

Persistent and emerging water quality issues in Canada: an overview of some on-going research

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Canada

- World's 2nd largest country
- ~9% of surface area occupied by water (891,000 km²)
- 8 of the 20 largest lakes in the world are in Canada
- Aquatic research conducted at ~half of the country's 98 universities

Some Major Issues in Water Science

1. Cultural eutrophication
2. Contamination by mercury
3. Nanoparticles
4. Pharmaceuticals and personal care products
5. Climate change
6. Invasive species
7. Other stressors

Cultural Eutrophication

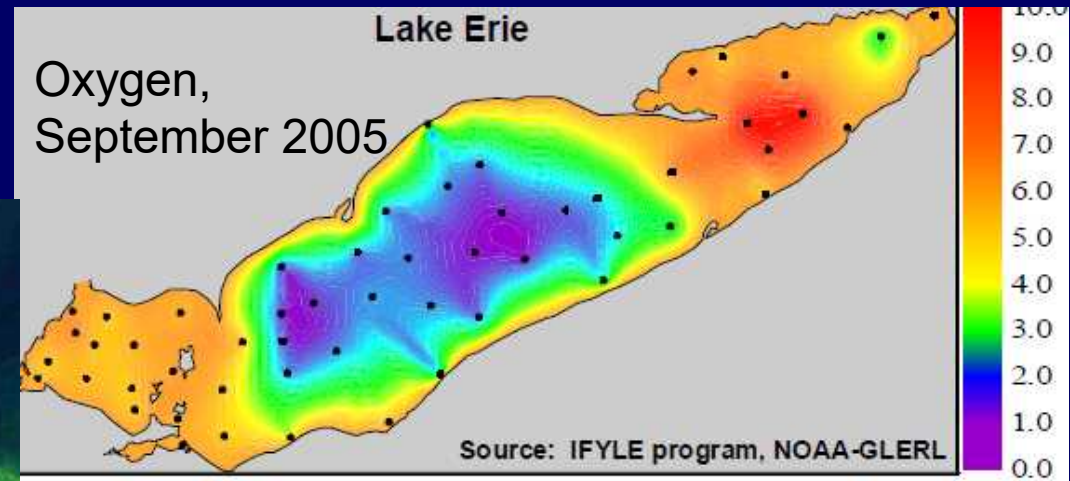
- In the late 1960s, eutrophication was severe certain sections of the Great Lakes, especially Lake Erie
 - problems included water column anoxia and massive algal blooms



- International Joint Commission (IJC) required a 50% reduction in loading for point source releases of phosphorus. Non-point sources were not addressed.

The problem returns

- Since the mid-1990s, dissolved reactive P has increased and Harmful Algal Blooms (HABs) have returned, with enormous cyanobacteria blooms (*Microcystis aeruginosa*, *Anabaena* spp.) in western Lake Erie, and seasonal anoxia in the central basin.



Sources: IJC (2013), LEEP (2013)

Key questions include:

1. role of changes in agricultural practises and fertilizer use in the watershed on Lake Erie's water quality
2. Role of nonpoint sources of nutrients (and chemical discrimination of P sources)
3. climate change induced changes in episodic precipitation
4. microbial species and genomic composition
5. nutrient recycling by invasive species (zebra mussels)

Canadian faculty:

Jan Ciborowski (Univ. Windsor)

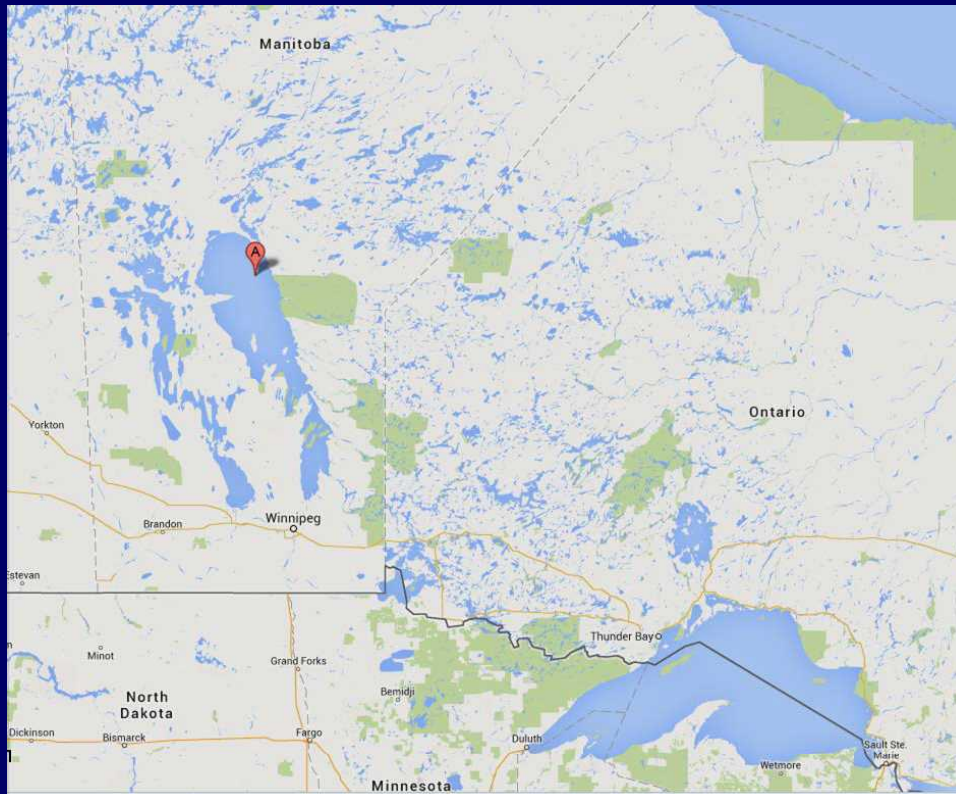
Bill Taylor (Univ. Waterloo)

Lewis Molot (York Univ.)

