The effects and management of multiple stressors in Muskoka's ecosystems

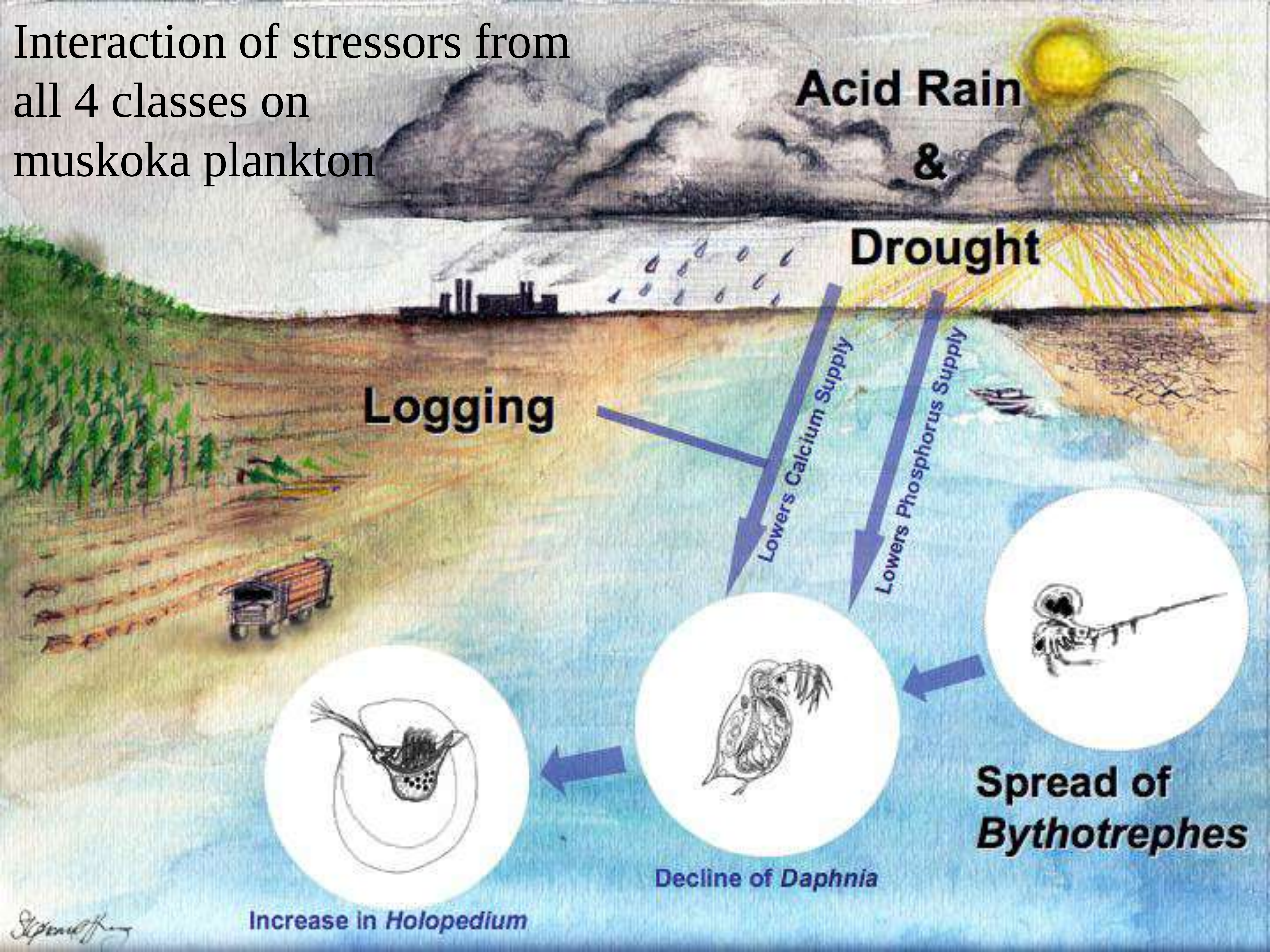
Norman Yan

York U & DESC

Categories of ecological stressors

- With indirect effects on biota, operating through changes in their habitat
  - Changes in habitat chemistry, i.e. pollution
  - Changes in habitat physics
- With direct effects on biota
  - Harvesting
  - Species introduction

Interaction of stressors from all 4 classes on muskoka plankton



What is changing in Muskoka lakes

- Water chemistry
  - Sulphate, acidity, **calcium**, salt, phosphorus, colour
- Physics
  - Precipitation, temperature
- Harvesting
  - More control of logging than in the past, fishing?
- Species Introductions
  - Bass, **spiny water flea**, …

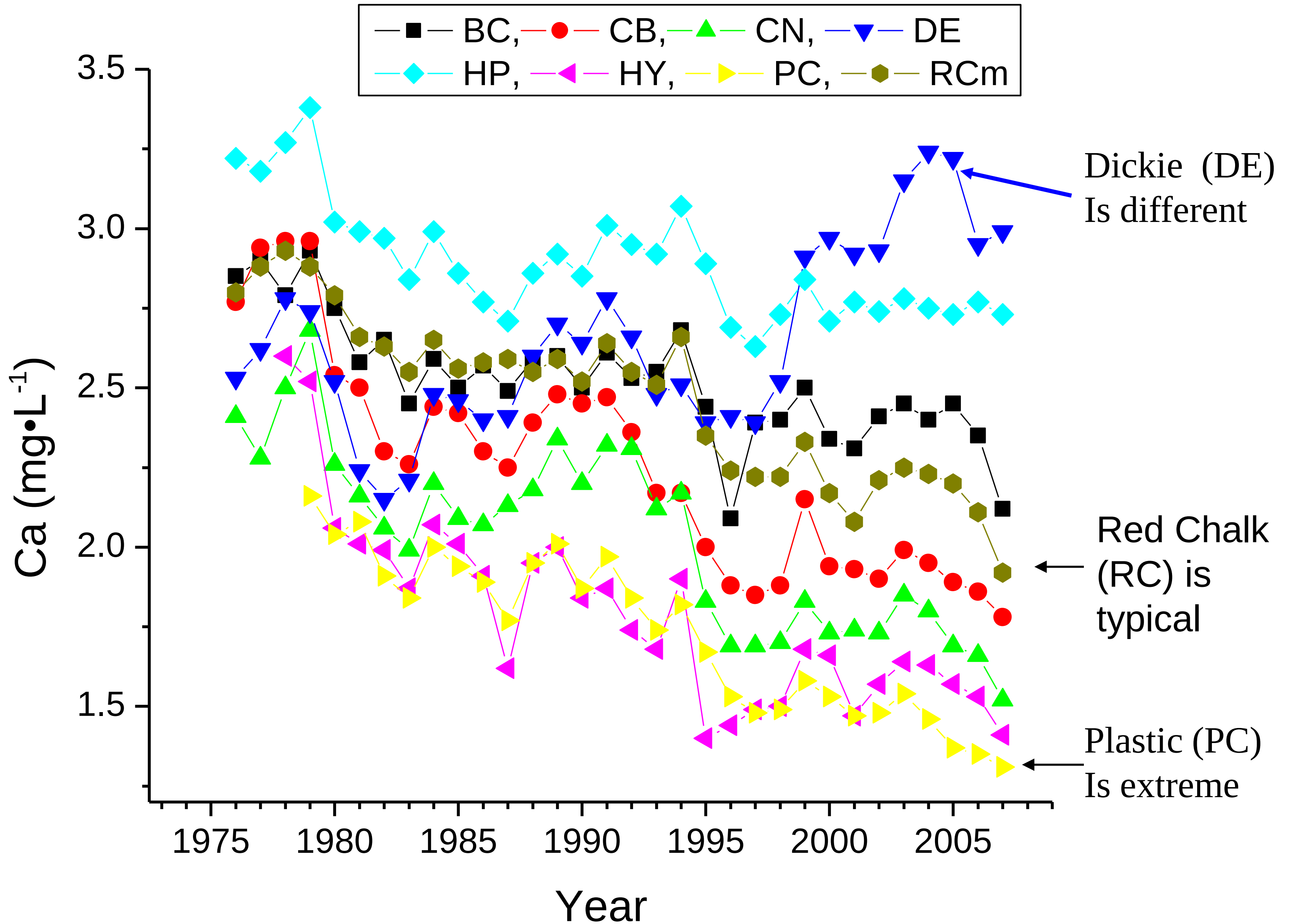
Change in water chemistry in 36 Muskoka lakes over the last 25 years*

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 press)

Calcium (Ca) changes in Dorset lakes*



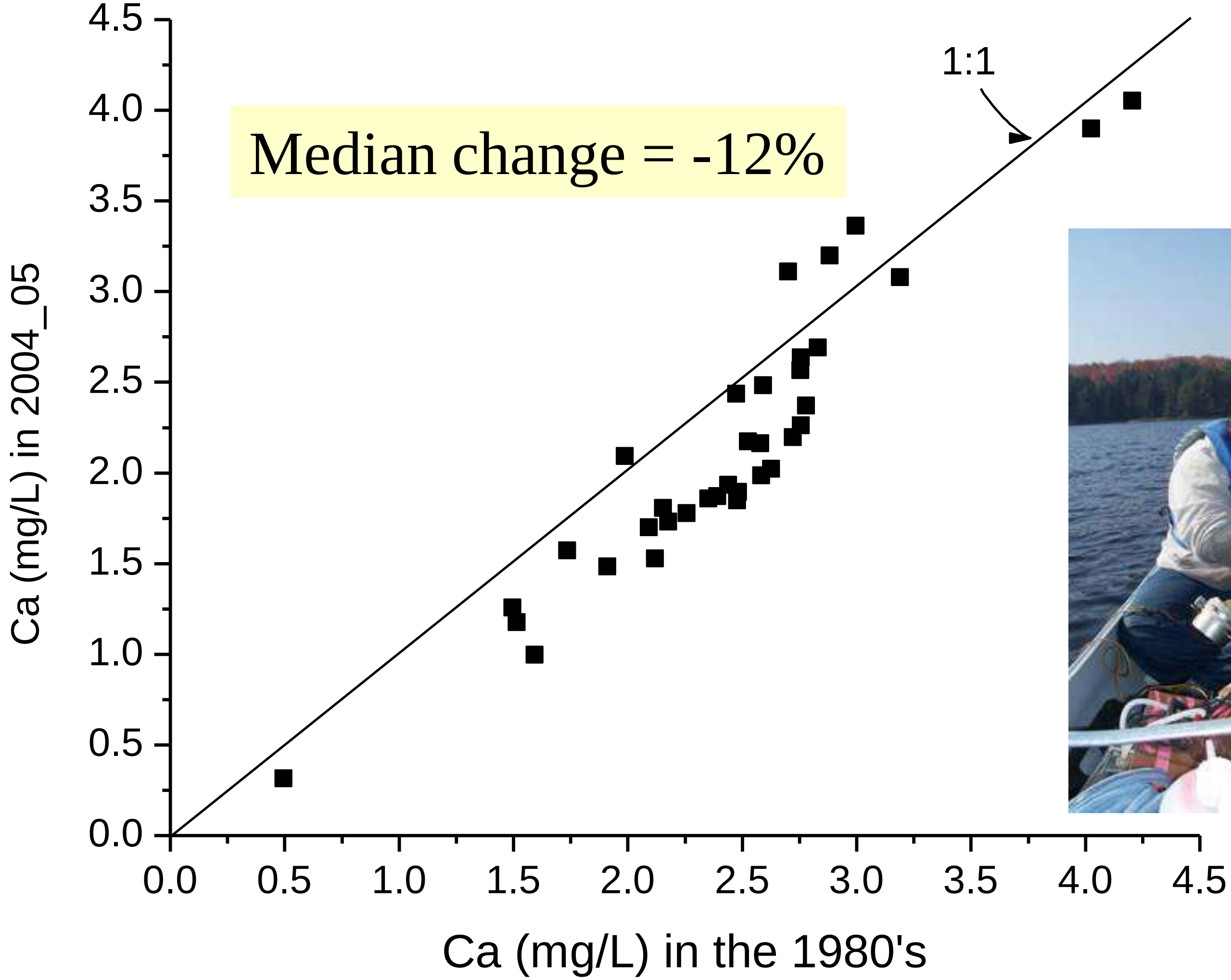
*Molot and Dillon 2008, Yan et al. 2008, Paterson, MOE unpubl)

Why is Dickie Lake different?*

Ca load from all unguaged sources	– 2700 kg/yr
Dust suppressant added/yr since 1998	– 10,450 L
Ca concentration in suppressant solution	– 196 g/L
Ca added in dust suppressant since 1998	– 2050 kg/yr

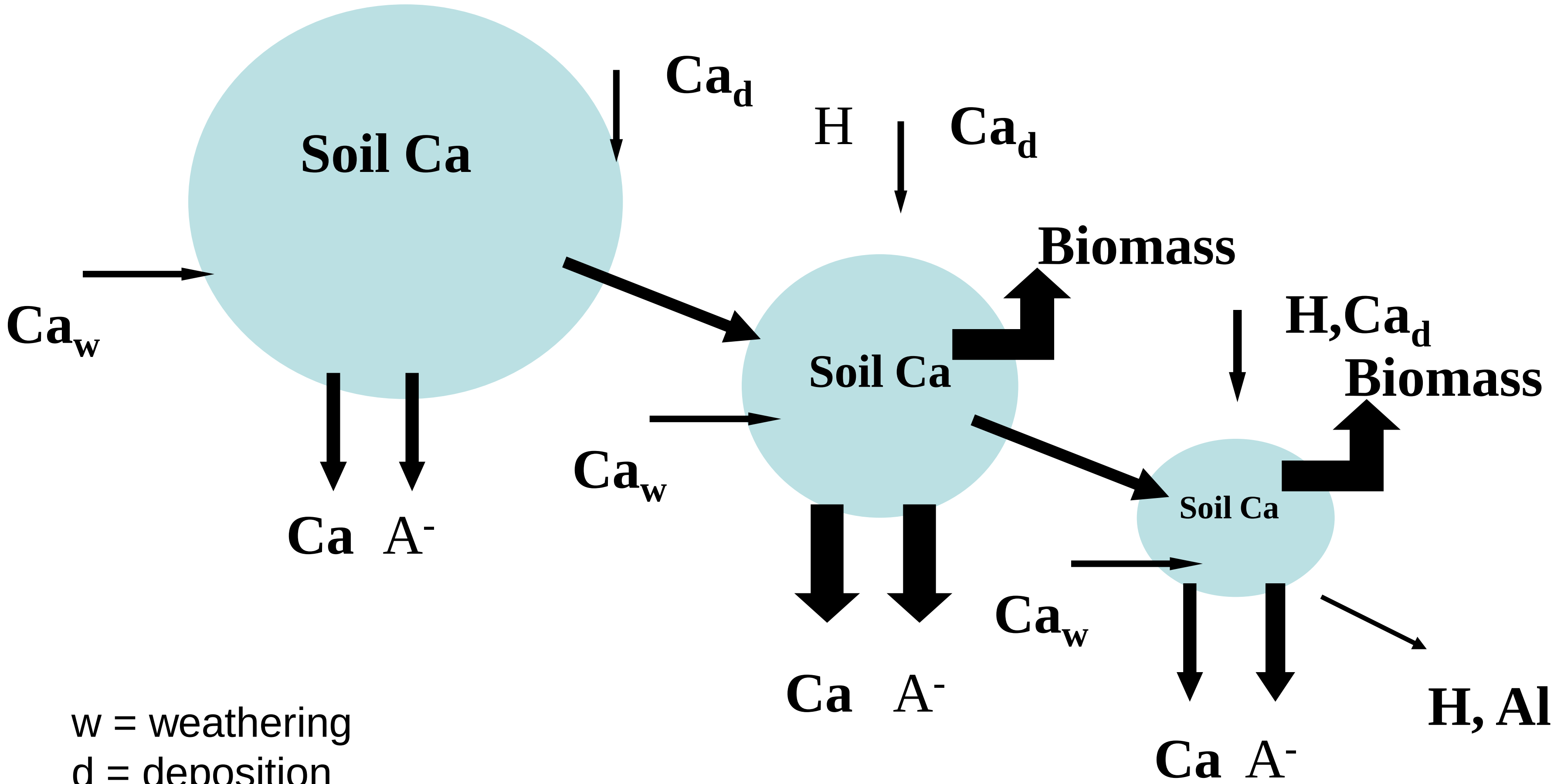
*Yao, McConnell, Somers, Yan, Watmough and Scheider (in press)

Ca decline in 37 Muskoka/Haliburton lakes*



*Michelle Palmer's PhD vs. 1980's DESC data

Why is lake water calcium (Ca) falling? Acid rain and harvesting are depleting soil reserves. Drought is lowering supply

