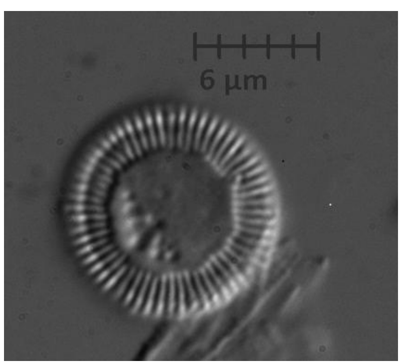
	Echo	Cul de Sac	Whitefish
Max Depth (m)	**37**	**32**	**66**
Area (ha)	**667**	**138**	**24,876**
TP_{epi} (µg/L)	**11.6**	**9.6**	**11.7**
pH	**8.01**	**7.98**	**7.73**

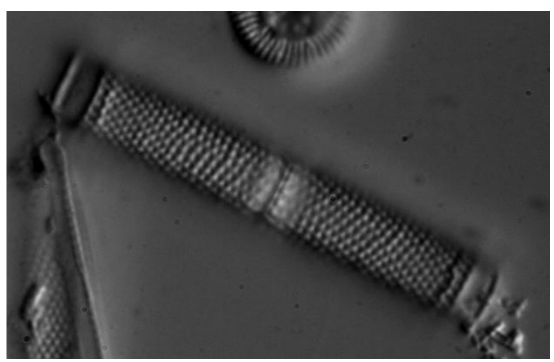
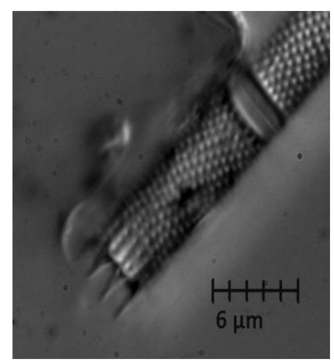
Cores were collected Fall 2014 and sectioned in 0.5 cm intervals

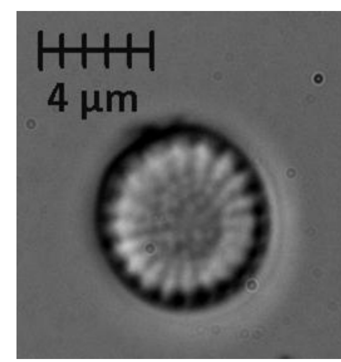
(Map: Kathryn Hargan)

Diatom Results

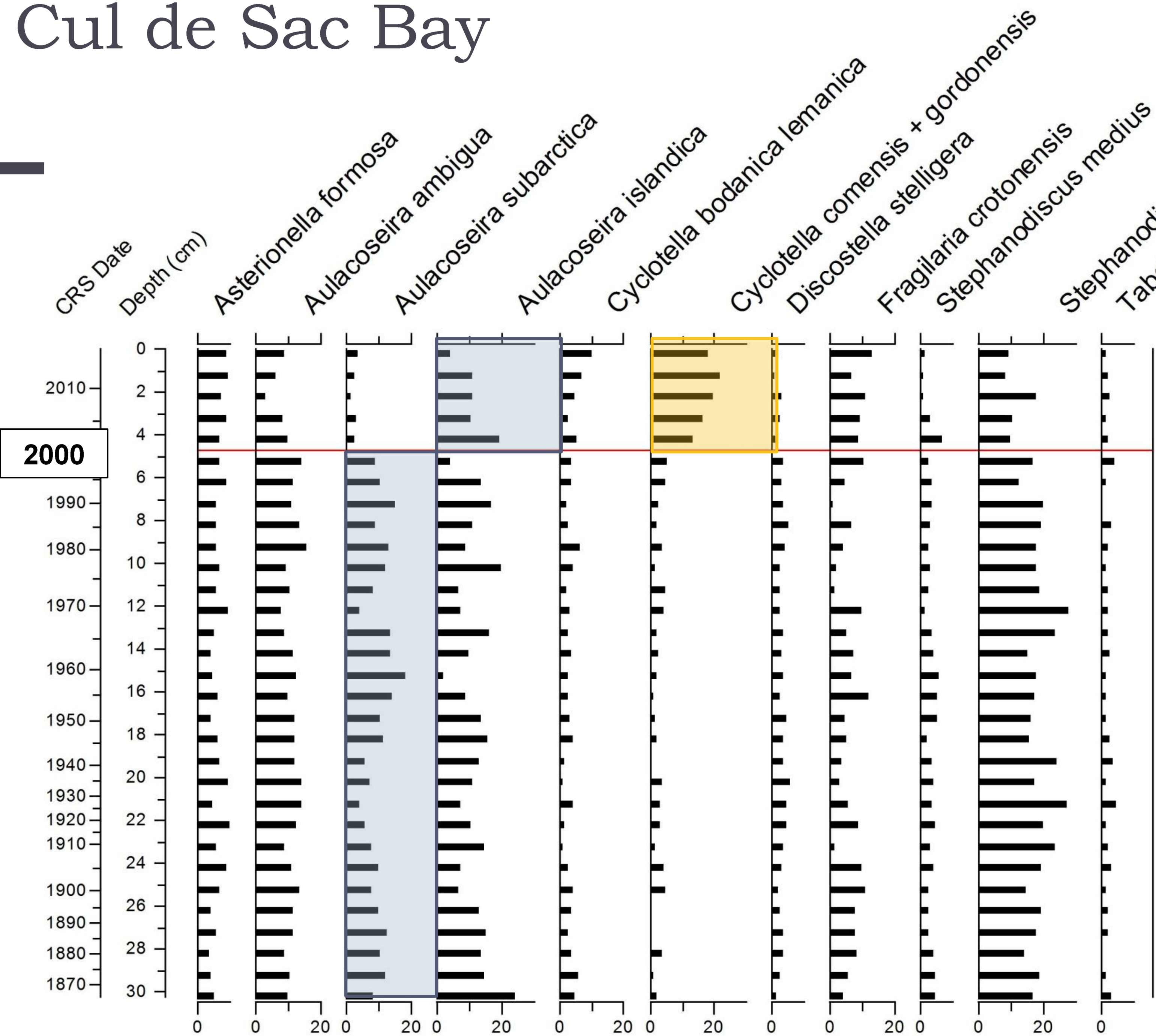
- Taxon-specific shifts across all bays suggest changes in thermal stratification (Rühland et al. 2015)
  - Changes in small cyclotelloid taxa and heavily silicified *Aulacoseira* taxa
  - Although the timing of change varies among embayments
- Diatom taxa with higher nutrient optima (e.g. *Stephanodiscus minutulus*) decrease slightly over the sediment record



