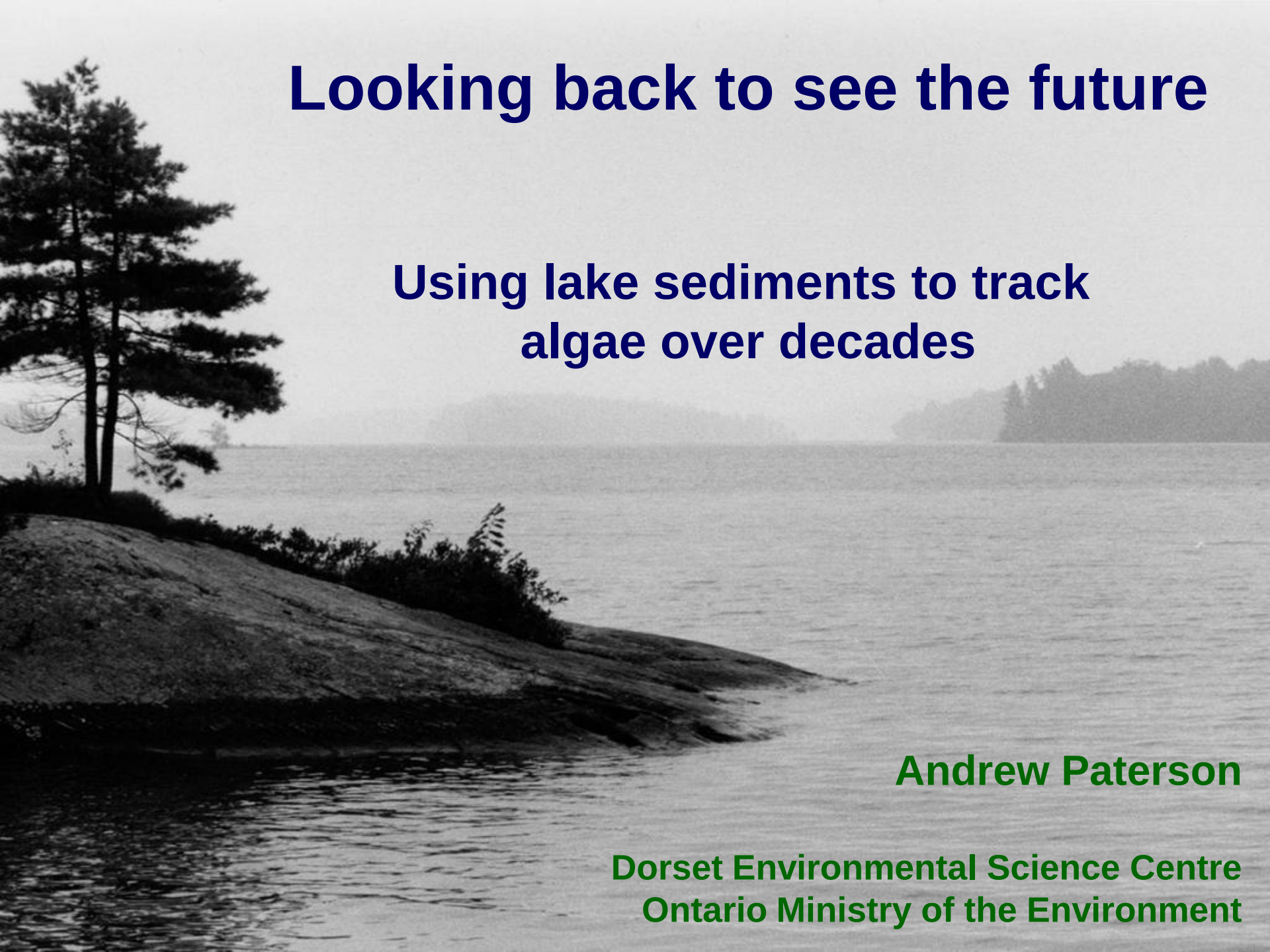


Looking back to see the future

Using lake sediments to track algae over decades

Andrew Paterson

Dorset Environmental Science Centre
Ontario Ministry of the Environment

“…the water foul, frequently with a green scum of vegetable matter…”

- Major Joseph Delafield, LOW, 1823

(Photos: Bev Clark)

Algal blooms:

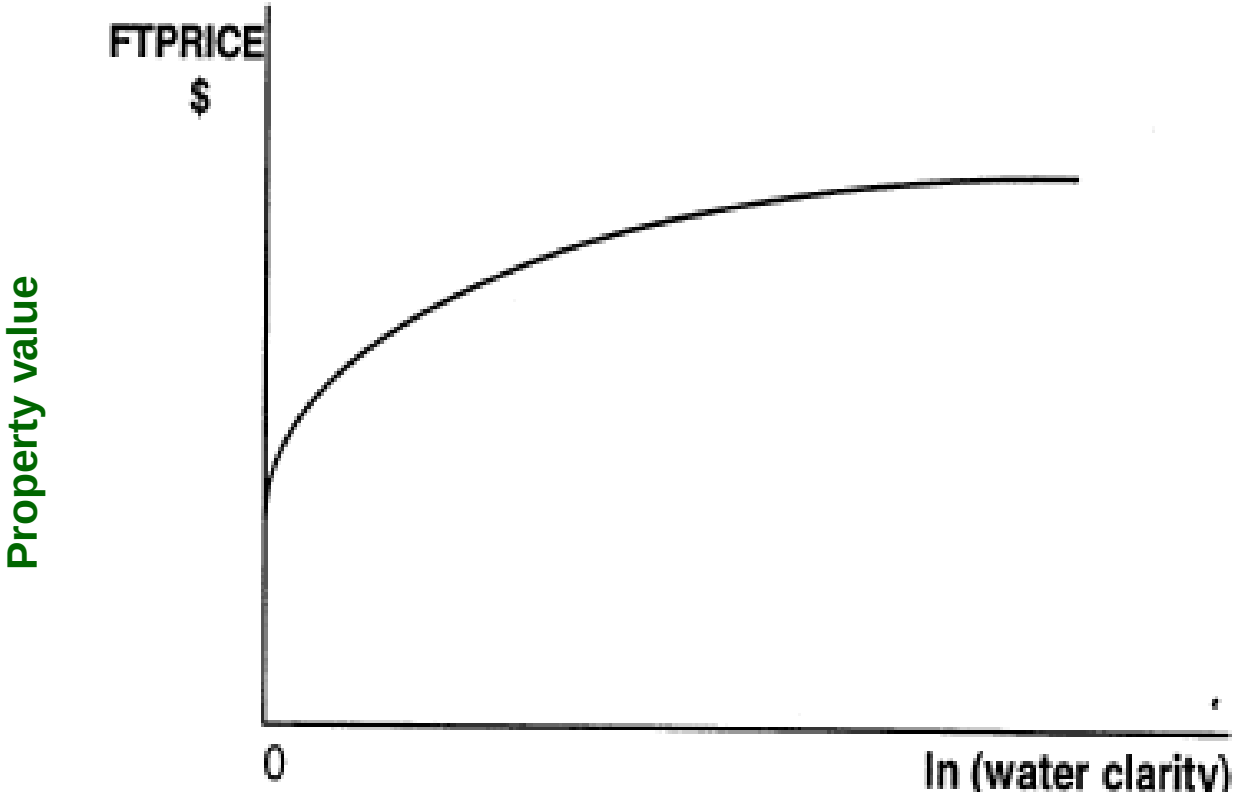
1) Reduced water clarity

2) Loss of deep-water oxygen

3) Toxins

4) Taste and odour

Property values are a function of amount of frontage, location, structural components and WATER QUALITY



Consultants report, State of Maine

Property value

Water quality

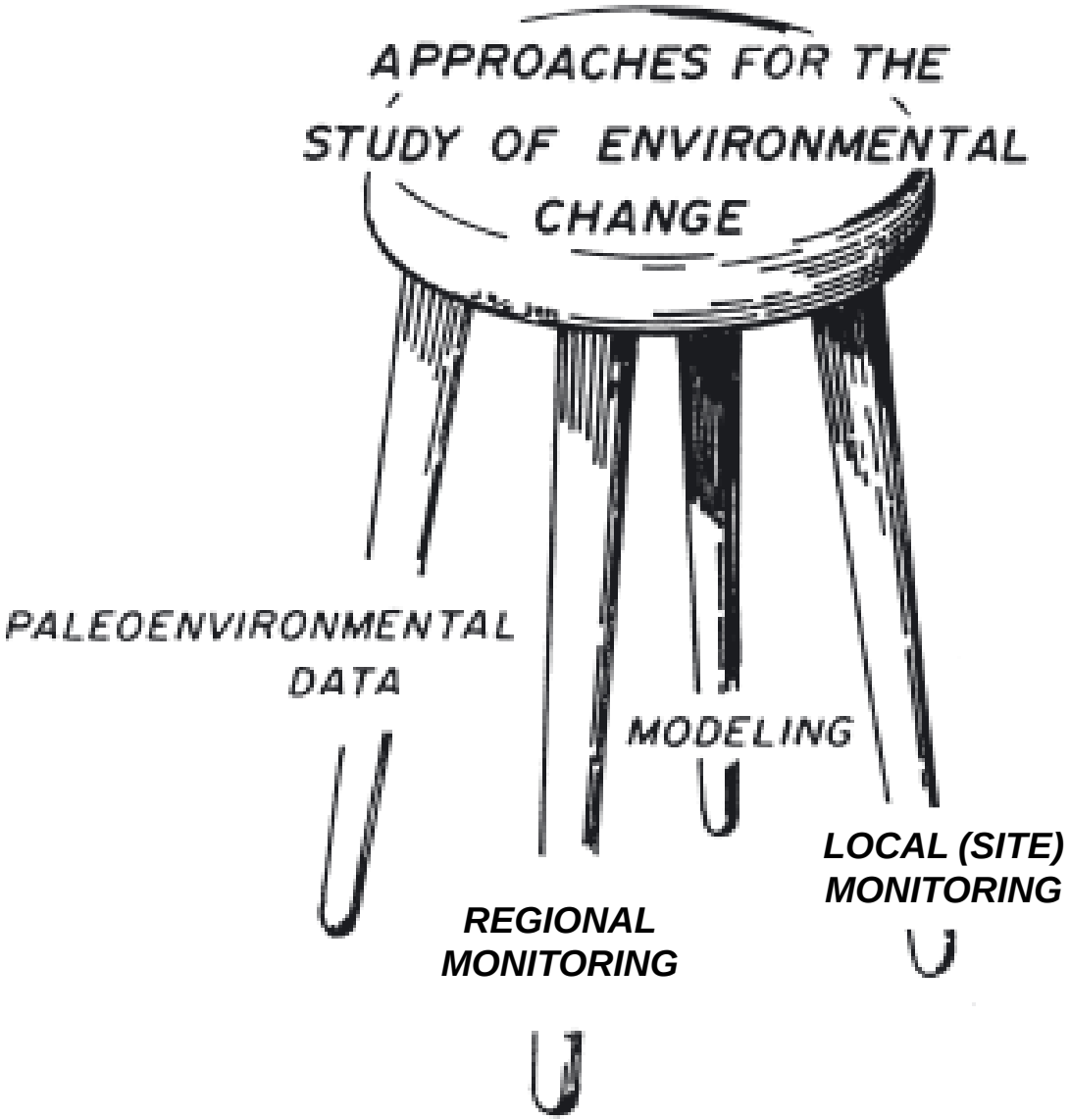
(Bracebridge Examiner, October 19th, 2005)

Aphanizomenon

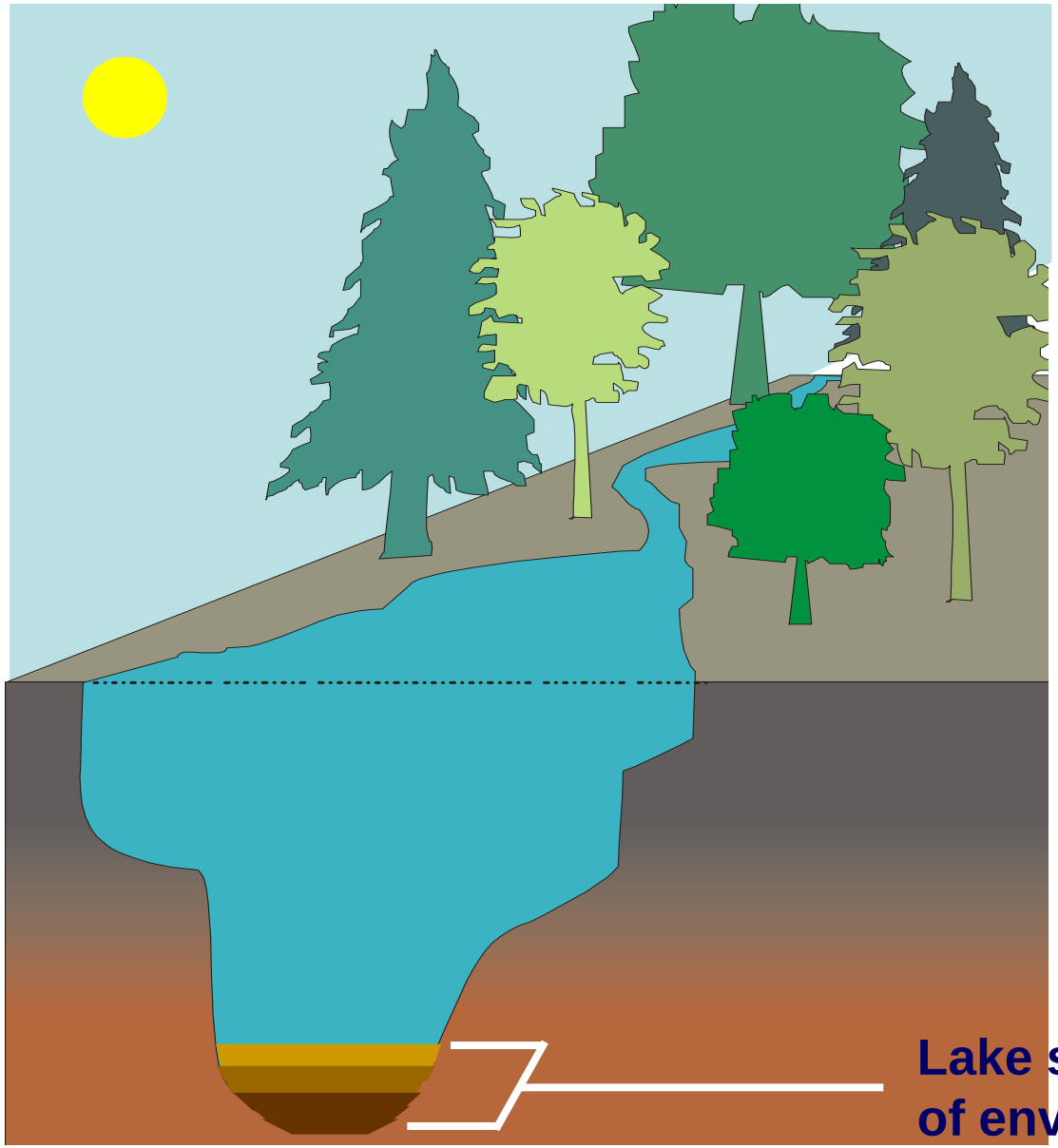
Why is this happening?

What caused this?

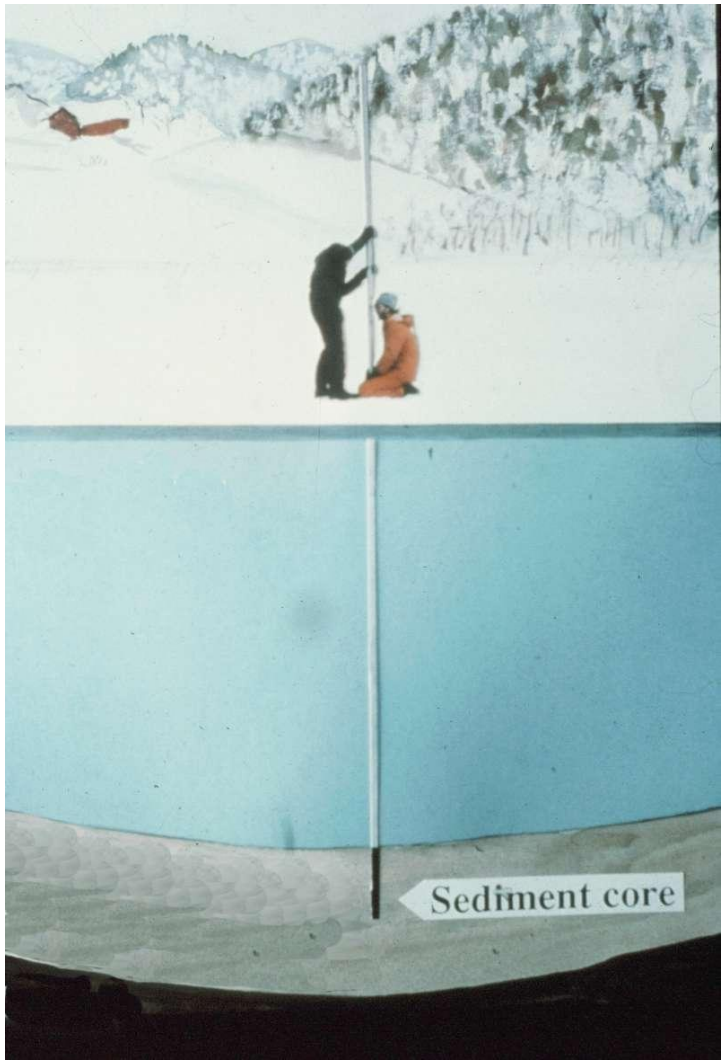
Will it happen again?



