

RESULTS OF SEDIMENT CORE TAKEN FROM CLOVERLEAF LAKES, SHAWANO COUNTY, WISCONSIN

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On 12 July 2007 sediment cores were taken from near the deep area in all three lakes of the Cloverleaf Chain of Lakes using a gravity corer. Table 1 shows the locations, water depth, and length of sediment core collected. Samples from the top of the cores and a section deeper in the core were kept for analysis. It is assumed that the upper sample represents present conditions while the deeper sample is indicative of water quality conditions at least 100 years ago.

Table 1. Core location, water depth, and total length of core.

| LAKE | Latitude | Longitude | Water Depth (ft) | Sediment Core Depth (cm) |
|-------|-------------|-------------|------------------|--------------------------|
| PINE | N 44.68958° | W 88.65792° | 36 | 66 |
| GRASS | N 44.69119° | W 88.66946° | 43 | 47 |
| ROUND | N 44.69132° | W 88.67565° | 38 | 48 |

Results

Aquatic organisms are good indicators of water chemistry because they are in direct contact with the water and are strongly affected by the chemical composition of their surroundings. Most indicator groups grow rapidly and are short lived so the community composition responds rapidly to changing environmental conditions. One of the most useful organisms for paleolimnological analysis is diatoms. They are a type of alga which possess siliceous cell walls and are usually abundant, diverse, and well preserved in sediments. They are especially useful as they are ecologically diverse and their ecological optima and tolerances can be quantified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. They also live under a variety of habitats, which enables us to reconstruct changes in nutrient levels in the open water as well as changes in benthic environments such as aquatic plant communities. Figure 1 shows photographs of four diatom species that were common in the sediment cores.

While diatoms were plentiful in the both sections from the cores in Grass and Pine lakes and the top section of the core from Round Lake, they were absent from the bottom section. This is unusual but it does occasionally happen. This is more common in very hardwater lakes

