Emerging Issues for our Lakes:

reduced federal government engagement, despite the rising threat of multiple environmental stressors in Canada

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Friends of the Muskoka Watershed

YORK UNIVERSITÉ UNIVERSITY
redefine THE POSSIBLE.

Acknowledgements – my co-authors

Michelle Palmer

Acknowledgements – cont’d

- For funding
  - MOE’s EMRB & DESC
  - NSERC – DG’s, CAISN, SG’s, RTI’s, CREATE
  - CFI – FLAMES lab
  - York U
- For the invitation
  - Judi

It is timely to reflect on emerging conditions: Rare damaging events appear to be less rare that we once thought

From the Atlantic.com: wave approaching Miyako City from the Heigawa estuary in Iwate Prefecture

Some large threats appear to have worsened*

Sandy produced N. America’s 1st climate refugees*

NYdailynews.com

And we are approaching several environmental thresholds

- for phosphorus: Reserves will be depleted in 50-100 years
  - Cordell D. et al. 2009. Gobal Environmental Change 19: 292
- For capture fisheries: 68% of FAO fisheries are fully exploited, over-exploited or collapsed
  - Anderson et al. 2012. ICES J. Mar. Sci. 69: 1491
- For water in western Canada: caused both by irrigation and climate change
  - Rood and Wandersteen 2010. Water Resour. Manag 24: 1605

But there is reduced federal interest in environmental management in Canada

- Changes in many federal acts that reduce protection and oversight
- Withdrawal of support for ELA
- Surplusing of many environmental scientists
- Muzzling of the rest, leading to a Democracy Watch law suit

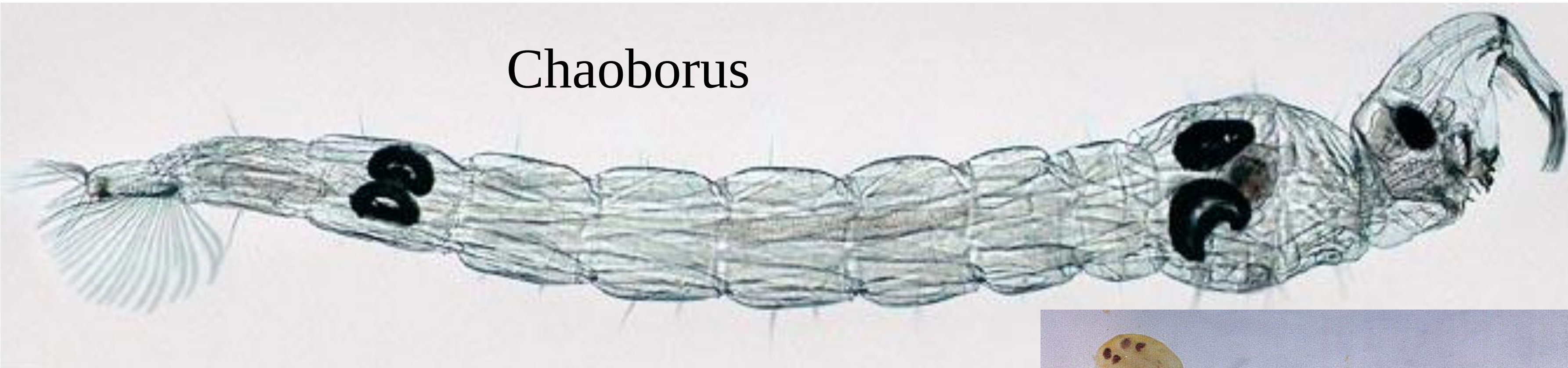
My approach to this reflection on emerging issues for Muskoka lakes

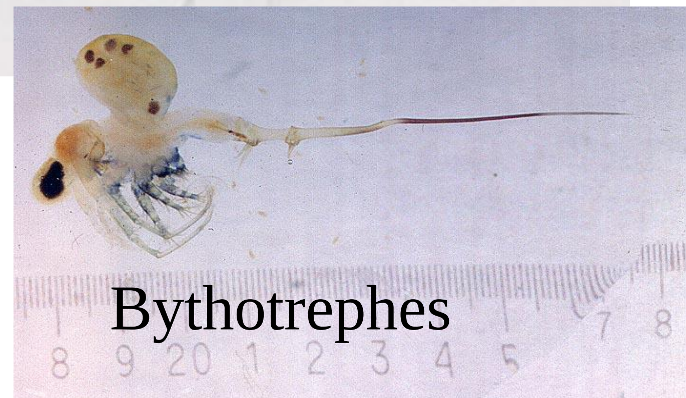
1. Introduce the data (zooplankton in Dorset Ontario)
2. Prove that multiple stressors are on the rise
3. Prove these stressors interact
4. Consider what changes might occur in the next few decades
5. Consider if and how Canadians are preparing for these changes
6. Prove reason for concern, but also for hope

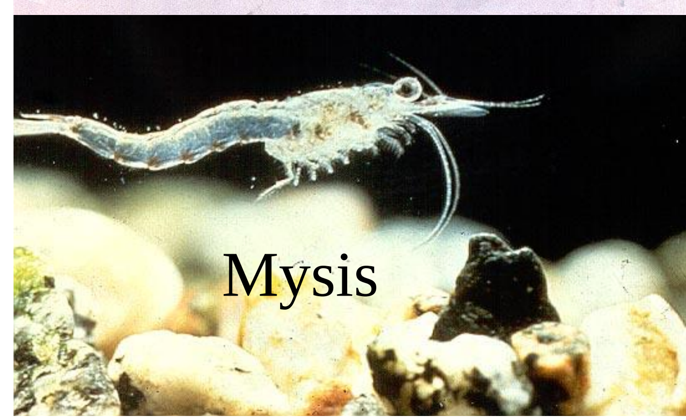
1. Introducing the data: zooplankton of Dorset-area lakes

- Why my interest in plankton?
  - We’d be hungry, dim-witted and likely dead without plankton
  - They keep our lakes clean, and fuel food webs
  - They are very sensitive to environmental stressors

The “giant” predatory zooplankton

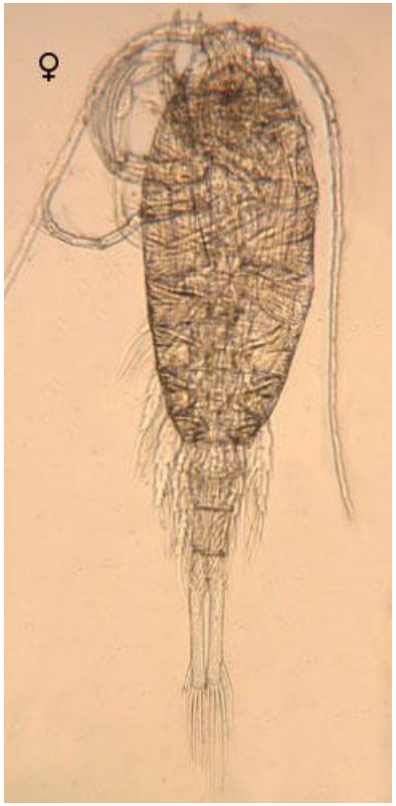






their main prey: Cladocera and Copepoda

Cladocera
eg. *Daphnia*



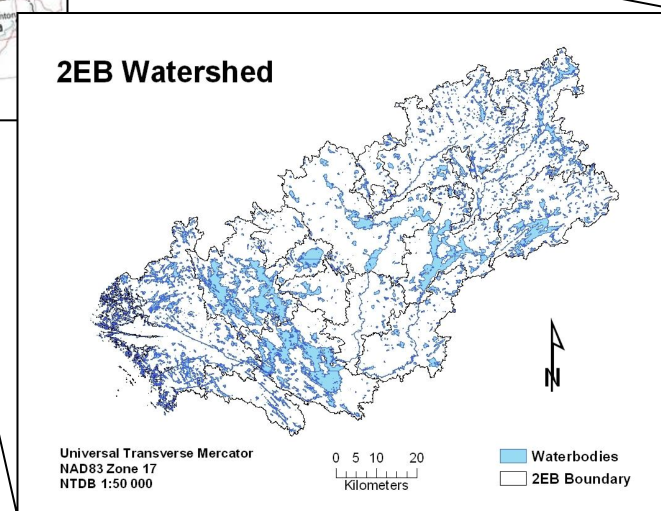
Copepoda
eg. *Limnocalanus*

They are sensitive to many stressors*

- water chemistry – TP, pH, Ca, Cl, metals
- physics – PAR, UVR, wind, temperature
- Glacial history - accidents of location and time
- competition for available, high quality food
- parasites
- native vertebrate & invertebrate predators
- Info-chemicals
- invading predators and competitors
- hybridization and selection
- **And these stressors interact!**

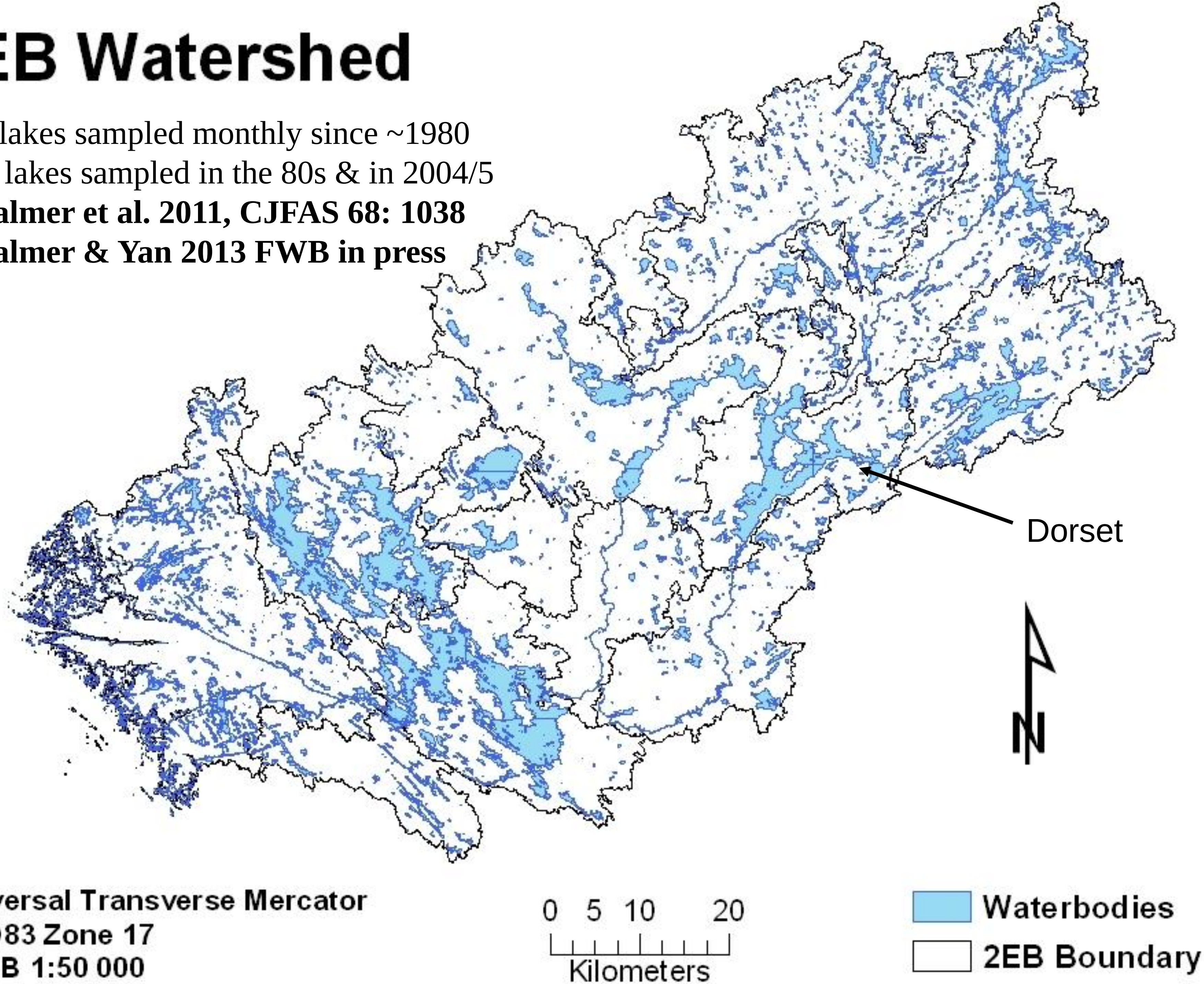
*stressors that have influenced zooplankton in my research

Where are the data from?



2EB Watershed

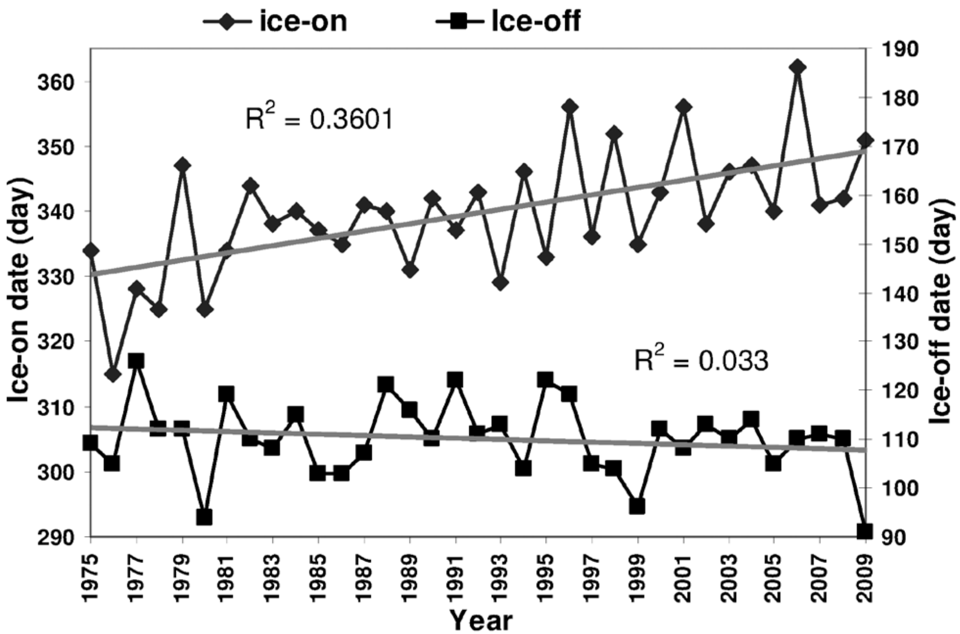
8 A lakes sampled monthly since ~1980
~40 lakes sampled in the 80s & in 2004/5
- **Palmer et al. 2011, CJFAS 68: 1038**
- **Palmer & Yan 2013 FWB in press**

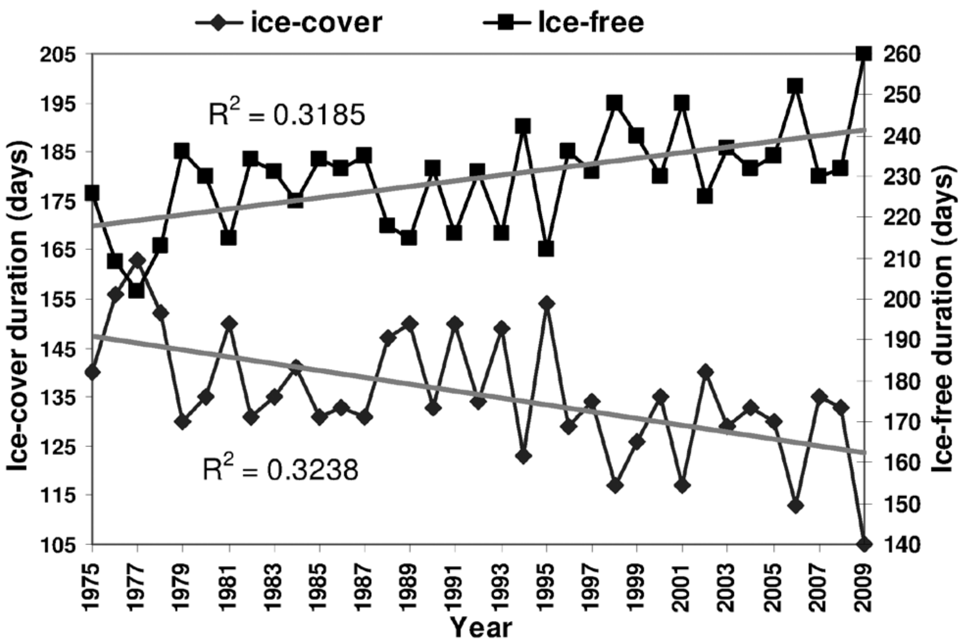


Plastic Lake – one of the main study lakes

2. Proof that many stressors are on the rise?

- Physical factors linked to the climatic and the watershed changes
- Water quality factors linked local and regional anthropogenic drivers
- Ecological factors linked to novel predators