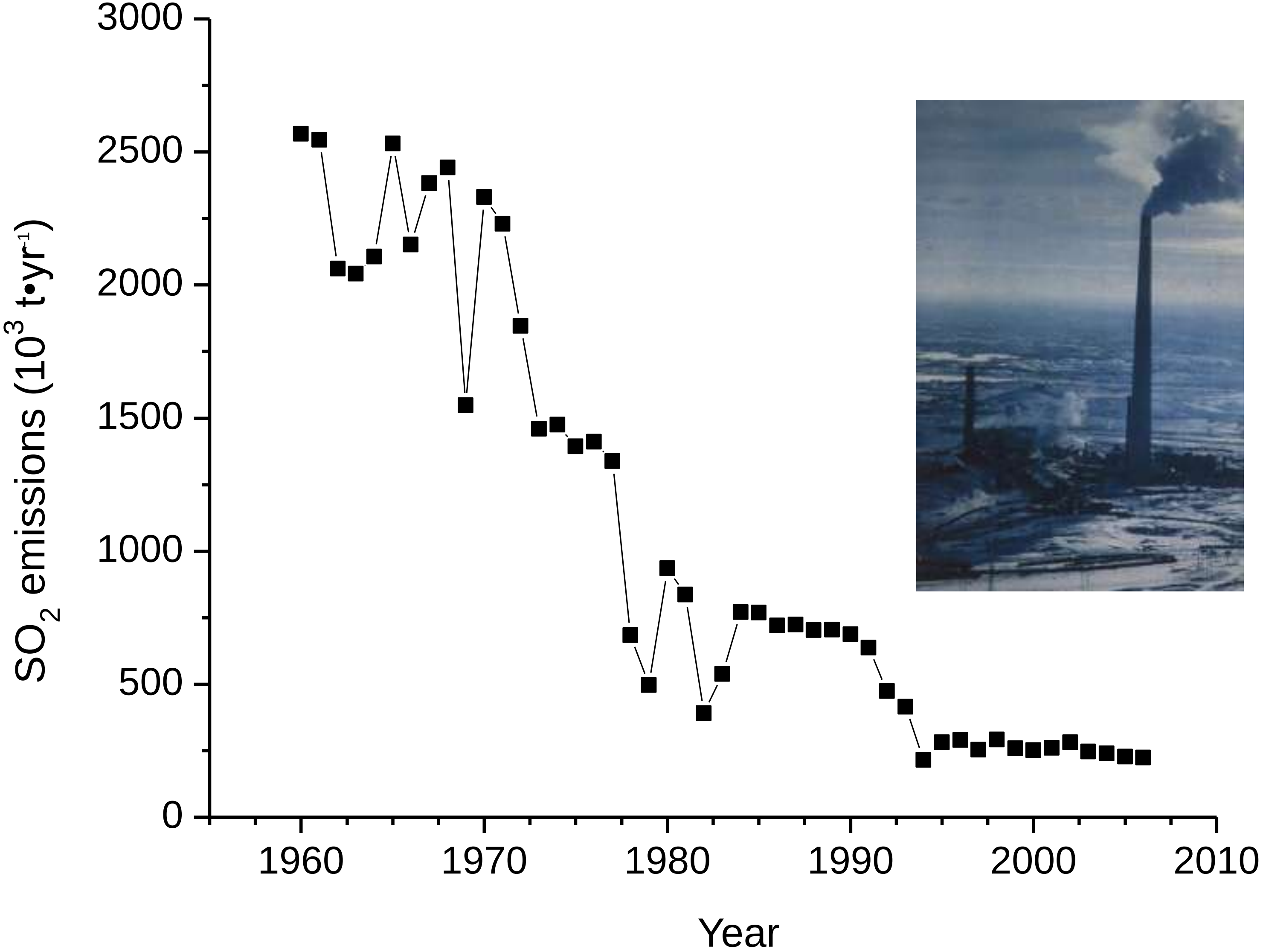


w = weathering
d = deposition
A$^-$ = anions
Biomass – tree mass
Al - aluminum

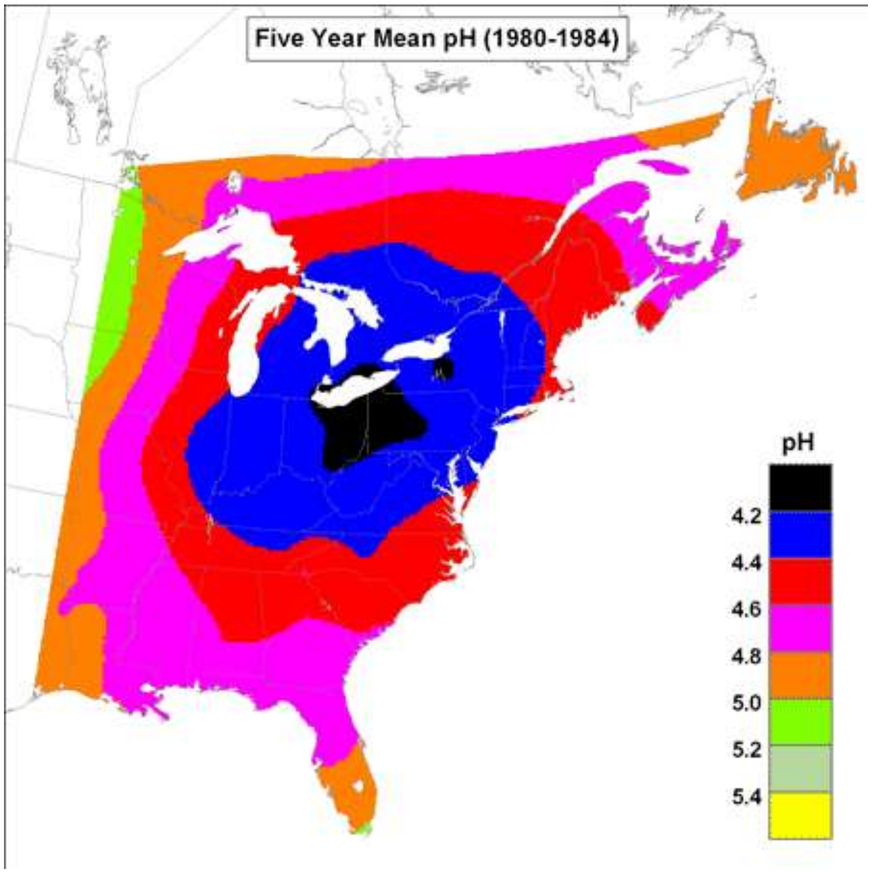
Thanks to S.Watmough, Trent U

SO_2 emissions have been reduced by 55% from 1980 levels in Canada, and by 40% in the USA

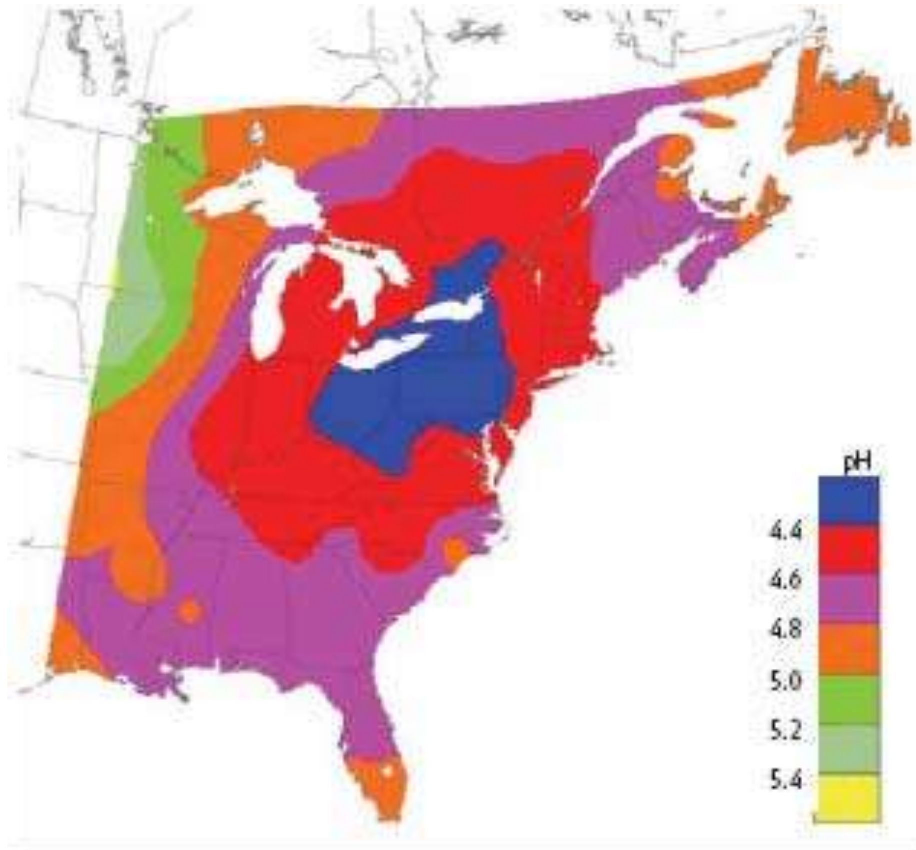
Emissions from Sudbury smelters



And rainfall acidity has declined, but it is still acid *



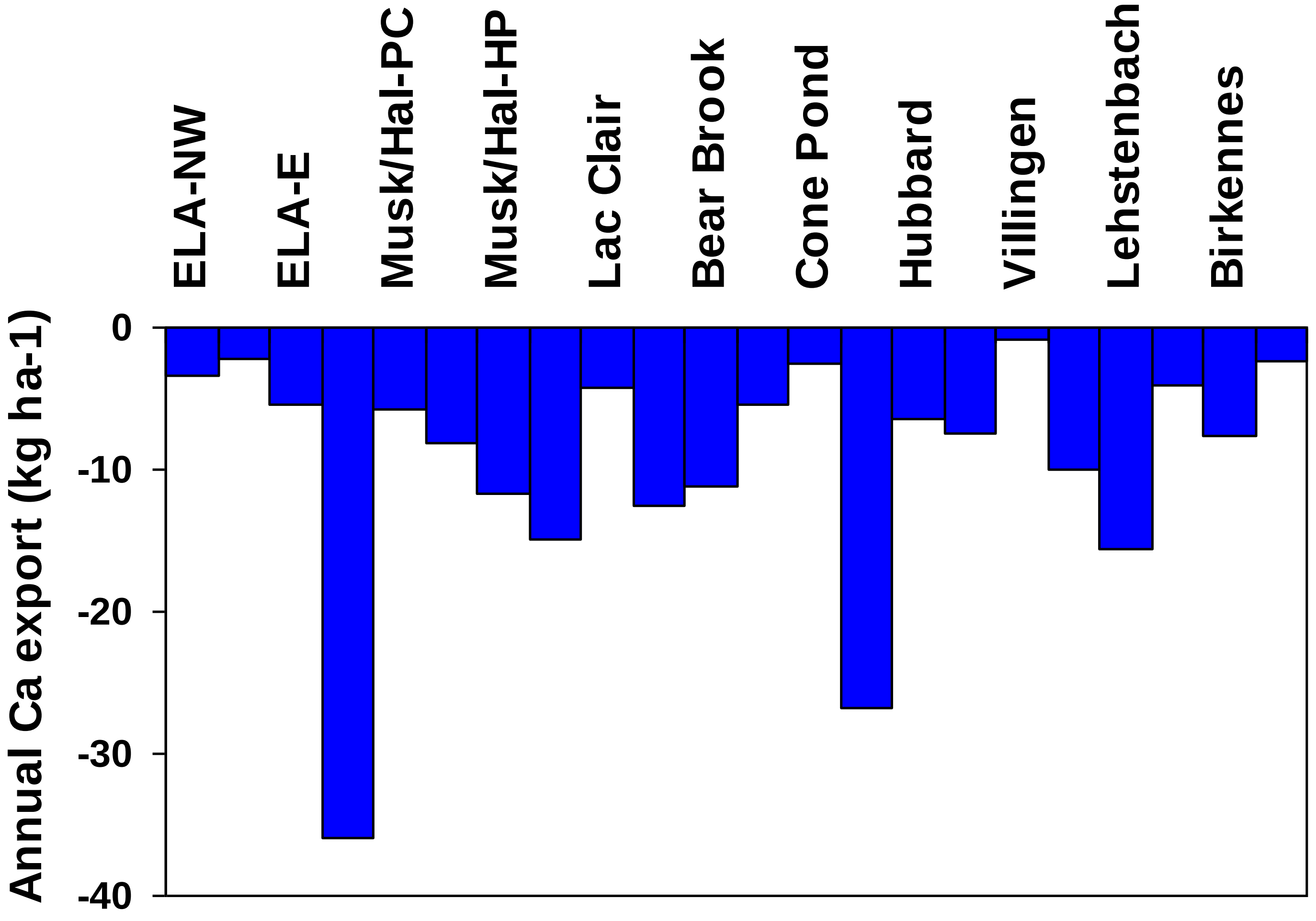
1980-1984



2000-2004

*US EPA and Env. Canada

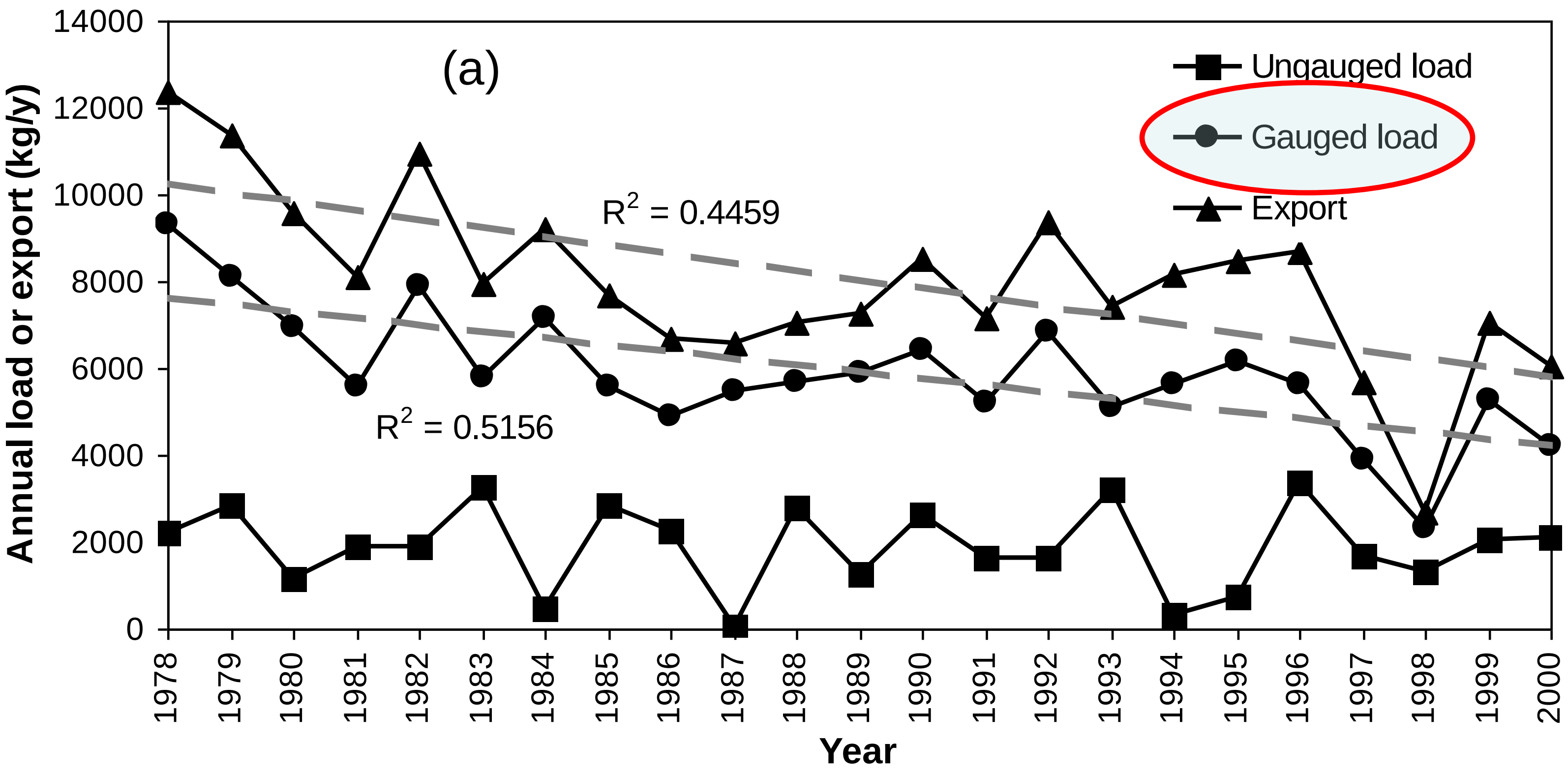
Hence, soils in 21 forests in eastern North America and Europe are still losing Ca*



* Watmough et al. 2005 Env. Monitor Asssess. 109: 1-36

Why is Ca falling in Red Chalk Lake:

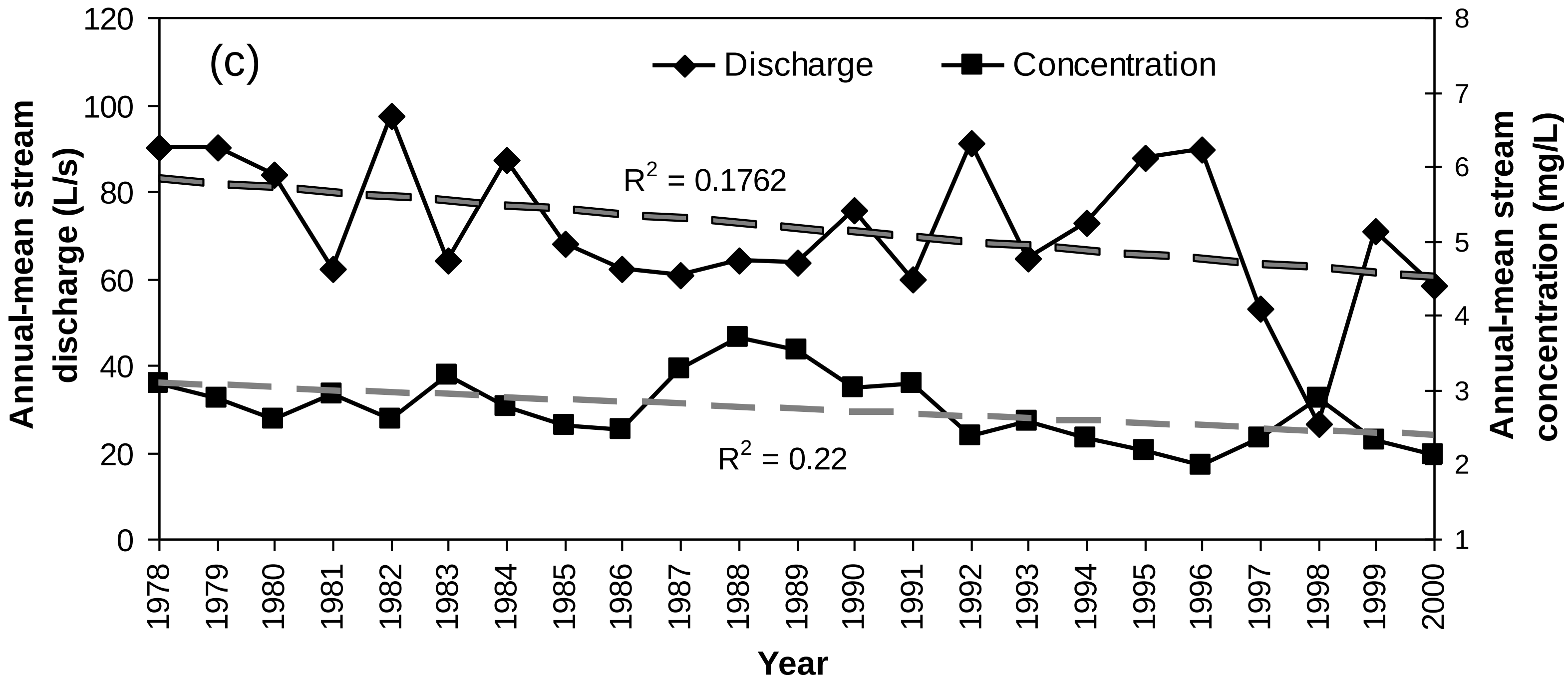
the Ca load has fallen by ~40%



Yao et al. (in press)

Why has the Ca load fallen?

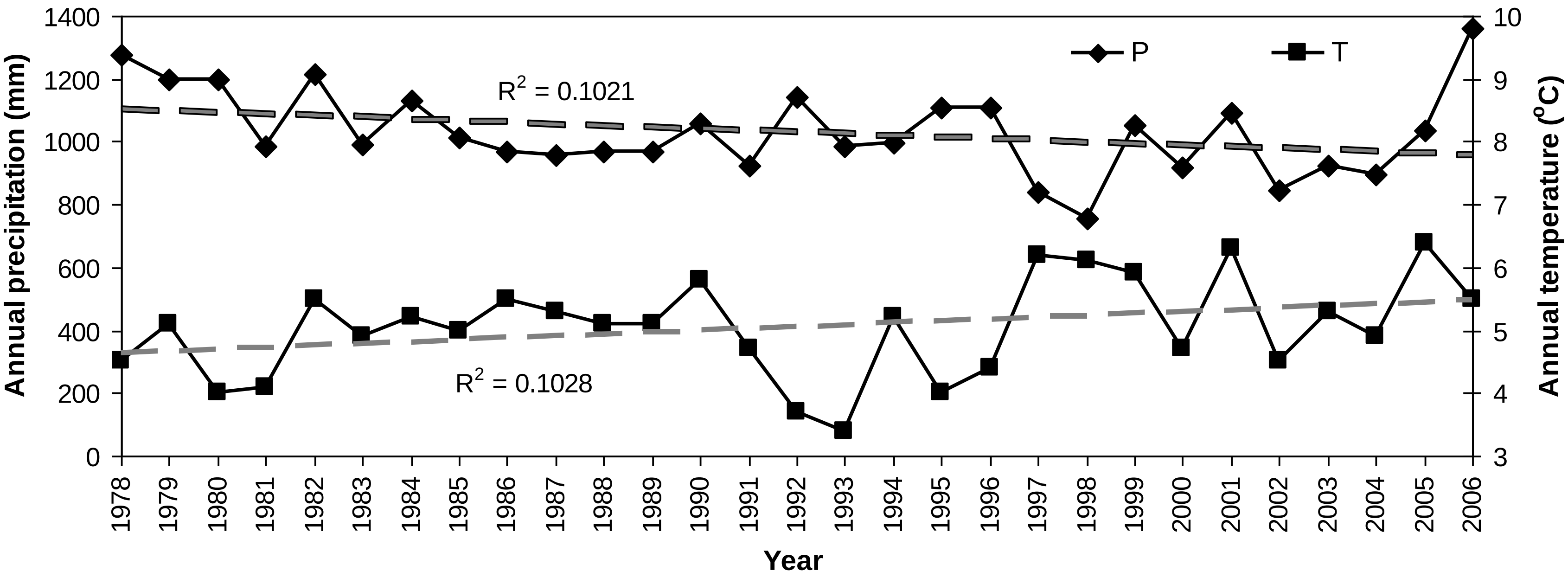
both stream runoff & Ca concentration have fallen



Yao et al. (in press)

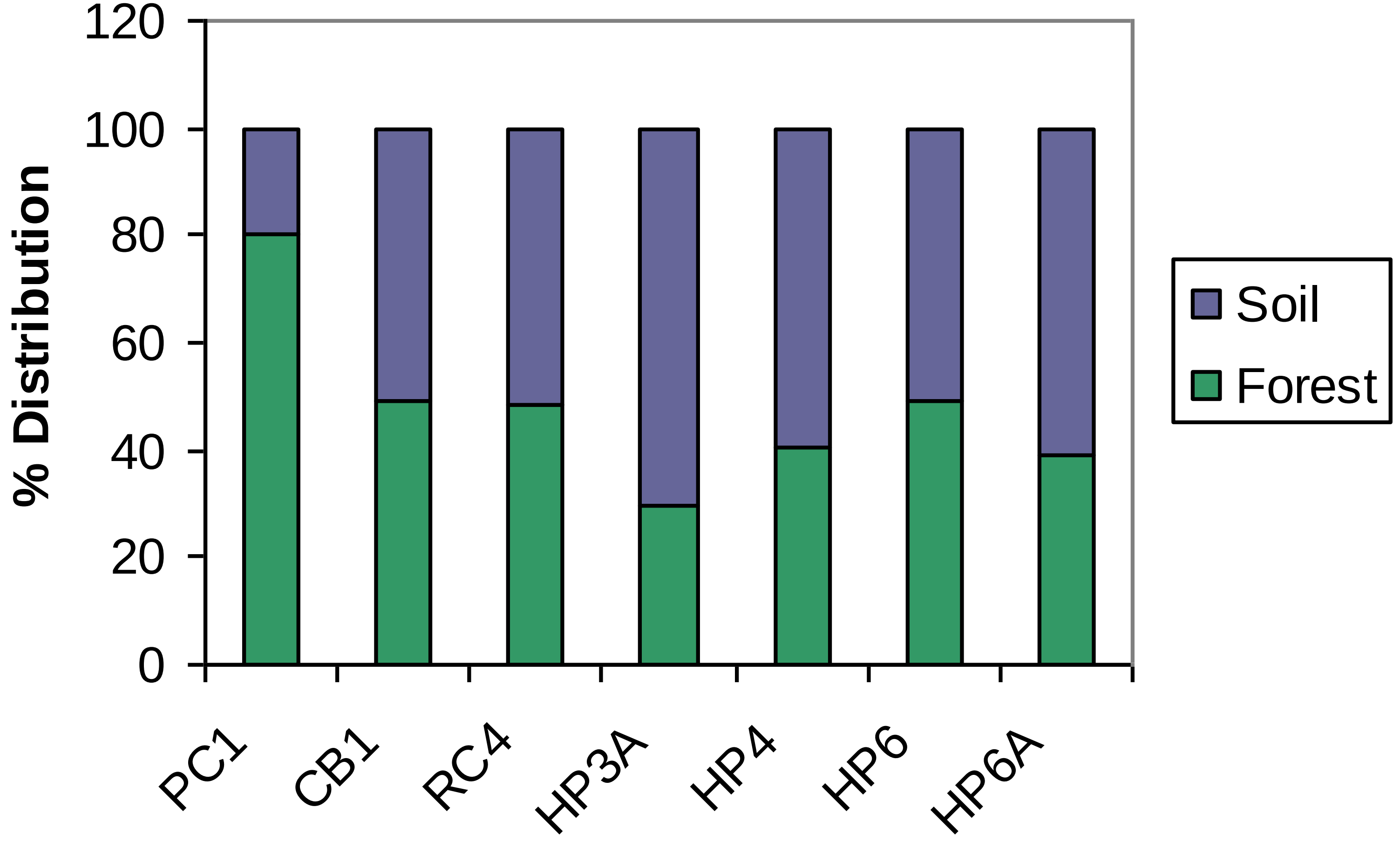
Why has runoff fallen?

Precipitation has fallen and temperature has risen



Yao et al (in press)

Logging + forest re-growth also matter because there is so much Ca in the trees

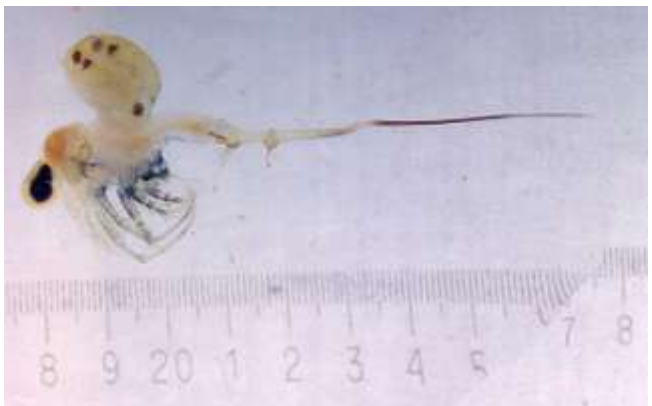


*from Watmough & Dillon 2003 Forest Ecol. Manag. 177:155-177

Why is lake water Ca changing

- Where it's increasing (atypical)
  - Dust suppressants, and likely winter de-icing of roads are increasing Ca load from watersheds, more than natural loads are decreasing
- Where it's decreasing (typical)
  - Logging and afforestation lower Ca levels in soils
  - Drought and warming reduce unit runoff and Ca load
  - Acidification lowers exchangeable Ca levels in soil which lowers Ca supply, and, paradoxically
  - Current reductions in acid deposition lower exchange of remaining bases in soils, including Ca

Has calcium declined enough to cause harm to native biodiversity?



Bythotrephes
0.03% Ca

(Kim & Yan, under review)

Holopedium
0.3% Ca

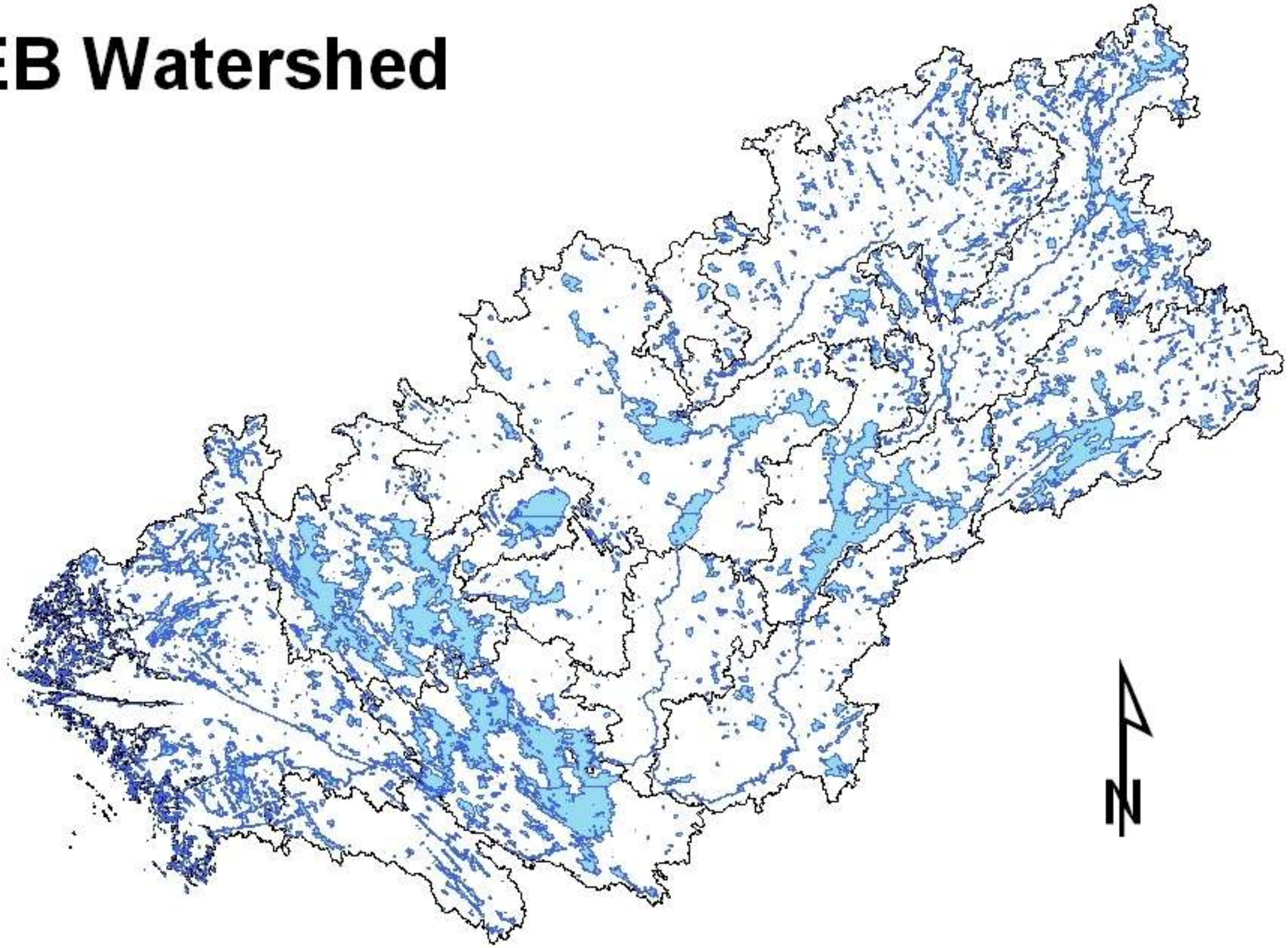
Daphnia
2-6% Ca

(Jeziorski & Yan, 2006)

Are we losing Ca-rich daphniids on the Canadian Shield?