(Modified from Smol 2005)



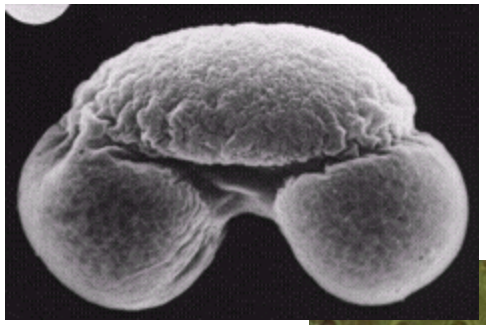
Lake sediments are archives of environmental change


Sediment core

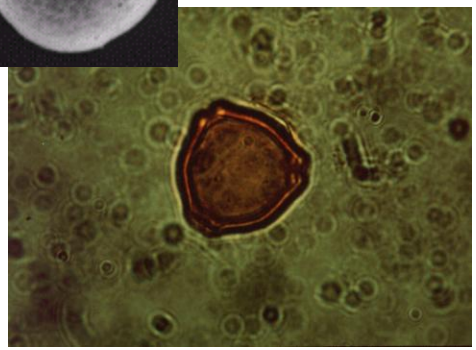
Fly ash and charcoal

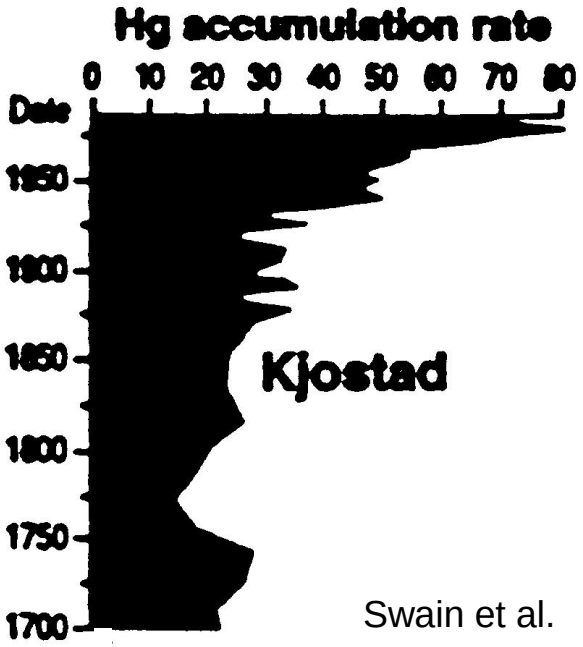
From the air and land

Contaminants

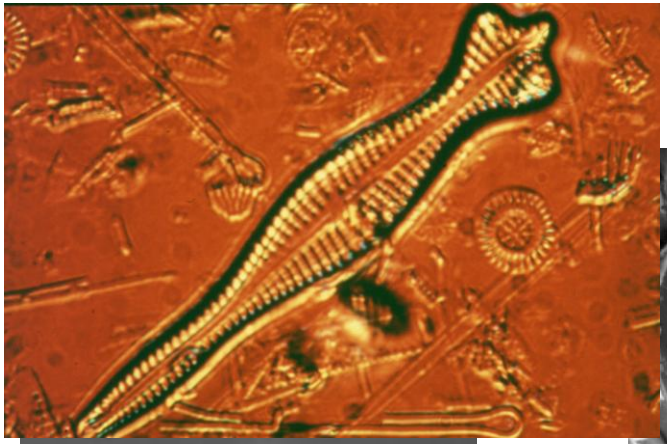


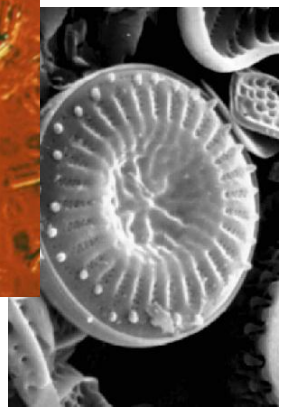
Pollen

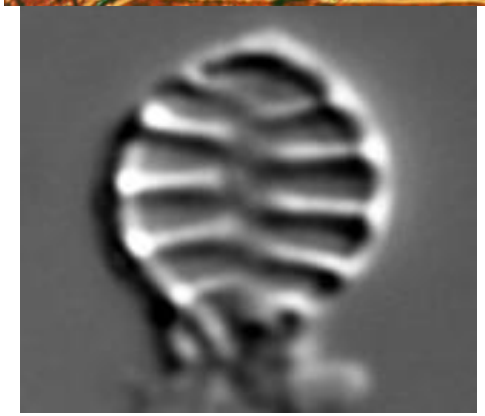




Swain et al.

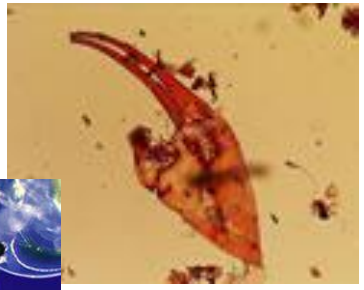






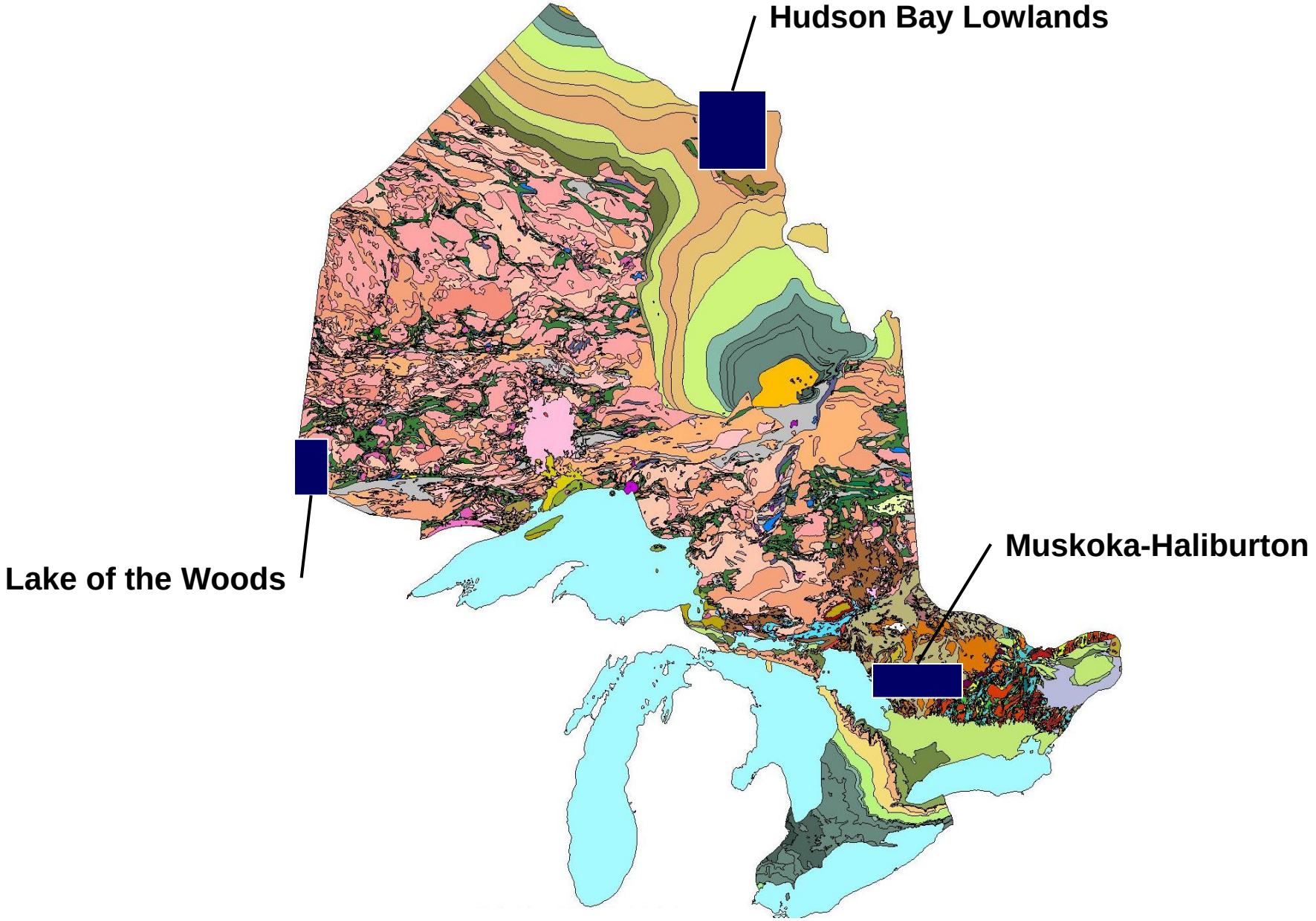
Algae

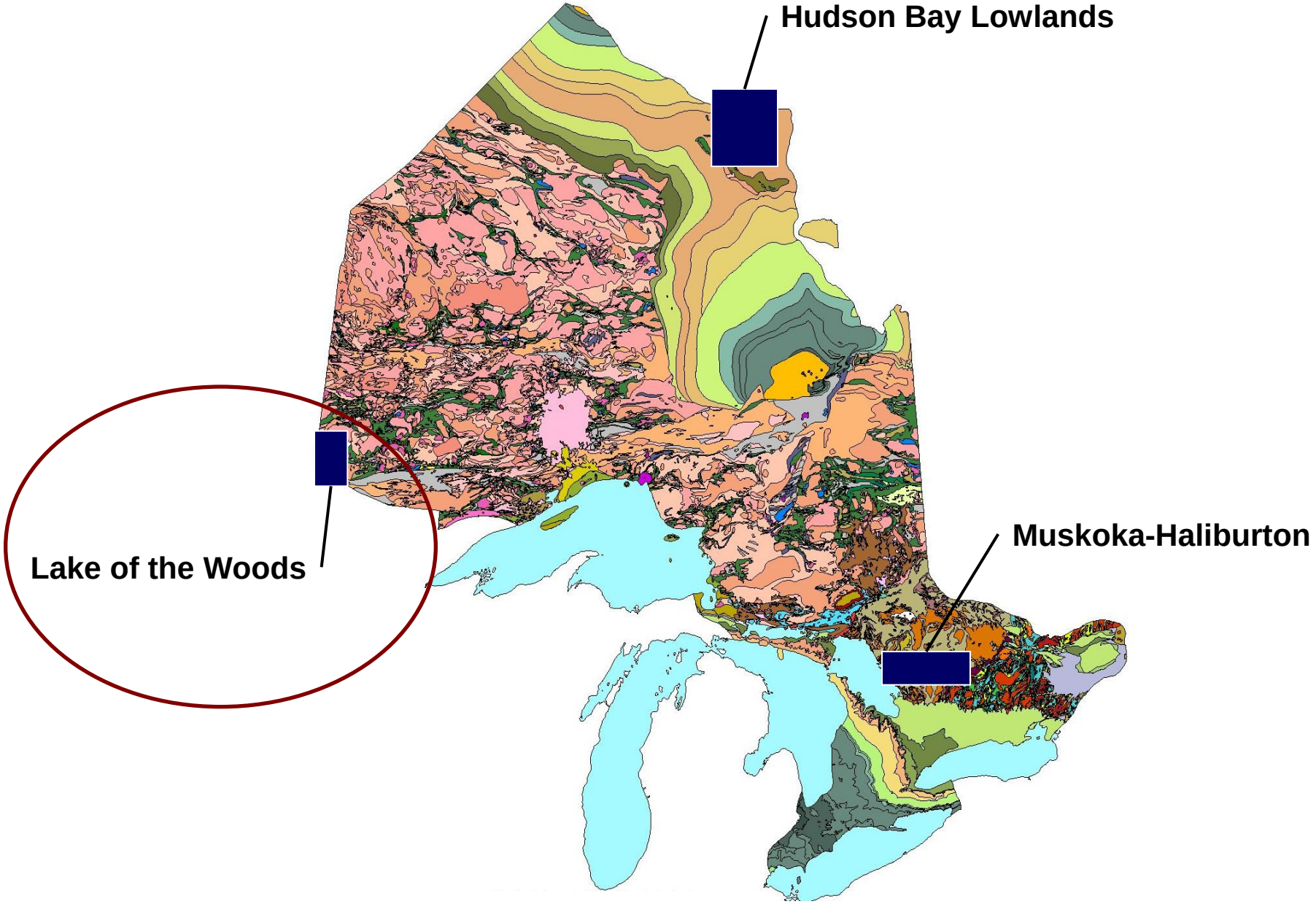
From the lake

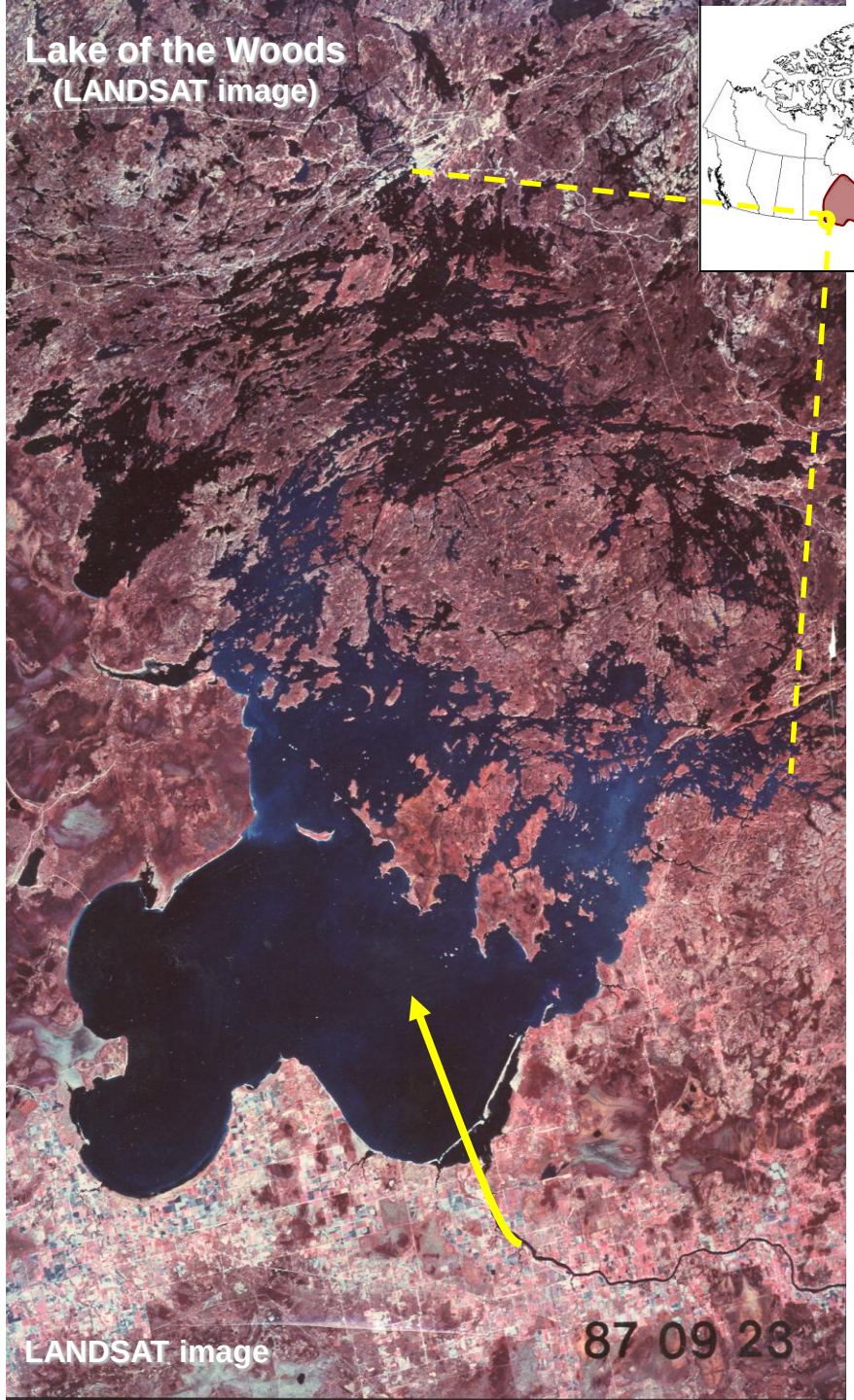


Water fleas
(zooplankton)

Midges
(chironomids)


Hudson Bay Lowlands
Lake of the Woods
Muskoka-Haliburton


Hudson Bay Lowlands
Lake of the Woods
Muskoka-Haliburton



"The islands were numerous and crowded…"

- Major Joseph Delafield, 1823

- **large surface area (~ 385,000 ha)**
- **over 14,500 islands**
- **flow is north**
- **~75% of tributary inflow and 75% of the TP load comes from the Rainy River (Hargan et al., submitted)**

Management issues

Severe blue-green blooms/toxic

Development pressure

Fisheries management

Invasive species

Hydrological management / Shoreline erosion

Climate change

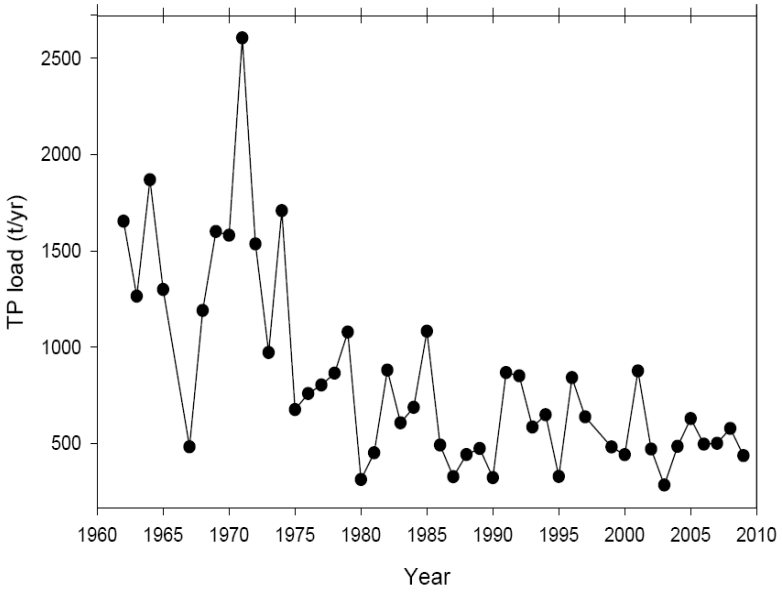
(Photo: Bev Clark)

A disconnect in Lake of the Woods?

