Assessing Present Threats to Freshwater Ecosystems in Canada

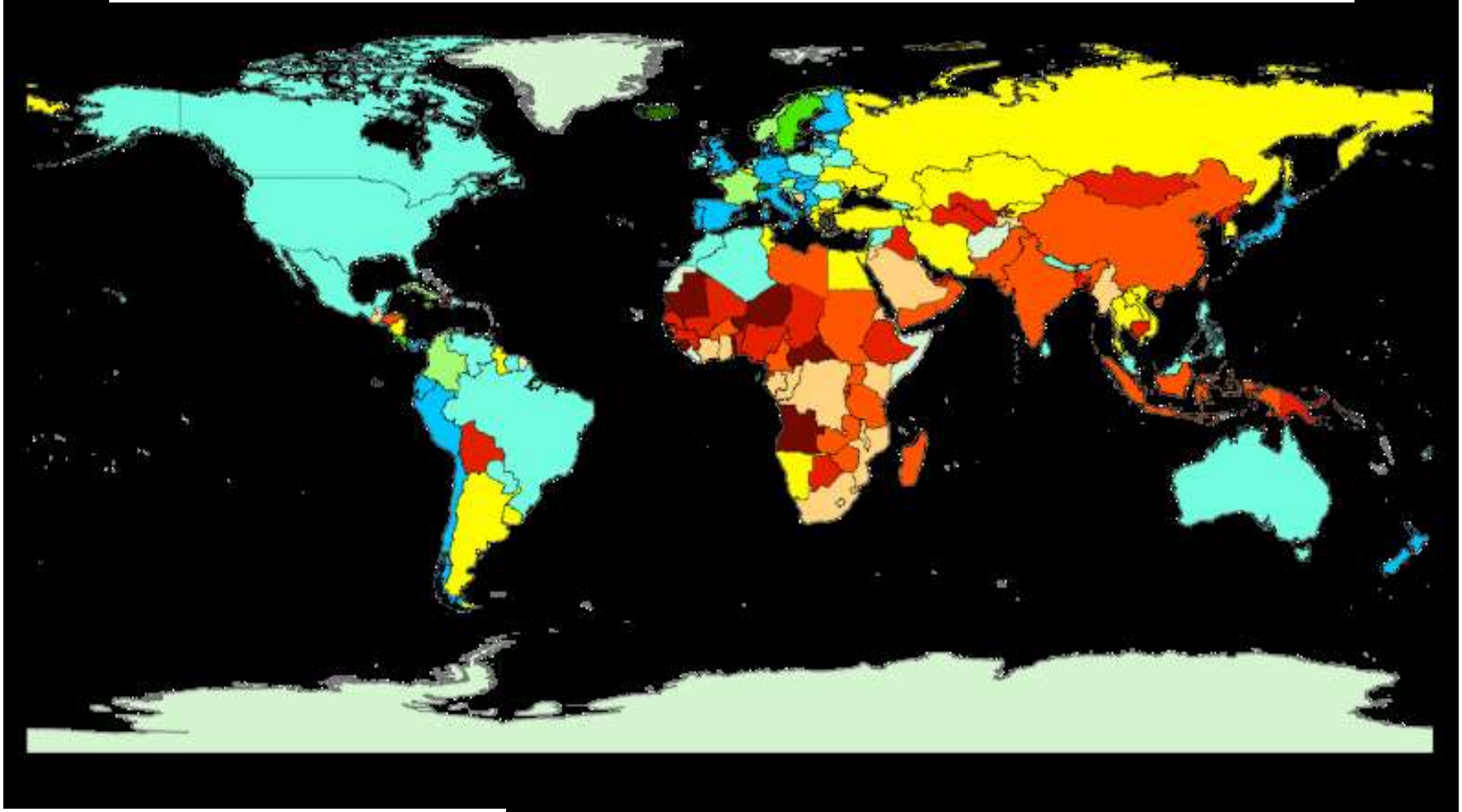
by

Norman Yan

Kristi Rudmik, Mark Verschoor, John Yawney, Michelle Palmer, Dallas Linley & Martha Celis Salgado

York University

The myth that we're good environmental stewards
2010 Environmental Performance Index*



35 43 48 53 59 65 72 77 85 90
Environmental Performance Index

*Yale Centre Env. Law & Policy
Columbia Inter. Earth Sci. Info. Network
World Economic Forum
Joint Research Centre European Commission
See http://epi.yale.edu
*thanks to Ken Black for the source

Our scores were relatively low for air pollution, fisheries, climate change, but apparently good for water*

2010 Environmental Performance Index
Canada compared with our income group

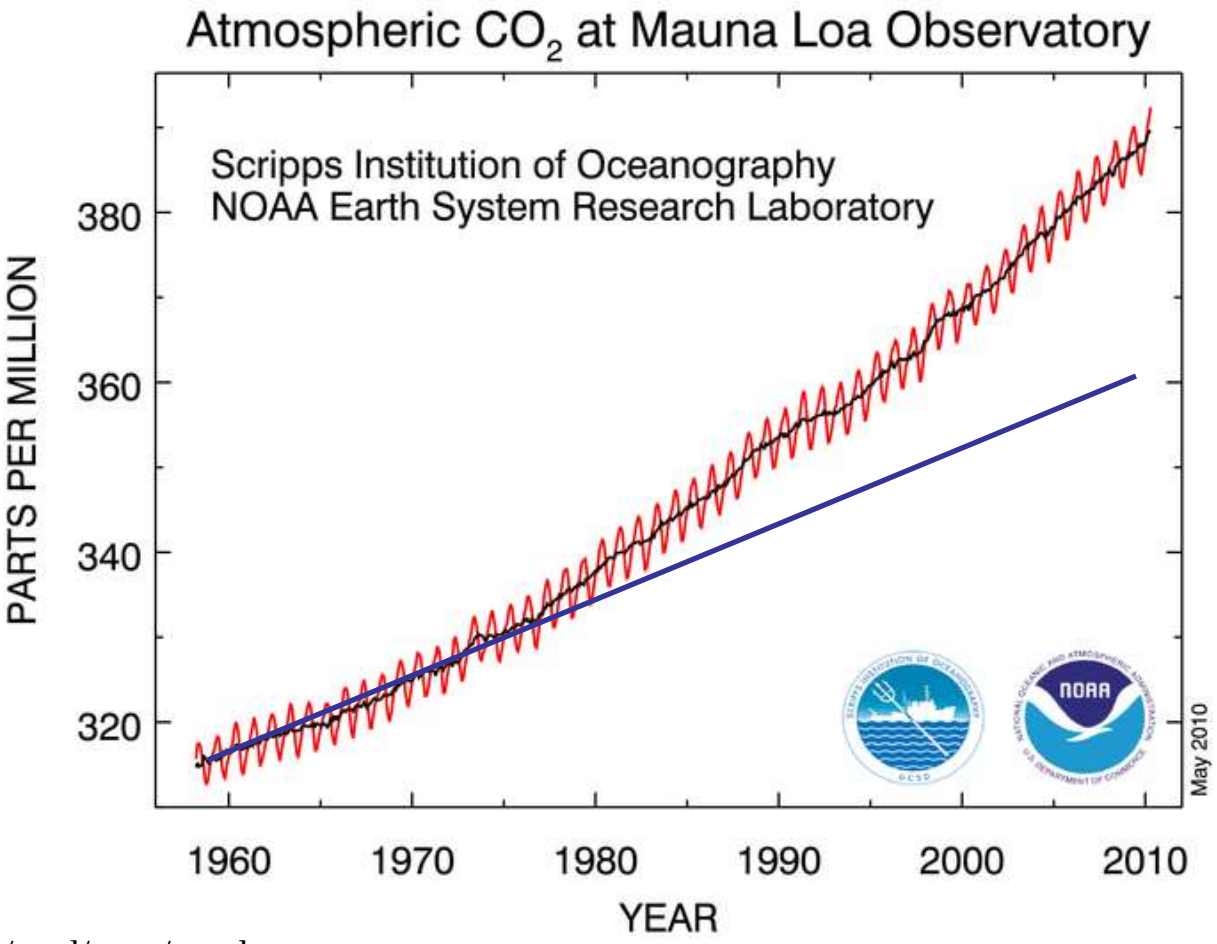
Policy Category	Canada	Income Group
Environ. burden of disease	86.9	86.3
Health effects of air pollution	97.4	84
Health effects of water pollution	**100**	**99.9**
Environ. effects of air pollution	25.3	40.7
Environ. effects of water pollution	**90.7**	**68.4**
Biodiversity	62	53
Forestry	100	99
Fisheries	33.8	55.8
Agriculture	89.5	72.2
Climate Change	37.3	44.3

*http://epi.yale.edu

Preamble

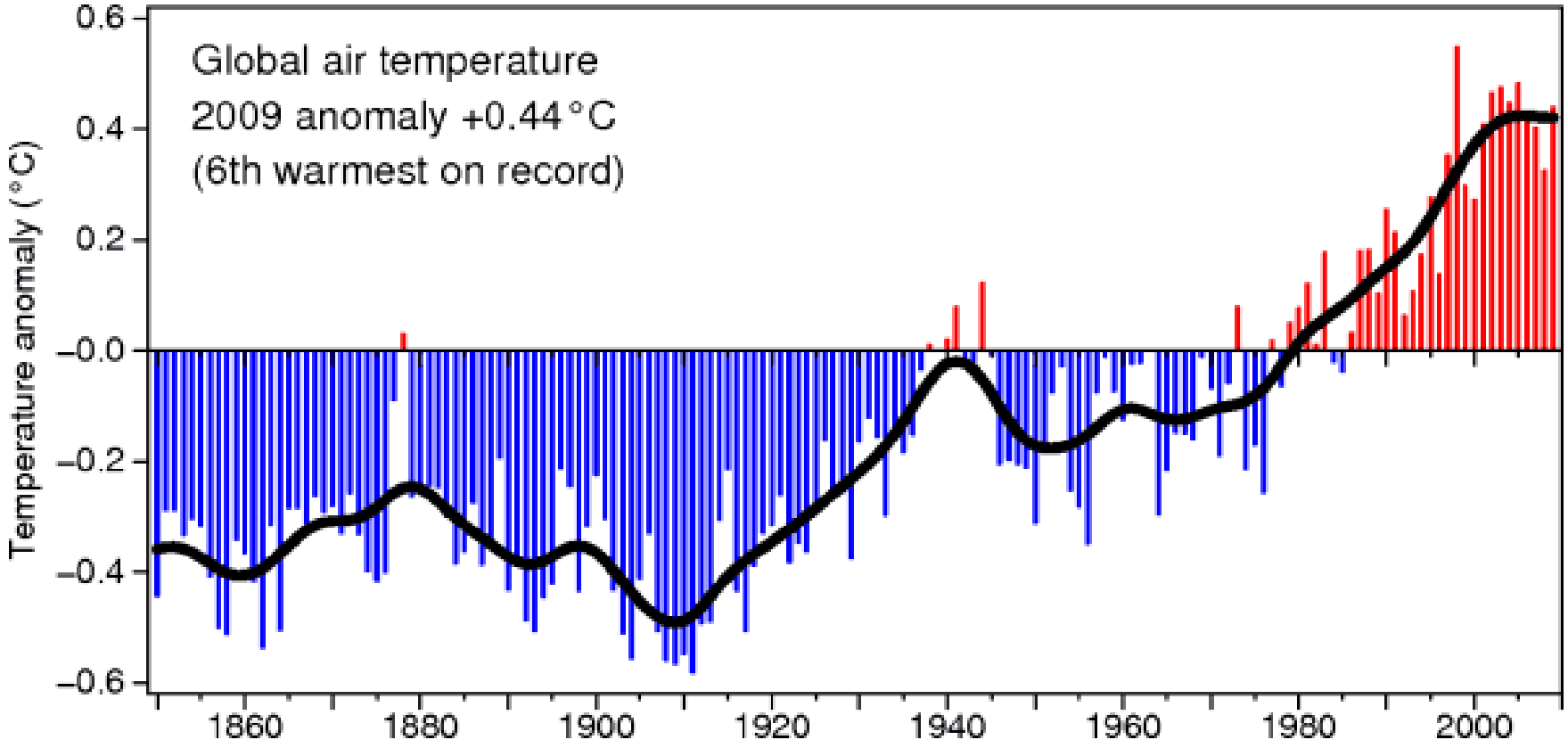
- My assigned task: to assess the present status of freshwater ecosystems in Canada, for a mixed-background audience
- My response: It can't be done properly, for both *fundamental* and *practical* reasons. The reasons why are daunting, but, I believe, can be overcome

The fundamental problem to assessing present conditions: the environmental present is fleeting



