RESULTS OF SEDIMENT CORE TAKEN FROM CEDAR LAKE, MANITOWOC COUNTY, WISCONSIN

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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 paleolimnological 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 1, 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 aquatic plants or the lake bottom.

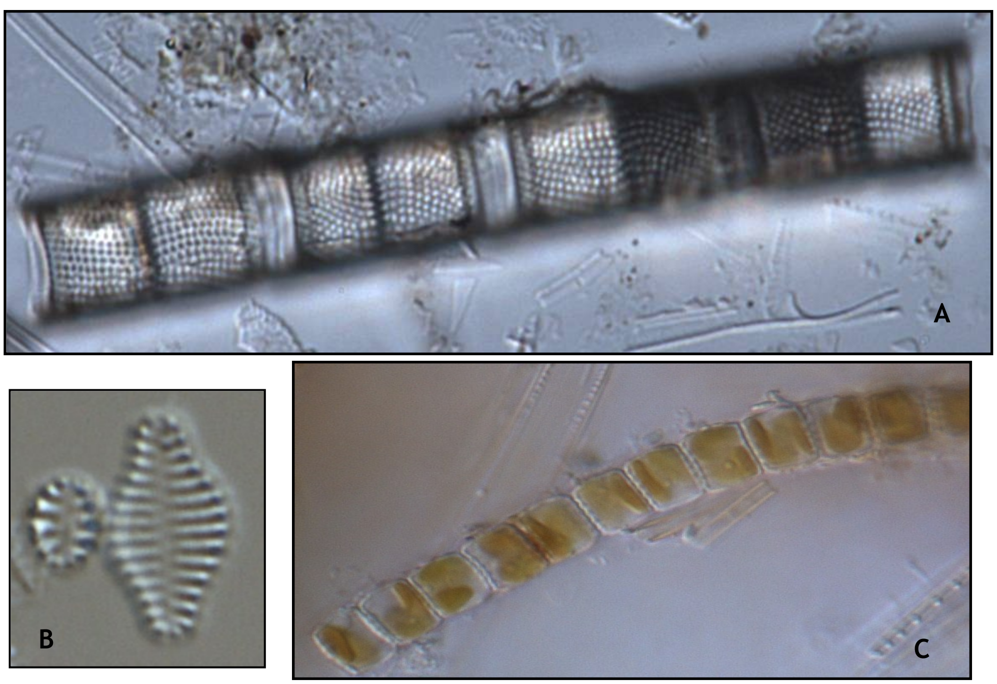

Figure 1. Photomicrographs of the diatoms commonly found in the Cedar Lake sediment core. The top diatom, *Aulacoseira am*bigua (A), is found in the open water environments while the bottom two diatoms are part of the benthic *Fragilaria* (B and C). The latter two diatoms are commonly found attached to substrates such as aquatic plants. The top diatom, *A. ambigua*, was a part of the diatom community in bottom sample.

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 concentrations, water clarity, and pH conditions as well as alterations in the aquatic plant (macrophyte) community.

On 4 October 2012 a sediment core were taken from near the deep area (N43°55.427' W87° 56.106) of Cedar Lake using a gravity corer. Samples from the top of the core (0-1 cm) and a section (34-36 cm) 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.

Results

In Cedar Lake the presettlement diatom community was dominated by diatoms that grow attached to substrates, such as submerged aquatic vegetation (SAV). Planktonic diatoms, those that float in the open water, composed less than 20% of the diatom community (Figure 2). At the present time, at greater percentage of the diatoms are nonplanktonic taxa. In the top and bottom samples most of the nonplanktonic diatoms are in the group benthic *Fragilaria* (Figure 2). These diatoms grow in long filaments and are frequently found attached to SAV.

In the top sample the abundance of the planktonic diatoms *Aulacoseira* spp. decline and are replaced by benthic *Fragilaria* spp. This is an indication that there are more aquatic plants at the present compared with historical times. This is despite the fact that water levels are likely generally higher now because of the high capacity well which augments the lake's water level. Deeper water would be expected to facilitate growth of planktonic diatom growth.

