# Tracking historical water quality changes using diatoms in Bigstone Bay, Lake of the Woods, Ontario: a paleolimnological assessment

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## Background

- Phosphorus is a major limiting nutrient for algal growth
- Recently, blue-green algal blooms are thought to have increased in frequency and magnitude in the northern parts of Lake of the Woods (LoW), an international water body straddling the borders of Ontario, Manitoba and Minnesota (Fig. 1)
- However, historical accounts also suggest that algal blooms have long occurred in LoW

## Research Objectives

- Can diatom assemblages be used to track changes in historical lake water quality in LoW?
- What is the rate, magnitude, and timing of these changes?
- What are the underlying mechanisms of any ecological changes? (e.g. human impacts, climate change, etc.)
- How differently do diatom assemblages change between a reference site and impact (i.e. elevated nutrient) sites in LoW?

## LoW Site Description

- Morphologically and hydrologically complex system
- Dams constructed in the northern outlets near Kenora, Ontario between 1890-1905 increased average water level by ~2 m[1]
- There is a strong south to north nutrient gradient, decreasing from Rainy River northward to Kenora[1]

### Bigstone Bay (impact site)

- Elevated [TP]: seasonally variable (e.g. 13-32 µg/L)[2]
- Algal blooms occur in late summer early autumn
- Located in hydrologically quiet bay
- Thermally stratifies[3]

Diatom trends will be compared to:

- **Whitefish Bay (reference site):** lower [TP] (7.5 – 10 µg/L)[2] and no algal blooms
- **PP-1 (impact site):** elevated [TP] (17-25 µg/L)[2] and algal blooms occur

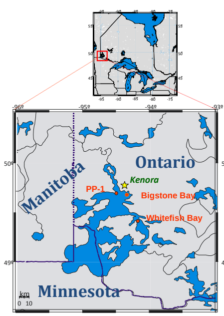




**Figure 1.** Location of three study sites in LoW, Ontario.

## Methods

- Sediment cores were collected using a Glew gravity corer
- 35.5 cm core sectioned into 0.5 cm intervals
- Chronology established through $^{210}Pb$ and $^{137}Cs$ activities
- Minimum of 400 diatom valves enumerated from 54 samples
- Historical water quality changes assessed using a diatom-inferred TP (DI-TP) model
- Diatom data were summarized using principal components analysis (PCA) with PCA axis 2 (PC2) used for comparative analysis
- Sedimentary Chl *a* estimated for each core interval[4]
- Paleolimnological data were compared to Kenora temperature records (since 1899) and Whitefish Bay ice-out records (since 1964)

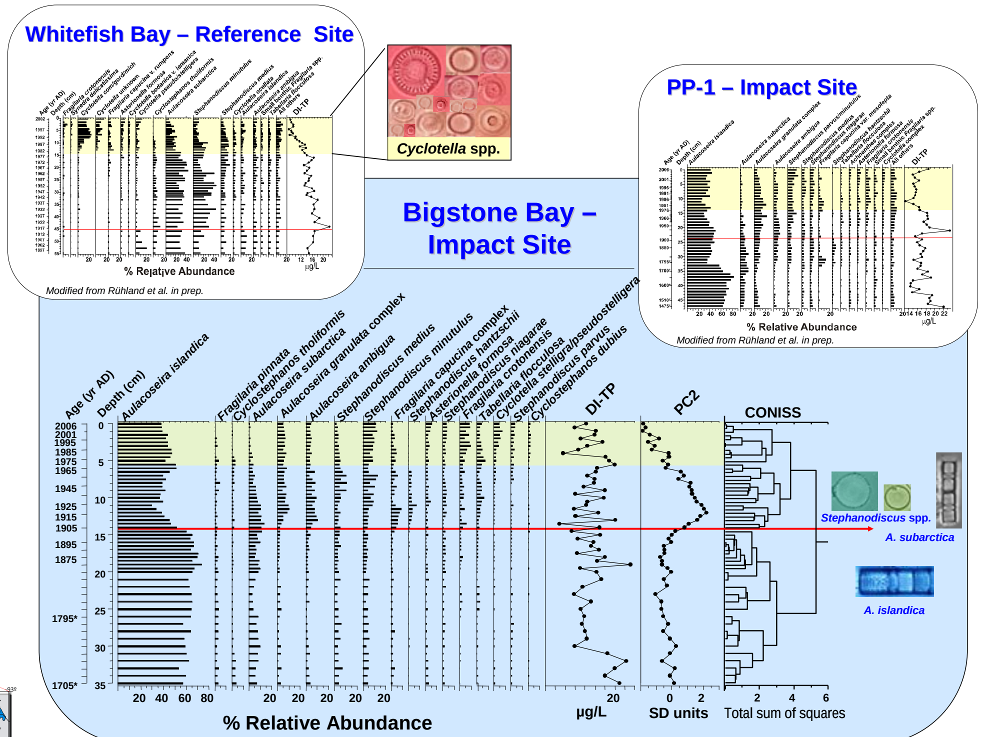
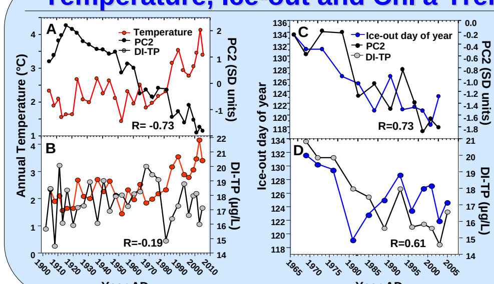




