A paleolimnological assessment of nutrients and primary production in bays of Lake of the Woods that sustain Lake Trout

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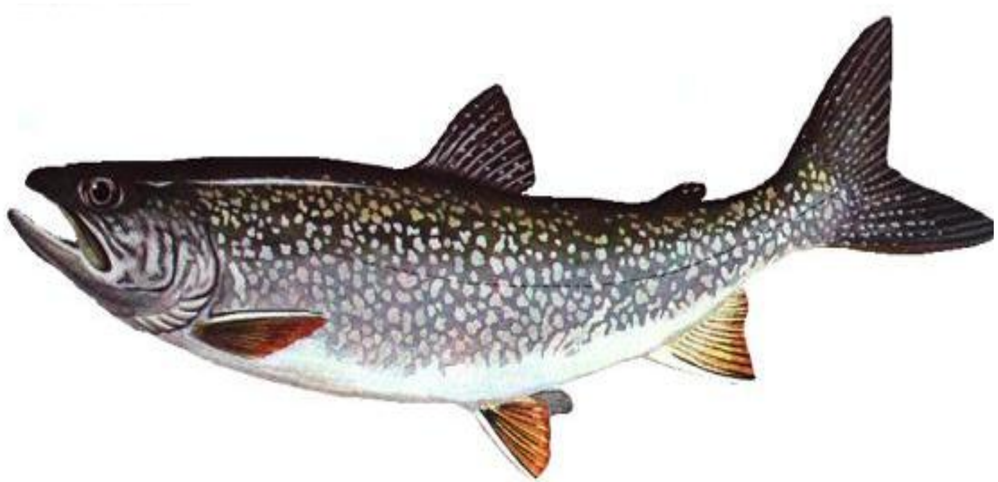
PEARL

Queen's University

(Map: Hilary Dugan)

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
- Valuable natural resource that is important to Ontario's recreational fisheries

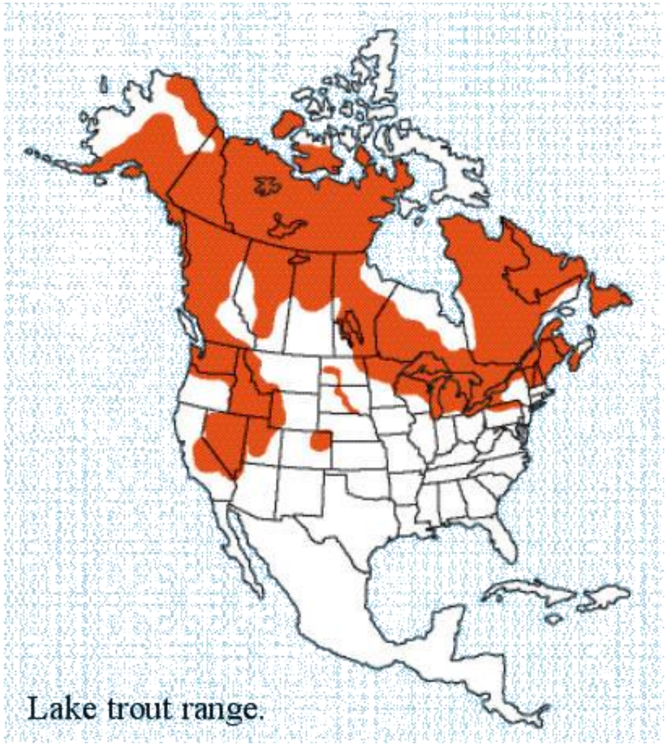


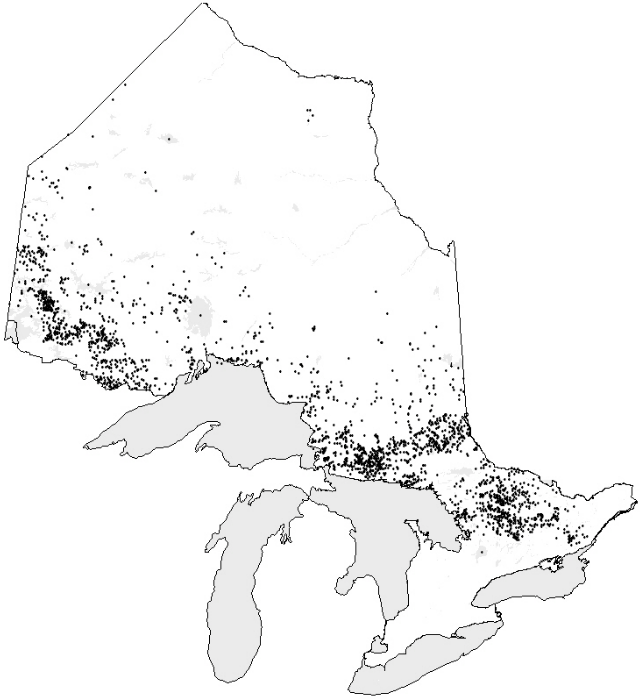
Lake Trout *(Salvelinus namaycush)*

(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 (OMNRF 2006)

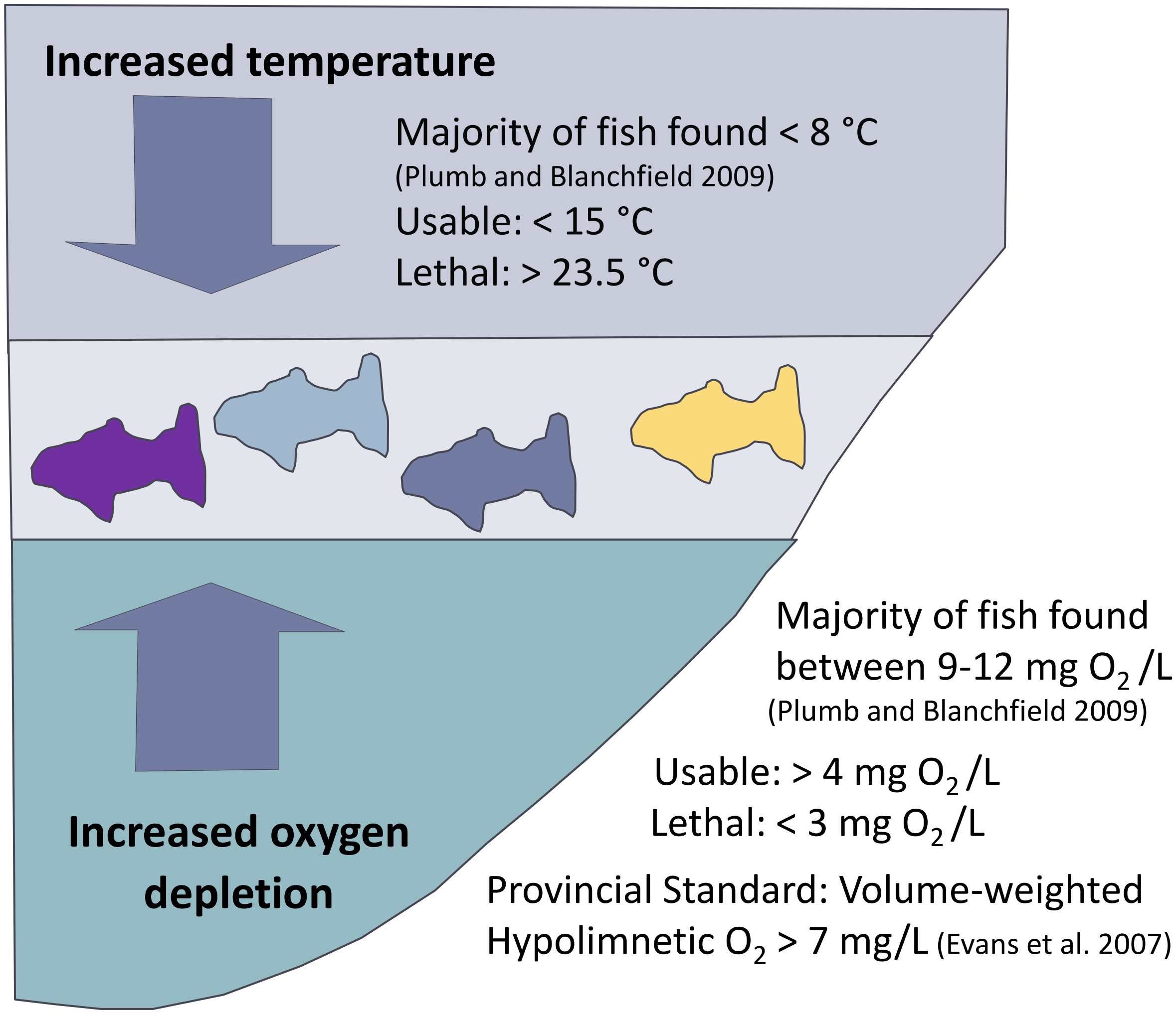




(OMNRF 2006)

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

Habitat Requirements



Current stressors impacting Lake Trout habitat :

- Shoreline development
- Land-use change
- Invasive species
- Eutrophication
- Climate warming
- Changing inputs from terrestrial environment
- Shifts in food web structure

Figure modified from Ficke et al. (2007)

Lake of the Woods

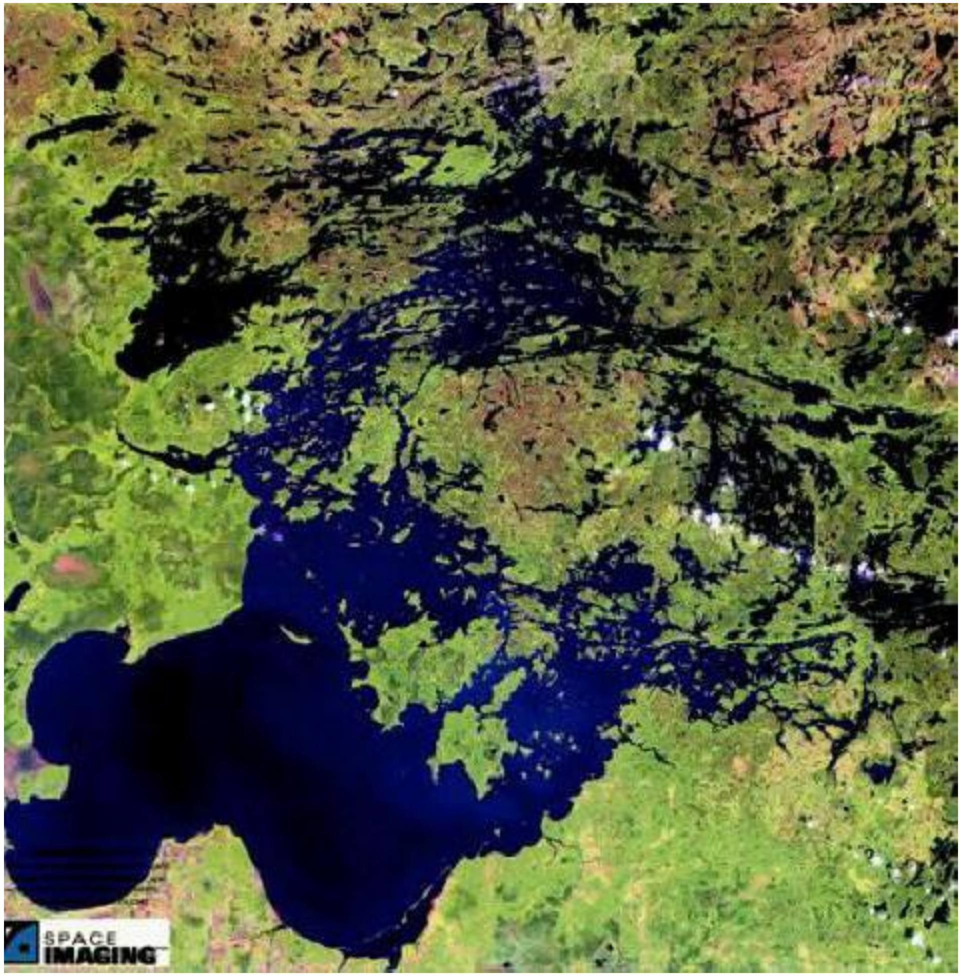
- International waterbody located in Ontario, Manitoba and Minnesota

(Photo: https://www.google.ca/maps/place/Lake+of+the+Woods/)

Lake of the Woods

- Hydrologically and morphologically complex
  - Surface area ~ 385, 000 ha
  - > 14, 000 islands
  - > 10, 000 km of shoreline
  - Made up of many distinct depositional basins
  - Controlled water level – dams constructed between ~ 1887-1925

(Hyatt et al. 2011)



(Photo: http://www.thunderbolts.info/tpod/2008/arch08/081224lake.htm)