Photo by Derek Taylor, U Buffalo

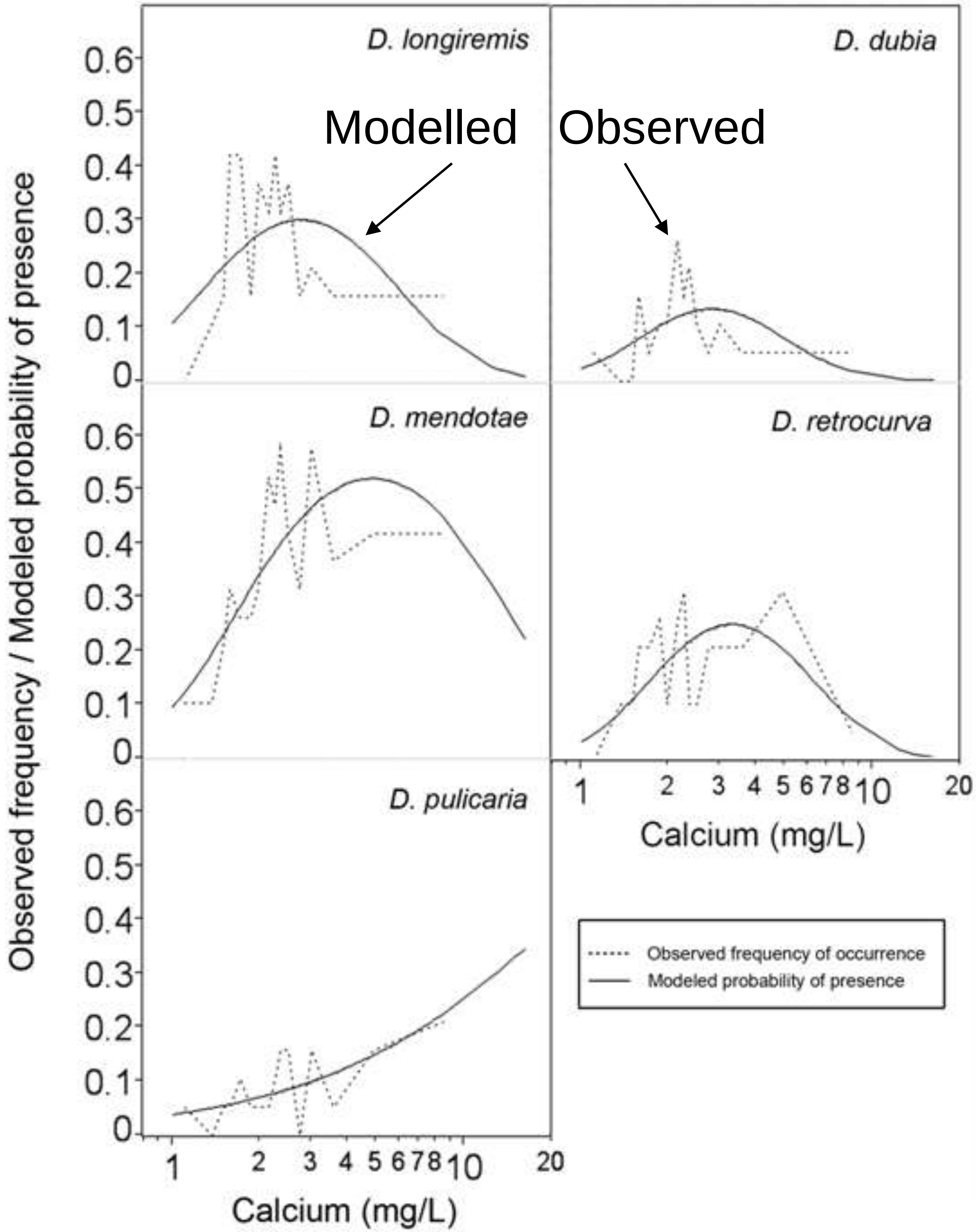
2EB Watershed



Universal Transverse Mercator
NAD83 Zone 17
NTDB 1:50 000

0 5 10 20
Kilometers

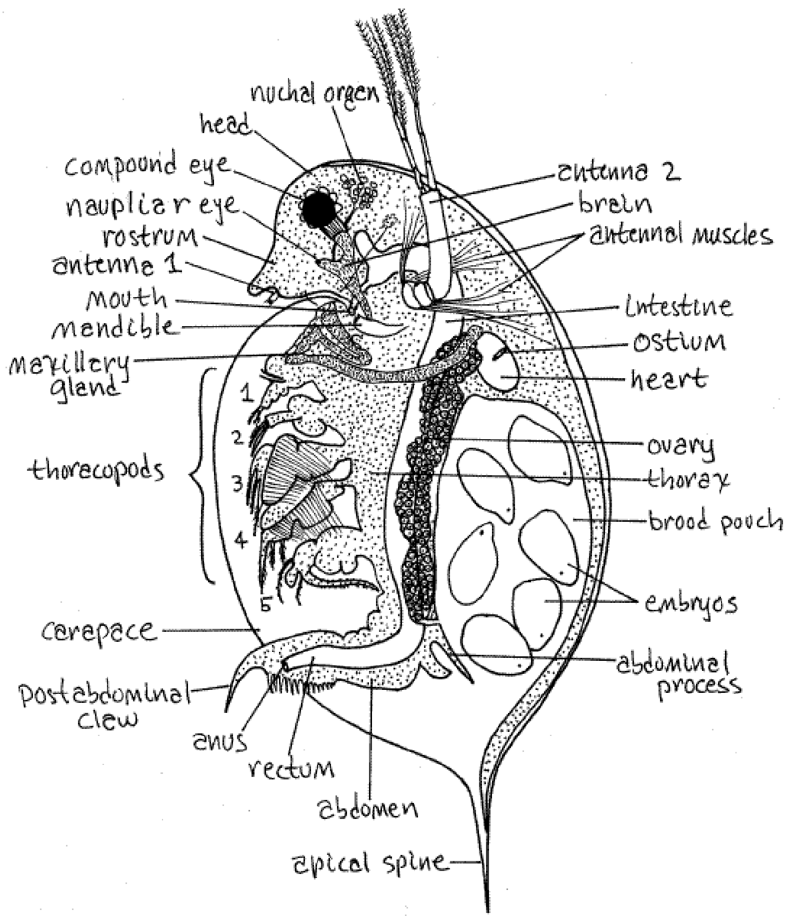
Waterbodies
2EB Boundary



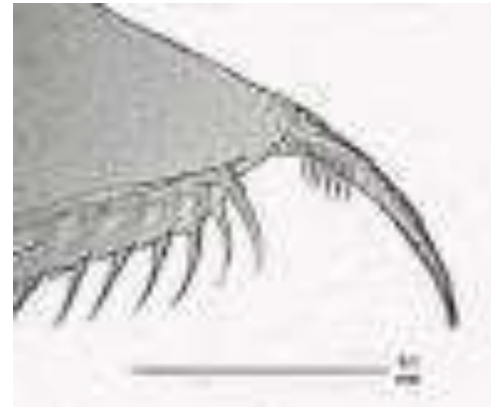
Pattern of occurrence
of 5 Ca-rich *Daphnia*
falls at Ca levels <2 mg/L
(Cairns et al. under review)

Might they have disappeared
From these lakes?

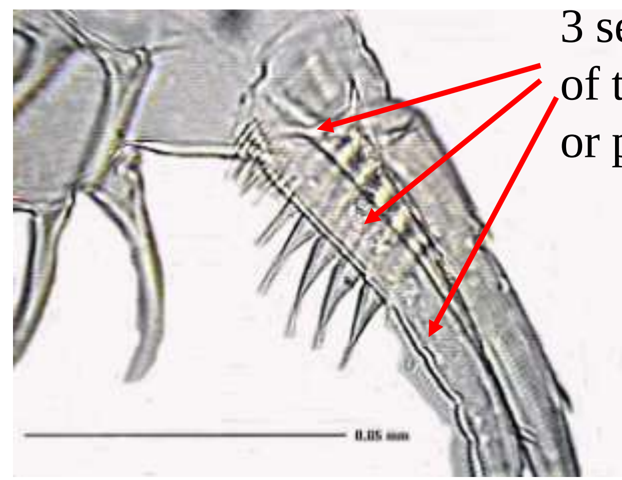
A daphniid paleolimnology primer



Sketch of a daphniid



Abdomen with claw



Pectins on abdominal claw

Primer in paleolimnology 2*

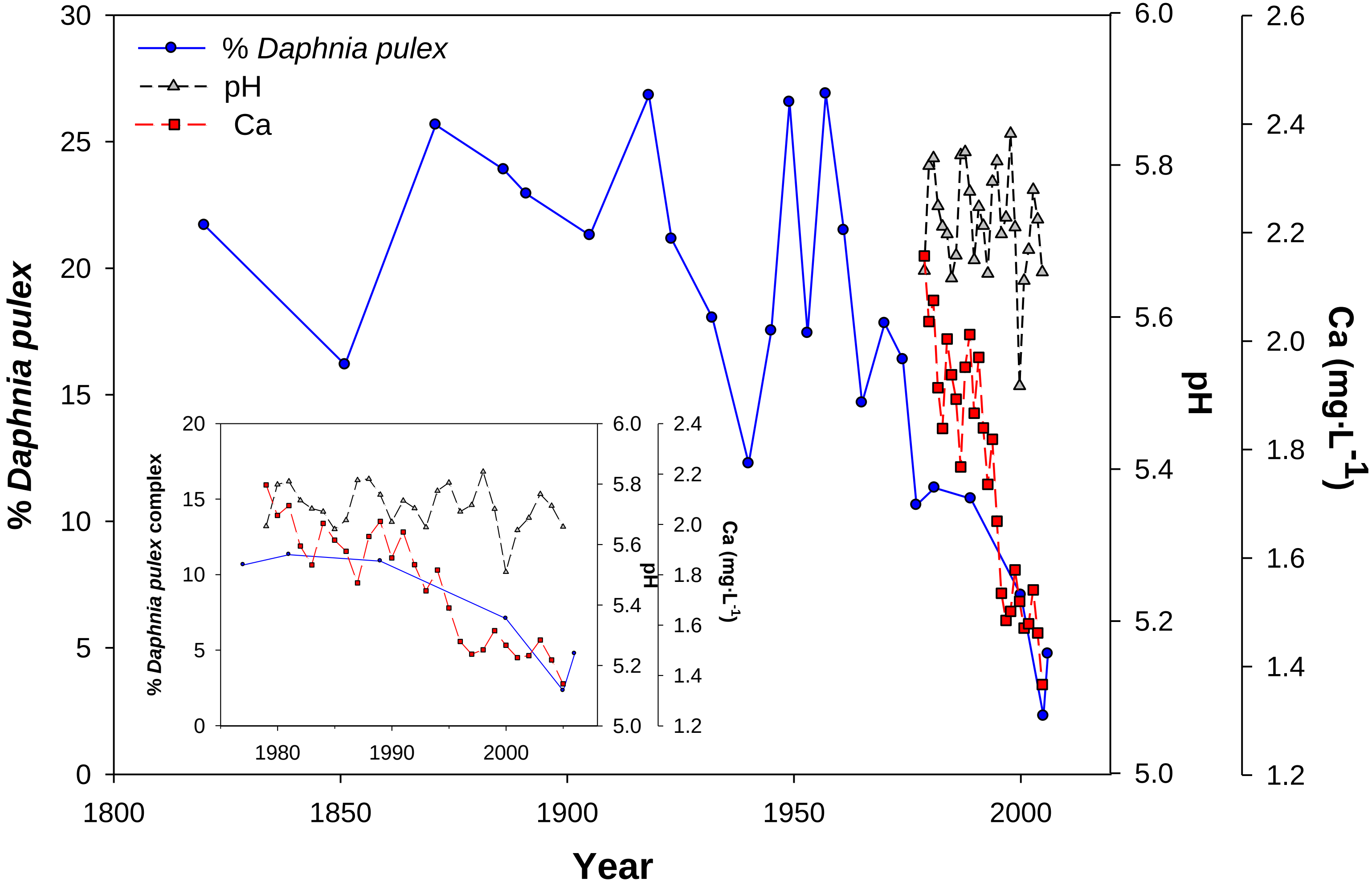
Preparing to
take a core

Retrieving
a core

Sectioning
the core

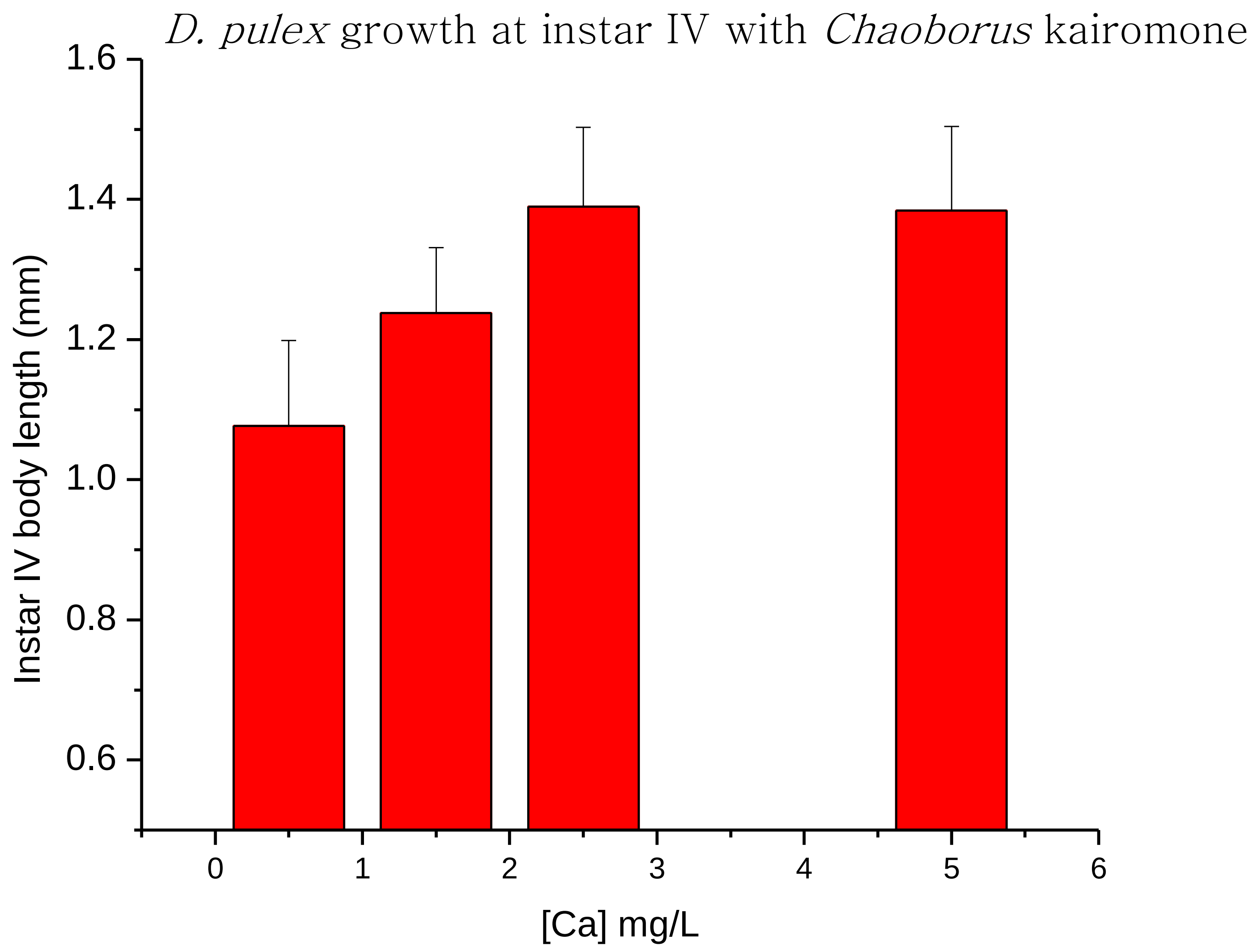
*from J. Smol website, Queen's U

Loss of *Daphnia* from Plastic Lake*



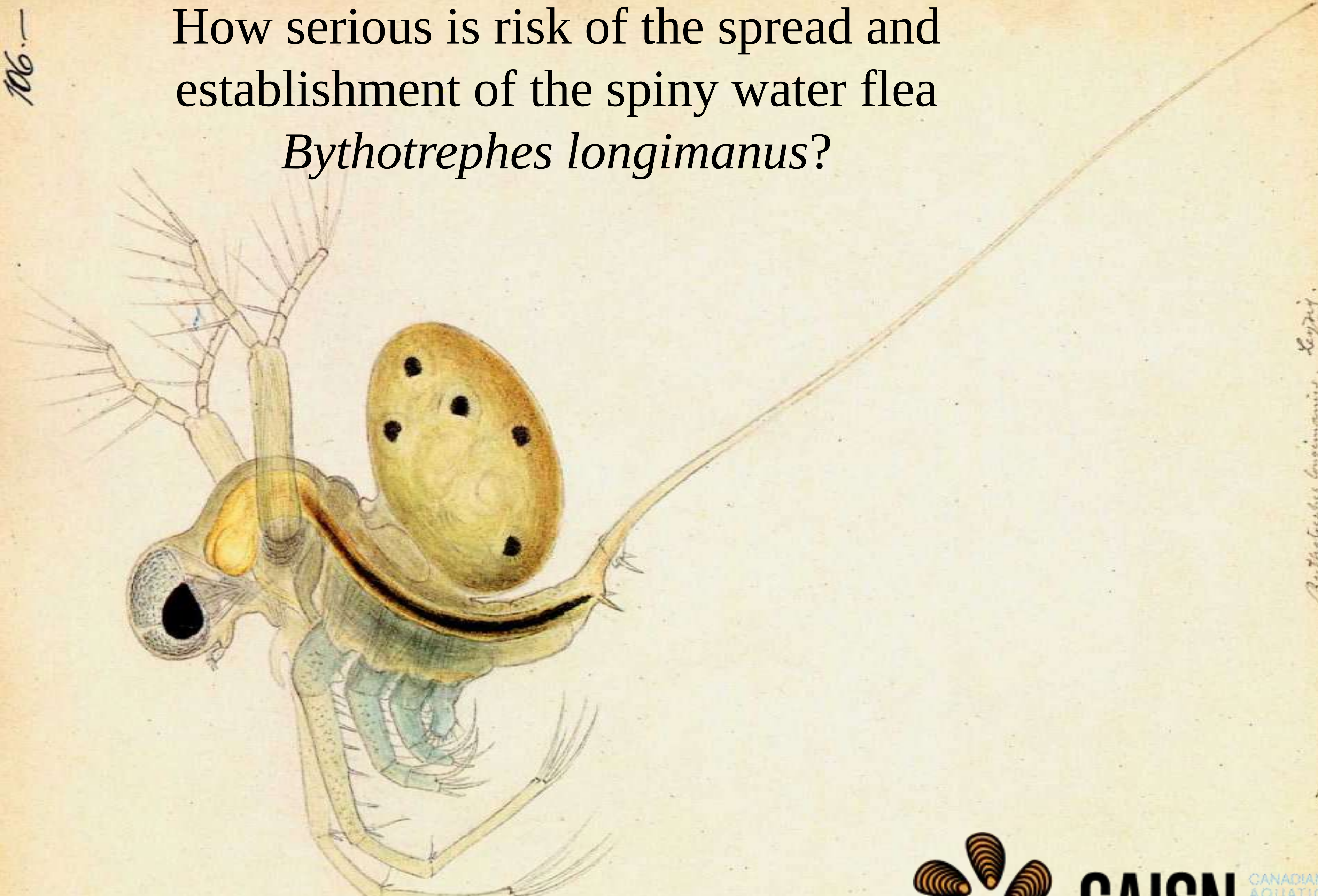
*Jeziorski, Yan, Paterson…11 others & Smol (2008)

