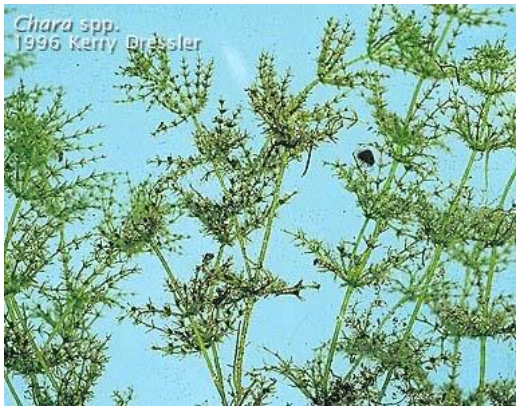
The threat of Calcium (Ca) decline for the life in Muskoka (& Haliburton) lakes

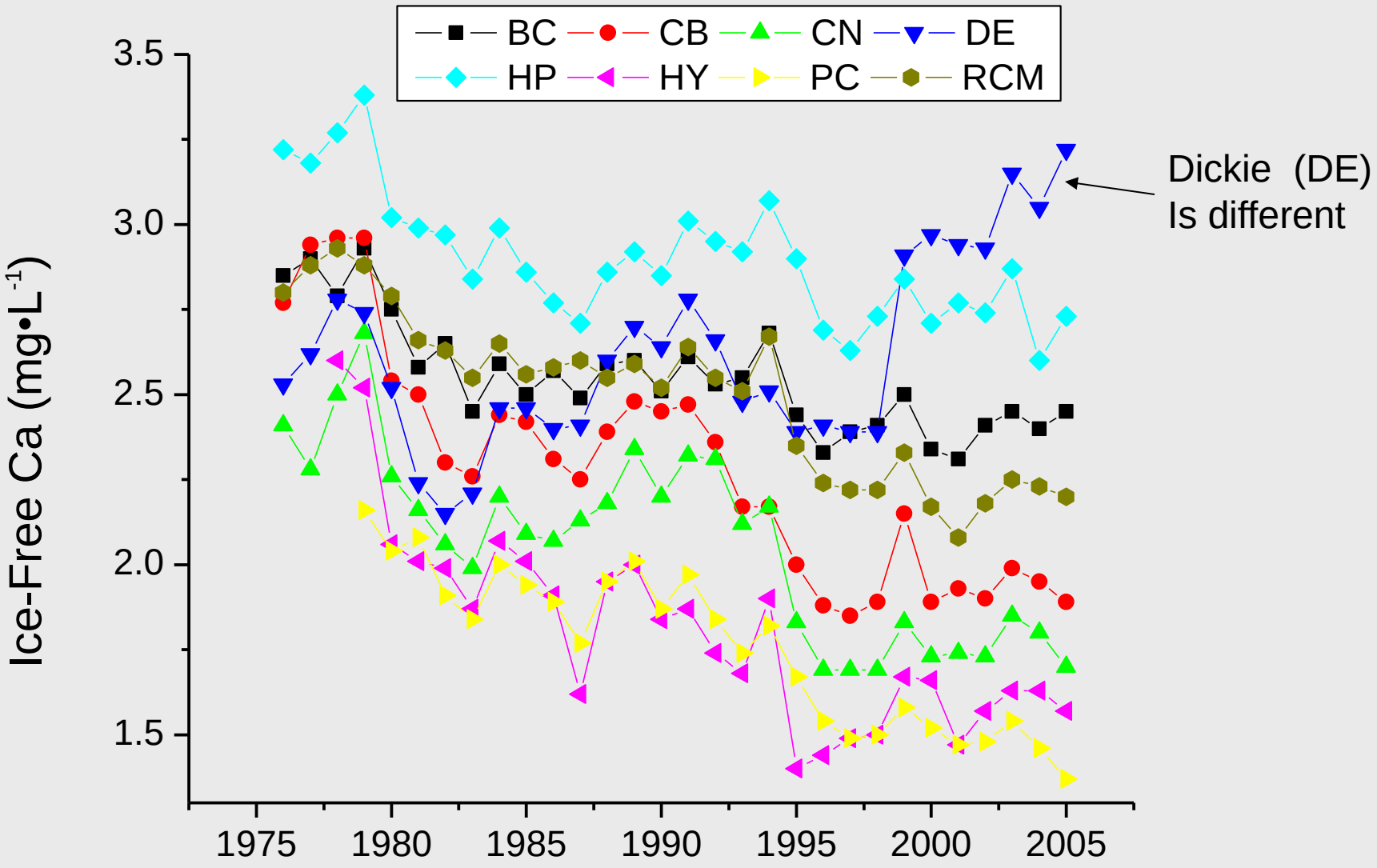
by Norman Yan, York University



My objectives

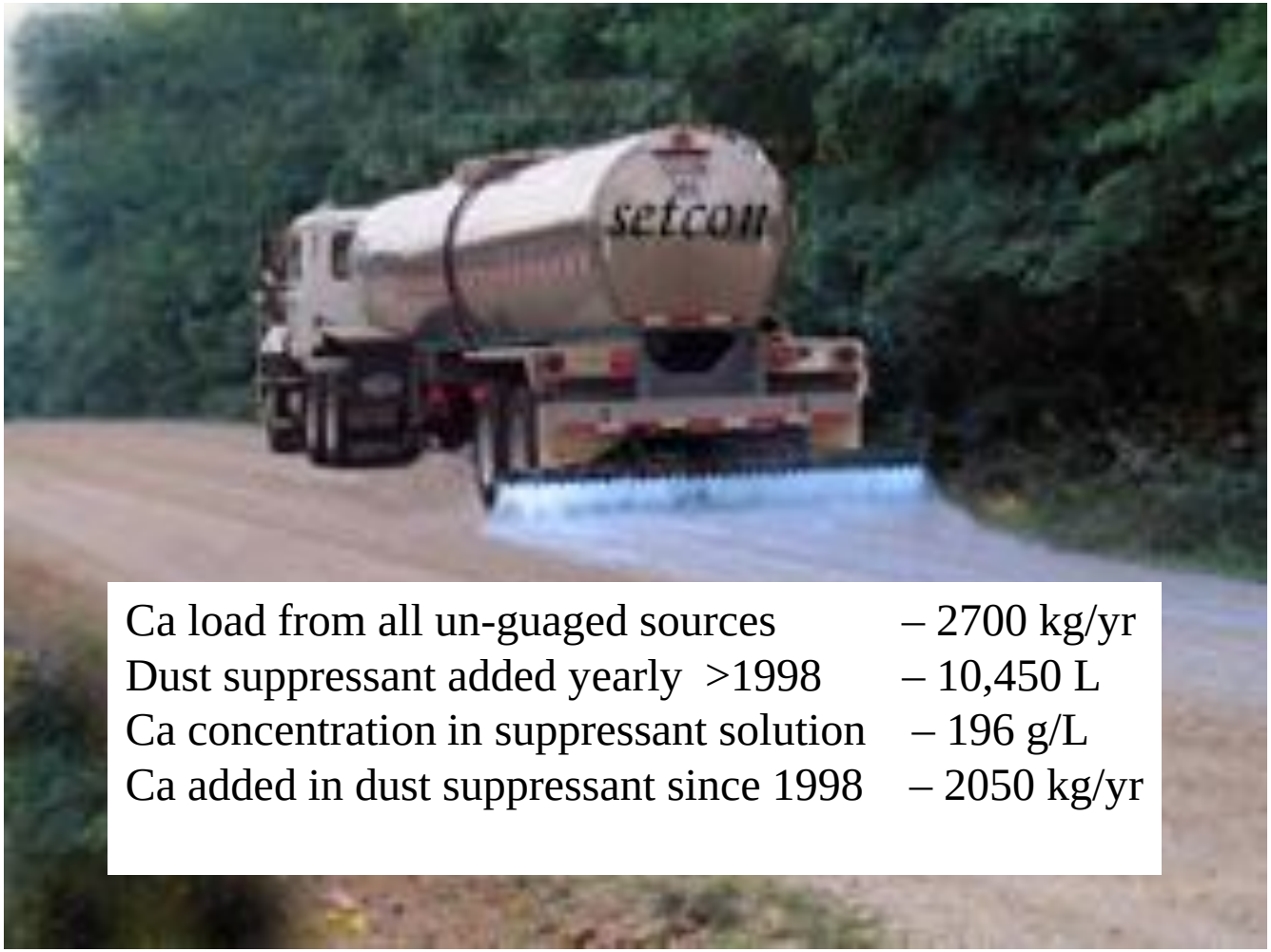
1. Briefly review evidence for and causes of environmental Calcium (Ca) decline, with its link to acidification and logging
2. Determine if Ca has fallen enough to damage aquatic life, using my “little living lawnmowers” (animal plankton) as miner’s canaries
3. Consider the long-term implications of Ca decline and what we can do about it.

Calcium (Ca) decline in 7 of 8 Dorset lakes*



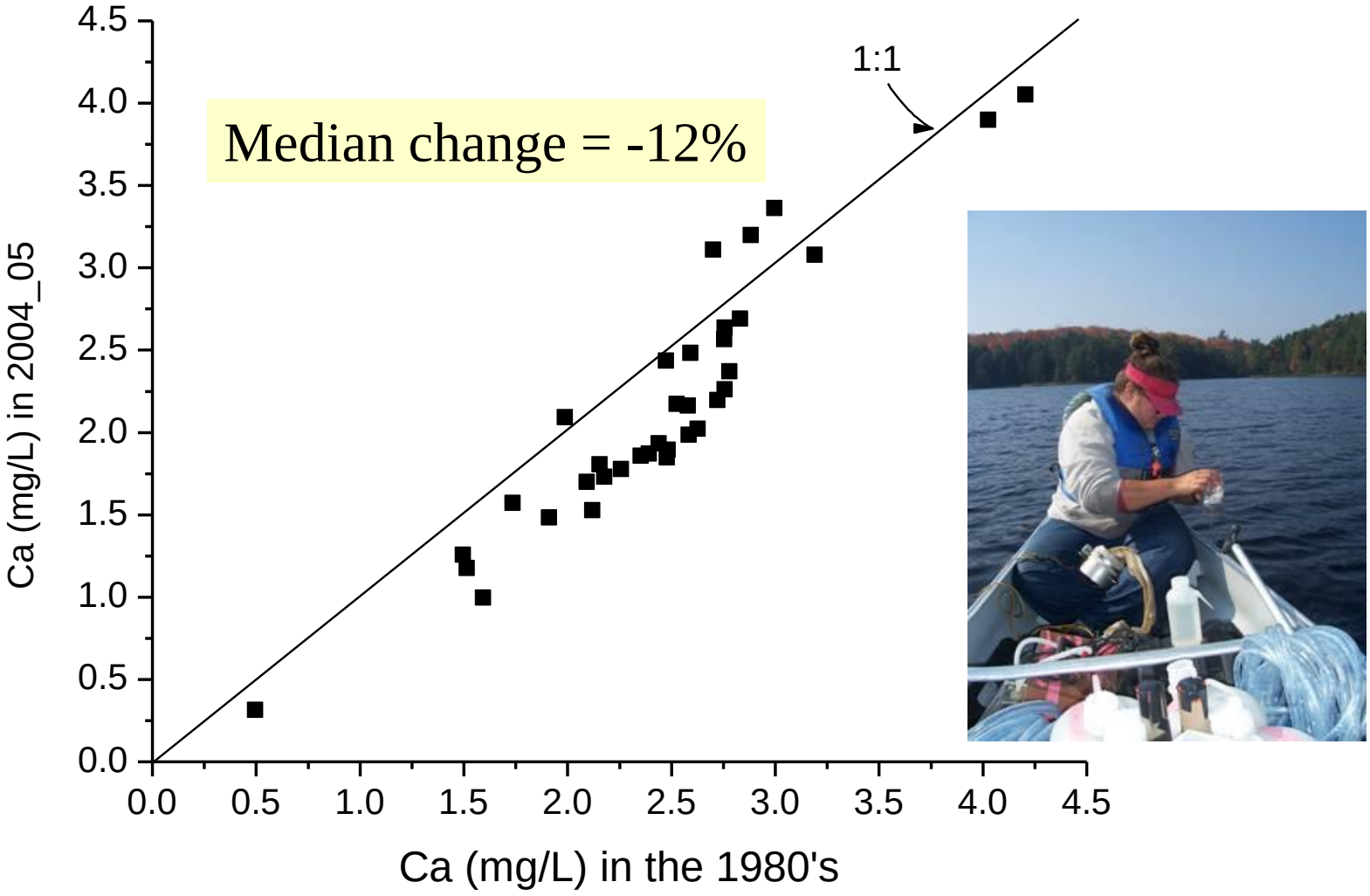
*Molot and Dillon 2008, Yan et al. 2008, (Dorset Special Issue of CJFAS, May 2008)

Why are calcium levels rising in Dickie Lake?



