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:

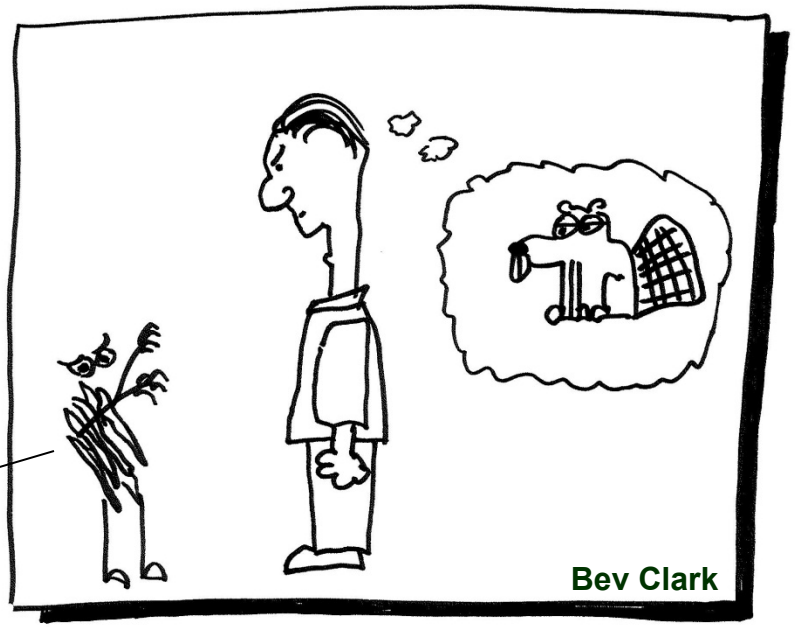
1) Reduced water clarity

2) Loss of deep-water oxygen

3) Toxins

4) Taste and odour

(Bracebridge Examiner, October 19th, 2005)



Aphanizomenon

Applied Economics, 2014
Vol. 46, No. 10, 1122–1126, http://dx.doi.org/10.1080/00036846.2013.851778

Routledge
Taylor & Francis Group

Water quality and cottage prices in Ontario

Julia Clapper[a] and Steven B. Caudill[b,c,d,*]

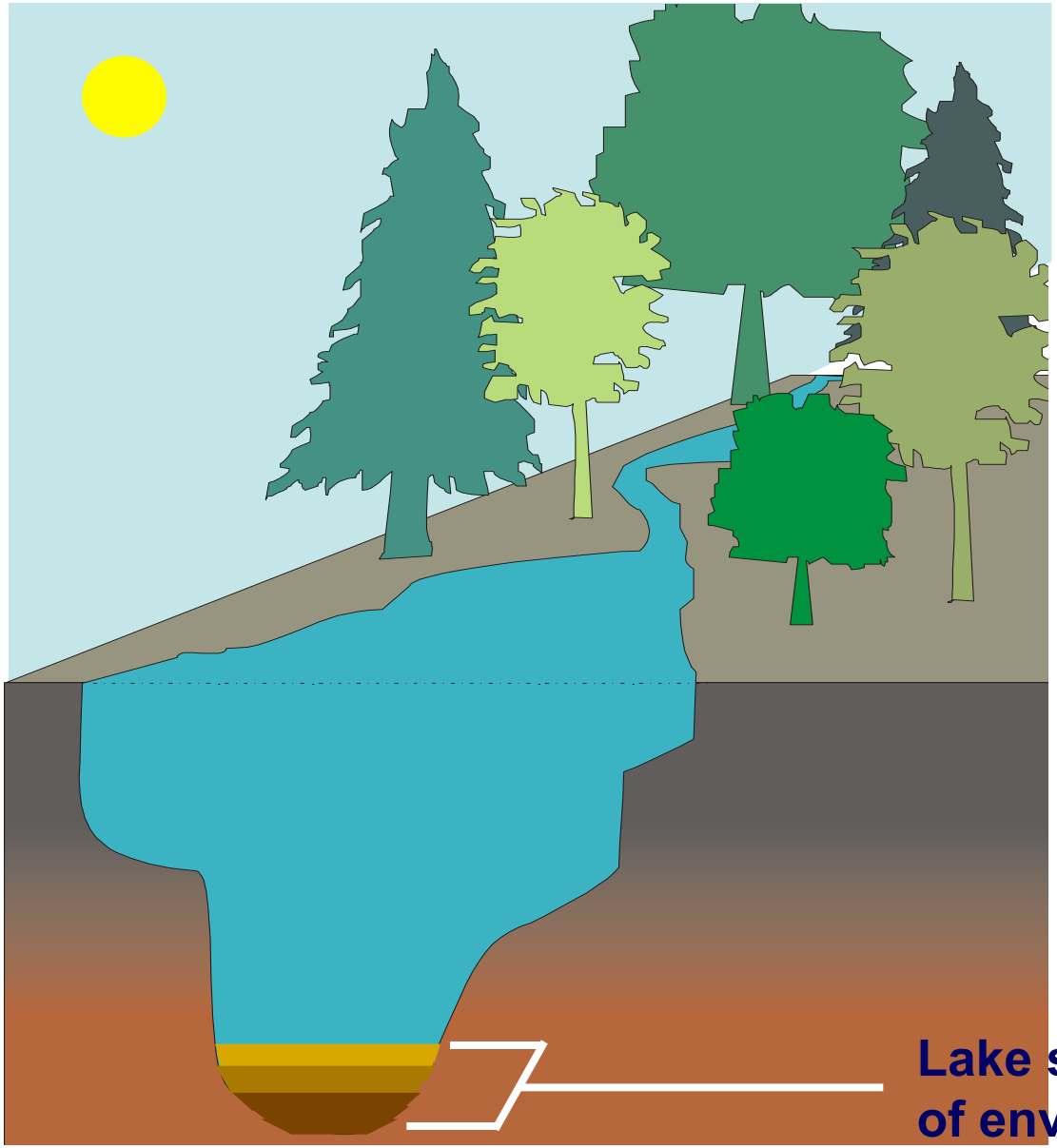
[a]*AutoZone, Memphis, USA*
[b]*Department of Economics, Rhodes College, 38112-1690 Memphis, USA*
[c]*University of Sassari, Sassari, Italy*
[d]*Auburn University, Auburn, AL 36849, USA*

Prices rise by ~6% for every metre increase in water clarity

Why is this happening?

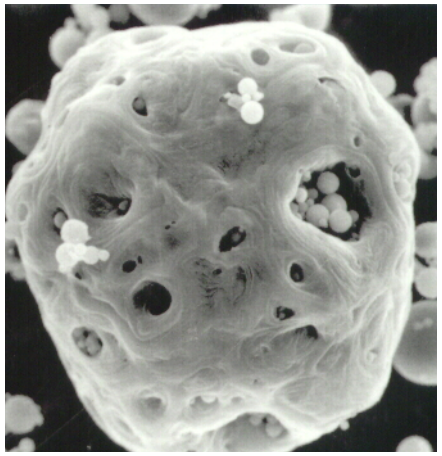
What was the cause?

Will it happen again?



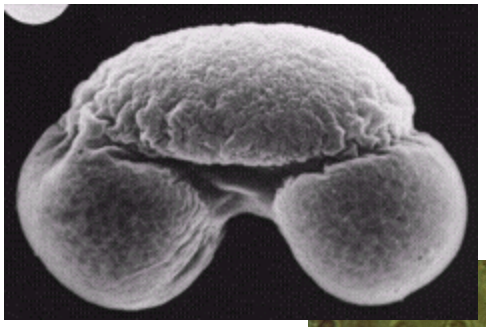
Lake sediments are archives of environmental change

Fly ash and charcoal

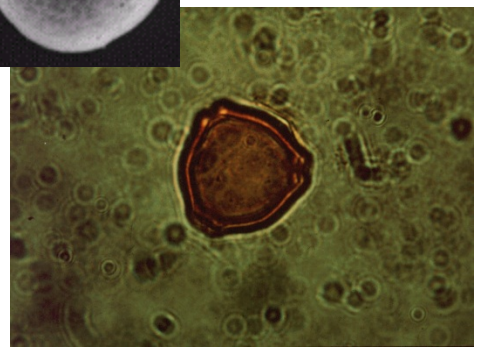


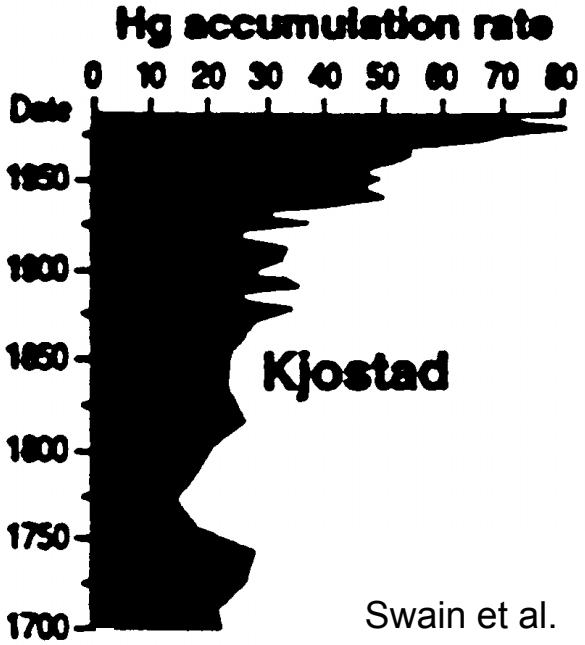
From the air and land

Contaminants

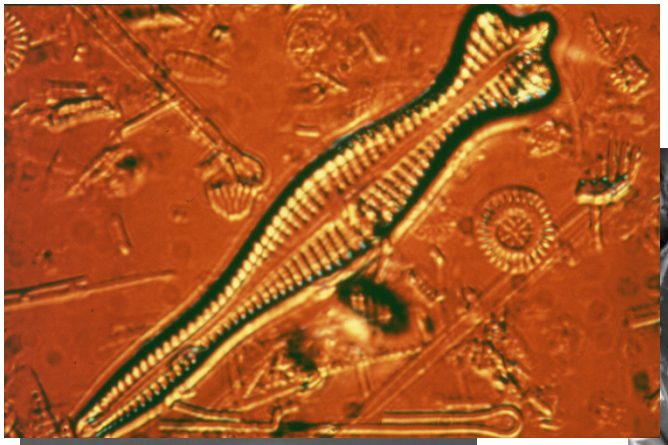


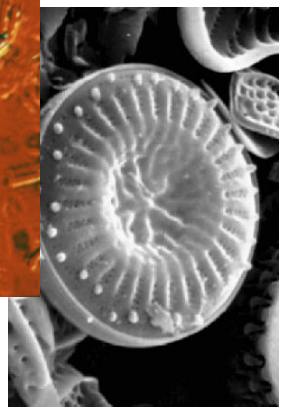
Pollen

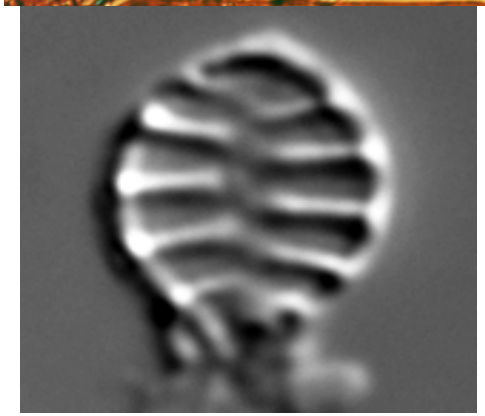




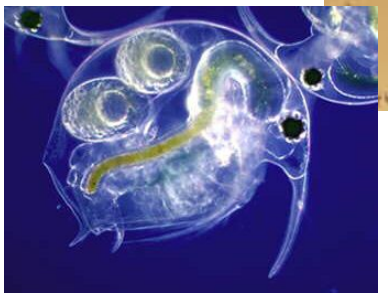
Swain et al.

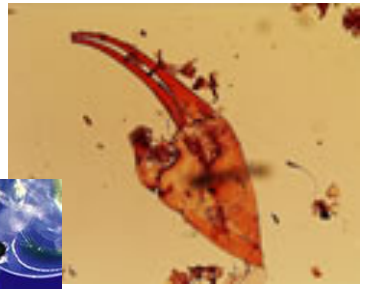






Algae



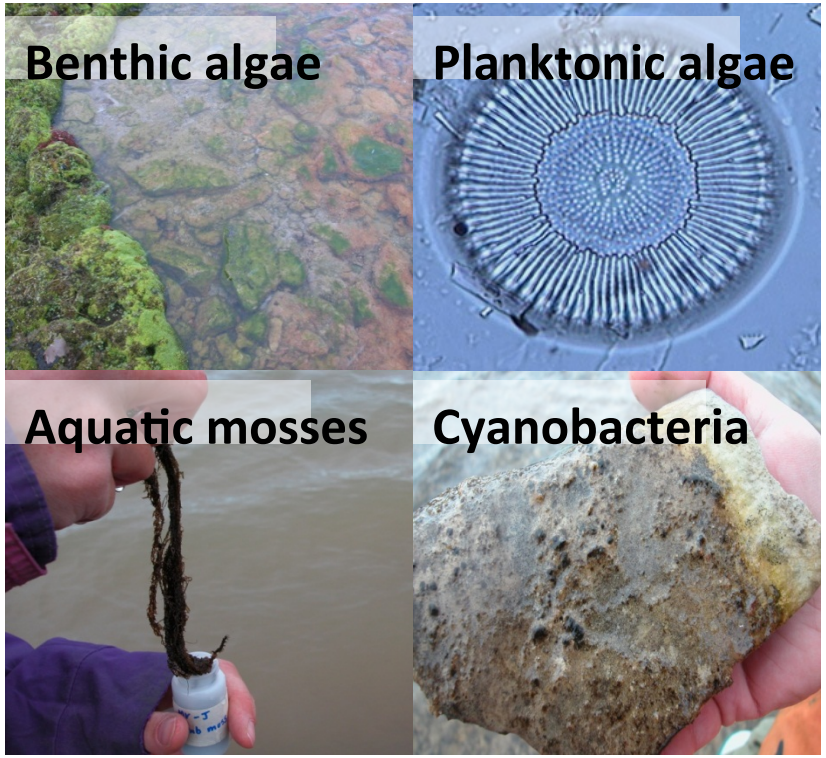


Water fleas
(zooplankton)