(Photo: T. Sellers)

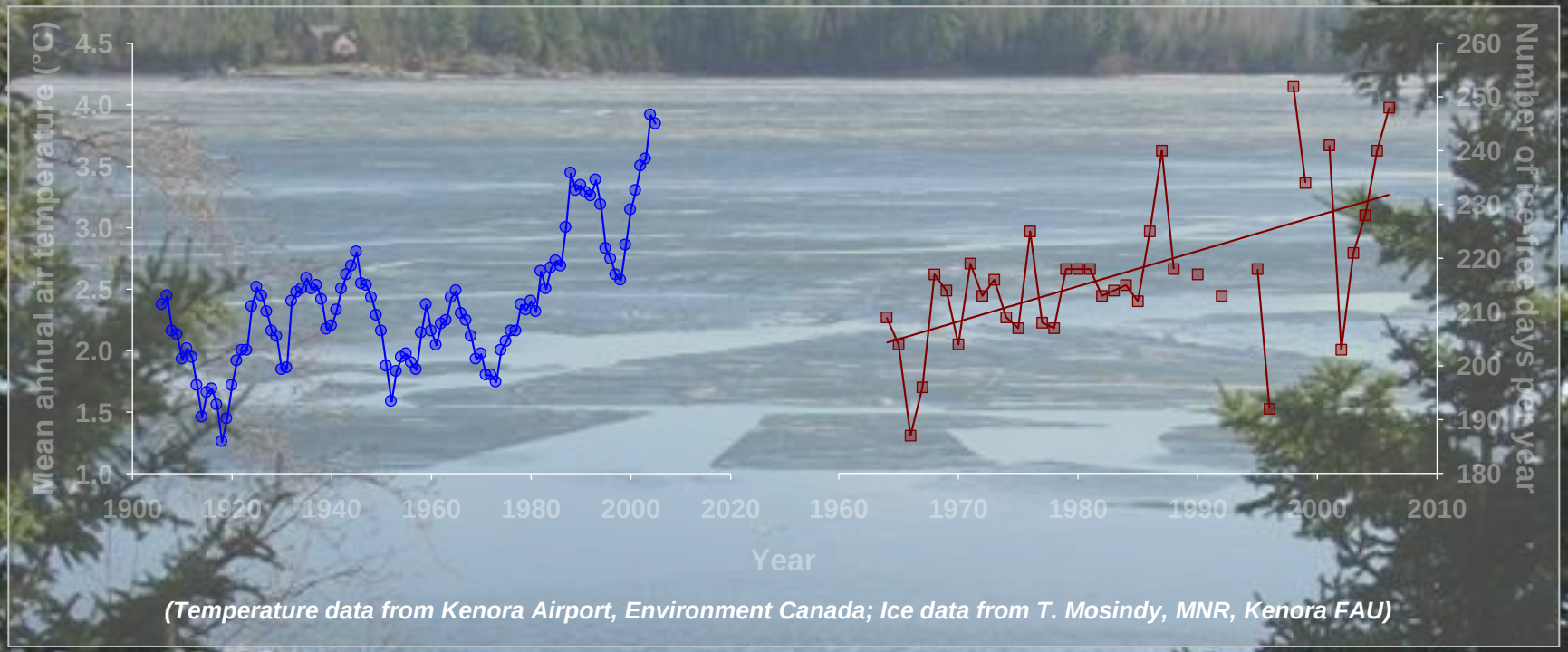
Perception that cyanobacterial blooms have increased in intensity and duration in recent years

≠

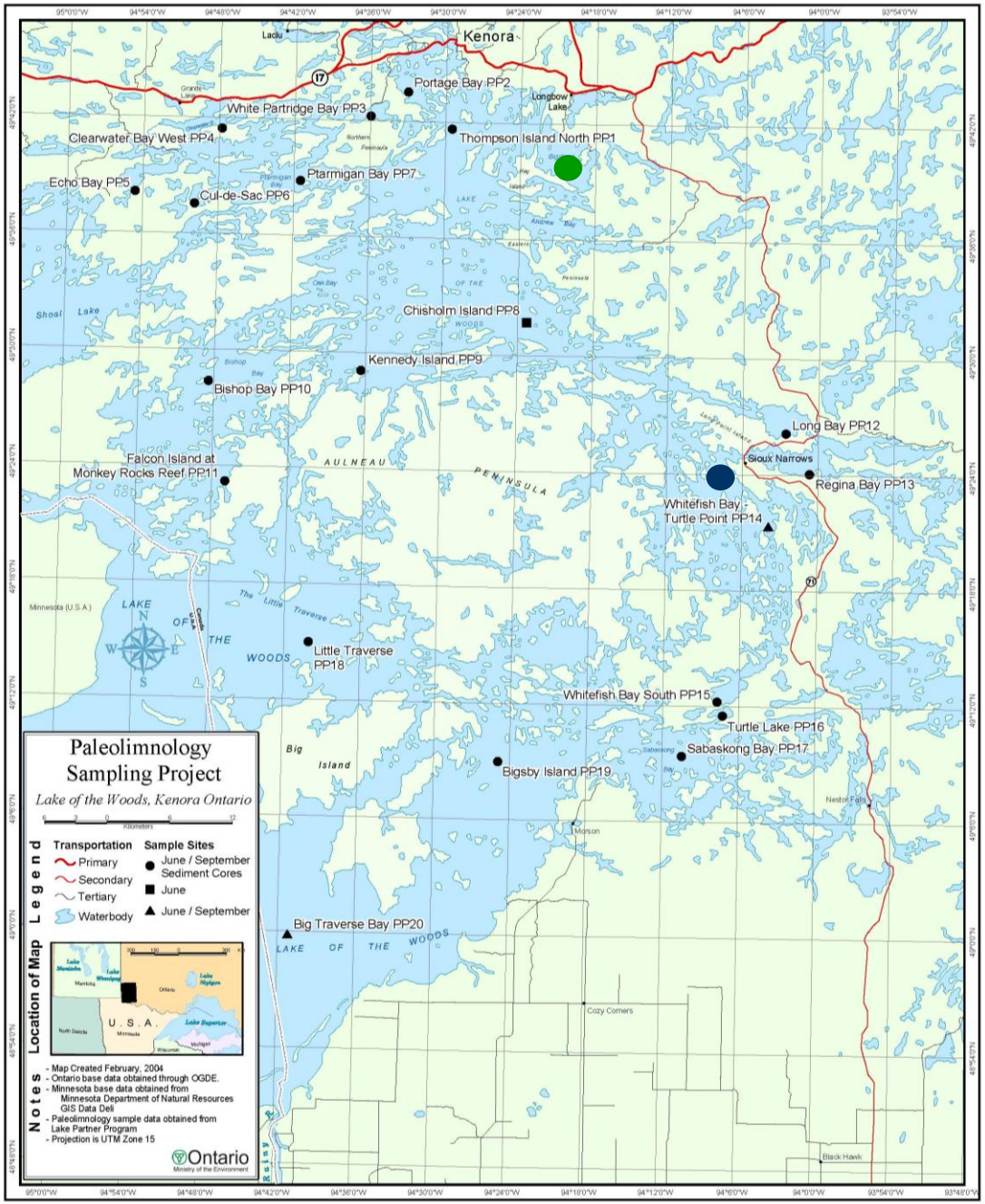


A decline in phosphorus loading from the Rainy River

A region sensitive to recent warming



(Temperature data from Kenora Airport, Environment Canada; Ice data from T. Mosindy, MNR, Kenora FAU)

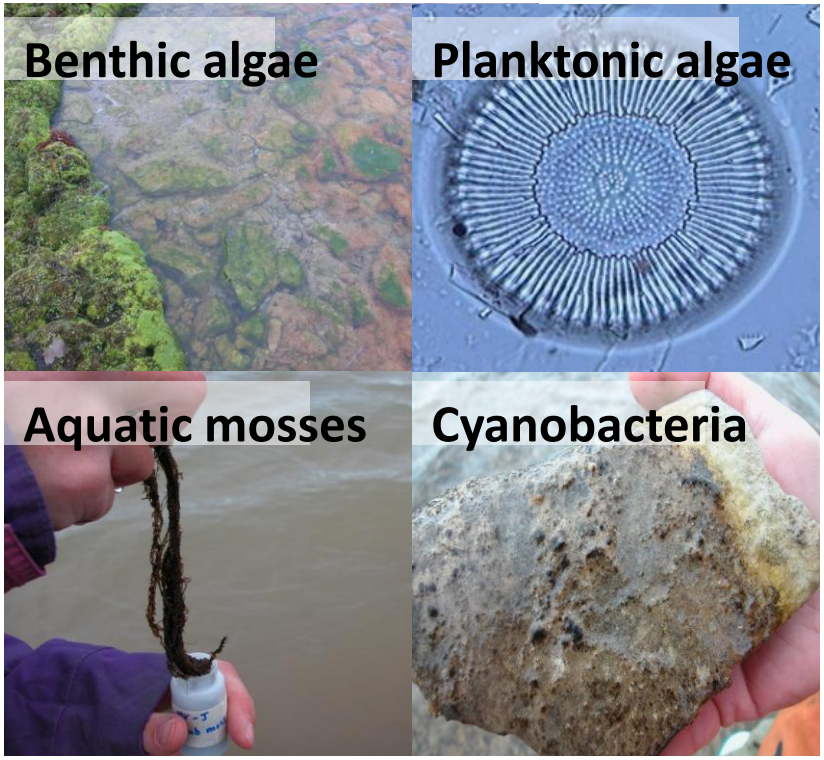


Sampling sites

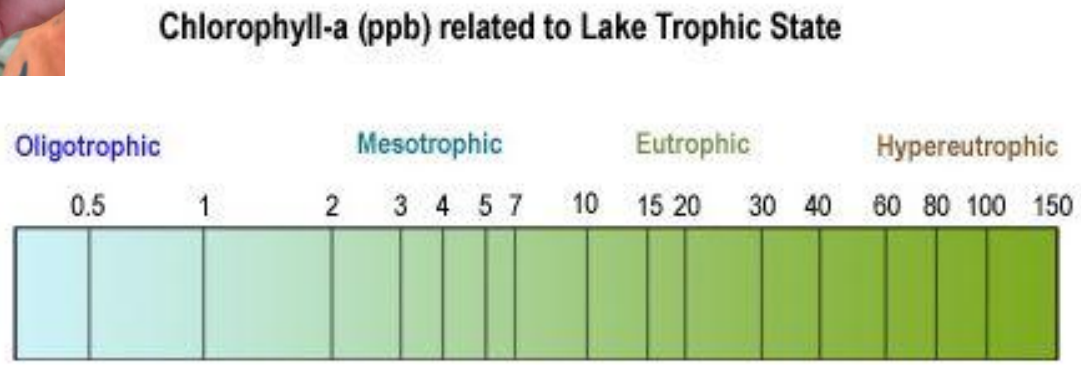
- **Reference site**
  (no blue-greens)
- **Impacted site**
  (lots of blue-greens)

(Photo: K. Rühland)

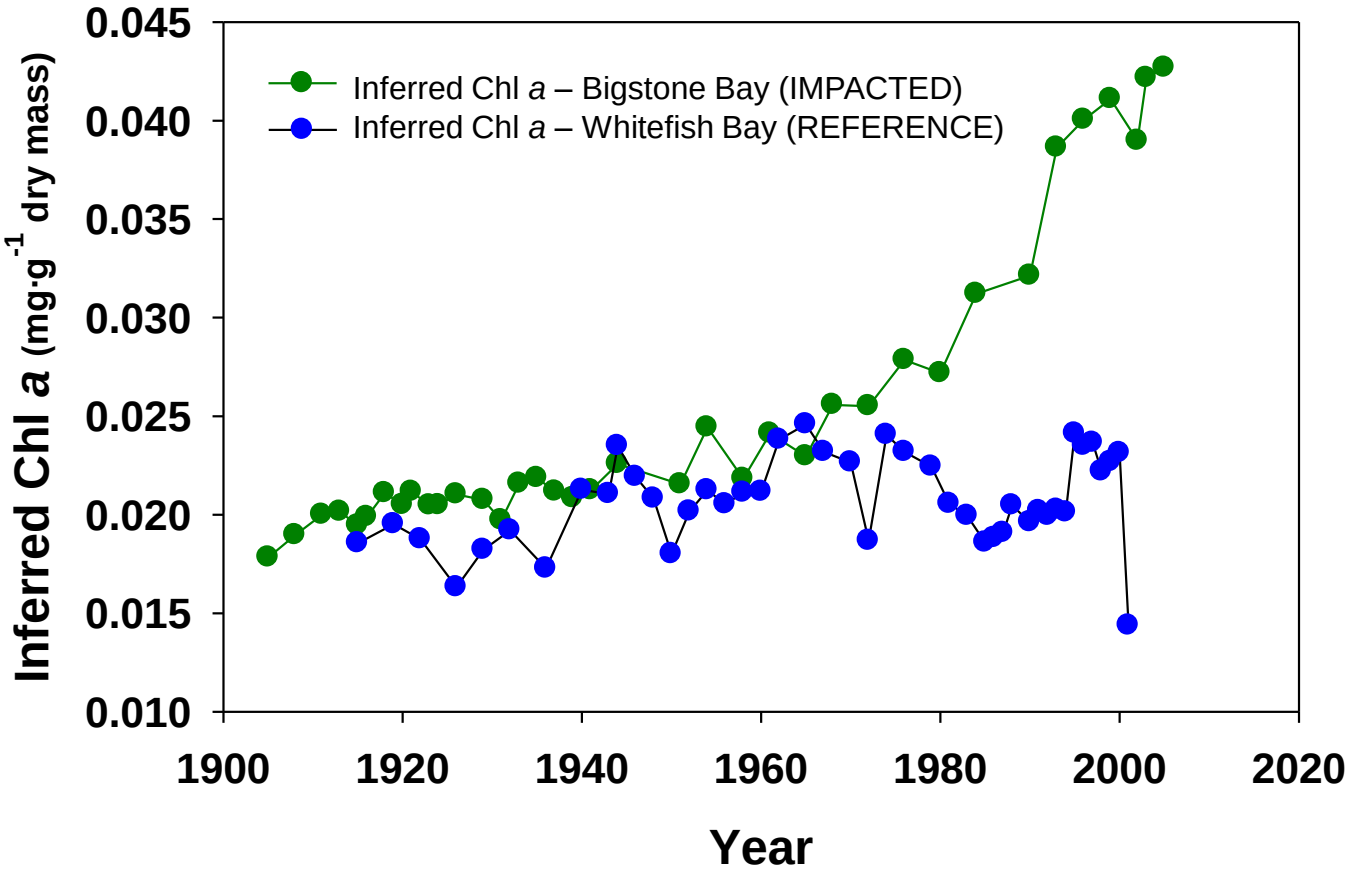
➔Sediment chlorophyll *a* concentrations inform about past changes in the amount of algae



