Assessment of water quality in Nova Scotia using paleoecological indicators

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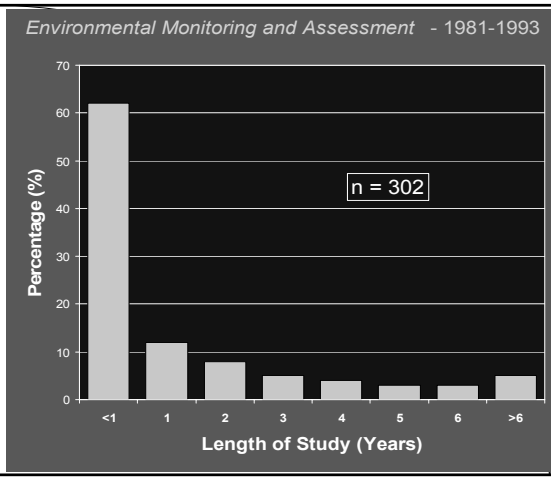
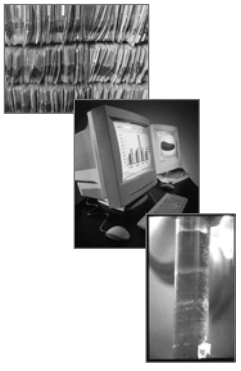
http://biology.queensu.ca/~pearl/maritimes



NEED TO KNOW……..

- What was the pre-disturbance condition?
- What is the range of natural variability?
- Have conditions changed?
  - How? How much? How fast? When?
- What is the cause of the change?
- How much improvement can be expected?

Techniques to Assess Environmental Change



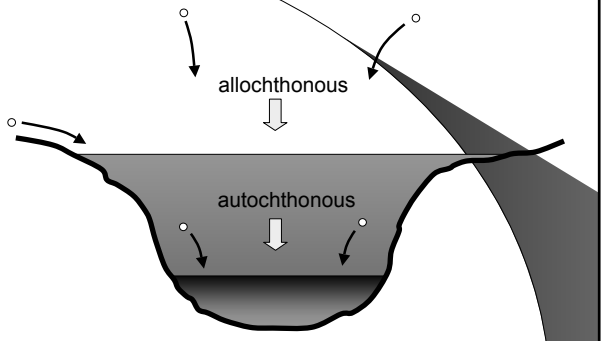
- **historical measurements**
- **modelling**
- **paleolimnology**

TEAM

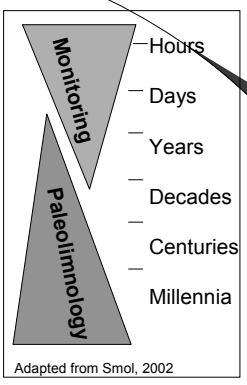
Trends in Eutrophication and Acidification in the Maritimes

- 5 year NSERC Strategic Grant
  - Started November, 2002
- Study water quality in Nova Scotia and southern New Brunswick using paleolimnological and modeling techniques.
- Main themes: eutrophication and acidification
- Total Lakes: 154
- Website: http://biology.queensu.ca/~pearl/maritimes

What contributes to the paleorecord?