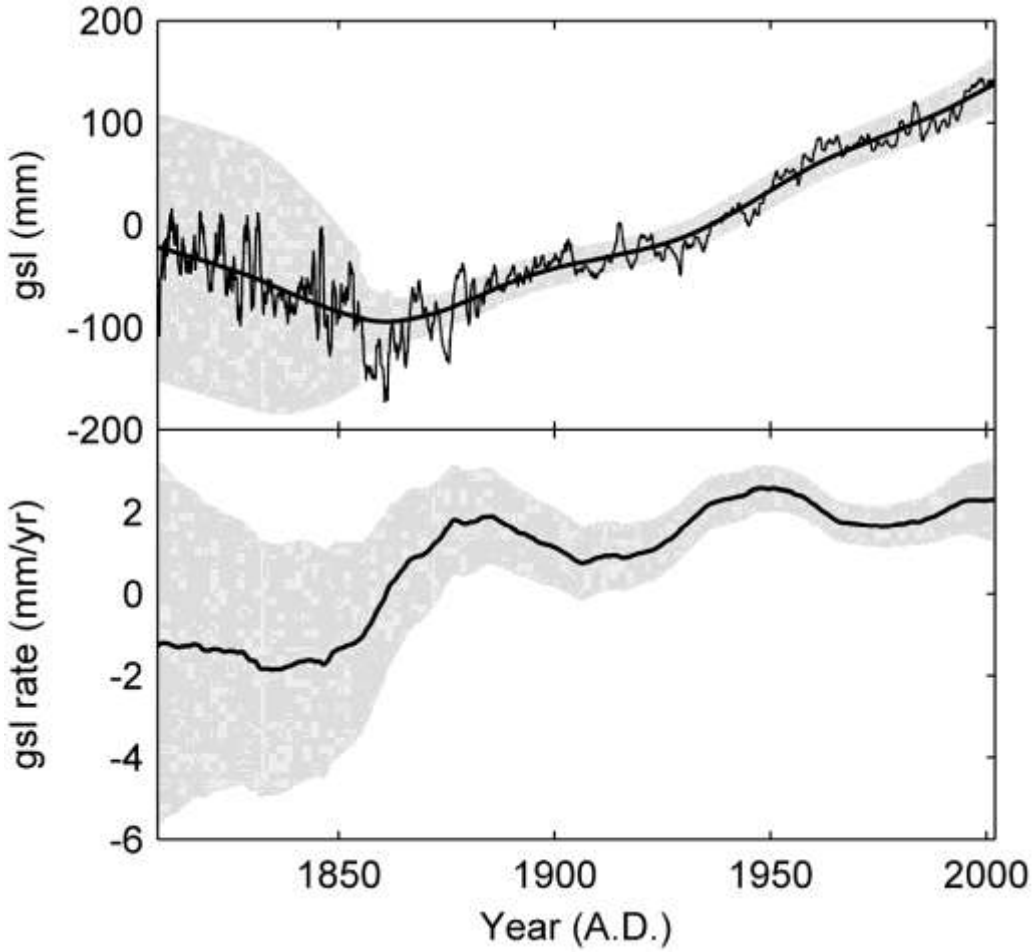
www.esrl.noaa.gov/gmd/ccgg/trends

The world is warming



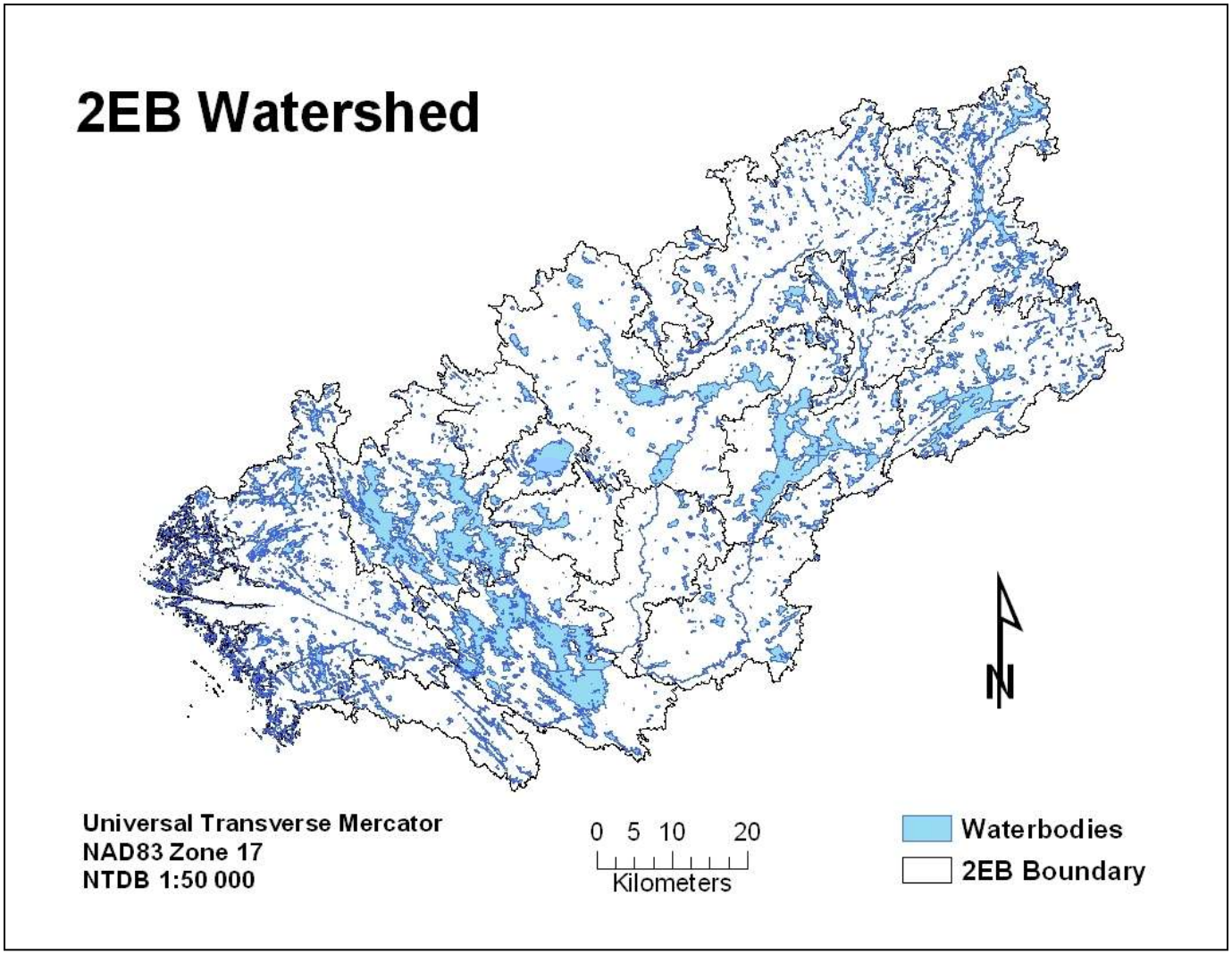
http:/www.cru.eua.ac/uk/cru/infor/warming/ and
Brohan et al. J. Geophysical Research 111, D12106
Doi: 10.1029/2005JD006548

Sea levels are rising globally

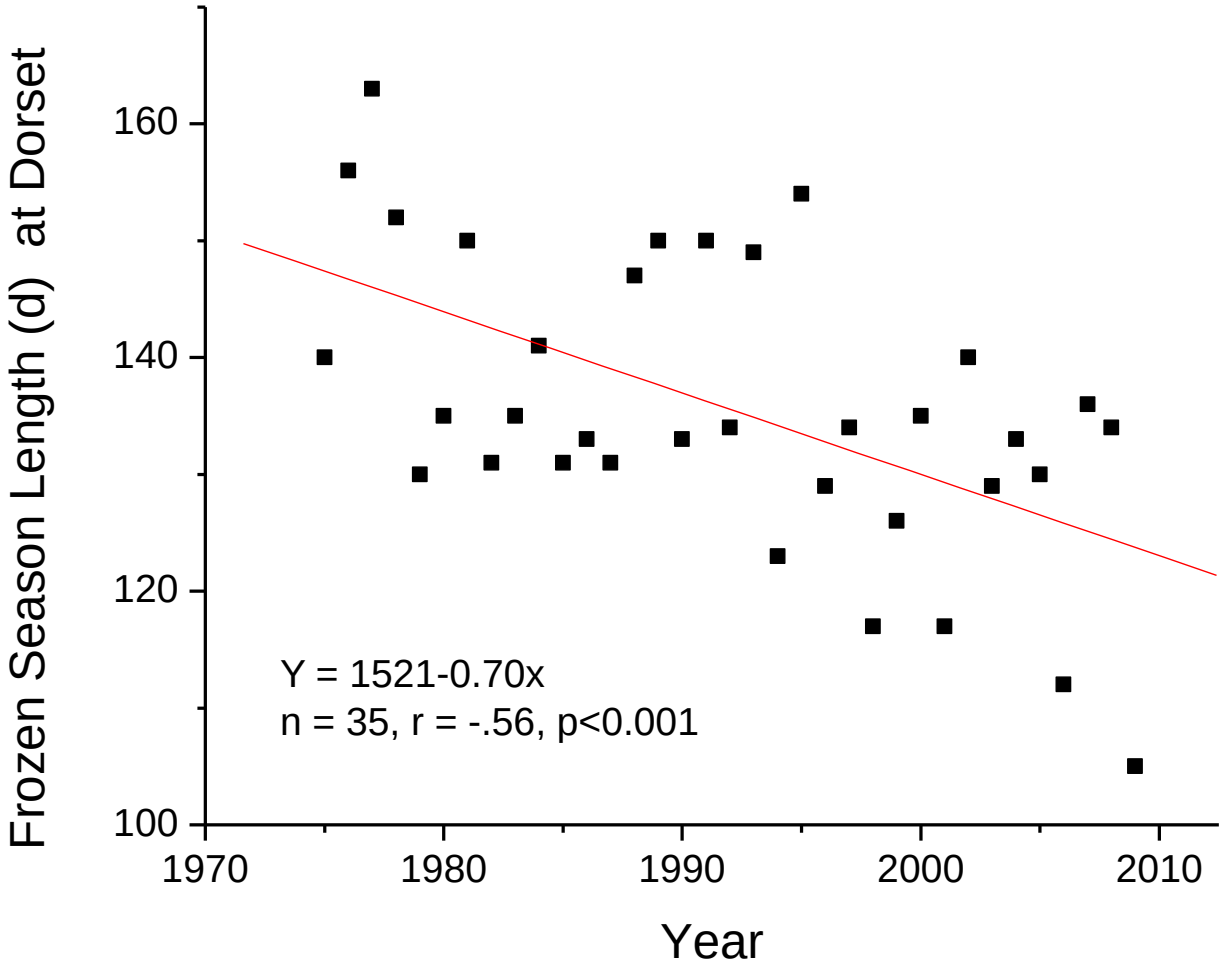


Jevrejeva et al. 2006 J. Geophysical Res 111: C09012

Is Muskoka's water environment also changing?



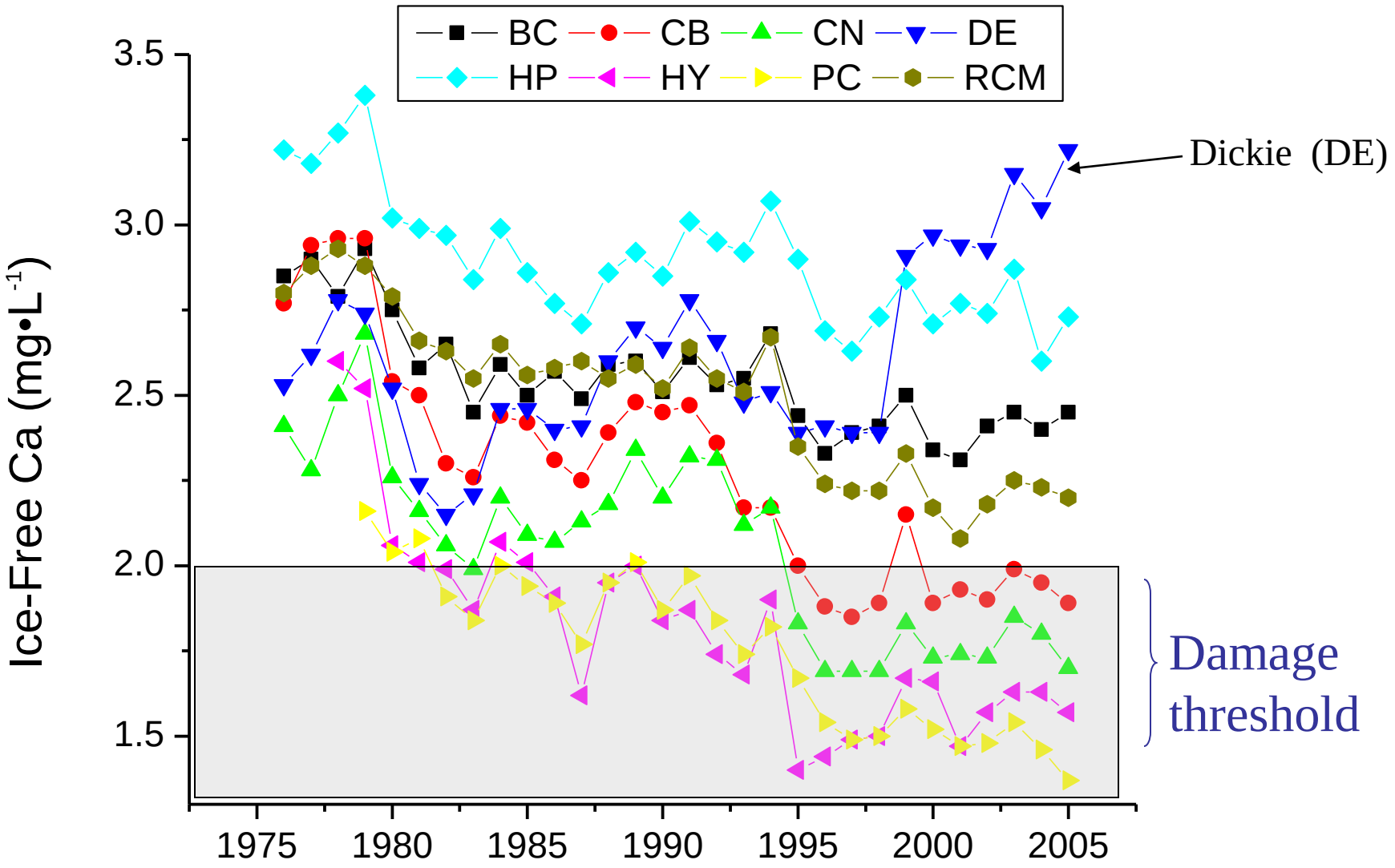
Muskoka's climate is changing: duration of ice cover on Grandview Lake*