**Figure 2.** Relative abundances of the most common diatom taxa found throughout LoW cores and the diatom-inferred total phosphorus (DI-TP) for Whitefish Bay, PP-1, and Bigstone Bay. Principal Component Analysis axis two (PC2) scores measured in standard deviation (SD) units and cluster analysis (CONISS) are shown for Bigstone Bay. The red lines correspond to dam construction and consequent diatom taxa changes consistent with an increase in water level and nutrients. The yellow boxes represent recent (~ last 3 decades) diatom assemblage changes consistent with increases in temperature and earlier ice-out dates. Asterisks' next to 'year AD' represent dates that were beyond the range of $^{210}Pb$ dating, and thus were extrapolated.

## Temperature, Ice-out and Chl *a* Trends





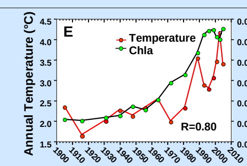




**Figure 3.** Temperature trends (Kenora, ON Canada), lake-ice records (Whitefish Bay, LoW Ontario) and paleolimnological data from Bigstone Bay, LoW, Canada. (A) mean annual temperature vs Principal Component Analysis axis 2 (PC2), (B) mean annual temperature vs diatom-inferred TP (DI-TP), (C) ice-out day of year vs PC2, (D) ice-out day of year vs DI-TP, and (E) mean annual temperature vs sedimentary chlorophyll *a*. A 5-year running mean was applied to the temperature and ice-out records.

## Results and Discussion

### General trends

- Diatoms indicative of higher nutrient levels were commonly found throughout the core (Fig. 2)

### Dam construction (ca. 1895-1905)

- Substantial decreases in the relative abundance of *Aulacoseira islandica* concurrent with substantial increases in diatoms commonly associated with eutrophication including the *Fragilaria capucina* complex, *F. crotonensis, A. granulata,* and *S. hantzschii*
- Changes are consistent with a modest increase in nutrients resulting from flooding, however there is no clear trend in DI-TP
- PP-1 and Whitefish Bay show distinct nutrient increases (DI-TP) (insets to Fig. 2)

### Recent changes (ca. mid-1970s)

- Increases in taxa indicative of lower TP optima
- *Cyclotella* taxa occur in substantial abundances for the first time at all 3 sites (most notably Whitefish Bay and Bigstone Bay)

### Temperature, lake-ice and Chl *a* trends

- PC2 scores strongly correlated to annual temperature trends (Fig. 3A) and a weak relationship to DI-TP (Fig. 3B)
- PC2 scores highly correlated to increase in ice-out (Fig. 3C) & DI-TP (Fig. 3D)
- These relationships suggest increased temperature and a reduction in ice-cover in recent decades are influencing diatom changes
- Similarly, high correlations between diatom trends and temperature and ice-out data were also observed in PP-1 and Whitefish Bay
- Chl *a* was highly correlated to mean annual temperature (Fig. 3E)

## Conclusions

- Historically, [TP] in Bigstone Bay has been relatively high and variable
- Temperature and ice-out trends closely linked to diatom changes, particularly in the last ca. 30 years
- All 3 sites showed important relationships to recent warming and, as expected, this change is pronounced in the reference site
- Diatom trends at all 3 sites indicate [TP] has not increased recently
- Increases in algal production (Chl *a*) at Bigstone Bay (and PP-1)
  - Highly correlated to recent warming
  - Likely tracking algal blooms
  - Synergistic effects between warming and nutrients may trigger algal blooms
- Our results suggest that recent diatom shifts in LoW are best explained by recent warming and associated limnological changes

## References

**1.)** Pla, S., Paterson, A.M., Smol, J.P., Clark, B.J., & Ingram, R. (2005) *J. Great Lake Res.* **31**, 253-266. **2.)** Ontario Ministry of the Environment, *Lake Partner Program.* **3.)** Chen, H., Burke, J.M., Dinsmore, W.P., Prepas, E.E., & Fedorak, P.M. (2007) *Lake Reserv. Manage*. **23**, 169-178. **4.)** Michelutti, N., Wolfe, A.P., Vinebrooke, R.D., Rivard, B., & Briner, J.P. (2005) *Geophys. Res. Lett*. **32**, L19715, doi:10.1029/2005GL023693.

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