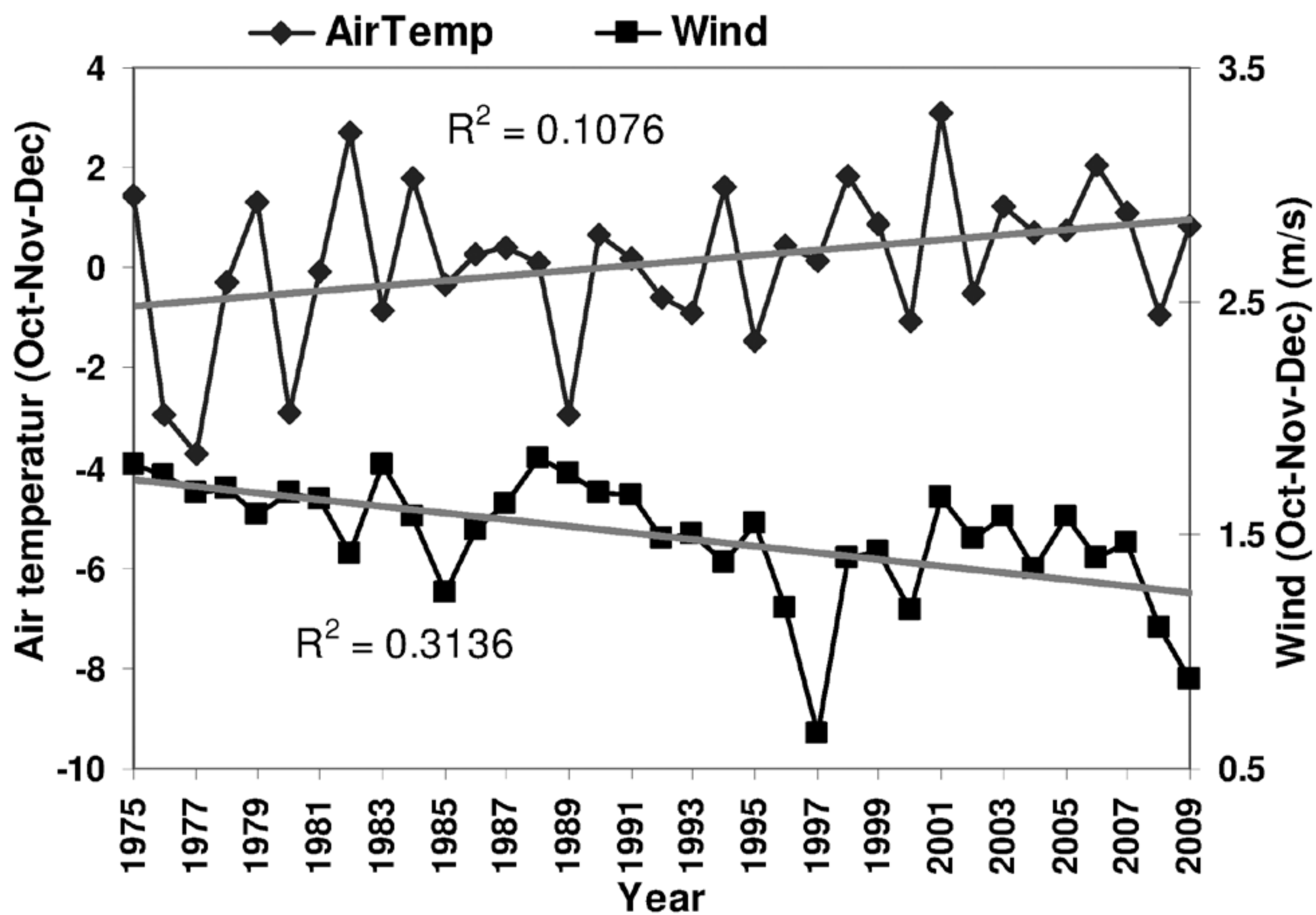
Lake physics is changing eg. Dickie Lake

Muskoka lakes
are freezing later,
not unfreezing earlier

They are ice-free
3 weeks longer than
3-4 decades ago

*Yao et al. 2013 Inland Waters

Autumnal physical factors are changing



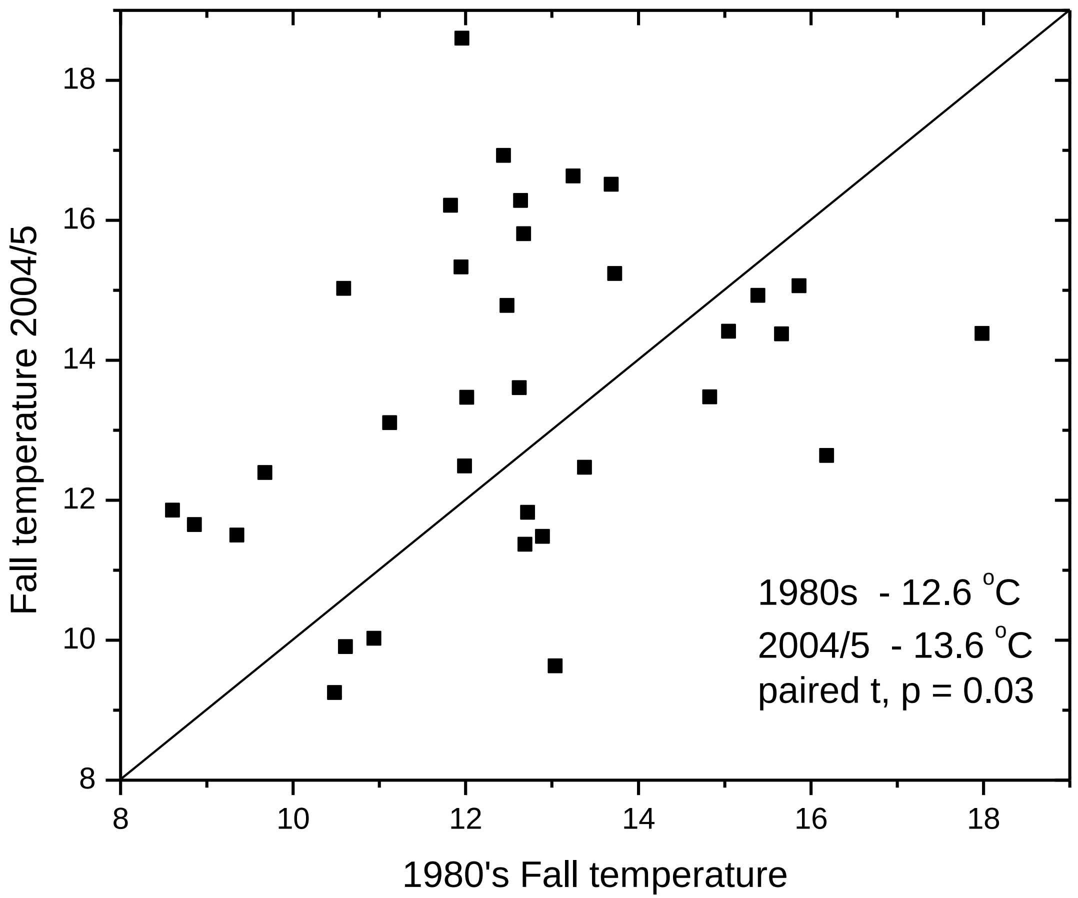
*Yao et al. 2013

the Dorset A lakes have warmed*

Metric	trend test	change/ decade
Epilim. Temperature (^oC)	2.7**	0.8
Metalim. Temperature (^oC)	2.5*	0.5
Hypolim. Temperature	1.1	NS
lake temperature (^oC)	2.1*	0.4
thermocline depth	-2.4*	-0.2
10 ^oC depth	-1.3	NS
Secchi depth (m)	1.1	NS
Vol with DO <4 mg/L	1.5	NS

*Palmer, Yan and Somers in revision

& fall temperatures warmed regionally (n= 32) *

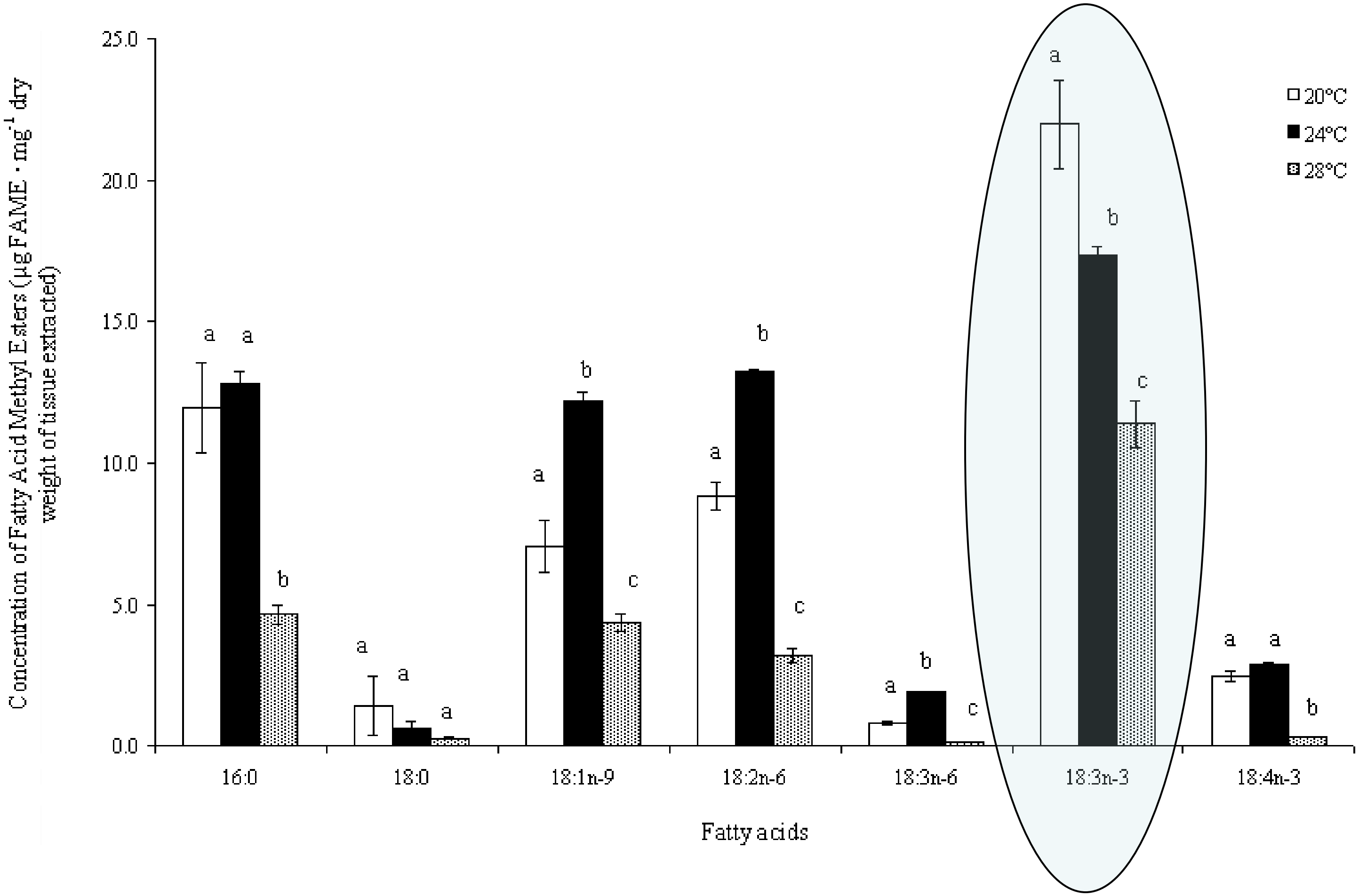


*Palmer and Yan 2013 Freshwater Biol. in press

When waters warm

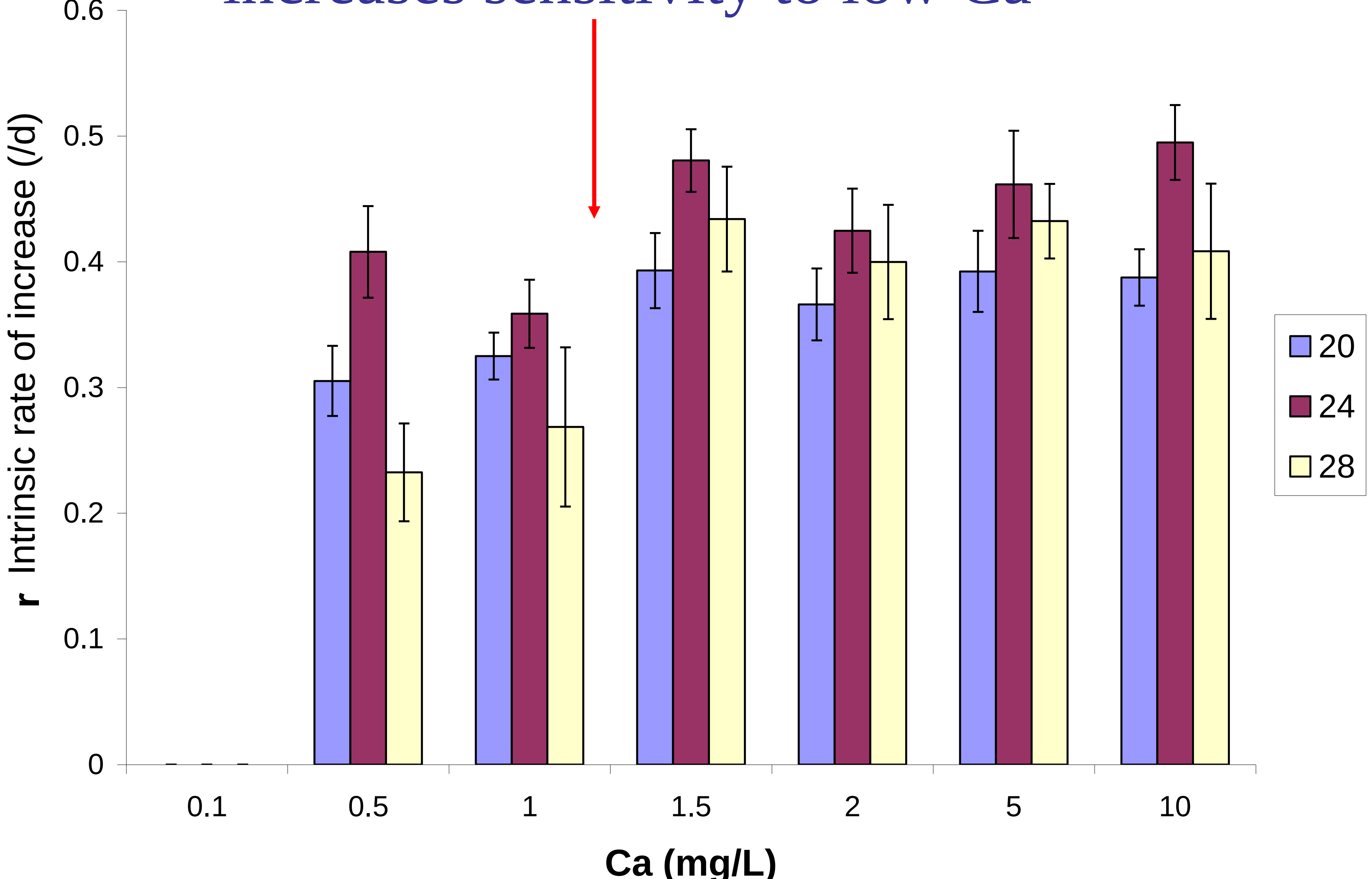
- There are direct effects on plankton at >24 ^{o}C
  - Reduced growth (eg. Ashforth and Yan 2008, Person et al. 2010)
  - Alterred community composition (Palmer & Yan in press)
- There are also indirect effects
  - Loss of essential long-chain fatty acids (Fushino et al. 2011)
  - More sensitivity to falling Ca (Ashforth and Yan 2008)

e.g., Rising temperature lowers ALA (18:3n-3), an essential omega 3 FA, in green algae*



