Reconstructing Past Environmental Conditions From Diatom Abundance in Lake Sediments at Black Rock Forest, Orange County, New York

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ABSTRACT

This study used surface sediment samples from five Black Rock Forest ponds to establish a correlation between environmental parameters and diatom assemblages. Efforts to reconstruct the environmental history of the ponds were attempted. The present study addressed two main questions concerning Black Rock Forest ponds: (1) Are there detectable changes in diatom assemblages among the five ponds. (2) Do the diatom assemblages correlate with environmental parameters?

*The environmental parameters are pH, conductivity, ammonium, nitrate, phosphorous, silicate, and calcium. The results of this study suggest that there is a correlation between environmental variables and some diatom assemblages ($p= 0.05$). The detectable changes found among the five ponds are as follows. Tabellaria fenest*rata is highly abundant in acidic environments of Tamarack, Sutherland, and Jim's Pond. *Tabellaria flocculosa* is abundant in all five ponds. *Eunotia sudetica* is abundant in acidic ponds (Tamarack, Sutherland, and Jim's Ponds) and absent in alkaline environment. *Frustulia rhomboides* is significantly abundant in Tamarack Pond (greater than 20%). *Surirella ovalis* is most abundant in Aleck Meadow R. 1. *Nitzschia sp. A* is most abundant in Upper Reservoir. *Neidium affine var. affine* is most abundant in Jim's Pond. This information is interesting and will form the guideline for future investigation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

People depend on forests for their economic, environmental, and enjoyment values. Before forests were cleared for farms and cities, they covered about 60 percent of the earth's land area. Today, forests occupy about 30 percent of the land (Encyclopedia Americana, 1994). Human activities have had tremendous impact on modern forests. Since the Industrial Revolution, great expanses of forests have been eliminated because of deforestation and industrial pollution. Forest ecosystems are highly affected by such anthropogenic activities. Factories often release poisonous gases into air and dangerous wastes into lakes and rivers. Air pollutants may combine with rain, snow, or other precipitation and fall to earth as acid deposition. Any precipitation that has a pH value of less than 5.6 is considered to be acid precipitation (Tyson, 1992). The three main sources of acid deposition are coal burning, base metal smelting, and fuel combustion in vehicles. One of the main causes of acid rain is sulfur dioxide. Natural sources of this gas are volcanoes, sea spray, and rotting vegetation. However, the anthropogenic sources of sulfur dioxide include the burning of fossil fuels, such as coal and oil. Nitric oxide and nitric dioxide are also components of acid rain. All three gases rise into the atmosphere and are oxidized in clouds to form acid (Tyson, 1992). Ice cores taken from glaciers in Greenland reveal that snow that fell about two hundred years ago had a pH of 7. This clearly shows how much humans have acidified the atmosphere since the dawn of Industrial Revolution (Tyson, 1992).

In forests, acid deposition lowers the pH of soils. When acid rain falls to the ground, some of the acid is neutralized in the soil, and only the water that runs directly into streams and ponds is significantly acid. Soils that are formed from limestone rock have a large capacity to neutralize the acid. Soils formed from granite rocks are already acid and their neutralizing capacity can be exhausted within a few years. This has happened in some areas in the Northeast of the U.S., and eastern Canada (Tyson, 1992).

In spring, the first melting of acid-laden snow destroy some fish life due to rapid changes in water chemistry. As an area becomes more acidified, fish are unable to reproduce, and gradually disappear. When the eggs of amphibians such as frogs and salamanders are released in acidic ponds, the eggs fail to develop properly. At the same time, multifarious aquatic plants are killed. Larger plants such as water lilies may disappear, while acid-tolerant mosses and algae can form dense mats, depleting oxygen and further disturbing the freshwater ecology. Eventually, a lake or stream becomes almost lifeless.

Another important effect of acid deposition is the corrosion of materials. Sulfur dioxide is thought to be the main agent causing this damage. Although sulfur dioxide levels have been reduced in some cities, sulfuric and nitric acids in the rain are likely to continue damaging steel and copper.

There is a growing scientific evidence that acid rain causes forest and crop damage. In New England areas, evergreens exposed to frequent acidic showers and fogs undergo slowed growth rates that correlate with periods of increasing acid precipitation. It is quite difficult to protect a lake or stream from the effects of acid deposition. Because of the detrimental effects on lake ecosystems, lake acidification has become a topic of discussion during the last few decades.

Since diatoms are sensitive indicators of lake water pH, they have been used in assessing impacts of atmospheric pollutants and watershed land use on lake pH. (Dixit et al, 1992). Diatoms are powerful indicators of aquatic environmental change. They replicate rapidly and respond quickly to environmental change. Because of their abundance, a small sample is sufficient for analysis. Changes in diatom assemblages correspond closely to shifts in other biotic communities such as other algae, zooplankton, aquatic macrophytes, and fish. More than 5000 diatom taxa exist and over 100 taxa can be found in single sediment sample. Diatoms have narrow optima and tolerances for many environmental variables. In addition, they are preserved well because their cell walls are made up of resistant opaline silica. Thus, diatoms are a good candidate for quantifying environmental characteristics. They have been used as an indicator for environmental change such as eutrophication, acidification, thermal effluents, metal contamination, salinification, forest fires and land use changes (Dixit et al, 1992).

Very little is known about long-term ecological processes in Black Rock Forest ponds and how they have been affected by anthropogenic disturbances. The goal of this project is to establish a correlation between environmental parameters and diatom assemblages in order to reconstruct the environmental history of the lakes at Black Rock Forest, Cornwall, NY (Appendix A). Long cores will eventually be used for this purpose. The diatom assemblages in the sediments will reflect anthropogenic modifications of the lake ecosystem.

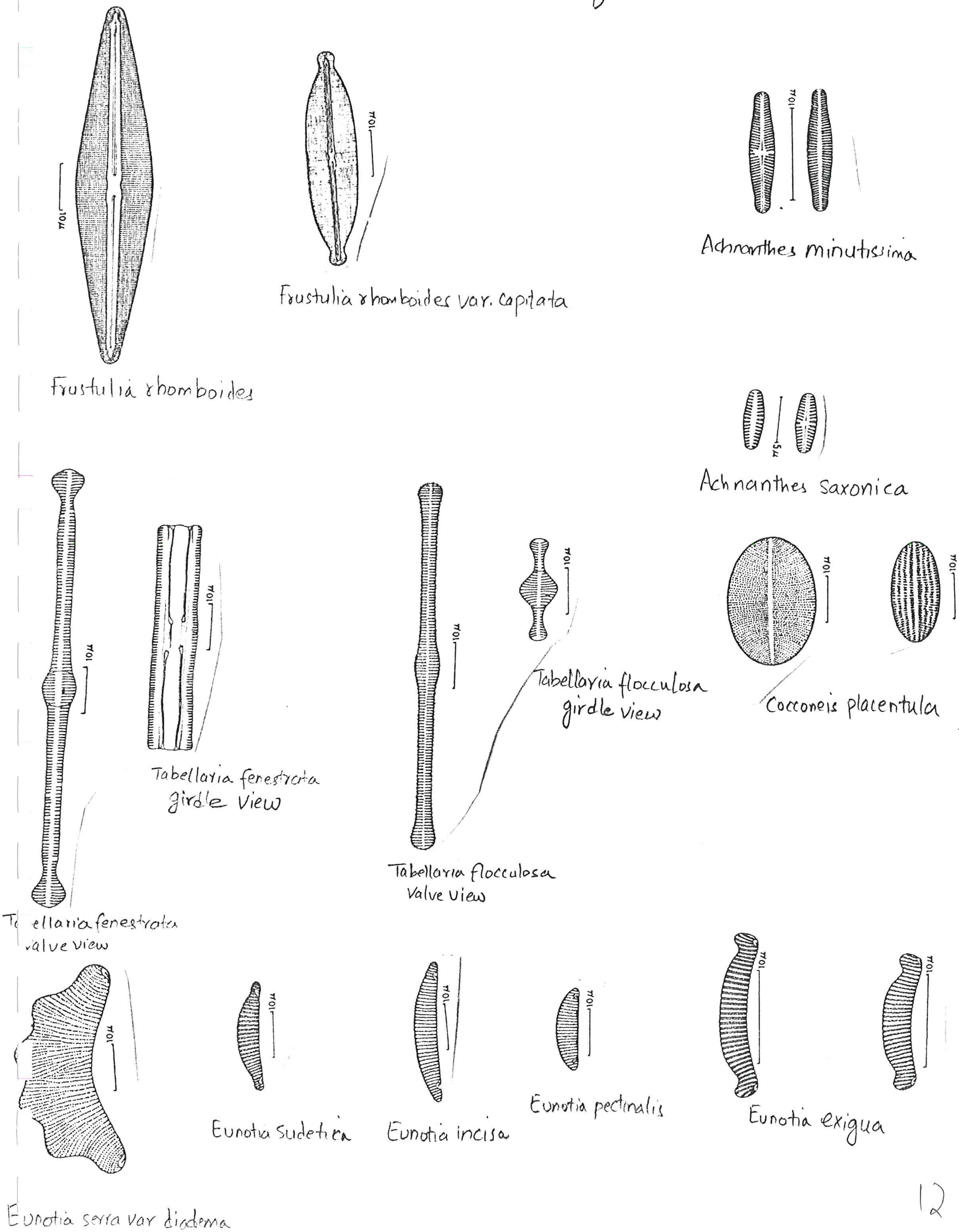
In this project, the relationship between a set of surface-sediment diatom assemblages and environmental parameters from five freshwater ponds in Black Rock Forest is determined (Appendix B). The study is designed to address the following questions concerning Black Rock Forest ponds: (1) Are there detectable changes in diatom assemblages among the five ponds? (2) Can the diatom assemblages correlate with environmental parameters?

General Characteristics of Diatoms

Diatoms are single-celled microscopic plants belonging to the algal class *Bacillariophyceae*. The cell wall of a diatom is composed of silica (SiO_2). The taxonomy of diatoms is based on the structure of the siliceous valves. A diatom has two valves, each of which is connected to a circular piece of silica known as a girdle. One valve with its girdle fits over the other girdle with its valve. The outer one is known as epitheca and the inner one as the hypotheca. The valve in most freshwater diatoms is the larger surface. Therefore, most diatoms in cleaned preparation are seen in this view. The portion of a valve is bent at about 90 degrees and it joins half of the girdle. This part of the valve is known as the valve mantle. The parts of the girdle are firmly united to the valve mantles; hoewever, they often separate when the diatoms are cleaned. Therefore, the clean diatoms are usually found as separated valves (Patrick & Reimer, 1966).

The valve surface usually consists of pores, or alveoli. In some cases, thickened ribs is present in a definite pattern for a given taxon. Other structures which may be present are various processes and a raphe (Barber et al, 1981). Figure 1 shows pictures of some freshwater diatoms.

Figure 1: Pictures of Diatoms



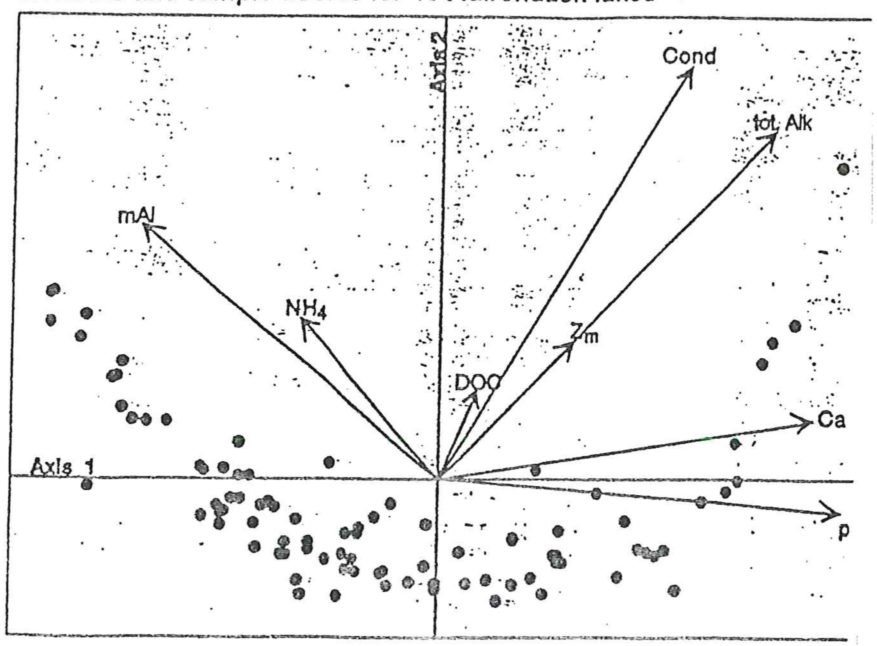
Diatoms are present in fresh water and saline environments. They generate oxygen, and supply high quality food for animals. They are abundant in all aquatic environments where sufficient light is present. Scientists have studied samples from different locations in the U.S. and Canada for plant physiology, cell division, molecular genetics, forensic medicine, archaeology, and petroleum exploration (Dixit et al, 1992). Different diatom communities live in open waters of lakes. Two major groups of diatoms are generally recognized. The centric diatoms exhibit radial symmetry, while the pennate diatoms are bilaterally symmetrical (Crawford et al, 1990).

Diatoms are biomonitors of lakewater quality. Fossil diatoms have been used with great success to infer past lakewater chemistry. To date, reliable diatom-pH transfer functions have been developed for the Adirondacks, northern Great Lakes, northern New England, the Rocky Mountains and the Sierra Nevada in the U.S. and parts of Canada (Birks et al, 1993). The Adirondack Lakes and the Black Rock Forest ponds, NY, have similar environmental characteristics. The two important parameters of this study are acidity of the ponds and water chemistry variables. Previous studies are used to illustrate these variables.

Comparison With Other Regional Studies

Dixit et al studied the surface sediments of 46 Adirondack Lakes. In order to see the relationship between diatom species distributions and water chemistry variables, a CCA test is used (Figure 2). The CCA is a direct gradient analysis technique in which the ordinate axes are constrained to be a linear combination of environmental variables. In CCA, taxa and samples can be directly related to measured environmental variables (Dixit et al, 1992). Figure 2 examines the relationship between water chemistry characteristics and diatom taxa identified from the surface sediments of 46 Adirondack lakes. Water chemistry variables for this study include monomeric Al, NH_4, dissolved organic carbon (DOC), and calcium.

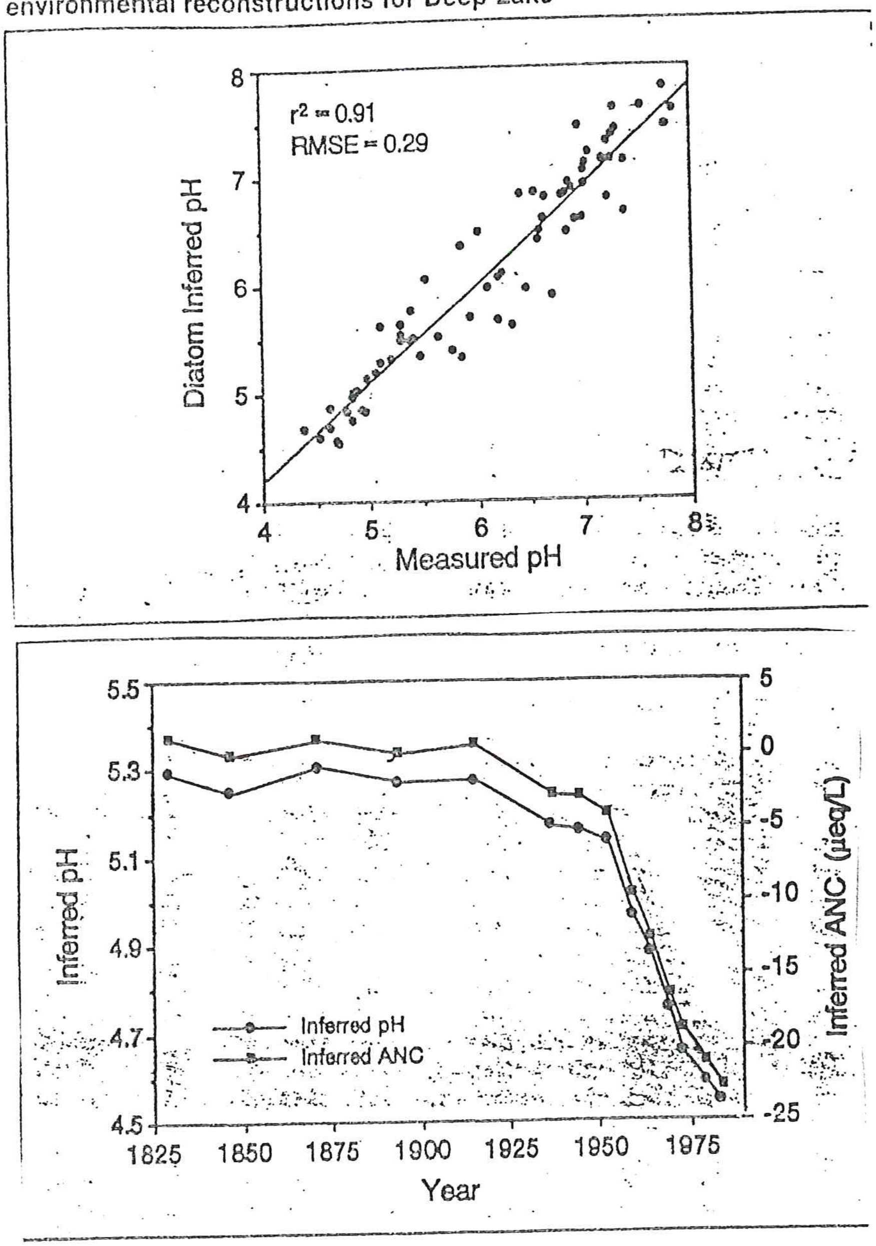
Canonical correspondence analysis biplot showing environmental variables and sample scores for 46 Adirondack lakes[a]

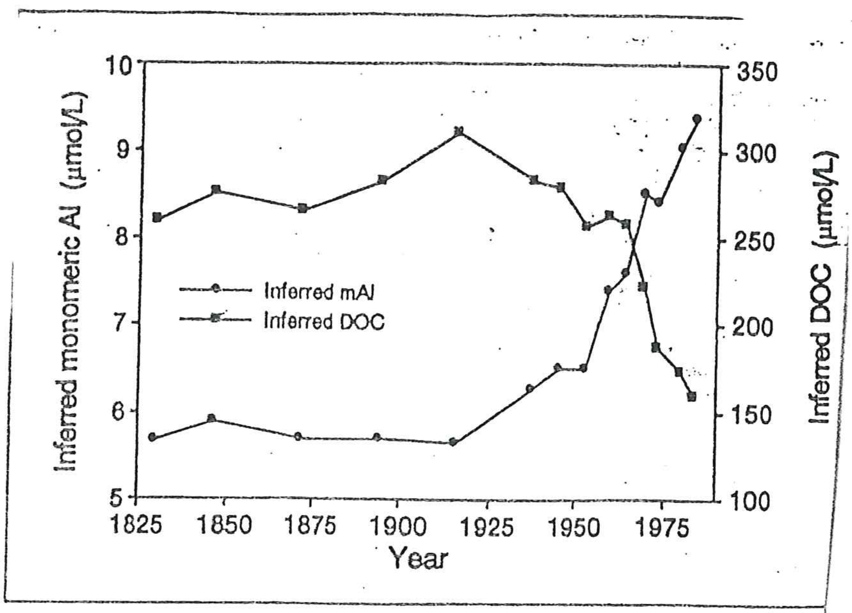


Arrows mark environmental variables and species are shown as points. Arrows point in the direction of the maximum value of that variable and the length of the arrow is a measure of the amount of variance among diatom assemblages explained by the variable. This figure demonstrates that low-pH waters in the Adirondacks have high monomeric Al concentrations, whereas high pH waters have high conductivity, alkalinity, and Ca^{+2} values (Dixit et al, 1992). It also shows that diatom assemblages are sensitive to multiple environmental characteristics, but that some characteristics have a much stronger influence than others do.

Once the dominant environmental variables that determine the species distributions have been identified, transfer functions can be generated to infer environmental characteristics from diatom assemblage data. A weighted-averaging regression and calibration approach is widely used for diatom inferences. This method assumes unimodel response surfaces of diatom species distributions to environmental variables such as pH. An example of this approach is shown in Figure 3 for Deep Lake, Adirondacks, NY.

Diatom-based pH predictive model for Adirondack lakes and environmental reconstructions for Deep Lake





RMSE = Root mean squared error.

This figure shows the strong relationship between measured and diatom inferred pH [r^2 = .91]. It also demonstrates the relationship between inferred pH and inferred acid neutralizing capacity (ANC) and between inferred monomeric Al and inferred DOC. It is evident that pre-1925 lake water pH, ANC, monomeric Al and DOC remained relatively constant over time. The pH was 5.3 in the past with no ANC but the lake acidified further after 1925. Monomeric Al concentrations increased dramatically and DOC concentrations declined (Dixit et al, 1992). Determining past lakewater monomeric Al concentration can help to answer questions related to fisheries. Due to toxic concentrations of Al, fish loss has increased in acidified lakes. Deep Lake is currently fishless, whereas until 1930s, the presence of trout fisheries was evident. DOC inferences are useful in separating natural acidity from anthropogenic related acidification. The inferences indicate the availability of toxic metals in the past.

Another study in the Adirondack region reveals clear evidence of acidification during the period from 1920 to 1970. Eighty percent of the lakes showed a decrease in alkalinity. High $SO4^{-2}$ and NO_3^{-1} concentrations are responsible for the low pH. Several metals are important indicators of acid deposition. Pb and Zn are by-products of fossil-fuel combustion and smelting; their presence in lake sediments may provide evidence of the deposition of atmospheric pollutants (Binford et al, 1990). Pb may provide the clearest evidence, as it is least affected by possible biological and physical processes that can displace or disguise acidification signals. Because dissolution of these elements occurs with decreasing lake pH, declines in Ca, Mn, or Zn provide important indirect evidence of lake-water acidification. The major shifts in taxonomic composition represented in the sediments, and the fish data demonstrate that acidification has effects on aquatic biota as well as water chemistry (Binford et al, 1990).

The geology of an area can also play a key role in anthropogenic acidification processes. Today, Big Moose Lake is one of the 200 lakes in Adirondack Park that can no longer sustain aquatic life because of its acidified waters. Due to anthropogenic lake acidification, many lakes in the Adirondacks were treated with calcium carbonate to raise pH and restore fisheries. In Holmes Lake, diatom assemblages reflect post-settlement disturbances (Rhodes, 1991). An increase in *C. stelligera* marked forest clearance. Furthermore, liming decreased the acidobionts species.

Another study undertaken on twelve Adirondack lakes explains three hypothetical causes of lake acidification. The first cause is the long-term leaching of base cations from soils and wetland development. The second cause is the watershed disturbances such as fires, logging, and recovery of vegetation. The third main cause is increased atmospheric deposition of strong acids. The most relevant explanation for the recent acidification is increased atmospheric deposition of sulfur and nitrogen as a result of combustion of fossil fuels (Binford et al, 1990).

Site Description

Black Rock Forest (BRF) is endowed with numerous ponds, spread in an area of a 3785 acre (1500 ha), located in the Hudson Highlands on the west bank of the Hudson River about 50 miles north of New York City (Appendix A). The Hudson River cuts the Hudson Highlands between Newburgh and Peekskill. The Hudson Highlands rises more than 180 m above the adjacent lowlands and reaches a maximum elevation of 400 m. The regional bedrock geology is mainly Precambrian gneiss and granite. The forests of this region are part of the Quercus-Castanea region of the eastern deciduous forest. The climate is characterized by cold and dry air from the northern continental interior, warm and humid air from the Gulf of Mexico and adjacent subtropical waters, and maritime air originating from the North Atlantic Ocean (Maenza-Gmelch, 1997). BRF has eight major ponds. In this project, lake sediments for five ponds is studied. The five ponds are Aleck Meadow Reservoir (AMR), Upper Reservoir (UR), Tamarack Pond (TP), Sutherland Pond (SP), and Jim's Pond (JP). Table 1 lists a brief summary of general characteristics of the five ponds.

Table 1. General Information on Ponds in BRF

Pond	Latitude (N)	Longitude (W)	Elevation	Surface Area	Shoreline length	Maximum Depth	Year of Origin
	(deg min sec)	(deg min sec)	(meters)	(hectares)	(kilometers)	(meters)	
AMR	41 24 22	74 00 55	314	3.0	0.7	7.0	1910-1915
UR	41 24 41	74 00 24	298	6.1	1.2	9.0	approx. 1900
TP	41 23 42	74 01 37	398	7.3	1.2	2.0	1926
SP	41 23 29	74 02 15	380	4.1	1.2	2.5	Pleistocene
JP	41 23 13	74 01 14	381	5.7	1.5	2.0	1917-1922

Following data was available from the previous years for comparison. Table 2 presents the mean pH readings of BRF ponds (surface readings) and their associated fish species taken by Dr. Carl Schofield for the year 1985 (Kimple, personal communication).