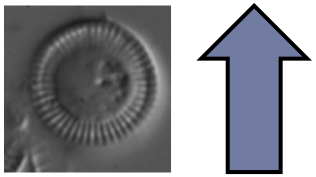





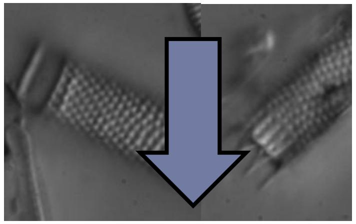
Cul de Sac Bay



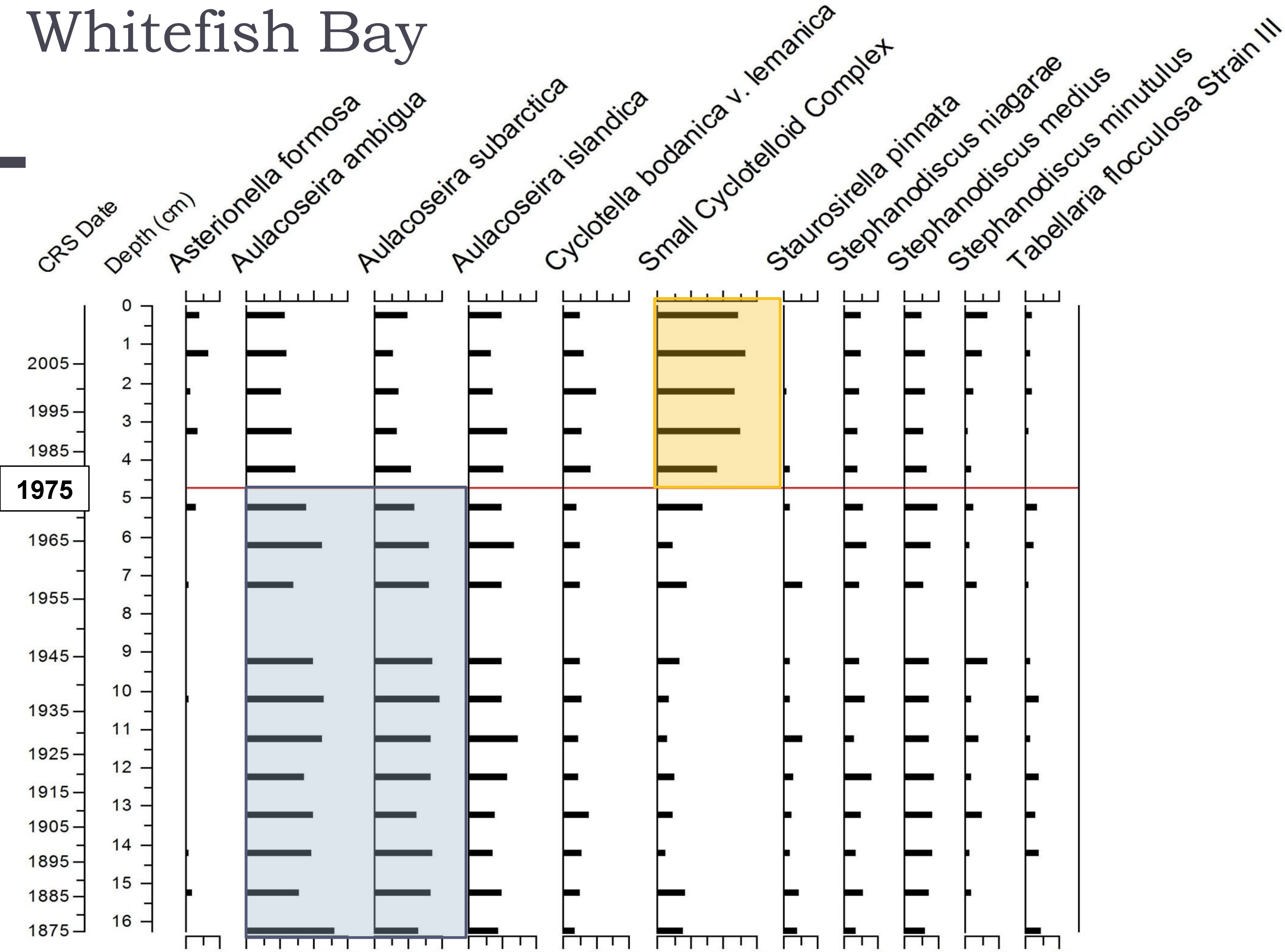
Increase in *Cyclotella comensis* and *C. gordonensis*