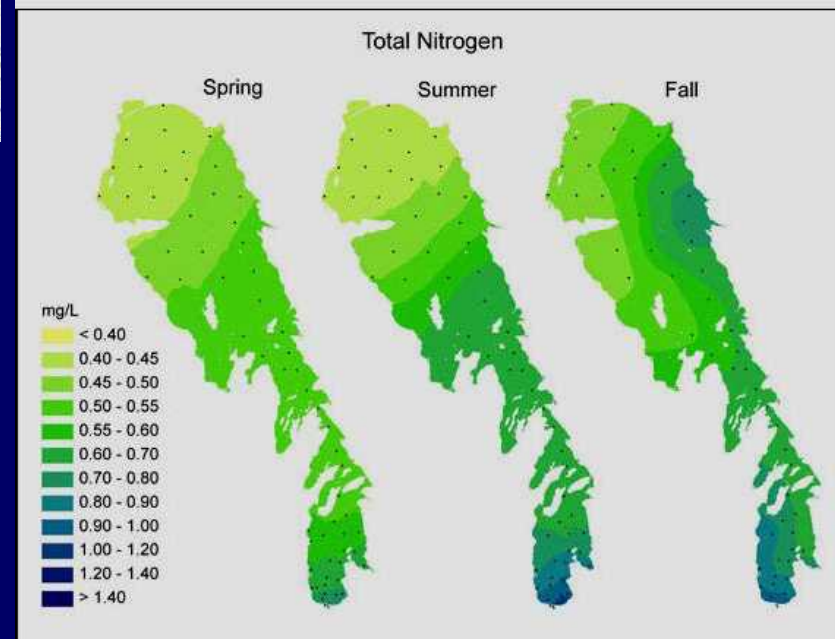
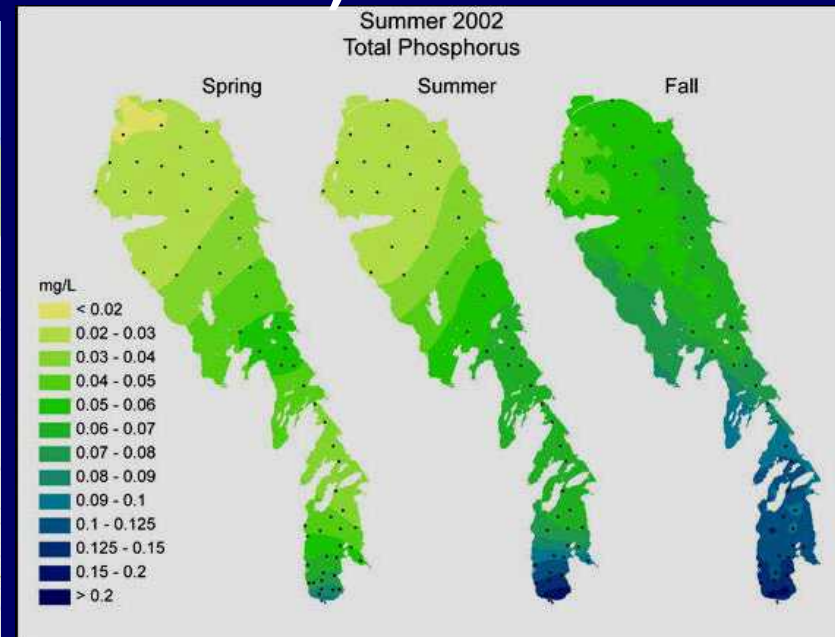
George Arhonditsis (Univ. Toronto)

Peter Dillon (Trent Univ.)

Lake Winnipeg (Manitoba)



- eutrophication occurred since mid-1990s
- elevated N and P associated with eutrophication



Eutrophication of Lake Winnipeg and elsewhere

- problem associated with increased livestock production and fertilizer use in USA, input from city of Winnipeg, land development in the watershed, and increased spring flooding (Schindler et al. 2012)
- Some argument over whether nitrogen or phosphorus was the limiting nutrient

Canadian faculty:

Greg McCullough (Univ. Manitoba)

Margaret Docker (Univ. Manitoba)