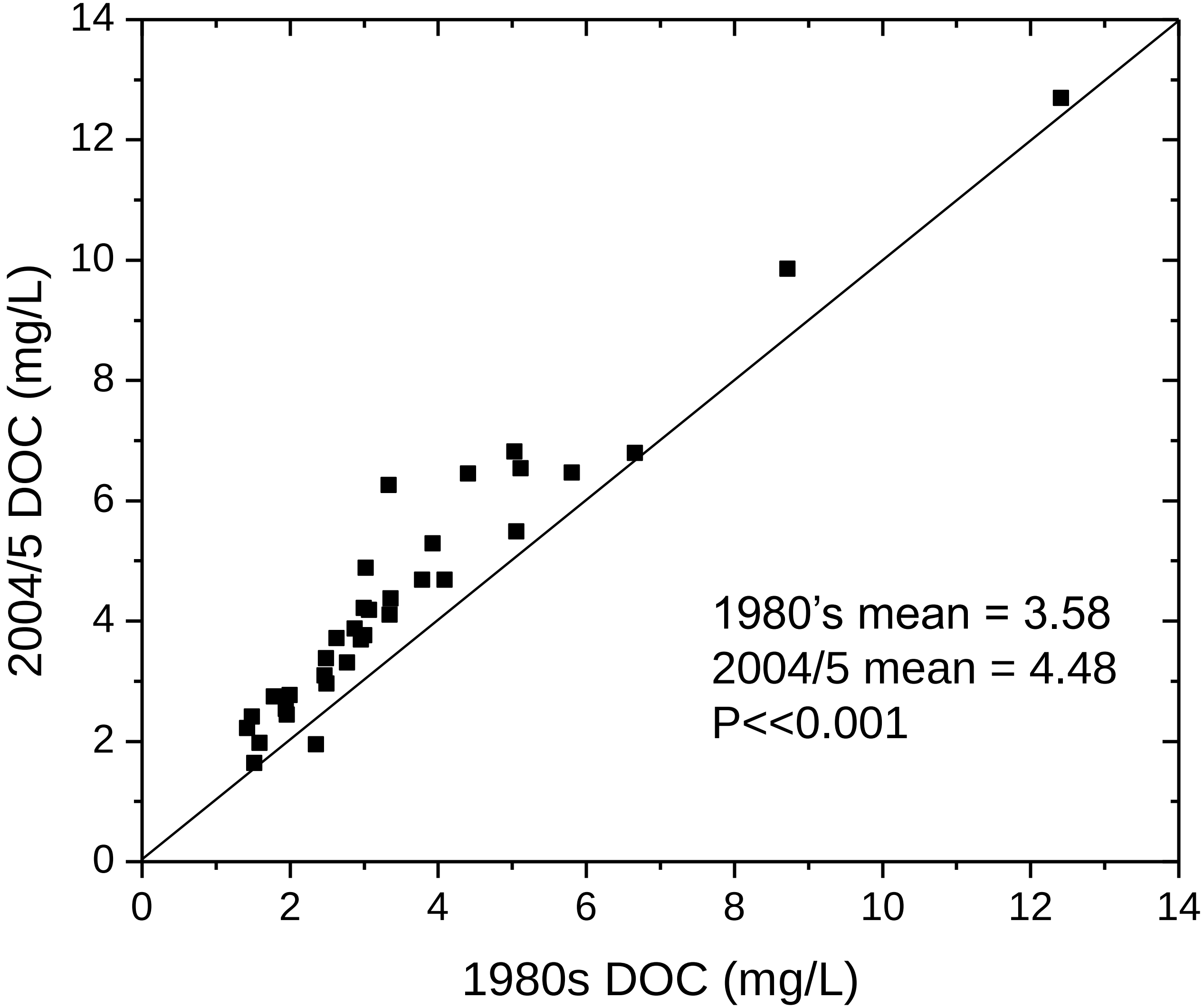
*Fuschino et al. 2011. J. Phycol. 47: 763

Temperature >24 ºC reduces growth and increases sensitivity to low Ca*



Ashforth & Yan (2008) L&O 53: 420

Water quality is changing:
Dissolved Organic Carbon (DOC) is rising*

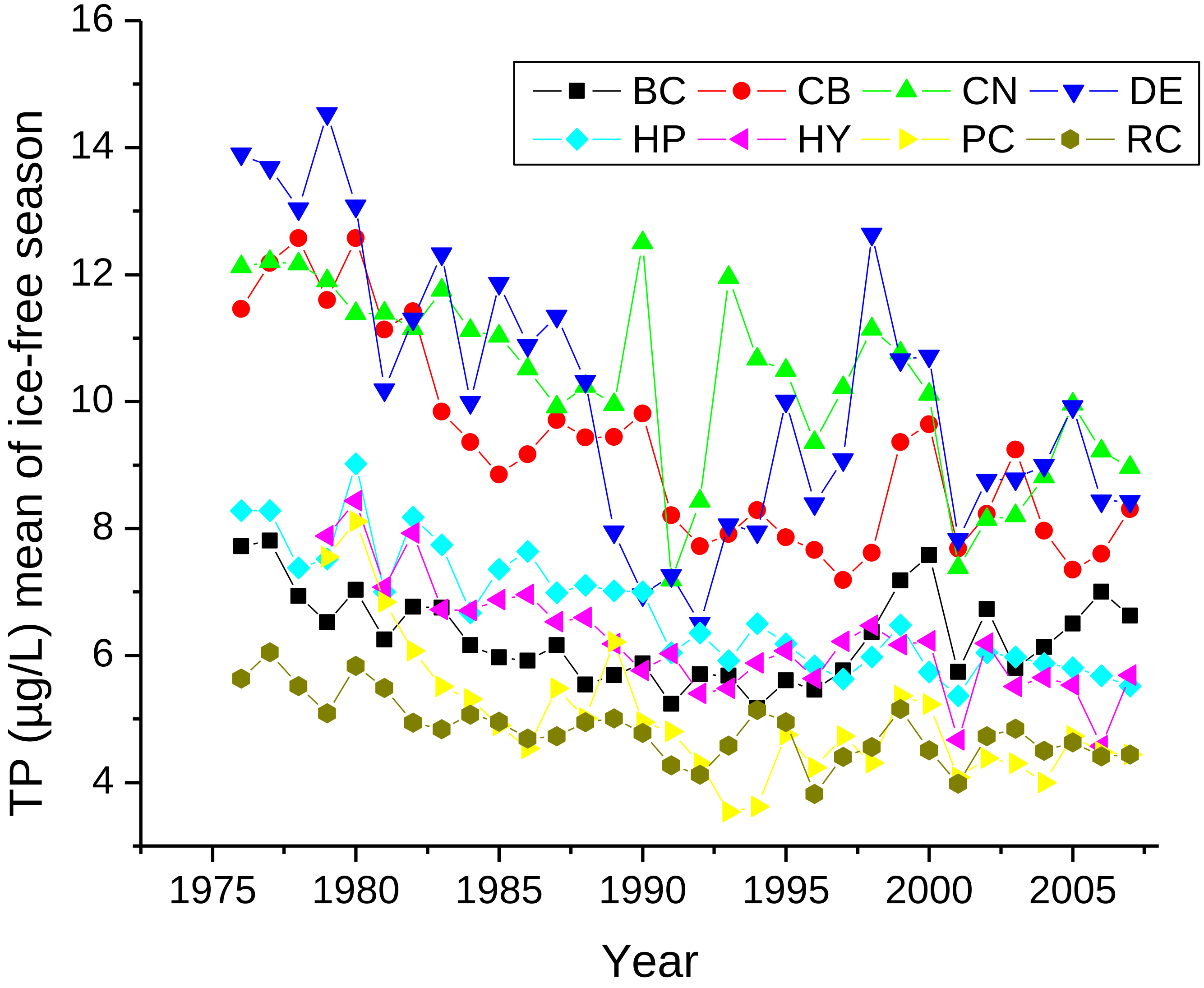


*Palmer and Yan 2013 FWB in press

What might rising DOC produce?

- Shallower and warmer euphotic zones
- Less UV penetration
- Change in speciation and transport of metals
- More heterotrophic food chains
- Changes in seston stoichiometry, higher C:P
- Increased abundance of invertebrate predators
- Alterred mate selection in fish
- Etc.

Water quality is changing: TP is falling



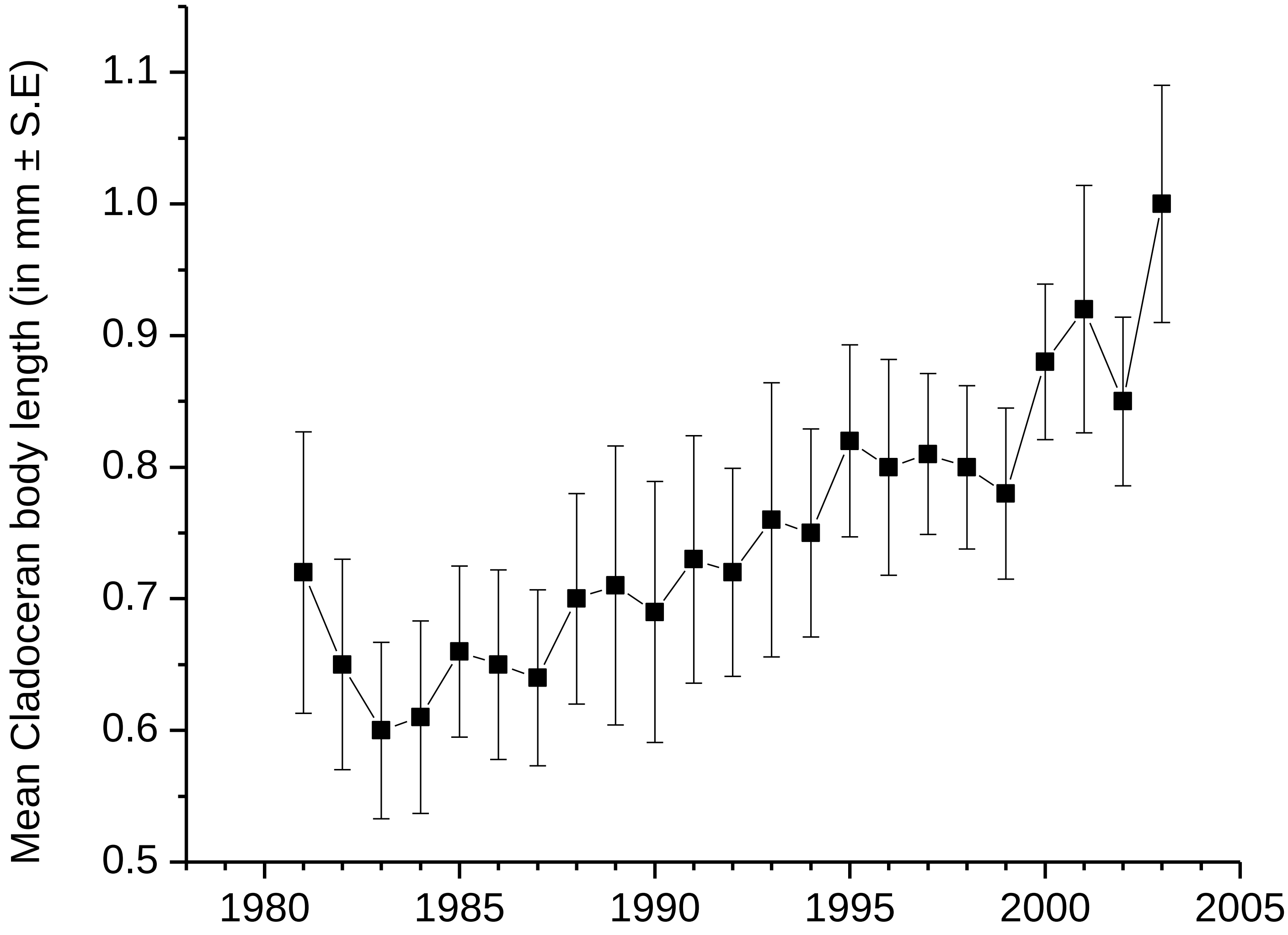
Andrew Paterson

*Hall and Smol (1996), Paterson et al. (OMOE data)

What might falling TP do?

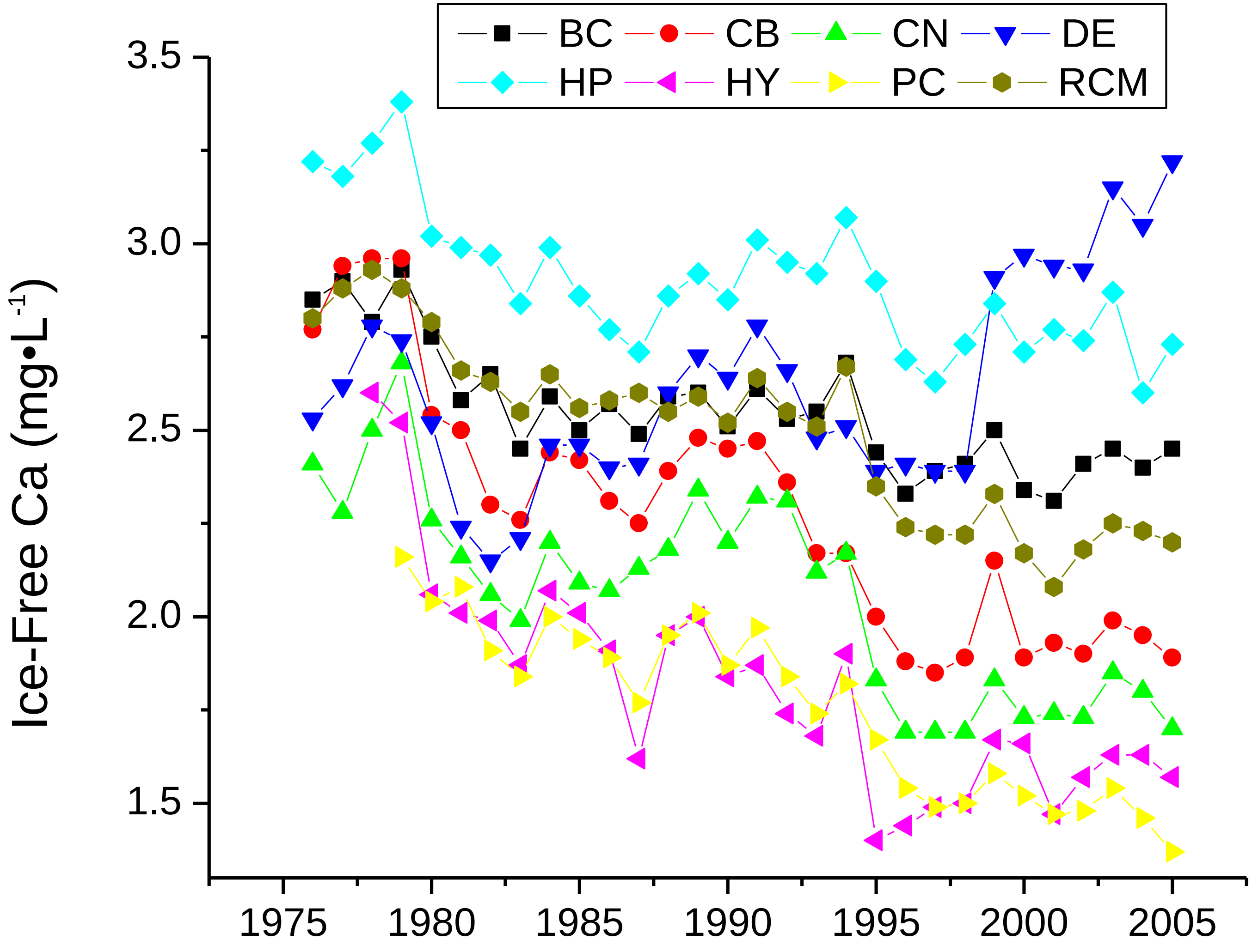
- lower food quantity, with implications for water clarity, anoxia, etc.
- Change food quality
- Alter species composition
- Alter competition among herbivores
- **Change mean body size of herbivores**

