Assessing the implications of multiple stressors & recent diatom shifts in the Lake of the Woods, ON, Canada

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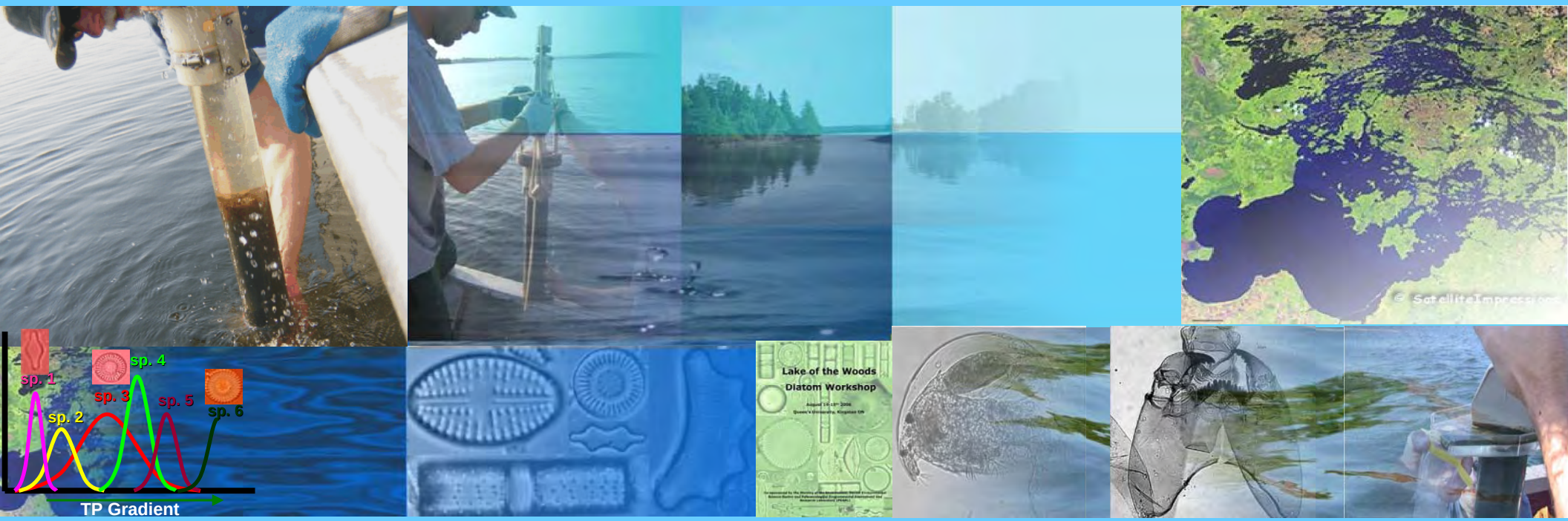
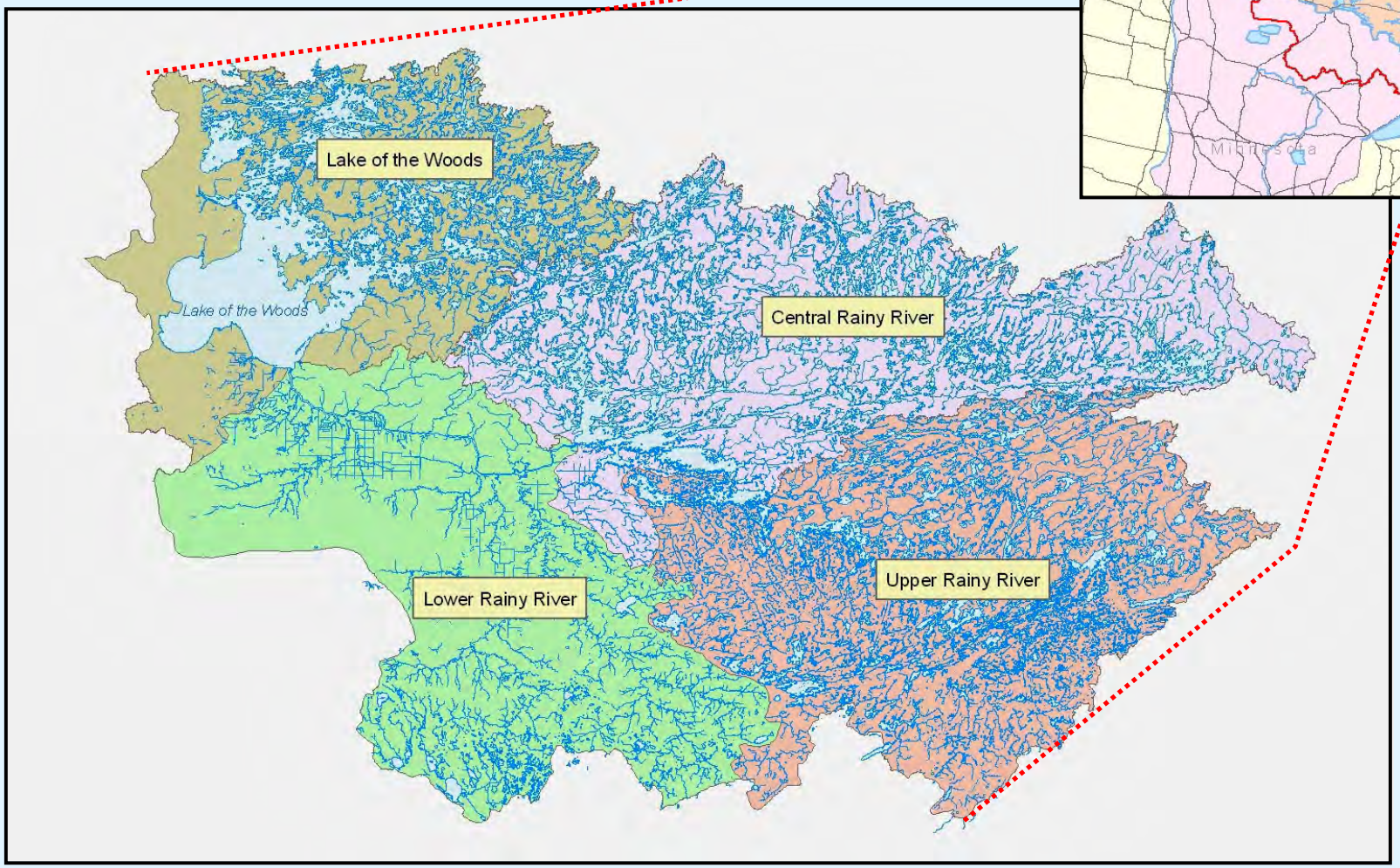
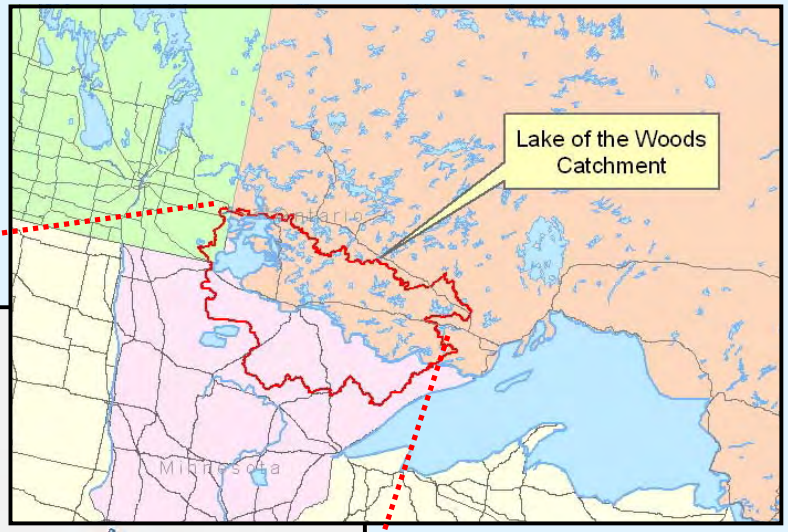


[1]PEARL, Queen's University, Kingston ON, Canada: [2]Ontario Ministry of the Environment, Dorset: [3]Trent University, Peterborough, ON, Canada: [4]Gartner Lee, Bracebridge, ON, Canada

Lake of the Woods Water Quality Forum 2009

The Lake of the Woods: A complex system



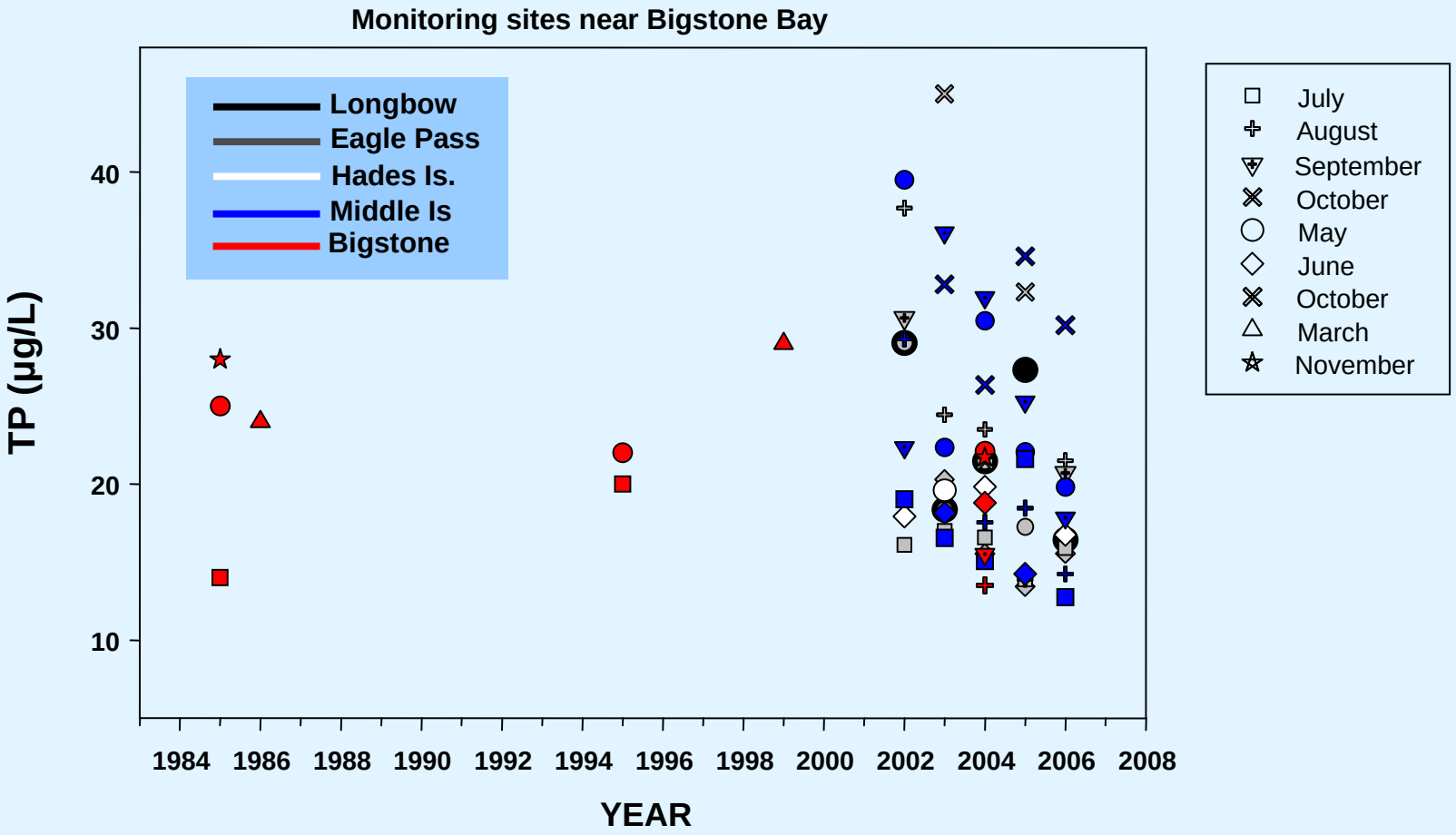


Maps by Gartner Lee Ltd.

