RESULTS OF SEDIMENT CORE TAKEN FROM RED LAKE, DOUGLAS COUNTY, WISCONSIN

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December 2010

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

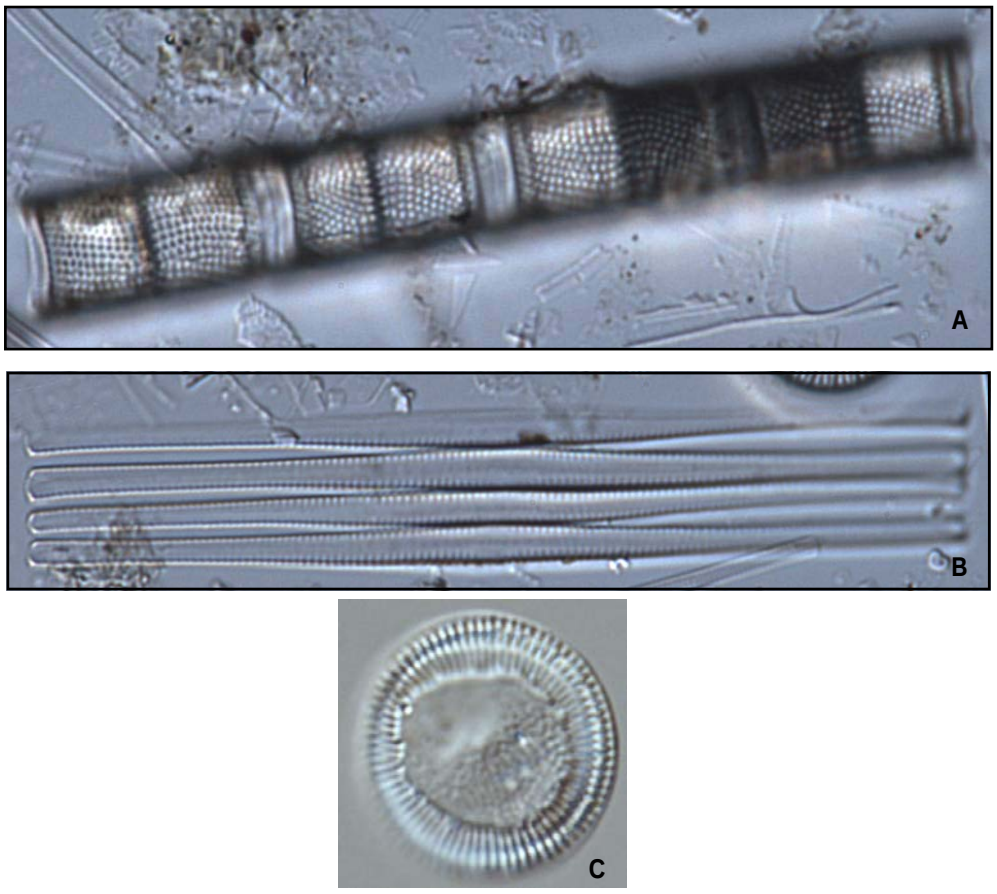

Figure 1. Photomicrographs of the diatoms *Aulacoseira am*bigua (A), *Fragilaria crotonensis* (B), and *Cyclotella michiganiana* (C). These were common diatoms found in the core. All of these diatoms are found in the open water of the lake and are considered planktonic diatoms. *A. am*bigua and *C. michiganiana* indicate low to moderate nutrient levels while *F. crotonensis* indicates higher nutrient levels.

open water areas while others grow attached to objects such as 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 concentrations, water clarity, and pH conditions as well as alterations in the aquatic plant (macrophyte) community.

On 6 October 2010 a sediment core were taken from near the deep area (N46.17412° W91.76801°) of Red Lake in about 36 feet of water using a gravity corer. Samples from the top of the core (0-1 cm) and a section (30-32 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 Red Lake, historically the major component of the diatom community are those species that float in the open water of the lake. The major taxa of these planktonic diatoms in the bottom sample were the chain forming diatom *Aulacoseira ambigua* and *Cyclotella michiganiana* (Figure 2). These diatoms are common in lakes throughout the Upper Midwest with low to moderate nutrient levels. The diatom *A. ambigua* grows in the upper part of the water column while *C. michiganiana* is found in the middle part of the water column and requires good water clarity for its growth.