And low Calcium is the cause. It slows daphniid growth delaying maturity



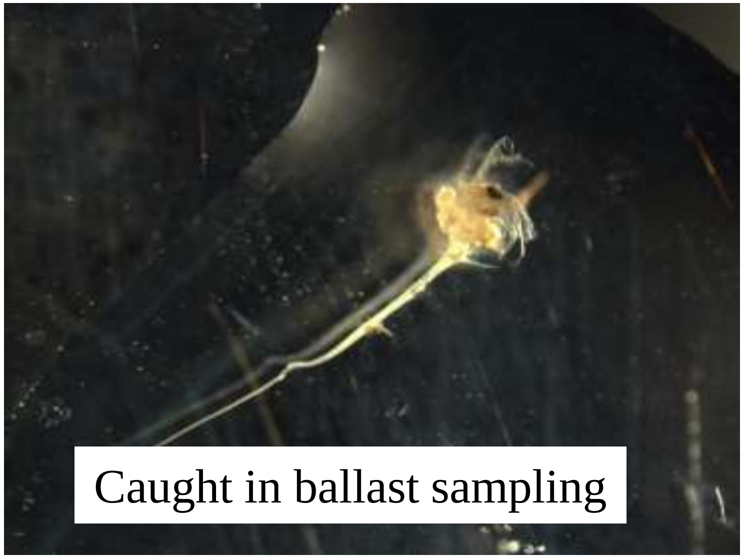
*Riessen, Linley, Altshuler and Yan (L&O, under review)

How serious is risk of the spread and establishment of the spiny water flea *Bythotrephes longimanus*?



CAISN
CANADIAN AQUATIC INVASIVE SPECIES NETWORK

A *Bythotrephes* photo gallery from N. America


Caught in ballast sampling

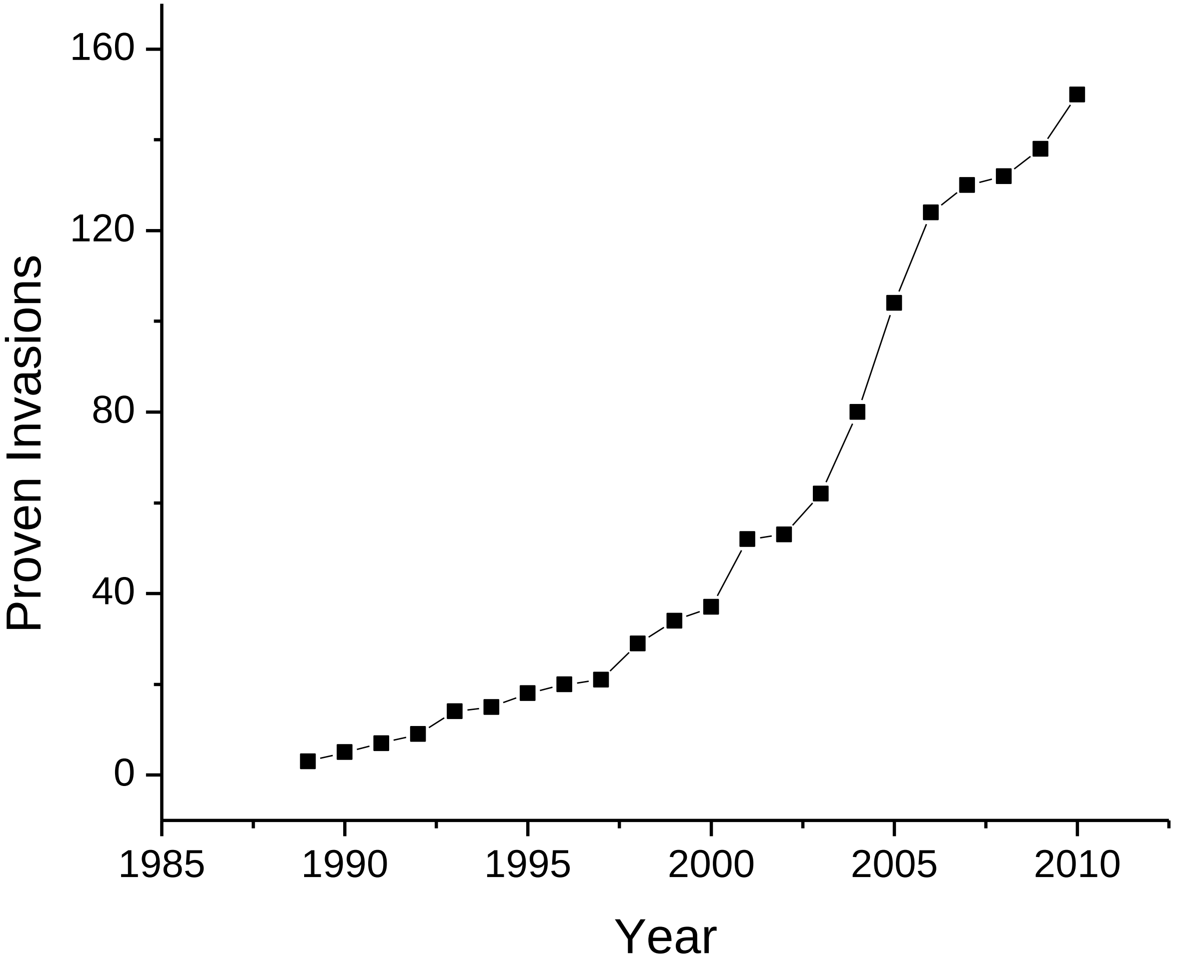

In a L. Rosseau cisco (Bev Clarke)


Laurie Wesson’s hand in Rainy River

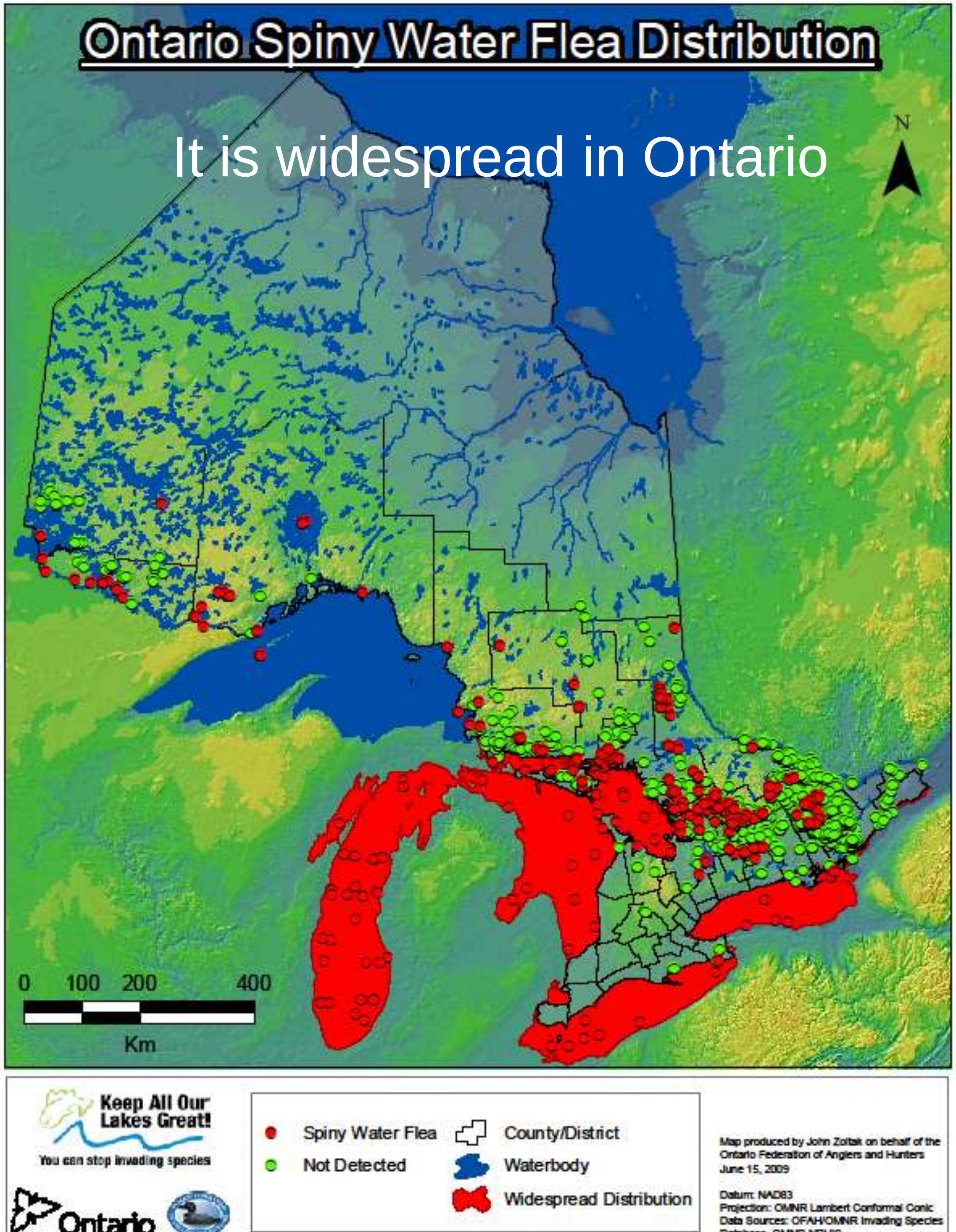

On Dave Garton’s hand


On fishing line
In L. Erie
Andrea Jaeger

It is spreading rapidly in Ontario



It is widespread in Ontario



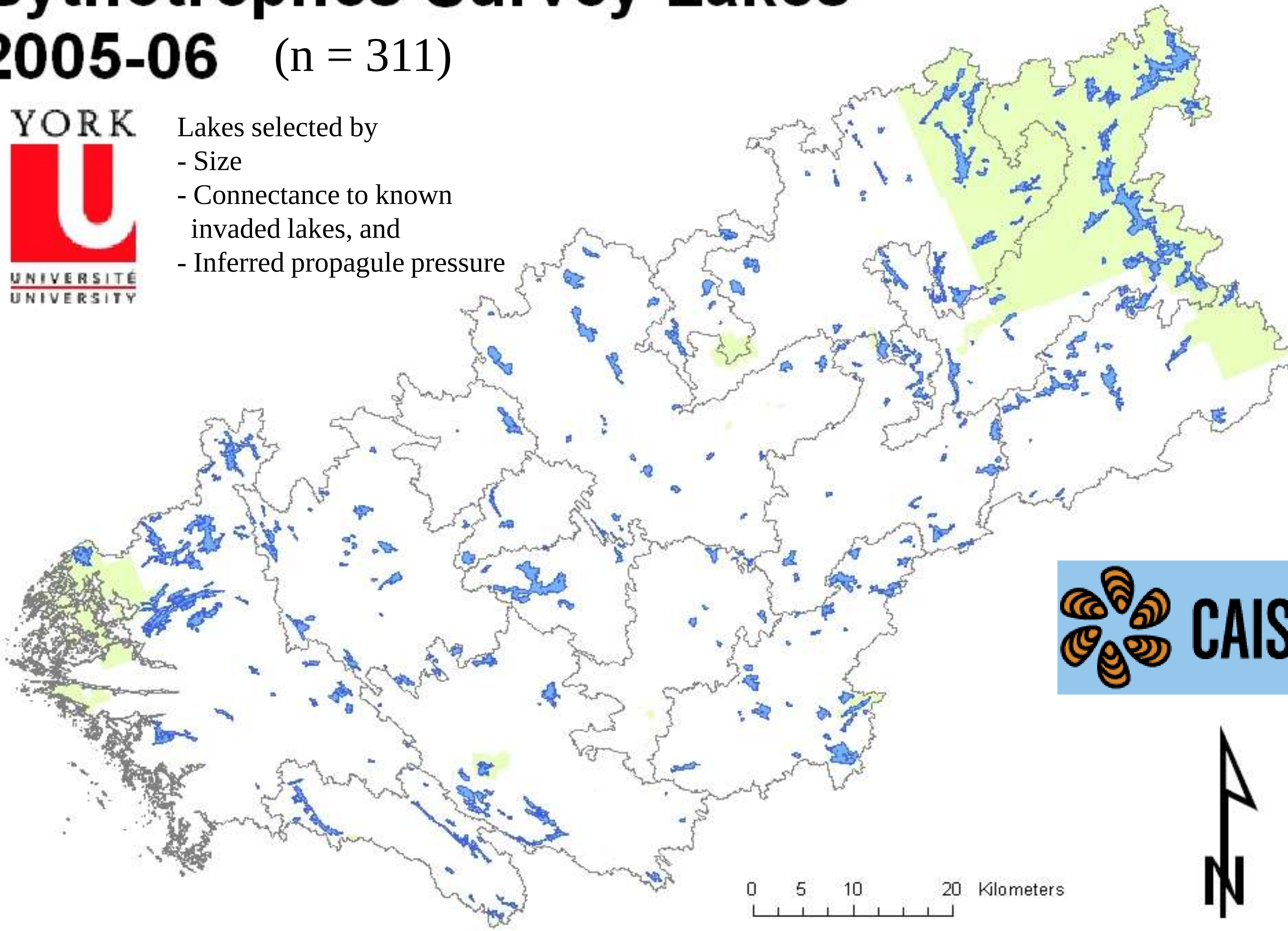
Losses of native crustacean zooplankton species richness (a measure of the value - indigenous biodiversity)

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%

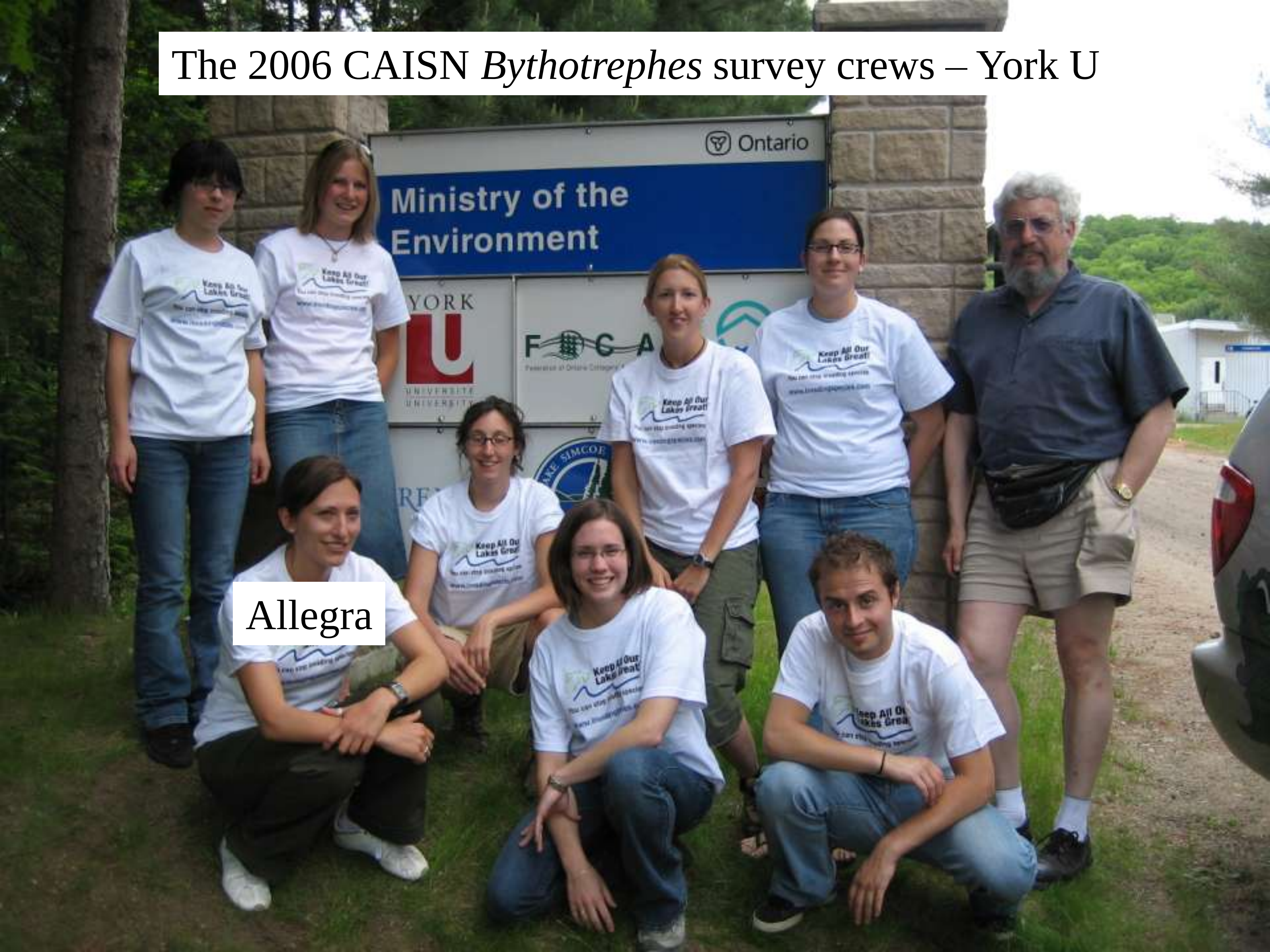
Bythotrephes Survey Lakes 2005-06 (n = 311)

