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REGIONAL COPPER-NICKEL STUDY

STREAM PERIPHYTON

Minnesota Environmental Quality Board

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INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

ABSTRACT

Periphyton communities were sampled in the Regional Copper-Nickel Study Area (Study Area) during 1976 and 1977. Diatoms were the most abundant algal component and Achnanthes minutissima was the most abundant diatom taxa. Periphyton production was highest in spring and fall.

Periphyton communities in the Study Area are related to stream order. As stream order increases, production increases and the relative abundance of acidophilous diatoms decreases.

Current taconite mining operations have caused some shifts in the dominant species but not in periphyton diversity or production. In general, streams affected by mining have higher relative abundances of A. minutissima and lower relative abundances of acidophilous species.

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INTRODUCTION

Stream periphyton communities are composed of bacteria, fungi, protozoa, and algae which grow attached to substrates. The primary producers, composed of various algal groups, are the most studied component of the periphyton community and have been referred to as the phyco-periphyton (Collins and Weber 1978). Under most conditions, diatoms dominate the phyco-periphyton comprising about 90% of the algae cells (Hynes 1970, Potter et al. 1975). Diatom species are widespread and occur under a wide variety of conditions. A large number of species is normally present; as environmental conditions change different species flourish. The factors considered most important in determining the distribution and dominance of diatoms include: temperature, light, current velocity, substrate, pH, nutrients, and the concentration of various anions and cations. Their importance to diatoms has been reviewed by Patrick (1977) and Blum (1956).

Seasonal changes in stream periphyton communities are not well understood. Most diatom species are present throughout the year and attain dominance when conditions become optimal. Whitton (1976) described a spring and fall diatom bloom in streams while the green algae become more important during midsummer. The spring diatom maximum occurs as water temperatures and light intensity increase and before leaves develop on overhanging vegetation. The fall maximum occurs as leaves begin falling and streams begin to cool (Hynes 1970). Species such as Cocconeis placentula and Navicula cryptocephala have midsummer maxima while other species occur as winter, spring, or fall dominants (Peters et al. 1968). Primary productivity generally increases with warmer temperatures and greater light intensity, although Waters (1961) and Peters et al. (1968) reported spring and fall maximums in chlorophyll a production, a measure of algal standing crops. Douglas (1958) related seasonal changes in diatom population size to the populations of grazing invertebrates. This aspect of seasonality has not been extensively studied.

Patrick (1958) reported that similar diatom communities developed under similar ecological conditions and stated that most diatom species are ubiquitous. Patrick (1967) also discussed the relation of the species pool, invasion rate and size of habitat to diatom communities. As any one of these factors increase, the number of rare taxa in the population also increases.

Studies of community succession along a stream have been made but no definitive data have been presented. Longitudinal changes in stream periphyton communities can be expected as chemical and physical parameters change along the length of a stream (Regional Copper-Nickel Study 1978b). Butcher (1946) stated that there is a decrease in planktonic diatoms and an increase in planktonic green and blue-green algae as one moves downstream from the source of a stream. Increased primary production by periphyton occurs between the headwaters (1st through 3rd order streams) and the midreaches (4th to 6th order streams) followed by a decrease further downstream (Wetzel 1975, Cummins 1976).

Periphyton communities have been extensively studied because they provide most of the instream primary production in first through sixth order streams. In recent years interest has grown in periphyton communities as indicators of water quality (Cairns et al. 1972 , Patrick 1973; 1975). The use of periphyton to monitor environmental changes has been suggested because periphyton respond rapidly to changes in water quality, they are sessile organisms subjected to all water quality changes, and sampling is relatively easy in comparison to other stream organisms. Lowe (1973) compiled the available autecological data for diatoms to facilitate the assessment of water quality through biological sampling.

Several parameters are used to analyze periphyton communities: chlorophyll a, ash-free dry weight, cell counts and species proportional countes (Weber 1973). Measures of diversity and/or the number of species in the community are also important parameters (Patrick 1973). With this information, an estimate of the productivity and diversity of the diatom community can be made and the water quality assessed.

Because of the importance of periphyton to stream ecosystems and their usefulness in assessing water quality, a study of stream periphyton in the Regional Copper-Nickel Study Area (Study Area) was initiated in May, 1976. This study was designed to characterize: 1) the relative productivity of periphyton communities in various Study Area streams; 2) diatom species distributions and dominant species within the Study Area; 3) the relation of diatom communities to stream order; 4) the effect of current mining practices on periphyton communities; and 5) some of the factors responsible for the observed diatom distributions and dominance. With this characterization, prediction of the potential impact of copper-nickel development on periphyton communities should be possible for streams which were intensively sampled and to a lesser degree in streams which were not sampled during this study. This characterization is not meant to be a baseline which could be used to quantitatively assess the impact of copper-nickel development in future years. A statistical analysis of the periphyton data will be made available in another report.

METHODS

Study Area

The Study Area encompasses 5516 km^2 in Lake and St. Louis counties in northeastern Minnesota (Figure 1). The area is divided into two major watersheds by the Laurential Divide; water south of the divide flows to Lake Superior while water north of the divide flows to Hudson Bay. Within the Study Area there are 2623 km (1630 miles) of streams.

Streams in the Study Area are generally bog stained, soft water streams. Alkalinity ranges from 1 to 190 ppm $CaCO_3$ but is generally less than 50. Because the source of many of the streams is in bogs, low pH is found in headwater streams; median pH ranges from 66 in headwater streams to 7.5 in downstream reaches. The streams consist of long flat reaches connected by short riffles. Average gradients range from 4.7 m/km to .8 m/km. Substrates in Study Area streams range from silt, sand, and/or detritus in pools to gravel, rubble, or bedrock in riffles.

Sampling Area and Stations

Periphyton sampling was concentrated in the area east of Biwabik and south of Ely in the area of greatest potential for copper-nickel development. This area is unshaded in Figure 1. In 1976 sampling stations were located in riffle areas within those watersheds which had the greatest potential for impact from copper-nickel mining. Stations were designated "primary", "secondary", or "tertiary" depending on the sampling intensity scheduled for the station (Table 1). Primary stations were located in downstream portions of the watershed and were sampled quantitatively and qualitatively. These stations were selected to reflect the culmination of conditions within the watershed. Secondary stations were also sampled quantitatively and qualitatively but less frequently than primary stations and were located in upstream portions of watersheds or in areas already impacted by taconite mining or copper-nickel exploration. Tertiary stations were sampled only qualitatively and were located throughout the Study Area so that overall distributions of periphyton species in the Study Area could be examined.

Additional stations were sampled in 1977 and were located over a larger portion of the Study Area. Emphasis was placed on sampling stations more evenly distributed over the various stream orders found in the Study Area. These stations, designated stream classification stations (SCS) were sampled in an attempt to determine the relationship between stream order and periphyton communities.

Field and Laboratory Procedures

Quantitative periphyton samples were collected from glass slide artificial substrates. These slides were suspended between 5 and 15 cm below the water for three week colonization periods in an area of moderate current. Individual slides were analyzed for chlorophyll, total cell counts, and diatom species proportional counts. In 1976, three replicate slides were analyzed for each of these parameters. Cell counts were not made in 1977 because of time limitations. At primary stations in 1977 three slides were analyzed for chlorophyll while four replicate diatom species proportional counts were made. During 1977 two diatom species proportional counts and three chlorophyll analyses were made at secondary stations and at SCS stations. Chlorophyll samples were analyzed by the methods described by UNESCO (1966) and Lorenzen (1967). Cell counts were made by sedimenting an aliquot of sample for 24 hours. These samples had been preserved in Lugol's solution. Subsample size was estimated by scanning a wet mount of the slide. Cells were counted on an inverted microscope and separated into general groups (e.g. filamentous Cyanophyta). Permanent diatom slides were prepared by clearing the frustules by the "potassium persulfate oxidation" method in 1976 (Weber 1973) and the "permanganate" method (Hendley 1974) in 1977. Diatoms were then mounted in Hyrax according to procedures described by Weber (1973). Species proportional counts consisted of counting and identifying 500 half cells (Weber 1973).

Qualitative samples were collected by scraping wood, aquatic vegetation and rocks, and by pipetting samples from soft substrates at each station sampled. Species proportional counts of diatoms were carried out on a composite sample from the qualitative collection. Complete field and laboratory methods are described in Operations Manual - Aquatic Biology (Regional Copper-Nickel Study 1977).

Data Analysis

In the following results section "sample" is defined as the mean of the available replicates from a station on one date for the parameter discussed (i.e. chlorophyll *a*, cell counts, and species proportional counts). For qualitative collections and quantitative collections where only one replicate was analyzed, a sample represents a single value rather than a mean but is used synonymously with the sample described above. Therefore, quantitative and qualitative data were treated similarly in the analyses but were always analyzed separately.

Annual means discussed are the average of the samples from three selected sampling dates in each of the sampling years: 1976 and 1977. These dates were selected because they had samples available from the greatest number of stations. These dates were the following: late May, mid-August, and late September, 1976 and late May, late July, and mid-August, 1977. Where samples were lacking for a station on any date, the annual mean was calculated on the available samples.

The calculation of means for groups of sites (e.g. grouped by stream order) used samples from the six dates listed above. When statistical comparisons were made between groups of stations, annual means from individual stations were treated as individual measurements within the groups. Frequency of occurrence data was calculated individually on samples of each date. "Frequently collected taxa" were taxa that had a frequency of occurrence greater than or equal to 50% for all stations sampled in any sampling date.

Dominant taxa comprised at least 5% of any sample on any date. Dominance values were calculated by assigning dominant taxa the following values: most abundant taxa = 4; second most abundant taxa = 3, third most abundant taxa = 2; fourth most abundant taxa = 1; and other taxa greater than 5% = 0. These numbers were then summed across sites for each taxon on each date. The ratio of each sum to the maximum for that date was converted to a percentage to obtain the dominance value for a taxon on a date. The maximum number used in each ratio was four times the number of sites sampled on that date.

Species diversity ($1/\Sigma Pi^2$) was calculated using sample values. The index was calculated on the data from species proportional counts. Species and varieties were treated as individual taxa in the calculation of diversity. Genus level identifications were used in diversity calculations for six genera: Cymbella, Melosira, Navienla, Nitzschia, Pinnularia and Synedra. The species in these genera were pooled to genus level as a result of the quality control program in 1976 (Regional Copper-Nickel Study 1977). This program indicated that taxonomic errors were present in the identification of species within these genera.

Cluster Analysis

Analysis of patterns of similarity between periphyton communities using quantitative data was based on calculating of the Bray-Curtis similarity coefficient using relative abundance percentages (Boesch 1977). This coefficient is also called "percentage similarity" when used in percentage data, or the Czekanowski coefficient. This coefficient of similarity was selected from many possible coefficients because it gives most weight to large differences in percent relative abundance rather than small differences (Boesch 1977, Clifford and Stephenson 1975). Because of the variability present in the data it was thought that small differences might not be significant and therefore should not determine the similarity or dissimilarity of stations.

The percent similarity coefficient is as follows:

$S_{jk} = \Sigma \min (P_{ij}, P_{ik})$ where $P_{ij} = \frac{x_{ij}}{\Sigma x_{ij}}$ is the relative abundance of the ith taxon at site j. This coefficient ranges from 0 to 1 where 1 = identical sites.

Calculations of similarity between sites in one sampling period were based on an edited data matrix including only those taxa conprising at least 5% of the "mean sample" for at least one of the stations sampled. Relative abundance of a taxon was still calculated relative to the total abundance of all diatom taxa. Exclusion of the rare species has very little effect on the analyses and saves considerable amounts of computer time. The matrix of similarity coefficients between pairs of sites was analyzed by cluster analysis to determine whether sites could be classified into groups according to the patterns of relative abundance of dominant species.

The method of clustering used has been called group average (Bresch, 1977) and unweighted pair-group method using arithmetic averages (UPGMA) (Sneath and Sokul, 1973). This is a hierarchical, agglomerative method in which sites are grouped so as to minimize the distance between two groups of entities, defined as the mean of all distances between members of one group to members of the other.

This method has been widely used in aquatic ecology (Boesch, 1977) and tends to preserve the original expressed in the matrix of similarity coefficients.

Cluster analysis of qualitative data employed the Jacard coefficient of similarity, and the group average method of clustering described above.

RESULTS AND DISCUSSION

Distribution of Diatoms in the Study Area

Diatoms were the major component of the phycoperiphyton in the Study Area comprising an average of 87% of the algal cells enumerated in 1976 (Table 2). This is similar to results reported by Potter et al. (1975). Within the Study Area, 433 diatom taxa were identified. Appendix 1, Table 1 indicates the distribution between watersheds of diatom taxa collected. Species in the genera Cymbella, Navicula, Nitzschia, Melosira, Pinnularia, and Synedra are not indicated but the species are listed in Appendix 1, Table 2.

The number of taxa collected within any watershed was correlated with sampling effort in those watersheds (correlation coefficient = .90). The number of taxa found and the number of qualitative and quantitative samples collected is listed in Table 3. Because water quality is similar in all Study Area watersheds (Regional Copper-Nickel Study 1978c), no difference in the species lists for individual watersheds of equal size in the Study Area would be expected since diatom species lists are similar under similar ecological conditions as discussed by Patrick (1968). Small differences in stream conditions in the Study Area should be indicated by shifts in dominant taxa.

Dominant Diatom Taxa

Tables 4 and 5 present the dominance values for species which occurred as a dominant in qualitative and quantitative periphyton samples. According to the dominance index, Achnanthes minutissima was the most dominant taxon during all qualitative and quantitative sampling periods. This species comprised from .45% to 16.07% of the mean relative diatom abundance for samples collected at stations sampled quantitatively (Table 6) and overall it comprised 40.96% and 27.99% of the diatoms enumerated in 1976 and 1977, respectively (Table 7). As these data indicate, A. minutissima was less abundant in 1977 than in 1976. In 1977 taxa such as Synedra spp. and Cocconeis placentula increased in abundance.