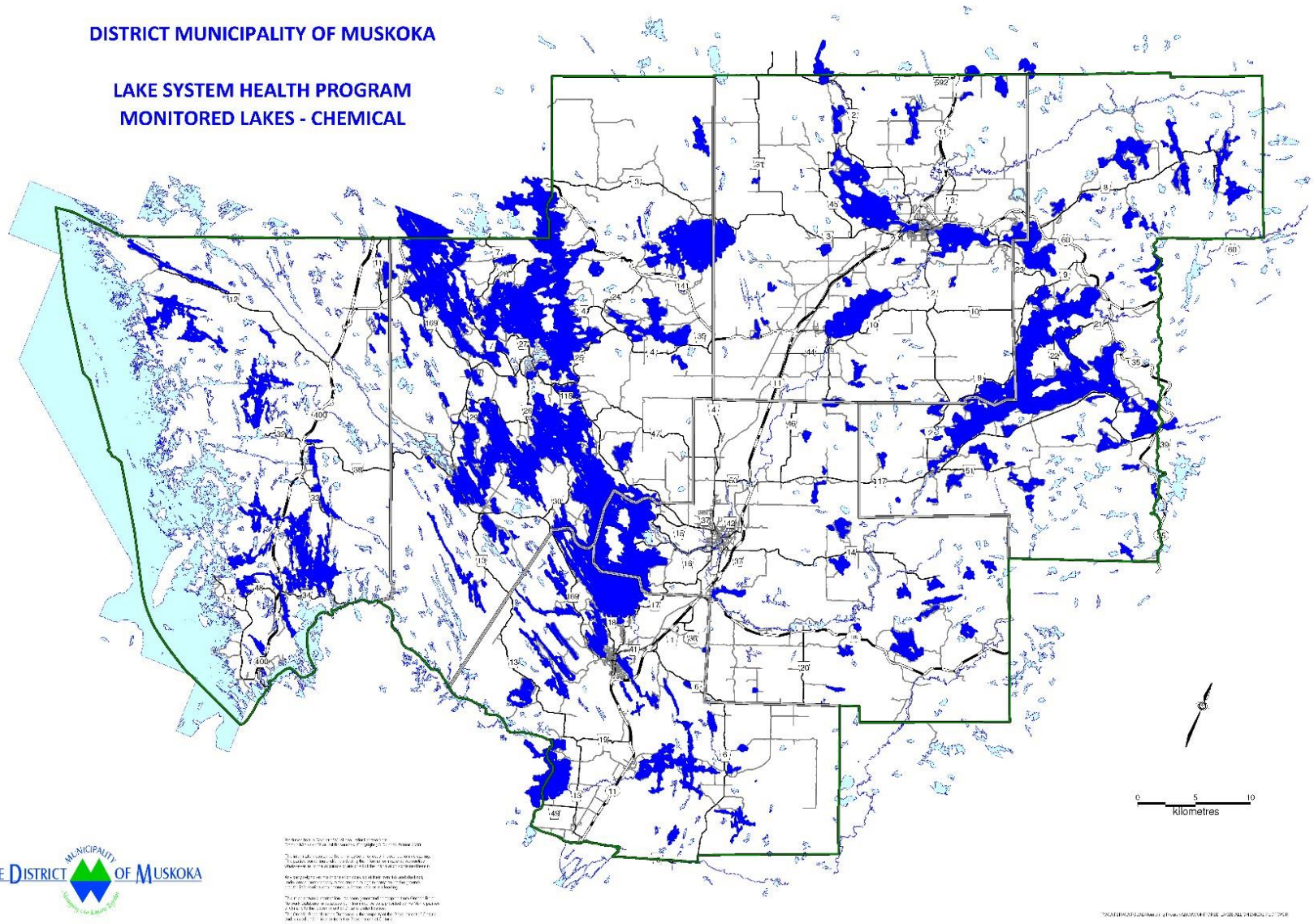
Ca load from all un-guaged sources	– 2700 kg/yr
Dust suppressant added yearly >1998	– 10,450 L
Ca concentration in suppressant solution	– 196 g/L
Ca added in dust suppressant since 1998	– 2050 kg/yr

Ca decline in 37 Muskoka/Haliburton lakes*

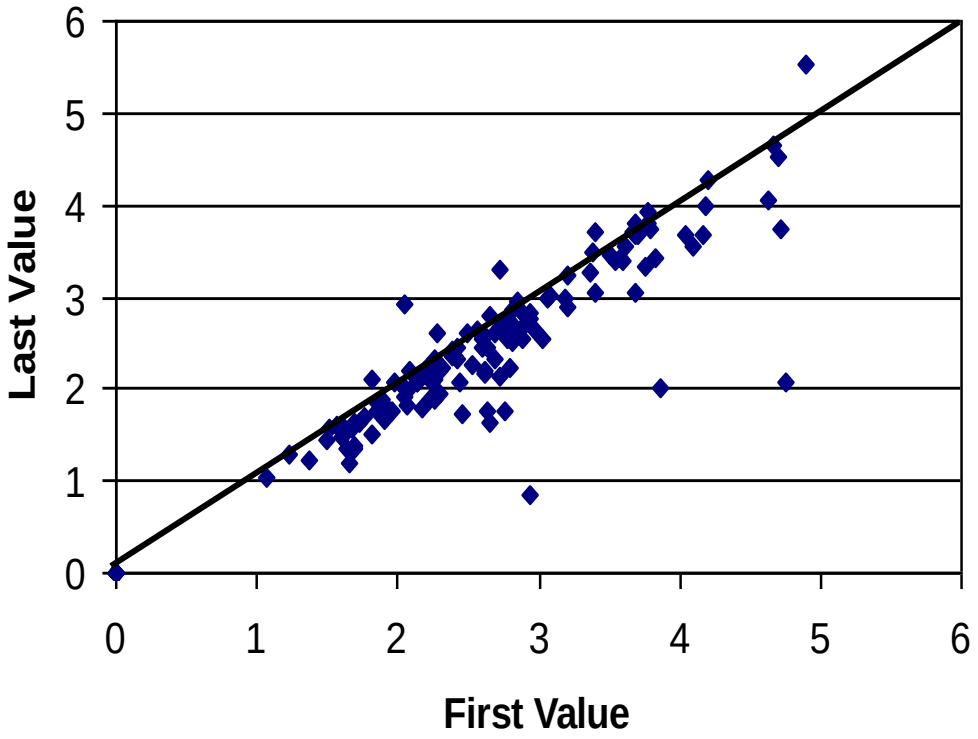


*Michelle Palmer's PhD vs. old DESC data

Muskoka's Recreational Water Quality Monitoring Program



Is Ca changing across the District?

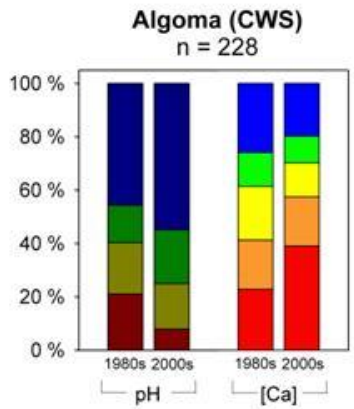


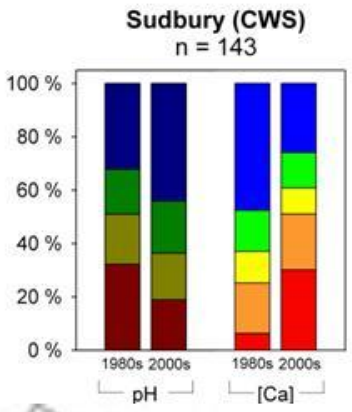
Calcium (<5 mg/l)

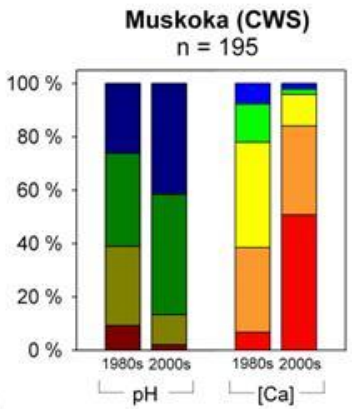
First Value – 2004-6
Last Value – 2007-9

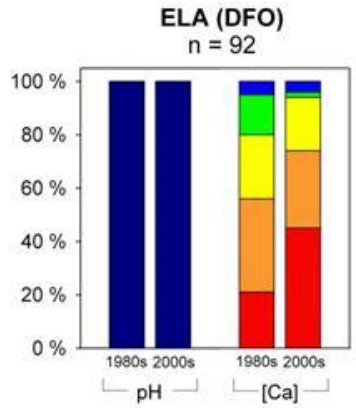
r = 0.926
Intercept = 0 (Yes)
Slope = 1 (No <1)

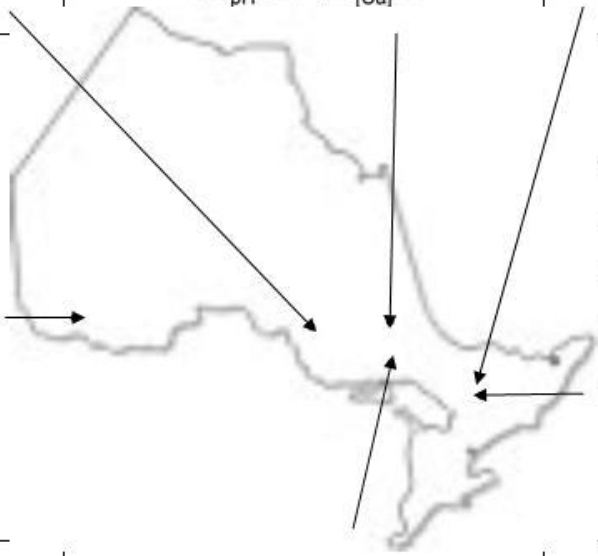
Ca has fallen between the two time periods in 90% of the low Ca lakes

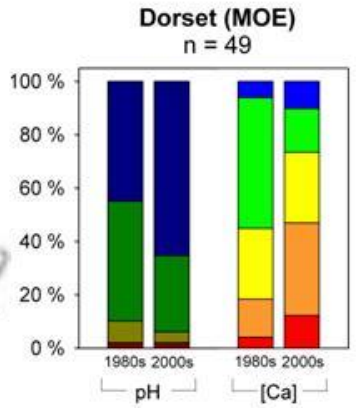


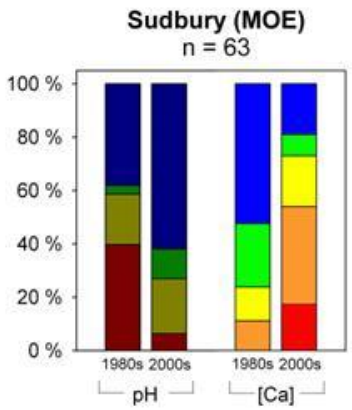


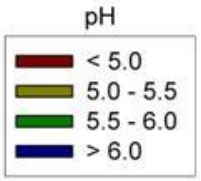


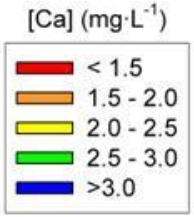








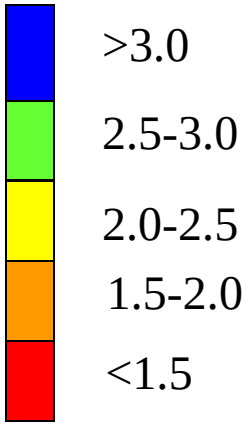




Jeziorski et al. (2008)
Science 322: 1374

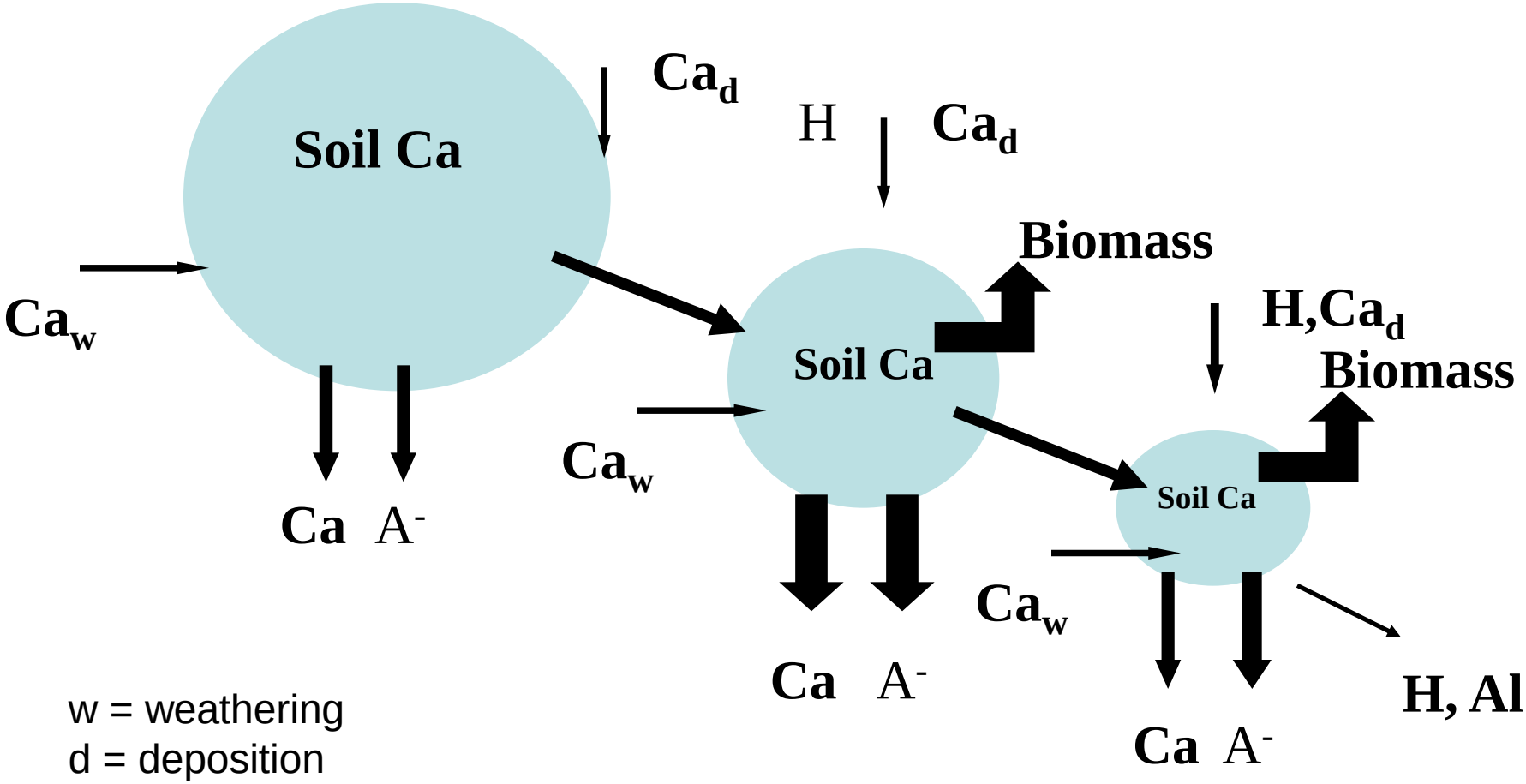
<u>Data Providers</u>
Keller (MOE)
Paterson (MOE)
Palmer (York)
Jeffries (EC)
Turner (ELA)
Weeber &
McNicoll (CWS)

Ca mg.L^{-1}



Why is lake water calcium (Ca) falling?