From the lake

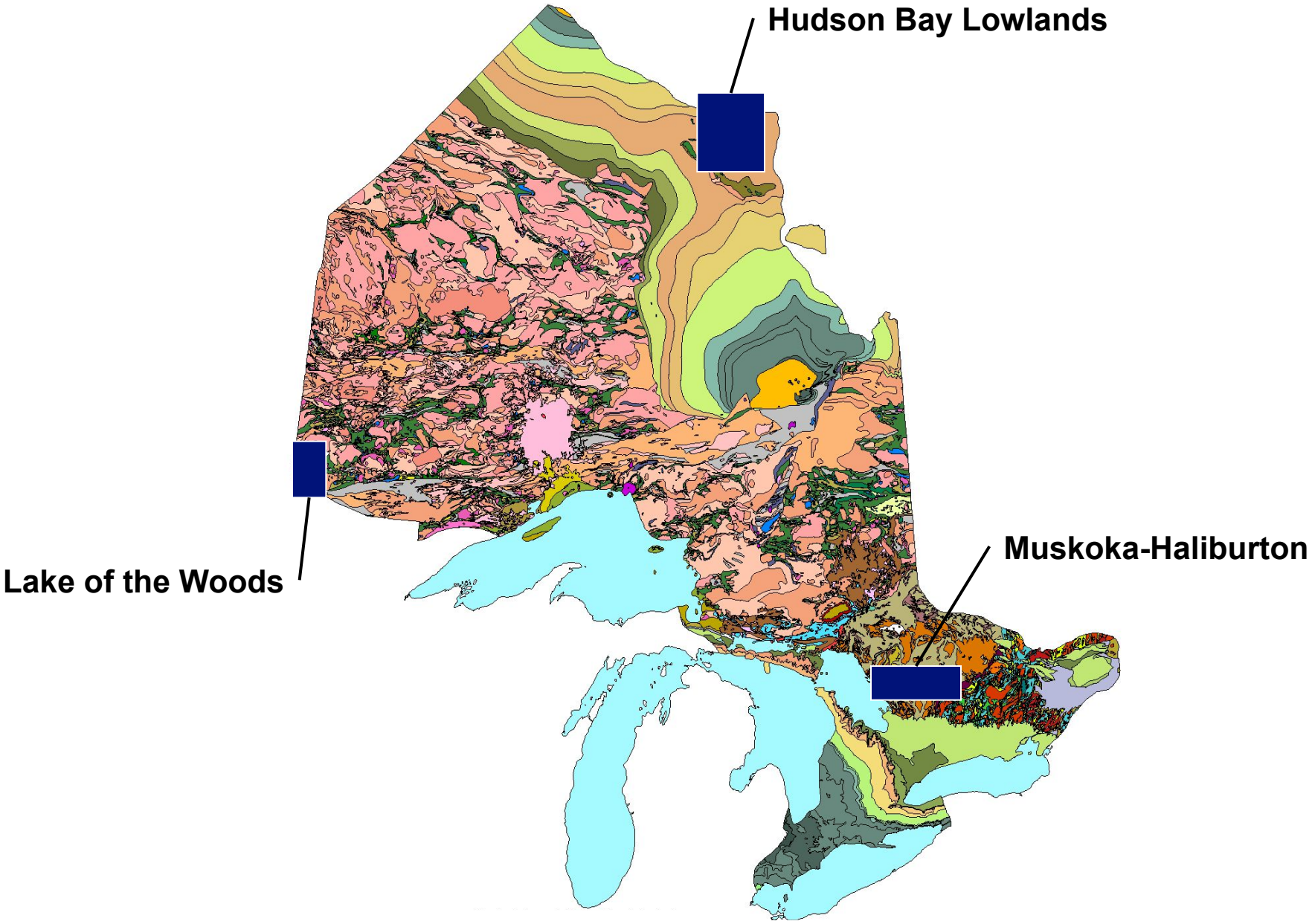
Midges
(chironomids)

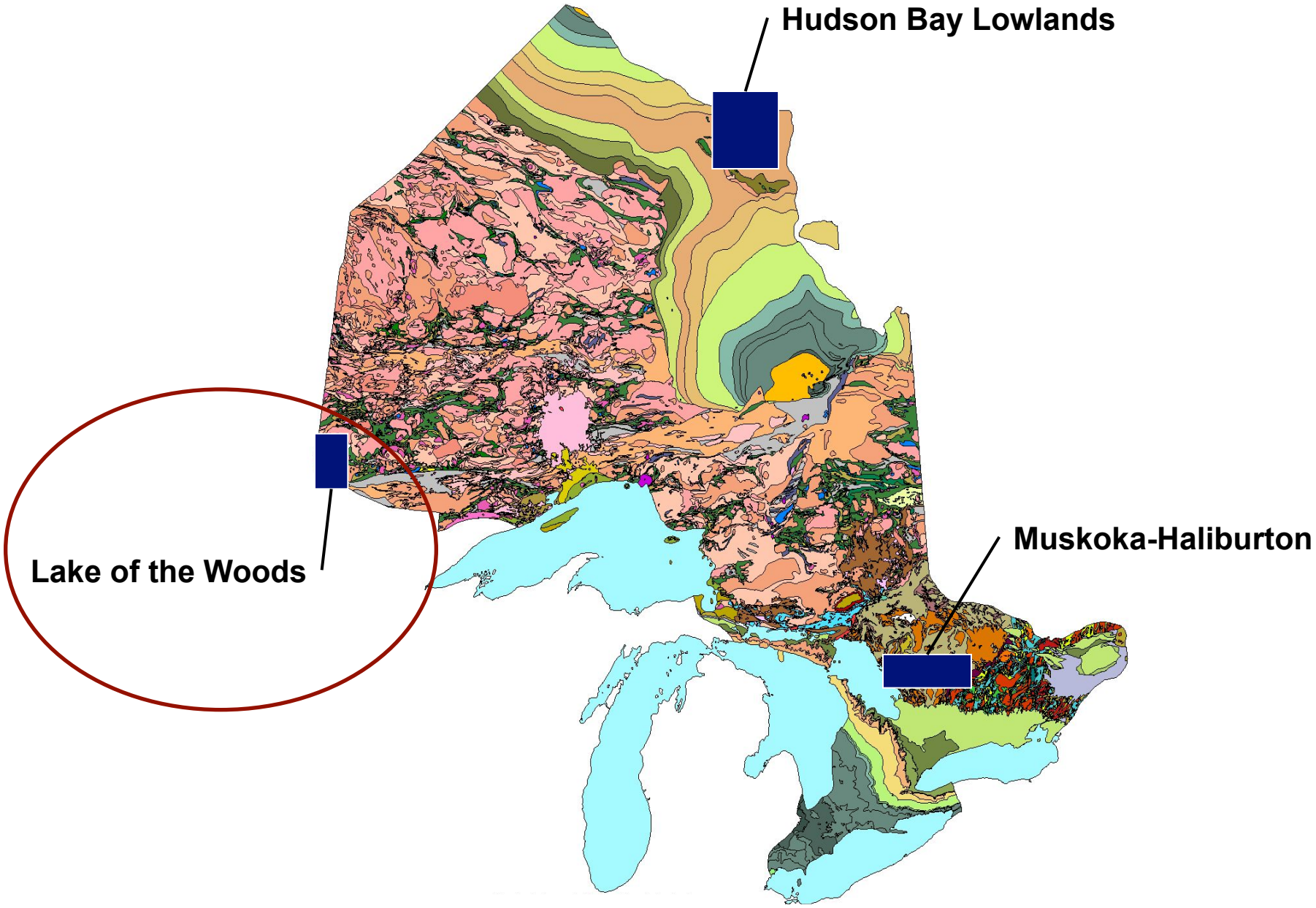
➔Sediment chlorophyll *a* concentrations inform about past changes in the amount of algae

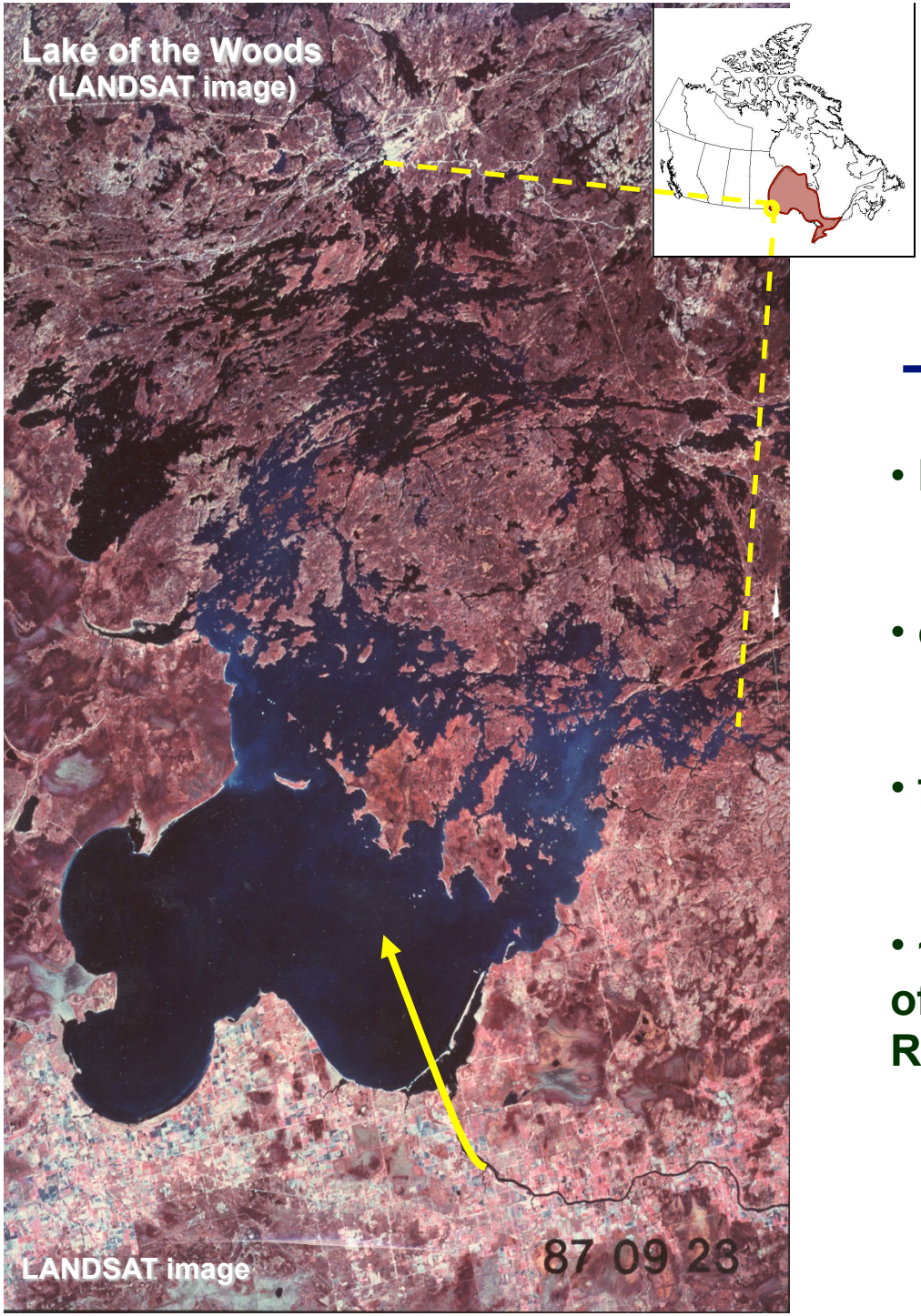


Chlorophyll *a* occurs in all photosynthetic eukaryotes and the cyanobacteria

Chlorophyll-a (ppb) related to Lake Trophic State


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)

“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”

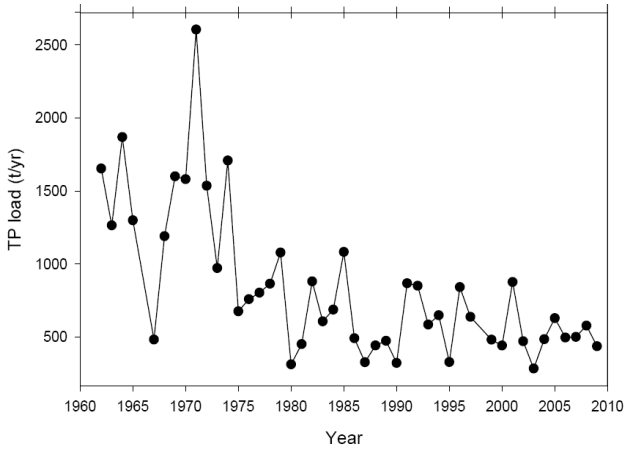
- S. J. Dawson, Summer 1857

A disconnect in Lake of the Woods?

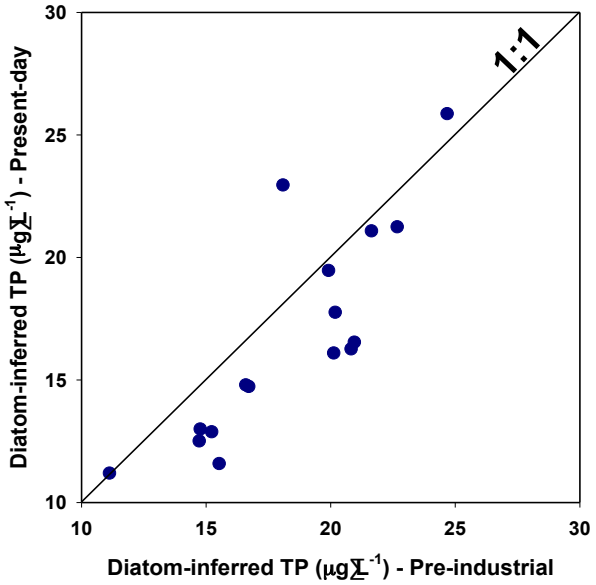
(Photo: T. Sellers)