Dominance of periphyton communities by A. minutissima has been reported in lakes (Stockner and Armstrong 1971, Johnson unpublished) and streams (Douglas 1958, Dillard 1968, Sherman and Phinney 1971, Archibald 1972, Moore 1972). This species is characteristic of clean well aerated water (Lowe 1974) and has been described as one of the most ubiquitous diatoms known (Peterson 1943 cited in Lowe 1974). The reason for increases in Synedra and C. placentula is unclear.

Other taxa which were among the three most dominant taxa during any sampling period in quantitative samples were Achnanthes linearis, A. linearis var. pusilla, C. placentula, Synedra spp., Diatoma tenue var. elongatum, Navicula spp. and Nitzschia spp. (Table 4). In qualitative samples, the same taxa occurred among the three most dominant taxa as in quantitative samples. In addition Tabellaria flocculosa, Fragilaria pinnata and F. crotonensis occurred in the top three taxa only in qualitative samples.

Tables 4 and 5 also list the most frequently collected taxa which are taxa with a frequency of occurrence equal to or greater than 50%, in at least one sampling period. Dominant taxa always belong to the most frequently collected group.

The taxa listed in Tables 4 and 5 are those which are likely to occur in any Study Area stream.

Seasonal Patterns of Dominant Diatoms

Table 8 lists the sampling periods during which dominant diatom taxa reached their maximum relative abundance in quantitative samples. Figures 2 through 4 graphically display the seasonal changes in four of the dominant species at stations where the most continuous sampling was done and the species was abundant. A. minutissima is the most dominant taxa at all times of the year and exhibits a spring and fall maximum with a mid-summer low (Figure 2). A. linearis (including A. l. var. pusilla) tends to be inversely related to A. minutissima; it exhibits a midsummer maximum, at least in the presence of A. minutissima (Figure 2). As indicated on Table 8, A. linearis can peak in the spring and A. linearis var. pusilla can peak in the fall.

C. placentula had a midsummer bloom (Table 8 and Figure 3). Most other dominant diatoms had spring maximums. Species such as Tabellaria spp. and Diatoma tenue var. elongatum probably have fall maximums but sampling was discontinued too early to observe this peak if it occurred. Synedra spp. exhibited spring and fall maxima (Table 8 and Figure 4).

The seasonal patterns for diatom species are poorly understood. Lowe (1974) presents limited data on seasonality and much of the seasonal data are conflicting. For example, Lowe (1974) reports a fall maximum for C. placentula but in the present study and in data reported by Peters et al. (1968) C. placentula had a midsummer maxima. Summer maxima have been reported for A. minutissima (Stockner and Armstrong 1971, Moore 1972) which is contrary to the current study. These differences probably reflect the complex set of factors governing the time when a diatom obtains its peak abundance. Factors such as current velocity and temperature which are important to diatom development will fluctuate differently in relation to season in different streams.

Diatom Diversity

Table 9 presents the 1976 and 1977 diversity $\left(\frac{1}{\Sigma p_i^2}\right)$ for quantitative samples collected at primary and secondary stations averaged over three sampling periods per year. Greatest mean annual diversity was observed at KC-1 and F-1 with values of 8.0 and 7.5 respectively; SL-1 and P-1 had the lowest diversity, with values of 1.8 and 2.2.

No clear seasonal trends are evident in the data from primary sites (Figure 5). Major changes in diversity appear to be related to changes in the relative abundance of the dominant taxa such as *A. minutissima*, *A. linearis*, and *C. placentula*. Two examples of this relationship are presented in Figure 6.

Diversity $\frac{1}{(\Sigma p_i^2)}$ was calculated for qualitative samples collected in 1977 (Table 10). Diversity in qualitative samples ranged from 2.4 to 28.4 in April, 1977, and from 2.8 to 63.0 in August, 1977. No clear patterns in diversity were evident although diversity was generally greater in qualitative than in quantitative samples.

Diatom species diversity in the Study Area is misleading because of the cominance of *A. minutissima* at many stations. Archibald (1972) reported that the dominance of *A. minutissima*, a clean water species, in some South African streams caused diversity in "clean" streams to be lower than diversity in "polluted" streams. Therefore diatom diversity in Study Area streams does not adequately reflect water quality differences.

Similarity of Periphyton Communities

The cluster analysis of quantitative diatom data from primary and secondary stations (Appendix 2, Figures 1-6) provided a method of determining patterns of similarity in periphytic diatom communities. To determine groups of similar stations the percentage of times that stations occurred in the same cluster at the .5 level in 1976 was calculated (Figure 7). After examining the clusters, this level was chosen as a level at which clusters could be interpreted. Values from .4 to .75 have been used to define significance in other aquatic biological studies (Herricks and Stanhope 1976, Burlington 1962, Cairns et al. 1970). This analysis was not performed on the 1977 data as fewer stations were sampled and there was poor success in retrieving samplers.

Two sets of stations always clustered together: 1) BB-1 and D-1; and 2) P-1 and SL-1. The sites BB-1, D-1, P-1, SL-1, P-2, and P-5 clustered together in greater than 66 percent of the analyses. Other groups formed were less frequent. Station K-2 in the Shagawa River was unique as it clustered only once with site E-1. It appears that the most important factor determining these groups is the abundance of A. minutissima.

Because of the overall dominance of a few diatom species in Study Area streams, a comparison of stations was made based on mean abundance of five dominant taxa in 1976 (Figure 8) and four dominant taxa in 1977 (Figure 9). In each year, the annual mean was calculated from data for three sampling dates. Three general groups were defined based on the relative abundance of A. minutissima. The cutoff points for each group were chosen to reflect the groupings evident from the data in Figures 8 and 9. The groups were defined as follows: 1) group 1 stations where A. minutissima is greater than 49 percent; 2) group 2 stations where the relative abundance of A. minutissima is between 15 and 49 percent; and 3) group 3 stations where the abundance of A. minutissima is less than 15 percent.

In 1976 several other observations could be made concerning the similarity of stations. Group 1 includes those stations which cluster analysis grouped together with one exception, SR-1. SR-1 is included in the cluster group because it occurred in only one data set which was clustered in 1976.

In group 2, a subgroup of F-1 and KC-1 is evident based on the high abundance of T. flocculosa (> 10 percent). Also, K-8, a member of group 2, is different because Gomphonema parvulum comprised 27.5 percent of the diatoms at this station, higher than at any other station sampled quantitatively (Table 4).

The sites K-2 and K-5 comprise group 3 but are different from one another because of the dominance of C. placentula at K-2 and A. linearis at K-5 (Figure 8).

In 1977 the three groups were composed of a slightly different set of stations. One of the reasons for this appears to be the increased abundance of Synedra spp. at several stations. Group 1 consisted of stations SL-1, D-1 and SL-2. P-1 could also be included in this group although the abundance of A. minutissima was 45.9 percent. A subgroup within group 2 and 3 consisted of SR-3, K-8 and E-1, all of which had high populations of

Synedra spp. Also within group 3, K-2 and BI-1 formed a subgroup dominated by C. placentula. K-1 was different from other stations because of the dominance of G. angustatum (35.8 percent) at this station in 1977 (Table 4).

The groups of stations defined by dominant diatoms are similar to the station groups defined by the Water Quality Section (Regional Copper-Nickel Study 1978c). Group 3 stations which were characterized by high relative abundance of A. minutissima were also characterized by high conductivity. Lower conductivity resulted in less abundant A. minutissima and higher abundance of other diatoms (groups 2 and 3). A. linearis is one of the species which replaces A. minutissima. A. linearis and A. linearis var. pusilla are closely related to A. minutissima ecologically although A. minutissima appears slightly less sensitive to the addition of any material into the environment (Reimer personal communication). This sensitivity is reflected in the increased relative abundance of these two taxa with decreasing conductivity. The high relative abundance of T. flocculosa defined the subgroup of F-1 and KC-1, which were stations with low pH. The presence of C. placentula probably indicates inorganic nutrients, particularly at station K-2 since it prefers elevated levels of inorganic nutrients. The Water Quality Section did not report levels of inorganic nutrients significantly higher at K-2 than elsewhere in the Study Area (Regional Water Quality Study 1978c) although it seems possible because of high nitrogen and phosphorus concentrations in Shagawa Lake upstream. Another explanation for the dominance of C. placentula could be selective grazing by invertebrates at K-2 (Reimer, personal communication, Patrick 1975; 1978). The dominance of G. angustatum and G. parvulum at K-1 and K-8 is difficult to explain since these prefer alkaline conditions and pH at these sites is neutral to slightly acid.

Patterns of Production

Average values of production as measured by chlorophyll a showed similar seasonal patterns for all sites and for primary sites only in 1976 and 1977 (Figures 10 and 11). Peak production was recorded in late June and early July; a second peak occurred in September. During late July and August chlorophyll production was low.

High mean cell numbers were recorded in May, 1976, at primary stations when chlorophyll a was low (Figure 11). During the remainder of 1976 there was a better relationship between cell numbers and chlorophyll a.

The seasonal patterns of periphyton production in Study Area periphyton are similar to those reported in the literature (Waters 1961, Peters et al. 1968) and generally reflect a spring and fall diatom bloom. The use of glass slide artificial substrates introduces a sampling bias in cell counts and probably does not reflect the midsummer increase in green and blue-green algae. These samplers are more efficient in sampling diatoms than other groups (Reimer, personal communication).

Stations P-1, P-2, K-1, and K-2 were the most productive sites based on 1976 mean annual chlorophyll a values while highest average cell densities were at BI-1 and K-1 (Table 11). Lowest cell densities were recorded at KC-1 and F-1. KC-1 also had low mean annual chlorophyll a as did SR-3 and F-1. Primary production, therefore, is generally higher in the larger streams in the Study Area and can be related to stream order.

Relationship Between Stream Order and Periphyton Communities

Average primary production as measured by chlorophyll a generally increased with increasing stream order (Figure 12), although in 1977 a decrease was noted in fifth order streams. These patterns are similar to those discussed by Cummins (1975; 1976). Table 12 presents water quality values averaged by stream order. Because pH increases with increasing stream order the relationship between the realtive abundance of acidophilous diatoms to stream order was examined. The acidophilous taxa defined by Lowe (1974) found in the Study Area are listed in Table 13.

Figures 13 and 14 present the mean relative abundance of acidophilous diatoms found in qualitative and quantitative samples and average pH in relation to stream order. The abundance of acidophilous diatoms decreases with increasing stream order with the exception of fifth order streams where a slight decrease in pH occurs.

Figure 15 presents a scatter plot of pH versus percent relative abundance of acidophilous diatoms in May, 1976 and September, 1976 qualitative samples. Linear regressions were calculated for each data set after excluding the circled points. These points were impacted sites which, it was thought, would not fit the model. The shift in regression lines is a result of higher pH in September than in May. The correlation coefficients (r values) for these data sets were -.69 (May, 1976) and -.85 (September, 1976).

Correlation coefficients (Spearman's Rank Correlation) between stream order and percent relative abundance acidophilous diatoms are listed in Table 14. These coefficients ranged from -.5 to -1.0, which indicated a strong relationship between stream order and the relative abundance of acidophilous diatoms.

In 1976 quantitative data, decreases in the relative abundance of *Eunotia* spp., *T. fenestrata*, and *T. flocculosa*, the most abundant acidophilous taxa, can be noted with increasing stream order (Table 15). An exception is the increase of *T. fenestrata* in fifth order streams. Generally *C. placentula*, *A. linearis* (including *A. linearis* var. *pusilla*), and species of *Gomphonema* increase in abundance with increasing stream order.

Diatom taxa that occurred at greater than 50 percent of the stations within any stream order during 1977 qualitative collections are listed in Tables 16 and 17. Acidophilous diatoms such as *Eunotia* spp. and *Frustulia rhomboides* decrease in frequency within increasing stream order. In the April/May 1977 sampling period *D. tenue* var. *elongatum* and *F. capucina* increased with increasing stream order. *T. fenestrata* and *T. flocculosa* generally became less frequent with increasing stream order although *T. fenestrata* increased in fifth order during April/May 1977 and *T. flocculosa* was constant across stream orders during this period.

There was no observable difference in the mean number of acidophilous diatoms occurring at sites within each stream order in August, 1977 (Table 18). A one-way analysis of variance of qualitative data showed no significant differences ($P > .05$) between the mean number of species or between mean species diversity $\left(\frac{1}{\Sigma P_i^2}\right)$ among stream orders from both the April/May and August, 1977 sampling periods. This is in contrast to the results of Mack (1953, cited in Hynes 1970) who noted an increase in algal diversity in a downstream direction.

A cluster analysis of stations was performed on the qualitative data from August, 1977 using the Jacand coefficient of similarity (Figure 16). This data set was chosen because the greatest array of stations was available. In general, at the .58 level sites clustered by stream order, with sites in an adjacent stream order or with closely situated sites in the same watershed. Table 19 lists those taxa which were present at more than 50% of the stations within a cluster and therefore are responsible for the formation of the cluster. A large number of taxa were characteristic of all sites with small groups of species in each cluster. Group one (first and second order streams) has a large number of acidophilous taxa and Meridion circulare which is characteristic of bog drainages. In the other groups of sites there is a mixture of taxa which Lowe (1974) has classified as alkaphilous, indifferent and acidophilous.

These data indicate that there is a relationship between stream order and diatom communities in the Study Area. As stream order increases there is an increase in periphyton production and a decrease in the relative abundance of acidophilous diatoms. Although not studied it is probable that there is a corresponding increase in the relative abundance of alkaphilous diatoms. It also appears that most diatom species occur within all stream orders but that changing ecological conditions such as pH allow different species and/or groups to flourish in different stream orders.

Currently Impacted Streams

Several streams in the Study Area are currently impacted by taconite mining, contact with the copper-nickel resource, or copper-nickel exploration.

Mine Dewatering--Currently operating taconite mines are pumping mine water into the Partridge River, Dunka River and Unnamed Creek. The effect of this pumping has been to raise the conductivity, alkalinity, and pH of the receiving waters (Regional Copper-Nickel Study 1978c). The average conductivity at sites with mine dewatering is 270 μ mho/l compared to 54 μ mho/l at other sites. Stations BB-1, P-5, P-1 and SL-1 are all impacted by taconite mine dewatering, and form a group of stations which in 1976 were characterized by high abundance of A. minutissima. At unimpacted stations with physical conditions similar to impacted sites, A. minutissima is still dominant but A. linearis became more abundant and A. minutissima less abundant (Table 6). Another species change occurs in first and second order impacted stations. T. flocculosa and other acidophilous diatoms which are abundant at unimpacted first and second order sites were rare at impacted stations. Figure 19 illustrates these two shifts in diatom species.