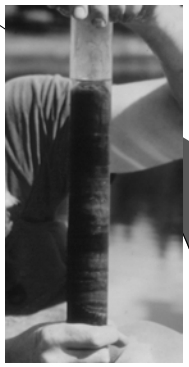


A Matter of Time Scales…

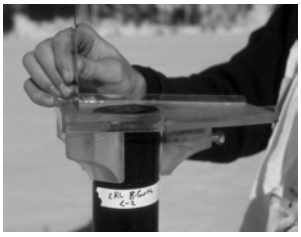


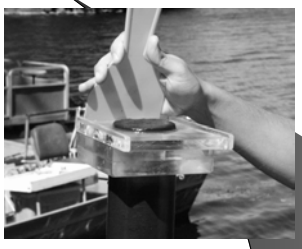
Adapted from Smol, 2002

Surface sediment gravity coring

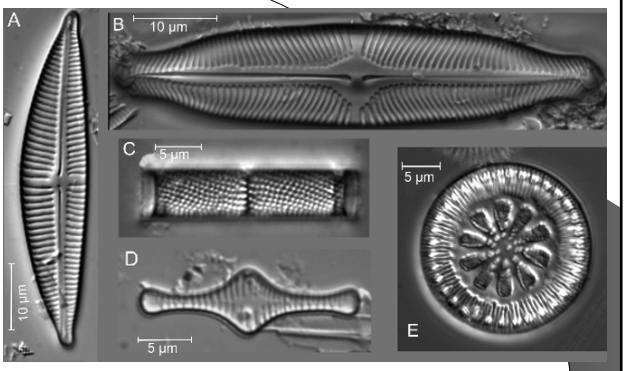


Close-Interval Sectioning





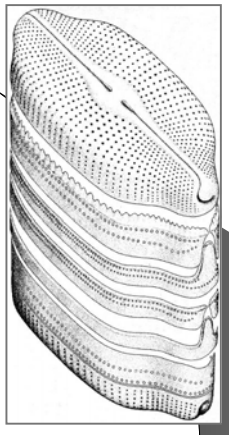
Freshwater diatoms

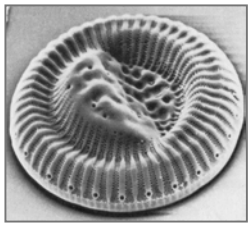


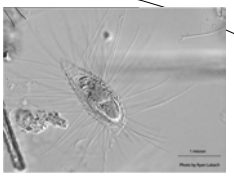
Photos: K. Laird and B. Cumming; Fig. 5.4 in Smol (2002)

Diatoms

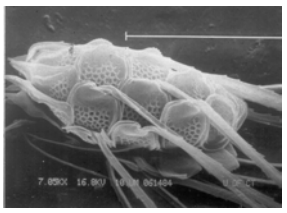
- Bacillariophyta
- abundant and diverse
- excellent environmental indicators
- siliceous cell walls (frustules)







Scaled Chrysophytes
(e.g. *Mallomonas*)



Chrysophyte Scales

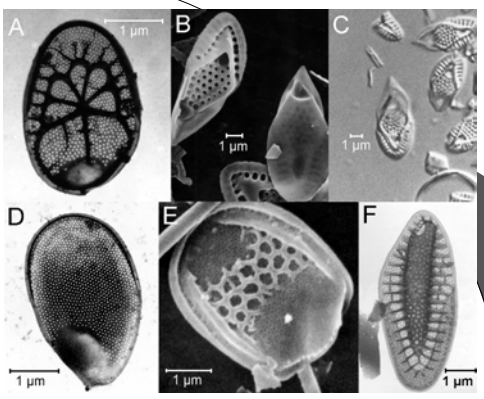
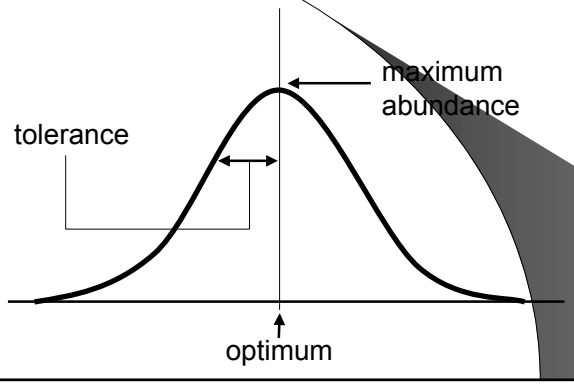


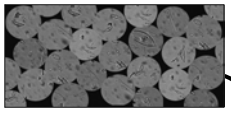
Figure 5.5 in Smol (2002)