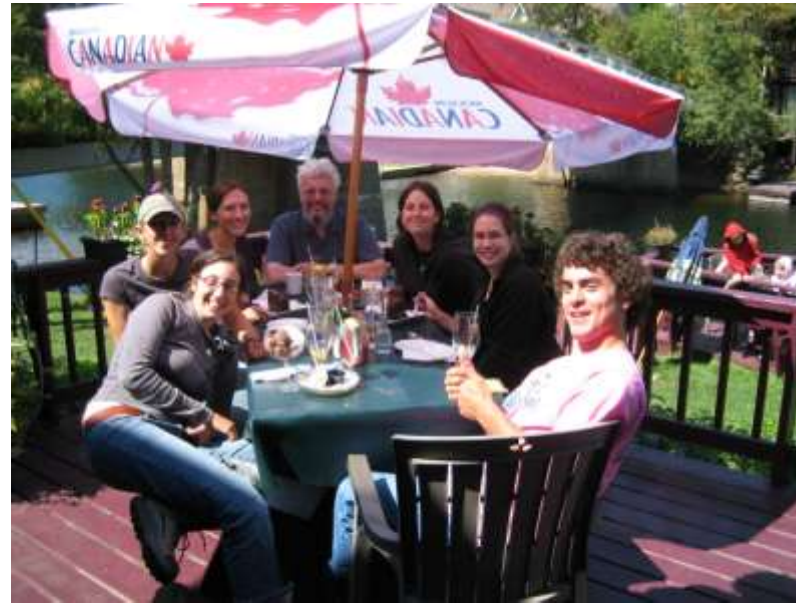
Lakes selected by
- Size
- Connectance to known invaded lakes, and
- Inferred propagule pressure



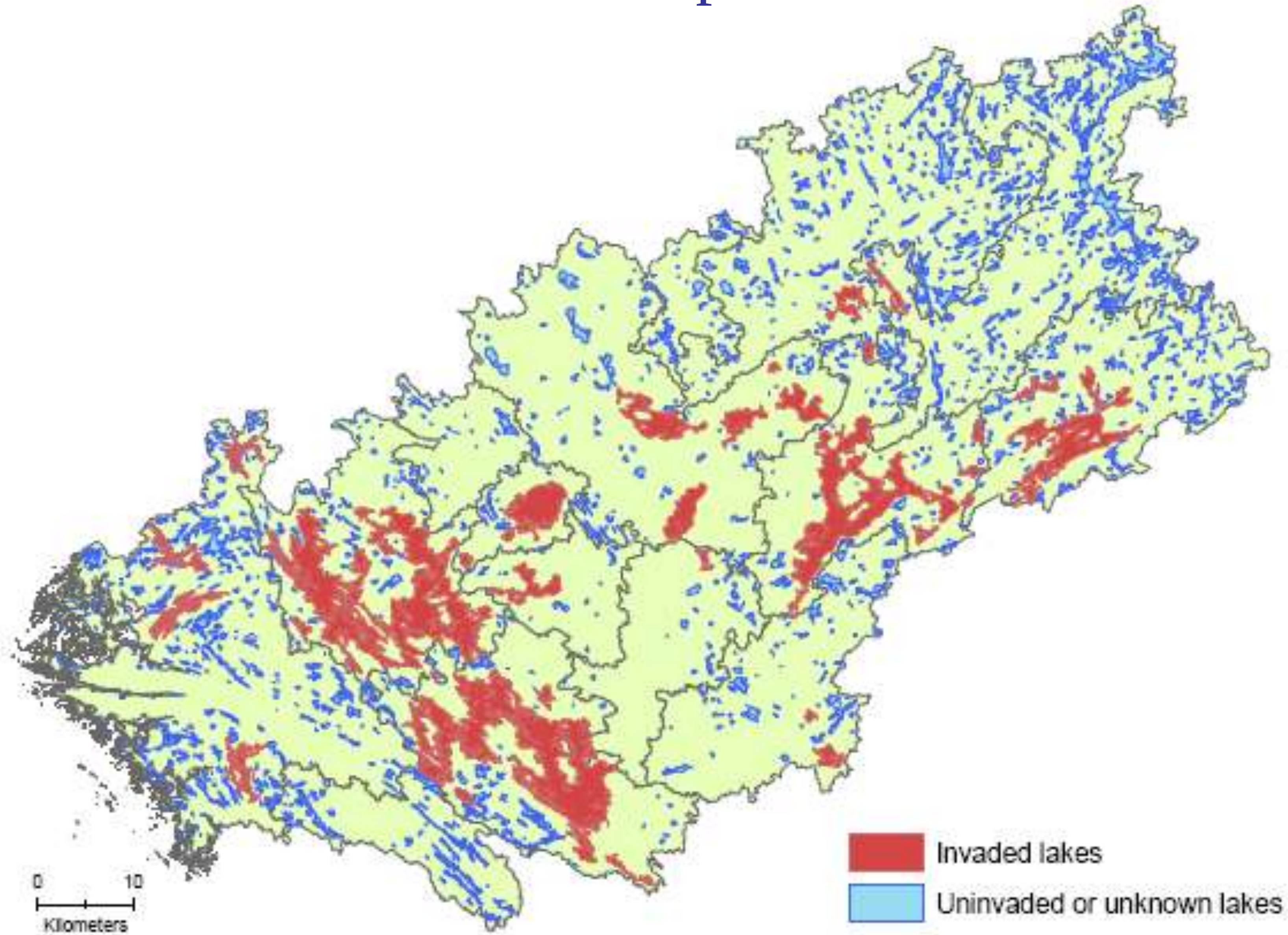
CAISN

The 2006 CAISN *Bythotrephes* survey crews – York U



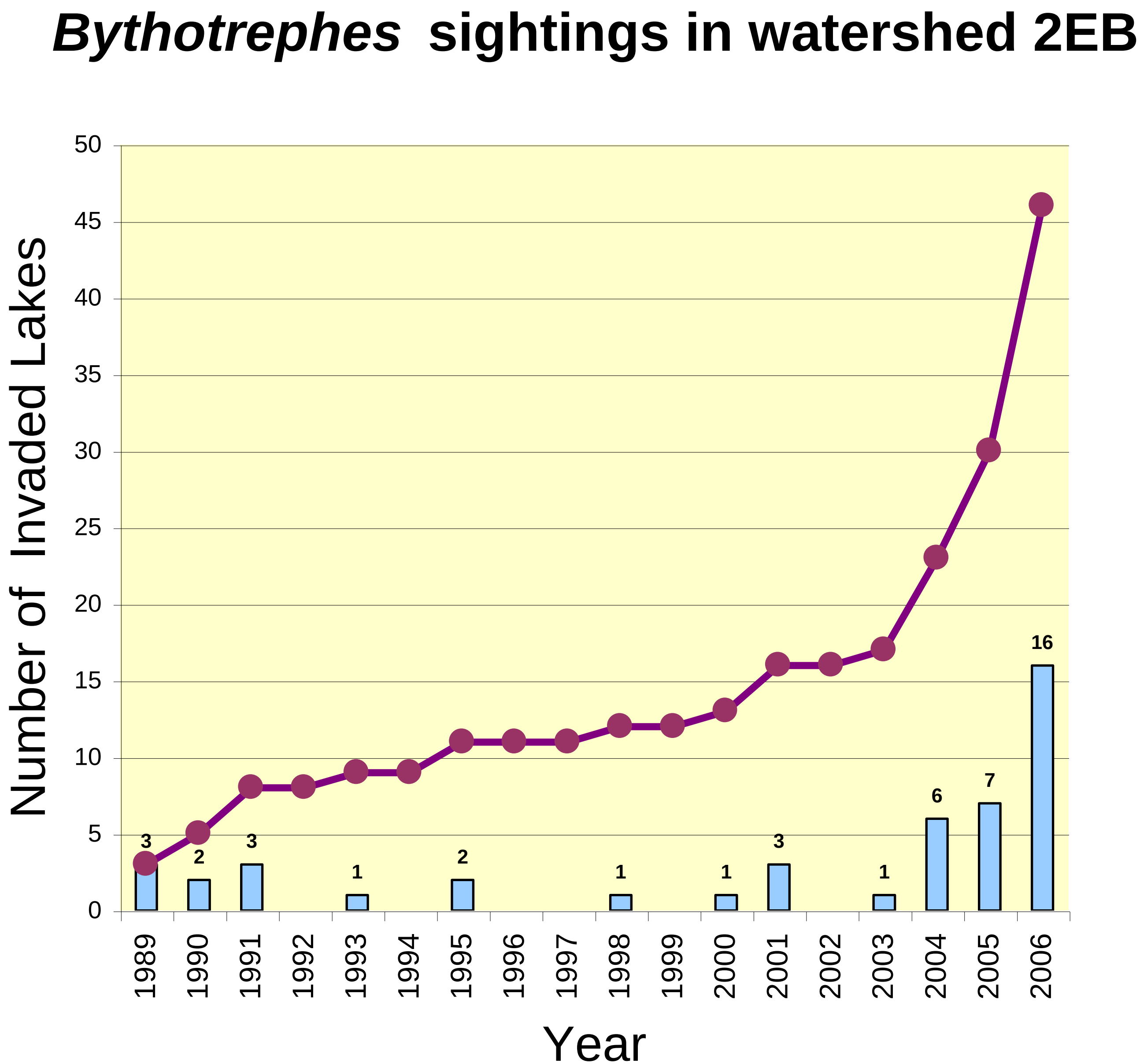

CANADIAN

The invasion is more widespread then we knew.

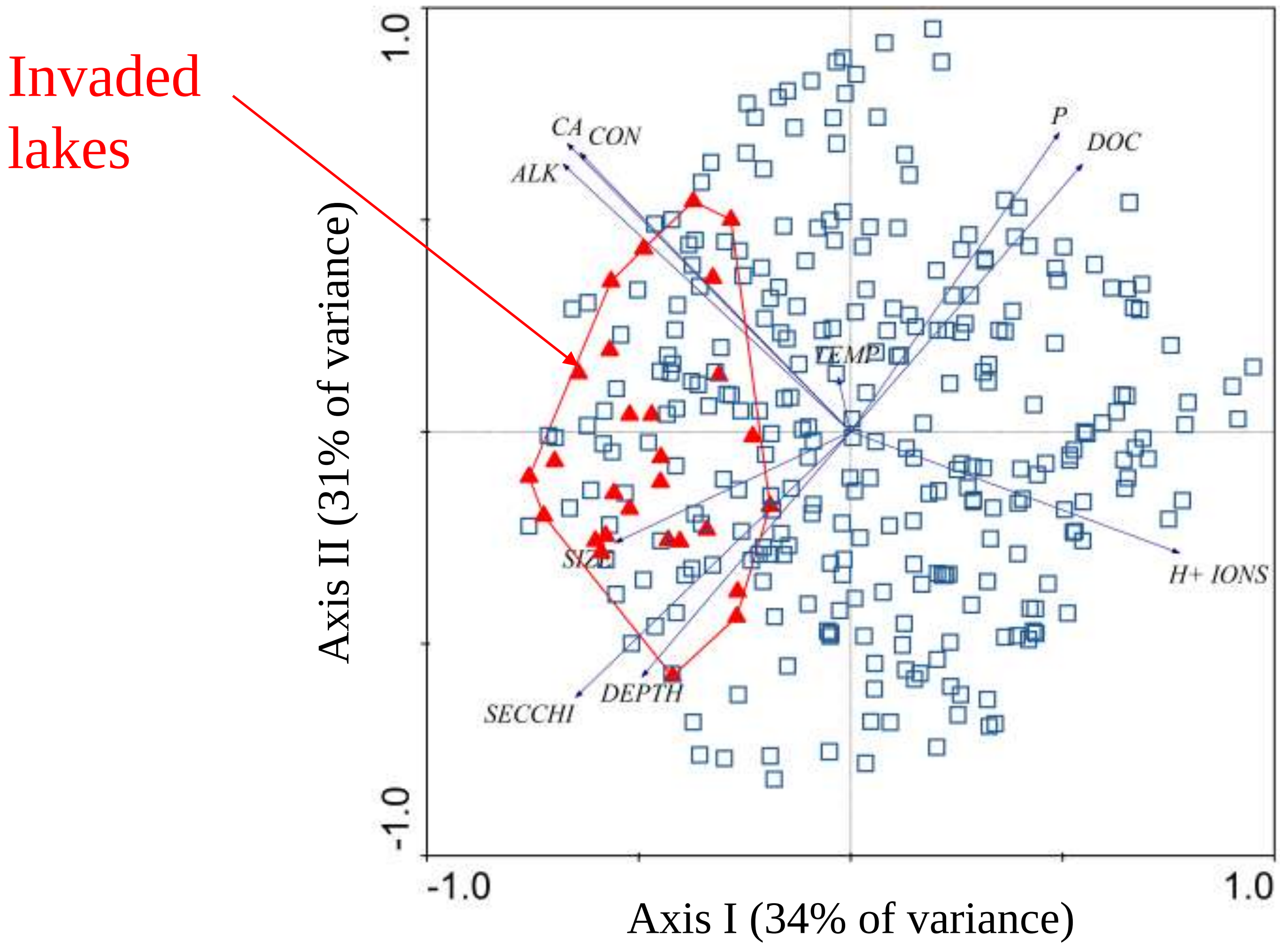


Map from Gertzen and Leung (in press)

We doubled the number of known invasions in the 1st survey

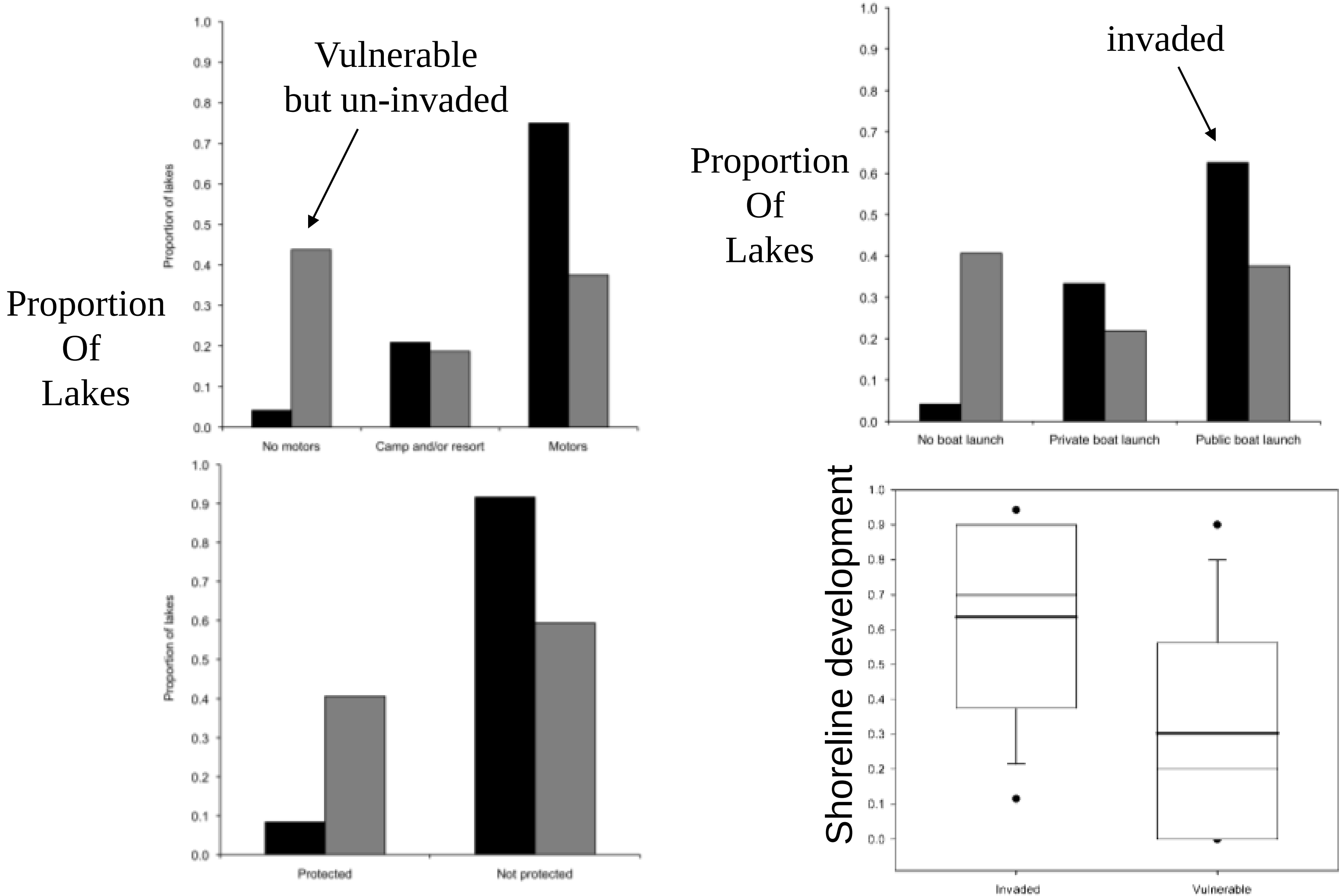


What regulates spread and establishment:
PCA on ranked physical chemistry of 311 lakes



Weisz and Yan (2010), Wang and Jackson (in press)

What separates invaded from uninvaded lakes with suitable habitat (Weisz & Yan 2010)?



