ASSESSEMENT OF WATER QUALITY IN LAKE OWEN, BAYFIELD COUNTY WISCONSIN BY THE USE OF FOSSIL DIATOMS

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Introduction

Questions often arise concerning how a lake's water quality has changed through time as a result of watershed disturbances. In most cases there is little or no reliable long-term data. Questions often asked are if the condition of the lake has changed, when did this occur, what were the causes, and what were the historical condition of the lake? Paleoecology offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution. These remains include diatom frustules, cell walls of certain algal species, and subfossils from aquatic plants. The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. Using the fossil remains found in the sediment, one can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

The purpose of this study is to assess water quality throughout Lake Owen and to compare present water quality with historical levels. On 28 October 2005, sediment samples were taken from 7 locations in Lake Owen (Figure 1). At two of the sites (1 and 5) sediment cores were collected. Sediment from the top of these cores and sections deeper in the core were collected and returned to the lab. It is assumed that the upper sample represents present conditions while the deeper sample is indicative of water quality conditions prior to European settlement over 100 years ago. These samples were analyzed for lead-210 and other radiometric elements, to confirm that these depths represent the time periods assumed. Additional surface samples were collected at 5 other sites to examine the diatom community.

Sites 1 through 5 were collected in relatively deep water (Table 1) and characterize the open water quality conditions in each of these basins. Unlike the other sites, Site 6 was in a bay which had shallower water. There is significant shoreland development around this bay. Site 7 was also located in a bay but shoreland development is less dense. This site was meant to serve as a control to assess the impact of shoreland development on the bay at Site 6.

Table 1. Location of sampling sites and water depth where samples were taken.

Site	Latitude	Longitude	Water Depth (ft)
1	N 46° 18.078'	W 91° 11.483'	72
2	N 46° 17.438'	W 91° 12.587'	54
3	N 46° 18.075'	W 91° 13.035'	52
4	N 46° 16.871'	W 91° 13.786'	50
5	N 46° 15.783'	W 91° 15.215'	85
6	N 46° 14.484'	W 91° 15.934'	28
7	N 46° 16.378'	W 91° 14.314'	27

Results

In order to determine if the top of the core was deposited recently and the bottom sample was deposited at least 130 years ago, samples were analyzed for the naturally occurring radionuclides lead-210 ^{210}Pb) and radium-226 (^{226}Ra). Lead-210 has a half life of 22.26 years which means it can be detected after deposition for about 130-150 years. Since ^{226}Ra represents background levels, and the ^{210}Pb concentrations at the bottom of the cores were less than zero (meaning it was undetectable) (Table 2)