Table 20 presents comparisons of productivity, diversity and number of taxa at sites impacted by mine dewatering and unimpacted sites. There appear to be no major differences in the productivity of impacted and unimpacted sites. Although mean diversity for 1976 at impacted sites appears lower than at unimpacted sites, a t-test indicated no significant difference ($P < .05$). A larger number of diatom taxa were found at impacted sites than at unimpacted sites.

The effect of taconite operations has been to favor the development of A. minutissima in affected streams. In first and second order streams acidophilous species are less abundant because of increased pH and in third and fourth order streams with elevated conductivity the abundance of species such as A. linearis is reduced. The overall species list found at impacted and unimpacted sites are probably similar since water quality differences are not large enough to produce dramatic shifts in the biological communities.

Unnamed Creek--In Unnamed Creek elevated levels of heavy metals are present in addition to high conductivity. A further impact in this first order stream is fluctuating flow as a result of erratic pumping of mine water. Table 21 presents a comparison of several biological parameters from Unnamed Creek, Filson Creek, and Keeley Creek. Primary production in Unnamed Creek is similar to that in other first and second order streams. Diatom species diversity was lower in Unnamed Creek at BB-1 than in other first and second order streams, although at upstream sites on Unnamed Creek diversity was higher than in Filson or Keeley creeks (Regional Copper-Nickel Study 1978a). These apparent inconsistencies are probably caused by the fluctuating flows in Unnamed Creek although insufficient data is available to prove this hypothesis.

Dominant diatoms are also different (Regional Copper-Nickel Study 1978a). A. minutissima is the most abundant diatom species in Unnamed Creek as in the rest of the Study Area. In addition D. tenue var. elongatum, Denticula tenuis and F. construens were abundant. These taxa, while present on the list of dominant taxa for the Study Area (Table 4), were not found in the rest of the Study Area during the same time periods as they were found in Unnamed Creek in 1976. These taxa were also more abundant in Unnamed Creek than in the rest of the Study Area. The diatom percentage in Unnamed Creek ranged from 90 to 99 percent which is higher than that found in the Study Area in general.

As in the impacted sites discussed earlier, no significant impact seems to have occurred in Unnamed Creek. No radical shifts in the dominance of algal groups such as mentioned by Patrick (1978) in relation to heavy metals has occurred. A copper effect would not be expected as levels are below the toxic level of 70 μg Cu/l discussed by Patrick (1977). On the other hand, nickel concentration in Unnamed Creek is at a level (123 μg/l) where some effect may occur. Patrick (1977) reported nickel levels as low as 2-10 μg/l would cause shifts in the major periphyton groups while Hutchinson (1973) reported that 100 μg/l was toxic to algae. Because diatoms are still dominant in Unnamed Creek it does not appear that such an effect has occurred. The dominance of D. tenue var. elongatum has probably resulted from the high dissolved solids and cold temperatures. D. tenue var. elongatum is very tolerant of high dissolved solids or conductivity (Lowe 1974) and normally blooms in the spring when temperatures are low (see Seasonal Patterns of Dominant Diatoms). No data are available on Denticula tenuis while F. construens has ecological requirements similar to Diatoma.

Filson Creek-- Filson Creek flows across the mineralized Gabbro contact and contains elevated levels of heavy metals (median values of 8.0 μg Cu/l and 5.95 μg Ni/l). Comparisons can be made with Keeley Creek which is a similar headwater stream with lower heavy metal levels (median values of 1.95 μg Cu/l and 3.3 μg Ni/l). No effect in the dominant taxa, productivity or diversity is evident between Filson and Keeley creeks (Table 21 and Figure 8). Copper levels in Filson Creek are lower than levels where effects have been reported by Patrick (1977).

INCO Seeps--In the vicinity of Filson Creek copper-nickel exploration by INCO has caused elevated concentrations of copper (20-59 μg/l) and nickel (14-37 μg/l) to be present in seeps draining the exploration site. *A. minutissima* was the dominant species at station C above the input of copper and nickel while below this input species of *Eunotia* and *Tabellaria* were more dominant (Table 22). Colonization of glass slides appeared normal at the time of collection.

No effects were observed nor would be expected from copper and nickel in the seeps which were sampled because copper and nickel levels were below the level of potential effects reported by Patrick (1977).

Besch et al. (1972) found that groups of diatoms were good indicators of heavy metal pollution during field surveys in eastern Canada. Species groups which include *A. minutissima*, *Tabellaria* spp. and *Eunotia* spp. were reported as sensitive to copper and zinc pollution. These taxa were all present in Filson Creek, Unnamed Creek and the INCO seeps. Therefore the results reported by Besch et al. would seem to indicate that there has been no effect from heavy metals in Filson Creek, the INCO seeps, or Unnamed Creek since sensitive species are still abundant.

SUMMARY

Diatoms are the primary component of the periphyton communities in Study Area streams comprising an average of 87% of the algal cells. The most important diatom species is Achnanthes minutissima which was dominant throughout the year and the Study Area. Other important taxa included A. linearis, Cocconeis placentula, Synedra spp., Diatoma tenue var. elongatum and Tabellaria flocculosa.

The diatom communities demonstrated a spring and fall maximum in production. Also most of the dominant species were most abundant in the spring and fall. No clear seasonal patterns in species diversity were evident although diversity appeared related to changes in the relative abundance of the most dominant taxa.

Two aspects of the periphyton community are related to stream order. First primary production increases with increasing stream order and secondly the abundance of acidophilous species decreases. The species present is similar in all stream orders.

Several groups of similar stations are evident based on relative abundance of diatom taxa. In general, stations impacted by taconite mining were more similar to one another than to unimpacted stations. Also, stations in first and second order streams tend to be similar to one another while stations in third and fourth order streams tend to be similar to each other.

The effect of current taconite mining seems to be a shift in species which favors the dominance of A. minutissima in all streams and the reduction in the abundance of acidophilous species in first and second order streams.

In third and fourth order streams the species shift is not dramatic as impacted sites are similar to unimpacted sites in these stream orders. In first and second order streams the shift is more dramatic as the impacted sites resemble third and fourth order sites more closely than they resemble unimpacted first and second order streams.

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Appendix 1. Diatom species found in the Study Area.

Table 1. Distribution of diatom taxa in Study Area watersheds.

Table 2. Species of the pooled genera: *Cymbella*, *Melosira*, *Navicula*, *Nitzschia*, *Pinnularia*, and *Synedra*.

Table 1. Distribution of diatom taxa in Study Area watersheds (1=present, 0=absent)

TAXA	TAXA NUMBER	WATERSHED														
		Range	Fall	Shagawa	Kawish	Bear Island	Isabel.	Filson	Birch	Dunka	Stony	St. Louis	Partr.	Embar.	White face	Cloquet
ACHNANTHES AFFINIS	2	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0
ACHNANTHES CLEVEI	3	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0
ACHNANTHES CLEVEI V. ROSTRATA	4	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
ACHNANTHES EXIGUA	5	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0
ACHNANTHES EXIGUA V. CONSTRICT	6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ACHNANTHES FLEXELLA	7	0	1	0	1	0	1	0	1	1	1	1	1	1	1	0
ACHNANTHES HUSTEDTII C.F.	8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
ACHNANTHES LANCEOLATA	9	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
ACHNANTHES LANCEOLATA V. APICU	10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
ACHNANTHES LANCEOLATA V. DUBIA	11	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0
ACHNANTHES LANCEOLATA V. LANCE	12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ACHNANTHES LANCEOLATA V. OHISS	13	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0
ACHNANTHES LEWISIANA	14	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
ACHNANTHES LEVANDERI	15	0	0	1	1	1	1	1	1	1	1	0	1	0	1	0
ACHNANTHES LINEARIS	16	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ACHNANTHES LINEARIS V. PUSILLA	17	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ACHNANTHES LINEARIS V. CURTA	18	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ACHNANTHES LINEARIS V. MUTICA	19	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
ACHNANTHES MARGINULATA	20	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ACHNANTHES C.F. NOLTI	21	0	1	0	0	0	0	0	0	0	1	1	0	1	0	0
ACHNANTHES PERAGALLI V. FOSSIL	23	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
ACHNANTHES MINUTISSIMA	24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ACHNANTHES PERAGALLI	25	0	0	1	1	1	1	0	1	0	1	0	0	0	0	0
ACHNANTHES SAXONICA	26	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0
ACHNANTHES SMITHII	27	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ACHNANTHES STEWARTII	28	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0

Table 1. Distribution of diatom taxa in Study Area watersheds (1=present, 0=absent)

(cont.)

TAXA	TAXA NUMBER	Range	Fall	Shagawa	Kawish	Bear Island	Isabel.	Filson	Birch	Dunka	Stony	St. Louis	Partr.	Embar.	White face	Cloquet
ACHNANTHES SUBLAEVIS V. CRASSA	29	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
AMPHIPLEURA SP.	30	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0
AMPHIPLEURA PELLUCIDA	31	0	1	0	1	1	1	1	1	1	1	1	1	1	0	0
AMPHORA SP.	32	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0
AMPHORA COFFEAEFORMIS	33	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
AMPHORA OVALIS	34	0	1	1	1	0	1	1	1	1	1	1	1	1	0	0
AMPHORA OVALIS V. AFFINIS	35	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AMPHORA PERPUSILLA	37	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0
ANOMOEONEIS SP.	38	0	0	0	0	0	1	1	0	1	1	1	1	0	0	0
ANOMOEONEIS SERIANS	39	0	0	0	1	1	1	1	1	0	1	1	1	1	0	0
ANOMOEONEIS SERIANS V. ACUTA	40	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0
ANOMOEONEIS SERIANS V. APICULA	41	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0
ANOMOEONEIS SERIANS V. BRACHYS	42	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0
ANOMOEONEIS VITREA	43	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ANOMOEONEIS ZELLENSIS	44	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
ASTERIONELLA FORMOSA	46	0	1	1	1	1	1	0	1	0	1	1	1	0	0	0
ATTHEYA ZACHARIASI	48	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CALONEIS SP.	49	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0
CALONEIS AMPHISBAENA	50	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
CALONEIS BACILLUM	51	0	0	1	1	0	0	0	1	1	0	0	1	0	0	0
CALONEIS LEWISII	52	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
CALONEIS VENTRICOSA	53	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CALONEIS VENTRICOSA V. TRUNCAT	54	0	0	1	0	1	0	0	1	1	0	0	1	0	0	0
CALONEIS VENTRICOSA V. SUBUNDU	55	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CALONEIS VENTRICOSA V. MINUTA	56	0	0	0	1	0	1	0	1	0	1	1	0	1	0	0
CARPTOGRAMA CRUCICULA	59	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
COCCONEIS SP.	60	0	0	1	1	0	1	0	1	1	0	1	1	0	0	0
COCCONEIS DIMINUTA	61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
COCCONEIS PLACENTULA	62	0	1	1	1	1	1	0	1	1	1	1	1	1	0	0
COCCONEIS PLACENTULA V. EUGLYP	63	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0
COCCONEIS PLACENTULA V. LINEAT	64	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
COCCONEIS PEDICULUS	65	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0
CYCLOTELLA SP.	68	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 1. Distribution of diatom taxa in Study Area watersheds (1=present, 0=absent)

(contd..)

TAXA	TAXA NUMBER	Range	Fall	Shagawa	Kawish	Bear Island	Isabel.	Filson	Birch	Dunka	Stony	St. Louis	Partr.	Embar.	White face	Cloquet
CYCLOTELLA C.F. ANTIGUA	69	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CYCLOTELLA BODANICA	70	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
CYCLOTELLA COMPTA	71	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
CYCLOTELLA GLOMERATA	72	0	1	1	1	1	1	0	1	1	1	1	1	1	0	0
CYCLOTELLA GLOMERATA V. ANGUST	73	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CYCLOTELLA KUTZINGIANA V. RADI	74	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
CYCLOTELLA MENEGHINIANA	75	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0
CYCLOTELLA STELLIGERA	77	0	1	1	1	1	1	0	1	0	0	1	1	0	0	0
CYMBELLA SP.	80	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
DENTICULA SP.	110	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0
DENTICULA ELEGANS	111	0	1	0	1	0	1	0	1	1	0	1	1	1	0	0
DENTICULA TENUIS	112	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
DIATOMA SP.	113	0	0	1	0	0	1	0	0	1	1	0	1	1	0	0
DIATOMA ANCEPS	114	0	1	1	1	0	0	0	1	0	0	0	1	1	0	0
DIATOMA ELONGATUM	115	0	1	0	0	1	0	0	1	1	0	1	1	0	0	0
DIATOMA HIEMALE	116	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
DIATOMA HIEMALE V. MESODOM	117	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
DIATOMA TENUE	118	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
DIATOMA TENUE V. ELONGATUM	119	0	1	0	1	0	1	0	1	1	1	1	1	1	1	0
DIATOMA VULGARE	120	0	0	0	1	0	0	0	1	1	1	1	0	0	0	0
DIATOMA VULGARE V. BREVE C.F.	121	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
DIPLONEIS SP.	122	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1
DIPLONEIS ELLIPTICA	123	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
DIPLONEIS FINNICA	124	0	0	1	0	1	0	0	1	0	1	0	1	0	0	0
DIPLONEIS OCULATA	125	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
DIPLONEIS OVALIS	126	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
DIPLONEIS PUELLA C.F.	127	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0
DIPLONEIS SMITHII	128	0	1	0	1	0	1	0	1	0	1	0	0	0	1	0
ENTOMONEIS SP.	130	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
ENTOMONEIS ORNATA	131	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0
EPITHEMIA SP.	132	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0
EPITHEMIA SOREX	133	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
EUNOTIA SP.	135	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 1. Distribution of diatom taxa in Study Area watersheds (1=present, 0=absent)

(contd.)

