PALEOECOLOGICAL STUDY OF ROUND LAKE, SAWYER COUNTY

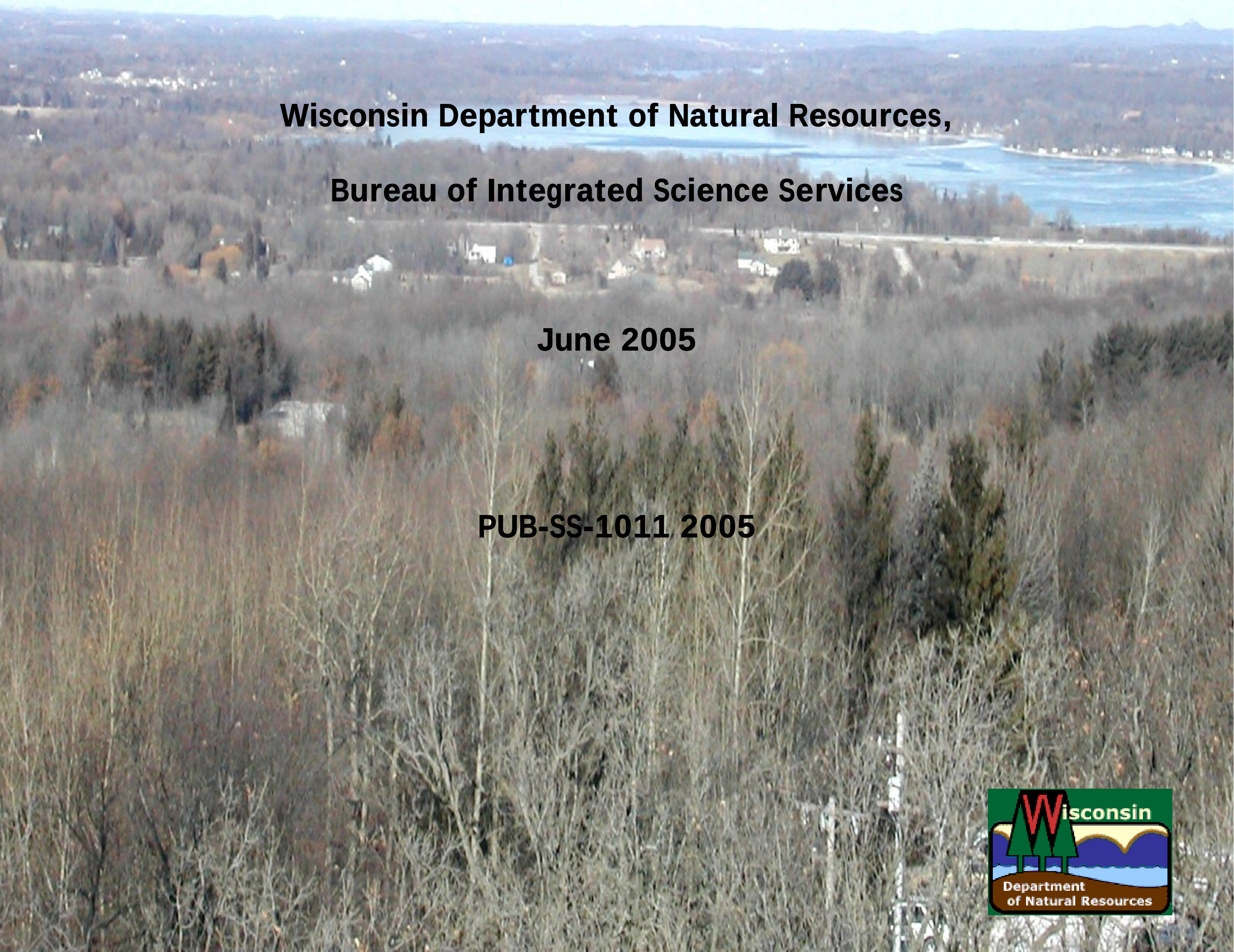
Paul J Garrison

Wisconsin Department of Natural Resources,

Bureau of Integrated Science Services

June 2005

PUB-SS-1011 2005



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.