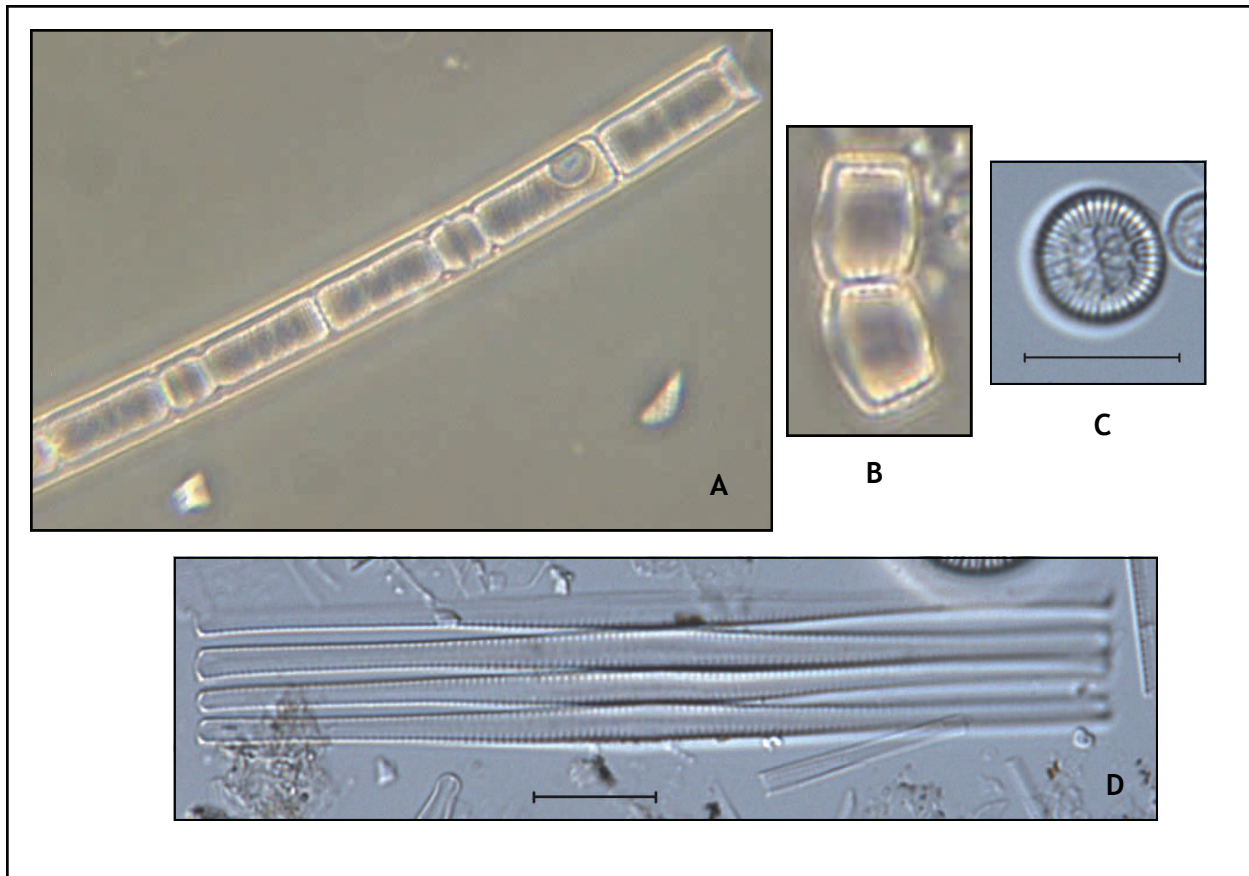


Figure 1. Photomicrographs of diatoms common in the lakes of this study. The diatom on the top left (A) *Aulacoseira ambigua* typically is found in open water environments while the picture to the right (B) is *Staurosirella pinnata* which is commonly found attached to substrates such as downed trees and aquatic plants in lakes. The diatom in at the extreme right (C) is *Cyclotella comensis* which is thought to be an invasive from northern Europe. The diatom at the bottom (D), *Fragilaria crotonensis* is also found in the open water.

where the higher pH values facilitate dissolution of the siliceous shells of the diatoms. It is unclear why there was dissolution of the diatom shells in Round Lake but it may be related to the high iron levels in the deeper sediments of the lake. Another lake which had high sediment iron levels also experienced complete dissolution of the diatom shells.

By determining changes in the diatom community it is possible to determine water quality changes that have occurred in the lake. The diatom community provides information about changes in nutrient, water color, and pH conditions as well as alterations in the aquatic plant (macrophyte) community.

Pine Lake The dominant diatoms at the top of the core were planktonic diatoms which grow in the open water of the lake. These type of diatoms made up over 60 per cent of the dia-

tom community (Figure 2). The dominant taxa were *Aulacoseira ambigua* and *Fragilaria crotonensis* which are pictured in Figure 1a and d. At the bottom of the core planktonic diatoms only made up about 20 per cent of the diatom community. The dominant diatoms were those that grow attached to aquatic plants or other bottom substrates. An example of this type of diatom is shown in Figure 1b. Studies have found that as nutrients increase, even by a small amount, planktonic diatoms become much more common. The large change in the diatom community from the bottom to the top of the core in Pine Lake indicates there has been an increase in nutrients during the last 100 years. It is likely the increase in nutrients has not been more than $5 \mu\text{g L}^{-1}$ since the dominant diatom taxa are usually found in lakes with moderate nutrient levels. Benthic *Fragilaria* grow on substrates such as aquatic plants (weeds). Their decline from the bottom to the top of the core does not mean there are less plants at the present time compared with historical times. It is more likely that the plant community