Table 2. Major ponds in Black Rock Forest and associated fish species (data taken in 1985). X represents presence of the fish in the pond.

Ponds	Mean pH	Bullhead	Pickerel	Yellow Perch	Golden Shiner	Pumkinseed	Lg- mouth Bass
AMR	6	X	X			X	
UR	6.3	X			X		
TP	4.8	X	X	X		X	X
SP	5.3	X	X	X		X	
JP	NA	X	X				

Dr. Carl Schofield of Cornell University developed the following classification system for pH and fish population. If the pH range is greater than 6.0, fish populations present are in satisfactory condition and water quality poses no immediate problems. A pH range of 6.0-5.0 is considered endangered and the fish populations present in this range are often at reduced levels. The pH range of less than 5.0 is classified as a critical condition and the fish populations are almost non-existent. Figure 4 shows pH vs. elevation for four ponds.

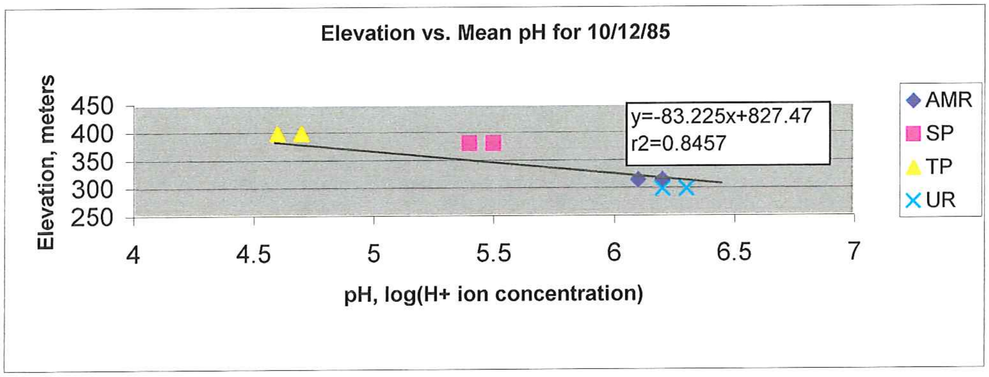


Figure 4. pH values for each pond are taken from Table 2 (in 1985). Jim Pond's pH values were not available.

BRF ponds and the Adirondack Lakes have similar environmental characteristics. The studies done on twelve Adirondack Lakes explained three hypothetical causes of lake acidification (long-term leaching of base cations from soils and wetlands, water shed disturbances and increased atmospheric deposition of strong acids) (Binford et al, 1990). The same scenario can be applied to the environment of Black Rock Forest. The pH readings taken from the ponds in 1985 indicate that Aleck Meadow and the Upper Reservoir showed pH readings in satisfactory range. Sutherland Pond showed pH readings in the endangered range. Tamarack Pond showed pH readings within the critical range, severely affecting fish survival rates (Table 2). Currently, Tamarack Pond sustains no biological life. Thus, it can be hypothesized that as this pond became more acidified, fish were unable to reproduce and gradually disappeared. The extinction of flora and fauna is due to the amount of acid deposition that has fallen in that region. Acid rain also changes the chemistry of the water. It leaches calcium and magnesium out of the soil and carries them into streams and ponds. Acid precipitation draws toxic metals out of sediments and into water, where the toxic metals harm fish and other aquatic organisms. Industrial pollution can also be a contributing factor to decreases in pH. The pollution releases nitrates and sulfates and combines with rain or snow causing acid deposition. In figure 3, the r^2 values (0.84) verifies a strong correlation between elevation and pH. The closer the r^2 values to one, the greater the correlation. As the elevation decreases, the pH values increase. Figure 4 also confirms this inverse relationship.

Table 3 presents pH values for the period of 1985-1998.

Table 3. pH values from ponds during 1985-1998

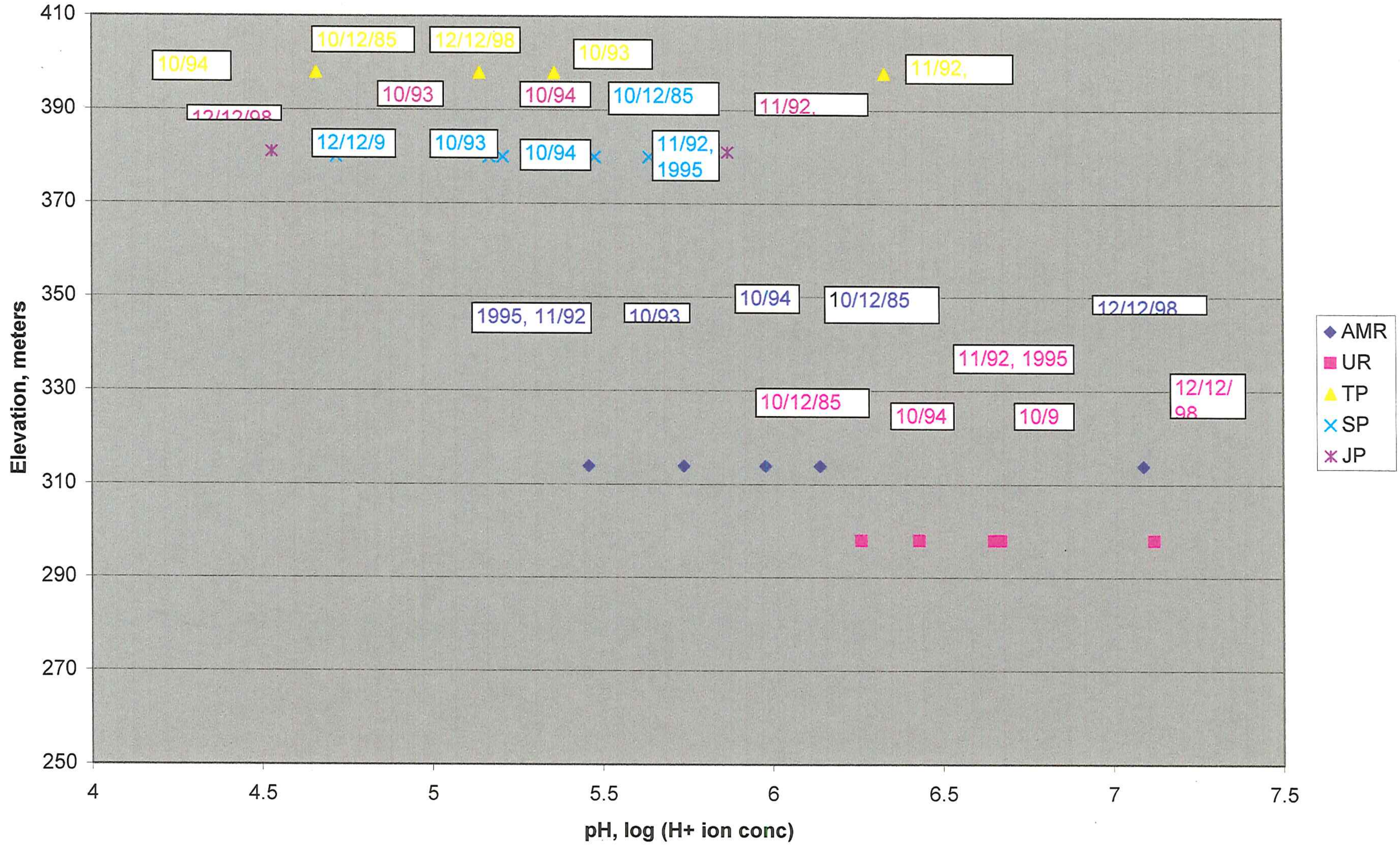
Pond Name	pH 10/12/85	pH 11/92	pH 10/93	pH 10/94	pH 1995	pH 1998
AMR	6.14	5.46	5.74	5.98	5.46	7.09
UR	6.26	6.65	6.67	6.43	6.65	7.12
TP	4.66	6.33	5.36	4.37	6.33	5.14
SP	5.48	5.64	5.17	5.21	5.64	4.72
JP	NA	5.87	4.86	5.29	5.87	4.53

On the next page, Figure 5 shows elevation vs. pH for five ponds based on Table 3. It can be seen that since 1985, AMR does not show any systematic pattern pH change. Upper Reservoir has become more basic. TP, SP, and JP show no systematic pattern in pH change. However, SP and TP have significantly acidified since 1995.

Forest ecosystems are highly affected by anthropogenic activities. Forest lakes are affected by acid rain because it lowers the pH and disturbs the freshwater ecology. It is clearly seen from Figure 5 that acid rain is a problem for the ponds at higher elevation.

There are three major point sources of pollution that leads to acid rain in the Black Rock Forest region. The jet stream blows from southwest to northeast. It carries lots of SO_2 from the Ohio Valley. Ohio valley has many oil refineries, steel mills and power plants. These jet streams directly target the New England region. The second reason is that there are acid-sensitive lakes in the northeastern region which are

Figure 5: **Elevation vs. pH for 1985-1998**



controlled by the nature of surrounding rocks. In northeast direction, there are gneiss and schist. Further north in the Canadian Shield, the rocks are mainly granite. These rocks have no buffering capacity and are easily eroded by acid rain. The third main reason is that although the SO_2 concentrations have declined in the northern region, the nitrogen oxide concentrations have not decreased. The source of NO is mainly automobiles. Nitrogen oxides have lower acidic effects because the biological and chemical processes can have alkaline generating compounds. Also, the natural source of acid rain is the fact that Black Rock Forest is a coniferous forest which tends to be acidic in nature.

METHODS

Field Work at Black Rock Forest

On December 12, 1998, cores and associated water chemistry data from five Black Rock Forest ponds were collected for diatom and laboratory analysis. At Upper Reservoir, an eleven-cm core was collected. At Aleck Meadow Reservoir, cores were collected at three different locations to see whether there are variations in diatom assemblages (Appendix C). Push-core/check valve technique was used to get the core. The uppermost 2-cm of surficial sediment was used for diatom analysis for Aleck Meadow Reservoir and Upper Reservoir. Sediment samples that were provided by Richard Bopp were also used for Sutherland, Jim, and Tamarack Ponds. For these ponds, the uppermost 1-cm of surficial sediment was used. At all ponds, water samples were collected near the sediment/water interface with a peristaltic pump. The water was filtered with a 0.45-micrometer filter by using the pressure of the pump to push the water through the filter. For Sutherland and Jim's Pond, water samples were not filtered in the field due to the loss of the filter. These water samples were finally filtered in February 1999. Conductivity, temperature, pH were also measured in the field.

Laboratory work at Lamont-Doherty Earth Observatory

The geochemistry lab at Lamont-Doherty Earth Observatory was used for storing the core and water samples, performing alkalinity titrations, and sectioning of the cores at defined intervals. To 30-ml water sample bottles, 50 microliters of 50% concentrated H_2SO_4 was added and was stored at 4 ^{o}C for nutrient analysis. 250-ml bottles were used to do alkalinity titrations. Titrations were performed on shallow waters of Aleck Meadow, Sutherland, Jim's, Upper Reservoir, Tamarack Ponds, and deep waters of Upper Reservoir and Aleck Meadow. The mV, pH, and volume of acid added were recorded while performing the titration. The alkalinity is determined by the following method. The highest and the lowest pH and mV values were used for pH calibration and for determining the slope and the intercept. Since not all the pH values were recorded during titration, the non-recorded pH values were calculated by adding the slope and the intercept and multiplying the resultant value with mV (Appendix D). The gran function was calculated by (initial volume (ml)+acid added (ml))*10^{-pH}. The gran plot identifies the point at which all the alkalinity has been titrated and shows where the build up of free hydrogen ions begins (Morgon et al, 1996). The alkalinity and the percent error was calculated by using the gran function (Appendix D). The alkalinity was measured in milliequivalent per liter (meq/L). Amount of acid added and gran function were plotted against each other. A straight line was drawn on the scatter plot. If the plotted values were below zero, the alkalinity was not calculated and it was assumed to be zero for those sites (Appendix D).

Laboratory work at Armonk, NY

The lab work was conducted at Louis Calder Center-Biological Field Station of Fordham University in Armonk, NY. For the analysis of diatom assemblages, diatom valves were separated from the sediment matrix by treating the samples with potassium dichromate and a strong oxidizing acid (HNO_3) following methods outlined by Smol (1983). The goal of this digestion process was to isolate diatoms and remove all the organic matter. The matter after heating was centrifuged and aspirated few times to remove all the acid. The diatoms settled at the bottom of the testubes. These samples were diluted with distilled water either at 10 or 20% and were evaporated onto coverslips. Once dried, the coverslips were mounted on glass slides with resin. Table 4 shows the grams of sediments used for each prepared slide. These values are later used in finding number of cells per gram sediment and percent abundance of species.

Table 4. Grams of sediments used for each sample.

Ponds	Grams on the sample cover slip
Aleck Meadow Reservoir 1 at 10% dilution	0.0023
Aleck Meadow Reservoir 2 at 20% dilution	0.0052
Aleck Meadow Reservoir 3 at 10% dilution	0.0023
Upper Reservoir at 20% dilution	0.0133
Tamarack Pond at 10% dilution	0.0007575
Sutherland Pond at 20% dilution	0.00164
Jim's Pond at 10% dilution	0.000518

Diatom frustules were counted and identified at a magnification of 100X by using epiflourescence microscope. On the whipple, the partial frustules that were more than half were counted. Diatom nomenclature followed Hustedt, Patrick & Reimer (1966) as well as other sources. Appendix E lists the diatom species found in surficial sediments of

BRF ponds. Appendix F list the name of the species identified for the corresponding ponds with the number of counts, number of cells per gram of sediment and the percent of the abundance of that species. The number of cells per gram of sediment is calculated by using the formula: (number of counts/ grams of sediment used) * grid ratio * number of grids/2. Fourteen species with highest abundance are used to establish correlation between environmental parameters and diatom assemblages.

The water chemistry variables used to characterize the study ponds were calcium (Ca), silica (SiO_2), nitrate (NO_3^{-1}), soluble reactive phosphorous (SRP), and ammonium (NH_4^{+1}). Samples were analyzed for SRP using the molybdate-ascorbic method (A.P.H.A., 1985, Bran+Luebbe Analyzing Technologies 1986a), ammonium (NH_4^+-N) using the phenolhypochlorite method, and nitrate (NO_3^-) using (after reduction to NO_2^- in a Cd-Cu column) the sulfanilamide-NNED method (A.P.H.A., 1985, Bran+Luebbe Analyzing Technologies 1986b, 1987). Calcium was analyzed in Atomic Absorption Spectrophotometry whereas all the other variables were analyzed in the auto analyzer (Traacs 800). For Nitrogen and SRP, measurements signify ug N/L, ug P/L respectively.

RESULTS

I. Physio-chemical Investigations of BRF Ponds

The mineral requirements of diatoms are similar to those of most plants. The major chemicals are phosphates, nitrogen (usually in the form of ammonium or nitrates), sulfates, calcium, magnesium, potassium, iron, manganese, and silicon. Trace elements are also beneficial in the growth of diatoms (Patrick and Reimer, 1966). The major elements investigated at BRF ponds are given in Table 5.

Table 5. Physio-chemical values investigated for five BRF ponds based on the field data collected on 12/12/98. S is abbreviated for shallow water values and D is for deep water values.

Ponds	Temperature (o C)	pH	Alkalinity (m eq/L)	Conductivity (u S/cm)	NH_4^+ (ug N/L)	NO_3^- (ug N/L)	SRP (ug P/L)	SiO_2 (mg/L)	Ca (mg/L)
AMR		7.09		39					
(S)	6.2		0.534		9.3	17.3	7.9	2.8	3.9
(D)	6.7		0.051		11.0	18.6	5.6	3.1	3.5
UR		7.12		109					
(S)	6.4		0.103		11.4	5.9	13.3	4.8	5.1
(D)	6.5		0.103		9.7	5.2	10.8	4.8	4.7
TP		5.14		25					
(S)	4.3		0		7.0	10.8	5.5	2.8	1.1
SP		4.72		44					
(S)	4.2		0		5.1	37	2.8	1.0	3.1
JP		4.53		42					
(S)	3.4		0		103.4	91.6	4.4	0.4	3.1

Figures 6 to 12 show graphs of elevation vs. water chemistry variables for 12/12/98 data.

Figure 6. Elevation vs. pH for the data collected on 12/12/98.

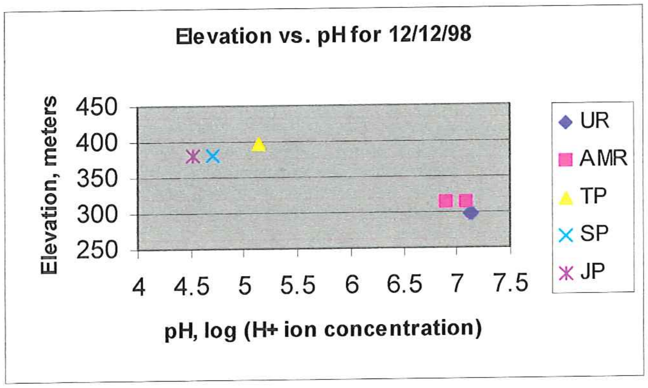


Figure 7. Elevation vs. Conductivity for the data collected on 12/12/98.

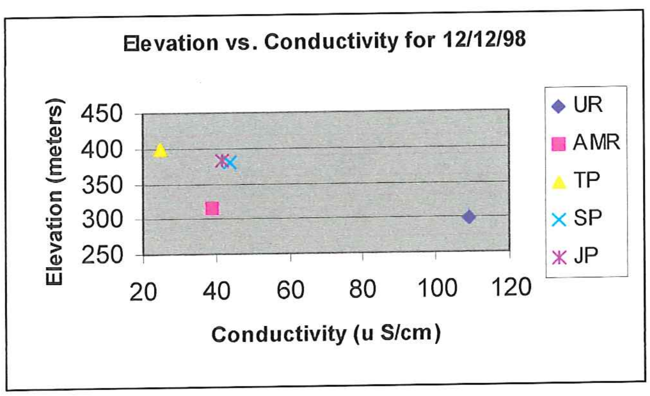


Figure 8. Elevation vs. Ammonium for the data collected on 12/12/98.

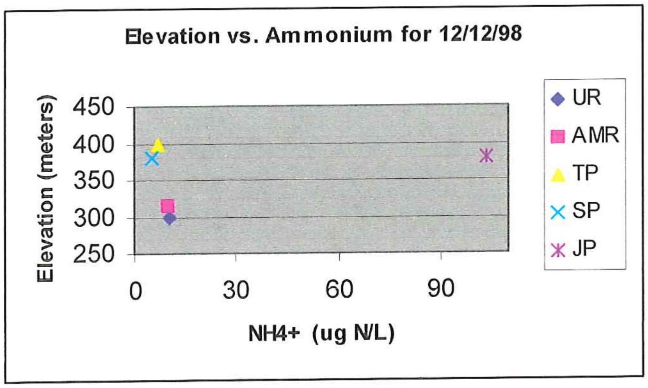


Figure 9. Elevation vs. Nitrate for the data collected on 12/12/98.

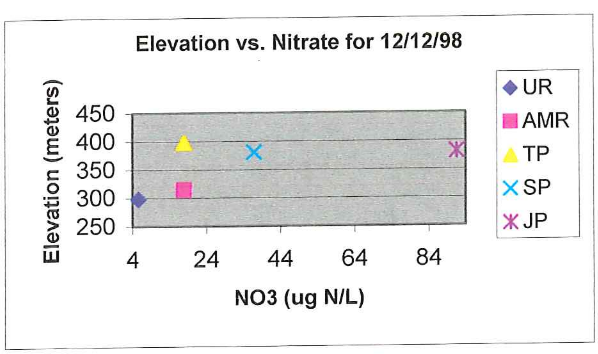


Figure 10. Elevation vs. Phosphorous for the data collected on 12/12/98.

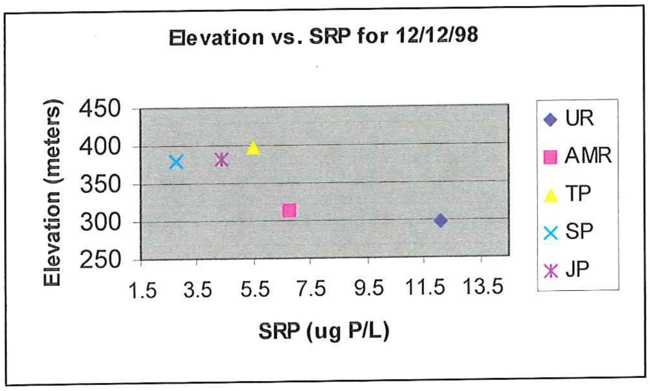


Figure 11. Elevation vs. Silica for the data collected on 12/12/98.

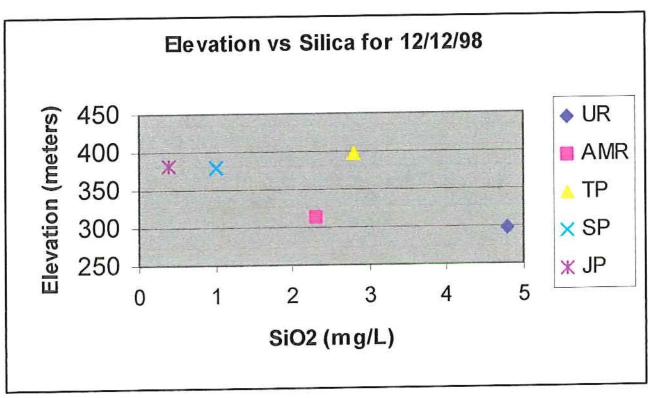


Figure 12. Elevation vs. Calcium for the data collected on 12/12/98.

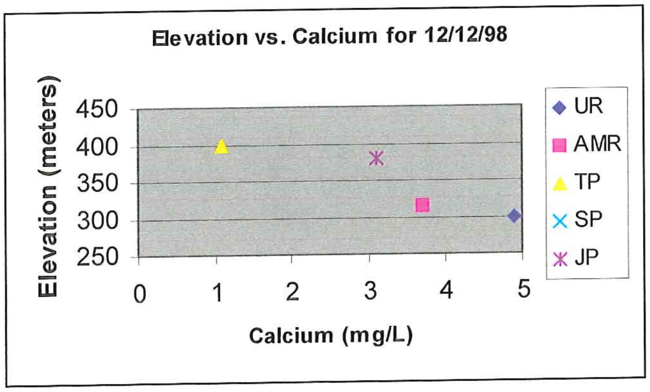


Table 5 shows that pH varies between 4.53 to 7.12. It is seen from Figure 6 that Upper Reservoir has the highest pH whereas Jim's Pond has the lowest. Sutherland and Jim's Pond are the most acidic ponds. The alkalinity values vary from nil to 0.103 (Table 5). All errors on alkalinity values were 1.3% or less. The alkalinity of the highly acidic ponds are found to be nil. The conductivity value for Upper Reservoir is significantly higher than the other ponds (Figure 7). The ammonium values are significantly higher for Jim's Pond (Figure 8). Upper Reservoir has the lowest nitrate concentration and Jim's Pond has the highest concentration with Sutherland, Aleck Meadow Reservoir, and Tamarack Ponds respectively (Figure 9). Following observations can be made from figures 10, 11, and 12. For phosphorous, silica, and calcium values, Upper Reservoir has the highest concentration. Sutherland Pond has the lowest phosphorous concentration and Jim's Pond has the lowest silica concentration. Calcium is lowest in Tamarack Pond (Figure 12).

II. Microscopic Investigation of Sediments for Diatoms

To find out whether there are any detectable changes in diatom assemblages, table 6 and 7 are tabulated. Table 6 lists the top five common species found with their percent of abundance in descending order.

Table 6. Five most common diatom species found in surficial sediments in ponds within BRF. AMR1, 2, and 3 refers to cores collected at three different locations. Samples were diluted with distilled water either at 10% or 20%.

