Harmful Algal Blooms in Ontario Lakes: Causes and Management

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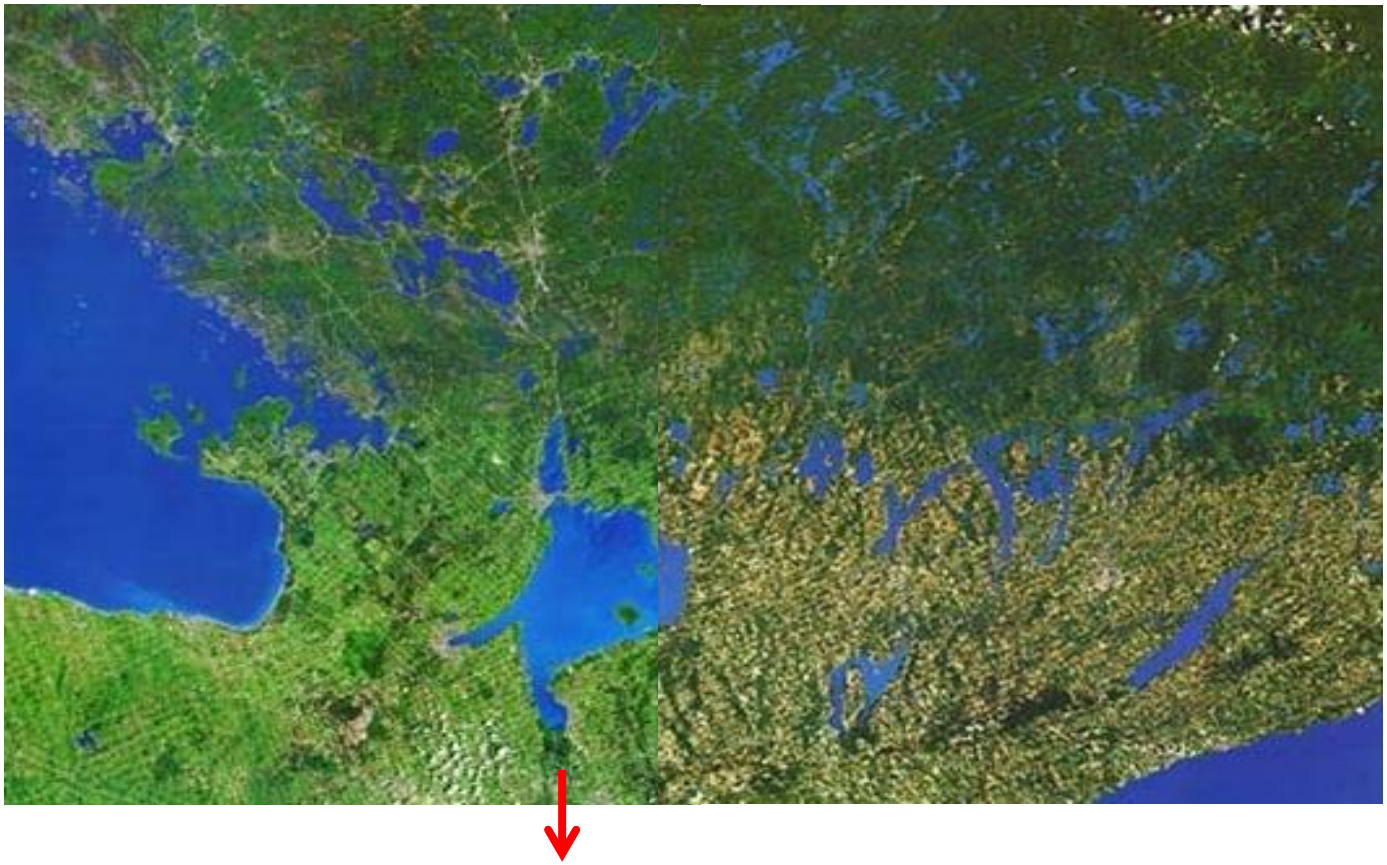
- About 3 million lakes in Canada, with perhaps 250,000 in Ontario

- Almost 3,900 Ontario lakes are greater than 3 sq km (3000 hectares) so most are small

WHERE ARE THE LAKES?

South-central Ontario: note the difference between dark green to the north and lighter pattern to the south. Red arrow points to the dividing line between different geology and land use.

Most of the lakes are north of this line.