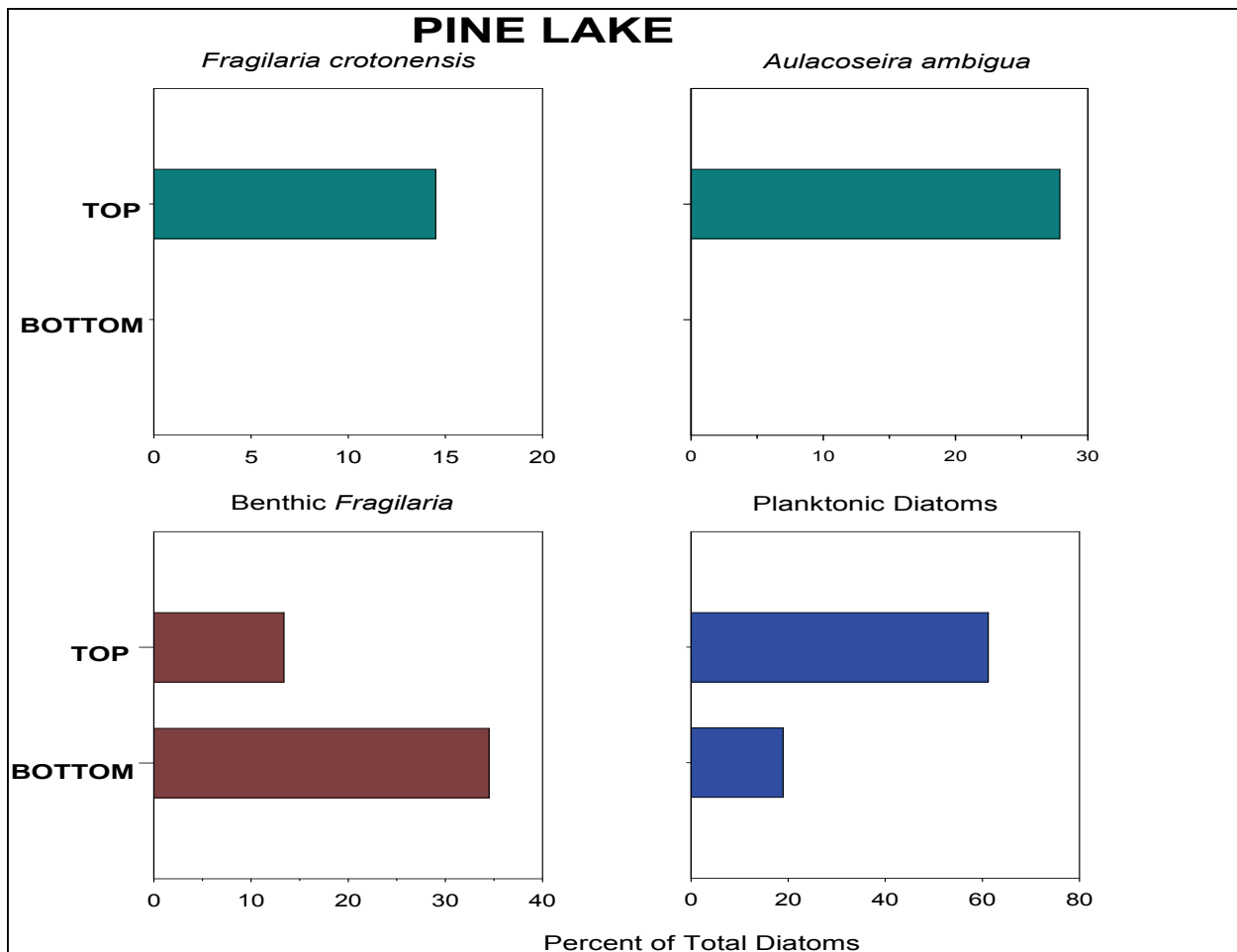


Figure 2. Changes in abundance of important diatoms found at the top and bottom of the sediment core from Pine Lake. The diatoms in the top panels are found in the open water of the lake while Benthic *Fragilaria* grow on substrates such as plants. The large increase in planktonic diatoms from the bottom to the top of the core indicates a small, but significant increase in nutrients.

at the present time is similar in distribution, although composition of the community may have changed.

Grass Lake Unlike Pine Lake, the diatom community does not indicate a significant change in nutrients from the bottom to the top of the core. Planktonic diatoms were the dominant type of diatoms in both the top and bottom of the core from Grass Lake (Figure 3). This is surprising since the lakes are adjacent to each other and connected. It would be expected the diatom community at the bottom of the cores from the lakes would be similar even if the community at the top of the cores were different. It is likely that the bottom section of the core from Grass Lake was not deposited prior to European settlement. The sediment in the location where the core was taken may have been previously disturbed, for example, by