Round Lake is a 3054 acre lake located in Sawyer County near the city of Hayward. The maximum depth is 74 feet with a mean depth of 33 feet. Two sediment cores were collected from Round Lake on 5 June 2003. The cores were collected with a gravity corer with a 6.5 cm plastic liner. The cores were collected from the deep area of the lake. The location of the coring site was 46º 01.217' north, 91º 18.581' west in a water depth of 15.9 meters (52 ft) (Figure 1). The cores were sectioned into 2 cm intervals for the entire core (47 and 48 cm). Both cores were combined for radiometric and geochemical analyses. The cores were dated by the ^{210}Pb method and the CRS model used to estimate dates and sedimentation rate. The diatom community was analyzed to assess changes in nutrient levels and changes in the macrophyte community and geochemical elements were examined to determine the causes of changes in the water quality and changes in oxygen conditions in the bottom waters.

Results and Discussion

Dating

In order to determine when the various sediment layers were deposited, the samples were analyzed for lead-210 (^{210}Pb). Lead-210 is a naturally occurring radionuclide. It is the result of natural decay of uranium-238 to radium-226 to radon-222. Since radon-222 is a gas (that is why is sometimes is found in high levels in basements) it moves into the atmosphere where it decays to lead-210. The ^{210}Pb is deposited on the lake during precipitation and with dust particles. After it enters the lake and it is in the lake sediments, it slowly decays. The halflife of ^{210}Pb is 22.26 years (time it takes to lose one half of the concentration of ^{210}Pb) which means that it can be detected for about 130-150 years. This makes ^{210}Pb a good choice to determine the age of the sediment since European settlement began in the mid-1800s. Sediment age for the various depths of sediment were determined by the constant rate of supply (CRS) model (Appleby and Oldfield, 1978). Bulk sediment accumulation rates (g cm^{-2} yr^{-1}) were calculated from output of the CRS model (Appleby and Oldfield, 1978). Accumulation rates of geochemical variables were computed for each sediment depth by multiplying the bulk

Figure 1. Map of Round Lake showing the coring site. The water depth at the site was 52 feet.

sediment accumulation rate (g cm^{-2} yr^{-1}) by the corresponding concentration (mg g^{-1}) of each constituent in the bulk sediment.

There can be problems with this dating technique. For example, when sediment has moved after it was deposited, large changes in sediment deposition over the last 150 years, and errors associated with lab analysis with sediments that are over 100 years old. For these reasons the accuracy of the ^{210}Pb dates is verified by other methods. These methods usually involve measuring parameters that are known to have been deposited at a certain time and comparing stratigraphic changes in the core in Round Lake with other lakes in the region.

Cesium-137 (Cs^{137}) 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 and thus the ^{137}Cs peak in the sediment core should represent a date of 1963. The depth of these peaks is very close to the date of 1963 calculated by the ^{210}Pb model indicating that the model results are very good.

Sedimentation Rate

The mean sedimentation rate for the last 120 years was 0.011 g cm^{-2} yr^{-1}. This is the third lowest of 45 lakes that have been measured in Wisconsin lakes (Figure 2). This low rate indicates soil erosion in the watershed has been relatively low during the last 150 years (period of European settlement).