	Species	% abundance	Error bar
AMR 1. 0-1 cm 10%			
	Tabellaria flocculosa	8.1	+/- 1.6
	Tabellaria fenestrata	7.8	+/- 1.5
	Surirella ovalis	7.2	+/- 1.5
	Navicula radiosa	5.4	+/- 1.3
	Navicula explanata	4.5	+/- 1.2
AMR 2. 0-1 cm 20%			
	Tabellaria flocculosa	7.9	+/- 1.2
	Eunotia pectinalis	7.9	+/- 1.2
	Achnanthes minutissima	7.2	+/- 1.2
	Melosira granulata	6.8	+/- 1.1
	Fragilaria pinnata var. pinnata	6.8	+/- 1.1
AMR 3. 0-1 cm 10%			
	Eunotia pectinalis	9.2	+/- 1.3
	Tabellaria fenestrata	6.8	+/- 1.1
	Tabellaria flocculosa	5.7	+/- 1.0
	Navicula radiosa	5.3	+/- 1.0
	Eunotia cf. Vanheurckii	5.3	+/- 1.0
UR 0-1 cm 20%			
	Tabellaria flocculosa	11.0	+/- 1.8
	Nitzschia species A	8.9	+/- 1.6
	Navicula radiosa	8.0	+/- 1.5
	Fragilaria pinnata var pinnata	5.9	+/- 1.3
	Achnanthes minutissima	5.6	+/- 1.3
TP 0-2 cm 10%			
	Frustulia rhomboides	20.2	+/- 2.7
	Eunotia pectinalis	15.8	+/- 2.4
	Tabellaria fenestrata	13.9	+/- 2.3
	Eunotia sudetica	13.9	+/- 2.3
	Eunotia cf. Vanheurckii	8.1	+/- 1.7
SP 0-2 cm 20%			
	Navicula radiosa	16.1	+/- 2.3
	Tabellaria flocculosa	14.8	+/- 2.2
	Tabellaria fenestrata	12.5	+/- 2.0

	Eunotia pectinalis	11.8	+/- 2.0
	Eunotia cf. Vanheurckii	7.5	+/- 1.6
JP 0-2 cm 10%			
	Tabellaria fenestrata	15.1	+/- 2.2
	Navicula radiosa	11.2	+/- 1.9
	Tabellaria flocculosa	8.7	+/- 1.7
	Neidium affine var. affine	8.7	+/- 1.7
	Eunotia sudetica	8.3	+/- 1.6

This table is used to create Table 7, which lists top fourteen most common species with their percent abundance among the study ponds.

Table 7. Fourteen most common diatom species found in study ponds. The genus is abbreviated. Values in red ink represent the top five common species of each pond from Table 6.

Ponds	*A.minutissima*	*E.cf. Vanheurckii*	*E.pectinalis*	*E. sudetica*	*F.pinnata var. pinnata*
	% abundance	% abundance	% abundance	% abundance	% abundance
AMR1	2.4	2.7	3.0	0.0	1.5
AMR2	7.2	3.7	7.9	0.0	6.8
AMR3	4.9	5.3	9.3	0.0	3.8
UR	5.6	3.9	8.0	0.0	5.9
TP	5.5	8.1	15.8	13.9	0.4
SP	0.0	7.5	11.8	6.6	0.0
JP	1.9	8.0	5.1	8.3	0.0
Ponds	*F.rhomboides*	*M.granulata*	*N.explanata*	*N.radiosa*	*N.affine var. affine*
	% abundance	% abundance	% abundance	% abundance	% abundance
AMR1	1.8	3.0	4.5	5.4	1.5
AMR2	0.4	6.8	1.7	5.9	0.7
AMR3	0.9	4.7	2.8	5.3	0.9
UR	0.3	2.1	0.0	8.0	0.0
TP	20.2	0.0	0.0	0.0	2.6
SP	0.1	2.3	0.3	16.1	4.9
JP	3.5	4.2	0.6	11.2	8.7
Ponds	*Nitzschia sp A*	*S. ovalis*	*T.fenestrata*	*T.flocculosa*	
	% abundance	% abundance	% abundance	% abundance	

AMR1	0.9	7.2	7.8	8.1	
AMR2	0.6	0.4	6.4	7.9	
AMR3	1.9	0.9	6.8	5.7	
UR	8.9	0.3	4.5	11.0	
TP	0.0	0.0	13.9	13.9	
SP	0.0	0.7	12.5	14.8	
JP	0.0	0.3	15.1	8.7	

III. Statistical Analysis performed to ascertain whether or not a correlation between environmental parameters and surface-sediment diatom assemblages exist

To establish a correlation between the environmental variables and surface-sediment diatom assemblages, percent abundance for each of the fourteen species were plotted against the arithmetic average measurements of shallow and deep water environmental variables (pH, conductivity, ammonium, nitrate, phosphorous, silica, and calcium). Regression and probability values are calculated. Among the fourteen species, correlation was found for seven diatom species. The decision about the significance of this result is made based on the p-values. Figures 13 to 29 show scattered plots, their regression lines, and the probability values for the seven most common diatom species. The seven diatom species are *Tabellaria fenestrarta, Frustulia rhomboides, Eunotia sudetica, E. cf. Vanheurckii, Neidium affine var. affine, Nitzschia sp. A.*, and *Fragilaria pinnata var. pinnata* . For *T. fenestrata*, correlations were established for pH, silica, phosphorous, and calcium.

Figure 13. Scattered plot of percentage abundance vs. pH for *Tabellaria fenestrata*. The correlation is significant at 95% confidence level.

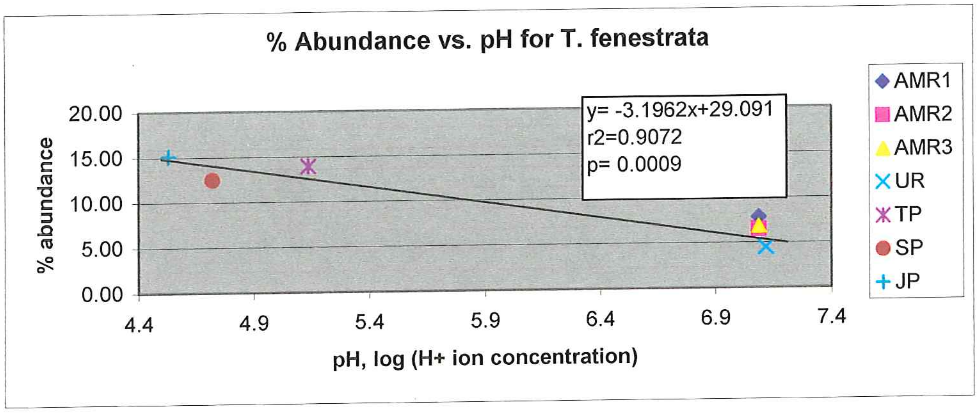


Figure 14. Scattered plot of percentage abundance vs. silica for *Tabellaria fenestrata*. The correlation is significant at 95% confidence level.

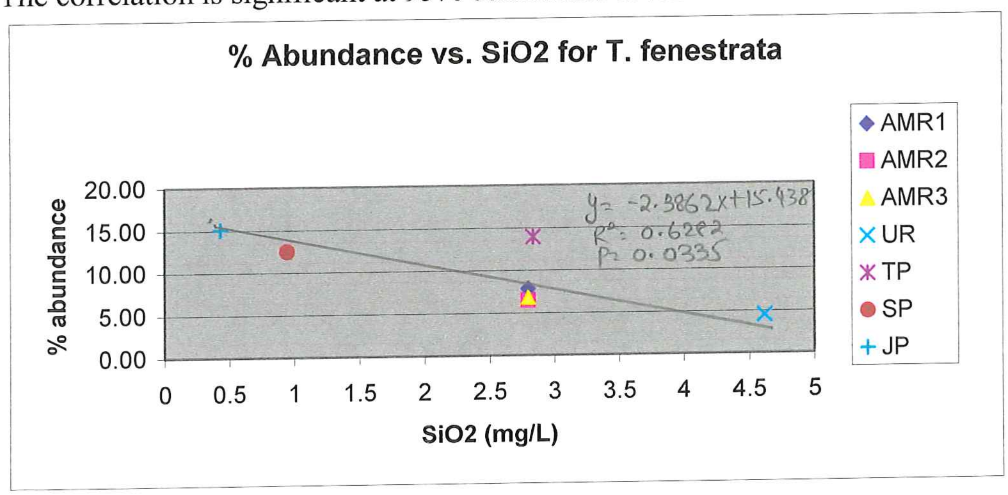


Figure 15. Scattered plot of percentage abundance vs. phosphorous for *Tabellaria fenestrata*. The correlation is significant at 95% confidence level.

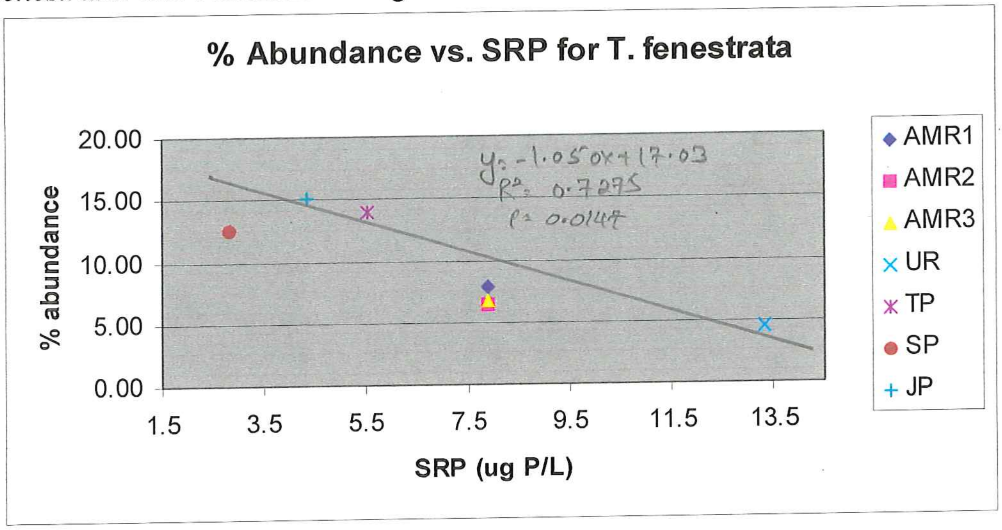
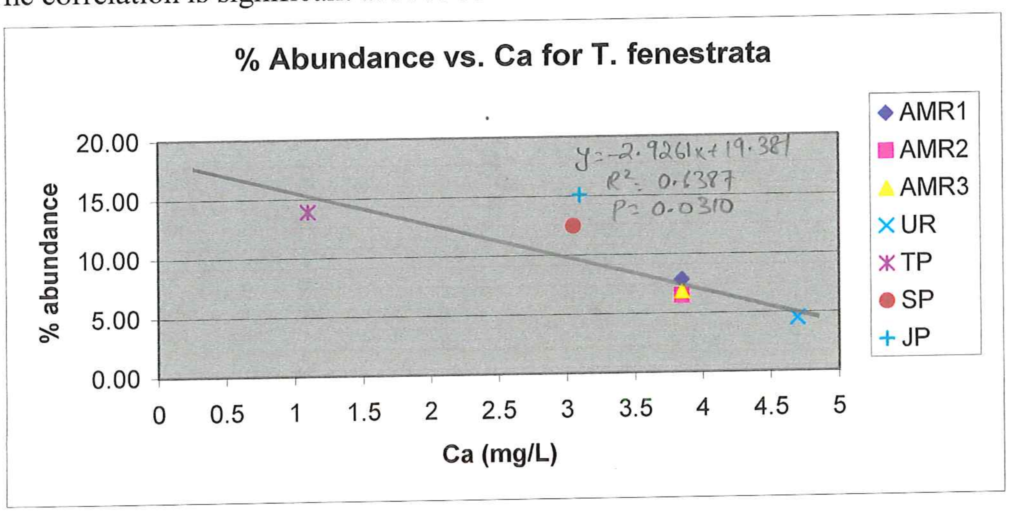
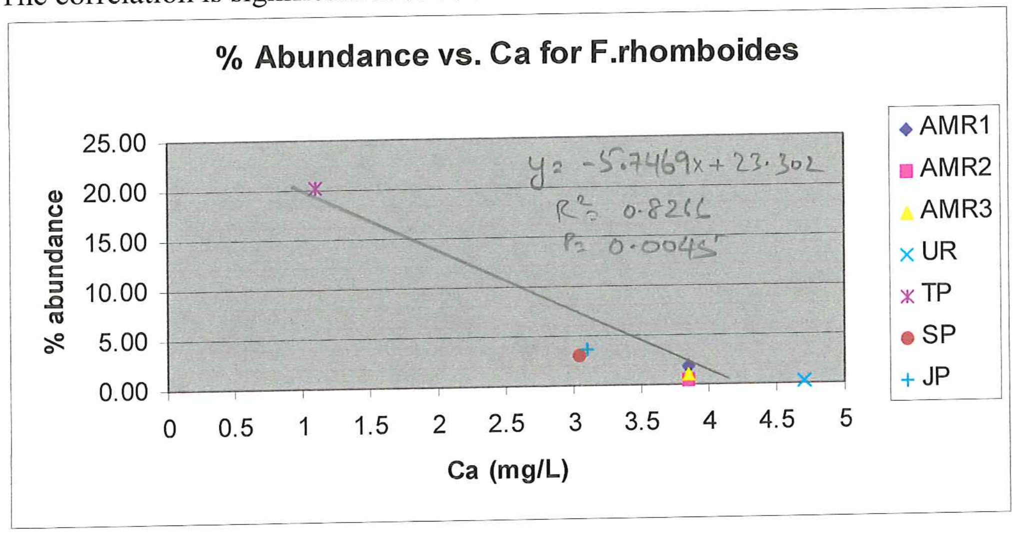


Figure 16. Scattered plot of percentage abundance vs. calcium for *Tabellaria fenestrata*. The correlation is significant at 95% confidence level.



For *Frustulia rhomboides*, correlation was found only with calcium.

Figure 17. Scattered plot of percentage abundance vs. calcium for *Frustulia rhomboides*. The correlation is significant at 95% confidence level.



For *Eunotia sudetica*, correlation was found for pH versus calcium.

Figure 18. Scattered plot of percent abundance vs. pH for *Eunotia sudetica* . The correlation is significant at 95% confidence level.

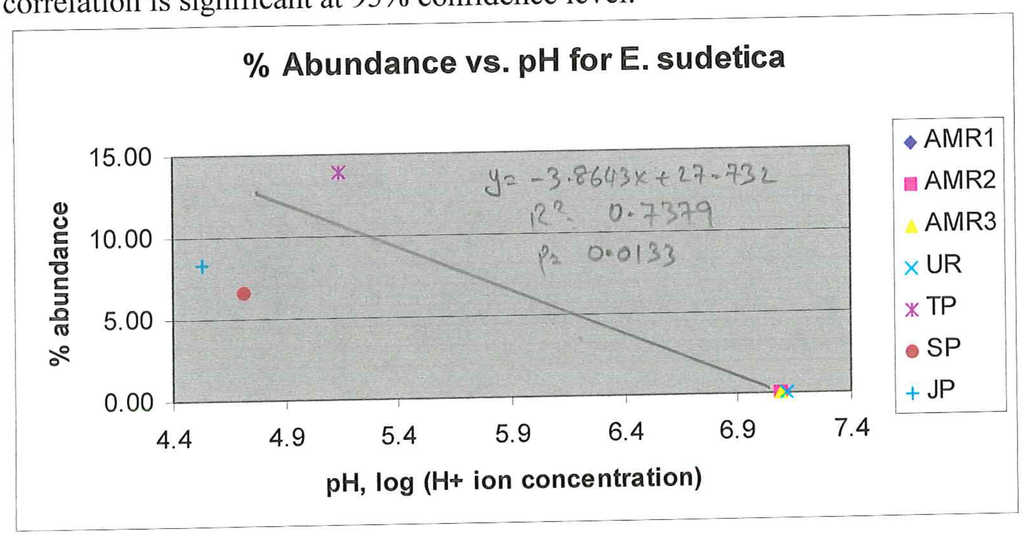
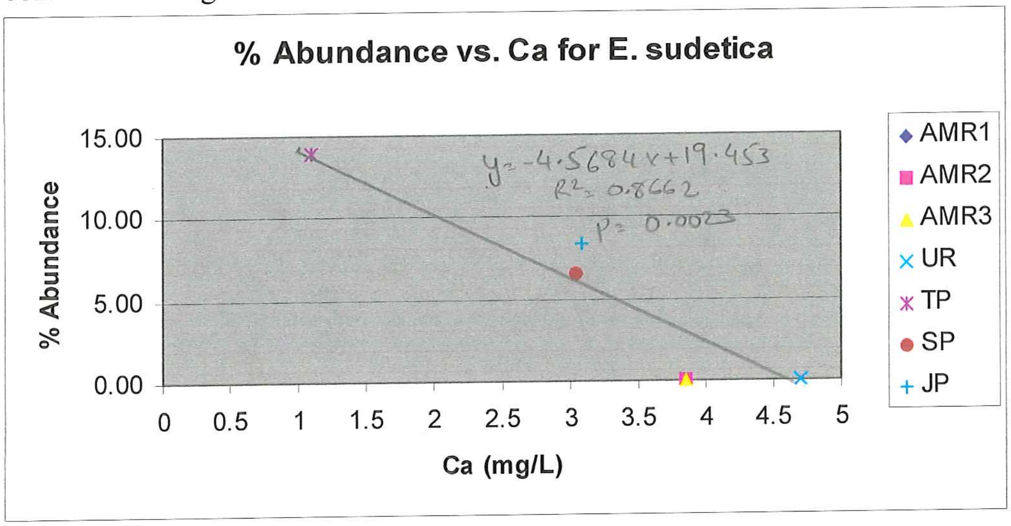
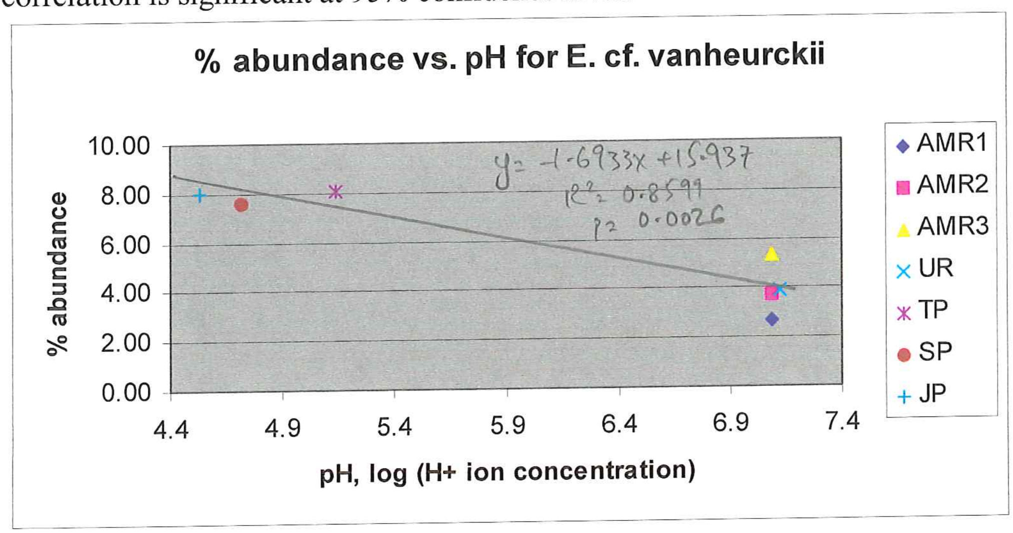


Figure 19. Scattered plot of percent abundance vs. calcium for *E.sudetica*. The correlation is significant at 95% confidence level.



For *Eunotia cf. vanheurckii*, correlation was found for pH only.

Figure 20. Scattered plot of percentage abundance vs. pH for *E. vanheurckii*. The correlation is significant at 95% confidence level.



For *Neidium affine var. affine*, correlation was established for pH, ammonium, silica, and nitrate.

Figure 21. Scattered plot of percentage abundance vs. pH for *N. affine var. affine*. The correlation is significant at 95% confidence level.

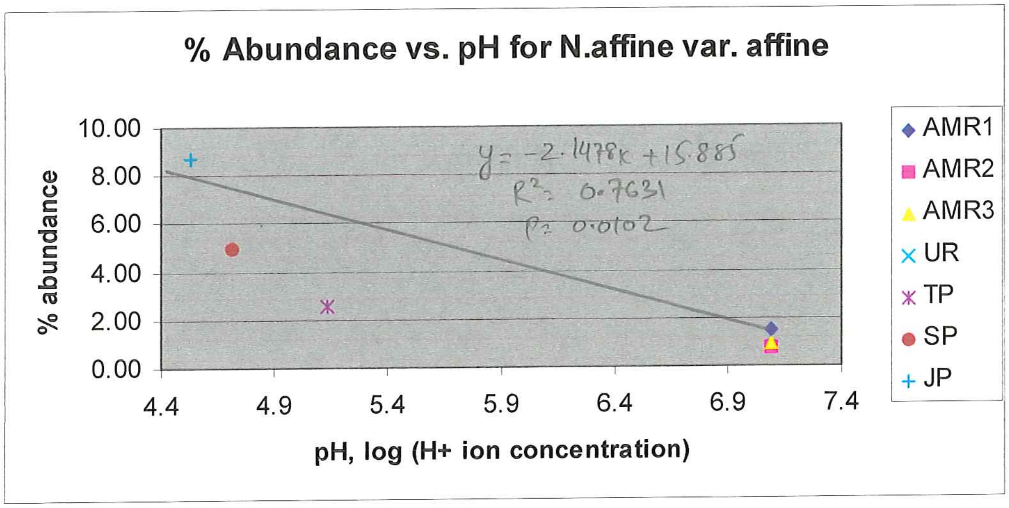


Figure 22. Scattered plot of percent of abundance vs. ammonium for *Neidium affine var. affine*. The correlation is significant at 95% confidence level.

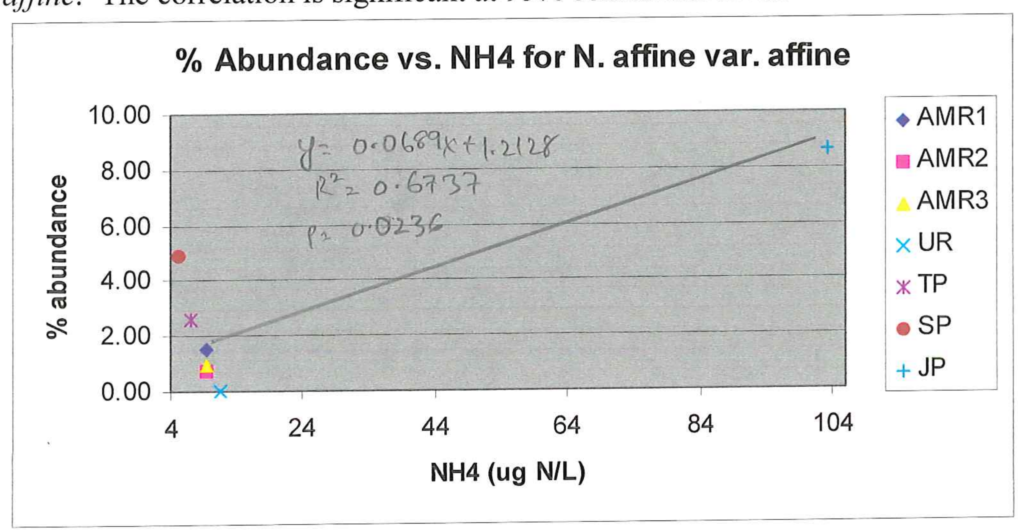


Figure 23. Scattered plot of percent of abundance vs. silica for *N. affine var. affine*. The correlation is signifincant at 95% confidence level.