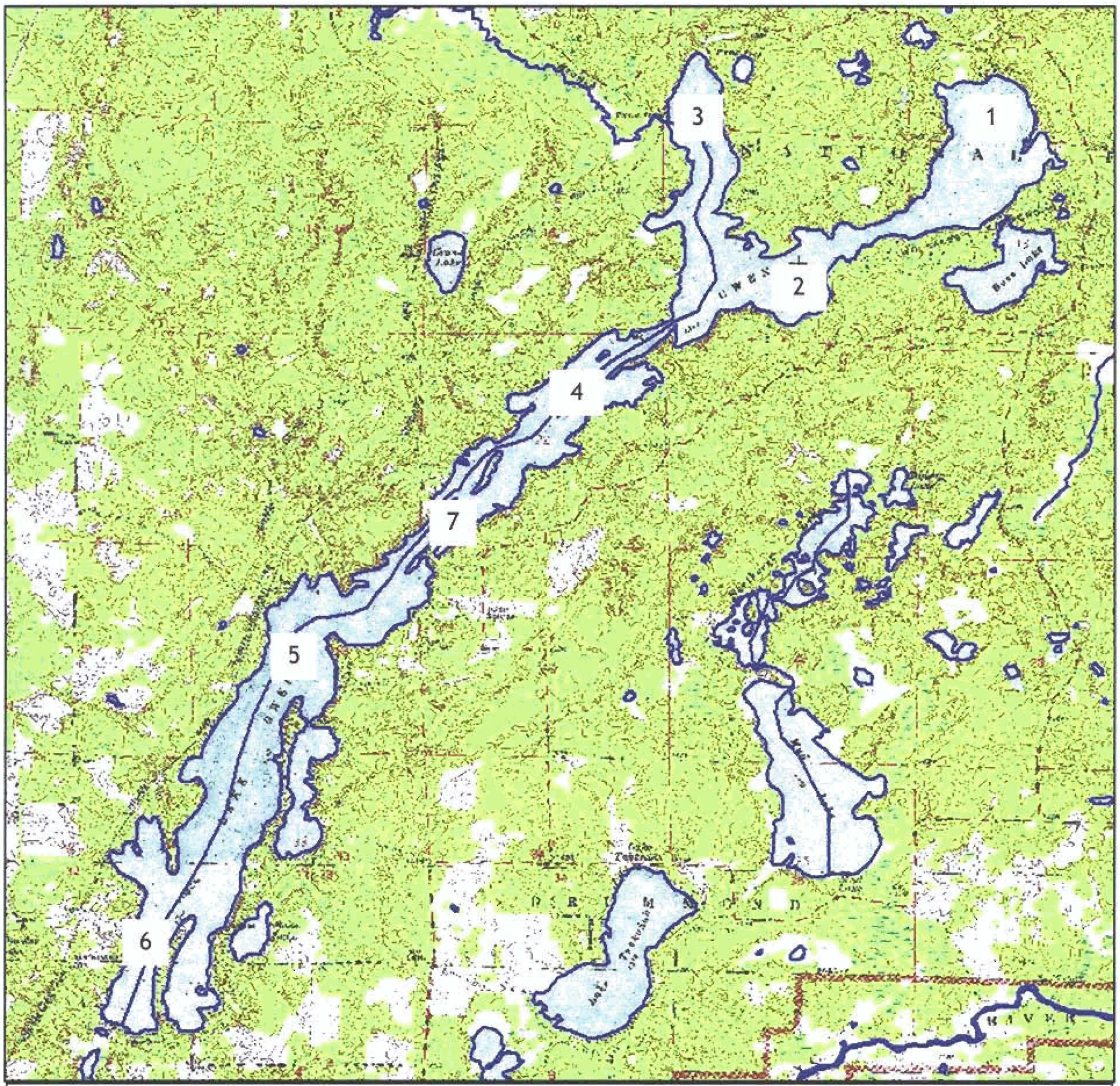

Figure 1. Map of Lake Owen showing the sampling sites. At all sites surface sediments were collected. At sites 1 and 5 top/bottom cores were collected.

these samples were deposited at least 130 years ago. It is not possible from this data to determine how much older than 130-150 years ago the samples were deposited, but this analysis does confirm that at both sites the samples were deposited prior to logging and cottage building. The ^{210}Pb concentration at the top of the core is within levels found at the top of nine cores from other softwater Wisconsin lakes (range = 5.11-73.78 pCi g^{-1}). This indicates that the top of the cores was likely recently deposited.

The samples were also analyzed for cesium-137. Since cesium-137 (^{137}Cs) was a byproduct of atmospheric nuclear testing it can be used to identify the period of maximum atmospheric nuclear testing (Krishnaswami and Lal, 1978). The peak testing occurred by the USSR in 1963. While the analysis performed on these cores will not identify the ^{137}Cs peak, concentrations at the bottom of the core should be very low. This analysis is a confirmation of the ^{210}Pb analysis.

Table 2. Amount of ^{210}Pb ^{226}Ra, and ^{137}Cs found in the core samples. Units are pCi g^{-1}.

		Lead-210	Radium-226	Cesium-137
Site 1	Top	47.043	0.186	3.262
	Bottom	-0.615	-0.026	0.086
Site 5	Top	46.784	0.143	4.657
	Bottom	-0.108	0.309	0.154

Aquatic organisms are good indicators of a lake's water quality 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 paleoecological analysis are diatoms. These are a type of algae which possess siliceous cell walls, which enables them to be highly resistant to degradation and are usually abundant, diverse, and well-preserved in sediments. They are especially useful, as they are ecologically diverse. Diatom species have unique features as shown in Figure 2, which enable them to be readily identified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. Some species float in the open water areas while others grow attached to objects such as rooted aquatic plants or the lake bottom. 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 and pH conditions as well as alterations in the aquatic plant (macrophyte) community.