Lake of the Woods

- Reported increases in the severity and frequency of cyanobacterial blooms in northern regions
- Algal blooms documented in LOW since the 1800s
- Lake listed as an "impaired waterbody" in Minnesota

(Clark and Sellers 2014)

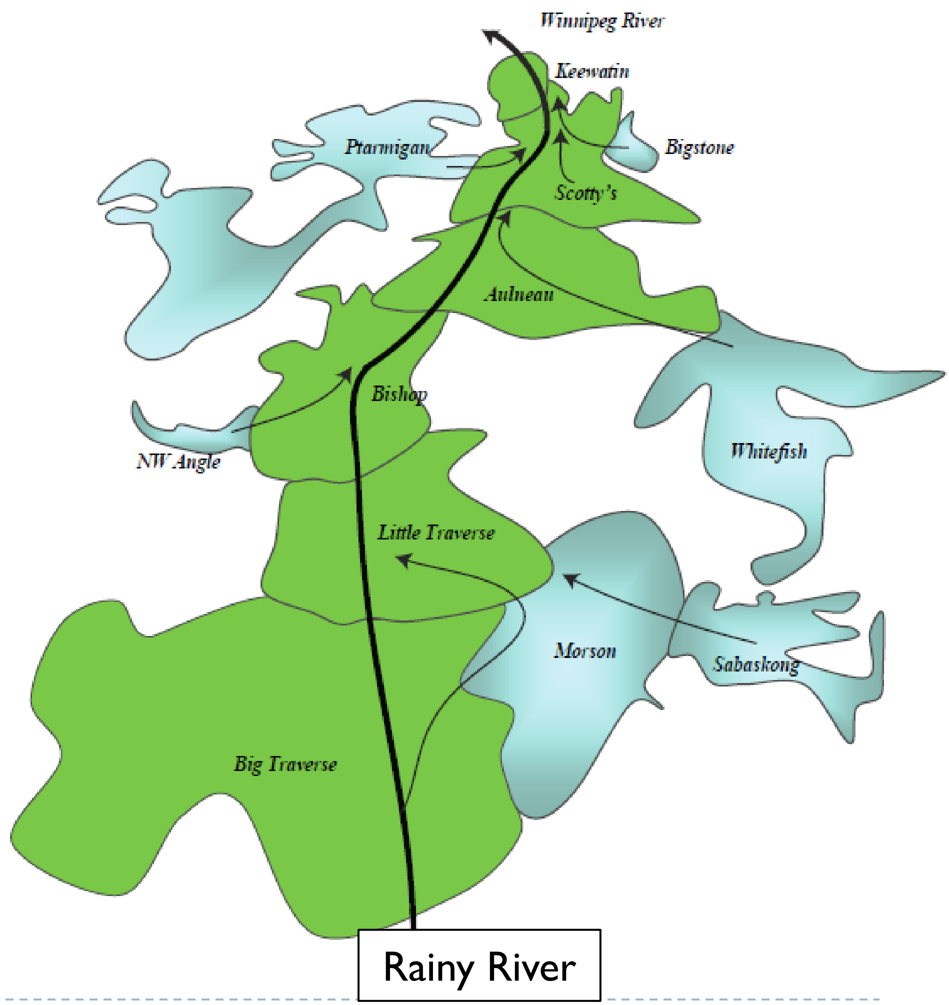
October 2006

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

Lake of the Woods

- Primary source of TP is from the Rainy River
  - Creates a north-south gradient of phosphorus
- Substantial decrease in annual TP load since the 1970s
  - Still a large internal phosphorus load

(Hargan et al. 2011)



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

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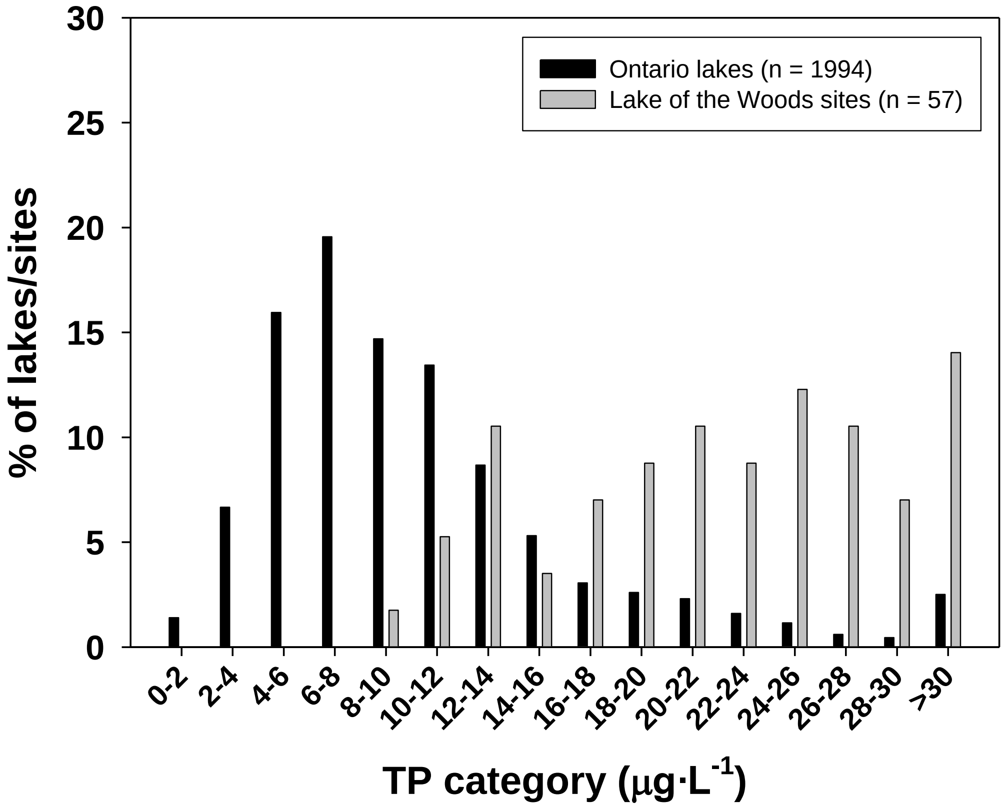

(Figure: Andrew Paterson)

Lake of the Woods

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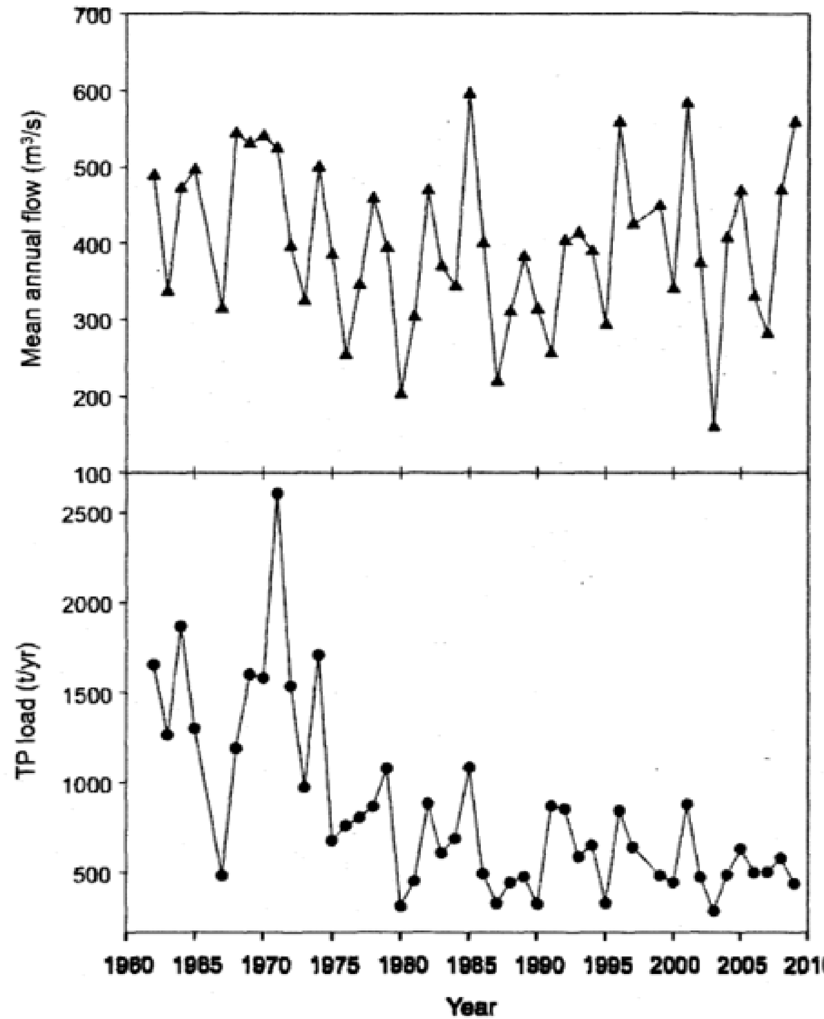
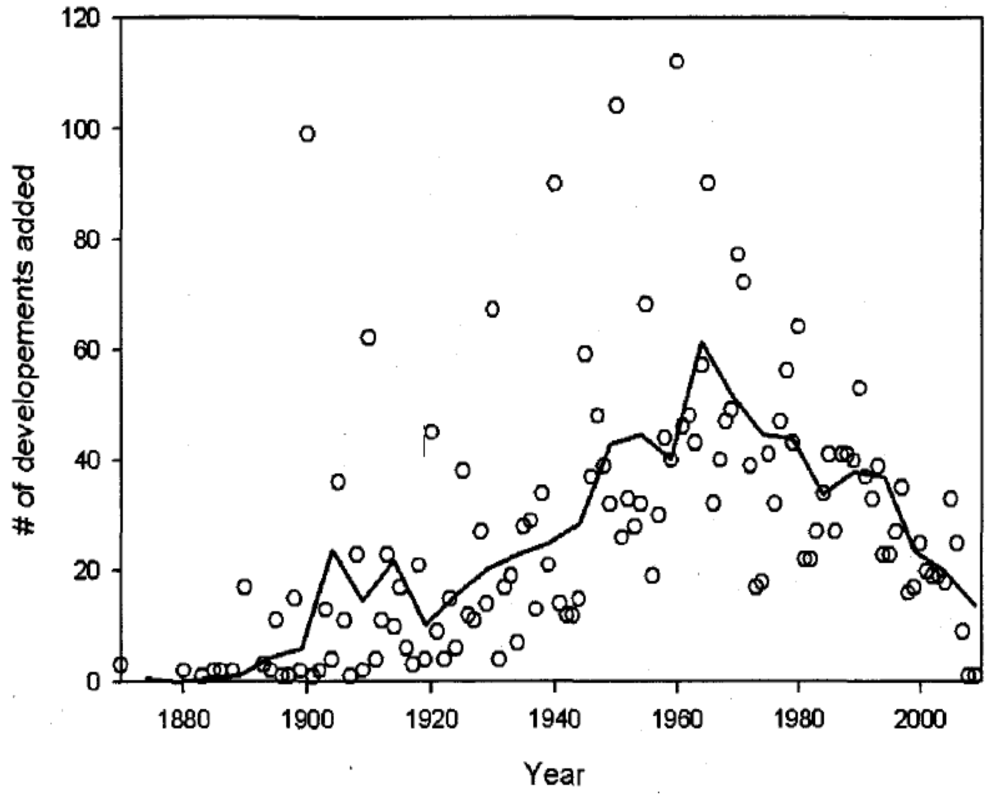


(Figure: Hargan et al. 2011)

Lake of the Woods

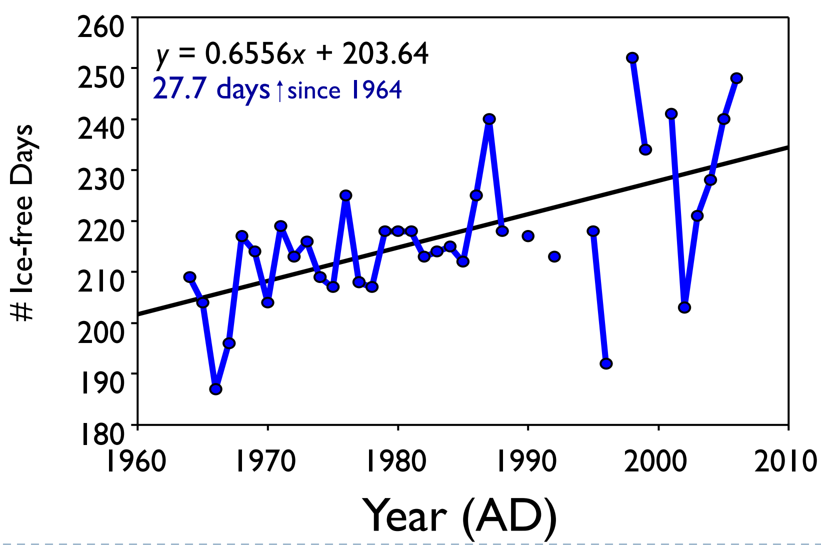
- Shoreline development also a source of TP
- Development began during the late-1800s and peak in the mid-1960s
- Minor source in overall TP budget, but plays a larger role in isolated bays (> 1/3 of P load)