Chlorophyll *a* occurs in all photosynthetic eukaryotes and the cyanobacteria



Inferred Chl *a* – Lake of the Woods – Impacted Site vs Reference Site



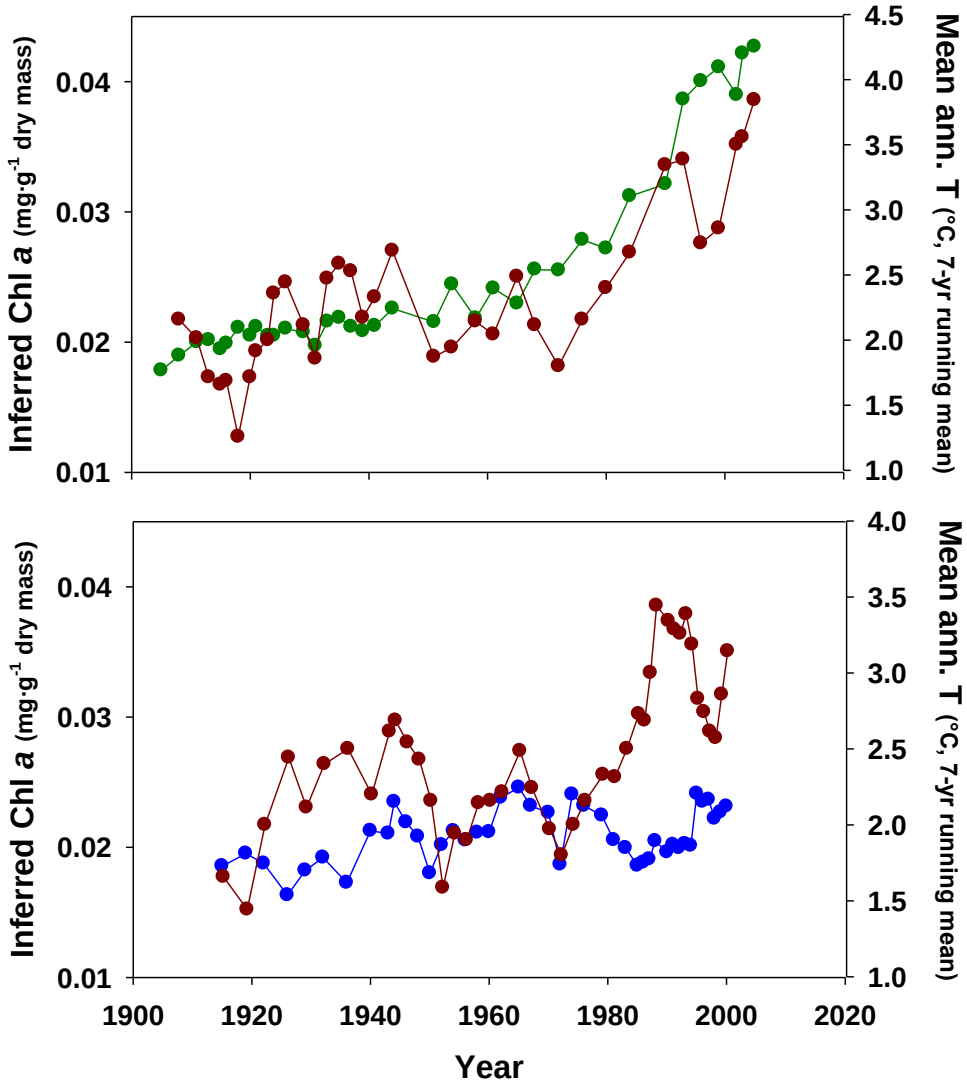
Inferred Chl *a* versus mean annual air temperature

Impact site vs mean annual air T°

r = 0.81, p <0.001 , n = 36

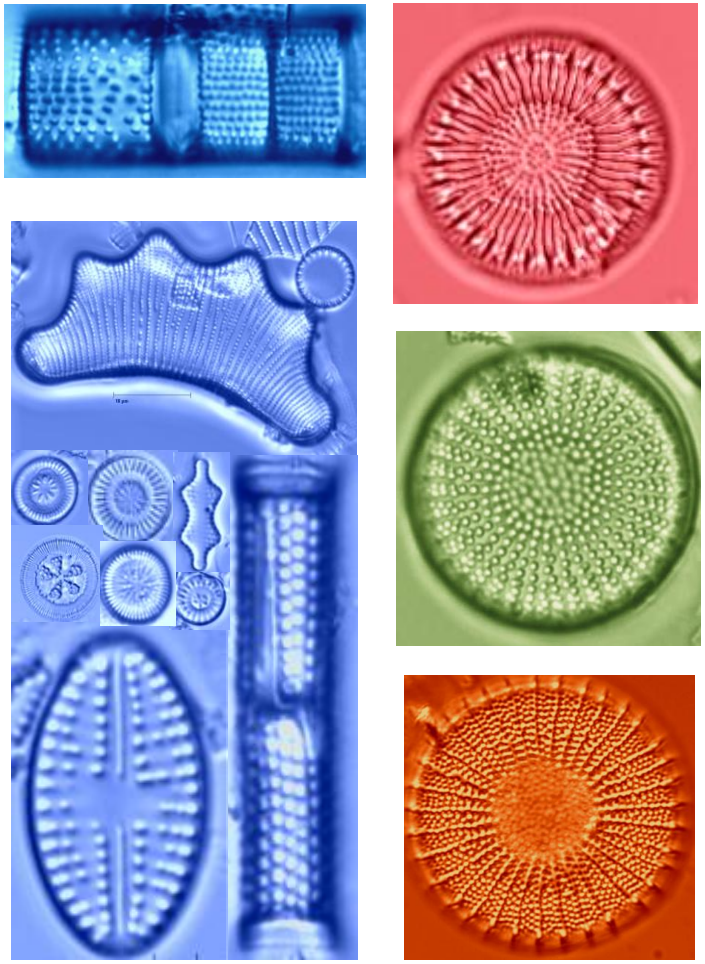
Reference site vs mean annual air T°

r = 0.07, p = 0.66, n = 43

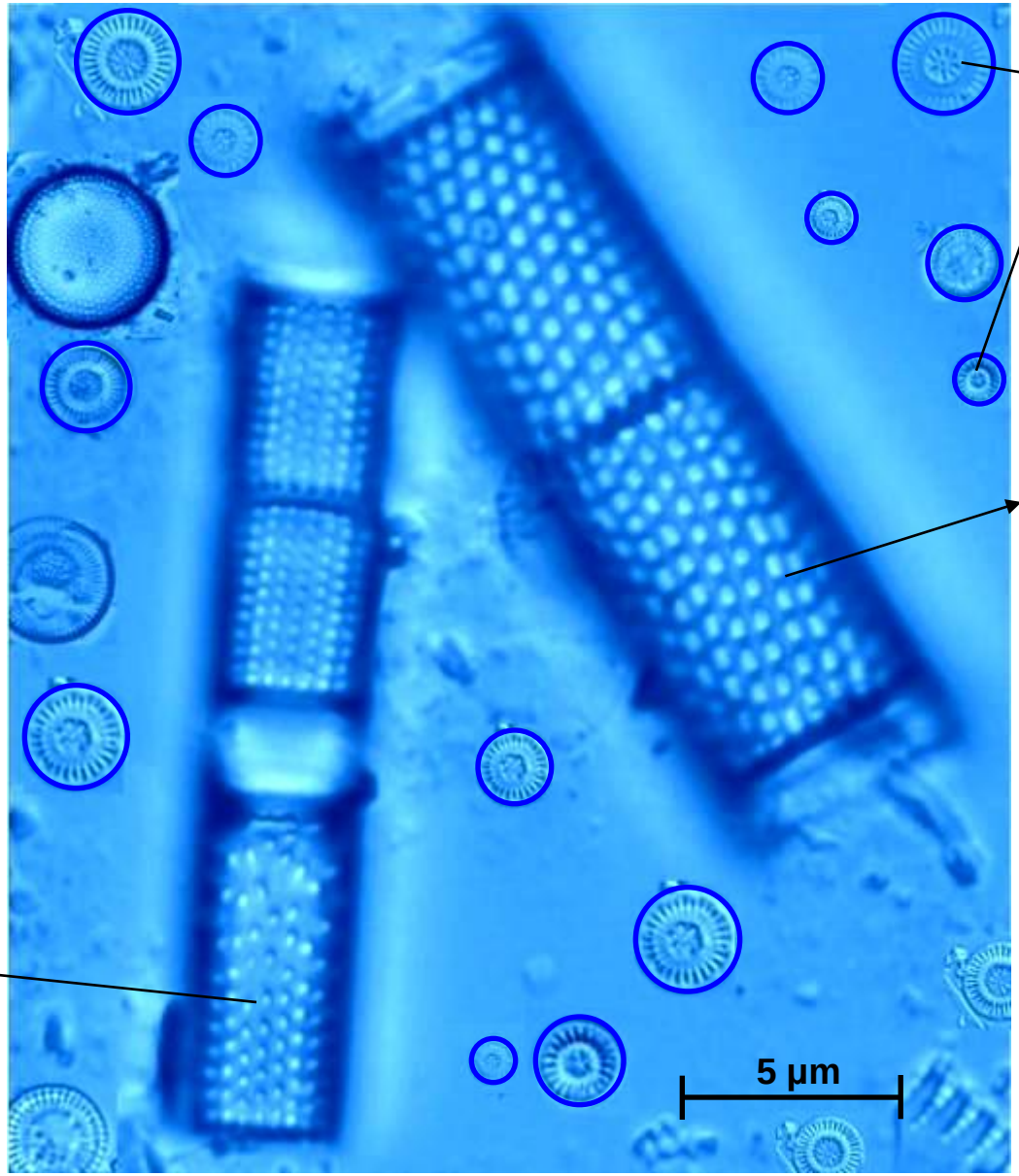


Diatoms: sensitive indicators of climate warming

- single-celled, microscopic algae
- well preserved in lake sediments
- taxonomically specific ornamentation
- sensitive to environmental and climatic change
- respond rapidly to environmental change



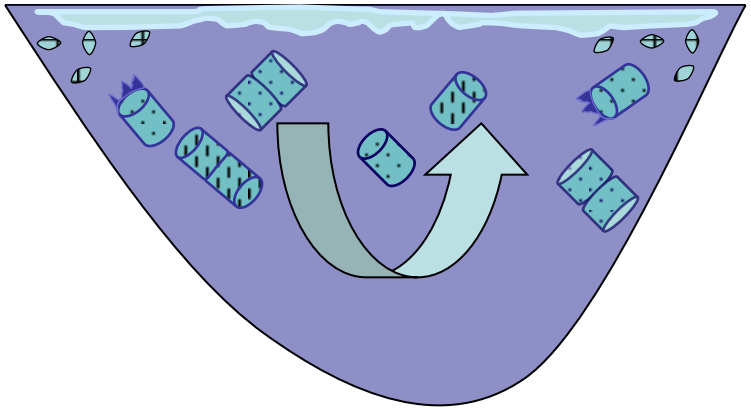
Diatoms and warming: *Cyclotella - Aulacoseira*



Warming favours small diatoms

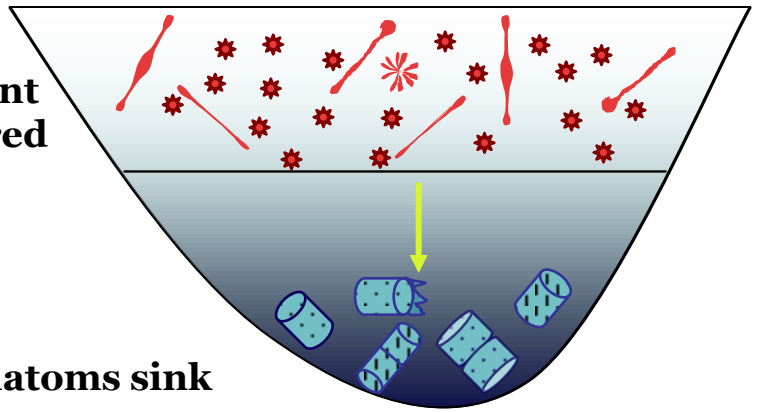
Longer ice-cover period

Mixed water column



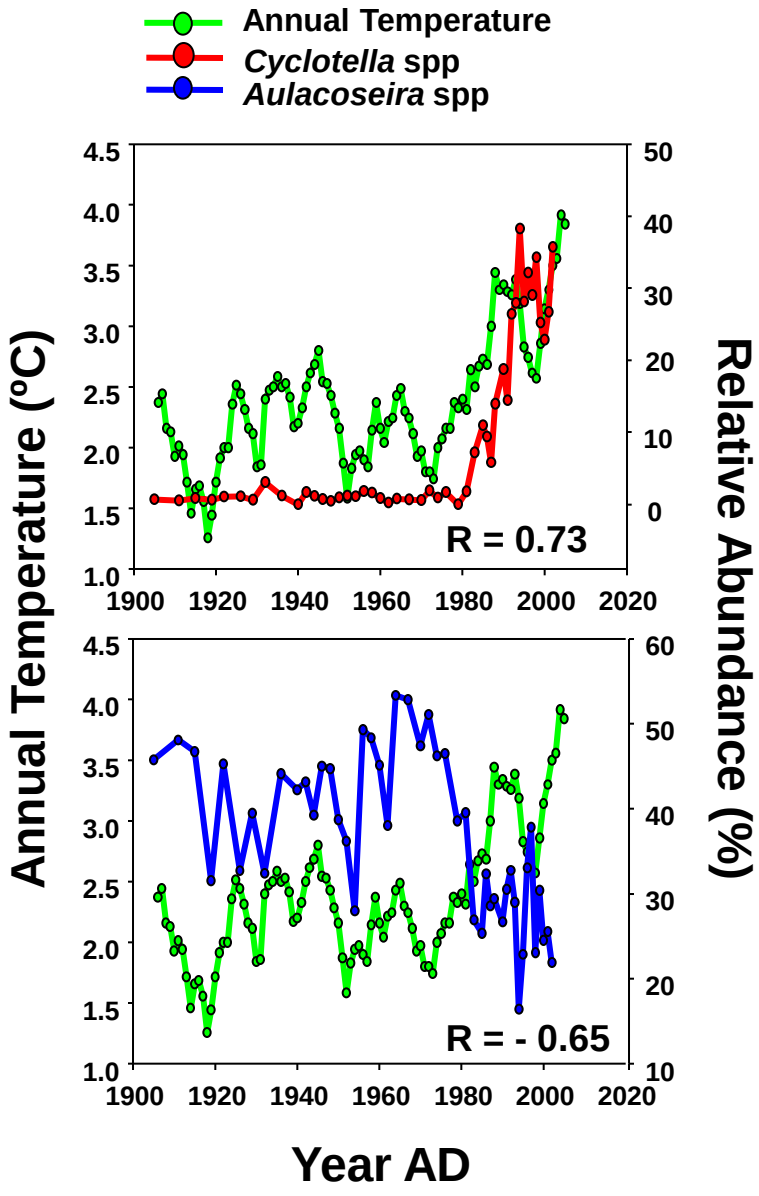
Stratified and/or less ice

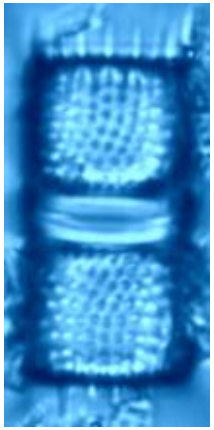
Smaller & buoyant plankters favoured



Heavier diatoms sink

Whitefish Bay, Lake of the Woods, Ontario





(Rühland, Paterson, Smol 2008)

A disconnect in Lake of the Woods?