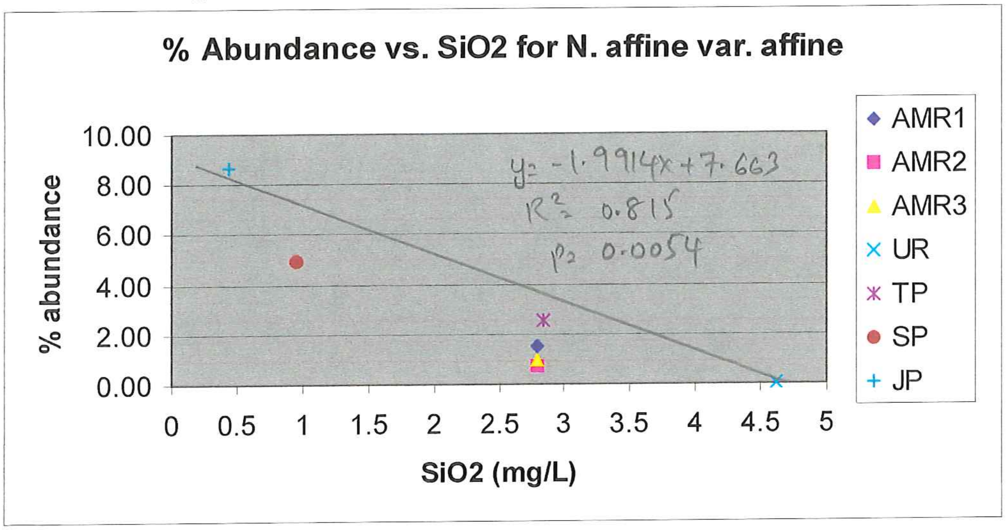
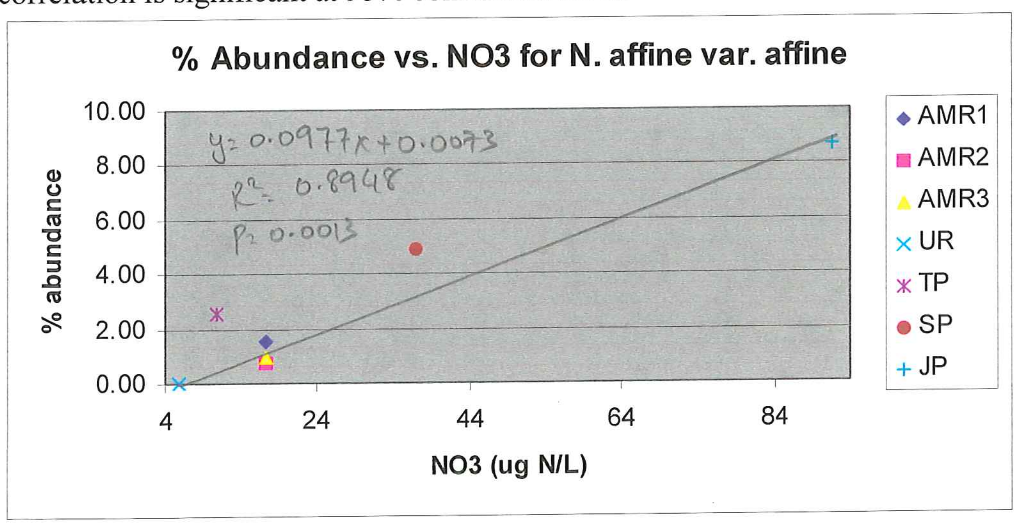


Figure 24. Scattered plot of percent of abundance vs. nitrate for *N. affine var. affine*. The correlation is significant at 95% confidence level.



For *Nitzschia sp.A*, correlation was found for silica, SRP, and conductivity.

Figure 25. Scattered plot of percentage abundance vs. silica for *Nitzschia spA*. The correlation is significant at 95% confidence level.

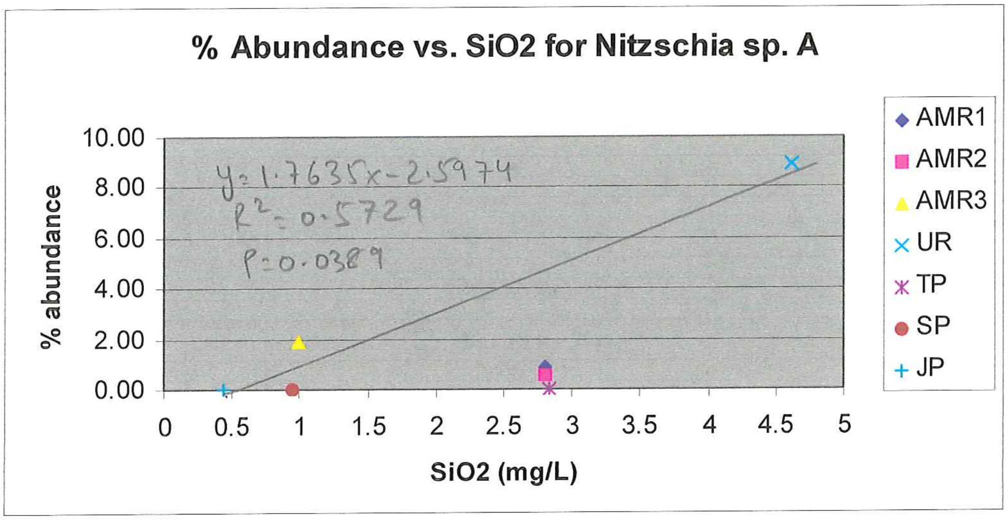


Figure 26. Scattered plot of percent abundance vs. phosphorous for *Nitzschia sp A*. The correlation is significant at 95% confidence level.

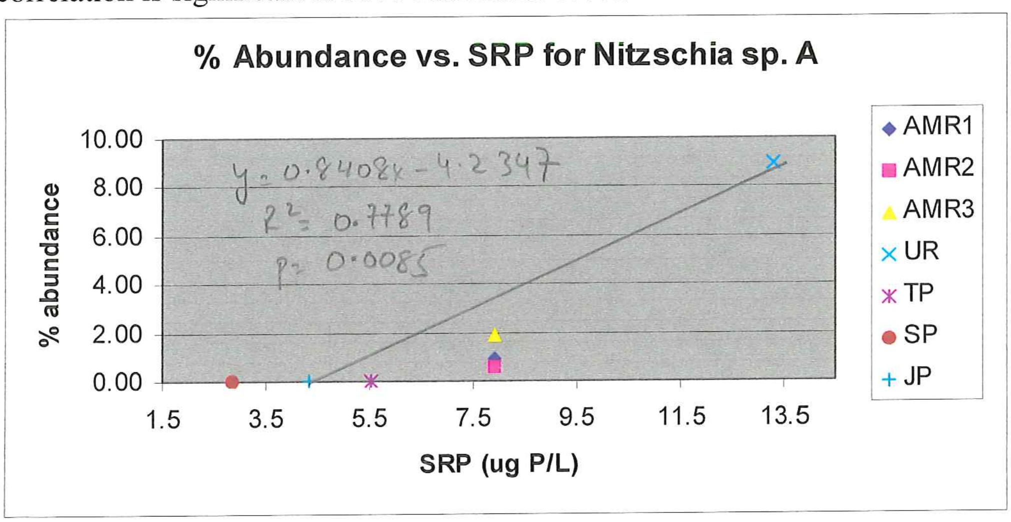
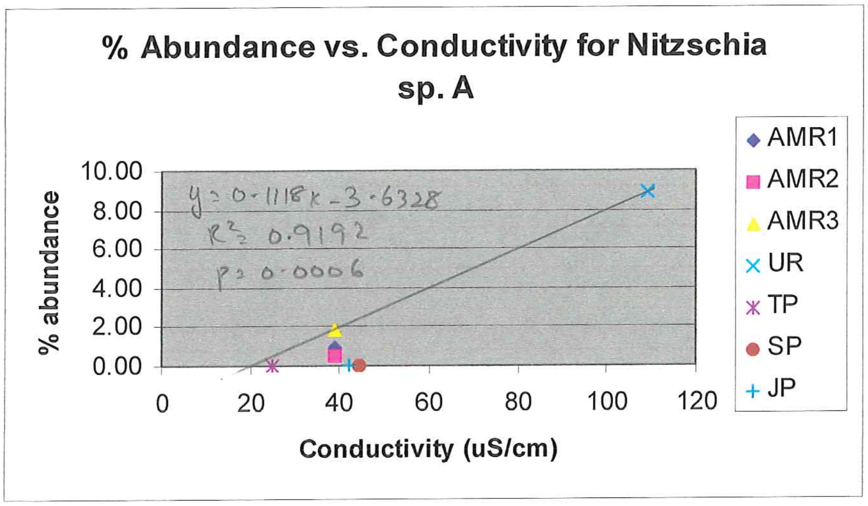


Figure 27. Scattered plot of percentage abundance vs. conductivity for *Nitzschia sp. A*. The correlation is significant at 95% confidence level.



For *Fragilaria pinnata var. pinnata*, correlation was found with pH, and phosphorous.

Figure 28. Scattered plot of percent abundance vs. pH for *F. pinnata var. pinnata*. The correlation is significant at 95% confidence level.

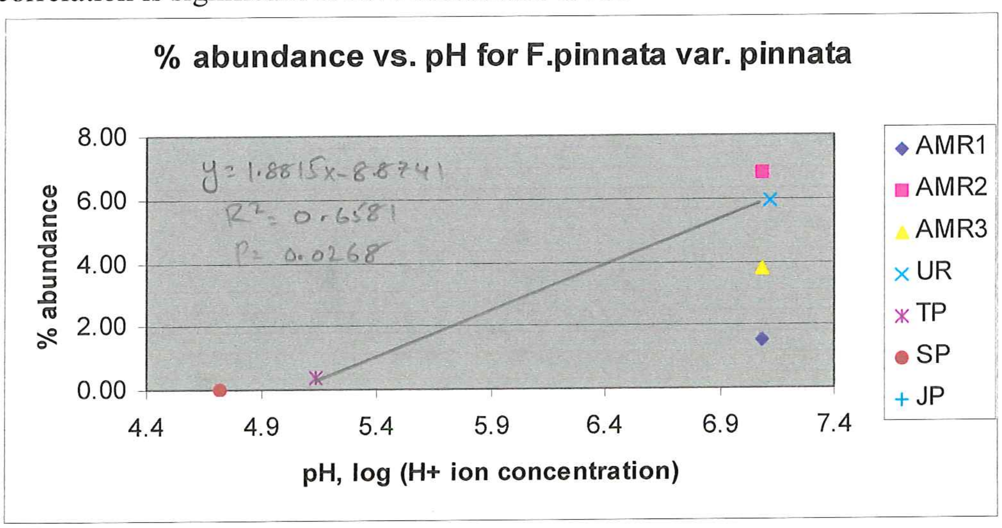


Table 8. Significant p-values for diatom species for which correlation is established.

Species	pH	NH4 ug N/L	SiO2 mg/L	SRP ug P/L	NO3 ug N/L	Ca Mg/L	Conductivity uS/cm
T. fenestrata	0.0009		0.0335	0.0147		0.0310	
F. rhomboides						0.0045	
E. sudetica	0.0133					0.0023	
E. cf.vanheurckii	0.0026						
N. affine var.affine	0.0102	0.0236	0.0054		0.0013		
Nitzschia sp. A			0.0389	0.0085			0.0006
F. pinnata var. pinnata	0.0268			0.0369			

Table 9. Significant r^2 values for diatom species for which correlation is established.

Species	pH	NH4 ug N/L	SiO2 mg/L	SRP ug P/L	NO3 ug N/L	Ca Mg/L	Conductivity uS/cm
T. fenestrata	0.9072		0.6282	0.7275		0.6387	
F. rhomboides						0.8266	
E. sudetica	0.7379					0.8662	
E. cf.vanheurckii	0.8599						
N. affine var.affine	0.7631	0.6737	0.815		0.8948		
Nitzschia sp. A			0.5729	0.7789			0.9192
F. pinnata var. pinnata	0.6581			0.6147			

DISCUSSION

For Upper Reservoir, the calcium, SRP and SiO_2 values are relatively high (Table 5). For Jim's Pond, the NH_4^+ and NO_3^- concentrations are significantly high. Dixit et al (1992) have shown that low pH water has low conductivity, alkalinity, and calcium values. Table 5 shows that this notion is also applicable for Jim's and Sutherland Pond. Upper Reservoir has the highest pH and the highest calcium concentration. This project had intended to answer two main questions. The first important question is:

Are there detectable changes in diatom assemblages among the five ponds?

Table 6 shows that there are variations found in diatom assemblages at three locations of Aleck Meadow Reservoir. In Aleck Meadow R. 1, two most common genus are *Tabellaria* and *Navicula*. Aleck Meadow R. 2 has the most variety of species compared to AMR 1 and AMR3. Aleck Meadow R 3 has *Tabellaria* and *Eunotia* as the most common genus. *Tabellaria flocculosa* is present in all three sites with the highest percentage abundance at AMR 1 (8.1%). *Tabellaria fenestrata* is present in AMR1 and 3 and is most abundant in AMR 1. *Navicula radiosa* is also abundant in AMR1 and AMR 3 being most abundant in AMR 1. *Eunotia pectinalis* is abundant in AMR 2 and 3 being most abundant in AMR 3.

Upper Reservoir is the only pond with the abundance of *Nitzschia Sp.* A. Tamarack Pond is the only pond with the abundance of *Frustulia rhombo*ides (20.2%). Compared to other ponds, this pond has the highest percentage abundance for *Eunotia pectinalis* (15.8%). In addition, *Eunot*ia is the most common genus with three different species (*pectinalis, sudetica,*and *vanheurckii*) (Table 6).

Sutherland Pond has the highest percentage abundance *for Navicula radiosa*, and *Tabellaria flocculosa* compared to other ponds. Like AMR 3, this pond has the two most common genus of *Eunotia* and *Tabellaria*. Compared to other ponds, Jim's Pond has the highest percentage abundance of *Tabellaria fenestrata*. This is the only pond with *Neidium affine var. affine* being abundant (Table 6).

Following changes are detectable in diatom assemblages among the five study ponds (Table 7). It can be seen that *Tabellaria fenest*rata is highly abundant in acidic environments of Tamarack, Sutherland, and Jim's Pond. *Tabellaria flocculosa* is abundant in all five ponds. *Eunotia sudetica* is abundant in acidic ponds (Tamarack, Sutherland, and Jim's Ponds) and absent in alkaline environment. *Frustulia rhomboides* is significantly abundant in Tamarack Pond (greater than 20%). *Surirella ovalis* is most abundant in Aleck Meadow R. 1. *Nitzschia sp. A* is most abundant in Upper Reservoir. *Neidium affine var. affine* is most abundant in Jim's Pond. The second important question under investigation is:

Do the diatom assemblages correlate with environmental parameters?

The diatom assemblages are correlated with some of the environmental variables for *T. fenestrata, F. rhomboides, E. sudetica, E. vanheurckii, N. affine var. affine, Nitzchia sp. A, and F. pinnata* as seen from Tables 8 & 9 and Figures 13-29. Probability values provide a sense of strength of the evidence against the null hypothesis. The cutoff point that decides significance is 0.05. Any test resulting in a p-value under 0.05 is significant. Therefore, null hypothesis is rejected. The lower the p-value, the stronger the evidence.

Figure 13 indicates that higher amount of *Tabellaria fenestrata* is found in acidic waters of Jim's, Sutherland, and Tamarack Ponds. The population of this species decreases dramatically in alkaline ponds (Upper Reservoir and Aleck Meadow R. 1, 2, and 3). A strong relationship between percentage abundance and pH exists due to its low p- value (0.0009) and high r^2 value (0.91).

Figure 14 indicates that there is an inverse relationship between percentage abundance of *T. fenestrata* and SRP. A correlation exists between the two variables (r^2= 0.73) and the p-value (0.015) further strengthens this correlation. Figure 15 indicates that the percentage abundance decreases with the increase of silica. Jim's Pond has the highest amount of *T. fenestrata* with the lowest amount of silica. A relationship between the two variables exists. The p-value is 0.03.

Figure 16 clearly shows that higher amount of *T. fenestrata* is found in water low in calcium. For example, Tamarack Pond has the lowest calcium concentration but highest percentage abundance of *T. fenestrata.* The p-value of 0.03 makes the relationship between the two variables significant.

Figure 17 demonstrates that *Eunotia sudetica* is abundant in acidic ponds (Tamarack, Jim's and Sutherland) and absent in alkaline ponds of Aleck Meadow R. 1, 2, and 3 and Upper Reservoir. The relationship between the percent abundance of this species and pH exists. The p-value of 0.01 verifies the significance of this relationship. The percentage abundance of *E.sudetica* seems to be inversely related to amount of calcium (Figure 17). Tamarack Pond has the lowest amount of calcium with the highest percentage abundance of *E. sudetica.* A strong relationship between the two variables exists. The p-value of 0.002 and r^2 value of 0.87 further verifies the significance of this relationship.

Figure 18 demonstrates that higher amount of *E. cf. Vanheurckii* is found in acidic ponds (Jim's, Sutherland and Tamarack). A strong correlation between percentage abundance of this species and pH exists. The p-value of 0.003 and r^2 value of 0.86 also makes this relationship significant.

Figure 19 shows that percentage abundance of *Frustulia rhomboides* is inversely related to amount of calcium. *F.rhomboides* is significantly abundant in Tamarack Pond (20.2%) whereas the percentage abundance of this species is less than 5% for the other ponds. The r^2 value of 0.83 indicates a strong correlation between the two variables. The p-value of 0.004 further makes this relationship significant.

Figure 20 shows that higher amount of *Neidium affine var. affine* is found in acidic ponds of Jim's, Sutherland, and Tamarack Ponds. The r^2 value of 0.76 indicates a correlation between the two variables. The p-value of 0.01 further signifies a strong correlation. Figure 21 shows that *N.affine var. affine* is most abundant in Jim's Pond where the ammonium concentration is the highest (103.4 ug N/L). The r^2 value of 0.67 indicates a correlation between ammonium and percentage abundance of this species. The p-value of 0.02 further signifies this correlation.

Figure 22 also shows that *N. affine var. affine* is most abundant in Jim's Pond where the nitrate concentration is highest (91.6 ug N/L). The r^2 value of 0.89 confirms a strong correlation between the two variables. The p-value of 0.001 further verifies a strong correlation.

Figure 23 shows that *N. affine var. affine* is abundant where silica concentration is lowest. In this case, Jim's Pond has the lowest concentration of silica and the highest percentage abundance of *N. affine var. affine*. The p-value of 0.005 signifies a strong relationship with the r^2 value of 0.82. It is clearly noted that *N. affine var. affine* is most abundant in Jim's Pond which has the lowest pH with the highest concentration of ammonium, nitrate, and the lowest amount of silica.

Figure 24 shows that Upper Reservoir has the highest abundance of *Nitzschia sp. A* and the highest amount of SRP. The percentage abundance of this species is zero for most acidic ponds (Tamarack, Sutherland and Jim's). A relationship between percentage abundance and SRP exists. The p-value of 0.009 verifies that this correlation is significant.

Figures 25& 26 also show Upper Reservoir has the highest abundance of *Nitzschia Sp. A* and the highest amount of silica and phosphorous respectively. The p-values of 0.04 for silica and 0.009 for phosphorous verify this correlation being significant.

Figure 27 shows that Upper Reservoir has the highest abundance of *Nitzschia sp. A* and the highest amount of conductivity (109 u S/cm). There is a strong relationship between the two variables ($r^2 = 0.92$). The p-value of a 0.0007 further confirms this correlation being very significant.

Figure 28 shows that the alkaline ponds (AMR1, 2, 3, and Upper Reservoir) have the highest abundance of *Fragilaria pinnata var. pinnata*. The p-value of 0.03 further confirms the significance of this correlation.

Figure 29 shows that higher abundance of *F. pinnata var. pinnata* is found in ponds with higher SRP values. The p-value of 0.04 further indicates the correlation between two variables.

Figure 30 estimates the uncertainty of prediction for pH values. *Tabellaria fenestrata* is chosen due to its lowest probability value (0.0009). The estimated error for the predicted pH values is calculated to be 1.39. This represents the spread of distribution for the percent abundance of *Tabellaria fenestrata*.

The articles written on Adirondack Lakes reconstruct past environmental conditions and substantiate evidence for lake acidification. For BRF ponds, Figure 5 showed no systematic decrease in pH among ponds. Therefore, based on available pH values, no conclusions can be made that there is a loss of alkalinity. Studies done in Adirondack region show shifts in taxonomic composition of diatoms in the sediment, and the fish data to demonstrate that acidification has effects on aquatic biota as well as water chemistry. Dr. Carl Schofield's study provides evidence for acidification due to decline in fish population. However, conclusions can not be made on lake acidification based on the taxonomic composition of the identified diatoms.

Binford et al (1990) noted that *Tabellaria quadriseptata* is an excellent acidification indicator and has been found to increase in New England lakes. Binford et al also writes that *Asterionella ralfsii var. americana* is an important taxon in pH reconstruction, because it commonly occurs in high percentages. Both of these species were not identified in the present study. *Eunotia exigua* is commonly found in very low pH environments (Binford et al, 1990). In the present study, this species was found in all five ponds but at a very low percent abundance.

Cyclotella stelligera, the most frequently occurring taxon in Adirondack lakes, is not common in lakes with pH < 5.5. Its decline in Big Moose Lake is suggestive of an acidification trend (Binford et al, 1990). This present study identifies the diatom species of BRF ponds for the first time. There is no published evidence of the presence of *Cyclotella stelligera* in the past. This species is present at very low percent in all study ponds except Sutherland Pond.

This study did find some detectable changes of diatom assemblages among five study ponds. It is also found that some diatom assemblages do correlate with the water chemistry variables. No conclusions can be arrived at by comparing the diatom assemblages of Adirondack regions with the BRF ponds. First of all, most of the articles reconstruct past environmental conditions and substantiate their evidence by using other biological indicators such as chrysophyte, cladocera (algal microfossils) and larval chrinomids remains, in addition to diatoms. Furthermore, their study includes numerous lakes in the Adirondack region in addition to highly advanced statistical analysis of their data.

CONCLUSION

Analysis of sediment cores has given important new insights. Species of diatoms among the five study ponds have been identified for the first time. The samples for the present study were collected during winter and may not represent the condition of other seasons. Therefore, in order to get the complete picture, one must collect samples in different seasons. Furthermore, in order to see the spread of distribution of percent abundance of a diatom species, the uncertainty of prediction for all water variables still need to be calculated.

The fresh water ponds of Black Rock Forest indicate that diatom assemblages and species are related to water chemistry variables. In future, long core can be used in order to reconstruct past environmental conditions.

This study provides information that can be used in designing future studies. Data collected for this study might more accurately represent current environmental conditions if multiple water samples were taken either before or after analysis.

Research such as this serves to increase our knowledge of Black Rock Forest diatom ecology as well as providing us with a means of reconstructing past environmental conditions of this site.

ACKNOWLEDGMENTS

I wish to express my humble and profuse thanks to my mentor John Wehr, Director of Louis Calder Center- Biological Field Station of Fordham University, for teaching me how to prepare slides, identify diatoms, all the other lab techniques, and solving day to day problems. I am also grateful for his permission to use his lab. I would also express my gratitude to my advisor, Martin Stute of Barnard College for his help in the field, and his guidance throughout the year.

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I must also extend my sincere appreciation to my parents, my sisters and brother-in-laws, and friends, Mona Chin, Hanna Lieu, and Fatima Fasihuddin for their encouragement and support. This work is supported by grants from the Environmental Science Department of Barnard College and Black Rock Forest Consortium.

REFERENCES

Batterbee, R.W., Davis, R.B., Smol, J.P., Merilainen, J. (1986) Diatoms and Lake Acidity. Netherlands: Dr. W. Junk Publishers.

Batterbee, R.W., Fritz, S.C., Juggins, S. (1993) Diatom Assemblages and Ionic Characterization of Lakes of the Northern Great Plains, North America: A Tool for Reconstructing Past Salinity and Climate Fluctuations . Can. J. Fish. Aquat. Sci. 50: 1844-1856.

Barber, H.G., Haworth, E.Y. (1981) A Guide to the Morphology of the Diatom Frustule. Freshwater Biological Association Scientific Publication No. 44.

Barker, P., Druart, J., Fontes, J., Gasse, F. (1994) Experimental dissolution of diatom silica in concentrated salt solutions and implications for paleoenvironmental reconstruction. Limn.ocean. 39(1): 99-110.

Biernet, R.W., Binford, M.W., Crisman, T.L., Sweets, R. (1990) Paleoecological Investigations of Recent Lake Acidfication in Northern Florida. Journal of Paleolimnology. 4: 103-137.

Binford, M.W., Charles, D.F., Furlong, E.T., Hites, R.A., Mitchell, M.J., Norton, S.A., Oldfield, F., Paterson, M.J., Smol, J.P., Uutala, A.J., White, J.R., Whitehead, D.R., Wise, R.J. (1990) Paleoecological investigation of recent lake acidification in the Adirondack Mountains, N.Y. Journal of Paleolimnology. 3: 195-241.

Birks, H.J.B., Camburn, K.E., Charles, D.F., Cumming, B.F., Dixit, S.S., Kingston, J.C., Smol, J.P., Uutuala, A.J. (1993) Diatom assemblages from Adirondack lakes (New York, USA) and the development of inference models for retrospective environmental assessment. Journal of Paleolimnology. 8: 27-47.

Bran+Luebbe Analyzing Technologies. (1987) Nitrate/nitrite in water and seawater. Industrial method no. 818-87T. Bran+Luebbe Analyzing Technologies, Buffalo Grove, I11.

Bran+Luebbe Analyzing Technologies. (1986c) Silicas in water and wastewater. Industrial method no. 785-86T. Bran+Luebbe Analyzing Technologies, Buffalo Grove, I11.

