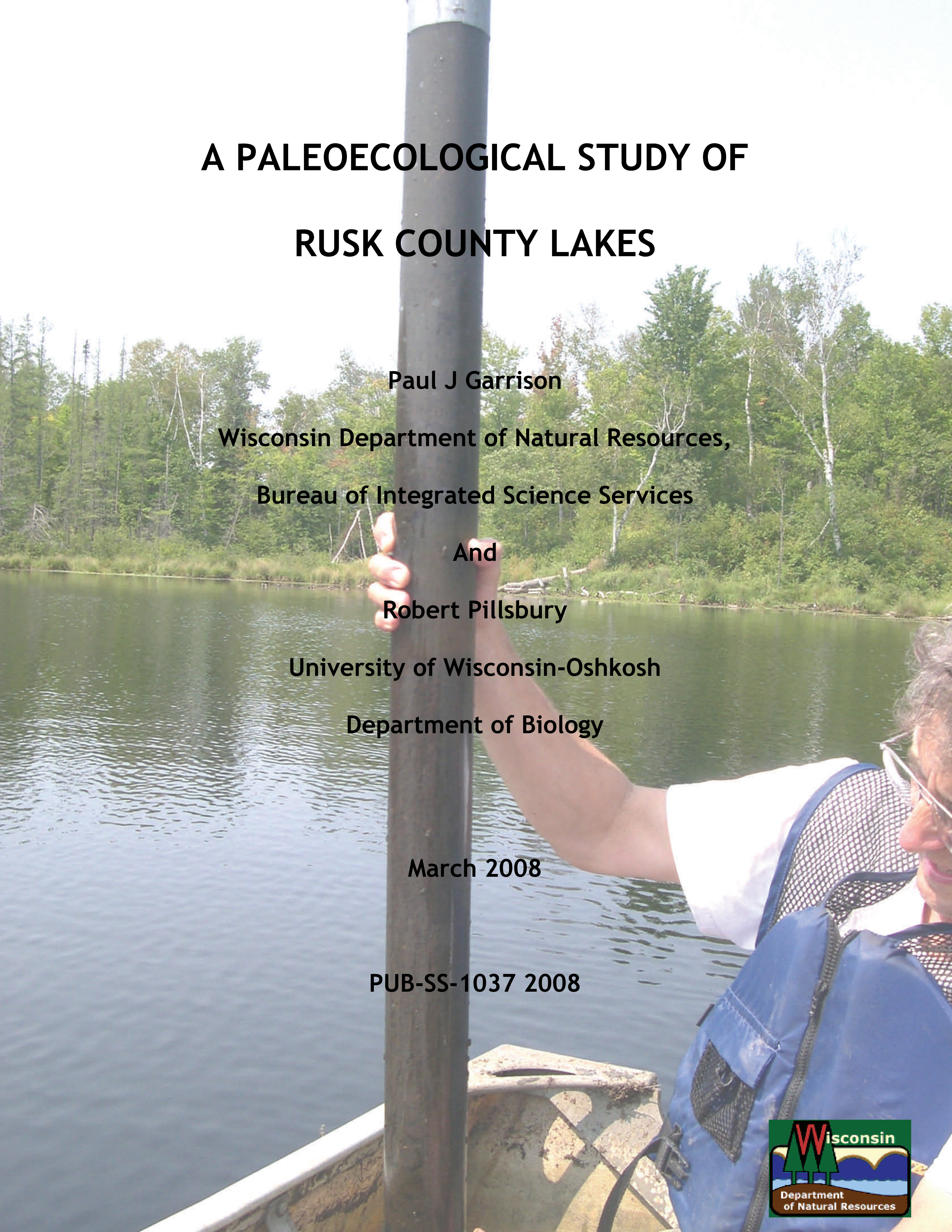

A PALEOECOLOGICAL STUDY OF RUSK COUNTY LAKES

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Introduction

Questions often arise concerning how a lake's water quality has changed through time as a result of watershed disturbances. In most cases there is little or no reliable long-term data. Questions often asked are if the condition of the lake has changed, when did this occur, what were the causes, and what were the historical condition of the lake? Paleoecology offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution. These remains include diatom frustules, cell walls of certain algal species, and subfossils from aquatic plants. The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. Using the fossil remains found in the sediment, one can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

A relatively inexpensive means of comparing present day conditions with pre-settlement conditions is top/bottom sediment cores. While a full core, which is assumed to cover a time period of European settlement, is collected, only the top and bottom sections are analyzed. It is assumed that the top section was deposited during the last 2-3 years. The bottom section is assumed to have been deposited prior to the arrival of Europeans during the latter part of the nineteenth century.

This report will examine selected the lakes of Rusk County have potentially been impacted by anthropogenic activities in two ways. The most common potential change in the lakes is eutrophication through the introduction of excess nutrients to the lakes. The other potential impact is a change in the pH of the lakes as a result of atmospheric acidification. While eutrophication may impact all lakes, only a specific type of lake is susceptible to acidification. These are seepage lakes (have no streams entering the lake) and receive very little groundwater input. That means that nearly all of their water input is from atmospheric sources.

This study included 2 lakes (Bass sec 16, North) that may be sensitive to acidification. The rest of the lakes were examined for the potential impact from nutrients. All of these lakes, except Three Lakes, No. 1 and North Lake, have anthropogenic activities in their watershed. These activities include agriculture and shoreland development. This top/bottom study will compare present day water quality conditions with pre-settlement conditions. The two "reference" lakes will act as a control for this study.

During August 13 and 14 2007, nine lakes were cored in Rusk County, WI. These lakes were cored with the help of Dr. Ken Parejko. The location of the lakes and some of their morphometric characteristics are presented in Table 1. The cores were collected with a gravity core with a plastic tube having an inside diameter of 6.8 cm. The cores were collected in the deepest area of each lake. The lakes sampled are listed in Table 1. The top and near he bottom of each core was collected and placed in plastic bags, kept cool and in the dark until returned to the laboratory. The samples were analyzed for percent water, percent organic matter, radiochemical variables (^{210}Pb, ^{137}Cs, ^{226}Ra), and the diatom community. The radiochemical variables were only analyzed on the bottom samples to see if they had been deposited at least 100 years ago. The analysis was done at the Wisconsin State Laboratory of Hygiene in Madison, WI. The diatom community was analyzed to assess changes in nutrient and Ph levels and changes in the macrophyte community.

At the same time that the cores were collected, selected water chemical parameters were also collected. These were largely nutrient variables as well as general water chemistry indicators for the lakes. These results are presented in Table 2.

Table 1. Lake morphometry, hydrologic type and sampling location of the study lakes. Drainage lakes have a surface stream entering and exiting the lake while seepage lakes do not have any streams.

	Hydrologic Type	Location	GPS Coordinates	Area (ac)	Sampling Depth (ft)
Amacoy	Drainage	T34 R 8 S25	45°33730 91°31818	278	19
Bass Sec 12	Seepage	T35 R 7 S12	45°42542 91°49258	88	29
Bass Sec 16	Seepage	T34 R 9 S16	45°52281 91°18200	27	19
Chain	Drainage	T33 R 8 S31	45°29594 91°43411	468	70
Fireside	Drainage	T33 R 8 S26	45°31983 91°32562	211	29
Island	Drainage	T33 R 8 S21	45°32330 91°37450	526	48
Mud*	Drainage	T33 R 8 S27	45°31462 91°34385	81	12
North	Seepage	T34 R 9 S3	45°45163 91°47865	11	25
Park	Seepage	T34 R 8 S25	45°50609 91°06950	16	6
Potato[1,2]	Drainage	T35 R 6 S24	45°32358 91°42793	534	20
Pulaski	Seepage	T33 R 7 S18	45°33779 91°27496	126	29
Three Lakes No. 1	Seepage	T36 R 9 S25	45°58006 91°42271	4	19

[1]No water chemistry samples were collected from Mud Lake

Table 2. Chemical characteristics of the study lakes. No water chemistry samples were collected from Mud Lake.

	Secchi (m)	Color (PTU)	pH	ANC (mg L^{-1})	Total P (µg L^{-1})	Total N (µg L^{-1})	Dissolved Silica	Chlorophyll *a* (µg L^{-1})
Amacoy	1.0	12.5	8.74	47	44	1120	11.30	34.3
Bass Sec 12	1.8	25	7.58	28	16	680	1.52	
Bass Sec 16	3.4	10	6.21	3	9	580	0.22	4.5
Chain	2.0	7.5	7.79	63	21	530	7.81	
Fireside	2.3	7.5	8.94	76	19	700	7.62	10.4
Island	1.8	5	8.67	68	22	610	5.81	10.9
North	2.5	25	6.28	4	10	620	0.23	3.2
Park	0.7	35	6.63	10	77	1960	0.72	60.8
Potato*	0.7	25	7.91	66	163	2480		82.1
Pulaski	2.8	7.5	6.35	14	12		0.21	2.4
Three Lakes No. 1	1.3	90	6.96	22	34	870	3.44	17.9

* sample collected Sept. 4, 2003

Two other Rusk County lakes (Potato, Bass sec 12) had previously been cored. The results from these top/bottom cores are included in this report. An analysis of Chain Lake, Chippewa County was also included as it is in the same chain as Island Lake.

Results and Discussion

Aquatic organisms are good indicators of water chemistry because they are in direct contact with the water and are strongly affected by the chemical composition of their surroundings. Most indicator groups grow rapidly and are short lived so the community composition responds rapidly to changing environmental conditions. One of the most useful organisms for paleolimnological analysis is diatoms. They are a type of alga which possess siliceous cell walls and are usually abundant, diverse, and well preserved in sediments. They are especially useful as they are ecologically diverse and their ecological optima and tolerances can be quantified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. They also live under a variety of habitats, which enables us to reconstruct changes in nutrient levels in the open water as well as changes in benthic environments such as aquatic plant communities. Figure 1 shows photographs of three diatom species that were common in the sediment cores.