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

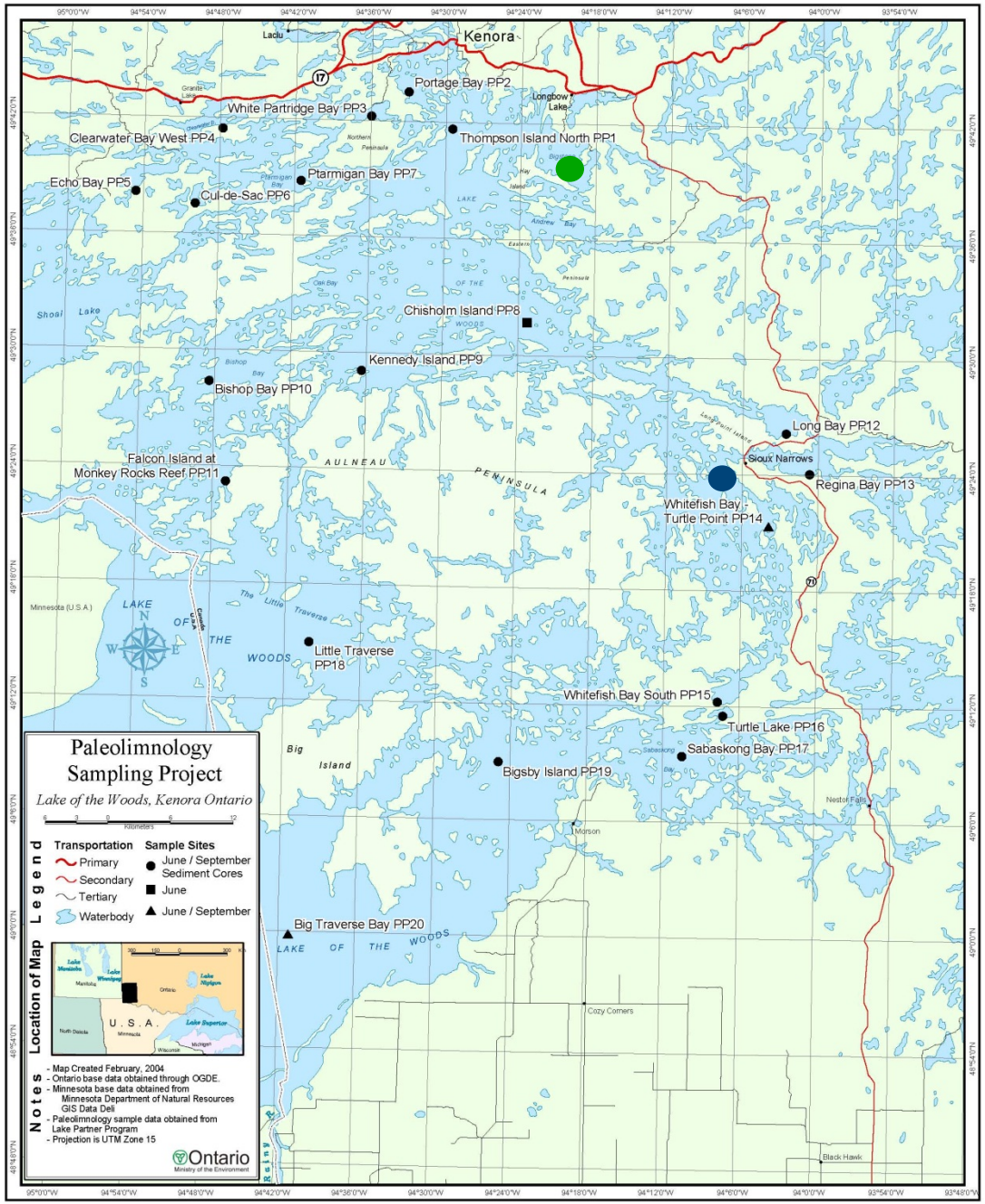
≠



A decline in TP loading from the Rainy River



No change or a slight decline lake [TP], based on monitoring and paleo data

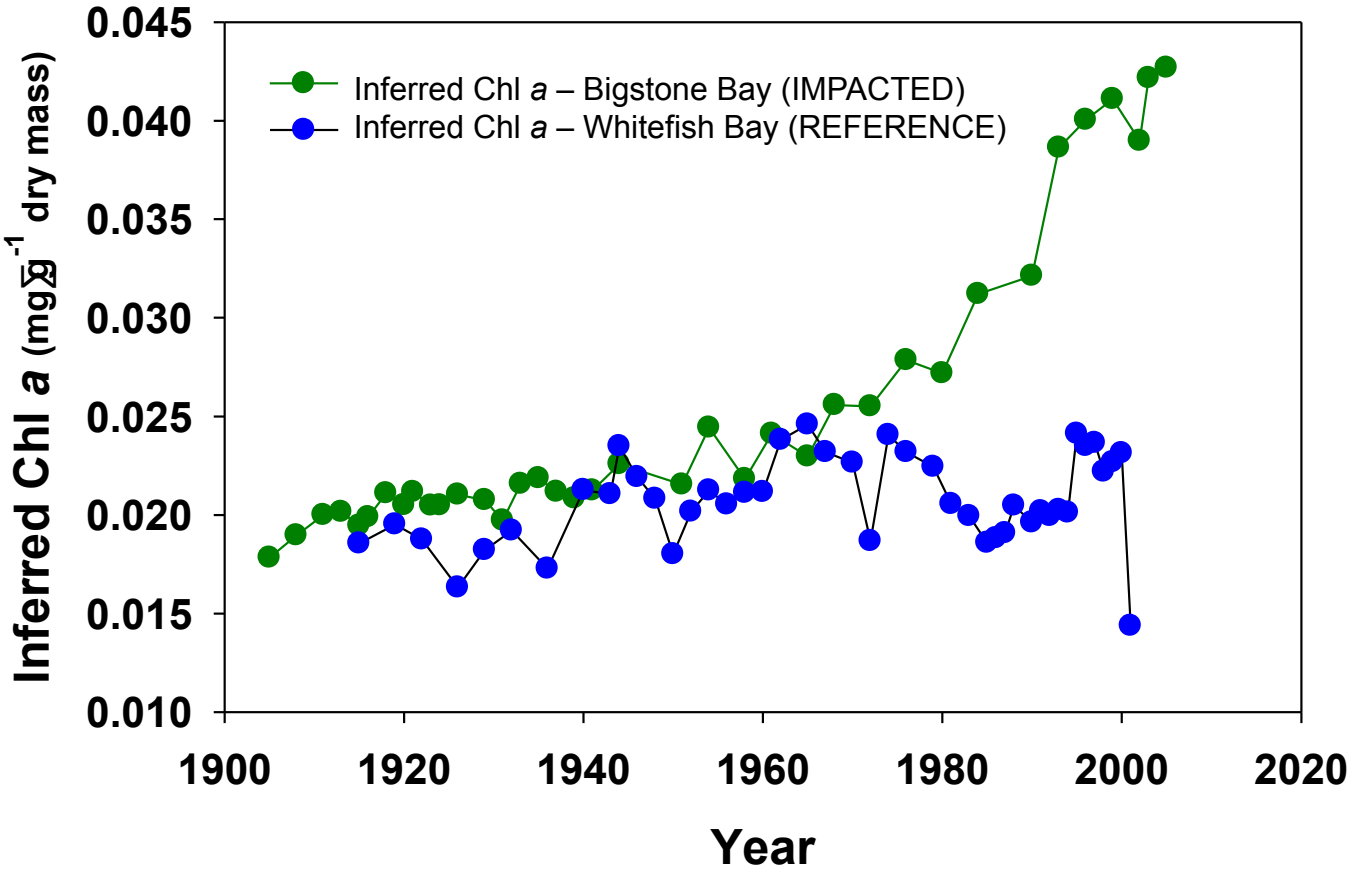


Sampling sites

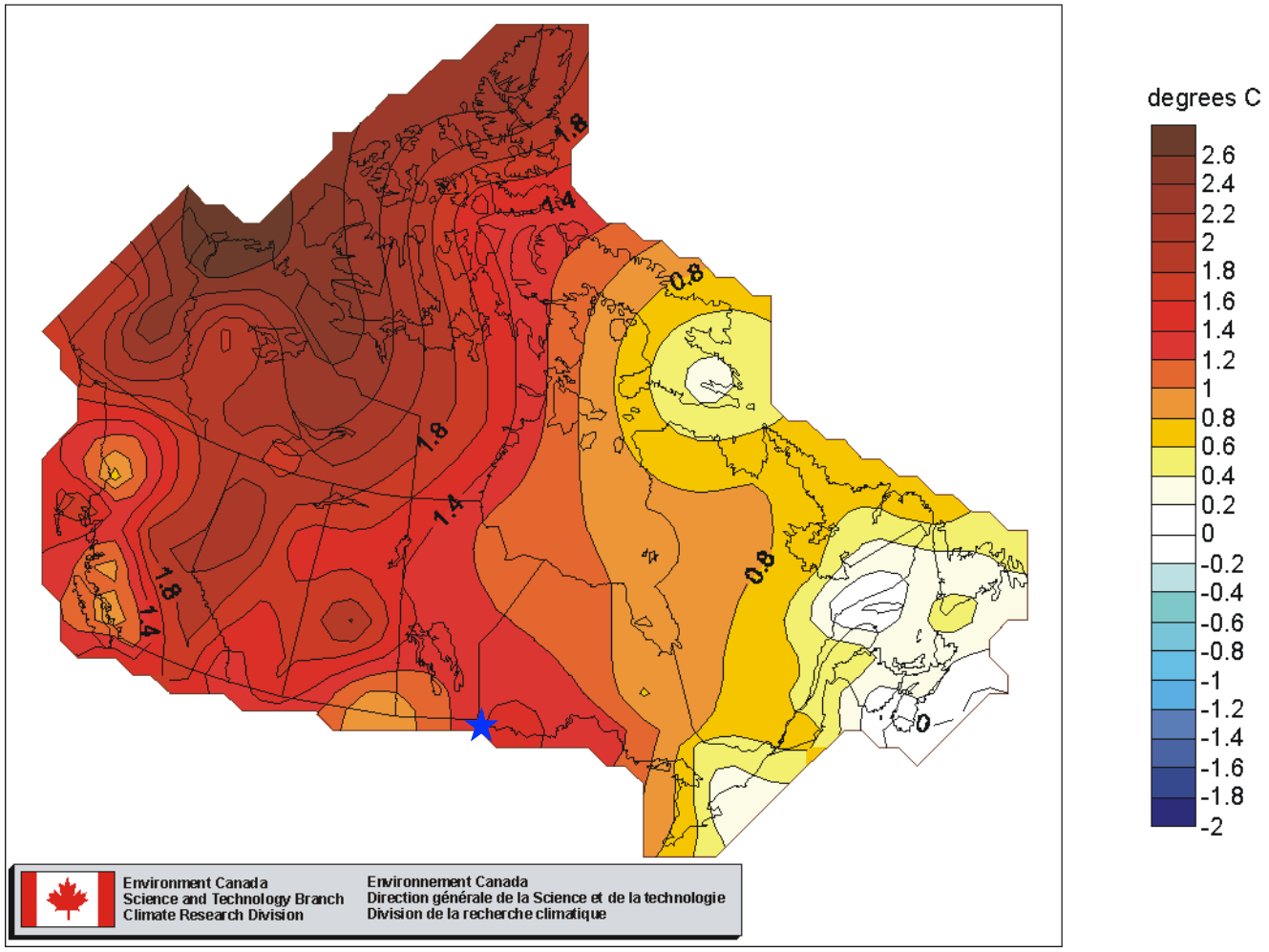
- **Reference site**
  (no blue-greens)
- **Impacted site**
  (lots of blue-greens)

(Photo: K. Rühland)

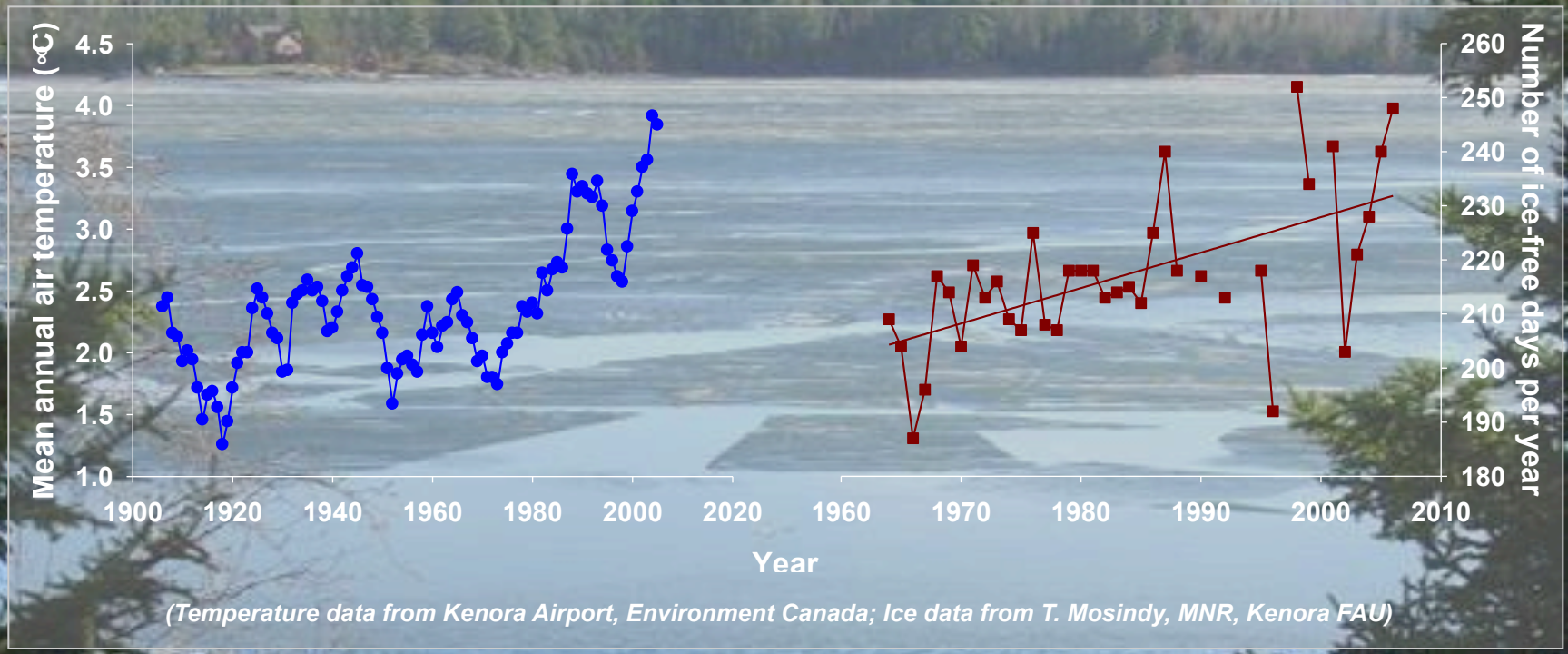
Inferred Chl *a* – Lake of the Woods – Impacted Site vs Reference Site