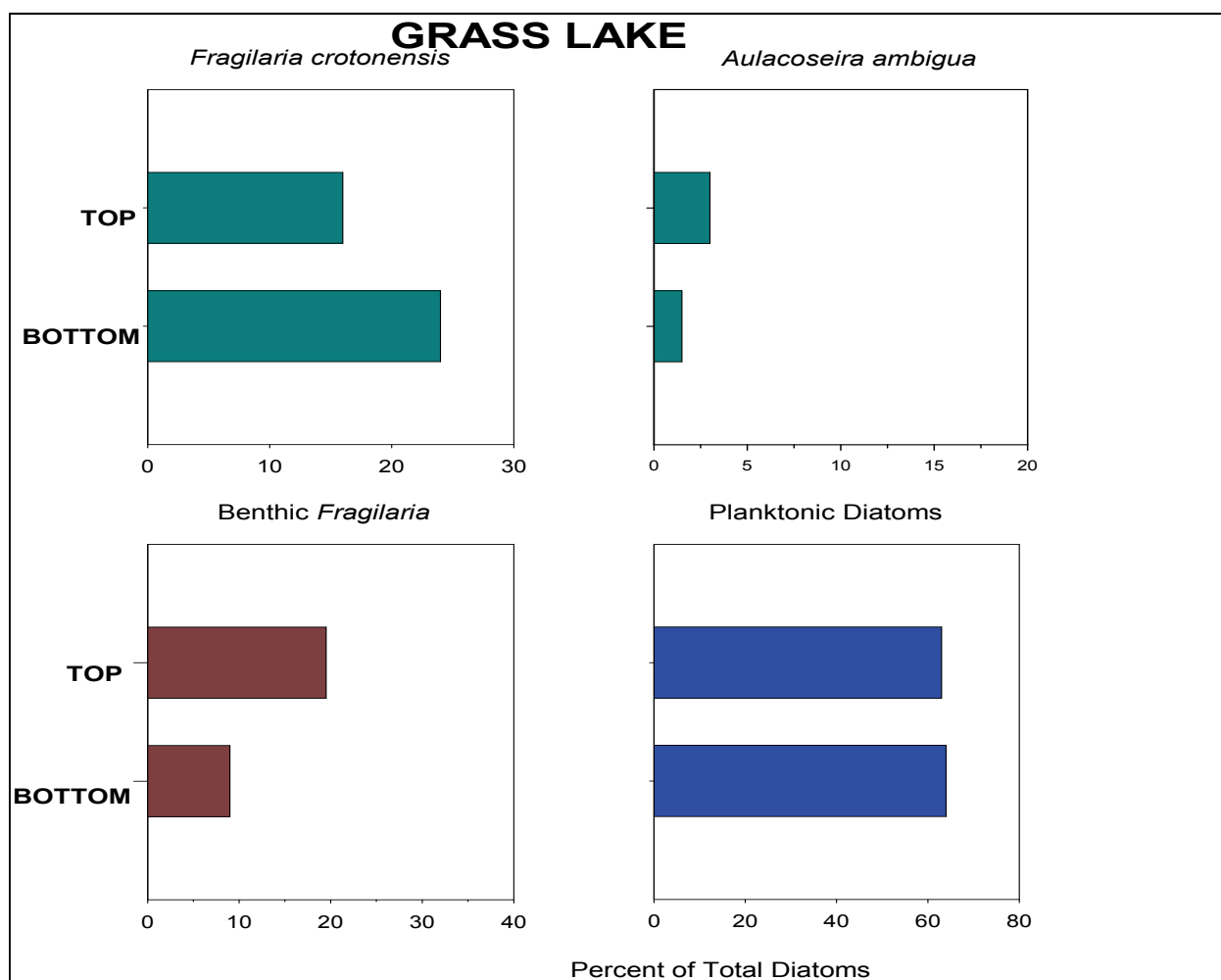


Figure 3. Changes in abundance of important diatoms found at the top and bottom of the sediment core from Grass Lake. Unlike Pine Lake there was not a significant change in the diatom community from the bottom to the top of the core. This likely indicates the core was either not long enough or the coring site had been previously disturbed.

a boat anchor. It is also possible that the length of the core was not great enough. The core from Pine Lake was 20 cm longer than the one from Grass Lake. In most other lakes, the length of the core from Grass Lake (47 cm) would have been long enough to cover over 100 years, but the sedimentation rate in Grass Lake may be usually high.

Since I have no confidence that the bottom section represents a pre-settlement time period it is not possible to directly compare changes in the core from top to bottom. If we assume that the pre-settlement diatom community in Grass Lake was similar to Pine Lake then Grass Lake has undergone similar changes in nutrient levels as Pine Lake. As with Pine Lake there has also not been a significant change in the aquatic plant community either.

Round Lake As mentioned previously, no diatoms were preserved in the bottom section of this core. It is likely that the diatom community found at the bottom of the core from Pine Lake was the historical community in Round Lake. If this is true then there have been greater increases in nutrients in this lake than the other two lakes. While planktonic diatoms comprised about 60 per cent of the diatom community in the surface sediments of Pine and