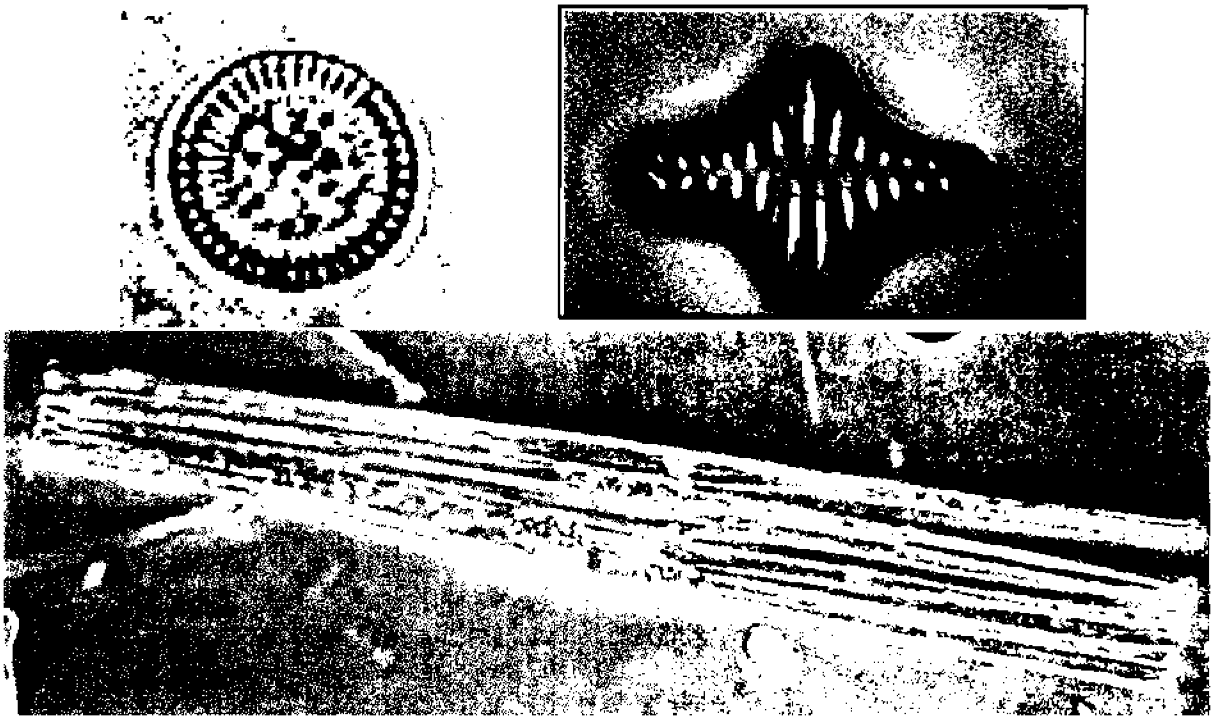

Figure 2. Examples of diatoms found in Lake Owen. The diatom in the upper left, *Cyclotella comensis*, was the dominant taxa at the top of the core at Site 1. The diatom on the upper right is *Staurosira construens* which typically grows attached to rooted aquatic plants. The diatom filament at the bottom is *Fragilaria crotonensis* which grows in the open water. Increases in this diatom indicate increased nutrient levels, especially nitrogen.

Deep Water Basins

The diatom community indicates that the northern third of Lake Owen has higher nutrient levels than the southern part. At site 1 the dominant taxa was *Cyclotella comensis* (pictured in Figure 2). The abundance of this taxa was greatest at Site 1 but it was also found in significant numbers at sites 2 and 3 (Figure 3). It is believed this diatom is an introduced species from northern Europe (Stoermer 1993, 1998). This diatom has been found in sediments deposited since 1950 in the Great Lakes (Stoermer et al. 1985; 1990; 1993) as well as inland lakes in northern lower Michigan (Fritz et al. 1993; Wolin and Stoermer 2005) and northern Wisconsin (Garrison 2005). The diatom *C. comensis* typically is found growing in the open water in the middle part of the water column. This means that this taxa is found in lakes with good water clarity but elevated nutrient levels in the deeper waters. Studies indicate that this diatom responds to increased phosphorus and nitrogen levels (Schelske et al. 1972; Wolin and Stoermer 2005).