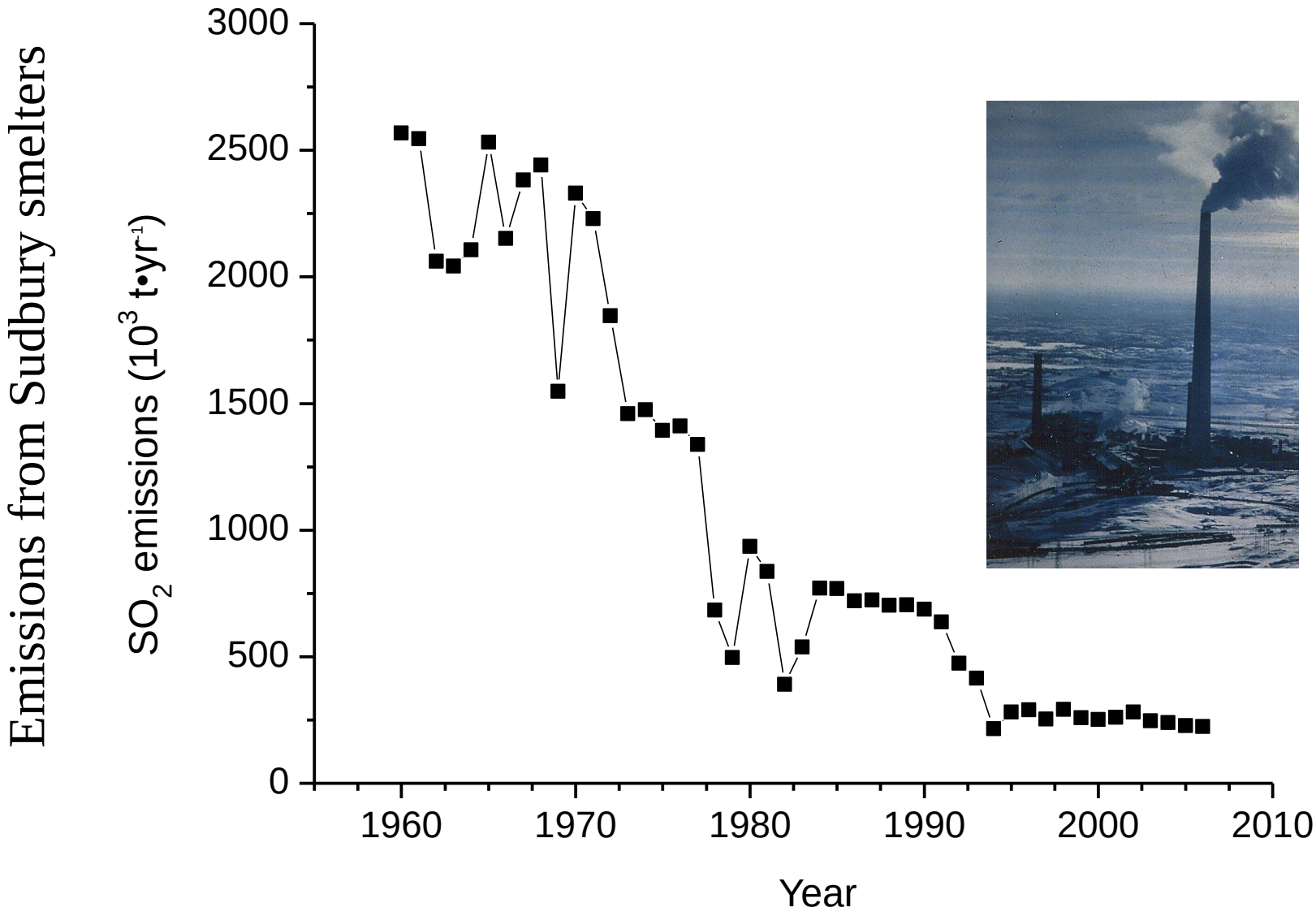
Acid rain and logging/afforestation are depleting soil Ca



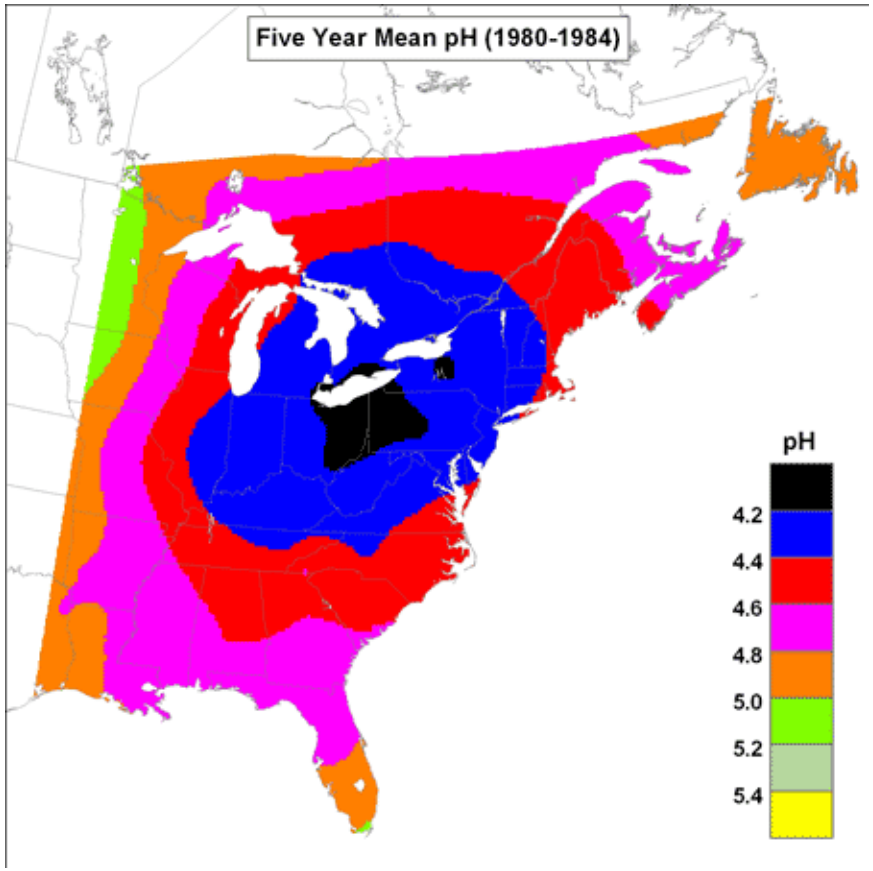
w = weathering
d = deposition
A^- = anions
Biomass – tree mass
Al - aluminum

Thanks to Shaun Watmough, Trent U

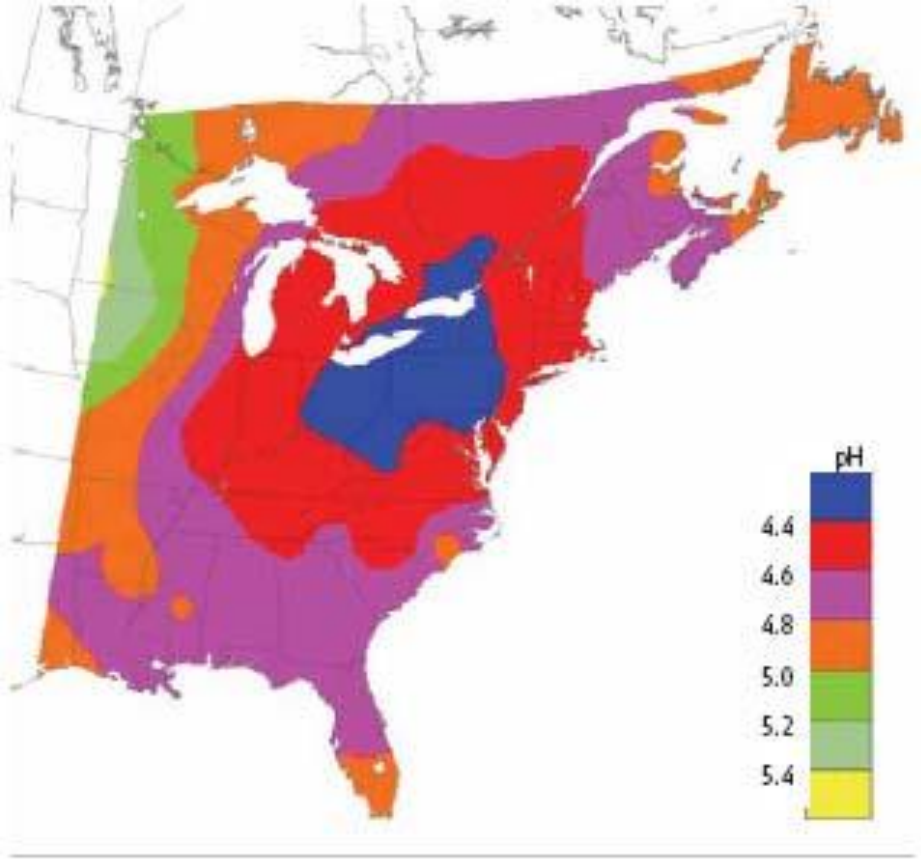
SO_2 emissions have been reduced by 55% from 1980 levels in Canada, and by 40% in the USA