* data from Ron Ingram, DESC

Muskoka's water chemistry is changing, e.g. Calcium

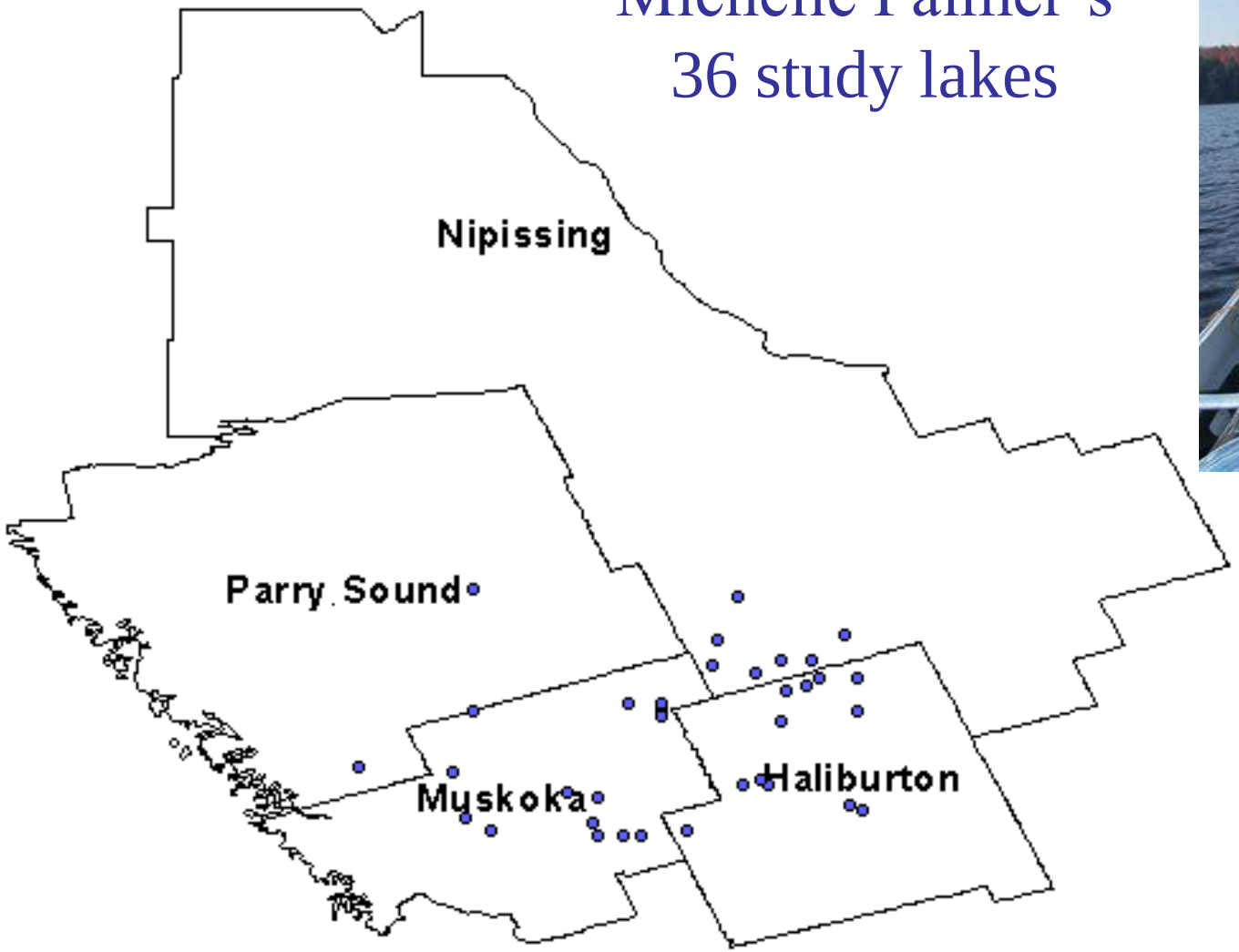
Calcium in 8 Dorset study lakes*



*Molot and Dillon 2008, MOE DESC data

The changes are occurring across the region

Michelle Palmer's
36 study lakes



Change in water chemistry in 36 regional lakes over the last 25 years*

Parameter	% change 1980's - 2004/5
alkalinity	21%
sulphate	-29%
pH	4%
calcium	-7%
magnesium	-5%
conductivity	-12%
chlor_a	-16%
TP	-11%
DOC	24%
ammonia	9%
chloride	89%
sodium	45%
iron	-15%
manganese	-20%

Biology is changing too

*Palmer, Yan, Paterson and Somers (in prep)

The fundamental problem: I was asked to assess the present, but

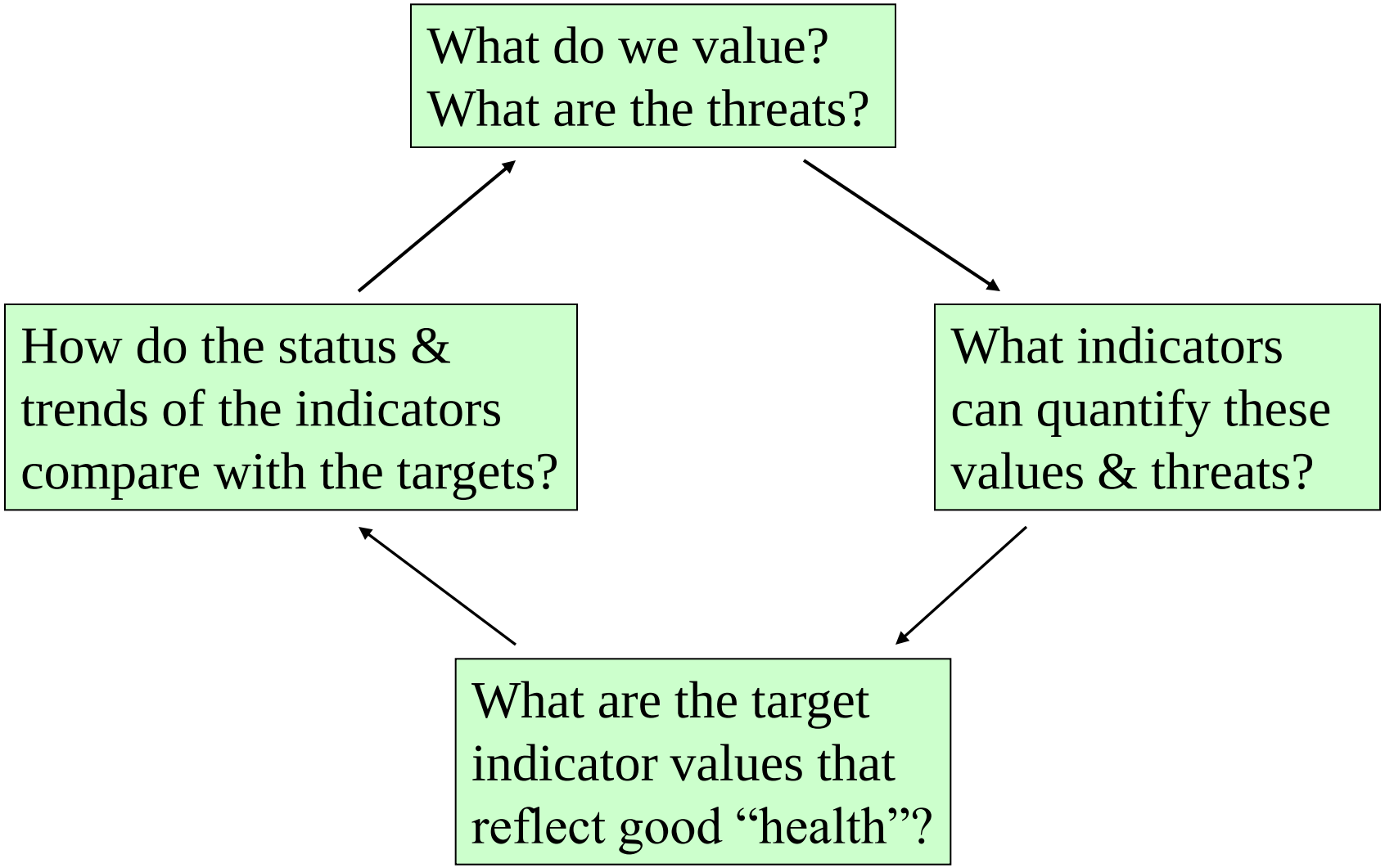
- The present is a fleeting link between a usually unrecorded past, and an always uncertain future
- The physics, chemistry and biology of lakes are changing
- Periods of relative stability are shortening, as global and local changes are underway, so
- Any assessment of "the present" can only briefly be correct
- My first conclusion: We should assess our waters and the life they support more often than we have done in the past

The practical problems

Assessing the present state of our aquatic ecosystems requires:

1. A clear sense of our values
2. Indicators that reflect both these values and the threats to our resources
3. Targets for the indicators that quantify good condition
4. Knowledge of the rapidity of environmental change
5. Knowledge of the spatial distribution and complexity of the resource, and
6. Lots of field work based on all the above

A simple assessment cycle



There is no doubt that Canadians value our water more than our other natural resources*

1. Which of the following natural resouces are most important to Canada's future*

Group	N	Oil & Gas	Forestry	Fisheries	Fresh water	Unsure
male	468	22.4	9.2	4.3	62.9	1.2
female	532	21	13	3.5	60.4	2.1

* All values in %

*Nanos Research poll, spring 2009, funded by Gordon Foundation

**Thanks to Jim Rusak for the link to this survey

We also want a national plan for water

4. What is the top gov't priority for addressing Canada's fresh water challenges?

Group	N	more education & outreach	adopt a national water strategy	build new treatment plants	preserve river flows & lakes for biota	Forbid bulk water export	unsure
male	468	15	29	10	13	26	7
female	532	17	29	14	17	15	8

We are generally willing to allocate new tax dollars to this effort, if it works

5. How willing are you to pay more for cleaner water ?

Group	N	not willing	somewhat unwilling	neutral	somewhat willing	very willing	unsure
male	468	14	11	25	21	26	3
female	532	13	12	26	19	25	5