The diatom *Fragilaria crotonensis* (pictured in Figure 2) was found at all of the sites but its abundance was generally higher in the same sites where *C. comensis* was found. Its abundance appears depressed at Site 1 because of the high levels of *C. comensis*. Increased abundance of *F. crotonensis* has been found to indicate increases in nutrients (Fritz et al. 1993; Garrison and Wakeman 2000; Forrest et al. 2002), especially nitrogen (Stoermer et al. 1978; Wolin et al. 1991). *Asterionella formosa* often indicates increased nutrient levels but in Lake Owen, abundances were similar at all of the sites. Increased abundance of both *C. comensis* and *F. crotonensis* at Sites 1-3 compared with Sites 4 and 5 is additional evidence that this part of the lake has higher nutrient levels, especially nitrogen.

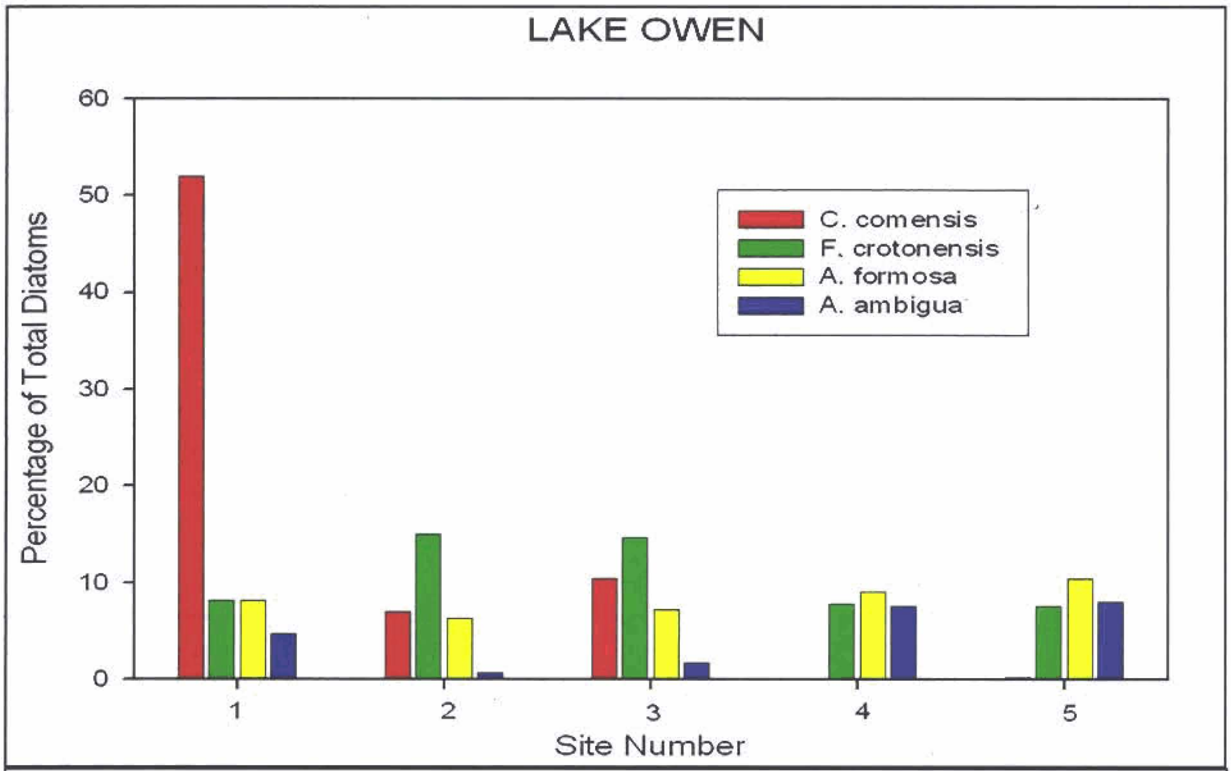

Figure 3. Abundance of common diatoms found in the surface sediments at Sites 1-5. The first diatom (*C. comensis*) is thought to have been introduced from northern Europe around 1950. This diatom as well as the next two are indicative of higher nutrient levels. *A. ambigua* is common in low nutrient lakes and its increased abundance at sites 4 and 5 indicate lower nutrients at these sites compared with the more northern sites.