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



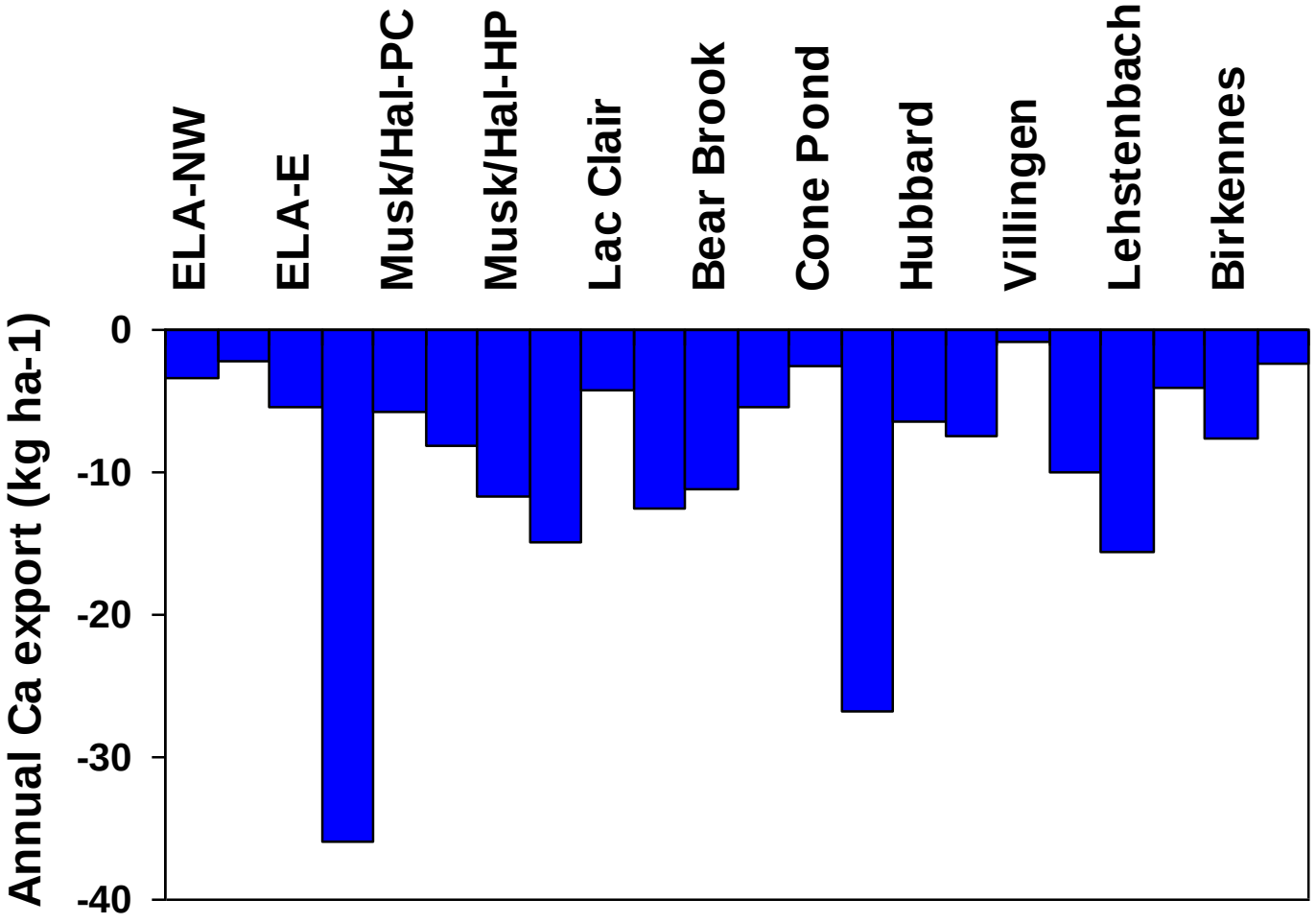
1980-1984



2000-2004

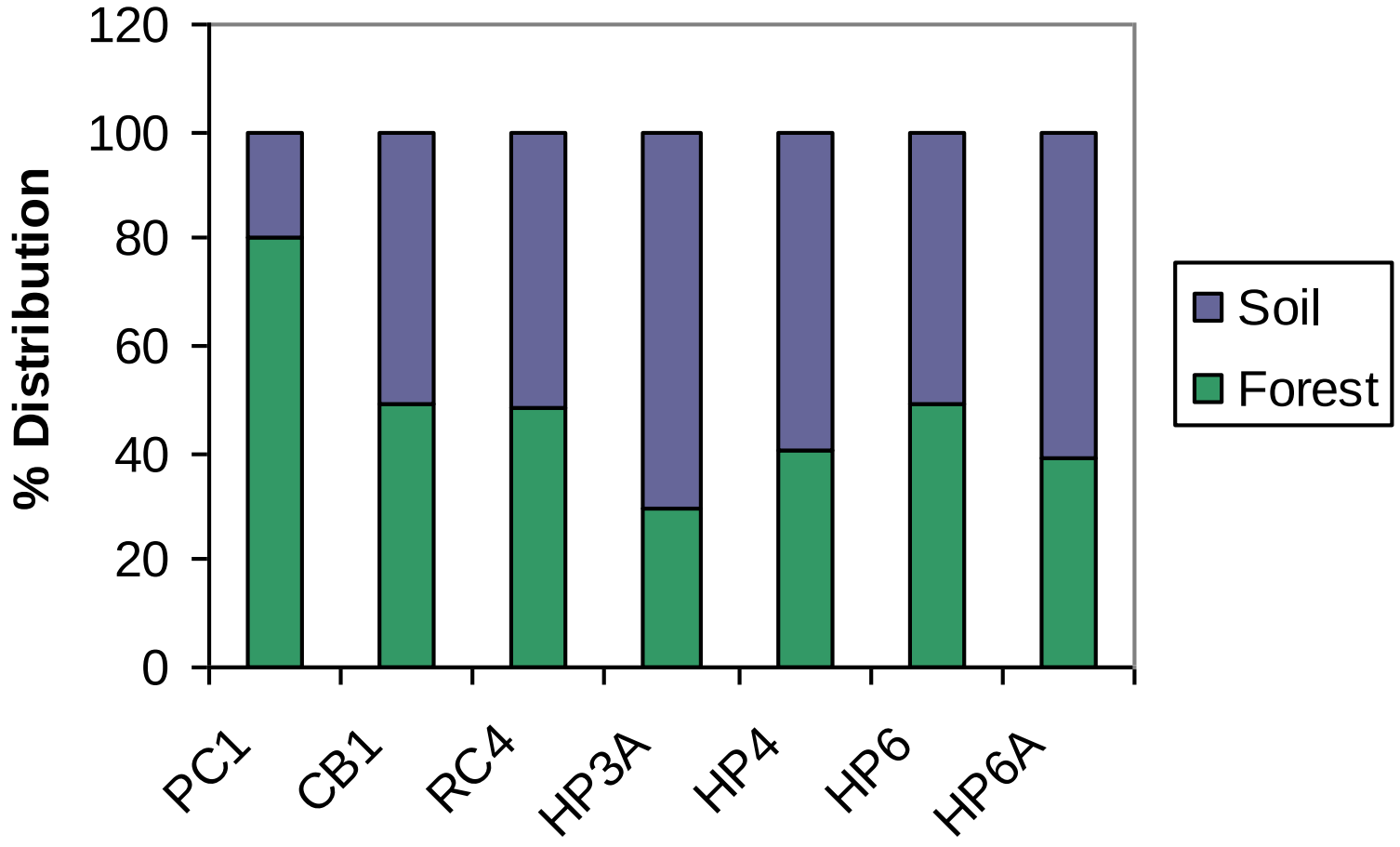
*US EPA and Env. Canada

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



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

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

Can Ca decline damage aquatic life, eg. Cause extinctions of animal plankton species? Animal plankton vary in size

Keratella
0.05 mm

Bosmina
0.3 mm

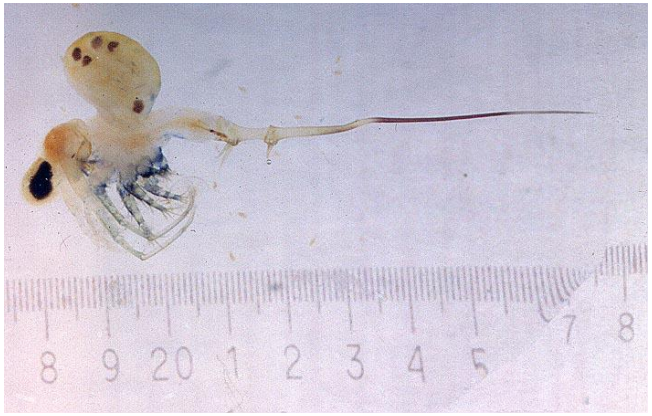
Bythotrephes
Spiny water flea
15 mm

They vary in food web position

Polyphemus
A predator

Daphnia
A herbivore

And. they also vary in Ca needs



Bythotrephes
0.03% Ca

(Kim & Yan in prep)

Holopedium
0.3% Ca

Daphnia
5% Ca

(Jeziorski & Yan, 2006)

Ca needs differ among species

Calcium content (% dry weight)

10.0
8.0
6.0
4.0
2.0
0.0

A A A A B C C C

Bosmina
L. minutus
M. edax
H. gibberum
D. ambigua
D. catawba
D. mendotae
D. pulex

Species

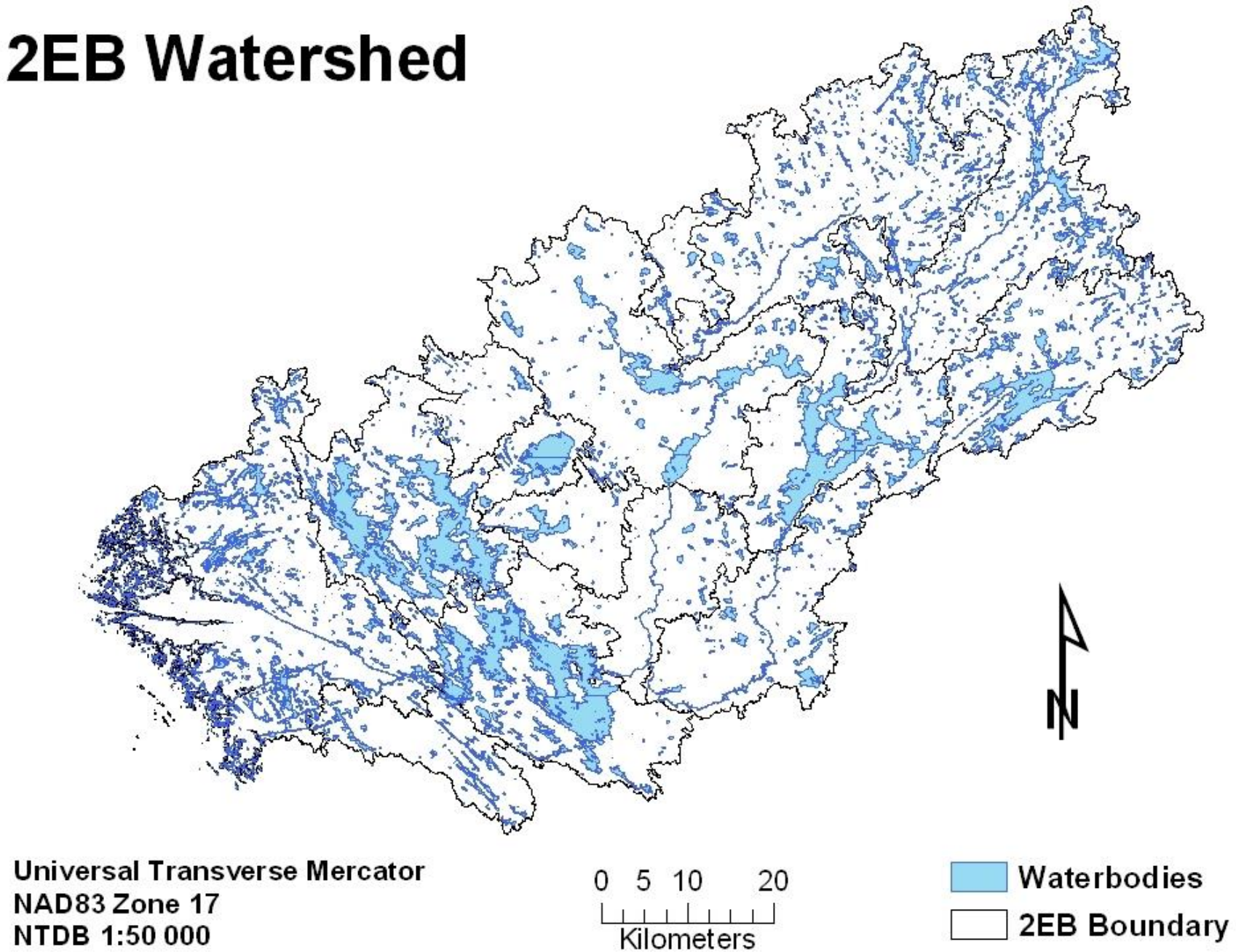
Jeziorski & Yan (2006)

The "little living lawnmower" *Daphnia**

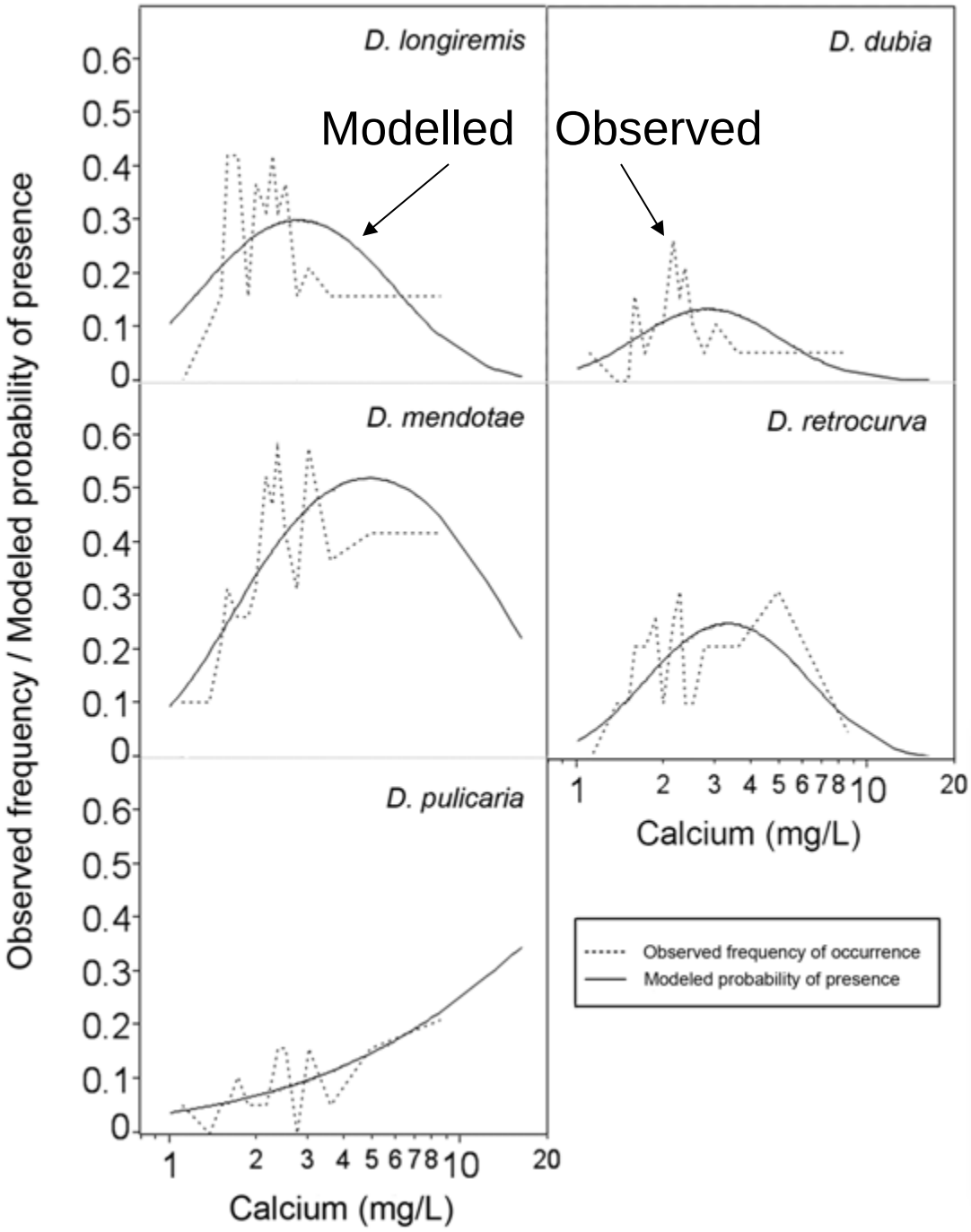
It's ~3% Ca

* Photo by D. Taylor, U of Buffalo

Muskoka, formally called..