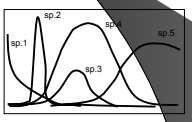
Gaussian (Unimodal) Response Curve



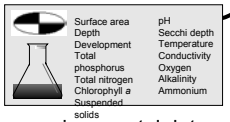
Construction of a Transfer Function

lake surface sediment samples

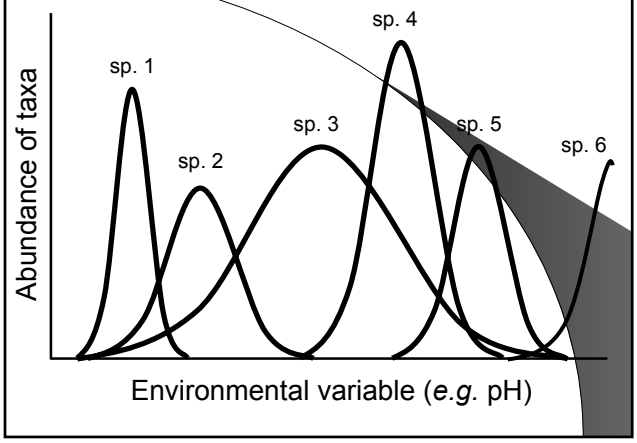


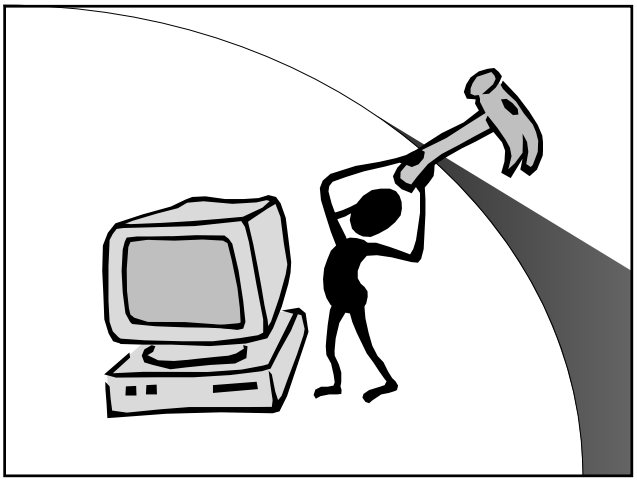


species response curves

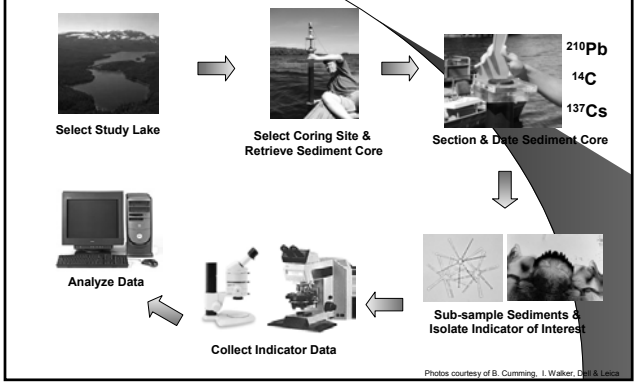


environmental data

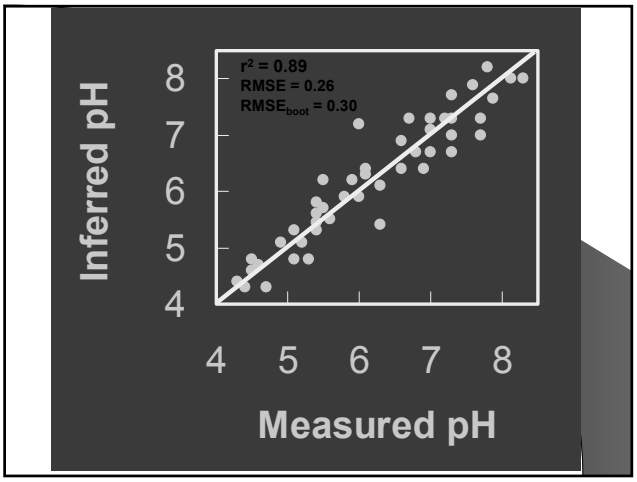




The Paleolimnological Approach



Photos courtesy of B. Cumming, I. Walker, Dell & Leica



Eutrophication

- Has increased development in the watersheds of Halifax lakes affected water quality?
- Have hypolimnetic O_2 levels decreased in NS brook trout lakes?
  - When?
  - By how much?
- Has increased shoreline developments in Kings County (NS) resulted in a decrease in water quality?
- What effects have park development and road construction had on two lakes in Cape Breton Highlands National Park?

- Total Lakes: 49

Eutrophication of Halifax Lakes

Brian Ginn – PhD Candidate (Queen's)

Top-bottom analysis to assess if water quality has changed with recent housing developments

Lakes: 6