The planktonic diatom *Aulacoseira ambigua* was generally found in higher abundance at the southern sites, 4 and 5 (Figure 3). This diatom is a commonly found in lakes of the Upper Midwest that possess good water clarity (Fitzpatrick et al. 2002; Garrison and Wakeman 2000; Garrison 2005a,b). It was historically very common in low nutrient lakes in the Upper Midwest (Camburn and Kingston 1986; Kingston et al. 1990). The higher levels in the southern sites is further confirmation of higher nutrient levels in the northern part of Lake Owen.

In order to estimate how present day water quality conditions compare with pre-settlement levels, sediment cores were collected at Sites 1 and 5. The diatom communities at the top and bottom of these cores were examined. As would be expected, at Site 1 where *C. comensis* was dominant in the surface sediments it was virtually absent in the bottom sample (Figure 4). Both *F. crotonensis* and *A. formosa* were found in higher abundance at the top of the core. This indicates that nutrient levels at the present time are elevated compared with those of 100 years. While it is unclear when these higher nutrient indicating diatoms first began to increase, Seiser (1981) reported that these diatoms

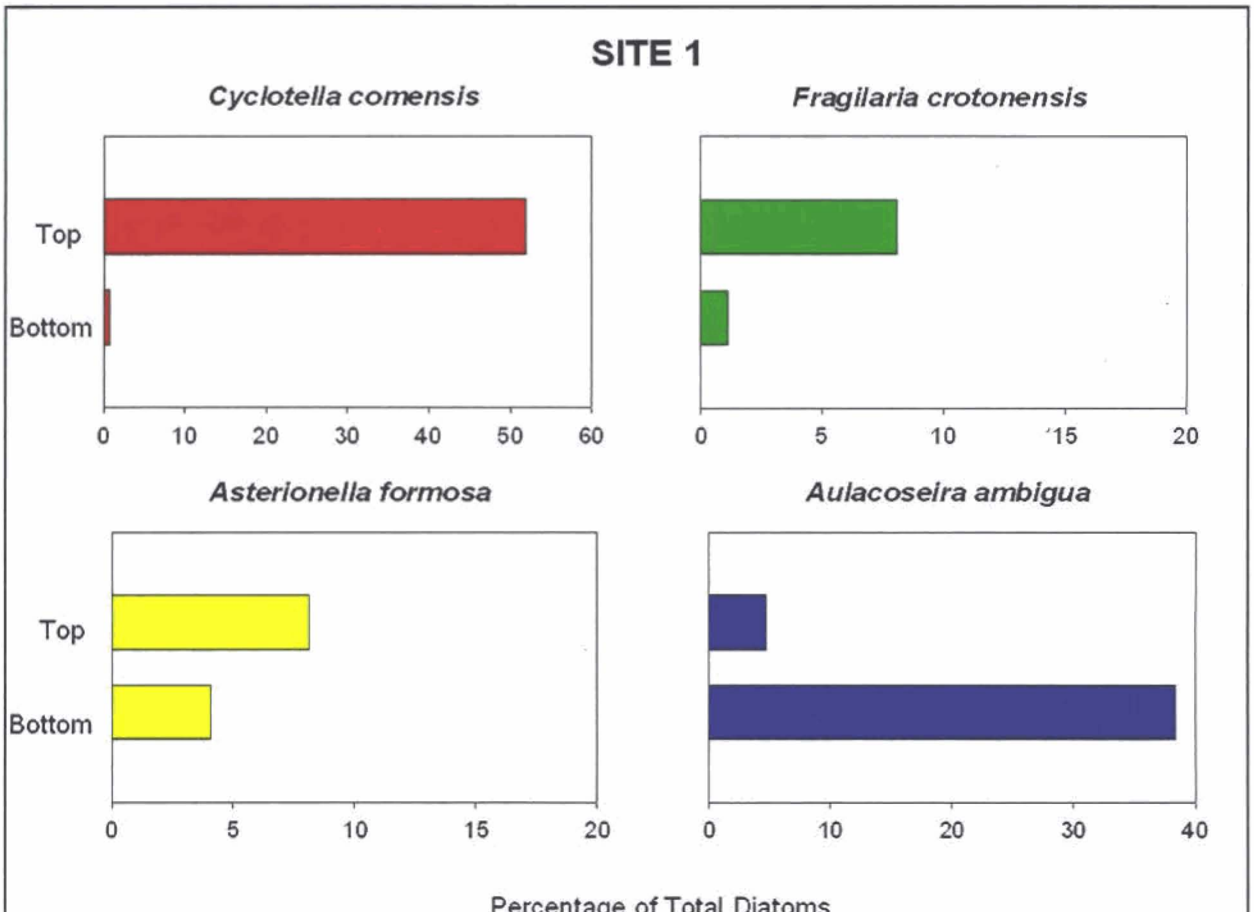

Figure 4. Comparison of common diatoms at the top and bottom of the core taken at Site 1. There is an increase in diatoms indicative of higher nutrients at the top of the core.

were an important part of the diatom community in 1979-80. Additional evidence of the increase in nutrients is provided by reduced abundance of *A. ambigua* in the surface sediments, since this taxa indicates low nutrient levels.

At Site 5, there is a significant increase in both *F. crotonensis* and *A. formosa* at the top of the core

