Paleolimnological analysis of Growler Lake sediment core

Paleolimnology Class Fall 2015
Research Questions to be Addressed

• How have environmental conditions in Growler Lake changed over time?
• Are there changes in lake conditions associated with the history of human influence in the catchment?
• Have environmental changes taken place since cottage development? (e.g. leakage from septic fields)
• Changes in lake productivity?
• How has catchment erosion changed over time and influenced the lake?
• Are there any influences of climate change on the lake?
• Has there been acidification in the past (due to acid rain)?
Methods – obtaining cores

• October 2, 2015: several cores were taken from Growler Lake using a gravity corer

• They were described and sectioned into 0.5 cm intervals
Core 7 was chosen for further analysis
→ 38 cm long
→ Taken from a depth of 20 m
1867
Village sold by Crown to Canadian Land and Emigration Co.

1895
Small-scale softwood logging

1935
Large-scale timber cutting (especially during WWII). Harvest declined from 1980s to mid-90s.

1995
Privately owned by 2 families, used for hunting and fishing

2003
Beginning of cottage development

Adapted from Growler Lake Plan, 2015
Loss On Ignition and $^{210}\text{Pb}$ and $^{137}\text{Cs}$ Dating

Christine Ridenour
Nelson Zabel
Loss On Ignition

• Determine moisture content (90°C), organic matter content (550°C), and mineral matter content (1000°C)
Loss On Ignition

Core 6

Core 7

Percent (%)

Depth (cm)

Organic Matter
Mineral Matter
Water Content
**210Pb Dating**

**Diffusion, release to atm.**

Decay to 210Pb

Deposition → “unsupported” disequilibrium with sediment 226Ra

Remains trapped in sediments

“supported”, equilibrium with sediment 226Ra

Decay to 210Pb

Background 210Pb: total = supported (unsupported = 0)
\textbf{210}^{\text{Pb}} \text{ Dating}

- Measure $^{226}\text{Ra}$ and total $^{210}\text{Pb}$ activity on sections using gamma spectrometer
  - $^{226}\text{Ra} \rightarrow \text{infer supported }^{210}\text{Pb}$
  - Unsupported $^{210}\text{Pb} = \text{total }^{210}\text{Pb} - \text{supported }^{210}\text{Pb}$
  - Calculate initial $^{210}\text{Pb}$ upon deposition and time since burial of unsupported $^{210}\text{Pb}$ based on decay rate $\rightarrow$ age
2¹⁰Pb Dating

• Pack freeze-dried sediment into tubes, apply epoxy resin to seal → trap ²²²Rn gas

• Let sit for 2-3 weeks, equilibrate ²²⁶Ra and ²¹⁰Pb

• Measure, calculations

• Apply age model – Constant Rate of Supply Model and derive sedimentation rates
$^{137}$Cs Dating

• Validation of $^{210}\text{Pb}$ dates
• When $^{210}\text{Pb}$ isn’t reliable – complications
• 1963: bomb testing and max atmospheric fallout
  • Anthropogenic isotope
Core 7 Dating

Radioisotope Activity

Age-Depth Model
Zone Determination

CONISS
Constrained Incremental Sum-of-Squares Clustering

• A method of grouping sediment sections based on their similarity, within the sediment stratigraphic sequence (with respect to depth).

Broken Stick Model
• Tests for the number of significant zones in a CONISS cluster tree.
Growler Lake’s History in Sedimentation

**Zone 5**
2003 to present
(± 0.10 yr)
Presently, 15 of the 27 (55.6%) lots on Growler Lake have been developed.

**Zone 4**
1959 to 2002
(± 1.15 yr)
Logging continued in this period, through the 1960s and 70s. Logging decreased in the late 70s, with evidence of logging persisting into the 1990s.

**Zone 3**
1939 to 1958
(± 2.11 yr)
Logging began to intensify during the period: the current Growler Lake Rd., originally a logging road, was developed around 1942.