The 2006 Muskoka lake survey crews from York U

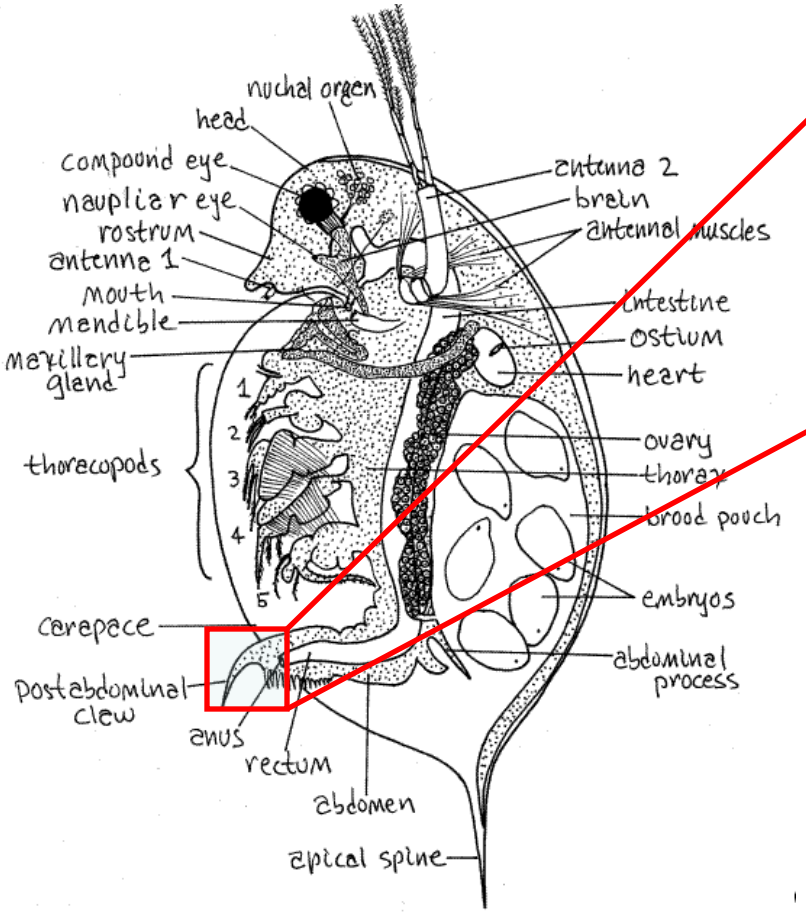


Pattern of occurrence
Of 5 *Daphnia* species
with Ca in 311 lakes
(Cairns & Yan under review)

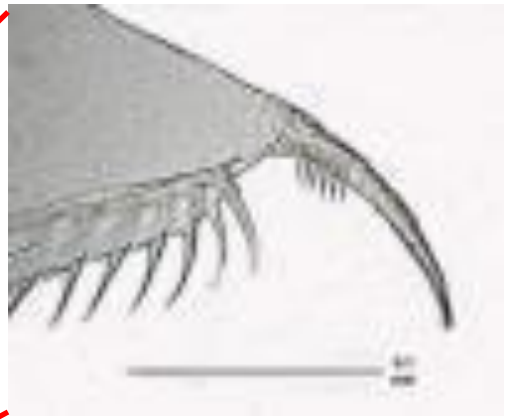
The occurrence of species
falls at Ca levels <2 mg/L

Might they have disappeared
From these lakes?

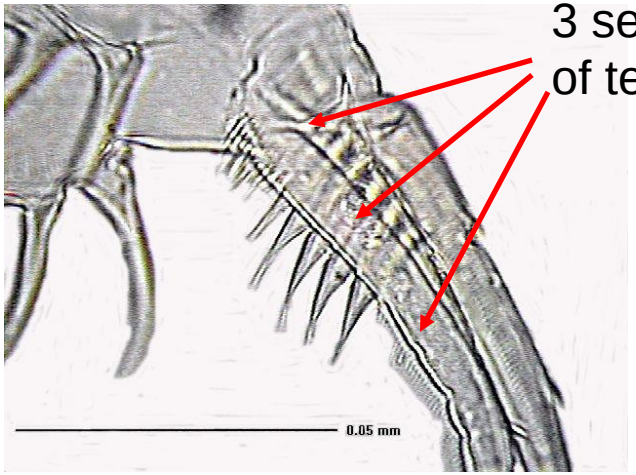
A primer in *Daphnia* "paleolimnology"



Sketch of a Daphnia



Abdomen with claw



3 sets of teeth

Teeth sets on abdominal claw

Primer in paleolimnology 2*

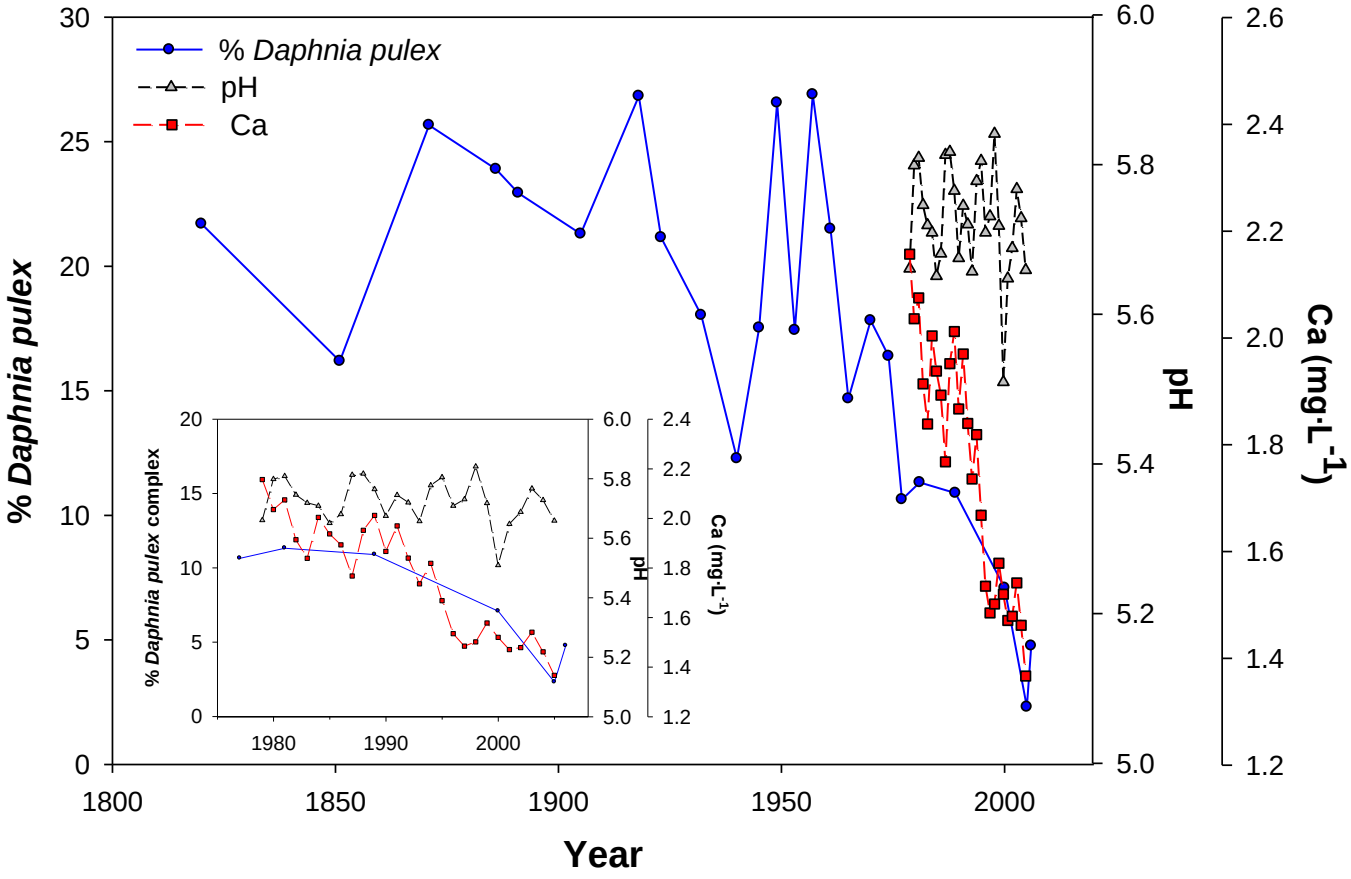
Preparing to
Take a core

Retrieving
The core

Sectioning
The core

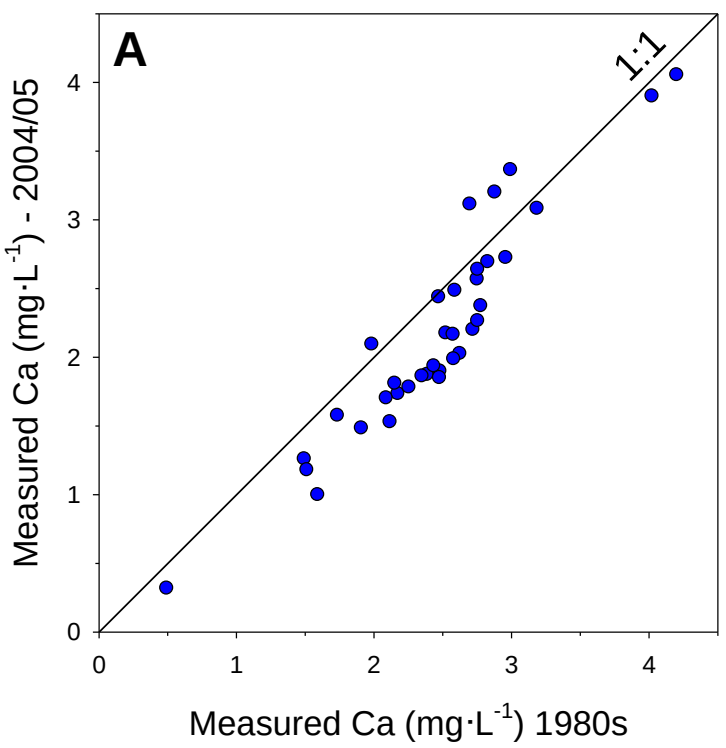
*from John Smol website, Queen's U

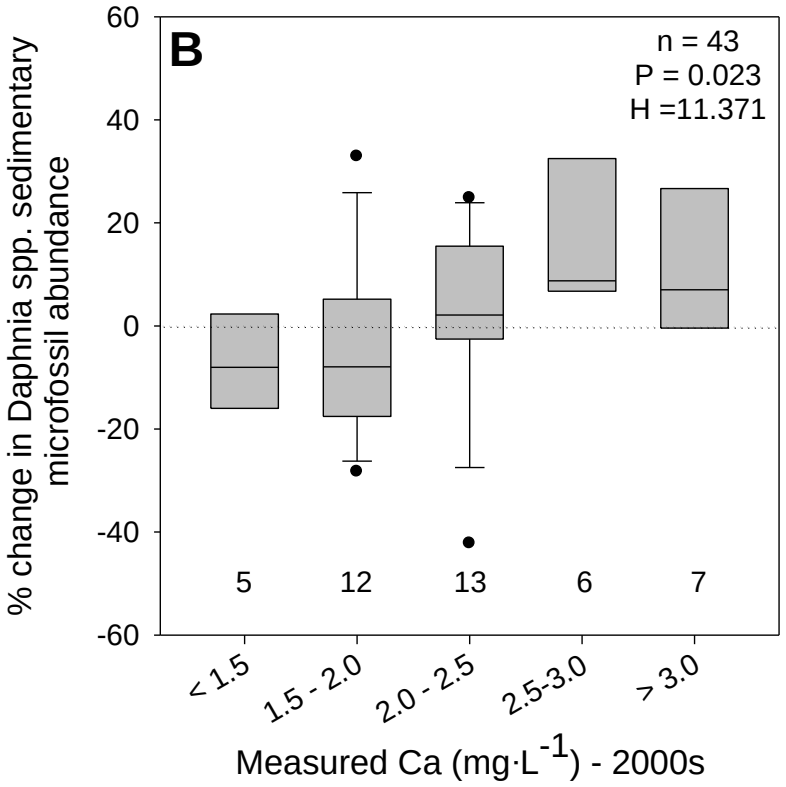
Loss of *Daphnia* from Plastic Lake core*



*Jeziorski et al. (2008)