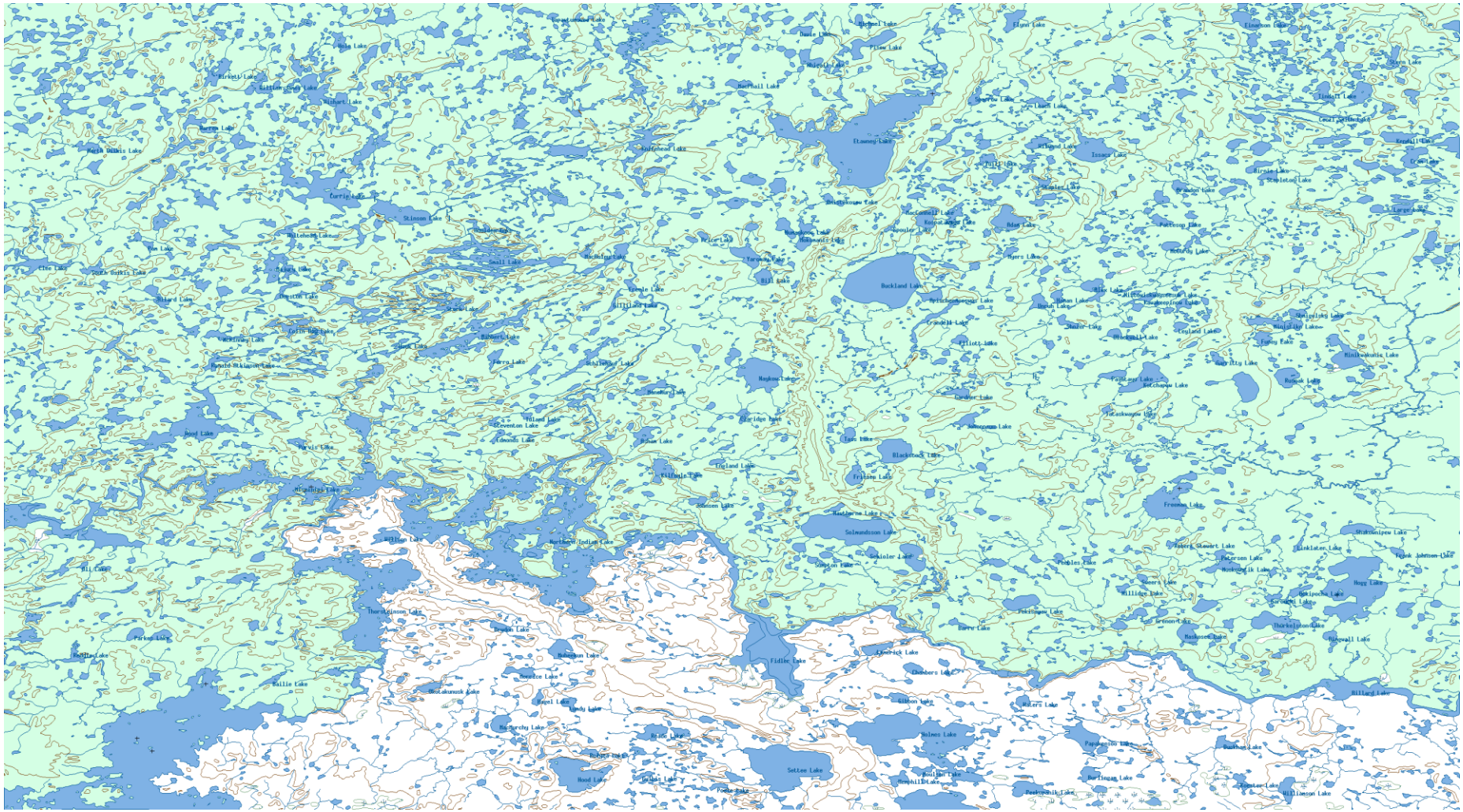


geological boundary

1 hr drive to Toronto

(Natural Resources Canada)

Lake ‘density’ is high north of the line (region is called the Precambrian Shield)

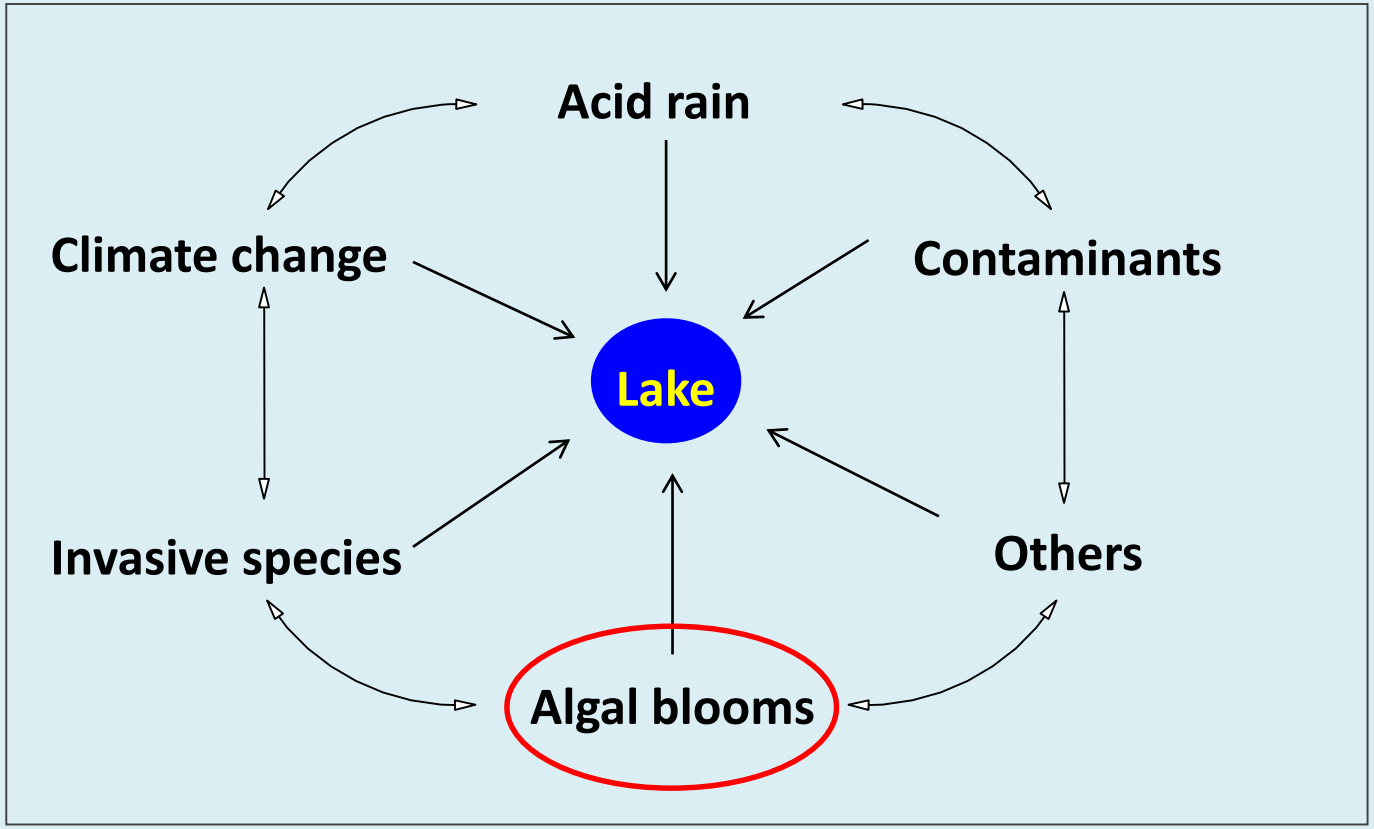


Most lakes are very remote without road access but…

- Small percentage are heavily ‘cottaged’ and a few have development (resource extraction) nearby: e.g., mines, forestry.

- But remoteness does not protect lakes from environmental stresses caused by human visitors (e.g., ice fishing), airborne deposition of chemicals or climate change

Common threats to water quality of inland lakes



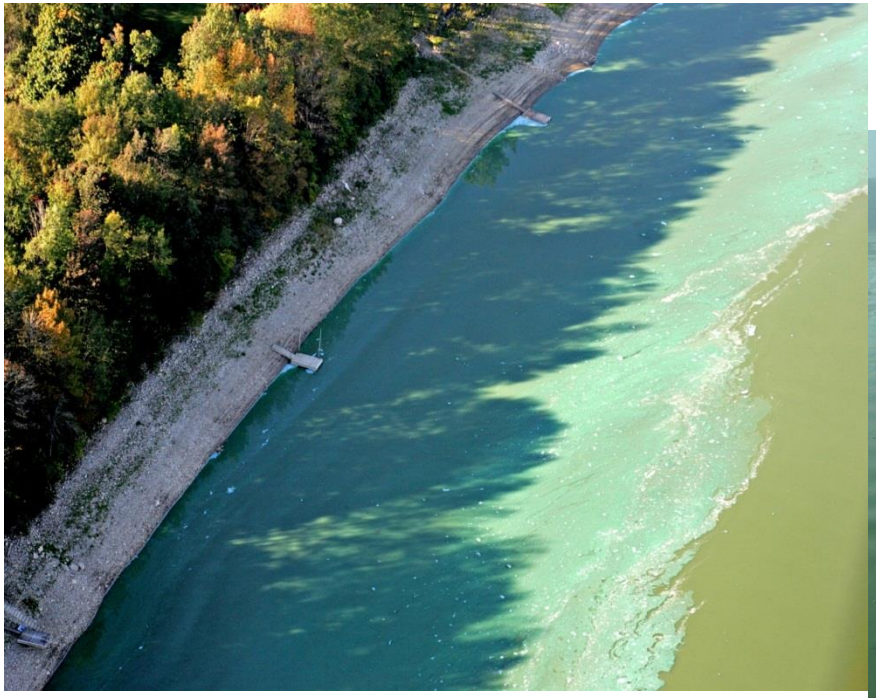
What is Eutrophication?