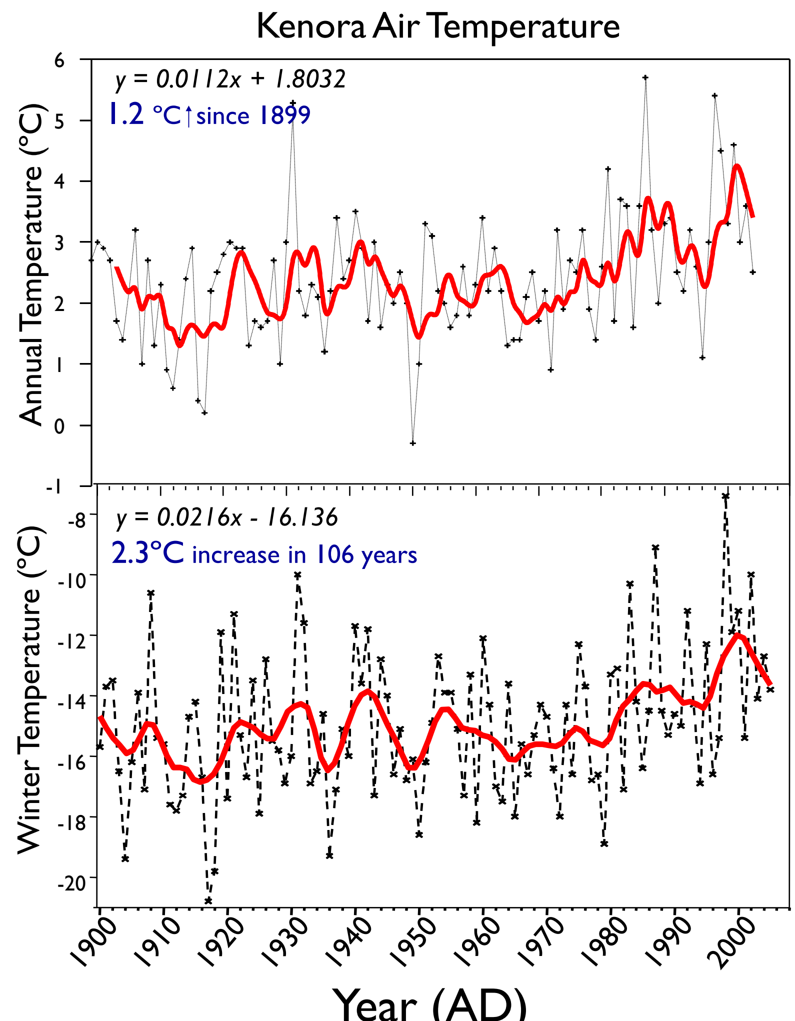


(Figure: Hargan et al. 2011)

Lake of the Woods

- Relatively high degree of warming
- Greatest increases in air temperature during winter months
- Ice-free period ~ 1 month longer than in 1964



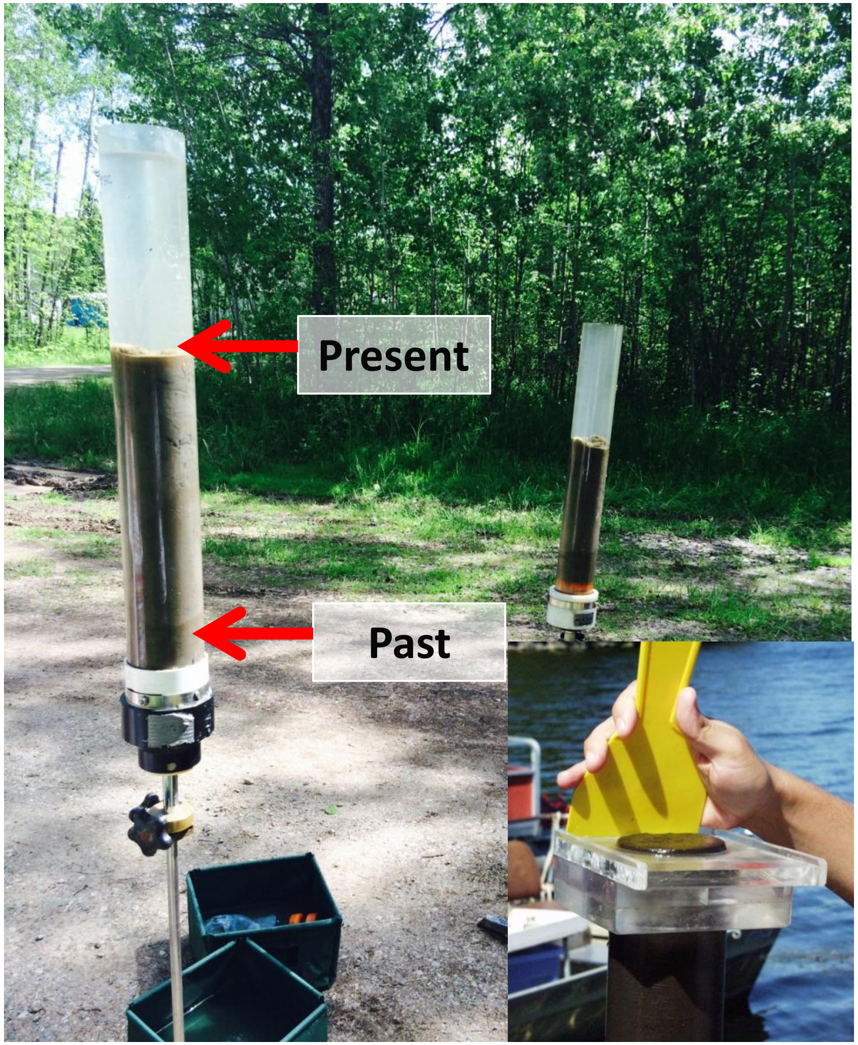


(Figures: Rühland et al. 2008, 2010)

Objectives

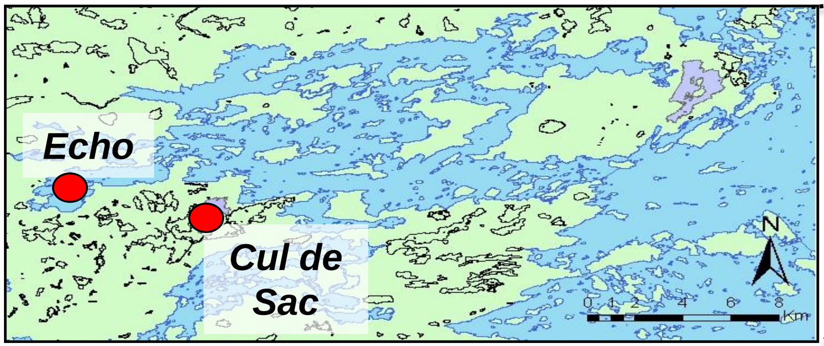
Detailed information about past conditions is needed to understand the influence of modern stressors on Lake Trout habitat

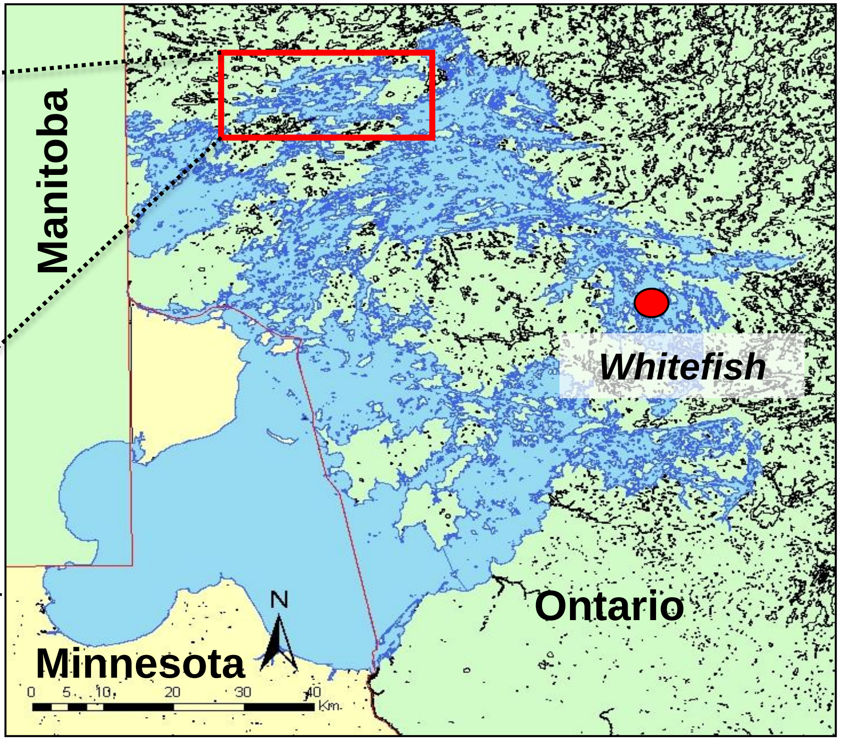
Goal is to reconstruct background conditions and assess how lake water quality has changed



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

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
VWHO (mg/L)	4.64	4.89	Not available

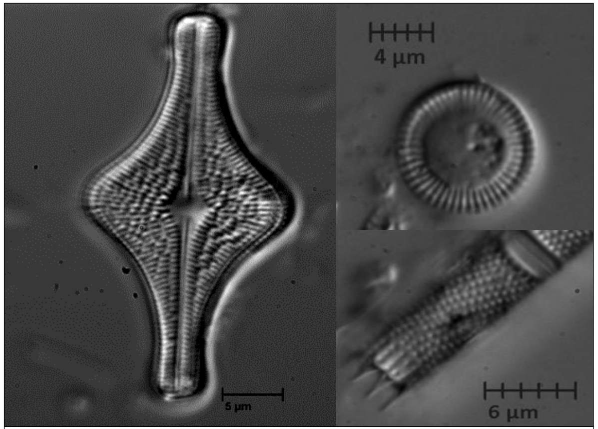
Cores were collected Fall 2014 and dated using ^{210}Pb radioisotopes

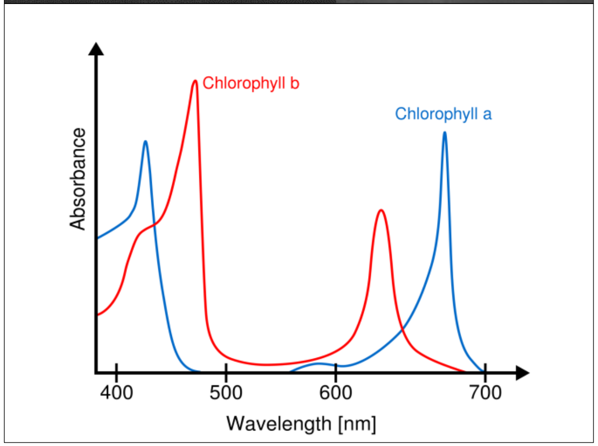
(Map: Kathryn Hargan)

Methods

Indicators to be analyzed:

- **Diatoms:**
  - Common siliceous algae
  - Used to reconstruct past [TP]
- **VRS-chlorophyll-*a***
  - Used to infer whole-lake primary production