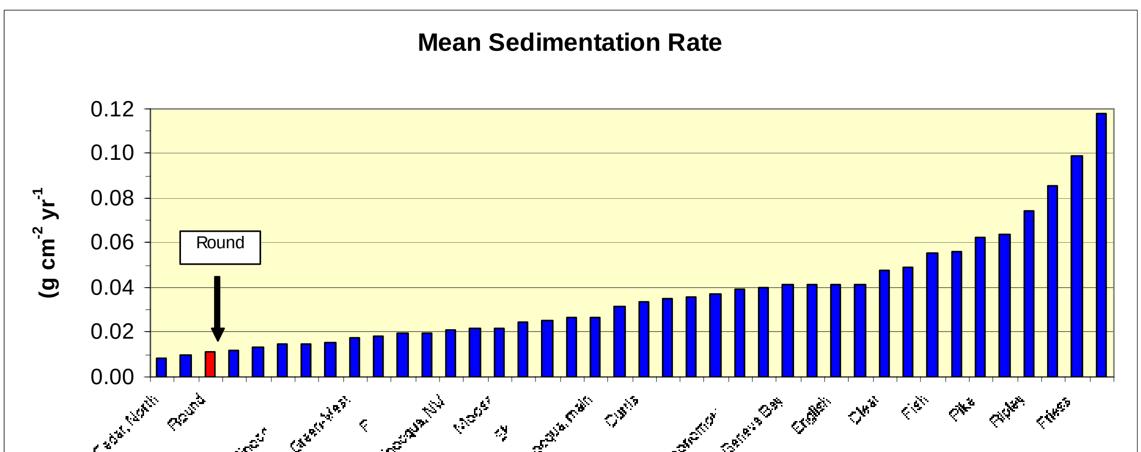


Figure 2. Mean sedimentation rate for the last 150 years for 40 Wisconsin lakes. The arrow indicates Round Lake.

More important than the mean sedimentation rate is the trend in this rate during the period of settlement. The sedimentation rate from 1890 until the early 1980s was fairly constant at

0.010 g cm^{-2} yr^{-1} but during the last 15 years the sedimentation rate has steadily increased and the peak rate was at the top of the core at 0.015 g cm^{-2} yr^{-1} (Figure 3). This recent increase in the rate indicates that watershed activities in recent years are having a greater impact on the lake's ecology.

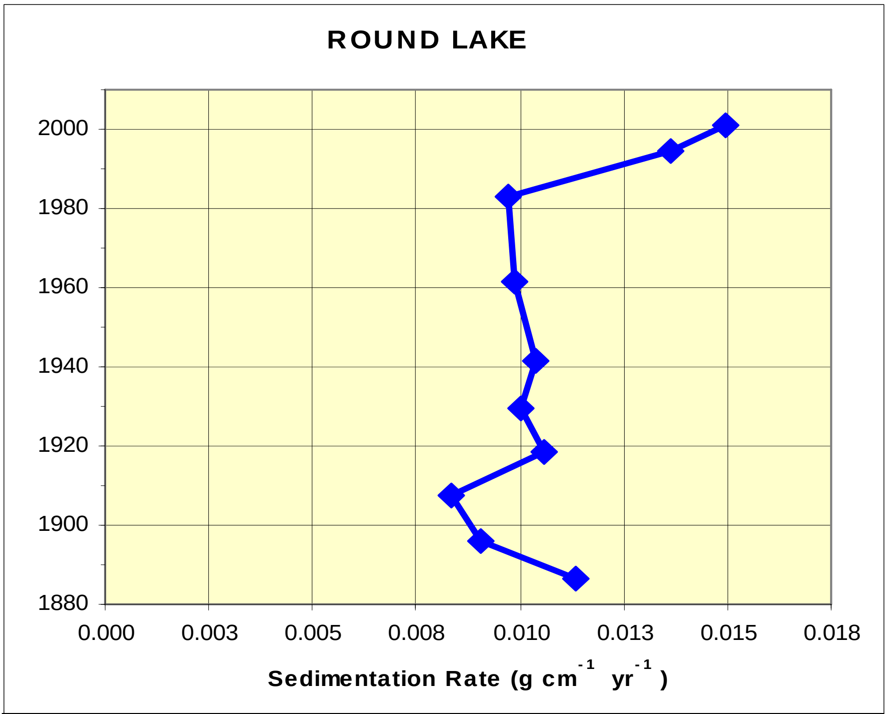


Figure 3. Sedimentation rate for Round Lake since the late 1800s. The recent increase in the rate is the result of elements deposited in the lake as a result of shoreline development.