In the top sample these species are largely replaced by *Fragilaria crotonensis* (Figure 2) and *Asterionella formosa* (not shown). Both of these species are some of the first diatoms to increase as a result of nutrient enrichment following human disturbances. Recent studies have shown that these diatoms respond more to an increase in nitrogen and not necessarily to an increase in phosphorus.

The percentage of planktonic diatoms was lower at the top compared with the bottom sample (Figure 2). The number of diatom species and the diversity of diatom community is greater at the top of the core (Table 1). This because there was an increase in the diatom species that grow attached to substrates such as submerged aquatic vegetation (SAV). This indicates that there is more SAV at the present time compared with prior to the construction of shoreline cottages. The increase in plants following cottage development is common in lakes. 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. The diatom community indicates this has happened in Red Lake.

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

	Number of diatom taxa	Diversity of diatom community
Top Sample	50	2.74
Bottom Sample	34	1.86

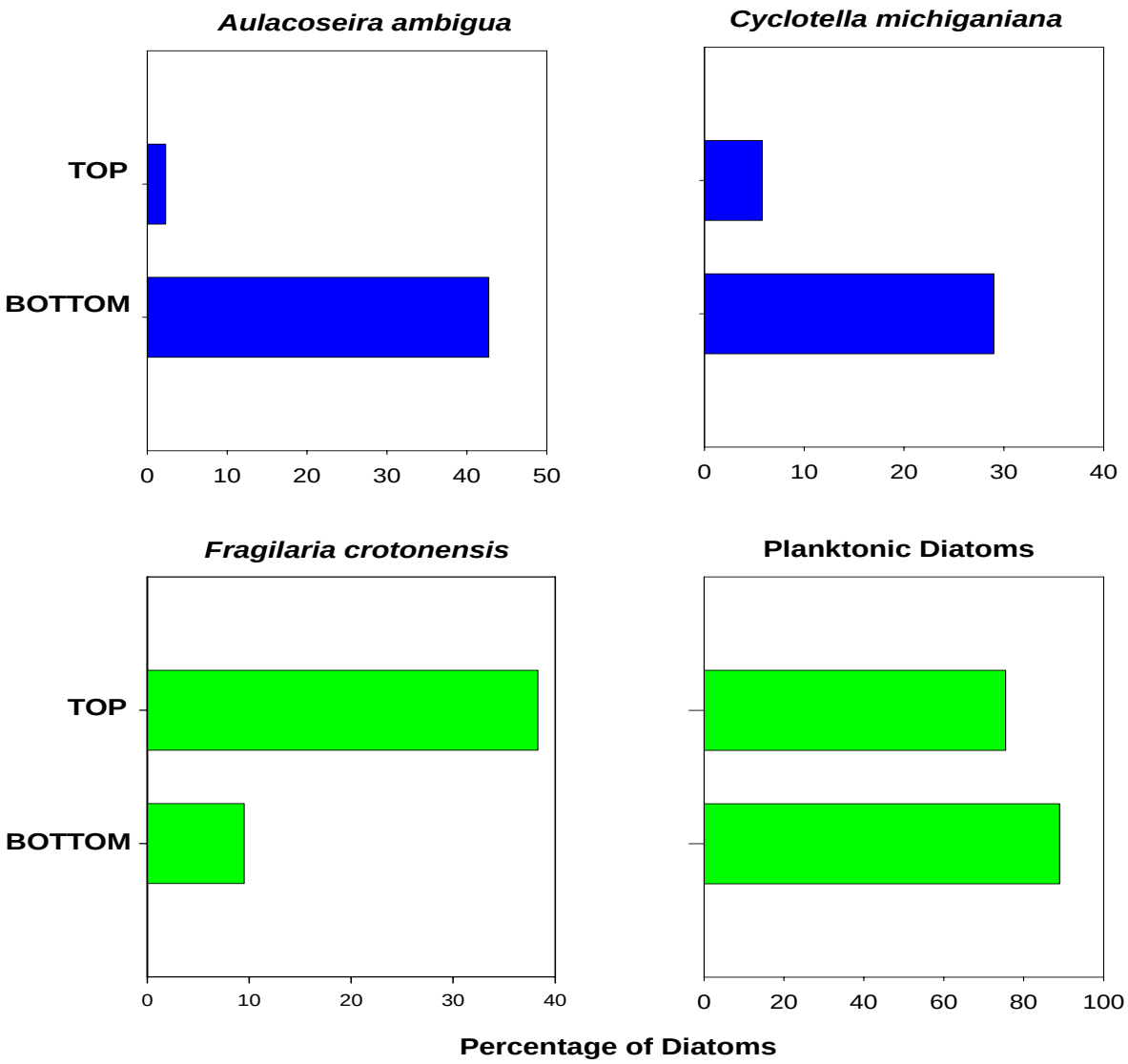

Figure 2. Changes in the abundance of important diatoms found at the top and bottom of the Red Lake sediment core. The dominant diatoms were planktonic diatoms which float in the open water. The decline in planktonic diatoms at the top of the core reflects an increase in the submerged aquatic plant community. The decline in *A. ambigua* and increase in *F. crotonensis* indicates a slight increase in nutrients.

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 Red Lake. The model indicates there has been a small increase in phosphorus of around 2-3 µg L^{-1}. We were not

able to apply the model to changes in nitrogen concentrations but it is likely the change has not be more than 0.1 mg L^{-1}.

In summary, the sediment core indicates that the greatest change that has occurred in Red Lake during the last 100 years has been an increase in the submerged aquatic vegetation. Nutrient levels have only increased a small amount. This is very common in lakes in northern WI that have shoreline development where there is an increase in SAV but little increase in nutrient concentrations. Although there is an increase in nutrient delivery from the developed area on the lakeshore, attached algae associated with the increased plant growth intercepts the nutrients and reduces the nutrient delivery to the open water of the lake. Other studies have shown, as the amount of nutrients that runoff from the watershed increases, eventually the algae attached to the SAV is not able to incorporate all of the nutrients and algal blooms result.

