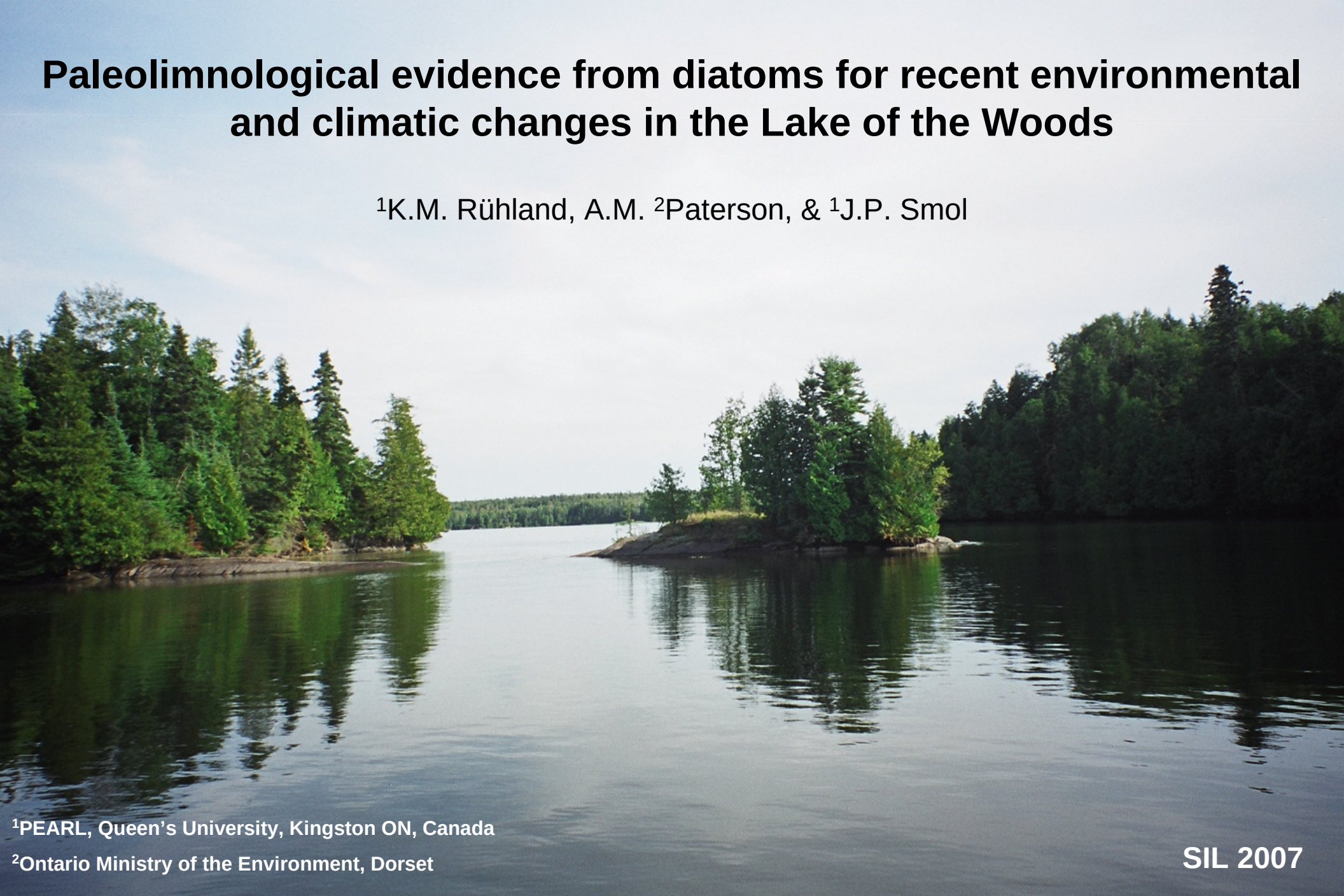
# Paleolimnological evidence from diatoms for recent environmental and climatic changes in the Lake of the Woods

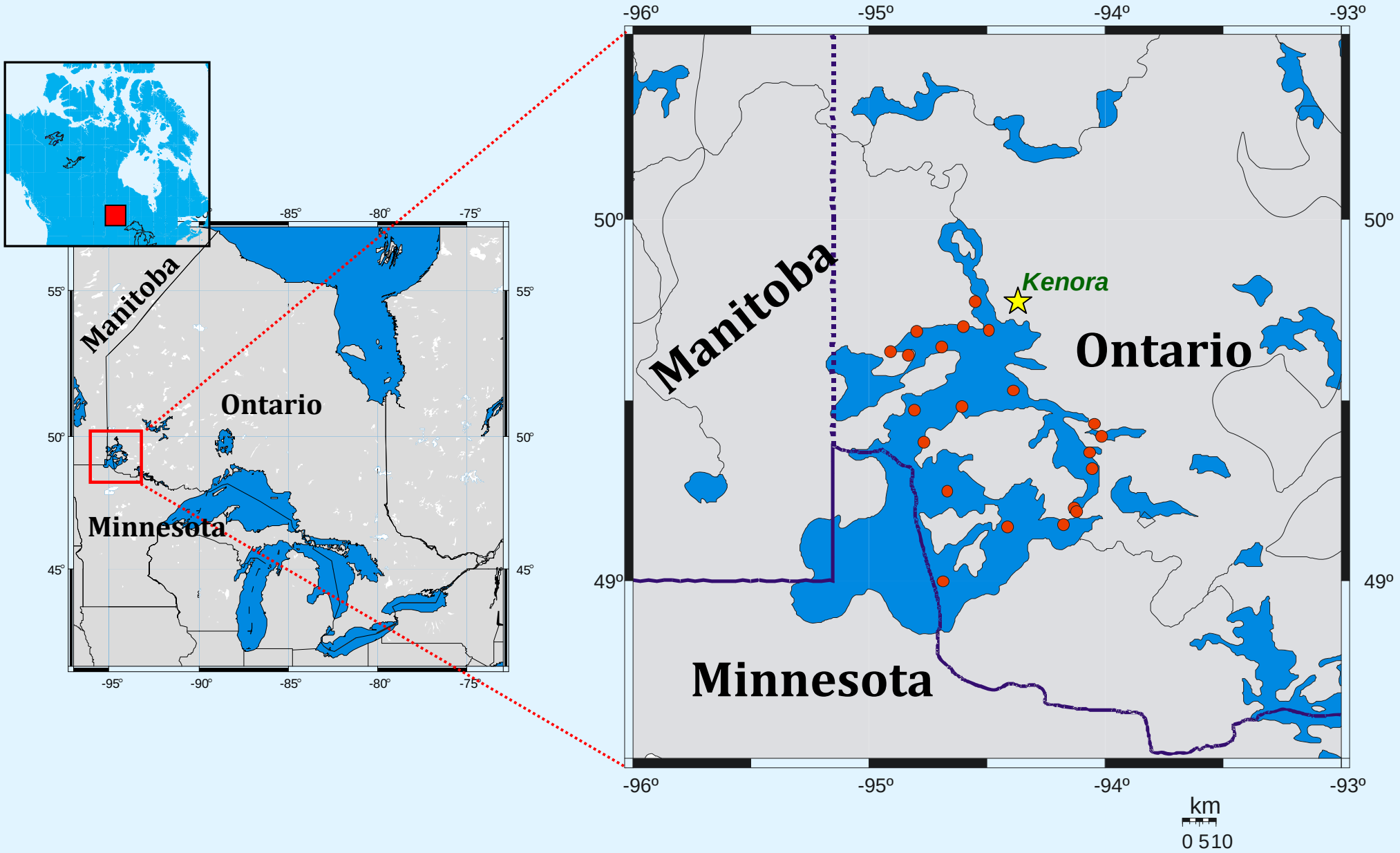
[1]K.M. Rühland, A.M. [2]Paterson, & [1]J.P. Smol



[1]PEARL, Queen's University, Kingston ON, Canada

[2]Ontario Ministry of the Environment, Dorset

SIL 2007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*Modified from Robertson & McCracken 2003*

# Development of an Algal Bloom - 2003




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

**“The islands were numerous and crowded, the water shoal and foul, frequently with a green scum of vegetable matter”**

- **Major Joseph Delafield, July 30th, 1823**

**“…the water became tinged with green, derived from a minute vegetable growth”**

- **S. J. Dawson, Summer 1857**

**“…deposits of green vegetable matter” in the lake’s bays during the summer.**

- **objection to a proposal to use LOW to supply clean water to Winnipeg 1883**

# 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?

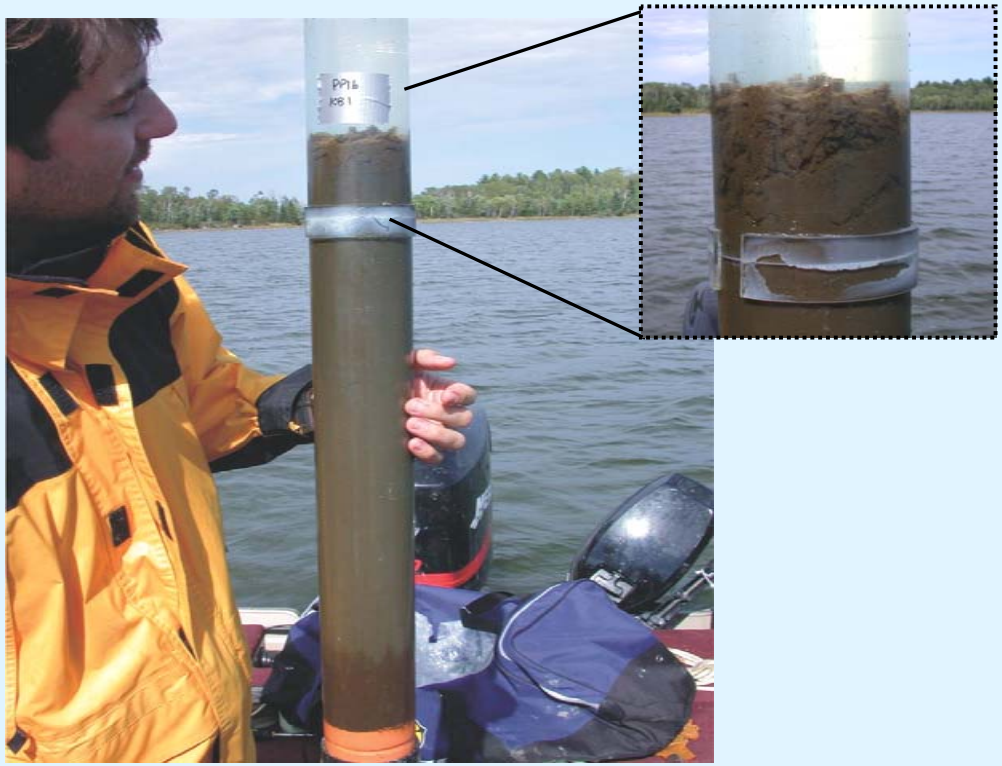
5) What are the possible reasons for this change?

# The Paleolimnological Approach

# Location of sampling sites for sediment cores


*Modified from Robertson & McCracken 2003*

# The Paleolimnological Method



## Core retrieval

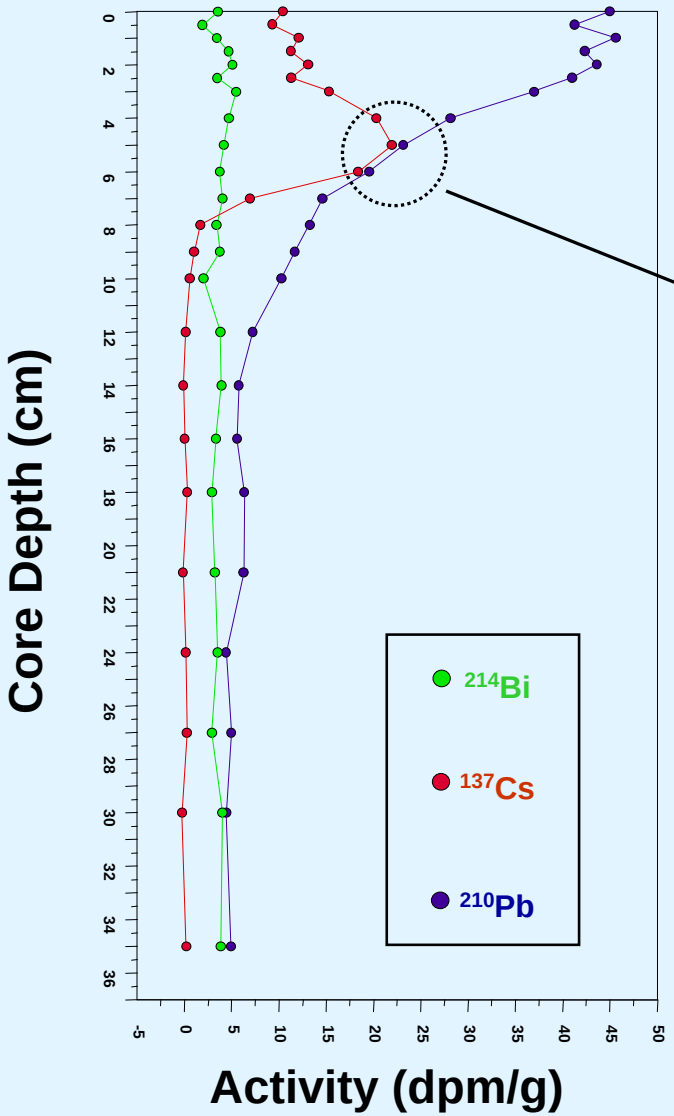
- gravity cores retrieved from deep, quiet locations
- undisturbed water-sediment interface = most recent deposits retrieved

# The Paleolimnological Method

## Core sectioning

- sediment is sectioned into intervals (Glew 1988 extruder)
- each 0.5 cm interval extruded into plastic sample bags