And our largest water concern is pollution

2. What is your greatest concern about Canada's fresh water (%)?

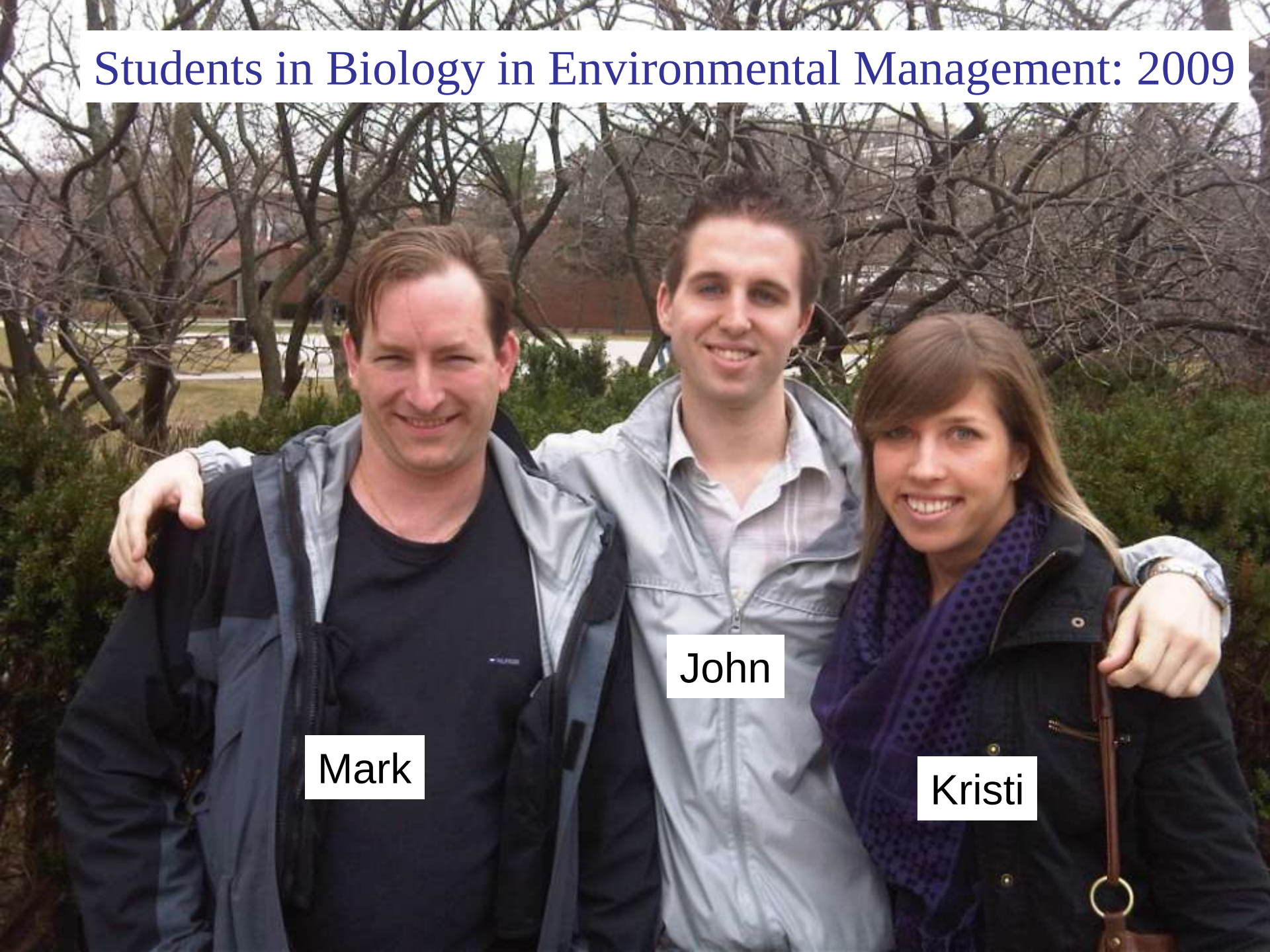
Group	N	Drinking water quality	Pollution	Waste & over-consumption	Bulk water exports	Unsure
male	468	17.6	40.2	19.9	20.8	1.6
female	532	19.3	39.5	24	14	3.2

*2009 Nanos Poll

Conclusions from the Nanos poll

- Canadians place higher value on our freshwater than on our other major natural resources. We believe that pollution is the largest threat, and we are fairly willing to have our taxes increase if it will reduce problems with, and threats to, our water.
- Given such sweeping support, what are we doing nationally to assess indicators that reflect our values and the known threats, and why isn't this good enough for a national assessment?

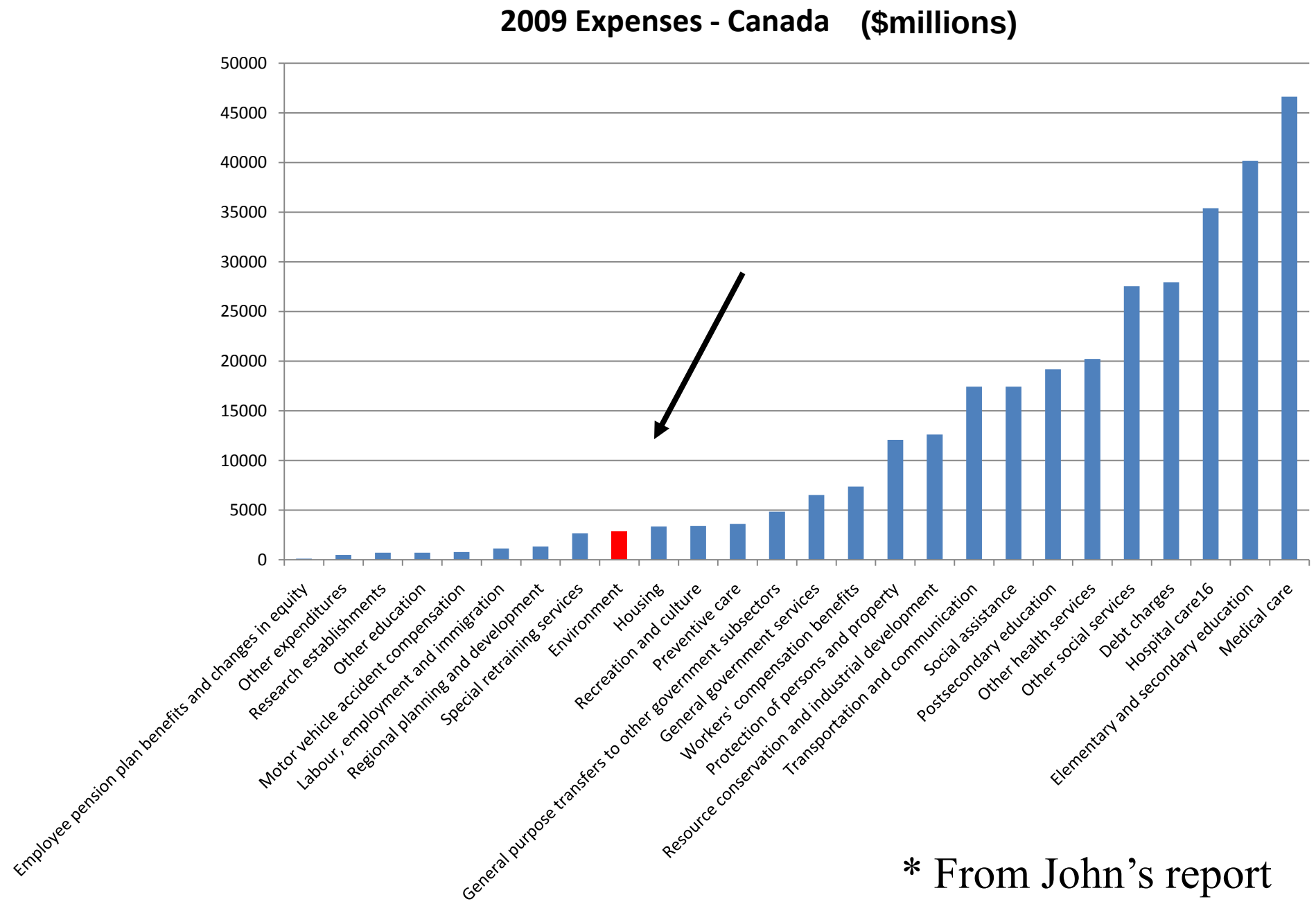
Students in Biology in Environmental Management: 2009



Mark, John & Kristi's projects

- John Yawney: Assessing the present issues in Canadian freshwater ecosystems: a financial report
- Kristi Rudmik*: Freshwater quality monitoring in northern and western Canada: is a national assessment possible?
- Mark Verschoor: A survey of ecosystem assessments in Canada's Great Lakes

*the student doing eastern Canada dropped the course



* From John's report

What do we need to do to assess the condition of our freshwater resource?

- Sample our surface waters choosing sites based on the number and variability of our waters and the life they support
- Measuring indicators that reflect what we value about our water and its life, and the main threats
- To compare with targets for those indicators
- Repeated at time and space scales that capture the dynamics, and
- Report the results regularly

Sadly, we are not doing this very well at a national level

Threats to Canada's Great Lakes – Mark's project

	LGL's	Winnipeg	G Slave	G Bear
POLLUTION				
Nutrients – TP and N	+	+++		
Toxins - metals, organics etc.	+			
Acid Rain	+	+		
Mine Drainages			++	
Pulp and Paper mill discharges			+	
Commercial/Industrial inefficiency	+++	+		
Combined sewers	+++	+		
Solid Waste Disposal	+++	+		
Vehicle Use	+++	+		
Wastewater Treatment and Pollution	+	+++		
INVASIVE SPECIES				
Aquatic & Terrestrial	+++	+		
HABITAT LOSS/CHANGES				
Habitat Fragmentation	++			
Water Level Fluctuations	++	+	++	
Extent of Hardened Shoreline	+++	+		
Sediment Deposition	+	+	+	
Artificial Structures	+++	+		
Coastal Wetland Area	+++	++		
Land Cover Adjacent	+++	++		
of Special Lakeshore Communities	++	+++		
Nearshore Land Use	++	+++		
Groundwater and Land: Use and Intensity	+	++		
Base Flow Due to Groundwater Discharge	+	+		
Groundwater-Dependant Plant & Animal Communities	+			
Agriculture Practices	+	+++		
Agricultural Pest Management	+	++		
Urban Density	+++	+		
Brownfields	++			
Ground Surface Hardening	+++	+		
RESOURCE UTILIZATION				
Logging			++	+
Overfishing	+	++	+	
Water Withdrawals	+	++		
Energy Consumption	+++	++		
CLIMATE CHANGE				
Ice Duration on the Great Lakes	+	+	+	+
Effect on Crop Heat Units	?	?	?	?
Increased evaporation			+	+
Loss of permafrost layer & land slumping			+	++
Extreme weather patterns & increased erosion	+	+	+	++

Stressor classes for*
37 indicator groups
In the Laurentian GL's
Great Slave &
Great Bear lakes

\+ Present
++ Serious
+++ Harmful

*from Mark's paper

Indicator summary from Mark's paper

stressor classes in the Great Lakes

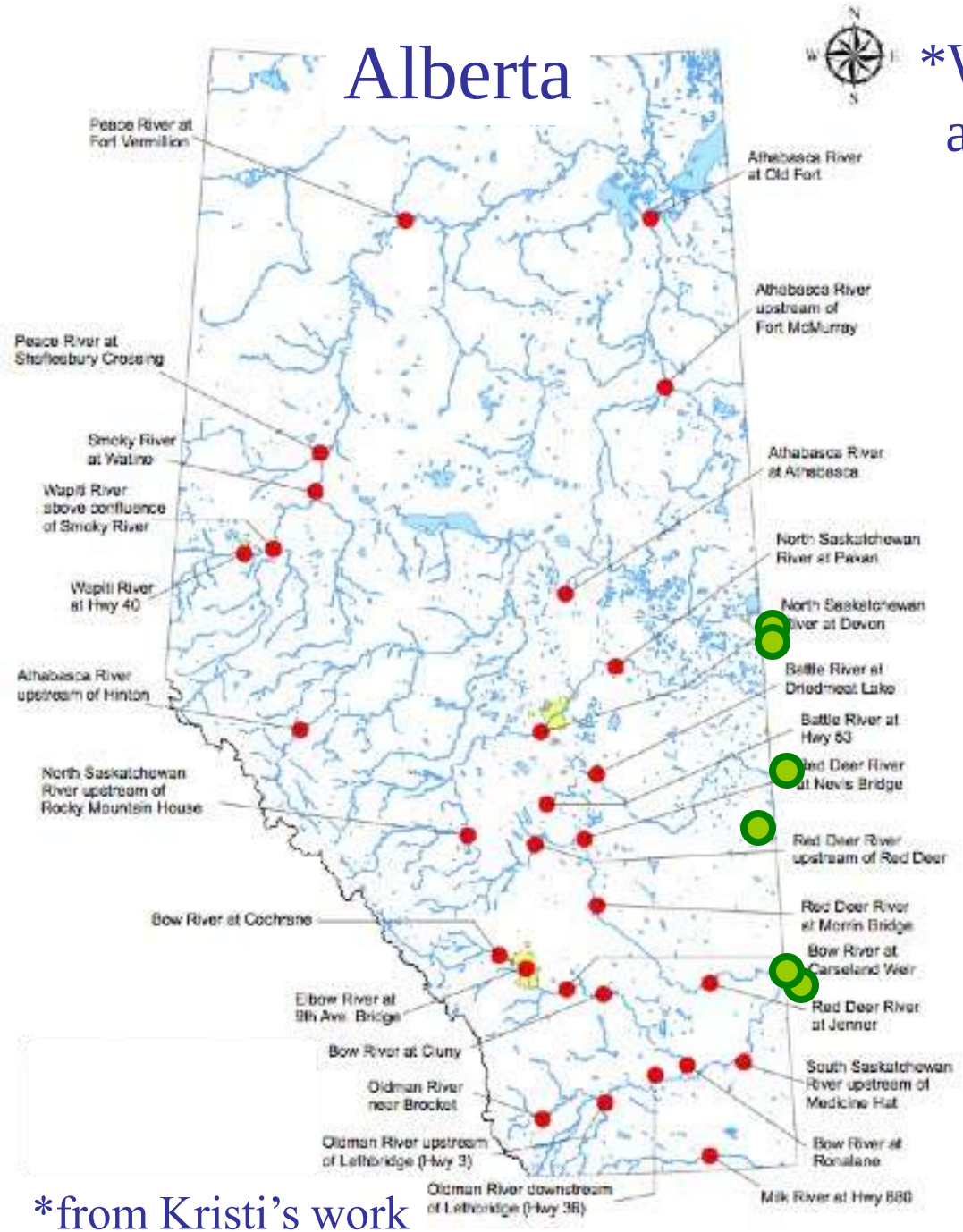
Stressor Category	Laurentian GL's	Lake Winnipeg	Great Slave	Great Bear
Chemical pollutants	XXXX	XX	X	
Invasive species	XXX	X		
Habitat loss/alteration	XXXX	XXX	X	
Overuse of resources	XX	XX	XX	X
Climate change	X	X	X	XX