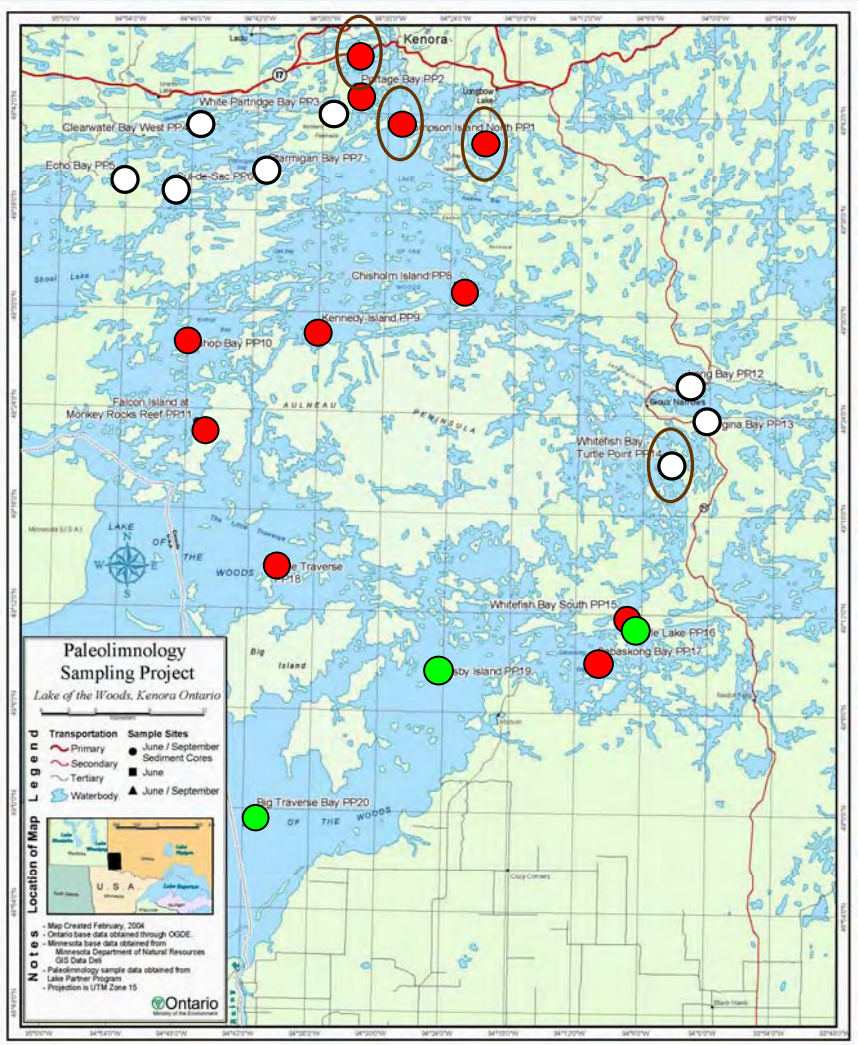
The LoW: waters flow north from the Rainy River

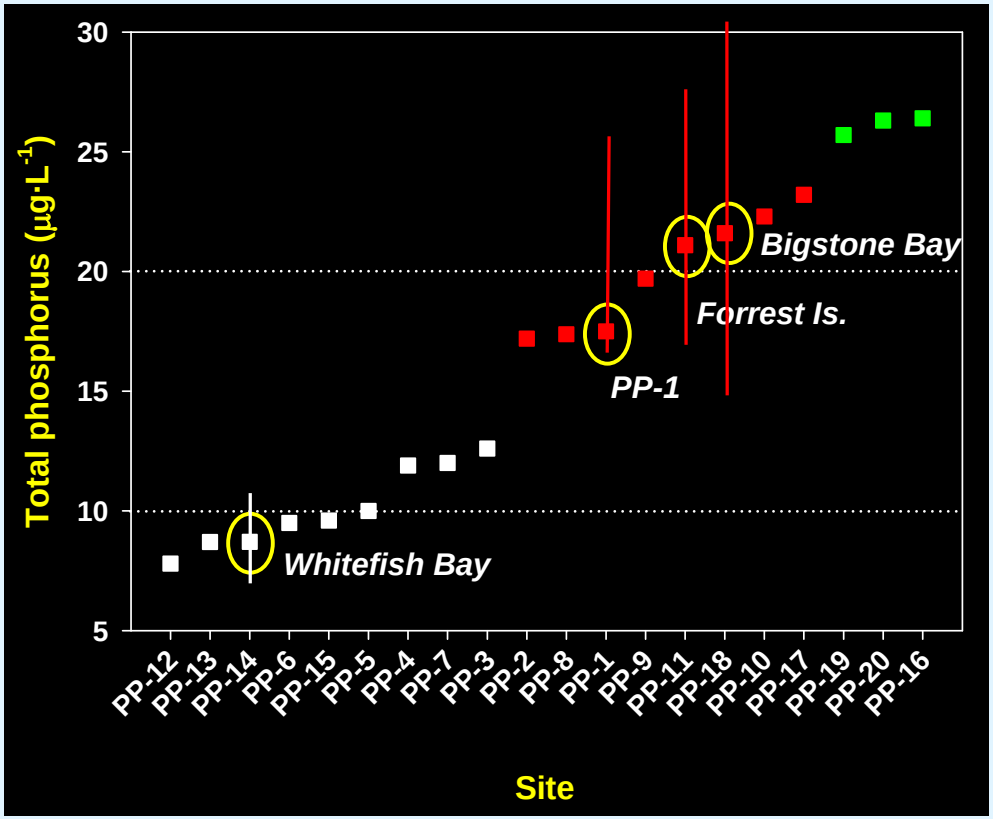
Modified from Robertson & McCracken 2003

Long-term monitoring LoW: high seasonal/interannual variability



Strong spatial nutrient gradient [TP]





Summer measurements

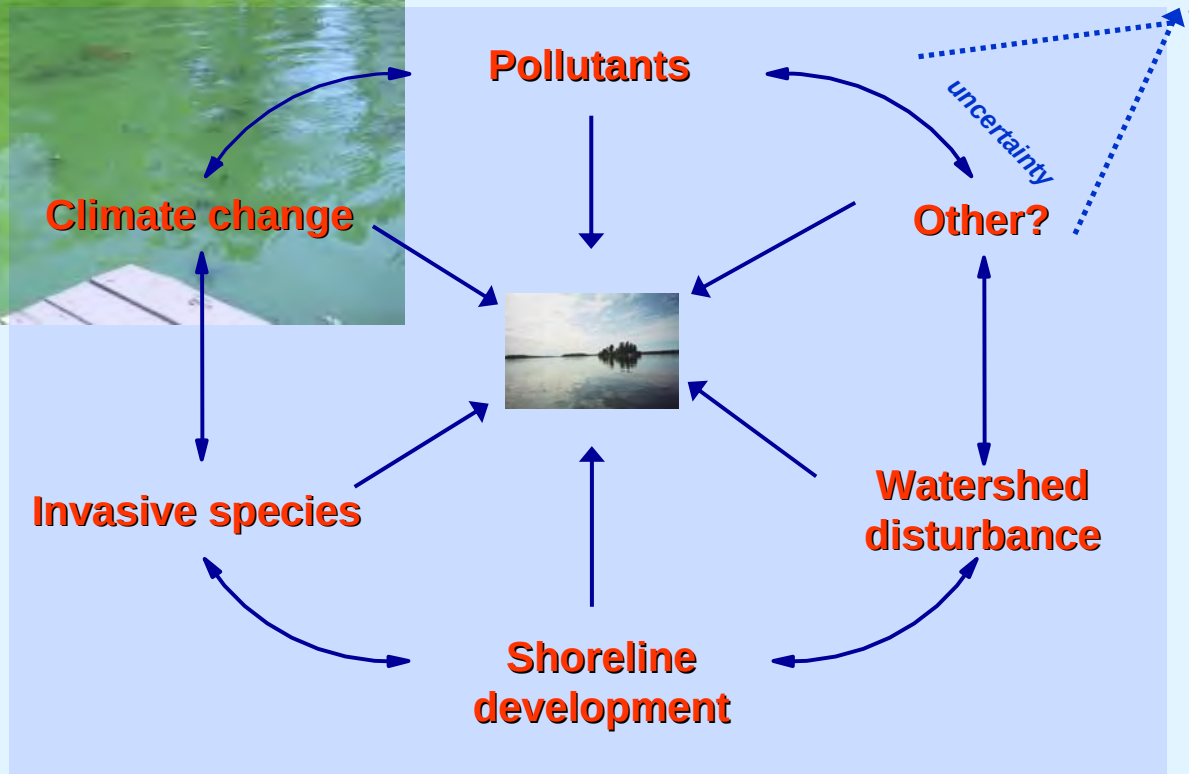
Lake of the Woods training set

Pla et al. 2005*J. Great Lakes Res.* **31**

Multiple threats to water quality and ecology

"Novel combinations of ecosystem stressors may be resulting in novel community composition in aquatic systems…"

Quinlan et al. 2008 Can. J. Fish. Aquat. Sci. 65



"Climate change will affect lakes in very complex ways….future studies need to consider multiple stressor effects."

Keller 2007 Environ. Rev. 15

Development of an Algal Bloom - 2003

**(Terra MODIS images –
G. McCullough, U. of Winnipeg)**

Some Important Lake Management Questions:

1) What is the ‘natural’ or baseline condition of the lake?

2) Has the water quality changed since pre-development (or pre-industrial) times?

3) If so, when did these changes occur?

4) What is the direction and magnitude of this change?

5) What are the possible reasons for this change?

The Paleolimnological Approach

Paleolimnology can provide us with many of these answers

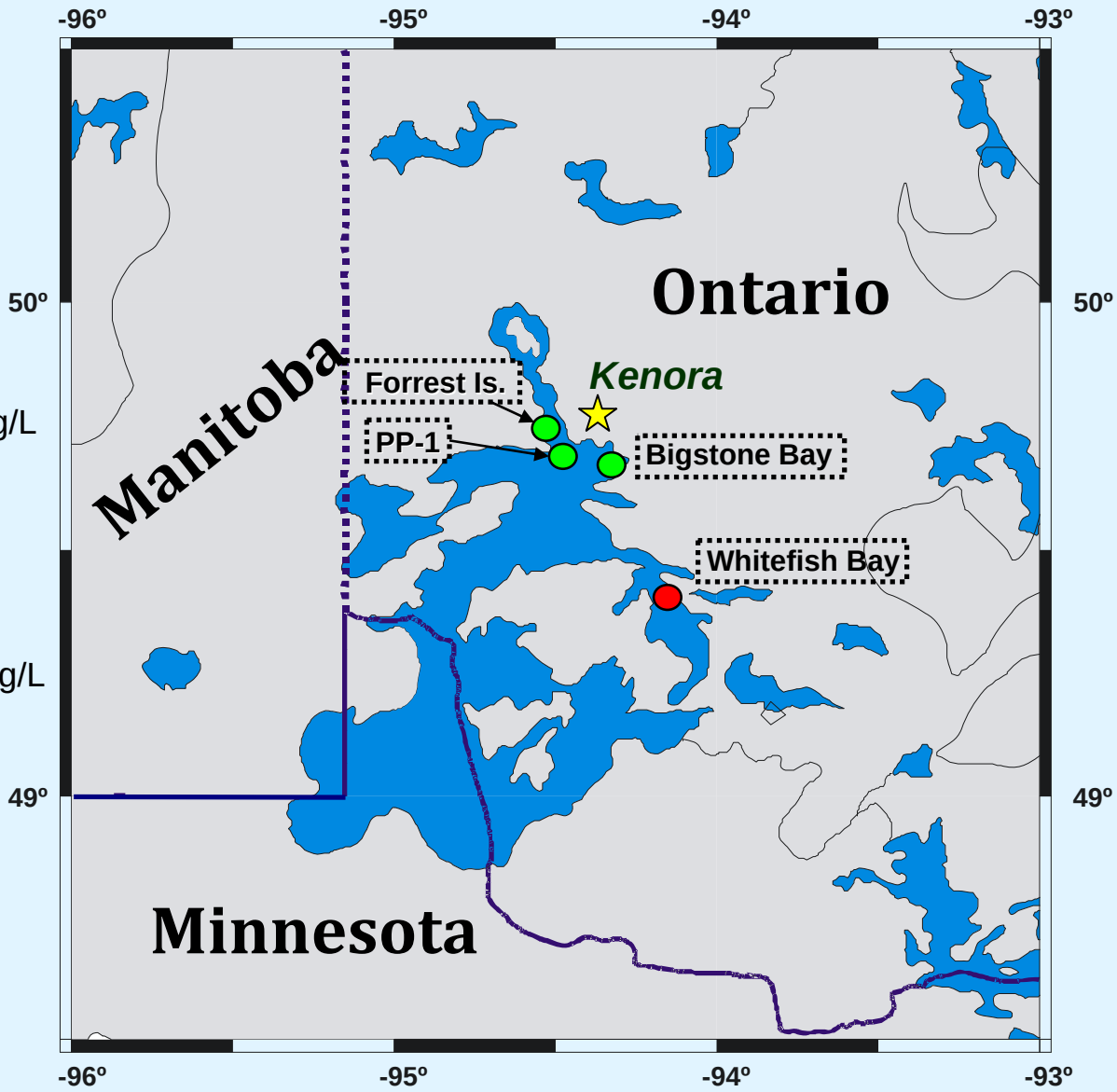
Location of sampling sites for sediment cores