- Biological productivity of lakes, like farm fields, is limited by availability of plant nutrients, most importantly, phosphorus (P).
- When P from human sources is added to a lake, the lake becomes more productive → this means higher rates of growth of microscopic algae which are the base of aquatic food chains. Ecologists refer to microscopic algae as 'phytoplankton'.
- Dense algal populations can turn the water green. When this happens we say that a 'bloom' has formed.

Cyanobacteria bloom in Lake Erie. The green colour is caused by high concentration of the main photosynthetic pigment, chlorophyll.

When there is too much phosphorus → algal yields increase.

Too much phosphorus from cities and farms in the Grand River reservoir (left) and the Bay of Quinte (Lake Ontario) produced massive blooms of photosynthetic blue-green algae (aka cyanobacteria)

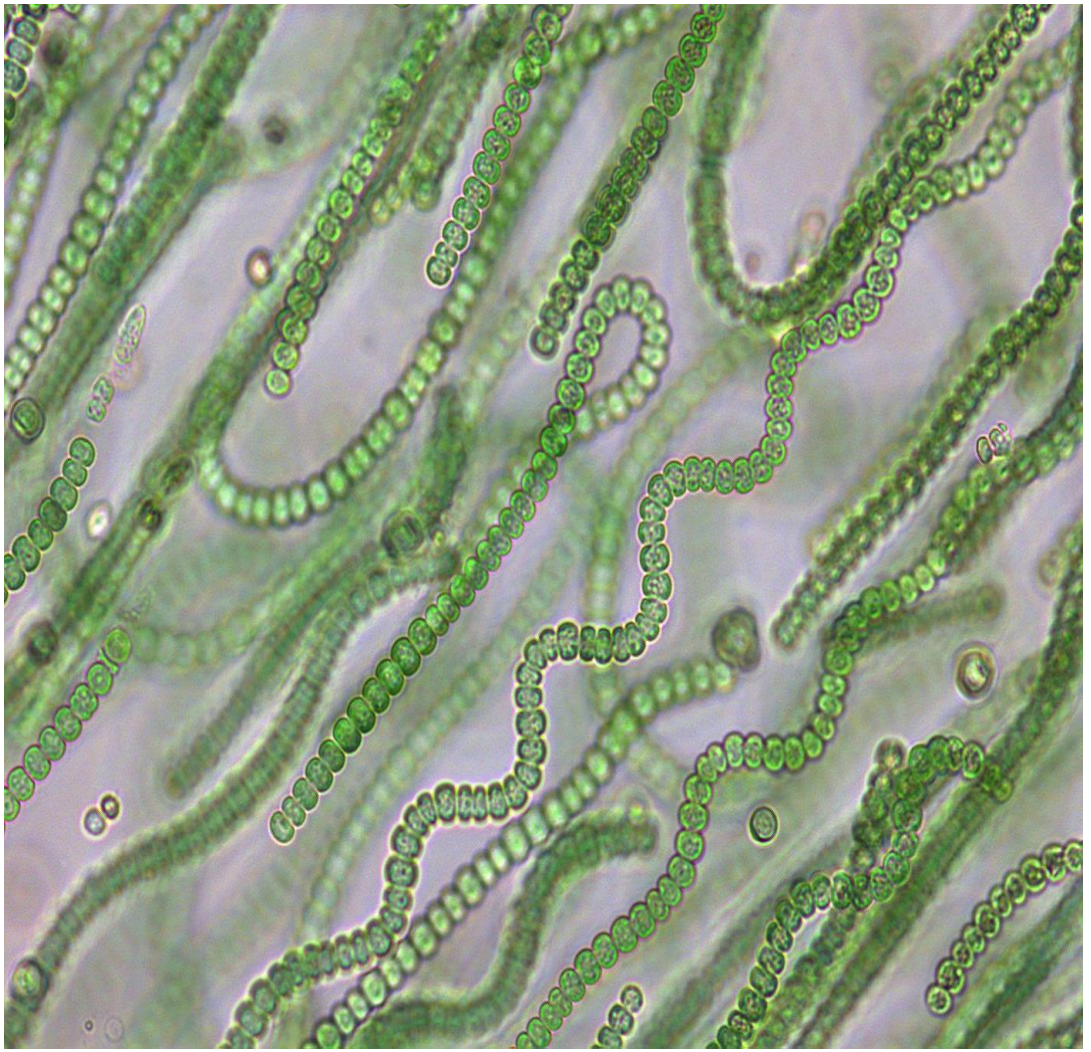


Water samples from two lakes near Huntsville, Ontario: Three Mile (left) and Brandy (right) in 2013

Blooms cause:

- reduced water clarity
- loss of deep-water oxygen
- toxins
- taste and odour compounds

Massive summer blooms are caused by microscopic algae called cyanobacteria



Cyano species are buoyant and sometimes accumulate on the surface.

Large blooms are visible in near earth orbit

So, why do we not like cyanobacteria blooms?

- Some strains produce liver and nerve toxins → public health threat.

The New York Times

Algae Can Poison Your Dog

Dogs have become fatally ill after frolicking in water infused with the toxic algae, owners said.

A golden retriever playing last year at Lady Bird Lake in Texas, which has been closed recently because of algae blooms that could kill dogs. Ralph Barrera/Austin American-Statesman, via Associated Press

- Some strains produce compounds that alter taste and odour in drinking water supplies.

Negative impacts on recreation and property values. Who wants to live next to or swim in a toxic lake?

Bloom ecology: External conditions have to be right for a bloom to occur

1) Lots of phosphorus

2) Low winds so there is little turbulence

3) Warm temperatures, lots of sunlight

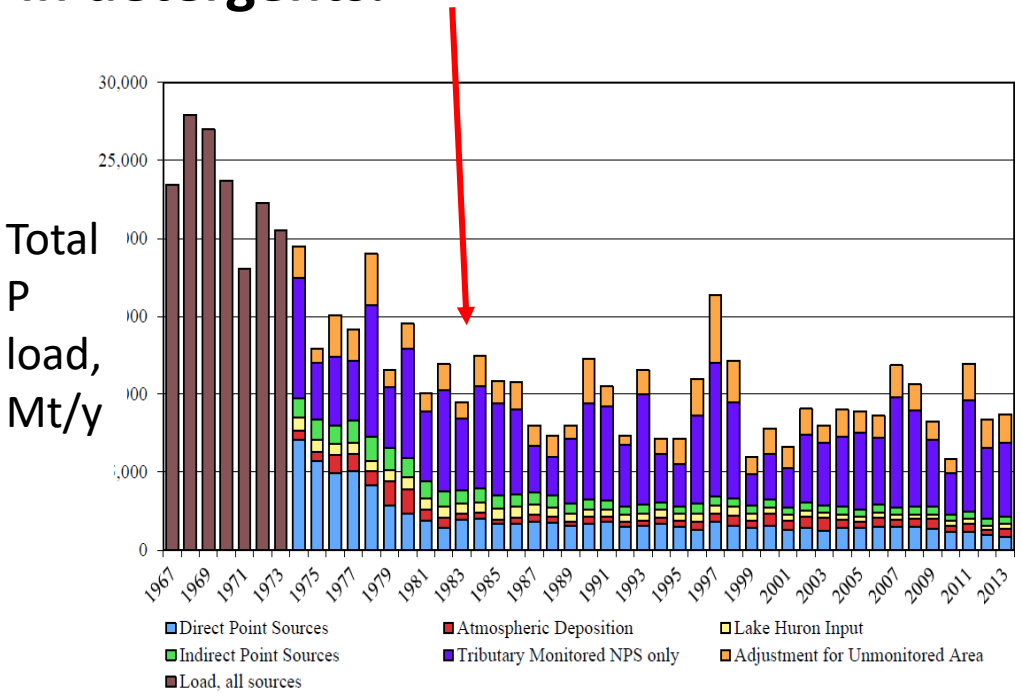
This side of lake was experimentally fertilized with phosphorus