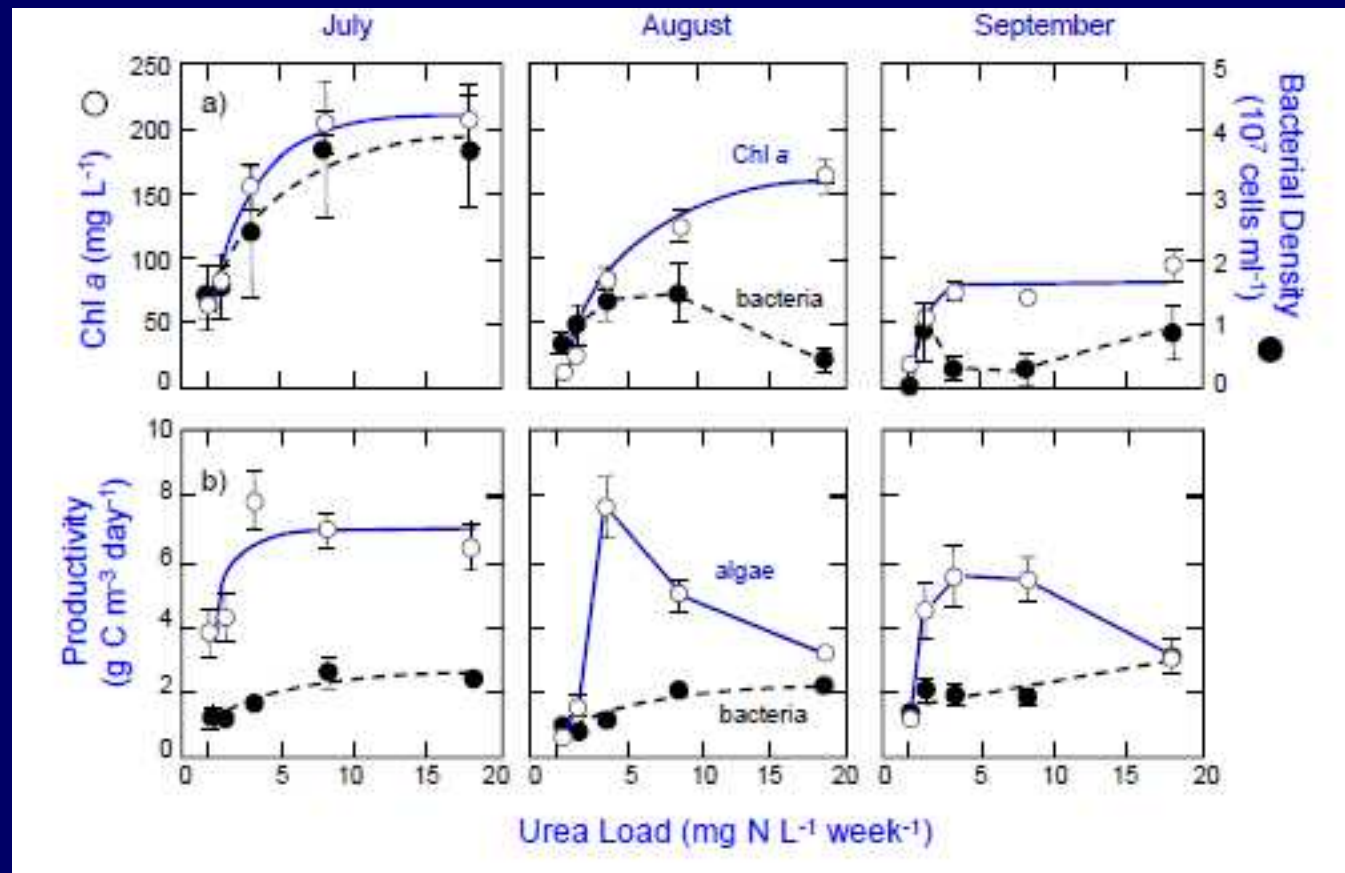
Yonas Dibike (Univ. Victoria)

Peter Leavitt (Univ. Regina)

Warwick Vincent (Laval Univ.)

Eutrophication Debate: N or P or both?

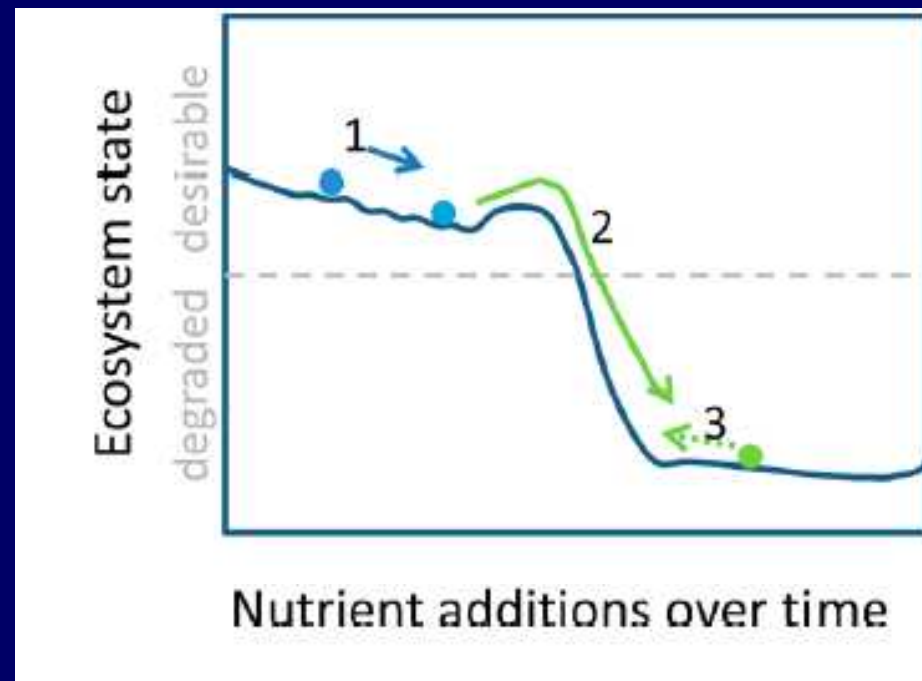
- Classical work done at Experimental Lakes Area and other locations demonstrated P regulation of primary production
- Work from the prairies, where P levels in agriculturally impacted lands can be high, suggested N could limit production