# The Paleolimnological Method



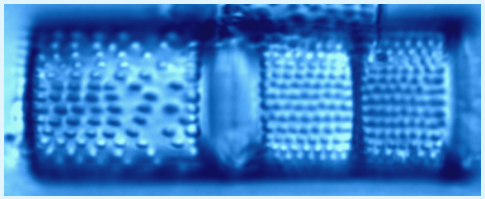
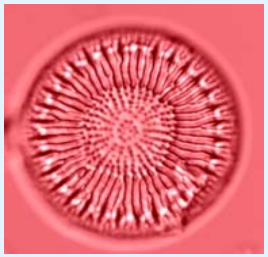

## Dating the sedimentary sequences

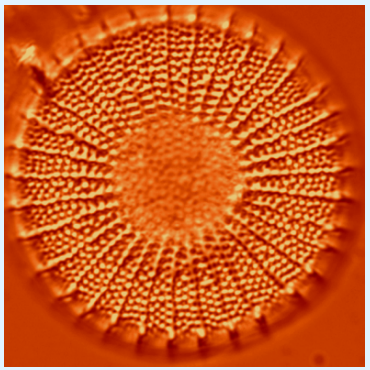
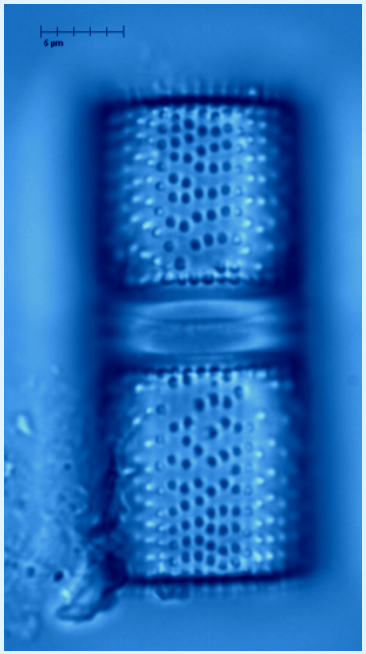
- $^{210}$Pb (radioisotope)
- $^{137}$Cs peak ca. 1963
  - corresponds to nuclear test ban treaty

# The Paleolimnological Method

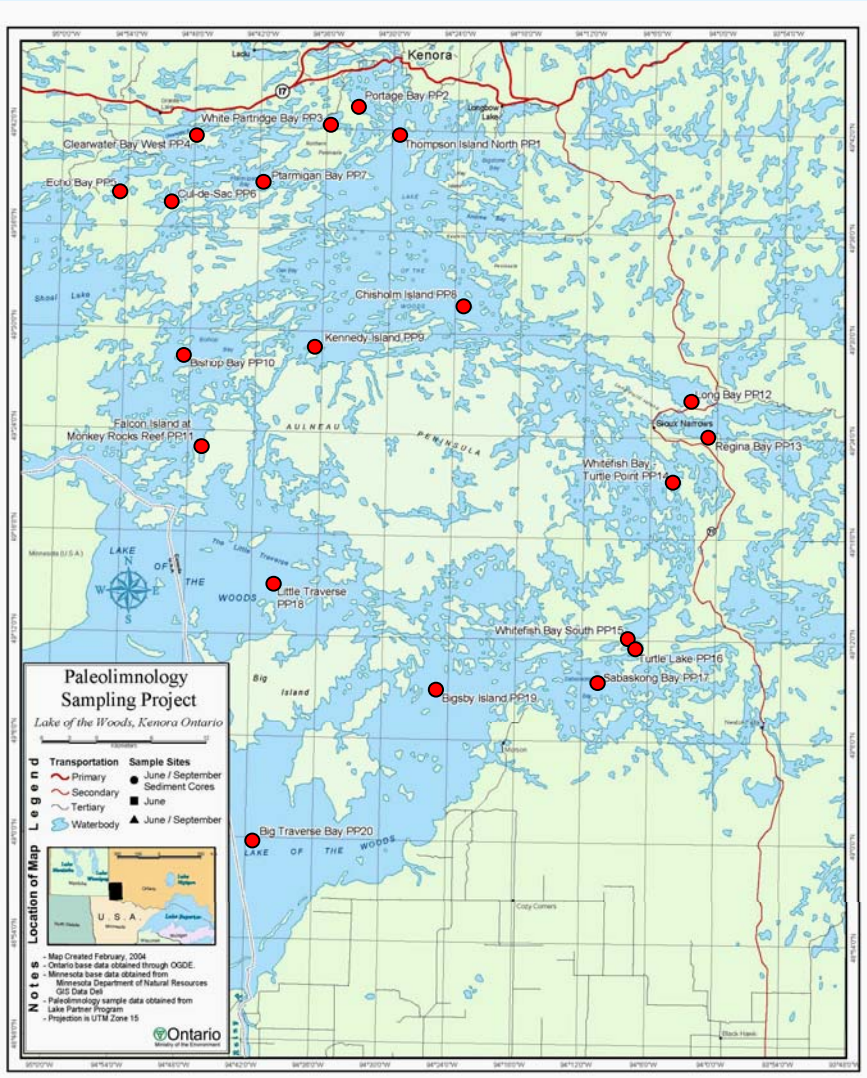
## Diatoms as Indicators of Environmental Change