Summary for the Great Lakes*

- There are many simultaneous categories of threats, not just pollutants, and the key threats differ among the lakes
- There are targets for pollutants, but rarely for other stressors.
- For the Laurentian GL's, both positive and negative trends exist; many indicators are not within targets; and many others are not tracked regularly
- The northern lakes are threatened by climate change, persistent organic pollutants, mining, and resource harvesting
- Invading species are a threat in the Laurentian GL's and L. Winnipeg
- New pollutants are appearing
- Planning is mainly done lake by lake, by local groups

*from Mark's paper

Alberta



*from Kristi's work

*What are the regional stressors, and what data are contributing to national WQ assessments?

- Prairie Provinces Water Board (6 sites)
- Long Term River Network Monitoring Program (27 sites)

33 sites total, 31 sent to CCME

The Stressor Classes:

TN & TP

Municipal effluents

Industrial effluents

Climate change

Agricultural activities

Increased water demand

Forestry

Kristi found that the various jurisdictions had different concerns:

- BC: waste abatement, pulp mills, waterfowl, highway runoff, gasoline, lake aeration, mining, natural erosion, agriculture, forestry
- AB: N &P, municipal and industrial effluents, climate change, agriculture, water demand and forestry
- SK: agricultural and industrial land use, water use, and “human activities”
- MB: municipal and industrial discharges, N & P, agriculture, forestry
- Ykn: green house gases and climate change
- Nnvt & NWT: petroleum-based energy increase, climate change, mining, forest fires, road construction

All provinces and territories are concerned with the effects of multiple stressors on water quality*

*each stressor category noted by the agency adds 30% opacity

* From John's work

Concerns about climate change impacts on water quality were not universal

*from John and Kristi's work

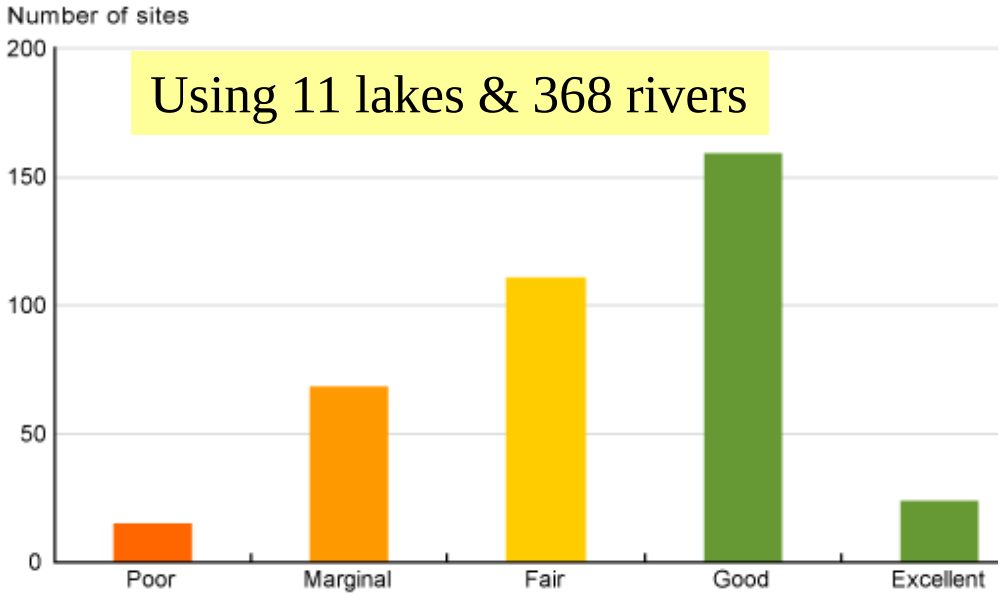
The CCME has an Environmental Sustainability Indicator

- **Canadian Environmental Sustainability Indicator** (CESI)

- uses freshwater quality indicator as a measure of habitat suitability for life
- based on applications of a Water Quality (actually a water chemistry) Index
- translates lots of data on multiple chemical stressors into an overall rating
- takes the number, extent and frequency of target departures into account linearly

$$\text{CCME WQI} = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right)$$

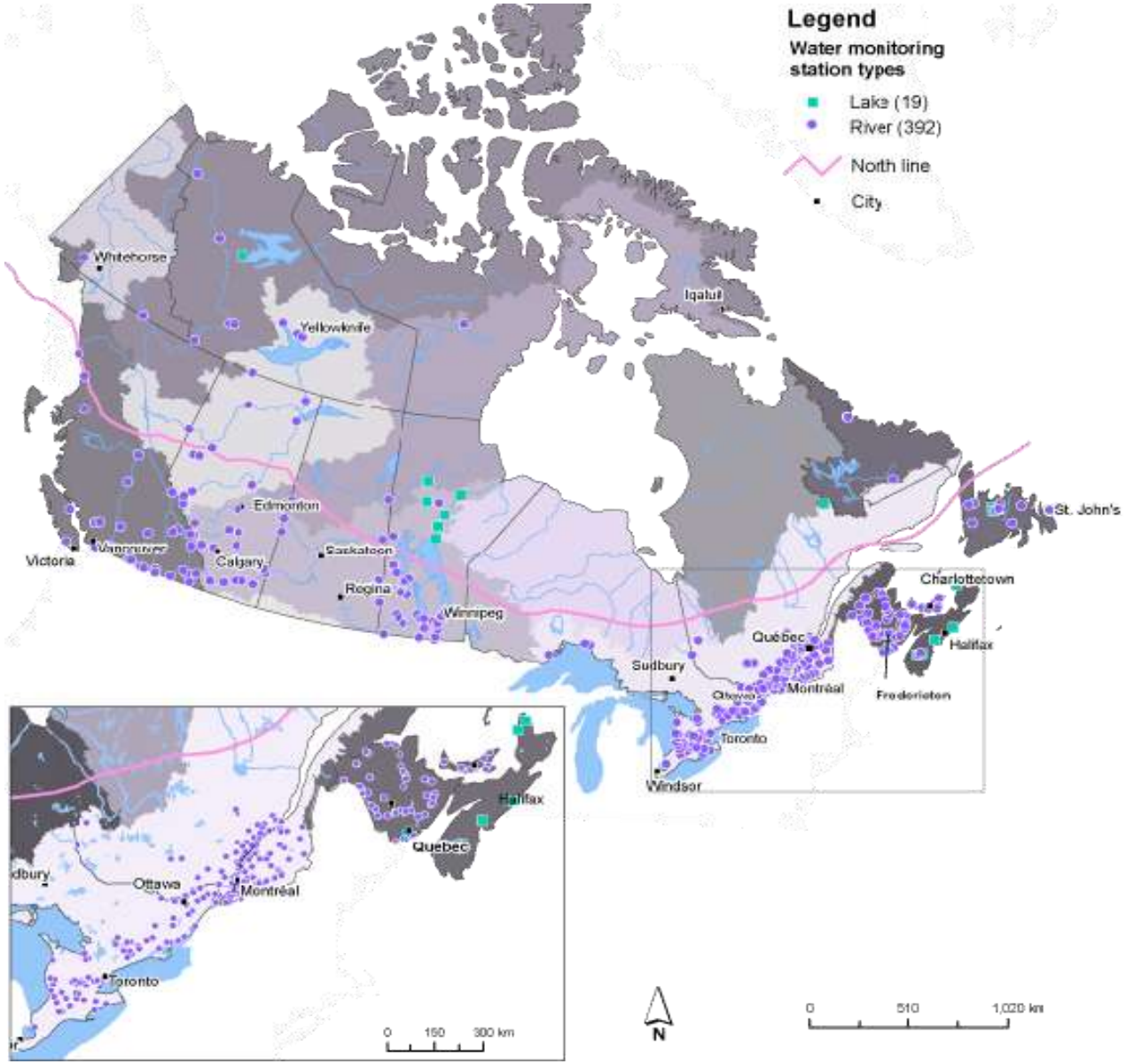
RATING	INTERPRETATION
Excellent (95.0 to 100.0)	Water quality **never**/ **very rarely** exceeds guidelines
Good (80.0-94.9)	Water quality **rarely** exceeds guidelines
Fair (65.0 to 79.9)	Water quality **sometimes** exceeds guidelines
Marginal (45.0 to 64.9)	Water quality **often** exceeds guidelines
Poor (0 to 44.9)	Water quality **usually** exceeds guidelines



Status of freshwater quality for protection of aquatic life at monitoring sites in southern Canada, 2004 to 2006

50% were 'Good' or 'Excellent'

the locations of the CESI water quality sites don't reflect the distribution of our water resource



And there are issues with the CESI data if we wish to use them for national assessments*

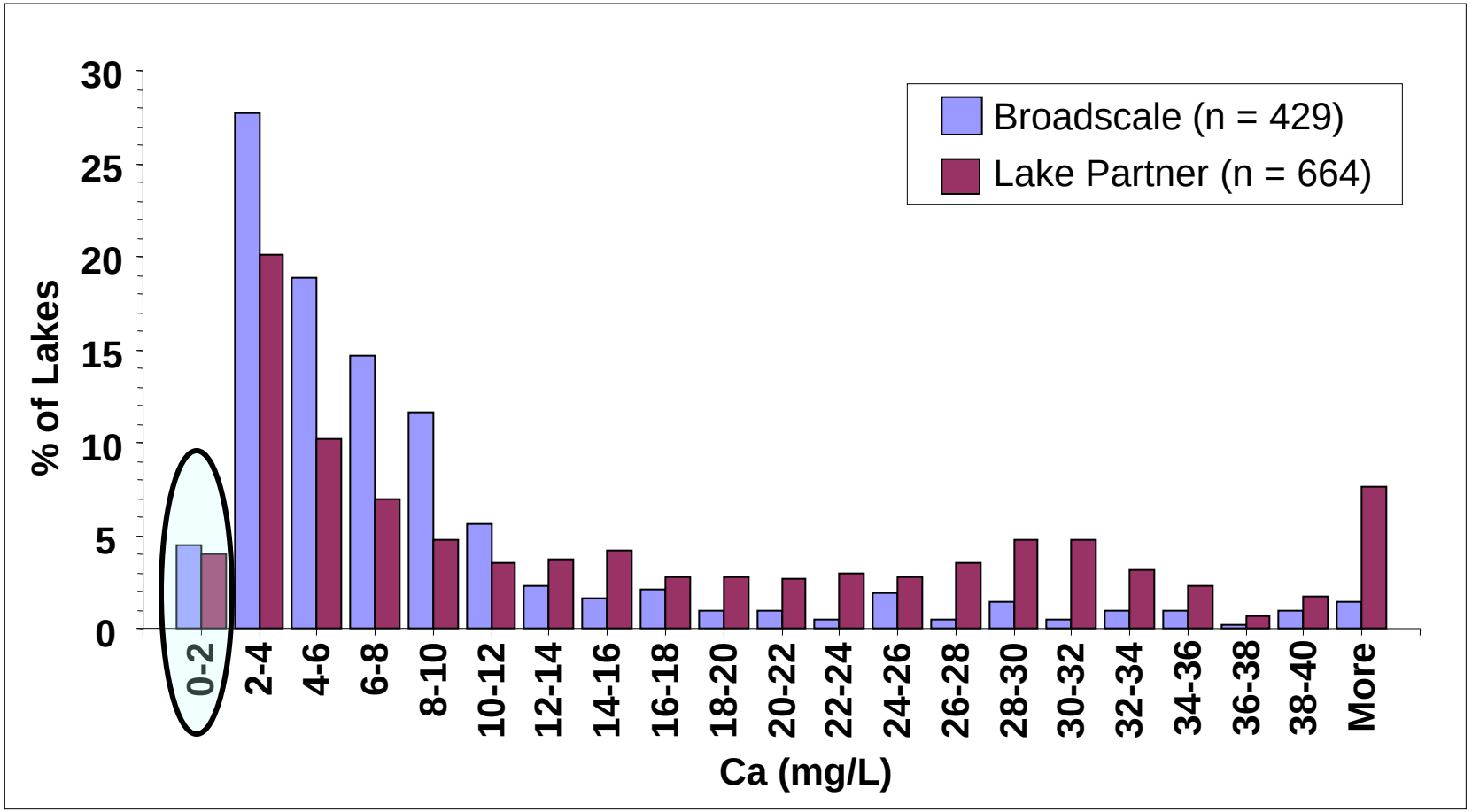
- The CCME provides general guidance on using their proposed WQI, but the choice of parameters, guidelines and time periods, as well as the number of samples to include is up to each contributor (CESI 2008)
- There is no national network of monitoring sites designated specifically to report the state of Canada's water quality in a representative way at different geographic scales (CESI 2008)
- The collection of monitoring networks was not designed to be representative of Canada and its watersheds, but simply to respond to federal, provincial or regional needs and resources (CESI 2007)
- Because sampling techniques vary, adoption of a consistent Canada-wide approach remains a challenge (CCME 2006)
- The WQI assumes interactions of pollutants are additive, an optimistic assumption, and only pollutants are included, not any other class of stressors
- My conclusion: We really don't know the state of our water resources nationally, and we won't ever know if this is how we make the attempt.