Peter Leavitt
(Univ. Regina)

Eutrophication Debate: Does it matter which element?

- Baulch (2013) suggests that both nutrients may require control depending on biogeochemistry of the area and its connectivity to other systems
- Objective should be to prevent state changes to undesirable conditions, or vast improvement involving state change from degraded systems



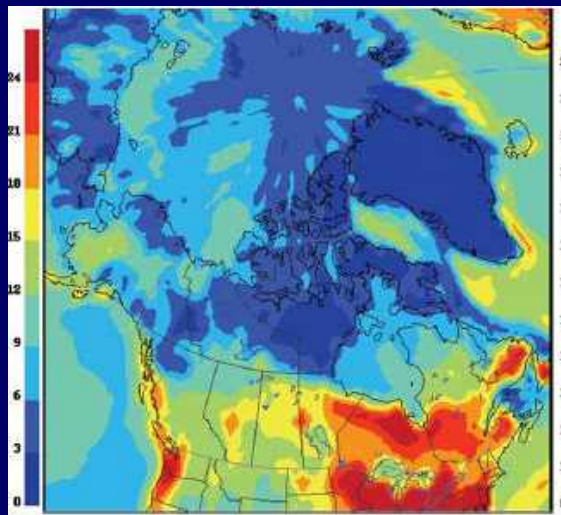
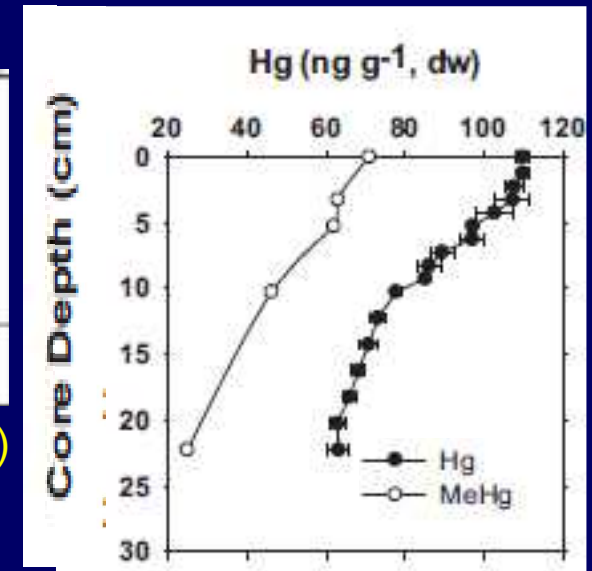
H. Baulch (2013)

Mercury Accumulation

- derived from natural and anthropogenic sources
- long-distance airborne contamination
- major concern world-wide
- concern across Canada, especially in Arctic, and downstream of Athabasca region of Alberta where oilsands development takes place



Brazeau et al. (2013)



Total mercury deposition rate across Canada ($\mu\text{g m}^{-2} \text{yr}^{-1}$). Kirk et al. (2012)

Research Needs (Mercury)

- source(s) of Hg to different ecosystems
- degree of coupling between atmospheric deposition of Hg and human and wildlife exposure (speciation, production of MeHg, bioaccumulation)

Canadian faculty:

Vincent St. Louis (Univ. Alberta)

Jules Blais (Univ. Ottawa)

Karen Kidd (Univ. New Brunswick)

Craig Hebert (Carleton Univ.)

Derek Muir (Univ. Toronto)

Nanoparticles

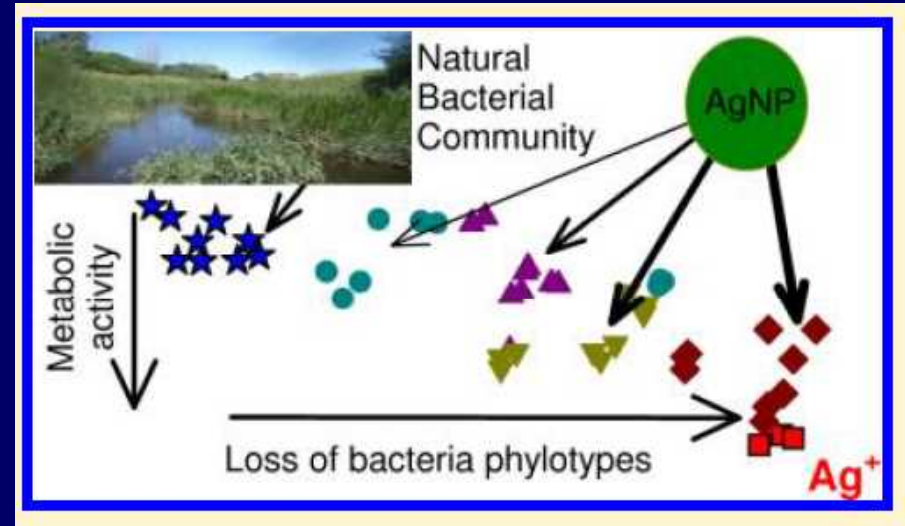
Silver nanoparticles:

- Antimicrobial properties
- Used in 100s of products:
 - Socks and other textiles
 - Baby products and toys
 - Cosmetics and bandages
 - Food wrappers
 - Washing machines
 - Sprayed on Tokyo subway

Canadian faculty:

Chris Metcalfe (Trent Univ.)
Holger Hintelmann (Trent Univ.)
Paul Frost (Trent Univ.)
Marguerite Xenopoulos (Trent Univ.)

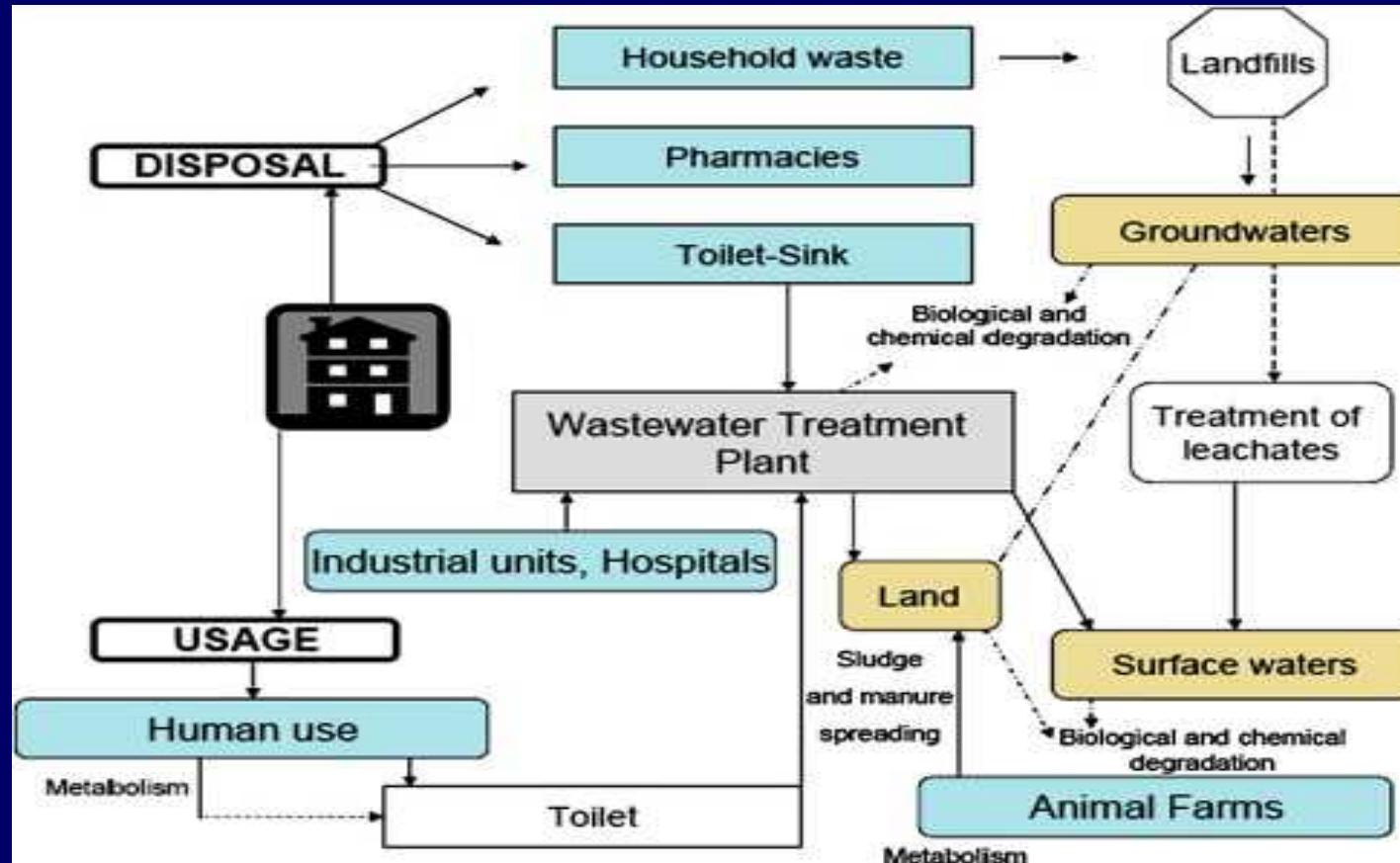
However:



- Reduced production and community structure of natural bacterial populations
- Reduced production of natural populations of algae
- Acute and chronic toxicity to *Daphnia magna*

Das et al. (2012)