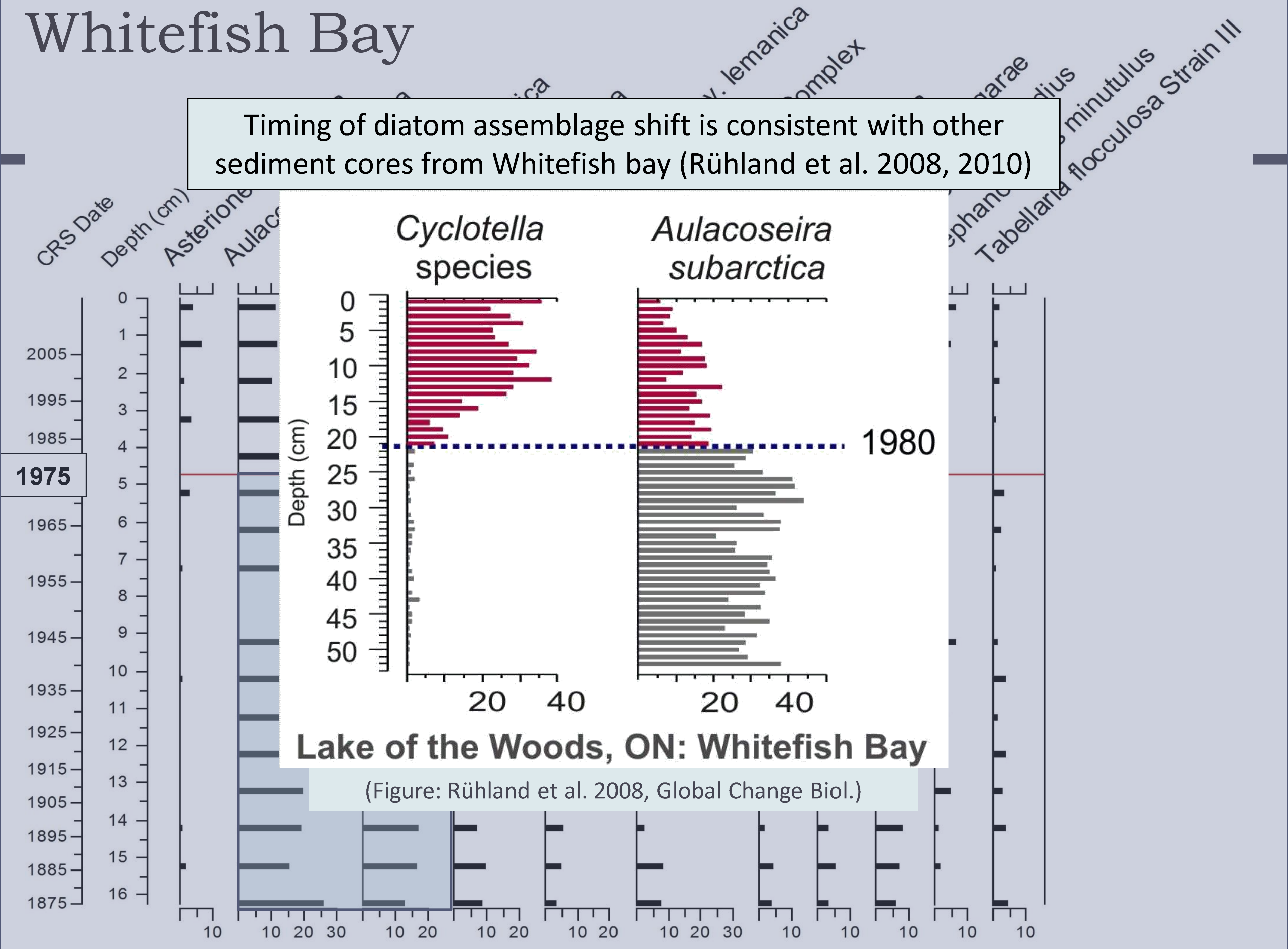
Decrease in *Aulacoseira ambigua* and *A. subarctica*