There has been a loss of species diversity and taxa richness between the bottom and top samples of the core (Table 1). This likely indicates there has been an increase in nutrient levels as this often results in a simplification of the diatom community.

Table 1. Number of species and diatom community diversity in the core from Cedar Lake.

	Number of diatom taxa	Diversity of diatom community
Top Sample	31	2.41
Bottom Sample	46	2.63

In northern WI, many lakes with shoreline development have experienced an increase in submerged aquatic plants (SAV). Dr. Susan Borman recently conducted a study in lakes in the northwestern part of WI where she compared the SAV community in the 1930s with the present day community. She found that lakes with cottages have more plants and the species have shifted to those that are larger and grow closer to the lake's surface. This same thing has occurred in southern and central WI but often these lakes have higher phosphorus load-

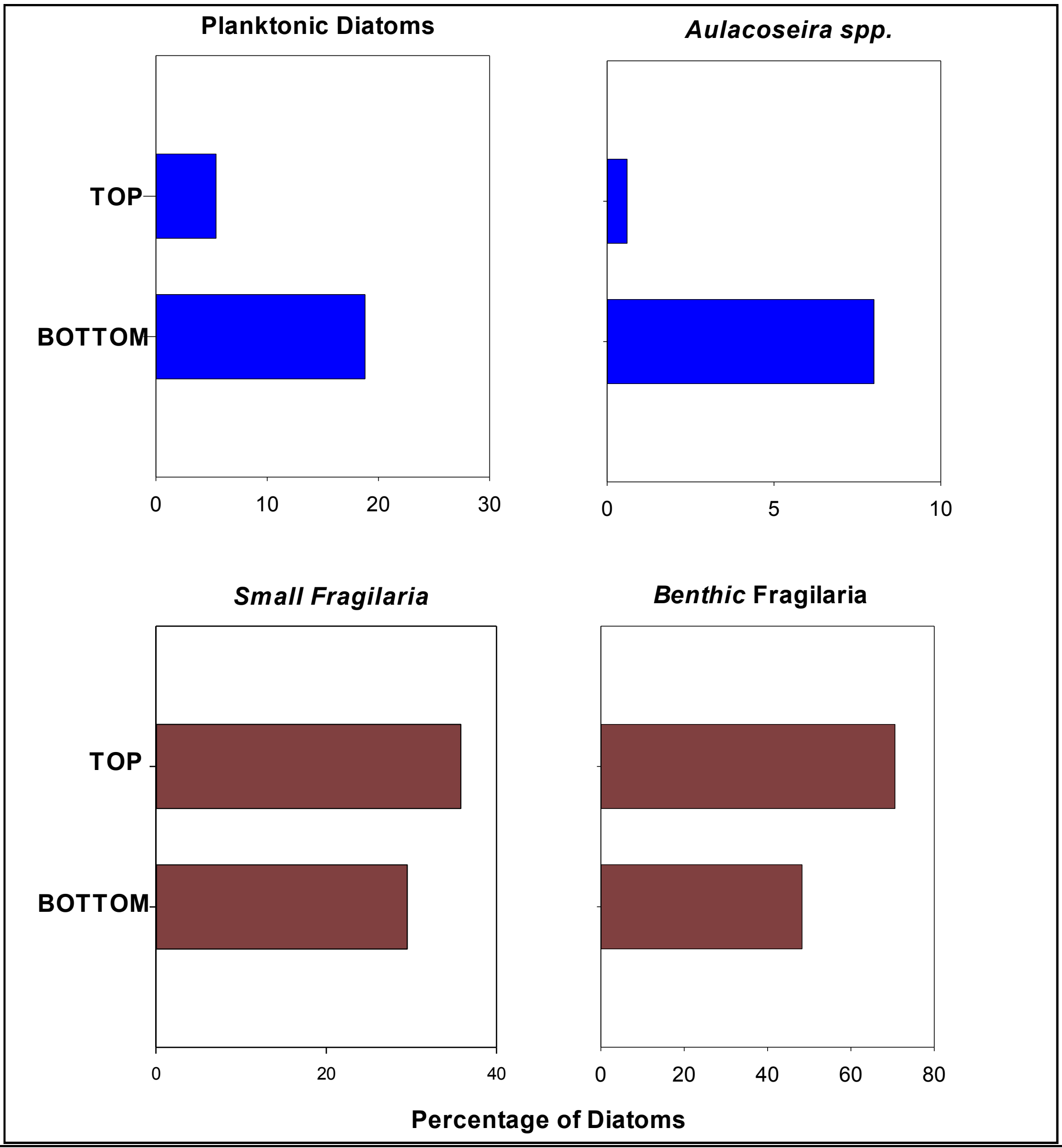

Figure 2. Changes in the abundance of important diatoms found at the top and bottom of the Cedar Lake sediment core. The dominant diatoms at the bottom of the core were nonplanktonic and they became more dominant at the top of the core. This indicates an increase in growth of submerged aquatic vegetation. Benthic and small *Fragilaria* grow attached to aquatic vegetation.

ing rates and planktonic diatoms become more important. The fact that this has not happened in Cedar Lake indicates that phosphorus increases have been moderate.

Diatom assemblages historically have been used as indicators of nutrient 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.

Such a model was applied to the diatom community in the core from Cedar Lake. The model indicates there has been an increase in phosphorus of around 6 µg L^{-1}. The model predicted a present day mean summer phosphorus concentration of 21 µg L^{-1} but the measured concentration for the last 3 years is 12-17 µg L^{-1}. The model over estimates the present day concentration because benthic *Fragilaria* are such a large part of the diatom community. These diatoms have a wide range of phosphorus tolerance and are commonly found in eutrophic lakes. The model predicts that the historical phosphorus concentration was 15 µg L^{-1} which is about what it is now. The decline in *taxa* richness and species diversity supports the indication that phosphorus levels have increased during the last century. It is likely that the presettlement phosphorus was about 10-12 µg L^{-1}.