TAXA	TAXA NUMBER	Range	Fall	Shagawa	Kawish	Bear Island	Isabel.	Filson	Birch	Dunka	Stony	St. Louis	Partr.	Embar.	White face	Cloquet
EUNOTIA ARCUS	136	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
EUNOTIA CURVATA	138	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1
EUNOTIA CURVATA V. CAPITATA	139	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
EUNOTIA DIODON	140	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0
EUNOTIA ELEGANS	141	1	0	0	0	0	0	1	1	1	1	0	0	1	1	0
EUNOTIA EXIGUA	142	0	0	0	1	1	0	1	1	1	0	0	0	0	0	0
EUNOTIA FABA	143	0	0	0	1	1	0	1	1	0	1	0	1	1	0	0
EUNOTIA FLEXUOSA	144	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0
EUNOTIA FORMICA	145	0	1	0	0	0	0	0	1	1	1	0	1	1	0	0
EUNOTIA INCISA	146	1	0	0	1	1	1	1	1	1	1	1	0	1	1	0
EUNOTIA PECTINALIS V. VENTRIOS	147	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
EUNOTIA LAPPONICA	148	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
EUNOTIA MONDON	150	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0
EUNOTIA NAEGELLII	151	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0
EUNOTIA PECTINALIS	152	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
EUNOTIA PECTINALIS V. MINOR	153	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1
EUNOTIA PRAEMINOR C.F.	154	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
EUNOTIA PRAERUPTA	155	0	0	0	1	1	0	1	1	1	1	0	1	1	0	0
EUNOTIA PRAERUPTA V. BIDENS	156	0	0	0	1	0	0	1	1	1	1	0	1	1	0	0
EUNOTIA PRAERUPTA V. MINOR	157	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
EUNOTIA PRAERUPTA V. INFLATA	158	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0
EUNOTIA SEPTENTRIONALIS	159	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
EUNOTIA ROSTELLATA	161	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
EUNOTIA SUECIA	162	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
EUNOTIA SERRA V. DIADEMA	163	1	1	0	0	0	0	1	1	1	0	0	1	1	0	0
EUNOTIA TAUTONENSIS	164	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
EUNOTIA TENELLA	165	0	0	0	0	0	0	1	0	1	1	0	1	1	1	0
EUNOTIA VANHEURCKII	167	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0
EUNOTIA VANHEURCKII V. INTERME	168	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0
FRAGILARIA SP.	169	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
FRAGILARIA BICAPITATA	170	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0
FRAGILARIA BREVISTRIATA	171	0	0	1	1	0	1	0	1	1	1	0	1	1	1	0
FRAGILARIA BREVISTRIATA V. CAP	172	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0

Table 1. Distribution of diatom taxa in Study Area watersheds (1=present, 0=absent)

(contd.)

TAXA	TAXA NUMBER	Range	Fall	Shagawa	Kawish	Bear Island	Isabel.	Filson	Birch	Dunka	Stony	St. Louis	Partr.	Embar.	White face	Cloquet
		WATERSHED														
FRAGILARIA BREVISTRIATA V. INF	173	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
FRAGILARIA CAPUCINA	174	0	1	1	1	0	1	1	1	0	1	1	1	1	1	0
FRAGILARIA CONSTRICTA	175	1	0	0	0	1	1	1	0	0	0	0	1	0	1	1
FRAGILARIA PINNATA V. STRICTA	176	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
FRAGILARIA CONSTRUENS	177	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FRGILARTIA CONSTRUENS V. BIROD	178	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
FRAGILARIA CONSTRUENS V. PUMIL	179	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FRAGILARIA CONSTRUENS V. VENTE	180	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FRAGILARIA CROTONENSIS	181	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1
FRAGILARIA INFLATA	182	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0
FRAGILARIA LEPTOSTAURON	183	0	0	1	1	1	1	0	0	1	1	0	1	1	1	0
FRAGILARIA LEPTOSTAURON V. DUB	184	0	0	1	1	0	1	1	1	1	1	1	1	0	1	0
FRAGILARIA PINNATA	185	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
FRAGILARIA PINNATA V. LANCETTU	186	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
FRAGILARIA PINNATA V. INTERCED	187	0	0	0	0	1	1	1	1	1	0	0	1	0	0	0
FRAGILARIA VAUCHERIA	188	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
FRAGILARIA VAUCHERIA V. CAPITE	189	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
FRAGILARIA VIRESENS	190	1	1	1	1	0	1	1	1	0	1	1	1	1	0	0
FRAGILARIA VIRESENS V. CAPITAT	191	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0
FRAGILARIA PARASITICA	192	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
FRUSTULIA SP.	193	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
FRUSTULIA RHOMHOIDES	194	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0
FRUSTULIA RHOMBOIDES V. CAPITA	195	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
FRUSTULIA RHOMBOIDES V. SAXONI	196	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
FRUSTULIA RHOMBOIDES V. VIRIDU	197	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
FRUSTULIA WEINHOLDII	198	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
GOMPHONEMA SP.	199	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
GOMPHONEMA APICATUM	200	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
GOMPHONEMA ACUMINATUM	201	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
GOMPHONEMA ACUMINATUM V. CORON	202	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
GOMPHONEMA ACUMINATUM V. CLAVU	203	0	1	0	0	0	1	0	1	0	1	1	1	1	0	0
GOMPHONEMA ACUMINATUM V. PUSIL	204	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
GOMPHONEMA AFFINE	205	0	1	0	1	0	0	0	1	0	1	1	0	0	0	0

Table 1. Distribution of diatom taxa in Study Area watersheds (1=present, 0=absent)

(cont.)

TAXA	TAXA NUMBER	WATERSHED														
		Range	Fall	Shagawa	Kawish	Bear Island	Isabel.	Filson	Birch	Dunka	Stony	St. Louis	Partr.	Embar.	White face	Cloquet
GOMPHONEMA AFFINE V. INSIGNE	206	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
GOMPHONEMA ANGUSTATUM	207	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
GOMPHONEMA ANGUSTATUM V. SARCP	209	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
GOMPHONEMA ACUMINATUM V. ELONG	210	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
GOMPHONEMA CONSECTOR	212	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
GOMPHONEMA BREBISSONII	213	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0
GOMPHONEMA CLEVEI	214	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1
GOMPHONEMA CONSTRICTUM	215	0	1	0	1	0	0	0	0	1	1	1	1	1	0	0
GOMPHONEMA GIBBA	216	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
GOMPHONEMA GRACILE	217	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0
GOMPHONEMA DICHOTOMUM	218	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0
GOMPHONEMA GRUNOWII	219	0	1	0	1	0	1	1	1	1	1	1	1	1	1	0
GOMPHONEMA INSTABILIS	220	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
GOMPHONEMA INTRICATUM	221	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
GOMPHONEMA OLIVACEOIDES	222	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
GOMPHONEMA OLIVACEUM	223	0	1	1	0	0	0	0	1	1	0	0	1	1	0	0
GOMPHONEMA ANGUSTATUM V. INTER	224	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
GOMPHONEMA PARVULUM	225	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
GOMPHONEMA GROVEI	226	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
GOMPHONEMA SUBCLAVATUM	227	0	1	1	1	1	0	0	1	0	0	0	1	1	0	0
GOMPHONEMA MANTANUM	228	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
GOMPHONEMA SUBTILE	229	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
GOMPHONEMA TRUNCATUM	230	0	1	1	1	0	1	1	1	0	1	1	1	0	0	0
GOMPHONEMA TRUNCATUM V. CAPITA	231	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
GYROSIGMA SP.	232	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0
GYROSIGMA ATTENUATUM	233	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
HANNAEA ARCUS	235	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
HANTZSCHIA SP.	236	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
HANTZSCHIA AMPHIOXYS	237	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
MELOSIRA SP.	238	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MERIDION SP.	249	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
MERIDION CIRCULARE	250	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
MERIDION CIRCULARE V. CONSTRIC	251	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Table 1. Distribution of diatom taxa in Study Area watersheds (1=present, 0=absent)

(contd.)

TAXA	TAXA NUMBER	Range	Fall	Shagawa	Kawish	Bear Island	Isabel.	Filson	Birch	Dunka	Stony	St. Louis	Partr.	Embar.	White face	Cloquet
NAVICULA SP.	252	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NEIDIUM SP.	331	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0
NEIDIUM AFFINE	332	0	1	0	0	1	0	1	1	0	0	0	0	0	1	0
NEIDIUM IRIDIS V. AMPLIATUM	333	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
NEIDIUM BISULCATUM	334	0	0	0	0	1	1	1	1	1	1	0	0	0	1	0
NEIDIUM GRACILE V. AEQUALE	336	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
NEIDIUM HERCYNICUM C.F.	337	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
NEIDIUM AFFINE V. LONGICEPS	340	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
NEIDIUM IRDIS	341	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NITZSCHIA SP.	342	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
OPEPHORA MARTYI	388	0	0	1	1	1	1	0	1	0	0	1	0	0	0	0
PINNULARIA SP.,	390	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PLEUROSIGMA SP.	426	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
RHIZOSOLENIA SP.	428	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
RHICOSPHENIA CURVATA	432	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
RHOPALODIA SP.	433	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
RHOPALODIA GIBBA	434	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
STAURONEIS SP.	435	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0
STAURONEIS ACUTA	436	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
STAURONEIS ANCEPS	437	0	0	1	1	0	1	0	1	1	1	0	1	1	0	0
STAURONEIS ANCEPS V. GRACILIS	438	0	0	0	1	0	0	0	1	0	1	1	0	1	0	0
STAURONEIS ANCEPS V. LINEARIS	439	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
STAURONEIS KRIEGERI	440	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0
STAURONEIS IGNORATA	441	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
STAURONEIS PHOENICENTEROM	442	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0
STAURONEIS PHOENICENTEROM V. G	443	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
STAURONEIS SMITHII	444	0	0	0	1	0	1	0	0	1	1	1	1	0	1	0
STAURONEIS SMITHII V. INCISA	445	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
STENOPTEROBIA SP.	446	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
STENOPTEROBIA INTERMEDIA	447	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
STEPHANODISCUS SP.	448	0	1	1	1	1	1	0	1	1	1	1	0	1	0	0
STEPHANODISCUS ASTREA	449	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0
STEPHANODISCUS ASTREA V. MINUT	450	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0

Table 1. Di[illegible]ibution of diatom taxa in Study Area watersheds (1=present, 0=absent) (contd..)

TAXA	TAXA NUMBER	Range	Fall	Shagawa	Kawish	Bear Island	Isabel.	Filson	Birch	Dunka	Stony	St. Louis	Partr.	Embar.	White face	Cloquet
STEPHANODISCUS INVISITATUS	452	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
STEPHANODISCUS NIGARAE	453	0	1	1	1	0	0	0	1	0	0	1	0	0	0	0
STEPHANODISCUS TENUIS	454	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SURIRELLA SP.	455	0	0	0	1	1	0	1	0	1	1	1	1	1	1	0
SURIRELLA ANGUSTA(TUM)	456	0	1	1	1	1	1	1	1	0	1	1	1	1	0	0
SURIRELLA ELEGANS	457	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
SURIRELLA DELICATISSIMA	458	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0
SURIRELLA DIDYMA	459	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
SURIRELLA LINEARIS	460	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
SURIRELLA OVALIS	461	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
SURIRELLA OVATA	462	0	1	0	0	0	1	1	0	0	0	1	1	1	1	0
SURIRELLA OVATA V. PINNATA	463	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
SURIRELLA ULNA	464	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
SYNEDRA SP.	465	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TABELLARIA SP.	493	0	1	0	1	1	1	0	1	1	1	1	1	1	0	0
TABELLARIA FENESTRATA	494	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TABELLARIA FLOCCULOSA	495	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		0	1	1	1	1	1	1	1	1	1	1	1	1	0	0

Table 2. Species of the pooled genera: Cymbella, Melosira, Navicula, Nitzschia, Pinnularia, and Synedra.

CYMBELLA ACUTIUSCULA
CYMBELLA AFFINIS
CYMBELLA ANGUSTATA
CYMBELLA ASPERA
CYMBELLA CESATII C.F.
CYMBELLA CISTULA
CYMBELLA CISTULA V. GIBBA
CYMBELLA CUSPIDATA
CYMBELLA CYMBIFORMIS
CYMBELLA CYMBIFORMIS V. NONPUN
CYMBELLA DILUVIANA
CYMBELLA HEBRIDICA C.F.
CYMBELLA HETEROPLEURA V. SUBRO
CYMBELLA INAEQUALIS
CYMBELLA LAEVIS
CYMBELLA LUNATA
CYMBELLA MICROCEPHALA
CYMBELLA MINUTA
CYMBELLA MINUTA
CYMBELLA MINUTA V. PSEUDOGRACI
CYMBELLA MINUTA V. SILESIACA
CYMBELLA NAVICULIFORMIS
CYMBELLA PROSTRATA V. AUERSWALDI
CYMBELLA PROXIMA C.F.
CYMBELLA SINUATA
CYMBELLA SUBAEQUALIS
CYMBELLA TRIANGULUM
CYMBELLA TUMIDA
CYMBELLA TUMIDULA C.F.
CYMBELLA TURGIDULA

MELOSIRA AMBIGUA
MELOSIRA ARCTICA
MELOSIRA DISTANS
MELOSIRA DISTANS V. ALPIGENA
MELOSIRA GRANULATA
MELOSIRA GRANULATA V. ANGUSTIS
MELOSIRA ISLANDICA
MELOSIRA ITALICA
MELOSIRA ITALICA V. TENUISSIMA
MELOSIRA VARIANS

Table 2 (contd.)