Impact Site

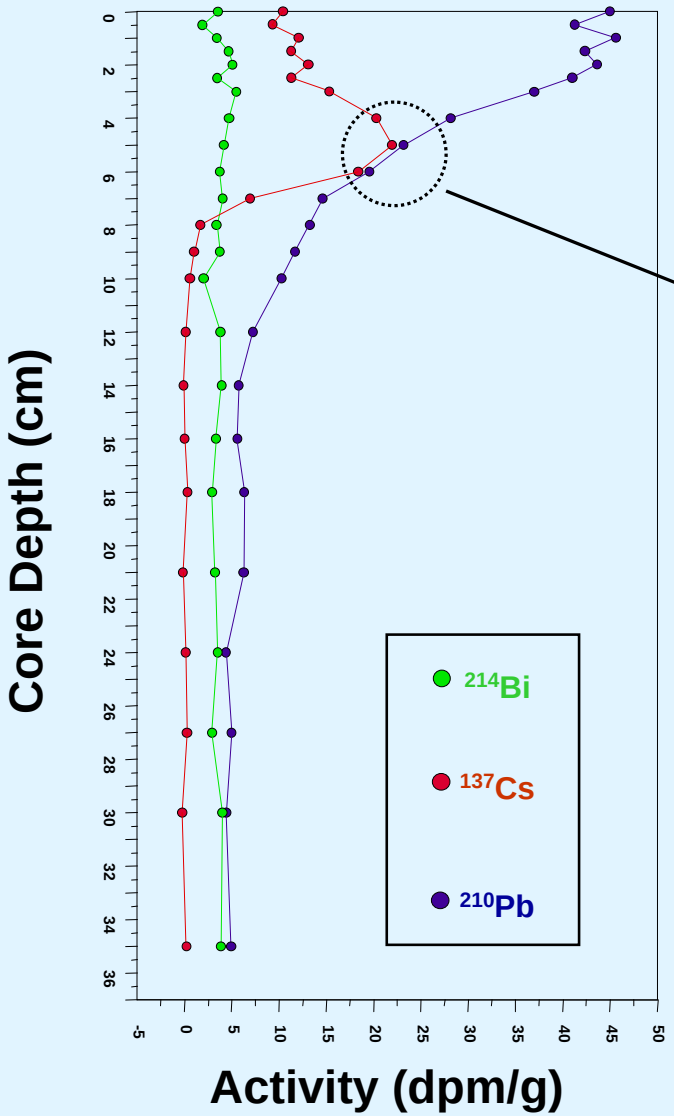
[TP] range: ~17-38 µg/L

Reference Site

[TP] range: ~7.5-10 µg/L



The Paleolimnological Method



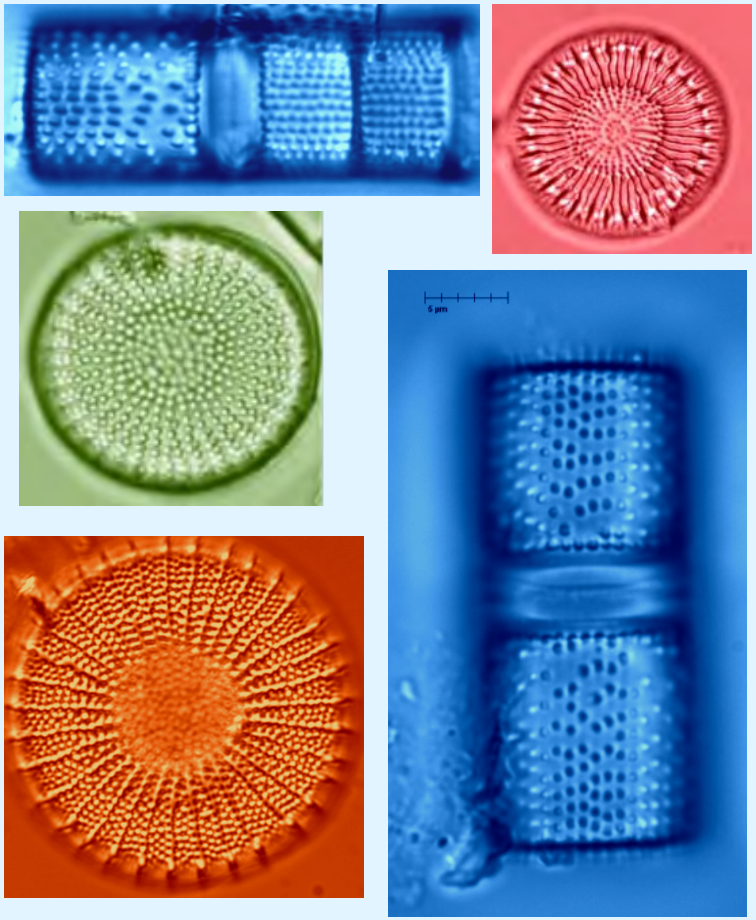
Dating the sedimentary sequences

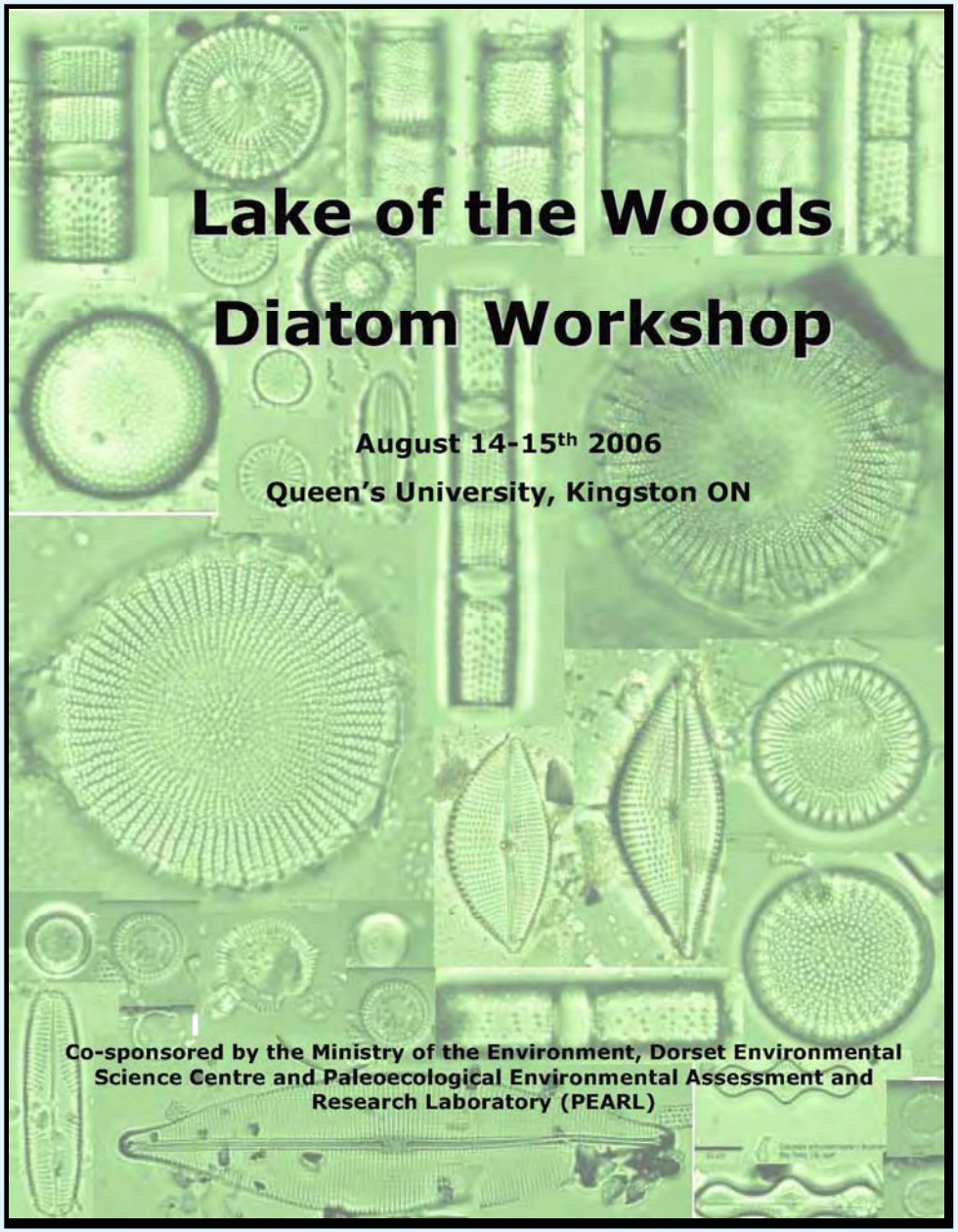
- ^{210}Pb (radioisotope)
- ^{137}Cs peak ca. 1963
  - corresponds to nuclear test ban treaty

The Paleolimnological Method

Diatoms as Indicators of Environmental Change

- well preserved in lake sediments
- remain stable in sedimentary sequences
- taxonomically specific ornamentation
- many have narrow optima and tolerances
- respond rapidly to environmental change





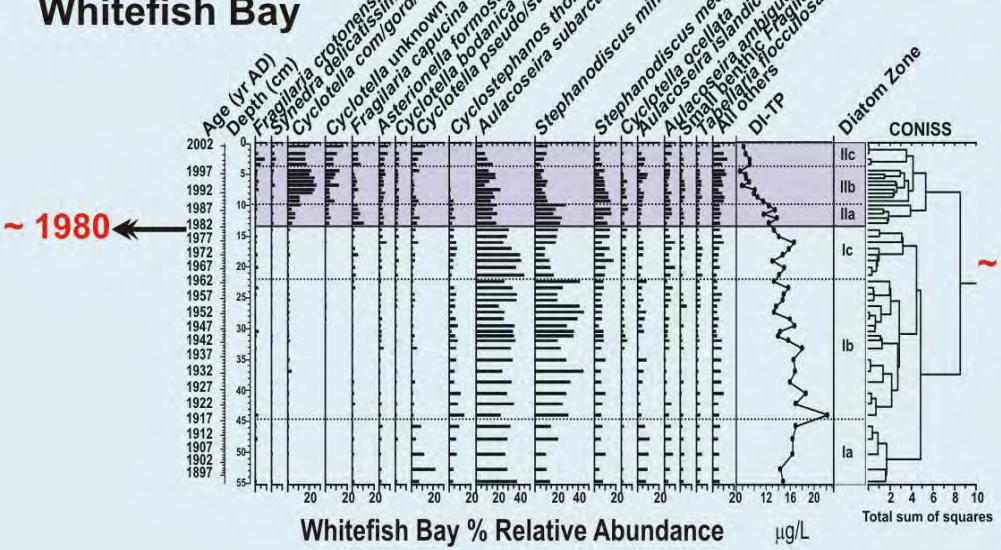
- **Exchange of diatom datasets requires taxonomic consistency**