*From Kristi's report

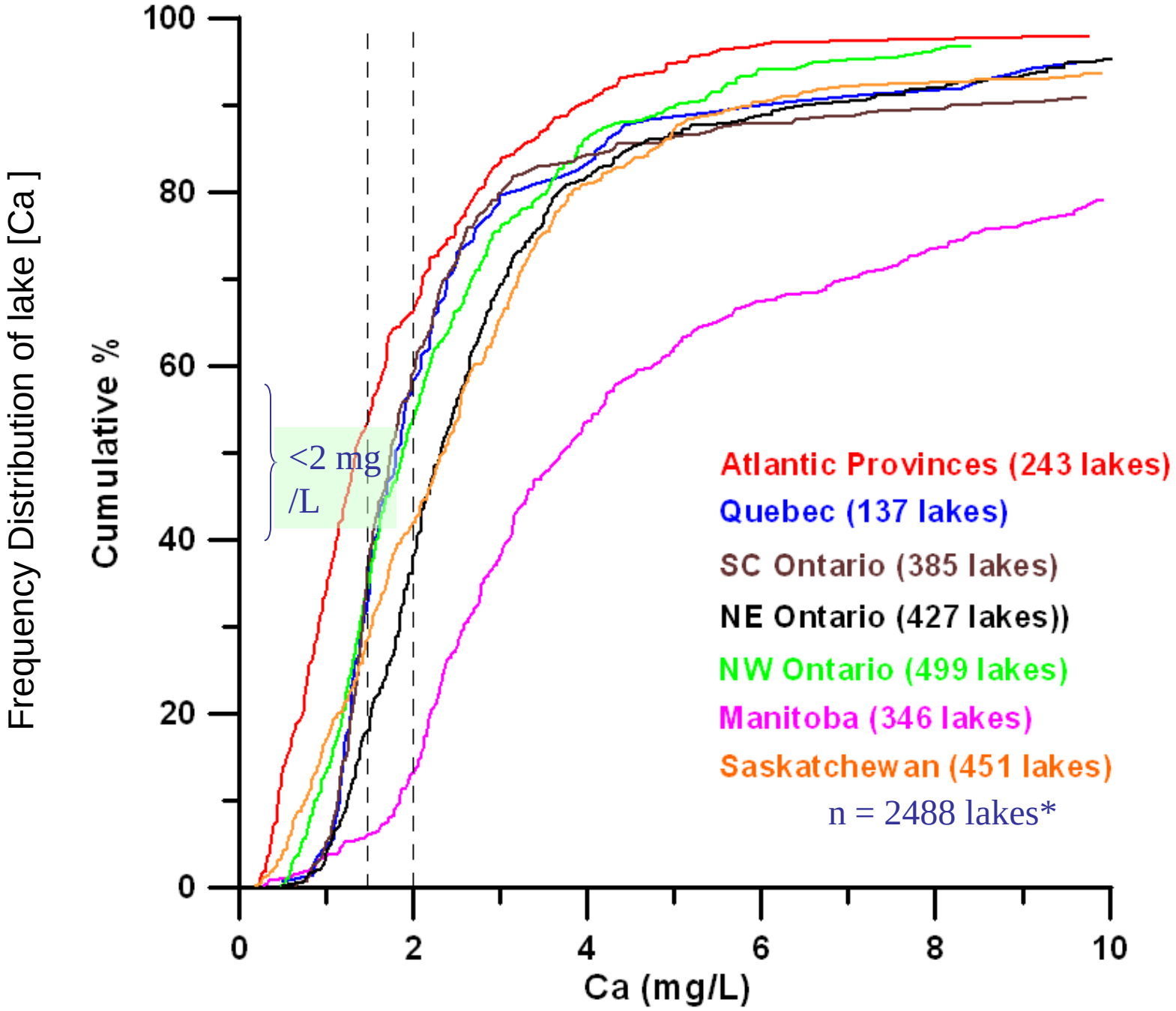
There are other water quality data sets

- Environmental Effects Monitoring Regulation data for control sites
- Large volunteer data sets, eg. Ontario's Lake Partner Program
- National acid rain sampling sites
- But how they represent the resource, our values, and all key threats must be assessed before they can be used for large scale assessments

Distribution of spring Ca concentrations across Ontario lakes as sampled by the Broadscale Monitoring (2008-09) and Lake Partner Programs (2008)*



*from Anna DeSellas (MOE, unpubl. data)



*from D. Jeffries (Env. Can.)

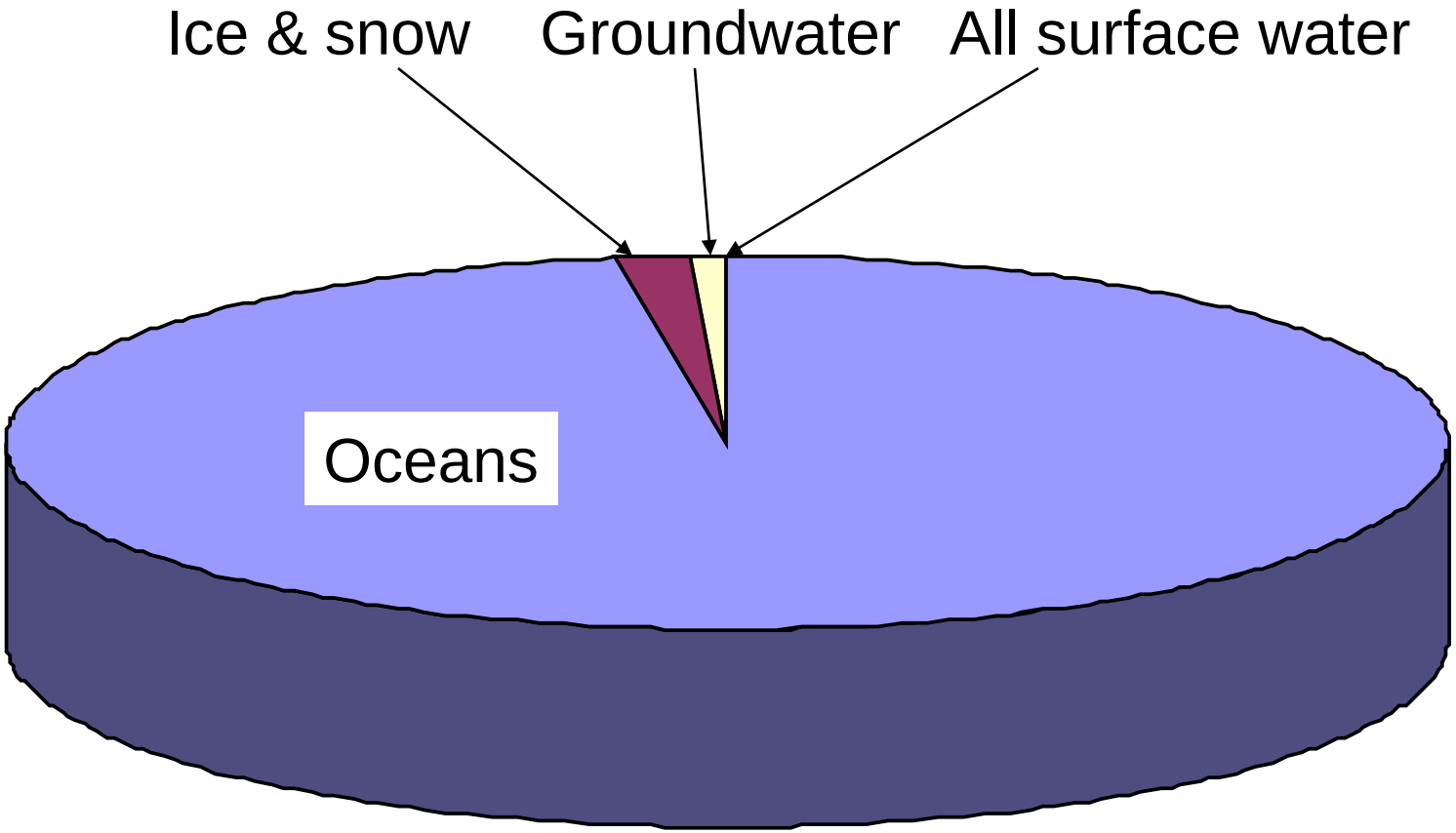
Summary of fundamental and practical constraints

- Change is the only constant, and rate of change may be accelerating
- Muskoka is not exempt from these changes
- We Canadians value our water, and want it protected and improved. We need assessments as part of this process, but such an assessment at a national scale is complicated by:
  - the multiplicity of threats and threat types, thus the need for many indicators
  - Lack of targets that reflect factors other than water chemistry
  - the relatively small financial investment in the environment and its assessment, at least nationally
  - the lack of a national sampling program that reflects the location and diversity of our waters
  - The tiny number of lakes included in the assessment
  - issues with the current CESI

Given these constraints what can we do?
Start by agreeing on the facts

1. We care about our fresh water, want it protected, and suspect that it is not currently in good shape
2. We have very little usable freshwater
3. The issue is complex with multiple stressor classes linked to multiple causes: a simple additive index may not capture this complexity
4. Conditions are changing rapidly
5. Our water quality targets rarely consider climate change.
6. Not all stressor types can be managed the same way, eg. invading species should not be managed like pollutants.
7. Not all of our problems have a local cause
8. We can solve problems, but it takes time

2. We have relatively little useable freshwater



Water in the oceans: 97.5%
In ice and snow packs: 1.76%
Fresh groundwater: 0.76%
Surface and air freshwater: 0.0086%
Including all biota