NAVICULA ABSOLUTA
NAVICULA ACCOMODA
NAVICULA AMERICANA
NAVICULA AMPHIBOLA
NAVICULA ARVENSIS
NAVICULA ATOMUS
NAVICULA BACILLUM
NAVICULA BICEPHALA
NAVICULA BRYOPHILA
NAVICULA CANALIS
NAVICULA CAPITATA
NAVICULA CAPITATA
NAVICULA CAPITATA V. HUNGARICA
NAVICULA COCCONEIFORMIS
NAVICULA CONTENTA
NAVICULA CONTENTA V. BICEPS
NAVICULA CRYPTOCEPHALA
NAVICULA CUSPIDATA
NAVICULA CUSPIDATA V. AMBIGUA
NAVICULA DECUSSIS
NAVICULA DIGNA
NAVICULA ELGINENSIS
NAVICULA ELGINENSIS V. LATA
NAVICULA ELGINENSIS V. NEGLECT
NAVICULA ELGINENSIS V. ROSTRAT
NAVICULA EXIGUA
NAVICULA EXIGUA V. CAPITATA
NAVICULA GASTRUM
NAVICULA GRACILE
NAVICULA GREGARIA C.F.
NAVICULA GYSINGENSIS
NAVICULA HASSIACA
NAVICULA HUNGARICA
NAVICULA HUSTEDII
NAVICULA INDIFFERENS
NAVICULA LAEVISSIMA
NAVICULA LANCEOLATA
NAVICULA LATEROPUNCTATA
NAVICULA MENISCULUS V. UPSALIE
NAVICULA MINIMA
NAVICULA MINUSCULA
NAVICULA MUTICA
NAVICULA MUTICA V. COHNII
NAVICULA NOTHA
NAVICULA PARATUNKAE
NAVICULA PELLICULOSA
NAVICULA PLACENTA
NAVICULA PROTRACTA
NAVICULA PSEUDOSCUTIFORMIS

Table 2 (contd.)

NAVICULA PUPULA
NAVICULA PUPULA
NAVICULA PUPULA V. CAPITATA
NAVICULA PUPULA V. ELLIPTICA
NAVICULA PUPULA V. MUTATA
NAVICULA PUPULA V. RECTANGULAR
NAVICULA RADIOSA
NAVICULA RADIOSA V. PARVA
NAVICULA RADIOSA V. TENELLA
NAVICULA RHYNCHOCEPHALA
NAVICULA RHYNCHOCEPHALA V. GER
NAVICULA SALINARUM
NAVICULA SALINARUM V. INTERMED
NAVICULA SCHROEDERI V. ESCAMBI
NAVICULA SECRETA V. APICULATA
NAVICULA SECURA
NAVICULA SEMEN
NAVICULA SEMINULUM
NAVICULA SEMINULUM V. HUSTEDTI
NAVICULA SIMILIS
NAVICULA SP.
NAVICULA SUBFASCIATA C.F.
NAVICULA SUBHAMULATA
NAVICULA SUBTILISSIMA
NAVICULA TANTULA
NAVICULA TENELLOIDES
NAVICULA TRIPUNCTATA
NAVICULA VIRIDULA
NAVICULA VIRIDULA
NAVICULA VIRIDULA V. ARGUNENSI
NAVICULA VIRIDULA V. LINEARIS
NAVICULA VIRIDULA V. ROSTELLAT
NAVICULA WALLACEI
NITZSCHIA ACCOMMODATA
NITZSCHIA ACICULARIS
NITZSCHIA ACICULARIS V. AFRICA
NITZSCHIA ACUS
NITZSCHIA AMPHIBIA
NITZSCHIA ANGUSTATA
NITZSCHIA BACATA
NITZSCHIA CAPITELLATA
NITZSCHIA CLAUSII
NITZSCHIA COMMUNIS
NITZSCHIA COMMUTATA
NITZSCHIA CONFINIS
NITZSCHIA CRYPTOCEPHALA
NITZSCHIA C.F. (PALAECEA)
NITZSCHIA DISSIPATA
NITZSCHIA EPIPHYTICA

Table 2 (contd.)

NITZSCHIA EXPLANATA C.F.
NITZSCHIA FASCICULATA
NITZSCHIA FILIFORMIS
NITZSCHIA FONTICOLA
NITZSCHIA FRUSTULUM
NITZSCHIA FRUSTULUM V. PERMINU
NITZSCHIA FRUSTULUM V. SUBSALI
NITZSCHIA GRACILIS
NITZSCHIA HANTZSCHIANA
NITZSCHIA IGNORATA C.F.
NITZSCHIA KUTZINGIANA
NITZSCHIA LINEARIS
NITZSCHIA MINUSCULA
NITZSCHIA OBTUSA
NITZSCHIA PALEA
NITZSCHIA RECTA
NITZSCHIA ROMANA
NITZSCHIA SIGMA
NITZSCHIA SIGMOIDEA
NITZSCHIA SINUATA V. TABELLARIA
NITZSCHIA SPICULUM
NITZSCHIA STAGNORUM
NITZSCHIA SUBLINEARIS
NITZSCHIA SUBTILIS
NITZSCHIA TROPICA
NITZSCHIA TRYBLIONELLA
NITZSCHIA TRYBLIONELLA V. VICT
NITZSCHIA VIVAX
PINNULARIA ABAJUENSIS
PINNULARIA ABAUJENSIS V. LINEA
PINNULARIA ABAUJENSIS V. ROSTR
PINNULARIA ABAUJENSIS V. SUBUN
PINNULARIA ACROSPHAERIA
PINNULARIA APPENDICULATA
PINNULARIA BICEPS
PINNULARIA BIPECTINALIS
PINNULARIA BOREALIS
PINNULARIA BRAUNI
PINNULARIA BRAUNI V. AMPHICEPH
PINNULARIA BREBISSONII
PINNULARIA BREBISSONII V. DIMI
PINNULARIA BREVICOSTATA
PINNULARIA CAUDATA
PINNULARIA DACTYLUS
PINNULARIA DIVERGENS
PINNULARIA FORMICA
PINNULARIA GENTILIS
PINNULARIA INTERMEDIA

Table 2 (contd.)

PINNULARIA LATEVITTATA V. DOMI
PINNULARIA MAIOR
PINNULARIA MESOLEPTA
PINNULARIA MESOLEPTA V. ANGUST
PINNULARIA MICROSTAURON C.F.
PINNULARIA MORMONORUM
PINNULARIA NODOSA
PINNULARIA RUTTNERI
PINNULARIA STREPTORAPHE
PINNULARIA SUBCAPITATA
PINNULARIA SUBCAPITATA V. PAUC
PINNULARIA SUBSOMATOPHORA
PINNULARIA TERMITINA
PINNULARIA VIRIDIS
PINNULARIA VIRIDIS V. MINOR

SYNEDRA ACTINASTRIODES
SYNEDRA ACUS
SYNEDRA AMPHICEPHALA C.F.
SYNEDRA AMPHICEPHALA V. AUSTRIACA
SYNEDRA CAPITATA
SYNEDRA CYCLOPUM
SYNEDRA DELICATISSIMA
SYNEDRA DELICATISSIMA V. ANGUS
SYNEDRA DEMERARAE C.F.
SYNEDRA FILIFORMIS V. EXILIS
SYNEDRA INCISA
SYNEDRA MINUSCULA
SYNEDRA NANA
SYNEDRA PARASITICA
SYNEDRA PARASITICA V. SUBCONSTRICTA
SYNEDRA PULCHELLA
SYNEDRA PULCHELLA V. LACERATA
SYNEDRA RADIANS
SYNEDRA RUMPENS
SYNEDRA RUMPENS V. FAMILIARIS
SYNEDRA RUMPENS V. FRAGILAROID
SYNEDRA RUMPENS V. SCOTICA C.F
SYNEDRA SOCIA
SYNEDRA TENERA
SYNEDRA ULNA
SYNEDRA ULNA V. CONTRACTA
SYNEDRA ULNA V. RAMESI

Appendix 2. Cluster analysis of quantitative diatom data.

Figure 1. Dendrogram of diatoms collected quantitatively in May, 1976. Original data matrix was edited at the 5%.level of relative abundance before clustering.

Figure 2. Dendrogram of diatoms collected quantitatively in August, 1976. Original data matrix was edited at the 5% level of relative abundance before clustering.

Figure 3. Dendrogram of diatoms collected quantitatively in late-September, 1976. Original data matrix was edited at the 5% level of relative abundance before clustering.

Figure 4. Dendrogram of diatoms collected quantitatively in May, 1977. Original data matrix was edited at the 5% level of relative abundance before clustering.

Figure 5. Dendrogram of diatoms collected quantitatively in late-July, 1977. Original data matrix was edited at the 5% level of relative abundance before clustering.

Figure 6. Dendrogram of diatoms collected quantitatively in August, 1977. Original data matrix was edited at the 5% level of relative abundance before clustering.

Figure 1. Dendrogram of diatoms collected quantitatively in May, 1976. Original data matrix was edited at the 5% level of relative abundance before clustering

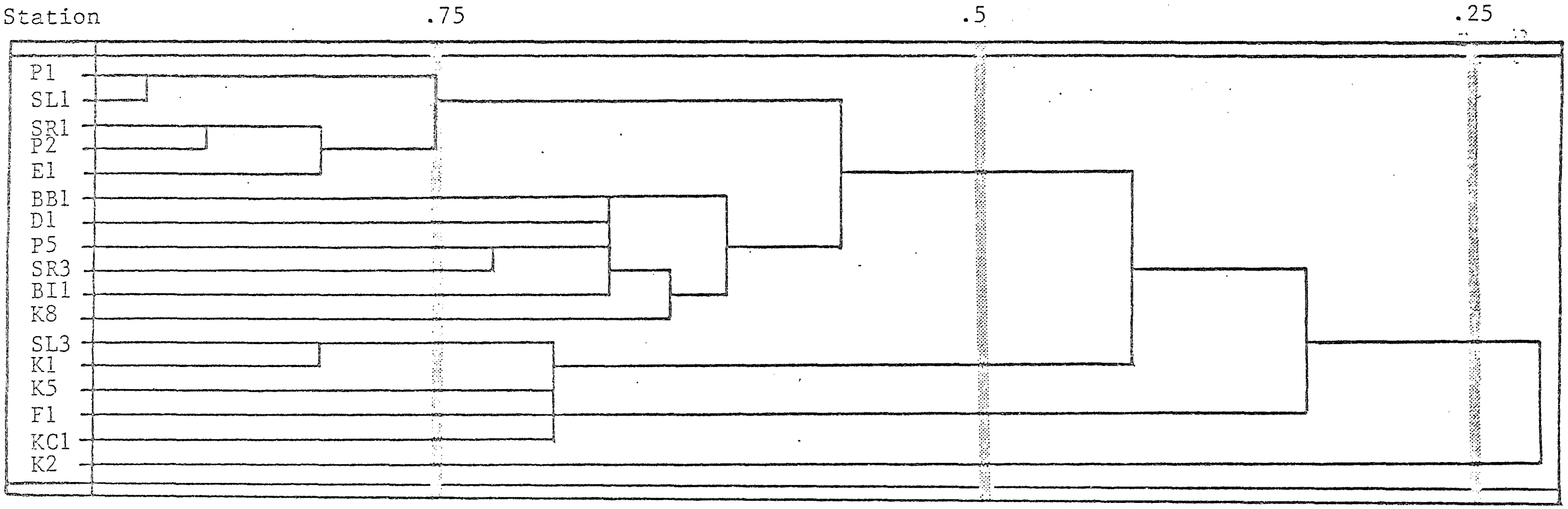

Figure 2. Dendrogram of diatoms collected quantitatively in mid-August, 1976. Original data matrix was edited at the 5% level of relative abundance before clustering.

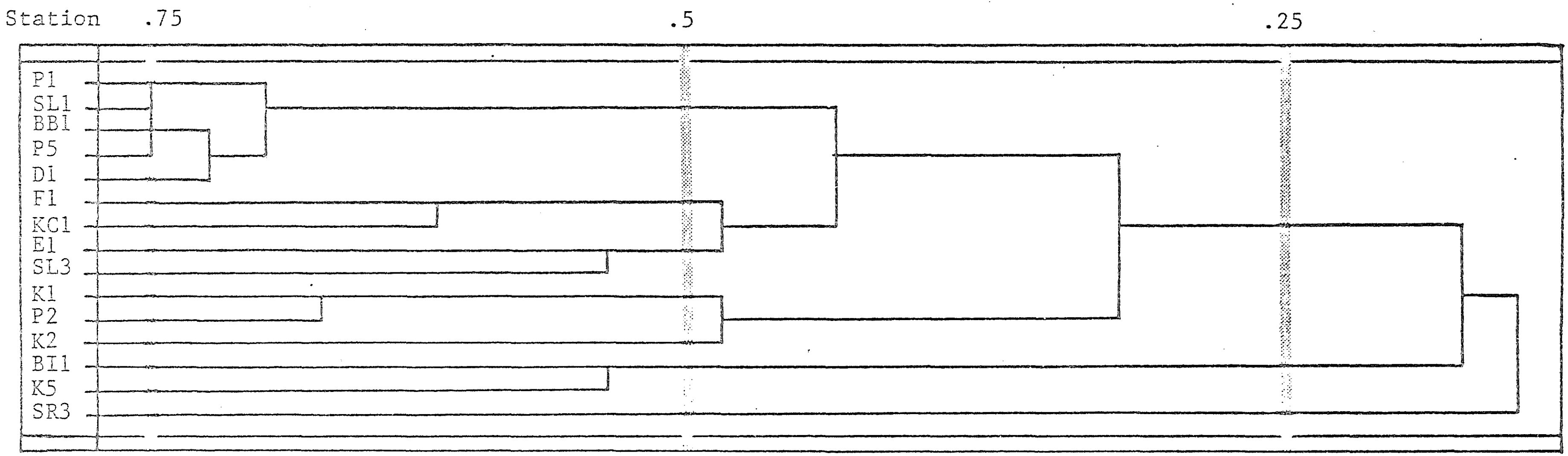

Figure 3. Dendrogram of diatoms collected quantitatively in late-September, 1976. Original data matrix was edited at the 5% level of relative abundance before clustering.