- **Diatom workshop, August 2006**

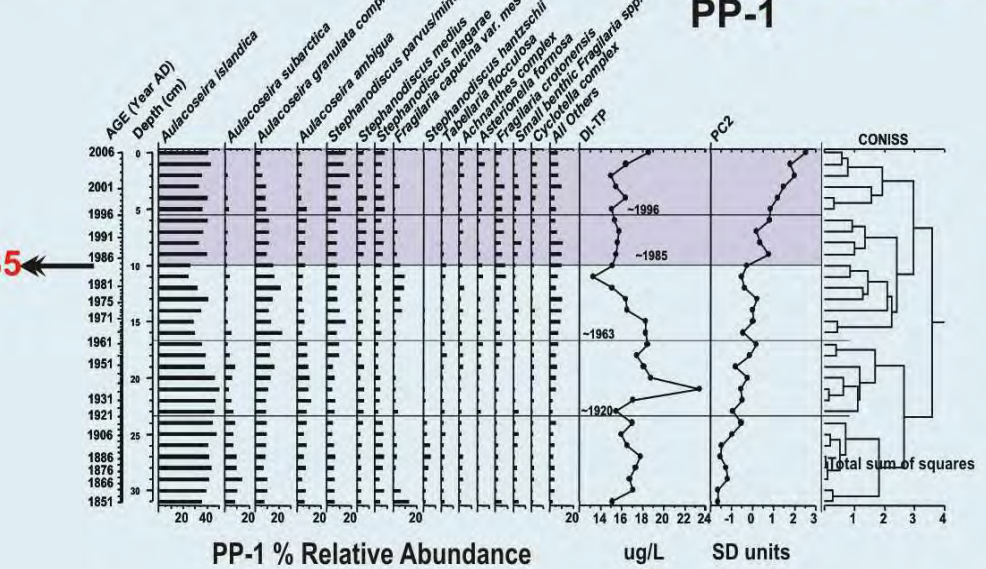
http://biology.queensu.ca/low/

DIATOM ANALYSIS

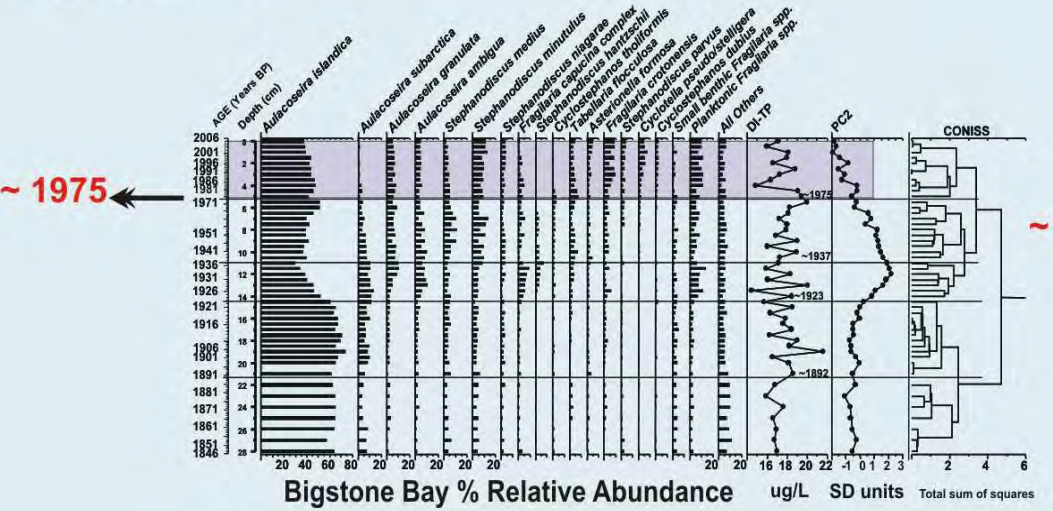
REFERENCE SITE:
Whitefish Bay



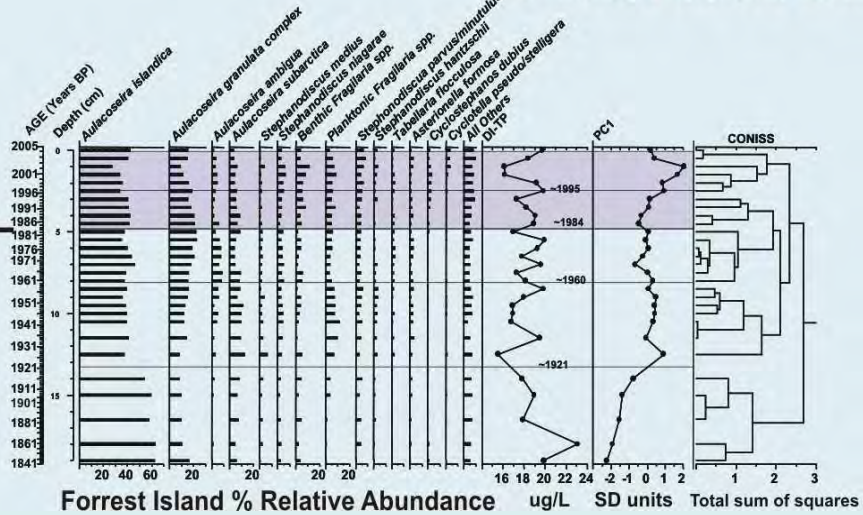
IMPACT SITE:
PP-1



IMPACT SITE:
Bigstone Bay



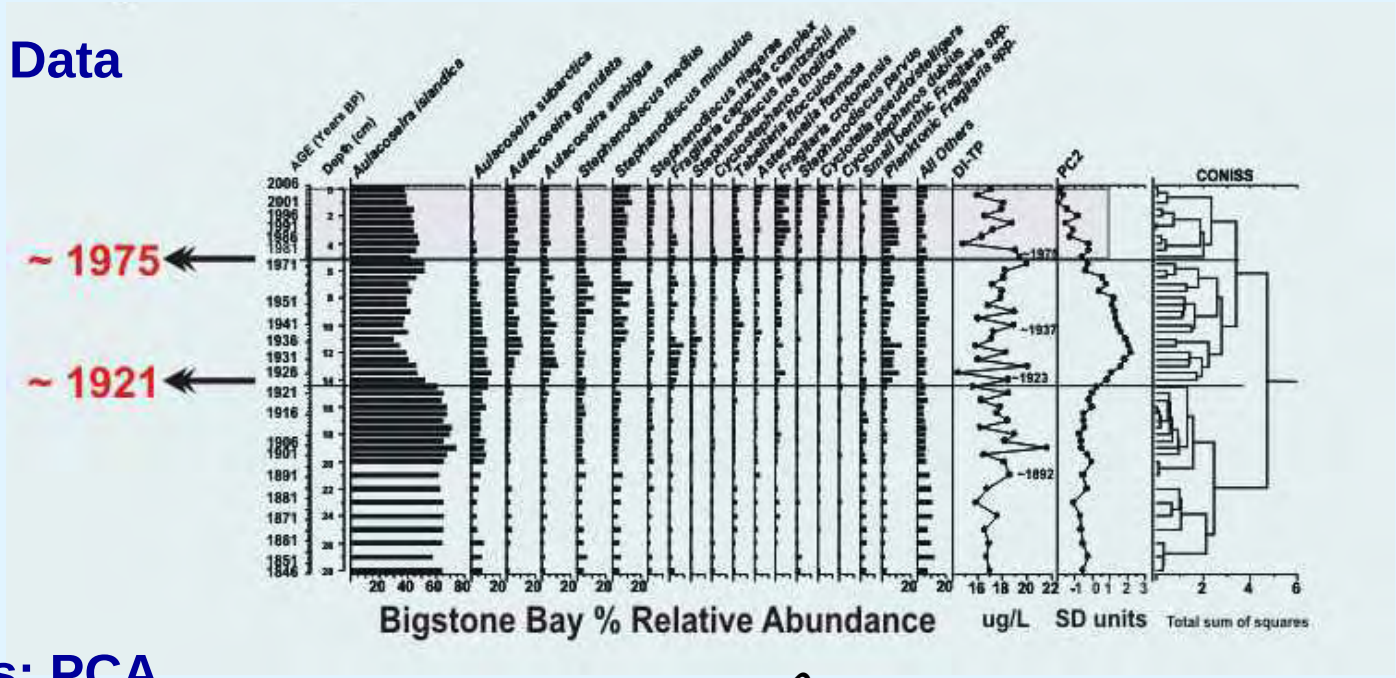
IMPACT SITE:
Forrest Island Site



Rühland et al. in prep.

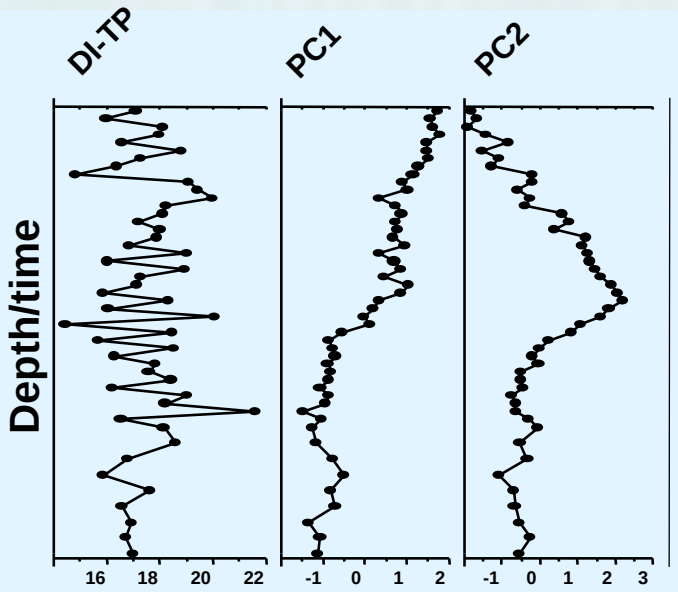
Summary of Diatom Trends: PCA & DI-TP

Diatom Primary Data



Data Summaries: PCA

- Compare among sites & other env. variables
  - timing
  - magnitude
  - direction



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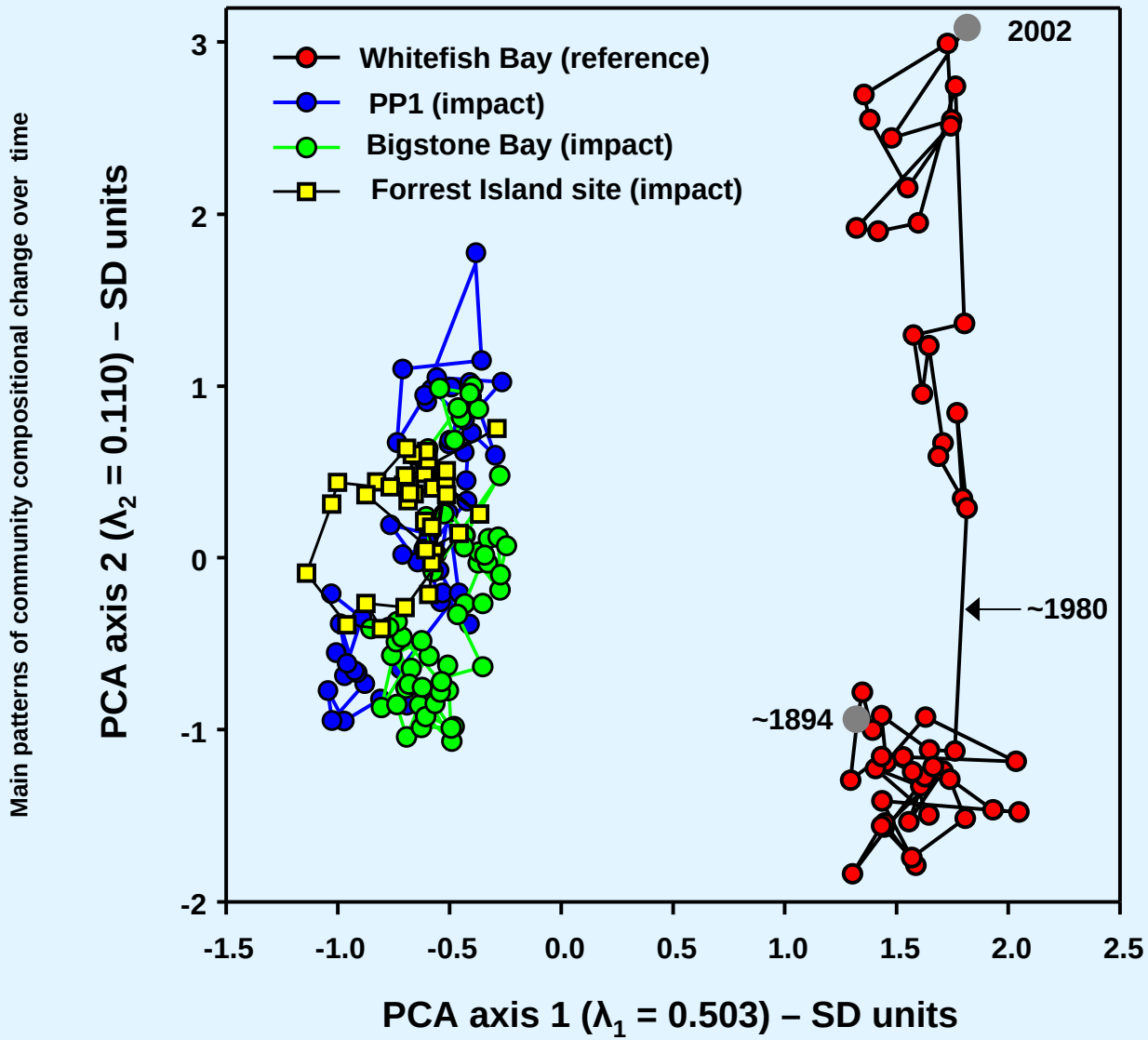
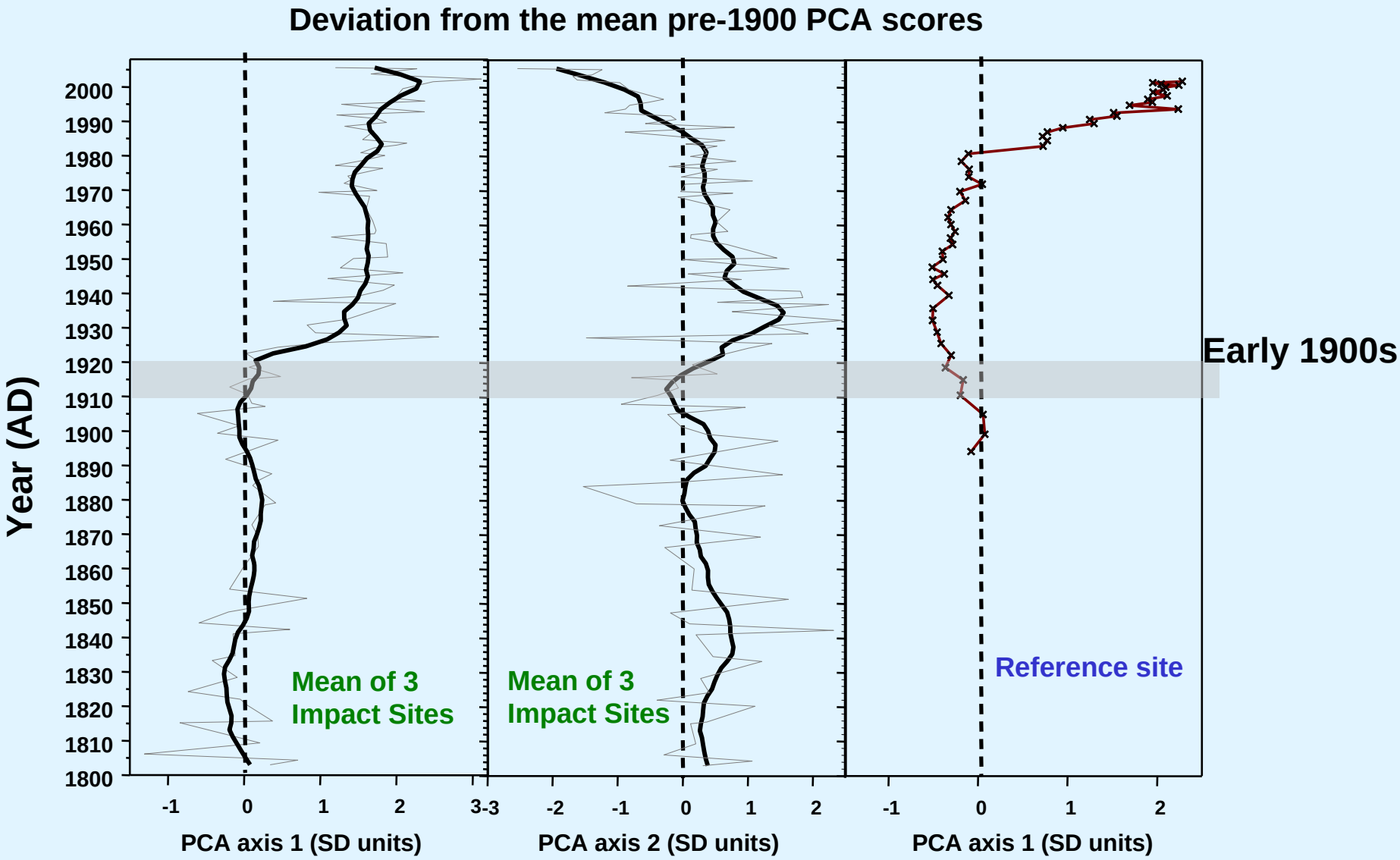
Summary of Diatom Trends: trajectories through time



Difference between impact sites and reference site is apparent

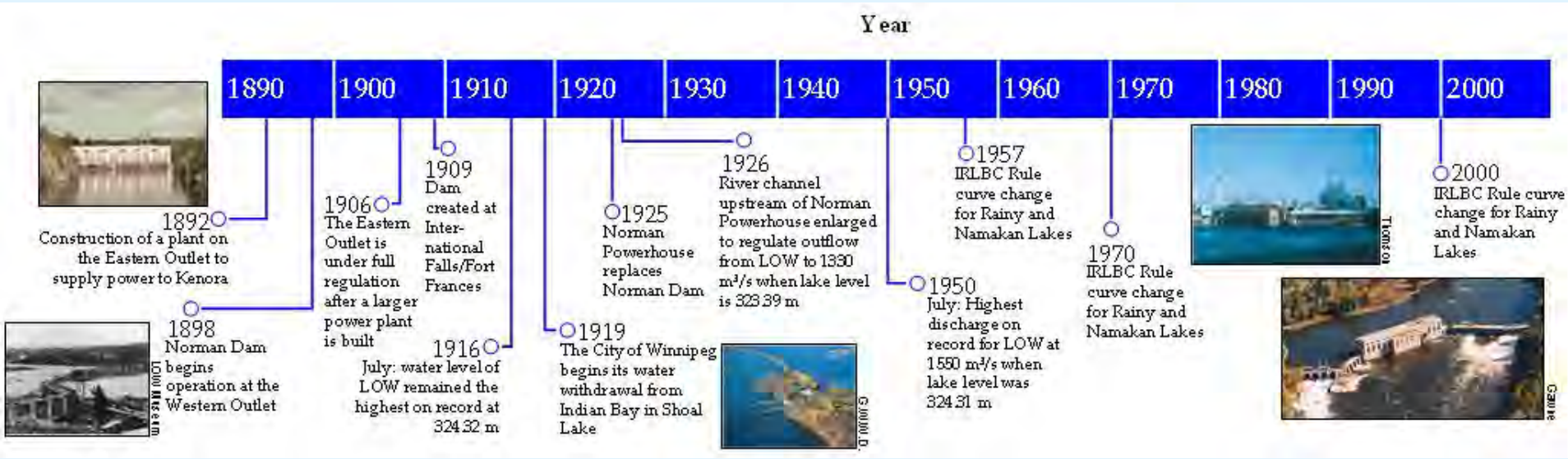
Rühland et al. in prep.