Reference Lakes

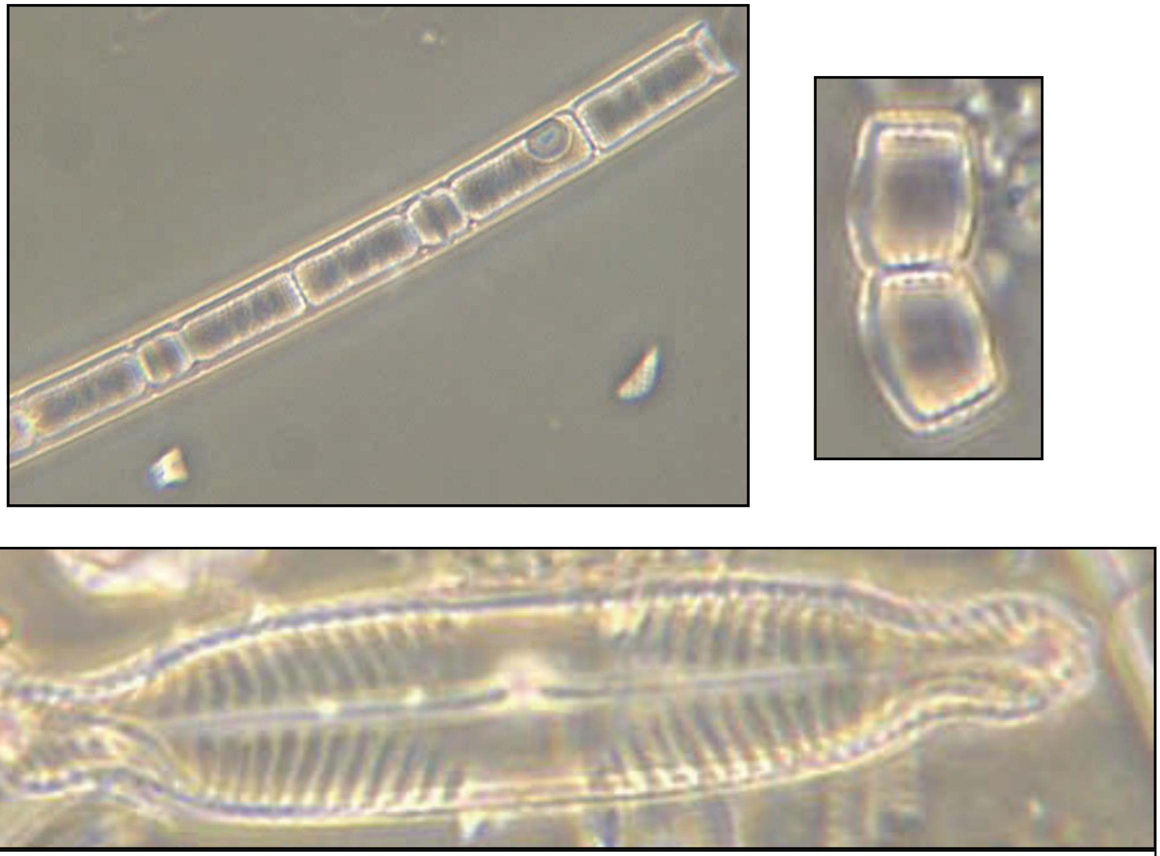

Figure 1. Photomicrographs of diatoms common lakes of this study. The diatom on the top left (*Aulacoseira ambigua*) typically is found in open water environments while the picture on the right is *Staurosirella pinnata* which is commonly found attached to substrates such as downed trees and aquatic plants in lakes. The diatom in the bottom photo is *Pinnularia biceps* which is often found in acidic environments. It was the dominant diatom in the bottom sample from Bass Lake, section 16.

North Lake and Three Lakes No. 1 were considered reference lakes since their watersheds are completely forested and there is no shoreland development. There has been logging in the past in their watersheds but nothing within at least the last 20 years.

<u>Three Lakes No. 1</u> This lake has undergone some change in the diatom community as shown in Figure 2. The amount of planktonic diatoms is greater in the surface than it is in the bottom sample. This increase is largely the result of more taxa in the genera *Aulacoseira*, specifically *A. ambigua* and *A. distans* (Figure 2). Other studies have found that the amount of planktonic diatoms increases as nutrient levels rise. The loss of benthic *Fragilaria* and *Eunotia* in the top sample compared with the bottom sample indicates that has not been a significant change in the amount of macrophytes in the lake. Benthic *Fragilaria* grow as long chains and frequently are found amongst macrophyte beds. They may grow on the plants and utilize nutrients excreted by the plants, or use the plants as an protection from wave action. Weighted averaging modeling indicates that the change in phosphorus has only

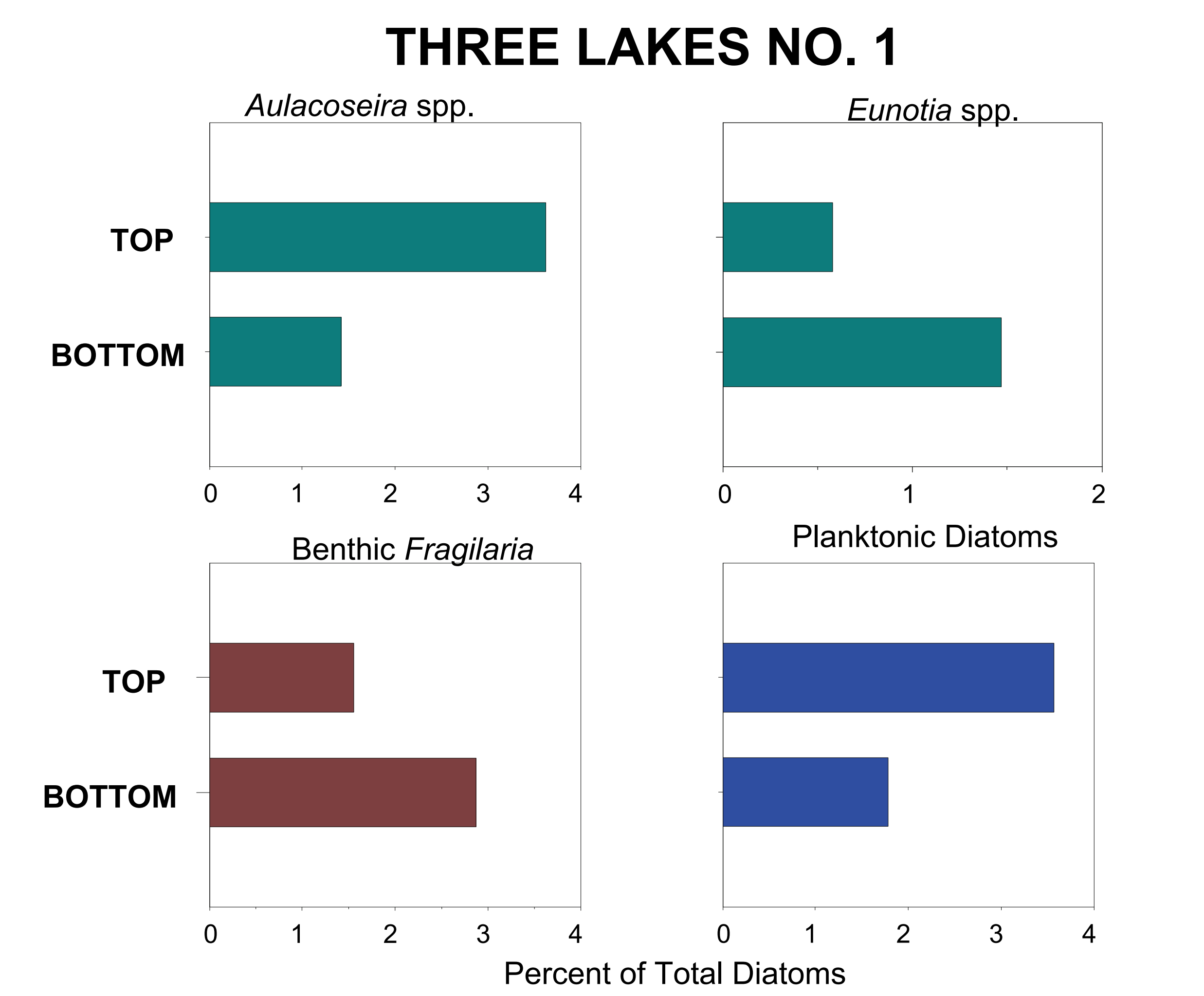

Figure 2. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

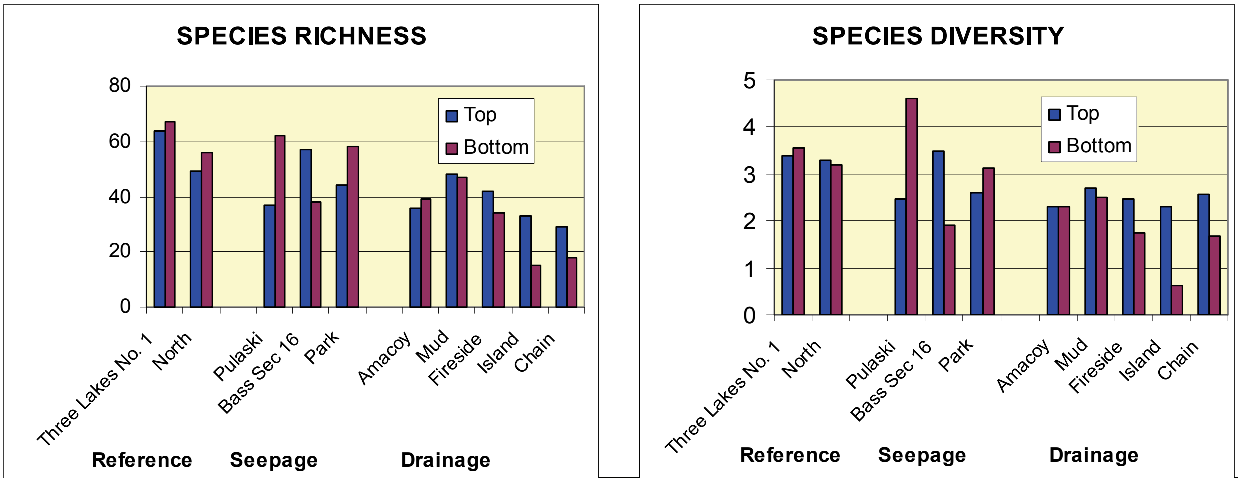

Figure 3. Species richness and diversity from the study lakes. Lake are grouped: reference, seepage,

been 1-2 µg L^{-1}.