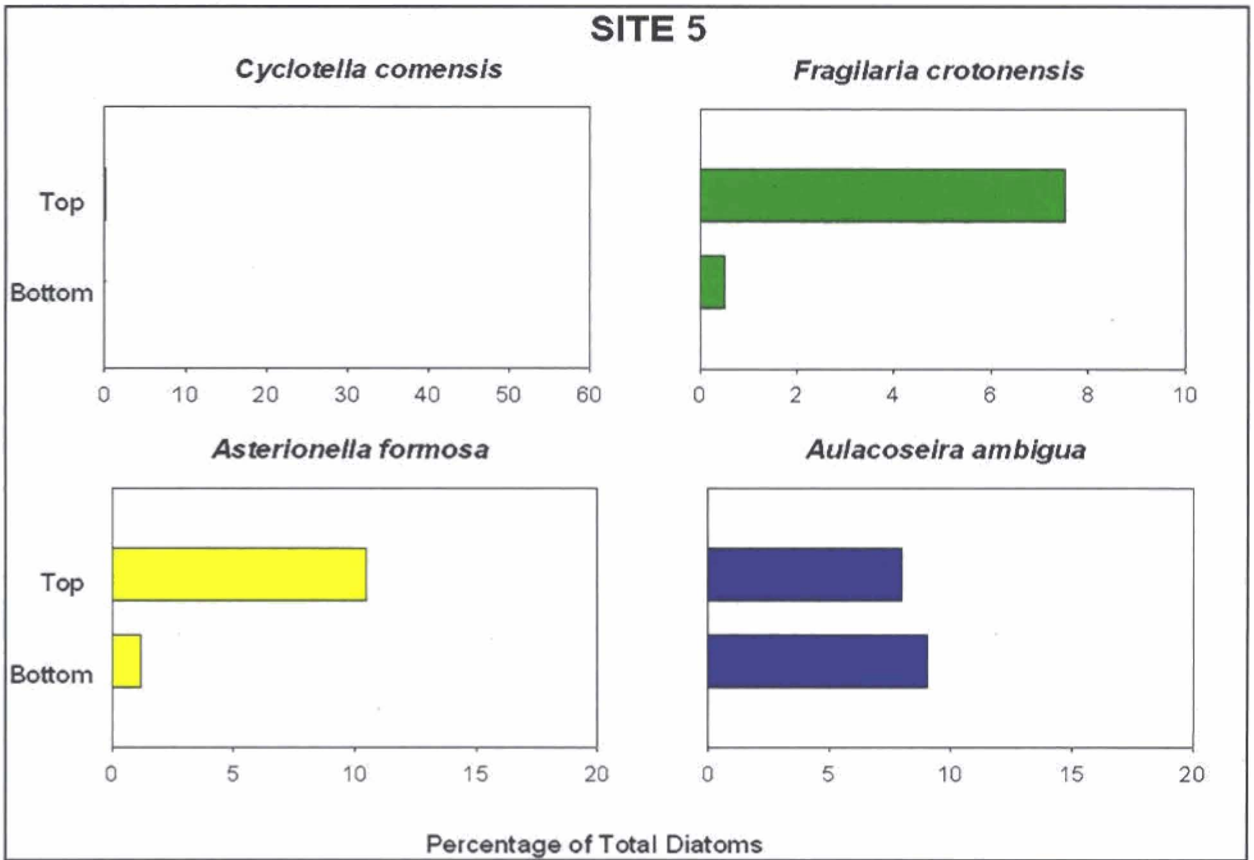

Figure 5. Comparison of common diatoms at the top and bottom of the core taken at Site 1. There is an increase in diatoms indicative of higher nutrients at the top of the core.

(Figure 5), indicating that nutrient levels have also increased in this part of the lake during the last 100 years. Even though *C. comensis* was only found in very low numbers in the surface sediments at this site, there has been an increase in nutrient levels at this site during the last 100 years.

Shallow Water Bays

A comparison was made of conditions in Sister Bay (Site 6) with those at Site 7. There is considerable development on the shore of Sister Bay but very little around the bay at Site 7. Because of the shallow water depth of these bays, the diatom community is much different than it is at the other sites. At both sites most of the diatoms are taxa that grow attached to substrates such as rooted aquatic plants. Some of the taxa seem to prefer higher nutrient levels and have been shown to increase in abundance as phosphorus runoff increases from the watershed. The taxa *Staurosira construens* (pictured in Figure 2) as well as small *Fragilaria* are more common under higher phosphorus concentrations (Garrison and Fitzgerald 2005) while the diatom *Pseudostaurosira brevistrata* prefers low nutrient levels. Both *S. construens* and small *Fragilaria* where found in higher abundance at Site 6 (Figure 6). Conversely, *P. brevistrata* was more common at Site 7. The diatom community indicates that nutrient levels may be higher at Site 6 compared with Site 7. This may be a consequence of the more intense development around Sister Bay. Cores from other lakes in northern Wisconsin have shown that one of the most common impacts of shoreline development has been an increase in macrophyte growth (Fitzpatrick et al. 2002; Garrison 2005a). Work being conducted by Sue Borman for her PhD dissertation at U. of Minnesota shows that a comparison of the composition of the macrophyte communities from the 1930s, when shoreline development was low, and the present day results in change in the macrophyte comunity from low growing species to those which grow nearer the surface and have larger leaf surface areas. This change in the plant community also seems to be accompanied by a change in the substrate from sand to more mucky material.