Bran+Luebbe Analyzing Technologies. (1982) Calcium in water and wastewater. Industrial method no. 785-86T. Bran+Luebbe Analyzing Technologies, Buffalo Grove, I11.

Charles, D.F., Cumming, B.F., Dixit, S.S., Smol, J.P. (1991) Variability in diatom and chrysophyte assemblages and inferred pH: paleolimnological studies of Big Moose Lake, New York, USA. Journal of Paleolimnology. 5: 267-284.

Crawford, R.M., Mann, D.G., Round, F.E. (1990) The Diatoms. Great Britain: Cambridge University Press.

Cumming, B.F., Smol., J.P. (1993) Development of diatom-based salinity models for paleoclimatic research from lakes in British Columbia (Canada). Hydrobiologia. 269/267: 179-196.

Cumming, B.F., Smol, J.P., Wilson, S.E. (1994) Diatom-salinity relationships in 111 lakes from the Interior Plateau of British Columbia, Canada: the development of diatom-based models for paleosalinity reconstructions. Journal of Paleolimnology. 12: 197-221.

Cumming, B.F., Smol, J.P., Wilson, S.E. (1996) Assessing the reliability of salinity inference models from diatom assemblages: an examination of a 219-lake data set from western North America. Can. J. Fish. Aquat. Sci. 53: 1580-1594.

DeWolf, H., Vos, P.C. (1993) Diatoms as a tool for reconstructing sedimentary environments in coastal wetlands; methodological aspects. Hydrobiologia. 269/270: 285-296.

Dixit, S.A., Dixit, S.S., Smol, J.P. (1992) Long-Term Trends in Lake Water pH and Metal Concentrations Inferred from Diatoms and Chrysophytes in Three Lakes near Sudbury, Ontario. Can. J. Fish. Aquat.Sci. 49(Suppl. 1): 17-23.

Dixit, S.S. Kingston, J.C., Smol, J.P. (1992) Diatoms: Powerful indicators of environmental change. Environ. Sci Technol. 26(1): 23-33.

Dixit, S.S., Leavitt, P.R., Stager, J.C. (1997) Assessing Impacts of Past Human Activity on the Water Quality of Upper Saranac Lake, New York. Journal of Lake and Reservoir Management. 13(2): 175-184.

Dixit, S.S., Smol, J.P. (1990) Patterns of pH change inferred from chrysophyte microfossils in Adirondack and northern New England lakes. Journal of Paleolimnology. 4: 31-41.

Douglas, M.S.V., Smol, J.P. (1995) Periphytic Diatom Assemblages from High Arctic Ponds. J. Phycol. 31: 60-69.

Kimple, A. (1998) Personal Communication.

Krammer, K., Lange-Bertalot, H. (1988) Dinophyceaca. In Su Bwasserflora von Mitterleuropa Germany.

Krammer, K., &H. Lange-Bertalot. (1988) Bacillariophyceae. 1,2,3. In Su Bwasserflora von Mitterleuropa Bacillariophyceae, Germany.

Jensen, N.G., (1985) A translation of Hustedt's "Die Kieselalgen, S. Teil." The Pennate Diatoms. Koeltz Scientific Books, Koenigstein, Germany.

Maenza-Gmelch, T.E. (1997) Holocene vegetation, climate, and fire history of the Hudson Highlands, southeastern New York, USA. The Holocene 7.1: 25-37.

McMinn, A., Roberts, D. (1996) Relationships between surface sediment diatom assemblages and water chemistry gradients in saline lakes of the Vestfold Hills, Antarctica. Antarctic Science. 8(4): 331-341.

Morgon, J.J., Stumm, W. (1996) Aquatic Chemistry. Canada: John Wiley & Sons, Inc.

Patrick, R.., & C. Reimer. (1966) The diatoms of the United States exclusive of Alaska and Hawaii. Vol 1. The Academy of Natural Sciences of Philadelphia, Philadelphia. Monograph 13: 1-668.

Patrick, R.., & C. Reimer. (1975) The diatoms of the United States exclusive of Alaska and Hawaii. Vol 2. Part 1. The Academy of Natural Sciences of Philadelphia, Philadelphia. Monograph 13: 1-213.

Smol, J.P. (1983). Paleophycology of a high arctic lake near Cape Herschel, Ellesmere Island. Can. J. Bot. 61: 2195-2204.

Tyson, P. (1992) Acid Rain. NY: Chelsea House Publishers.

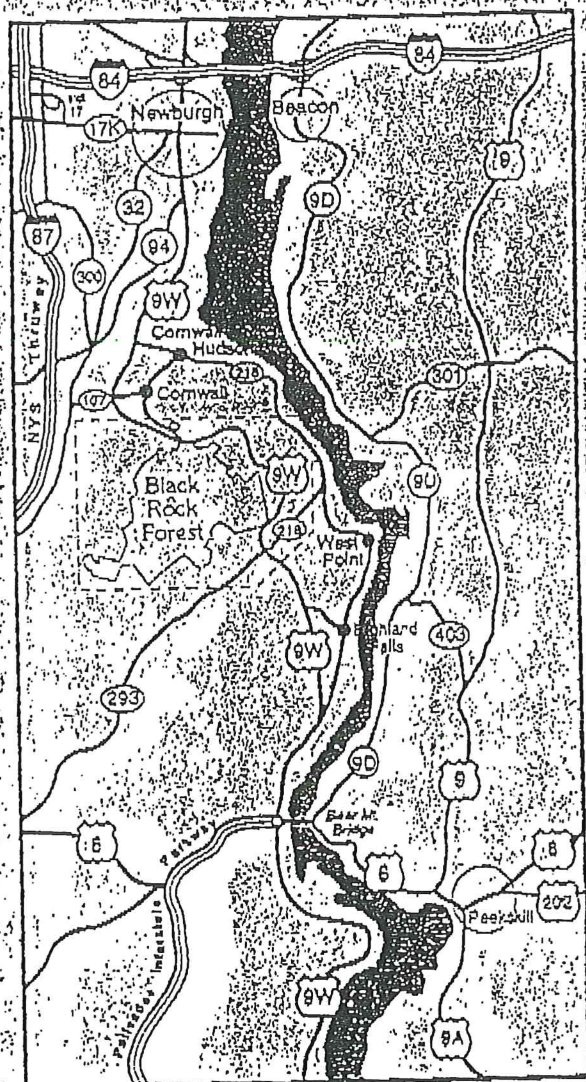
Rhodes, T.E., (1991) A Paleolimnological record of anthropogenic disturbances at Holmes Lake, Adirondack Mountains, New York. Journal of Palelimnology. 5: 255-261.

Encyclopedia Americana. (1994) Vol 11. P. 582-588.

APPENDIX A

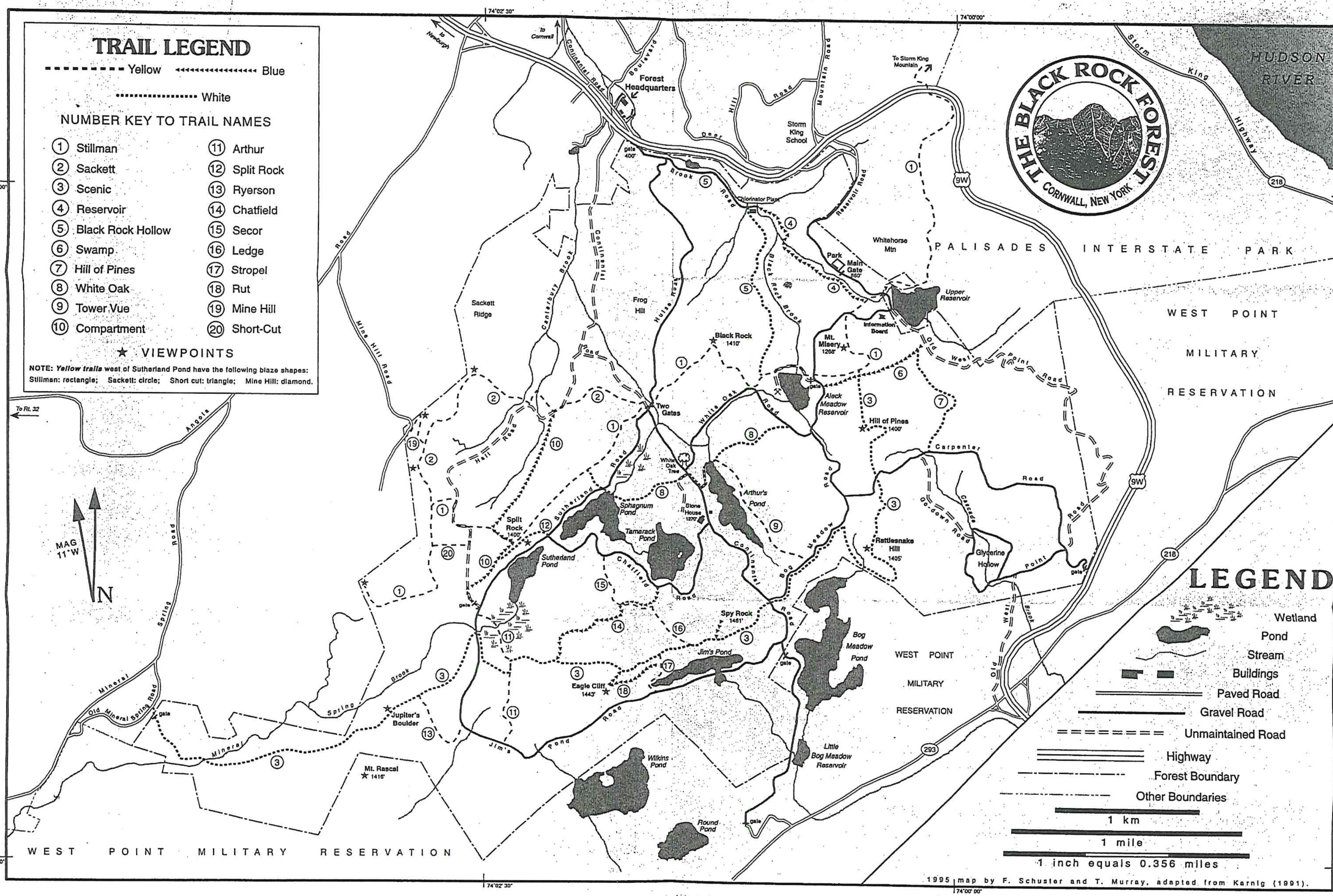
BRF Index Map

Black Rock Forest
Index Map



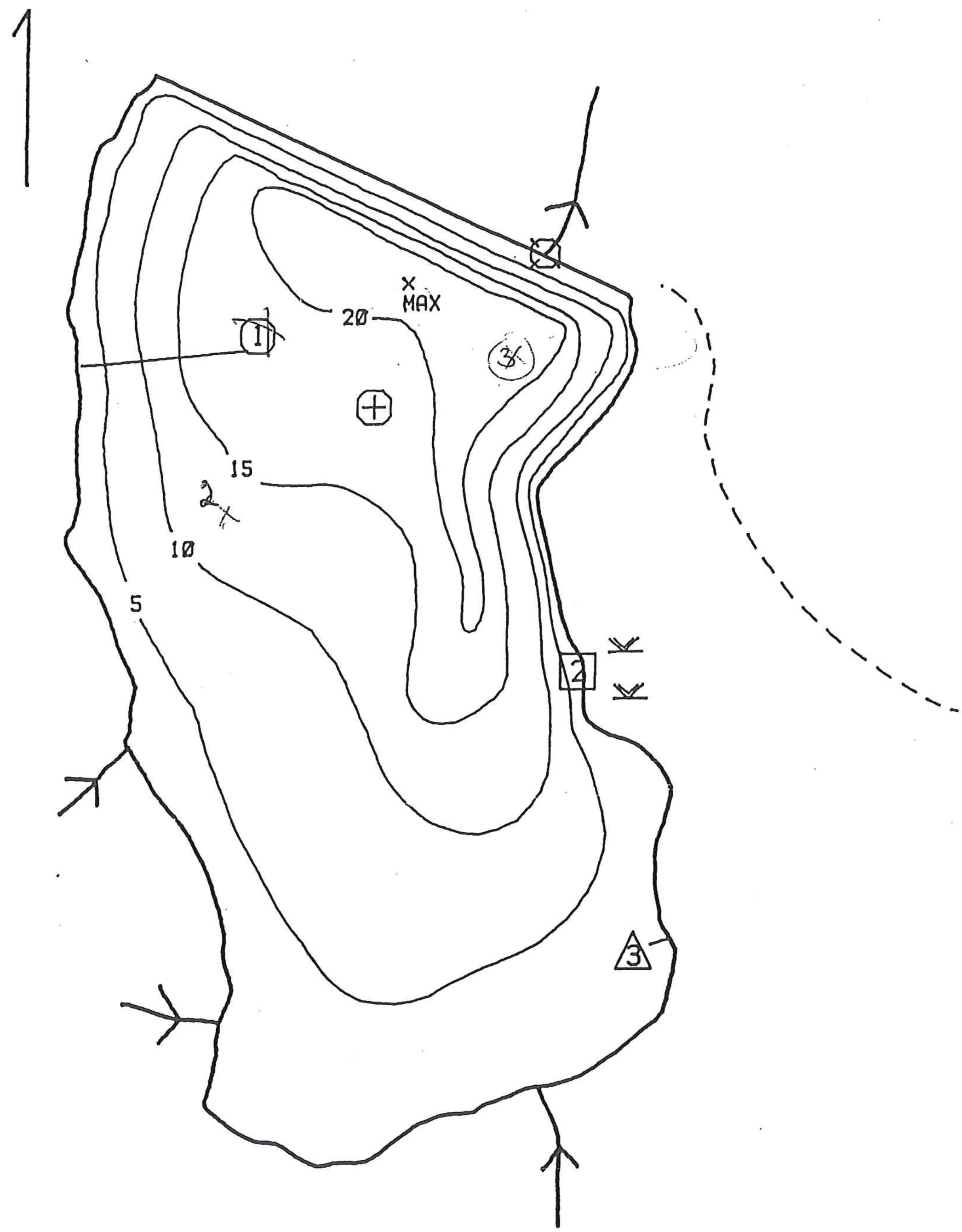
APPENDIX B

BRF Map with All the Ponds


THE BLACK ROCK FOREST
CORNWALL, NEW YORK
TRAIL LEGEND
Yellow
Blue
White
NUMBER KEY TO TRAIL NAMES
1 Stillman
2 Sackett
3 Scenic
4 Reservoir
5 Black Rock Hollow
6 Swamp
7 Hill of Pines
8 White Oak
9 Tower Vue
10 Compartment
11 Arthur
12 Split Rock
13 Ryerson
14 Chatfield
15 Secor
16 Ledge
17 Stropel
18 Rut
19 Mine Hill
20 Short-Cut
★ VIEWPOINTS
NOTE: Yellow trails west of Sutherland Pond have the following blaze shapes: Stillman: rectangle; Sackett: circle; Short cut: triangle; Mine Hill: diamond.
LEGEND
Wetland
Pond
Stream
Buildings
Paved Road
Gravel Road
Unmaintained Road
Highway
Forest Boundary
Other Boundaries
1 km
1 mile
1 inch equals 0.356 miles
1995 map by F. Schuster and T. Murray, adapted from Karnig (1991).
HUDSON RIVER
Storm King Highway
PALISADES INTERSTATE PARK
WEST POINT MILITARY RESERVATION
Forest Headquarters
Storm King School
Whitehorse Mtn
Upper Reservoir
Park Main Gate
Information Board
Mt. Misery 1268'
Black Rock 1410'
Hill of Pines 1400'
Aleck Meadow Reservoir
Two Gates
Frog Hill
Sackett Ridge
White Oak Tree
Arthur's Pond
Stone House
Sphagnum Pond
Tamarack Pond
Split Rock 1400'
Sutherland Pond
Spy Rock 1461'
Jim's Pond
Eagle Cliff 1443'
Rattlesnake Hill 1405'
Glycerine Hollow
Bog Meadow Pond
Little Bog Meadow Reservoir
Wilkins Pond
Round Pond
Jupiter's Boulder
Mt. Rascal 1416'
Chlorinator Plant
To Storm King Mountain
to Cornwall
to Newburgh
To Rt. 32
MAG 11°W
N
Continental Road
Mountain Road
Reservoir Road
Hulse Road
Hall Road
Mine Hill Road
Spring Road
Old Mineral Spring Road
Mineral Spring Brook
Angola Road
Carpenter Road
Go-down Road
Old West Point Road
Jim's Pond Road
Bog Meadow Road
White Oak Road
Chatfield Road
Sutherland Road
Black Rock Brook
Canterbury Brook
41°25'00"
41°22'30"
74°02'30"
74°00'00"