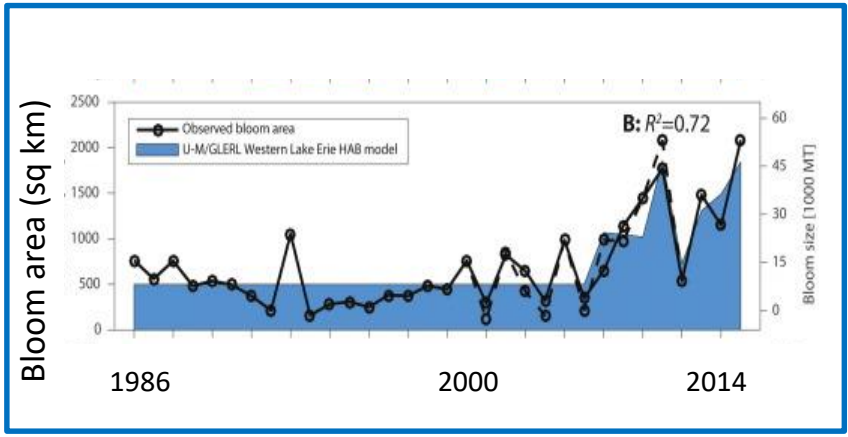
Lake divided with curtain so that basins could be compared

Lake 226 in Experimental Lakes Area NW Ontario

- Ecologists have known since the 1960's that blooms of cyanobacteria are associated with high concentrations of phosphorus, i.e., they do well when waters are rich in nutrients and crowd out other, more benign, algal species.
- Even though the mechanism which allowed cyanobacteria to displace other species was not known until recently, managers knew that lowering the amount of P 'exported' to lakes from sewage treatment plants, farms, city streets, golf courses, septic systems, etc would lower the risk of cyanobacteria blooms occurring and their severity.
- This lead to the 1972 US-Canada Water Quality Agreement which focused on lowering P exports from wastewater treatment plants to the Great Lakes because untreated sewage is a major P source. Much success but…

Lake Erie P concentration declined beginning early 1970's as sewage treatment plants discharged less P due to effective treatment and banning of P in detergents.





Bloom severity improved, BUT sadly, blooms worsened in late 1990s → climate signal? Some years are worse then others.

A bloom hovered over the municipal drinking water intake pipe in western Lake Erie for Toledo, Ohio, in 2014 for 2 weeks, causing 400,000 people to rely on bottled water.

Summary

What do we know?

- Higher P increases risk of cyanobacteria blooms.
- **Management programs have shown that less P lowers risk of blooms.**
- Cyanobacteria growth rates are high above 20^{o}C. They don't like cool water so, warmer temperatures increases risk of cyanobacteria blooms.

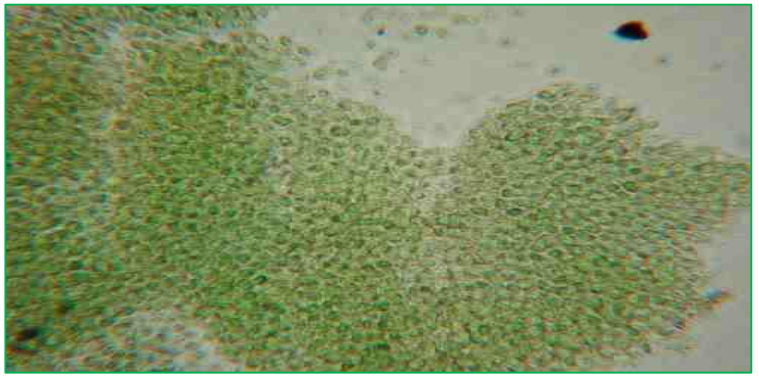
What don't we know?

- We don't know the nature of the mechanism that allows cyanobacteria to displace other types of algae as P levels increase (until recently)…
- Or the reason for increased incidence (occurrence) of blooms in last 20 years. Climate signal?

New research on 'unknown' mechanism in last decade by Ontario scientists has shed light on resurgence of blooms

Sediments become anoxic (no O_2) →
specific form of iron is released from anoxic seds →
allows cyanos to dominate algae in warm waters

is replaced by



- Oxygen depletion along the lake bottom is a hallmark characteristic of productive (eutrophic) lakes → caused by large amounts of settling algae which in turn is a consequence of too much P.

- Note – sometimes surface sediments in shallow waters can become anoxic, especially bays and coves protected from winds

- When bottom becomes anoxic and releases enough ferrous iron → cyanos displace their more benign algal competitors

Brief Summary of Mechanism

High phosphorus level leads to…

→ high spring algal pop'n which dies and settles to bottom where decomposition consumes oxygen faster than it is resupplied from above

→ lack of oxygen ('anoxia') in sediments causes ferrous iron release into overlying water

→ cyanobacteria bloom (in warm water)

Management implications: We can't manage iron but we can ensure adequate oxygen concentrations at sediment/water boundary to prevent blooms

New scientific knowledge allows us to ask two related questions of any management program:

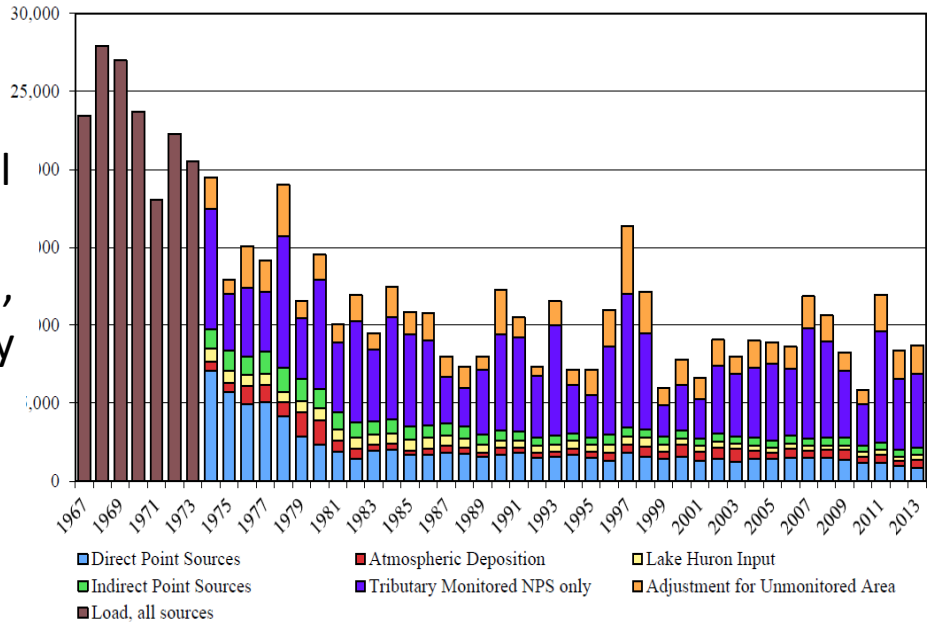
1) Will a proposed management program lower algal population size and make the lake less green (leaving aside which species will dominate for the moment)?