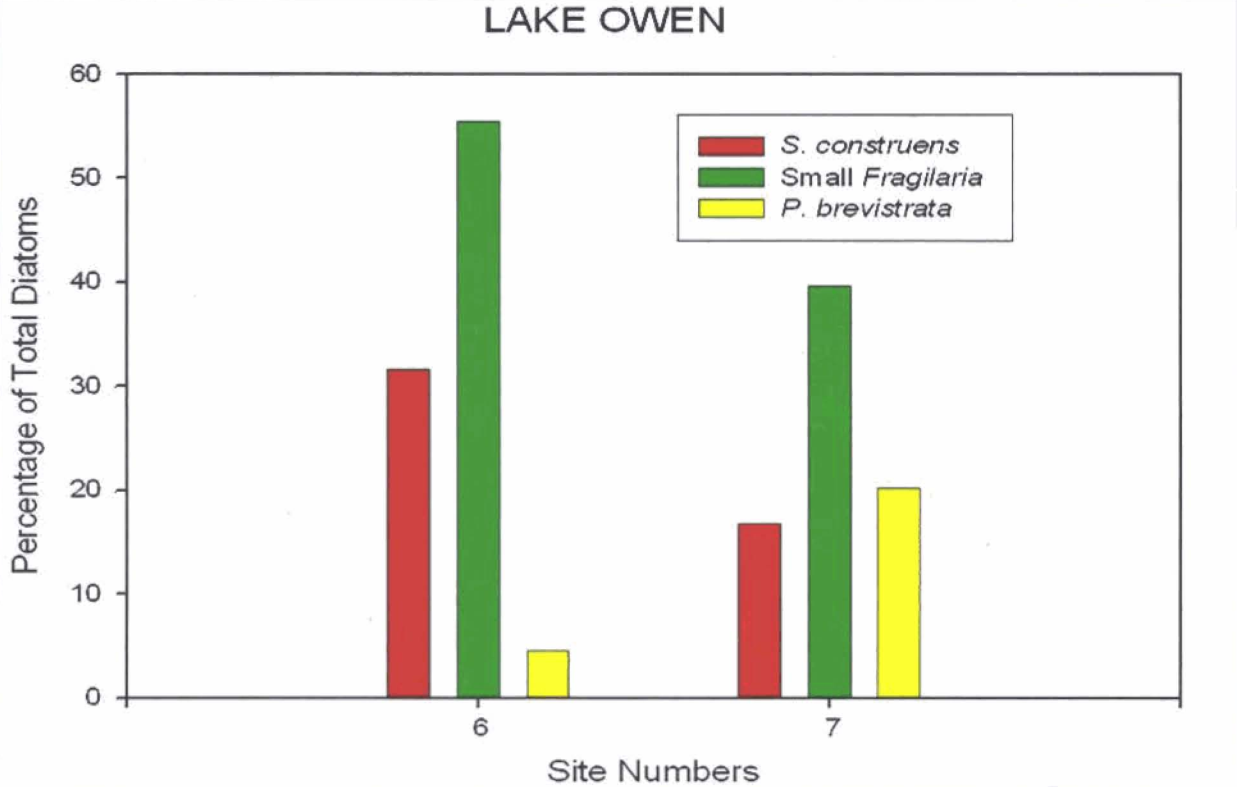

Figure 6. Comparison of common diatoms in the surface sediments at the shallow water sites. The first two taxa are indicative of higher nutrient levels.

Summary

- The diatom community indicates that even though the nutrient levels and water clarity of Lake Owen at the present time are good, there are differences between the lake basins. The northern third of the lake possesses higher nutrient levels when compared with the rest of the lake. Most of the diatoms that indicate this trend grow in the middle part of the water column in an area known as the metalimnion. Because they reside in this area, this implies that water clarity is still good. However, their presence is an indication that the water quality of the lake is starting to deteriorate. The top/bottom cores indicate that this trend is not only happening in the northern part of the lake but also in the rest of the lake. The increased nutrient levels are in part because of phosphorus but nitrogen is probably increasing at a faster rate.
- Unlike many other northern Wisconsin lakes that have significant shoreline development, there does not appear to be a significant increase in rooted aquatic plants in response to development. This is probably because most of the shoreline contains a good amount of native vegetation. This buffer area intercepts nutrients and sediment which runs off lawns and often causes increased plant growth.
- Shoreline development may be having an adverse affect on the lake in Sister Bay. When compared with a bay which contains low development, the diatom community in Sister Bay indicates somewhat elevated nutrient levels in the bay with greater development.

Recommendations