And they are lost whenever Ca < 2 mg/L*





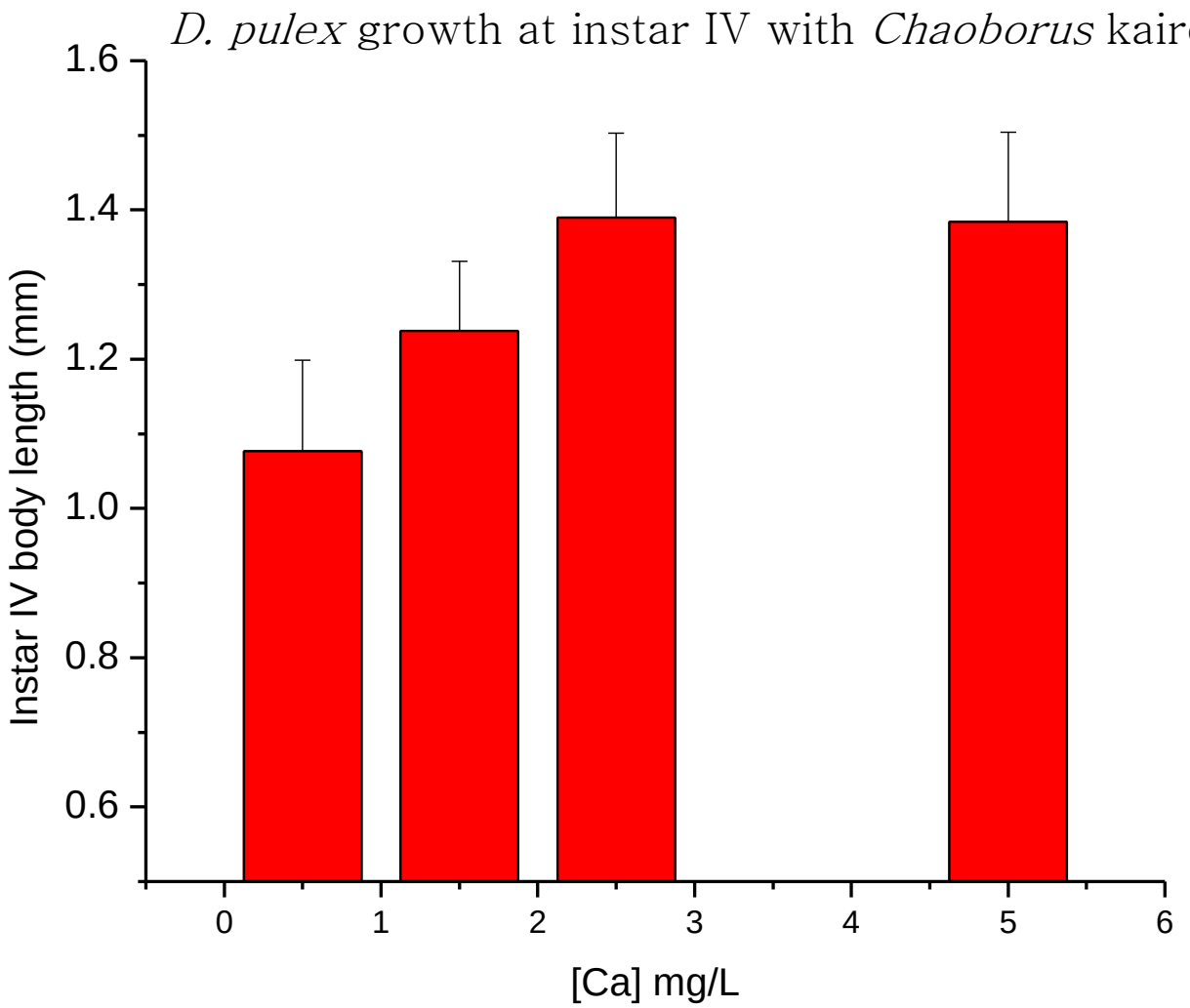
*Michelle Palmer & Anna DeSellas' work in Jeziorski et al. (2008)

Correlation vs. Causation?

- There are both spatial and temporal patterns suggesting loss of Ca-rich life (i.e. ecological damage) associated with low Ca, i.e Ca ~1.5 to 2 mg/L, but
- has low Ca actually caused the damage?

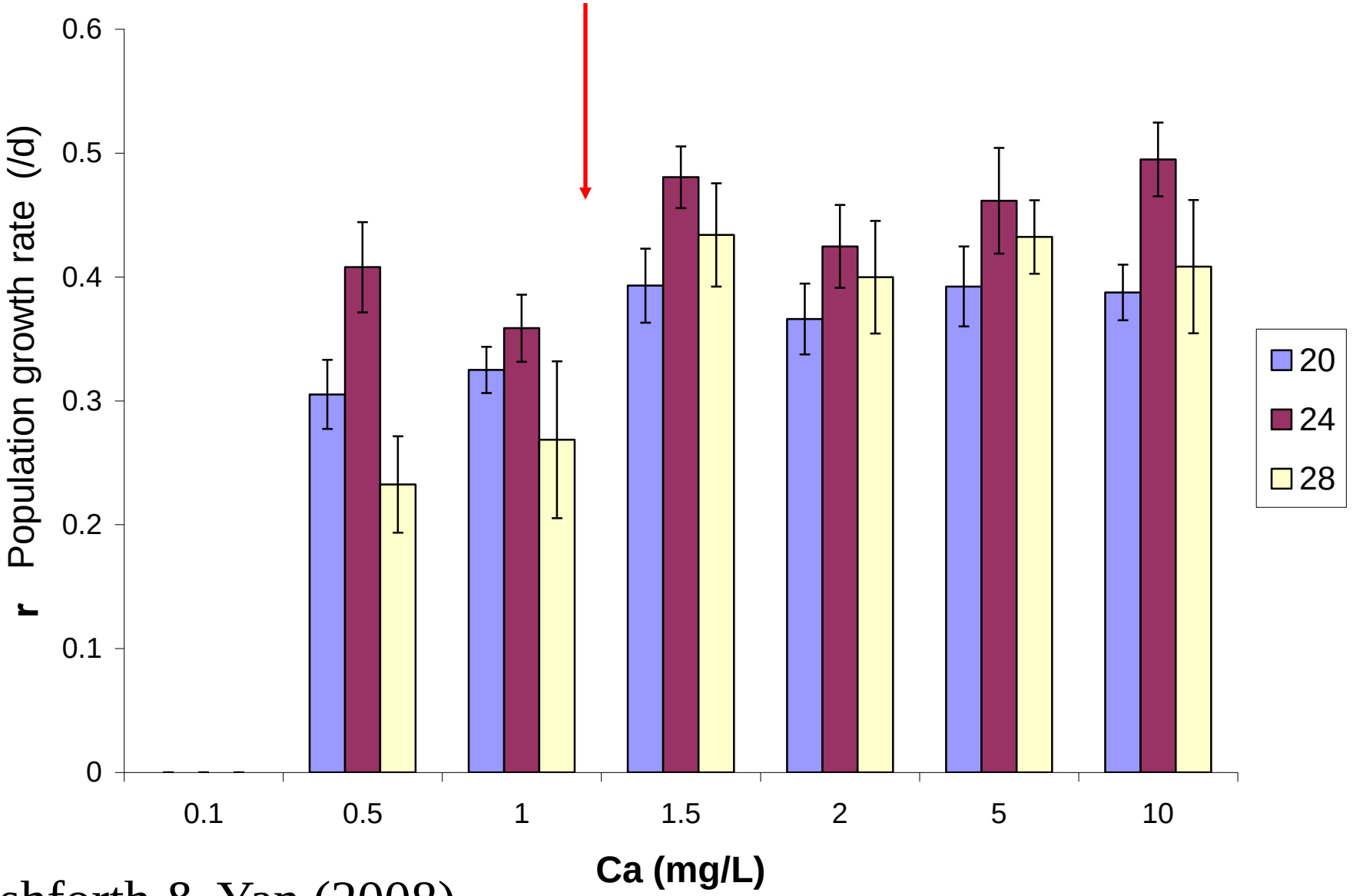
The FLAMES lab at Dorset

Ca <2 mg/L reduces *Daphnia* growth in the lab*



*Riessen, Linley, Altshuler and Yan (under review)

And low individual growth reduces population growth At Ca levels <1.5 mg/L



Ashforth & Yan (2008)

But can Ca decline cause such losses in lakes, not just in the lab?

2 day replacement bioassay

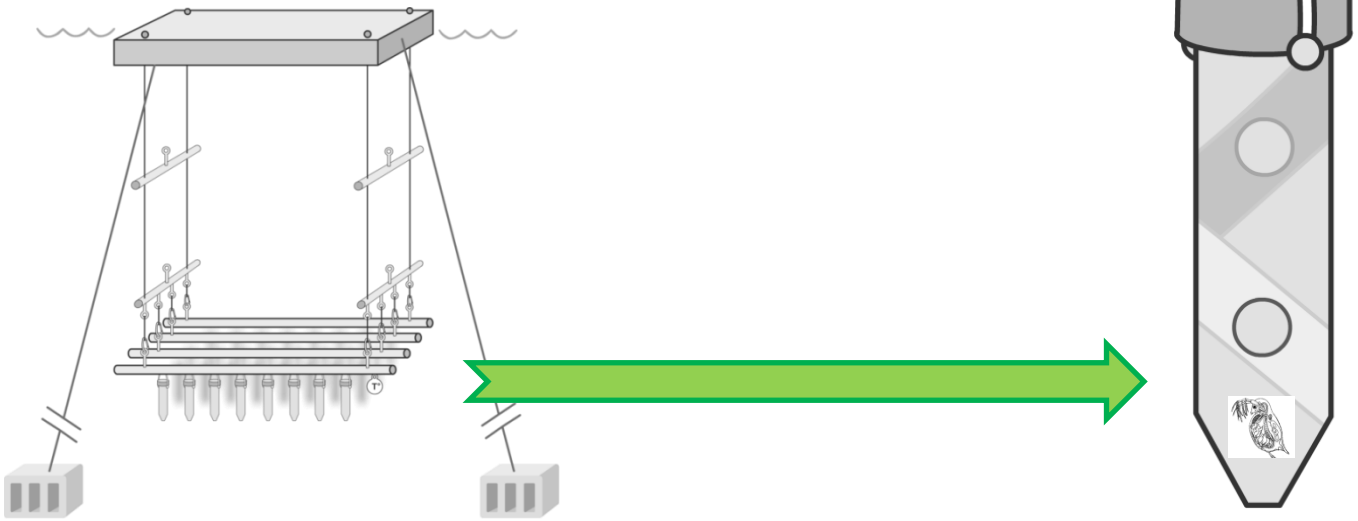
- Lakes with 4 [Ca]s - 1.1, 1.3, 1.4, 2.4 mg/
- 17 day endpoint (July-Aug ‘08)
- Transfer to new tubes in field
- Open treatments with or without added food
- Closed treatment with added Ca and Ca+food