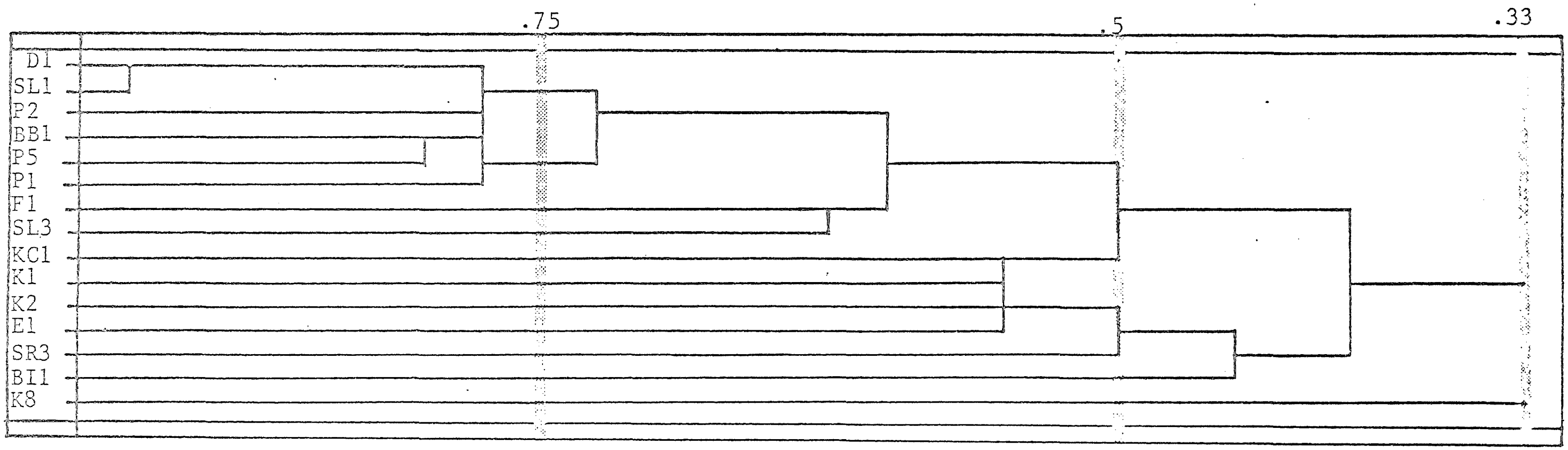

Figure 4. Dendrogram of diatoms collected quantitatively in May, 1977.
Original data matrix was edited at the 5% level of relative abundance before clustering.

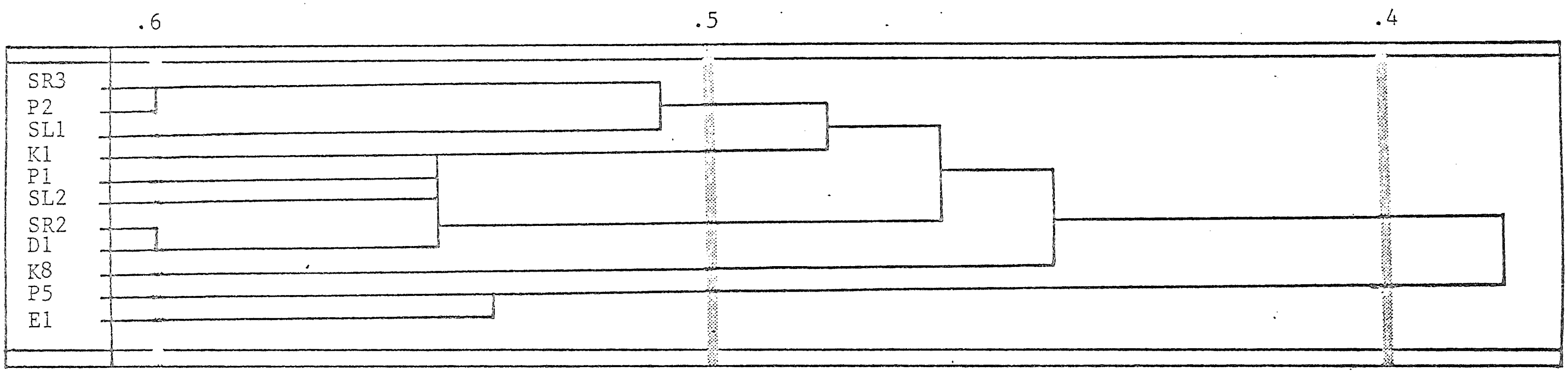

Figure 5. Dendrogram of diatoms collected quantitatively in late-July, 1977. Original data matrix was edited at the 5% level of relative abundance before clustering.

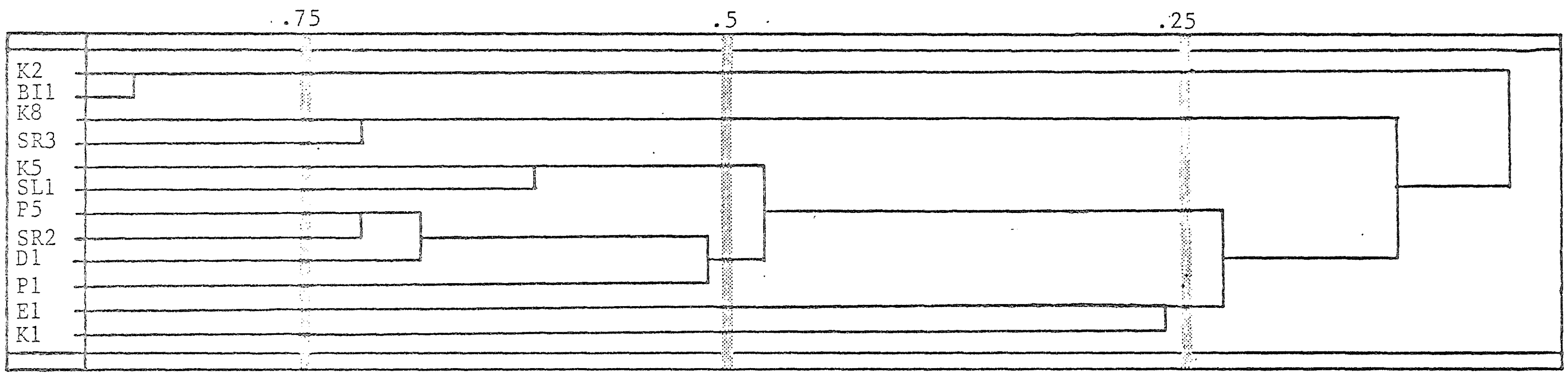

Figure 6. Dendrogram of diatoms collected quantitatively in August, 1977. Original data matrix was edited at the 5% level of relative abundance before clustering.

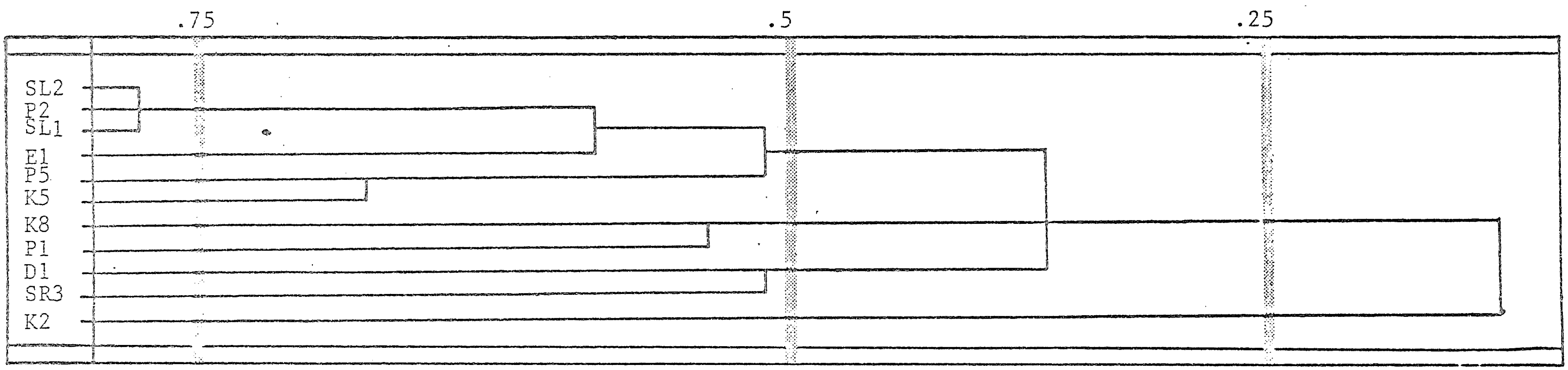

Table 1. Periphyton sampling intensity.

STATION DESIGNATION	YEAR	CHLOROPHYLL			CELL COUNTS			SPECIES PROP. COUNTS			QUALITATIVE		
		A	B	C	A	B	C	A	B	C	A	B	C
Primary	1976	6	3	6	6	3	5	6	3	5	3	6	3
	1977	6	3	6	0	0	0	6	3	3	2	14	2
Secondary	1976	6	3	6	6	3	3	6	3	3	3	18	2
	1977	6	3	6	0	0	0	3	3	3	2	14	2
Tertiary	1976	0	0	0	0	0	0	0	0	0	2	18	2
	1977	0	0	0	0	0	0	0	0	0	2	14	2
Primary (SCS)	1976	0	0	0	0	0	0	0	0	0	0	0	0
	1977	3	3	3	0	0	0	3	3	2	2	14	2
Secondary (SCS)	1976	0	0	0	0	0	0	0	0	0	0	0	0
	1977	0	0	0	0	0	0	0	0	0	2	14	2

A. Number of scheduled sample periods.

B. Colonization period (weeks).

C. Number sample sets analyzed.

Table 2. Mean number of blue-green, green and diatom cells per mm^2 of glass slide artificial substrate and percent diatom cells observed in 1976.

Site	Blue-green	Green	Diatoms	% Diatom
BB-5	25	32	1068	95
KC-1	24	48	638	90
F-1	42	38	458	85
P-5	34	35	1875	96
BI-1	188	162	3471	91
D-1	55	35	1115	93
E-1	17	43	153	72
SL-3	78	331	667	62
K-1	139	150	860	75
P-1	21	12	1891	98
P-2	106	312	1764	81
SL-1	20	17	2255	98
SR-3	281	53	1761	84
K-1	96	650	2924	80
K-5	119	20	1990	93
K-3	65	13	1385	95
$\bar{x}$	73	131	1339	87

*Mean for sampling periods May, August and late September, 1976

Table 3. Number of taxa identified and the number of samples collected within each watershed.

Watershed	# Species Found	# Samples Taken
Range	24	1
Fall	78	12
Shagawa	65	10
Kawishiwi	93	24
Isabella	87	23
Filson	67	8
Birch	130	48
Dunka	80	18
Stony	97	38
St. Louis	79	27
Partridge	104	45
Embarrass	84	19
Whiteface	64	4
Cloquet	30	2

TABLE 4. Dominance values (D) and frequency of occurrence (F) for diatom species collected qualitatively.

TAXA	My/Jn 76 D	My/Jn 76 F	L Sept 76 D	L Sept 76 F	Fb/Mr 77 D	Fb/Mr 77 F	Ap/My 77 D	Ap/My 77 F	Aug 77 D	Aug 77 F
Achnanthes lanceolata v. dubia	0	17	0	3	0	NOT DETERMINED	1.5	9	0	33
A. linearis	13.8	90	1.8	65	0		11.8	85	19.8	93
A. linearis v. curta	1.7	31	0	6	0		0	32	0	44
A. linearis v. pusilla	0	69	0	13	0		2.2	74	15.1	88
A. marginulata	0	0	0	0			0	47	0	51
A. minutissima	67.2	100	53.2	100	83.3		62.5	100	95.3	100
Amphipleura pellucida	0	17	3.7	71	0		0	9	0	23
Anomoeoneis vitrea	0	66	3.7	58	0		0	65	2.3	47
Asterionella formosa	1.7	31	1.2	23	0		0	6	0	9
Cocconeis placentula v. lineata	0	38	0	35	0		0	63	5.2	63
Cyclotella glomeruta	0	31	0	16	0		0	11	0	14
C. meneghiniana	1.7	21	0	32	0		0	37	2.3	37
Cyclotella spp.	0	34	8.1	34	0		0	44	0	74
Cymbella lunata	0	0	1.2	97	0		0	0	0	0
C. minuta	4.3	100	3.7	97	0		5.2	0	0	0
Cymbella spp.	0	100	0	97	0		0	88	2.3	100
Diatoma anceps	1.7	0	0	0	0		0	0	0	0
D. tenue v. elongatum	10.3	52	1.2	13	25		13.2	41	0	16
Eunotia curva	0	62	0	42	0		0	50	0	63
Eunotia pectinalis v. minor	0	0	0	16	0		1.7	24	0	37
Eunotia spp.	2.6	66	8.1	69	0		8.8	50	10.5	98
Fragilaria capucina	0	10	5.0	13	8.3		0	29	0	23
F. construens	0	76	5.0	61	0		0	32		
F. construens v. pumilla	0	24	0	3	0		2.2	68	7.0	91
F. construens v. venter	0	79	8.1	48	0		7.4	68	6.4	91
F. crotonensis	0	0	12.4	52	0		0	18	0	14
F. pinnata	10.3	79	3.2	42	0		16.9	65	26.2	95
F. vaucheria	10.3	79	4.0	39	16.7		2.2	56	0	56
F. virescens	0	3	0	0	0		.7	32	0	16
Fragilaria spp.	0	0	21.1	52	0		0	59	0	40
Gomphonema angustatum	0	76	0	42	50		7.4	76	0	70
G. clevei	0	0	0	0	0		0	27	0	51
G. olivareoides	0	0	0	0	0		0	0	0	0
G. parvulum	0	52	0	84	0		0	68	0	77
Gomphonema spp.	0	0	0	0			0	41	0	37
Melosira granulata	7.8	83	5.6	84	0		1.5	88	0	0