Status: In Progress

Photo: Calvin Chan

❖NS Brook Trout Sport Fishery worth:

➢**$57 million** (2002)

❖Stocked annually in ~ 400 lakes

❖Need cool, well-oxygenated water

➢Dissolved O_2 over 5.0 mg/L

Brylinsky, 2002:

❖studied hypolimnetic O2 levels in 20 lakes over a 25 year period.

❖Originally: 11 "good" habitat, 9 "poor"

❖Now: all 20 "poor" trout habitat

"it is not possible to determine to what extent, if any, the trophic status of these lakes has changed" – Brylinsky, 2002

Eutrophication of NS Brook Trout Lakes

Dr. Sergi Pla (Post-doc, Queen's)

Laura Schrumm (MSc Student, Queen's)

Determine if hypolimnetic O_2 levels have decreased in NS lakes stocked with brook trout.

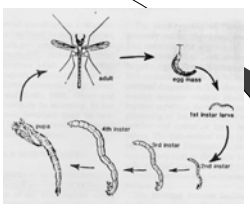
Also: revisions to Lakeshore Capacity Model (LCM) by Peter Dillon (Trent)

Lakes: 30

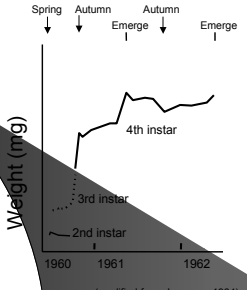
Status: Cores collected July, 2003
Analysis starts Jan. 2004

Photo: B.K.Ginn

Chironomid life cycle

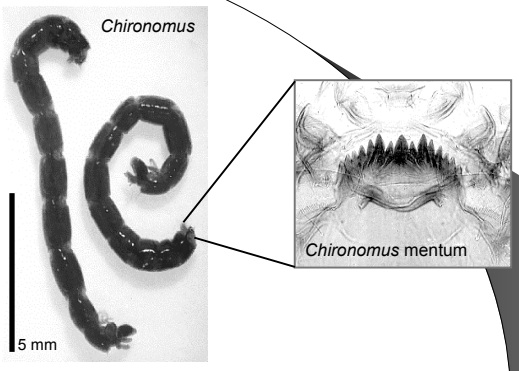


(Drawing: Walker 1987)

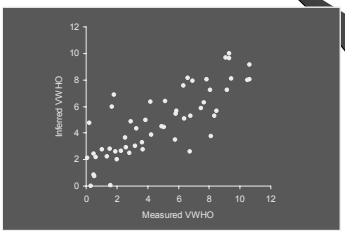


(modified from Jonasson 1964)