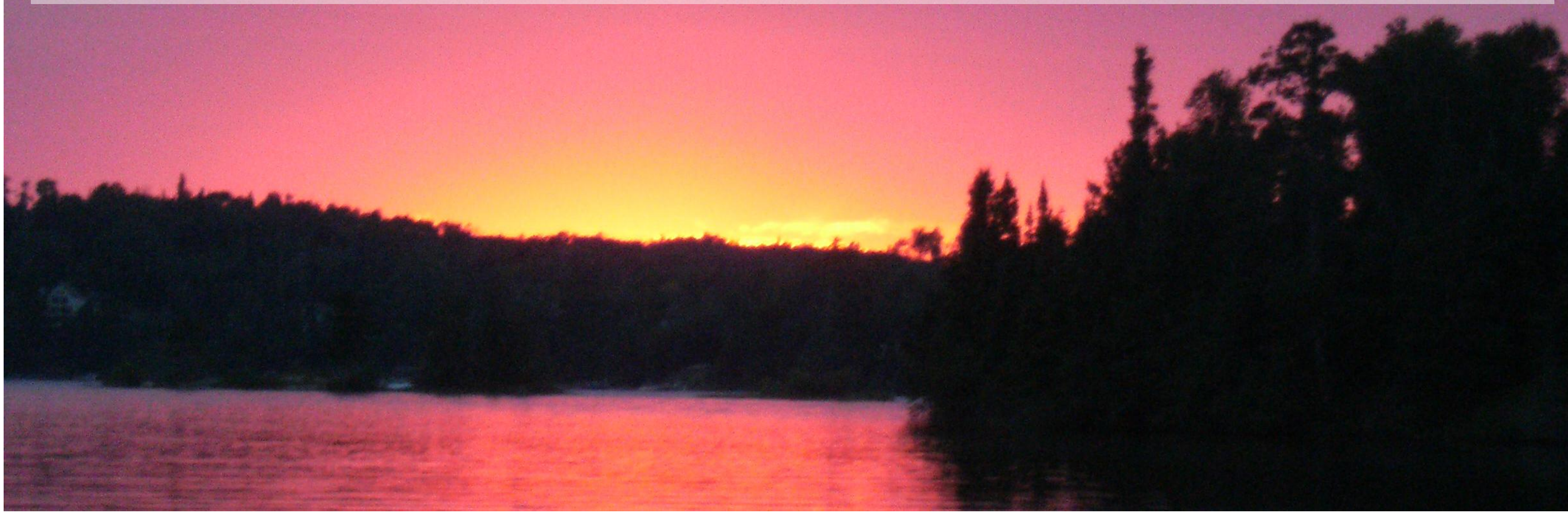




(Photo: http://post.queensu.ca/~pearl/cf8/cf8pics.html, https://en.wikip edia.org/wiki/Chlorophyll_a)

Research Questions

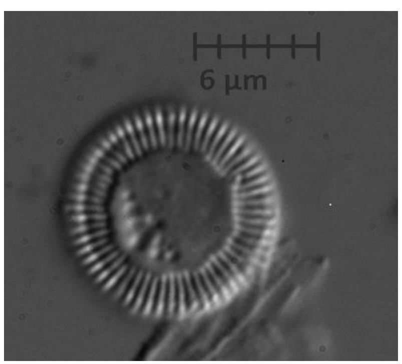
1. How have diatom assemblages and sedimentary-inferred chlorophyll-*a* changed over the past ~150 years in three northern bays in Lake of the Woods?
2. What are the “natural” or baseline conditions?
1. How have TP and whole-lake primary production changed?
2. Are there similar trends across bays (timing/nature/magnitude)?

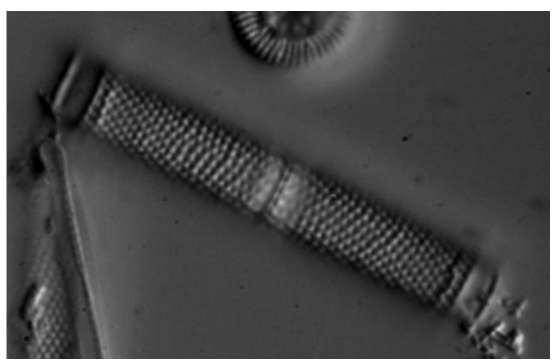


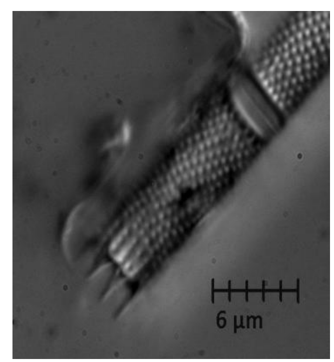
(Photo: Jamie Summers)

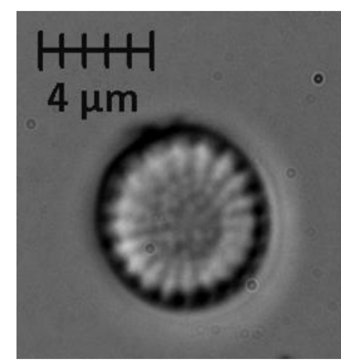
Diatom Results Summary

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

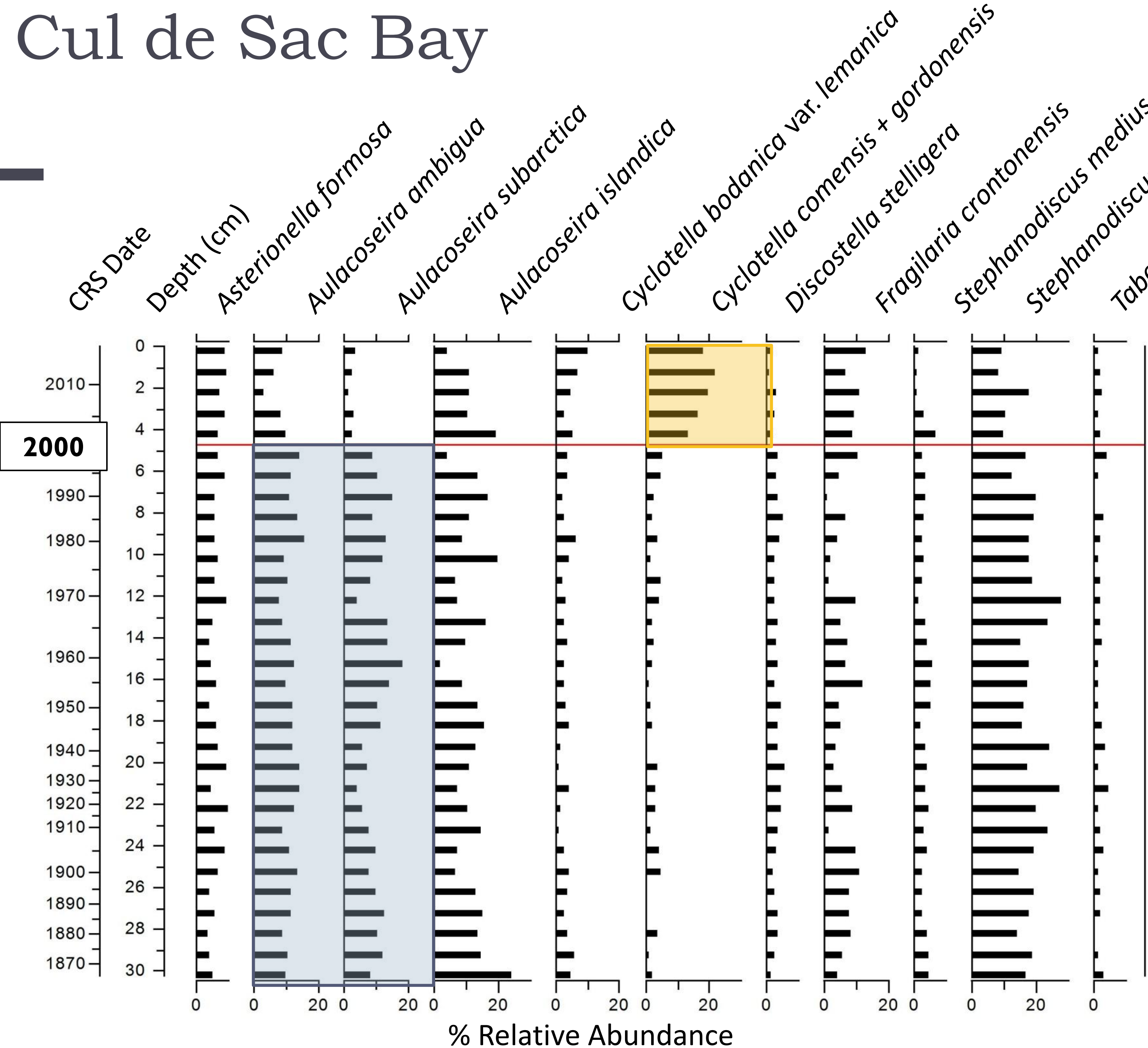




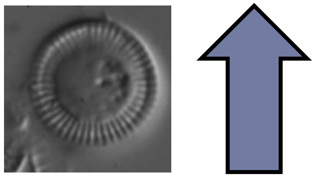




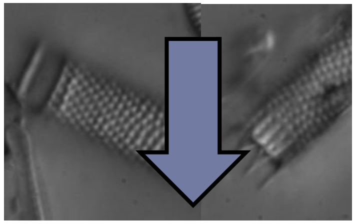
Cul de Sac Bay



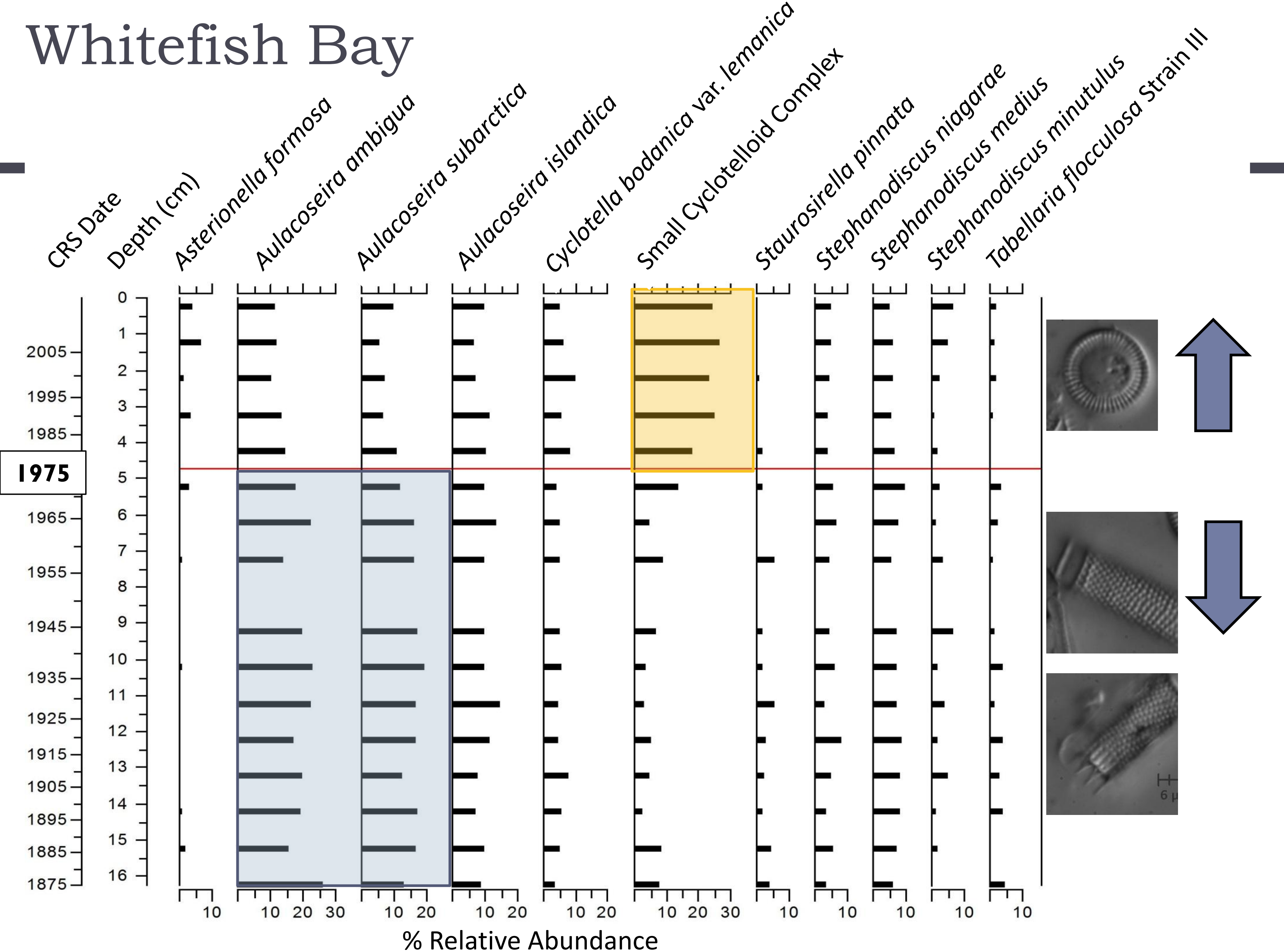
Increase in *Cyclotella comensis* and *C. gordonensis*