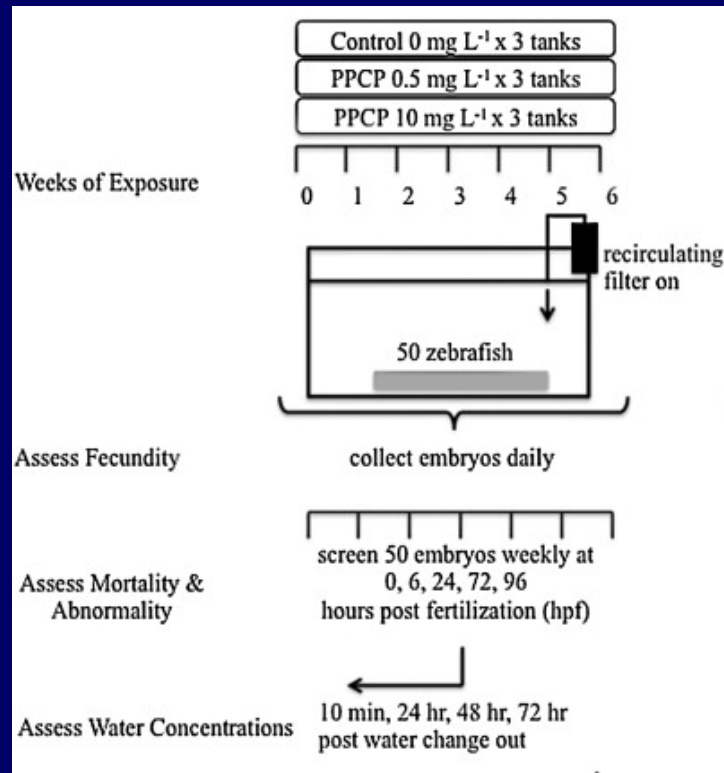
Pharmaceutical and Personal Care Products



Kostopoulou
and Nikolaou
(2008)

- diverse array of compounds, including high use drugs, fragrances and sunscreen agents, and anti-microbials
- issue expected to grow
- lack of understanding on pharmacokinetics and pharmacodynamics in aquatic species and effects of chemical mixtures

Chronic, low-dose PPCP exposure



- Single drugs, mixtures, waste water effluent (WWE) cause reduced fecundity and kidney tubule damage
- Several drugs, mixtures and/or WWE cause atretic oocytes and apoptosis, altered sex steroids, mortality of embryos and developmental abnormalities

J. Wilson

Canadian faculty:

Joanna Wilson (McMaster Univ.)

Karen Kidd (Univ. New Brunswick)

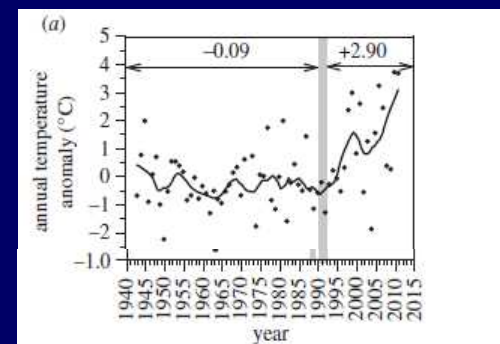
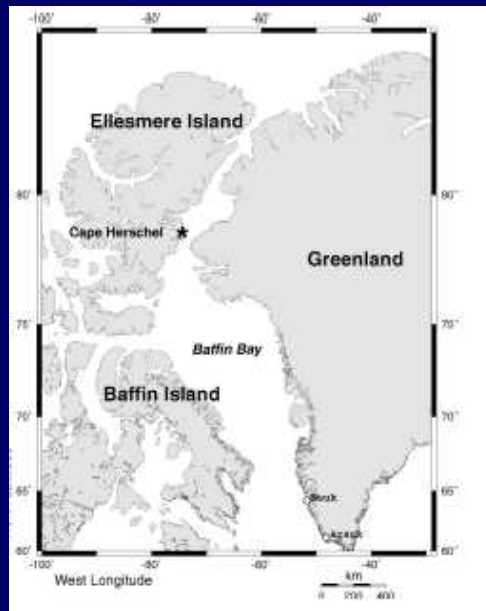
Chris Metcalfe (Trent Univ.)

Mark Servos (Univ. Waterloo)

Vance Trudeau and Tom Moon (Univ. Ottawa)

Climate Change

- Climate warming has altered freeze-up and ice-off dates of temperate lakes across Canada
- loss of some arctic ecosystems (ponds)
- alteration of physical limnology of lakes, littoral habitats, interspecific interactions
- direct and indirect effects on biota



mean temp.
anomaly

One of few areas of Canada that had not registered warming previously, loss of subarctic refuge

Ponds in the high Arctic drying up for the first time. Smol and Douglas (2007)

Rühland et al. (2013)

Research Questions

- Enormous array of issues related to habitat availability and quality, physical and chemical limnology
- interaction of climate change with other stressors
- phenology of species (terrestrial and aquatic)

Point of Interest (and concern):

The Experimental Lakes Area in northwestern Ontario is one location where climate change research is conducted. The federal government has passed ownership of the facility off, and it is currently funded for only 1 year by the provinces of Ontario and Manitoba

Canadian faculty:

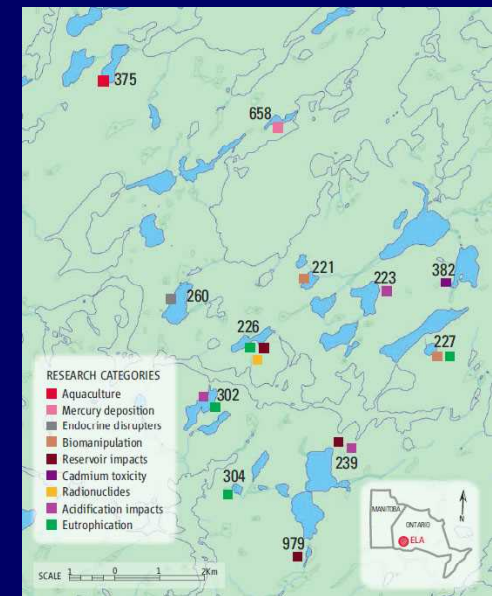
John Smol (Queens Univ.)

Marianne Douglas (Univ. Alberta)

Warwick Vincent (Laval Univ.)

Rolf Vinebrooke (Univ. Alberta)

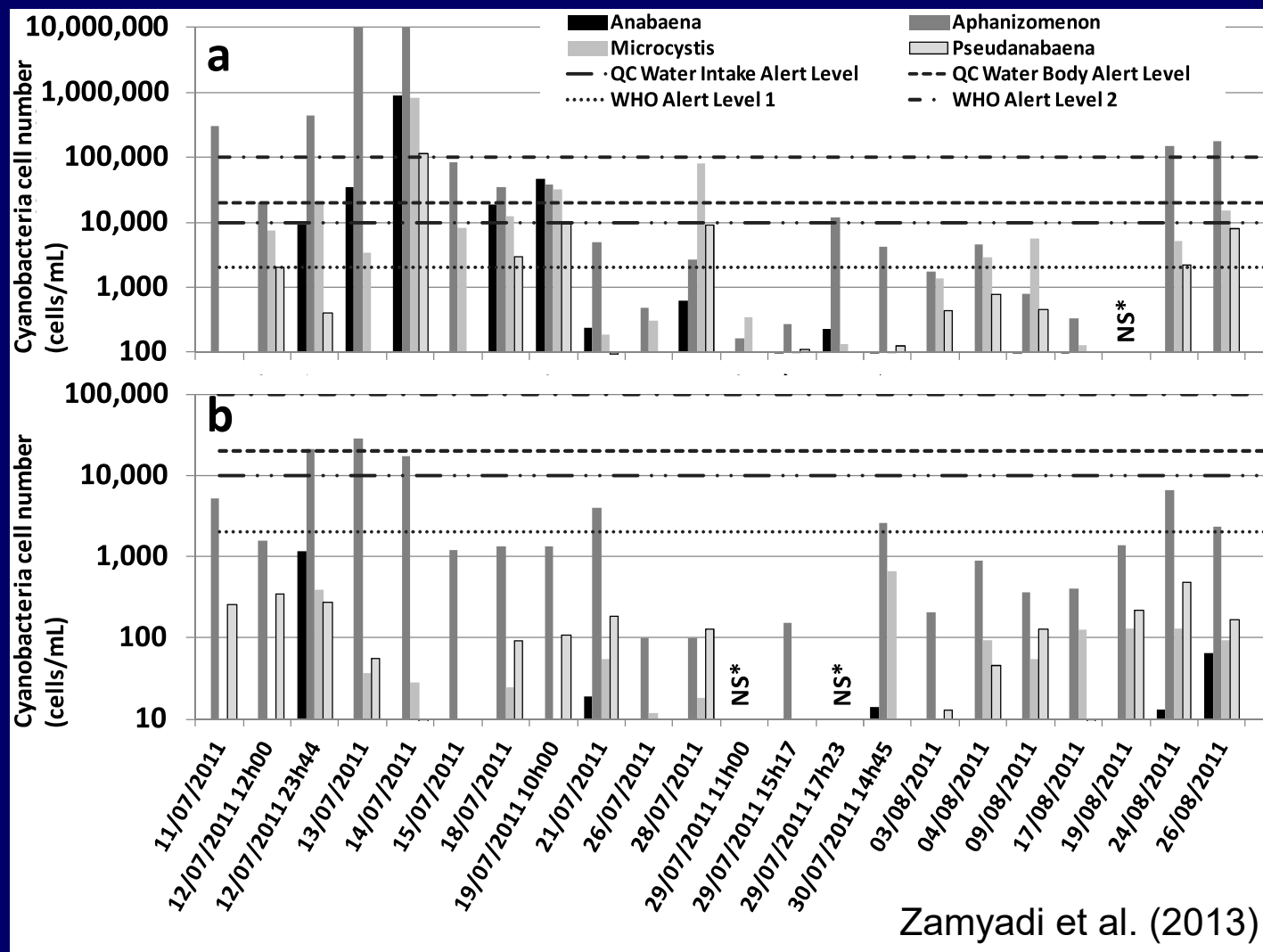
Helen Baulch (Univ. Saskatchewan)



Cyanobacteria in Drinking Water

Cell Density at Water Intake

Cell Density in Treated Water



Drinking water treatment is not equally effective for all species of cyanobacteria, and depends on the coagulant used. Intracellular toxins can potentially end up in treated drinking water.