Chironomid head capsules as indicators

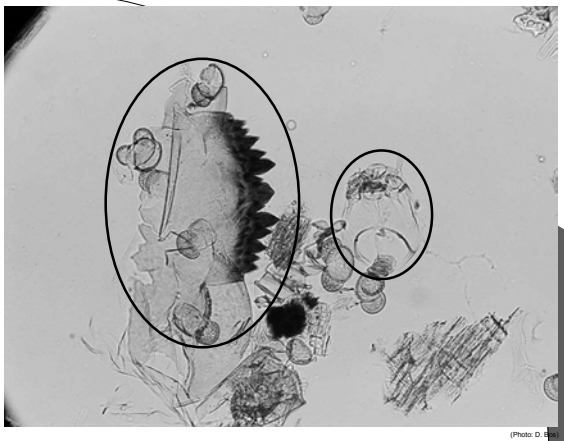


Predictive O_2 Model Based on Aquatic Communities



(from Ontario lakes)

(modified from Quinlan & Smol 2001)



Eutrophication of Kings County Lakes, NS

Study if lake water quality has declined due to increased shoreline development using paleolimnological and modelling techniques.

Lakes: 11

Status: Starts May, 2005

Aylesford Lake, Photo: Municipality of Kings Co.

Eutrophication in Cape Breton Highlands National Park

Study two lakes identified by Park officials that have been potentially affected by eutrophication and land use changes (highway construction).

Will use paleolimnological and modelling techniques

Photo Courtesy Airscapes

Lakes: 2

Status: Starts May, 2005

Acidification of Southern New Brunswick Lakes

Anne Harris (MSc Student, Queen's)

Determine if LRTAP / CWS monitoring lakes in Fundy National Park, Charlotte Co., and York Co. have acidified dues to inputs of anthropogenic strong acids.

Photo: Calvin Chan

Lakes: 30

Status: Started May, 2003

Acidification

- Maritimes continually cited in *Canadian Acid Rain Assessments* as "**an area for which more study is needed**"
- Have lakes in NB and NS acidified since 1850?
  - Develop paleolimnogical inference models
  - Assess change in pH and DOC since 1850
  - Biogeochemical models (e.g. MAGIC)
- When did these lakes acidify, by how much, and is there recovery?
  - Assess timing of acidification trajectories on a sub-set of lakes
  - Biogeochemical models
- Total: 105 lakes

Acidification of Nova Scotia Lakes

Encompasses both paleolimnological and modeling components to study 72 LRTAP monitoring lakes across Nova Scotia.

Paleolimnology (PI: J. Smol and B. Cumming):

- Brian Ginn (PhD Candidate, Queen's) – diatoms and chrysophytes
- Mike Rate (MSc Student, Queen's) – scaled chrysophytes
- Calvin Chan (BSc Honours Student, Queen's) – long-term changes in Little Wiles Lake, Bridgewater
- Laura Stewart (BSc Honours Student, Queen's) – reproducibility between sediment cores in Kejimkujik Lake

Modelling (PI: P. Dillon and T. Clair):

- Marta Wolniewicz (PhD Student, Trent) – MAGIC modelling
- Colin Whitfield (MSc Student, Trent) – Modelling Kejimkujik Lakes -

Nova Scotia Acidification: Preliminary Results

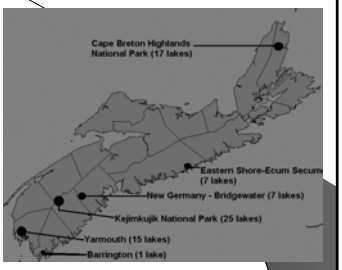
Field work and analysis by Brian Ginn.

Objectives:

- To assess changes between current and pre-industrial diatom flora in 6 lakes from southern Nova Scotia.
- To see if coloured (high DOC) lakes are affected the same as clear (low DOC) waters?

Nova Scotia

- 9400 lakes
- Acid-sensitive geology
- Acid precipitation
- Strong marine influence
- Two weather masses
  - Continental (central Canada + midwest USA)
  - Eastern seaboard (eastern USA)
- LRTAP – monitored southwest NS since 1983, semi-annual samples



Map of LRTAP study areas in Nova Scotia.