**Zone 2**
1883 to 1938
(± 10.89 yr)
Continued decline of logging industry - into 1890s. Logging company declared bankruptcy in 1895. Little to no logging impact is presumed during this time.

**Zone 1**
... to 1882
(± 13.99 yr)
Decline of the local lumber industry from the boom in early 1870s.

Source: Growler Lake Plan 2015
C and N elemental and isotope analysis

Eric McQuay
Janina Ries
Introduction to Geochemistry

• Gives insight into lake productivity, nutrient balance, source of organic matter

• Addresses questions regarding:
  - How catchment erosion has changed and influenced the lake
  - Changes associated to human activity in the catchment
Methods – Geochemistry

Sample Preparation:

• Place subsamples in test tubes
• Add 10% HCl, test pH (should be about 1) and heat in water bath for 2 hours to remove carbonates
• Aspirate, rinse with de-ionized water
• Repeat daily until neutral pH
• Aspirate and freeze dry
• Remove coarse fraction with 500 µm dry sieve
• Weigh about 2 mg of fine fraction into tin cups

Send to University of Waterloo Environmental Isotope Laboratory
   → Elemental analyzer attached to a mass spectrometer
Organic Material in Lake Sediment

Recycling by Respiration

Aquatic productivity

Catchment Erosion

A McQuay Original, 2015
Isotopic Enrichment

● Carbon isotopes are generally used to determine Productivity

● Photosynthesis preferentially takes up lighter Carbon isotopes leading to enrichment of heavier isotopes

● The proportion of isotopes is recorded in organic matter in the sediment

A McQuay Original, 2015
Organic Matter Source and Isotopic analysis

- The sediment contains a mix of terrestrial and aquatically derived organic material.
- This complicates the interpretation of isotopic data.
- Catchment erosion can still be addressed with C/N ratios.

Modified from Meyers and Teranes, 2001
C/N and Times of Change

(1745-1820)  (1820-1915)  (1915-2010)  (2010-present)

Δ^{13}C

Algae

Grasses

Trees, leaves, bark
Results

[Diagram showing the results of organic carbon (org C%), nitrogen (%N), C/N ratio, δ^{13}C, and δ^{15}N over different years, with aquatic and terrestrial data lines indicated.]
Results

**Zone 1 & 2 (1745-1820)**

- Pre human conditions
- Higher organic carbon content in zone 1 than zone 2 shows natural variability in lake productivity
- Mix of terrestrial and aquatic organic material
- Period of increased catchment erosion around 1765
Results

**Zone 3 & 4 (1820-1915)**

- Generally increasing catchment erosion through whole period

- Softwood logging started toward the end of zone 3 (1987) which could account for the large increase in terrestrial organic material seen around 1900

- Constant $\%C_{org}$ suggests increased nutrient loading from catchment erosion during this period
Results

Zone 5-6 (1915-2010)

- Large scale logging of Hardwood occurred 1920-1970s
- Little to no signal of increased terrestrial input of organic matter
- Low $%C_{org}$ suggests more erosion of inorganic material from catchment
- Low productivity during this period could be result of increased turbidity
Results

Zone 7 (2010-present)

- Cottage development has largely occurred during this period

- Increase in %Corg and aquatic derived organic material suggests that cottage development may be having an effect on the lake

- However it is also possible that this is a signal of fresh organic matter that has yet to undergo degradation
1850

1875

1900

1925

1950

1975

1995

2000

2003

1867

1895

Village sold by Crown to Canadian Land and Emigration Co.

1875

1900

1925

1950

1975

1995

2000

2003

Small-scale softwood logging

This period does not correspond to a similar increase as seen during softwood logging. Perhaps due to increased erosion of inorganic material.

Data suggest either an increase in nutrient loading from cottage development, or fresh organic material that has not been degraded yet.

Increased C/N and $\% C_{\text{org}}$ match up well with softwood logging dates. Constant $\% C_{\text{org}}$ suggest increase in nutrients from catchment erosion.

1935

Privately owned by 2 families, used for hunting and fishing

1938

Large-scale timber cutting (especially during WWII). Harvest declined from 1980s to mid-90s.