RED LAKE
Douglas County

Top (0-1 cm)

TAXA	Number	Prop.
Achnanthidium macrocephalum (Hustedt) Round et Bukhtiyarova	2	0.005
Achnanthidium minutissimum (Kützing) Czarnecki	11	0.028
Achnanthidium minutissimum var. gracillima (Meister) Lange-Bertalot	1	0.003
Achnanthidium minutissimum var. inconspicua Østrup	1	0.003
Amphora copulata (Kützing) Schoeman et Archibald	2	0.005
Amphora veneta Kützing	2	0.005
Asterionella formosa Hassal	37	0.093
Aulacoseira ambigua (Grunow) Simonsen	9	0.023
Aulacoseira granulata (Ehrenberg) Simonsen	2	0.005
Cyclotella bodanica var. lemanica Müller	48	0.120
Cyclotella meneghiniana Kützing	3	0.008
Cyclotella michiganiana Skvortzow	23	0.058
Cymbella spp.	5	0.013
Diploneis oculata (Brébisson) Cleve	2	0.005
Encyonema silesiacum (Bleisch) Mann	5	0.013
Encyonopsis cesatii (Rabhenhorst) Krammer	8	0.020
Encyonopsis microcephala (Grunow) Krammer	8	0.020
Epithemia adnata (Kützing) Brébisson	4	0.010
Eucocconeis flexella (Kützing) Cleve	1	0.003
Fragilaria capucina Desmazières	3	0.008
Fragilaria capucina var. rumpens (Kützing) Lange-Bertalot	2	0.005
Fragilaria crotonensis Kitton	122	0.305
Fragilaria crotonensis var. oregona Sovereign	31	0.078
Fragilaria sepes Ehrenberg	2	0.005
Gomphonema acuminatum Ehrenberg	2	0.005
Gomphonema patricki Kociolek et Stoermer	1	0.003
Gomphonema pumilum (Grunow) Reichardt et Lange-Bertalot	2	0.005
Gomphonema spp.	5	0.013
Karayevia clevei (Grunow) Bukhtiyarova	1	0.003
Navicula cryptotenella Lange-Bertalot ex Krammer et Lange-Bertalot	4	0.010
Navicula radiosa Kützing	1	0.003
Navicula trivialis Lange-Bertalot	1	0.003
Nitzschia cf. hantzschiana Rabenhorst	1	0.003
Nitzschia incognita Legler et Krasske	1	0.003
Nitzschia linearis var. subtilis Hustedt	1	0.003
Nitzschia perminuta (Grunow) Peragallo	1	0.003
Opephora olsenii Møller	1	0.003
Planothidium joursacense (Héribaud) Lange-Bertalot	2	0.005
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	1	0.003
Platessa conspicua (Mayer) Lange-Bertalot	1	0.003
Sellaphora pupula (Kützing) Meresckowsky	4	0.010
Stauroneis gracilior (Rabenhorst) Reichardt	1	0.003
Staurosira construens Ehrenberg	1	0.003
Staurosira construens var. venter (Ehrenberg) Hamilton	3	0.008
Staurosirella pinnata (Ehrenberg) Williams et Round	3	0.008
Surirella linearis var. constricta Grunow	1	0.003
Synedra biceps Kützing	1	0.003
Tabellaria flocculosa (strain IIIp) sensu Koppen	21	0.053
Tabellaria flocculosa var. linearis Koppen	3	0.008
unknown pennate	2	0.005
TOTAL	400	1.000