Summary of Diatom Trends: PCA downcore



Rühland et al. in prep.

Early 1900s events: LoW water levels are highest on record

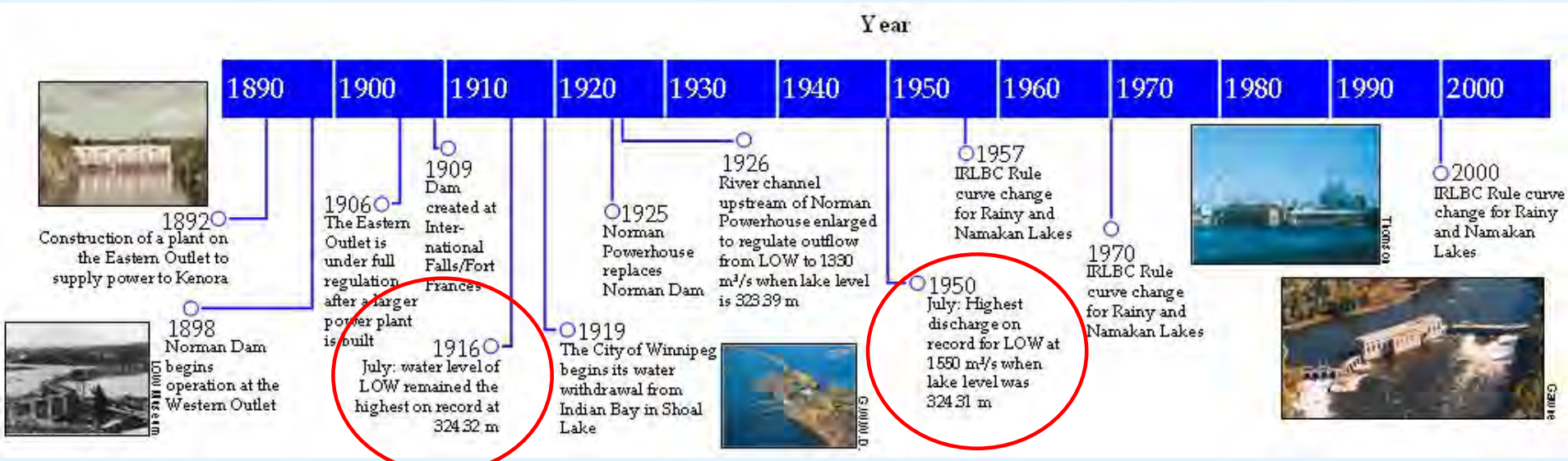


Historical timeline

- **1887**: Rollerway Dam built on western outlet to Winnipeg R.
- **1892**: Power plant constructed on eastern outlet for Kenora
- **1898**: Norman Dam begins operation
- **1906**: Larger power plant built & eastern outlet fully regulated

From DeSellas et al. SOBR

Early 1900s events: LoW water levels are highest on record



Historical timeline

- **1916: July water level of LOW highest on record**
  - **IJC recommended the expansion in the outflow capacity of the lake**
  - **benefits shown in 1950 when a flood containing 40% more water occurred but LOW was contained to a lower level**

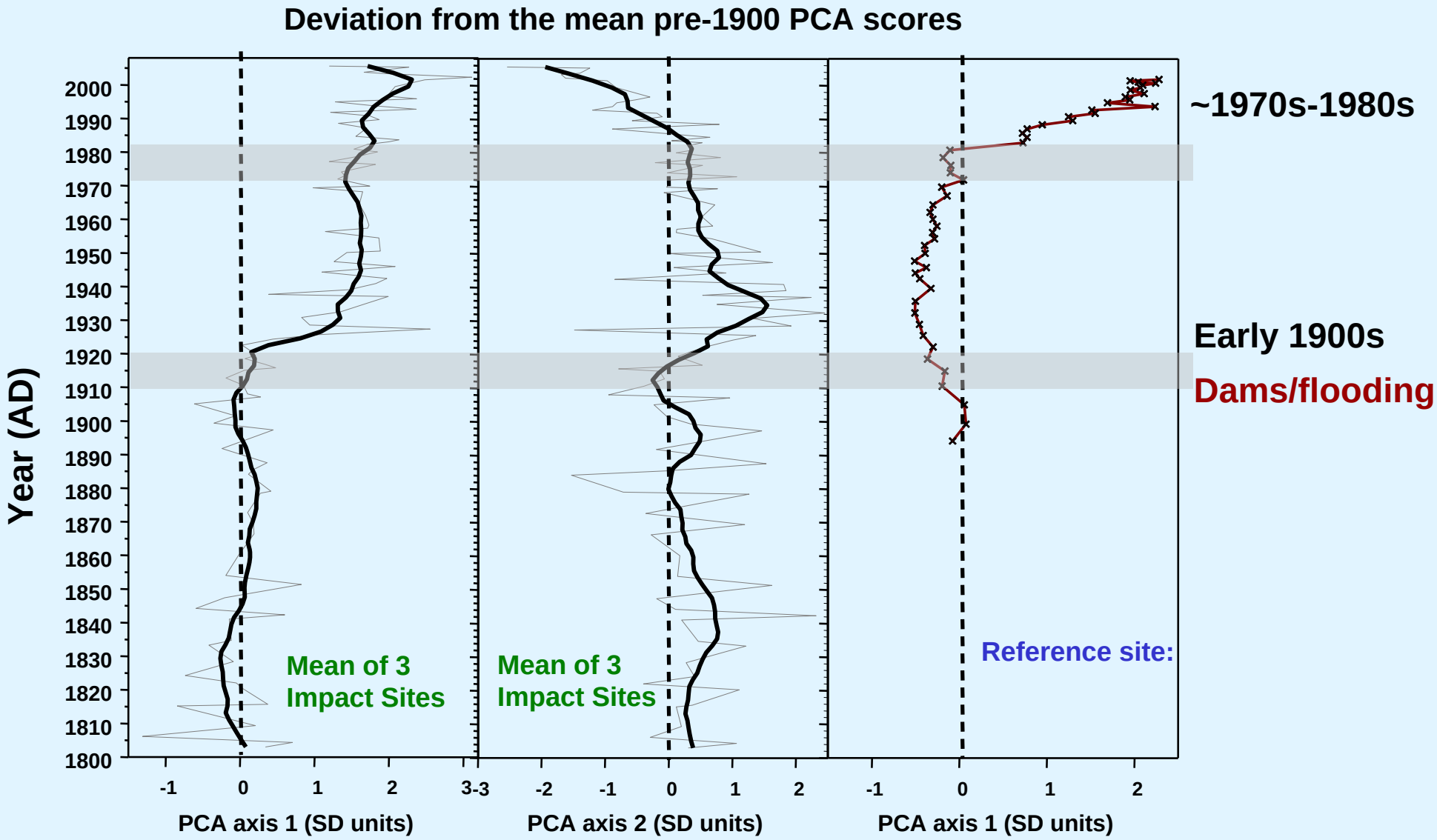
From "Managing the Water Resources of the Winnipeg River Drainage Basin". LWCB 2002.

From DeSellas et al. SOBR

Flooding: government dock at the foot of Main St., Kenora ca. 1916

Photo courtesy of the Lake of the Woods Museum, Kenora

Summary of Diatom Trends: PCA downcore



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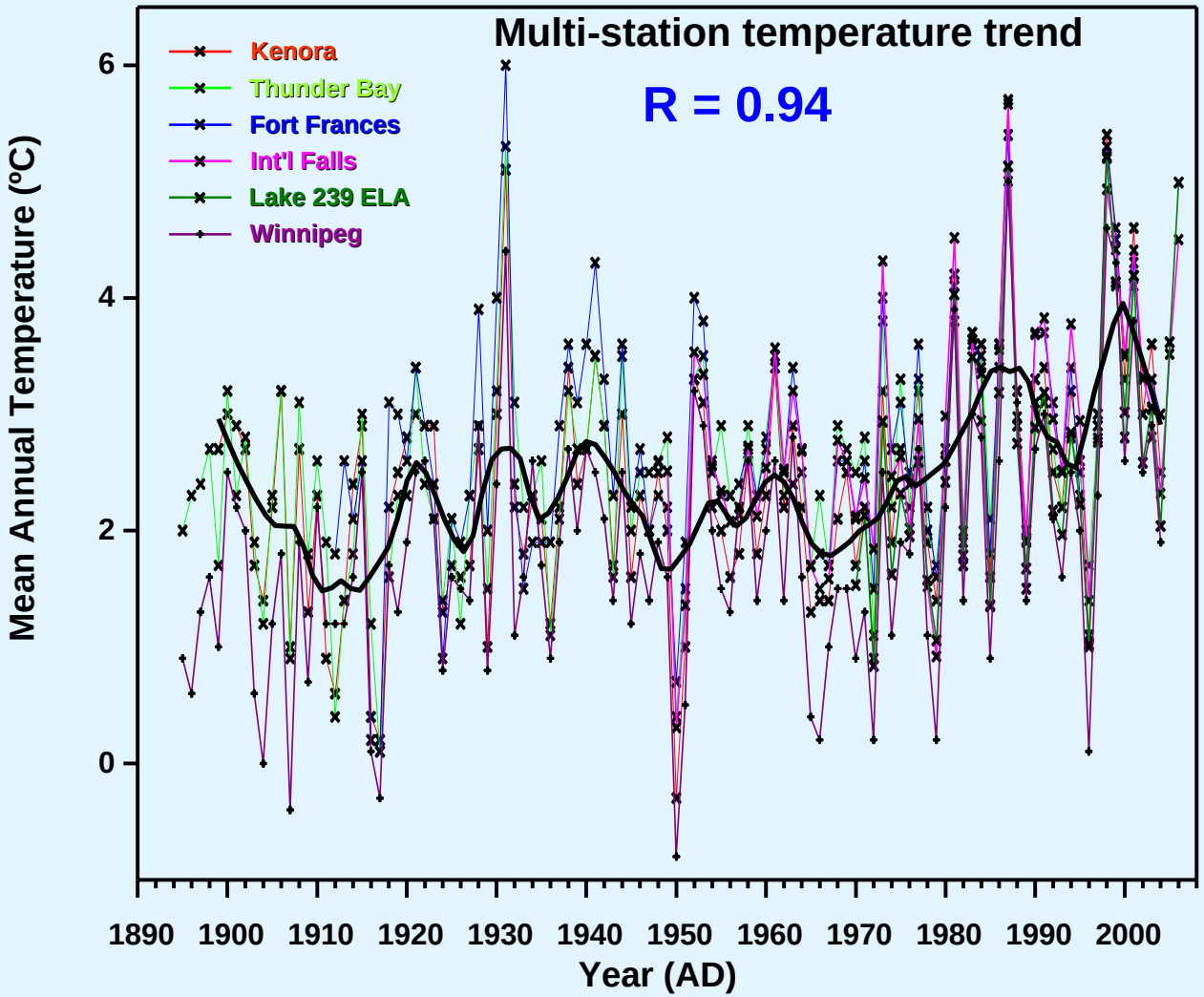
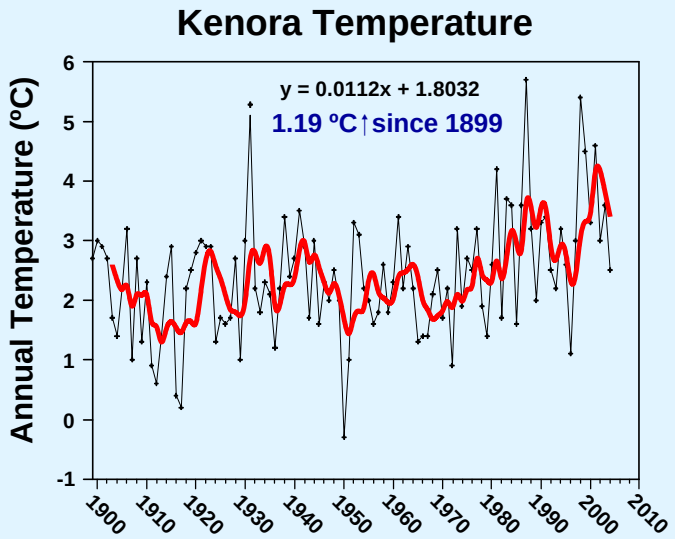
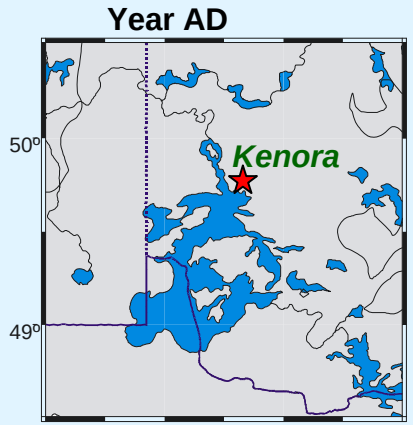
The Instrumental Record

Mean Annual Temperature in Kenora increased by **~1.2º C** in last 106 years







Environment Canada data

(http://www.cccma.ec.gc.ca/hccd/)

