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A Diatom-based, Paleolimnological Study of Rush Lake, Wisconsin

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Abstract:

Rush Lake, located in Winnebago County, Wisconsin, is a shallow, eutrophic, lake/wetland dominated by cattails. This system has been historically important for fishing and waterfowl production. A sediment core (374cm) was taken by employing a modified Livingstone piston corer. The core was dated with carbon-14 yielding an age date at the base of the core of 4110 +/- 40 C-14-yr. B.P. The core sediments were sampled for diatoms at 10-cm intervals, starting at 5cm (37 samples). Diatoms were counted for a total of 300 per sample. Typical of shallow lakes, the core showed signs of being extensively reworked. Sediment is often remixed due to wave action, plant roots, burrowing invertebrates, foraging carp, other bottom feeders, and periodic drying. Despite this, multivariate analysis of diatoms (PCA) suggests that this system has become more eutrophic. The multivariate analysis is consistent with a pollen analysis and is likely due to human induced deforestation. There is no evidence (i.e., increase in % planktonic diatoms) that the lake had ever developed a pelagic zone for an extended period of time.

Aerial Photo of Rush Lake taken September 2004

Introduction

Paleolimnology explores the history of a watershed by the examination of lake sediment. Patterns observed in lake sediment cores can possibly provide insight to many of the past environmental conditions (i.e. climate, pH, and trophic level). Rush Lake (88° 48'W; 43 °56') is located in the counties of Winnebago and Fond du Lac (Wisconsin), covers 3,070 acres (Figure 1, U.S. Geological Survey) and has an average depth of 30.48 45.72 cm (Northern Environmental, 2002). Water is supplied by six surrounding watersheds. Each waterbed is very small (Figure 2, Northern Environmental, 2002).

Approximately 15,000 years ago, the recession of the Green Bay Lobe from its maximum extent was punctuated by periods when the ice margin stabilized and end moraines formed. Rush Lake was formed after the deposition of the Rush Lake moraine closed the south end of the sediment-filled bedrock valley. The Native Americans

Figure 1
Topographic map Rush Lake (U.S. Geographical Society).

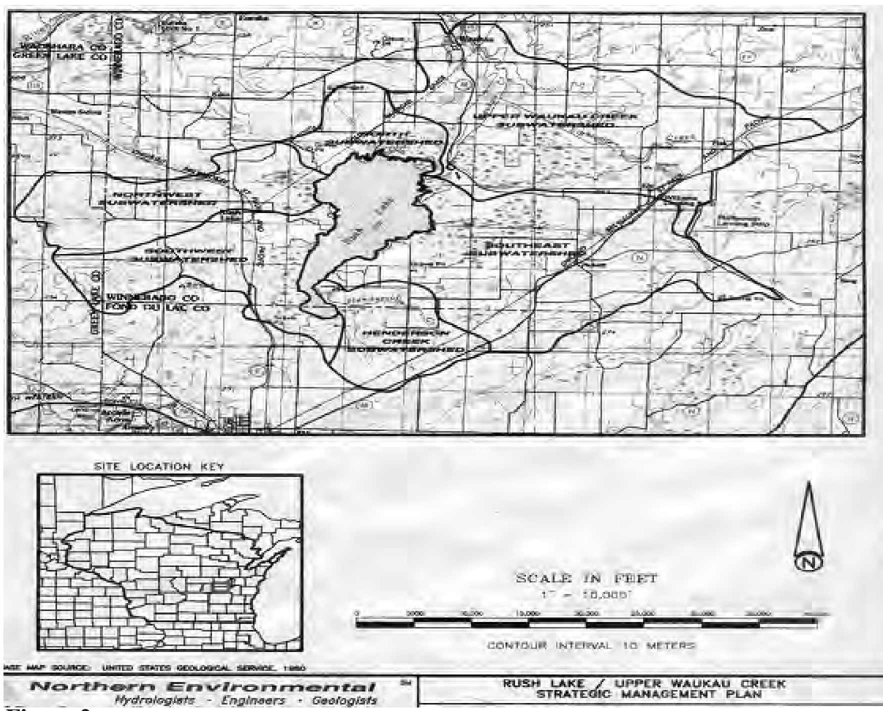

Figure 2
Rush Lake map (Northern Environmental).