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

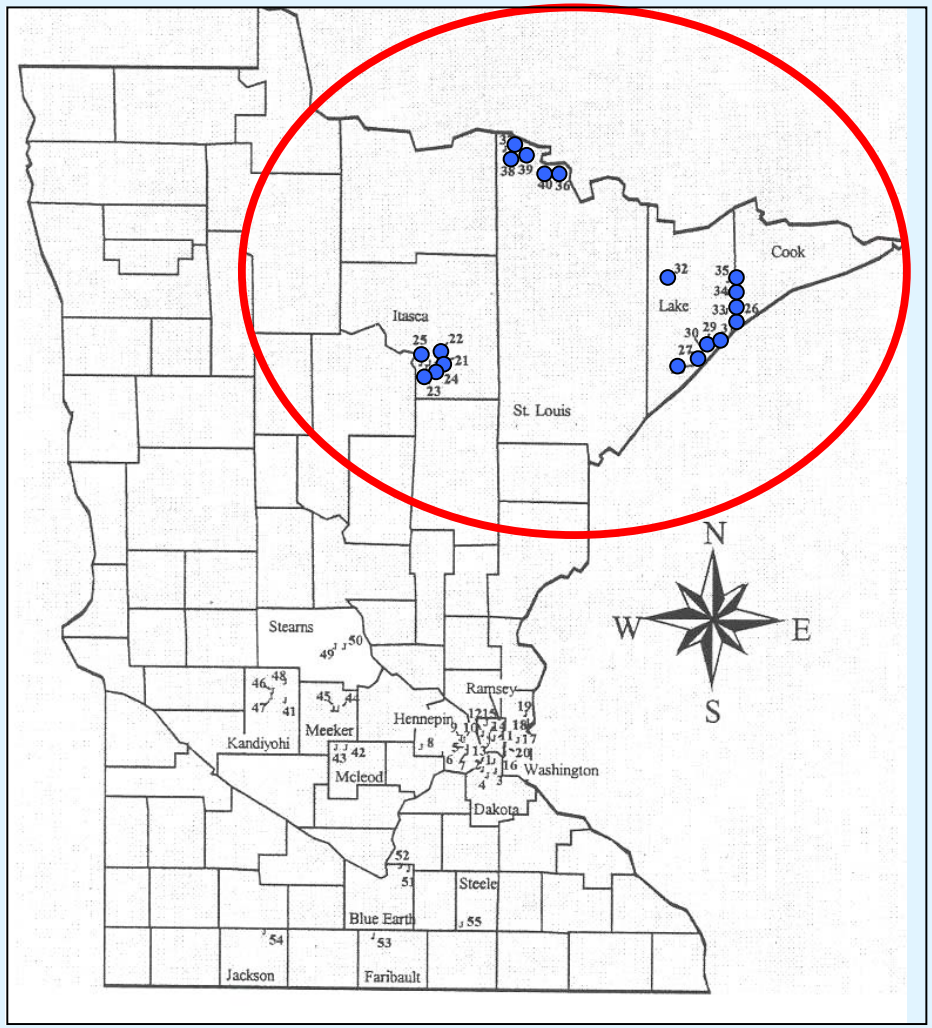



# Developing Models for Predicting Total Phosphorus




Lake of the Woods training set

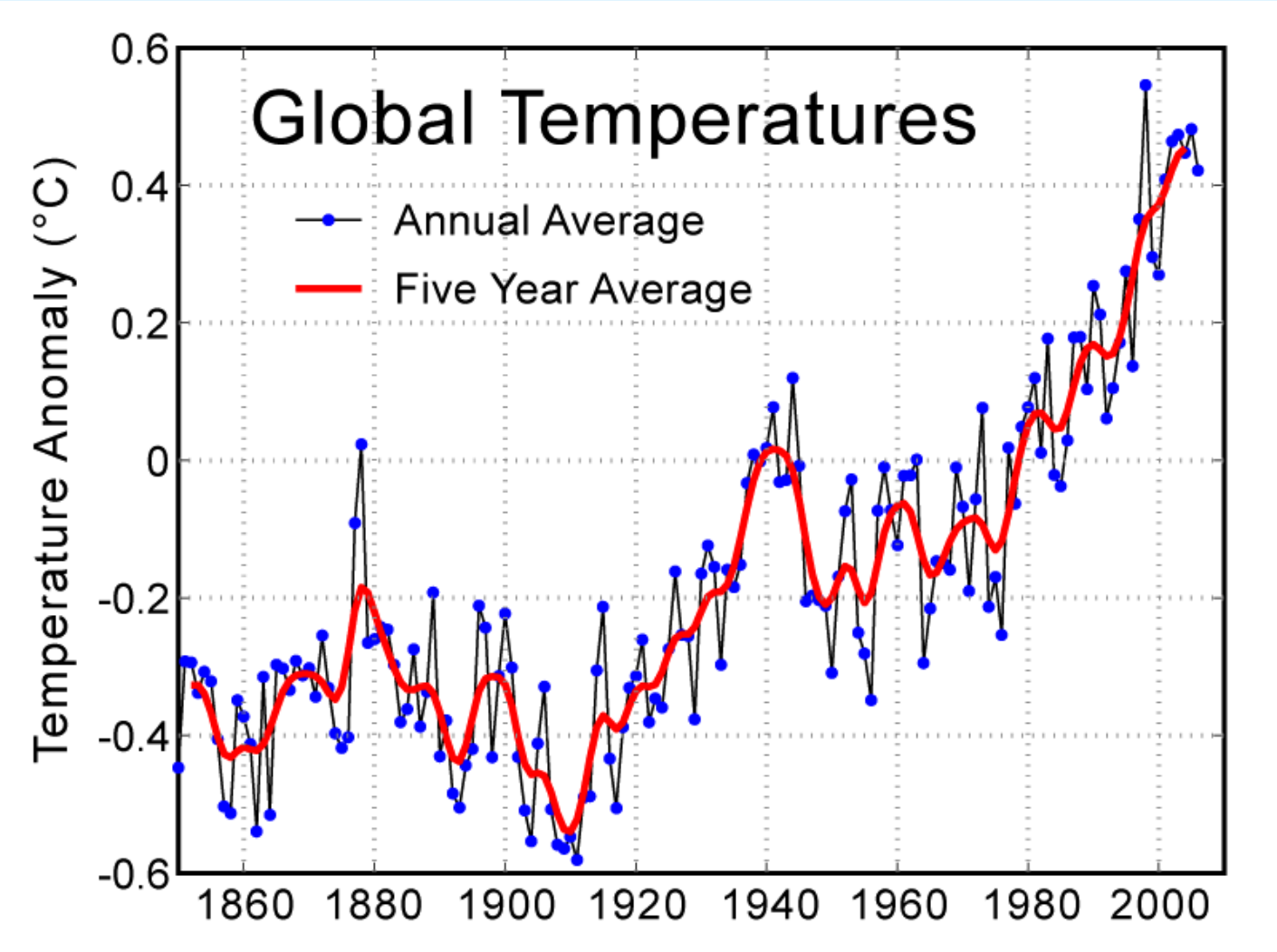
+



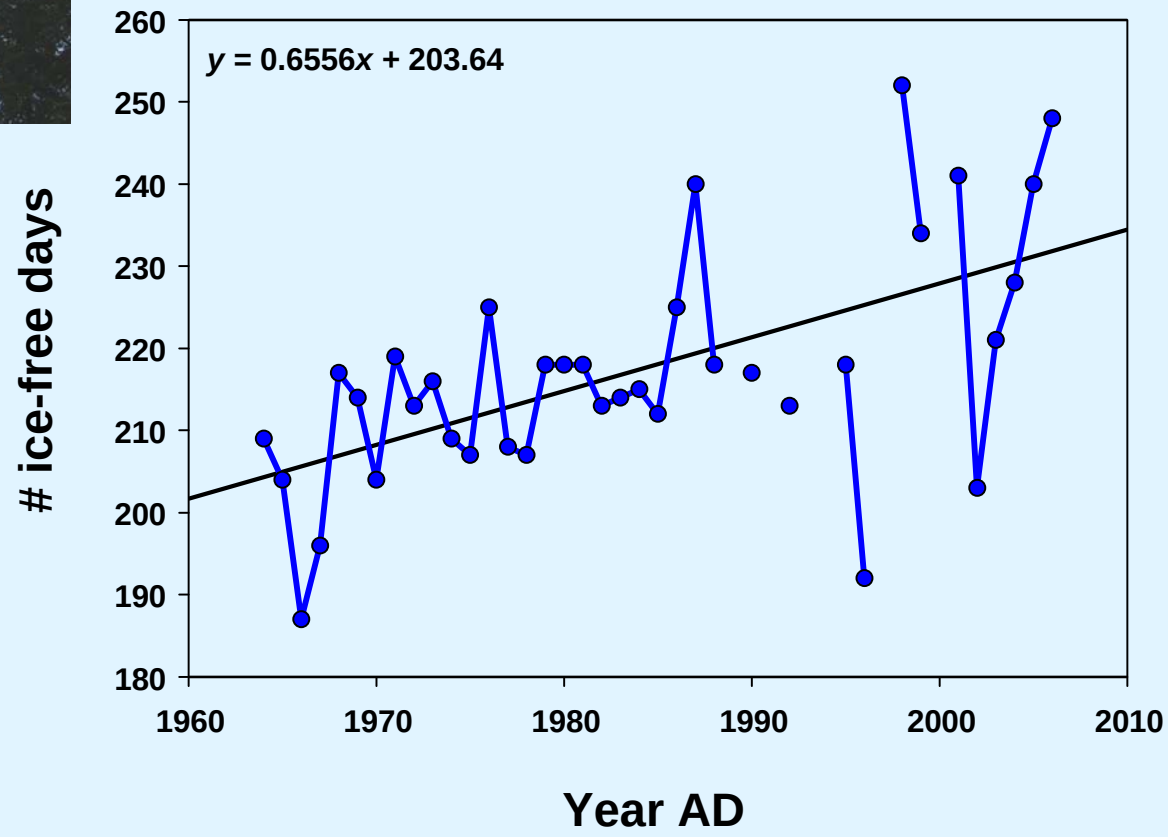

Minnesota training set

*St. Croix Research Stn, Natural Resources Res. Stn Duluth*

# The Instrumental Record

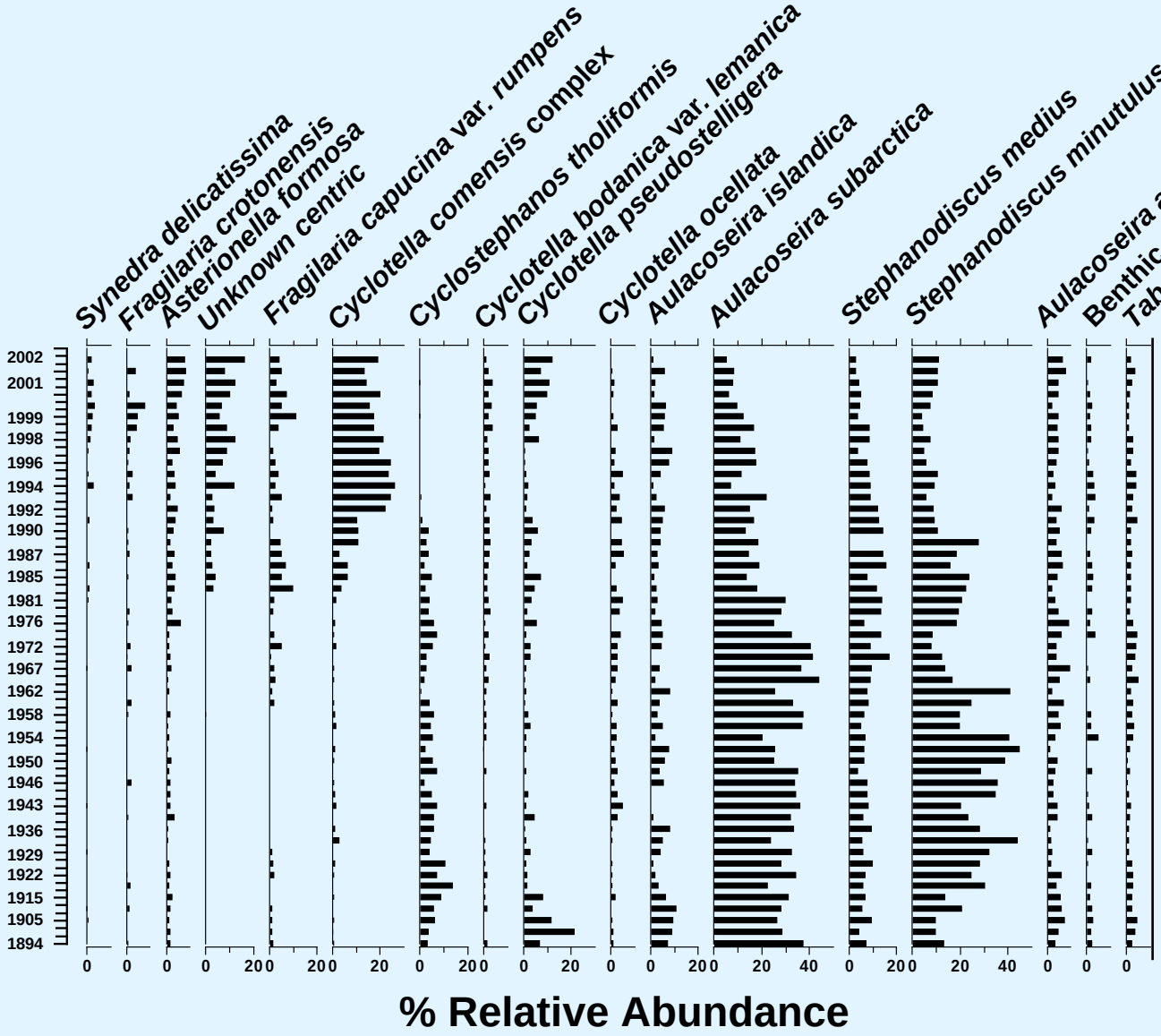


# Historical Ice Cover Records



# Whitefish Bay Diatom Profile

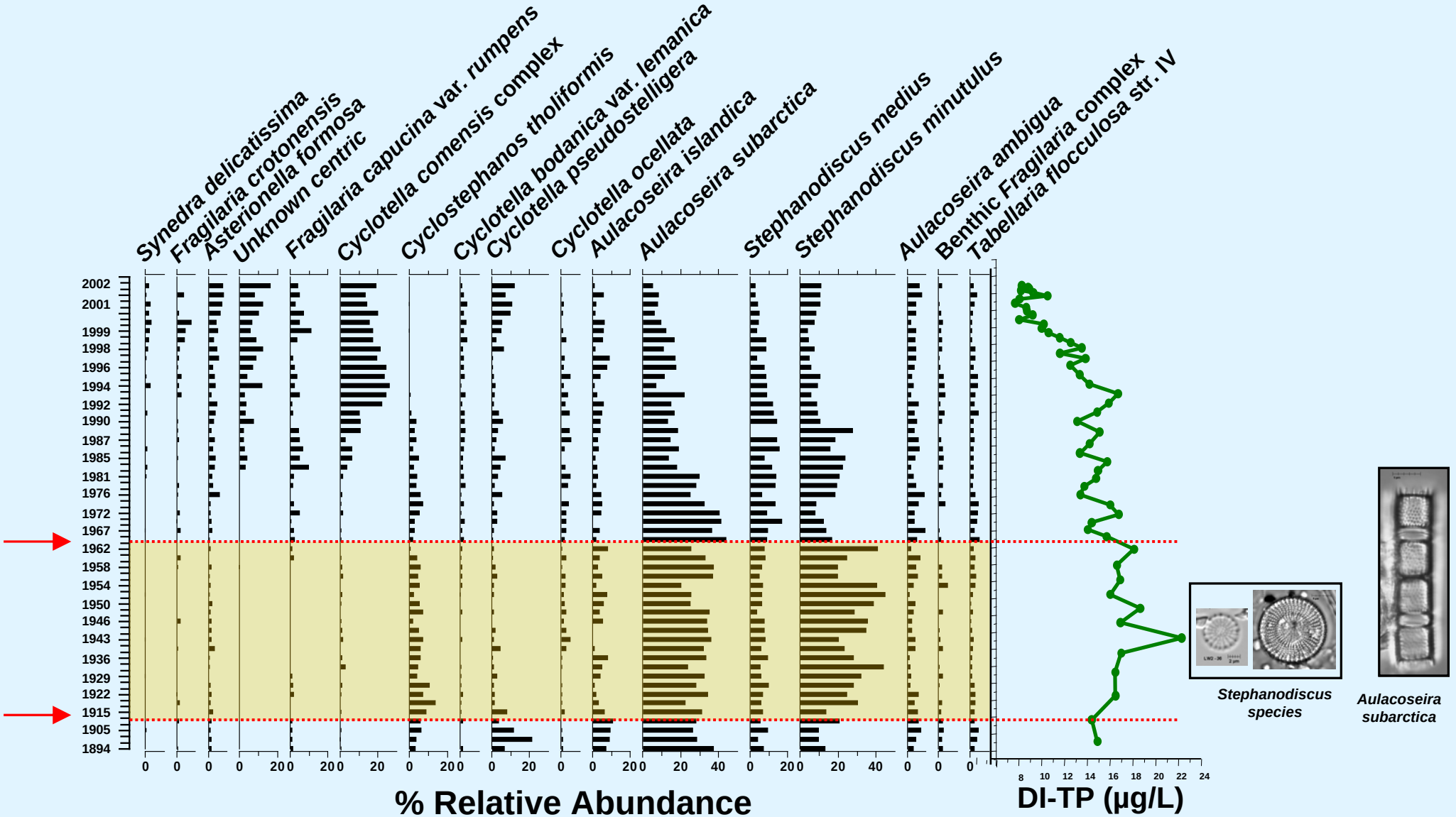