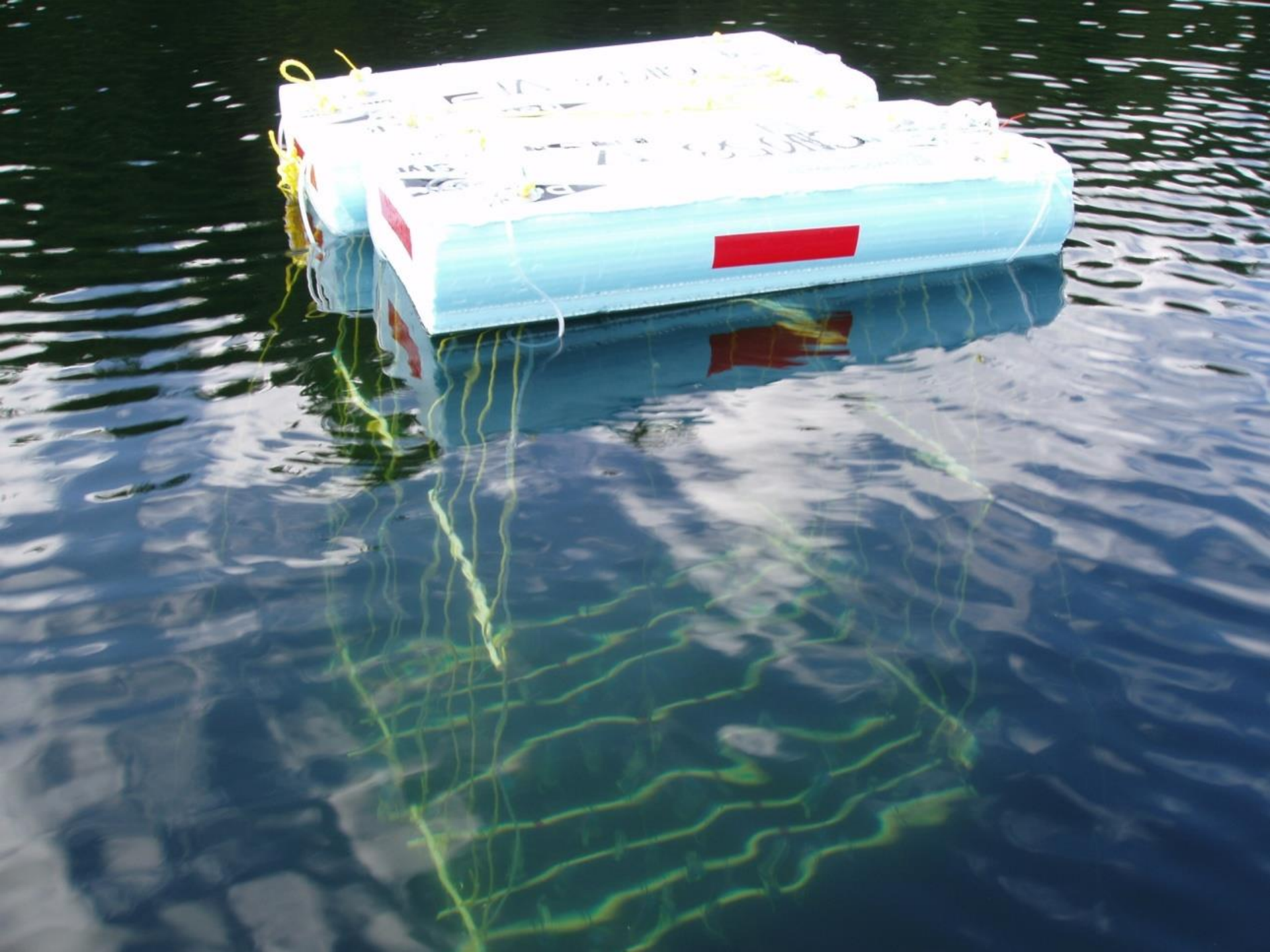
Animals examined in lab

- # of neonates
- # of shed carapaces
- Verify survival

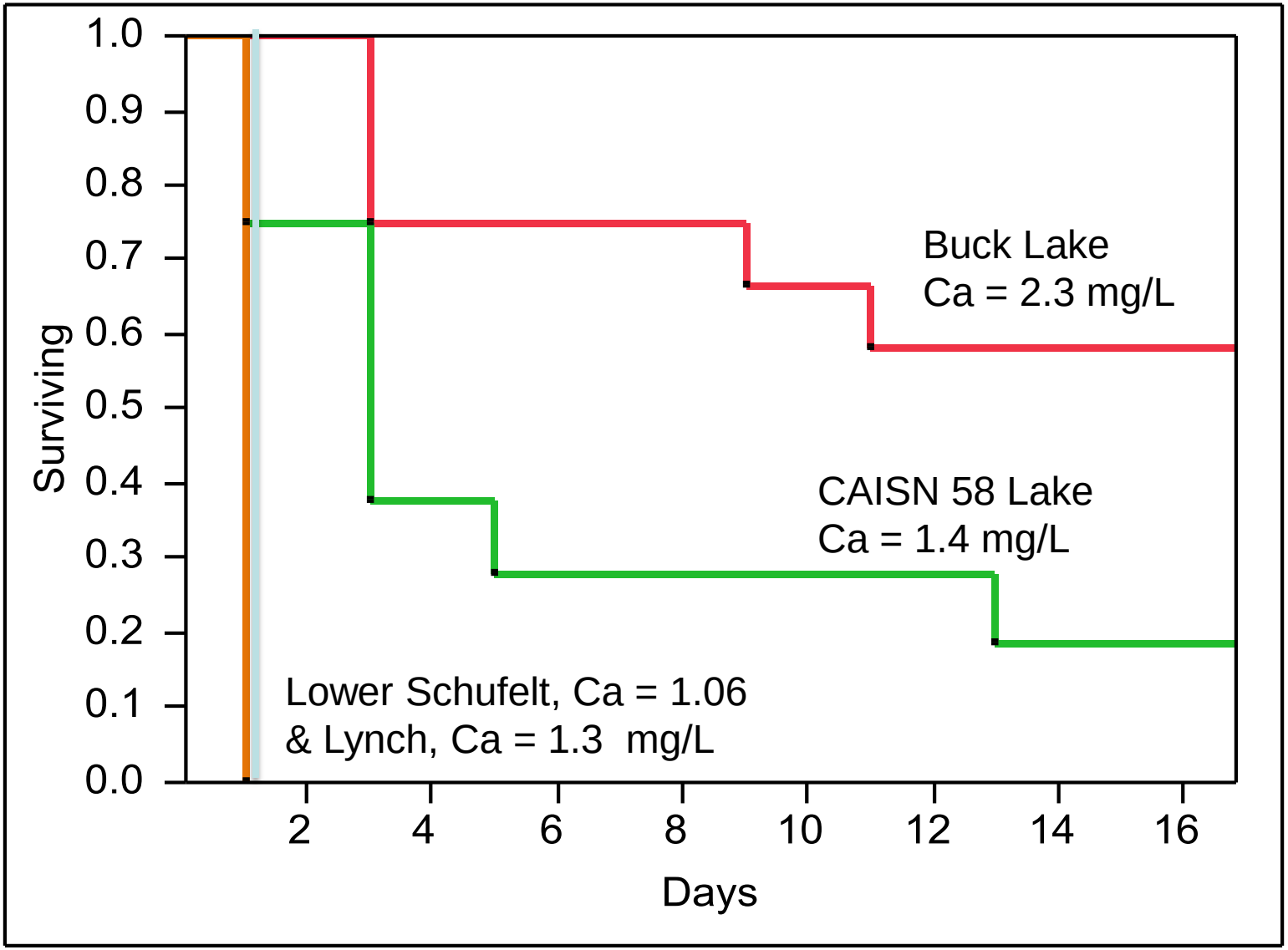
Experimental Set up

Treatment	Screen size	Lowest Ca 1.1 mg/L	Low Ca 1.3 mg/L	Mid Ca 1.4 mg/L	Reference 2.3 mg/L
Raw	53um				

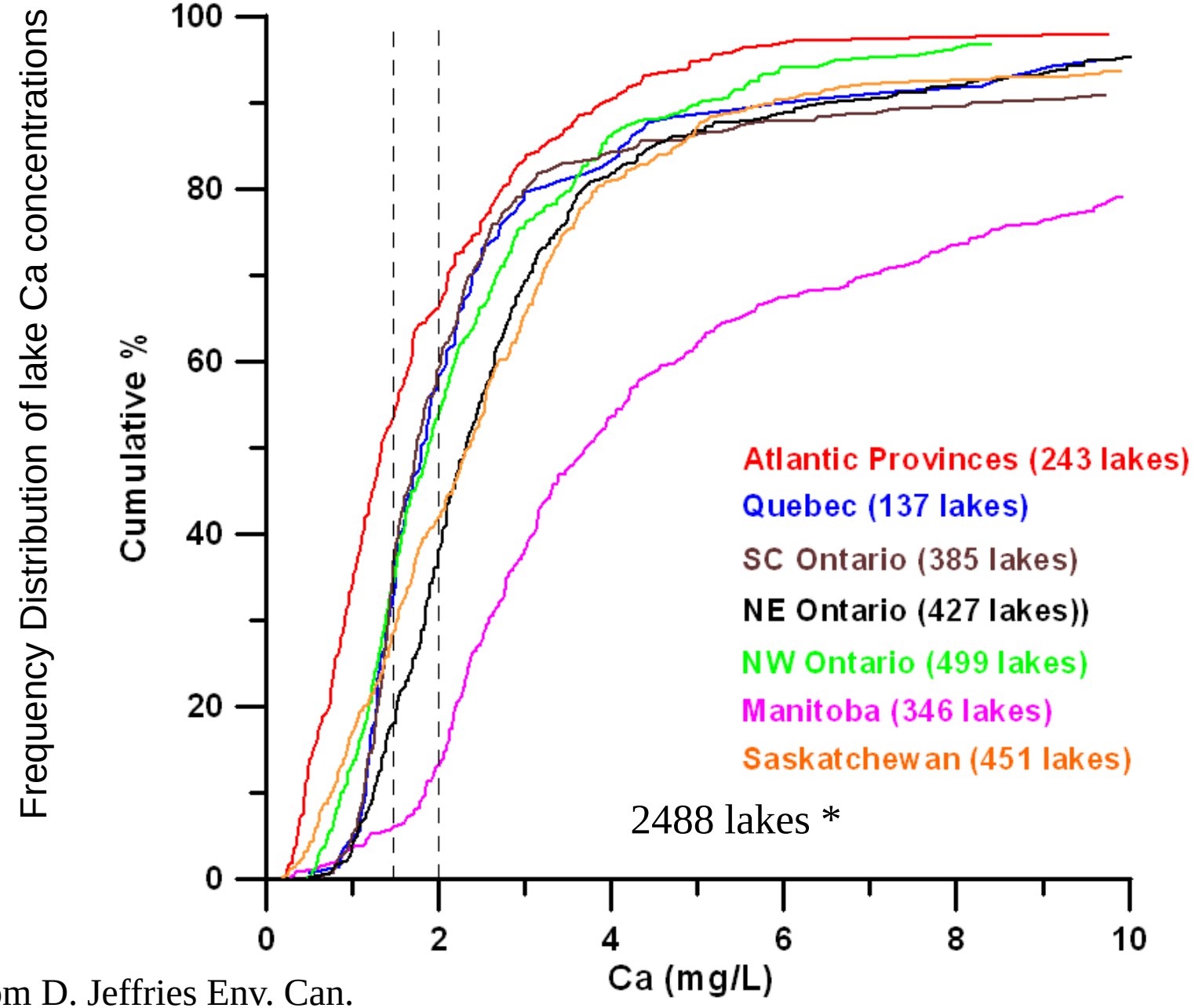




Survival of young *Daphnia* over 17 days in the open tubes (Cairns & Yan in prep.)



We have a lot of lakes with Ca levels this low in Canada (n=2488)*

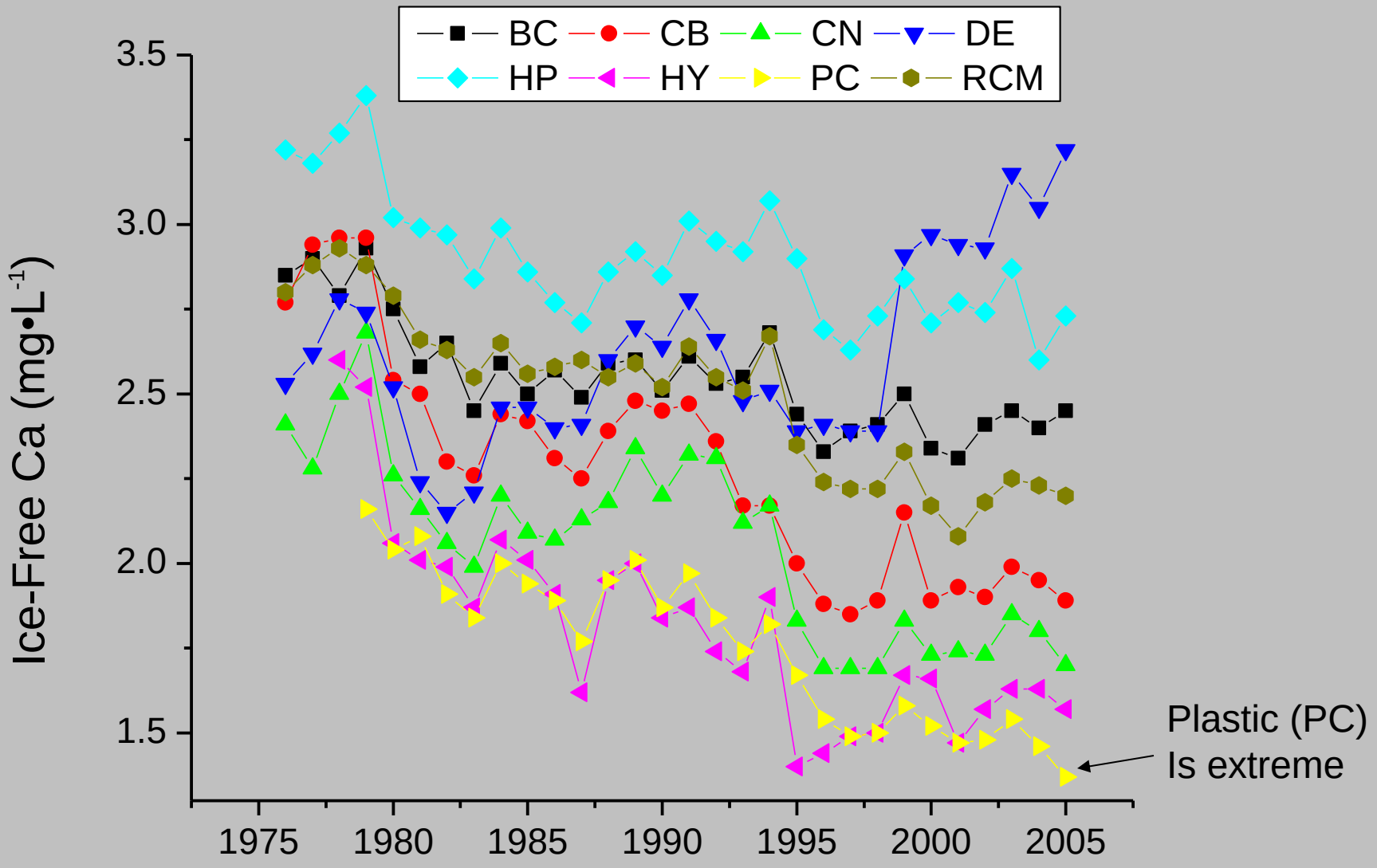


*from D. Jeffries Env. Can.

In summary

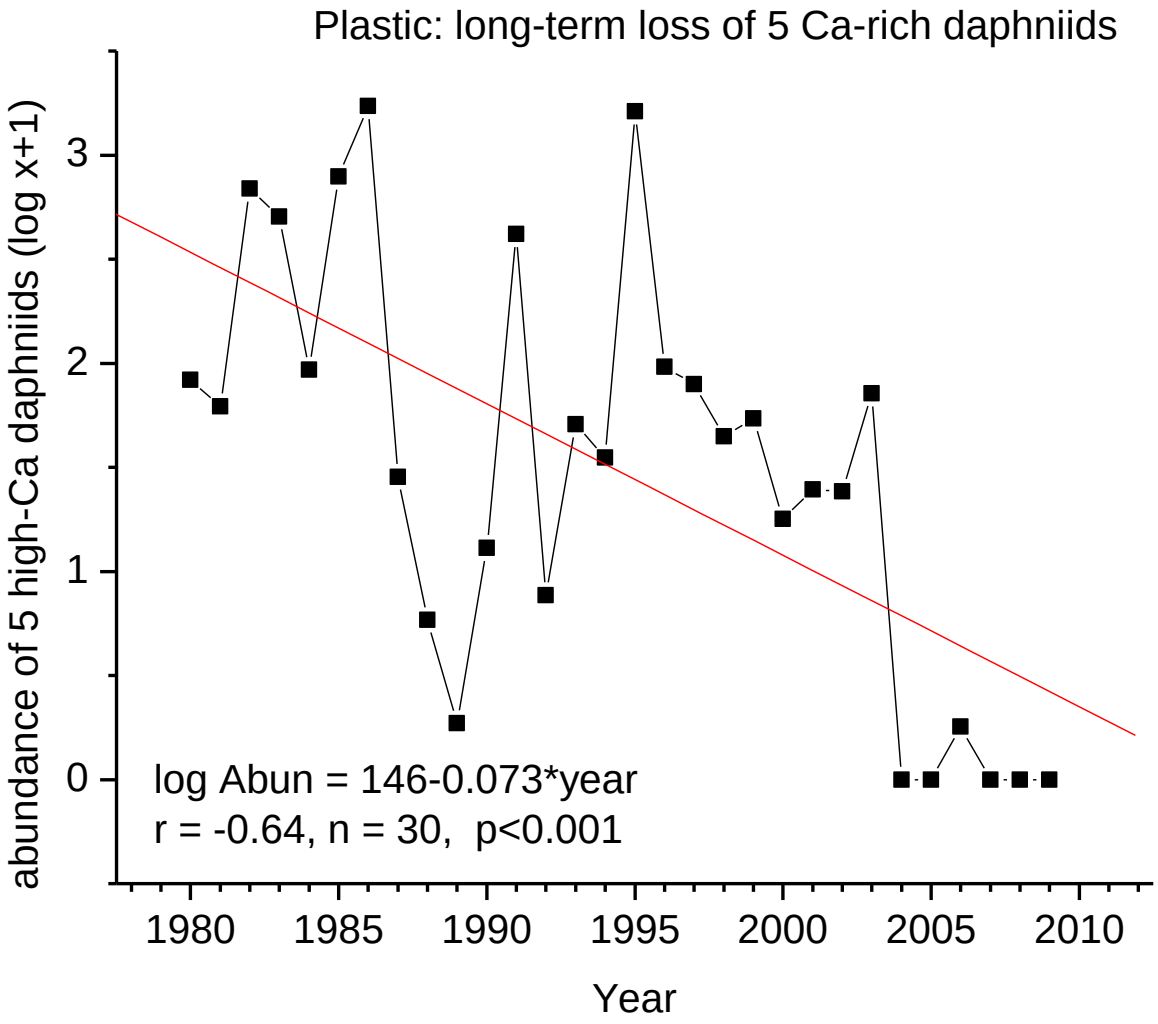
- Most Canadian Shield lakes have low Ca levels, and levels have been falling of late
- The decreases are linked to our thin, mineral-poor soils, decades of acid rain, a few logging cycles, and paradoxically, recent reductions in acid input.
- Levels below 1 mg/L may soon be common.
- The few Ca-rich aquatic species we have studied are in trouble at <1.5-2 mg/L of Ca, and we have a lot of such lakes
- Calcium decline is also an emerging threat to our forests (Watmough at Trent U)
- So far we have seen impacts on water fleas, and likely on crayfish, but other Ca-rich life is also at risk