called this lake "Appucaway" (pronounced as A-pah-ke-ah-kun-nee), meaning "where the rushes or flags grow" (*Oshkosh Northwestern*, 1851). This name suggests a shallow lake/wetland system. Historical records show that Rush Lake was a productive source of fur-bearing animals and fish (Mitchell, 2004; Northern Environmental, 2002). The water level remained unaltered by humans until 1847, when a series of power-generating dams were placed on Waukau Creek (Figure 1, U.S. Geological Survey), which is the outflow from Rush Lake. The level of Rush Lake rose 30.48 cm and caused the lake to double in surface area (Mitchell, 2004; Northern Environmental, 2002).

During the 1920's, the railroad commission ordered the last remaining dam removed to abate flooding (Northern Environmental, 2002; Mitchell, 2004). Once again, natural processes were allowed to control the water level of Rush Lake. During this period, records indicate the lake dried out on several occasions in: 1921, 1931, 1934, and 1939 (Mitchell, 2004). In 1946, a new dam was commissioned to improve duck and fish habitat by providing a constant water level so Rush Lake became well known for its fish and waterfowl production (Mitchell, 2004; Northern Environmental, 2002).

Currently, the dam-regulated water level has become more controversial as undesirable species like carp and bullhead have become dominant (Mitchell, 2004; Northern Environmental, 2002), turbidity has increased, while bull rushed and ducks have decreased (Mitchell, 2004; Northern Environmental, 2002). Due to increased human influence in the watershed, Rush Lake is experiencing an increase in eutrophication (Mitchell, 2004; Northern Environmental, 2002).

Diatom (Phylum Bacillariophyta) (Figure 3 and Figure 4) fossils (siliceous frustules) in sediment cores are good indicators of pH, salt content, and eutrophication (Battarbee, 1984). Diatoms are found in all aquatic habitats and species preferences can be used to make predictions about current and past conditions (Lowe, 1974). Because of their wide dispersion, diatoms reflect the quality of the water in lakes and streams. Diatoms are also the primary food for many invertebrates and vertebrates (Davis and Norton, 1978).

Figure 3
Picture of typical diatoms found in Rush Lake (Center: *Cyclotella Schumannii*, upper right center: *Flagilaria pinneta*, lower left: *Nitzschia amphibian*)

Figure 4
Examples view of the corner of Figure 3 Center: *Flagilaria capucina var. vaucheriae*

There is one main problem associated with the analysis of sediment cores from a shallow lake/wetland. Sediment is often remixed due to wave action, plant roots, burrowing invertebrates, foraging carp, other bottom feeders, and periodic drying. Despite these problems, there may be some value in examining a core sample from Rush Lake for the following reasons: (1) The current and historic importance of this wetland to the regional landscape for fish and waterfowl production, (2) strong community and government support for the large-scale restoration of Rush Lake, and (3) poor and conflicting information on the historical conditions of Rush Lake. We examined the diatoms from a sediment core of Rush Lake to see if any information could be retrieved that would be helpful in making future management decisions.

Table 1
Water Chemistry and Conductivity/Temperature/Salinity Readings

Measurements	Average Values	Standard Deviation
Ca Hardness	129.66 mg/l	14.29
Total Hardness	226.66 mg/l	26.117
Chloride	27.16 mg/l	5.91
Nitrogen	1.7 mg/l	0
Phosphorous	1.0 mg/l	0
pH	7.43	.903
Temperature oC	18.89	4.106
Conductivity (mohs)	643.2	132.4
Salinity (ppt)	.33	.0739

Objectives

1. Given the problems often associated with wetland sediment cores, do the diatoms exhibit an interpretable pattern in the sediment core?
2. Does this pattern agree with other studies of Rush Lake?
3. Can information from this core be used in upcoming management considerations for Rush Lake?