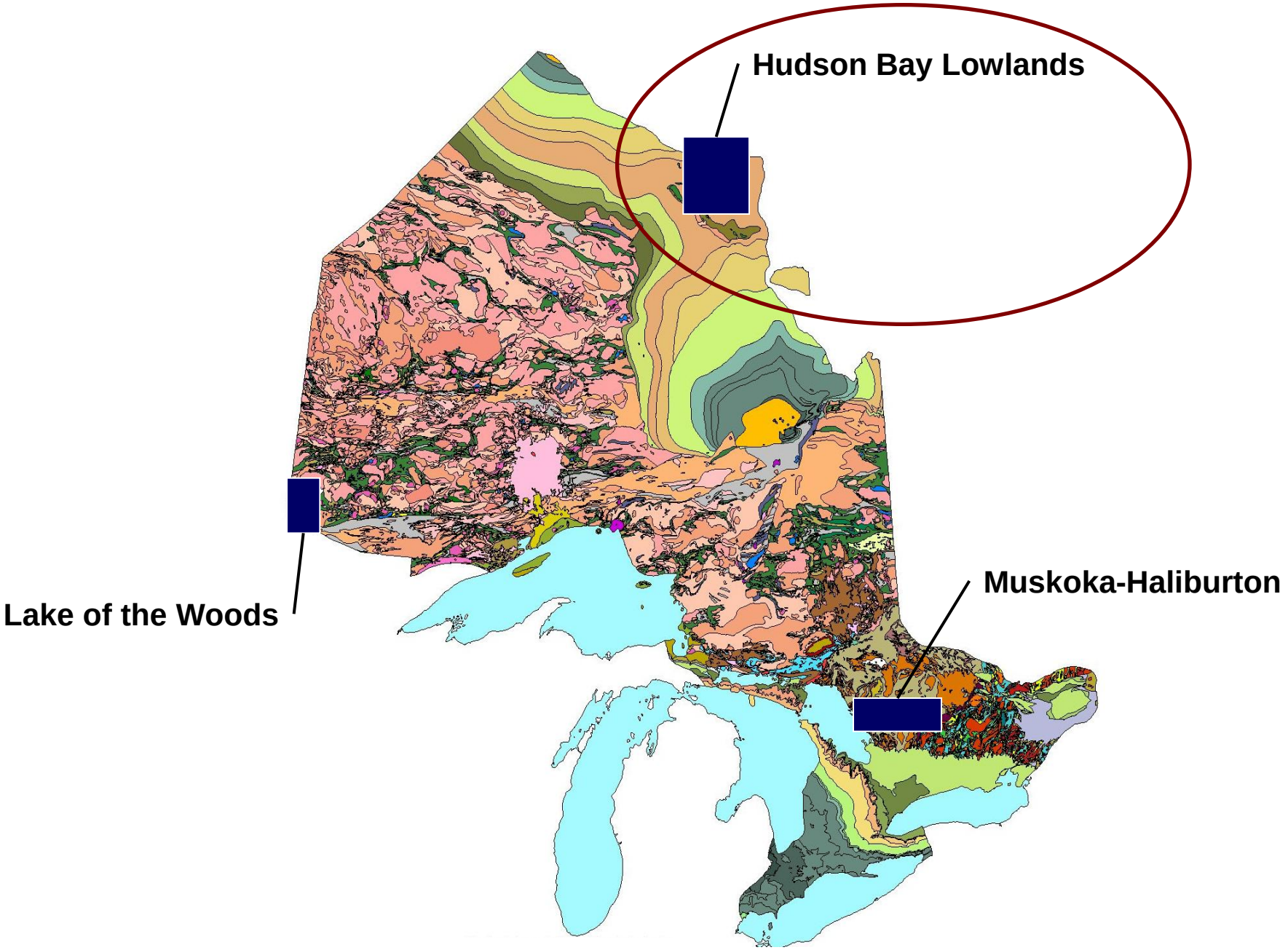
(Photo: T. Sellers)

Perception that cyanobacterial blooms have increased in intensity and duration in recent years

Possible mechanisms:

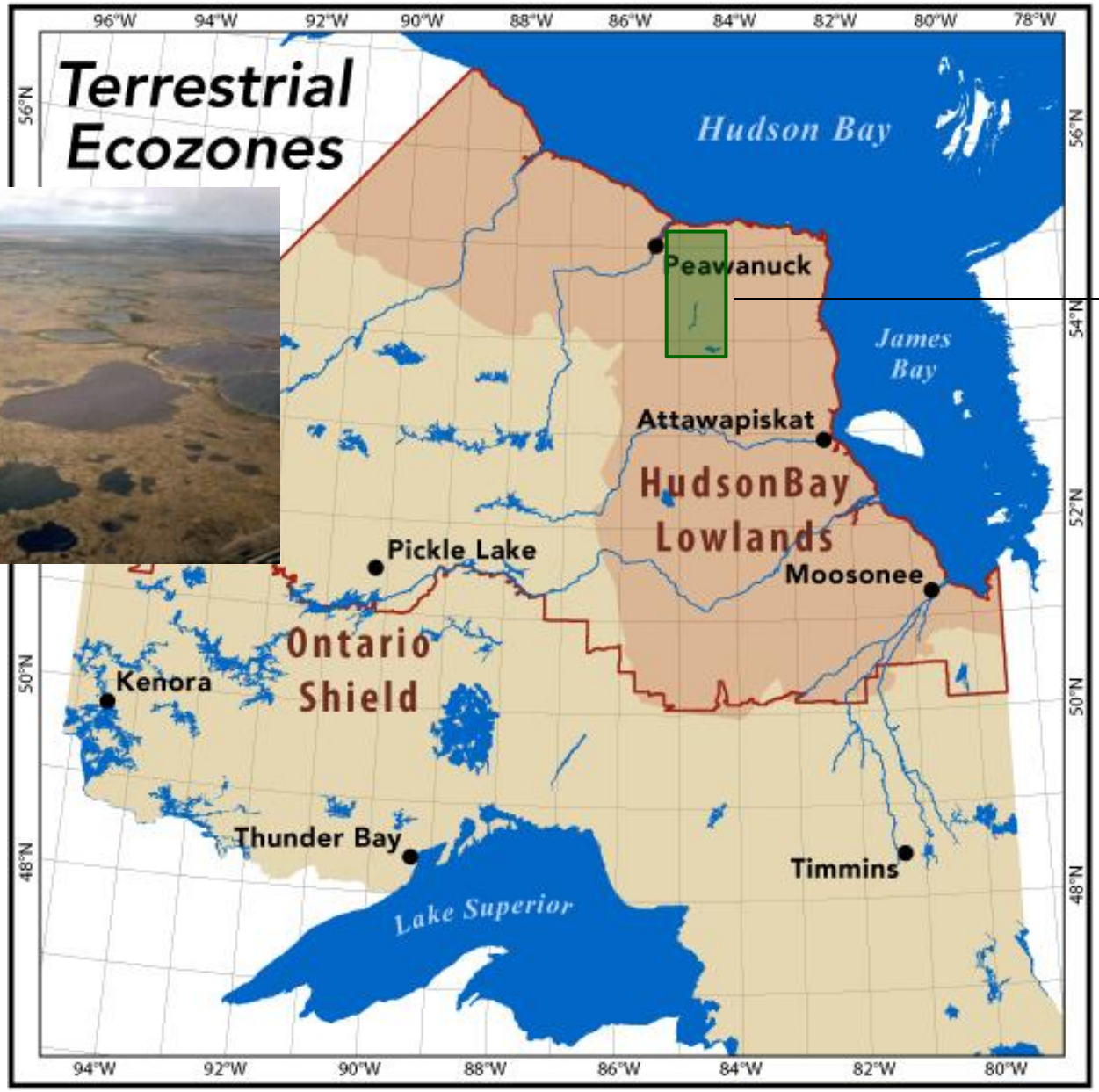
- **increased duration and strength of thermal stratification favouring buoyant algae, including blue-greens (PHYSICAL CHANGE)**

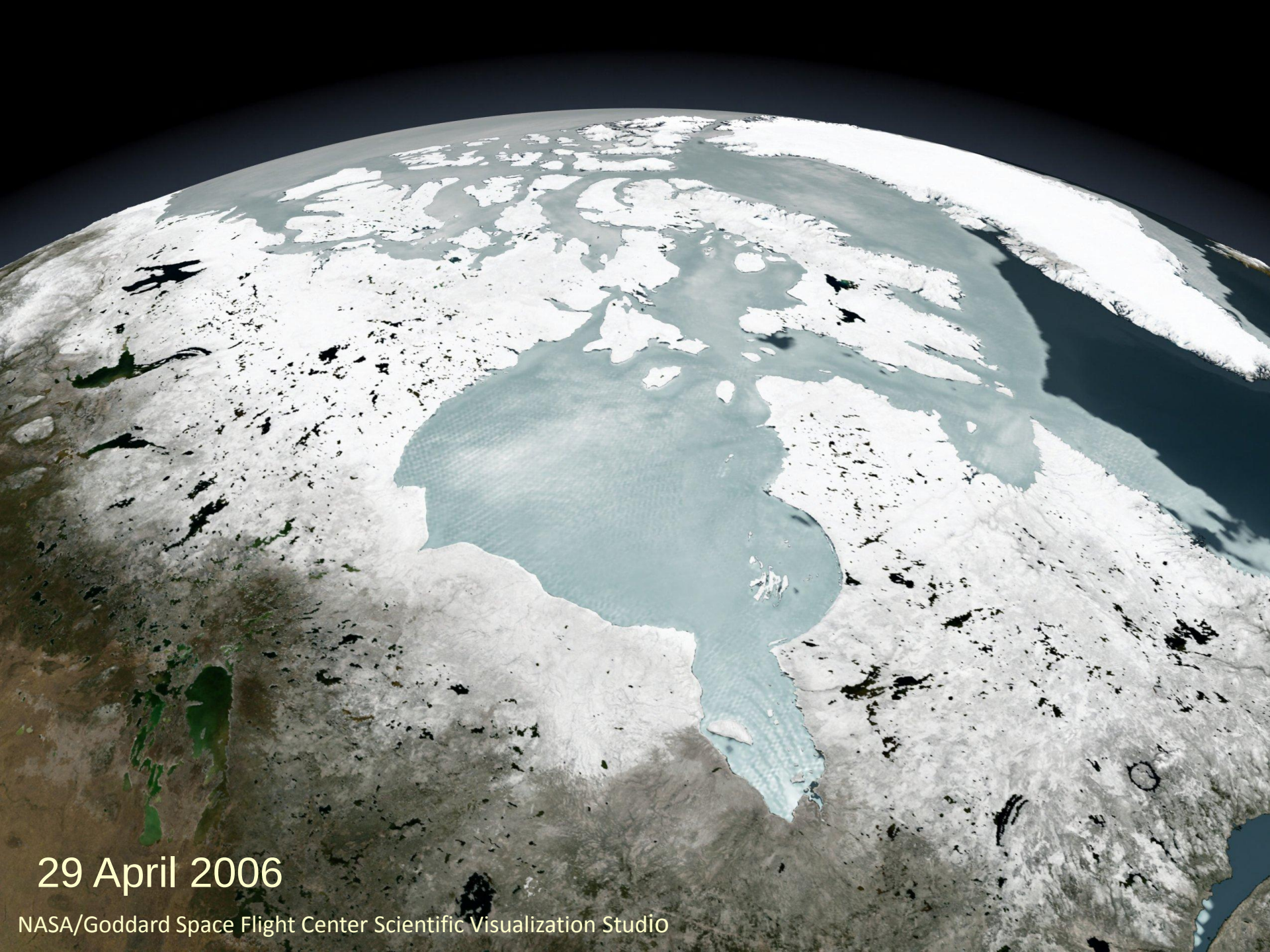
- **warmer temperatures and longer ice-free season that affects nutrients in favour of blue-greens (CHEMICAL CHANGE)**


Hudson Bay Lowlands
Lake of the Woods
Muskoka-Haliburton

Hudson Bay Lowlands, Ontario

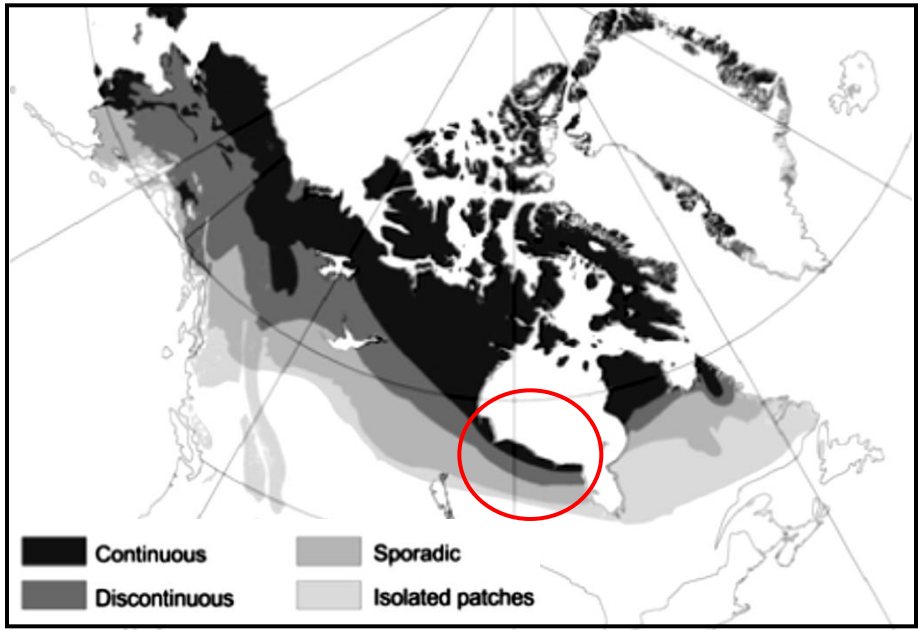
(Geological Survey of Canada)



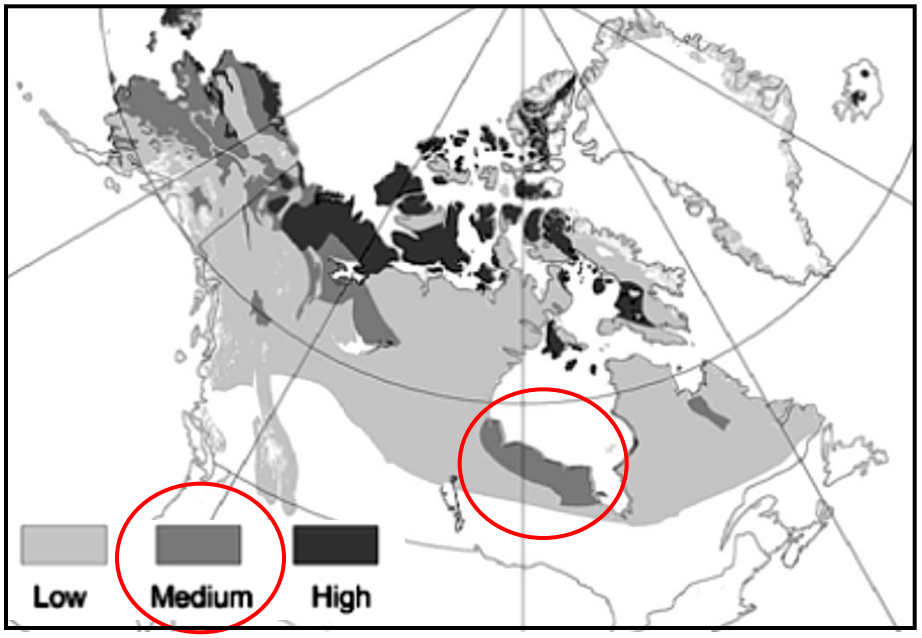

29 April 2006
NASA/Goddard Space Flight Center Scientific Visualization Studio

Distribution of permafrost and ground ice in N. America

Permafrost Zones



Ground Ice Volume

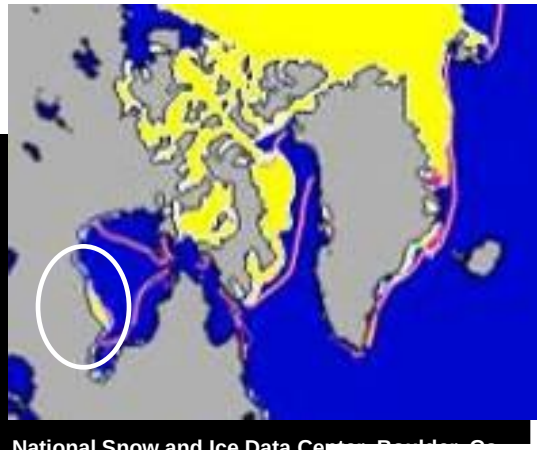


(Nelson et al. 2002)