Geochemistry

Geochemical variables are analyzed in order to estimate which watershed activities are having the greatest impact on the lake (Table 1). The chemical titanium (Ti) is found in soil particles, especially clays. Changes in Ti are an indication of changes in soil erosional rates throughout the lake's history. Zinc (Zn) is associated with urban runoff because it is a component of tires and galvanized roofs and downspouts. Nutrients like phosphorus and nitrogen are important for plant growth, especially algae and aquatic plants. Calcium and uranium are indications of use of soil amendments for lawns. Manganese is an indication of changes in oxygen levels in the bottom waters.

Prior to 1920, the geochemical accumulation profiles largely reflected changes in the sedimentation rate which indicates that landuse activities in the watershed were having a minimal impact on Round Lake's chemistry. After 1920, more significant changes occurred.

Table 1. **Selected chemical indicators of watershed or in lake processes.**

Process	Chemical Variable
Soil amendment	calcium, uranium
Soil erosion	aluminum, titanium
Urban	zinc, copper
Anoxia	manganese
Nutrients	phosphorus, nitrogen

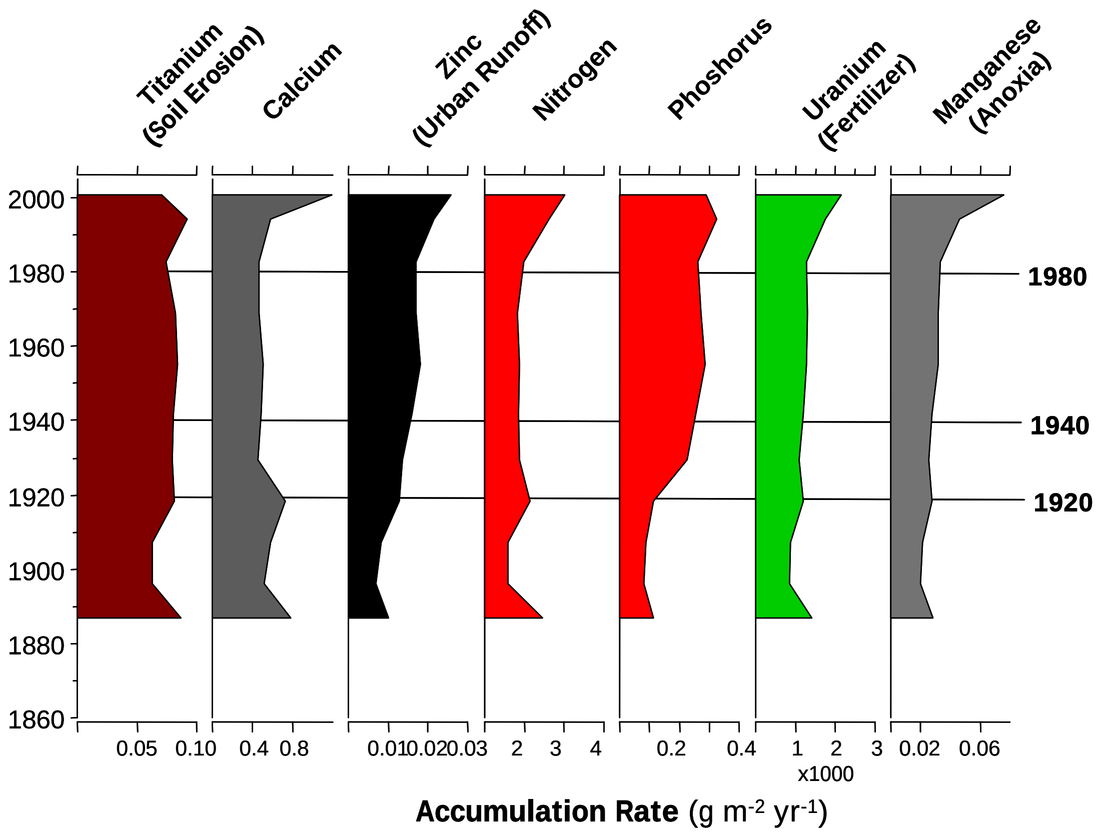


Figure 4. Profiles of selected geochemical elements. The increased deposition of most elements in recent years is the result of shoreline development.