Mean body length of water fleas is rising In Dorset A lakes*

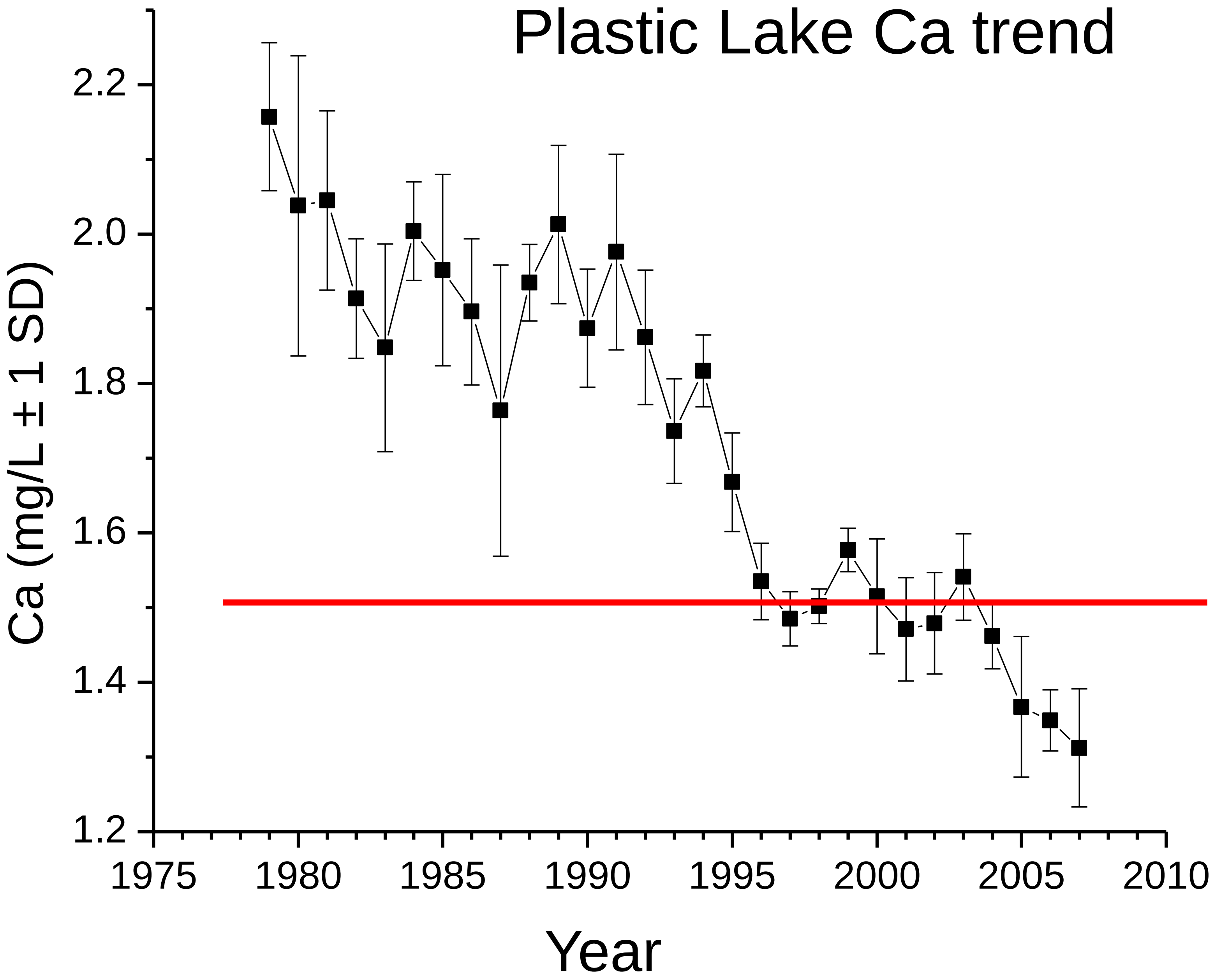


*Yan et al. 2008 CJFAS

Water quality is changing: Calcium (Ca) is falling



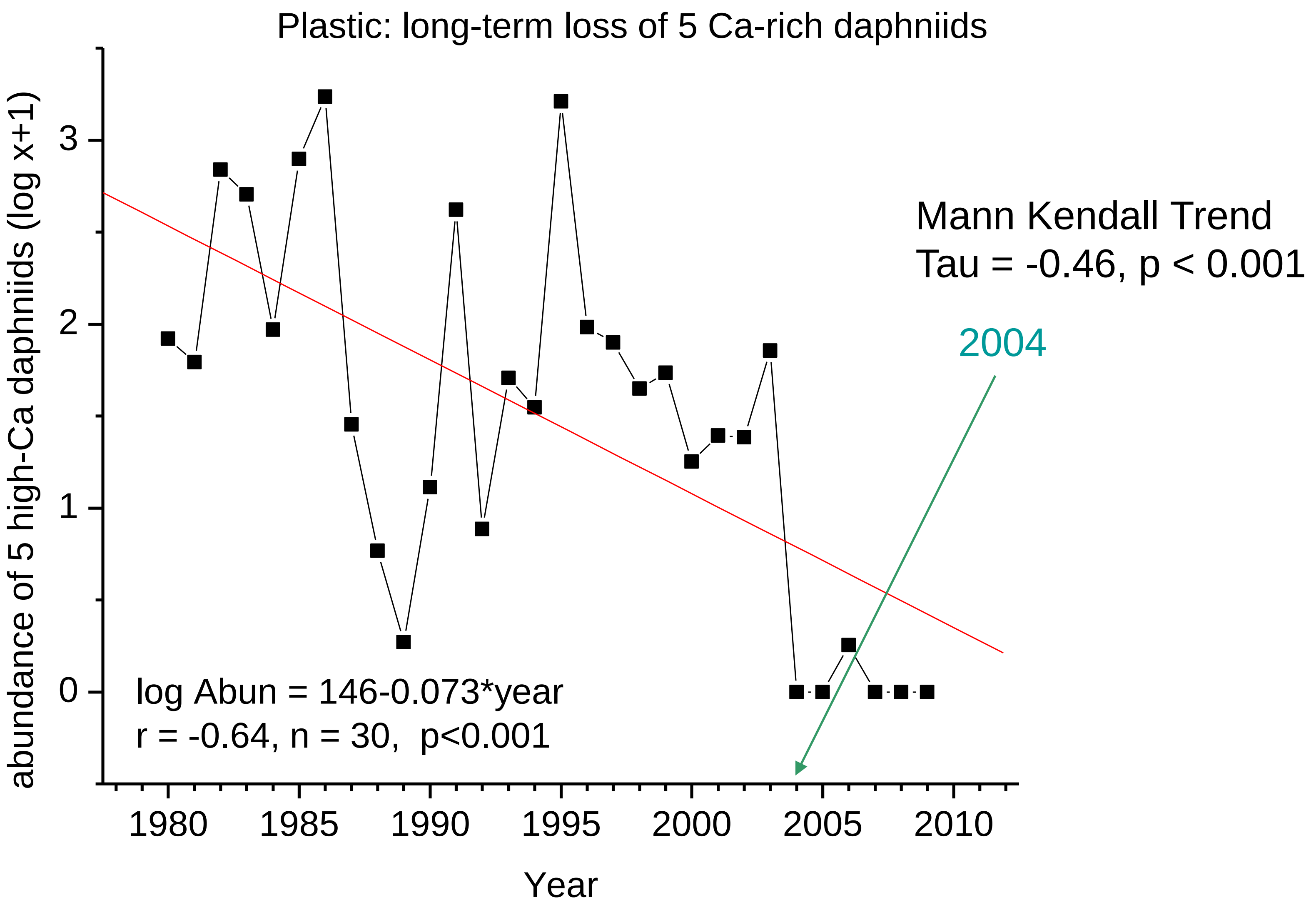
*Molot and Dillon 2008 CJFAS 65: 809; Yan et al. 2008 CJFAS 65: 781



