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**Introduction:**

Over the last two years Carleton University, the Friends of the Tay Watershed Association, Rideau Valley Conservation Authority (RVCA), and Mississippi Valley Conservation Authority (MVCA) have been working together on a project funded by the Ontario Trillium Foundation to increase awareness of water quality changes and aquatic plants in eastern Ontario lakes. The goals of this research project were to 1) determine how much water quality has changed in these lakes over the last 150 years or so and 2) to examine what affect, if any, zebra mussels have on aquatic plant growth in eastern Ontario lakes. In order to meet these goals 10 lakes in the RVCA watershed and 10 in the MVCA watershed that were located on the Canadian Shield and that represented a range of available phosphorus concentrations were selected for study. Phosphorus is the essential nutrient to algal growth in most lakes in the area. Among those selected, about an even number of these lakes were with and without zebra mussels.

**Results of the sediment core analyses (Research question 1)**

**How the study was done:**

To address our first question, how much has water quality changed in our study lakes over the last 150 years or so, we took sediment cores from all of the lakes. Because direct monitoring of water quality has only been carried out on most of the study lakes for a few years or decades we needed to use the natural record of environmental change preserved in lakes sediments to understand any long-term changes in water quality that may have occurred. Lake sediments build up over time, 24 hours a day and 365 days a year, thus providing an excellent natural archive of what has happened in the lake in the past (**Figure 1**).

*Figure 1: Example of the top of a lake sediment core.*

By taking a sediment core from a lake and sampling it at regular intervals along its length, we are able to reconstruct historical changes in a lake; similar to using tree rings to understand the past growth of a tree. We analyzed the surface and bottom sediment of these cores to provide a snap-shot of environmental change between the present-day and approximately 150 years ago.

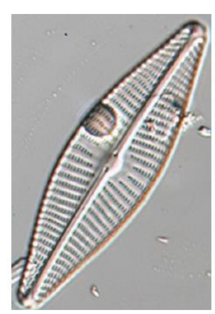

*Figure 2: Example of an individual diatom as seen under a microscope at 1000 times magnification*

The main item studied in the cores were microscopic algae called diatoms (**Figure 2**). Diatoms are the most numerous algae type in lakes and their cell walls are made of silica (i.e. glass) and therefore they preserve really well in the sediment record. There are thousands

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of different diatoms, each having different ecological preferences for nutrients, temperature and so forth. Thus by looking at what diatoms were living in the lake in the past, as well as at present, we are able to make strong inferences about the water quality. Diatoms are excellent indicators of historical water quality.

**What we learned:**

1) **The study lakes are in fairly good shape:**

This isn't surprising given that phosphorus concentrations in these lakes are still relatively low compared to Ministry of Environment and Climate Change objectives for total phosphorus (Figure 3).