## Reference site




# Whitefish Bay Diatom Profile

*ca. 1905 Rise in water level*

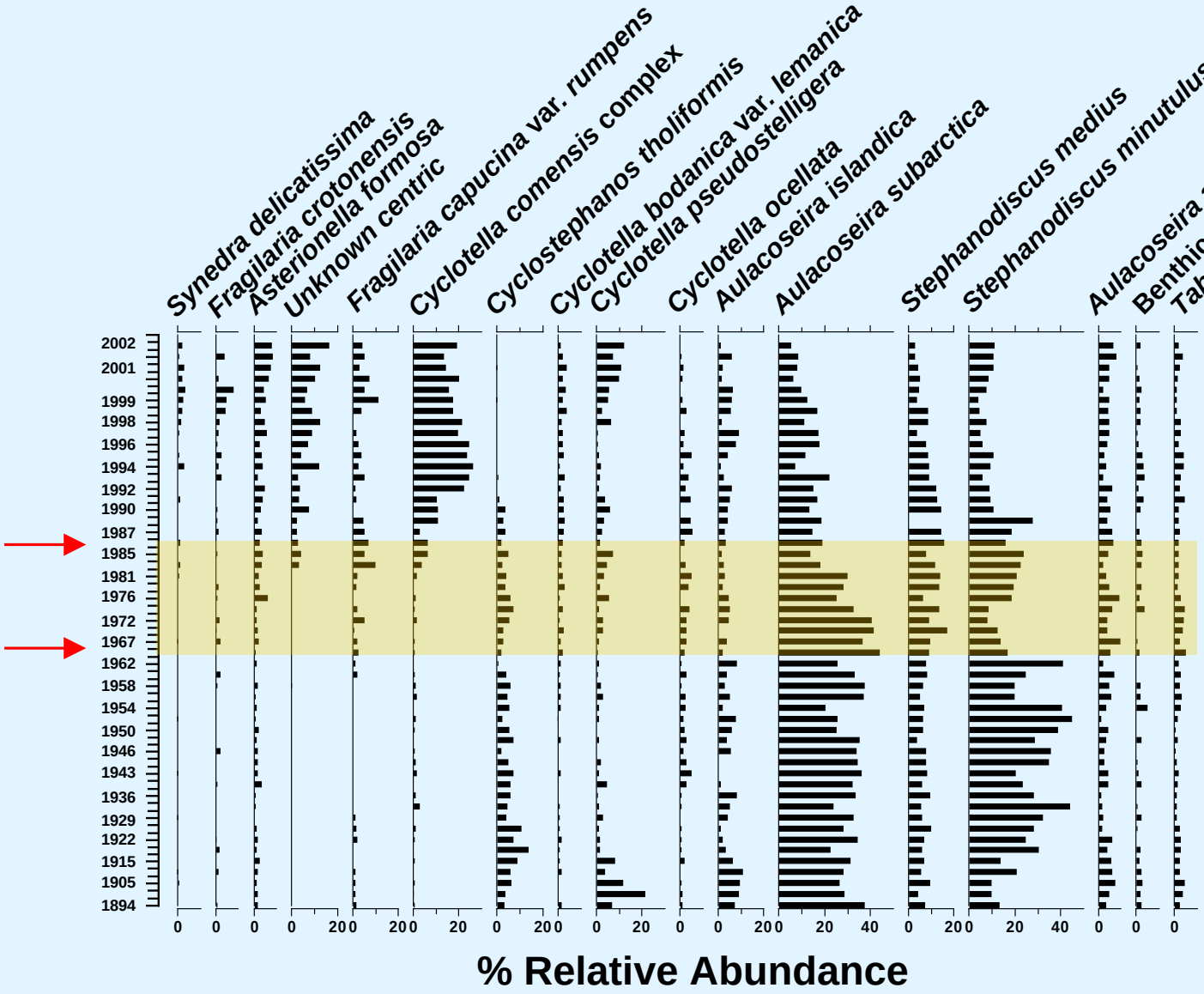
## Reference site



# Whitefish Bay Diatom Profile

*ca. 1966-1986 Canal*

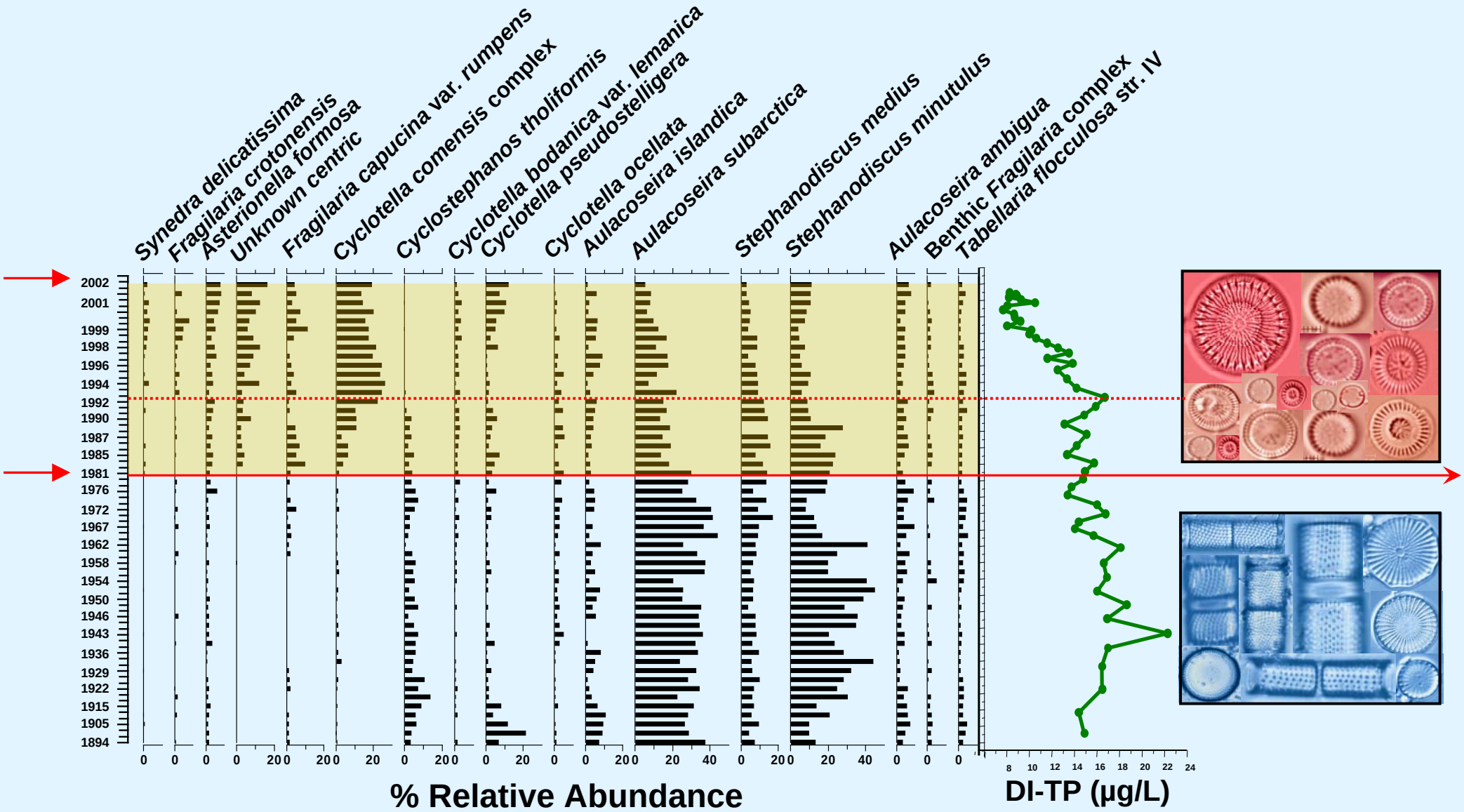
## Reference site




# Whitefish Bay Diatom Profile

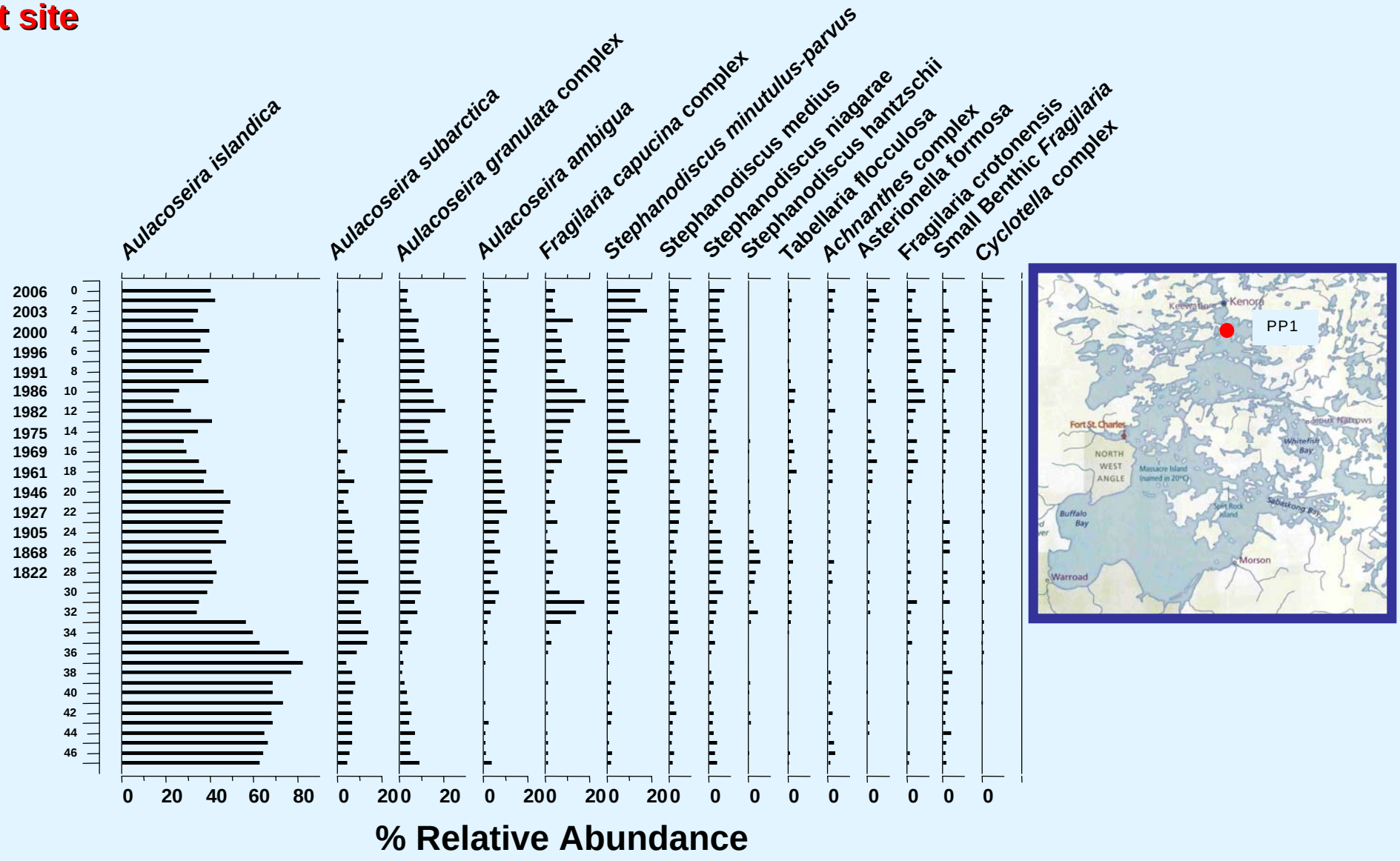
*1980 – present*

## Reference site



# PP1 Diatom Profile

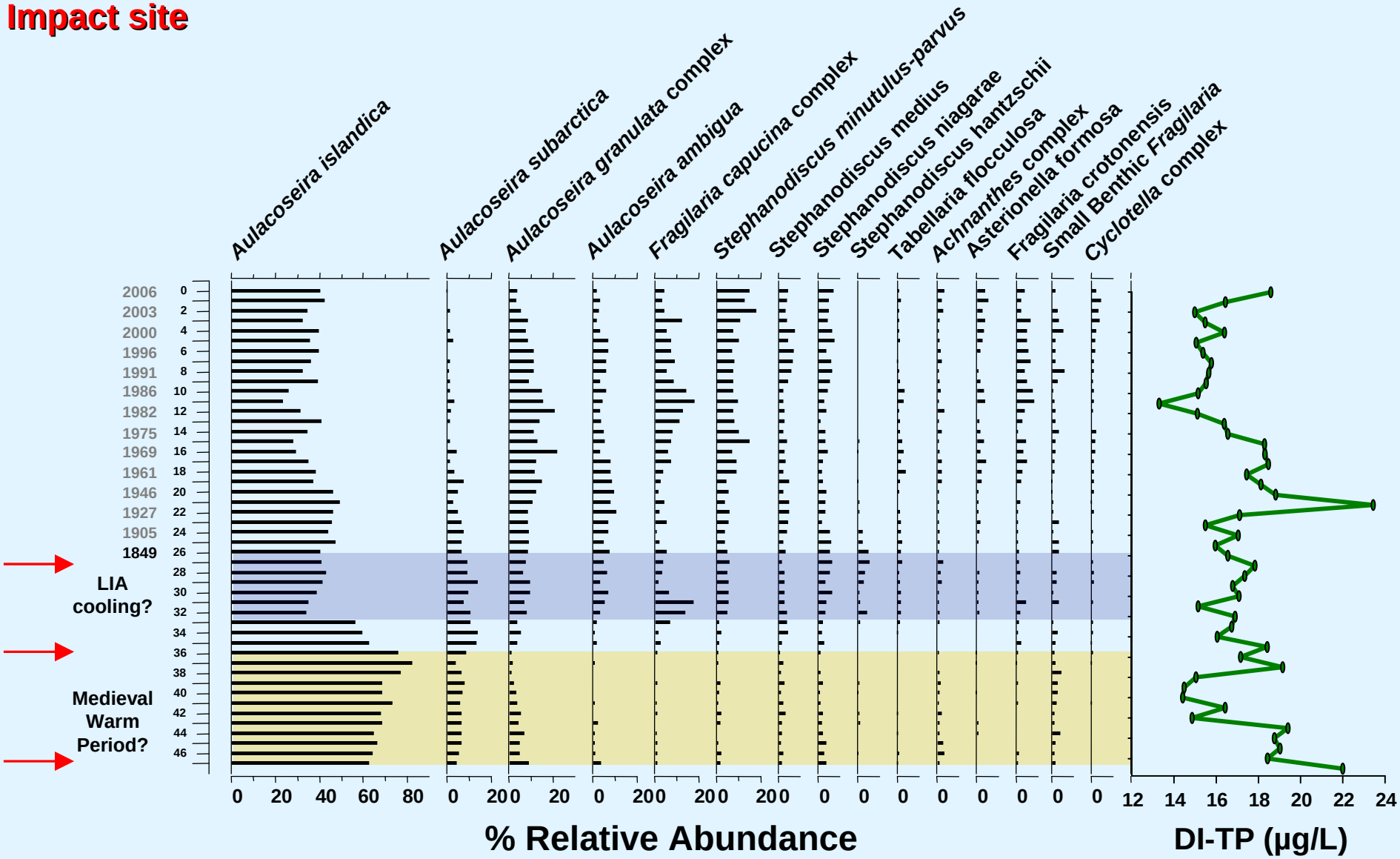