Source: McNulty, National Geographic April 2010

3. We must manage multiple stressors of our water, even in Muskoka, necessitating collaborative management

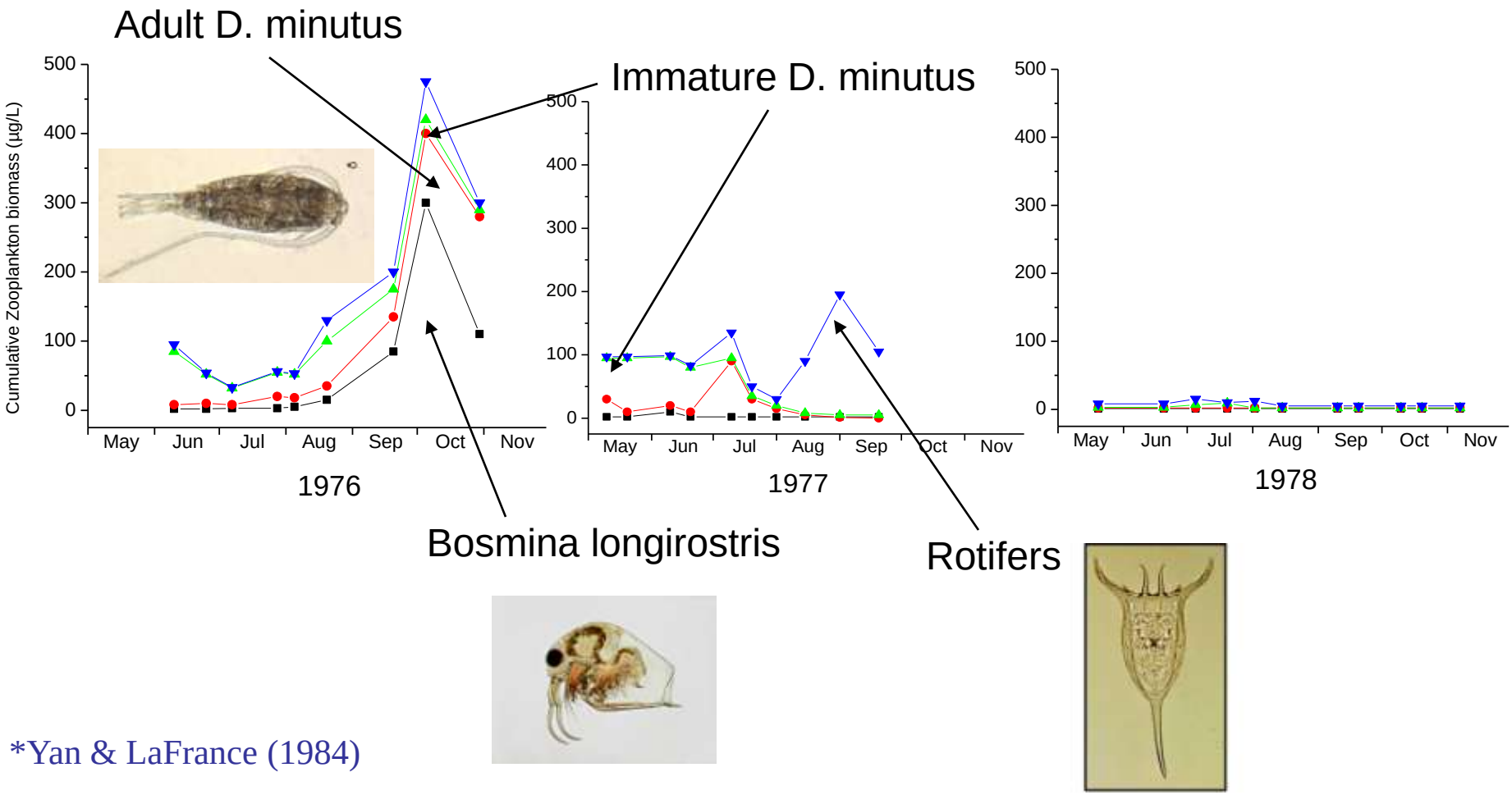
- Shoreline development
- Suburban spread
- Climate change
- Invading species
- Over-fishing
- Road salt
- Ca decline
- Water use
- Bass introductions
- Mercury
- Cadmium and zinc
- Ground level ozone
- Increasing drought
- Continuing acidity
- Flow alterations
- Agriculture runoff

3. Effects of multiple stressors on biota are usually not additive

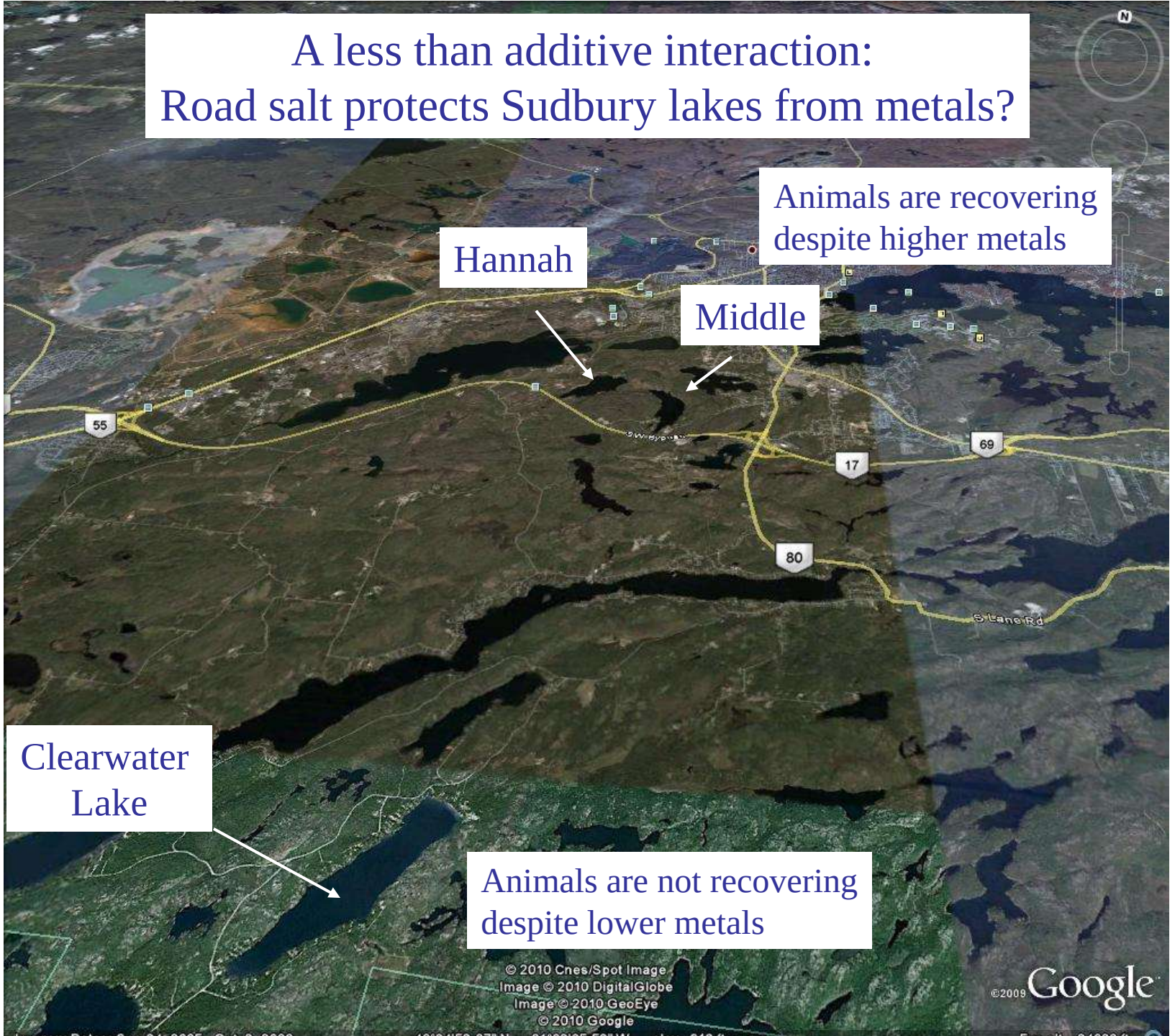
- Living communities adapt to stressors, losing some species, and changing gene pools. This may make them less able to cope with new stressors that have novel mechanisms of impact. Such multiple stressors will have more than additive effects
- Communities of species will likely be well adapted to new stressors with similar mechanisms of impact as past stressors. Hence, effects of these multiple stressors will be less than additive
- Losses in biodiversity increase vulnerability to new stressors, promoting “trophic cascades” and more than additive effects

3. Simplified communities are very vulnerable to new stressors:

Fertilizing Mountaintop Lake collapsed the animal plankton a more than additive effect



*Yan & LaFrance (1984)


A less than additive interaction:
Road salt protects Sudbury lakes from metals?
Animals are recovering despite higher metals
Hannah
Middle
Clearwater Lake
Animals are not recovering despite lower metals
55
17
69
80
S Lane Rd
© 2010 Cnes/Spot Image
Image © 2010 DigitalGlobe
Image © 2010 GeoEye
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What animals?

Daphnia

Bioassay of amended** Clearwater Lake water
Survival of Daphniids after 14 days:
a **less than additive** effect

Daphniid	control *	+Na	+Ca	+Na&Ca
D. pulex	0	80	100	100
D. mendotae	0	70	100	100
D. pulicaria	0	60	90	90
D. ambigua	0	70	80	80

***Control is Clearwater Lake water – all individuals died**

**amendments are additions of Na and/or Ca to Middle Lake levels

Data are from Celis Salgado (PhD thesis defended last week)

4. The only constant is change

- We need indicator data quickly and assessments frequently
- We must share these data broadly to inform decision making
- We need robust early warning indicators that respond to known threats
- Ecological redundancy is the best protection of our biota when the problems are complex and won’t soon be understood. Hence, we should protect (and measure) biodiversity

5. Climate change will alter the effects of other stressors, but is not reflected in our targets

21 day bioassay for Ca with *Daphnia pulicaria* at 3 temperatures

*Linley, Shead & Yan (in prep.)

6. Invading species should not be managed like chemical pollutants

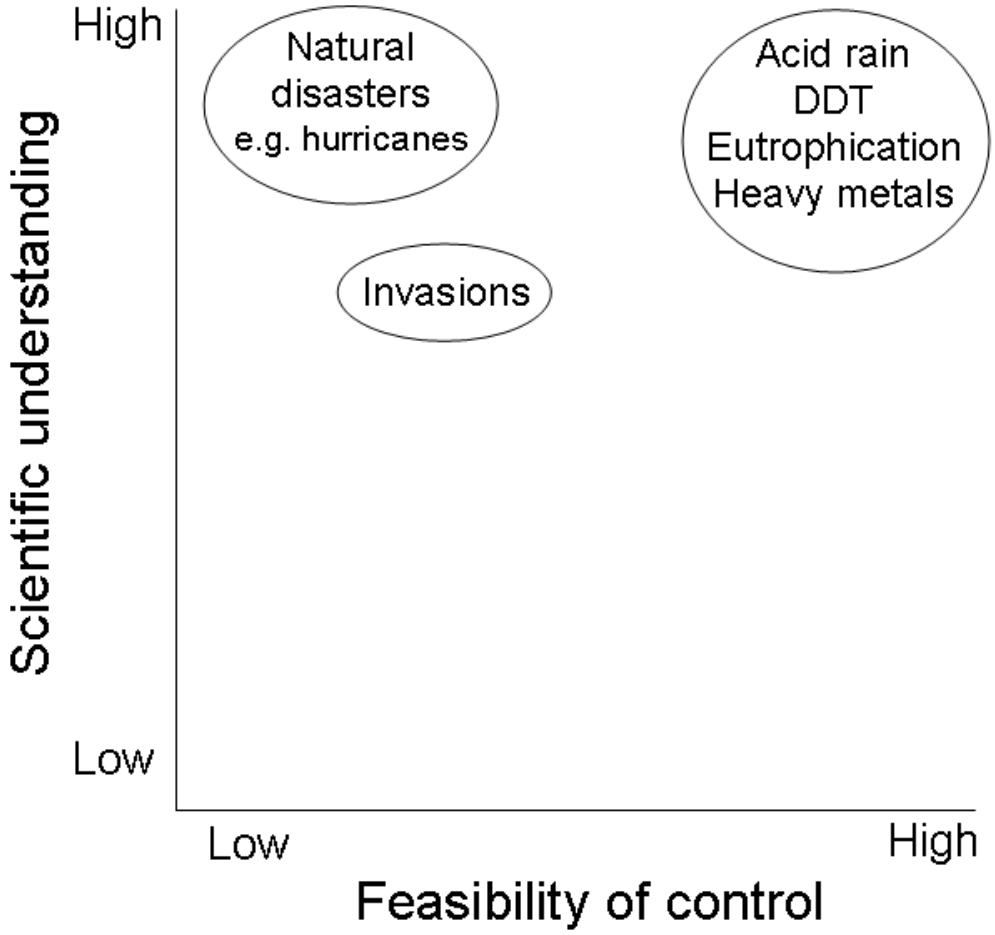
Bythotrephes – the spiny water flea

6. Estimating loss of animal plankton diversity to *Bythotrephes*

sites	Comment	% loss	Source
Harp Lake	14 pre- vs. 12 post-invasion years	**19.2**	Yan et al. 02,08
30 lakes	13 ref. vs. 17 invaded	**22.9**	Boudreau & Yan 03
18 lakes	11 ref vs. 7 invaded	**24.8**	Palmer unpubl.
28 lakes	changes 1980s to 04_05	**15.3**	Palmer unpubl.
15 lakes	4 ref. vs. 11 invaded	**22.7**	Strecker et al. 08
Simcoe	5 ref. vs. 2 invaded years	**25**	Yan et al. unpubl.
Great Lakes	3-4 ref vs. 10-12 invaded years	**22-32**	Barbiero pers. comm
CAISN lakes	166 ref. vs. 20 invaded lakes	**14**	Yan, Cairns, et al. unpub.