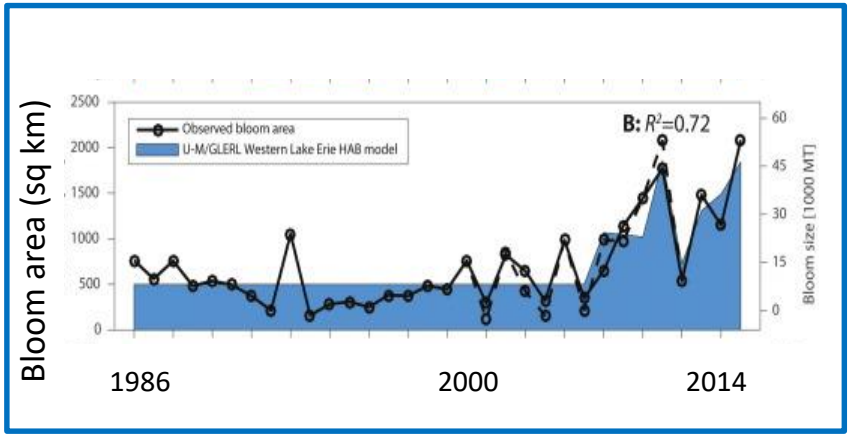
2) Will a proposed management program improve oxygen concentrations at the sediment/water boundary enough to prevent cyanobacteria blooms?

As we saw earlier, lowering P inputs from high levels will have a beneficial effect on blooms → they become less severe.

HOWEVER, blooms are getting worse and some even occur in lakes with low P. What does this mean?

Total P load, Mt/y

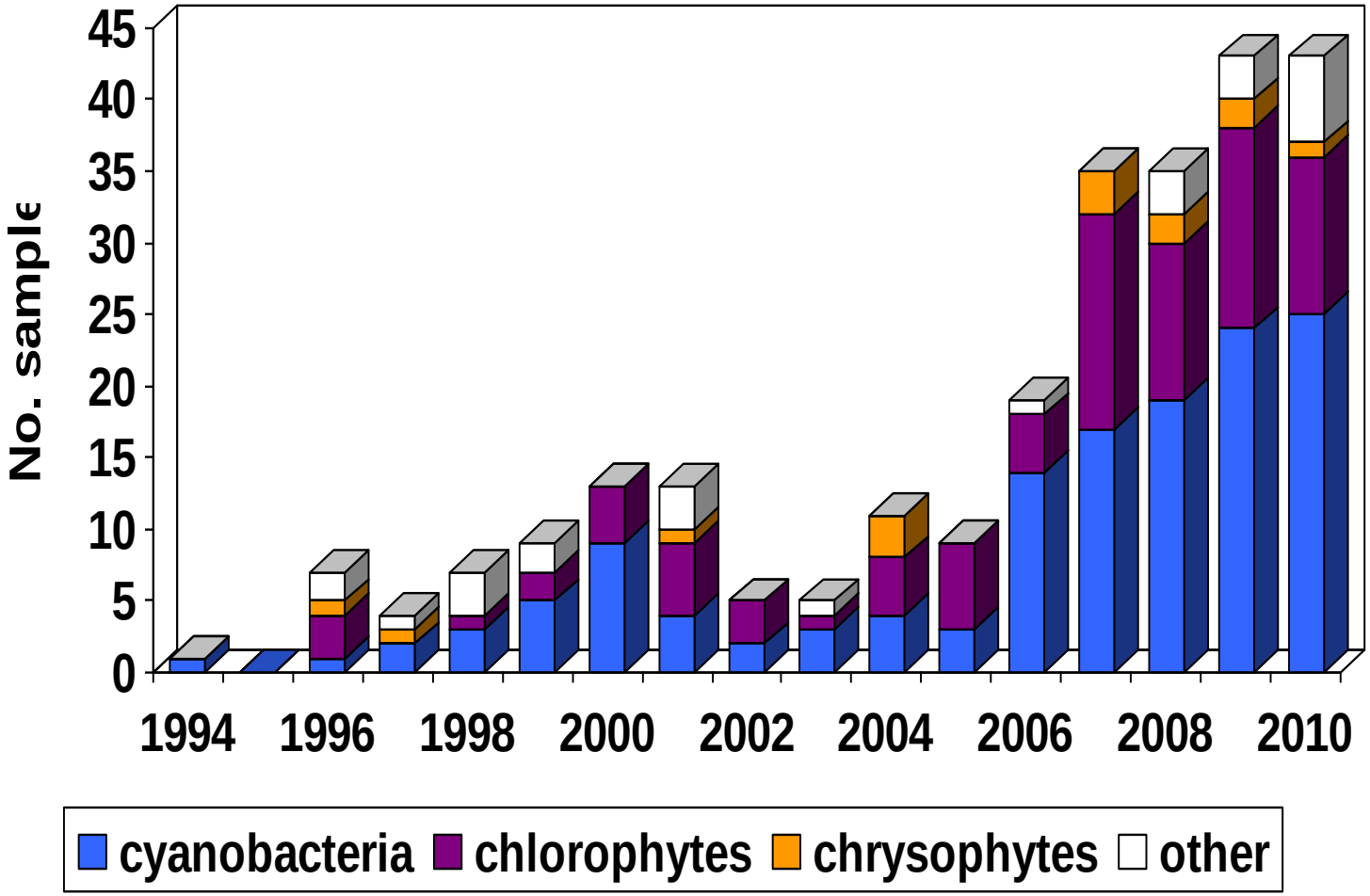




Is climate change worsening blooms?