Materials and Methods

A core sample was taken by employing the Livingstone Sampler at the east side of the lake (Kostka and others, 2002). The core was dated using carbon-14. The core sediments (total=365cm) were sampled for diatoms at 10-cm intervals, starting at 5cm (37 samples). Three hundred diatom values were counted and identified for each sample (Patrick, and Riemer, 1966; Kammer and Lange-Bertalot, 1986). When possible, the environmental preferences for each taxon were also recorded (Lowe 1974). Permanent diatom slides were prepared from the sediment by cleaning aliquots with 30% H_2O_2 and $K_2Cr_2O_7$, and mounting in Naphrax (Van Der Werff, A., 1955). Principal Component Analysis (PCA) was conducted on data from the diatom counts to help identify underlying patterns in diatoms community composition.

Water samples were taken from site 1 (Figure 1, U.S. Geological Survey) from June to August. The water was analysized for nitrogen (nessler method 8038), phosphorus (ortho-phosphate procedure method 8114), chloride (silver nitrate titration method 8225), total hardness (manver II titration method 8226), calcium hardness (method 8204), and pH according to standard methods of *Hach Water Analysis Handbook* (1992). A conductivity/temperature/salinity meter was used at sites 1- 13 (Figure 1, U.S. Geological Survey) monthly from June to August.

Results

The carbon-14 analysis indicated an age of 4110 +/- 40 C-14-yr. B.P at the base of the core. The water chemistry data are presented in Table 1. From the conductivity/temperature/salinity meter Table 1 represents the measurements from site 1-13 (Figure 1, U.S. Geological Survey).

Sixty-three diatom species were identified. The sediment samples located at 145 cm, 295 cm, and 365 cm showed very few countable diatom frustules and thus were not used in the ordination. Only diatoms present in at least three samples with greater than 3% relative abundance in at least one sample were included. Thirty-seven species of diatoms were used in the PCA analysis. The first two axes of the resulting ordination explained 50.6% of the variability in species composition. From this ordination, two non-overlapping groups of samples could be identified (Figure 5).

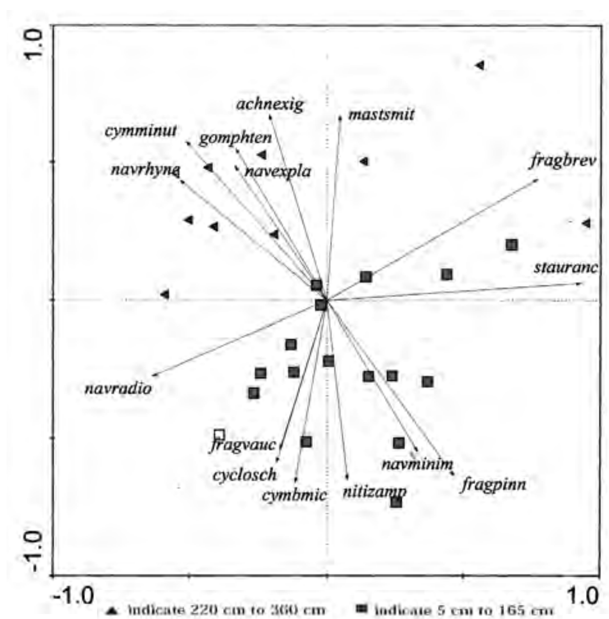

Figure 5 Principle Component Analysis graph. Species are arrows.