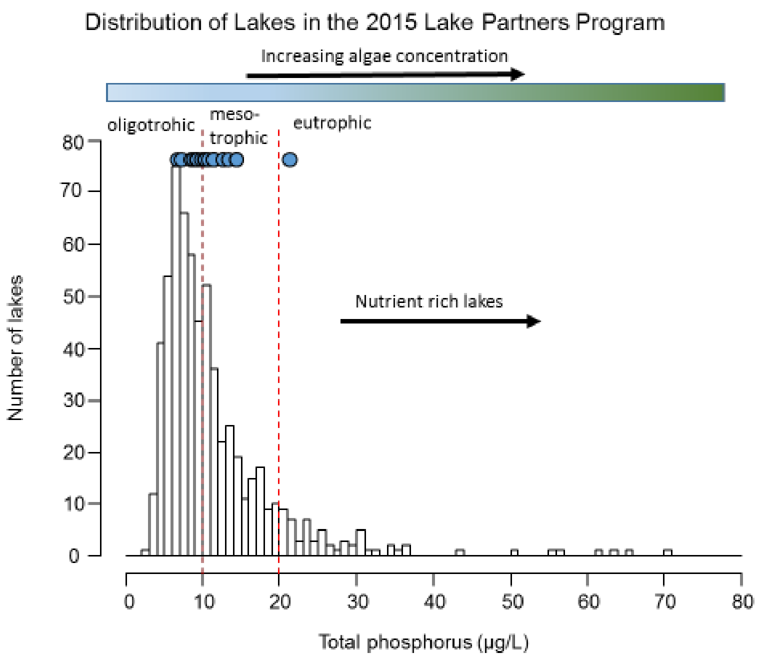


*Figure 3: The bars show the distribution of total phosphorus concentration of the over 600 lakes that were part of the MOECC Lake Partners Program in 2015. The blue dots show where our study lakes fall along this total phosphorus scale. All but one of our study lakes would be considered to have low (oligotrophic) to moderate (mesotrophic) phosphorus concentrations and therefore it would be expected that algae growth is controlled in our study lakes by a lack of phosphorus.*

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### 2) The lakes have undergone change over the last ~150 years but most of them not too much

The majority of our study lakes (about 70%) have undergone relatively little to moderate change in their diatom community over the last 150 years, suggesting that the water quality of these lakes hasn't changed drastically in that time (**Figure 4**). These lakes would be considered to have good to excellent water quality and again their modern phosphorus concentrations suggest that they currently have low to moderate phosphorus concentrations.

| | |
|---|---|
| Substantial (CD>1) | • Malcolm<br>• Adam<br>• Dalhousie<br>• Upper Rideau<br>• Green Bay |
| Moderate (CD 0.63-1) | • Sharbot<br>• Otty<br>• Burridge<br>• Big Gull<br>• Mosque<br>• Westport<br>• Shabomeka<br>• Kash<br>• Tommy<br>• Crosby<br>• Bennett |
| Little (CD <0.63) | • Christie<br>• Pine<br>• O'Brien<br>• Buck Bay |

*Figure 4: This table shows the amount of change that has occurred in the diatom community of the study lakes over the last ~150 years. Most of the study lakes have undergone a little to a moderate amount of change. More detailed studies have shown that the largest changes in some of these lakes occurred with the construction of the Rideau Canal (e.g. Upper Rideau).*

### 3) Most of the change in the diatom community that has occurred suggests slight nutrient enrichment and warmer temperatures

The biggest change we observed in the diatom community was a shift to larger diatoms that can float more easily in the water column (**Figure 5**). The most striking change in the diatom assemblages is that there are more of the diatom species *Fragilaria crotonensis* now then there was in the past. An increase in these types of diatoms is typically associated with slight nutrient enrichment to a mesotrophic state as well as warmer water temperatures. As temperatures increase, lakes have a longer ice-free period and stay thermally stratified for a longer period of time. That is, the warm water stays on the top of the lake and the colder, denser, water stays on the bottom for a longer period each year. This longer period of stratification gives a competitive advantage to diatoms that can float more easily, as the heavier diatoms sink out and eventually nearly disappear from the record.

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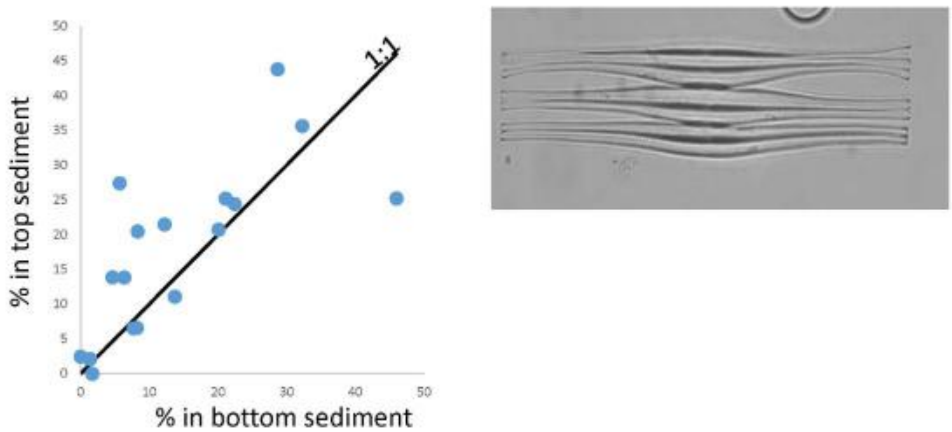