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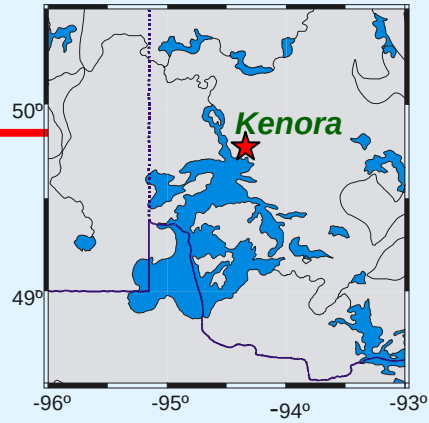
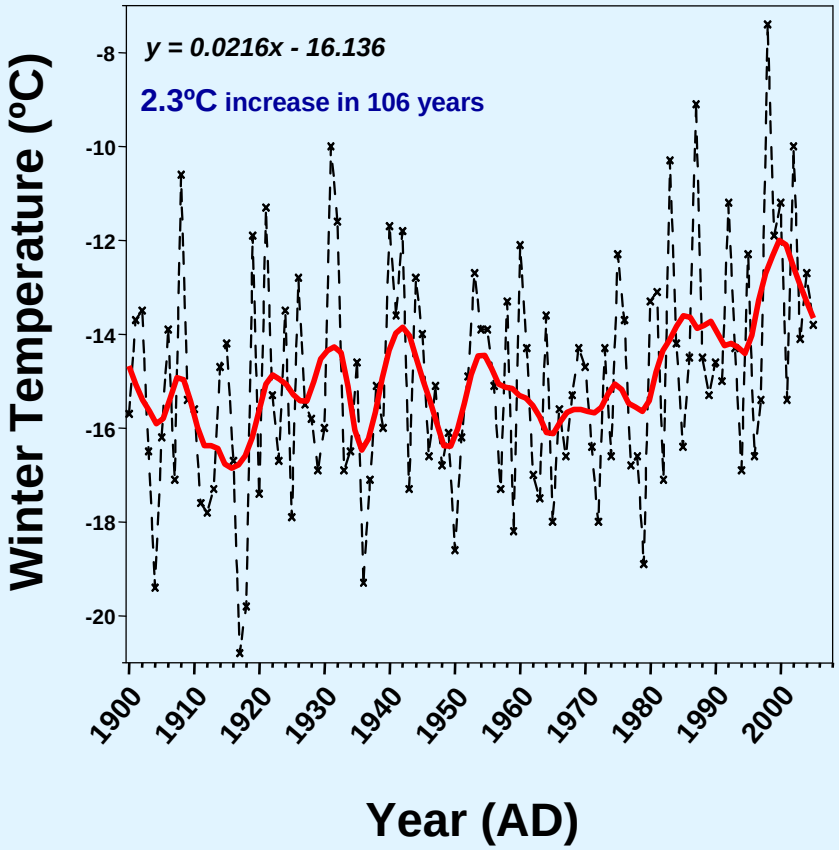
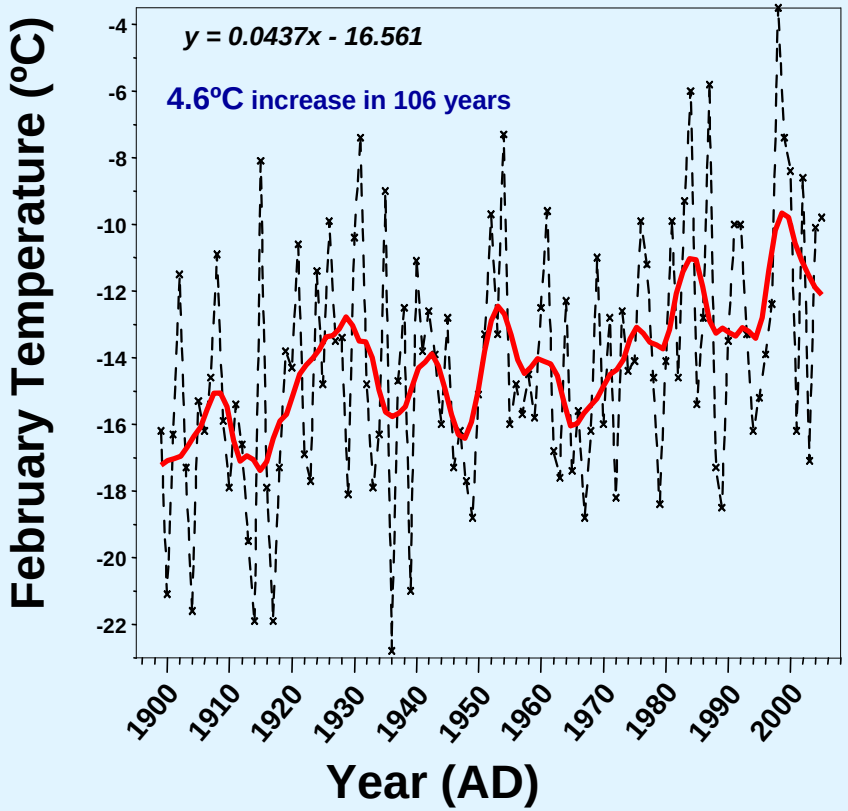
Kenora 100-year Temperature Record



Winter



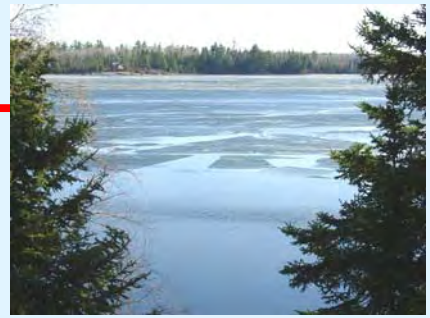
February



Rühland et al. in prep.

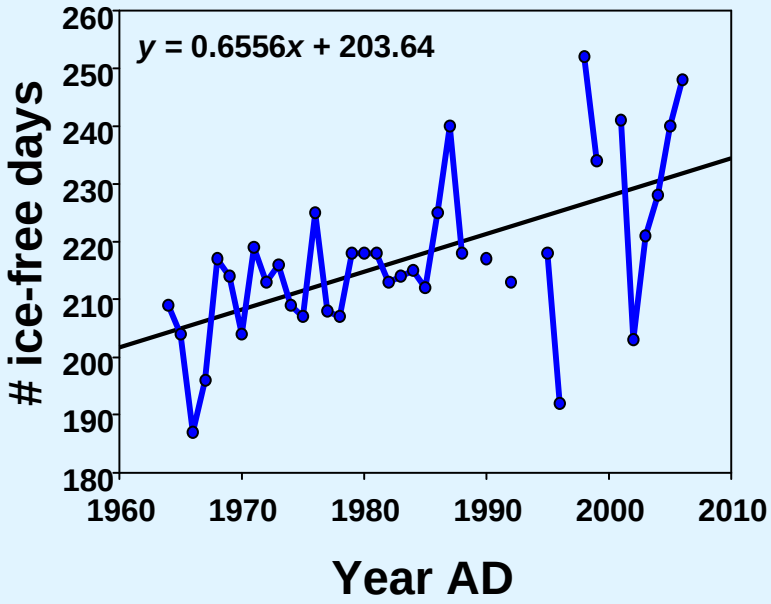
Environment Canada data
(http://www.cccma.ec.gc.ca/hccd/)

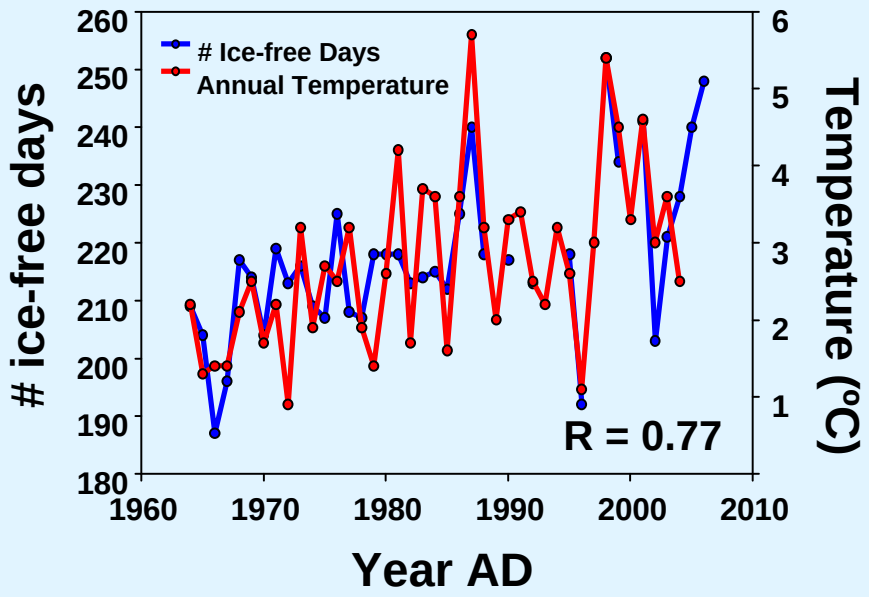
Whitefish Bay Ice Cover Record



"The longer & colder a winter is, the earlier lakes freeze & the later they thaw."

David M. Livingstone 2005





- Ice-free period increased by **27.7** days since 1964
- Corresponds to increased temperatures

Data from Ministry of Natural Resources, Kenora, Ontario, Canada

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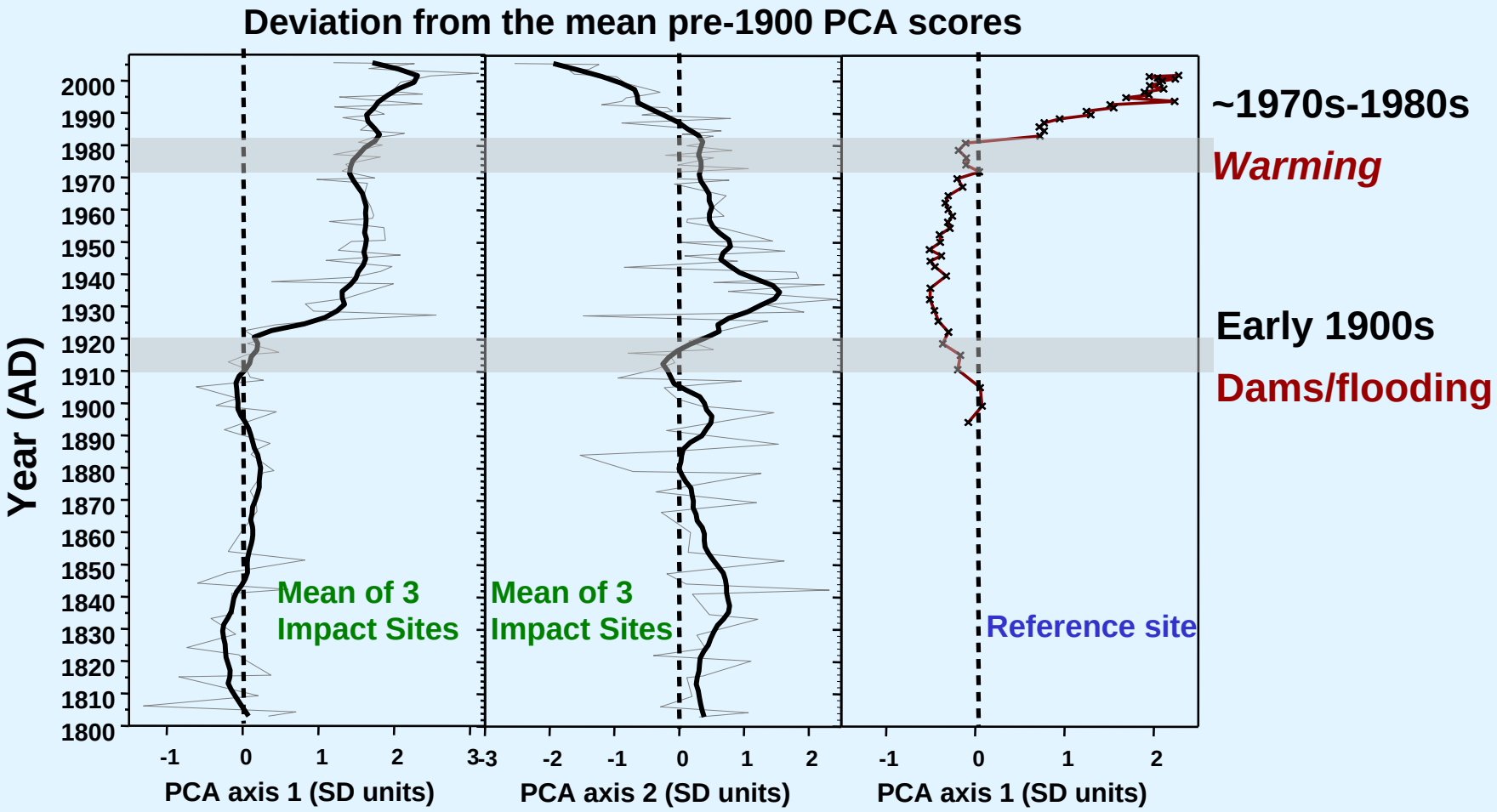
Summary of Diatom Trends:

Diatom compositional changes (PCA scores) agree with timing of hydromanagement activities in early 1900s and warmer temperatures in the last few decades