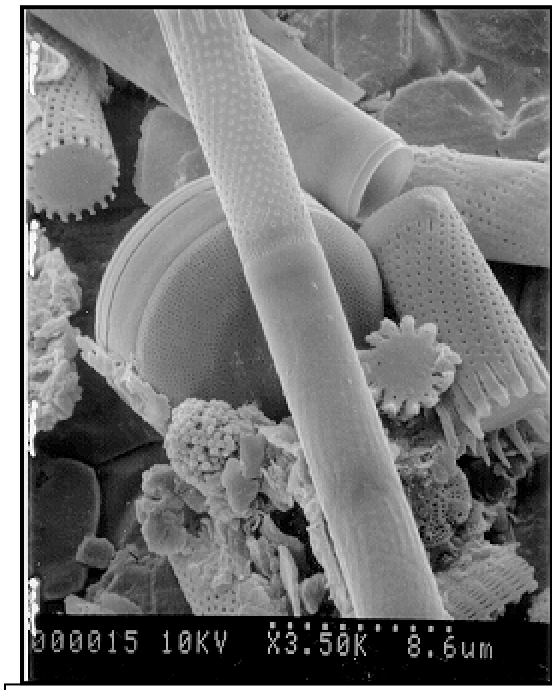
The major geochemical elements were largely unchanged for the time period 1920 through the late 1980s with the exception of zinc and phosphorus. Both of these elements increased after 1920 and remained elevated compared with historical levels. Deposition rates remained at an elevated accumulation rate until the 1980s. Zinc is one of the most common metals in urban runoff because of it is a component in tires and galvanized roofs and downspouts (Bannerman et al. 1993; Good 1993; Steuer et al. 1997). Since much of the zinc delivered to the lake comes from street runoff, the increase in the deposition rate indicates increased urbanization in the watershed. In the case of Round Lake, increased urbanization is probably because of the increase in vehicle traffic and construction of buildings around the lake. During the period 1920-85 phosphorus increased more rapidly than zinc and only potassium increased at the same rate during this time period. It is unclear what caused this increase.

The deposition rates of titanium (soil erosion), uranium (synthetic fertilizer), nitrogen, phosphorus, and calcium (soil amendment) all increased during the last 15 years (Figure 4). In fact the highest rates, with the exception of titanium and phosphorus, occurred at the top of the core. The titanium accumulation rate, which is an indication of soil erosion since it is associated only with clay particles, showed a small increase during the 1990s. In general the core indicates that soil erosion in the watershed has not delivered a lot of sediment to the deeper area of the lake. The increase in the other elements indicates that shoreline development is having an impact upon the lake. The increase in nitrogen, uranium, and calcium are probably the result of urbanization near the lakeshore, especially lawn care. Uranium is typically found associated with synthetic fertilizers applied to crops and lawns. Nitrogen and phosphorus are large components of fertilizers and their increase during the last 2 decades probably indicates fertilizer usage around the lake for lawn maintenance. Calcium is often used as a soil amendment for lawns in the form of lime.

As the bottom waters become increasing devoid of oxygen, manganese (Mn) is mobilized from the sediments (Engstrom et al. 1985). This manganese then moves into the deepest waters resulting in enrichment of manganese in the sediments of the deeper waters in Round Lake. The increase in Mn began during the 1950s (Figure 4). During the last ten years the deposition rate has been higher than any other time during the last 120 years. This trend in Mn indicates that the bottom waters began to lose oxygen about 50 years ago but the amount of bottom waters that are devoid of oxygen has increased since 1995.

Diatom Community

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 5 shows photographs of two diatom species that were common in the sediment cores.