## Impact site



# PP1 Diatom Profile

~ AD 1100 – AD 1850

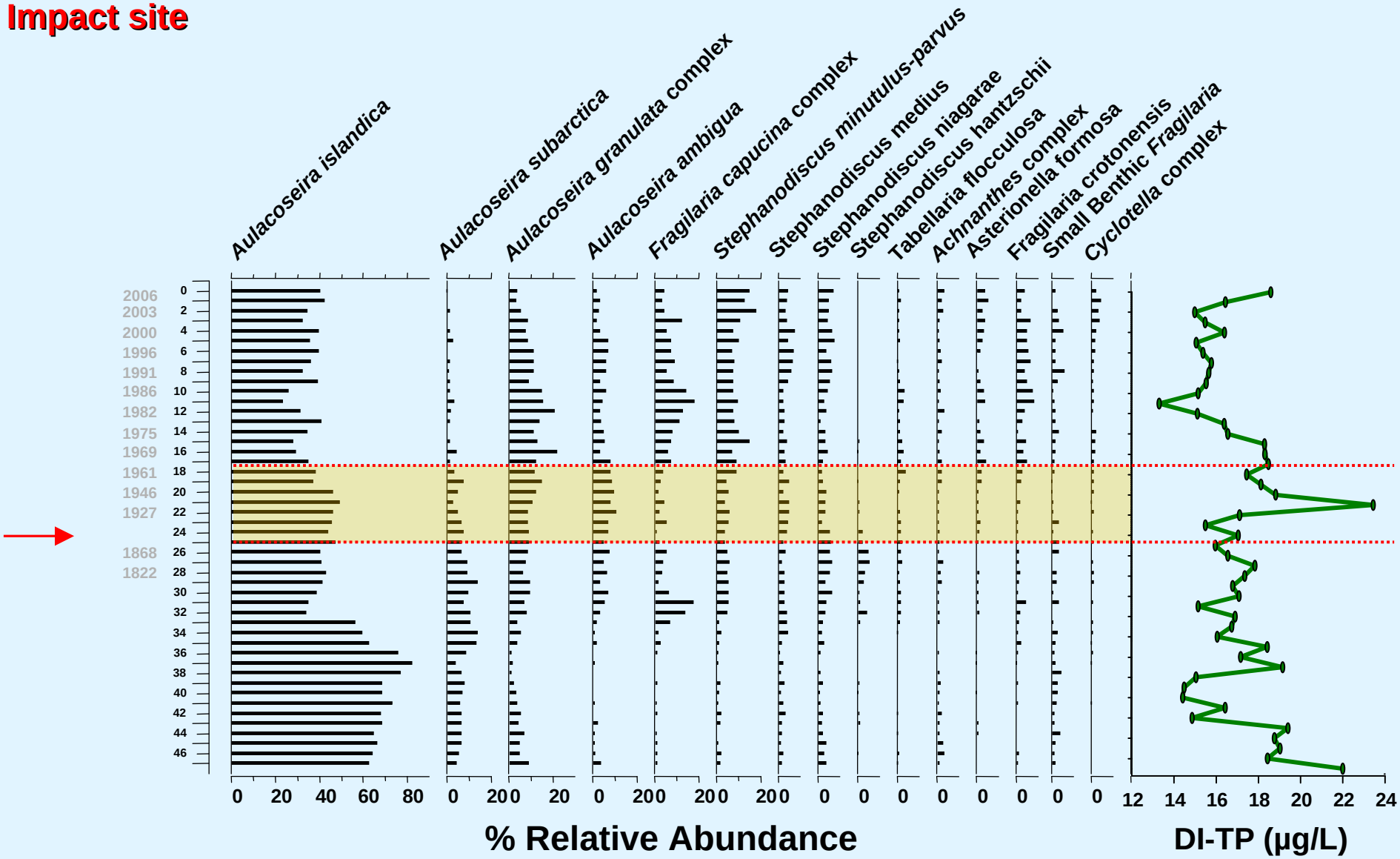
## Impact site



# PP1 Diatom Profile

*ca. 1905 Rise in water level*

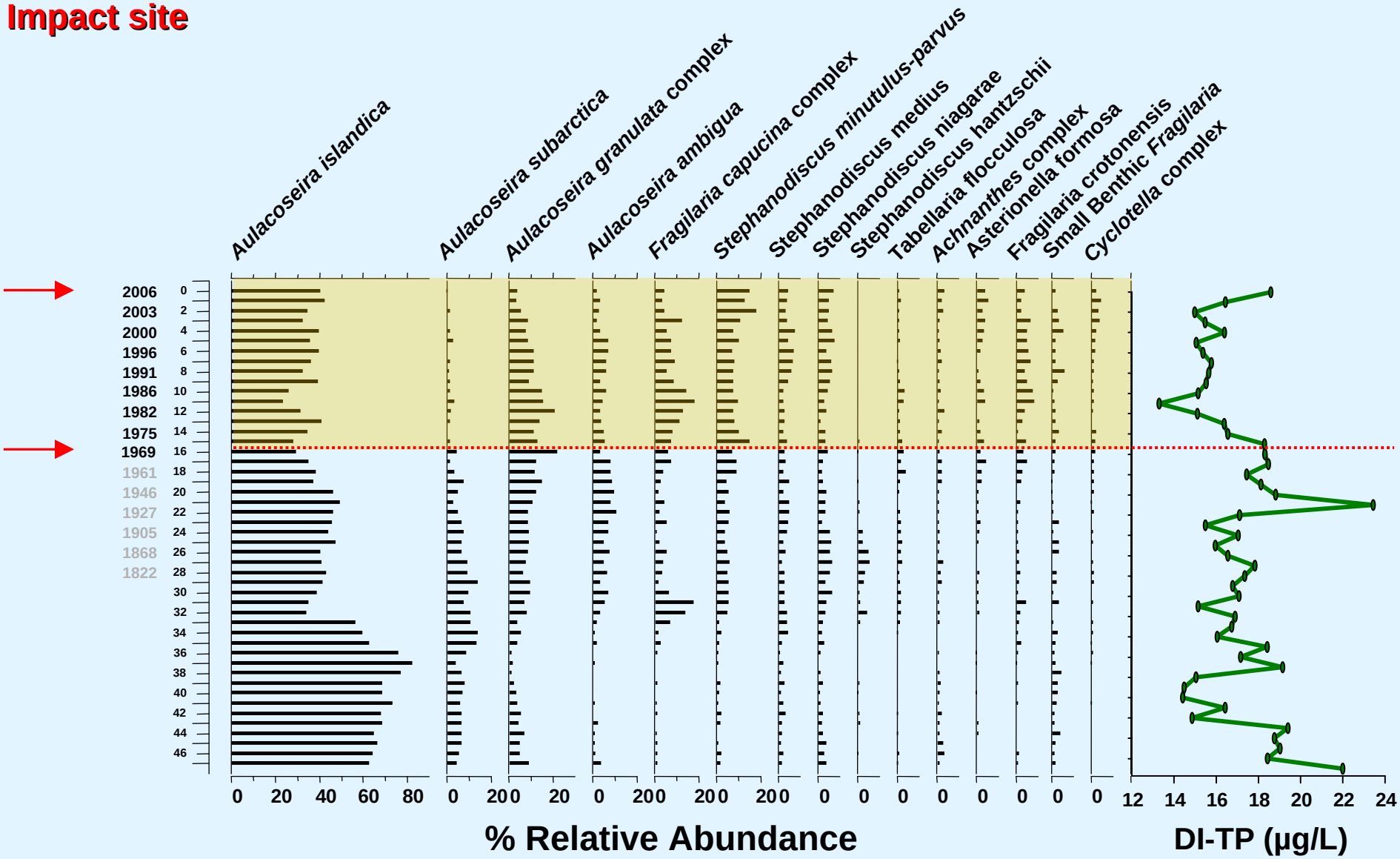
## Impact site



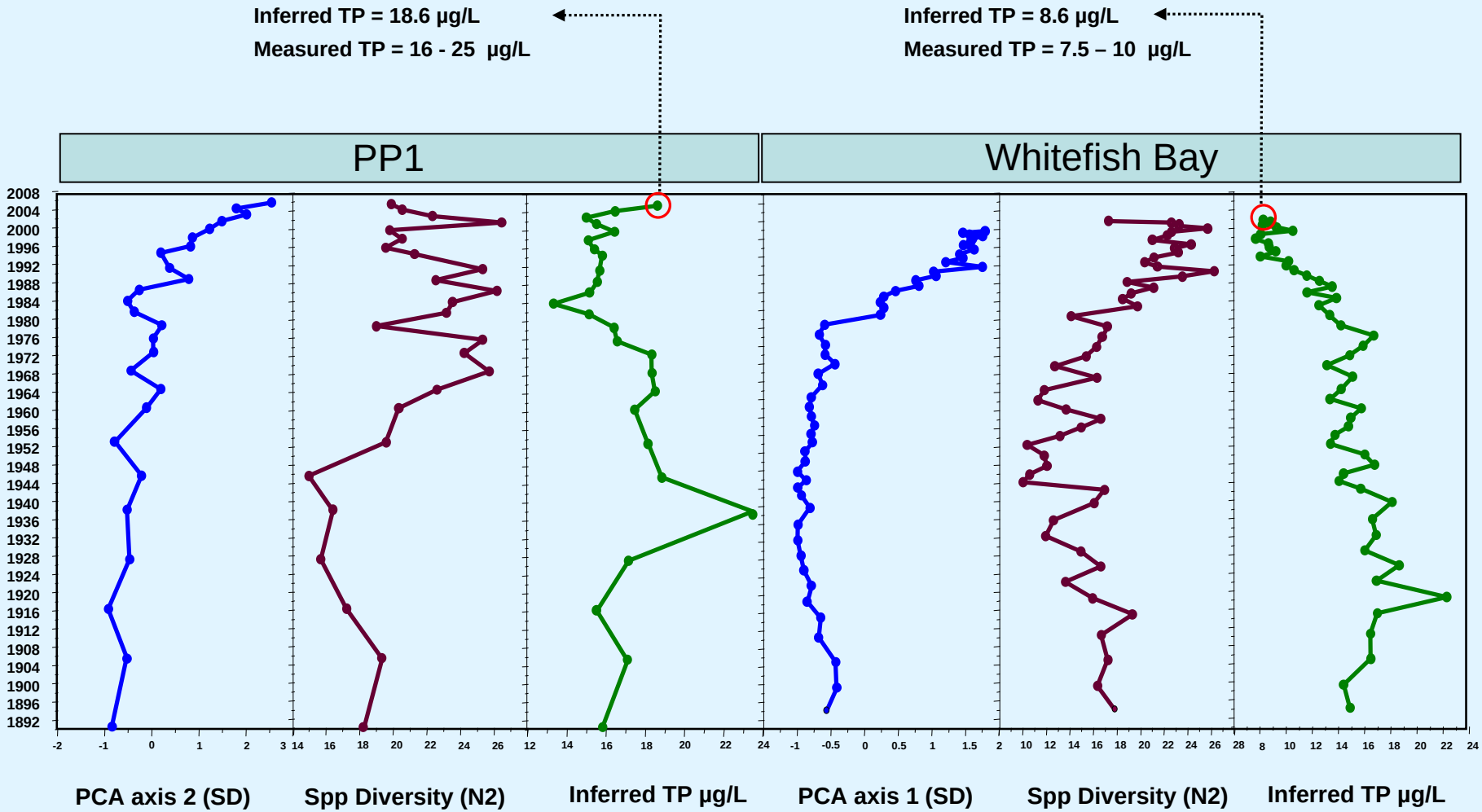
# PP1 Diatom Profile

*Last few decades*

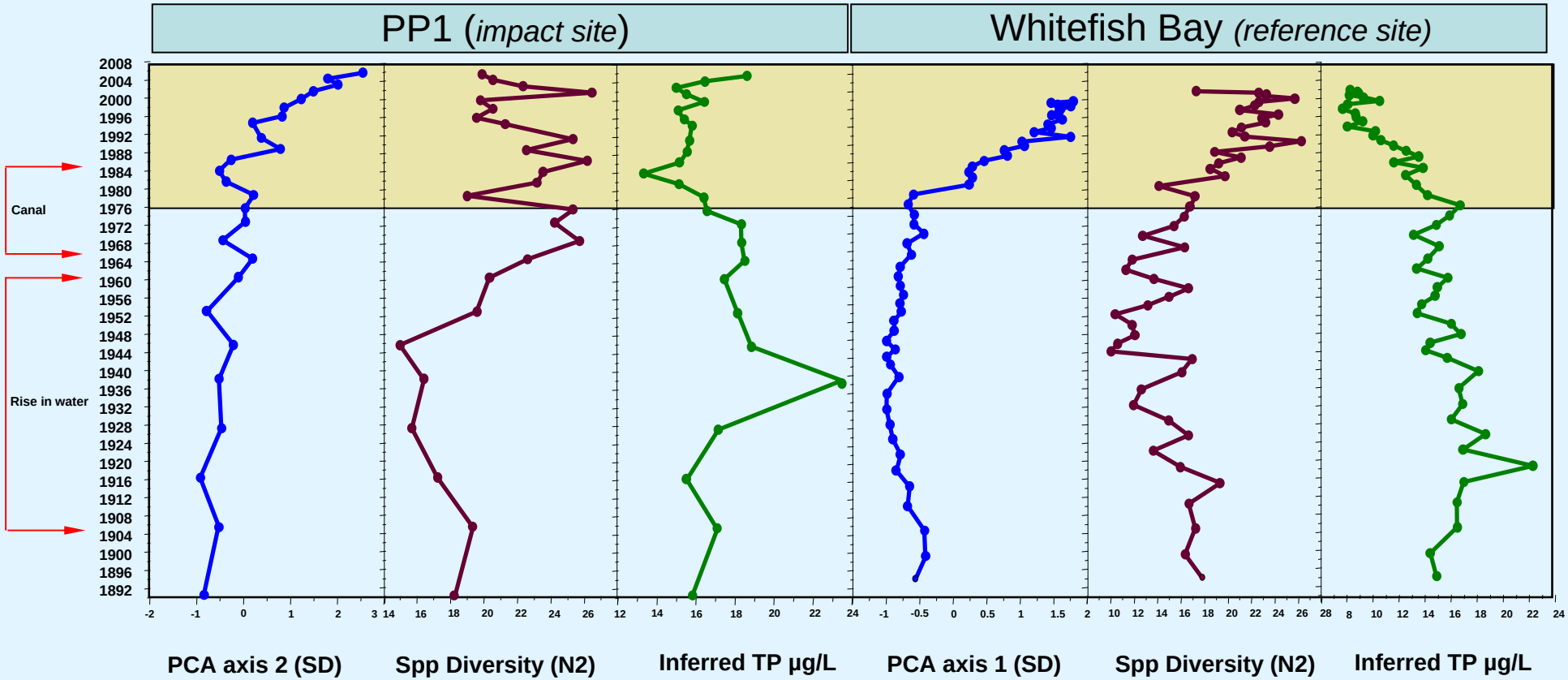
## Impact site



# Summary of Diatom Trends

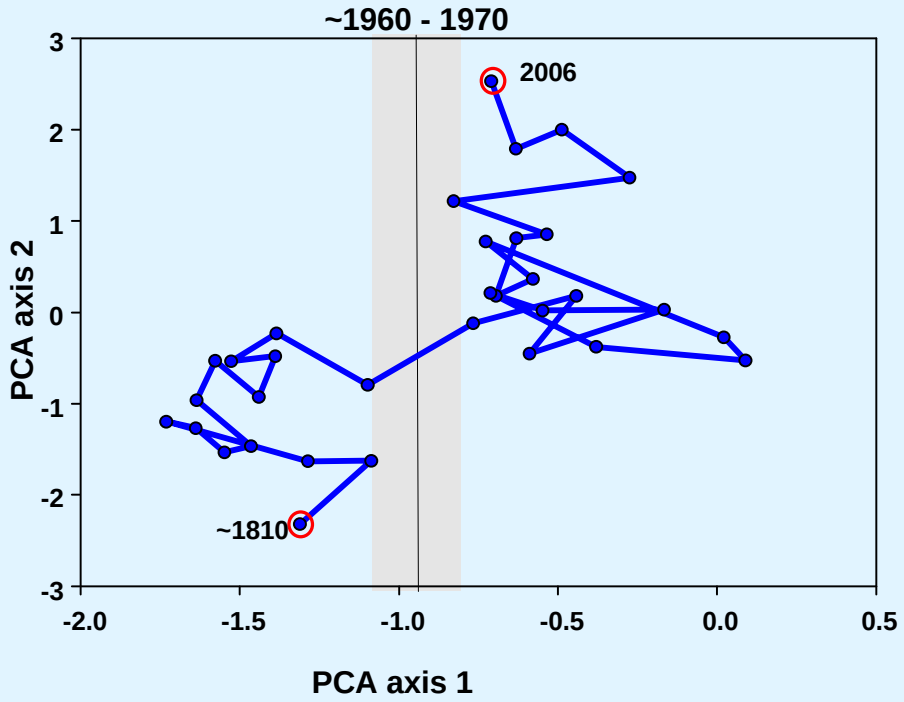