*Figure 5: A) The relative abundance of Fragilaria crotonensis in the bottom sediments compared to the top sediments. The blue circles represent the individual study lakes. When a blue dot is above the diagonal 1:1 line it means that lake has more Fragilaria crotonensisin the diatom community then it did in the past. The majority of blue dots are above that diagonal line indicating a fairly consistent pattern of change in the study lakes. B) A photo of Fragilaria crotonensis taken under the microscope is also shown.*

**Take aways:**

Our research has shown that:

1) **The study lakes in eastern Ontario are still in relatively good shape (low to moderate phosphorus concentrations). Let's keep them this way. This is the time when conservation efforts pay off!**

2) **They have undergone some nutrient enrichment and changes related to warming temperatures over the last ~150 years but remain healthy. We want to limit the speed of these changes before they become unhealthy!**

If these trends were to continue, eventually, over time, these study lakes will become nutrient rich (eutrophic) with ever increasing nuisance algae blooms. Once a lake becomes eutrophic it is very difficult to reverse that trend and it is therefore very important that conservation efforts remain in place now to build ecological resilience in these lakes to protect the water quality of these important ecosystems.

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**<u>Aquatic Plant mapping (research question 2)</u>**

**<u>How the study was done:</u>**

To address our second question, (what affect, if any, zebra mussels have on aquatic plant growth in eastern Ontario Lakes), we measured submerged aquatic plant biovolume in 11 lakes with evidence of zebra mussels and 9 lakes that do not have zebra mussels (**Figure 6**). Plant biovolume is a measure of the percent of the water column occupied by aquatic plants. If plants are growing right to the surface of the water they would have a biovolume of 100%, or, if plants grew only as high as half the water depth they would have a biovolume of 50%. Plant biovolume is a good measure of submerged plant abundance because it is only at high biovolumes when plants grow right to the surface that they become a nuisance to lake users. It has been suggested that plant biovolume values of around 40-60% are ideal to support fish habitat without being a nuisance to lake users and boaters.

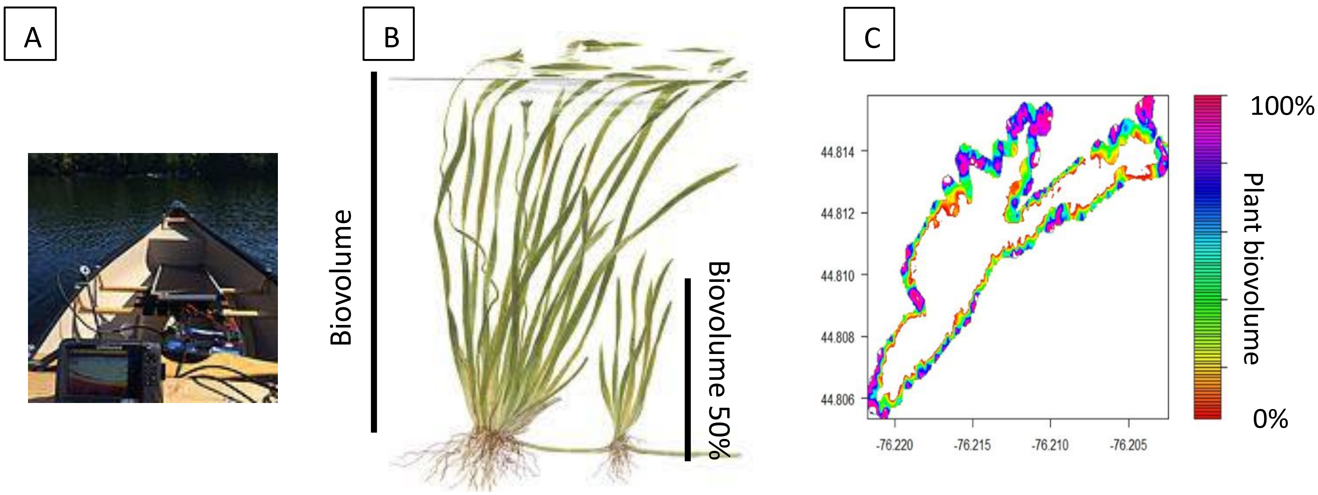


*Figure 6: A) Picture of a canoe outfitted with plant mapping echosounder. B) Example of plant biovolume at approximately 100% and 50% C) Example plant biovolume map from Adam Lake.*

Zebra mussels are a well-known invasive species in eastern North America. As zebra mussels are filter feeders, they can increase water clarity in a lake (**Figure 7**). This should provide more light for plant and algae growth at the bottom of a lake.