In summary, the sediment core indicates that there has been an increase in aquatic plants as well as an increase of in phosphorus concentrations of about 6 µg L^{-1} . The diatom community indicates that aquatic plants have been present in relative large amounts for a very long time. The presence of these plants helps buffer the open water from nutrients entering the lake. These plants have abundant growths of attached algae which intercept some of the nutrients and reduce algal blooms in the open water.

CEDAR LAKE
Manitowoc County

Top (0-2 cm)

TAXA	COUNT TOTAL Number	Prop.
Achnanthidium spp	1	0.002
Achnanthidium exiguum (Grunow) Czarnecki	5	0.010
Achnanthidium minutissimum (Kützing) Czarnecki	5	0.010
Amphora copulata (kützing) Schoeman et Archibald	6	0.012
Amphora pediculus (Kützing) Grunow	16	0.032
Asterionella formosa Hassal	2	0.004
Aulacoseira ambigua (Grunow) Simonsen	3	0.006
Cyclotella bodanica var. affinis (Grunow) Cleve-Euler	8	0.016
Cyclotella distinguenda Hustedt	2	0.004
Cyclotella michiganiana Skvortzow	2	0.004
Cyclotella ocellata Pantocsek	6	0.012
Mastogloia smithii Thwaites ex Smith	4	0.008
Navicula angusta Grunow	1	0.002
Navicula cryptocephala Kützing	4	0.008
Navicula cryptotenella Lange-Bertalot ex Krammer et Lange-Bertalot	2	0.004
Navicula cryptotenelloides Lange-Bertalot	4	0.008
Navicula lanceolata (Agardh) Ehrenberg	1	0.002
Navicula pseudoventralis Hustedt	22	0.044
Navicula recondita (Hustedt) Lange-Bertalot	22	0.044
Navicula spp.	2	0.004
Navicula vitabunda Hustedt	6	0.012
Nitzschia amphibia Grunow	2	0.004
Nitzschia gracilis Hantzsch ex Rabenhorst	1	0.002
Planothidium biporomum (Hohn et Hellerman) Lange-Bertalot	12	0.024
Pseudostaurosira brevistriata (Grunow) Williams et Round	83	0.166
Pseudostaurosira parasitica (Smith) Morales	4	0.008
Pseudostaurosira subsalina (Hustedt) Morales	1	0.002
Sellaphora laevissima (Kützing) Mann	2	0.004
Staurosira construens Ehrenberg	90	0.180
Staurosira construens var. venter (Ehrenberg) Hamilton	104	0.208
Staurosirella pinnata (Ehrenberg) Williams et Round	75	0.150
unknown pennate	2	0.004
TOTAL	500	1.000