The first group (older samples) all came from a core-depth of 360-220 cm. The diatom species best associated with this group were: *Nitzshia amphia, Navicula sublicidula, Cymbella cistula, Flagilaria pinnata, Cymbella microcephala, Flagilaria vaucheriae, Cyclotella schumannii,* and *Surirella linearis*. The second group (younger samples) was composed of samples for core depths between 5 and 165 cm. This younger group was associated with 12 dominant species that were mainly eutrophic in nature. They were: *Cymbella minuta, Cymbella cymbiformis, Navicula rhynchocephala, Achnanthes exigua, Gomphonema tenullum,Navicula diluviana, Navicula explanata, Fragilaria brevistriata, Stauronies anceps, Mastogloia smithii,* and *Synedra rumpens vflagillariodes* (Figures 5 and 6).

Discussion

The diatom frustuals throughout the core were dominated by species regarded as alkaliphilous and periphytic. Multivariate analysis showed that the two main diatom assemblages (older and younger) were separated by depth. The diatoms in the deeper sediments (360 cm to 220 cm) suggest mesotrophic to eutrophic conditions. The diatoms in more recent sediment (165 cm to 5 cm) indicate a higher degree of eutrophication (eutrophic-indicating taxon more common). This is consistent with the current water chemistry (Table 1).

The water chemistry in Table 1 shows high levels of calcium and manganese, which indicated hard water probably due to dolomite sediments. The presence of chloride and high conductivity may be from the road salt runoff (Table 1). This agrees with an increase in the relative abundance of brackish water diatoms (such as *Mastogloria smithii* and *Navicula rhynchocephala*) toward the top of the core (Figure 6).

The percentage pollen diagram for Rush Lake (Figure 7, Kostka, et.al., 2002) recorded a change from pine (*Pinus*) to oak (*Quercus*) dominated at 290 cm, and then at 80 cm, which is a change to more abundant grass (*Gramineae*). This result may reflect the deforestation within the watershed, which is consistent with the diatom record. Ragweed (*Ambrosia*) percentages decrease through time.

The carbon analysis done by Baeten, et.al. (1994) and Kostka, et. al., (2002) in Figure 8 showed periodic shifts in the percent carbonate carbon. They attribute these changes to shifts from marl-producing shallow pools (high-carbonate) to a deeper, open-water system (low carbonate).

Planktonic diatoms, however, were virtually absent from our analysis. This suggests there were no prolonged pelagic or open water areas. Also, at core depth of 145, 295, and 365 cm, there was a conspicuous lack of diatom frustules, which may occur from the wetland drying out. A shallow wetland that occasionally dried up is consistent with historical records of Rush Lake (Mitchell, 2004).

Although a significant amount of sediment reworking is evident, several trends can be seen. There is a general decline in *Quercus* (oak) and *Pinus* (pine) pollen (graph 5) as well as an increase in grass (*Gramineae*) pollen toward the sediment surface. This result may indicate deforestation by humans. This trend agrees with patterns seen in the diatom frustuals suggesting eutrophication from agricultural activities within the watershed.

The trend in the patterns observed have shown more eutrophication in the lake and require better agricultural practices. Green Lake (10 miles from Rush), which has