1980

1995

Beginning of cottage development

Adapted from Growler Lake Plan, 2015
Diatoms

Wathiq Mohammad
Casey Remmer
Steph Roy
James Telford
What are Diatoms?

- Diatoms are a major group of algae.
- Consist of a cell wall (frustule) made of silica.
- Silica frustules preserve in the sediment and can be used to identify the diatom species present at a given time.
- Diatom species are highly sensitive to ecological conditions.
- Therefore, diatom community composition can be used to reconstruct past lake conditions.
• ~0.5 g of sediment from each 0.5cm core interval is added to test tubes.
• A 50:50 mixture of sulfuric acid and nitric acid was then added to remove organic matter.
• Samples were then rinsed and aspirated until a neutral pH was reached.
• The resulting diatom slurry was mounted onto coverslips and dried, then mounted onto microscope slides.
• 300 diatoms are counted per slide and each species is calculated as a % abundance of the total diatom community.
• % abundances are then graphed to analyse changes through time.
Predominance of planktonic species throughout the core give us a general indication that the lake has remained in a fairly steady oligotrophic state throughout the time period.
**Eunotia zasuminensis** is a rare species that can be indicative of mild acidity and fluctuations in nutrient conditions.

**Cyclotella stelligera** can be indicative of increase in nutrients, has been known to increase during forest clearing.

**Fragilaria sp.**
common, primarily planktonic.

**Stauroneis sp.**
primarily in benthic habitat, characterized mainly as boreal or alpine.

**Tabellaria flocculosa**
primarily in planktonic habitat, dominant throughout the entire core.

**Aulacoseria sp.**
planktonic species, form colonies linked by spines.
Eunotia zasuminensis is a rare species associated with relatively low pH and increased nutrient conditions. The rapid decline in this species post ~1960 coincides with the later period of intensive logging within the catchment.

Cyclotella stelligera respond quickly to nutrient increase and have been associated with forest clearing and catchment disturbance.
Eunotia zasuminensis
Cyclotella stelligera
Cymbella sp.
Stauroneis sp.
Gomphonema sp.

Decrease in benthic species during the period of ~1900-1970.

Coincides with increase in minerogenic sediment.

Increase in sedimentation rates during this period may significantly disrupt the benthic environment.

Sedimentation rate and erosional processes may increase turbidity, conductivity, and decrease depth of light penetration.
Discussion

• Minimal change in diatom abundance and community composition through time suggests Growler Lake has maintained a steady level of productivity.
• Potential change in lake productivity due to logging in the area seen in small shifts in diatoms indicating increase in nutrient levels and pH.
• No evidence that cottage development has influenced nutrients and productivity in the lake.
Conclusions and Recommendations

• Period of change in diatom composition occurs during period of logging possibly related to high sedimentation rate.
• Difficult to discern a potential climate change signal.
• Further analysis should focus on the deeper sediment core section to improve temporal resolution.
Pigments

Stephanie Francis
Nicole Meyers
Emily Trendos
Purpose

Pigment analysis is a useful tool in paleolimnology for characterizing past and present algal communities in lakes and rivers.

Provide insight into past productivity and can act as an indicator of eutrophication.
Certain pigments are associated with specific algal groups.

<table>
<thead>
<tr>
<th>Taxonomic Group</th>
<th>Photosynthetic Pigments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanobacteria</td>
<td>chlorophyll a, chlorophyll c, phycocyanin, phycoerythrin</td>
</tr>
<tr>
<td>Chloroxybacteria</td>
<td>chlorophyll a, chlorophyll b</td>
</tr>
<tr>
<td>Green Algae (Chlorophyta)</td>
<td>chlorophyll a, chlorophyll b, carotenoids</td>
</tr>
<tr>
<td>Red Algae (Rhodophyta)</td>
<td>chlorophyll a, phycocyanin, phycoerythrin, phycobilins</td>
</tr>
<tr>
<td>Brown Algae (Phaeophyta)</td>
<td>chlorophyll a, chlorophyll c, fucoxanthin and other carotenoids</td>
</tr>
<tr>
<td>Golden-brown Algae (Chrysophyta)</td>
<td>chlorophyll a, chlorophyll c, fucoxanthin and other carotenoids</td>
</tr>
<tr>
<td>Dinoflagellates (Pyrrhophyta)</td>
<td>chlorophyll a, chlorophyll c, peridinin and other carotenoids</td>
</tr>
<tr>
<td>Vascular Plants</td>
<td>chlorophyll a, chlorophyll b, carotenoids</td>
</tr>
</tbody>
</table>
What are Algae?