There has been a slight decline in both species richness and diversity in the top sample compared with the bottom. This further supports the conclusion there has not been an increase in macrophytes but there has been an increase in the planktonic diatoms. Macrophyte communities support a much more diverse diatom community than is found in planktonic diatom community because there are so many varied habitats on the plants and sediments.

North Lake This lake possesses a diatom community that typical of acidic lakes. In contrast to the previous lake, the amount of planktonic diatoms has decreased (Figure 4). The change in composition

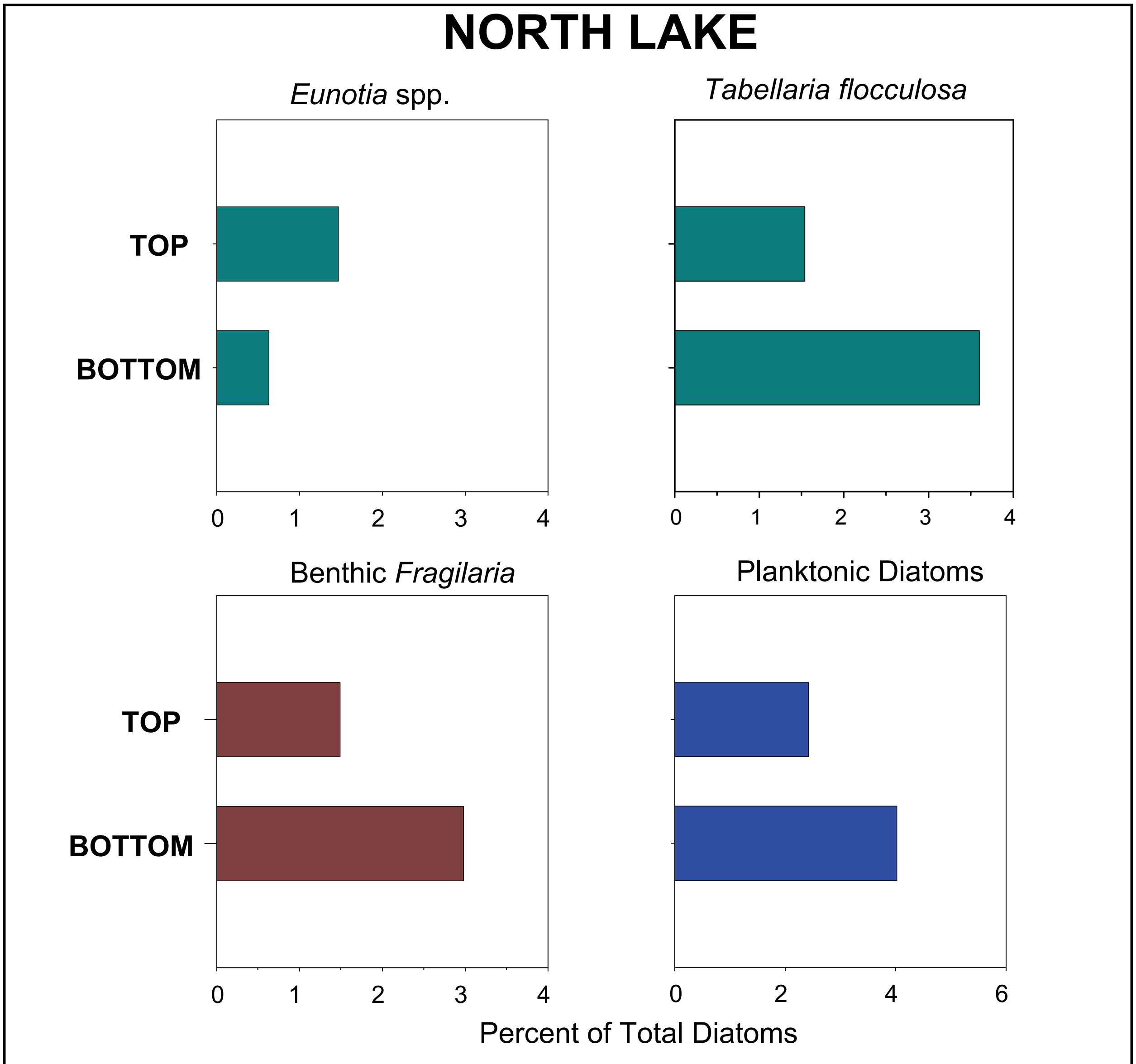

Figure 4. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

of the diatom community experiences a greater change between the bottom and top sample than experienced in Three Lakes No. 1. The largest changes are a decline in *Tabellaria flocculosa* from the bottom to the top and the virtual elimination of *Aulacoseira perglabra* in the surface sample. Although fewer species were found in the surface sample (Figure 3) the diversity was greater, reflecting at the surface, a community that had fewer dominant species.

North Lake seems to have a larger macrophyte community at the present time compared with presettlement time period. This is likely the result of past logging activities, but more importantly is associated with the road that leads to the lake shore. Undoubtedly, during runoff events, sediment is delivered to the lake and this has led to an increase in the macrophyte community. Unlike Three Lakes No. 1, the present day phosphorus level is similar to historic levels.

EUTROPHICATION

Seepage Lakes

Six of the 12 lakes discussed in this report are seepage lakes. This means there are no surface inlets or outlets to these lakes. They receive their water from precipitation, ground water, and overland flow near the lake shore. Two of these lakes have been discussed in the previous section.

<u>Pulaski Lake</u> This lake has experienced an increase in planktonic diatoms, specifically *A. ambigua* Figure 5). This diatom is one of the most common species in the Upper Midwest, being found in oligotrophic to moderately eutrophic lakes. There was also a decrease in planktonic diatom *Cyclotella* which generally are indicative of lower nutrients. There was also a large decline in species richness and diversity from the bottom to the top of the core. This decline was much greater than was experienced in the reference lakes. These trends indicate there has been an increase in nutrients during the last century in this lake. In many lakes in northern WI with shoreland development, there has been little or no increase in nutrients but an increase in the macrophyte community. If there has been an increase in the macrophytes in this lake, it is over shadowed by the large increase in planktonic diatoms. Modeling indicates that the increase in phosphorus has been around 3-4 $\mu g\ L^{-1}$.

<u>Bass Lake Section 12</u> This lake has also experienced an increase in planktonic diatoms, especially *A. ambigua* (Figure 6). There was also a large decline in benthic *Fragilaria*. These diatoms typically are associated with macrophytes and sediments. As with Pulaski Lake, this lake has experienced increase in nutrients at the present time compared with historical conditions. There is some agricultural activity in the watershed and this appears to be introducing nutrients to this lake. The modeling indicates that phosphorus levels have increased slightly more than Pulaski Lake, about 5 $\mu g\ L^{-1}$.

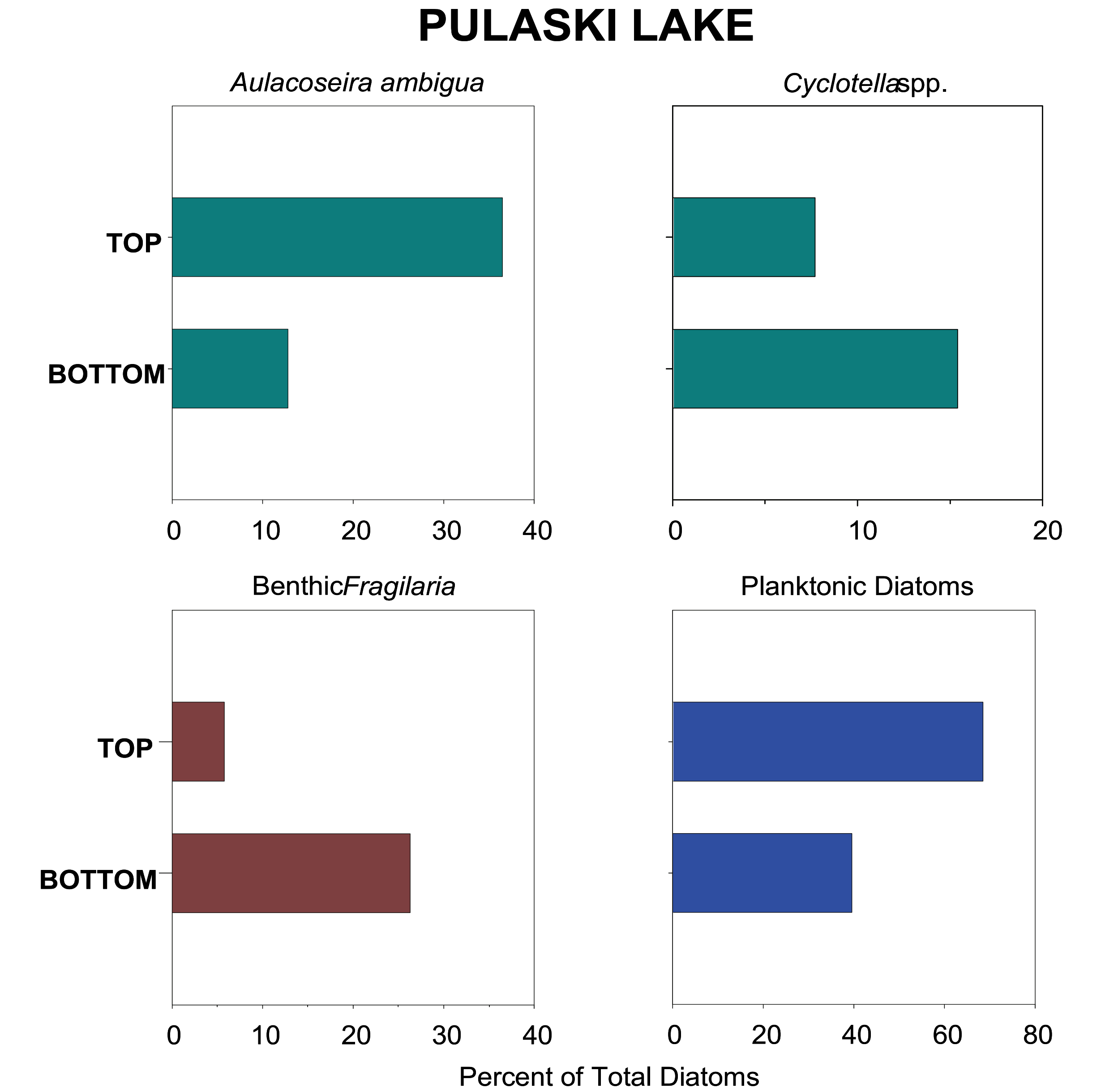

Figure 5. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

Because this core was not analyzed as part of this study, the diatom analysis was different. Specially, fewer diatom valves were counted. This means that species richness and diversity for this lake can not be compared with other lakes in this study. This is because as more diatoms are counted in a sample the taxa richness increases. The diversity is also influenced by the total number of valves counted. Since the same number of valves were counted in the top and bottom samples of this core, richness and diversity can be compared within the core. Unlike Pulaski Lake, the species richness and diversity