# Summary of Diatom Trends

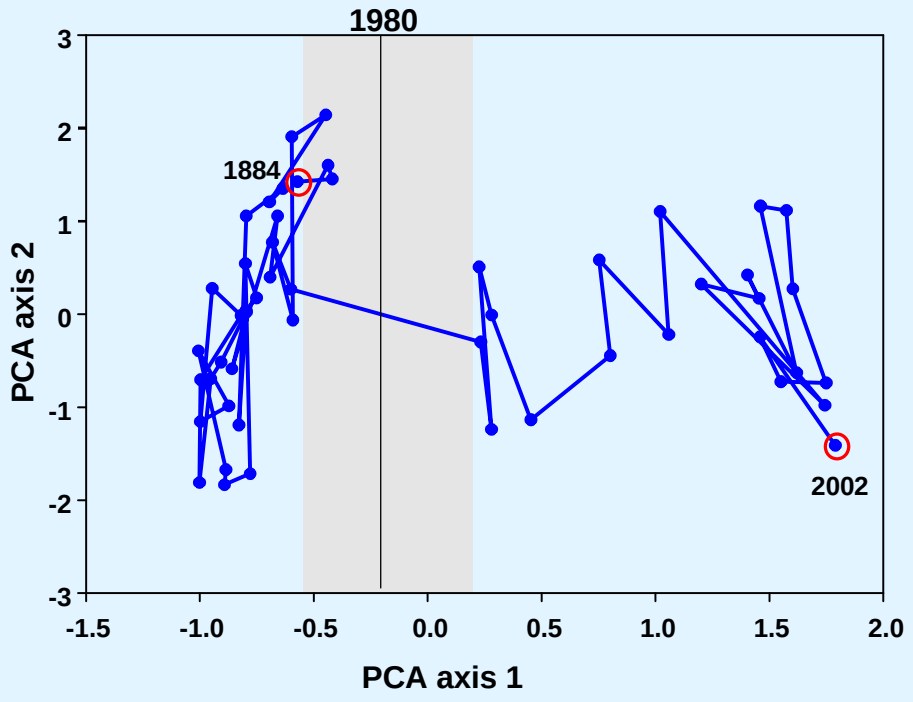


# Summary of Diatom Trends

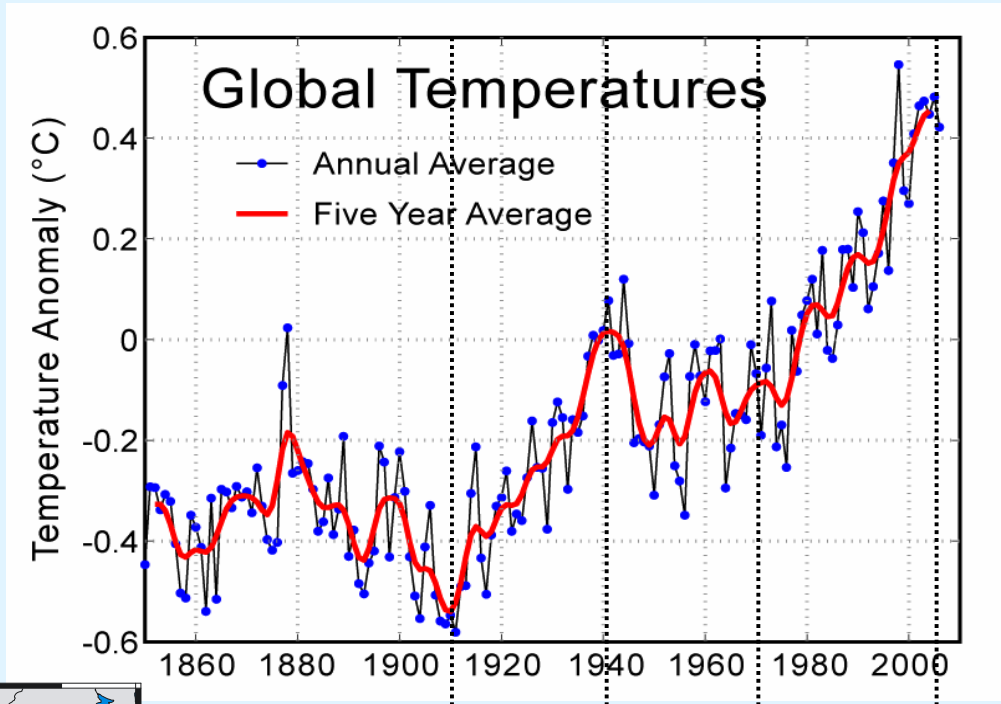
## PP-1 *(impact site)*

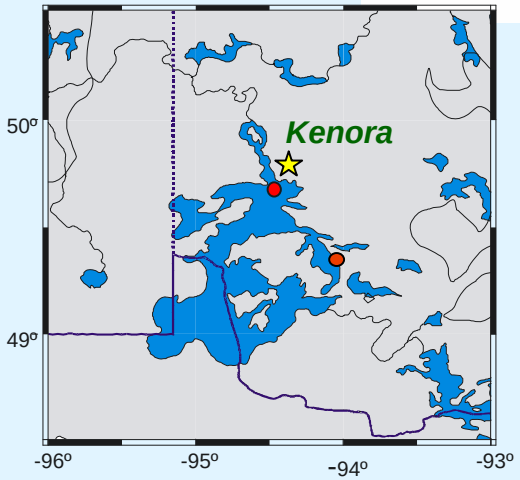


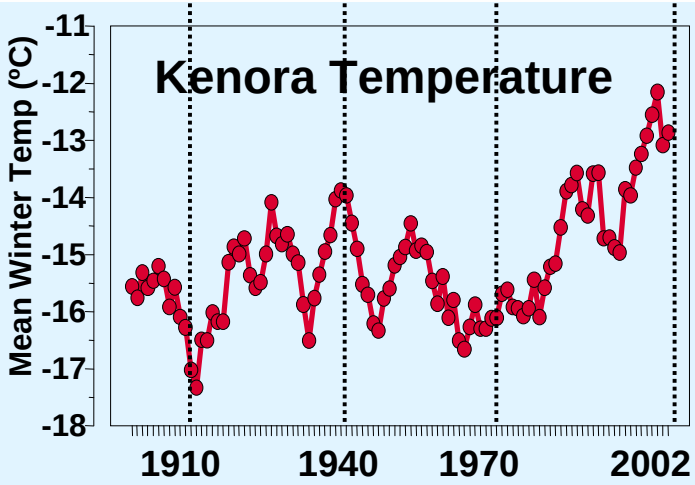

## Whitefish Bay *(reference site)*



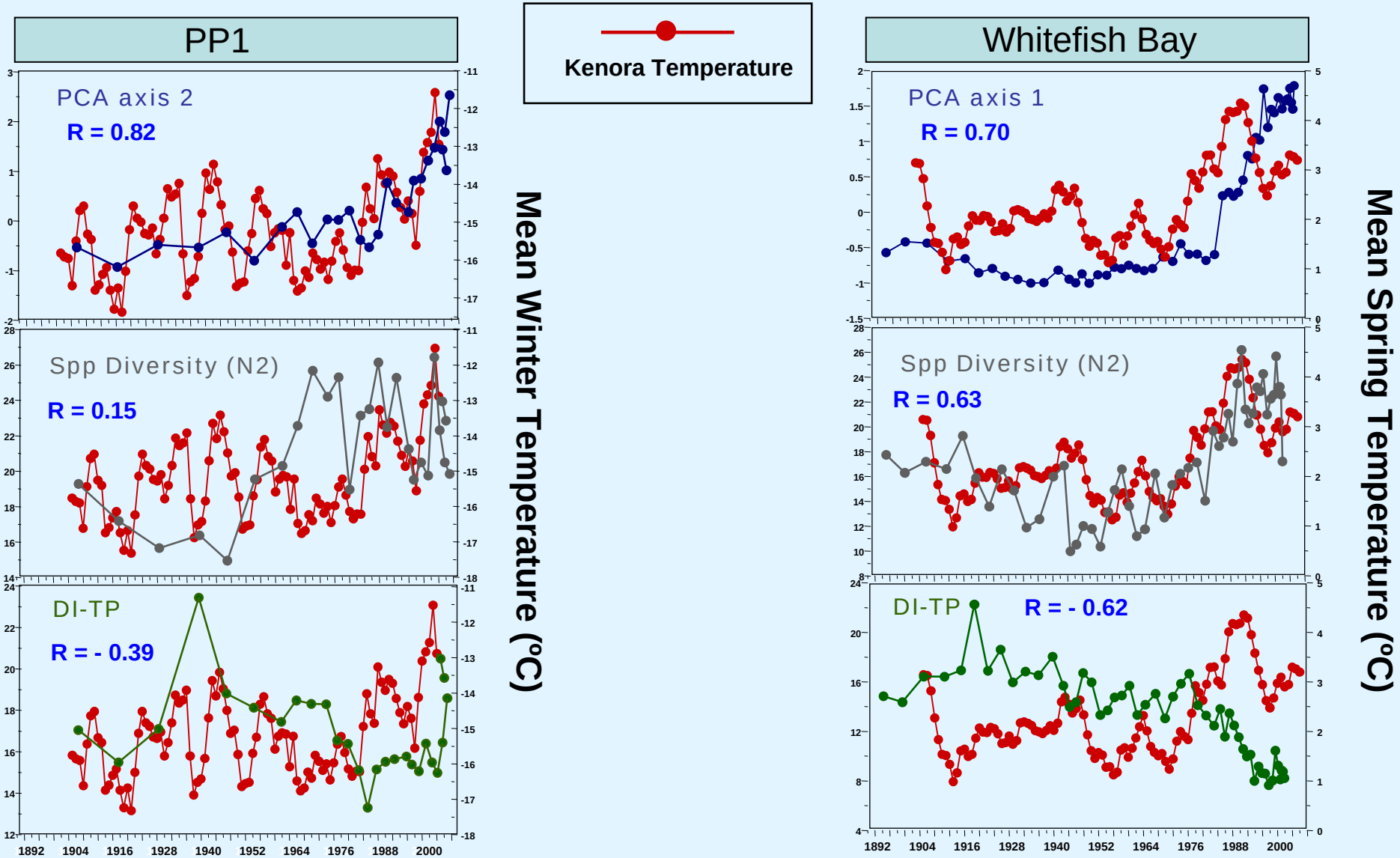
# Kenora 100-year Temperature Record



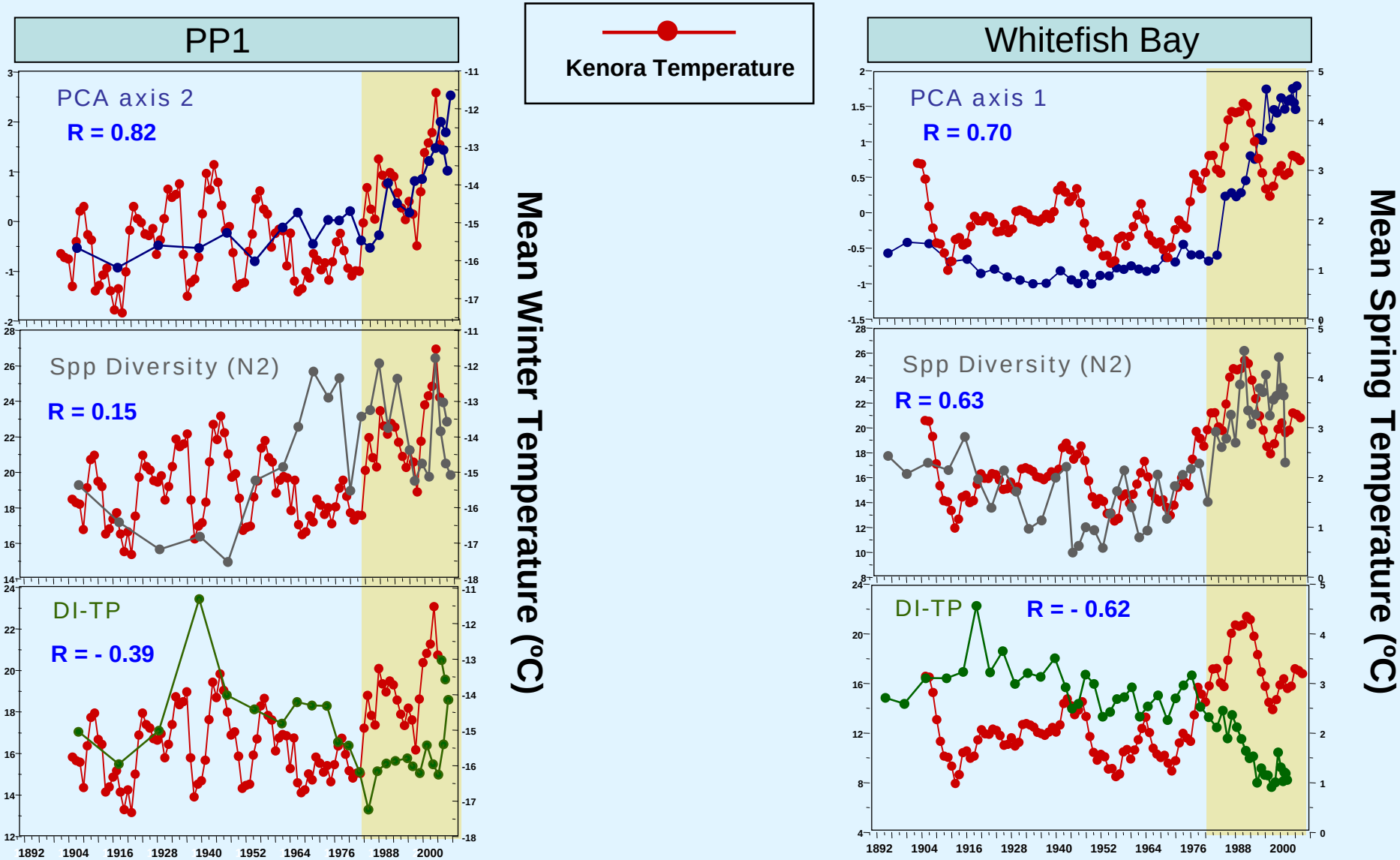



# Diatom – Temperature Relationships

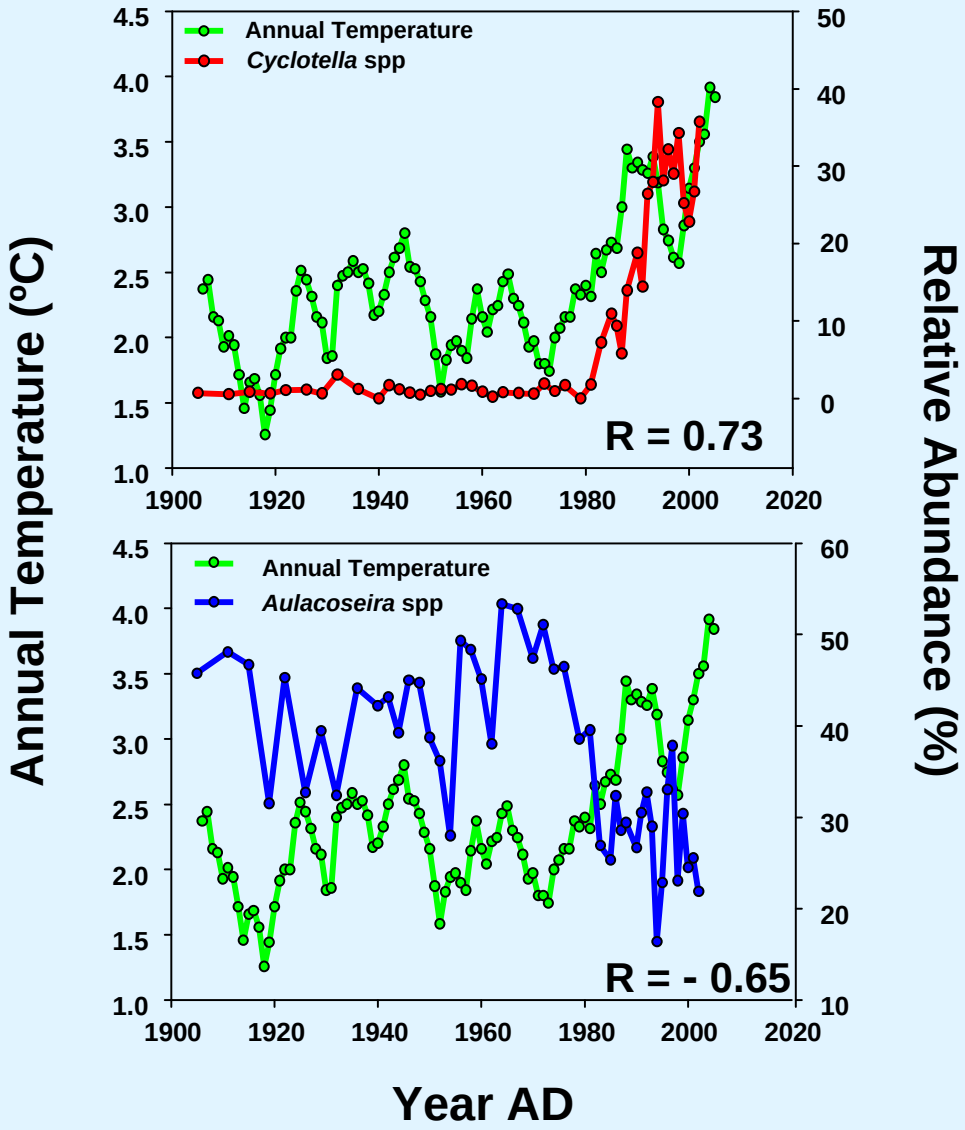