Lakes used in this study are located in: New Germany-Bridgewater, Yarmouth, Kejimkujik National Park

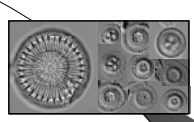
Map: Brian Ginn

Acid deposition

- 43% of Canada is sensitive to acid deposition.
- Cause: industrial emissions of SO_2 and NO_x
- Studies (1970's-1980's) → emission restrictions 1990's
- Many lakes show no recovery (esp. Maritimes)
- Most lakes lack background (pre-impact) data
- Nova Scotia: many acid lakes, monitored since 1983
  - No changes in pH
  - No recovery? Naturally acidic?

TOP

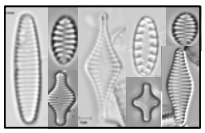
Deposited in recent lake environment



Open water diatoms more abundant

BOTTOM

Deposited in pre-industrial lake environment



Shallow water diatoms more abundant

Bridgewater – New Germany

Little Wiles Lake

- "Low" DOC (2.1 mg/L)
- Colour = 8
- pH = 5.3
- Alkalinity = -0.51 mg/L
- SO_4^{2-} = 4.8 mg/L
- NO_3^- = <0.02 mg/L
- Al = 0.0561 mg/L

Hirtle Lake

- "High" DOC (6.0 mg/L)
- Colour = 23
- pH = 6.1
- Alkalinity = 1.18 mg/L
- SO_4^{2-} = 2.6 mg/L
- NO_3^- = <0.02 mg/L
- Al = 0.0104 mg/L

2002 data. Courtesy Tom Clair, Environment Canada

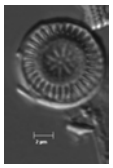
Results – Bridgewater: Hirtle Lake ("High" DOC)

Top (0.0-0.25 cm):

Species	Relative Abundance
Cyclotella stelligra	**24.2%**
Aulacoseira distans	15.5%
Tabellaria flocculosa IIIp	15.3%
Asterionella ralfsii var *americana*	8.2%

Bottom (15.00-15.25 cm):

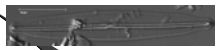
Species	Relative Abundance
Cyclotella stelligra	**24.2%**
Aulacoseira distans	22.2%
Tabellaria flocculosa IIIp	10.6%
Asterionella ralfsii var *americana*	3.8%



Results – Bridgewater: Little Wiles Lake ("Low" DOC)

Top (0.0-0.25 cm):

Species	Relative Abundance
Frustulia pseudomagaliesmontana	**12.4%**
Aulacoseira perglabra florinae	6.1%
Cyclotella stelligra	5.6%

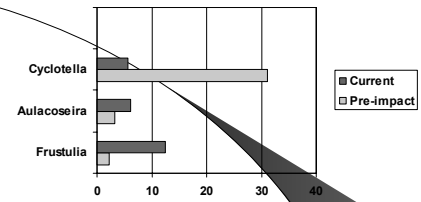


Bottom (15.00-15.25 cm):

Species	Relative Abundance
Frustulia pseudomagaliesmontana	2.2%
Aulacoseira perglabra florinae	3.2%
Cyclotella stelligra	**31.1%**

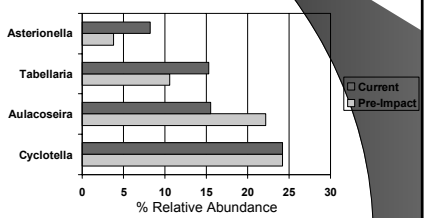
Little Wiles Lake

"Low" DOC



Hirtle Lake

"High" DOC



Yarmouth - Barrington

Lake George	Brenton Lake
➢ "Low" DOC (3.7 mg/L)	➢ "High" DOC (15.4 mg/L)
➢ Colour = 13	➢ Colour = 229
➢ pH = 5.9	➢ pH = 5.2
➢ Alkalinity = 0.56 mg/L	➢ Alkalinity = 1.01 mg/L
➢ SO_4^{2-} = 3.4 mg/L	➢ SO_4^{2-} = 4.7 mg/L
➢ NO_3^- = <0.02 mg/L	➢ NO_3^- = <0.06 mg/L
➢ Al = 0.0218 mg/L	➢ Al = 0.4494 mg/L