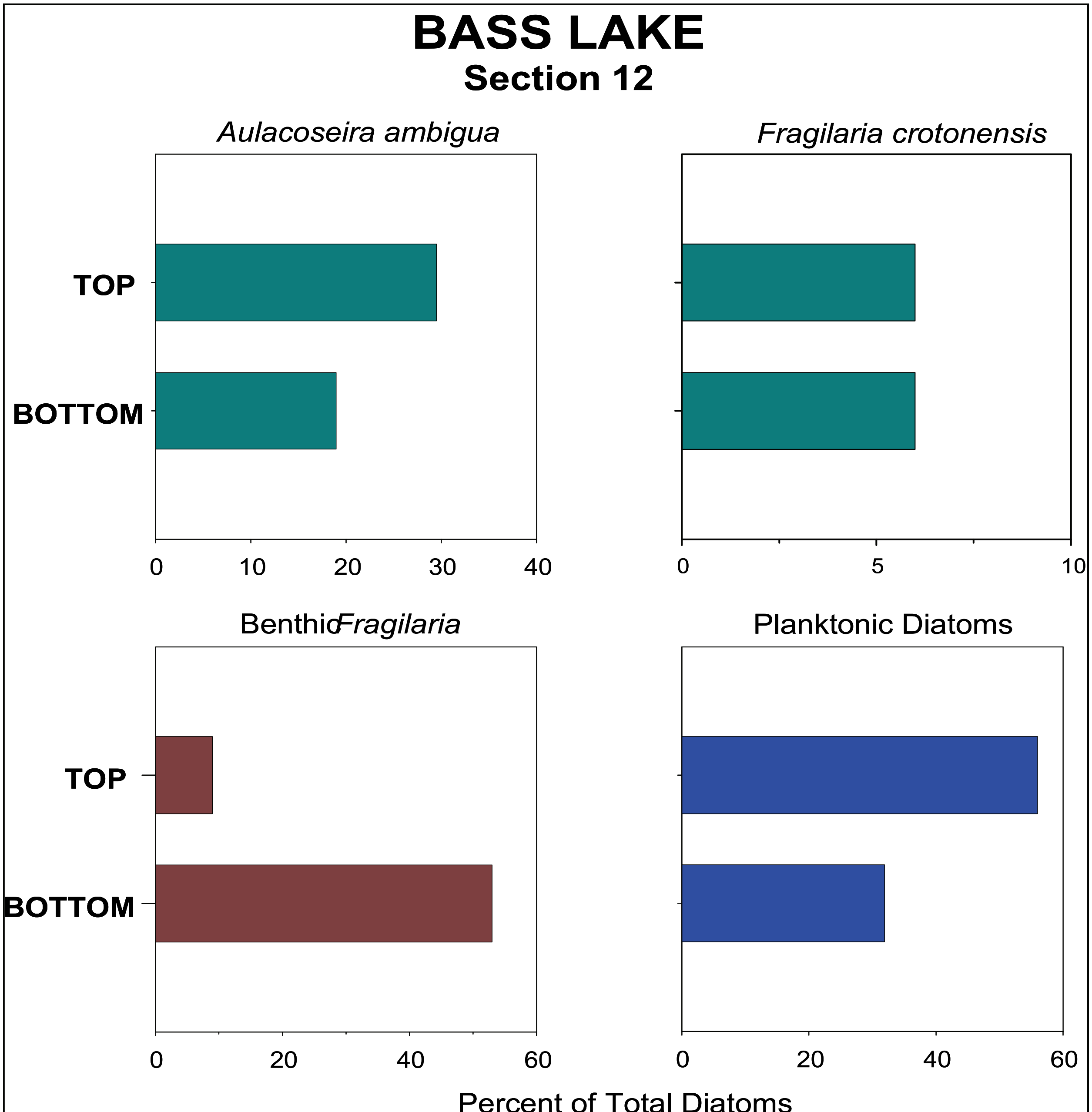

Figure 6. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

is similar at the top and bottom of the core. This is somewhat surprising. It is expected that richness and diversity would decline as was experienced in Pulaski Lake.

Bass Lake Section 16 This lake has under gone the greatest floristic change of any of the lakes in this study. This lake is a very softwater, acidic lake. The sample at the bottom of the core was dominated by the benthic diatom *Pinnularia biceps* (Figure 7). In the surface sample it was only present in very

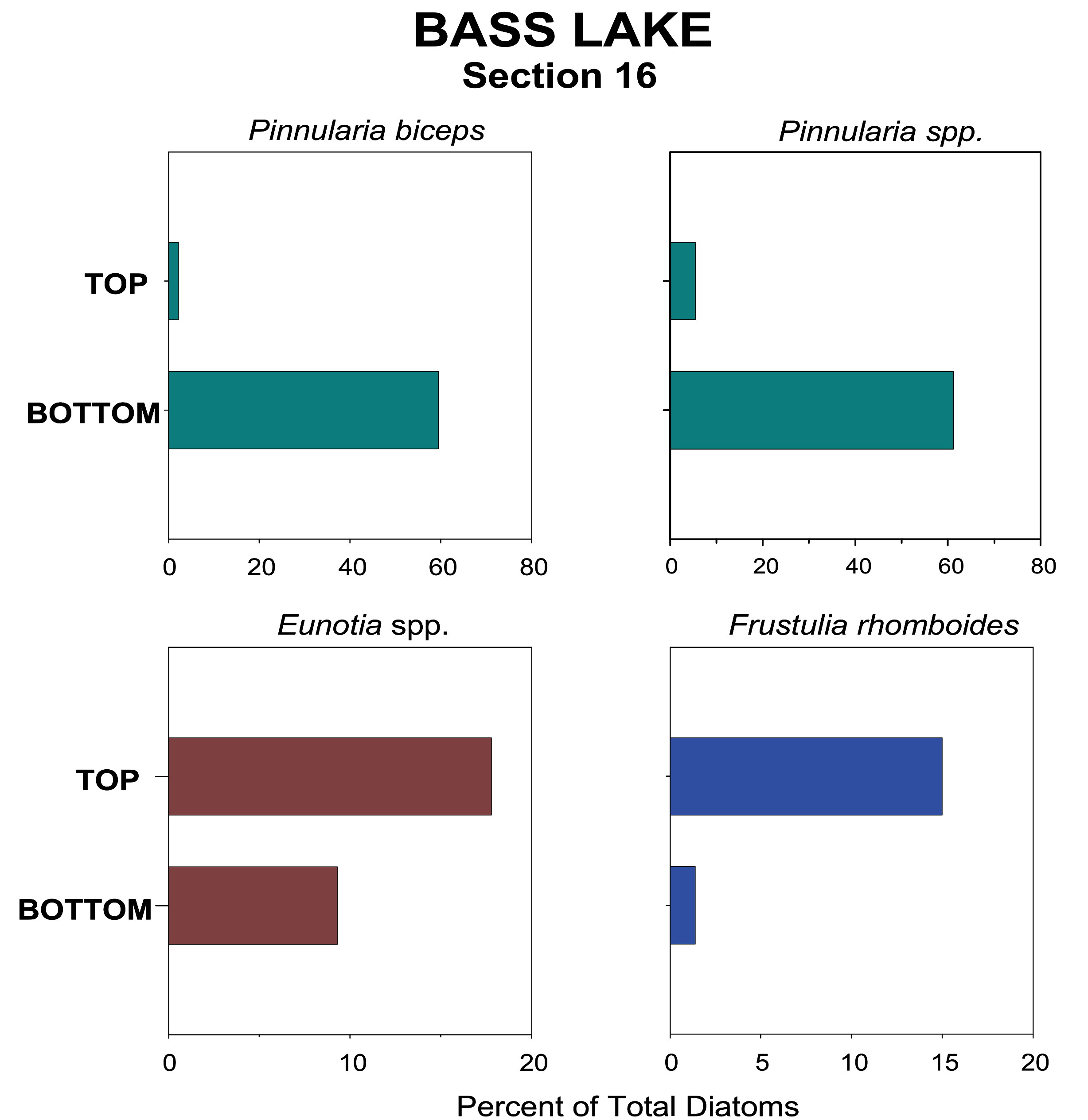

Figure 7. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

low numbers. It was replaced in the surface sample by *Frustulia rhomboides*, another acid loving diatom as well as a variety of species of the genera *Navicula*, *Eunotia*, and *Nitzschia*. Since this lake is an acidic seepage lake it is sensitive to acid precipitation as well as increased nutrients. The impact of acid rain will be discussed in a later section.