Annual Temperature Trend, 1948-2008



A region sensitive to recent warming

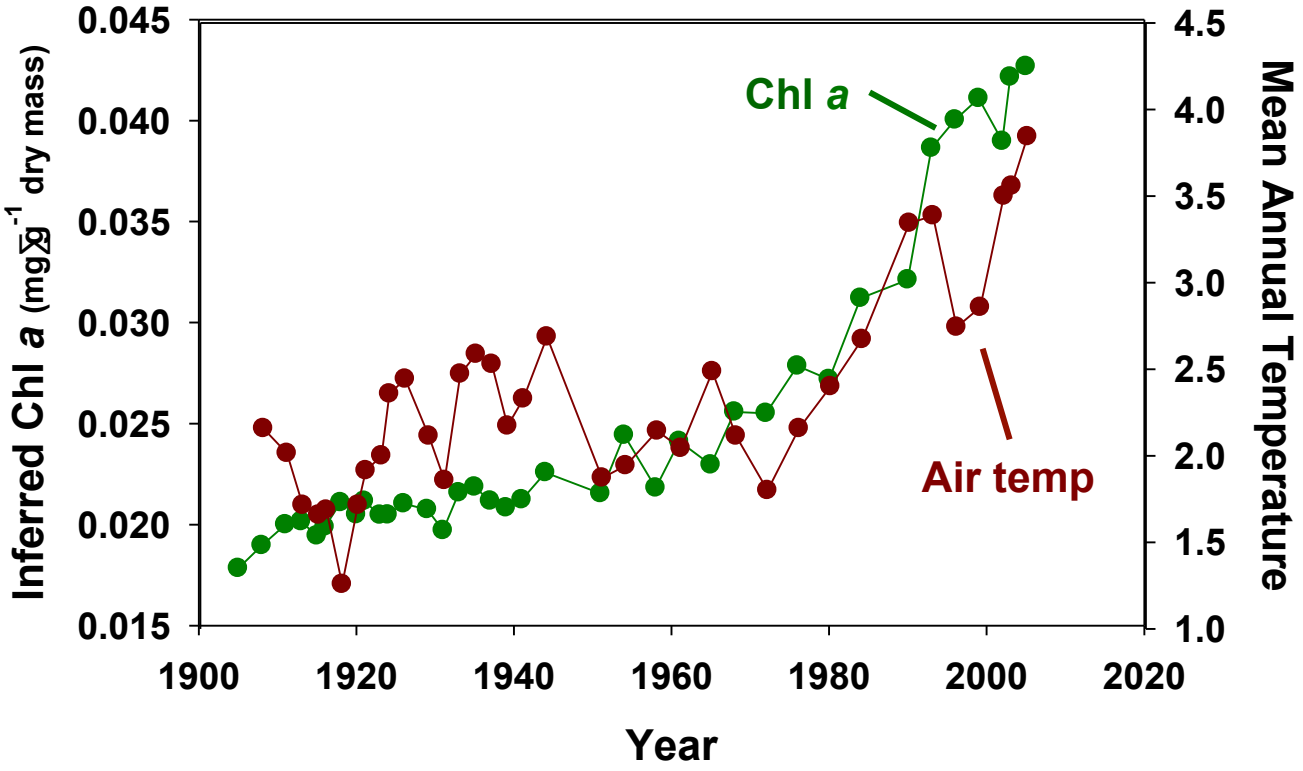


(Temperature data from Kenora Airport, Environment Canada; Ice data from T. Mosindy, MNR, Kenora FAU)

Inferred Chl *a* versus mean annual air temperature

Impact site (Bigstone Bay) vs mean annual air temperature

r = 0.81, p <0.001 , n = 36

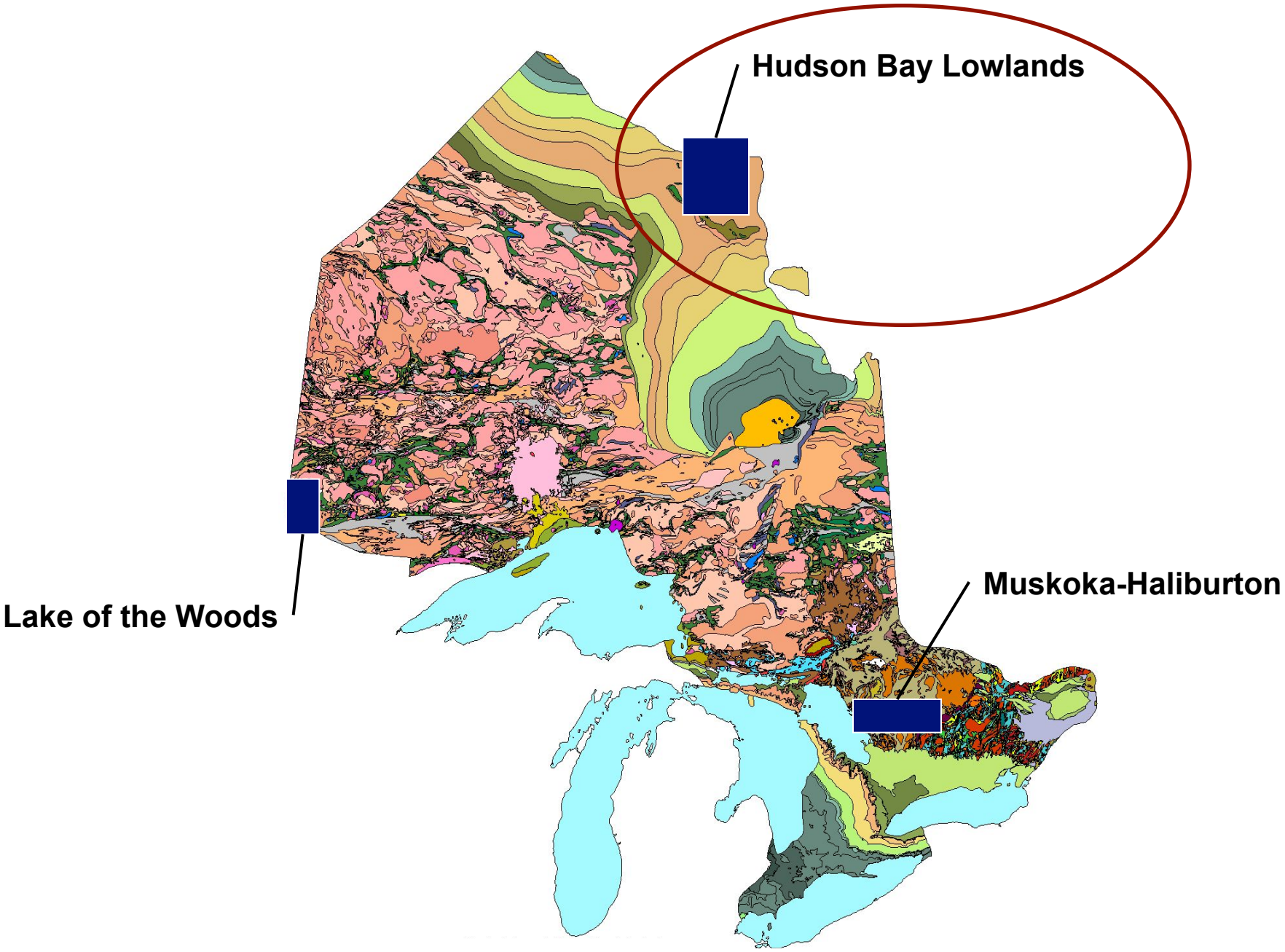


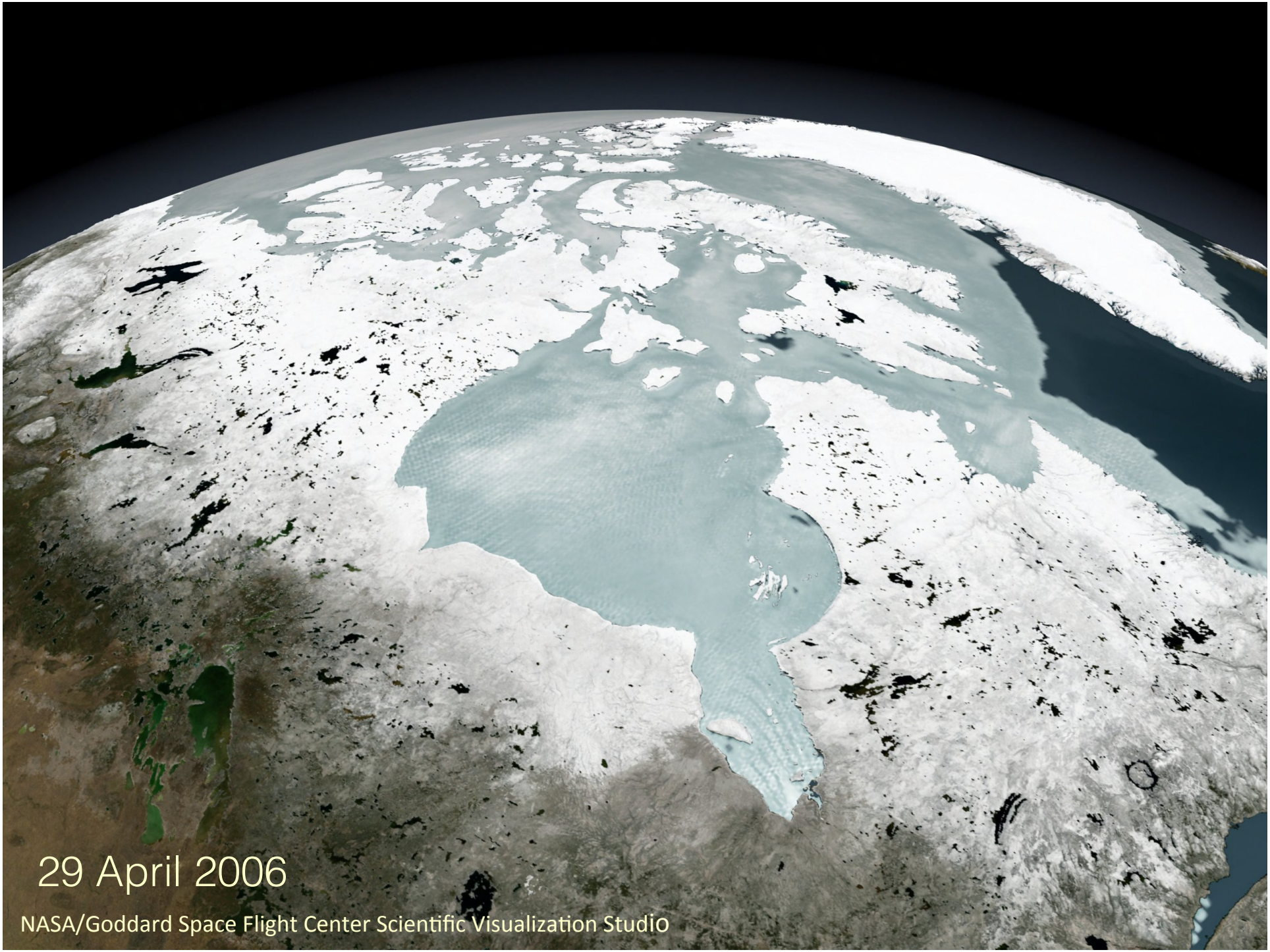
A disconnect in Lake of the Woods?

(Photo: T. Sellers)

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

<u>Perception is correct</u>, but warming is likely playing a key role


Hudson Bay Lowlands
Lake of the Woods
Muskoka-Haliburton


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

Distribution of permafrost and ground ice in N. America

Permafrost Zones

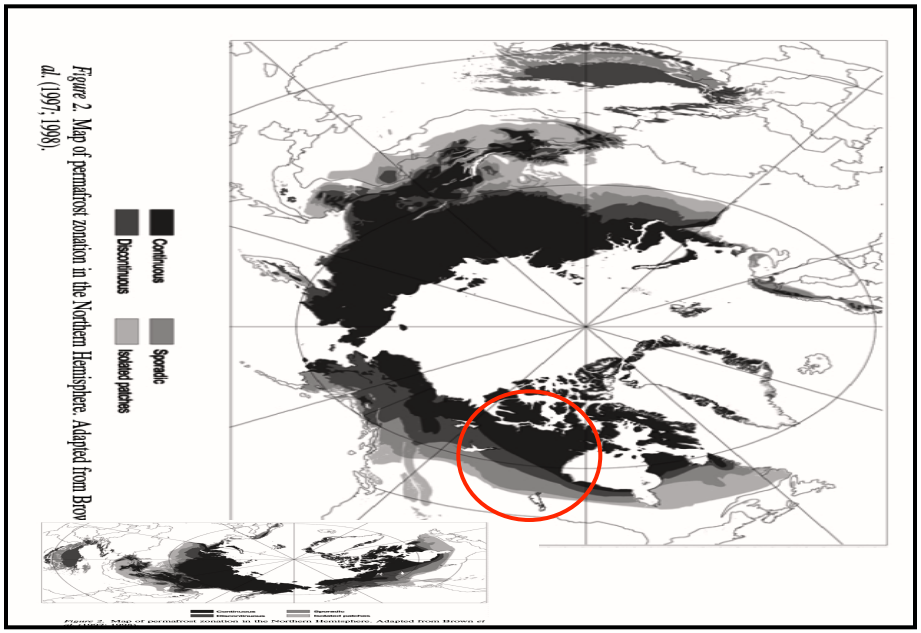


Figure 2. Map of permafrost zonation in the Northern Hemisphere. Adapted from Brow
al. (1997; 1998).