RED LAKE
Douglas County

Bottom (30-32 cm)

TAXA	COUNT TOTAL Number	Prop.
Achnanthidium minutissimum (Kützing) Czarnecki	4	0.010
Amphora copulata (Kützing) Schoeman et Archibald	1	0.003
Asterionella formosa Hassal	5	0.013
Aulacoseira ambigua (Grunow) Simonsen	171	0.428
Craticula cuspidata (Kützing) Mann	1	0.003
Cyclotella bodanica var. lemanica Müller	7	0.018
Cyclotella michiganiana Skvortzow	116	0.290
Encyonema silesiacum (Bleisch) Mann	1	0.003
Encyonopsis cesatii (Rabhenhorst) Krammer	5	0.013
Fragilaria crotonensis Kitton	31	0.078
Fragilaria crotonensis var. oregona Sovereign	7	0.018
Fragilaria sepes Ehrenberg	1	0.003
Fragilaria vaucheriae (Kützing) Petersen	4	0.010
Gomphonema clavatum Ehrenberg	1	0.003
Gomphonema gracile Ehrenberg emend Van Heurck	1	0.003
Gomphonema pumilum (Grunow) Reichardt et Lange-Bertalot	2	0.005
Gomphonema subtile Ehrenberg	2	0.005
Navicula cryptocephala Kützing	1	0.003
Navicula cryptotenella Lange-Bertalot ex Krammer et Lange-Bertalot	3	0.008
Navicula minima Grunow	1	0.003
Navicula oblonga Østrup	1	0.003
Navicula pseudoventralis Hustedt	1	0.003
Navicula trivialis Lange-Bertalot	1	0.003
Navicula spp.	1	0.003
Nitzschia angustata (Smith) Grunow	1	0.003
Nitzschia incognita Legler et Krasske	1	0.003
Planothidium joursacense (Héribaud) Lange-Bertalot	1	0.003
Staurosira construens Ehrenberg	3	0.008
Staurosira construens var. binodis (Ehrenberg) Hamilton	1	0.003
Staurosirella pinnata (Ehrenberg) Williams et Round	5	0.013
Synedra acus Kützing	1	0.003
Synedra delicatissima var. angustissima Grunow	1	0.003
Tabellaria flocculosa (strain IIIp) sensu Koppen	16	0.040
unknown pennate	1	0.003
TOTAL	400	1.000