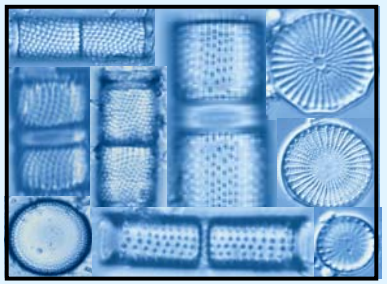
# Diatom – Temperature Relationships



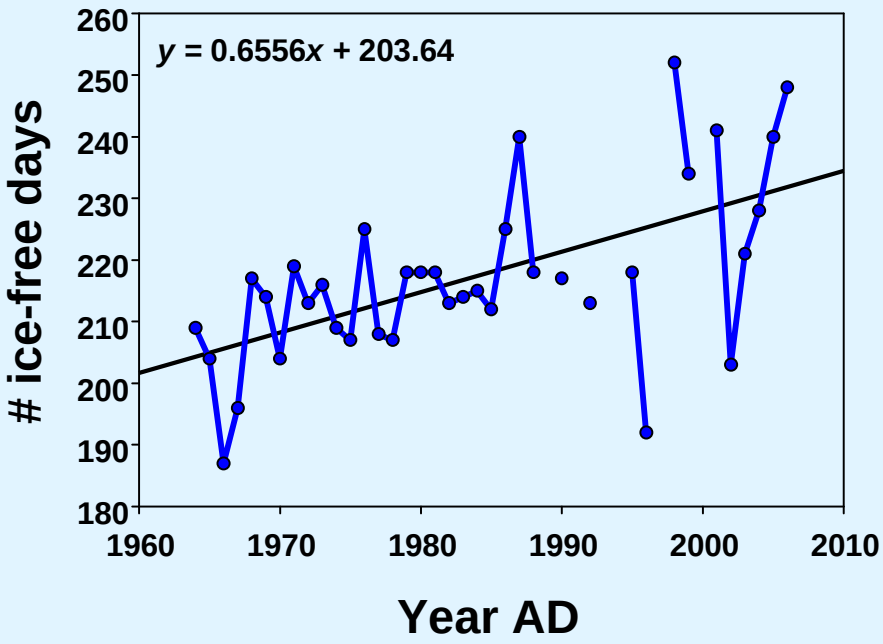
# Whitefish Bay: Taxon-Specific Relationships

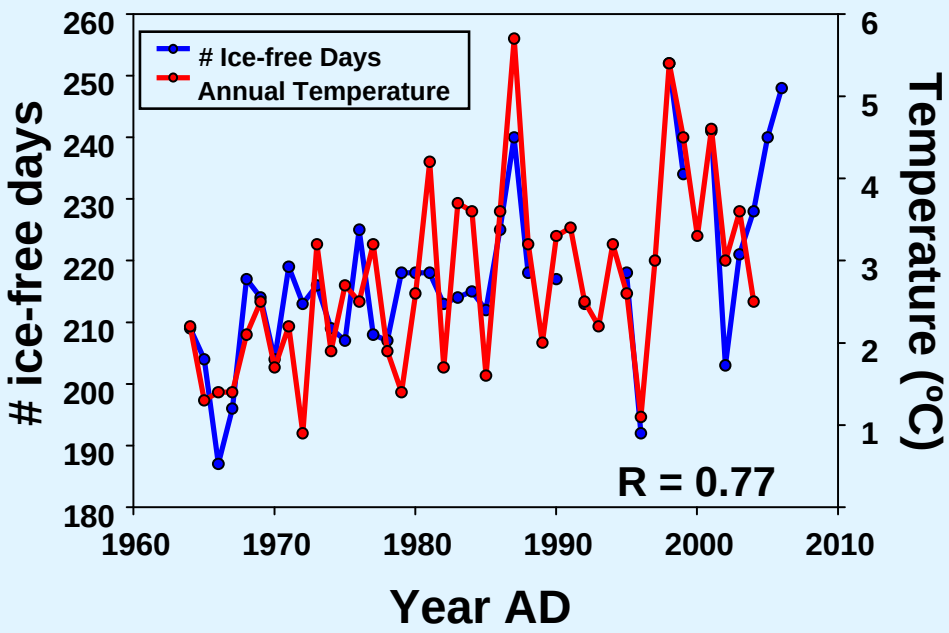
## Kenora Temperature Record



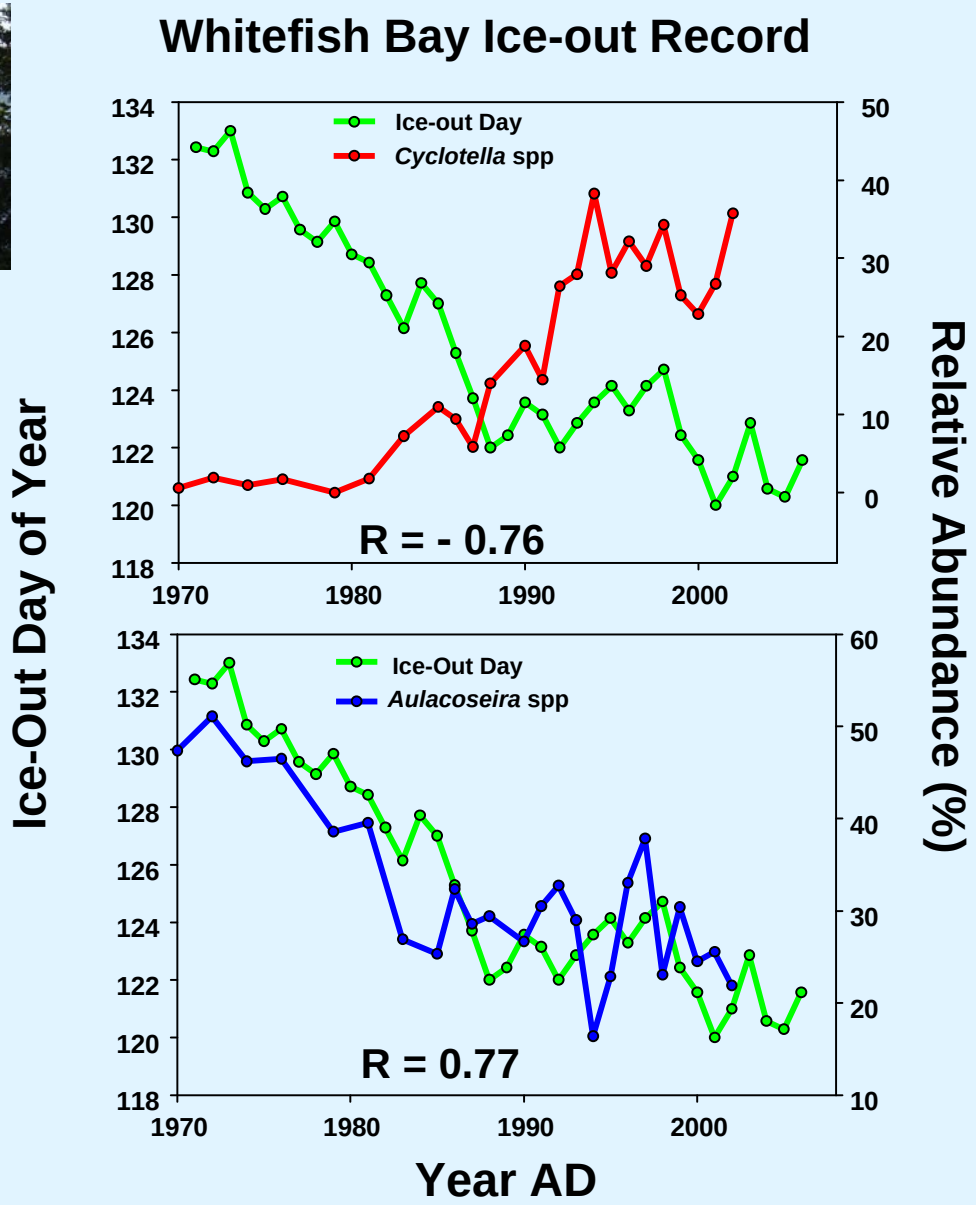
# Whitefish Bay Ice Cover Record

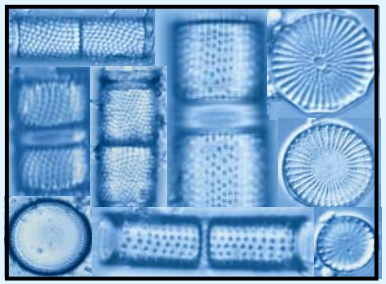


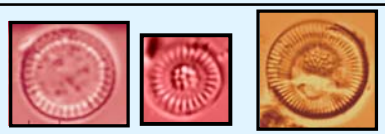

- Ice-free period increased by **27.7** days since 1964
- Corresponds to increased temperatures