APPENDIX C

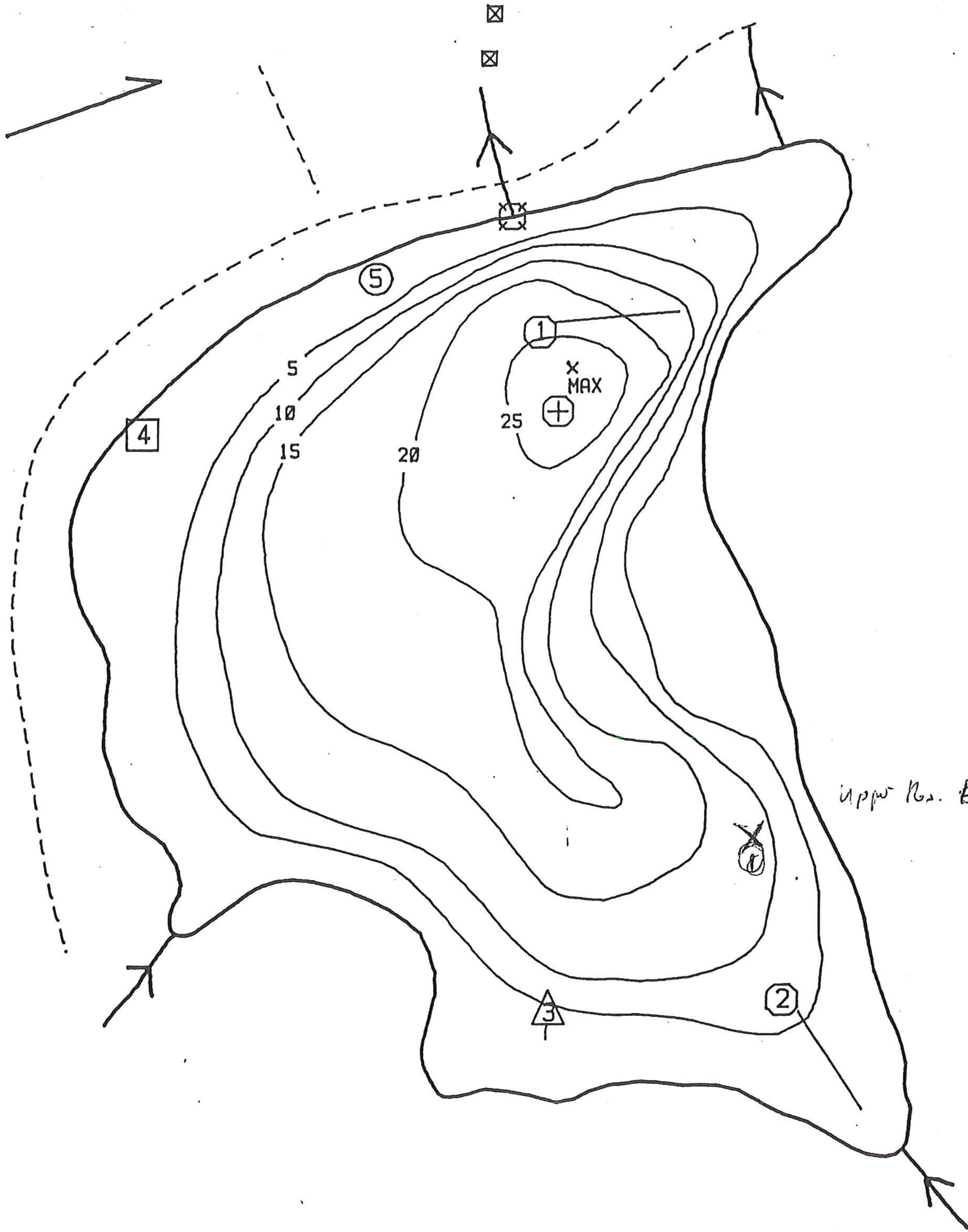
Individual Maps of the Study Ponds



ALECK MEADOW RESERVOIR
13-Ø222D
ALSC 5/14/87
CONTOUR INTERVAL: 5 FT
SURFACE AREA: 7 ACRES
MAXIMUM DEPTH: 22 FT

150'
MARSH/WETLAND
ROAD/TRAIL
CONTROLLABLE DAM

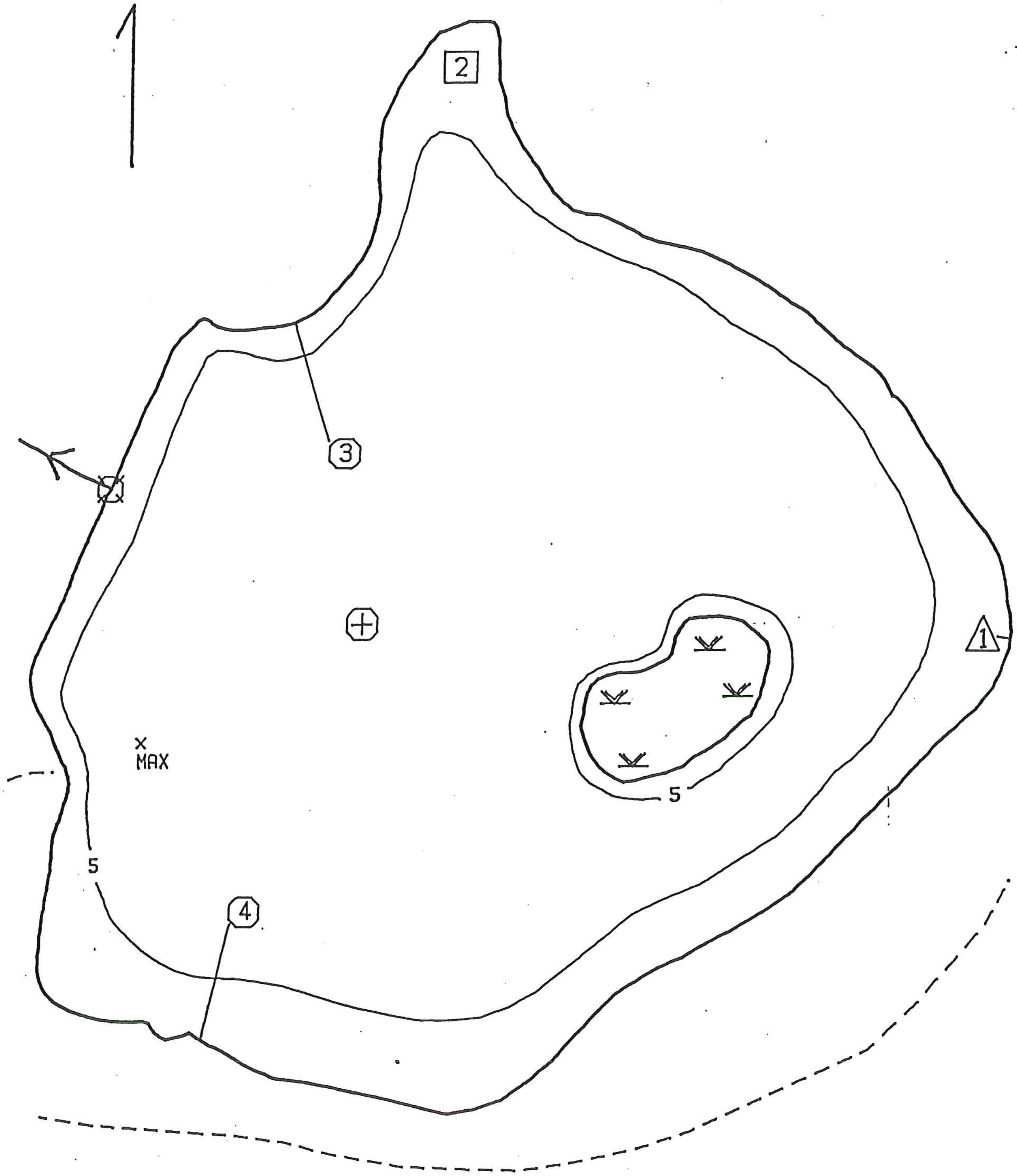
5/14/87
WATER CHEMISTRY
15Ø FT GILL NET
3Ø FT MINNOW NET
MINNOW TRAP



UPPER RESERVOIR
13-Ø223
ALSC 6/2/87
CONTOUR INTERVAL: 5 FT
SURFACE AREA: 15 ACRES
MAXIMUM DEPTH: 27 FT

175'
DWELLING
ROAD/TRAIL
CONTROLLABLE DAM

6/2/87
WATER CHEMISTRY
15Ø FT GILL NET
3Ø FT MINNOW NET
MINNOW TRAP
BEACH SEINE



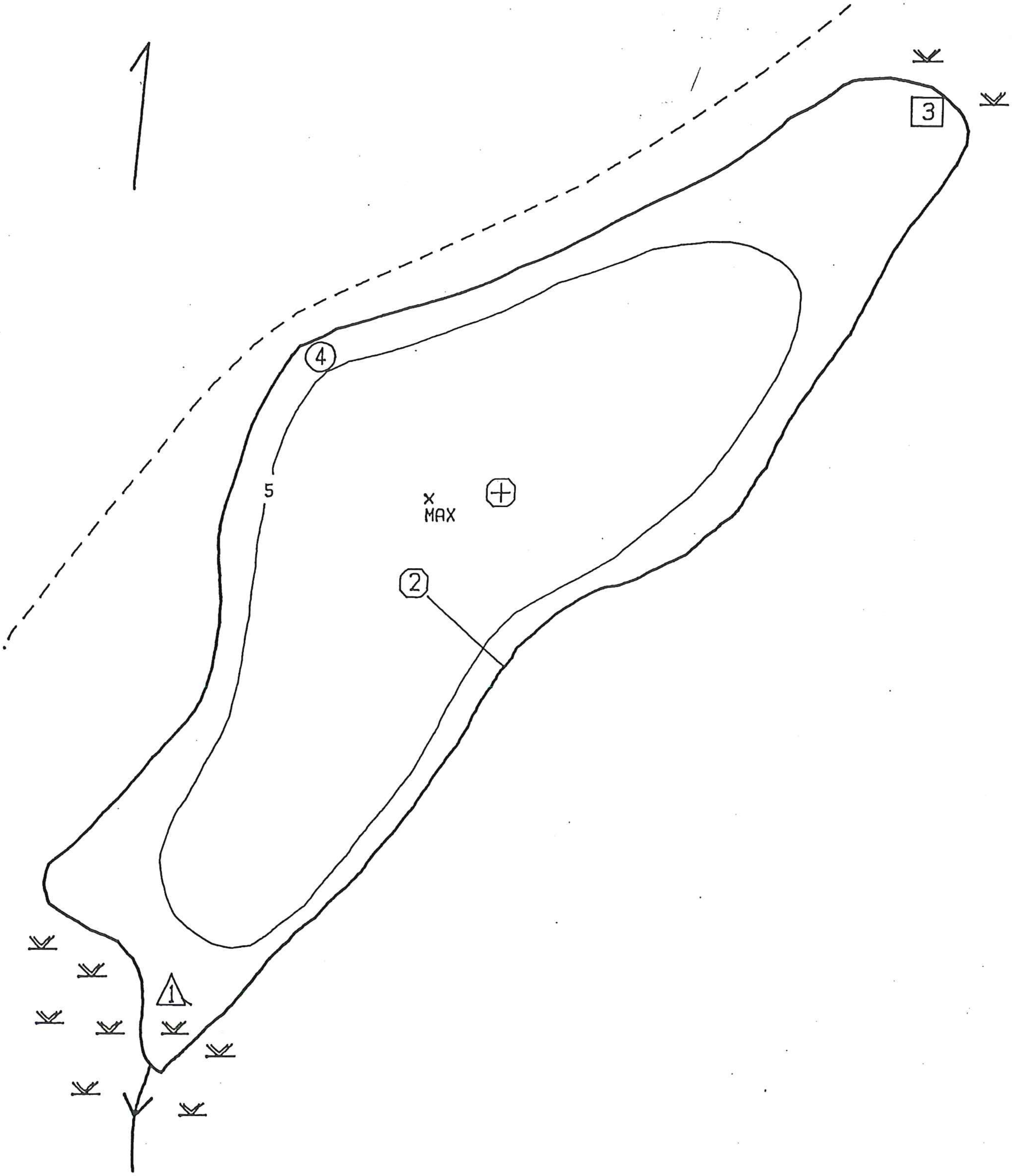
TAMARACK POND
13-Ø222G
ALSC 5/13/87
CONTOUR INTERVAL: 5 FT
SURFACE AREA: 18 ACRES
MAXIMUM DEPTH: 7 FT

175'
MARSH/WETLAND
ROAD/TRAIL
CONTROLLABLE DAM

5/13/87
WATER CHEMISTRY
15Ø FT GILL NET
3Ø FT MINNOW NET
MINNOW TRAP

63

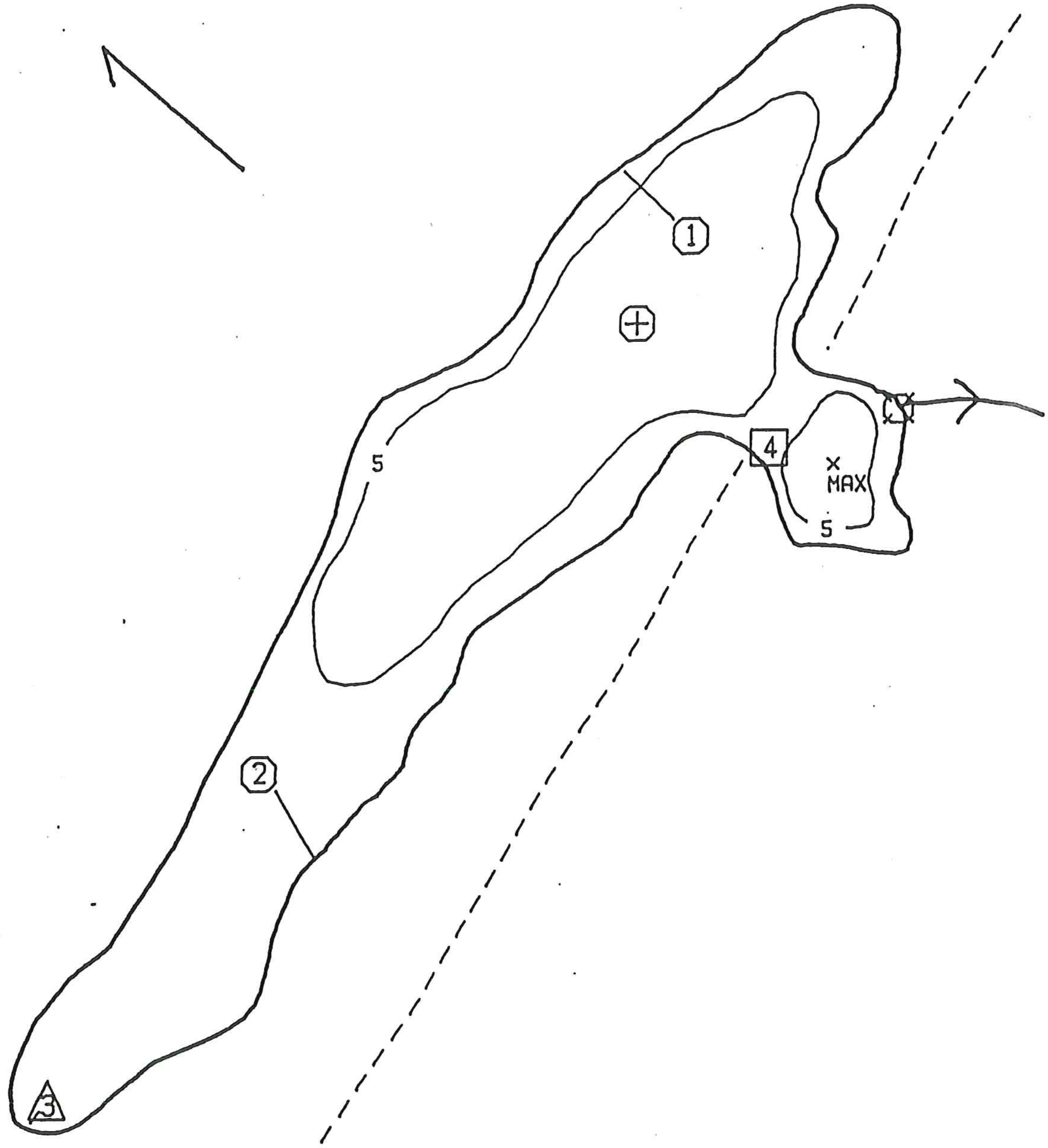
1



SUTHERLAND POND
13-Ø228
ALSC 4/23/87
CONTOUR INTERVAL: 5 FT
SURFACE AREA: 1Ø ACRES
MAXIMUM DEPTH: 8 FT

175'
MARSH/WETLAND
-- ROAD/TRAIL

4/23/87
WATER CHEMISTRY
15Ø FT GILL NET
3Ø FT MINNOW NET
MINNOW TRAP
BEACH SEINE



JIM'S POND
13-Ø199B
ALSC 5/13/87
CONTOUR INTERVAL: 5 FT
SURFACE AREA: 14 ACRES
MAXIMUM DEPTH: 7 FT

275'
-- ROAD/TRAIL
CONTROLLABLE DAM

5/13/87
WATER CHEMISTRY
15Ø FT GILL NET
3Ø FT MINNOW NET
MINNOW TRAP

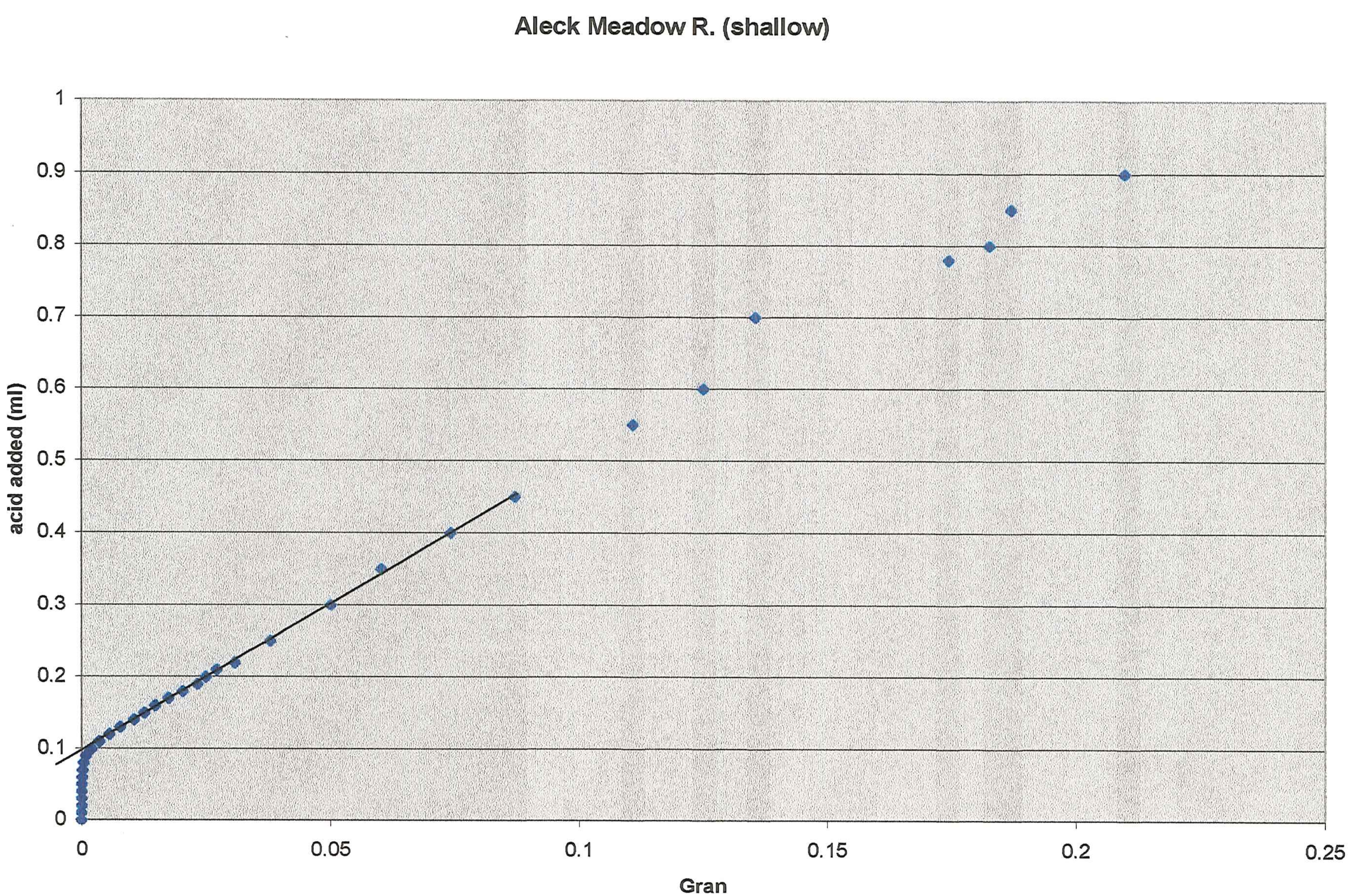
65

APPENDIX D

Alkalinity Values and Graphs for the Study Ponds

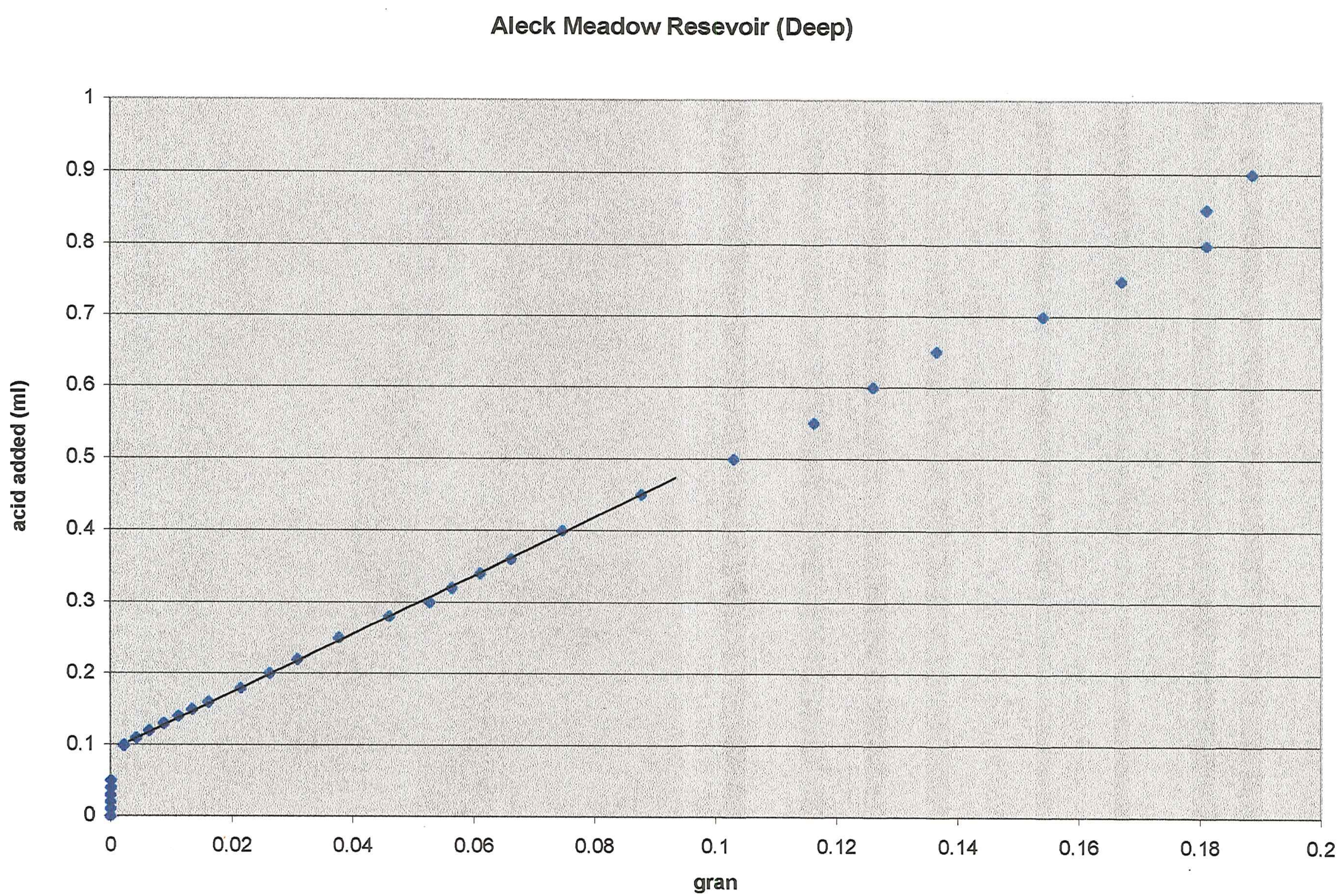
AM (Shallow)							
	mV	pH	Gran	acid added	182		
				(ml)	Aleck Meadow	0.1 Normal HCl	
	3	6.85	2.57082E-05	0			
	11	6.710901	3.54156E-05	0.01			
	21	6.537027	5.28557E-05	0.02			
	29	6.397928	7.2814E-05	0.03			
	37	6.258829	0.000100309	0.04			
	46	6.102342	0.00014383	0.05			
	55	5.95	0.000204275	0.06			
	66	5.754595	0.000320364	0.07			
	78	5.54	0.000525124	0.08			
	93	5.285135	0.000944389	0.09			
	113	4.937387	0.002103403	0.1			
	127	4.693964	0.003684426	0.11			
	138	4.502703	0.005723411	0.12			
	146	4.363604	0.007884568	0.13			
	154	4.23	0.010725198	0.14			
	158	4.154955	0.012748944	0.15			
	162	4.085405	0.014963997	0.16			
	166	4.015856	0.017563902	0.17			
	169	3.95	0.020440932	0.18			
	172	3.89	0.023470619	0.19			
	175	3.86	0.025150601	0.2			
	177	3.824595	0.027288371	0.21			
	179	3.77	0.030945396	0.22			
	184	3.68	0.038077422	0.25			
	192	3.56	0.050209589	0.3			
	197	3.48	0.06038176	0.35			
	202	3.38991	0.074321578	0.4			
	206	3.32036	0.087253631	0.45			
	212	3.216036	0.111005833	0.55			
	215	3.163874	0.125206507	0.6			
	217	3.129099	0.135718624	0.7			
	219	3.02	0.174553545	0.78			
	222	3	0.1828	0.8			
	225	2.99	0.187109124	0.85			
	227	2.94	0.209997297	0.9			
	ph calibration		fit of gran function				
	3	6.85					
	225	2.99					
	slope	intercept					
	-0.01739	6.902162	4.070973103	0.097213	slope	intercept	
			0.026980612	0.001066	SE slope	SE intercept	
			0.999385434	0.002544	r2	SE of estimate	
			22766.32114	14			
			alkalinity	0.053414	meq/l		
			+/-	0.000586	meq/l		

				1.096249	%		

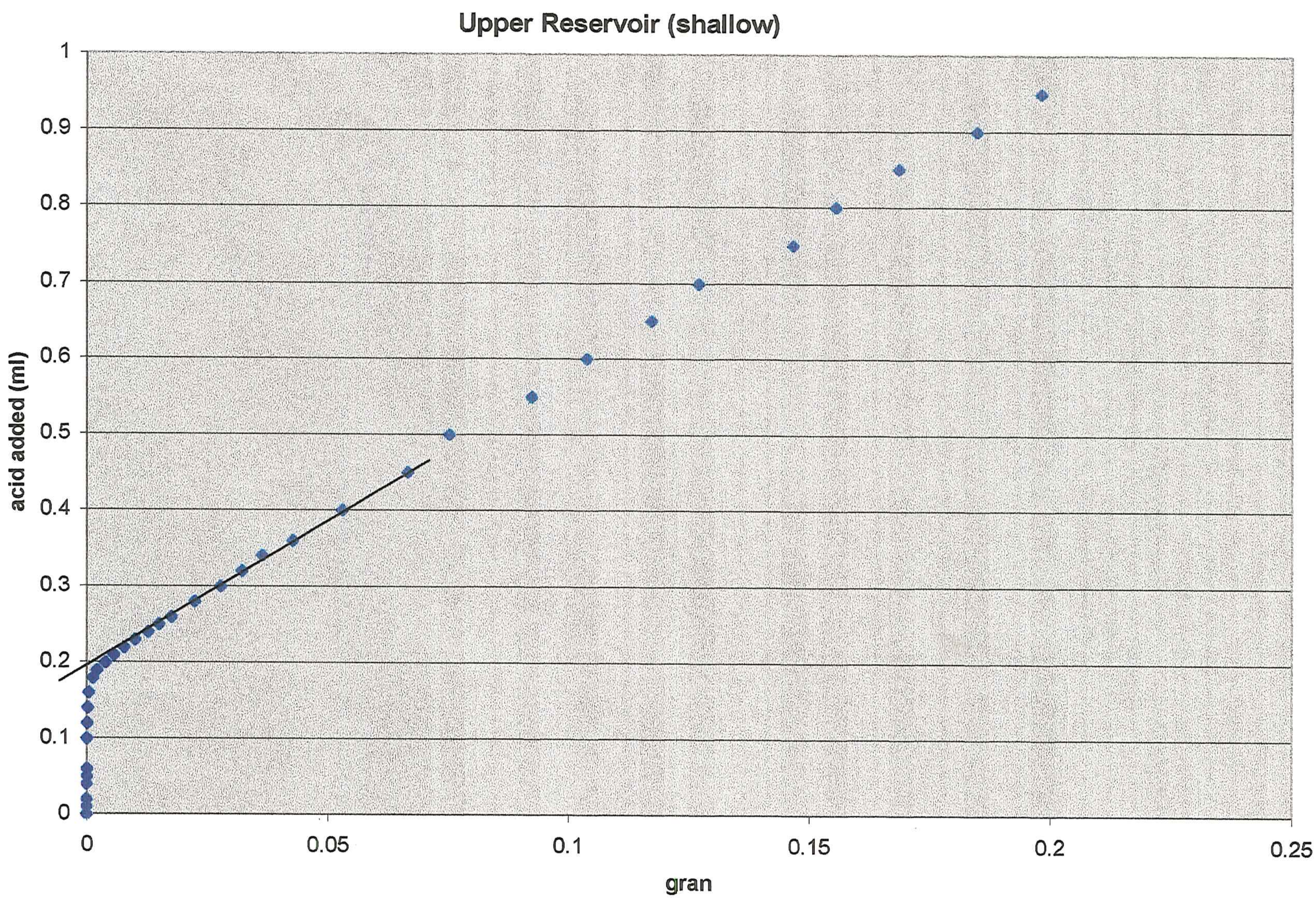


Aleck Meadow R. (shallow)
acid added (ml)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.05
0.1
0.15
0.2
0.25
Gran