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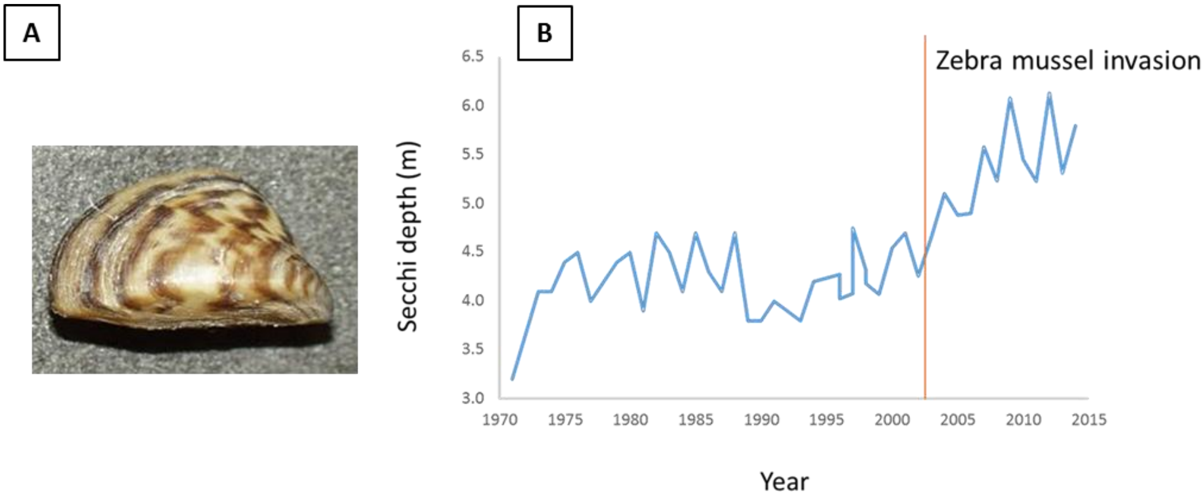


*Figure 7: A) Picture of a zebra mussel B) Example of how zebra mussels increased water clarity (secchi disk depth) in Otty Lake (data courtesy of the Otty Lake Association).*

**What we learned:**

1) **Plant biovolume can vary a lot within a lake:**

It is already known that the amount of plants can change a lot from one place to another in a lake. This is normal and has to do with the morphometry (shape) of the location, the steepness of the shoreline slope, and the amount of light available. It is worth pointing out however, that every single one of our study lakes had areas where the biovolume was 0% (no plants) to nearly right up to 100% (plants right to the surface of the water; **Figure 8**). This variability is natural.