Whitefish Bay



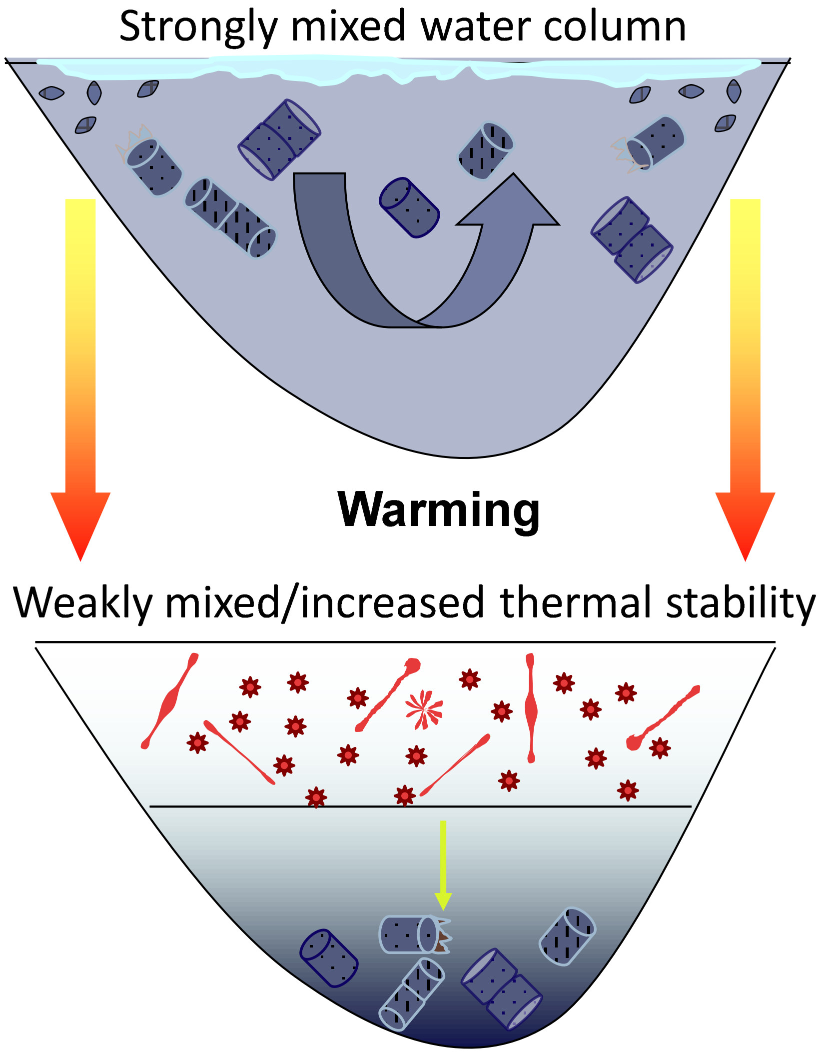
Whitefish Bay

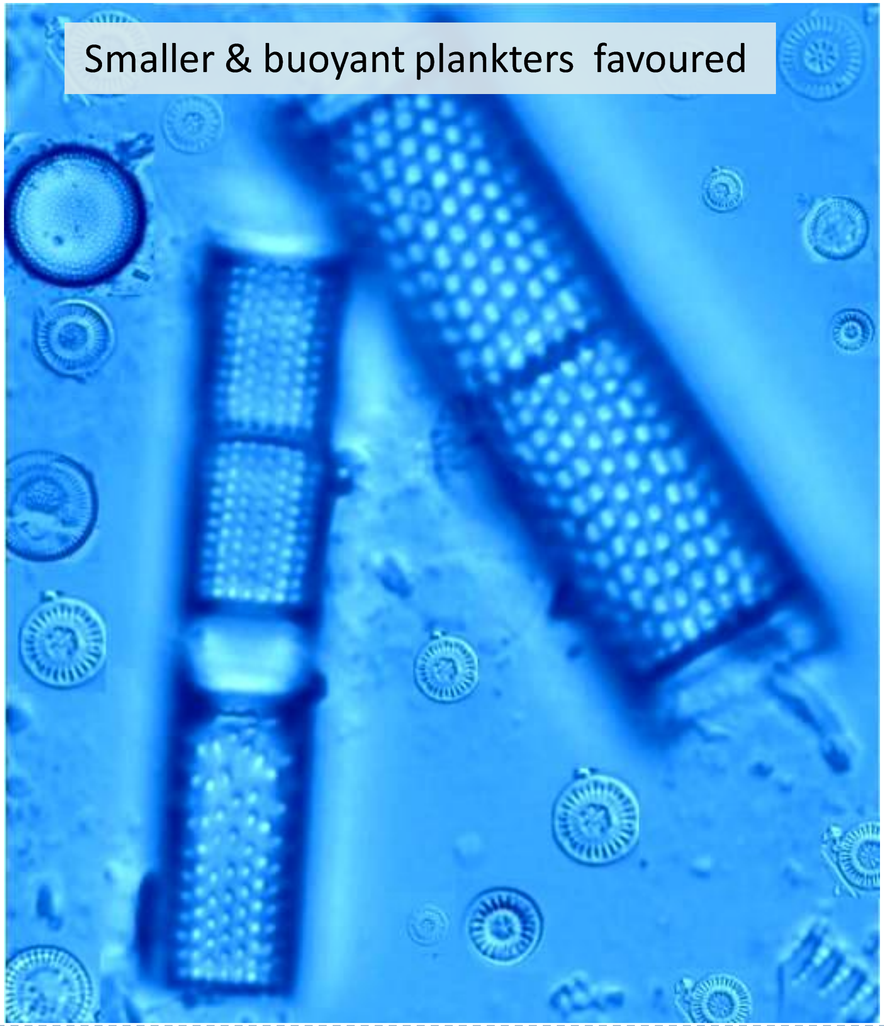


Timing of diatom assemblage shift is consistent with other sediment cores from Whitefish bay (Rühland et al. 2008, 2010)