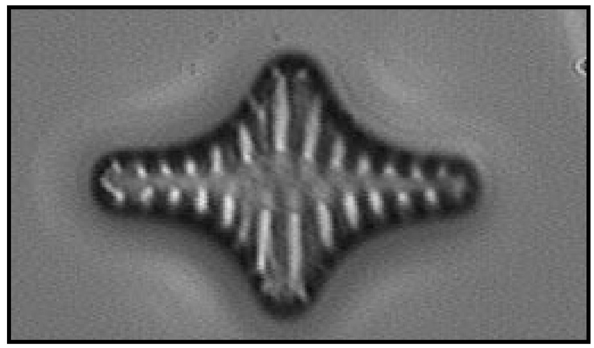


Figure 5. Micrographs of diatoms *Aulacoseira* (left) and *Staurosirella* (right). The diatom on the right is an example of the diatom group "Benthic *Fragilaria*." The diatom on the left is typically found floating in the open water and the diatom on the right is found attached to substrates such as submerged plants.

Prior to 1900 the diatom community indicates that Round Lake was typical of many northern lakes. Water clarity was excellent and aquatic vascular plants were present but in general not in large numbers. The most common diatom was the planktonic species *Aulacoseira ambigua*. This diatom was historically very common in oligotrophic lakes in the Upper Midwest (Camburn and Kingston 1986; Kingston et al. 1990) including nearby Lac Courte Oreilles and Grindstone Lake. Beginning around 1900 this diatom began to decline (Figure 6) indicating a subtle deterioration of the lake's water quality. *A*. ambigua continued to decline until the 1950s as was replaced by other planktonic diatoms *Cyclotella bodanica var. lemanica* and *Fragilaria crotonensis* that favor higher nutrients (Ennis et. al. 1983, Engstrom et al. 1985, Christie & Smol 1993, Stager et al. 1997). The planktonic diatom *Cyclotella comensis* first appears in very

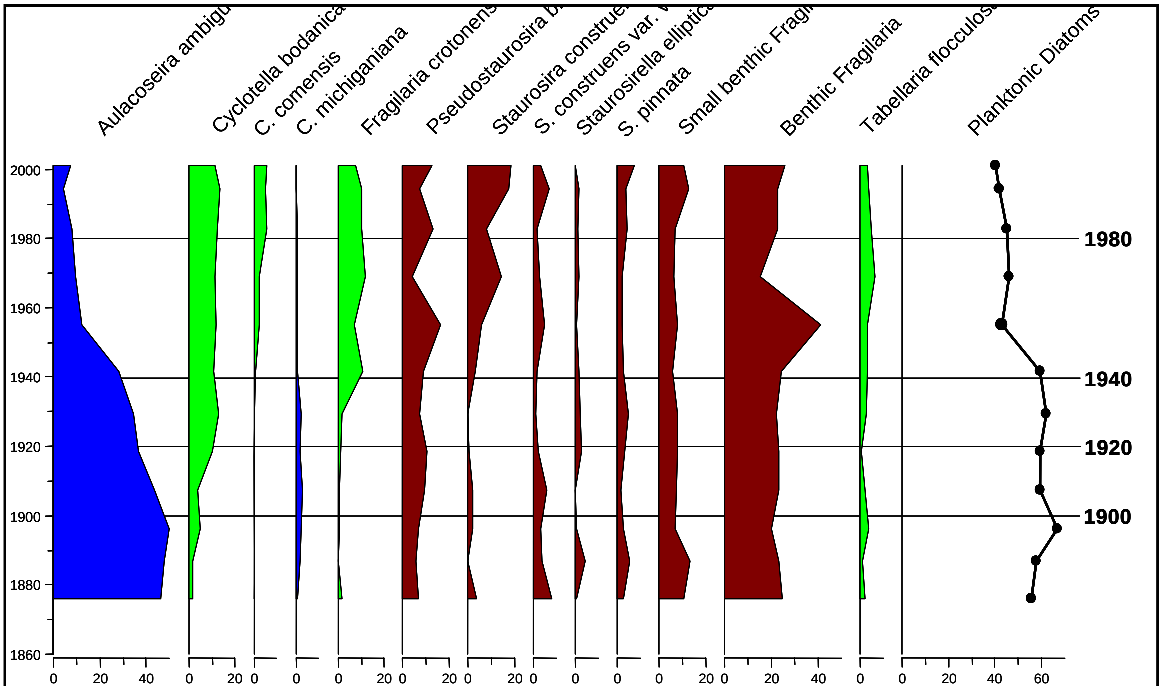


Figure 6. Profiles of selected diatom taxa. The taxa in blue are indicative of low nutrient levels while the taxa in green are indicative of moderate nutrient levels. The taxa in brown grow on substrates such as aquatic plants.