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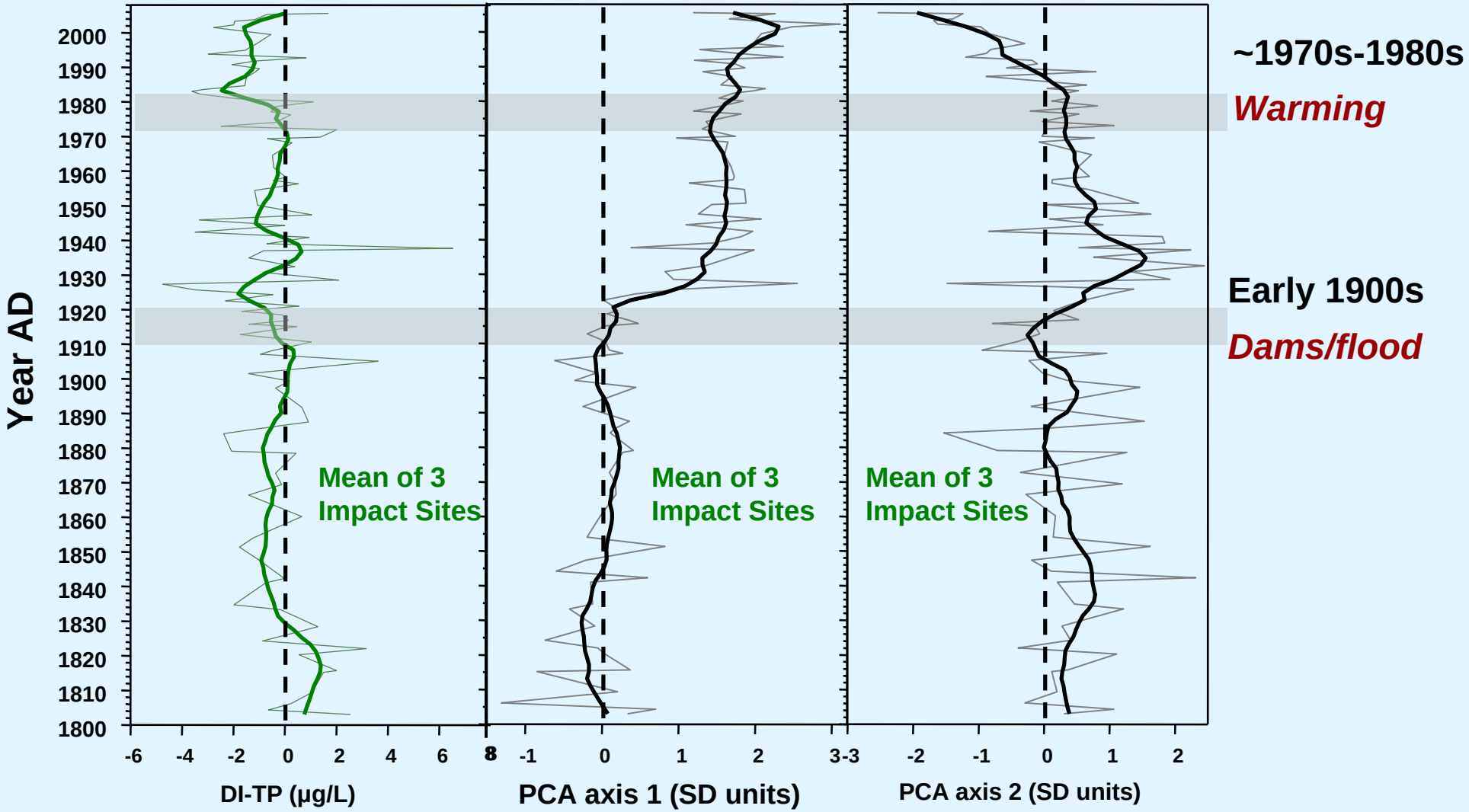
Summary of Diatom Trends: PCA & DI-TP downcore IMPACT SITES

Deviation from the mean pre-1900 diatom-inferred Total Phosphorus [DI-TP] & PCA scores



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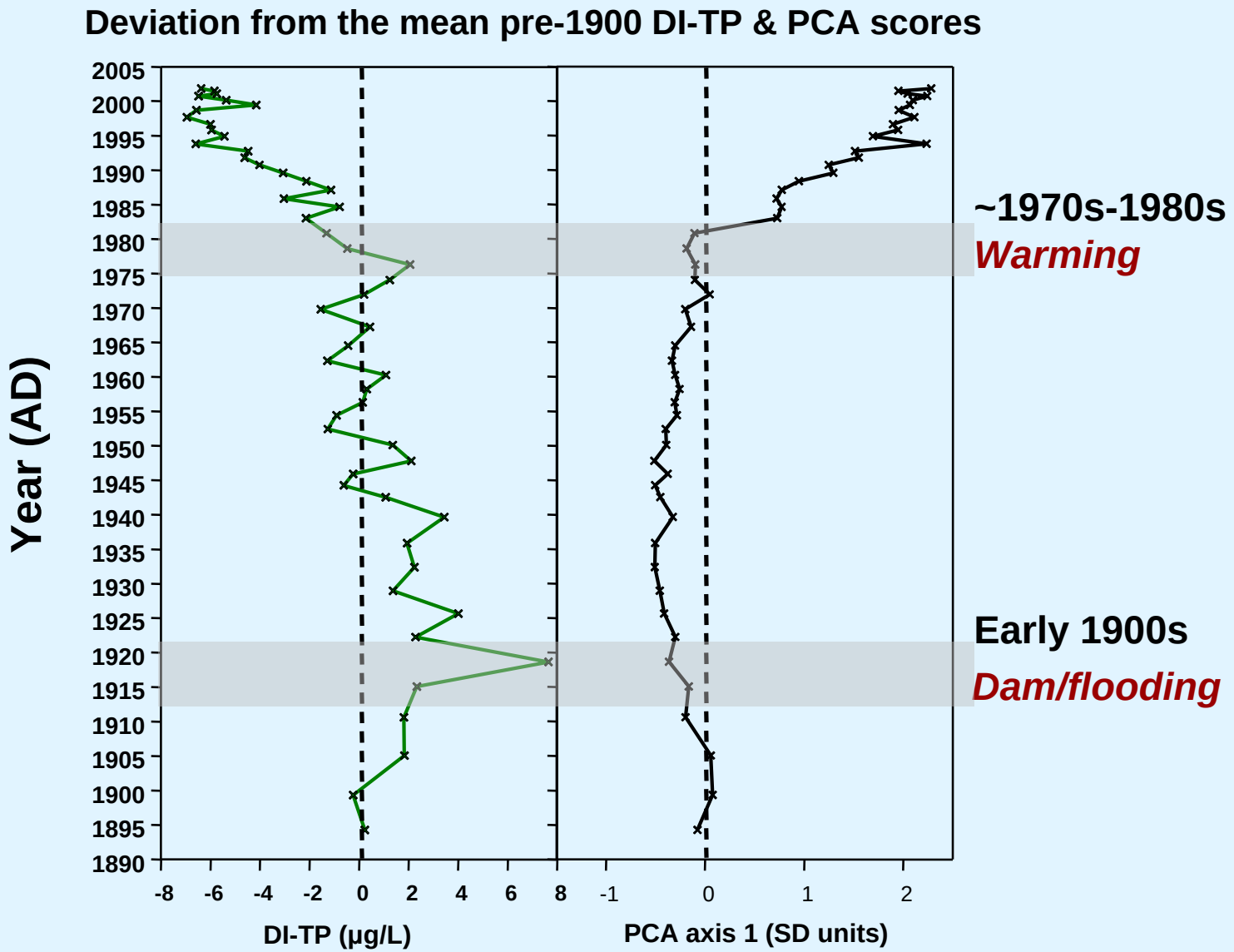
Summary of Diatom Trends: PCA & DI-TP downcore REFERENCE SITE



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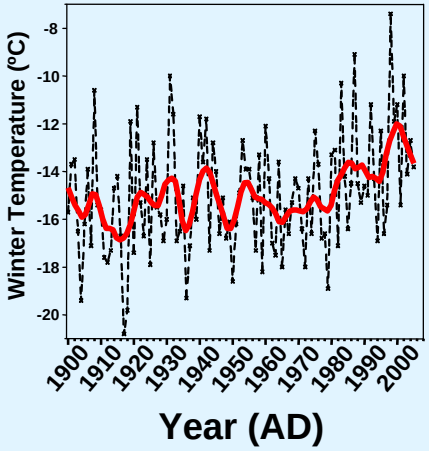
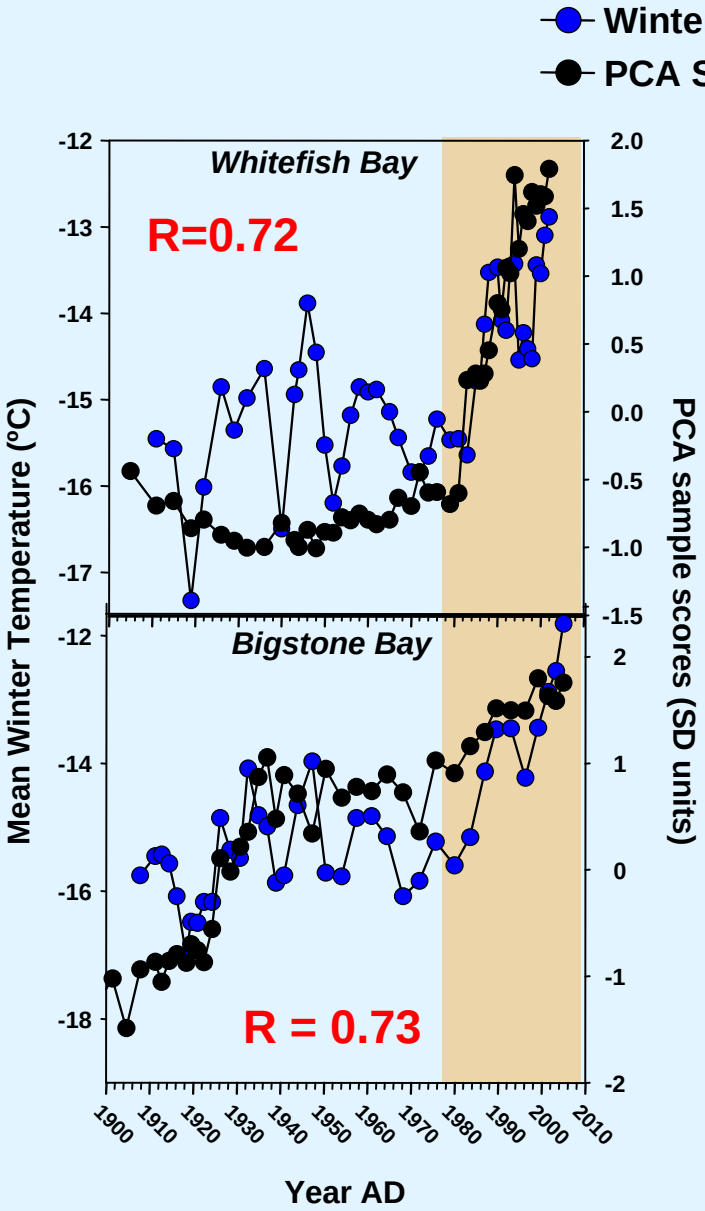
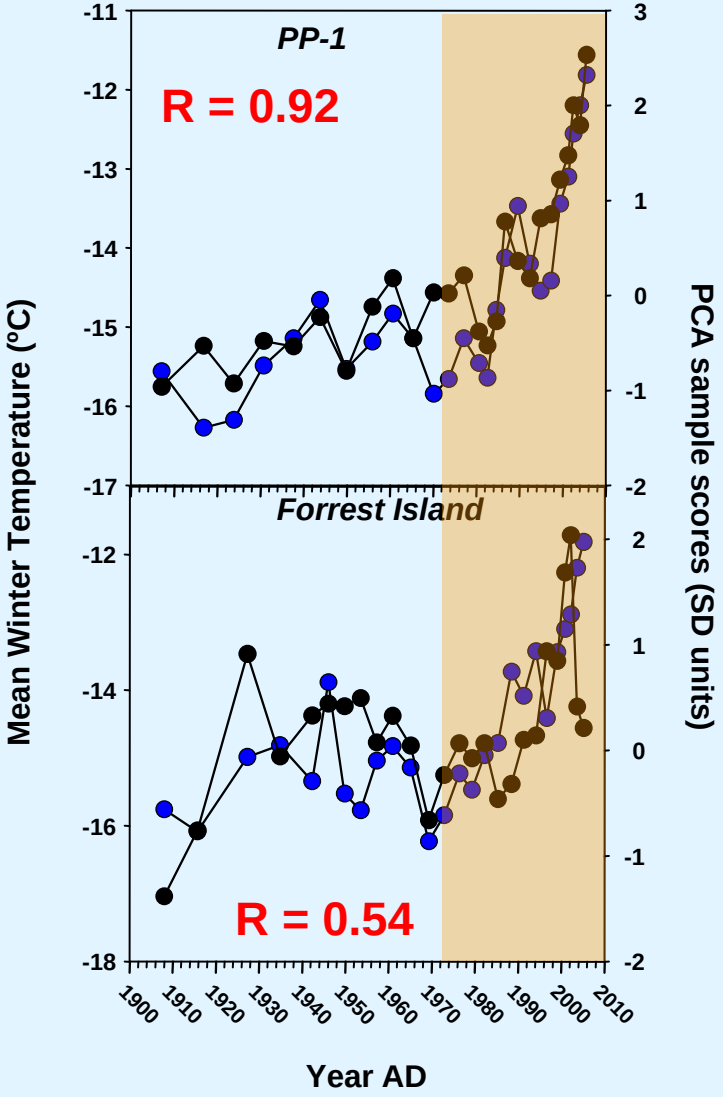
Diatom – Kenora Temperature Relationships