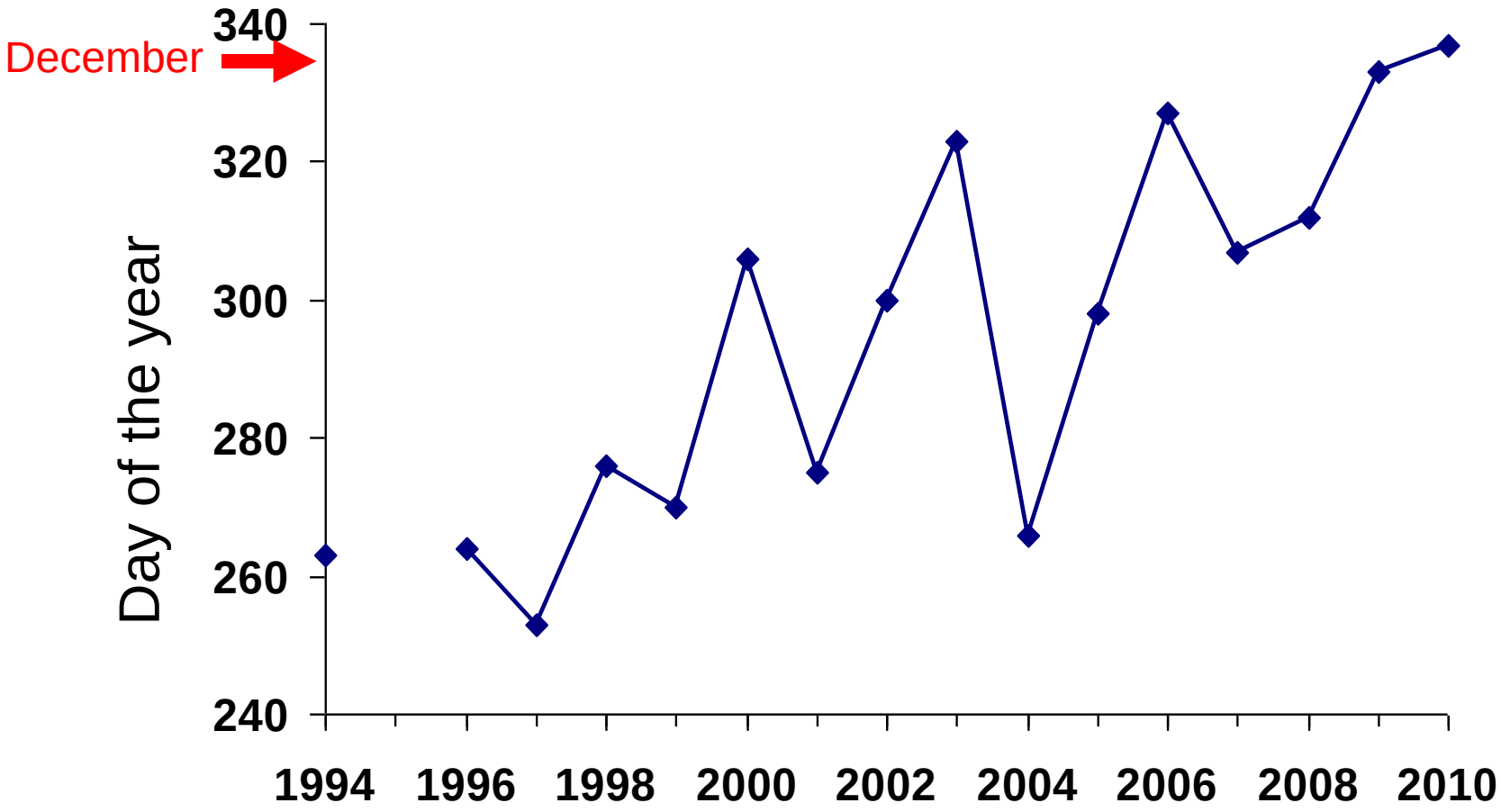
- cyanos like warm waters so our warmer spring and fall seasons has made habitat more suitable for growth from early summer to early fall
- shorter period of ice cover has lengthened the ice-free season, increasing risk of anoxia occurring earlier
- lower wind speeds associated with growing forests and climate change means less mixing of water → lowered re-supply of oxygen to sediments

Annual number of algal blooms reported by public to Ontario Ministry of Environment. Is the increase a climate change signal?



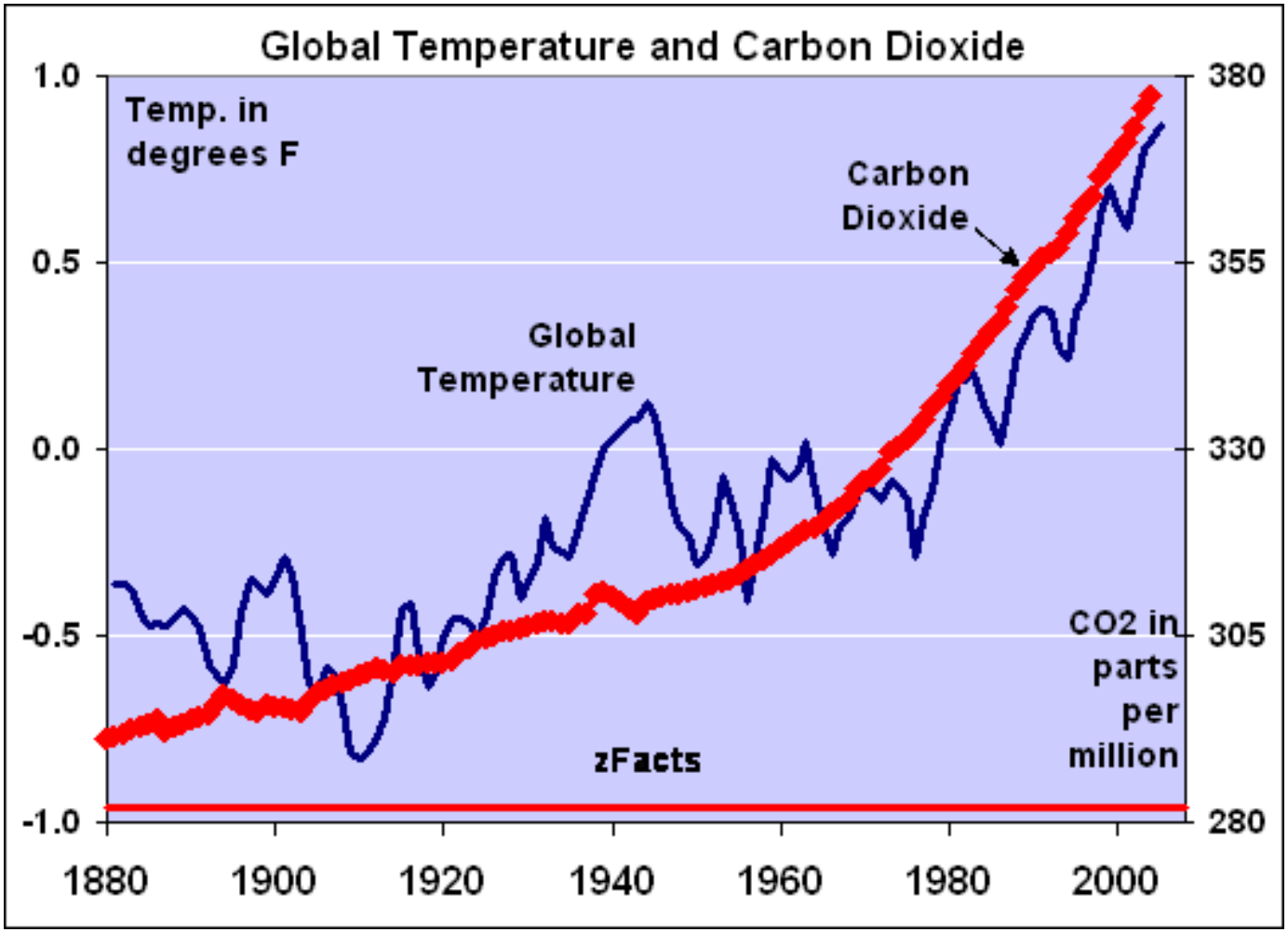
Source: MEPC

Last bloom samples in each year are submitted to Ministry increasingly late in the year. This means that blooms in recent years are occurring later in the fall → Climate change signal?