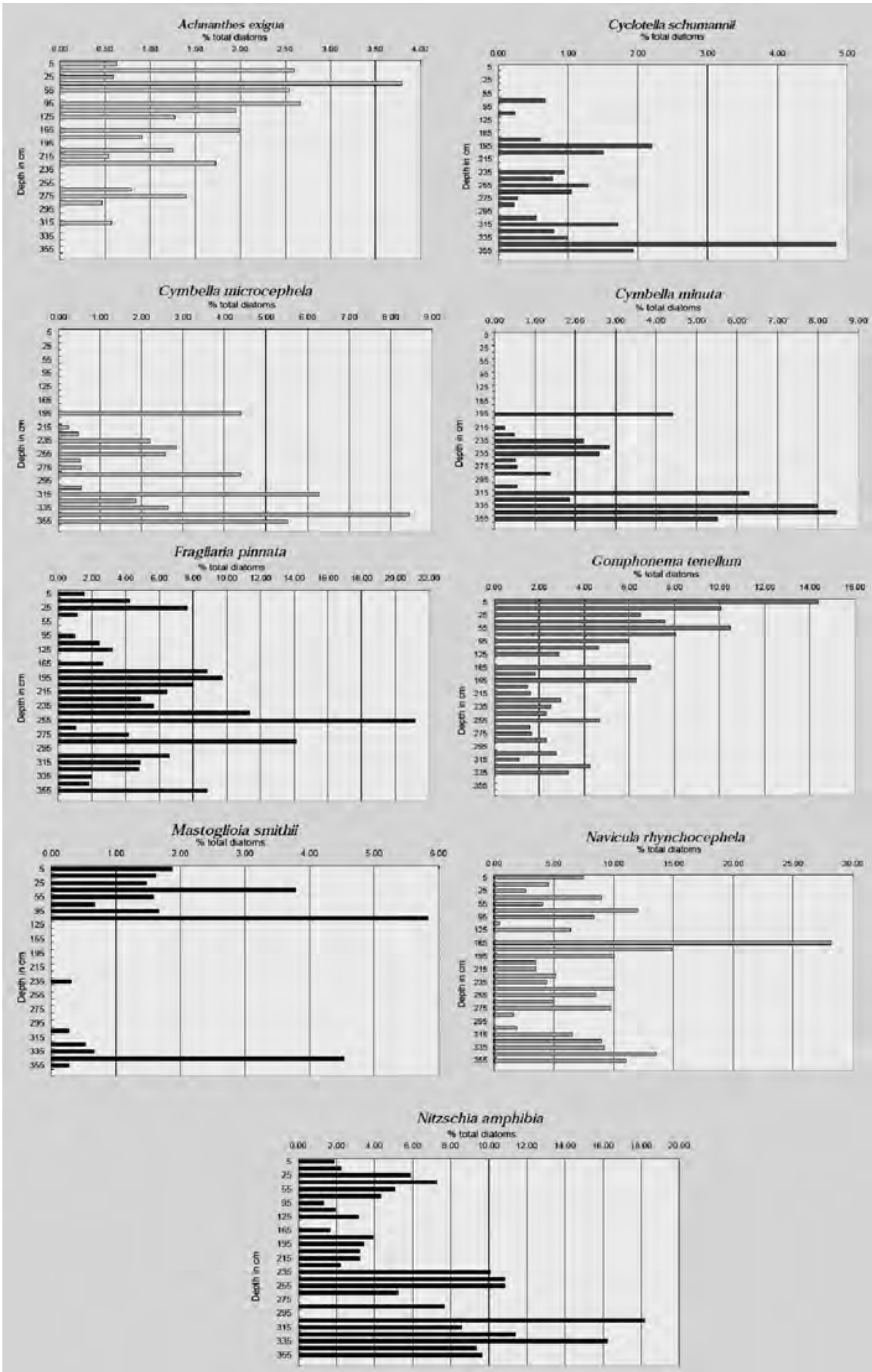

Figure 6 The percent relative abundance of fossil diatoms from the younger and older sediment of the core. Y axis = depth. X axis = percent.