(Figure: Rühland et al. 2008, Global Change Biol.)

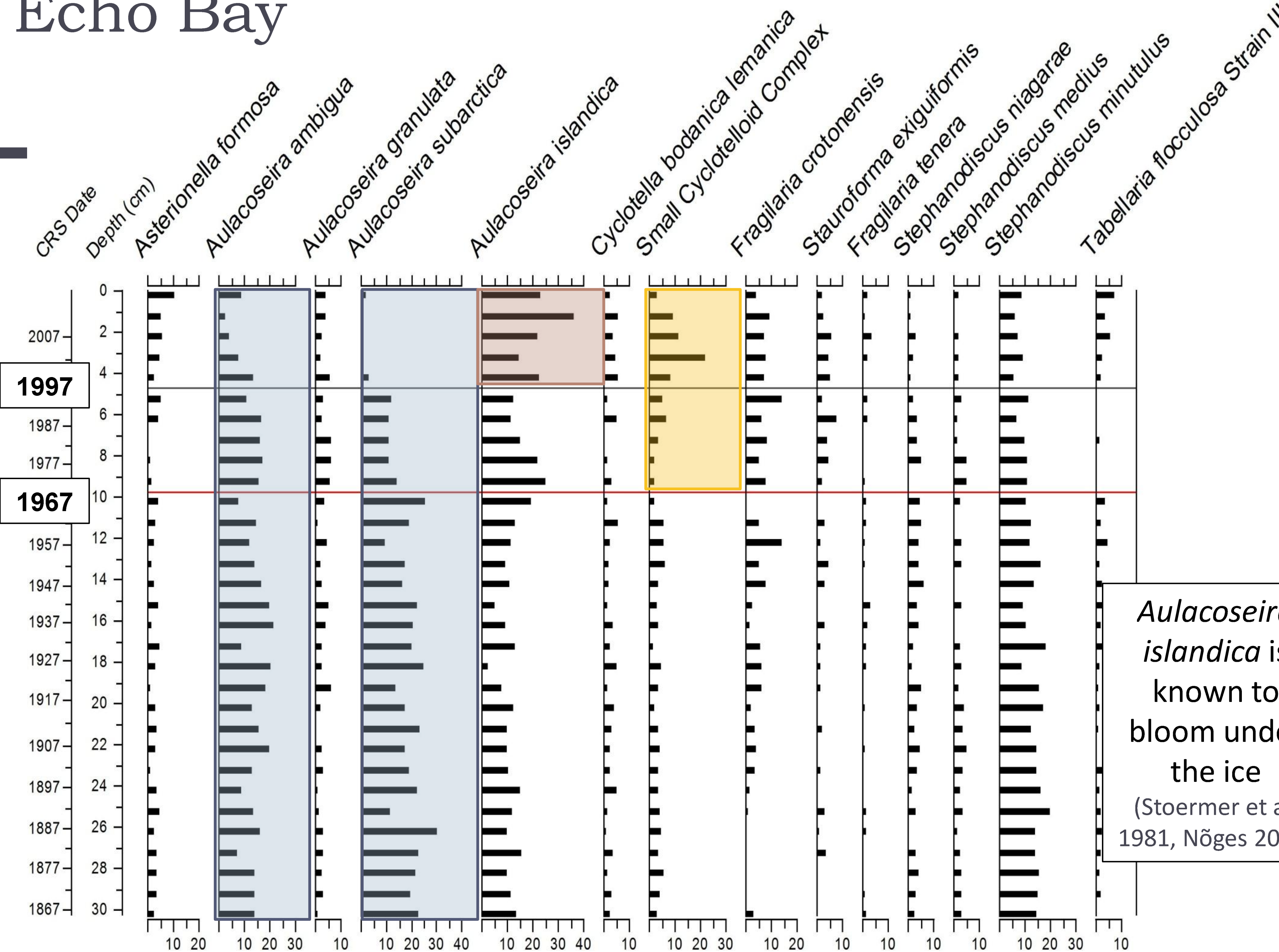
Diatom Assemblage Shifts & Climate Warming





(Rühland et al. 2015, Photo: Kathleen Rühland)