Unlike the lakes discussed previously, Bass Lake experienced a significant increase in species richness and diversity (Figure 3). This increase is due entirely to diatoms that grow on benthic substrates, e.g. macrophytes. Partly, there has not been an increase in planktonic diatoms because the pH is low, but also there has been little increase in nutrients. It is clear that activities in the watershed have impacted the lake. This impact has been manifested by increased productivity of the benthic community and not an increase in phosphorus. In fact, this lake had one of the lowest phosphorus concentrations-similar to the reference lake, North Lake (Table 2)

<u>Park Lake</u> In contrast to Bass Lake sec 16, this lake was the most eutrophic seepage lake of those discussed in this report. It also the shallowest lake with a maximum depth of about 10 feet. This lake experienced an increase in planktonic diatoms (Figure 8), although not as much as some of the other lakes. Because of the lake's depth, most of the diatom community is associated with benthic substrates. The fact that there has been an increase in planktonic diatoms is an indication of the increase in nutrients the lake has experienced. There has also been an increase in benthic *Fragilaria* which indicates an increase in macrophytes.

The diatom community experienced a decline in species richness and diversity during the last century which is a further indication of the increase in nutrients. The modeling indicates that phosphorus levels in this lake have more than doubled from the bottom to the top of the core.

Drainage Lakes

Drainage lakes are those that have a surface inlet and outlet. They often have a larger watershed than seepage lakes and thus are more susceptible to eutrophication. Conversely, in Wisconsin they are not susceptible to acidification because there are enough acid neutralizing materials in our soils. In this study six of the 12 lakes were drainage lakes. Table 1 lists these lakes.

<u>Amacoy Lake</u> This lake experienced a moderate increase in planktonic diatom species during the last century (Figure 9). Unlike the seepage lakes, there was a decline in *A. ambigua*. It was replaced by the planktonic diatom *Fragilaria crotonensis*. This diatom is commonly found in eutrophic lakes. Although it increases in response to increases in phosphorus levels, it may be more responsive to increased nitrogen concentrations.

There was little change in species richness or diversity from the bottom to the top of the core (Figure 3). This likely reflects the fact that the lake was moderately eutrophic historically. Nutrient levels during the time period represented at the bottom of the core were high enough that planktonic diatom dominated the community. With increased nutrient levels richness was unchanged. Even if the magnitude of the macrophyte community increased during the last century, the diatoms associated with these plants, were overwhelmed by the planktonic diatoms.

Mud Lake The diatom community of this lake is similar to that of Amacoy Lake. The surface sample had less of the planktonic diatom *A. ambigua* and more *F. crotonensis* compared with the bottom sample. The increase in *F. crotonensis* indicates an increase in nutrients, especially nitrogen, during

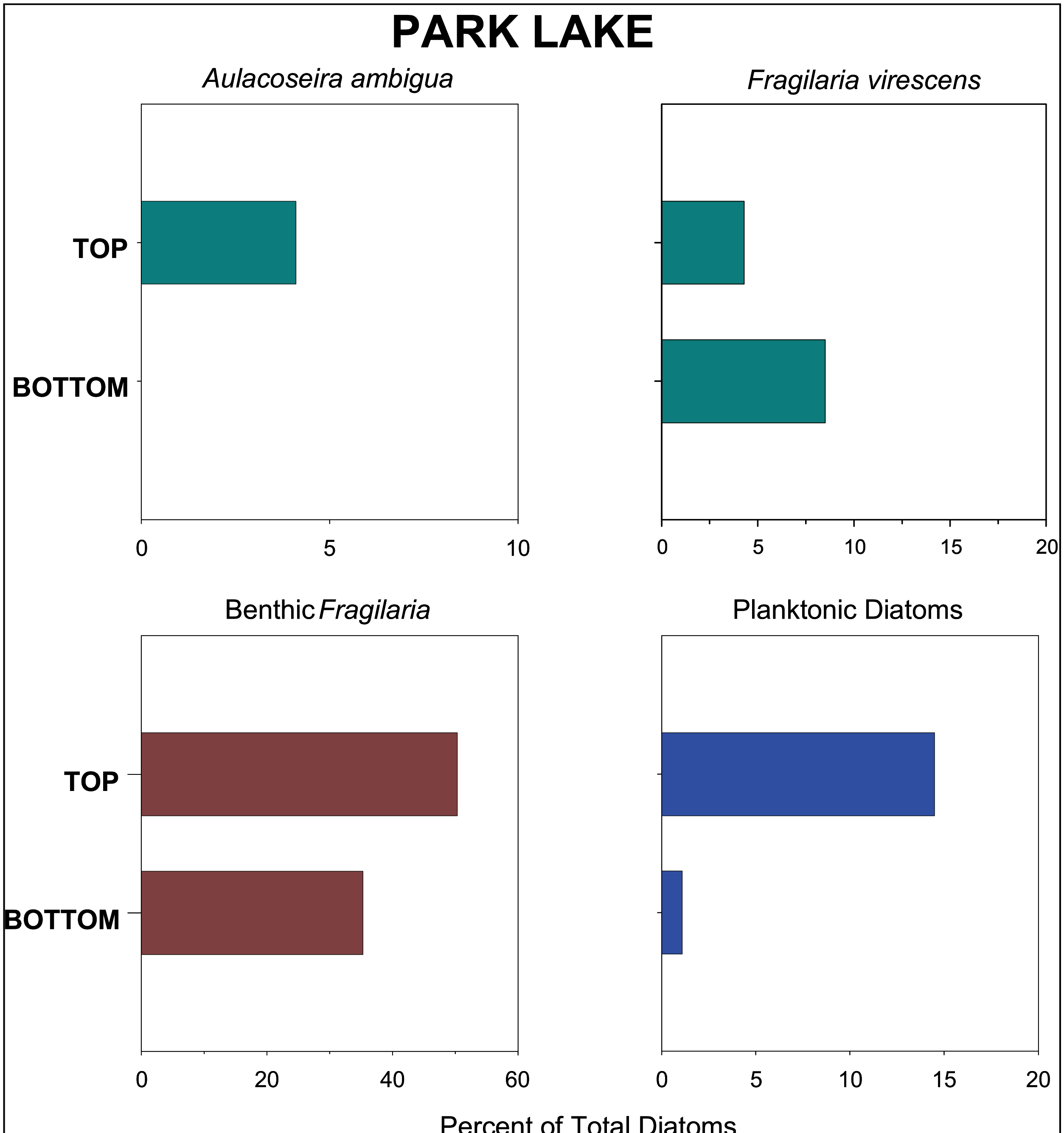

Figure 8. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

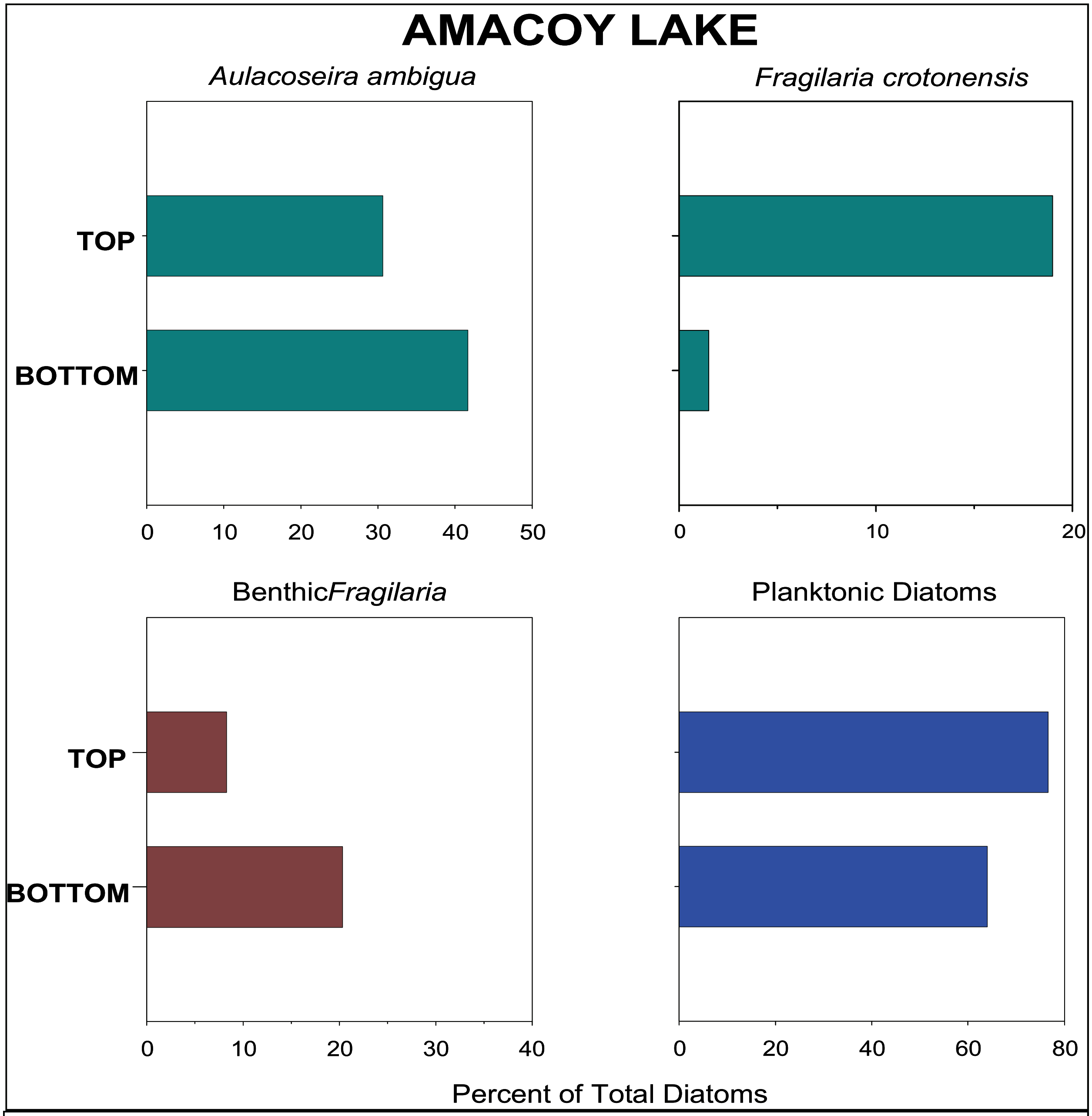

Figure 9. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

the last century.