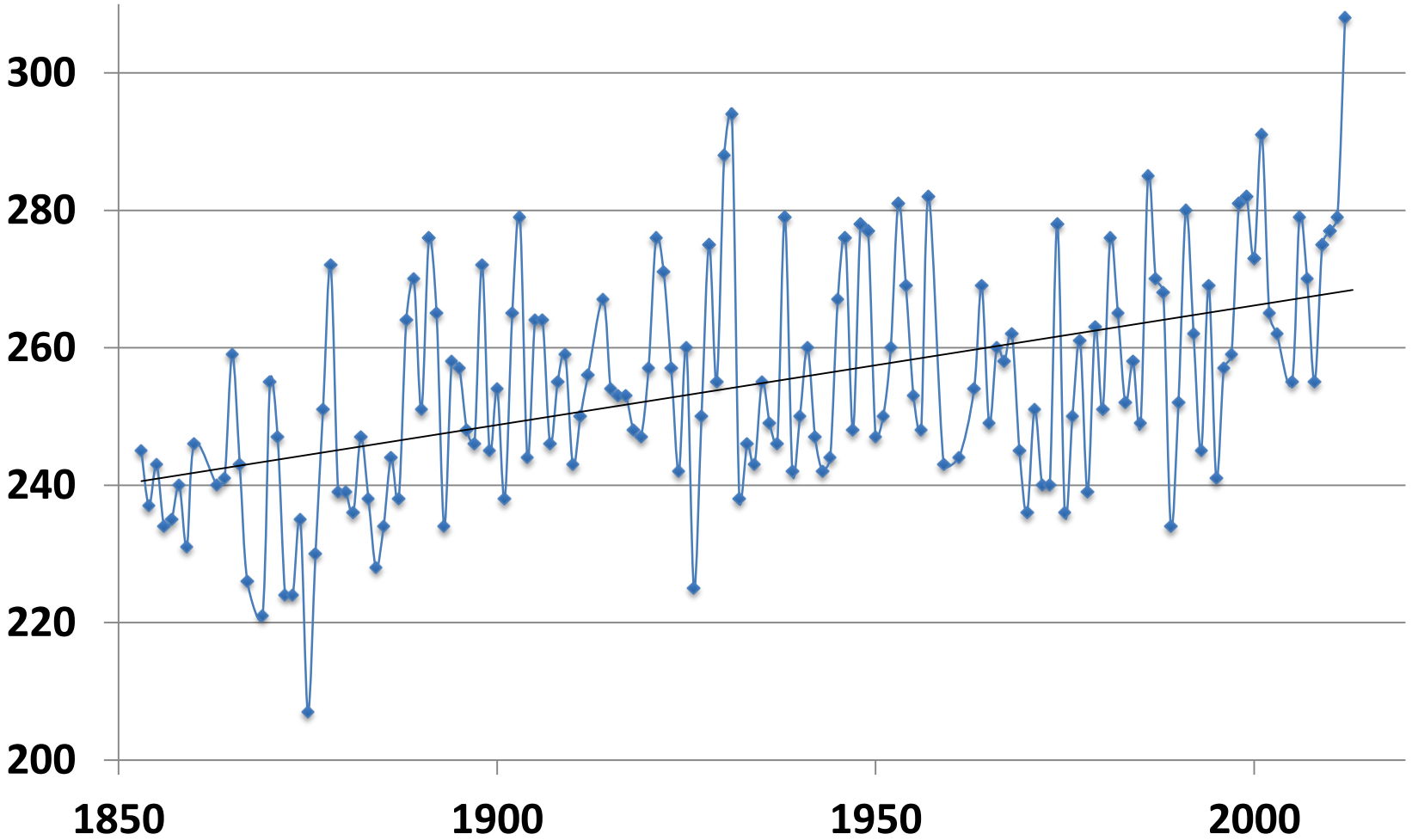
Source: OMOE

Global temperature has followed atmospheric CO_2 levels with some deviation: about an 0.8ºC increase in last century which is very large



http://zfacts.com/metaPage/lib/zFacts-CO2-Temp.gif

Lengthening of ice-free season in Lake Simcoe 1850-2013 (~30 days longer since 1850)



Avoiding the definition of a bloom

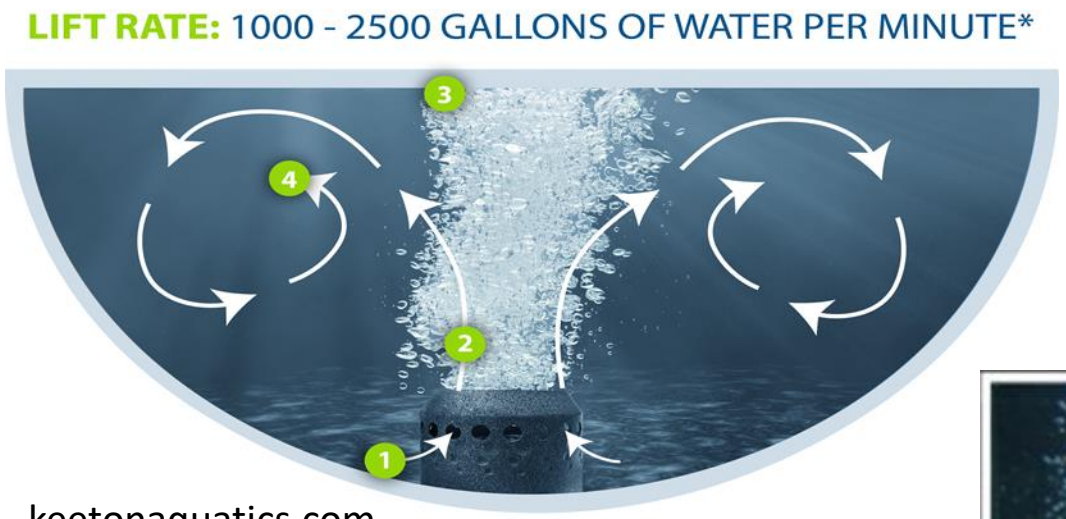
Definition was avoided for a good reason:

- If a lake turns green, then algal pop'n is large – perhaps this is a bloom even without surface accumulation (scum)
- If a thick surface accumulation occurs over a large area as in Erie, perhaps this is a bloom
- What if a surface accumulation occurs over a small area and is not thick because the lake is unproductive - is this a bloom?