low numbers in the early 1940s (Figure 6). This diatom has been found in a number of other lakes in northern Wisconsin that have fairly good water quality. This diatom also is common in the Great Lakes. As this diatom is common in northern European lakes but has not be found in North American lakes prior to the 1940s, Stormer (1993, 1998) theorizes this diatom is an introduced species from Europe. With the increase in diatoms that prefer higher nutrient levels, the diatom *Staurosira construens* also increased. This species typically grows attached to aquatic vascular plants (macrophytes) and seems to favor higher nutrient levels (Fitzpatrick et al. 2003, Garrison and Fitzgerald 2005). Starting in the 1950s the percentage of the diatom community that is found in the open water of the lake (planktonic) declined indicating a general increase in the amount of macrophyte growth in the lake. This increase in plant growth most likely is the result of shoreline development. 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. 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 macrophytes 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.

The sediment core from Round Lake indicates that prior to 1900 the lake was largely unimpacted by watershed activities associated with European settlers. These activities would have included logging and early tourism. As European settlement increased after 1900 subtle changes occurred in the diatom community indicating a slight increase in phosphorus levels and most likely a slight decline in water clarity. This change was not reflected in the geochemical record indicating any changes were minor. The diatom community continued to change during the first half of the twentieth century but the lake's environment was most affected after 1940. Around the middle of the twentieth century nutrient levels in the lake increased and the amount of aquatic vascular plants increased. These changes resulted in the slight decline in oxygen levels in the deepest waters of the lake.

The greatest change in the geochemical record has occurred during the last two decades. The soil erosion has not increased very much but there has been a significant increase in elements indicative of shoreline development. These elements, uranium, calcium, nitrogen, and phosphorus are mostly associated with soil amendments applied to lawns such as fertilizers and to neutralize acidity. During the last twenty years zinc deposition has also increased reflecting increased development in the watershed. Although the diatom community has not indicated a significant change in the lake's water quality during this time period, the large increase in manganese deposition indicates a significant decline in the oxygen levels of the bottom water of the lake. The decline in hypolimnion oxygen is a classic sign of increased eutrophication of a lake. Although the current water quality of Round Lake is good, the sediment core indicates that shoreline development is having a significant impact on the lake and if control measures are not instituted the lake's water quality could begin to significantly decline.

- The mean sedimentation rate for the last 150 years for Round Lake is one of the lowest measured in Wisconsin lakes.
- The sedimentation rate was fairly constant from 1885 until about 1990 when it began to increase and the rate at the top of the core is the highest measured.
- The geochemical profiles show that development in the watershed first began to impact the lake starting in the 1920s. The impact of this development has significantly increased in the last two decades.
- Evidence of this development is largely in the form of chemicals used in lawn maintenance such as fertilizers and other soil amendments.
- The diatom community indicates that water quality degradation first began around 1900 with a very small increase in nutrients but it has accelerated since 1960. While nutrient levels increased slightly, the most significant change in the lake was an increase in the growth of aquatic plants.
- Perhaps the most significant indication of the pressures exerted by shoreline development is the decline in oxygen levels in the bottom waters of the lake. This core indicates this first began around 1970 but it has accelerated in the last 15 years. A decline in oxygen levels is a classic early indicator of the beginning of eutrophication of a lake.
- The core shows that Round Lake has been impacted by shoreline development beginning around the 1920s. Runoff from development lead to an increase in macrophytes in the 1950s. This impact has accelerated during the last 15 years resulting in an increase in sediment infilling and loss of oxygen in the bottom waters. If this trend continues, the lake will be further degraded with nutrient levels increasing resulting in a loss of water clarity.

References

Appleby, P.G., & F. Oldfield, 1978. The calculation of lead-210 dates assuming a constant rate of supply of unsupported ^{210}Pb to the sediment. Catena. 5:1-8.