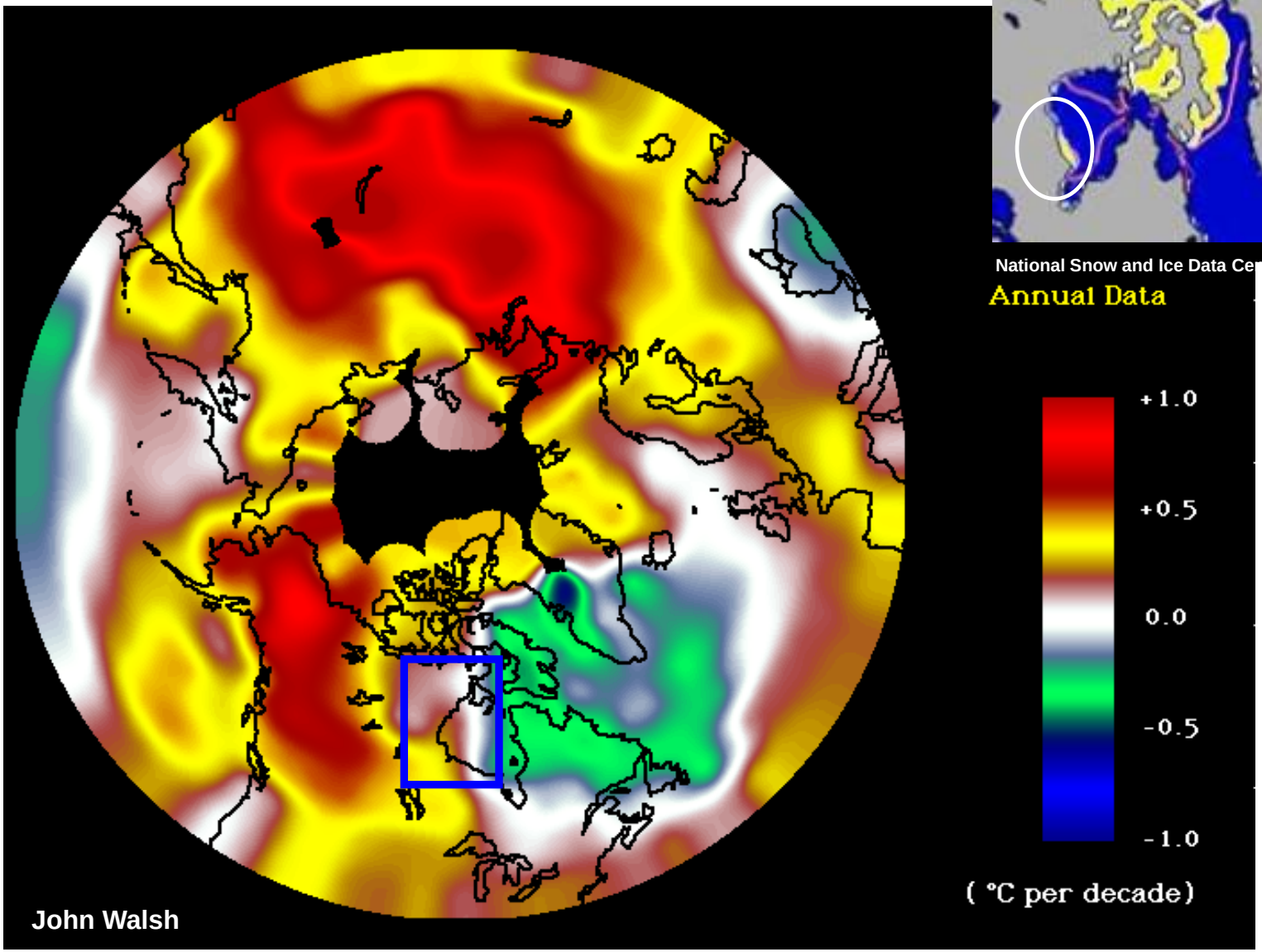
The Hudson Bay Lowlands:

- most southerly extend of continuous permafrost in Canada
- steep (geographically-narrow) permafrost gradient
- ground ice content is moderate (10-20% relative volume)

Arctic Temperature Trends 1966-1995

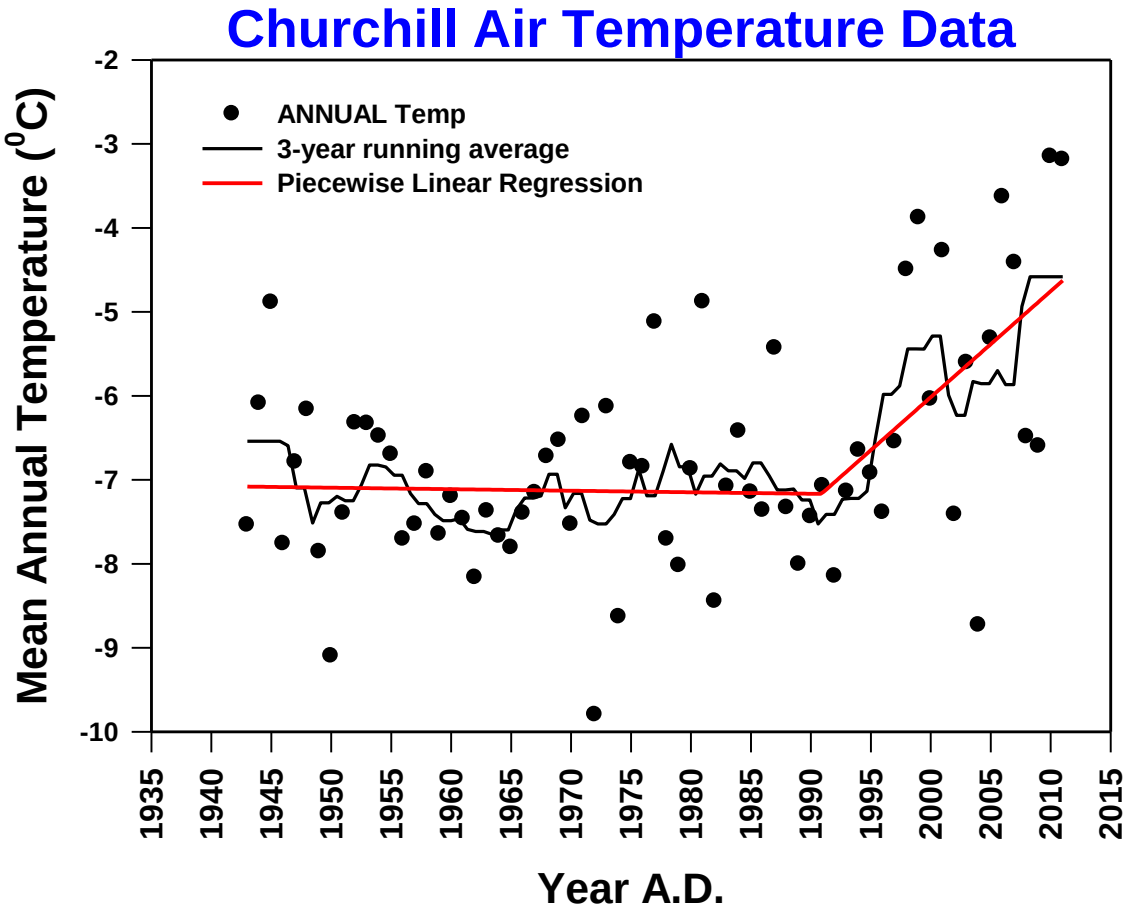


National Snow and Ice Data Ce



"…Hudson Bay area has recently undergone a climate regime shift, in the mid 1990s…"

Hochheim & Barber (2010) *J. Geophys. Res.*



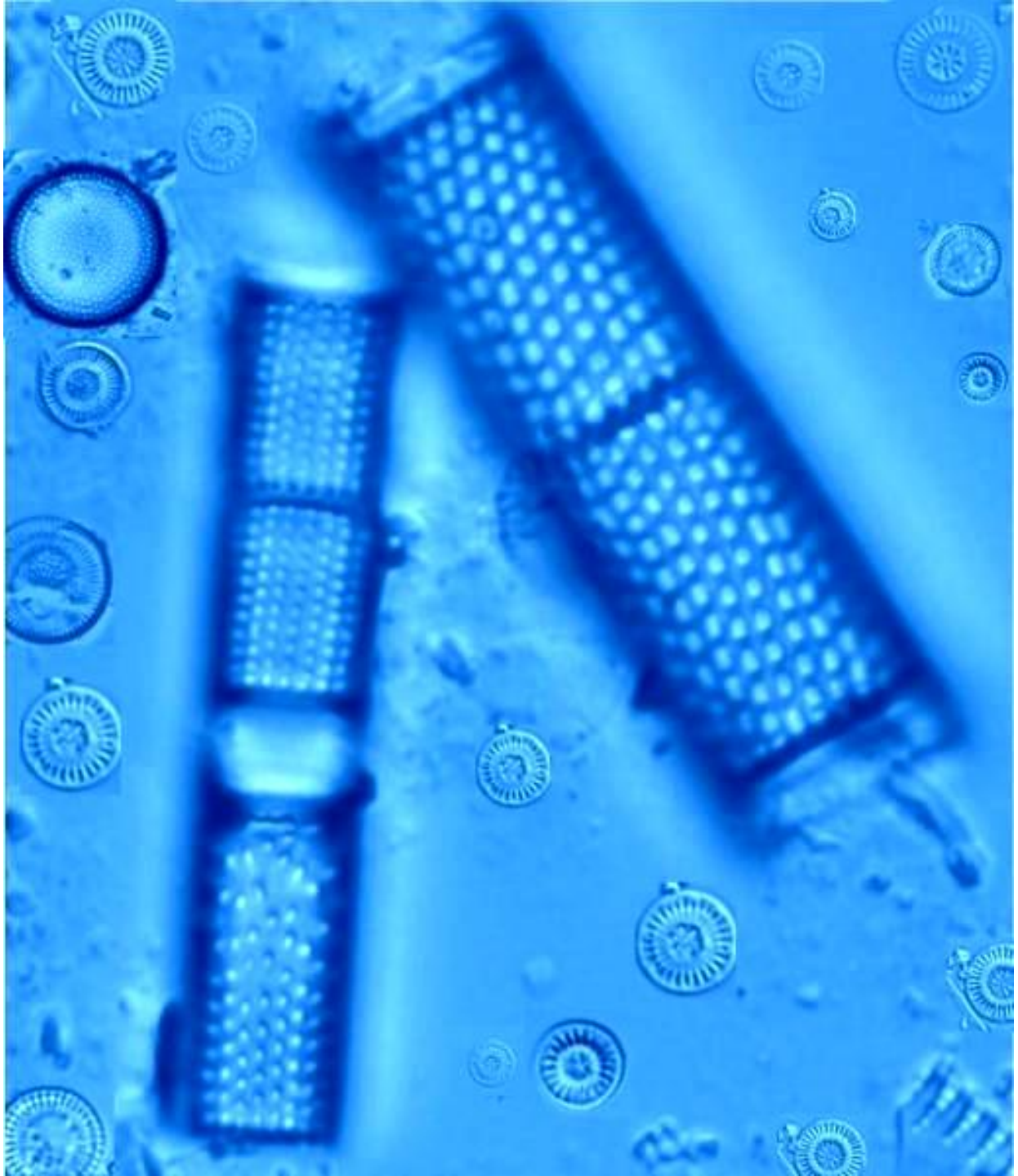
(Raw data: Environment Canada)

On-the-ground observations

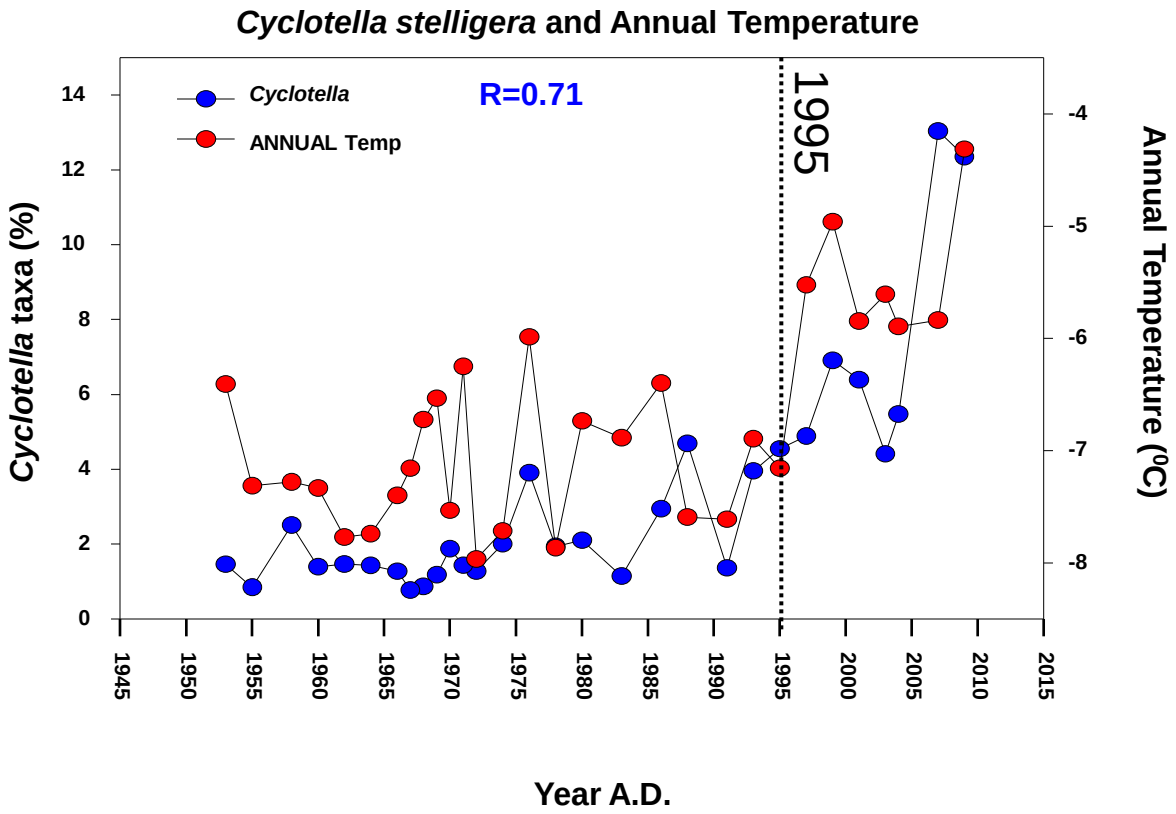
Recent evidence of:

- lower water levels
- increased prominence of aquatic vegetation
- expansion of populations of warm-tolerant fish species, such as pike

(Albert Chookomolin, personal communication)