- *Begin efforts to maintain Lake Owen's present water quality.* The sediment study found that the water quality of Lake Owen at the present time is not as good as it was 100 years ago. It is recommended that a detailed study be conducted to determine the major sources of nutrients to the lake.
- *Reduce the impact of shoreline development.* The sediment cores indicate that, unlike many other lakes with development, there has not generally been an increase in the growth of rooted aquatic plants. This is due, in part, because most of the shoreline has been left in a natural condition (Figure 7). Few homes have lawns that are maintained all the way to the shore. Maintaining natural shorelines or at least a 30 foot buffer should be strongly encouraged. Many studies have found that loss of natural shorelines allow additional nutrients and sediment to enter the lake as well as alter the biological community including amphibians and birds. It is also important to leave fallen trees in the lake. These are very important for insect and fish habitat.

Figure 7. Excellent example of the type of natural shoreline that should be encouraged.

- *Determine the source of the higher nutrients in the northern third of the lake.* The sediment study indicated that at sites 1-3 nutrients were higher than at the other sites. An effort should be made to find the source of these nutrients.
- *Reduce the impact of high density development.* The sediment study indicated that water quality in Sister Bay is worse than in the bay at Site 7. The development around Sister Bay is denser than the bay at Site 7. It is likely that runoff from the development is introducing nutrients and sediment into the bay. Runoff should be reduced by installing shoreline buffers and diverting runoff from impervious surfaces and lawns away from the lake where possible.

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