Ground Ice Volume

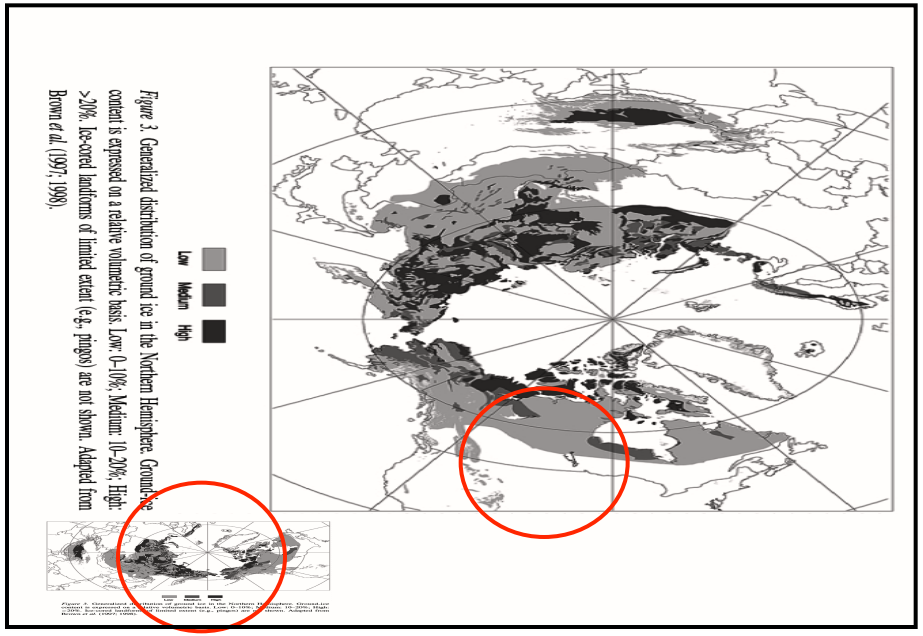


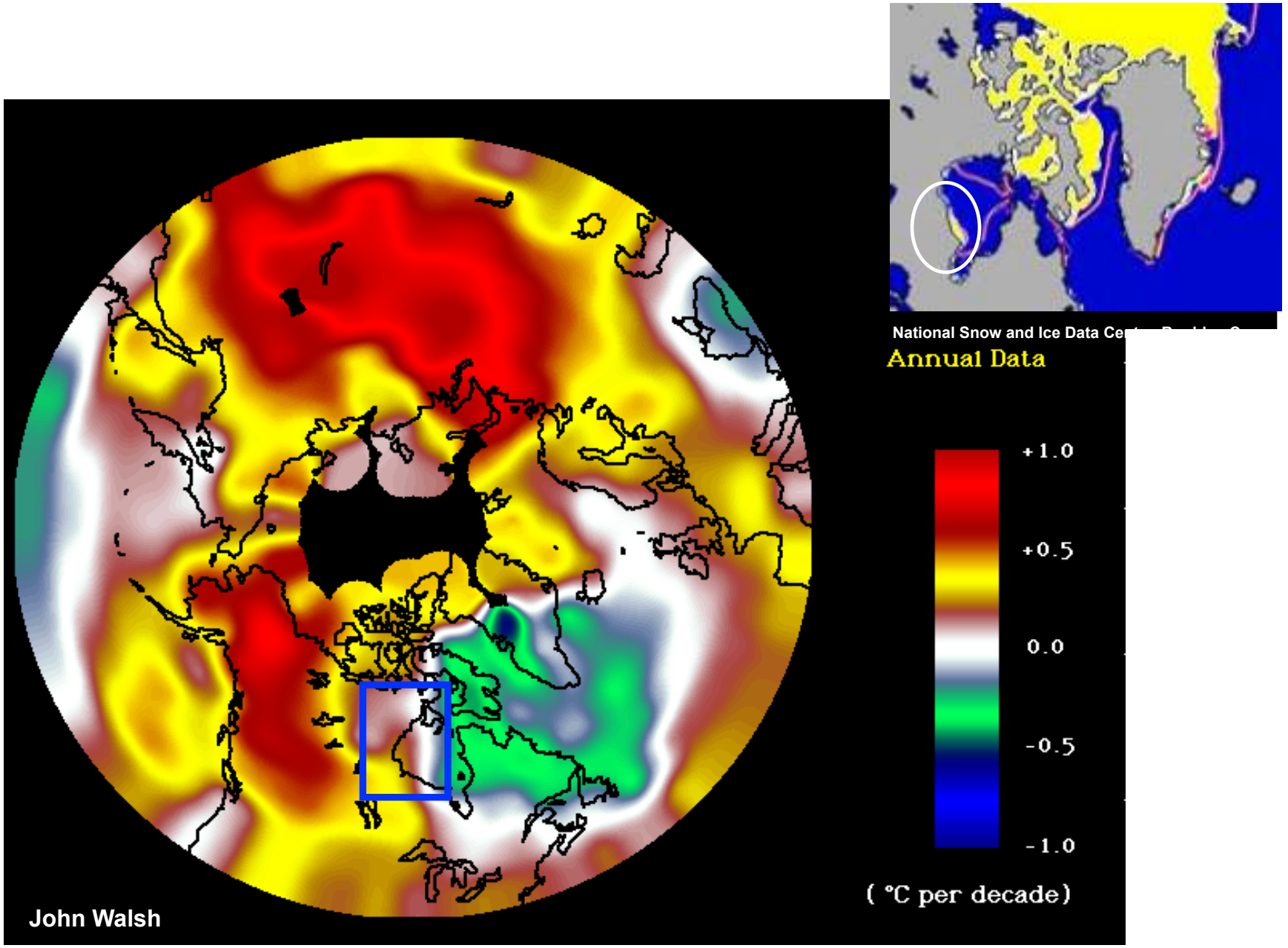
Figure 3. Generalized distribution of ground ice in the Northern Hemisphere. Ground-ice
content is expressed on a relative volumetric basis. Low: 0–10%; Medium: 10–20%; High:
>20%. Ice-cored landforms of limited extent (e.g., pingos) are not shown. Adapted from
Brown *et al.* (1997; 1998).

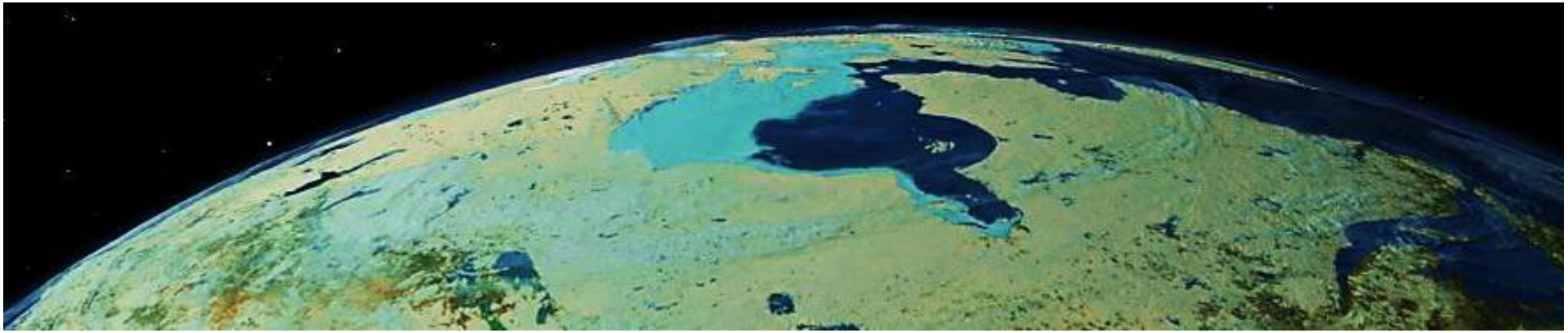
(Nelson et al. 2002)

The Hudson Bay Lowlands:

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

Arctic Temperature Trends 1966-1995



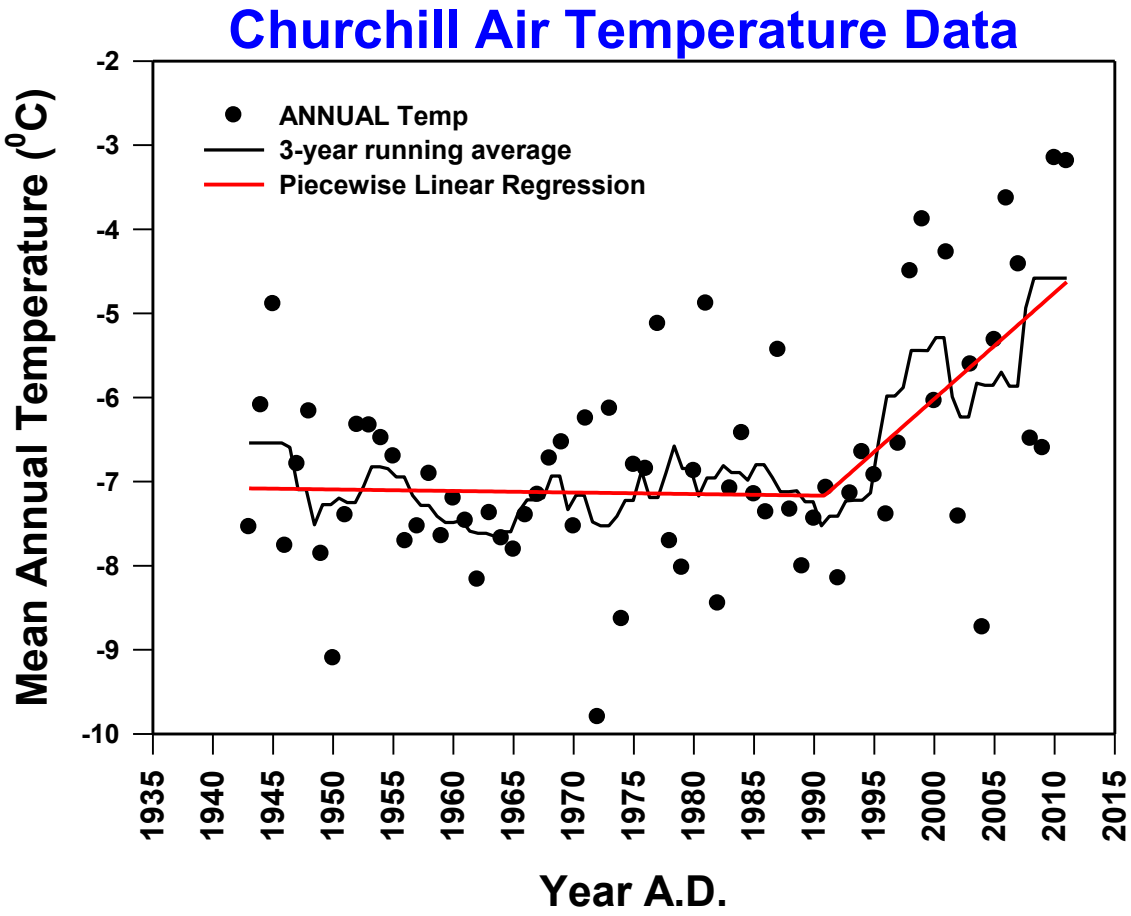


NASA/Goddard Space Flight Center

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

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

Since 1980 the melt season of ***Hudson Bay*** *has lengthened by 10 days per decade, the* ***largest increase reported for the entire Arctic*** (Markus et al. 2009).



(Raw data: Environment Canada)

On-the-ground observations

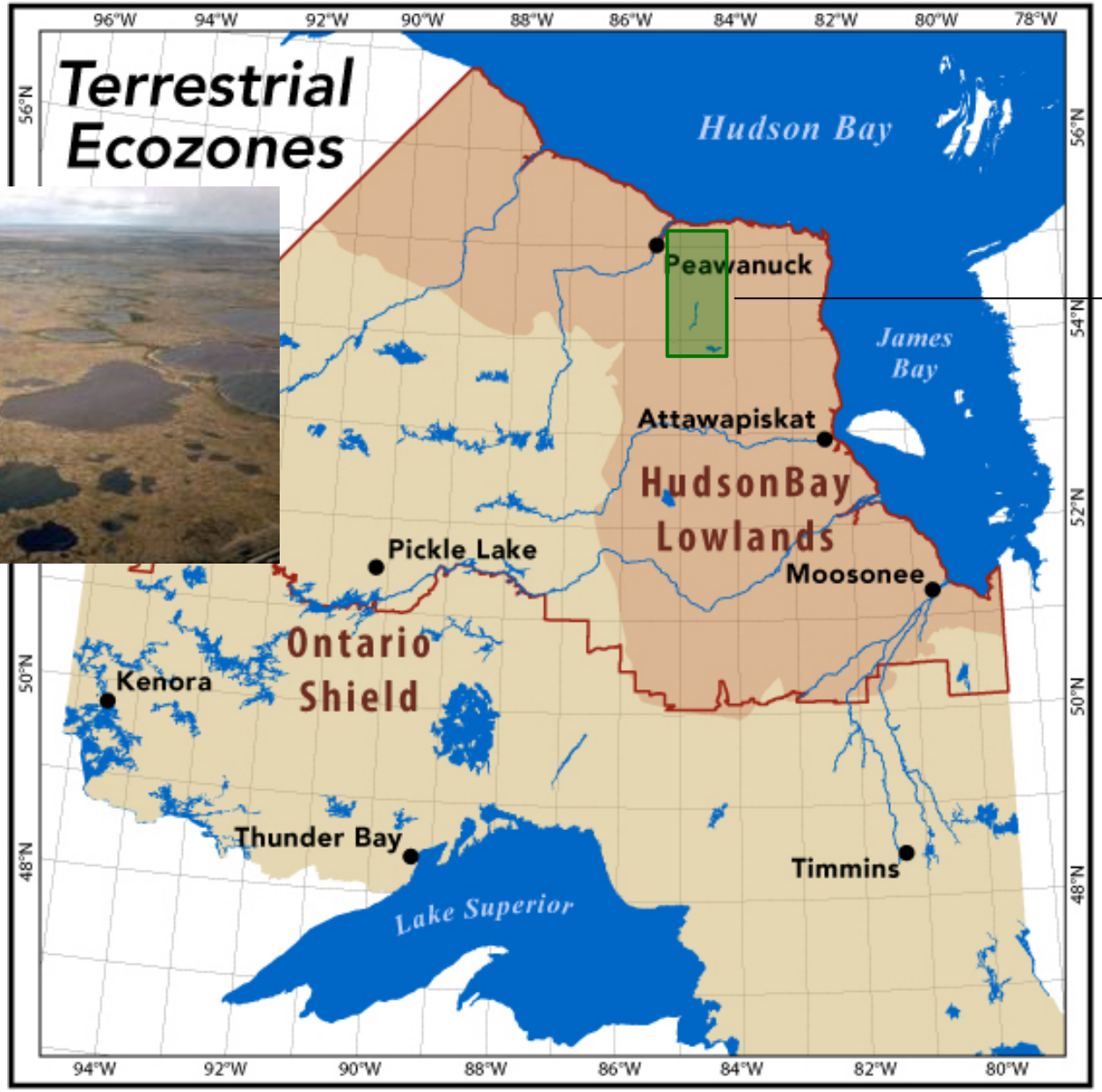
Recent evidence of:

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

(Albert Chookomolin, personal communication)

Hudson Bay Lowlands, Ontario

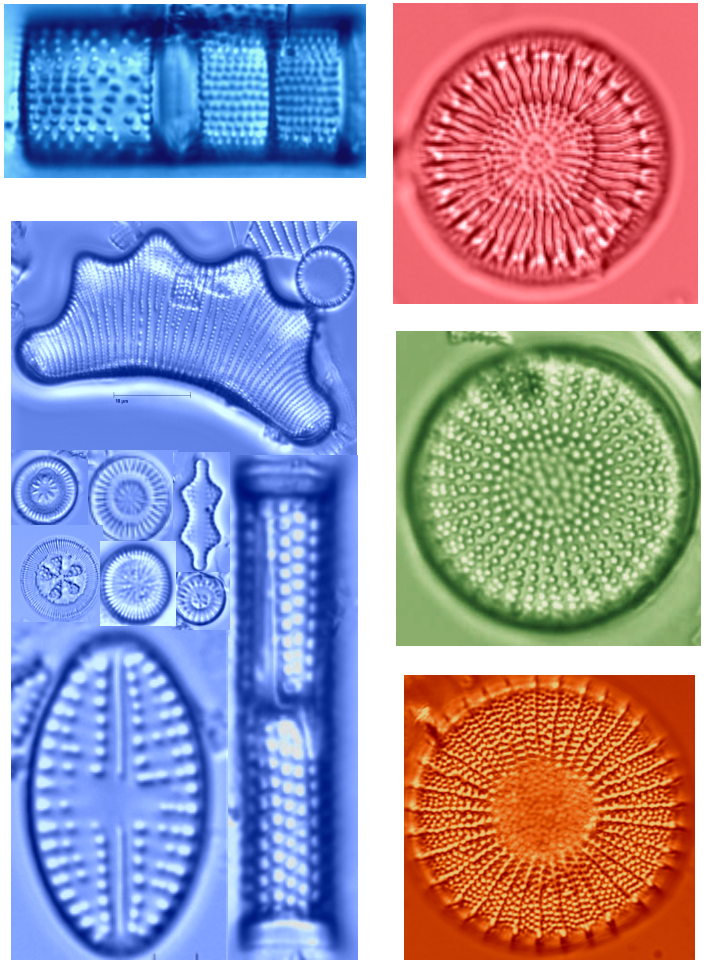
(Geological Survey of Canada)