TABLE 4. continued

TAXA	My Jn 76 D	My Jn 76 F	L Sept 76 D	L Sept 76 F	Fb Mr 77 D	Fb Mr 77 F	Ap My 77 D	Ap My 77 F	Aug 77 D	Aug 77 F
Melosira spp.	0	82	2.5	84	0	NOT DETERMINED	0	88	5.2	98
Meridion circulare	0	34	0	13	0		9.6	41	0	28
Navicula cryptocephala	2.6	97	5.0	100	0		0	0	0	0
N. radissa	0	0	1.2	100	0		0	0	0	0
N. secreta v. apiculata	0	0	0	0	0		1.5	0	0	0
Navicula spp.	0	100	0	100	0		.7	91	11.1	97.7
Neidium spp.	0	0	0	10	0		0	15	.6	17
Nitzschia acicularis	1.7	100	0	0	0		2.2	91.2	0	0
N. kutzingiana	0	0	2.5	100	0		0	0	0	0
N. palea	0	0	5.0	100	0		0	0	0	0
Nitzschia spp.	0	100	0	97	0		0	91	3 5	1
Pinnularia spp.	0	62	0	58	0		0	50	0	61
Synedra amphicephala	0	0	0	0	0		7.4	N.C.	0	0
S.delicatissima	0	100	0	0	0		2.9	100	0	0
S. minuscula	0	0	2.5	100	25		13.2	0	0	0
S. radians	0	0	0	0	0		9.6	N.C.	0	0
S. rumpens	11.2	100	2.4	100	0		2.2	0	0	0
S. rumpens v. familiaris	0	100	1.2	100	0		0	0	0	0
S. tenura	1.7	100	0	0	0		.7	100	0	0
S. ulna	17.2	100	2.4	100	16.7		11.8	0	0	0
Synedra spp.	0	100	0	100	0		0	100	22.7	98
Tabellaria fenestrata	9.5	79	1.6	65	24		5.2	79	2.9	72
T. flocculosa	31	90	3.2	58	0		34.6	91	18.6	95

N.C. = not calculated

TABLE 5. Dominance values (D) and frequency of occurrence (F) for diatoms species collected quantitatively

TAXA	My Jun 76 D	My Jun 76 F	L Jly 76 D	L Jly 76 F	Ma Aug 76 D	Ma Aug 76 F	E Sept 76 D	E Sept 76 F	L Sept 76 D	L Sept 76 F	L May 77 D	L May 77 F	L Jly 77 D	L Jly 77 F	Aug 77 D	Aug 77 F
Achnanthes lanceolata	0	41.2	0	42.9	0	60	0	66.7	0	40	0	9.1	0	8.3	0	0
A. linearis	4.4	29.4	17.9	100	13.3	80	33	100	15.0	73.3	0	63.6	0	75	0	72.7
A. linearis v. *pusilla*	30.9	82.4	35.7	71.4	36.7	93.3	0	33.3	0	60	0	36.4	39.6	83.3	45.5	90.9
A. minutissima	91.2	100	53.5	100	66.7	100	95.8	100	91.6	100	56.8	100	58.3	100	70.5	90.9
Amphipleura pellucida	0	35.3	0	42.9	0	53.3	0	83.3	1.7	60	0	0	0	8.3	0	36.4
Anomoeoneis serians	0	5.9	0	57.1	0	20.0	0	66.7	0	0	0	0	0	16.7	0	0
A. vitrea	4.4	82.4	0	71.4	0	86.7	0	66.7	0	86.7	0	54.5	0	41.7	0	45.5
Cocconeis placentula v. *lineata*	13.2	58.8	50.0	100	46.7	80	42	83.3	10	80	0	9.1	27	66.7	45.5	81.8
Cyclotella spp.	4.4	35.3	0	71.4	0	40.0	0	66.7	1.7	80	0	27.3	0	16.7	0	27.3
Cymbella spp.	5.9	94.1	0	85.7	0	93.3	0	100	5.0	86.7	0	100	2.1	91.7	0	81.8
Diatoma tenue v. *elongatum*	0	29.4	0	28.6	0	13.3	0	16.7	0	6.7	47.7	100	0	66.7	0	36.4
Eunotia sp	4.4	100	10.7	71.4	11.7	93.3	0	50	0	66.7	0	0	0	41.6	0	63.6
Fragilaria construens	1.5	47	10.7	57.1	1.7	80	0	33.3	3.3	80	0	18.2	0	0	0	0
F. construens v. *pumilla*	0	0	0	14.3	0	0	0	16.7	0	0	0	63.6	2.1	58.3	4.5	63.6
F. construens v. *venter*	0	41.2	3.6	28.6	0	60	0	16.7	6.7	60	0	36.4	0	33.3	0	36.4
F. crotonensis	0	70.6	0	28.6	0	40	0	50	0	40	0	36.4	0	16.7	0	18.2
F. pinnata	0	47.1	0	28.6	0	46.7	0	50	0	46.7	0	9.1	0	25	0	27.3
F. vaucheria	0	41.2	0	14.3	0	66.7	0	83.3	3.3	26.7	6.8	100	0	83.3	0	63.6
Fragilaria spp.	0	17.6	0	71.4	0	26.7	0	50	8.3	53.3	0	45.5	0	50	0	36.4
Gomphonema acuminatum	0	41.2	0	57.1	0	60	0	100	0	73.3	0	81.8	0	50	0	36.4
G. affine	1.5	11.8	0	0	0	0	0	16.7	0	0	0	0	0	50	0	9.1
G. angustatum	8.8	64.7	0	71.4	3.3	73.3	0	83.3	0	66.7	18.2	81.8	20.8	83.3	15.9	63.6
G. clevei	0	0	0	14.3	0	6.7	0	33.3	0	0	6.8	18.2	6.3	50	0	36.4
G. gracile	0	23.5	0	0	0	6.7	0	0	0	6.7	0	63.6	0	58.3	0	36.4
G. grunowii	0	0	0	0	0	0	0	0	0	6.7	0	54.5	0	25	0	27.3
G. parvulum	2.9	100	14.3	71.4	0	93.3	8.3	100	11.7	93.3	0	54.6	14.6	83.3	4.5	90.9
Gomphonema spp.	5.9	41.2	0	57.1	0	60	0	100	0	73.3	0	81.8	0	50	0	36.4
Melosira spp.	4.4	88.2	10.7	71.4	6.7	73.3	16.7	66.7	10	73.3	0	54.5	0	42	0	45.5
Navicula spp.	0	88.2	0	85.7	0	33.3	8.3	100	8.3	100	0	72.7	0	75	0	63.6
Nitzschia spp.	7.4	82.4	7.1	85.7	10.0	93.3	8.3	100	48.3	100	0	90.9	0	75	0	90.9
Synedra spp.	16.2	94.1	0	85.7	0	100	4.2	100	16.7	100	56.8	100	31.3	91.6	25.0	90.9
Tabellaria fenestrata	0	70.6	0	71.4	0	46.7	0	50	0	53.3	0	63.6	2.1	41.7	0	45.5
T. flocculosa	10.3	70.6	0	71.4	5.0	60	0	33.3	0	66.7	9.1	81.8	6.3	58.3	2.3	63.6

Table 6. Mean relative abundance of dominant diatom taxa. Means are calculated for May, August, and late-September, 1976, and May, late-July, and August, 1977.

	STATION																	
	1st order		2nd order						3rd order									
TAXA	BB-1		F-1		KC-1		P-5		BI-1		D-1		E-1		SL-2		SL-3	
Achnanthes lanceolata	0.27	--	2.4	--	0.87	--	0.03	0	0	0	0.13	0	0.27	0	--	0	0.27	--
A. linearis	1.87	--	4.8	--	0.97	--	0.97	0.47	0.2	0	0.13	0.03	4.1	0.13	--	2.25	4.07	--
A. linearis v. pusilla	3.03	--	2.4	--	5.43	--	4.3	5.33	27.13	12.6	1.8	4.93	9.17	18.73	--	25.05	18.33	--
A. minutissima	49.63	--	31.77	--	26.37	--	54.8	27.63	26.27	0.2	63.83	67.4	36.5	10.63	--	60.9	32.03	--
Amphipleura pellucida	0.43	--	0	--	0.03	--	0.9	0.07	0.73	0	0.23	0.03	3.1	0	--	0	0.83	--
Anomoeoneis vitrea	1.17	--	1.83	--	1.73	--	1.67	0.2	0.37	0	2.03	1.83	0.53	0	--	0.2	1.4	--
Cocconeis placentula	2.2	--	0.03	--	0.03	--	0.03	16.9	4.43	83.4	0.13	0	5.97	4.13	--	1.3	0.07	--
Cyclotella spp.	0.27	--	1.13	--	2.47	--	0.1	0	1.2	0	4.07	0.03	0.37	0	--	0	0.23	--
Cymbella spp.	3.9	--	1.73	--	1.57	--	2.7	2.7	0.53	0.2	1.67	1.9	1.17	0.83	--	0.5	2.37	--
Diatoma tenue v. elongatum	2.23	--	0	--	0	--	1.13	13.77	0	0	0.57	5.53	0	4.93	--	0.1	0	--
Eunotia spp.	1.77	--	5.3	--	6.43	--	0.57	1.17	1.37	0.8	1.43	0.07	1.0	1.47	--	0	2.23	--
Fragilaria spp.	0.03	--	0	--	2.3	--	1.43	0.4	0.23	0	0.1	0.43	0.47	0.2	--	0.4	3.23	--
F. construens	2.2	--	4.17	--	4.97	--	1.1	0	4.33	0	0.67	0.07	0.6	0	--	0	0.07	--
F. construens v. pumila	0	--	0	--	0	--	0	0.4	0	0	0	0.3	0	0.43	--	0.2	0	--
F. construens v. venter	0.9	--	1.93	--	1.63	--	1.07	0.13	5.53	0	1.4	0.47	0.2	0	--	0	0	--
F. vaucheriae	0.17	--	3.06	--	0.23	--	0.16	0.47	0.03	0.2	1.33	0.07	0.33	1.83	--	0.1	0.03	--
Gomphonema spp.	0.4	--	0.3	--	0.47	--	0.3	0.13	0.37	0	0	0.17	2.4	0.4	--	0.4	0.2	--
G. affine	0	--	0	--	0	--	0	0	0	0	0	0	0	0	--	0	0	--
G. angustatum	1.07	--	1.3	--	1.17	--	1.73	0.9	8.93	0	0.43	0.47	0.13	23.6	--	0.3	5.1	--
G. clevei	0	--	0	--	0	--	0	0	0	0	0	0.13	0	0	--	0	0	--
G. grunowii	0	--	0	--	0	--	0.1	0.07	0	0.2	0	0	0	0	--	0.4	0	--
G. parvulum	2.3	--	1.0	--	1.4	--	2.1	0.43	0.87	0	1.33	0.17	1.33	0.67	--	0.9	2.57	--
Melosira spp.	0.87	--	5.97	--	9.5	--	0.67	0.13	1.27	0	1.77	0.13	0.53	0	--	0.1	2.47	--
Navicula spp.	4.2	--	2.3	--	2.6	--	3.63	0.47	1.93	0	2.9	0.27	8.77	0.27	--	0.3	2.77	--
Nitzschia spp.	6.4	--	4.3	--	3.43	--	5.27	1.27	3.67	0	7.9	0.27	15.97	1.13	--	0.6	5.83	--
Synedra spp.	5.27	--	2.97	--	3.6	--	7.17	21.83	4.03	0.2	2.9	10.77	3.43	29.43	--	2.5	3.17	--
Tabellaria fenestrata	0.47	--	2.2	--	2.73	--	0.2	0	0.43	0	0.3	0.43	0.2	0	--	0.2	0.97	--
T. flocculosa	1.87	--	9.07	--	10.4	--	1.87	1.87	2.07	0	0.37	2.77	0.17	0.03	--	3.0	1.2	--

Table 6. Continued

TAXA	STATION 4th order K-2		P-1		P-2		SL-1		SR-1		SR-2		SR-3		K-1		5th order K-5		K-8	
Achnanthes lanceolata	3.03	0	0.3	0.07	0	0	0.03	0	0	--	--	0	0.3	0	0.03	0	0.65	0.1	0.2	0
A. linearis	4.9	0	0.3	0.4	1.43	1.25	0.63	0.07	0	--	--	0.2	26.7	0.37	0.4	0.2	0.1	0.65	1.7	0.17
A. linearis v. pusilla	0.03	0	0.07	0.1	11.3	30.65	4.6	26.2	15.6	--	--	3.75	1.77	1.4	19.77	0.65	55.4	26.7	1.85	0.37
A. minutissima	9.97	0.45	67.3	45.93	54.03	34.05	76.07	51.6	72.0	--	--	36.2	22.47	15.2	31.97	3.45	11.35	23.95	29.9	14.27
Amphipleura pellucida	0	0	0.3	0.07	0.2	0	0.03	0	0	--	--	0	1.77	0	0	0	0.05	0	0	0.03
Anomoeoneis vitrea	0	0	0.33	0.47	0.13	0.2	0.67	0.23	1.9	--	--	0.05	3.87	0.7	0.13	0	0.05	0.2	0.65	0.2
Cocconeis placentula	48.43	98.65	10.23	16.83	20.37	4.0	3.83	7.07	0	--	--	0	0.23	0	19.13	2.6	24.85	20.45	0.15	0.1
Cyclotella spp.	1.7	0	0	0.03	0	0.1	0.17	0	0	--	--	0.05	0.37	0	0.13	0.05	0	0.2	0.2	0.03
Cymbella spp.	1.6	0	4.77	2.8	0.27	0.7	0.5	0.7	0.7	--	--	1.1	2.27	0.77	0.7	0.15	0.4	0.5	0.55	1.23
Diatoma tenue v. elongatum	0	0.2	0.13	1.43	0	8.1	0	0.5	0.3	--	--	14.1	0	3.27	0	1.45	0	0.1	2.25	7.2
Eunotia spp.	0.23	0	0.07	0.03	0.4	0.1	0.47	0.07	0.4	--	--	0	6.1	0.13	0.13	0	0.95	0.1	0.05	0.03
Fragilaria spp.	0.7	0	0.27	0	0.63	0	0	0	0	--	--	0.55	3.53	0.4	0.03	0.55	0.2	0.1	0	0
F. construens	0.7	0	1.0	0	0.2	0	0.37	0.03	0	--	--	0	0.4	0	0.2	0	0.05	0	0.5	0
F. construens v. pumila	0	0	0	0.27	0	0	0	0.53	0	--	--	0.15	0	3.77	0	0.05	0	0.5	0	0.53
F. construens v. venter	1.63	0.1	0	0.1	0	0.2	0.13	0.03	0	--	--	0	0.03	0.87	0.1	0	0	0	0	0.13
F. vaucheriae	0.33	0.1	0.03	1.43	0.03	0.8	0.67	0.4	0	--	--	5.2	1.13	0.6	1.5	6.15	0.05	2.35	0.8	2.53
Gomphonema spp.	2.57	0	0.37	0.27	0.2	0	1.57	0.03	1.7	--	--	0.9	2.0	0.07	0.47	0.35	0.2	0	0	0.17
G. affine	0	0	0	0	0	0	0	0.1	0	--	--	0	0.27	0	0	0.05	0	0	2.55	0
G. angustatum	2.27	0	0.13	15.37	0.1	0	0.57	0.4	0	--	--	0.8	1.57	0.57	1.5	35.75	0.3	3.0	10.3	11.97
G. clevei	0	0	0	0.97	0	0	0.33	5.7	0	--	--	3.1	0	0	0	9.2	0	2.4	0	1.2
G. grunowii	0	0	0	0	0	0	0	0.03	0	--	--	0.2	0	0.9	0	0.35	0	3.45	0	0.03
G. parvulum	2.3	0	1.2	0.8	3.0	0.75	3.03	4.0	4.4	--	--	9.6	0.17	1.43	5.77	9.85	1.35	5.7	27.45	4.03
Melosira spp.	1.03	0.2	0.03	0.2	0	0	0.03	0	0.3	--	--	0	1.8	0.27	5.57	2.95	0.95	0.75	5.05	1.77
Navicula spp.	4.8	0.1	2.73	2.9	0.77	0.2	0.33	0.07	0.7	--	--	0.2	3.83	0.2	1.4	0.4	0.1	0.2	0.25	0.17
Nitzschia spp.	6.53	0.1	4.43	2.73	2.73	0.7	2.53	0.1	0.3	--	--	0.55	5.67	0.57	2.67	0.8	0.3	0.5	1.25	0.83
Synedra spp.	2.6	0	2.76	3.9	3.57	15.9	2.67	1.23	0.9	--	--	17.6	3.9	56.73	1.9	15.15	0.75	5.1	10.1	49.73
Tabellaria fenestrata	0.1	0	0	0.07	0	0.4	0	0	0	--	--	0.55	0.57	0.7	2.7	5.1	1.2	1.45	1.15	0.77
T. flocculosa	0.03	0	0.63	0.2	0	1.25	0	0.03	0	--	--	3.55	1.23	10.8	0	0	0.2	0.5	0.25	0.9