Bottom (34-36 cm)

lots of debris

TAXA	COUNT TOTAL Number	Prop.
Achnanthidium exiguum (Grunow) Czarnecki	4	0.008
Achnanthidium minutissimum (Kützing) Czarnecki	1	0.002
Amphora copulata (kützing) Schoeman et Archibald	4	0.008
Amphora ovalis (Kützing) Kützing	1	0.002
Aulacoseira ambigua (Grunow) Simonsen	18	0.036
Aulacoseira distans (Ehrenberg) Simonsen	2	0.004
Aulacoseira italica (Ehrenberg) Simonsen	16	0.032
Aulacoseira sp. 1?	2	0.004
Aulacoseira subarctica (Müller) Haworth	2	0.004
Brachysira microcephala (Kützing) Compère	2	0.004
Cavinula jaernefelti (Hustedt) Mann et Stickle	1	0.002
Cyclotella bodanica var. affinis (Grunow) Cleve-Euler	18	0.036
Cyclotella michiganiana Skvortzow	1	0.002
Cymbella cuspidata Kützing	1	0.002
Diploneis oculata (Brébisson) Cleve	2	0.004
Encyonema spp.	2	0.004
Fragilaria crotonensis Kitton	9	0.018
Gomphonema minutum (Agardh) Agardh	2	0.004
Gomphonema spp.	2	0.004
Navicula aurora Sovereign	3	0.006
Navicula cryptocephala Kützing	2	0.004
Navicula cryptotenella Lange-Bertalot ex Krammer et Lange-Bertalot	7	0.014
Navicula difficillima Hustedt	1	0.002
Navicula minima Grunow in Van Heurck	2	0.004
Navicula oligotraphenta Lange-Bertalot & Hofmann	4	0.008
Navicula pseudoventralis Hustedt	4	0.008
Navicula spp.	8	0.016
Navicula utermoehlii Hustedt	32	0.064
Navicula vulpina Kützing	2	0.004
Neidium affine (Ehrenberg) Pfitzer	5	0.010
Neidium spp.	4	0.008
Nitzschia gracilis Hantzsch ex Rabenhorst	1	0.002
Nitzschia linearis (Agardh ex Smith) Smith	1	0.002
Nitzschia spp.	1	0.002
Pinnularia borealis Ehrenberg	1	0.002
Psammothidium sacculum (Carter in Carter and Bailey-Watts) Bukhtiyarova in Bukhtiyarova and Round	42	0.084
Rossithidium pusillum (Grunow) Round et Bukhtiyarova	2	0.004
Sellaphora disjuncta (Hustedt) Mann	1	0.002
Sellaphora laevissima (Kützing) Mann	10	0.020
Sellaphora pupula (Kützing) Meresckowsky	4	0.008
Sellaphora sp. 1?	2	0.004
Staurosira construens Ehrenberg	90	0.180
Staurosira construens var. venter (Ehrenberg) Hamilton	63	0.126
Staurosirella pinnata (Ehrenberg) Williams et Round	85	0.170
Staurosirella pinnata var. acuminata A. Mayer	4	0.008
Synedra delicatissima Smith	26	0.052
unknown pennate	4	0.008
TOTAL	501	1.000