average = 21.80%

6. Invasions cannot be managed like pollutants: Prevention is a much better, perhaps the only, option*

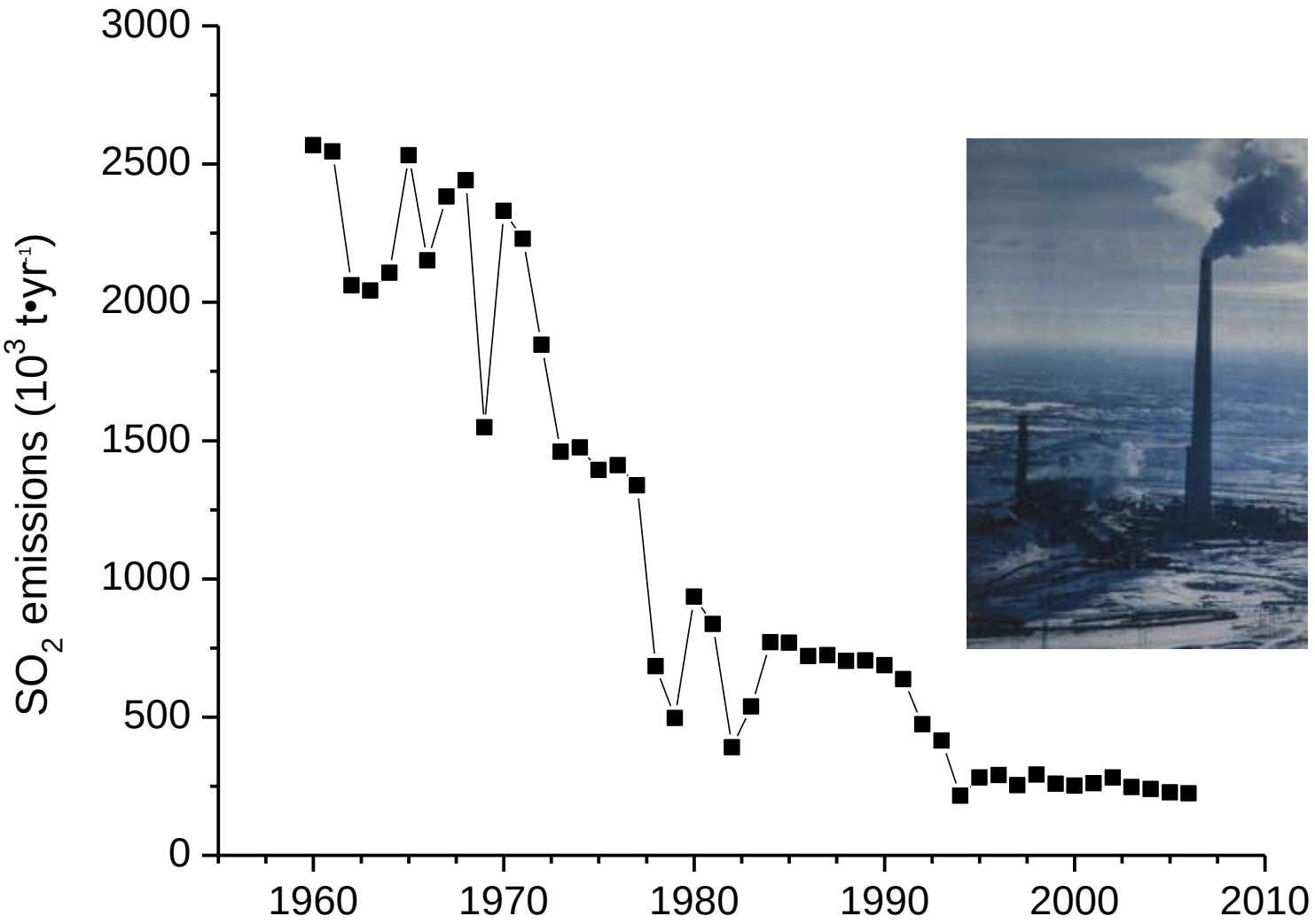


*Ricciardi, Palmer and Yan (in review)

7. We must manage at many scales, not just local

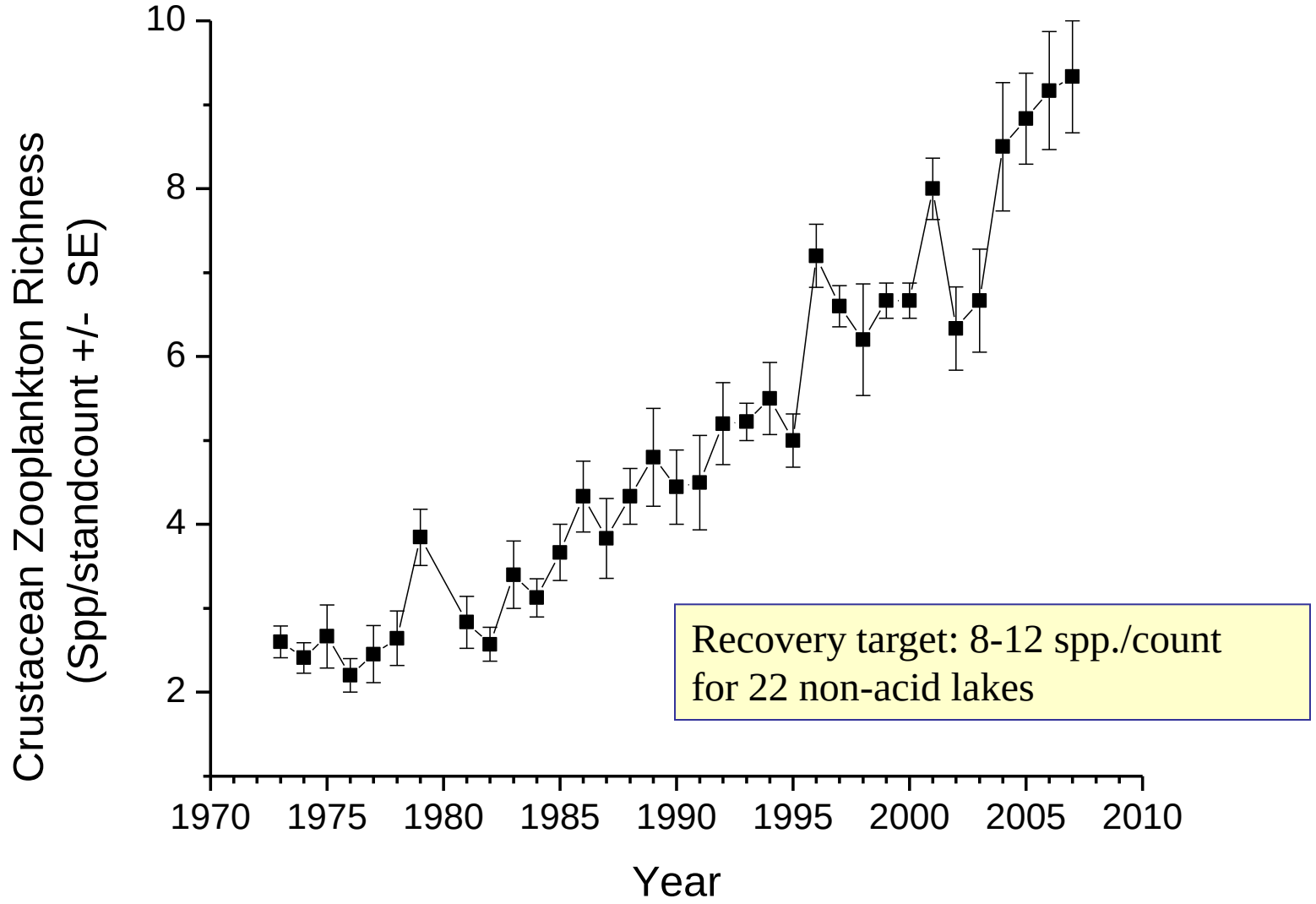
- We often aren't doing a bad job with local scale management, eg. Great Lakes AOC, Environmental Effects Monitoring regulations, Lake Simcoe, but
- We have largely dropped the ball on national-scale assessments, and
- We must also manage our water at an international scale
  - The USA's interest in Canadian water
  - Climate change and eutrophication
  - Invading species from foreign ports

8. Patience and long-term planning is a necessity



Keller et al. 1999

8. Plankton biodiversity has recovered in Middle Lake, but it took 32 years



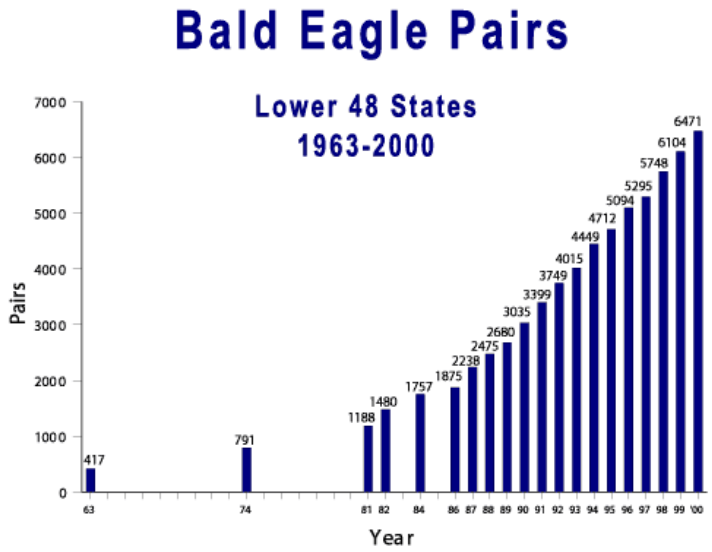
*Yan et al. 2004 Ecol. Letters 7:452-460, Yan & Keller (unpub)

There are other hopeful examples

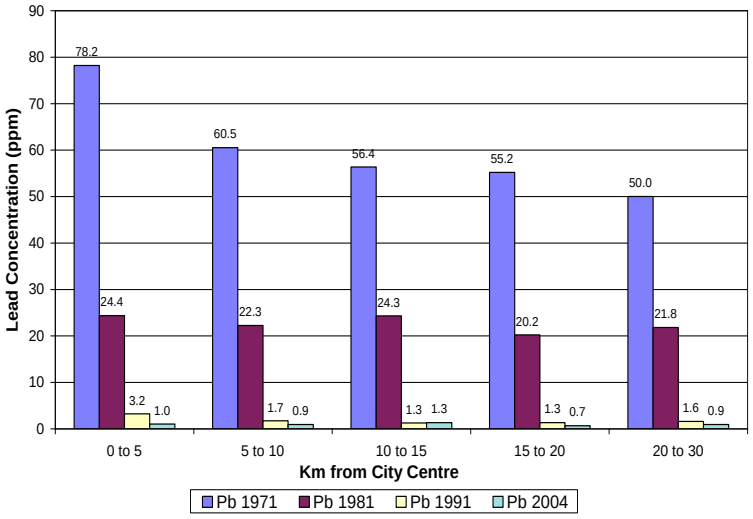
- We can learn from the progress we have made on the issues that started the environmental movement in North America, i.e.
  - Lead pollution
  - acid rain
  - DDT, and
  - lake eutrophication

Fish have returned to Clearwater Lake

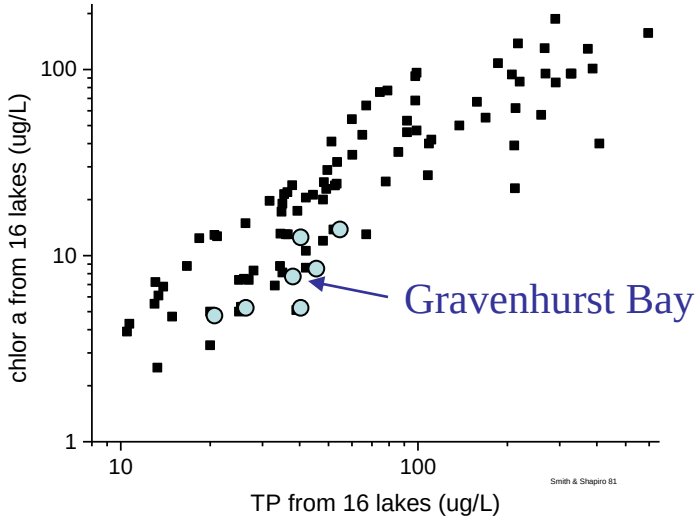
Eagles & other raptors are recovering



Lead in Toronto maples is plummeting



Lowering TP improves water quality



Conclusions

- Our national water assessments are currently poor, because
  - conditions are changing rapidly
  - multiple stressors are the norm, and their effects are not additive
  - our water quality targets rarely account for climate change
  - we often don't have targets for stressors other than pollutants
  - our assessment are designed to satisfy local, not national objectives
  - our sample sizes are too small for accurate national assessments
  - volunteer-based, provincial and industrial data sets may supplement the databases, but their use in national assessments is largely untested
  - there is little assessment in the north
  - we spend comparatively little money on the environment given its importance to Canadians

Conclusions (continued)

- We have all the water we're going to get, so we should look after it.
- Our best defense against multiple stressors is to protect biodiversity.
- We can't manage all classes of invaders in the same manner. Prevention may be the only option for invaders.
- Solutions require knowledge, patience and long term planning.
- Our local-scale water management of pollution has often improved, but our national and international management efforts fall short of what is needed
- We have solved enormous environmental problems in the past, and we can learn from these efforts to help solve current problems and prevent future ones. The question is, will we

“The cardinal human values are HUMILITY and HOPE”

Richard Outram