The diatom community in this lake had more species and greater diversity compared with Amacoy Lake (Figure 3). This likely reflects the smaller size and shallower depth of Mud Lake. This means that the diatoms associated with the macrophyte community comprise a greater part of the diatom assemblage. Compared with Amacoy Lake, Mud Lake experienced a greater increase in richness and diversity between the bottom and the top of the core. This indicates there has been more of an increase in

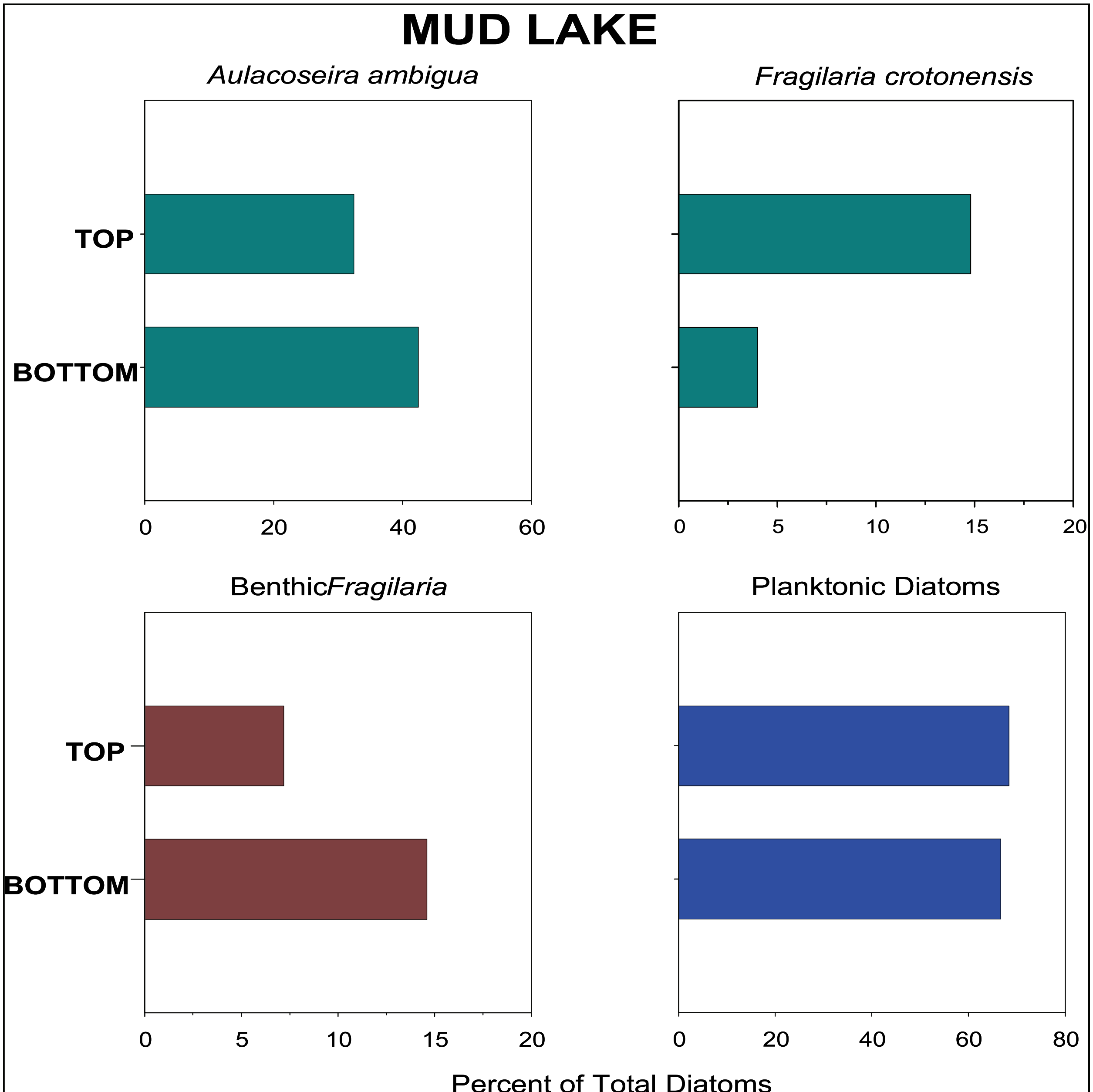

Figure 10. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

the macrophyte community in Mud Lake. The decline in benthic *Fragilaria* (Figure 10) reflects the higher level of nutrients in the surface sample compared with historical levels. As with Amacoy Lake, Mud Lake was historically moderately eutrophic.

Fireside Lake The lake is connected to Mud Lake by a narrow channel. Much of the diatom community is similar in both lakes. There are slightly less planktonic diatoms in the surface sample, largely as a result of decreased occurrence of *A. ambigua* (Figure 11). As with Mud Lake, there is an increase of

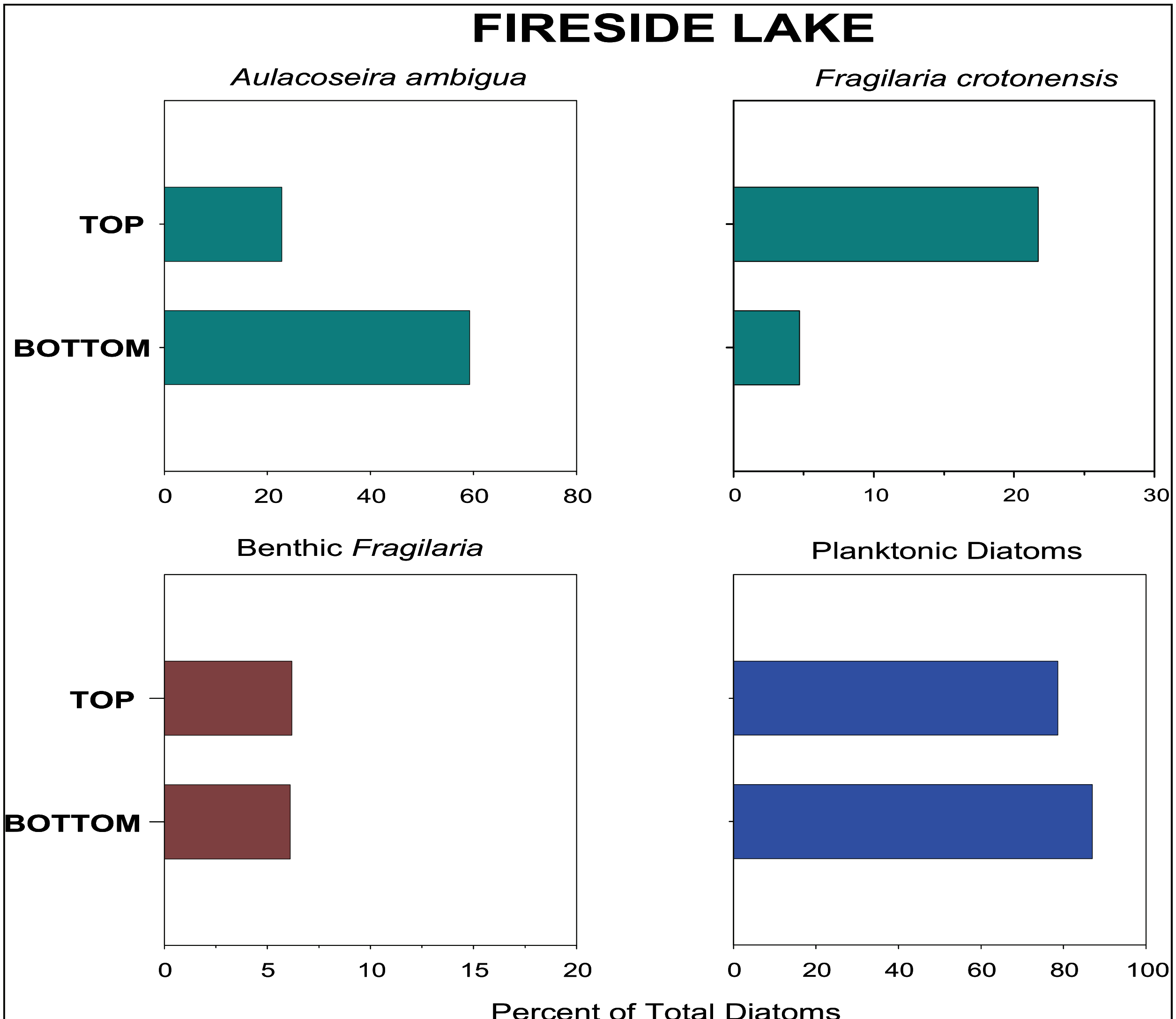

Figure 11. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

F. crotonensis in the surface sample, compared with the bottom sample. The increase in *F. crotonensis* indicates an increase in nutrients, especially nitrogen.

There were fewer species in Fireside Lake compared with Mud Lake. This was largely because Fireside Lake is larger which means the littoral area comprises a smaller portion of the lake. Since the number of species is greater in the littoral area, it is not surprising that Mud Lake had more diatom species. The diversity and number of species in the diatom community was higher in the surface sample compared with the bottom sample. This indicates there has been an expansion of the macrophyte community during the last century.