Bannerman, R.T., D.W. Owens, R.B. Dodd, and N.J. Hornewer. 1993. Sources of pollutants in Wisconsin stormwater. Wat. Sci. Tech. 28:241-259.

Camburn K.E. and Kingston J.C. 1986. The genus *Melosira* from soft-water lakes with special reference to northern Michigan, Wisconsin and Minnesota. In: Smol, J.P., Battarbee, R.W., Davis, R.B. and Meriläinen, J. (eds), Diatoms and Lake Acidity. Dr. W. Junk.Publishers, Dordrecht, The Netherlands. pp. 17-34.

Christie, C.E. & J.P. Smol, 1993. Limnological effects of 19th century canal construction and other disturbances on the trophic state history of Upper Rideau Lake, Ontario. Lake and Reserv. Manage. 12:448-454.

Engstrom, D.R., E.B. Swain, & J.C. Kingston, 1985. A paleolimnological record of human disturbance from Harvey's Lake, Vermont: geochemistry, pigments, and diatoms. Freshwat. Biol. 15:261-288.

Ennis, G. L., G. Northcote, & J.G. Stockner, 1983. Recent trophic changes in Kootenay Lake, British Columbia as recorded by fossil diatoms. Can. J. Bot. 61:1983-1992.

Fitzpatrick F.A., Garrison P.J., Fitzgerald S.A. and Elder J.F. 2003. Nutrient, trace-element, and ecological history of Musky Bay, Lac Courte Oreilles, Wisconsin, as inferred from sediment cores. U.S. Geological Survey Water-Resources Investigation Report 02-4225. 141 pp.

Garrison, P.J. and S.A. Fitzgerald. 2005. The role of shoreland development and commercial cranberry farming in a lake in Wisconsin, USA. J. Paleolimnol. 33:169-188.

Good, J.C. 1993. Roof runoff as a diffuse source of metals and aquatic toxicity in storm water. Wat. Sci. Tech. 28:317-321.

Kingston J.C., Cook R.B., Kreis R.G. Jr., Camburn K.E., Norton S.A., Sweets P.R., Binford M.W., Mitchell M.J., Schindler S.C., Shane L.C.K. and King G.A. 1990. Paleoecological investigation of recent lake acidification in the northern Great Lakes states. J. Paleolim. 4:153-201.

Krishnaswami, S. & D. Lal. 1978. Radionuclide limnochronology. In: Lerman, A. (ed.), Lakes: Chemistry, Geology, Physics. Springer-Verlag, NY: 153-177.

Stager, J.C., P.R. Leavitt, & S.S. Dixit, 1997. Assessing impacts of past human activity on the water quality of Upper Saranac Lake, New York. Lake and Reserv. Manage. 13:175-184.

Steuer, J., W. Selbig, N. Hornewer, and J. Prey. 1997. Sources of contamination in an urban basin in Marquette, Michigan and an analysis of concentrations, loads, and data quality. U.S. Geological Survey Water-Resources Invest. Rept. 97-4242.

Stoermer, E.F. 1993. Evaluating diatom succession: some peculiarities of the Great Lakes case. J. Paleolimnol. 8:71-83.

Stoermer, E.F. 1998. Thirty years of diatom studies on the Great Lakes at the University of Michigan. J. Great Lakes Res. 24:518-530.

Funding for this study was provided by Lac Courte Oreilles Indian Tribe and Wisconsin Department of Natural Resources. Field help was provided by Brett McConnell. Radiochemical analysis was provided by the Lynn West at the Wisconsin Laboratory of Hygiene. Geochemical analyses was provided by University of Wisconsin, Soil Testing Laboratory.

The Wisconsin Department of Natural Resources provides equal opportunity in its employment, programs, services, and functions under an Affirmative Action Plan. If you have any questions, please write to Equal Opportunity Office, Department of Interior, Washington, D.C. 20240.

This publication is available in alternative format (large print, Braille, audio tape. etc.) upon request. Please call (608) 276-0531 for more information.

PRINTED
ON RECYCLED
PAPER