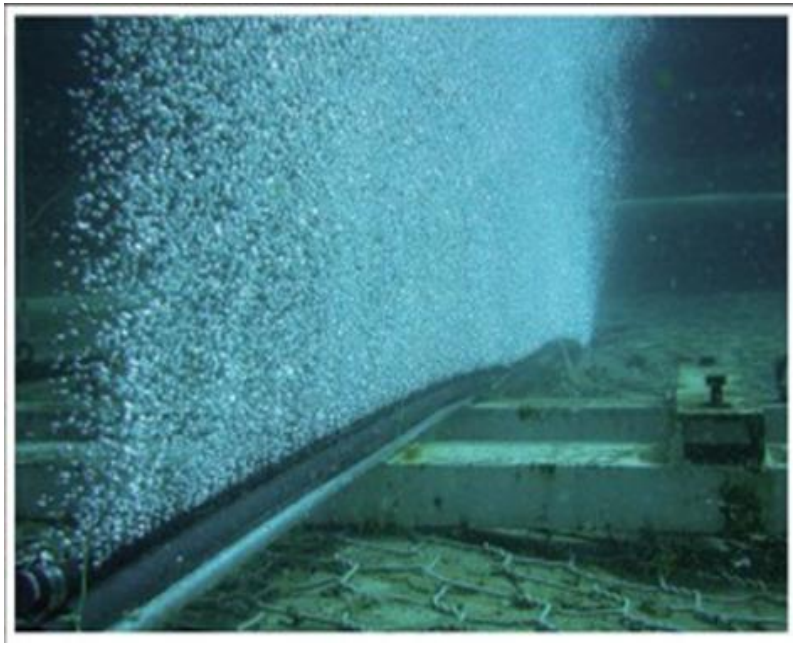
Emerging Issue in Ontario…

- Ontario cottagers have reported cyanobacteria blooms in several lakes with low P levels ('oligotrophic') where the risk of blooms has historically been very low. P levels are not increasing in some so perhaps this is a climate change signal.
- Preventing large P increases in oligotrophic lakes is important to keep algal pop'ns from increasing. However, it is impractical to prevent blooms in these unproductive by reducing human P inputs (conventional approach to managing eutrophic waters) because these inputs are small.
- Need a different management approach for oligotrophic lakes. What to do? Our research has provided a big clue: perhaps use aerators to add oxygen to sediment/water boundary.

Aeration might work but some would need design modifications to deliver more air to sediment surface around a lake as opposed to just fish habitat



keetonaquatics.com

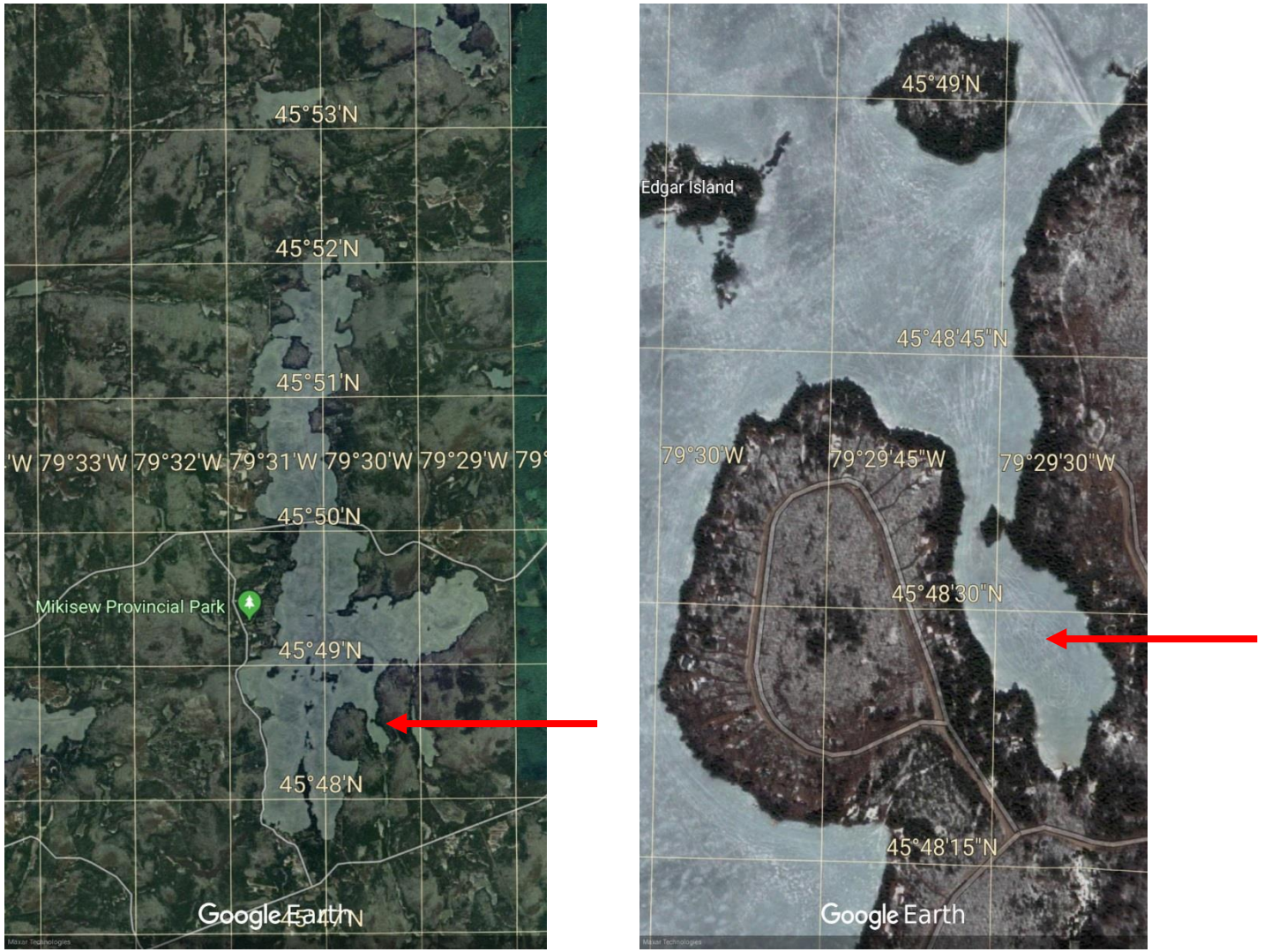


canadianpond.ca

- And rather than aerate the middle of an oligotrophic lake with one large aerator which is common, it might be more effective to identify and aerate ‘nursery’ areas with small aerators – nurseries are probably shallow coves and bays with restricted wind fetches

Tibean hypolimnetic aerator, canadianpond.ca

Bloom reported in small cove about 400 m long and 6 m deep in Eagle Lake in previous year. Sediments were anoxic by late July, 2019.



Research continues…

- Incomplete knowledge of some important questions. However, even if some scientists are skeptical about role of iron in governing bloom species and want to know more, there is more than enough evidence to implicate anoxia and temperature in bloom formation. We can manage oxygen.
- Can we identify cyano ‘nurseries’ in oligotrophic lakes and treat/manage these spots, say, with small aerators?

National Geographic

dogtrekker.com