What is changing in Muskoka lakes

- Water chemistry
  - Sulphate, acidity, **calcium**, salt, phosphorus, colour
- Physics
  - Precipitation, temperature
- Harvesting
  - I don't know
- Species Introductions
  - Bass, **spiny water flea**, …

So what do we do?
Norm's bold assertion

- All that is needed to solve environmental problems in a democracy is the collective **will to act**, with appropriate **knowledge** as a guide
  - The **will to act** flows from core beliefs, experience, and hopes for the future, tempered by the knowledge or perceptions of current reality
  - The **knowledge** comes from application of the scientific method
  - The will to act does <u>not</u> come solely from the knowledge

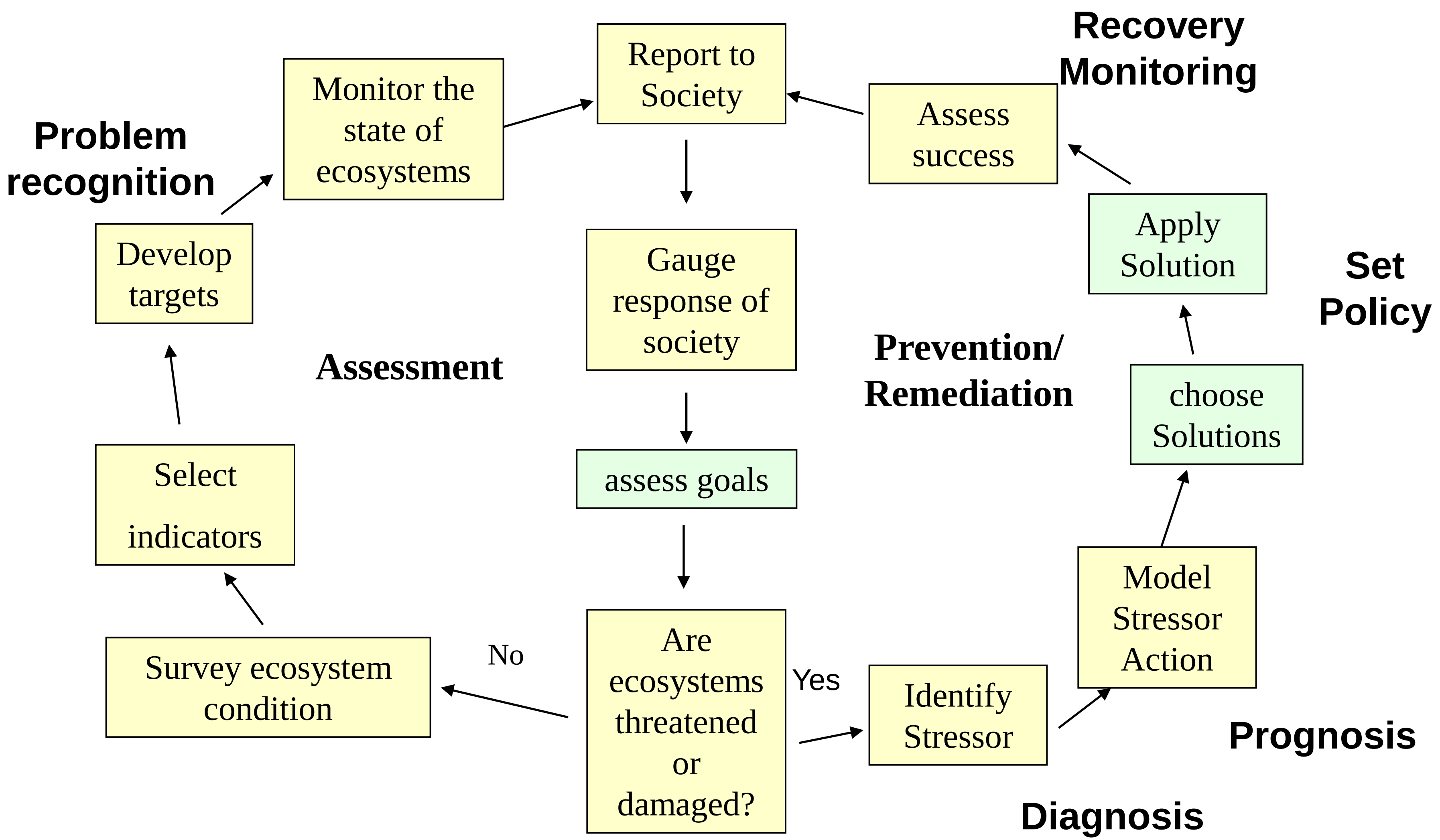
Case 1: the simplest situation

- There is societal consensus that the issue is real, and must be solved immediately.
- The problem is controllable, i.e. its causes can be identified and removed
- There is sufficient understanding to propose policies that should be effective

How do knowledge and will play out in case 1 to solve the problem?

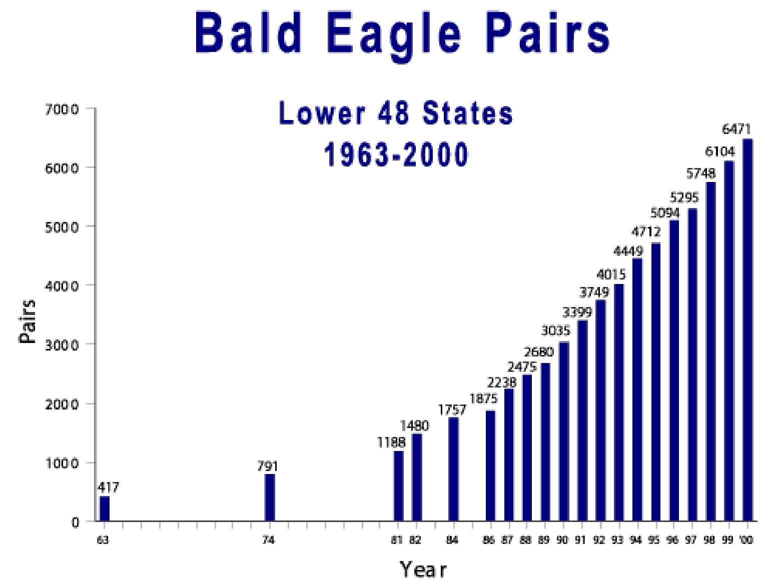
Case 1: Environmental management of "simple issues"

consensus exists, problems are understandable and controllable

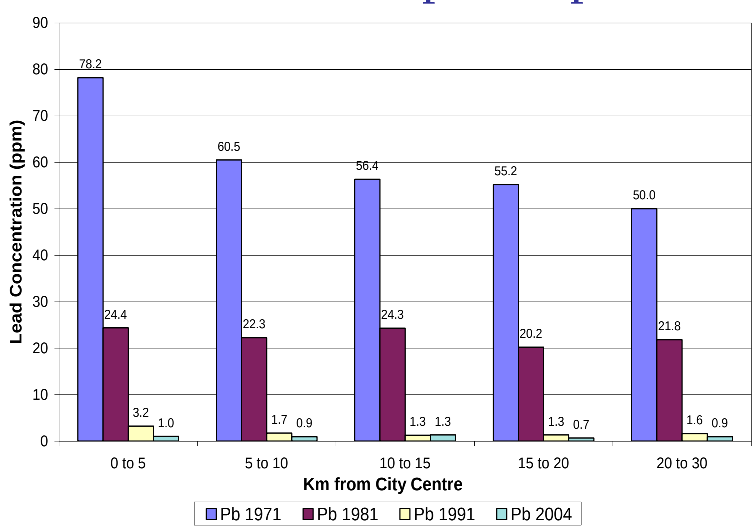


Fish have returned to Clearwater Lake

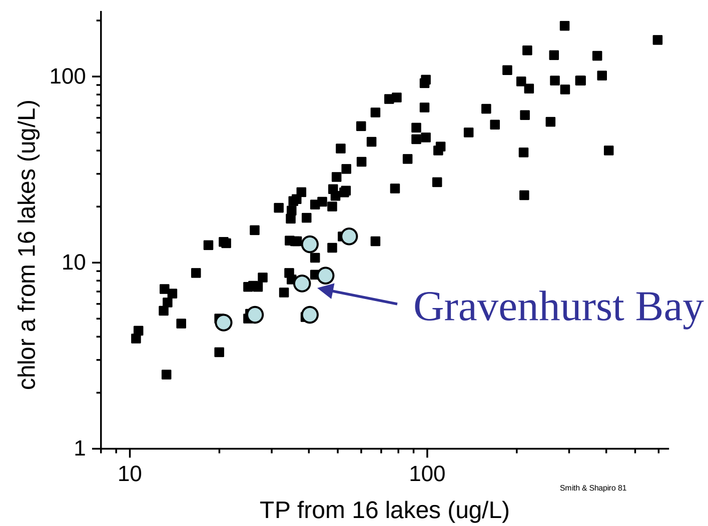
Eagles & other raptors are recovering



Lead in Toronto maples is plummeting



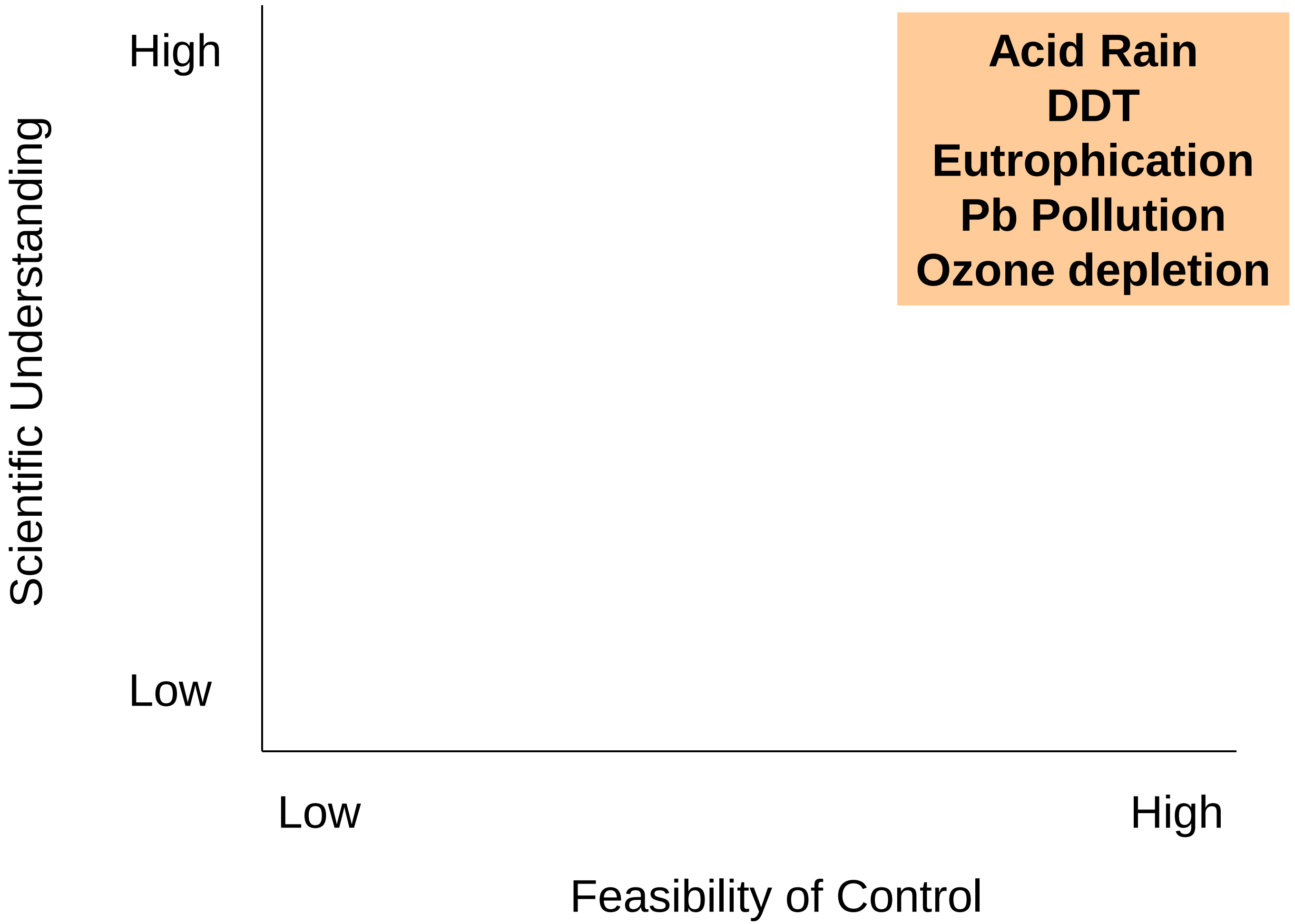
Lowering TP improves water quality



Case 1 characteristics

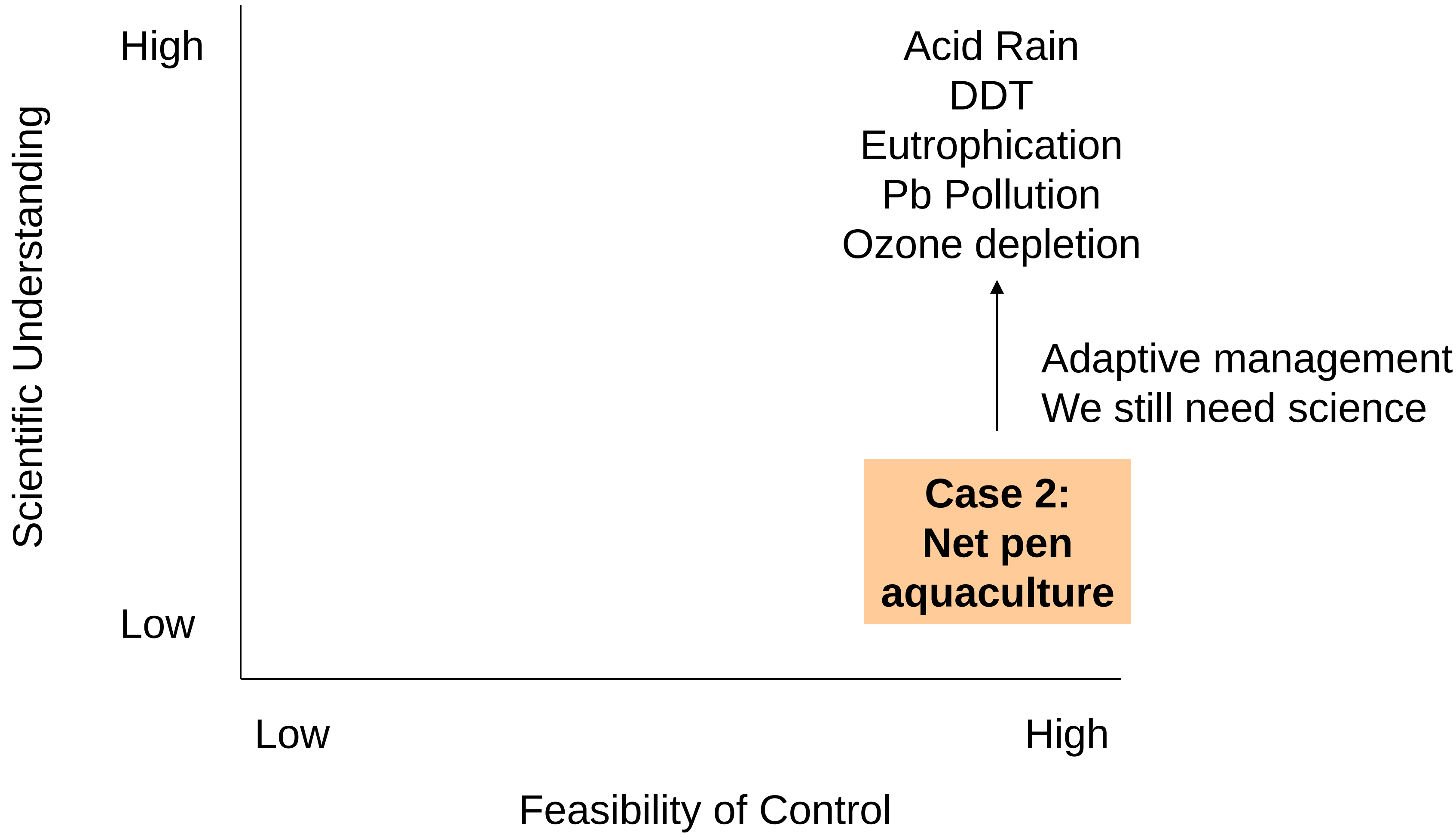
- ecosystems/resources that were valued by many
- were demonstrably damaged
- by anthropogenic causes,
- attributable to a few, well-heeled “culprits”,
- so “best-shot” dynamics applied
- leading to fairly obvious solutions.
- Because societal consensus existed, politicians instructed policy makers to act,
- Who generally instructed engineers to figure out what to do
- but it still took a decade or two to move from problem recognition to implementing preferred solutions. This was not easy.