And do we see damage in our long-term study lakes?

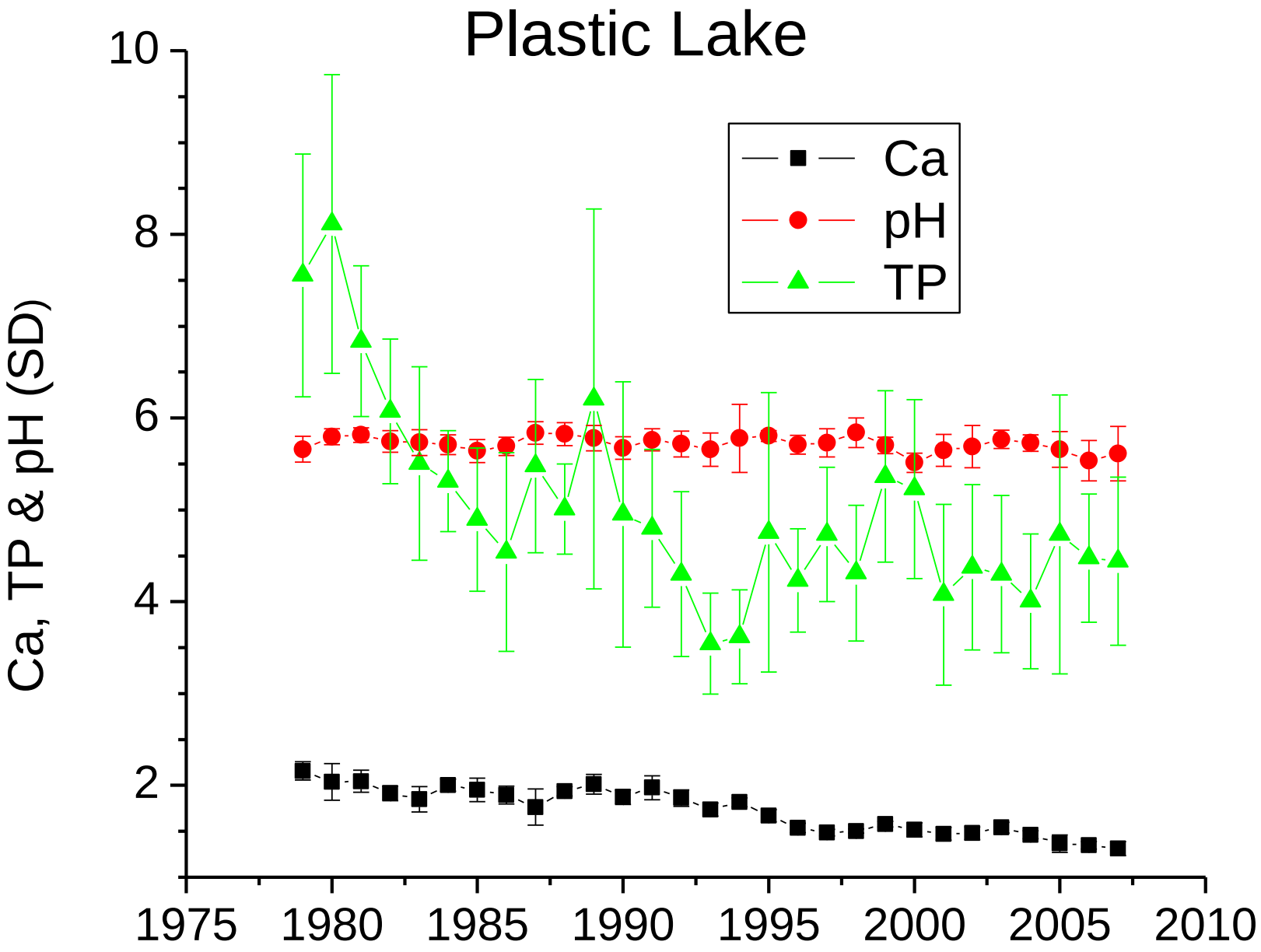


*Molot and Dillon 2008, Yan et al. 2008, (Dorset Special Issue of CJFAS, May 2008)

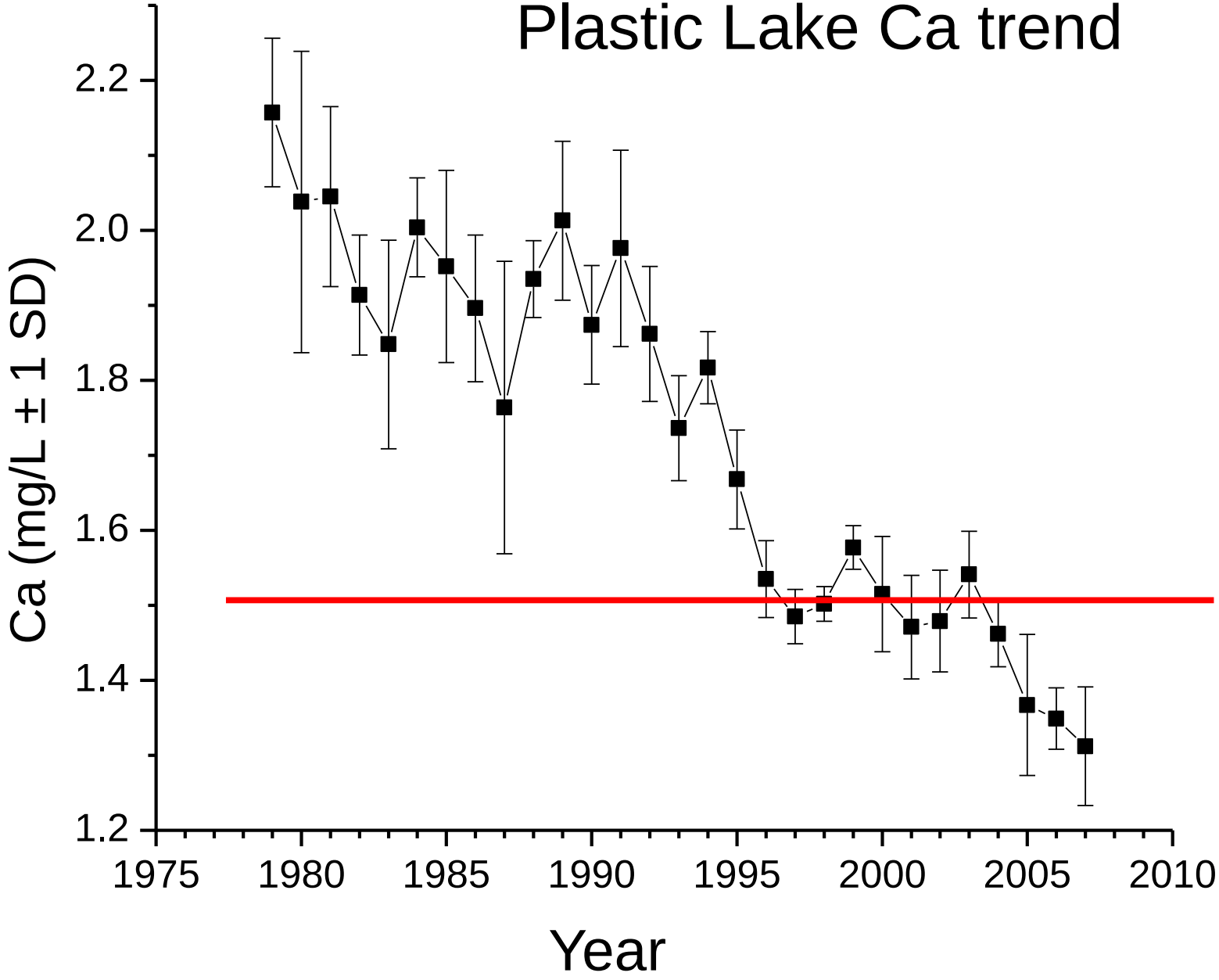
Are we losing Ca-rich species in Plastic Lake?



*Yan, Ingram, Keller, Witty, unpubl. data



Paterson et al. unpubl. MOE data

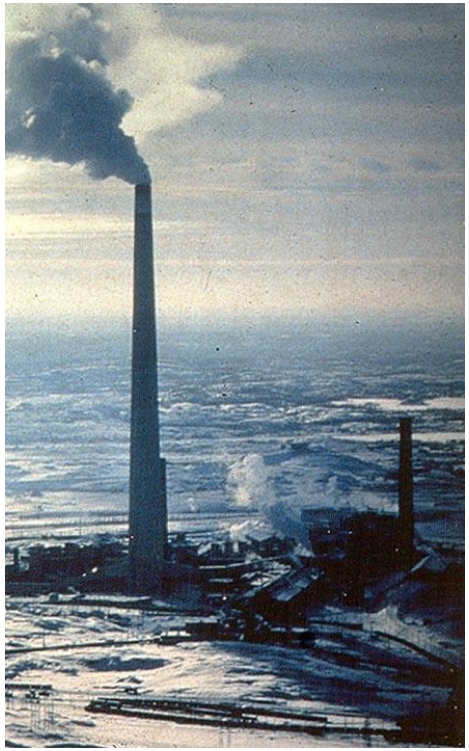

Plastic Lake Ca trend
Ca (mg/L ± 1 SD)
2.2
2.0
1.8
1.6
1.4
1.2
1975
1980
1985
1990
1995
2000
2005
2010
Year

MOE data

Summary

- We have increasingly strong evidence that Ca <1.5 mg/L is harmful to Ca-rich animal plankton
- A large % of eastern Canadian lakes are approaching or have dropped below this threshold
- The paleo-ecological Cladoceran record suggests Ca levels were not this low prior to acid rain.
- The potential counteracting effects of rising pH and falling Ca warrant research
- Damaging Ca thresholds may be higher than 1.5 mg/L for other Ca-rich taxa
- **Can anything be done?**

People have a huge effect on Ca dynamics



What can be done

- Quickly increase our knowledge about the extent and effects of Ca decline in Canada
  - Norm's MOE/York agreement
  - Additional research via the Muskoka watershed node of the Canadian Water Network
- Use the current and developing knowledge to help develop strategies to deal with the problem, eg.
  - further reductions in S and N emissions
  - Changes in forest management practices, including logging frequency alterations, bark, twigs, etc.
  - Ca supplementation (wood ash, dust suppressants)
  - Become gardeners of the forest
- Communicate the issue broadly

Acknowledgements to Paul for the invitation

NSERC Strategic and Discovery grant programs

Staff, funding & data from the OMOE's Dorset Environmental Science Centre, and the MOE's Best in Science Program

The Biology & other departments at York University

Canadian Aquatic Invading Species Network

Canadian Wildlife Service and NWRI

Recent & emerging Ca work in the lab

1. In print or press
    1. Ashforth, D. and N.D. Yan 2008 Limnol. Oceanogr. 53: 420-432.
    2. Cairns, A. and N.D. Yan 2009 Env. Reviews 17: 67-79.
    3. Jeziorski, A. et al. 2008. Science. 322:1374-1377.
    4. Jeziorski, A and N.D. Yan 2006 Can. J. Fish. Aquat. Sci. 63: 1007-1013.
    5. Yan, N.D. 2008 Can. J. Fish. Aquat. Sci. 65: 862-877.
    6. Yao, H. et al. 2011 Water Res. Res. (in press)

2. Under review
    1. Cairns, A, A. Jeziorski and N. Yan. Both Ca decline and polymixis reduce daphniid prevalence. CJFAS (under review).
    2. Cairns and Yan. A field experiment of the threat of Ca decline to daphniids…. Limnol. Oceangr. (under review)
    3. Riessen et al. Calcium, kairomones and growth of *Daphnia*. Limnol. Oceanogr (under review this month)