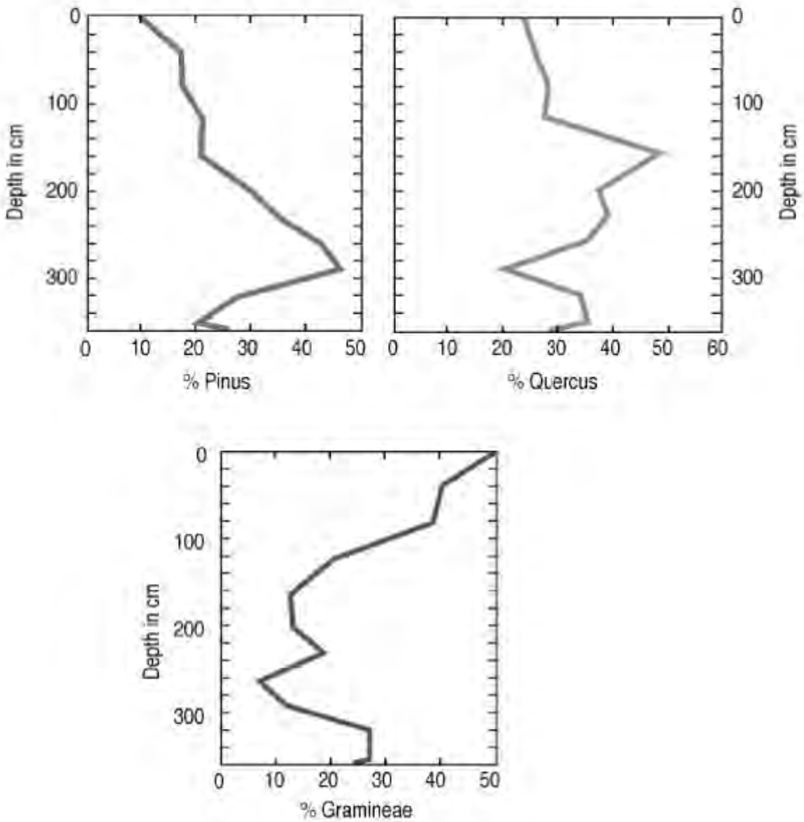

Figure 7 Percent pollen (Kostka and others, 2000.)

a very deep basin with well-preserved sediment, also shows signs (through sediment analysis) of becoming more eutrophic (Garrison, P., 2002). The similar interpretations of cores from Green Lake and Rush Lake suggest that even though the sediment in Rush Lake is more disturbed, it has captured the shift in trophic conditions likely common to that area.

Conclusions

1. Despite sediment reworking common to shallow/wetland systems, broad patterns (which suggest environmental changes) were apparent.
2. Patterns seen with the diatoms agree with current lake chemistry as well as the pollen record.
3. This study indicates the system has always been fairly productive (meso-eu trophic) and has become more eutrophic since European settlement. It is likely that human activity has altered the watershed to a more eutrophic condition (through logging and agricultural). This suggests that if the extensive restoration plans are carried out (erosion control, exotic species eradication), water quality may moderately improve.

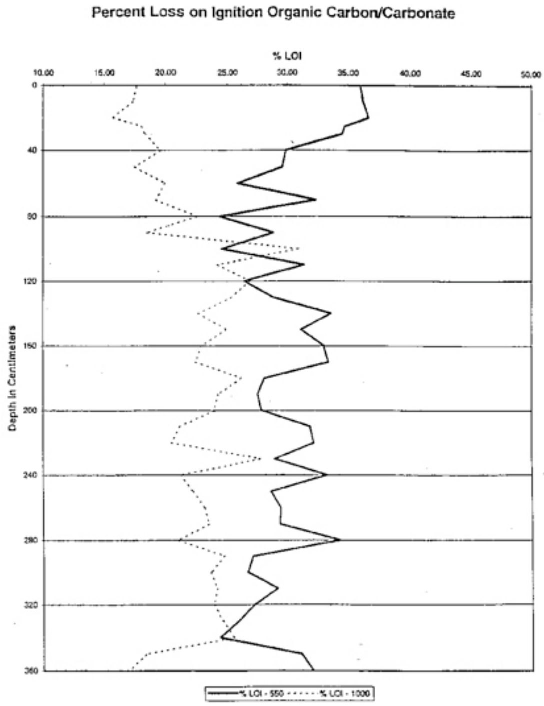

Figure 8 Percentage weight of organic carbon (550°C) and Carbonate (1000°C) in sediments from Rush Lake (Kostka and others, 2000.)

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United States Geological Survey Topographic Map.