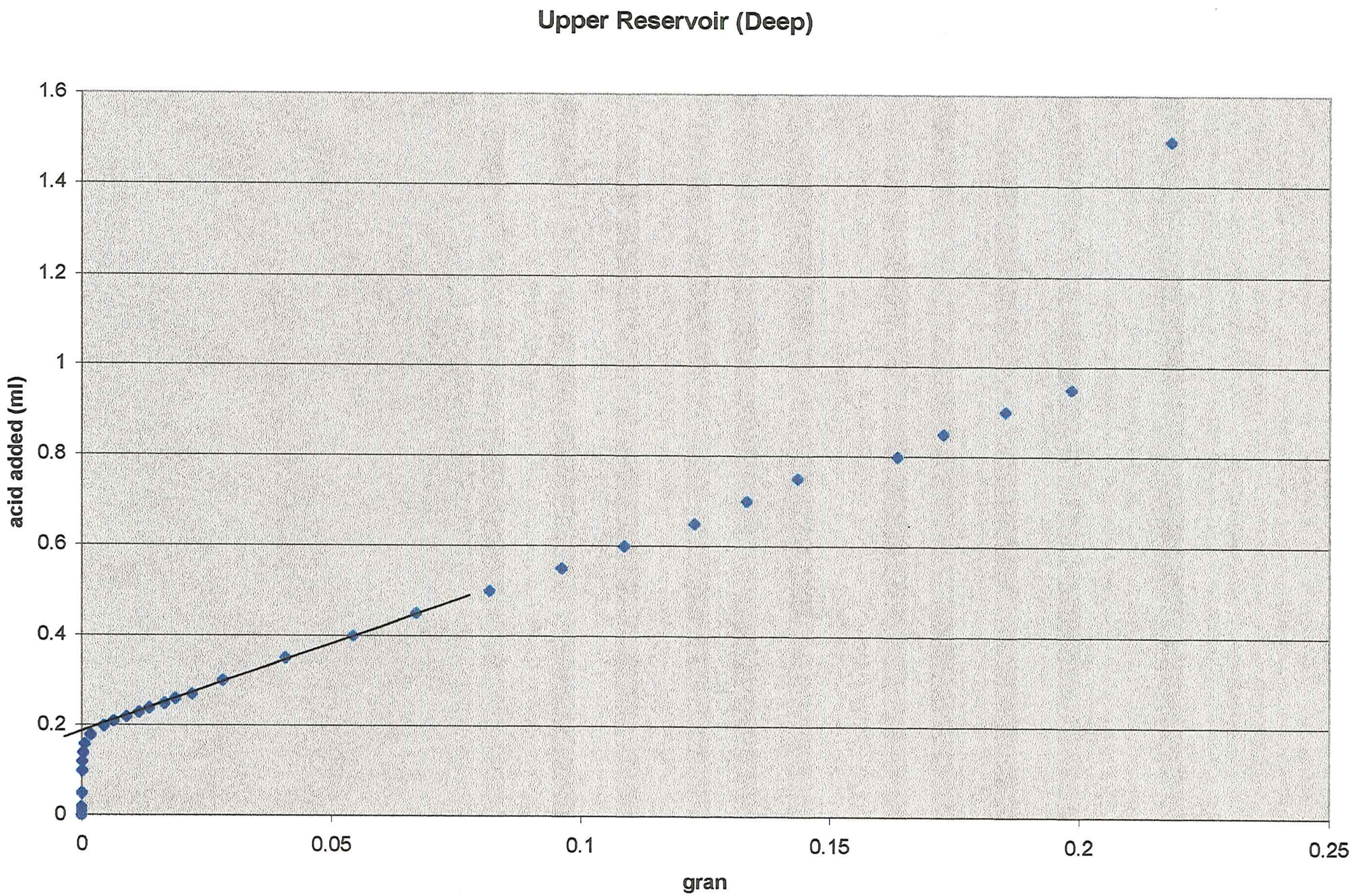
AM (deep)				182.9			
	mV	pH	Gran	V			
	21	6.56	5.03748E-05	0			
	24	6.507737	5.68199E-05	0.01			
	30	6.403211	7.22854E-05	0.02			
	36	6.298684	9.19604E-05	0.03			
	44	6.159316	0.000126763	0.04			
	49	6.072211	0.000154925	0.05			
	117	4.887579	0.002370676	0.1			
	131	4.62	0.004390104	0.11			
	142	4.452053	0.006463175	0.12			
	150	4.312684	0.008909187	0.13			
	156	4.208158	0.011334128	0.14			
	161	4.13	0.013569684	0.15			
	165	4.051368	0.016263913	0.16			
	172	3.929421	0.021538718	0.18			
	177	3.842316	0.026325253	0.2			
	181	3.772632	0.03091037	0.22			
	186	3.685526	0.037781623	0.25			
	191	3.598421	0.046180327	0.28			
	194	3.54	0.052835457	0.3			
	196	3.511316	0.056449109	0.32			
	198	3.476474	0.061171143	0.34			
	200	3.441632	0.066288181	0.36			
	203	3.389368	0.074781478	0.4			
	207	3.319684	0.087820661	0.45			
	211	3.25	0.103133399	0.5			
	214	3.197737	0.116353881	0.55			
	216	3.162895	0.126107621	0.6			
	218	3.128053	0.136678989	0.65			
	221	3.075789	0.154199584	0.7			
	223	3.040947	0.167125825	0.75			
	225	3.006105	0.181135633	0.8			
	225	3.006105	0.181184935	0.85			
	226	2.988684	0.188651949	0.9			
	ph calibration		fit of Gran function				
	21	6.56					
	211	3.25	4.034860536	0.093997	slope	intercept	
	slope	intercept	0.026291322	0.001208	SE slope	SE intercept	
	-0.01742	6.925842	0.99940593	0.002612	r2	SE of estimate	
			23552.23986	14			
			alkalinity	0.051392	meq/l		
			+/-	0.000661	meq/l		
				1.285381	%		


Aleck Meadow Resevoir (Deep)
acid added (ml)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
gran

UR (shallow)				184			
	mV	pH	Gran	V			
	11	6.74	3.34825E-05	0			
	10	6.757454	3.21653E-05	0.01			
	13	6.705093	3.62888E-05	0.02			
	17	6.635278	4.26221E-05	0.04			
	24	6.513102	5.64721E-05	0.05			
	27	6.460741	6.37116E-05	0.06			
	46	6.12912	0.000136752	0.1			
	55	5.972037	0.000196365	0.12			
	68	5.745139	0.000331138	0.14			
	82	5.500787	0.000581311	0.16			
	103	5.134259	0.00135202	0.18			
	116	4.907361	0.002279843	0.19			
	130	4.66	0.004029857	0.2			
	139	4.505926	0.005746287	0.21			
	147	4.366296	0.007925752	0.22			
	153	4.261574	0.010087563	0.23			
	159	4.156852	0.012839026	0.24			
	163	4.087037	0.015078928	0.25			
	167	4.017222	0.017709604	0.26			
	173	3.9125	0.022541261	0.28			
	178	3.82	0.027894934	0.3			
	182	3.755417	0.032370976	0.32			
	185	3.703056	0.036522797	0.34			
	189	3.633241	0.042896905	0.36			
	194	3.54	0.053181541	0.4			
	200	3.44125	0.06677727	0.45			
	203	3.388889	0.075354203	0.5			
	208	3.3	0.092494104	0.55			
	211	3.249259	0.103985417	0.6			
	214	3.196898	0.117341373	0.65			
	216	3.161991	0.127196791	0.7			
	219	3.1	0.146752141	0.75			
	221	3.074722	0.155589306	0.8			
	223	3.039815	0.168657104	0.85			
	225	3	0.1849	0.9			
	227	2.97	0.198177496	0.95			
	ph calibration		fit of gran function				
	11	6.74					
	227	2.97	4.029764357	0.188672	slope	intercept	
	slope	intercept	0.049101195	0.001894	SE slope	SE intercept	
	-0.01745	6.931991	0.998369545	0.003707	r2	SE of estimate	
			6735.582904	11			
			alkalinity	0.102539	meq/l		
			+/-	0.001029	meq/l		
				1.003897	%		


Upper Reservoir (shallow)
acid added (ml)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.05
0.1
0.15
0.2
0.25
gran

UR (Deep)				180.1			
	mV	pH	Gran	V			
	14	6.7	3.59347E-05	0			
	13	6.717664	3.45044E-05	0.01			
	14	6.7	3.59387E-05	0.02			
	27	6.470374	6.09903E-05	0.05			
	48	6.07	0.000153375	0.1			
	58	5.922804	0.000215278	0.12			
	70	5.710841	0.00035076	0.14			
	86	5.428224	0.000672473	0.16			
	110	4.99	0.001844793	0.18			
	133	4.598037	0.004549444	0.2			
	142	4.44	0.00654666	0.21			
	150	4.297757	0.009084204	0.22			
	156	4.191776	0.011595575	0.23			
	160	4.121121	0.013644907	0.24			
	165	4.032804	0.016722931	0.25			
	168	3.98	0.01888601	0.26			
	172	3.909159	0.022233377	0.27			
	178	3.803178	0.028383044	0.3			
	187	3.644206	0.040940324	0.35			
	194	3.520561	0.054439792	0.4			
	200	3.43	0.067080686	0.45			
	204	3.343925	0.081807385	0.5			
	208	3.273271	0.096286841	0.55			
	211	3.22028	0.108812247	0.6			
	214	3.16729	0.122967002	0.65			
	216	3.131963	0.133424569	0.7			
	219	3.1	0.143654261	0.75			
	221	3.043645	0.163603921	0.8			
	223	3.02	0.172805908	0.85			
	225	2.99	0.185216032	0.9			
	227	2.96	0.198517377	0.95			
	228	2.92	0.218331221	1.5			
	ph calibration		fit of gran function				
	14	6.7					
	228	2.92	3.896581655	0.186223	slope	intercept	
	slope	intercept	0.037443633	0.001522	SE slope	SE intercept	
	-0.01766	6.94729	0.999169633	0.002918	r2	SE of estimate	
			10829.57947	9			
			alkalinity	0.1034	meq/l		
			+/-	0.000845	meq/l		
				0.817227	%		



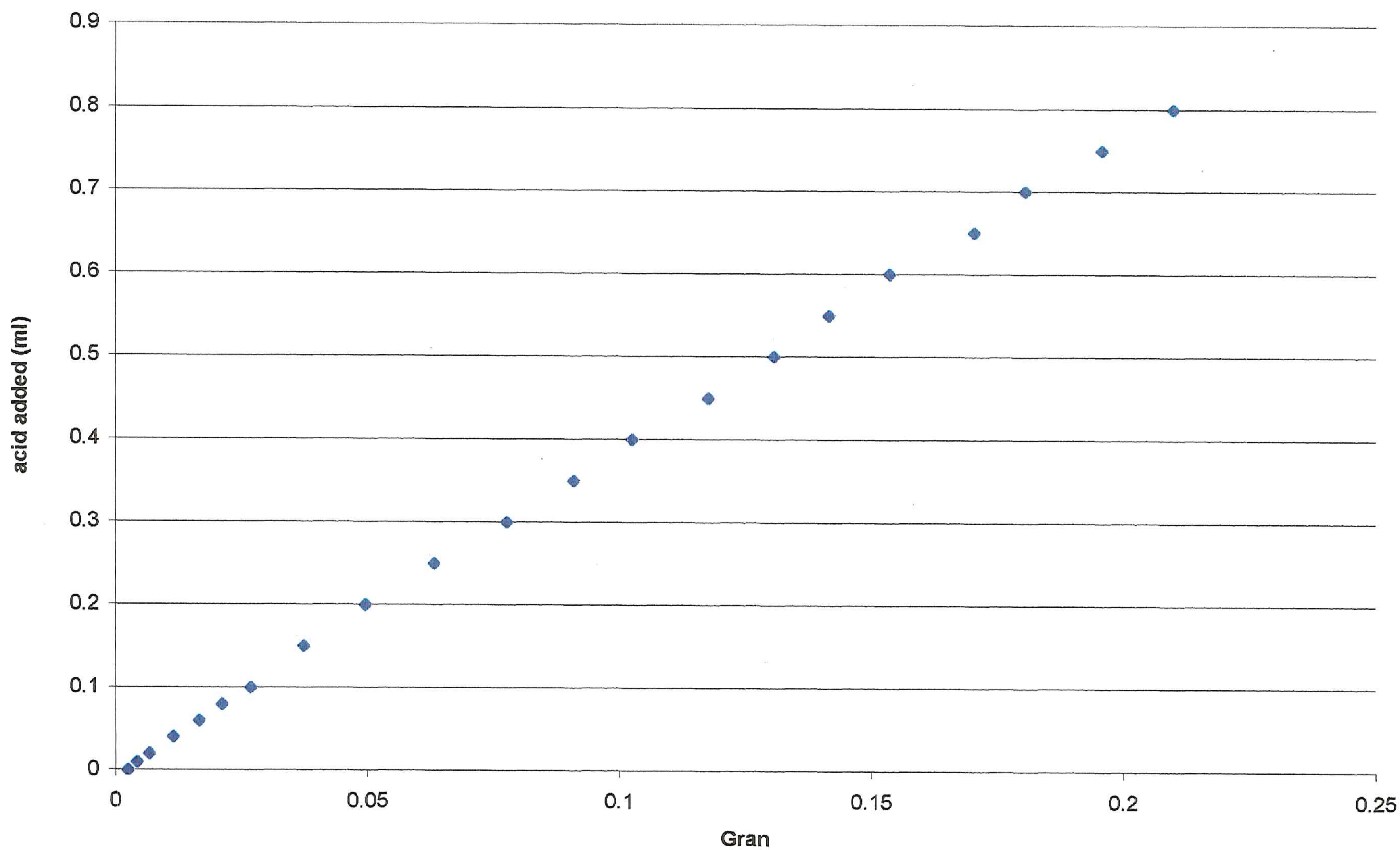
Upper Reservoir (Deep)
acid added (ml)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.05
0.1
0.15
0.2
0.25
gran

75

TP (shallow)				184.5
			x	y
	mV	pH	Gran	V
	115	4.93	0.002168	0
	131	4.64823	0.004148	0.01
	142	4.454513	0.006479	0.02
	150	4.313628	0.008963	0.03
	156	4.207965	0.011432	0.04
	161	4.119912	0.014002	0.05
	165	4.049469	0.016469	0.06
	172	3.926195	0.021877	0.08
	177	3.838142	0.026797	0.1
	181	3.767699	0.03152	0.12
	185	3.697257	0.037074	0.14
	188	3.56	0.05086	0.16
	194	3.538761	0.05342	0.2
	197	3.485929	0.060337	0.22
	200	3.433097	0.068157	0.26
	204	3.362655	0.080177	0.3
	208	3.292212	0.094321	0.35
	211	3.26	0.10161	0.4
	214	3.186549	0.120367	0.45
	217	3.15	0.13097	0.5
	219	3.098496	0.147501	0.55
	222	3.04	0.168813	0.6
	223	3.028053	0.173568	0.65
	225	3	0.1852	0.7
	227	2.97	0.198499	0.75
	228	2.94	0.212753	0.8
	ph calibration			
	115	4.93		
	228	2.94		
	-0.01761	6.955221		
	slope	intercept		
	-0.01761	6.955221		

JP (shallow)							
	mV	pH	Gran	V		.2 Normal HCl	182
	118	4.84	0.002631	0			
	131	4.612804	0.004439	0.01			
	142	4.420561	0.006911	0.02			
	155	4.193364	0.011663	0.04			
	164	4.036075	0.016755	0.06			
	170	3.931215	0.021333	0.08			
	175	3.83	0.026935	0.1			
	184	3.686542	0.037488	0.15			
	191	3.564206	0.049698	0.2			
	197	3.459346	0.063288	0.25			
	202	3.37	0.077765	0.3			
	206	3.302056	0.09096	0.35			
	209	3.249626	0.102659	0.4			
	212	3.19	0.1178	0.45			
	215	3.144766	0.130767	0.5			
	217	3.109813	0.141765	0.55			
	219	3.07486	0.153688	0.6			
	221	3.03	0.170459	0.65			
	223	3.004953	0.180628	0.7			
	225	2.97	0.19582	0.75			
	227	2.94	0.209882	0.8			
	ph calibration						
	118	4.84					
	225	2.97					
	slope	intercept					
	-0.01748	6.902243					

Jim's Pond (shallow)



APPENDIX E

List of Diatom Species Found in the Surficial Sediments of the Study Ponds

Species	AMR1 0-1 cm 10%	AMR2 0-1 cm 20%	AMR3 0-1 cm 10%	UR 0-1 cm 20%	SP 0-2 cm 20%	JP 0-2 cm 10%	TP 0-2 cm 10%
Achnanthes minutissima	X	X	X	X	X	X	X
Achnanthes saxonica	X				X	X	
Achnanthes stewartii	X						
Anomoeneis serians	X				X		
Anomoeneis vitrea				X	X	X	
Cymbella lunata	X	X	X		X		
Cocconeis plancentula var. lineata	X			X		X	
Cyclotella antiqua	X						
Cyclotella cyclopuncta	X						
Cyclotella stelligera	X	X	X		X	X	
Cymbella minuta	X			X			
Diatoma vulgare var. vugare	X			X			
Diploneis cf. petersinni /marginestriata or oculata	X						
Epithemia sorex	X			X			
Eunotia flexuosa						X	
Eunotia formica							X
Eunotia pectinalis	X	X	X		X	X	
Eunotia sudetica					X	X	X
Eunotia tenella					X		
Eunotia cf. vanheurckii	X			X	X	X	X
Eunotia. Exigua	X	X	X	X	X	X	X
Eunotia perpusilla	X						
Eunotia. Incisa var. incisa	X						
Eunotia. Serra var.diadema		X	X	X			
Fragilaria constricta	X	X	X	X		X	
Fragilaria pinnata var. pinnata	X	X	X	X			
Frustulia rhomboides	X					X	
Frustulia rhomboides var. capitata	X	X	X		X	X	X
Gomphonema acuminatum	X		X	X			

Gomphonema truncatum var. capitatum							
Gomphonema gracile					X		
Gomphonema trucatum var. turgidum	X			X			
Melosira. italica	X		X				
Melosira granulata	X		X		X	X	X
Meridion circulare var. constrictum	X						
Navicula bacillum	X	X			X		
Navicula cuspidata var. cuspidata	X						
Navicula explanata	X	X	X	X	X	X	
Navicula radiosa	X				X	X	
Neidium affine var. affine	X	X	X		X	X	X
Nitzschia sp A	X			X			
Nitzschia sp B	X						
Nitzschia sp C					X		
Pinnularia acuminata				X			
Pinnularia acuminata var. instabilis (P. hemiptera)	X						
Pinnularia. biceps	X			X	X		X
Pinnularia brevicostrata var. brevicostrata	X	X	X	X		X	
Pinnularia abaujensis	X	X	X	X	X		
Pinnularia braunii							X
Pinnularia cf. boyeri	X						
Pinnularia hilseana						X	X
Pinnularia maior var. maior	X				X	X	
Pinnularia sp (borealis)					X		
Surirella brebissonnii		X					
Synedra. Delicatissima		X		X	X		
Stauroneis phonicenteron	X	X	X		X	X	
S. rumpens			X	X	X		

Stauroneis anceps var. anceps	X						
Stauroneis phonicenteron f. gracilis				X			
Surirella ovalis	X	X		X	X		X
Surirella striatula	X						
Synedra ulna	X						
Tabellaria flocculosa	X	X	X	X	X	X	X
Tabellaria. Fenestrata	X	X	X	X	X	X	X

APPENDIX F

Diatom Counts and their Percent Abundance

Species	AMR1 0-1 cm 10%	0.0023	g sed used
No. of grids	76	100144	grid ratio
Date of counts	3/17/99	# cells/g sed	%abund
Achnanthes minutissima	8	1.32E+10	2.4
Achnanthes saxonica	5	8.27E+09	1.5
Achnanthes stewartii	1	1.65E+09	0.3
Anomoeneis serians	2	3.31E+09	0.6
Anomoeneis vitrea		0.00E+00	0.0
Cymbella lunata	3	4.96E+09	0.9
Cocconeis plancentula var. lineata	2	3.31E+09	0.6
Cyclotella antiqua	4	6.62E+09	1.2
Cyclotella cyclopuncta	5	8.27E+09	1.5
Cyclotella stelligera	11	1.82E+10	3.3
Cymbella minuta	11	1.82E+10	3.3
Diatoma vulgare var. vugare	5	8.27E+09	1.5
Diploneis cf petersinni /marginestriata or oculata	3	4.96E+09	0.9
Epithemia sorex	3	4.96E+09	0.9
Eunotia flexuosa		0.00E+00	0.0
Eunotia formica		0.00E+00	0.0
Eunotia pectinalis	10	1.65E+10	3.0
Eunotia sudetica		0.00E+00	0.0
Eunotia tenella		0.00E+00	0.0
Eunotia cf vanheurckii	9	1.49E+10	2.7
Eunotia exigua	10	1.65E+10	3.0
Eunotia perpusilla	2	3.31E+09	0.6
Eunotia incisa var. incisa		0.00E+00	0.0
Eunotia serra var.diadema	4	6.62E+09	1.2
Fragilaria constricta		0.00E+00	0.0
Fragilaria pinnata var. pinnata	5	8.27E+09	1.5
Frustulia rhomboides	6	9.93E+09	1.8
Frustulia rhomboides var. capitata	4	6.62E+09	1.2
Gomphonema acuminatum	3	4.96E+09	0.9
Gomphonema truncatum var. capitatum		0.00E+00	0.0
Gomphonema gracile	3	4.96E+09	0.9
Gomphonema trucatum var. turgidum	5	8.27E+09	1.5
Melosira. italica	5	8.27E+09	1.5
Melosira granulata	10	1.65E+10	3.0
Meridion circulare var. constrictum	3	4.96E+09	0.9
Navicula bacillum	5	8.27E+09	1.5
Navicula cuspidata var. cuspidata	1	1.65E+09	0.3
Navicula explanata	15	2.48E+10	4.5
Navicula radiosa	18	2.98E+10	5.4
Neidium affine var. affine	5	8.27E+09	1.5
Nitzschia sp A	3	4.96E+09	0.9
Nitzschia sp B	1	1.65E+09	0.3
Nitzschia sp C		0.00E+00	0.0
Pinnularia acuminata		0.00E+00	0.0
Pinnularia acuminata var. instabilis (P. hemiptera)		0.00E+00	0.0
Pinnularia. biceps	8	1.32E+10	2.4
Pinnularia brevicostrata var. brevicostrata	5	8.27E+09	1.5
Pinnularia abaujensis	2	3.31E+09	0.6

Pinnularia braunii		0.00E+00	0.0
Pinnularia cf. boyeri	2	3.31E+09	0.6
Pinnularia hilseana		0.00E+00	0.0
Pinnularia maior var. maior	5	8.27E+09	1.5
Pinnularia sp (borealis)		0.00E+00	0.0
Surirella brebissonnii	1	1.65E+09	0.3
Synedra. Delicatissima	2	3.31E+09	0.6
Stauroneis phonicenteron	11	1.82E+10	3.3
Synedra rumpens	10	1.65E+10	3.0
Stauroneis anceps var. anceps	12	1.99E+10	3.6
Stauroneis phonicenteron f. gracilis		0.00E+00	0.0
Surirella ovalis	24	3.97E+10	7.2
Surirella striatula	3	4.96E+09	0.9
Synedra ulna	2	3.31E+09	0.6
Tabellaria flocculosa	27	4.47E+10	8.1
Tabellaria fenestrata	26	4.30E+10	7.8
Rhopalodia sp	3	4.96E+09	0.9
Pinnularia formica	1	1.65E+09	0.3
Total Number of Frustules	334	5.53E+11	

Species	AMR2 0-1 cm 20%	0.0052	g sed used	
No. of grids	95	100144	grid ratio	
Date of counts	3/17/99	# cells/g sed	%abund	
Achnanthes minutissima	39	3.57E+10	7.2	
Achnanthes saxonica	33	3.02E+10	6.1	
Achnanthes stewartii	8	7.32E+09	1.5	
Anomoeneis serians	5	4.57E+09	0.9	
Anomoeneis vitrea		0.00E+00	0.0	
Cymbella lunata	10	9.15E+09	1.8	
Cocconeis plancentula var. lineata	3	2.74E+09	0.6	
Cyclotella antiqua	7	6.40E+09	1.3	
Cyclotella cyclopuncta		0.00E+00	0.0	
Cyclotella stelligera	23	2.10E+10	4.2	
Cymbella minuta	10	9.15E+09	1.8	
Diatoma vulgare var. vugare		0.00E+00	0.0	
Diploneis cf. petersinni /marginestriata or oculata	1	9.15E+08	0.2	
Epithemia sorex	2	1.83E+09	0.4	
Eunotia flexuosa		0.00E+00	0.0	
Eunotia formica	1	9.15E+08	0.2	
Eunotia pectinalis	43	3.93E+10	7.9	
Eunotia sudetica		0.00E+00	0.0	
Eunotia tenella	1	9.15E+08	0.2	
Eunotia cf. vanheurckii	20	1.83E+10	3.7	
Eunotia exigua	45	4.12E+10	8.3	
Eunotia perpusilla	1	9.15E+08	0.2	
Eunotia incisa var. incisa		0.00E+00	0.0	
Eunotia serra var.diadema	1	9.15E+08	0.2	
Fragilaria constricta	3	2.74E+09	0.6	
Fragilaria pinnata var. pinnata	37	3.38E+10	6.8	
Frustulia rhomboides	2	1.83E+09	0.4	
Frustulia rhomboides var. capitata	5	4.57E+09	0.9	
Gomphonema acuminatum	4	3.66E+09	0.7	
Gomphonema truncatum var. capitatum		0.00E+00	0.0	
Gomphonema gracile	1	9.15E+08	0.2	
Gomphonema trucatum var. turgidum	3	2.74E+09	0.6	
Melosira. italica	5	4.57E+09	0.9	
Melosira granulata	37	3.38E+10	6.8	
Meridion circulare var. constrictum	1	9.15E+08	0.2	
Navicula bacillum	1	9.15E+08	0.2	
Navicula cuspidata var. cuspidata	3	2.74E+09	0.6	
Navicula explanata	9	8.23E+09	1.7	
Navicula radiosa	32	2.93E+10	5.9	
Neidium affine var. affine	4	3.66E+09	0.7	
Nitzschia sp A	3	2.74E+09	0.6	
Nitzschia sp B	2	1.83E+09	0.4	
Nitzschia sp C	2	1.83E+09	0.4	
Pinnularia acuminata	2	1.83E+09	0.4	
Pinnularia acuminata var. instabilis (P. hemiptera)		0.00E+00	0.0	
Pinnularia. biceps	3	2.74E+09	0.6	
Pinnularia brevicostrata var. brevicostrata	3	2.74E+09	0.6	
Pinnularia abaujensis	2	1.83E+09	0.4	