2002 data. Courtesy Tom Clair, Environment Canada

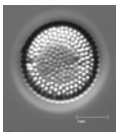
Results – Yarmouth: Brenton Lake ("High" DOC)

Top (0.0-0.25 cm):

Species	Relative Abundance
Asterionella ralfsii var americana	**49.8%**
Aulacoseira distans	2.0%
Aulacoseira ambigua	0.8%
Cyclotella stelligra	1.6%

Bottom (15.00-15.25 cm):

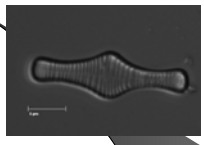
Species	Relative Abundance
Asterionella ralfsii var *americana*	5.6%
Aulacoseira distans	**13.3%**
Aulacoseira ambigua	9.3%
Cyclotella stelligra	3.3%



Results – Yarmouth: Lake George ("Low" DOC)

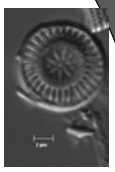
Top (0.0-0.25 cm):

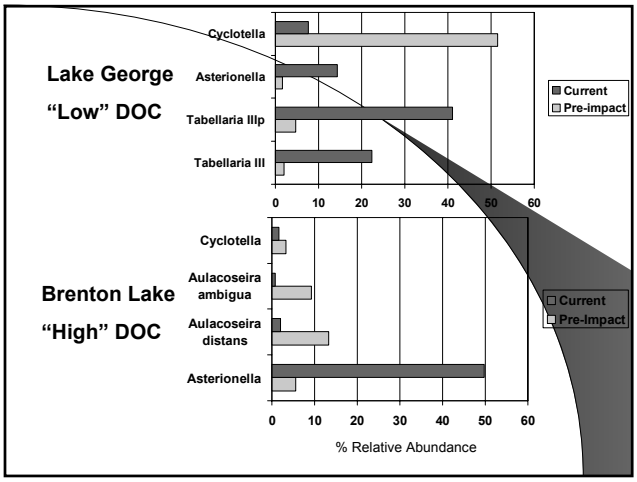
Species	Relative Abundance
Tabellaria flocculosa IIIp	**41.0%**
Tabellaria flocculosa III	22.3%
Asterionella ralfsii var. *americana*	14.3%
Cyclotella stelligra	7.6%



Bottom (15.00-15.25 cm):

Species	Relative Abundance
Tabellaria flocculosa IIIp	4.7%
Tabellaria flocculosa III	2.0%
Asterionella ralfsii var. *americana*	1.7%
Cyclotella stelligra	**51.5%**





Kejimkujik National Park

Beaverskin Lake	Pebbleloggitch Lake
➢ "Low" DOC (2.2 mg/L)	➢ "High" DOC (11.6 mg/L)
➢ Colour = < 5	➢ Colour = 149
➢ pH = 5.5	➢ pH = 4.4
➢ Alkalinity = -0.62 mg/L	➢ Alkalinity = -2.03 mg/L
➢ SO_4^{2-} = 2.0 mg/L	➢ SO_4^{2-} = 2.0 mg/L
➢ NO_3^- = <0.02 mg/L	➢ NO_3^- = <0.02 mg/L
➢ Al = 0.0158 mg/L	➢ Al = 0.2084 mg/L

2002 data. Courtesy Tom Clair, Environment Canada

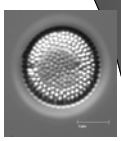
Results – Kejmikujik N.P.: Pebbleloggitch Lake ("High" DOC)

Top (0.0-0.25 cm):