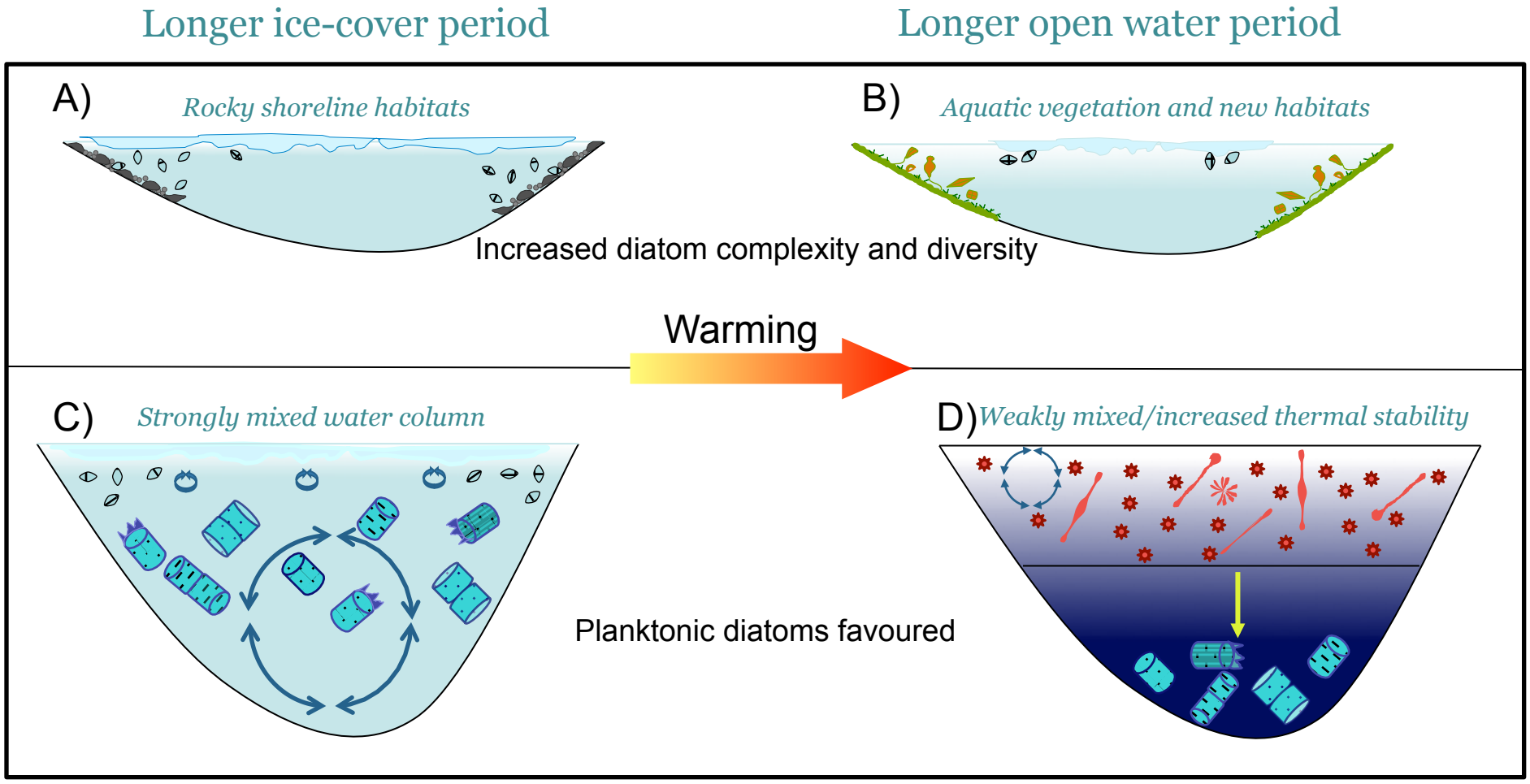
(Photos: Bill Keller)

Diatoms: sensitive indicators of climate warming

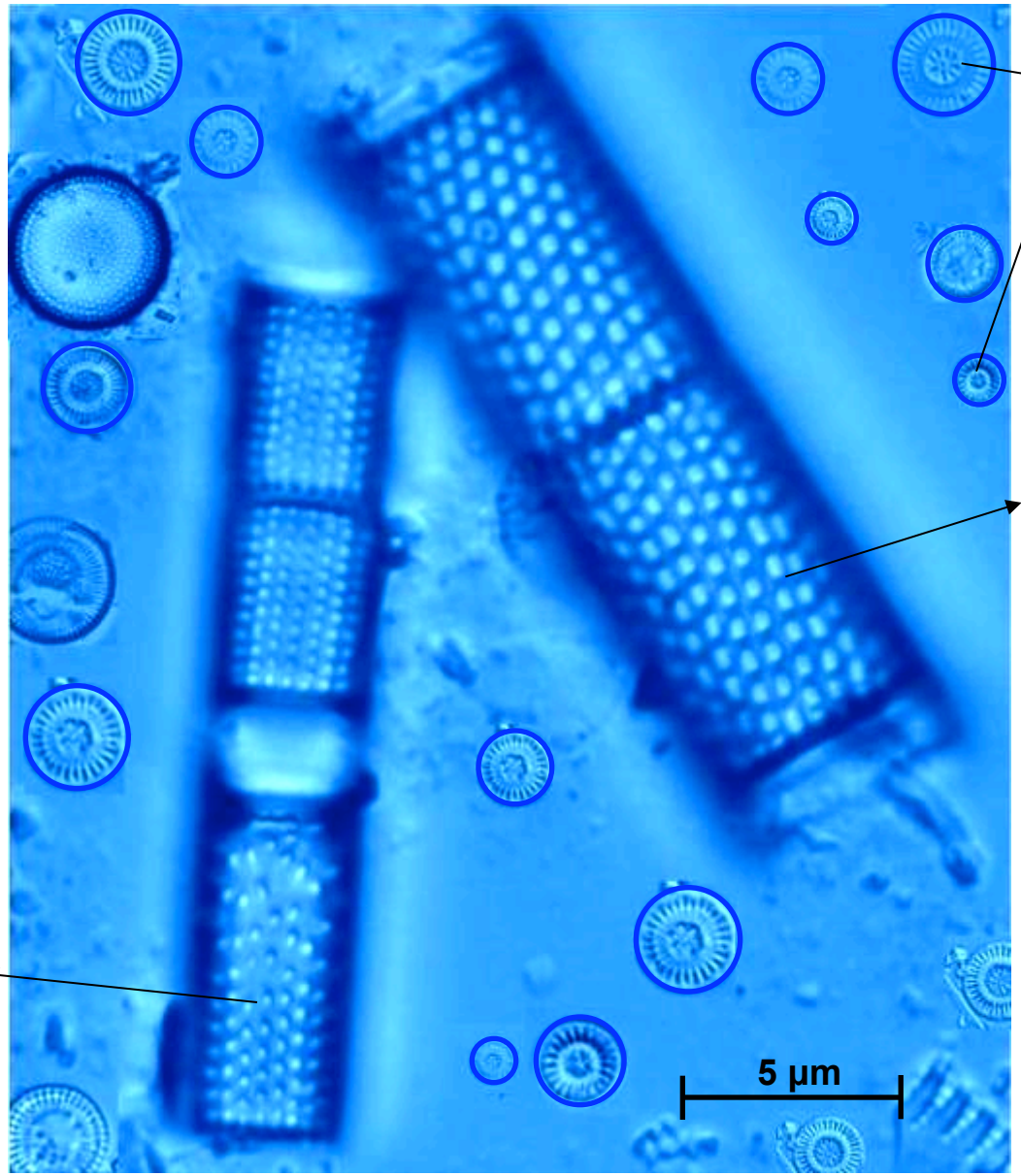
- single-celled, microscopic algae
- well preserved in lake sediments
- taxonomically specific ornamentation
- sensitive to environmental and climatic change
- respond rapidly to environmental change



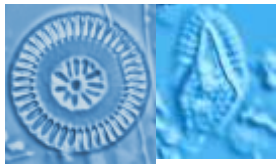
Diatoms and warming

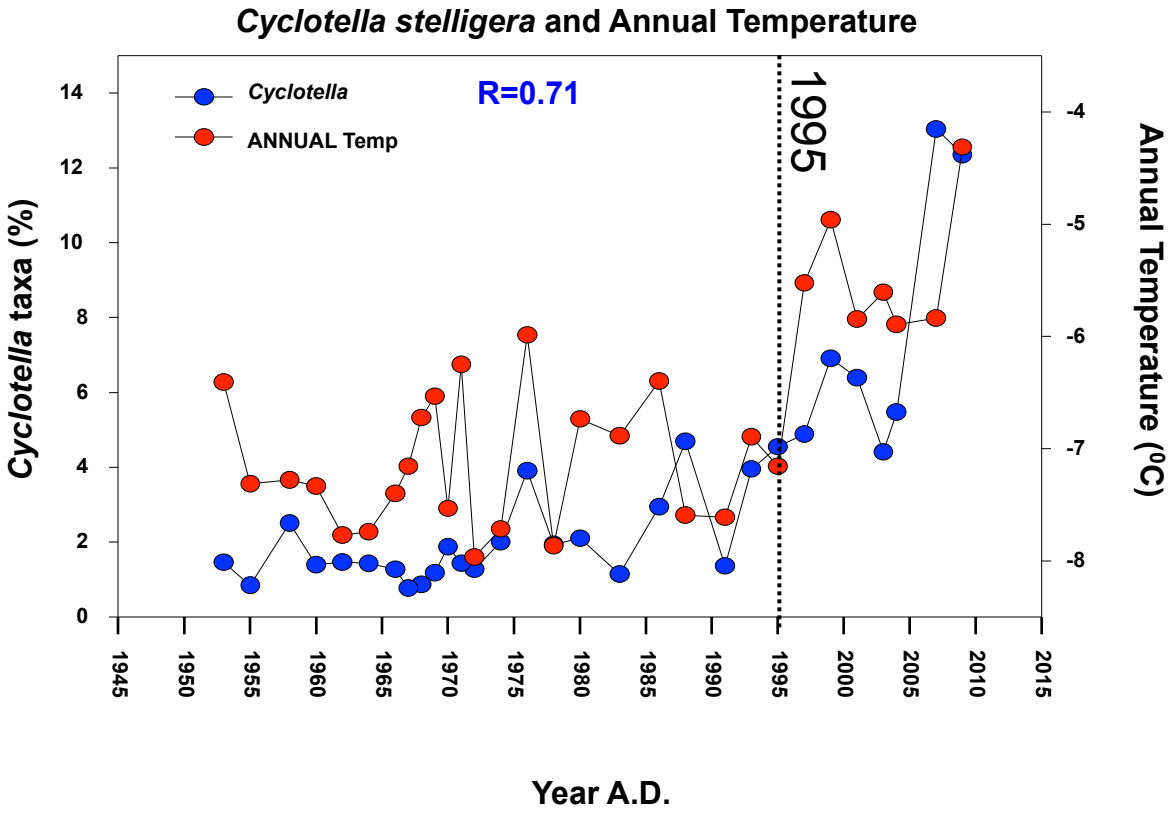


Diatoms and warming: *Cyclotella - Aulacoseira*

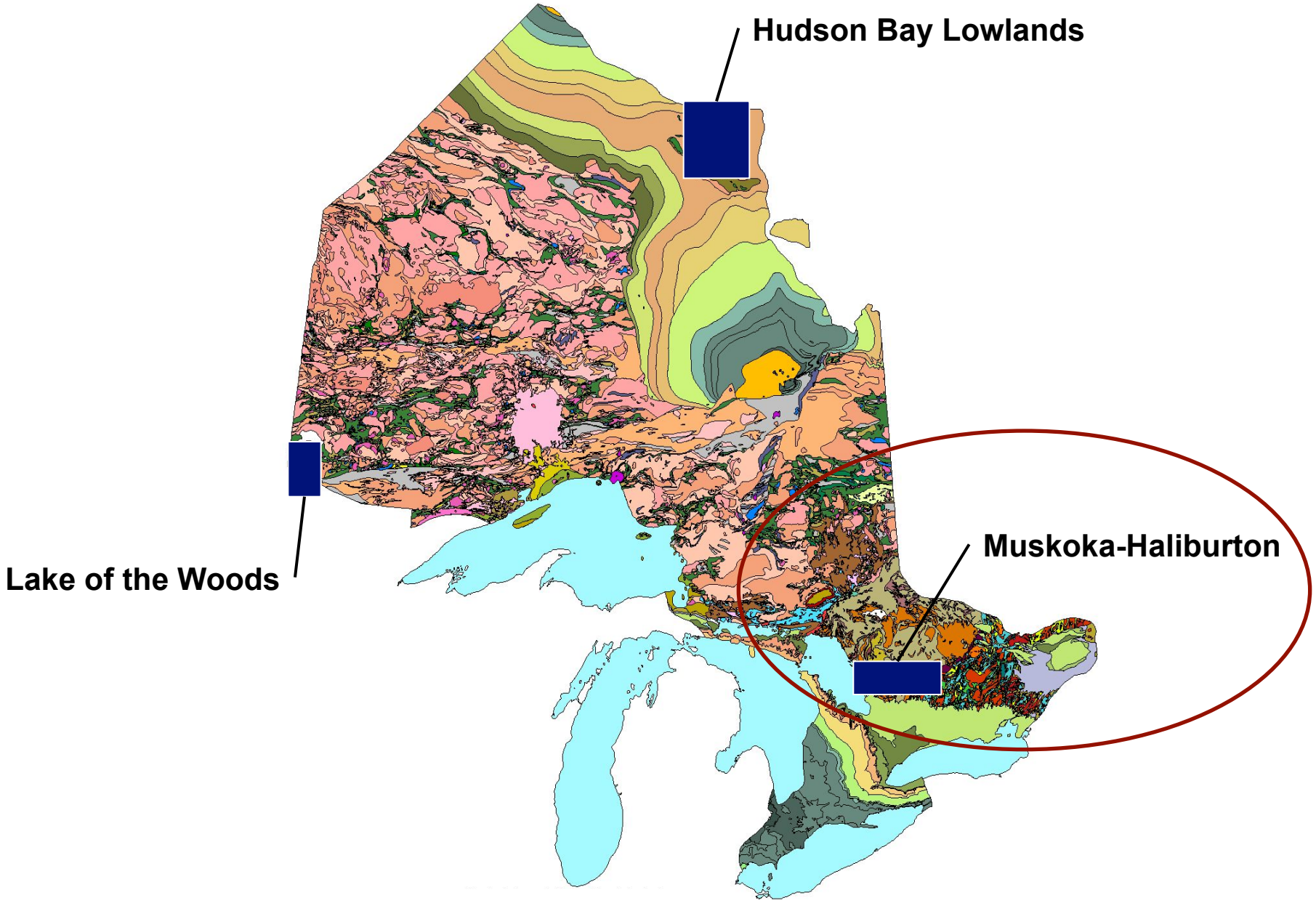


Recent diatom trends: North Raft Lake





(Rühland et al. unpublished)