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

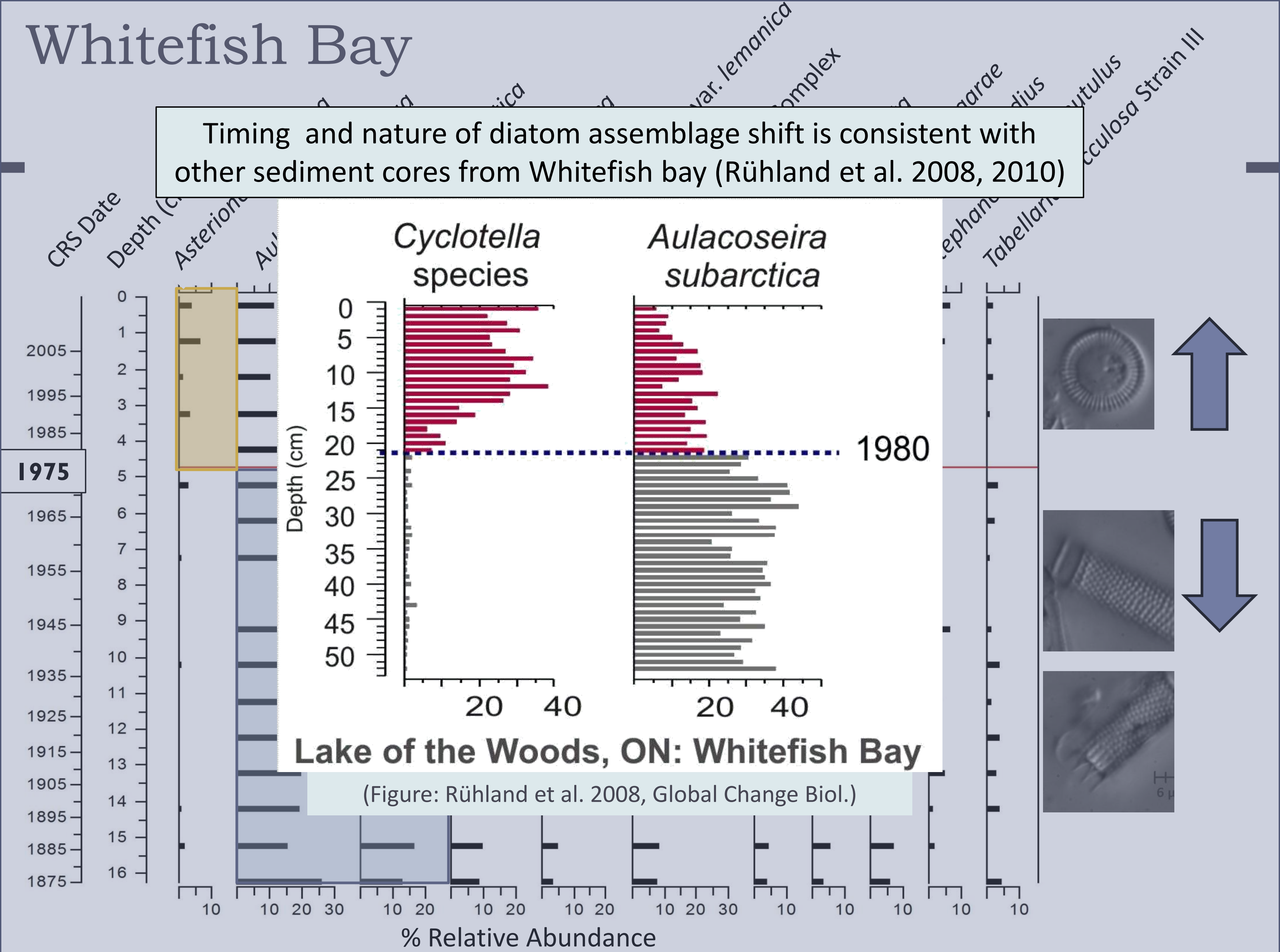


Whitefish Bay



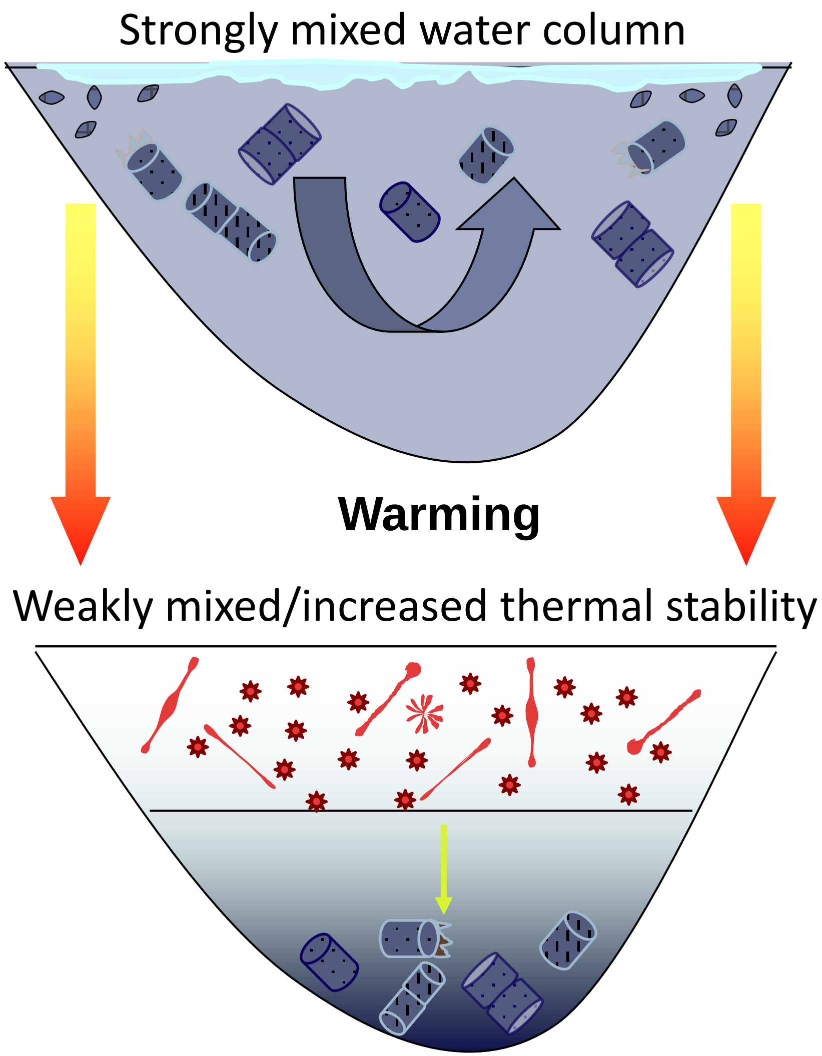
Whitefish Bay

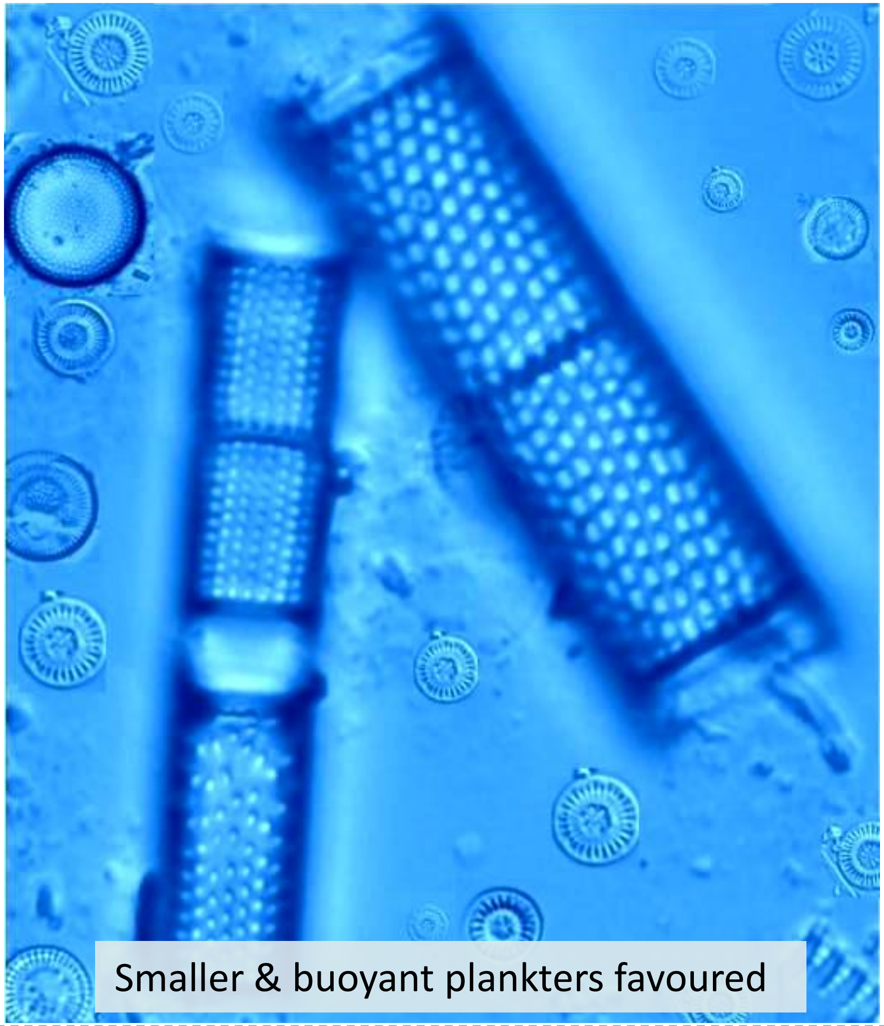
Timing and nature of diatom assemblage shift is consistent with other sediment cores from Whitefish bay (Rühland et al. 2008, 2010)



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

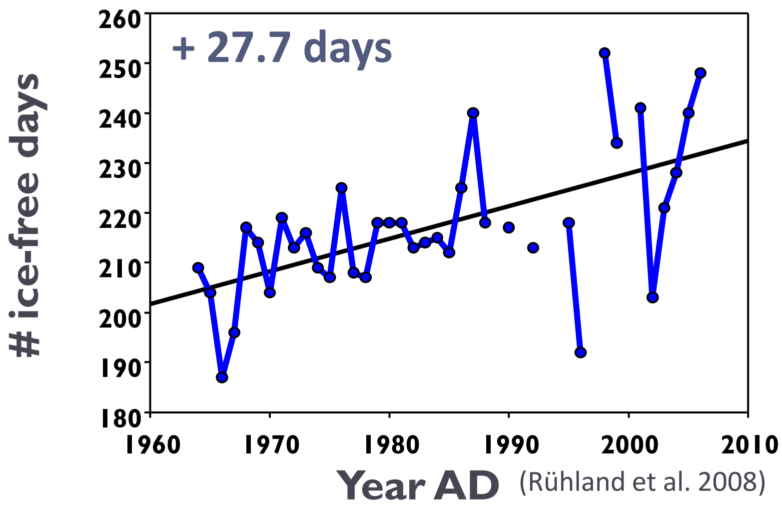
Diatom Assemblage Shifts & Climate Warming





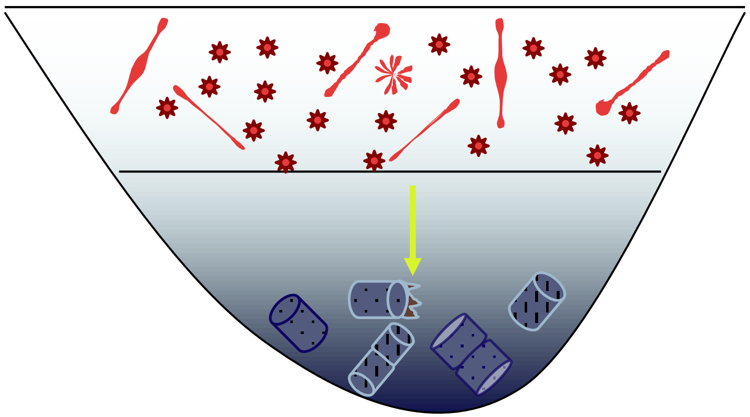
(Figure: Rühland et al. 2015)