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

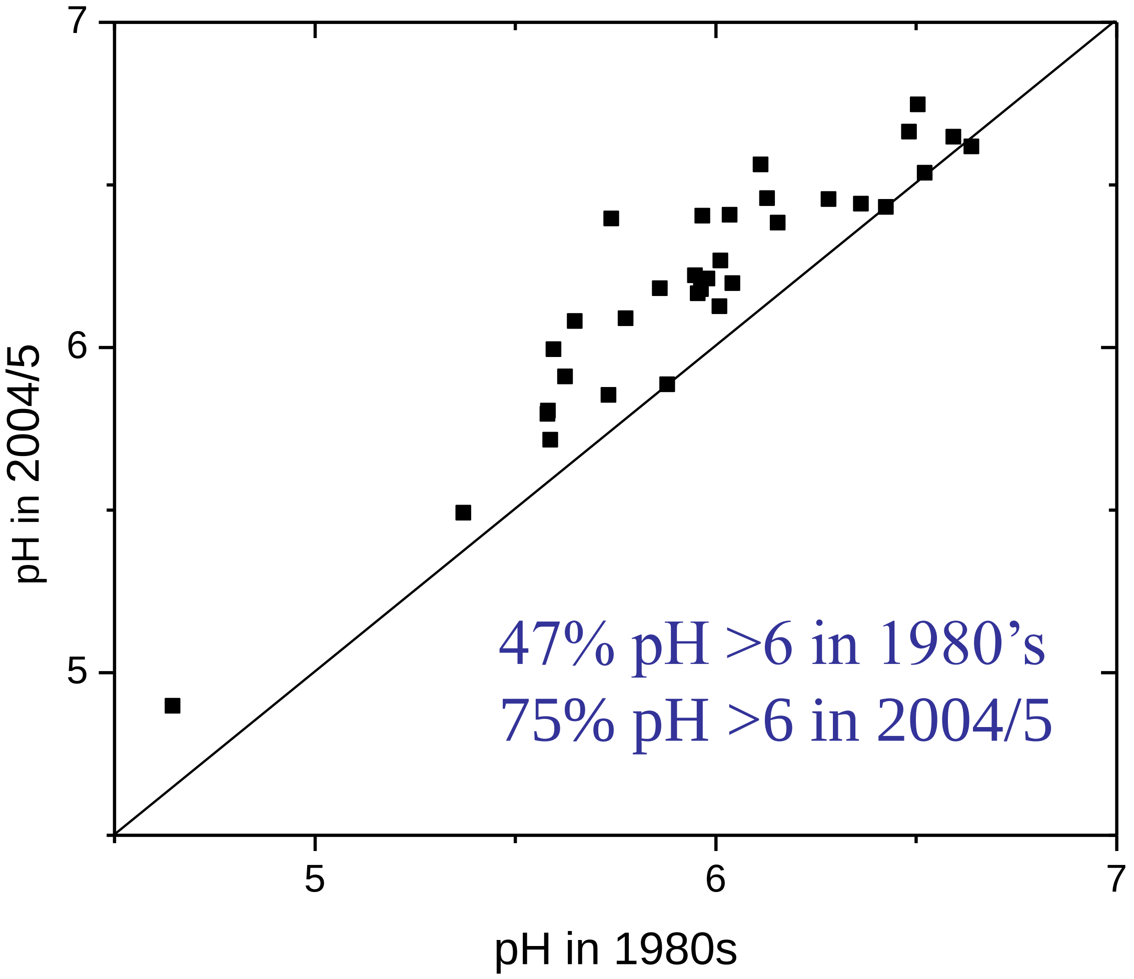
MOE data

Decline in abundance of 5 Ca-rich daphniids in Plastic Lake*



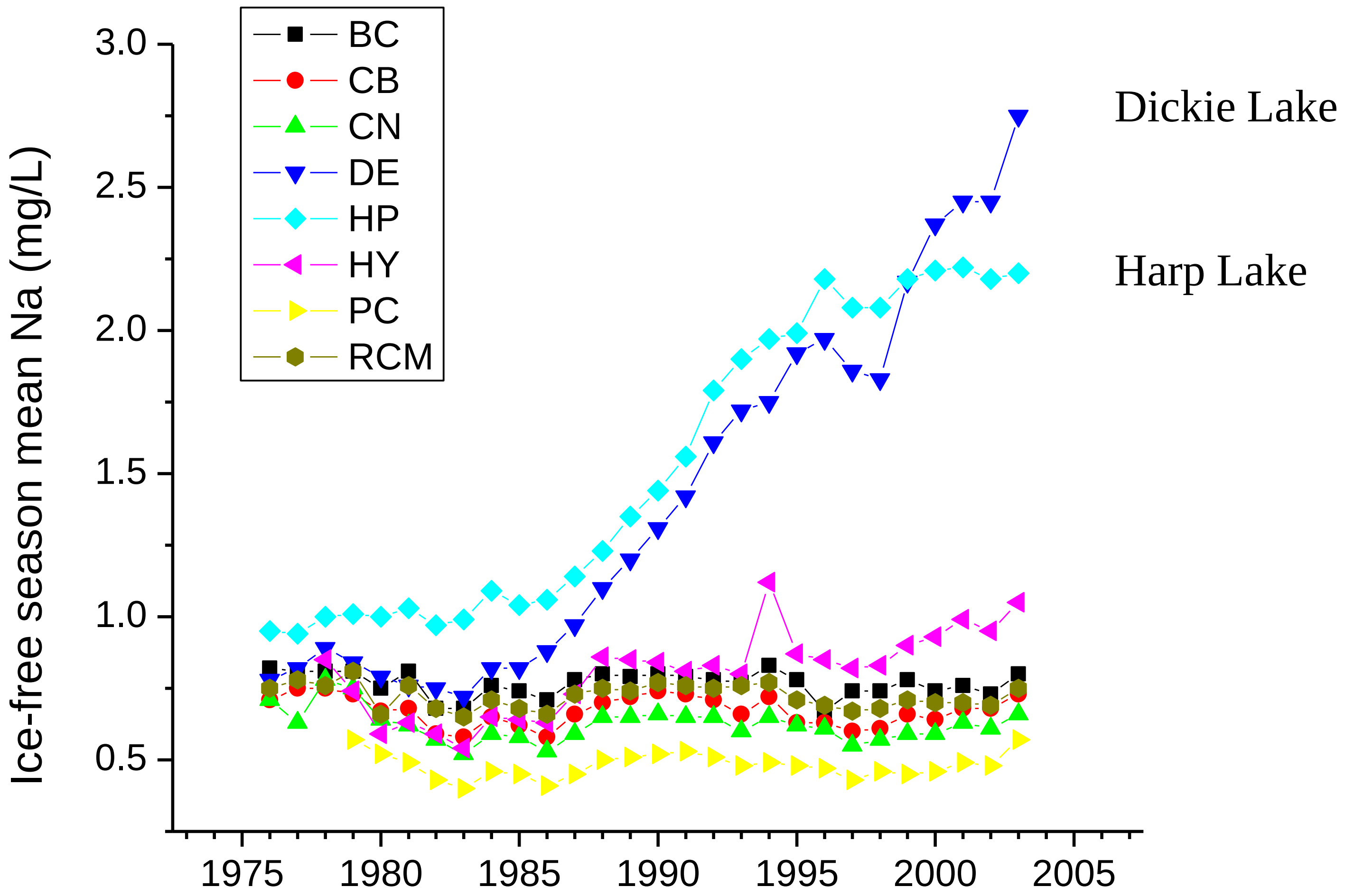
*Yan et al. unpubl data

Water quality is changing: pH is rising* with clear benefits for all biota



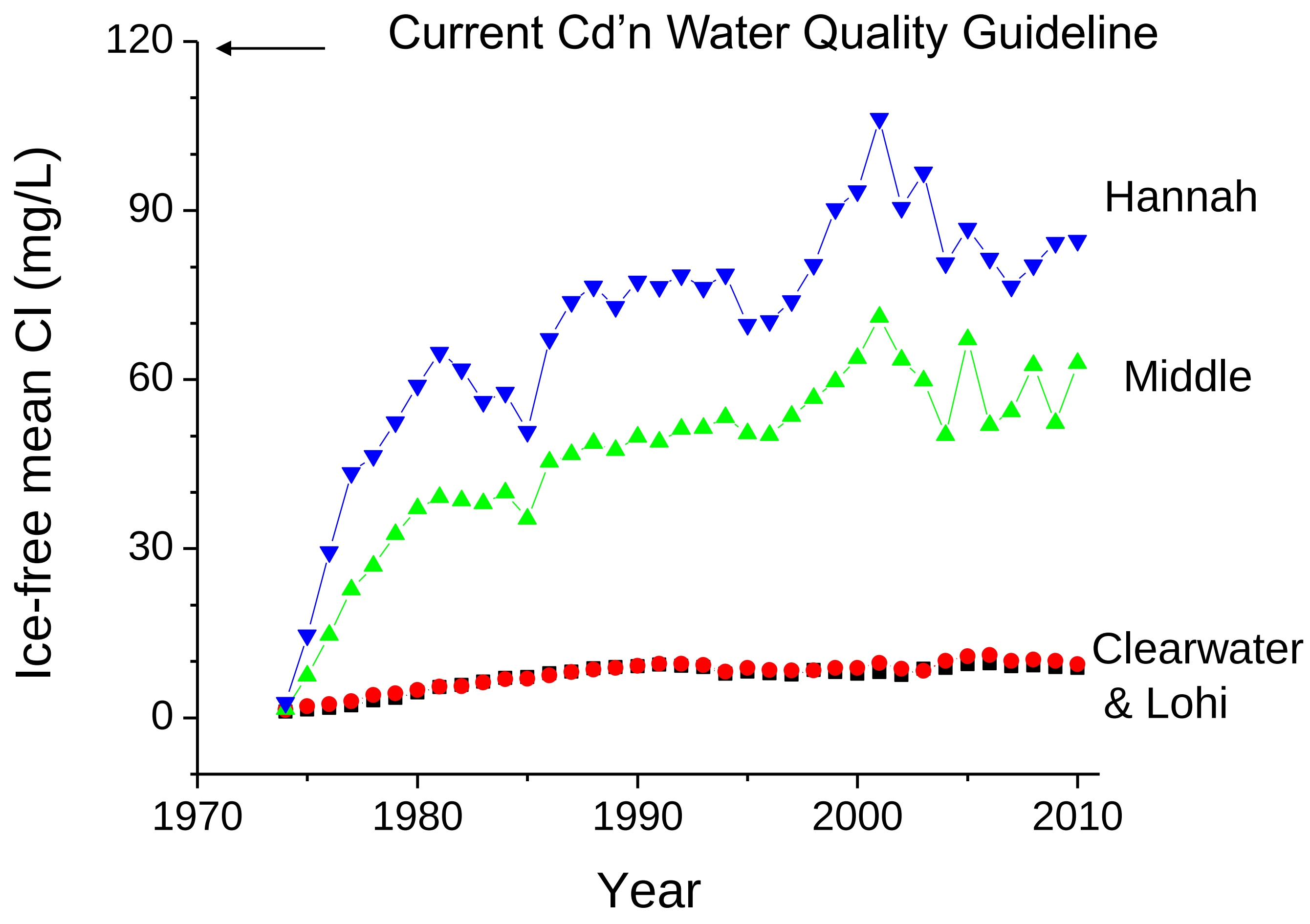
* Palmer et al. 2011 CJFAS 68: 1038

Water quality is changing:
NaCl is rising in lakes with many cottages*



*Molot and Dillon 2008 CJFAS 65: 809

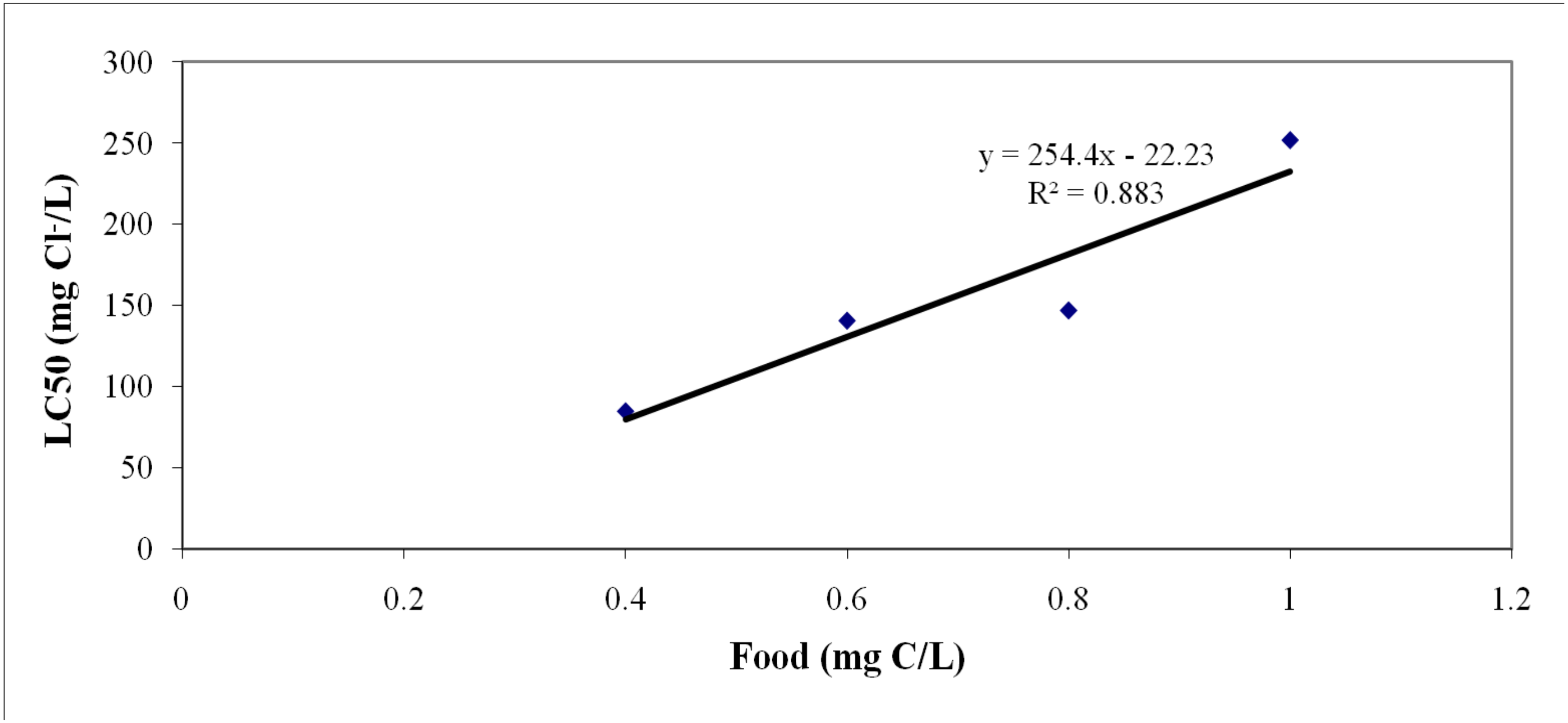
But especially in lakes with winter-maintained highways in their watersheds*



*data from Keller, Bailey, Heneberry, MOE

And what might rising chloride do if TP is low?

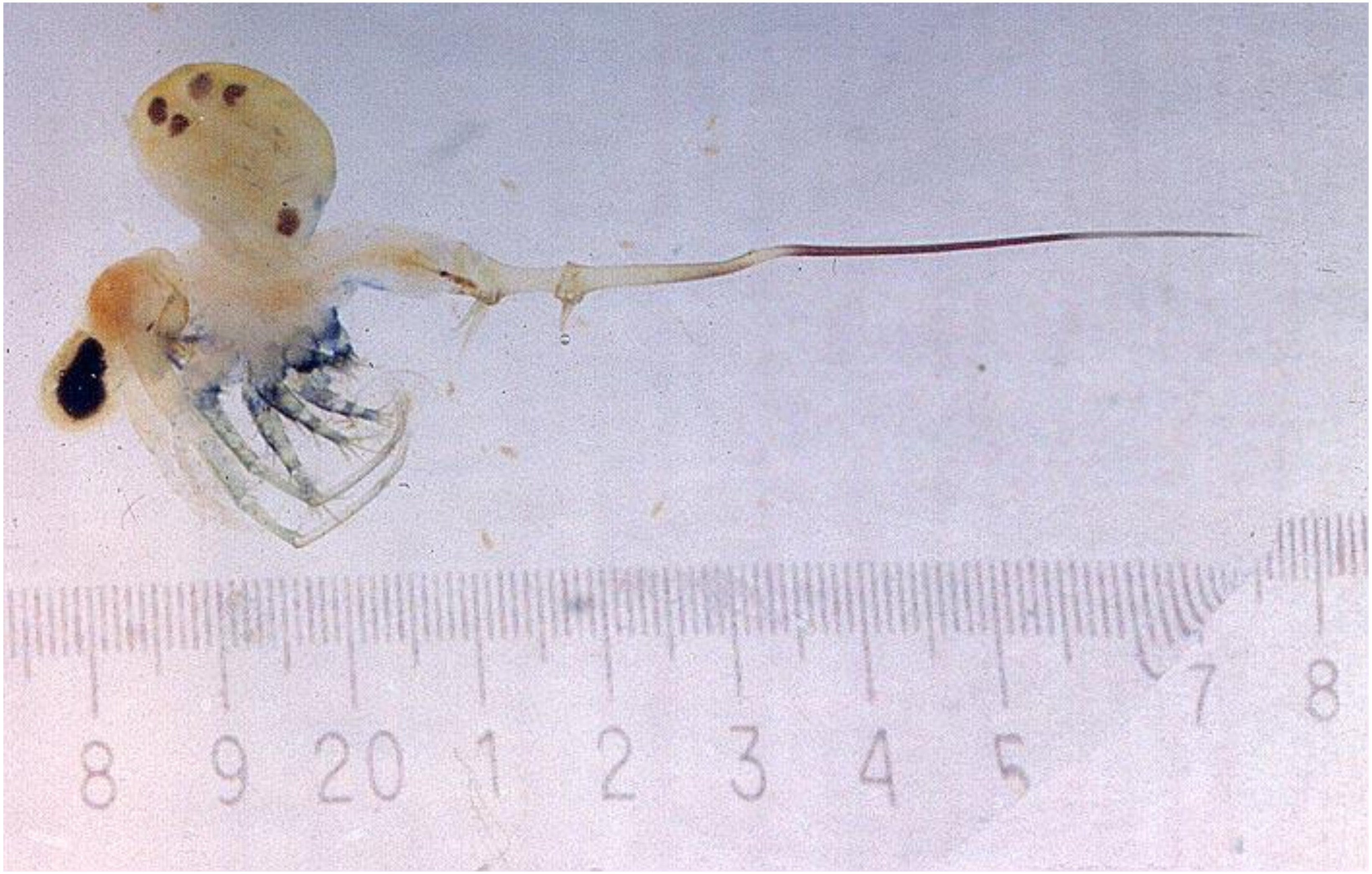
Daphnia are more sensitive to salt when food levels are low*



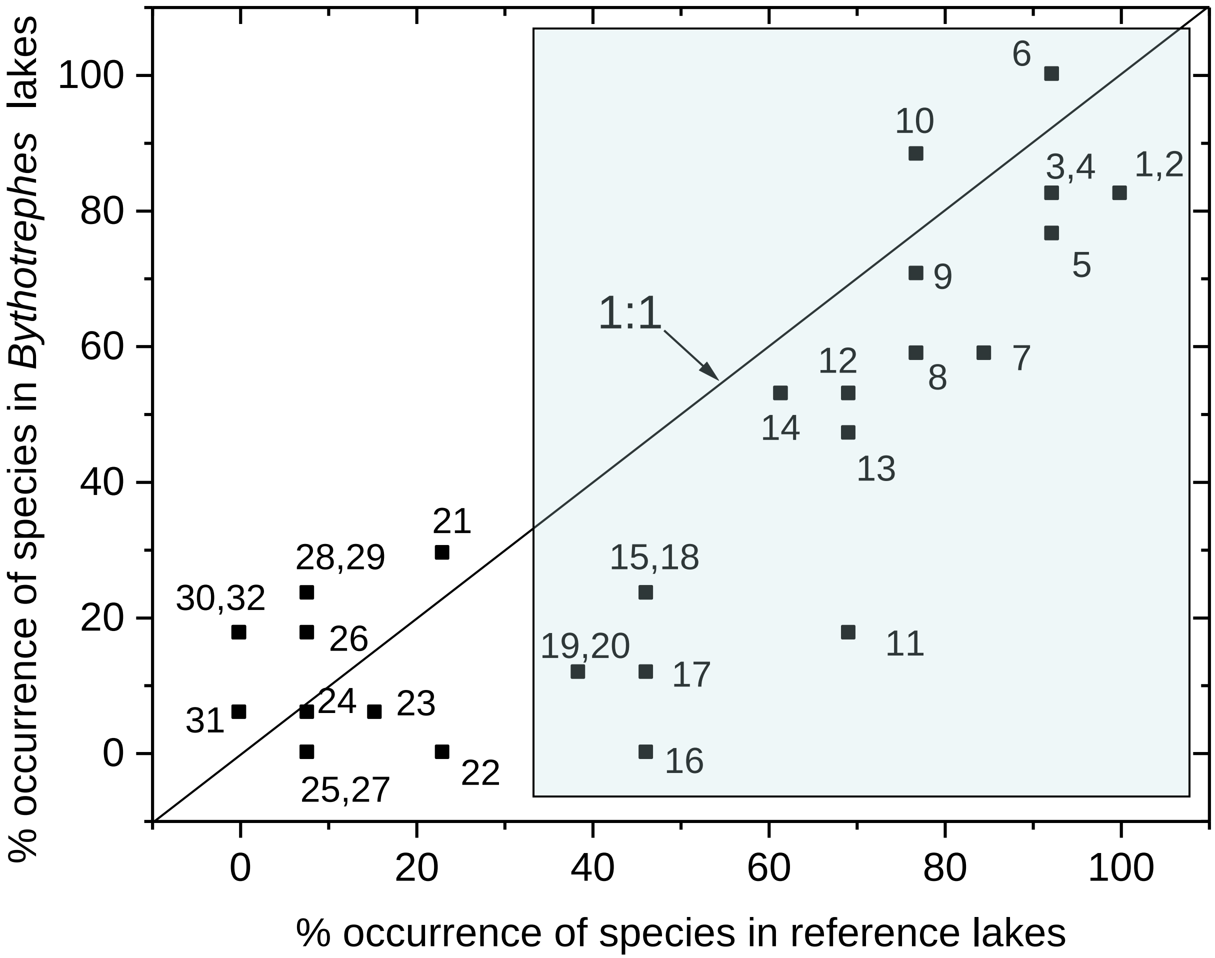
*Arran Brown's MSc work, York U, Oct 2012

Biossay on *D pulex/pulicaria* hybrid isolated from McFarlane Lake

And biota are changing: *Bythotrephes*



18 of the 20 most common species were less prevalent after invasion by *Bythotrephes*



Taxa	
1	D. b. tho
2	M. edax
3	D. mend
4	H. gibb
5	B. frey
6	L. min
7	S. oreg
8	D. birg
9	E. lacu
10	T. exte
11	D. dubi
12	D. long
13	B. long
14	C. scut
15	C. spha
16	D. cata
17	B. tub
18	A vern
19	P. ped
20	S. crys