Species	Relative Abundance
Asterionella ralfsii var americana	**40.6%**
Aulacoseira distans	6.8%
Tabellaria flocculosa III	0.4%
Cyclotella stelligra	0.0%

Bottom (15.00-15.25 cm):

Species	Relative Abundance
Asterionella ralfsii var *americana*	2.3%
Aulacoseira distans	**34.5%**
Tabellaria flocculosa III	5.0%
Cyclotella stelligra	0.0%



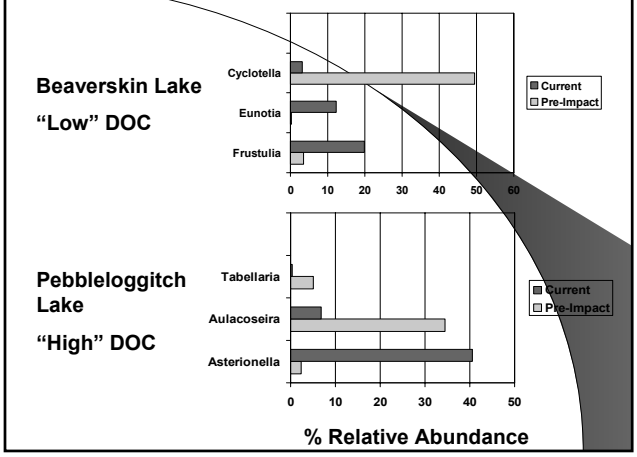
Results – Kejimkujik N. P.: Beaverskin Lake ("Low" DOC)

Top (0.0-0.25 cm):

Species	Relative Abundance
Frustulia pseudomagaliesmontana	**19.9%**
Eunotia curvata fo. *bergii*	12.3%
Cyclotella stelligra	3.2%

Bottom (15.00-15.25 cm):

Species	Relative Abundance
Frustulia pseudomagaliesmontana	3.6%
Eunotia curvata fo. *bergii*	0.3%
Cyclotella stelligra	**49.5%**



Conclusions

"Low" DOC lakes (Little Wiles, George, Beaverskin):

Major shift in diatom assemblage dominance:

- Pre-impact: dominated by circumneutral species (*Cyclotella stelligra*)
- Post impact: dominated by more acidophilic genera (*Frustulia, Eunotia, Tabellaria*)
- Conclusion: pH decrease in clear lakes

Future Directions

- Part of 72 lake study on acidification in NS LRTAP Lakes by Brian Ginn.
- Part of TEAM (NSERC Strategic Grant) (http://biology.queensu.ca/~pearl/maritimes)
- Assess timing of changes (^{210}Pb) – related to acid deposition?
- Infer pre-impact conditions (calibration set based on 72 lakes and Environment Canada semi-annual monitoring program data)

Conclusions

"High" DOC lakes (Hirtle, Brenton, Pebbleloggitch)

More subtle changes:

- Pre-impact: dominated by acidophilic (*Aulacoseira*) or circumneutral diatoms (*Cyclotella* in Hirtle Lake)
- Post Impact: dominated by *Asterionella ralfsii* var *americana* (except Hirtle Lake, but relative abundance did increase)
- Conclusion: more subtle pH decrease (buffered by organic acids), but *A. ralfsii* increase indicates some environmental change (possibly acidification-related Al mobility (Gensemer, 1990))

Acknowledgments

- Tom Clair, Environment Canada, Sackville, NB
- Cliff Drysdale (Kejimkujik NP) and J. Bridgland (Cape Breton Highlands NP)
- John MacMillan (NSDAFA), D. Taylor (NSDOEL), S. Mandaville (S&WCS-MH)
- Local NS property owners
- PEARL Maritimes Field Crews (2002, 2003)
- Project funded by NSERC Strategic Grant to: J.P. Smol, B.F. Cumming, and Peter Dillon
- Additional funding: Graduate Dean's Travel Grant and R.S. McLaughlin Scholarship to B.K. Ginn

http://biology.queensu.ca/~pearl/maritimes