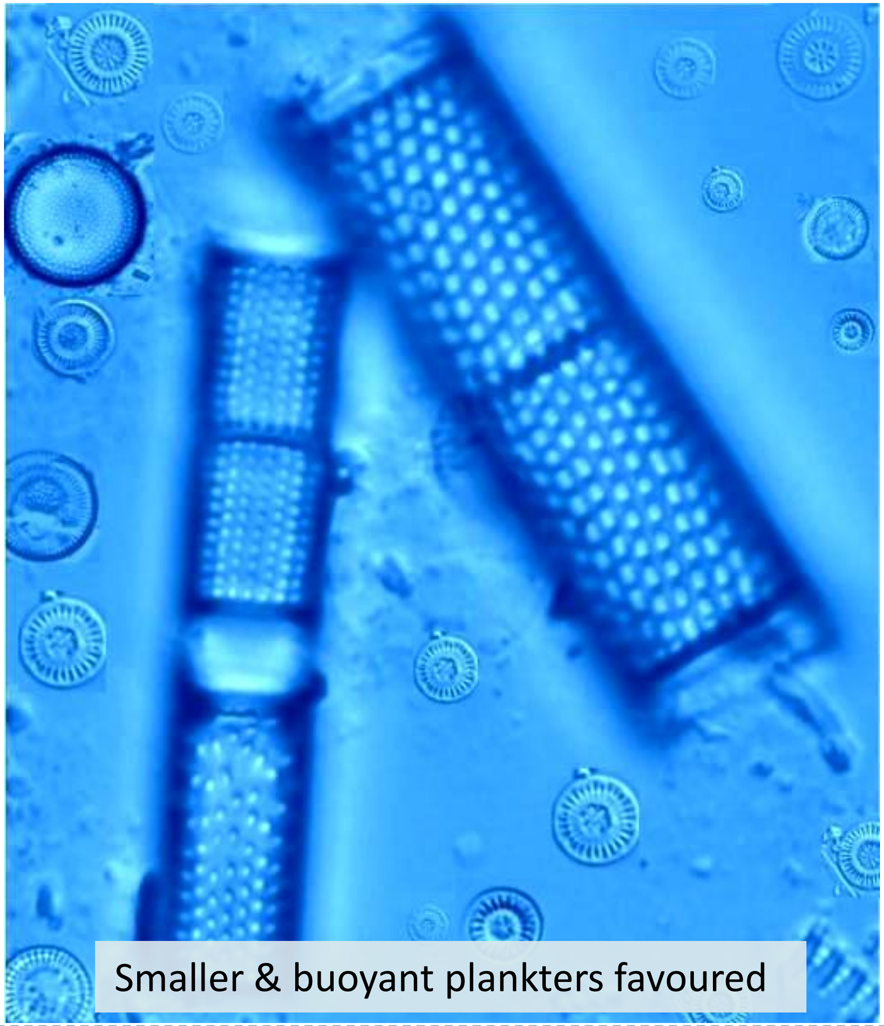
Diatom Assemblage Shifts & Climate Warming



(Rühland et al. 2008)

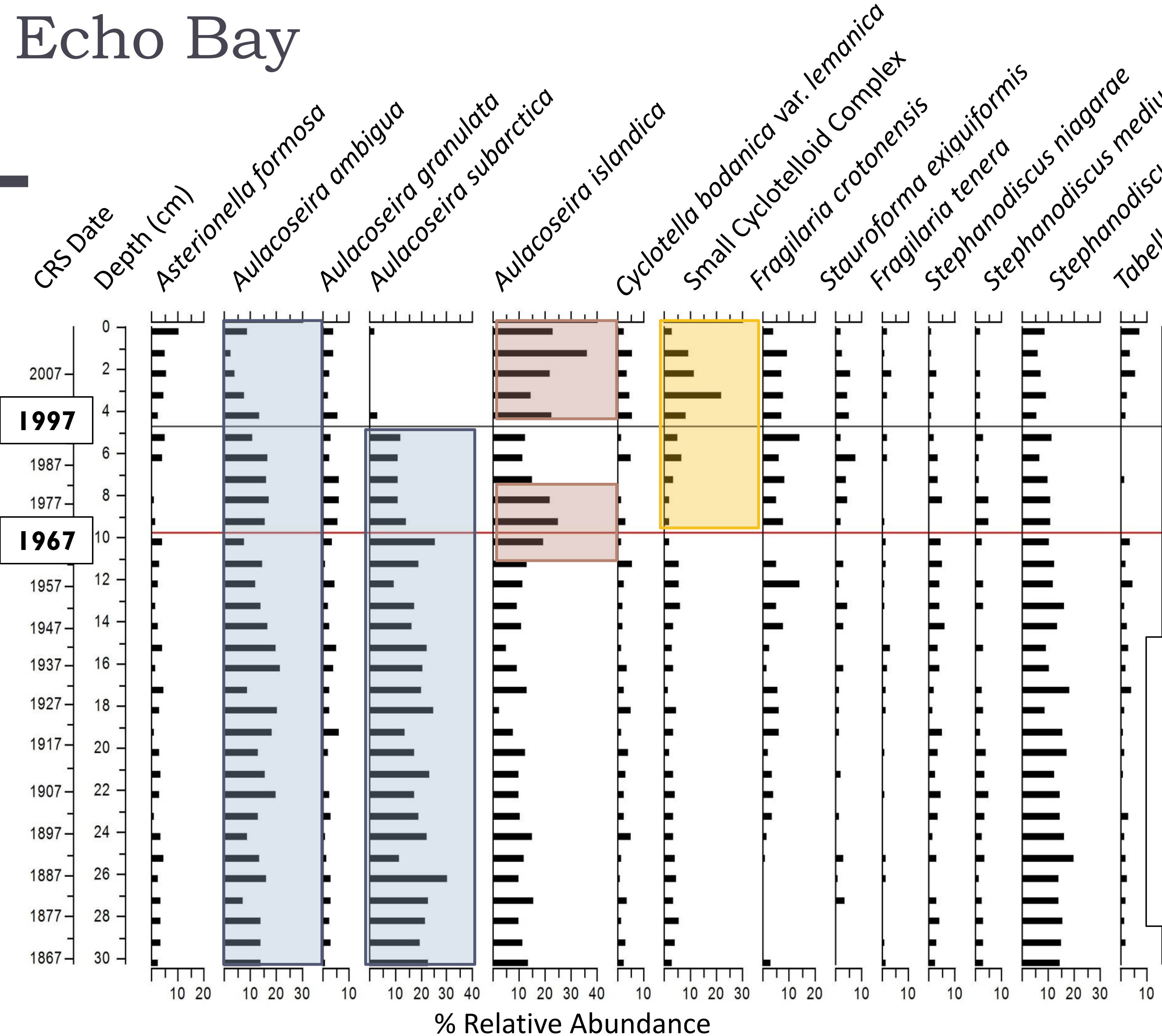
Weakly mixed/increased thermal stability





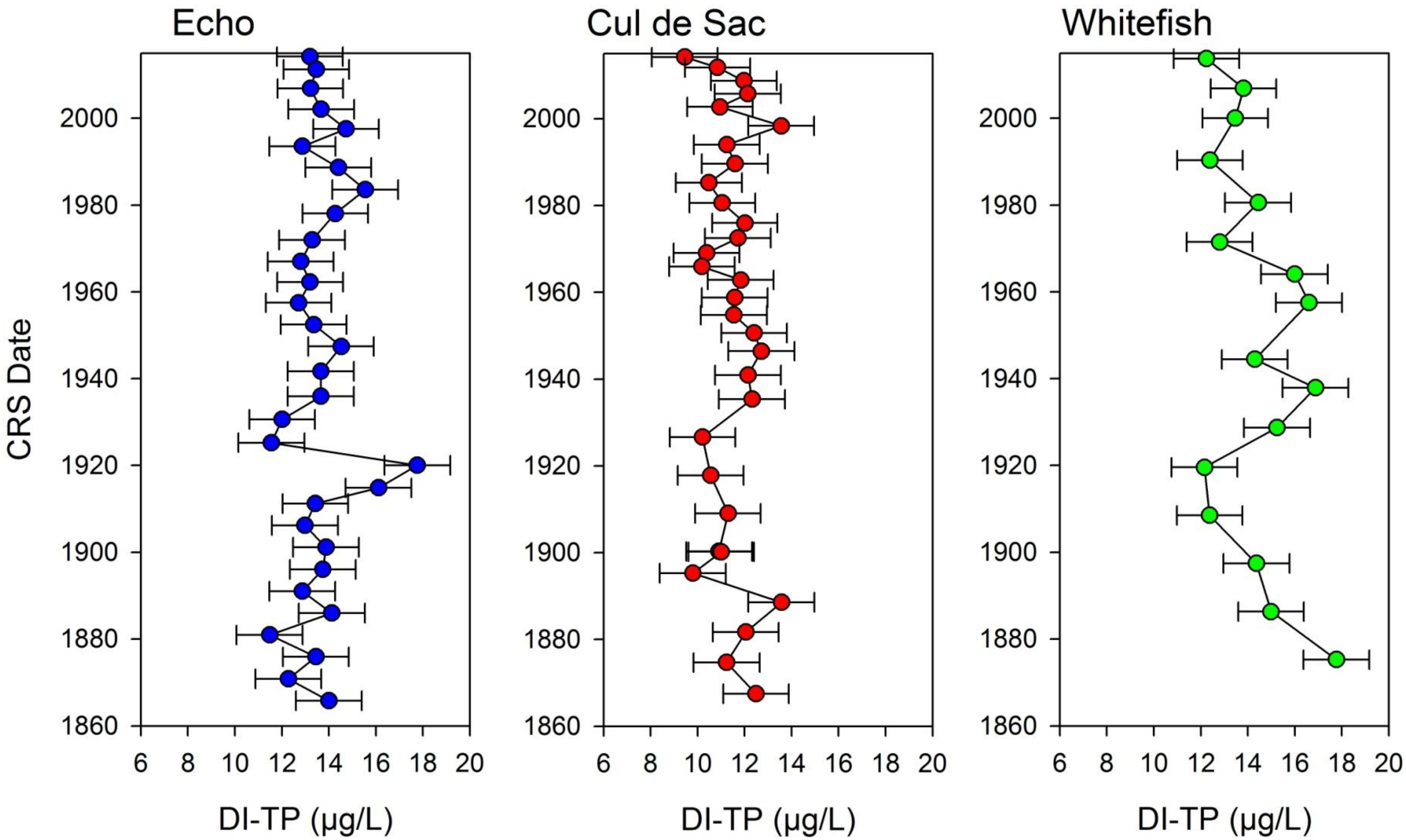
(Figure: Rühland et al. 2015)

Echo Bay



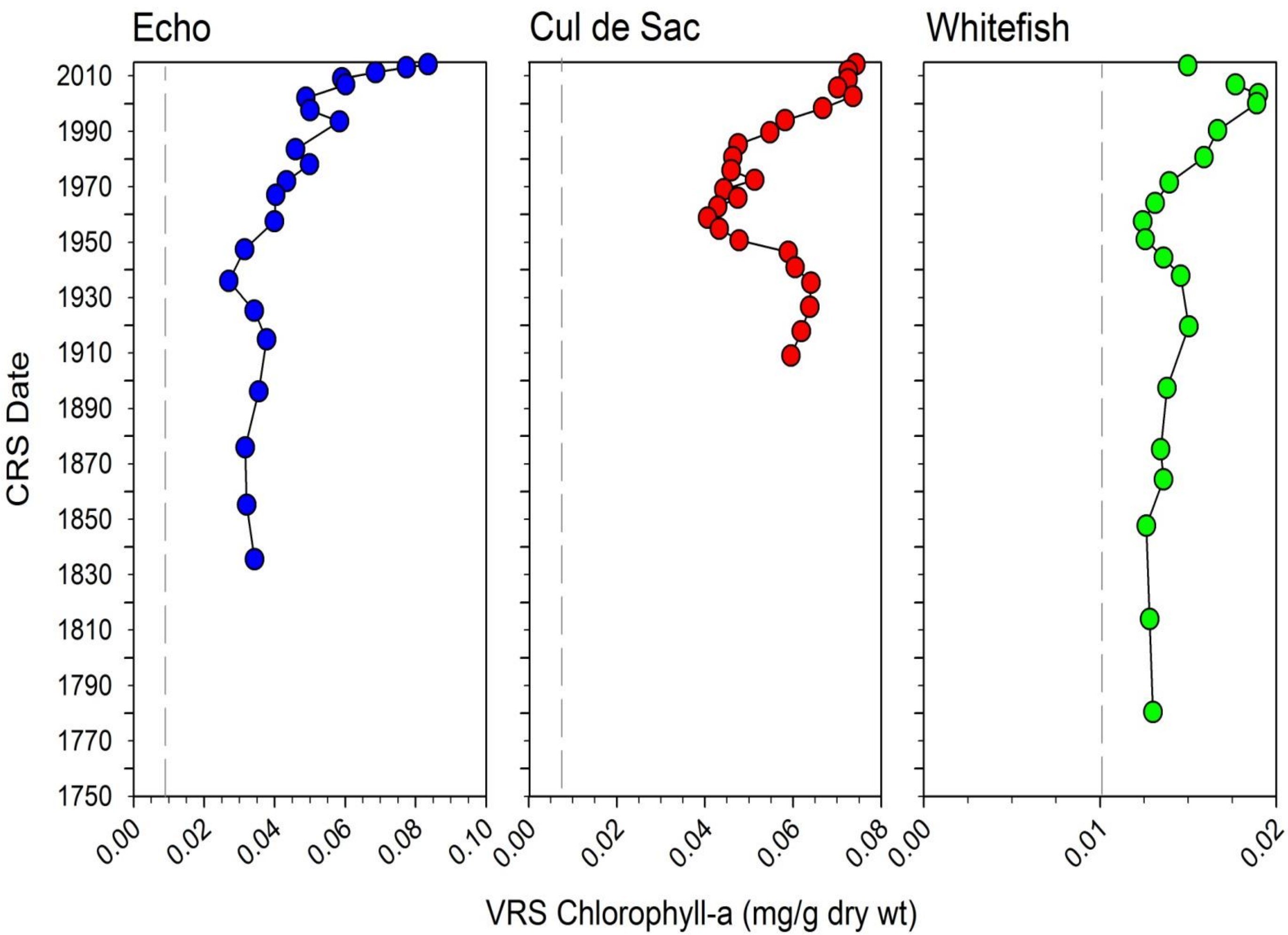
Aulacoseira islandica is known to bloom under the ice (Stoermer et al. 1981, Nõges 2004)