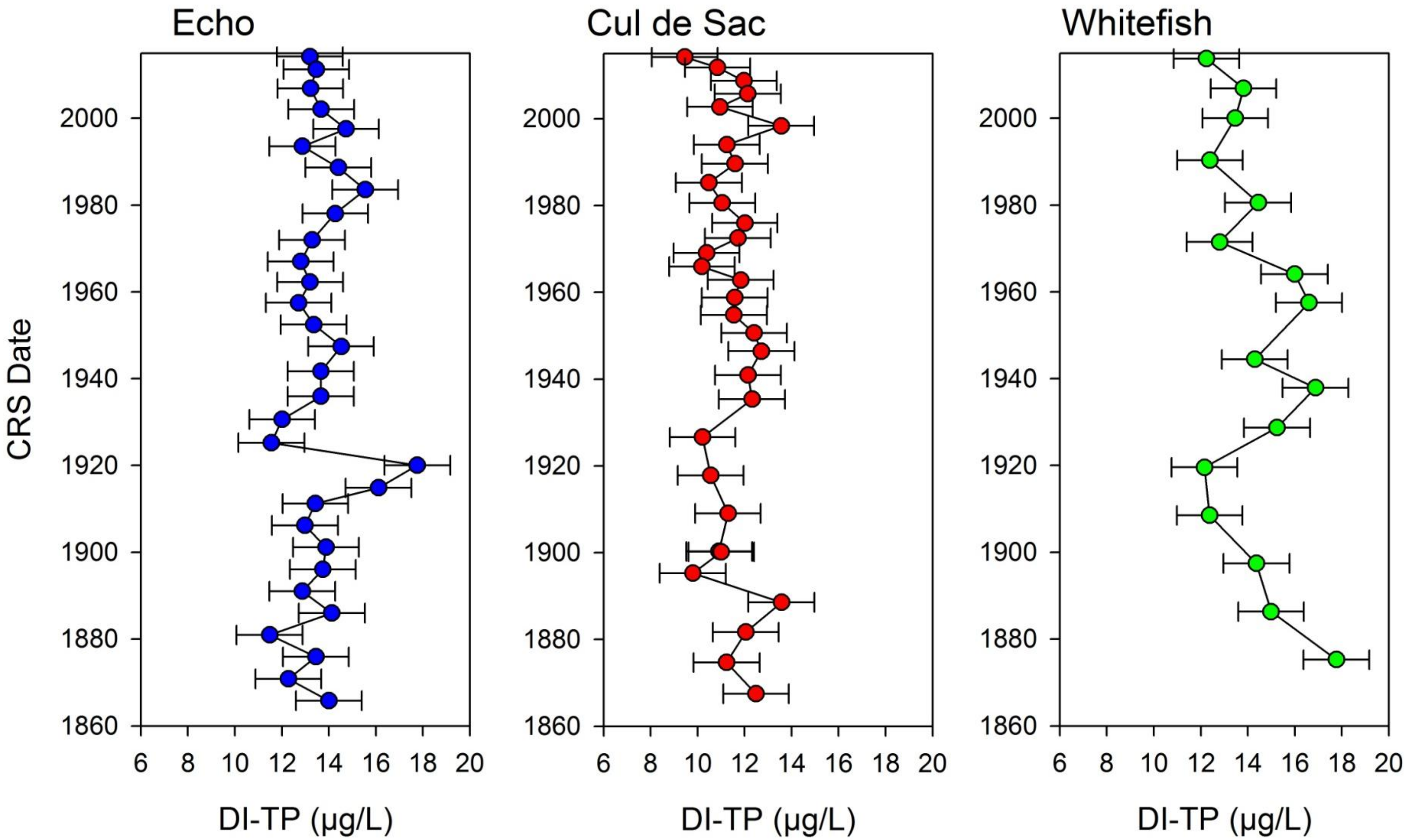
Echo Bay



Aulacoseira islandica is known to bloom under the ice

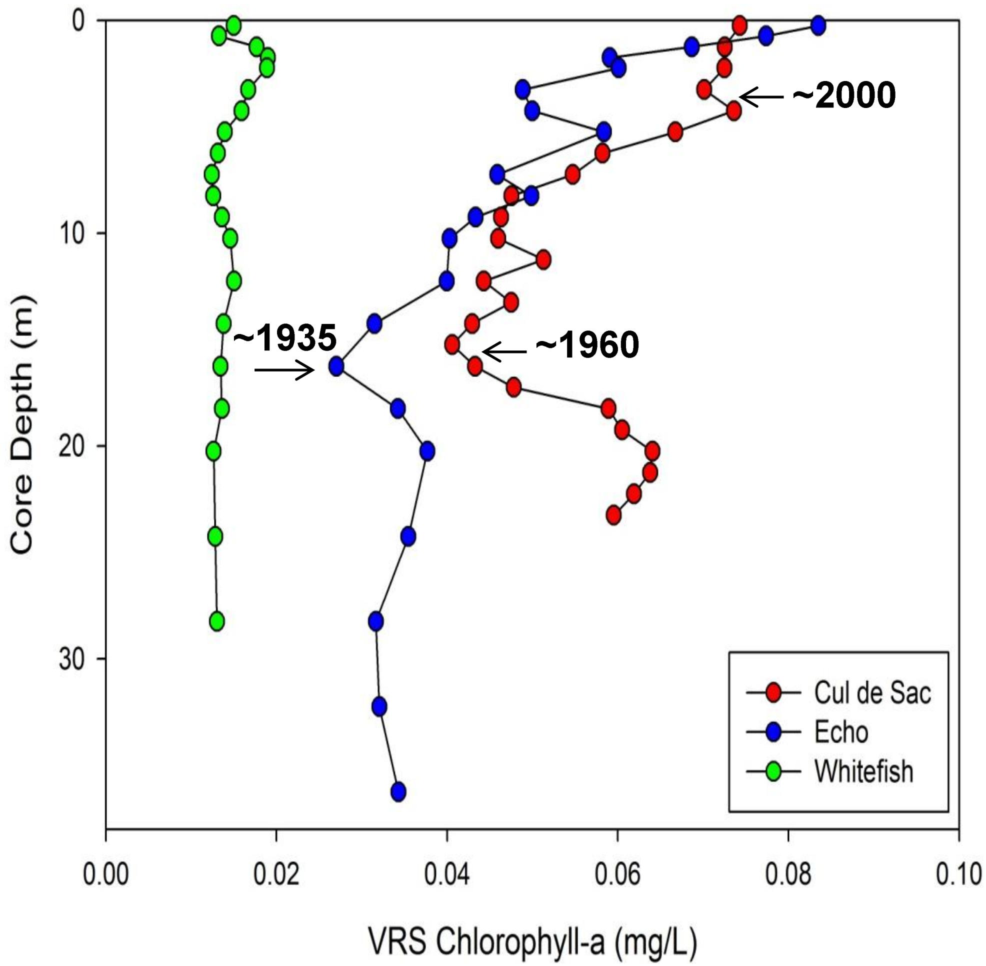
(Stoermer et al. 1981, Nõges 2004)

Diatom-inferred TP



Applied the Hyatt et al. (2011) TP model (R^2=0.58, RMSEP=0.15)

VRS-chlorophyll-*a*

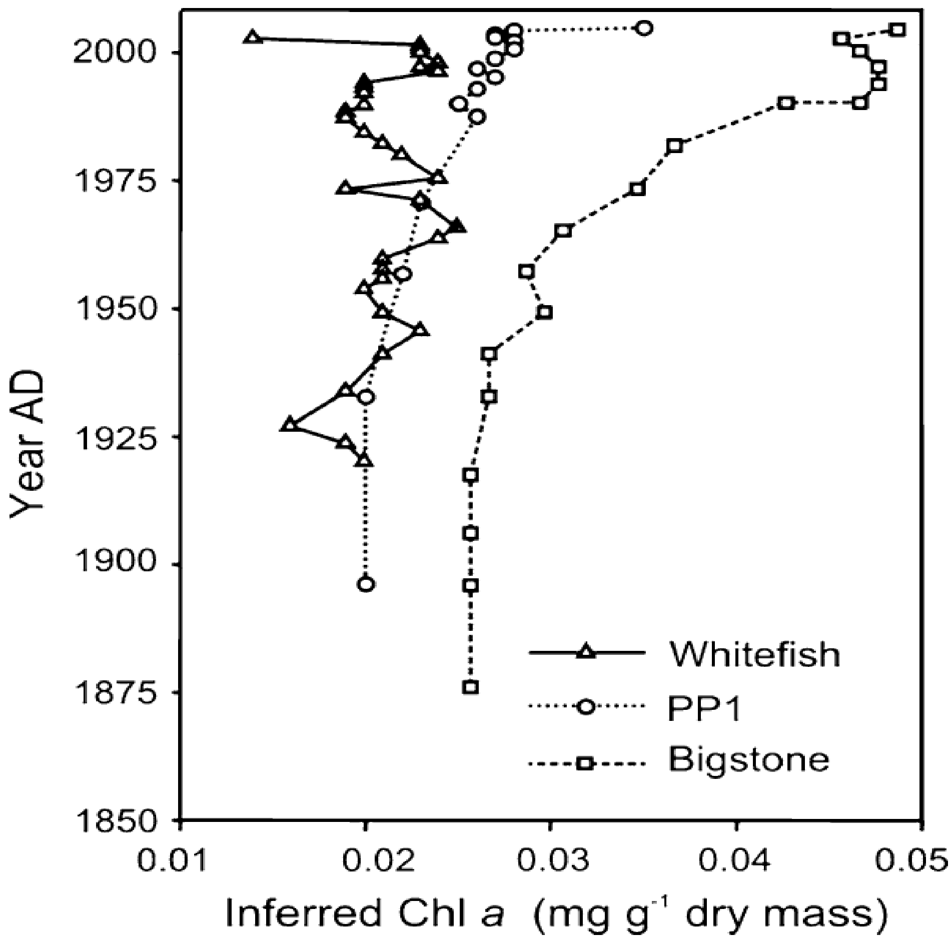


Similar trend in VRS-chlorophyll-*a* in Echo and Cul de Sac

•Increase starting in ~1935 in Echo and ~1960 in Cul de Sac

•Whitefish has low, relatively stable VRS-chlorophyll-*a* throughout sediment record (similar to trends observed in other Whitefish sediment cores; Michelutti et al. 2010)