Managing "simple" issues: Case 1



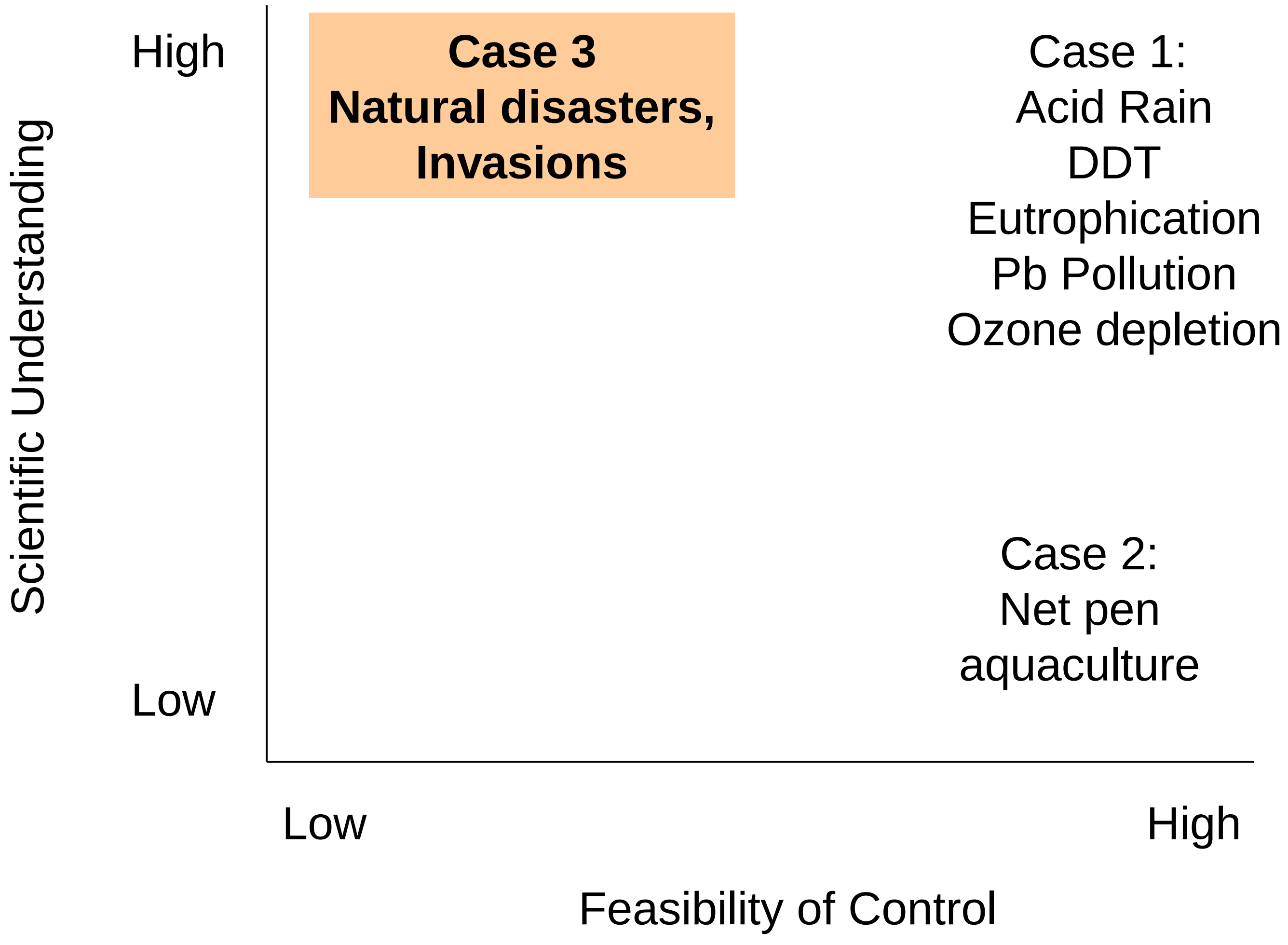
We need
Engineering
Policies
Communication,
Not science

Case 2: We have consensus, we can act, but we don't know what to do



Case 3: There is consensus, and the problem is understood, but can't be prevented

(eg. Ricciardi et al., April 2011, Bioscience)



Case 3:

How do **will** and **knowledge** play out? With consensus, the will to act is not an issue, but what policies should be implemented?*

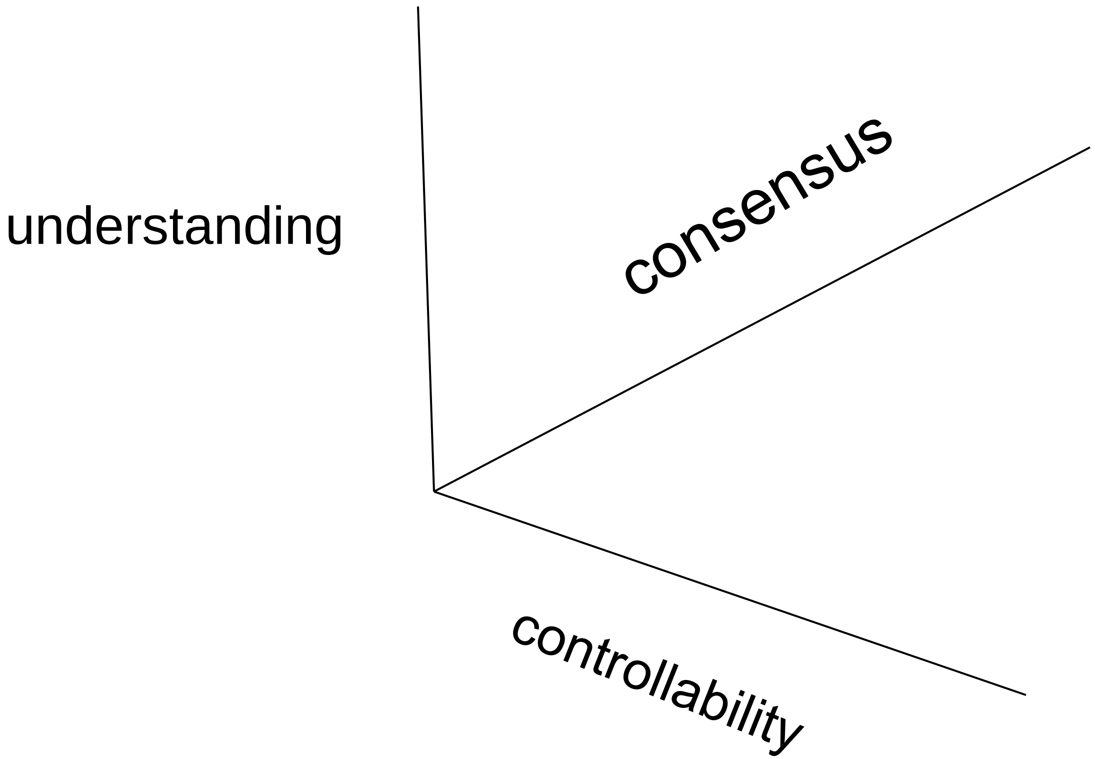
- Reduce damage with the best "band-aids" possible
  - Reduce vulnerability (manage for biodiversity)
  - Focus efforts on most vulnerable systems (we are in the process of doing this for *Bythotrephes*)
  - Develop early warning systems
  - Develop rapid assessment & response capability
  - Practise emergency preparedness
  - Ensure good coordination and reliable data access among all emergency responders
- These are very different actions than in cases 1 & 2

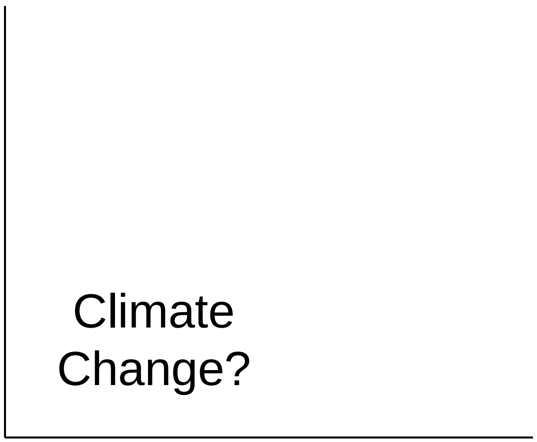
*Ricciardi et al. 2011

Calcium decline vs. *Bythotrephes*

- Case 1 vs. Case 3

But there is also a Case 4 (uncontrollable, and not understood), or perhaps a 3rd gradient
Where does climate change fit?





Case 4: What if there is effectively no consensus about the issue in society?

- There is no collective will to act
- What should environmental professionals do?
- We must building consensus, by becoming much more effective communicators

Difficulties in building consensus on climate change

- Climate change has many causes.
- There is no one culprit, in fact we are all responsible.
- There are large individual costs of the solution; hence,
- Weakest link dynamics apply.
- There are organized deniers, bent on preventing consensus;
- Hence, many politicians are not on board.
- Thus, there is inadequate societal will to act

What is the current climate change message from most scientists?

- We are predicting a dire future, and asking individuals to make costly changes in their homes and lives, when no one intended to harm the world with their actions, few have experienced any damaging symptoms yet, there is no culprit to blame, except us, and our message is one of hopelessness.
- Is there any wonder the message is ignored.

Why is our message flawed?

- Scientists rarely if ever consider beliefs, perceptions, emotions or experience in our messages, relying on facts, trends, and "sound" predictions, but
  - Beliefs matter to people, and must be addressed.
  - Perceptions matter
  - Feelings matter, so give people hope
  - Evil intentions, not bad outcomes, produce outrage so give time to intent not just outcome, in your messages
  - Experience matters, and few have experienced climate change. Find ways to make it real.
- So we need help in communicating the message
- Or we need to change the message from climate change to energy self-sufficiency

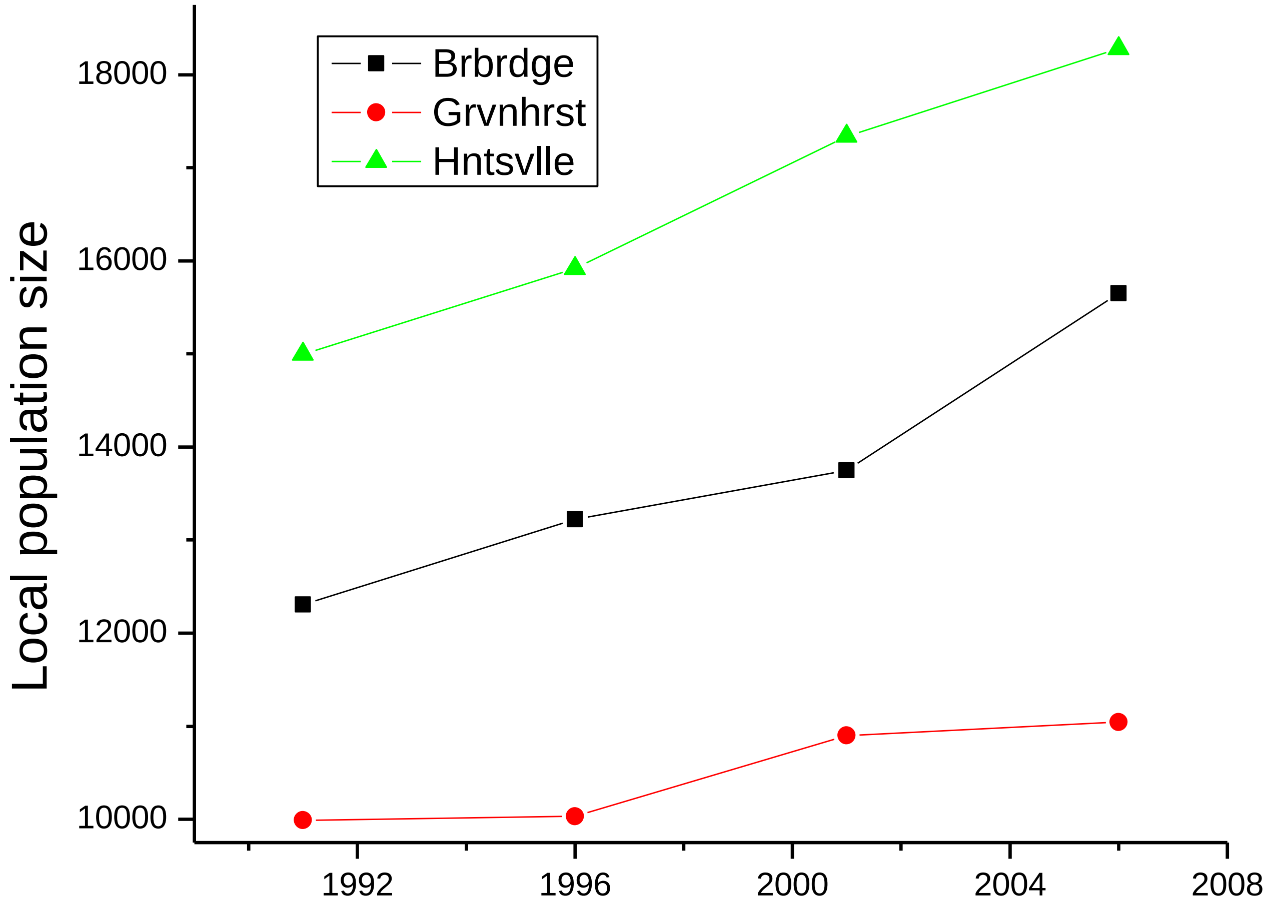
So to build consensus, we should..

- Recognize that dire forecasts published only in scientific journals do not build consensus. We must engage with society, and social scientists who have much to teach us about how people form opinions and reach decisions.
- Oppose all policies that reduce the free flow of knowledge
- Communicate better:
  - Un-muzzle government scientists
  - Break out of our academic silos
  - Move beyond dire predictions to offering hope & solutions
  - Become "honest advocates" of our knowledge to the public, policy makers and politicians.
  - Perhaps change the message entirely to one of energy self-suffiency

And in Muskoka, we should

- Think more holistically, of entire watersheds, not the forests or the lakes
- Place our known stressors in the understanding - controllability continuum to spur appropriate action
- Put our (competing) assumptions, beliefs and, especially our values on the table for all to see. Only then can common ground be found
- Take ownership! It's not MOE's or MNR's problem, it's ours
- Make longer-term plans
- Help our universities create a Muskoka environmental research chair with a clear mandate to improve understanding and recommend solutions to our local multiple stressors

Recognize our problems won't go away



And remember, in the words of Richard Outram*, that "the cardinal human values are humility and hope".

Acknowledgements

- Judi for the invitation
- NSERC, CAISN, the District of Muskoka, and Watershed Council for support
- My colleagues at the DESC, McGill and Queen's for years of fabulous interactions
- My York students, especially Michelle Palmer, Stephanie Hung, Erika Weisz, Allegra Cairns, Dallas Linley & Martha Celis for discussions and material for the talk