Diatom-inferred TP



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

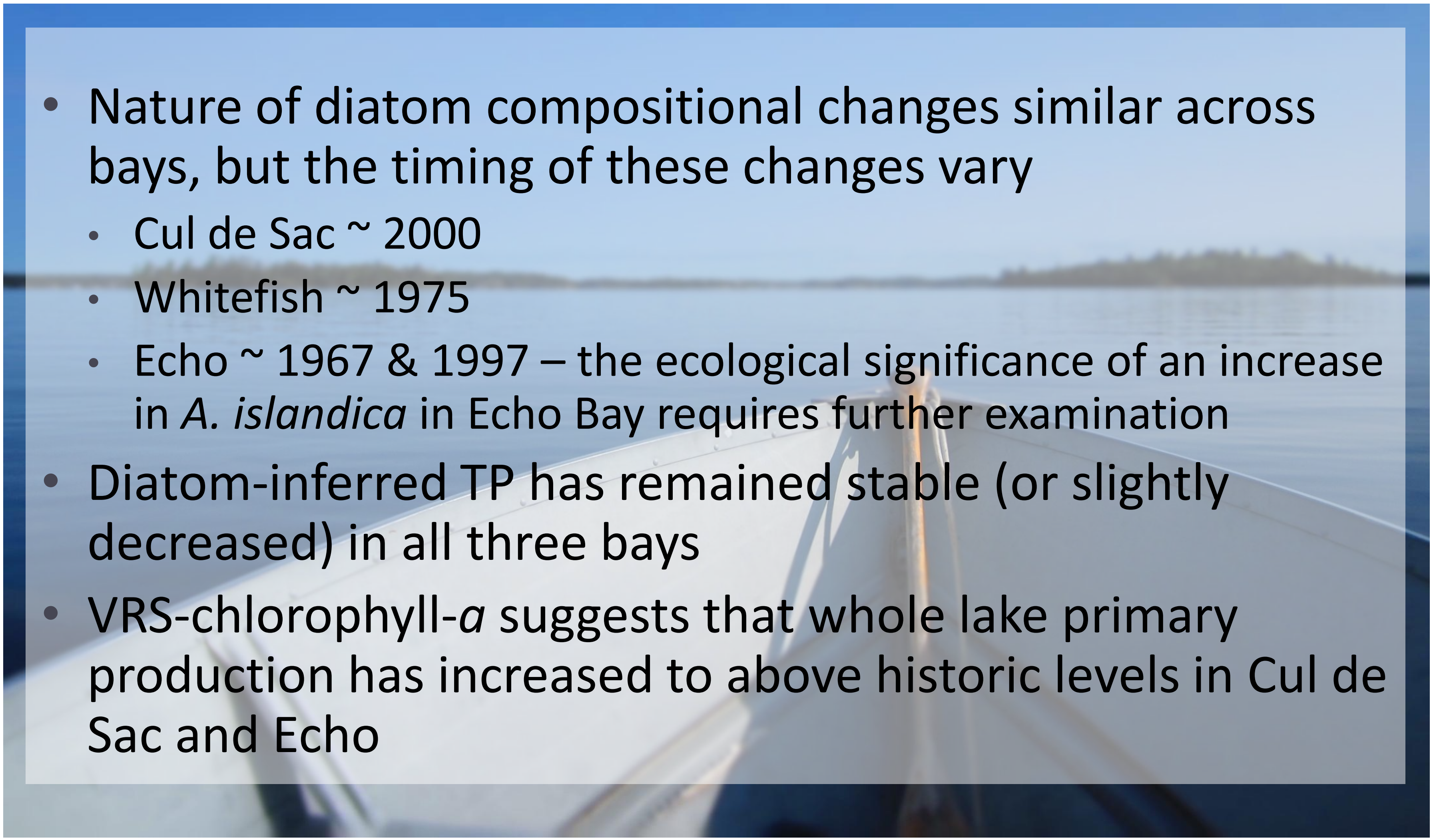
VRS-chlorophyll-*a*



- Similar trend in VRS-chlorophyll-*a* in Echo and Cul de Sac
- Whitefish VRS-chlorophyll-*a* similar to trends observed in the 2002 Whitefish sediment core (Michelutti et al. 2010)

Conclusions

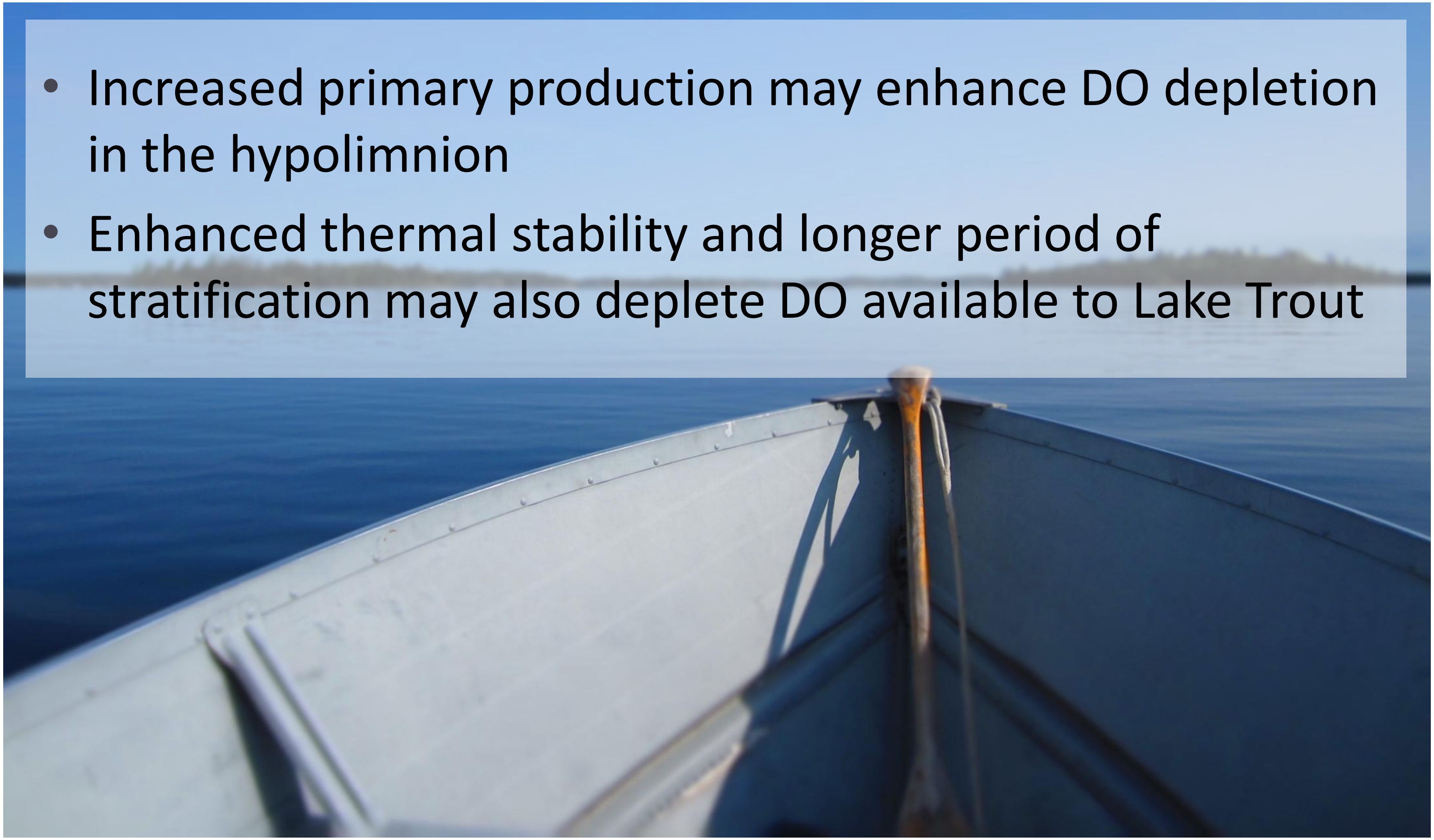
- Nature of diatom compositional changes similar across bays, but the timing of these changes vary
  - Cul de Sac ~ 2000
  - Whitefish ~ 1975
  - Echo ~ 1967 & 1997 – the ecological significance of an increase in *A. islandica* in Echo Bay requires further examination
- Diatom-inferred TP has remained stable (or slightly decreased) in all three bays
- VRS-chlorophyll-*a* suggests that whole lake primary production has increased to above historic levels in Cul de Sac and Echo



(Photo: Jamie Summers)

What does this mean for Lake Trout?

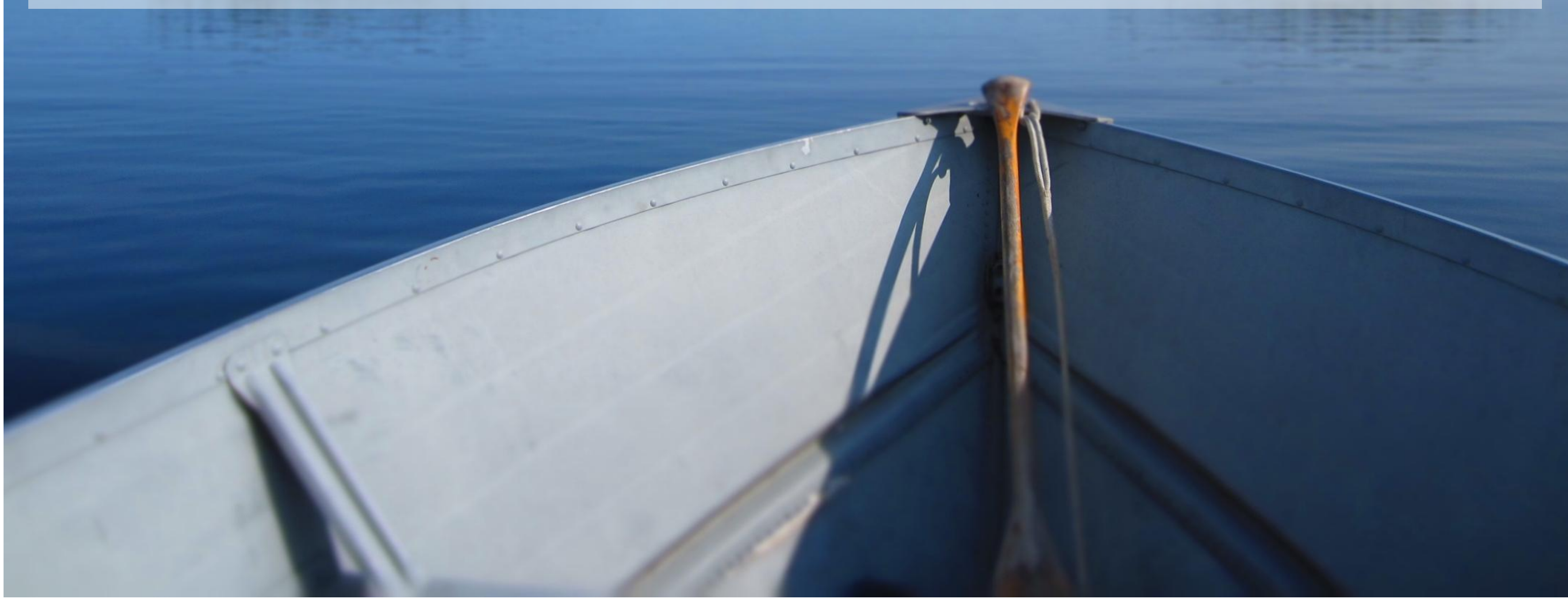
- Increased primary production may enhance DO depletion in the hypolimnion
- Enhanced thermal stability and longer period of stratification may also deplete DO available to Lake Trout



(Photo: Jamie Summers)

Next Steps

- Compare DI-TP with chironomid-inferred DO for the three bays
- Apply models to other 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