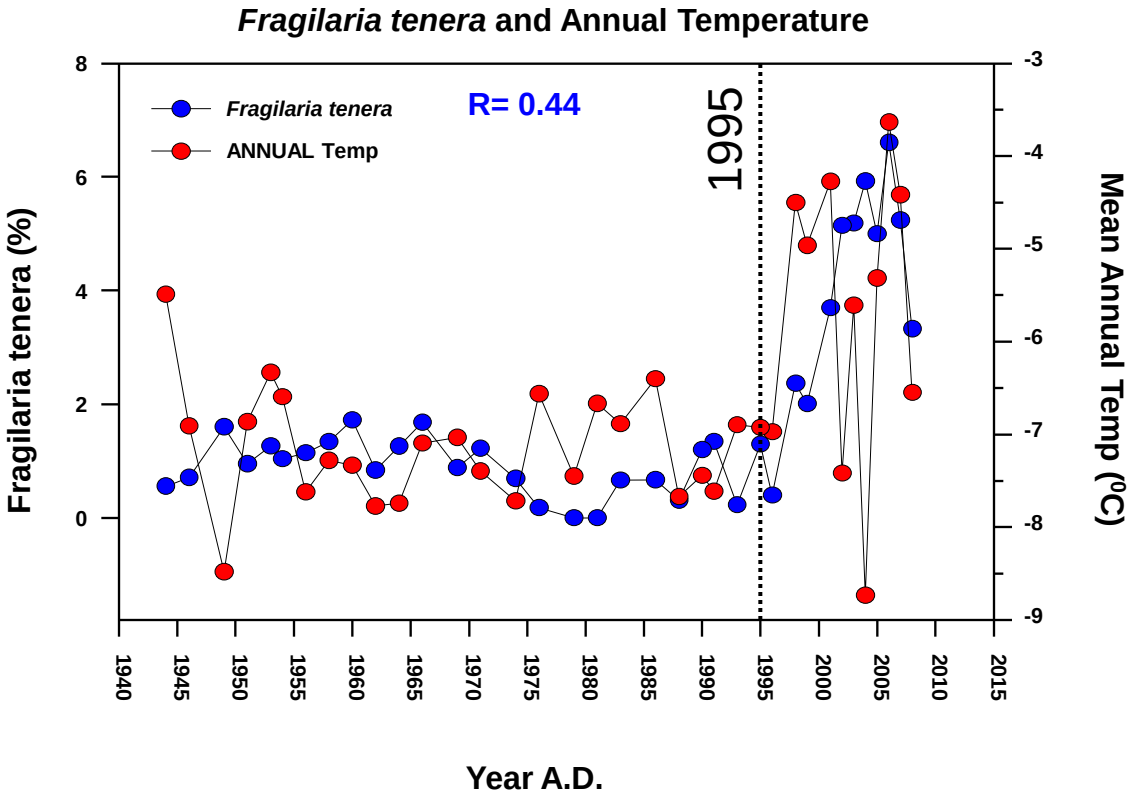


Recent diatom trends: North Raft Lake

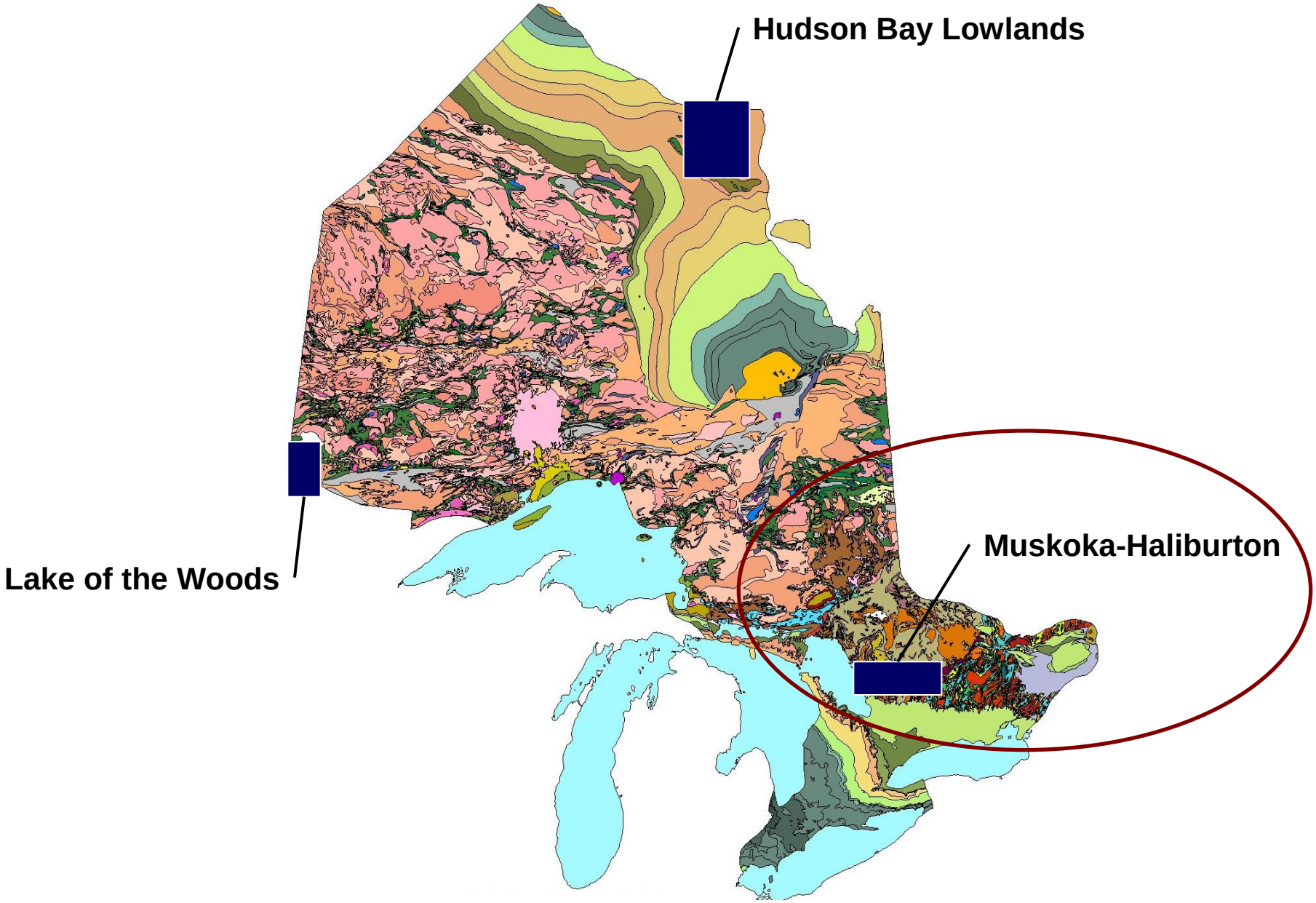


(Rühland et al. unpublished)

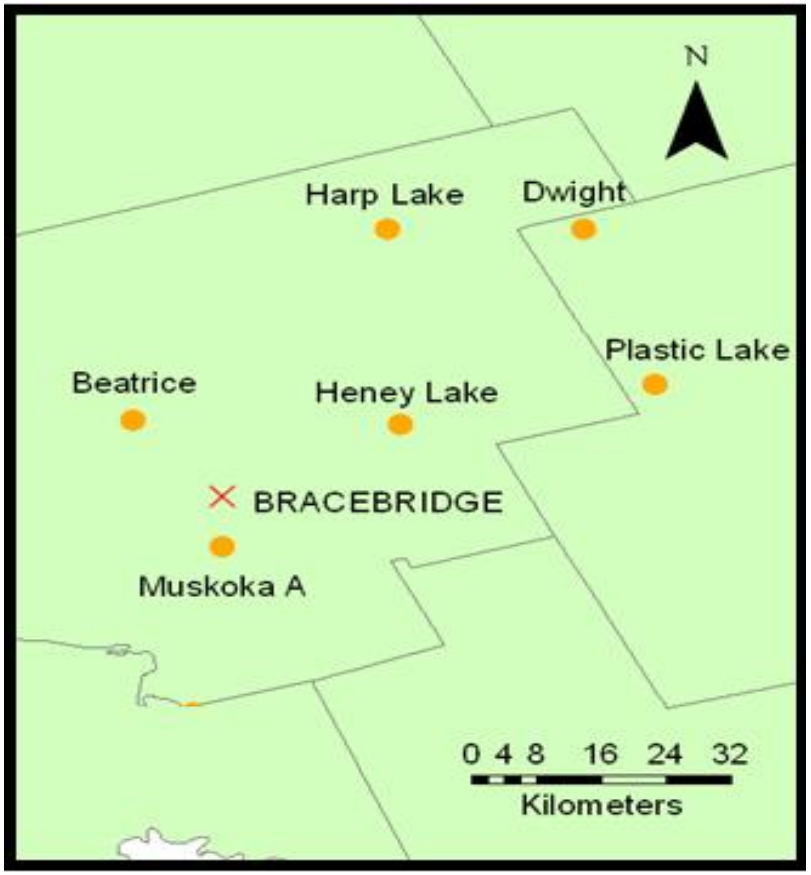
Recent diatom trends: Spruce Lake



(Rühland et al. unpublished)

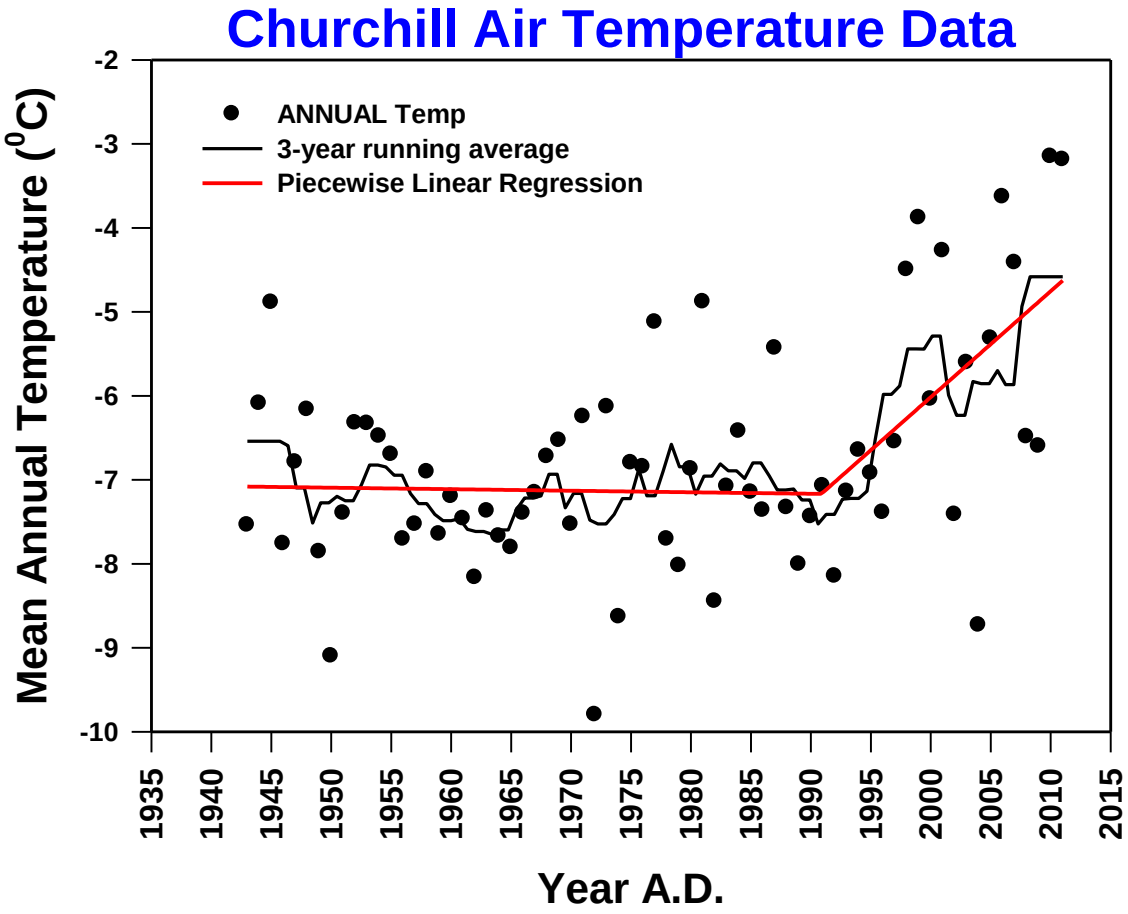

Hudson Bay Lowlands
Lake of the Woods
Muskoka-Haliburton

Climate trends in Muskoka



- Six climate stations within the Muskoka River Watershed
- **1984-2007**: Harp, Plastic & Heney
- **1973-2005**: Dwight
- **1938-2006**: Muskoka A
- **1876-2006**: Beatrice

(Source: Jason Kerr)



(Raw data: Environment Canada)

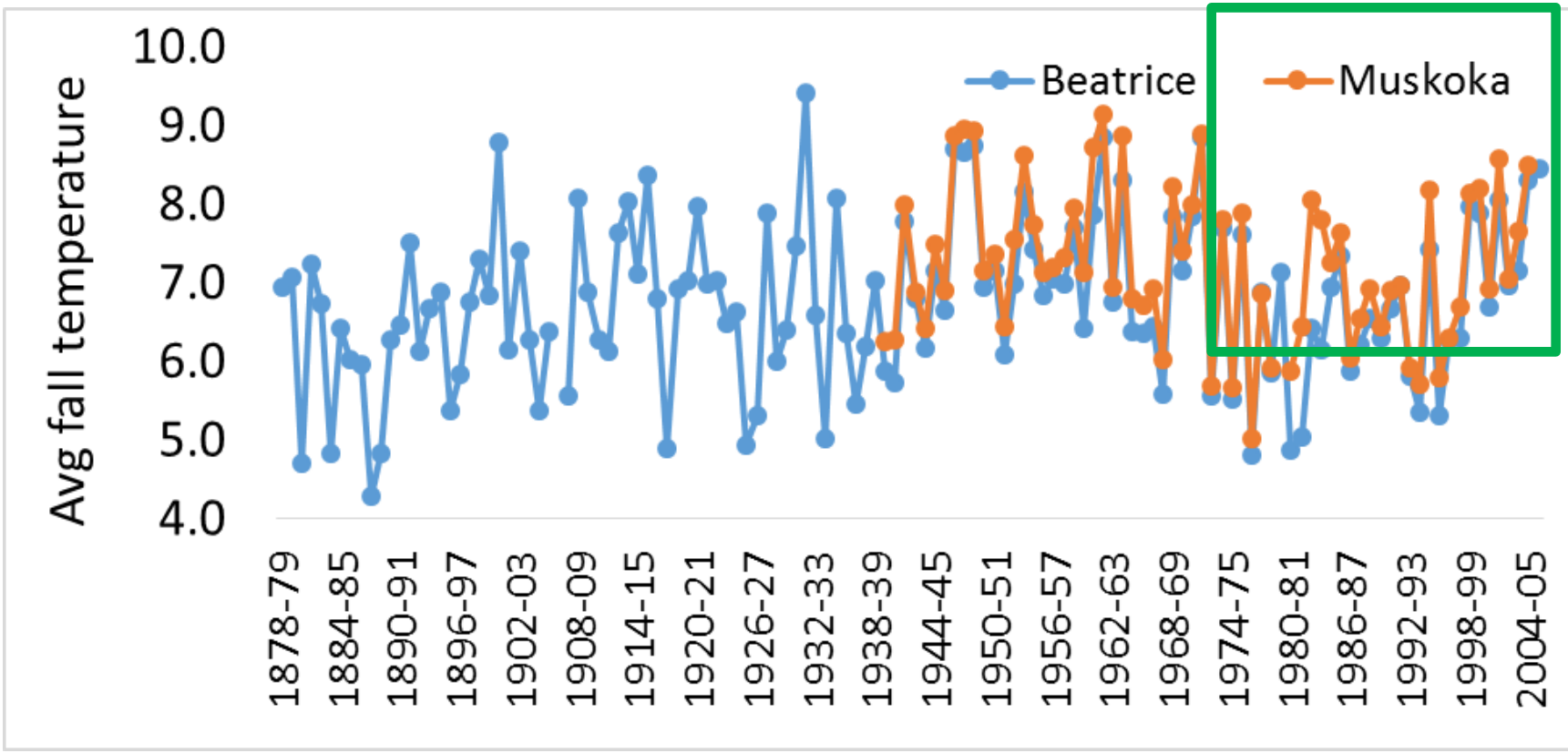
Climate trends in Muskoka

ANNUAL TRENDS

	Avg. Temp	Min Temp	Max Temp	Precip.
Beatrice			↑	↑
Muskoka				↑
Dwight				
Harp				
Heney				
Plastic				

(Source: Jason Kerr)

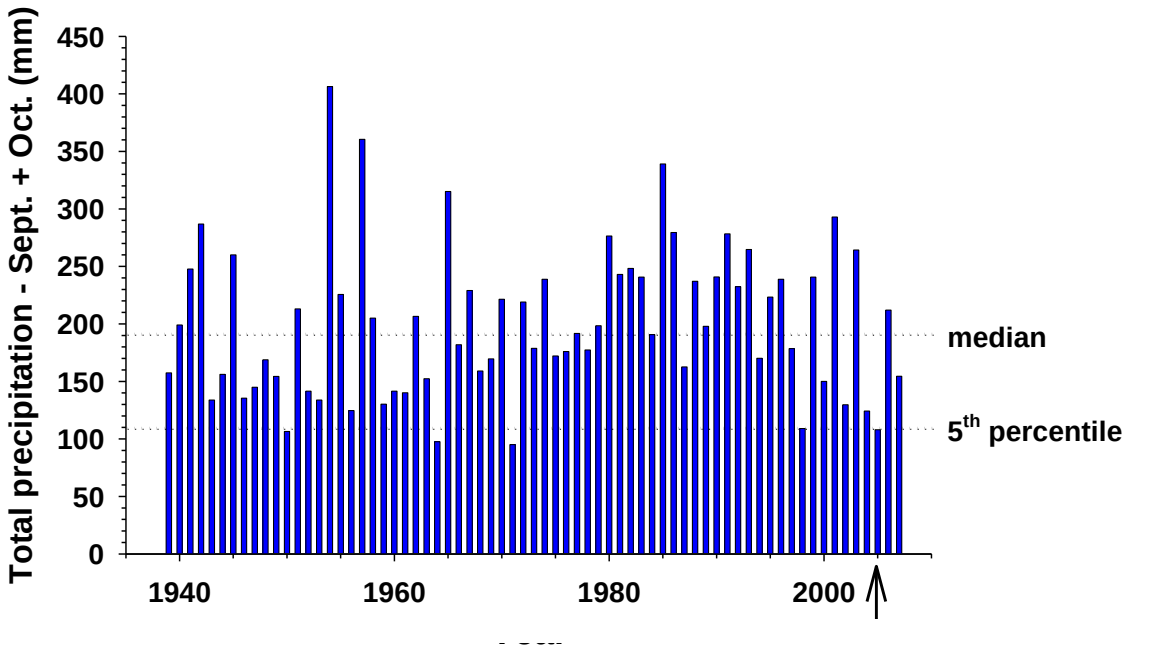
Fall warming in Muskoka



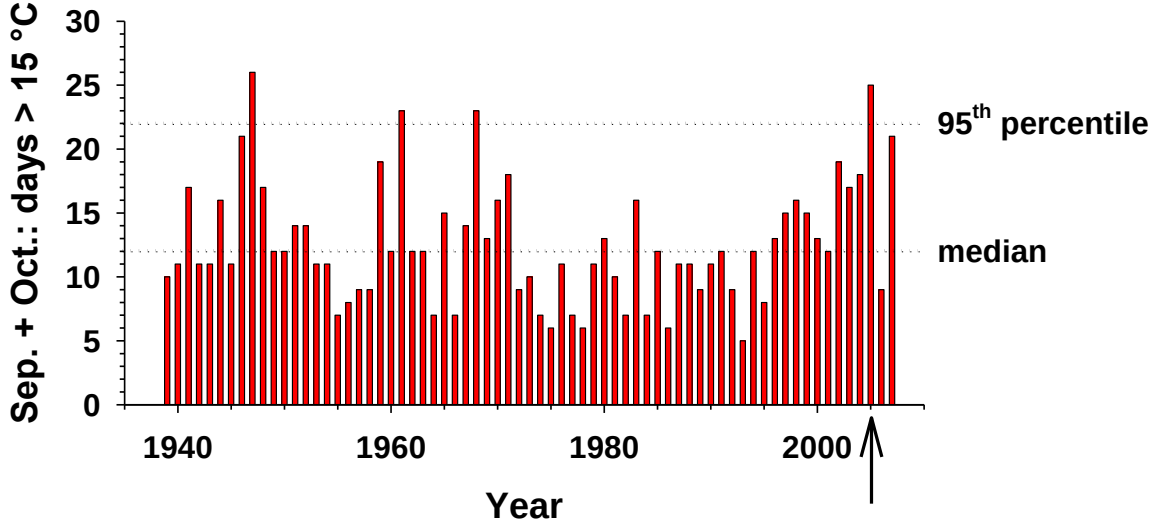
(Source: Jason Kerr)