Environmental Effects Monitoring Program

- Developed after years of reporting reproductive effects in fish near pulp mill effluent outfalls
- Clear need for structured industry-funded monitoring program
- Seek to identify effects on fish, fish habitat and use of fish caused by effluents
- Industries are required to meet regulatory requirements which include:
 - water quality studies
 - effluent characterization studies
 - sublethal toxicity testing
 - biological monitoring in the receiving environment
- May be applied to municipal and oil sands effluents, and assess modern treatment technologies and processes



Ovarian size in fish from reference (top) and bleached kraft mill effluent site (bottom)



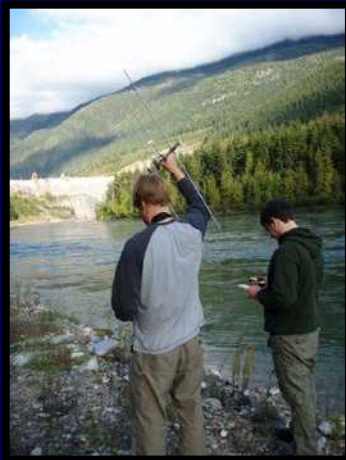
N. Hogan

Science and Engineering for Physical Habitat Management (Strategic Network called *HydroNet*)

Steven Cooke

Objectives

- i) Protection: identifying “critical” habitats and movement corridors, and identifying thresholds
- ii) Restoration: setting targets, design and monitoring
- iii) Mitigation and Compensation: what, when, how best to do, how much



RES'EAU-WaterNET Strategic Network

Madjid Mohseni

Vision: seeks to meet clean water demands and protect the health of small, rural and First Nations communities through collaborative research that produces integrated, game-changing technologies validated by industry and end-users.

Objective: Study of water quality variability from source to tap in Canadian small systems

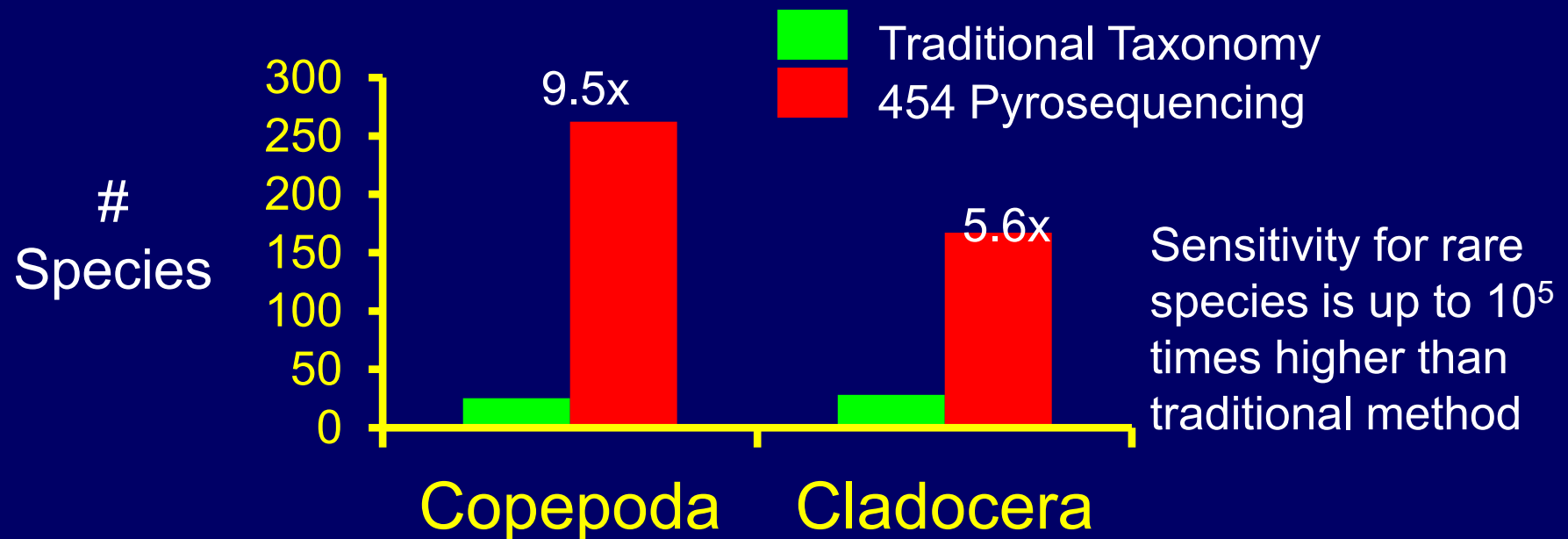
Objective: Study of water quality variability from source to tap in Canadian small systems

Canadian Aquatic Invasive Species (AIS) Network

Objectives

- 1) Early detection and identification of AIS
- 2) Rapid response to new invasions
- 3) AIS as part of multiple stressors
- 4) Reducing uncertainty in risk assessment of AIS impacts

Species Richness in Lake Ontario



Lots of opportunity to collaborate on Lake Biwa