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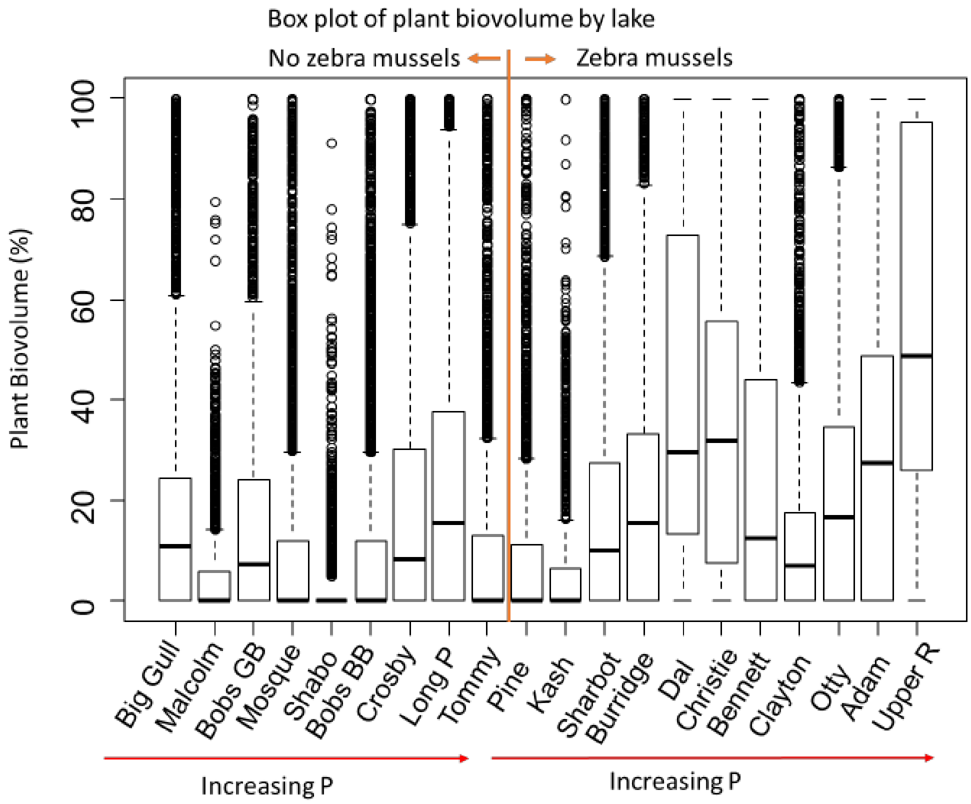


*Figure 8: Boxplots showing the plant biovolume measurements from each lake in 2015. The boxes with the whiskers show the range of most of the plant biovolume measurements and thick black line in the box shows the median (just as many points below as above) plant biovolume for each lake. The lakes have been grouped by the presence or absence of zebra mussels and arranged by total phosphorus concentration within that group.*

### 2) Plant biovolume is greater in lakes with zebra mussels:

Lakes with zebra mussels overall had significantly more plant biovolume in them than lakes without zebra mussels (**Figure 9**). The greater biovolume of plant growth in lakes with zebra mussels might be because more light is penetrating into these lakes as a result of the filter feeding. Another possibility, however, is that lakes with zebra mussels might just be better suited for plant growth due to more plant nutrient availability in the sediment. So it might be that zebra mussels are increasing plant growth by increasing light availability or that plants and zebra mussels just like the same kinds of lakes. We will be conducting further research this summer to figure out which explanation is more probable.

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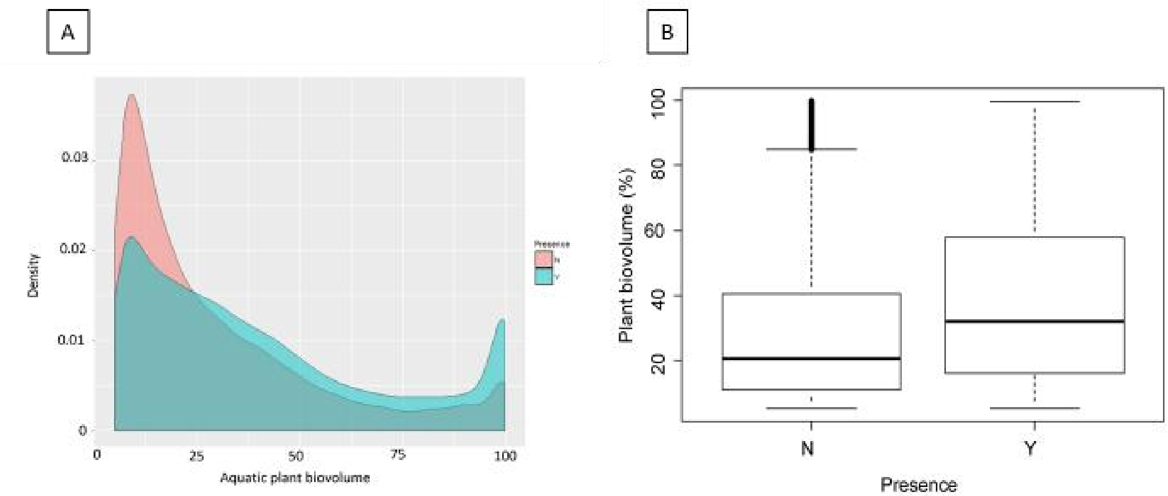