Potato Lake Similar to Mud Lake, the percentage of the planktonic community is largely unchanged

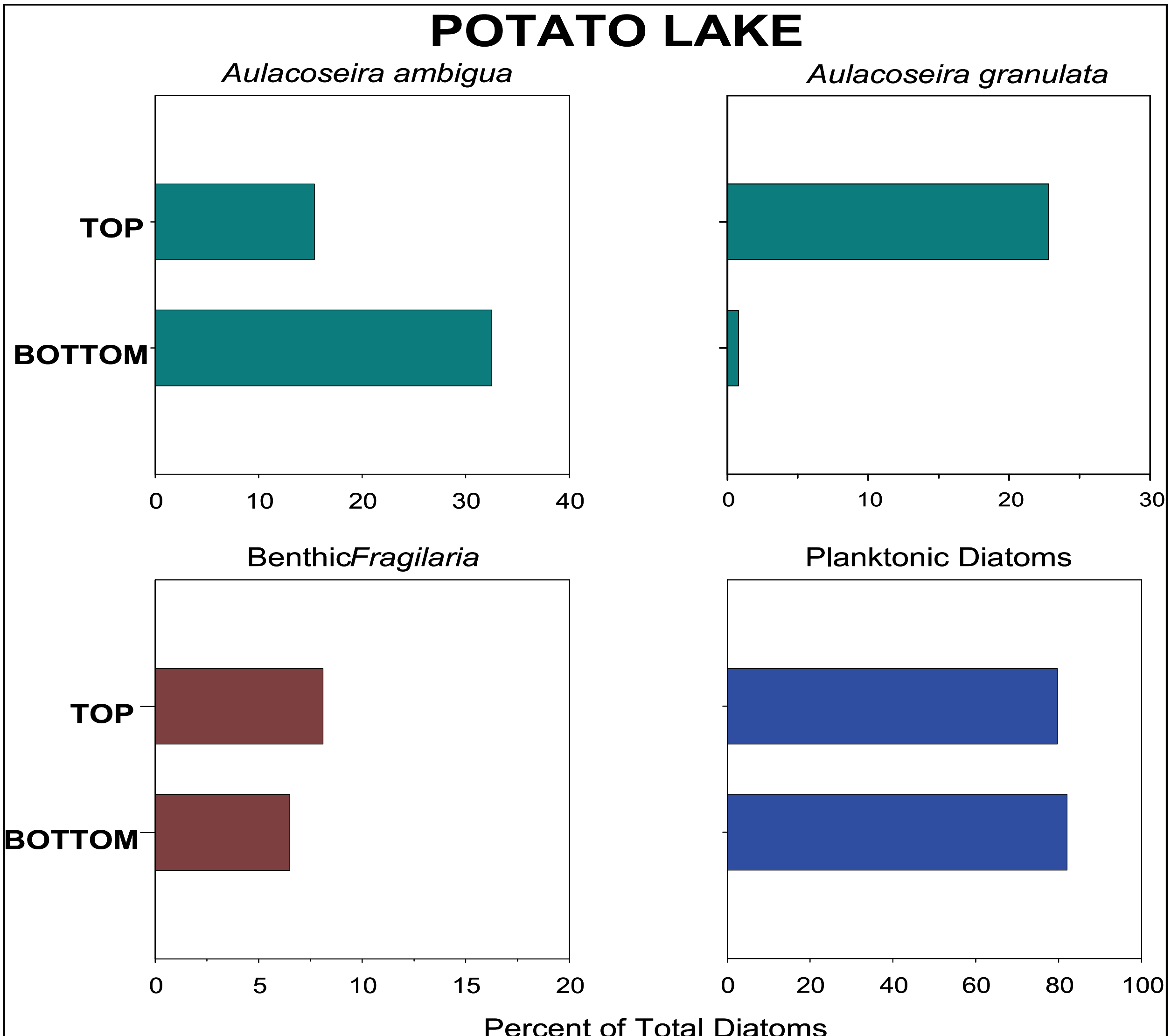

Figure 12. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

from the bottom to the top of the core. As with the previous two drainage lakes, there is a decline in *A. ambigua* (Figure 12). In Potato Lake the taxa that increases in *Ambigua granulata*. This species is also planktonic but it prefers higher nutrients than *A. ambigua*. This indicates that the phosphorus levels in this lake have increased during the last century. Unlike the previous two lakes, the percentage of benthic *Fragilaria* did not decline. This indicates that even though nutrient levels increased, macrophytes have also expanded. This is probably more obvious in Potato Lake because of its shallow depth and relatively large size.

As with the previous two lakes, historically Potato Lake was slightly eutrophic. The modeling indicates that the background phosphorus levels were slightly higher in this lake than the other two. Inferring phosphorus levels using the diatom community is difficult with relatively large, shallow lakes like Potato Lake. This lakes often experience significant internal phosphorus loading during the summer. Since the summer algal community is dominated by blue-green algae with few diatoms, the diatom community does not accurately reflect this increase in phosphorus. Therefore it is likely that changes in the diatom community do not fully reflect phosphorus levels in this lake. This is particularly true in the surface sample and it may also be true in the bottom sample.

Island and Chain lakes These lakes are connected to each other and water flow is from Chain into Island Lake. Therefore, it is not surprising that the diatom community in these lakes has undergone similar changes. These are the largest and deepest lakes in the study and their diatom communities

