A Diatom-based Regional Comparison Between Modern and Pre-industrial Water Quality in the Lake of the Woods, Ontario

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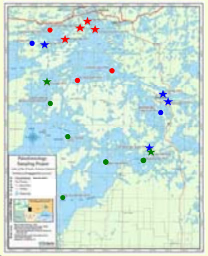
Background

Blue-green algal blooms in the northern basin of the Lake of the Woods (LOW) appear to have increased in frequency and intensity in recent years. This has generated much interest in determining whether or not there have been historical changes in total phosphorus (TP) concentrations that could explain the perceived recent increases in the severity of these blooms. To address these concerns, the following research questions were examined:

1. What is the 'natural' or baseline conditions of the LOW?
2. Is the lake naturally eutrophic?
3. Are diatom assemblages and water quality (e.g. [TP]) different today than in pre-industrial times (pre-1850's)?
4. If so, are these changes consistent throughout the northern part of the LOW?

Study Region



We examined 10 sites in the northern (Ontario) portion of the LOW spanning a relatively wide gradient of [TP].

FIGURE 1. Study region and location of the top-bottom study sites in the LOW. The 10 sites that were included in this top/bottom study are denoted by stars. All remaining sites are marked by circles. Sites are differentiated based on [TP]: blue (<10 µg/L), red (10-20 µg/L), and green (>20µg/L).

Methods

- Top-bottom paleolimnological approach was used to assess regional trends in water quality changes
- Differences in diatom assemblage composition between the top 0.5 cm interval (modern) and the bottom 0.5 cm interval (pre-1850's) of each sediment core was analyzed

Top
- Typically the top 0.5 cm
Modern environment

Bottom
- Depth >30 cm
Pre-impact (pre-1850) environment

FIGURE 2. Photo of a sediment core showing top & bottom (before & after) intervals.

- Bottom samples = pre-industrial conditions based on: ca. 1850 = 25-30 cm in many North American lakes[1]
    1. Bottoms samples > 30 cm
    2. In LOW full cores ca.1850 occurs at approx. 28 cm & 30 cm for PP1 & Bigstone Bay respectively[2]
- Diatom-based inference model for TP (DI-TP)[3, 4] used to estimate changes in [TP] since pre-industrial times

Preliminary Results

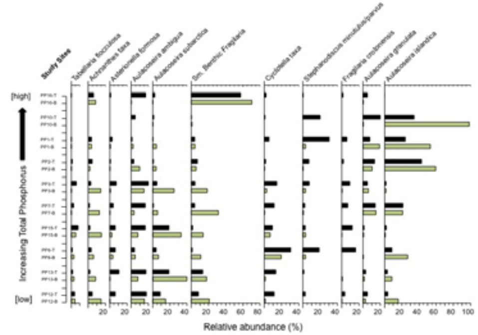


FIGURE 3. Simplified diatom stratigraphy comparing the relative percent abundances of the most common diatom taxa in modern and pre-industrial sediments for the 10 study sites. Modern diatom abundances are represented by solid bars and fossil assemblages by lightly shaded bars. Sites are arranged in order of increasing concentrations of total phosphorus.

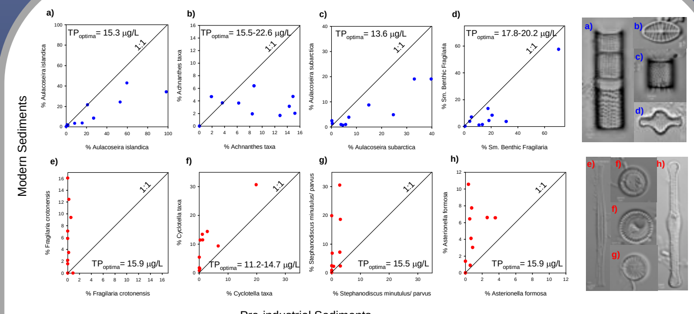


FIGURE 4. The relationship between pre-industrial versus modern percent relative abundances of: a) *Achnanthes* taxa, b) *Aulacoseira islandica*, c) *Aulacoseira subarctica*, d) small benthic *Fragilaria* taxa, e) *Cyclotella* taxa, f) *Stephanodiscus minutulus/parvus*, g) *Asterionella formosa*, and h) *Fragilaria crotonensis* for the 10 sites of LOW. Sites plotting above the 1:1 line indicate a higher relative abundance in surface sediments. TP optima cited are based on diatoms from LOW calibration set.[5]

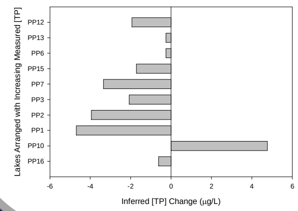


FIGURE 5. The change in diatom-inferred [TP] between modern and pre-industrial times. Negative results indicate a decrease in [TP] in the modern sediments and a positive result indicates an increase in [TP] in the modern sediments.

Results

- Clear assemblage changes were recorded among the more common diatom taxa since preindustrial times (**Fig. 3**)
- Shift from high abundances of benthic (e.g. *Achnanthes* spp.) and heavily silicified tychoplanktonic taxa (e.g. *Aulacoseira islandica*) in the preindustrial sediments to planktonic taxa (e.g. *Cyclotella* taxa & *Fragilaria crotonensis*) in the modern sediments (**Fig. 4**)
- Results from DI-TP reconstructions indicate that [TP] has decreased in all but one of the study sites, the exception being PP10 which showed an increase (**Fig. 5**)

Discussion

- Preliminary results suggest that many sites on the LOW have shown elevated nutrients since pre-industrial times
- Our results show an overall decreasing trend in [TP] since pre-industrial times in the majority of our study sites
- This is consistent with various other sites on the LOW[2] and other studies in the Minnesota lakes region[3, 6]
- The interaction of multiple environmental stressors including recent warming can affect aquatic ecosystems in very complex ways[7]
- Although [TP] is currently elevated in many of these sites, the apparent increase in the frequency and intensity of algal blooms in the northern basins of LOW does not appear to be solely attributed to *increasing* nutrient concentrations (e.g. TP)
- Shifts towards higher relative abundances of *Cyclotella* and other planktonic taxa suggest climate warming may be an important factor for driving the observed changes in diatom assemblages[8]

Future Directions

- Next step will involve incorporating the remaining top bottom sites, which cover a broader spatial scale and wider [TP] gradient
- Explore relationships between diatoms temperature and lake ice records
- Additional research is required to investigate the timing, magnitude and direction of changes in diatom assemblages and inferred water quality
- Future research will involve conducting detailed (full core) analyses of 3 ^{210}Pb-dated cores from basins of differing levels of local human disturbance, and thus variable levels of nutrient enrichment

Acknowledgements & Literature Cited

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(1) Smol (2008) *Pollution of Lakes and Rivers: A Paleolimnological Perspective*. 2nd Ed. Blackwell; (2) Rühland et al. (in prep); (3) Ramstack et al. (2003) *Journal of Paleolimnology*, **29**: 79-94; (4) Pla et al. (2005) *Journal of Great Lakes Research*, **31**: 253-266; (5) Paterson et al. (in prep); (6) Myrbo (2008) *Lake and Reservoir Management*, **24**: 349-360; (7) Keller (2007) Environmental Reviews, **15**: 99-112; (8) Enache et al. (in prep).