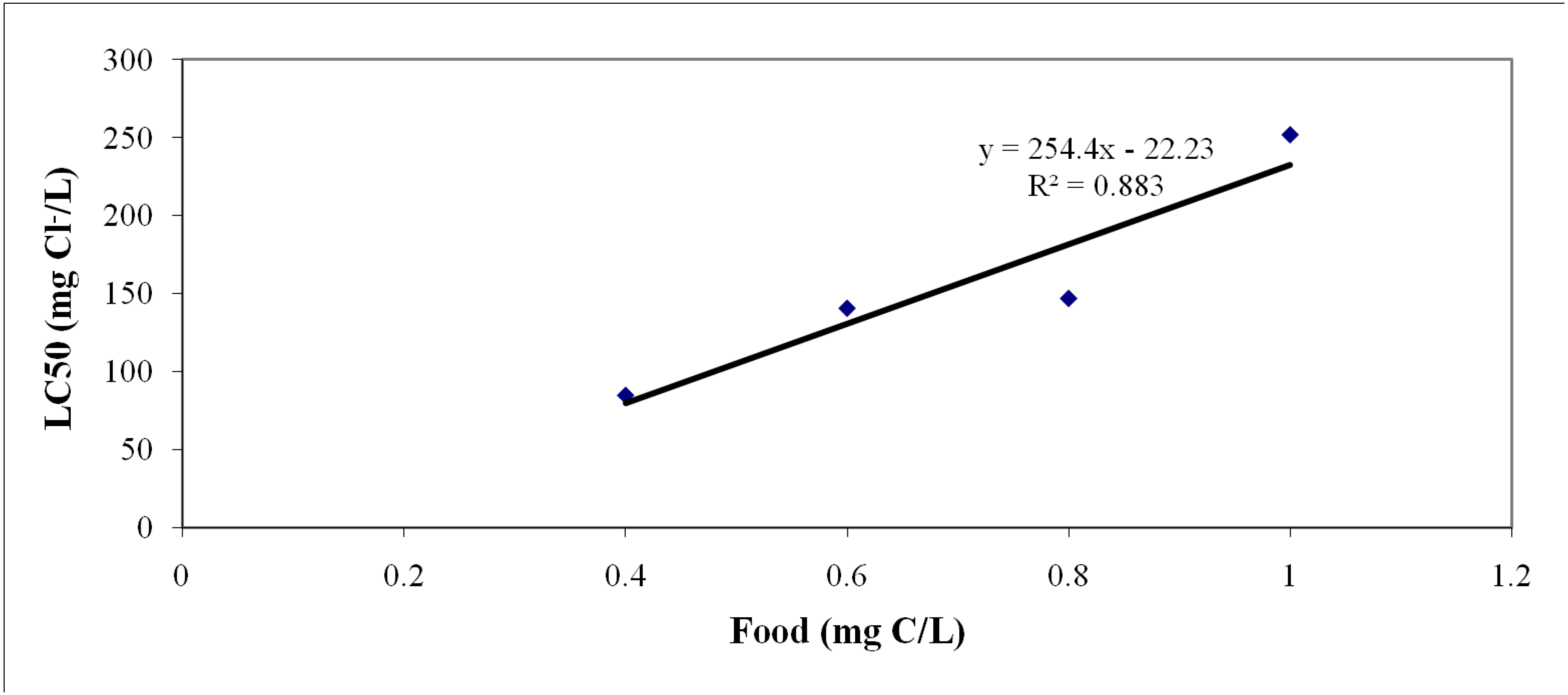
*Boudreau & Yan, 2003 CJFAS 60: 1307

So conditions in lakes are changing

- Physics – wind, temperature, mixing depths, heat content, turnover date, ice-cover duration
- Water quality – pH, TP, DOC, Ca, road salt
- Biota – bass, *Bythotrephes*, herbivore body size, phytoplankton composition
- **Are there interactive effects?**

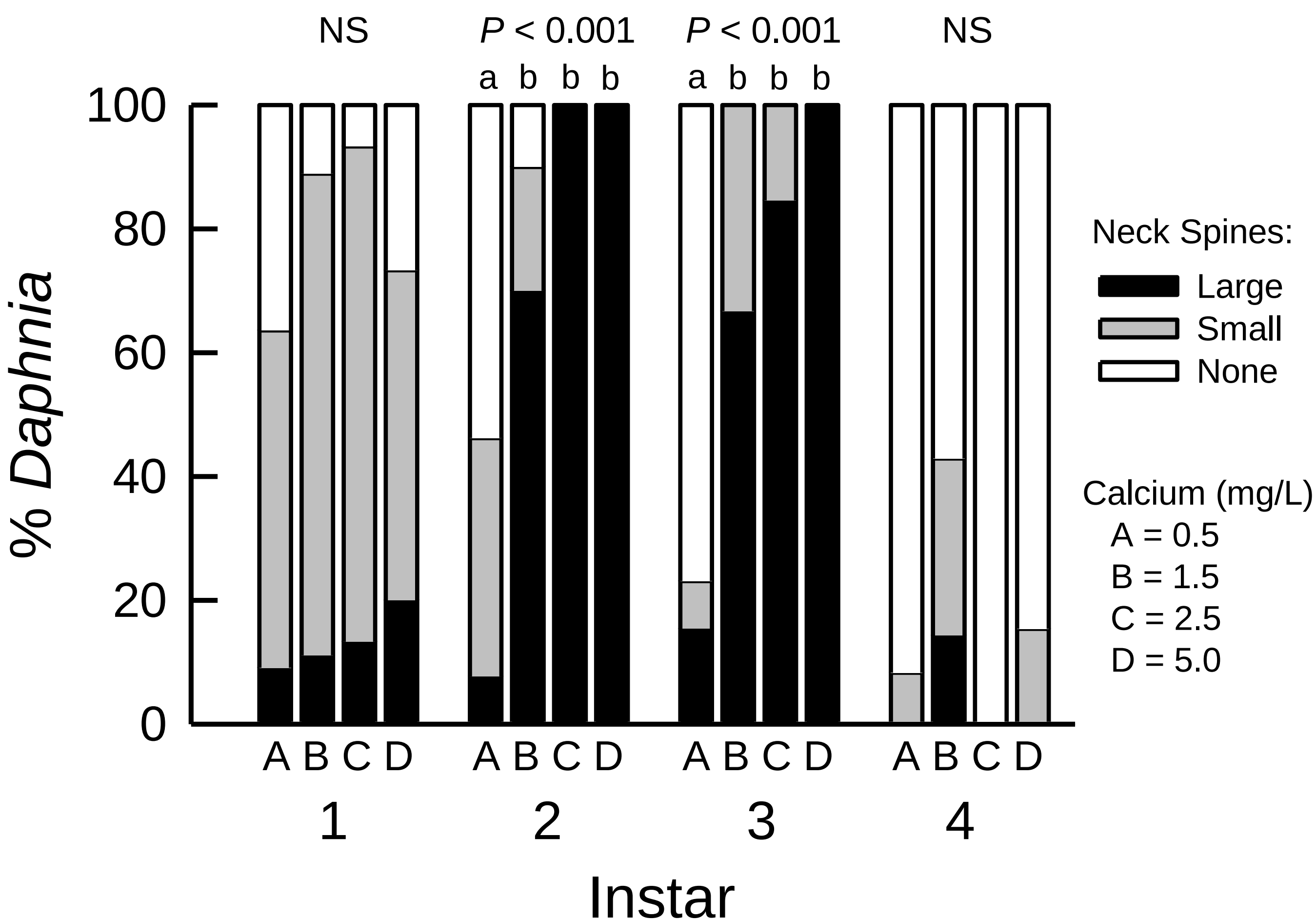
3. These stressors can interact

Lowering food levels increases sensitivity to road salt



These stressors can interact

Lowering Ca reduces neck teeth production, increasing vulnerability of daphniids to predators*

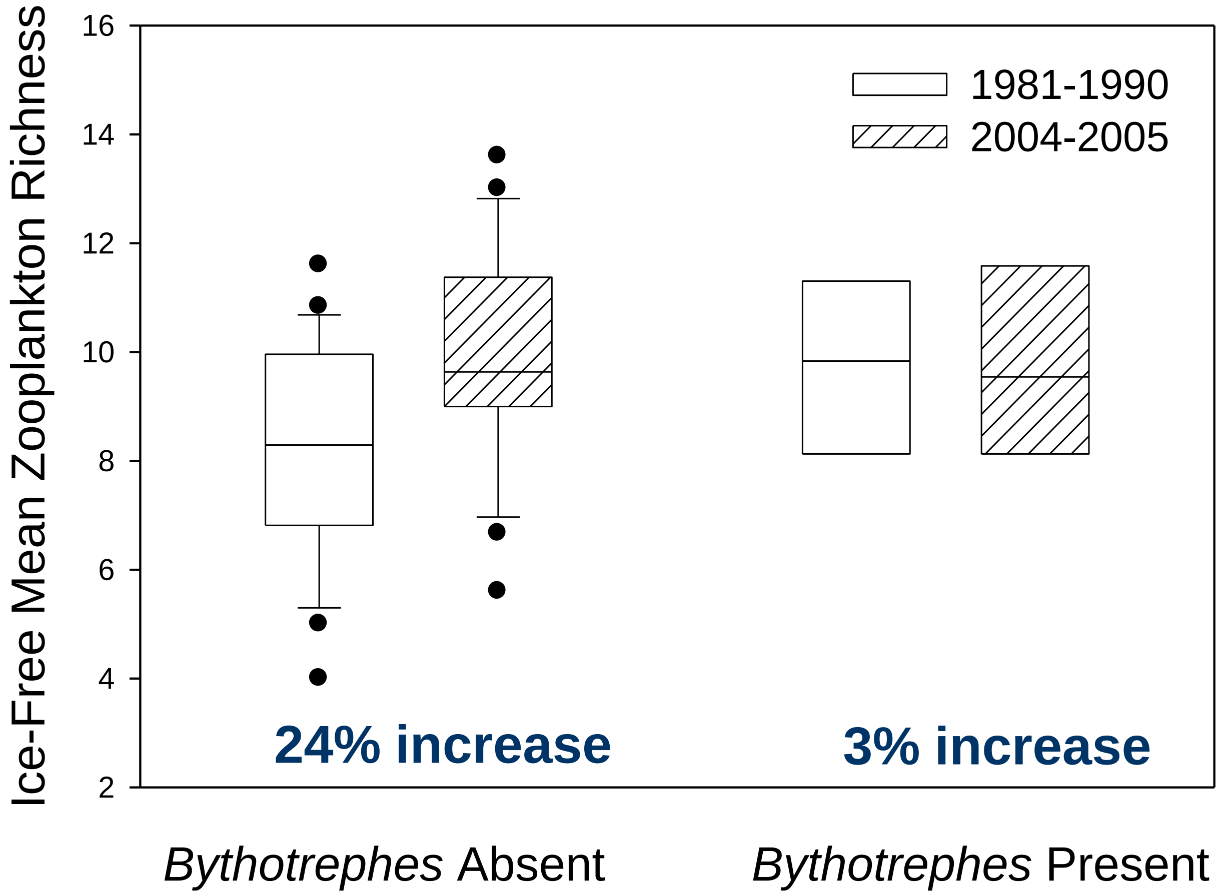


*Riessen et al. 2012 PNAS 109: 15377

These stressors can interact

Species richness in 36 lakes rose with rising pH and temperature, but not in the presence of *Bythotrephes**

- richness & diversity ↑
  - ↑ pH
  - ↑ temperature
  - ↑ TP
- *Bythotrephes* had a negative impact



*Palmer and Yan 2013 FWB

And there is evidence of a regime shift

Daphnia
Photo by Taylor

Holopedium
Painting by Sars

Daphnia

- Have higher Ca demand
- Have higher P demand
- Most are more vulnerable to invertebrate predators
- Are more acid-sensitive

Photo by D. Taylor

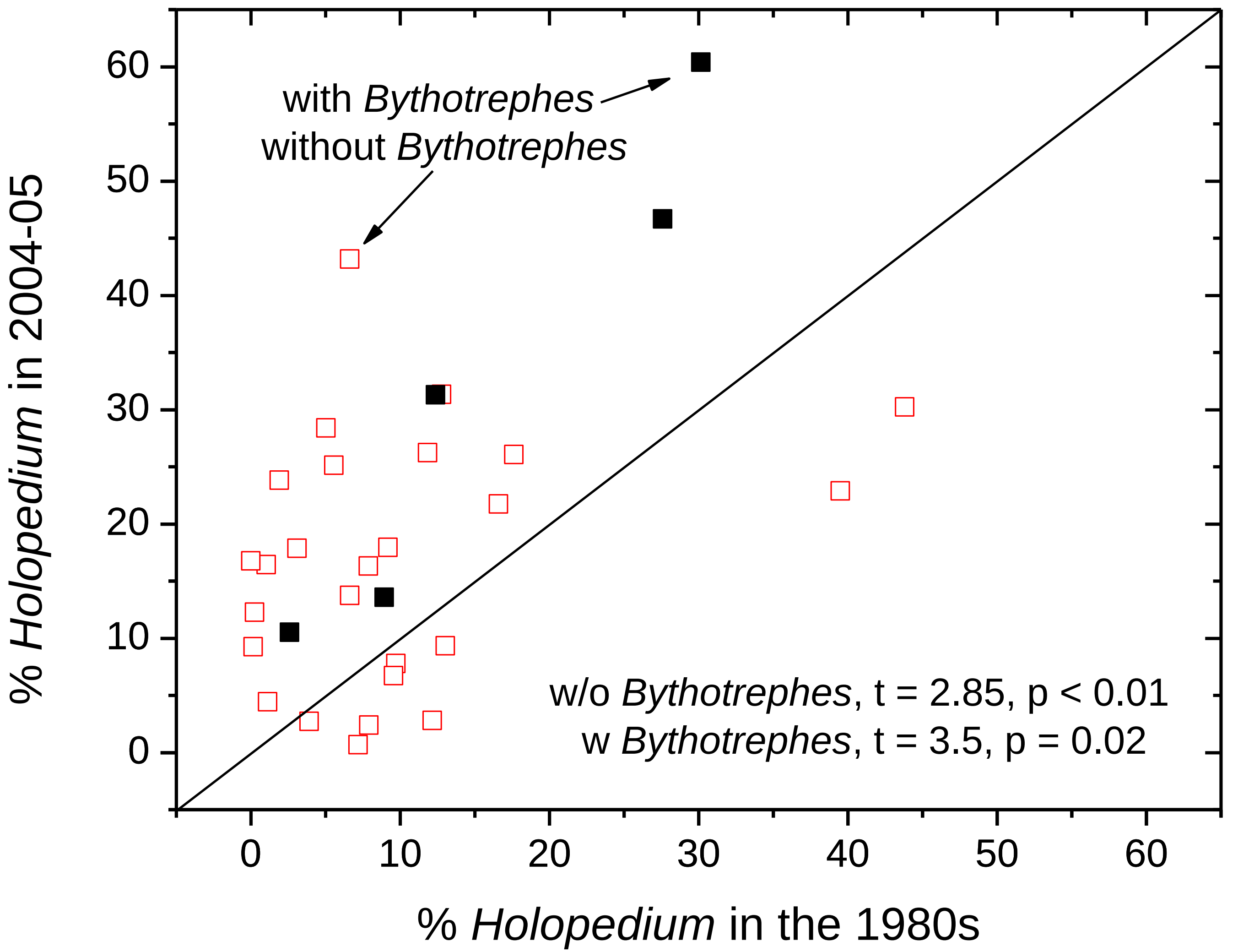
Holopedium

- Lower Ca demand
- Lower P demand
- Less vulnerable to invertebrate predators
- Acid tolerant

Painting by G.O. Sars

Evidence from the repeat of a broad-scale survey*

Change in relative abundance of *Holopedium* in the planktonic Cladoceran assemblage in 31 low Ca lakes, 5 invaded by *Bythotrephes*