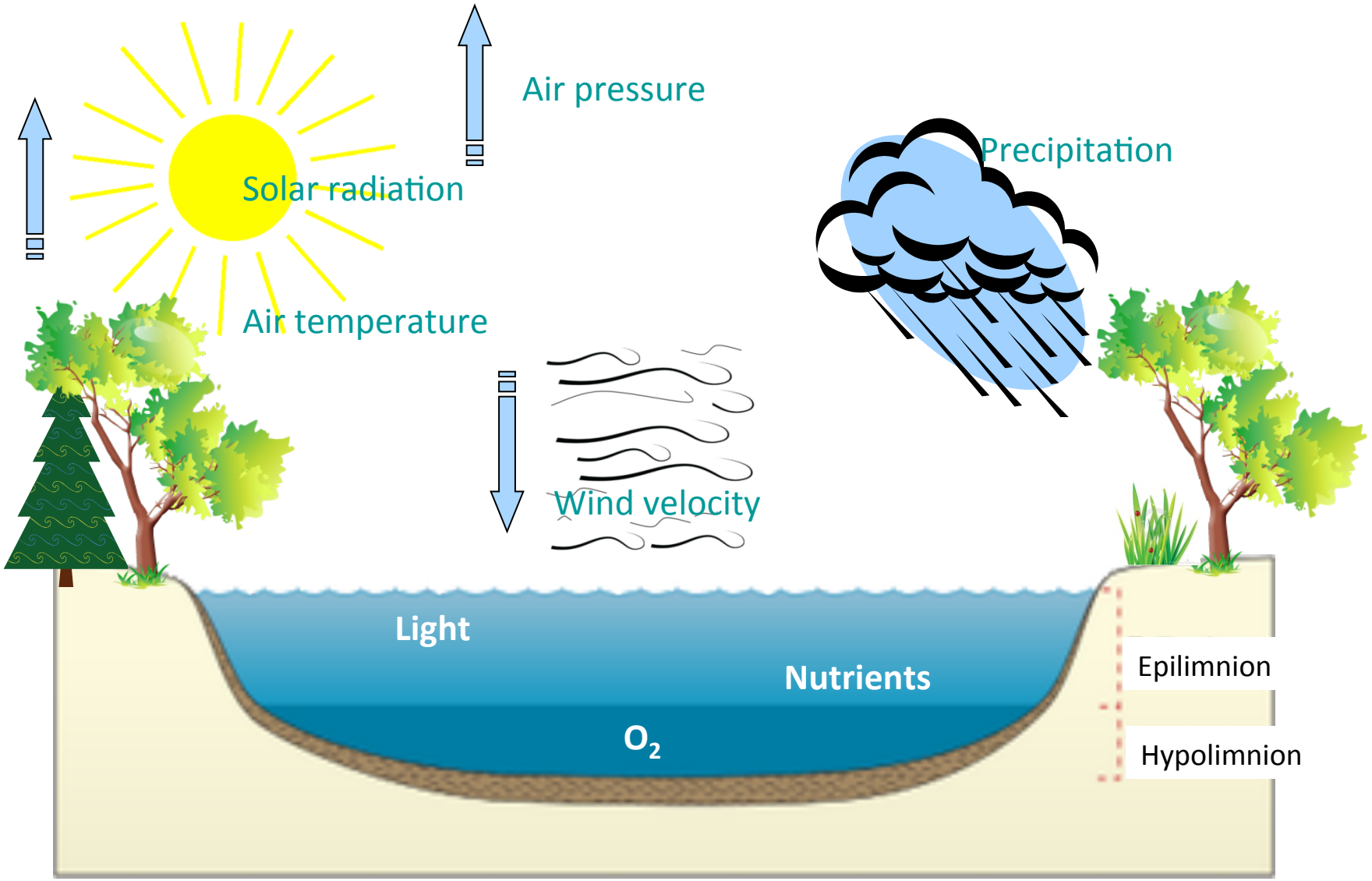

Hudson Bay Lowlands
Lake of the Woods
Muskoka-Haliburton

(Bracebridge Examiner, October 19th, 2005)

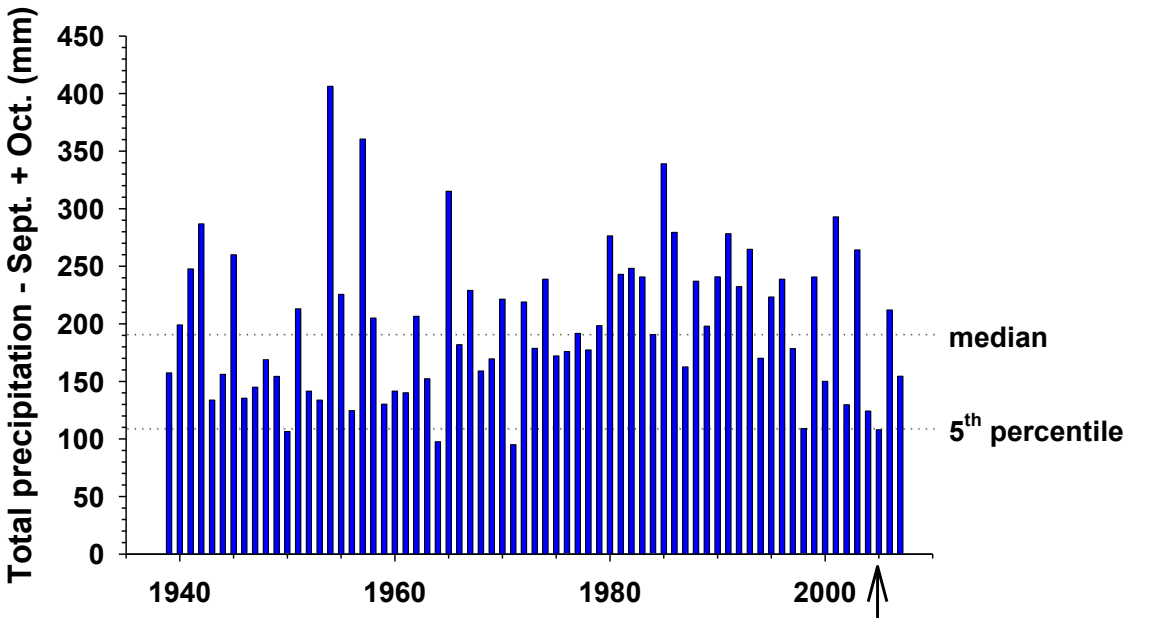
Three Mile Lake: 2005 algal scum

Source: Google Earth

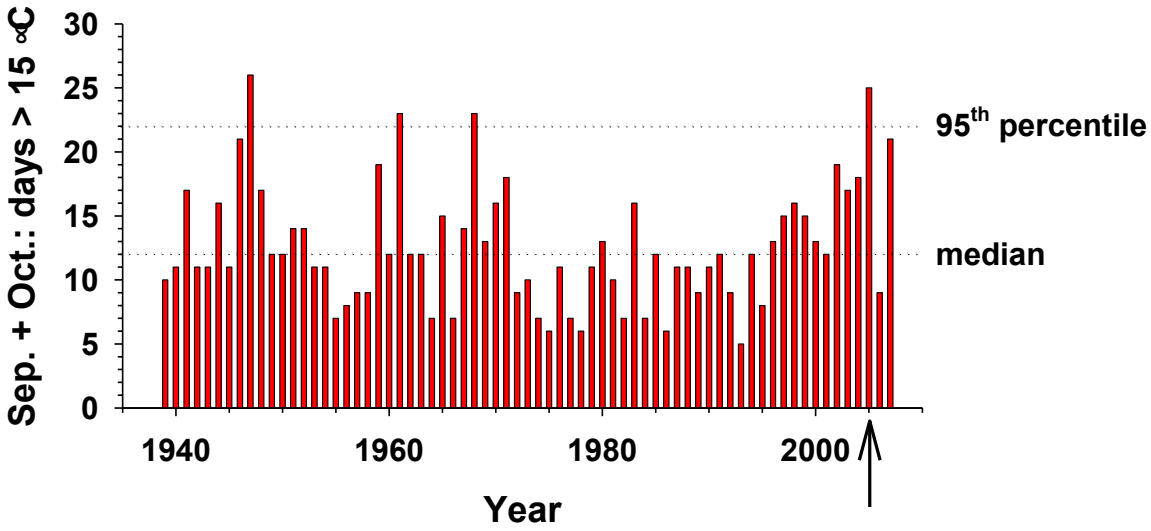
When does a bloom become a scum?