# Whitefish Bay: Taxon-Specific Relationships



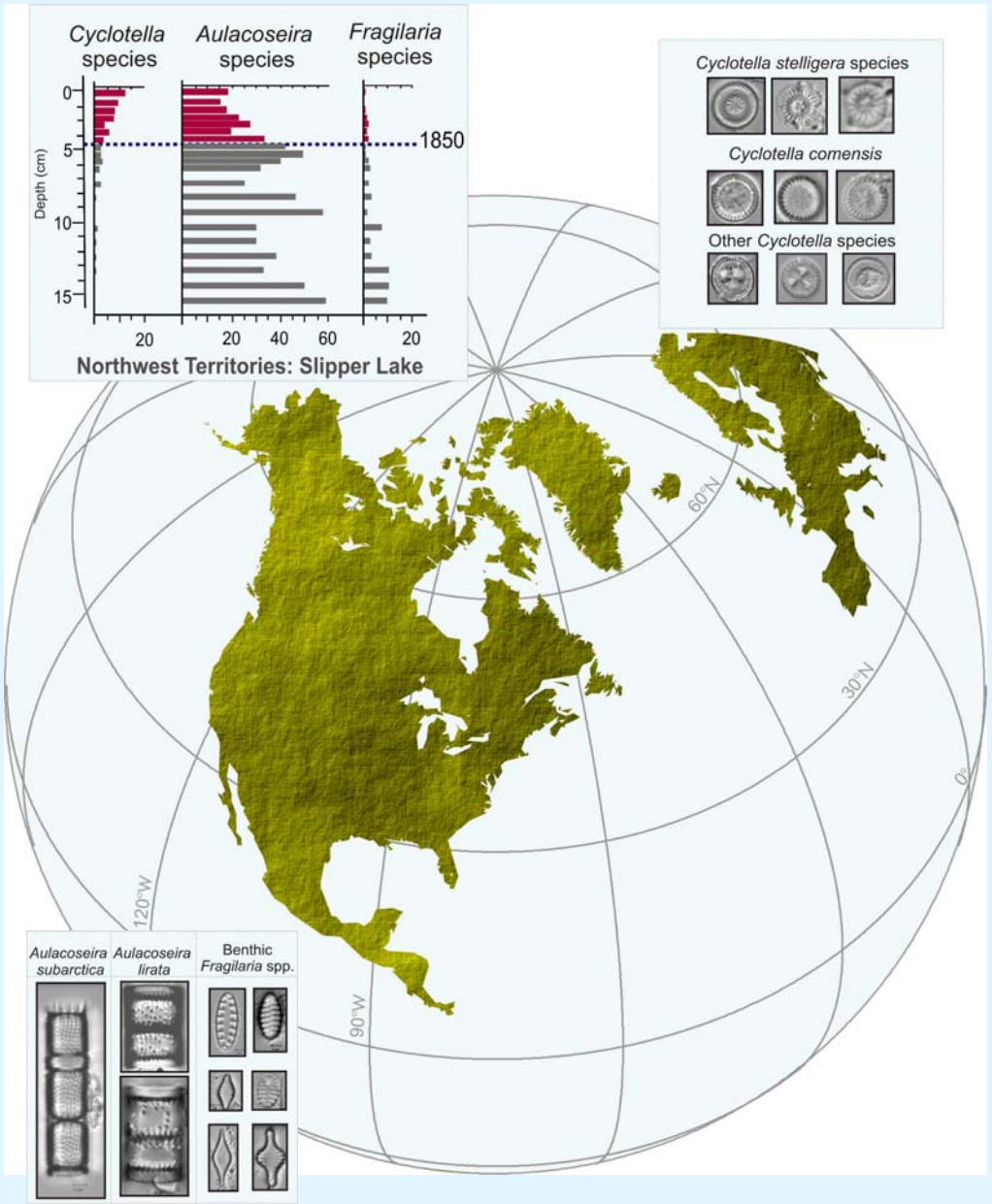



# Climatic Warming and the Lake of the Woods

| | |
|---|---|
| Length of ice cover | ↓ |
| Growing Season | ↑ |
| Thermal Stratification – onset, duration & strength | ↑ |
| *Cyclotella* species | ↑ |
|  Diatom-Inferred TP | ↓ |
| Allochthonous sources of TP | ↓ |

- Hemispheric-scale trend

# Climatic Warming and increases in *Cyclotella* species



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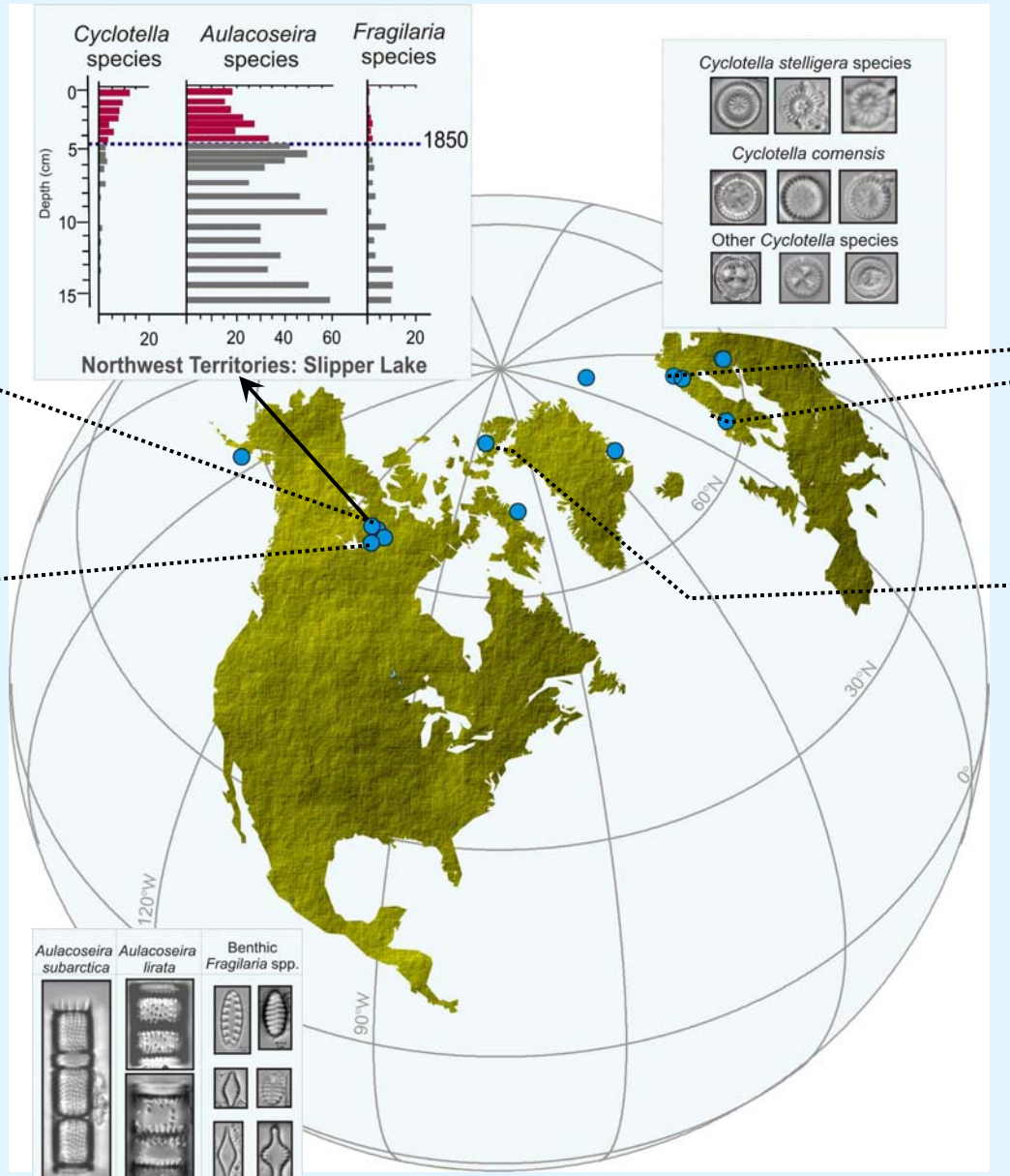


**Subarctic Canada**
***Rühland et al. 2003***

**Great Slave L. N.W.T**
***Stoermer et al. 1990***

**Subarctic Finland**
***Sorvari et al. 2002***

**Sweden**
***Bigler & Hall 2003***

**High Arctic Canada**
***Perren et al. 2003***

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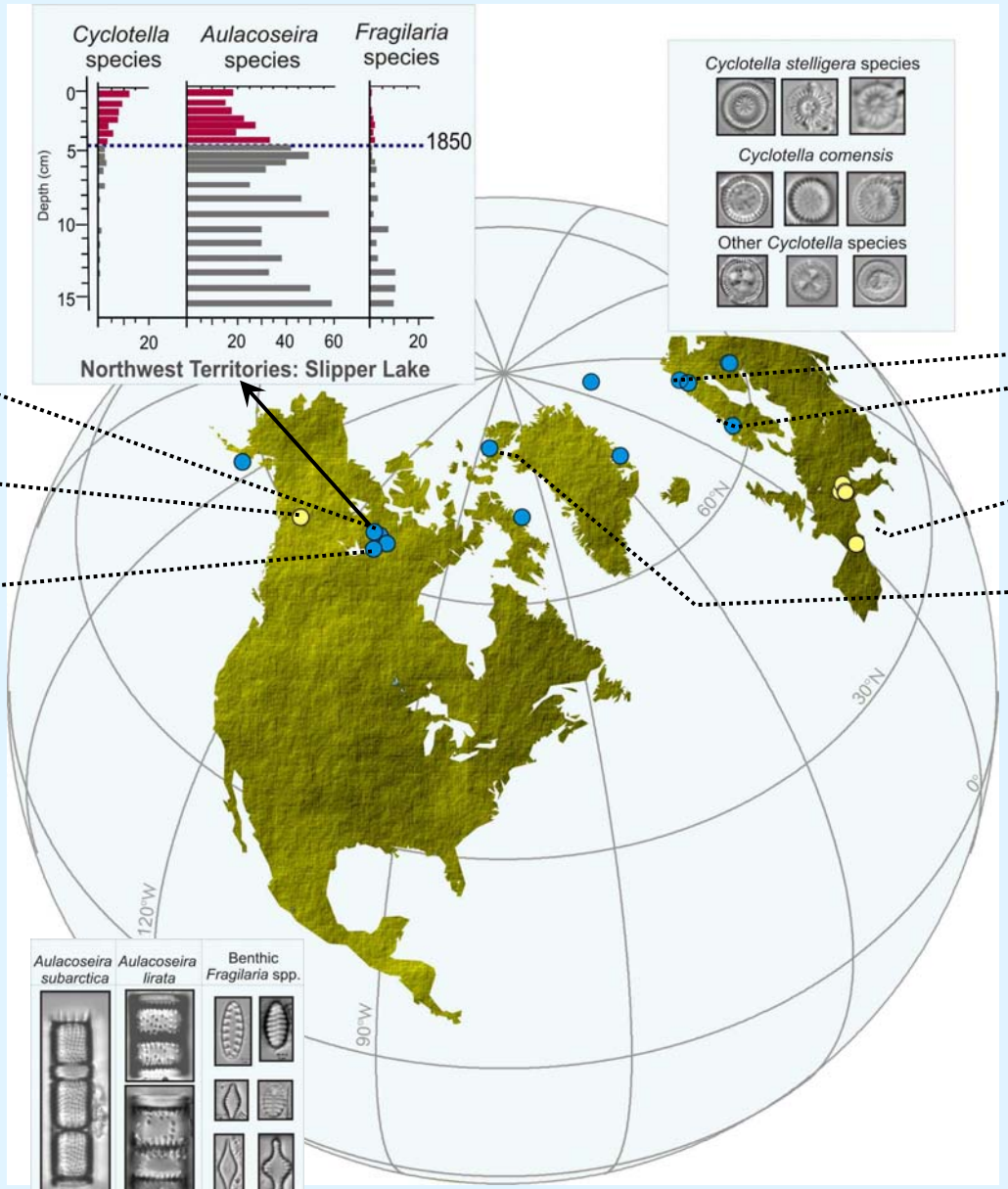


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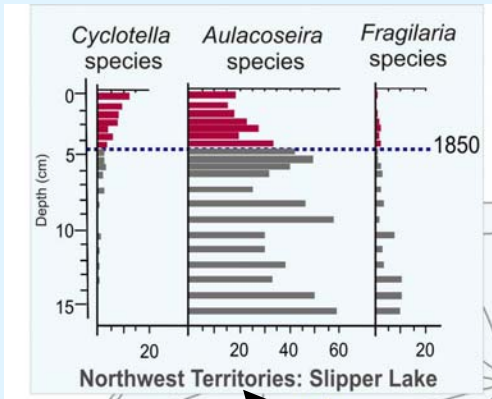


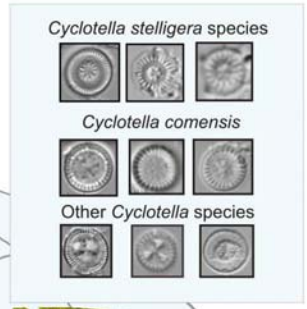











**Subarctic Canada**
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**Great Slave L. N.W.T**
***Stoermer et al. 1990***

**ELA NW ON**
***Enache et al. unpubl.***

**Subarctic Finland**
***Sorvari et al. 2002***

**Sweden**
***Bigler & Hall 2003***

**Spanish Pyrenees**
***Catalan et al. 2002***

**High Arctic Canada**
***Perren et al. 2003***

**NB Canada**
***Harris et al. 2006***

**SE ON**
***Forrest et al. 2002***

**SW ON**
***Werner et al. 2005***

***Northern Hemisphere-Scale Trend***

# Summary of Results

- Marked changes in diatom assemblages over last ca. 20-30 yrs
- Substantial decrease in DI-TP starting ca. 1980
- Timing of changes consistent between sites
- Changes consistent with temperature records
- Taxon-specific shifts correlated to temperature records
- Taxon-specific shifts correlated to historical ice-out record

# Concluding Remarks

- Phosphorus has long been an important component of the LOW
- Climatically-induced limnological changes = primary mechanism
- Climate must be considered an important part of the equation
- LOW fits into global pattern of recent taxon-specific diatom shifts

# Acknowledgements


- Bev Clark (MOE, Dorset)
- Mike Stainton (DFO, MB)
- Sergi Pla (formerly at PEARL)
- Tom Mosindy & Gavin Olson (MNR Kenora)
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- Joy Ramstack (St. Croix Watershed Research Station, MN)
- Mark Edlund (St. Croix Watershed Research Station, MN)
- Euan Reavie (Natural Resources Research Institute, Ely MN)
- Nolan Baratono (Minnesota Pollution Control Agency)