VRS-chlorophyll-*a*



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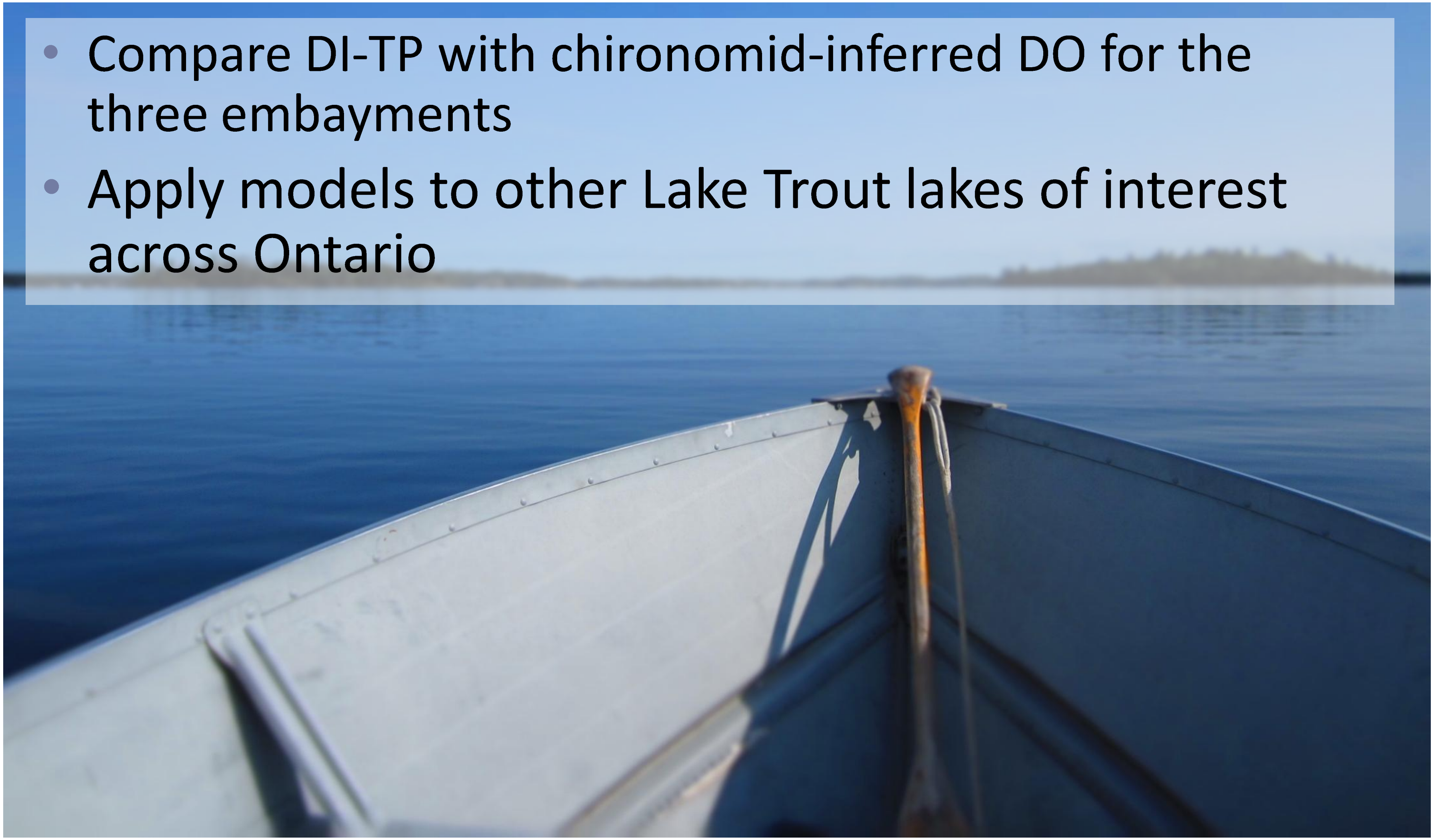
Conclusions

- Diatom assemblage changes across the three bays are characteristic of increased thermal stability
  - Taxon-specific shifts occurred in Cul de Sac and Echo in ~2000, whereas Whitefish experienced an earlier shift in ~1975
  - Currently investigating what an increase in *A. islandica* may mean in Echo Bay
- Diatom-inferred TP has decreased (or remained stable) in all three bays
- VRS-chlorophyll-*a* suggests that whole lake primary production has increased in Cul de Sac and Echo compared to Whitefish, which has been relatively unproductive through time

(Photo: Jamie Summers)

Next Steps

- Compare DI-TP with chironomid-inferred DO for the three embayments
- Apply models to other Lake Trout lakes of interest across Ontario



(Photo: Jamie Summers)

Acknowledgements

- NSERC
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- 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

Key Literature

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(Photo: Jamie Summers)