*Figure 9: Two ways of looking at the same data. A) A distribution plot of plant biovolume measurements in lakes without (pink) and with (blue) zebra mussels. Note that the pink no zebra mussel readings peak at the really low biovolume values whereas the blue zebra musselreadings are higher for all plant biovolume measurements >25%. This means that in lakes without zebra mussels you have more areas with little to no plants. B) A boxplot of plant biovolume for lakes with no zebra mussels (N) and lakes with zebra mussels (Y). Note that the lakes with no zebra mussels (N) have lower plant biovolume than lakes with zebra mussels (Y)*

**3) Plant biovolume is also greater in more nutrient rich lakes:**

We also found that as open water total phosphorous increased in our study lakes so did plant biovolume (**Figure 10**). There is likely not a direct link between the two because rooted aquatic plants get most of their nutrients from the sediment and we have measurements of the open water total phosphorus concentration. However, it is plausible that there is a correlation between the nutrient concentration in the sediment and the open water. Nevertheless in our data there is a statistically significant relationship that lakes with higher total phosphorus have more plant biovolume.

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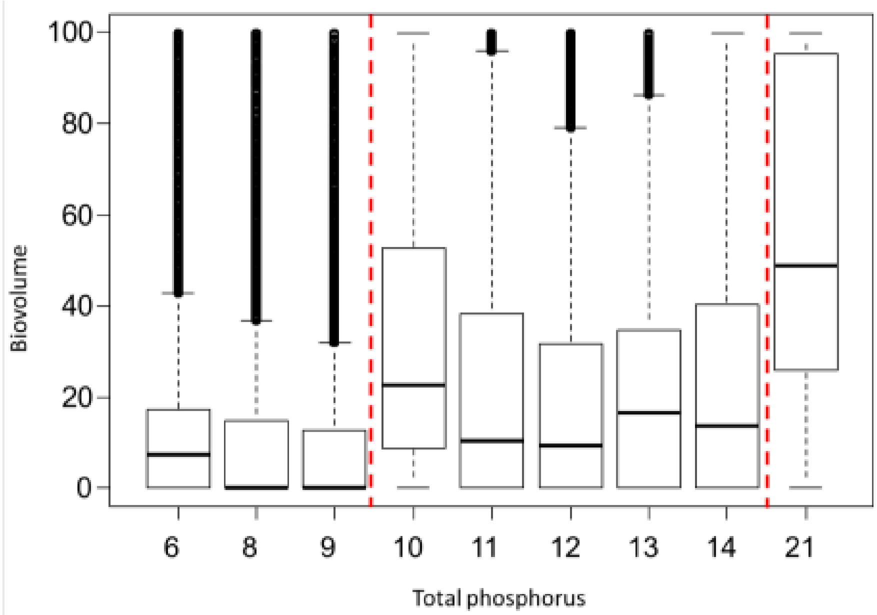


*Figure 10: Boxplot showing how plant biovolume increases as total phosphorus increases. The red dashed lines are the boundaries between oligotrophic, mesotrophic, and eutrophic lakes based on the MOECC classifications.*

**Take aways:**

This research has shown that:

1) **There is a lot of variability in the amounts of aquatic plants in lakes our lakes. This variability is natural and depends on a number of factors that are beyond our control.**

2) **Lakes with zebra mussels and higher total phosphorous concentrations have more plant biovolume (particularly sites with 100% biovolume that is the greatest nuisance to lake users). Invasive species and nutrient enrichment are factors we can try and control to help reduce nuisance plant biovolume!**

I should also mention that there is an aquatic invasive plant (Eurasian watermilfoil) that occurs in all of our study lakes and can form very dense stands. Some of the trends in high plant biovolume observed in this study may be centered around those plant beds dominated by Eurasian watermilfoil and my team and I at Carleton University will be investigating that this coming year.