*Jeziorski et al. PNAS under review

Handfuls of *Holopedium*

Contents of 1 net haul from Plastic Lake, August, 2011   Photo by R. Ingram

4. What might our children experience on these lakes when they are adults?

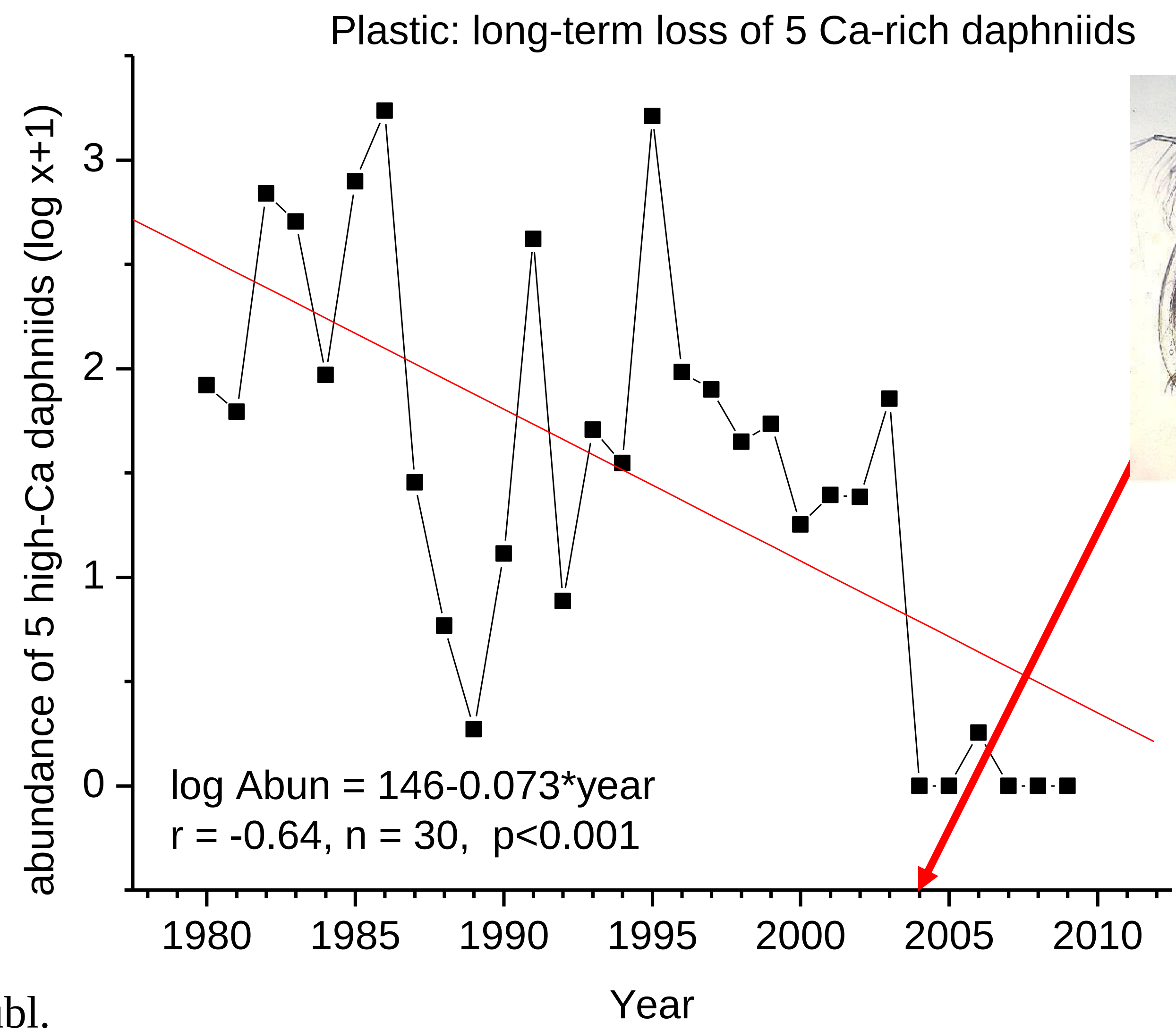
- Climate change:
  - Much shorter winter ice cover, and some lakes with no winter ice
  - Continued warming, increasing eutrophication threat
  - Shallow lakes will lose biota as they will get too hot
- Reduced food quality in food webs
  - Rising DOC leads increases C:P ratios in food supply, and has many other affects.
  - Diatom loss and warming waters reduce the supply of essential, long-chain omega 3 fatty acids in algae
- Decalcification
  - Lower soil Ca, poorer tree growth & lower lakewater Ca
  - Many calcareous species will give way to less crusty and more jelly-clad taxa, leading to filter clogging for water drawers

What will our children experience on these lakes when they are adults – cont'd?

- More people
  - more shoreline & fishing pressure, more pharmaceuticals, risk of eutrophication, and road salt use (if winters stay cold)
  - Changes in TP are uncertain, given links to hydrology, wetland, shoreline development and changes in soil acidity.
- More invading species:
  - Bass will continue to spread, lowering species diversity
  - *Leptodora* will succumb to *Bythotrephes*
  - More *Bythotrephes*, bloody red shrimp, *Dikerogammarus*
- Multiple stressors are the norm
- More surprises

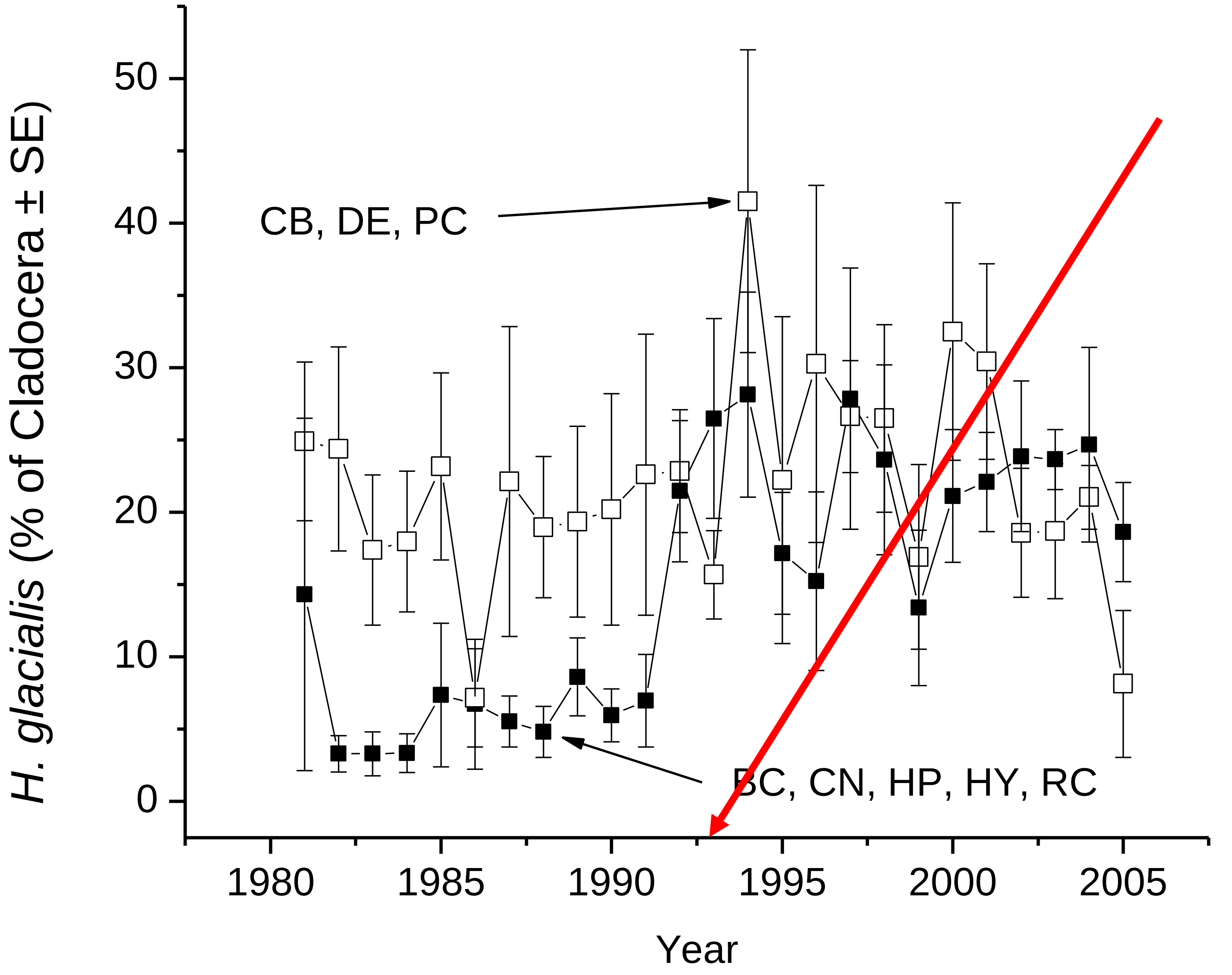
4. And changes may seem sudden

Sudden loss of 5 daphniids in Plastic Lake



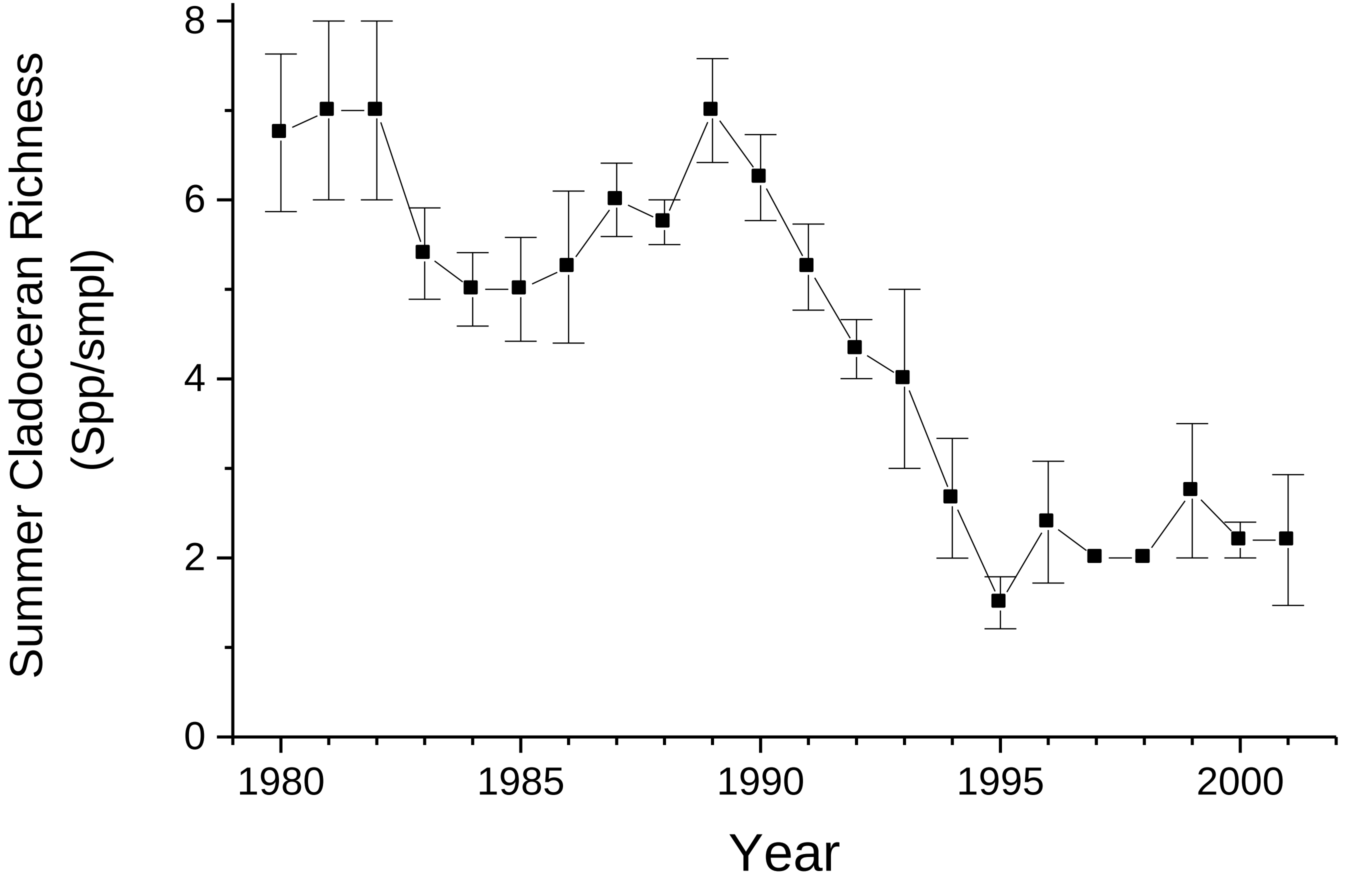
*Yan et al. unpubl.

Sudden rise of jellied species in Dorset lakes*



*Yan et al. unpubl

Rapid loss of species in Harp Lake*



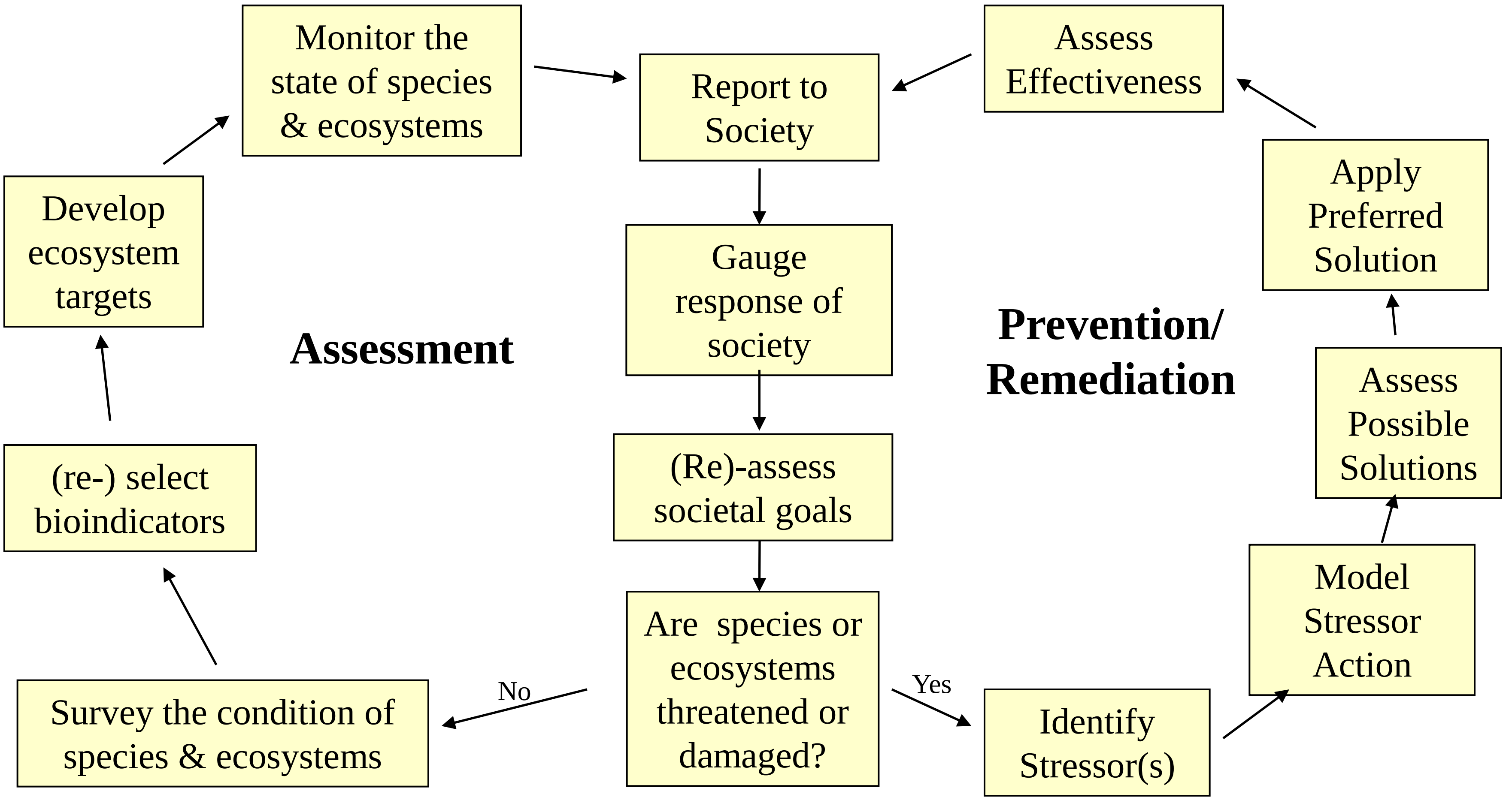
*Yan et al. 2002 Ecol. Letters 5: 481

5. Are we prepared for this rising complexity?

- Multiple changes in physics, chemistry, ecology and development pressures on lakes
- With both familiar and novel stressors
  - pharmaceuticals, road salt, new invaders
- That interact.
- Approaching thresholds
- Rapid changes in responding species
- That may represent regime shifts

Applied ecologists have clear roles in the environmental management process:

problem detection, SOE reporting, diagnosis, prognosis, effectiveness assessment



We have followed this “model” with demonstrable success, many times

- Acid Rain
- Ozone depletion
- Lead pollution from leaded gasoline
- Eutrophication of the Great Lakes, and Gravenhurst Bay
- DDT and other pesticides

But to succeed, we must

- Compare environmental condition with targets that reflect our values*
- Communicate these conditions to the public
- Distinguish actual from possible causes of problems*
- Model cause effect linkages well enough to plan remedial actions*
- Intervene to eliminate the cause(s)
- Re-assess environmental condition to see if our intervention worked

*Ehrlich, PR & GC Daily. 1993. Ecol. Appl. 3:558-560

What the federal government is doing is:

- Reducing our ability to detect problems, by reducing environmental assessment work
- Preventing our scientists from open communication with the public, keeping the public ignorant
- Cutting support for diagnostic research, such as at ELA.
- Reducing the federal workforce capable of modelling cause- effect linkages well enough to plan remedial actions, and reducing NSERC support of such work
- Reducing the numbers of sites where interventions to eliminate the causes are required

My simple view of environmental management

The cardinal Human Values are	To solve environmental problems In a functioning democracy Society needs only	The cardinal Human Flaws are
Humility →	Knowledge	← Arrogance
&	&	&
Hope* →	The Will to Act	← Despair

*Richard Outram

My simple view of a functioning democracy

- One which is freely and regularly elected by an informed* population
- And one which strikes a balance in its actions between the interests and the best values** of a majority of that population

*"Whenever the people are well-informed, they can be trusted with their own government" (Thomas Jefferson)

** Good values maximize the well-being of conscious beings, including mankind (Sam Harris)

There are two key gradients in government, the less important of which is the left-right gradient

	Left	Right
Authoritarian	Communism	Fascism
Non-authoritarian		

*From Ferris in Otto 2011

Non-authoritarian democracies promote human health*

Infant mortality vs freedom scores for 172 countries

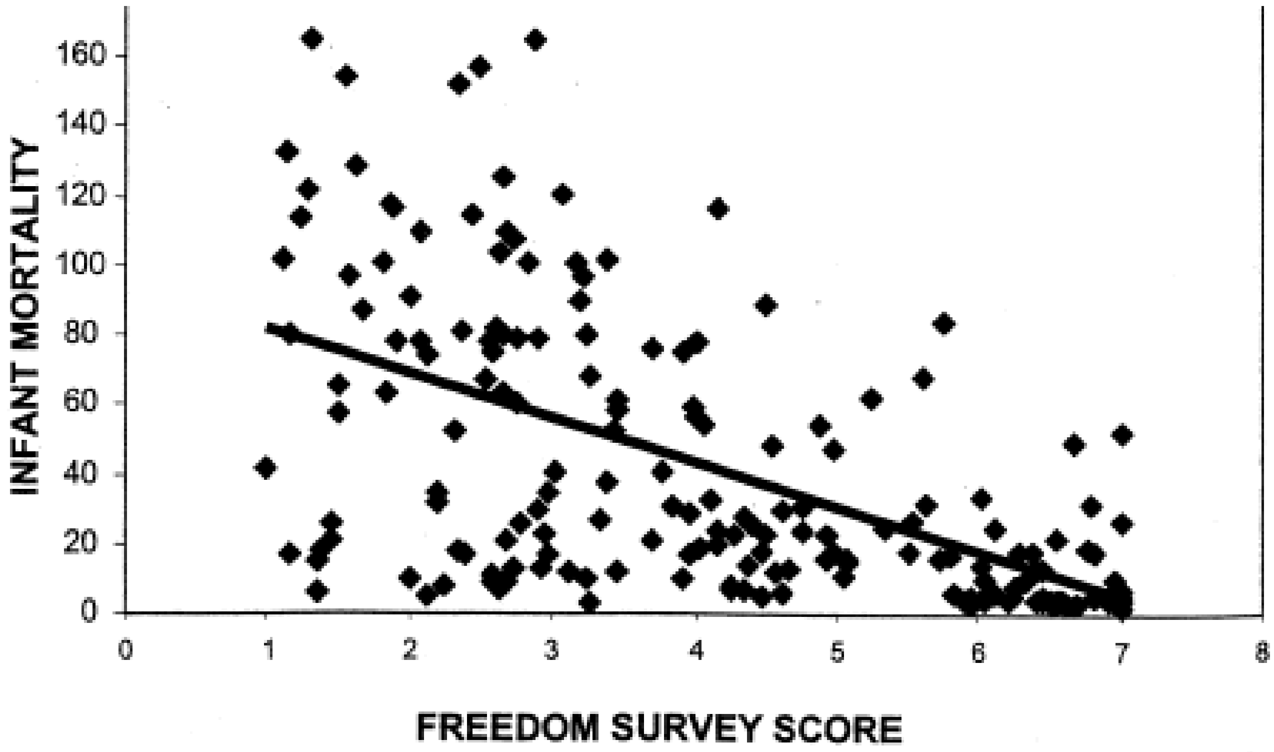
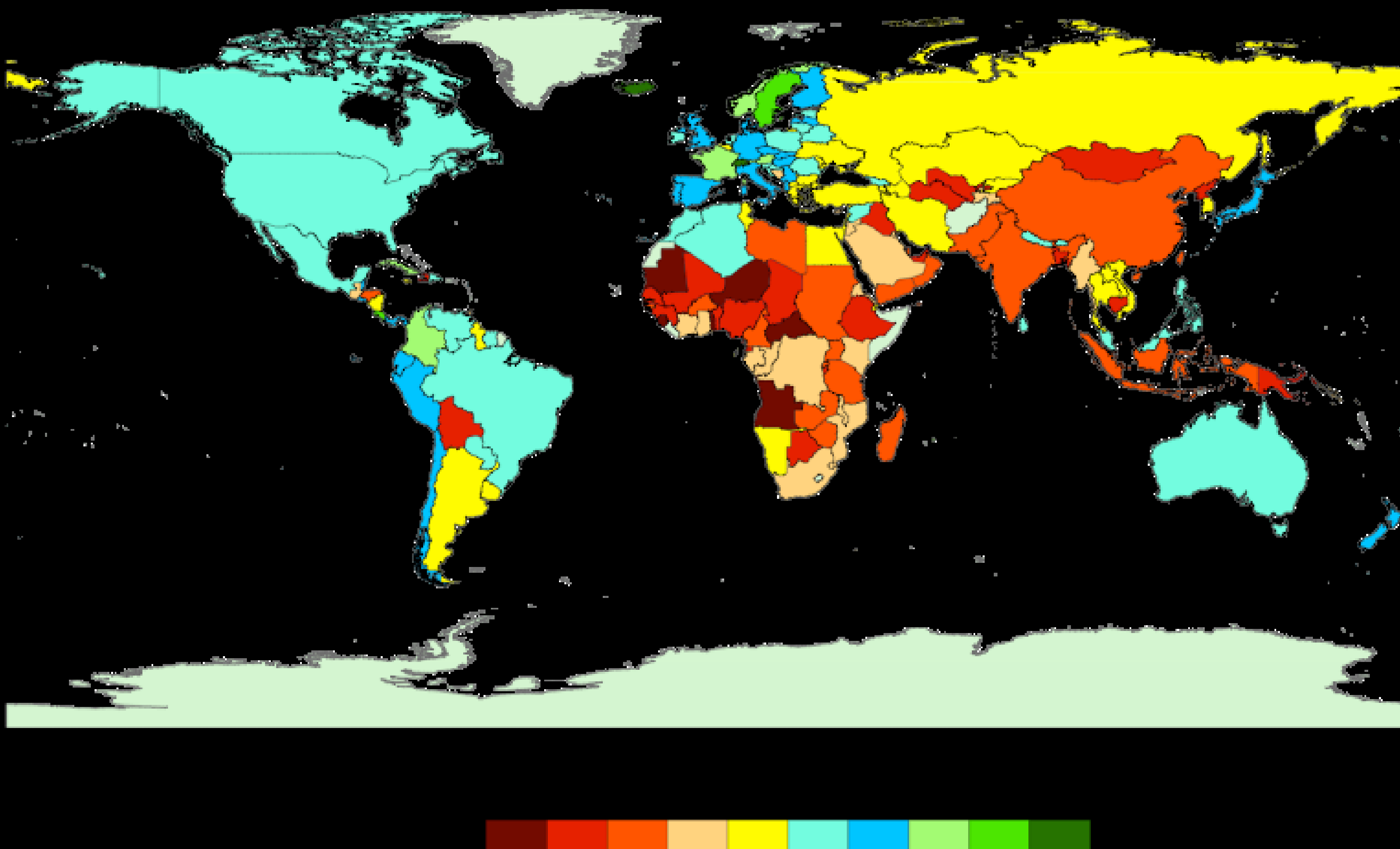


*Fig 7.1 in Seymour Garte. 2008. Where we stand: a surprising look at the real state of our planet
See www.freedomhouse.org for the freedom data

Do non-authoritarian governments promote environmental health?

2010 Environmental Performance Index (epi.yale.edu)*

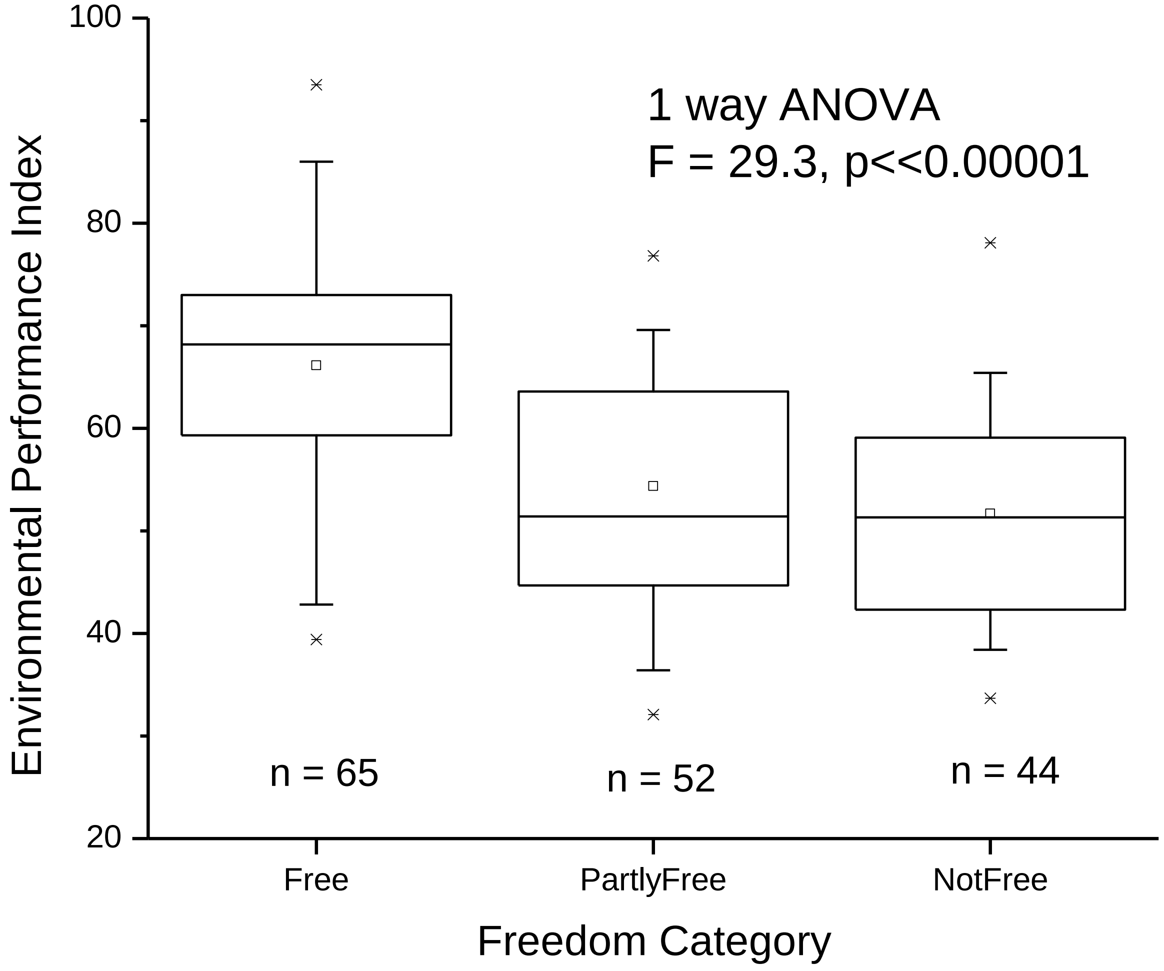


35 43 48 53 59 65 72 77 85 90

2010 Environmental Performance Index

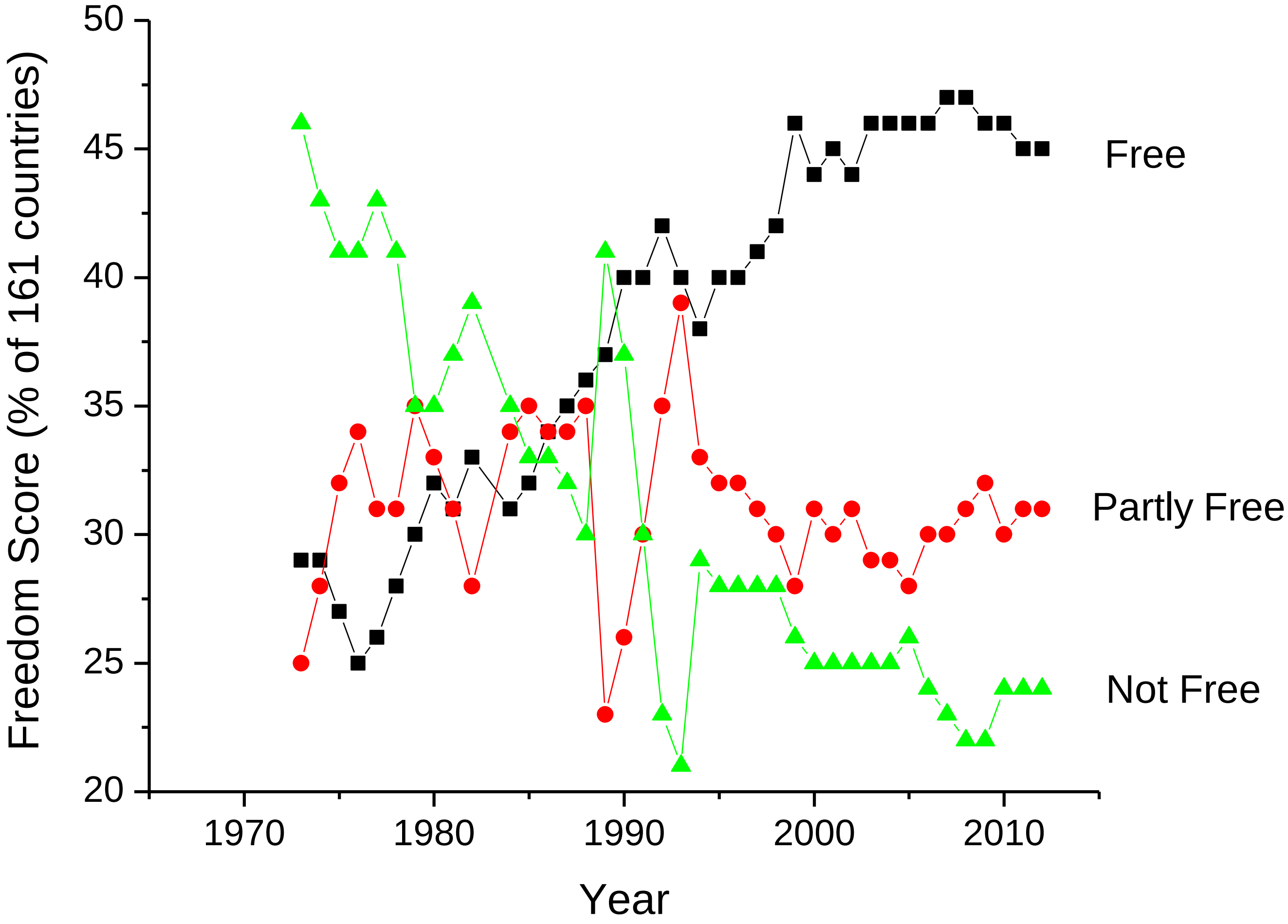
*Yale Centre Environmental Law & Policy
Columbia Inter. Earth Sci. Info. Network
World Economic Forum
Joint Research Centre European Commission

Does Freedom Promote Environmental Health?



2010 data on environmental performance and freedom from 161 countries, from
Emerson et al. 2010 Environmental Performance, Yale Center for Environmental Law and Policy
National Freedom Categories from www.freedomhouse.org
Yan unpub, Nov 2012

there is global cause for hope*



*data from Freedomhouse.org

Conclusions

- The physics, chemistry and ecology of our lakes is changing
- We know how to solve many current problems in our lakes, and how to prevent several emerging problems
- We also know what research is needed to prevent many emerging problems, but we are less able to act on this knowledge than in the past.
- Broadly-based knowledge and will must both be nurtured if our environment is to be protected