A large group of mostly aquatic, photosynthetic organisms.

All contain chlorophyll a.

Examples:

- Diatoms
- Euglenoids
- Dinoflagellates
- Charophytes
- Cyanobacteria
- etc.
What are algal pigments?

Chemical compounds used by algae to capture energy from the sun using photosynthesis.

Several different pigments are often present in an organism to maximize energy capture.
What are algal pigments?

3 main types:

1. Chlorophylls (Greenish pigments)

2. Carotenoids (Red, orange, yellow pigments)

3. Phycobilins (Range from red to purple to blue/green, only in cyanobacteria and red algae)

We can obtain these and their degraded forms from sediment samples.
Significance of Algae

**Benefits**

Algae, as primary producers, are an important food source for other organisms within an aquatic ecosystem, and produce large quantities of oxygen.

Larger algae can provide habitat for other organisms.

**Detriments**

Certain algal blooms can be toxic to the aquatic environment and make water unsafe to drink.

Excess of algae can reduce availability of dissolved oxygen, making it difficult for other species, such as fish, to survive.
Methods

1. Sub-samples taken from each section weighed
2. Samples are freeze dried
3. Pigments are extracted using extraction solvent and filters
4. Samples are dried with $N_2$ gas
5. Injection solution added and samples are run through HPLC system (High Performance Liquid Chromatography)
Data Analysis

Pigment identification
4: Chlide $\alpha$
9: Pheide $\alpha$ and zeaxanthin
13: Zea
17: Hydroxylated Chl $\alpha$
18: Dihydroxy Chl $\alpha$ and crypto
19: Chl $\alpha$
20: Chl $\beta$
25: Hydroxylated Pheo $\alpha$
26: Hydroxylated Pheo $\alpha$
27: Dihydroxylated Pheo $\alpha$
28: $\beta$-carotene
29: Pheo $\alpha$
30: Pheo $\alpha$
Data Analysis

- pigment spectra are examined from each of the 76 samples chromatographs
- ~ 15 - 30 pigment spectrums per sample
- stratigraphies are then created to allow for interpretation
Results

Chl a provides information about algal abundance.

Chl a:Pheo a ratio provides information about pigment preservation in the sediment.

Fucoxanthin is associated with organisms that indicate high water quality:
  > Diatoms
  > Chrysophytes
  > Dinoflagellates
Results

Chlorophyll-a and Fucoxanthin peak around the late 1990s, and decrease into the early 2000s.

An increase in the Chl-a: Pheo-a ratio occurs within this same interval.
Conclusions

Algal biomass remained constant through time.

Increased pigment concentrations in recent years attributed to better preservation.

Algal abundance decreased following cottage development.

Human activities have not altered primary production.
Growler Lake:
A Paleolimnological History
Summary of Findings

- Sediment characteristics and radioisotope dating helped to determine sedimentation rates in lake over 140 years, and tracked logging history in the watershed.
- C & N isotope data support sedimentation rate data and show the natural variability of Growler Lake.
- Diatom assemblage has been stable: no detectable impact from acidification or eutrophication.
- Pigment data show decrease in algal abundance after cottage development.
What can we conclude?

- Growler Lake is a healthy, relatively pristine, stable lake ecosystem.
- Cottage development has not resulted in nutrient pollution to Growler Lake.
- Historical logging activities have not greatly impacted Growler Lake.
- There is no evidence of acidification or climate change-related effects on Growler Lake.
Thank you!