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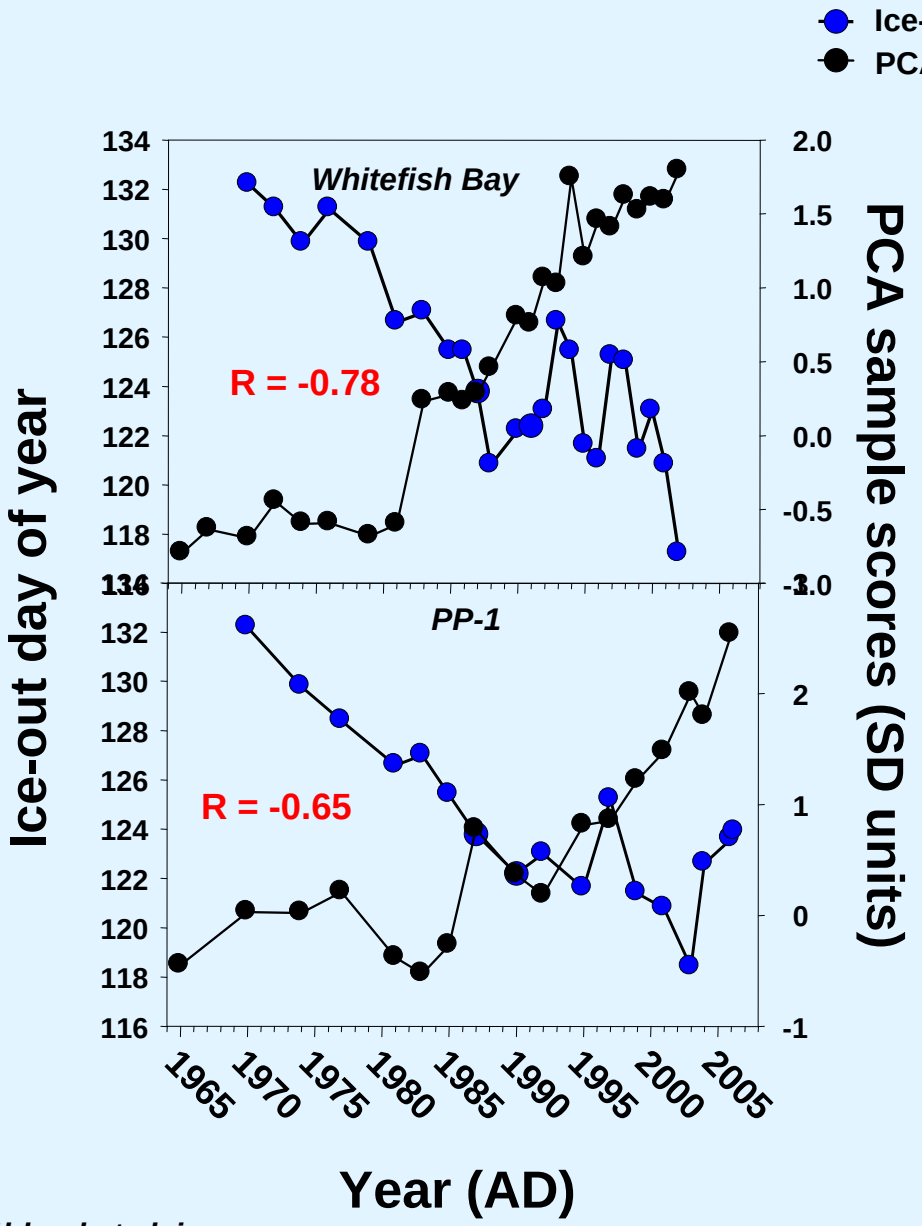
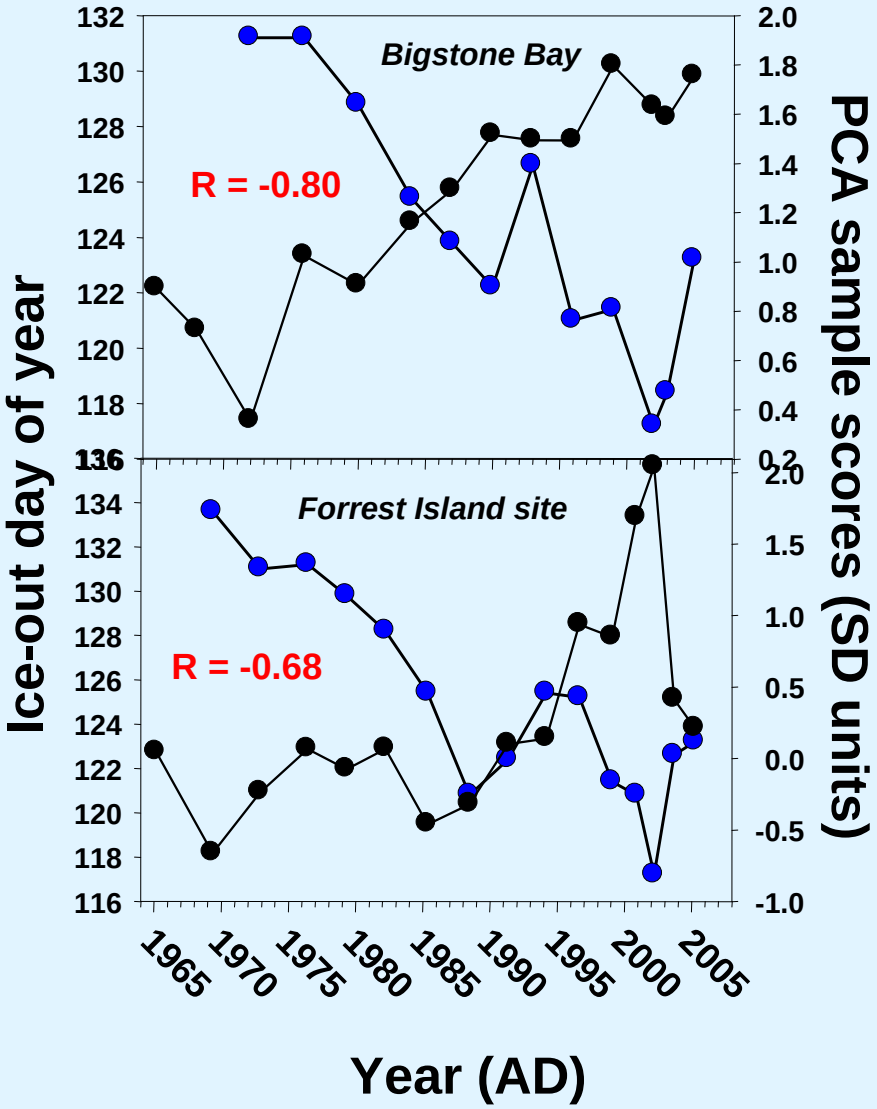
Diatom – Whitefish Bay Ice-out Relationships





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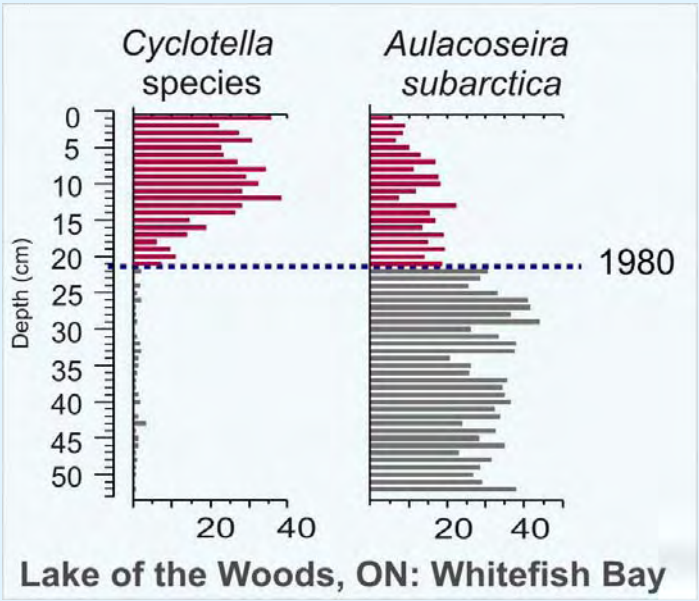
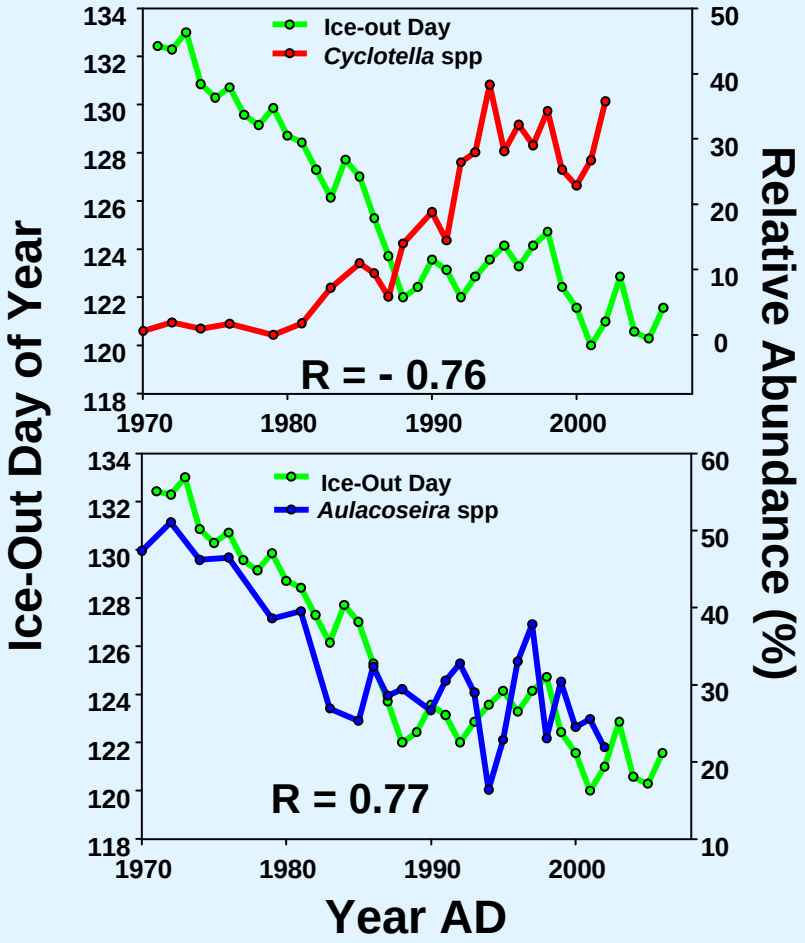
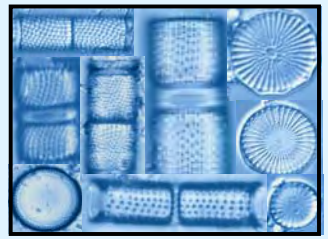
Taxon-specific Relationships

Whitefish Bay – Reference site







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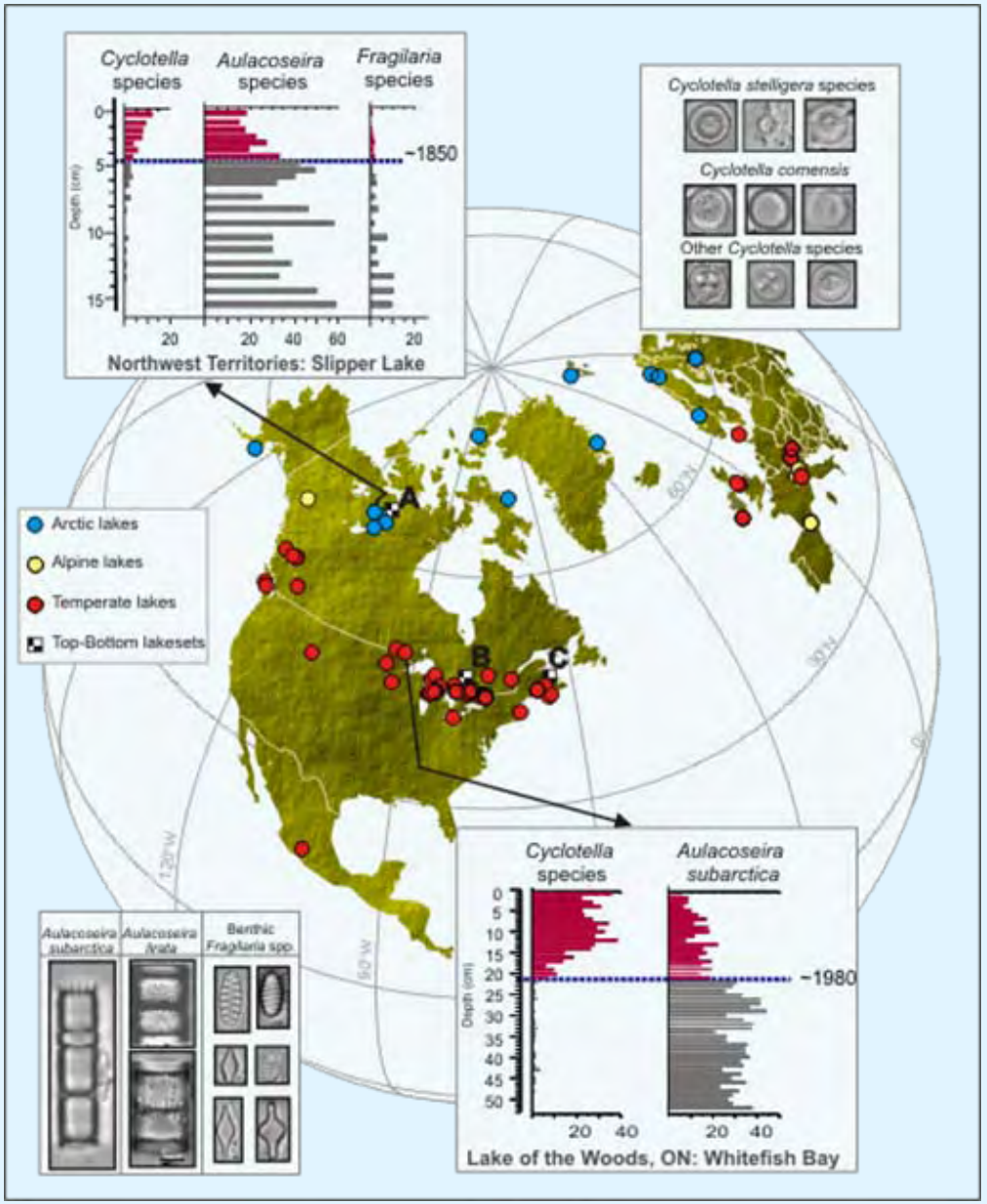
Warming & Hemispheric –scale shifts in *Cyclotella* Species



- Synthesis of >200 diatom-based paleo records
  - non-acidified/non-enriched lakes
- Changes in habitat structure/quality
  - hemispheric warming
- Increases in rel. abundances *Cyclotella* taxa
- Decrease in *Aulacoseira* and/or benthic *Fragilaria* taxa

- Spatially coherent picture that climate-driven taxon-specific changes are now evident across the Northern Hemisphere representing a wide spectrum of lakes.

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Summary of Results

- Diatom Assemblages
  - clearly different between impact sites & reference site
  - clearly similar among 3 impact sites
- Strong temporal coherence among all sites
  - ca. 1900s –post-dam construction & rise in water level
  - last few decades – increased temperatures & longer ice-free period
- DI-TP trends
  - minimal directional changes- 3 impact sites- main direction of diatom changes not tracking changes in [TP]
  - reference site decreasing trend post-1970s-80s
- High diatom correlations to temperature & lake-ice trends
- Taxon-specific shifts - warmer temperatures, longer ice-free period & associated changes in water column

Concluding Remarks

- Paleolimnological techniques
  - determines background ecological conditions
  - extends the environmental record
- Multiple stressors on LoW include hydro-management & recent warming
  - affect lake in complex ways
- Climatically-induced limnological changes = important mechanism
- Climate must be considered an important part of the equation

Acknowledgements

- Tom Mosindy (MNR Kenora)
- Gavin Olson (MNR Kenora)
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- Ron Ingram (MOE, Dorset)
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