(Bracebridge Examiner, October 19th, 2005)

2005 was the warmest/driest fall on record

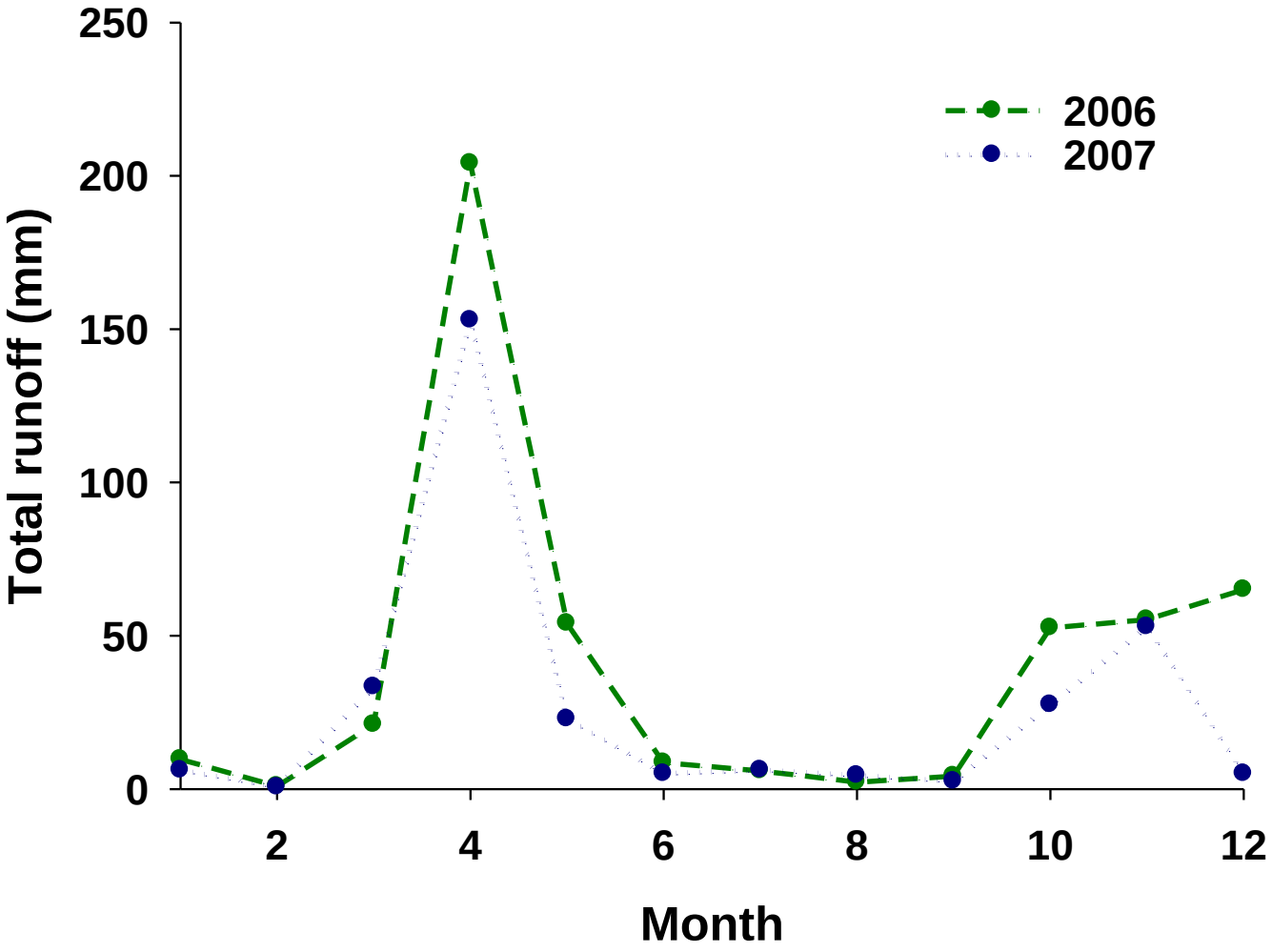


Precipitation

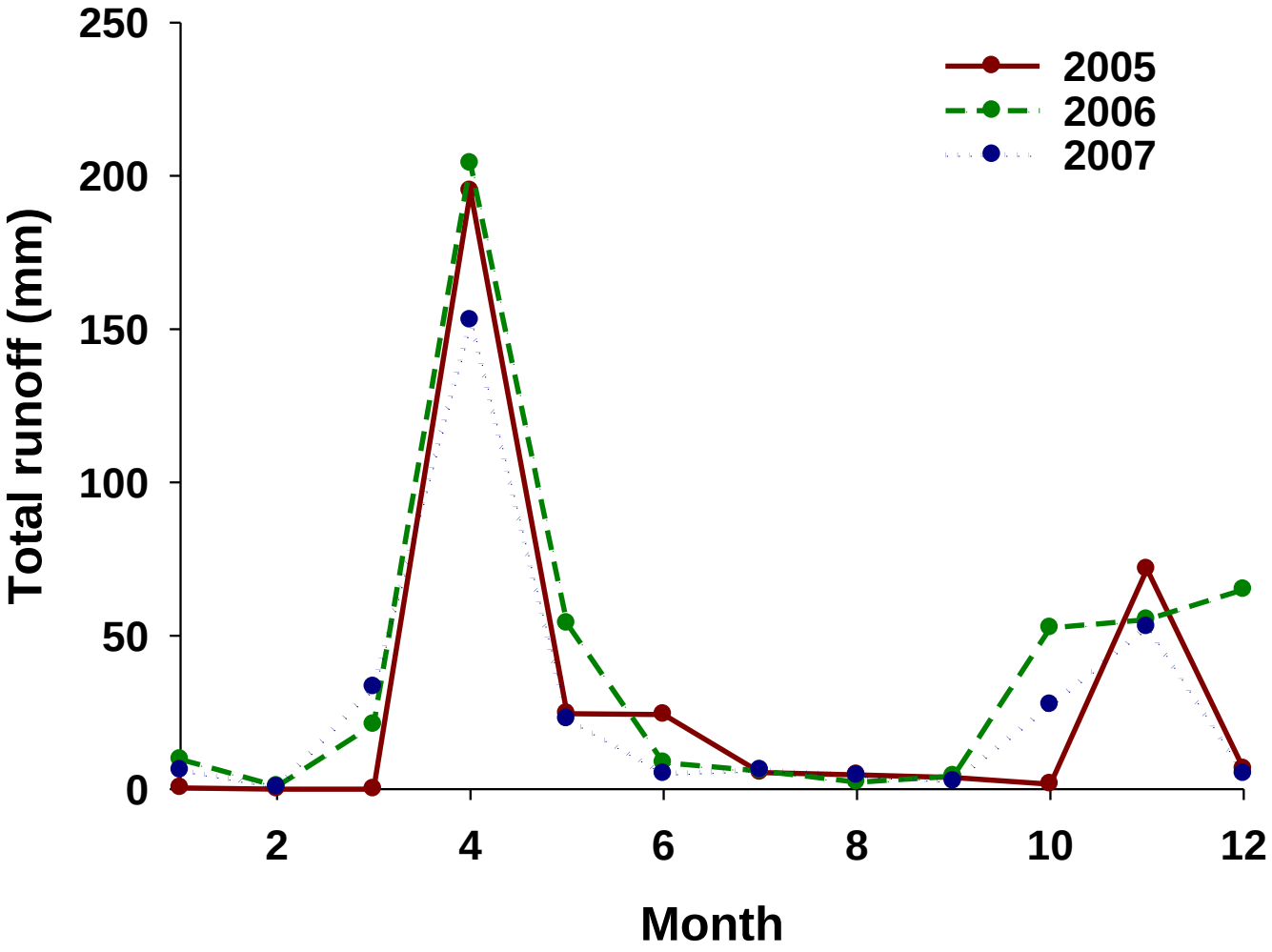


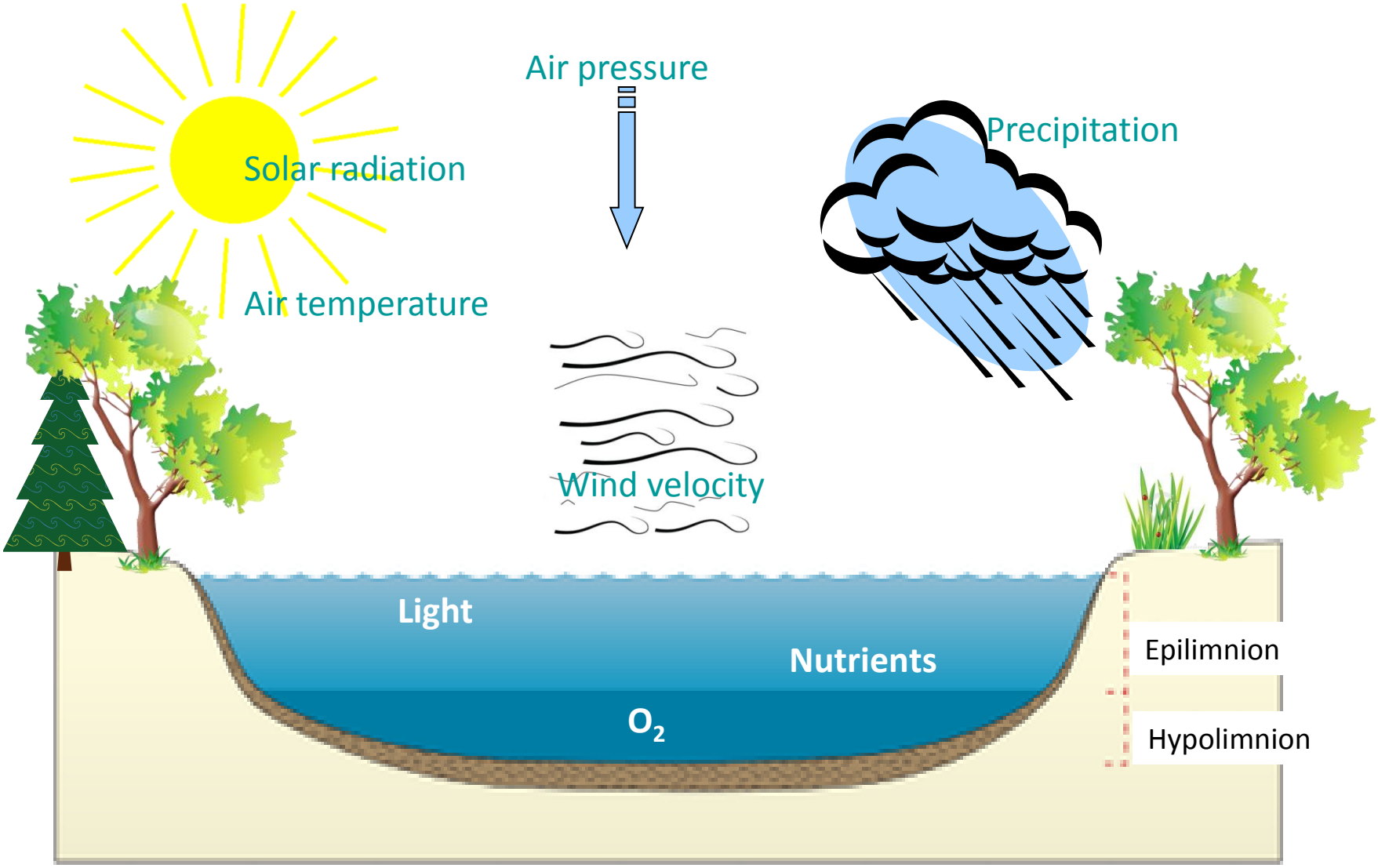
Temperature

Monthly runoff – Outflow (modeled)



Monthly runoff – Outflow (modeled)

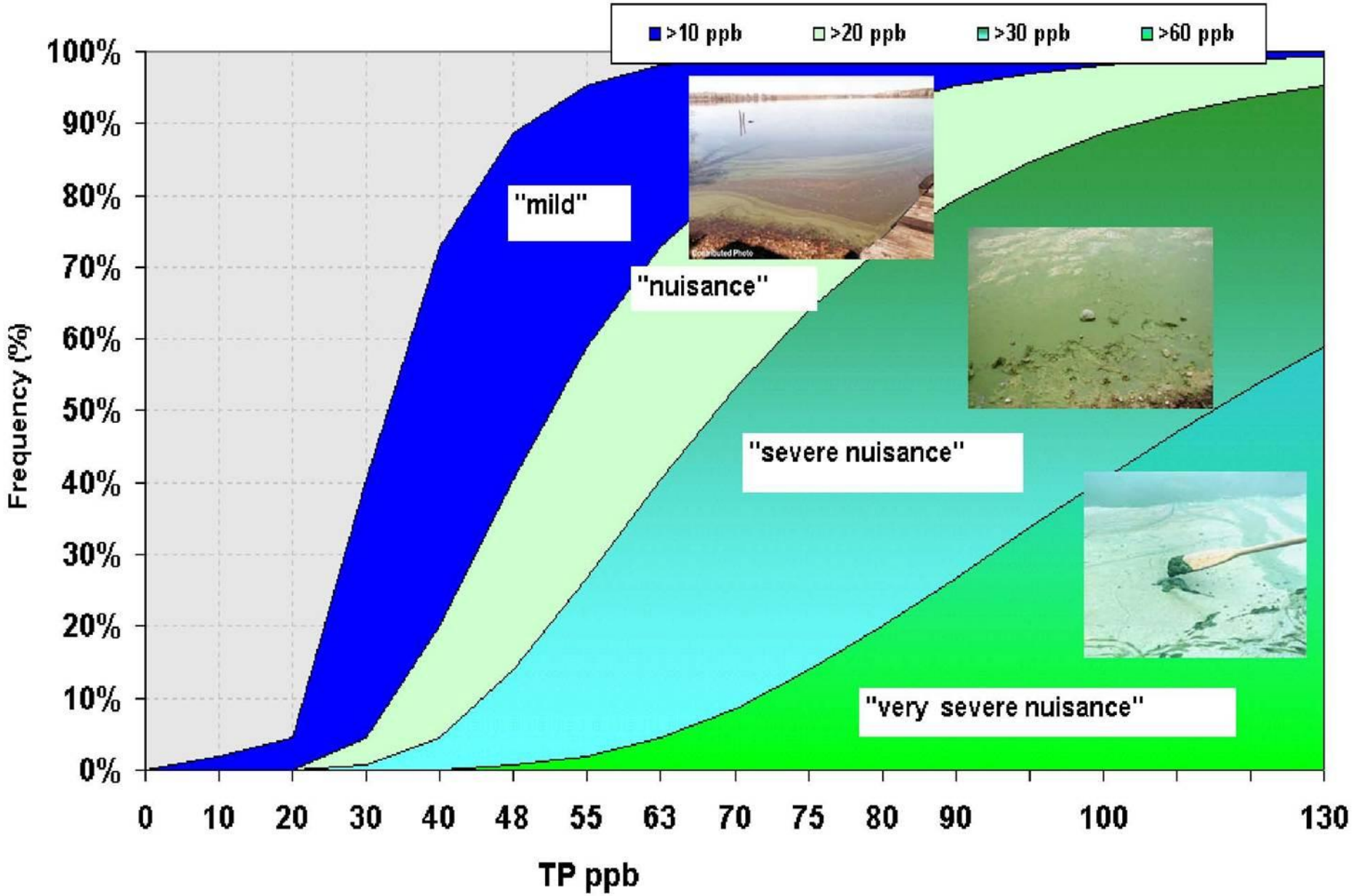



Air pressure
Solar radiation
Air temperature
Precipitation
Wind velocity
Light
Nutrients
O_2
Epilimnion
Hypolimnion

If algae are the music we hear from a radio…

Phosphorus controls the “volume” of algae

Chlorophyll-a interval frequency versus total phosphorus.



Other nutrients (esp. nitrogen), light, etc., influence what species are present – the "tuning"

Phosphorus controls the "volume" of algae

Climate is the aerial

Other nutrients (esp. nitrogen), light, etc., influence what species are present – the "tuning"

Phosphorus controls the "volume" of algae

Blue-greens like it hot!