Thank you

Key Literature

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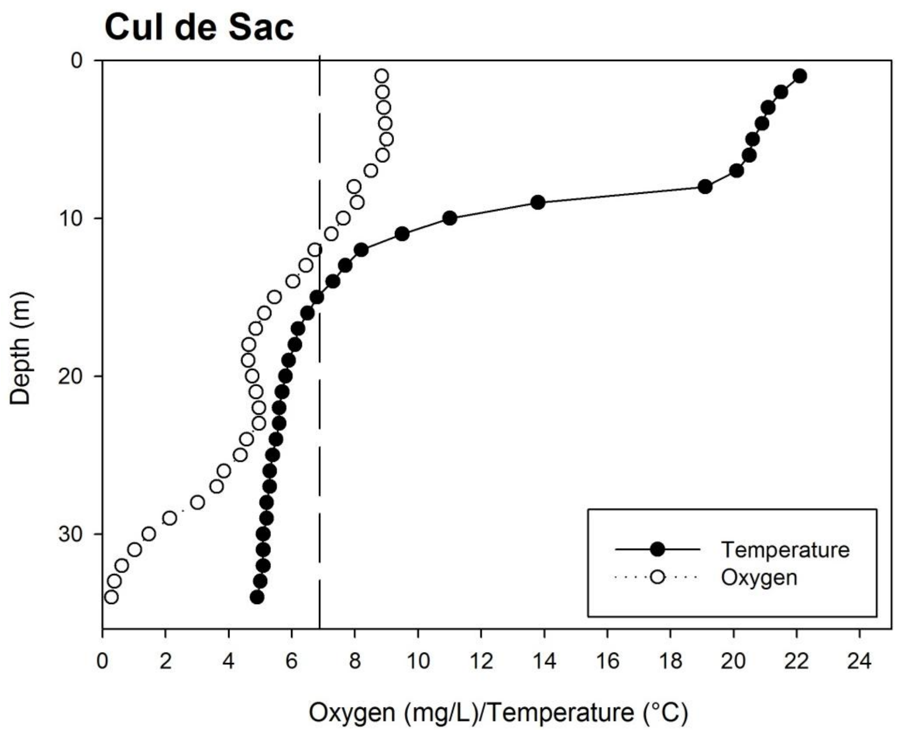
(Photo: Jamie Summers)

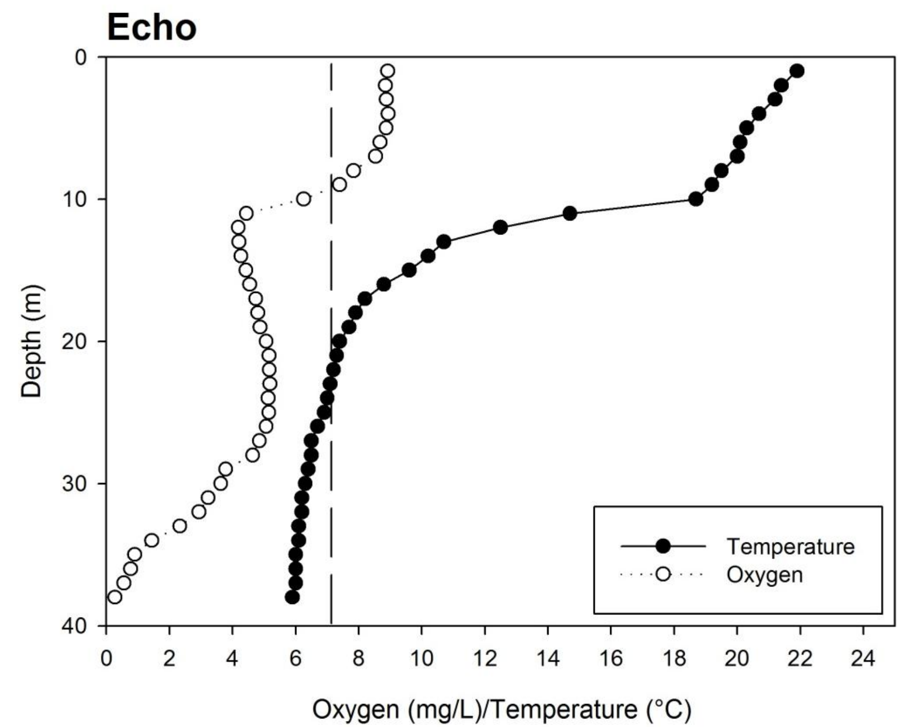
History of Lake Trout Management

- Present in many northern LOW bays
- In the 1980s, impacted by overharvesting, reduced hypolimnetic O_2, and high TP and chlorophyll-*a*
- Recent improvement in the quality of the Lake Trout fishery
  - Increases in population size, spawning and recruitment, and declines in fish mortality
- **Health of the Lake Trout population a concern due to low numbers of large-sized individuals**

(Clark and Sellers 2014)

September 2009 Temperature-Oxygen Profiles





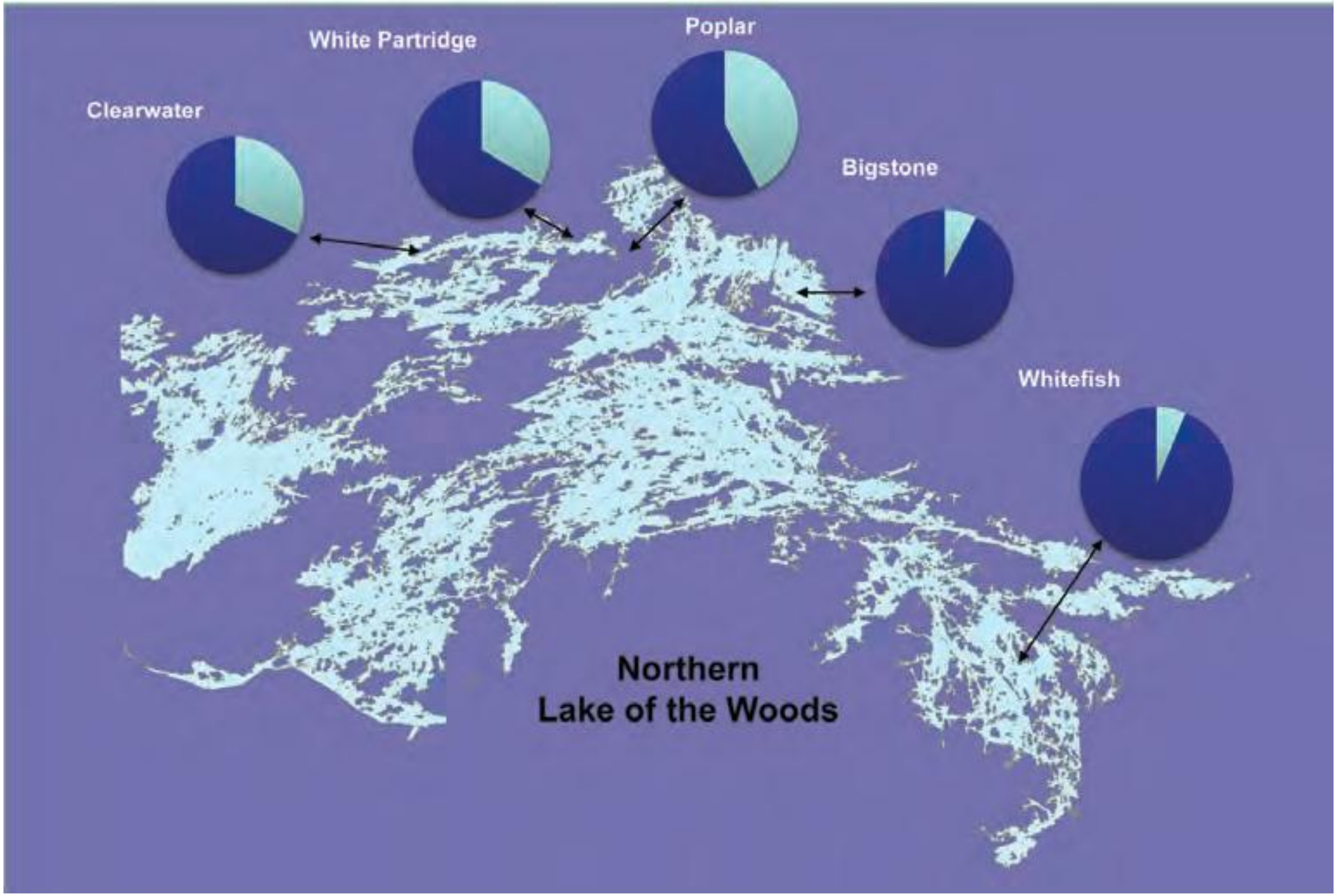
Note: Awaiting OMNRF data from 2012 sampling and temperature-oxygen profiles from Whitefish Bay have been requested

Volume Weighted Hypolimnetic Oxygen (mg/L)

Year	Cul de Sac	Echo
2004	5.62	Not Available
2005	5.63	5.85
2009	4.89	4.64

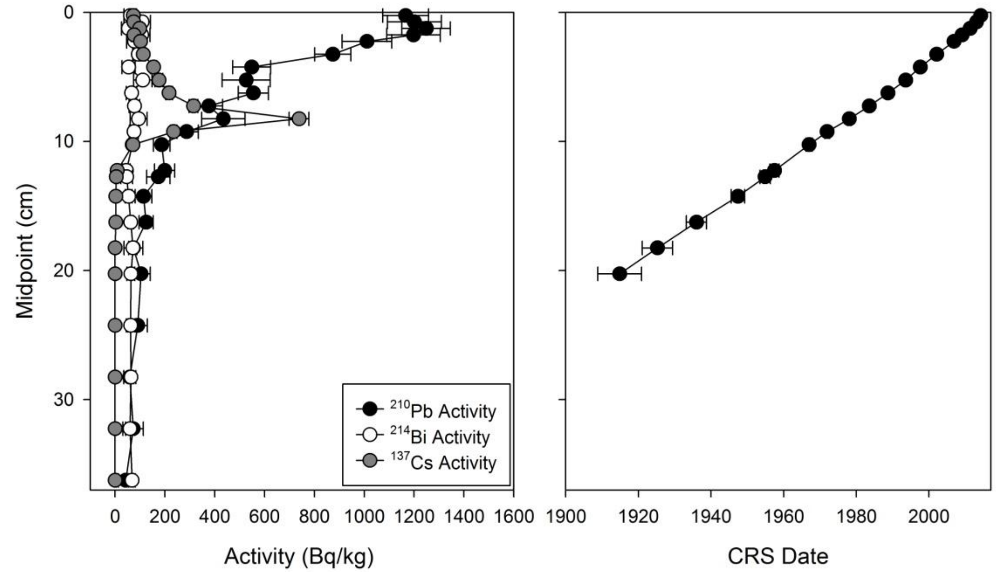
(Data from OMNRF and Hargan 2010)

Non-uniform contribution of phosphorus by shoreline properties

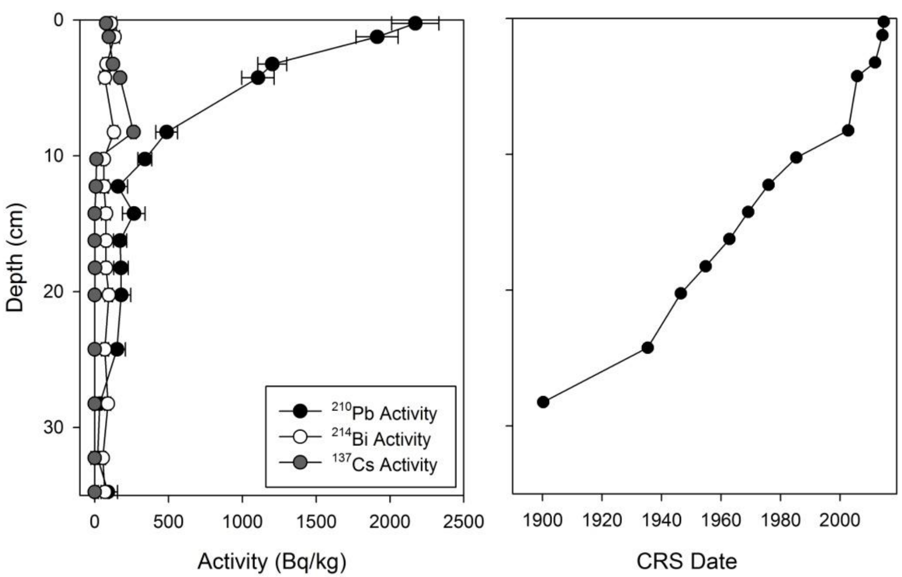


Radioisotope Profiles & Constant Rate of Supply Dating Models

Echo



Cul de Sac



Whitefish