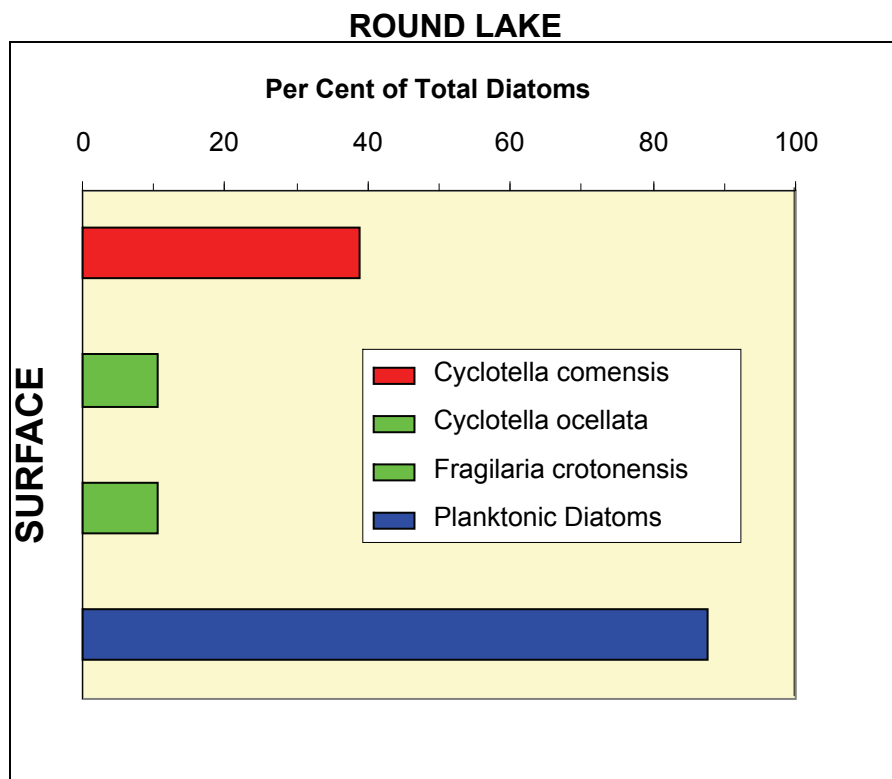


Figure 4. Abundance of common diatoms found in the surface of Round Lake. *C. comensis* is thought to be an invasive from northern Europe.

Grass lakes, they were almost 90 per cent of the community in Round Lake (Figure 4). The dominant diatom was the planktonic diatom *Cyclotella comensis*. This diatom is thought to be an invasive from northern Europe. It is thought to have arrived during the 1950s via Great Lakes shipping. It seems to indicate elevated nutrient levels. Only a couple of these diatoms were found in Grass or Pine lakes. One of the most common diatoms in the surface of the other two lakes was *F. crotonensis*. It only comprised about 10 per cent of the community in Round Lake. It is likely that nutrient levels, especially phosphorus has increased more in Round Lake than it has in the other lakes.

Diatom assemblages historically have been used as indicators of trophic changes in a qualitative way. In recent years, ecologically relevant statistical methods have been developed to infer environmental conditions from diatom assemblages. These methods are based on multivariate ordination and weighted averaging regression and calibration. Ecological preferences of diatom species are determined by relating modern limnological variables to surface sediment diatom assemblages. The species-environment relationships are then used to infer environmental conditions from fossil diatom assemblages found in the sediment core.

Table 2 shows the diatom inferred mean summer phosphorus concentrations for the three lakes. For a pre-settlement value, an the estimate at the bottom of the Pine Lake core is used for all three lakes. The estimated historical phosphorus concentration is 14 $\mu\text{g L}^{-1}$. The diatom community estimates the current phosphorus level as 17 $\mu\text{g L}^{-1}$ which is close to the concentration measured in the last few years. The phosphorus level in Grass is estimated to have increased more to 21 $\mu\text{g L}^{-1}$, while Round Lake is estimated to have increased the most to 24 $\mu\text{g L}^{-1}$.

Table 3. Diatom inferred summer phosphorus levels in the study lakes. The inference was done using the weighted averaging program WACALIB. This analysis requires an appropriate calibration dataset.

| LAKE | Estimated Summer Phosphorus ($\mu\text{g L}^{-1}$) | |
|-------|--|--------|
| | Top | Bottom |
| PINE | 17 | 14 |
| GRASS | 21 | (14) |
| ROUND | 24 | (14) |

In summary, the core from Round Lake only had diatoms in the surface section. The bottom section of the core from Grass Lake did not represent pre-settlement conditions but the Pine Lake core was a good core. If it is assumed that the diatom community present in the bottom section of the Pine Lake core is representative of historical conditions in all three lakes, then nutrient levels at the present time are higher than they were historically. Nutrient levels appear to have increased the least in Pine Lake and the most in Round Lake.