Pinnularia braunii		0.00E+00	0.0	
Pinnularia cf. boyeri	1	9.15E+08	0.2	
Pinnularia hilseana		0.00E+00	0.0	
Pinnularia maior var. maior	5	4.57E+09	0.9	
Pinnularia sp (borealis)		0.00E+00	0.0	
Surirella brebissonnii	2	1.83E+09	0.4	
Synedra delicatissima	3	2.74E+09	0.6	
Stauroneis phonicenteron	10	9.15E+09	1.8	
S. rumpens	7	6.40E+09	1.3	
Stauroneis anceps var. anceps	12	1.10E+10	2.2	
Stauroneis phonicenteron f. gracilis		0.00E+00	0.0	
Surirella ovalis	2	1.83E+09	0.4	
Surirella striatula	2	1.83E+09	0.4	
Synedra ulna	4	3.66E+09	0.7	
Tabellaria flocculosa	43	3.93E+10	7.9	
Tabellaria fenestrata	35	3.20E+10	6.4	
Pinnularia sp.	1	9.15E+08	0.2	
Total Number of Frustules	544	4.98E+11		

Species	AMR3 0-1 cm 10%	0.0023	g sed used	grids/2
No. of grids	115	100144	grid ratio	57.5
Date of counts	3/18/99	# cells/g sed	% abund	
Achnanthes minutissima	26	6.51E+10	4.9	
Achnanthes saxonica	33	8.26E+10	6.2	
Achnanthes stewartii	7	1.75E+10	1.3	
Anomoeneis serians	3	7.51E+09	0.6	
Anomoeneis vitrea		0.00E+00	0.0	
Caloneis ventricosa	6	1.50E+10	1.1	
Cymbella lunata	4	1.00E+10	0.8	
Cocconeis plancentula var. lineata		0.00E+00	0.0	
Cyclotella antiqua	5	1.25E+10	0.9	
Cyclotella cyclopuncta		0.00E+00	0.0	
Cyclotella sp.	5	1.25E+10	0.9	
Cyclotella stelligera		0.00E+00	0.0	
Cymbella minuta	11	2.75E+10	2.1	
Diatoma vulgare var. vugare	7	1.75E+10	1.3	
Diploneis cf. petersinni /marginestriata or oculata	3	7.51E+09	0.6	
Epithemia sorex		0.00E+00	0.0	
Eunotia flexuosa		0.00E+00	0.0	
Eunotia formica	3	7.51E+09	0.6	
Eunotia pectinalis	49	1.23E+11	9.2	
Eunotia sudetica		0.00E+00	0.0	
Eunotia tenella		0.00E+00	0.0	
Eunotia cf. vanheurckii	28	7.01E+10	5.3	
Eunotia. Exigua	16	4.01E+10	3.0	
Eunotia perpusilla	5	1.25E+10	0.9	
Eunotia. Incisa var. incisa		0.00E+00	0.0	
Eunotia. Serra var.diadema	8	2.00E+10	1.5	
Fragilaria constricta		0.00E+00	0.0	
Fragilaria pinnata var. pinnata	20	5.01E+10	3.8	
Frustulia rhomboides	5	1.25E+10	0.9	
Frustulia rhomboides var. capitata	6	1.50E+10	1.1	
Gomphonema acuminatum	10	2.50E+10	1.9	
Gomphonema truncatum var. capitatum		0.00E+00	0.0	
Gomphonema gracile	3	7.51E+09	0.6	
Gomphonema trucatum var. turgidum	1	2.50E+09	0.2	
Melosira. italica	5	1.25E+10	0.9	
Melosira granulata	25	6.26E+10	4.7	
Meridion circulare var. constrictum		0.00E+00	0.0	
Navicula bacillum	1	2.50E+09	0.2	
Navicula cuspidata var. cuspidata	4	1.00E+10	0.8	
Navicula explanata	15	3.76E+10	2.8	
Navicula radiosa	28	7.01E+10	5.3	
Neidium affine var. affine	5	1.25E+10	0.9	
Nitzschia sp A	10	2.50E+10	1.9	
Nitzschia sp B	1	2.50E+09	0.2	
Nitzschia sp C	2	5.01E+09	0.4	
Pinnularia acuminata	4	1.00E+10	0.8	
Pinnularia acuminata var. instabilis (P. hemiptera)		0.00E+00	0.0	
Pinnularia. biceps	6	1.50E+10	1.1	

Pinnularia brevicostrata var. brevicostrata	10	2.50E+10	1.9	
Pinnularia abaujensis		0.00E+00	0.0	
Pinnularia braunii		0.00E+00	0.0	
Pinnularia cf. boyeri	3	7.51E+09	0.6	
Pinnularia hilseana		0.00E+00	0.0	
Pinnularia maior var. maior	13	3.25E+10	2.5	
Pinnularia sp (borealis)		0.00E+00	0.0	
Surirella brebissonnii		0.00E+00	0.0	
Synedra. Delicatissima	5	1.25E+10	0.9	
Stauroneis phonicenteron	18	4.51E+10	3.4	
S. rumpens	20	5.01E+10	3.8	
Stauroneis anceps var. anceps	12	3.00E+10	2.3	
Stauroneis phonicenteron f. gracilis		0.00E+00	0.0	
Surirella ovalis	5	1.25E+10	0.9	
Surirella striatula	1	2.50E+09	0.2	
Synedra ulna	1	2.50E+09	0.2	
Tabellaria flocculosa	30	7.51E+10	5.7	
Tabellaria. Fenestrata	36	9.01E+10	6.8	
Pinularia sp	3	7.51E+09	0.6	
Synedra sp	3	7.51E+09	0.6	
Total Number of Frustules	530	1.33E+12		

Species	UR 0-1 cm 20%	0.0133	g sed used	
No. of grids	70	100144	grid ratio	
Date of counts	3/18/99	# cells/g sed	%abund	
Achnanthes minutissima	19	5.01E+09	5.6	
Achnanthes saxonica	5	1.32E+09	1.5	
Achnanthes stewartii		0.00E+00	0.0	
Anomoeneis serians		0.00E+00	0.0	
Anomoeneis vitrea	6	1.58E+09	1.8	
Cymbella lunata	10	2.64E+09	3.0	
Cocconeis plancentula var. lineata	1	2.64E+08	0.3	
Cyclotella antiqua	6	1.58E+09	1.8	
Cyclotella cyclopuncta	2	5.27E+08	0.6	
Cyclotella stelligera	6	1.58E+09	1.8	
Cymbella minuta	18	4.74E+09	5.3	
Diatoma vulgare var. vugare	1	2.64E+08	0.3	
Diploneis cf. petersinni /marginestriata or oculata	4	1.05E+09	1.2	
Epithemia sorex	5	1.32E+09	1.5	
Eunotia flexuosa		0.00E+00	0.0	
Eunotia formica		0.00E+00	0.0	
Eunotia pectinalis	27	7.12E+09	8.0	
Eunotia sudetica		0.00E+00	0.0	
Eunotia tenella	1	2.64E+08	0.3	
Eunotia cf. vanheurckii	13	3.43E+09	3.9	
Eunotia. Exigua	7	1.84E+09	2.1	
Eunotia perpusilla		0.00E+00	0.0	
Eunotia. Incisa var. incisa		0.00E+00	0.0	
Eunotia. Serra var.diadema		0.00E+00	0.0	
Fragilaria constricta		0.00E+00	0.0	
Fragilaria pinnata var. pinnata	20	5.27E+09	5.9	
Frustulia rhomboides	1	2.64E+08	0.3	
Frustulia rhomboides var. capitata	18	4.74E+09	5.3	
Gomphonema acuminatum	3	7.91E+08	0.9	
Gomphonema truncatum var. capitatum		0.00E+00	0.0	
Gomphonema gracile		0.00E+00	0.0	
Gomphonema trucatum var. turgidum		0.00E+00	0.0	
Melosira. italica		0.00E+00	0.0	
Melosira granulata	7	1.84E+09	2.1	
Meridion circulare var. constrictum	2	5.27E+08	0.6	
Navicula bacillum		0.00E+00	0.0	
Navicula cuspidata var. cuspidata		0.00E+00	0.0	
Navicula explanata		0.00E+00	0.0	
Navicula radiosa	27	7.12E+09	8.0	
Neidium affine var. affine		0.00E+00	0.0	
Nitzschia sp A	30	7.91E+09	8.9	
Nitzschia sp B		0.00E+00	0.0	
Nitzschia sp C		0.00E+00	0.0	
Pinnularia acuminata	1	2.64E+08	0.3	
Pinnularia acuminata var. instabilis (P. hemiptera)		0.00E+00	0.0	
Pinnularia. biceps	7	1.84E+09	2.1	
Pinnularia brevicostrata var. brevicostrata	3	7.91E+08	0.9	
Pinnularia abaujensis	1	2.64E+08	0.3	
Pinnularia braunii		0.00E+00	0.0	

Pinnularia cf. boyeri		0.00E+00	0.0	
Pinnularia hilseana		0.00E+00	0.0	
Pinnularia maior var. maior	4	1.05E+09	1.2	
Pinnularia sp (borealis)		0.00E+00	0.0	
Surirella brebissonnii		0.00E+00	0.0	
Synedra. Delicatissima	5	1.32E+09	1.5	
Stauroneis phonicenteron		0.00E+00	0.0	
S. rumpens	18	4.74E+09	5.3	
Stauroneis anceps var. anceps		0.00E+00	0.0	
Stauroneis phonicenteron f. gracilis	3	7.91E+08	0.9	
Surirella ovalis	1	2.64E+08	0.3	
Surirella striatula		0.00E+00	0.0	
Synedra ulna		0.00E+00	0.0	
Tabellaria flocculosa	37	9.75E+09	11.0	
Tabellaria. Fenestrata	15	3.95E+09	4.5	
Synedra sp.	3	7.91E+08	0.9	
Total Number of Frustules	337	8.88E+10		

Species	TP 0-2 cm 10%	0.000518	g sed used	grids/2
No. of grids	225	100144	grid ratio	112.5
Date of counts	3/18/99	# cells/g sed	%abund	
Achnanthes minutissima	15	3.26E+11	5.5	
Achnanthes saxonica		0.00E+00	0.0	
Achnanthes stewartii		0.00E+00	0.0	
Anomoeneis serians		0.00E+00	0.0	
Anomoeneis vitrea	1	2.17E+10	0.4	
Cymbella lunata		0.00E+00	0.0	
Cocconeis plancentula var. lineata		0.00E+00	0.0	
Cyclotella antiqua		0.00E+00	0.0	
Cyclotella cyclopuncta		0.00E+00	0.0	
Cyclotella stelligera		0.00E+00	0.0	
Cymbella minuta		0.00E+00	0.0	
Diatoma vulgare var. vugare		0.00E+00	0.0	
Diploneis cf. petersinni /marginestriata or oculata		0.00E+00	0.0	
Epithemia sorex		0.00E+00	0.0	
Eunotia flexuosa		0.00E+00	0.0	
Eunotia formica	3	6.52E+10	1.1	
Eunotia pectinalis	43	9.35E+11	15.8	
Eunotia sudetica	38	8.26E+11	13.9	
Eunotia tenella		0.00E+00	0.0	
Eunotia cf. vanheurckii	22	4.78E+11	8.1	
Eunotia exigua	15	3.26E+11	5.5	
Eunotia perpusilla		0.00E+00	0.0	
Eunotia incisa var. incisa		0.00E+00	0.0	
Eunotia serra var.diadema	1	2.17E+10	0.4	
Fragilaria constricta		0.00E+00	0.0	
Fragilaria pinnata var. pinnata	1	2.17E+10	0.4	
Frustulia rhomboides	55	1.20E+12	20.1	
Frustulia rhomboides var. capitata	11	2.39E+11	4.0	
Gomphonema acuminatum		0.00E+00	0.0	
Gomphonema truncatum var. capitatum		0.00E+00	0.0	
Gomphonema gracile		0.00E+00	0.0	
Gomphonema trucatum var. turgidum		0.00E+00	0.0	
Melosira. italica		0.00E+00	0.0	
Melosira granulata		0.00E+00	0.0	
Meridion circulare var. constrictum		0.00E+00	0.0	
Navicula bacillum		0.00E+00	0.0	
Navicula cuspidata var. cuspidata		0.00E+00	0.0	
Navicula explanata		0.00E+00	0.0	
Navicula radiosa		0.00E+00	0.0	
Neidium affine var. affine	7	1.52E+11	2.6	
Neidium bisulcatum	9	1.96E+11	3.3	
Nitzschia sp A		0.00E+00	0.0	
Nitzschia sp B		0.00E+00	0.0	
Nitzschia sp C		0.00E+00	0.0	
Pinnularia acuminata		0.00E+00	0.0	
Pinnularia acuminata var. instabilis (P. hemiptera)		0.00E+00	0.0	
Pinnularia biceps	3	6.52E+10	1.1	
Pinnularia brevicostrata var. brevicostrata		0.00E+00	0.0	

Pinnularia abaujensis		0.00E+00	0.0	
Pinnularia braunii	5	1.09E+11	1.8	
Pinnularia cf. boyeri		0.00E+00	0.0	
Pinnularia hilseana	1	2.17E+10	0.4	
Pinnularia maior var. maior		0.00E+00	0.0	
Pinnularia sp (borealis)	3	6.52E+10	1.1	
Surirella brebissonnii		0.00E+00	0.0	
Synedra delicatissima		0.00E+00	0.0	
Stauroneis phonicenteron		0.00E+00	0.0	
Synedra rumpens		0.00E+00	0.0	
Stauroneis anceps var. anceps		0.00E+00	0.0	
Stauroneis phonicenteron f. gracilis		0.00E+00	0.0	
Surirella ovalis		0.00E+00	0.0	
Surirella striatula		0.00E+00	0.0	
Synedra ulna		0.00E+00	0.0	
Tabellaria fenestrata	38	8.26E+11	13.9	
Tabellaria flocculosa	2	4.35E+10	0.7	
Total Number of Frustules	273	5.94E+12		

Species	SP 0-2 cm 20%	0.00164	g sed used	grids/2
No. of grids	185	100144	grid ratio	92.5
Date of counts	3/18/99	# cells/g sed	%abund	
Achnanthes minutissima		0.00E+00	0.0	
Achnanthes saxonica	3	1.69E+10	1.0	
Achnanthes stewartii		0.00E+00	0.0	
Anomoeneis serians	1	5.65E+09	0.3	
Anomoeneis vitrea	2	1.13E+10	0.7	
Cymbella lunata	2	1.13E+10	0.7	
Cocconeis plancentula var. lineata		0.00E+00	0.0	
Cyclotella antiqua		0.00E+00	0.0	
Cyclotella cyclopuncta		0.00E+00	0.0	
Cyclotella stelligera	2	1.13E+10	0.7	
Cymbella minuta	2	1.13E+10	0.7	
Diatoma vulgare var. vugare		0.00E+00	0.0	
Diploneis cf. petersinni /marginestriata or oculata		0.00E+00	0.0	
Epithemia sorex		0.00E+00	0.0	
Eunotia flexuosa		0.00E+00	0.0	
Eunotia formica		0.00E+00	0.0	
Eunotia pectinalis	36	2.03E+11	11.8	
Eunotia sudetica	20	1.13E+11	6.6	
Eunotia tenella	10	5.65E+10	3.3	
Eunotia cf. vanheurckii	23	1.30E+11	7.5	
Eunotia. Exigua	6	3.39E+10	2.0	
Eunotia perpusilla		0.00E+00	0.0	
Eunotia. Incisa var. incisa		0.00E+00	0.0	
Eunotia. Serra var.diadema		0.00E+00	0.0	
Fragilaria constricta		0.00E+00	0.0	
Fragilaria pinnata var. pinnata		0.00E+00	0.0	
Frustulia rhomboides	3	1.69E+10	1.0	
Frustulia rhomboides var. capitata	9	5.08E+10	3.0	
Gomphonema acuminatum		0.00E+00	0.0	
Gomphonema truncatum var. capitatum		0.00E+00	0.0	
Gomphonema gracile	12	6.78E+10	3.9	
Gomphonema trucatum var. turgidum		0.00E+00	0.0	
Melosira. italica		0.00E+00	0.0	
Melosira granulata	7	3.95E+10	2.3	
Meridion circulare var. constrictum		0.00E+00	0.0	
Navicula bacillum	1	5.65E+09	0.3	
Navicula cuspidata var. cuspidata		0.00E+00	0.0	
Navicula explanata	1	5.65E+09	0.3	
Navicula radiosa	49	2.77E+11	16.1	
Neidium affine var. affine	15	8.47E+10	4.9	
Nitzschia sp A		0.00E+00	0.0	
Nitzschia sp B		0.00E+00	0.0	
Nitzschia sp C		0.00E+00	0.0	
Pinnularia acuminata		0.00E+00	0.0	
Pinnularia acuminata var. instabilis (P. hemiptera)		0.00E+00	0.0	
Pinnularia. biceps	3	1.69E+10	1.0	
Pinnularia brevicostrata var. brevicostrata		0.00E+00	0.0	
Pinnularia abaujensis		0.00E+00	0.0	

Pinnularia braunii		0.00E+00	0.0	
Pinnularia cf. boyeri		0.00E+00	0.0	
Pinnularia hilseana		0.00E+00	0.0	
Pinnularia maior var. maior	4	2.26E+10	1.3	
Pinnularia sp (borealis)	3	1.69E+10	1.0	
Surirella brebissonnii		0.00E+00	0.0	
Synedra. Delicatissima	1	5.65E+09	0.3	
Stauroneis phonicenteron	3	1.69E+10	1.0	
S. rumpens	1	5.65E+09	0.3	
Stauroneis anceps var. anceps	1	5.65E+09	0.3	
Stauroneis phonicenteron f. gracilis		0.00E+00	0.0	
Surirella ovalis	2	1.13E+10	0.7	
Surirella striatula		0.00E+00	0.0	
Synedra ulna		0.00E+00	0.0	
Tabellaria flocculosa	45	2.54E+11	14.8	
Tabellaria fenestrata	38	2.15E+11	12.5	
Total Number of Frustules	305	1.72E+12		

Species	JP 0-2 cm 10%	0.000518	g sed used	
No. of grids	220	100144	grid ratio	
Date of counts	3/18/99	# cells/g sed	%abund	
Achnanthes minutissima	6	1.28E+11	1.9	
Achnanthes saxonica	11	2.34E+11	3.5	
Achnanthes stewartii		0.00E+00	0.0	
Anomoeneis serians		0.00E+00	0.0	
Anomoeneis vitrea	10	2.13E+11	3.2	
Cymbella lunata		0.00E+00	0.0	
Cocconeis plancentula var. lineata		0.00E+00	0.0	
Cyclotella antiqua		0.00E+00	0.0	
Cyclotella cyclopuncta		0.00E+00	0.0	
Cyclotella stelligera	8	1.70E+11	2.6	
Cymbella minuta	1	2.13E+10	0.3	
Diatoma vulgare var. vugare		0.00E+00	0.0	
Diploneis cf. petersinni /marginestriata or oculata		0.00E+00	0.0	
Epithemia sorex		0.00E+00	0.0	
Eunotia flexuosa	1	2.13E+10	0.3	
Eunotia formica		0.00E+00	0.0	
Eunotia pectinalis	16	3.40E+11	5.1	
Eunotia sudetica	26	5.53E+11	8.3	
Eunotia tenella		0.00E+00	0.0	
Eunotia cf. vanheurckii	25	5.32E+11	8.0	
Eunotia elegans	5	1.06E+11	1.6	
Eunotia. Exigua	12	2.55E+11	3.8	
Eunotia perpusilla		0.00E+00	0.0	
Eunotia. Incisa var. incisa		0.00E+00	0.0	
Eunotia. Serra var.diadema		0.00E+00	0.0	
Fragilaria constricta		0.00E+00	0.0	
Fragilaria pinnata var. pinnata		0.00E+00	0.0	
Frustulia rhomboides	11	2.34E+11	3.5	
Frustulia rhomboides var. capitata	8	1.70E+11	2.6	
Gomphonema acuminatum		0.00E+00	0.0	
Gomphonema truncatum var. capitatum		0.00E+00	0.0	
Gomphonema gracile		0.00E+00	0.0	
Gomphonema trucatum var. turgidum		0.00E+00	0.0	
Melosira. italica		0.00E+00	0.0	
Melosira granulata	13	2.76E+11	4.2	
Meridion circulare var. constrictum		0.00E+00	0.0	
Navicula bacillum		0.00E+00	0.0	
Navicula cuspidata var. cuspidata		0.00E+00	0.0	
Navicula explanata	2	4.25E+10	0.6	
Navicula radiosa	35	7.44E+11	11.2	
Neidium affine var. affine	27	5.74E+11	8.7	
Nitzschia sp A		0.00E+00	0.0	
Nitzschia sp B		0.00E+00	0.0	
Nitzschia sp C		0.00E+00	0.0	
Pinnularia acuminata		0.00E+00	0.0	
Pinnularia acuminata var. instabilis (P. hemiptera)		0.00E+00	0.0	
Pinnularia. biceps	6	1.28E+11	1.9	
Pinnularia brevicostrata var. brevicostrata	5	1.06E+11	1.6	

Pinnularia abaujensis		0.00E+00	0.0	
Pinnularia braunii		0.00E+00	0.0	
Pinnularia cf. boyeri		0.00E+00	0.0	
Pinnularia hilseana	4	8.51E+10	1.3	
Pinnularia maior var. maior	2	4.25E+10	0.6	
Pinnularia sp (borealis)		0.00E+00	0.0	
Surirella brebissonnii		0.00E+00	0.0	
Synedra. Delicatissima		0.00E+00	0.0	
Stauroneis phonicenteron	3	6.38E+10	1.0	
S. rumpens		0.00E+00	0.0	
Stauroneis anceps var. anceps		0.00E+00	0.0	
Stauroneis phonicenteron f. gracilis		0.00E+00	0.0	
Surirella ovalis	1	2.13E+10	0.3	
Surirella striatula		0.00E+00	0.0	
Synedra ulna		0.00E+00	0.0	
Tabellaria flocculosa	27	5.74E+11	8.7	
Tabellaria. Fenestrata	47	1.00E+12	15.1	
Total Number of Frustules	312	6.64E+12		

APPENDIX G

Probability Values for the Fourteen Most Common Species

Species	pH	NH3 (average)	SiO2(average)	SRP (aver	NO3 (average)
		ug N/L	mg/L	ug P/L	ug N/L
fenestrata	0.0009	0.2110	0.0335	0.0147	0.0995
flocculosa	0.1390	0.6491	0.7772	0.6714	0.8795
rhomboide	0.3337	0.9145	0.9823	0.5395	0.7921
sudetica	0.0133	0.5208	0.2943	0.1199	0.4452
s.ovalis	0.4068	0.7065	0.8535	0.8389	0.7322
affine	0.0102	0.0236	0.0054	0.0537	0.0013
nitzschia	0.2438	0.6699	0.0489	0.0085	0.3620
granulata	0.3731	0.6757	0.7625	0.8762	0.6547
explanata	0.1747	0.6874	0.8540	0.8024	0.7004
radiosa	0.3528	0.4973	0.1799	0.4347	0.2035
minutissim	0.1493	0.4900	0.0682	0.1269	0.1826
vanheurcki	0.0026	0.3348	0.1094	0.0613	0.1993
pectinalis	0.3951	0.3684	0.9177	0.5484	0.4792
pinnata	0.0268	0.4272	0.0747	0.0369	0.2241
	Ca (average)	conductivity			
	mg/L	uS/cm			
fenestrata	0.0310	0.1918			
flocculosa	0.1949	0.8866			
rhomboide	0.0045	0.3497			
sudetica	0.0023	0.3367			
s.ovalis	0.5967	0.7415			
affine	0.3992	0.4850			
nitzschia	0.1405	0.0006			
granulata	0.2028	0.7980			
explanata	0.4302	0.4900			
radiosa	0.4858	0.6048			
minutissim	0.8242	0.7160			
vanheurcki	0.0520	0.4194			
pectinalis	0.0867	0.6690			
pinnata	0.1036	0.2467			