2005 was the warmest/driest fall on record

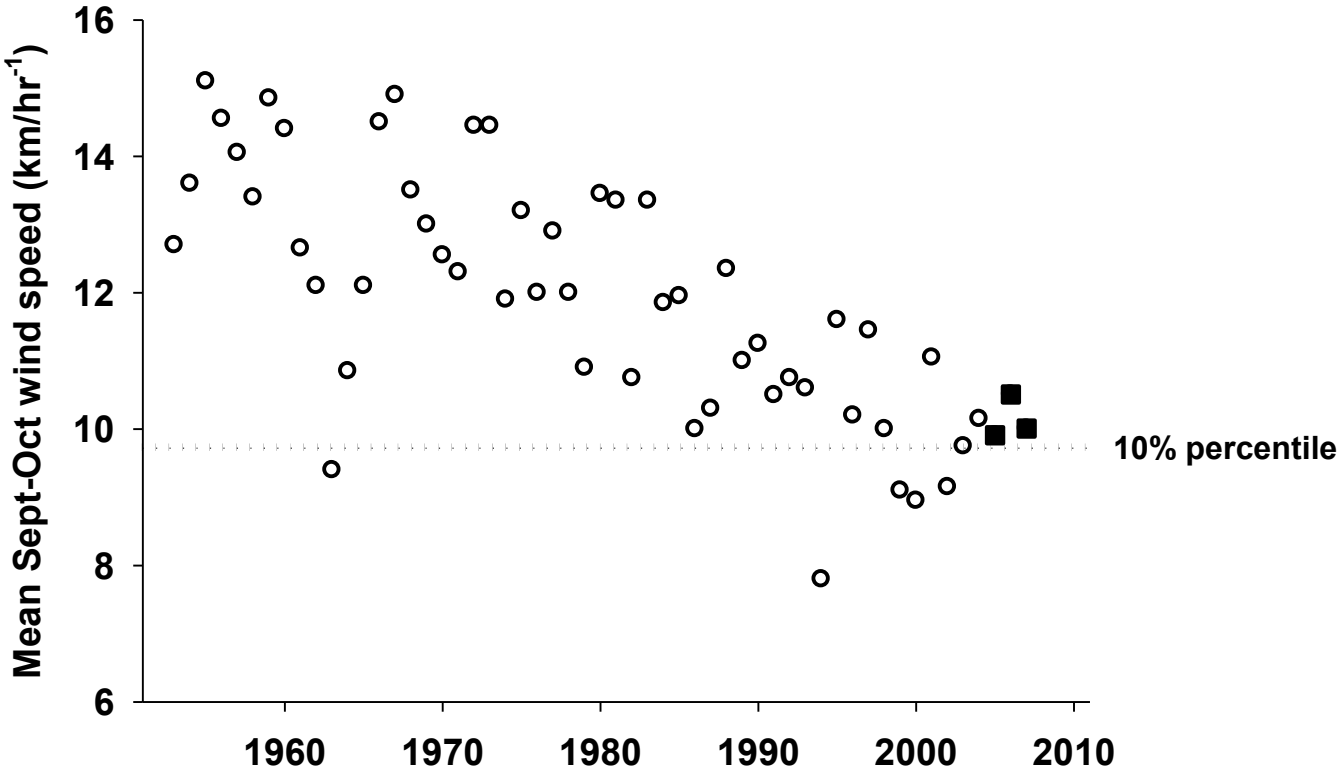


Precipitation

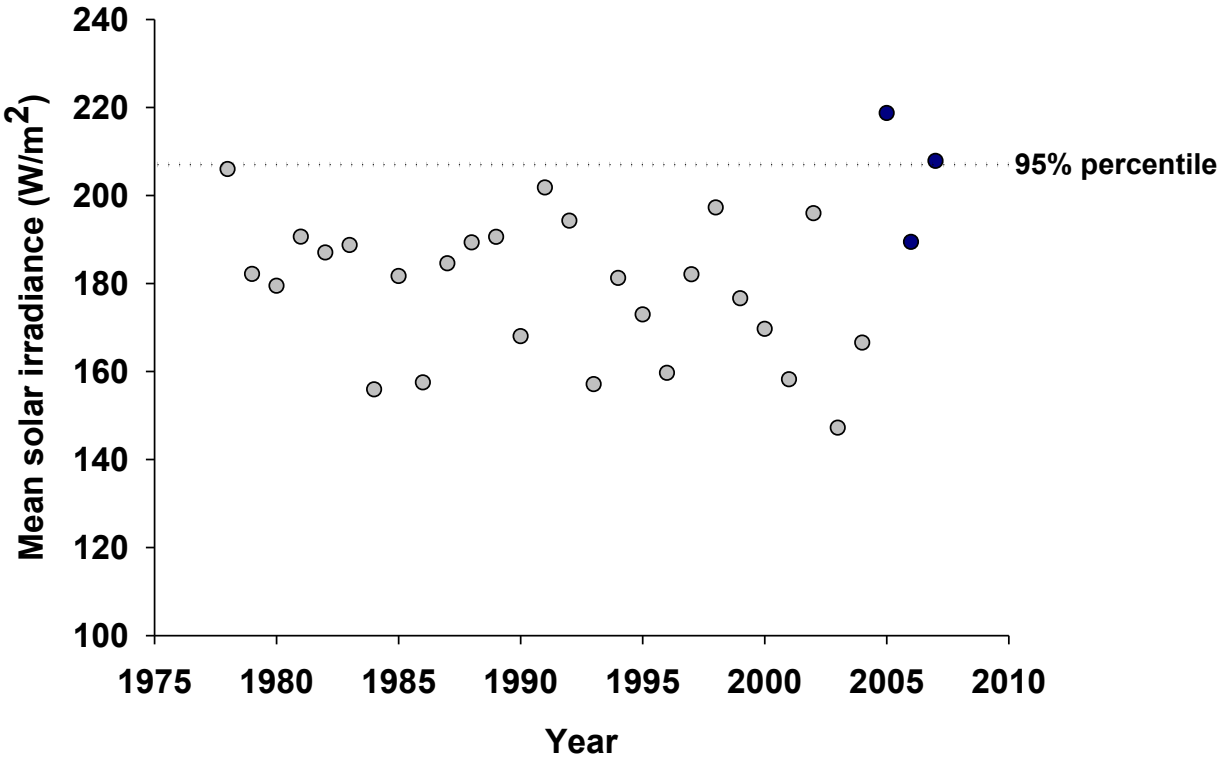


Temperature

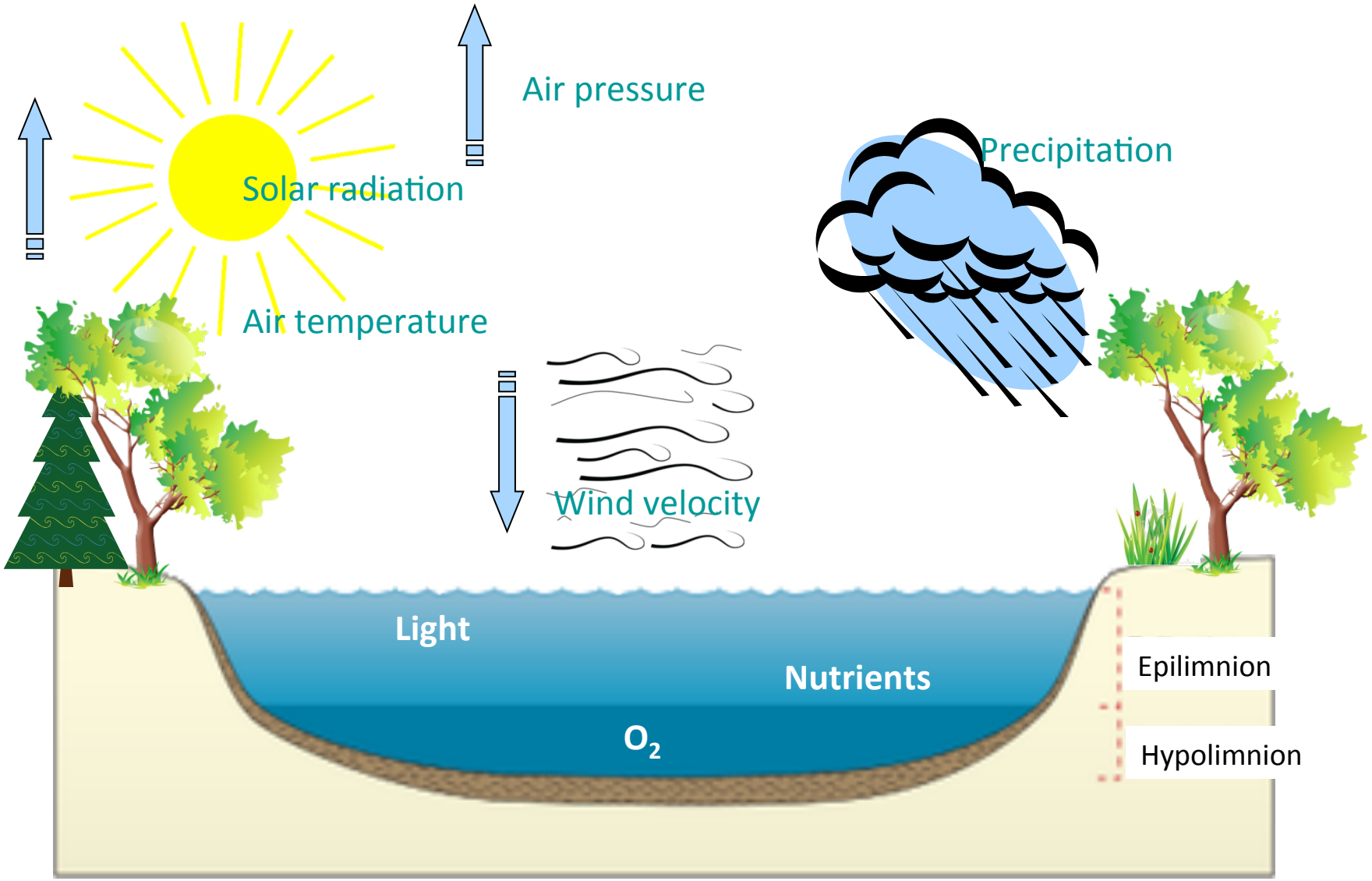
It was less windy in the fall of 2005



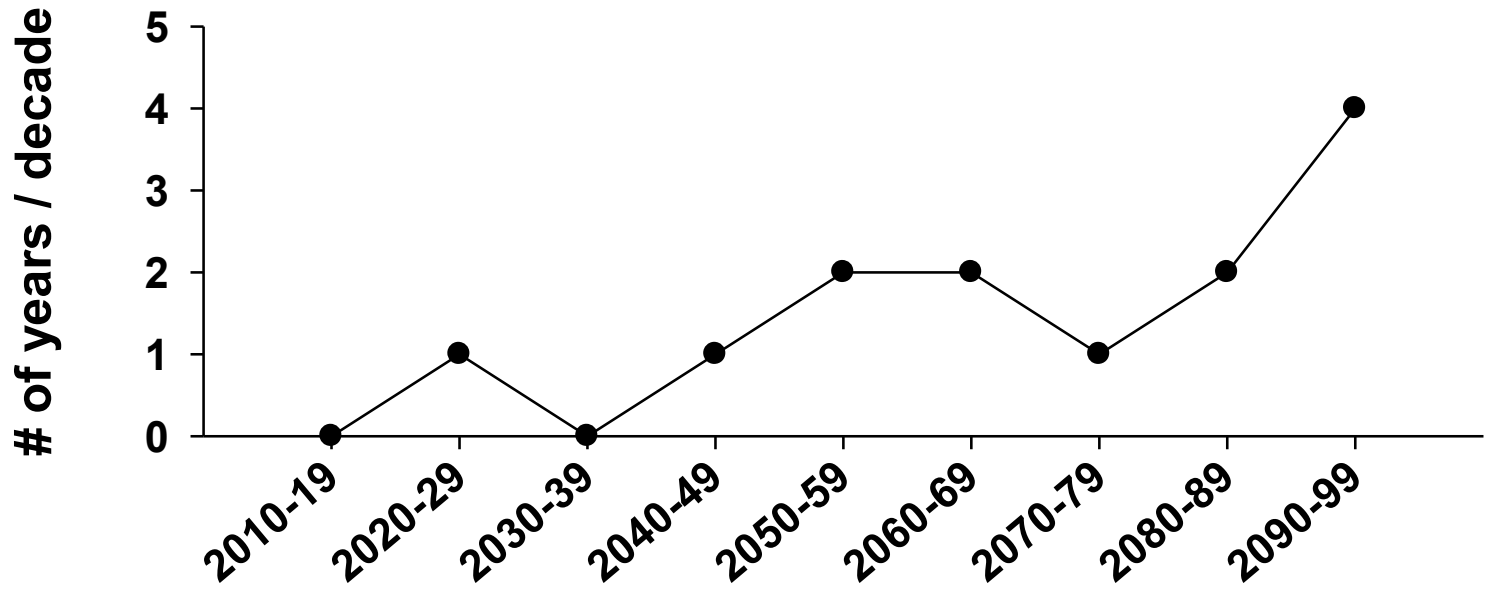
There were fewer clouds, on average



2005: The “perfect storm”



How likely are “perfect storm” conditions?



If algae are the music we hear from a radio…

Phosphorus controls the “volume” of algae

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”

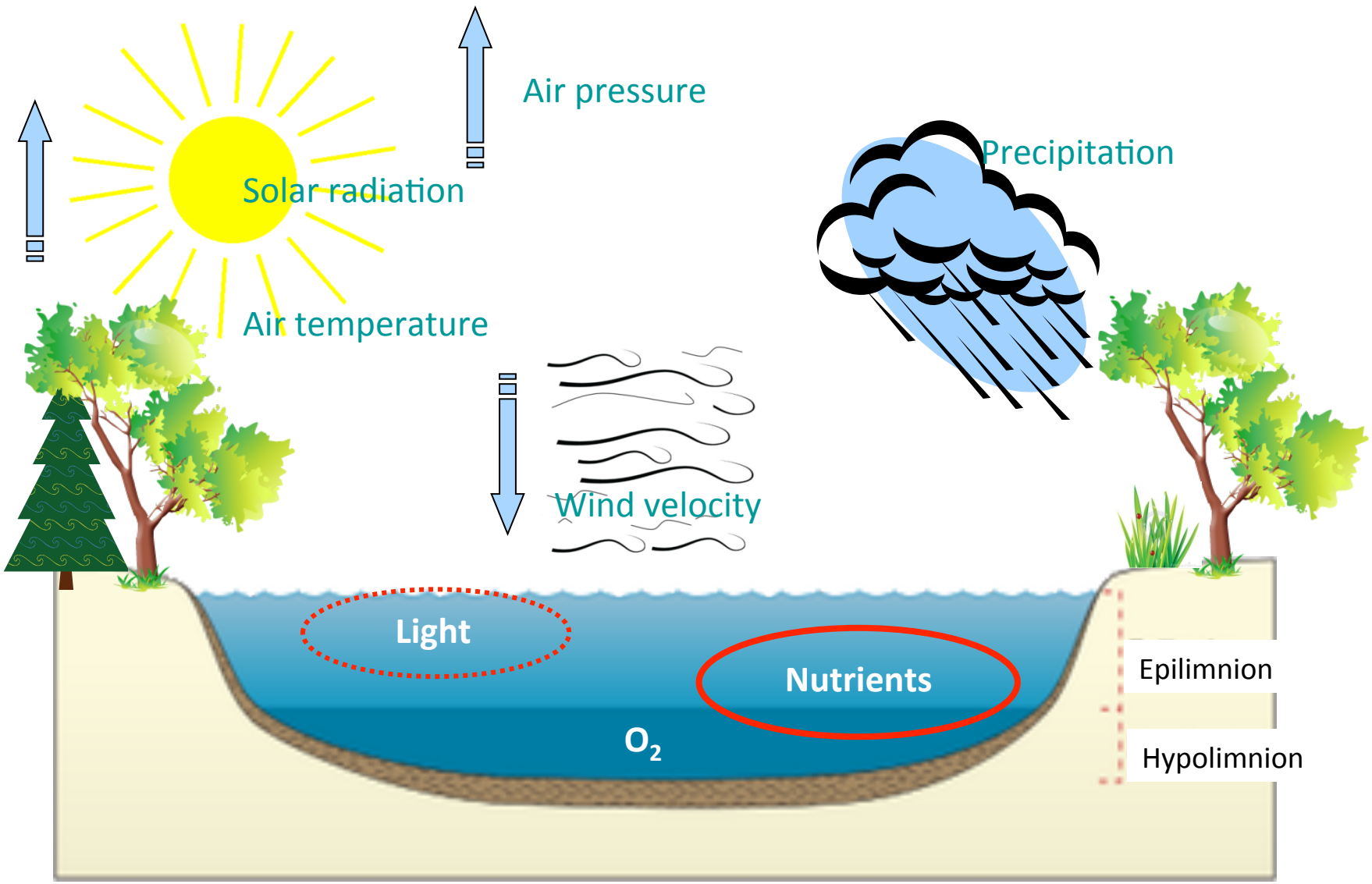
Phosphorus controls the “volume” of algae

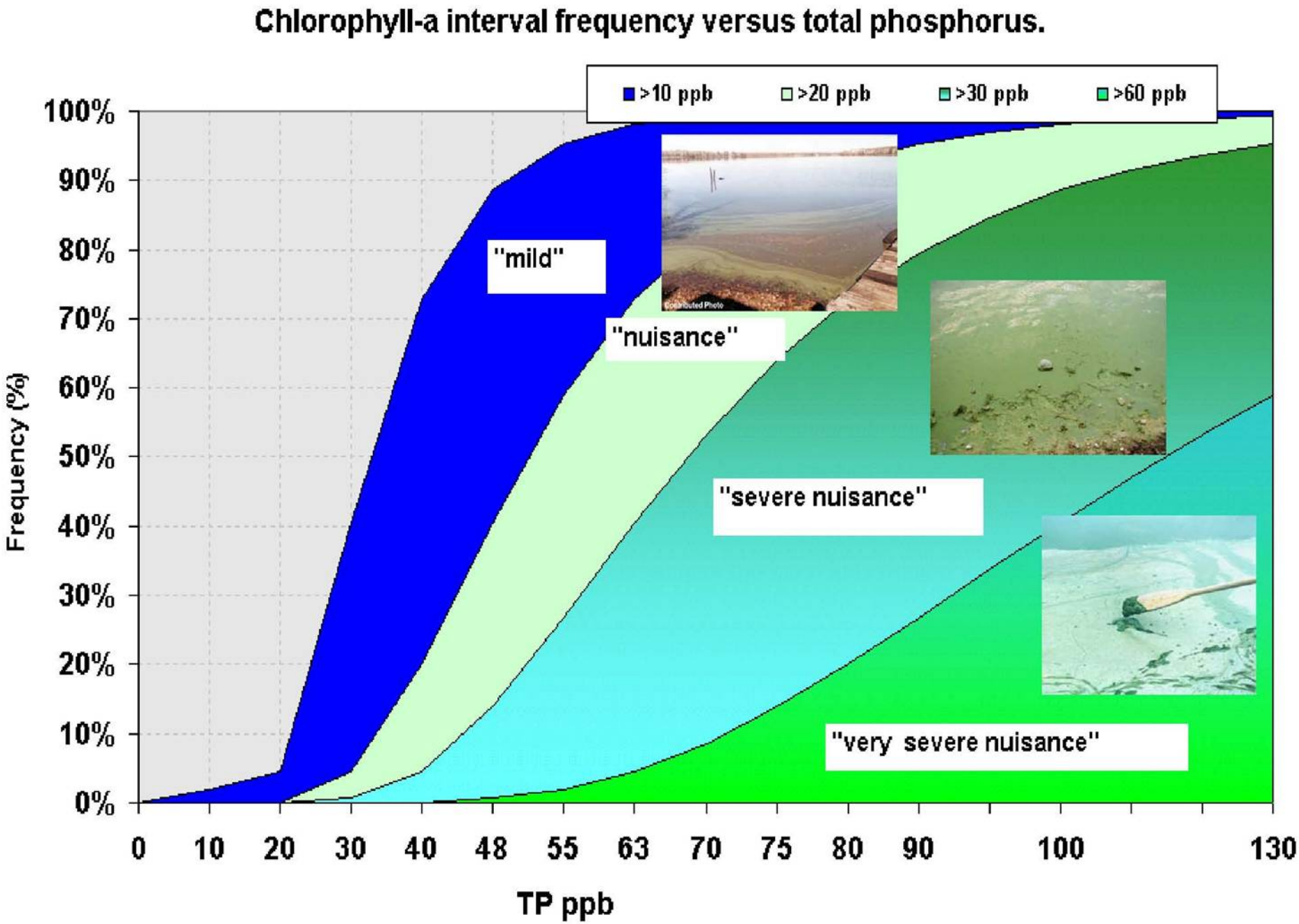
Why is this happening?

What was the cause?

Will it happen again?

What can we do about it?


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


Chlorophyll-a interval frequency versus total phosphorus.
>10 ppb
>20 ppb
>30 ppb
>60 ppb
"mild"
"nuisance"
"severe nuisance"
"very severe nuisance"
Frequency (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
48
55
63
70
75
80
90
100
130
TP ppb