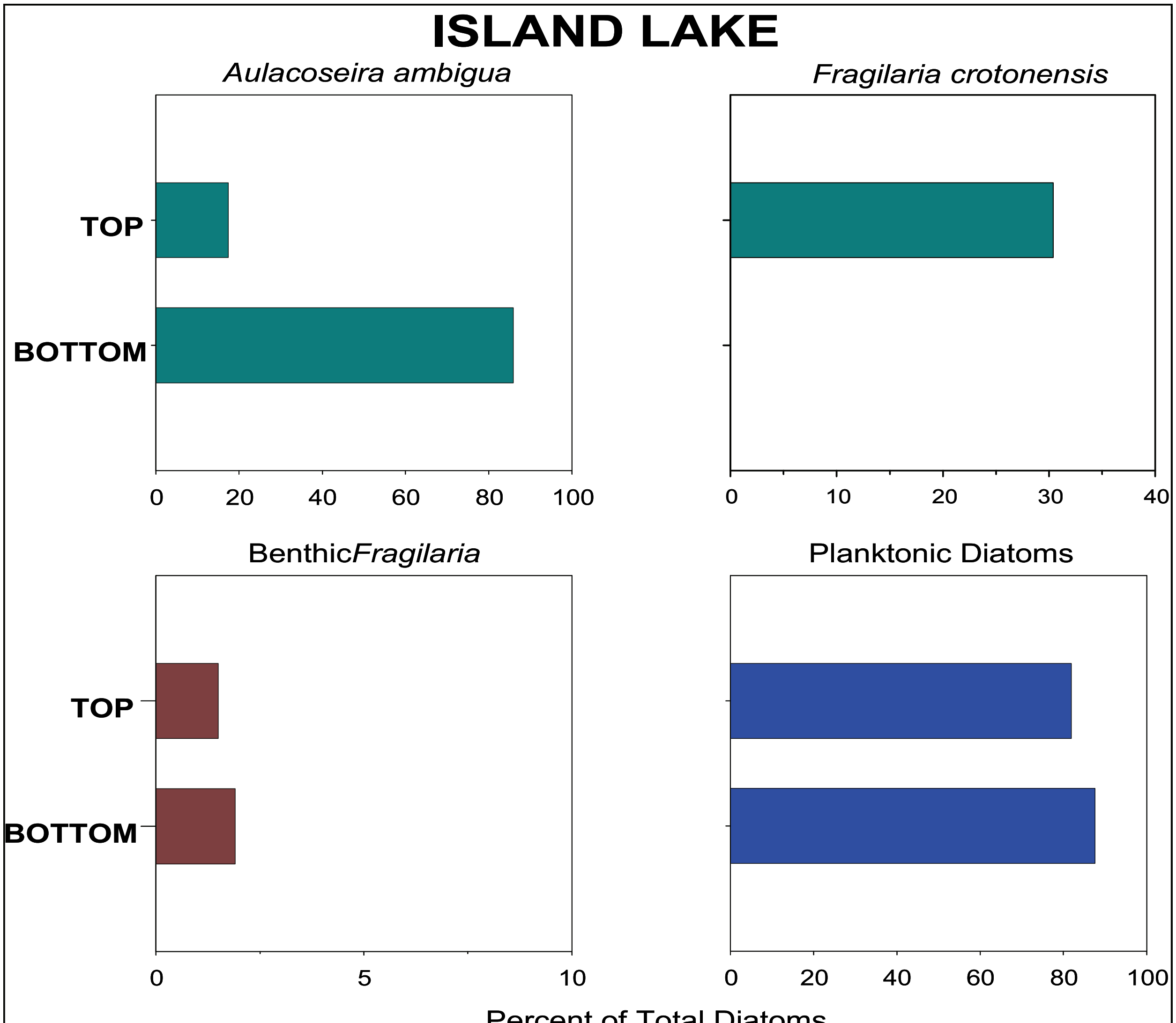

Figure 13. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

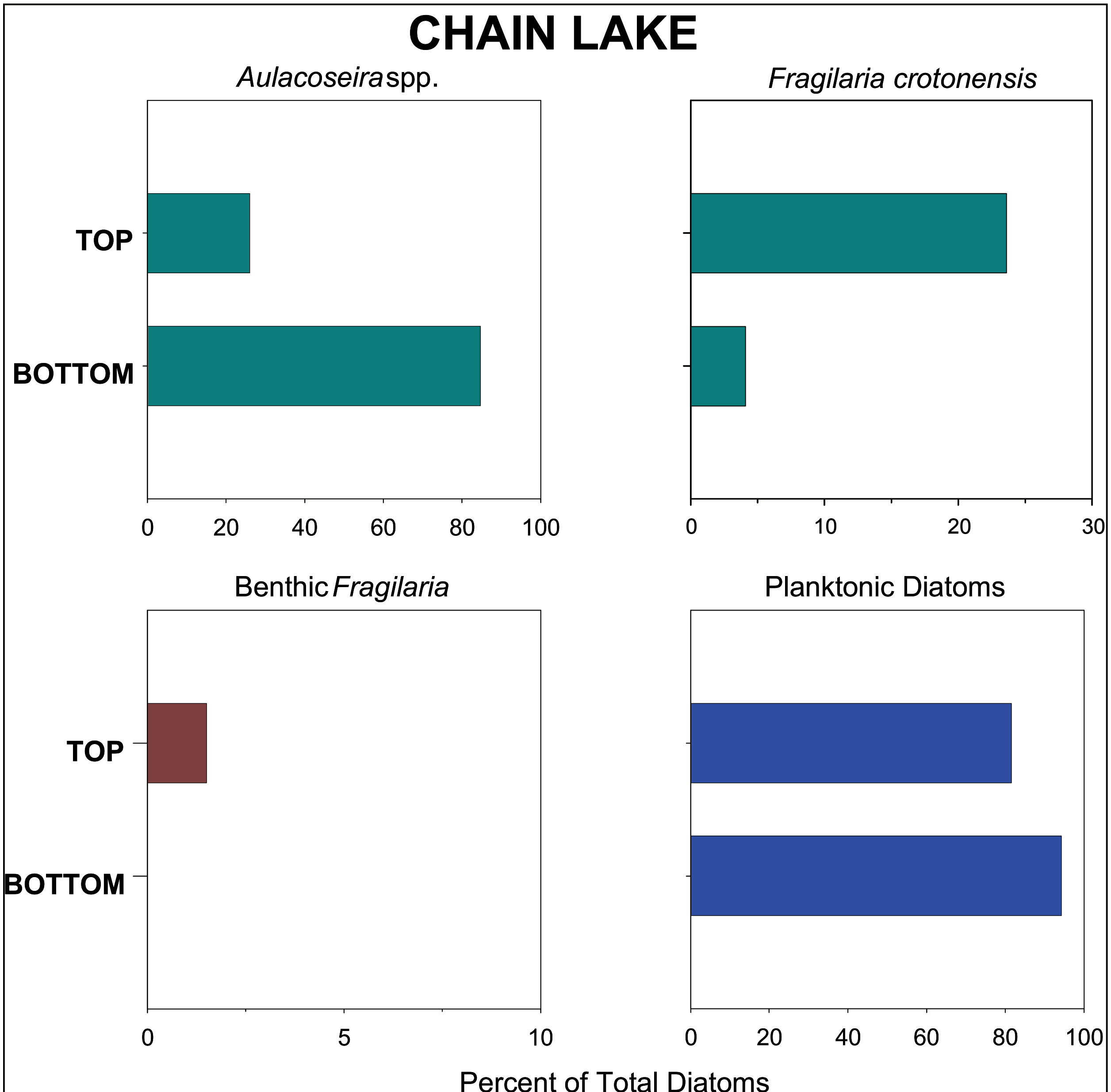

Figure 14. Changes in abundance of important diatoms found at the top and bottom of the sediment core.

are dominated by planktonic diatoms (Figures 13 and 14). They comprise over 80 per cent of the community. In both lakes there is a decline of *Aulacoseira* taxa and an increase in *F. crotonensis*. This indicates there has been a moderate increase in nutrients, especially nitrogen.

In both lakes there was a significant increase in species richness and diversity at the top of the core. This increase is largely the result of more diatom taxa that are associated with macrophytes. This indicates that there as been a significant increase in the macrophyte community during the last century.

Estimated changes in phosphorus

Diatom assemblages historically have been used as indicators of trophic changes in a qualitative way. In recent years, ecologically relevant statistical methods have been developed to infer environmental conditions from diatom assemblages. These methods are based on multivariate ordination and weighted averaging regression and calibration. Ecological preferences of diatom species are determined by relating modern limnological variables to surface sediment diatom assemblages. The species-environment relationships are then used to infer environmental conditions from fossil diatom assemblages found in the sediment core.

The inferred phosphorus analysis done on these lakes had a few problems. Because of the calibration dataset available does not include many taxa from acidic lakes, the model did not work well with some of the samples. Specifically it did not accurately estimate the surface phosphorus concentration in Bass Lake, section 16 or North Lake. The model also does not work well with shallow lakes that contain a significant number of diatom taxa that are associated with benthic environments. These diatoms typically are found in a wide range of nutrient levels. Because of the overall type of lakes in the dataset, phosphorus values are underestimated in these types of lakes.

Table 3 shows the observed and diatom inferred mean summer phosphorus concentrations. In the reference lakes, the model underestimated the phosphorus values in Three Lakes No. 1. The model did indicate a small increase in phosphorus. This is probably accurate and the increase seems to be about 1-2 µg L^{-1}. In the North Lake the models indicates a decrease in phosphorus from the bottom to the top of the core. This is most likely not accurate. Instead it appears the phosphorus levels in this lake have not changed.

For the seepage lakes, background phosphorus levels are lower than in the drainage lakes. This is not surprising as seepage lakes have smaller watersheds and thus less nutrients entering the lakes if the watershed is in a natural condition. With the exception of Bass Lake section 16, all of the seepage lakes have experienced an increase in phosphorus levels during the last century. The increase is around 3-5 µg L^{-1}. The exception to this is Park Lake. The model did not accurately estimate the present day phosphorus concentrations because the diatoms are dominated by benthic taxa. Also, one of the dominant taxa, *Fragilariforma virescens* was not in the calibration dataset. The model does estimate a doubling of the phosphorus levels.

For most of the drainage lakes the modeling indicates little increase in phosphorus levels in the last 100 years. The exception to this was Potato Lake. As would be expected with shallow lakes, the

Table 3. Diatom inferred summer phosphorus levels in the study lakes. The inference was done using the weighted averaging program WACALIB. This analysis requires an appropriate calibration dataset. The calibration dataset used was from Wisconsin lakes. However, this analysis does not perform well if enough diatom taxa present in the core are not in the calibration dataset. This was true for some of the acidic and shallow lakes. This analysis also may not accurately reflect summer P levels in shallow lakes that experience significant internal loading during the summer. This likely occurs in Potato Lake. Therefore the estimated phosphorus in the surface sample is an underestimate of peak summer levels. See the text for more detail.

		Inferred Summer Phosphorus (µg L^{-1})	
	Observed	Top	Bottom
Reference Lakes			
Three Lakes No. 1	34	8	6
North	10	7	11
Seepage Lakes			
Pulaski	12	14	11
Bass sec 12	16	17	12
Bass sec 16	9		8
Park	77	15	8
Drainage Lakes			
Amacoy	44	20	19
Mud		20	19
Fireside	19	19	18
Potato	163	35	21
Island	22	17	17
Chain	21	24	22

model underestimates present day phosphorus levels but it does indicate a significant increase in phosphorus during the last 100 years. Estimating summer phosphorus levels using the diatom community may not be accurate in relatively large shallow lakes like Potato Lake. These lakes often experience significant internal loading of phosphorus during the summer from the sediments. This occurs because: 1) wind driven waves suspend sediment in the water column where algae may access the phosphorus, 2) as algal blooms occur, photosynthesis increases the pH resulting in more phosphorus being released from the sediments, and 3) some blue-green algae are able to initially grow on the surface of the sediments and as light levels are reduced they migrate up into the water column. Since diatoms in these types of lakes typically only grow in the spring and perhaps the fall, they do not reflect summer phosphorus levels when they are at their highest. What the diatom community is able to estimate is spring phosphorus levels.

In Potato Lake the estimated increase in phosphorus during the last century reflects increased phosphorus in the early part of the growing season. Since spring phosphorus levels have increased it is very likely summer levels have increased even more. With higher P levels in the spring, the algal community would be larger and this would cause greater internal loading.

Big Round Lake in Polk County is a large shallow lake like Potato Lake. A full core collected from this lake showed little change in the diatom community but a significant shift in blue-green algae after the 1940s. This shift was the result of higher phosphorus levels, primarily because of internal loading.

ACIDIFICATION

Two of the lakes in this study are susceptible to acidification because of their low buffering capacity (alkalinity) (Table 2). These are Bass Lake section 12 and North Lake. Their pH values were 6.2-6.3 which is lower than most lakes. These are both seepage lakes which is part of the reason they are sensitive. Because of their low alkalinity values, they only receive small amounts of ground water input. If more than about 5-10 per cent of their water input is from groundwater, they would have higher pH levels. There is enough buffering materials (calcium) in the soils so that if more groundwater enters the lake pH values would be higher.

The diatom community indicates that Bass Lake is the more acidic of the two lakes. There are almost no planktonic species and the diatom community is one that is typically found in acidic lakes. The diatom communities in both lakes indicate that neither of these lakes had a pH below 5.0 historically. In fact it would appear that the pH levels have not changed significantly in either lake. These lakes, especially Bass Lake have been impacted more by nutrient input than acidification.

Summary

This study used the diatom community in sediment cores to estimate how current nutrient and pH levels in selected Rusk County lakes compare with pre-settlement levels. Two of the lakes were used as potential reference lakes because their watersheds are forested and undeveloped. Three Lakes No. 1 appears to naturally have elevated phosphorus levels. The phosphorus levels over the last century may have increased but only be a small amount. North Lake naturally has low phosphorus levels and these have not changed in the last century. However, the macrophyte community has increased, most likely as a result of sediment runoff from the road leading to the lake.

The seepage lakes historically had phosphorus concentrations lower than the drainage lakes. This is not surprising as their watersheds typically are smaller. This means there are less nutrients entering the lake. All of the seepage lakes, with the exception of Bass Lake section 16, have experienced an increase in phosphorus during the last century. The increase has been on the order of 3-5 μg L^{-1}. Bass Lake section 16 has not experienced an increase in phosphorus but it has seen an increase in the macrophyte community.

While the drainage lakes naturally had a higher phosphorus concentration, they have generally not seen an increase in phosphorus levels during the last century. Some of them have experienced an increase in the amount of macrophytes. This is especially true for Island Lake. This response of increased macrophytes is one that frequently occurs.

Almost the first significant ecological change that occurs with an increase in nutrients is more macrophyte growth. Apparently, sediment brought into the lake because of watershed disturbance alters the littoral environment allowing growth of larger macrophyte species. Once these larger plants get established they produce more organic matter and their architecture reduces water movement and helps retain the finer sediments in the near shore area.

This response has been found in most northern Wisconsin lakes that have largely forested watersheds but some shoreland development. Paleolimnological studies have shown that usually in these lakes phosphorus levels have not increased but the macrophyte community has been altered. A study conducted by Dr. Susan Borman comparing macrophyte communities in the 1930s with those now in seepage lakes in northwestern WI found direct evidence of this. She found that many lakes historically has macrophyte communities composed of species which are short growing and relatively sparse. Now, many of these lakes have macrophyte communities dominated by taller growing species which possess much larger leaf surfaces. All of these lakes that have experienced this change have forested watersheds but some shoreland development.