Table 7. Annual mean percent relative abundance of dominant taxa collected quantitatively.

TAXA	1976	1977
Achnanthes lanceolata	0.52	0.01
A. linearis	3.13	0.44
A. linearis var. *pusilla*	10.69	11.18
A. minutissima	40.96	27.99
Amphipleura pellucida	0.51	0.01
Anomoeoneis vitrea	1.09	0.31
Cocconeis placentula	8.24	18.25
Cyclotella spp.	0.73	0.04
Cymbella spp.	1.61	1.01
Diatoma tenue var. *elongatum*	0.39	4.33
Eunotia spp.	1.7	0.28
Fragilaria spp.	0.77	0.22
F. construens	1.27	0.01
F. construens var. *pumilla*	0	0.51
F. construens var. *venten*	0.86	0.15
F. vancheriae	0.58	1.59
Gomphonena spp.	0.80	0.21
G. affine	0.17	0.01
G. angustatum	2.15	6.65
G. clevei	0.02	1.62
G. grunowii	0.01	0.40
G. parvulum	3.62	2.74
Melosira spp.	2.22	0.46
Navicula spp.	0.39	0.41
Nitzschia spp.	4.66	0.73
Synedra spp.	3.63	16.43
Tabellaris fenestrata	0.78	0.69
T. flocculosa	1.73	1.86

Table 8. Number of stations where dominant taxa reach their peak abundance during each sampling period. Taxa must also comprise at least 2 percent of sample to be considered at peak abundance.

	1976					1977		
Taxa / Month	MY	JY	A	E-S	L-S	M	JY	A
Achnanthes linearis	1	2	4	3	5	1	0	1
A. linearis v. *pusilla*	9	3	4	0	0	0	5	5
A. lanceolata	0	0	3	0	1	0	0	0
A. minutissima	8	0	2	2	6	4	5	3
Amphipleura pellucida	0	0	0	0	3	0	0	0
Anomoeoneis vitrea	1	1	3	1	3	2	0	0
Cocconeis placentula	0	3	5	1	1	0	2	8
Cyclotella spp.	1	0	0	0	4	0	0	0
Cymbella spp.	6	2	1	1	2	3	1	1
Diatoma tenue v. *elongatum*	2	0	0	0	0	9	0	0
Eunotia spp.	3	3	4	0	0	0	0	2
Fragilaria construens	3	1	2	0	2	0	0	0
F. construens v. *pumila*	0	1	0	0	0	0	1	0
F. construens v. *venter*	1	1	2	0	2	0	0	0
F. vaucheriae	2	0	2	1	2	2	3	1
Fragilaria spp.	1	0	0	0	4	0	0	0
Gomphonema spp.	2	1	1	2	1	0	0	0
G. angustatum	5	1	1	0	1	1	3	2
G. clevei	0	0	0	1	0	0	4	2
G. grunowii	0	0	0	0	0	0	1	1
G. parvulum	6	1	1	0	6	0	3	3
G. affine	1	0	0	0	0	0	0	0
Melosira spp.	0	3	2	1	4	0	1	1
Navicula spp.	3	0	1	3	8	0	1	0
Nitzschia spp.	0	0	2	3	12	0	1	1
Synedra spp.	6	0	3	1	6	9	2	0
Tabellaris fenestrata	4	0	0	1	1	1	2	0
T. flocculosa	5	1	1	1	0	3	2	0

Table 9. Species diversity $\left(\frac{1}{\Sigma P_i^2}\right)$ of diatom communities colonizing glass slides at primary and secondary stations.

Site	M	A	L-S	$\bar{x}$	M	L-JY	A	$\bar{x}$
P-1	1.4	2.2	3.0	2.2	1.9	3.3	5.0	3.4
BB-1	4.6	2.9	4.1	3.9	--	--	--	--
BI-1	2.7	2.2	10.2	5.0	--	1.4	--	1.4
SR-3	4.0	1.9	12.9	6.3	2.0	2.5	3.5	2.7
SL-3/2	3.3	9.0	5.8	6.0	1.5	--	2.4	2.0
P-5	3.2	2.7	3.5	3.1	2.5	2.8	3.4	2.9
K-5	1.8	2.7	---	2.3	--	6.4	3.4	4.9
K-2	5.5	1.4	7.5	4.8	--	1.04	1.01	1.0
F-1	10.1	7.4	5.0	7.5	--	--	--	--
KC-1	9.98	8.0	6.1	8.0	--	--	--	--
SL-1	1.27	2.43	1.62	1.8	1.45	3.31	3.29	2.7
E-1	2.19	7.4	1.76	3.8	2.0	2.4	5.8	3.4
D-1	3.59	2.43	1.60	2.5	3.88	1.5	1.65	2.4
SR-1/2	1.83	2.07	3.00	2.3	4.8	3.2	--	4.0
P-2	1.74	2.97	2.71	2.5	3.4	--	2.2	2.8
K-1	2.50	4.79	5.3	4.2	2.97	7.52	--	5.3
K-8	4.49	6.04	2.92	4.5	2.86	1.51	5.08	3.2

Table 10. Species diversity $\left(\frac{1}{\Sigma P_i^2}\right)$ of qualitative diatom samples collected in 1977.

Site	Ap/My	A
BC-1	2.32	5.73
BI-1	6.97	8.12
C4-1	8.49	6.30
D-1	11.62	9.35
D-2	16.37	15.12
D-3	--	8.14
DC-1	--	4.36
E-1	11.04	4.41
E-2	28.36	8.72
F-1	10.06	11.44
I-1	19.98	6.31
K-1	9.83	2.80
K-2	22.19	14.41
K-5	6.86	11.08
K-6	3.25	3.63
K-7	3.63	8.54
K-8	5.43	6.03
KC-1	3.29	9.24
KC-2	2.40	5.31
LJ-1	--	19.7
LI-2	--	5.97
LI-3	--	6.84
N-1	--	3.38
NR-1	--	8.75
NW-1	5.40	20.42
P-1	4.01	6.07
P-2	9.58	4.25
P-3	2.46	12.75
P-4	11.43	2.71
P-5	10.7	13.79
SC-1	6.42	16.12
SE-1	--	11.25
SE-2	12.67	14.42
SG-1	5.99	
SH-1	5.37	12.34
SL-1	5.03	7.82
SL-2	19.21	5.59
SP-1	--	7.17
SR-1	--	5.78
SR-2	10.81	4.56
SR-3	16.49	7.10
SR-4	9.31	50
SR-5	9.67	5.86
T-1	6.96	13.23

Table 11. Mean annual* chlorophyll a and cells/mm^2 determined from samples collected on glass slide artificial substrates.

Sites	$\bar{x}$ Chlorophyll a	$\bar{x}$ cells/mm^2
BB-1	3.97	1109
KC-1	2.70	385
F-1	4.21	388
P-5	5.59	1819
BI-1	6.03	3784
D-1	4.34	1225
SL-3	6.27	1104
K-2	8.13	1148
P-1	8.93	1923
P-2	12.66	2179
SL-1	5.29	2290
SR-3	3.09	2095
K-1	7.15	3669
K-5	4.86	2128
K-8	6.69	1496

*mean of samples collected in May, mid-Augist, and late September, 1976.

Table 12. Median water quality data averaged by stream order.

Stream Order	Specific Conduct (mhol/l)	Total P (g/m)	Total N (mg/l)	pH	Alk. (mg/l)	Ca (mg/l)	Turb (NTU)
1*	18.5	90	2215	6.7	55	14.8	2.5
2	55.5	25.7	1158.3	6.4	18	4.6	2.0
3	86.9	29.3	1109.2	6.7	36.3	8.2	2.7
4	89.3	21.7	716.2	7.0	33.2	8.6	2.7
5	50.8	18.8	612/5	6.9	18.8	6.2	1.9

Table 13. Acidophilous diatom taxa found in the Study Area. [1]

Achnanthes flexella
Cyclotella bodanica
C. glomerata
Eunotia spp.
Frustulia rhomboides
Gomphonema subtile
Melosira distans
Navicula seminula var. *hustedtii*
Stauroneis anceps
Stenopterobia intermedia
Synedra nana
S. tenera
Tabellaria fenestrata
T. flocculosa

[1] Based on Lowe (1974)

Table 14. Correlation coefficients[1] for comparisons between stream order and mean percent relative abundance of acidophilous diatoms.

Stream order vs. acidophilous diatoms.

Period 1 (Quant.)	-.8
Period 1 (Qual.)	-1.0
Period 4 (Quant.)	-.8
Period 6 (Quant.)	-.8
Period 8 (Qual.)	-.5
Period 13 (Qual.)	-.8

[1]Spearmans rank correlation test.

Table 15. Mean annual* percent relative abundance of dominant diatom taxa averaged by stream order. Samples collected from glass slide artificial substrates in 1976.

	STREAM ORDER			
	2nd	3rd	4th	5th
Achnanthes lanceolata	1.1	0.17	0.61	0.29
A. linearis	2.25	2.13	5.66	0.73
A. linearis v. pusilla	4.04	14.11	5.56	25.67
A. minutissima	37.65	39.76	50.31	24.41
Amphipleura pellucide	0.31	1.22	0.38	0.02
Anomoeoneis vitrea	1.74	1.08	1.15	0.28
Cocconeis placentula	0.03	2.56	13.85	14.71
Cyclotella spp.	1.23	1.47	0.37	0.11
Cymbella spp.	2.0	1.44	1.69	0.55
Diatoma tenue v. elongatum	0.38	0.14	0.07	0.75
Eunotia spp.	4.1	1.51	1.28	0.38
Fragilaria spp.	1.24	1.01	0.855	0.08
F. construens	3.41	1.42	0.45	0.25
F. construens v. pumilla	0	0	0	0
F. construens v. venta	1.54	1.78	0.30	0.03
F. vaucheriae	1.15	0.43	0.37	0.78
Gomphonema spp.	0.36	0.74	1.40	0.22
G. affine	0	0	0.05	0.85
G. angustatum	1.4	3.65	0.77	4.03
G. clevei	0	0	0	0
G. grunowii	0.03	0	0	0
G. parvulum	1.5	1.53	2.35	11.52
Melosira spp.	5.38	1.51	0.53	3.86
Navicula spp.	2.84	4.09	2.19	0.58
Nitzschia spp.	4.33	8.34	3.70	1.41
Synedra spp.	13.74	3.38	2.73	4.25
Tabellaria fenestrata	1.71	0.48	0.11	1.68
T. flocculosa	7.11	0.95	0.32	0.15

* Mean of sampling periods May, August and late September, 1976.

Table 16. Percent frequency of occurrence of diatoms by stream order in April, 1977. Taxa included have a 50% frequency of occurrence in any stream order.

TAXA	STREAM ORDER 1st	2nd	3rd	4th	5th
Achnanthes linearis	50	83	100	71	100
A. linearis var. pusilla	50	83	75	71	80
A. linearis var. curta	50	17	42	14	40
A. marginulata	0	83	58	43	20
A. minutissima	100	100	100	100	100
Anomoeoneis serians var. brachysira	25	50	33	28	20
A. vitrea	25	67	75	71	60
Cocconeis placentula	100	33	42	57	20
Cyclotella spp.	25	83	42	28	60
Cymbella spp.	75	83	83	100	100
Diatoma tenue var. elongatum	25	17	25	57	100
Eunotia spp.	75	83	50	14	20
E. curvata	50	83	58	28	0
E. diodon	50	0	0	0	0
E. elegans	50	0	0	0	0
E. incisa	50	17	25	14	20
E. pectinalis var. minor	50	17	33	14	0
E. praerupta var. inflata	50	50	25	28	0
Fragilaria spp.	25	50	75	57	80
Fragilaria capucina	0		33	28	80
F. constricta	50	17	0	0	0
F. construens	50	33	42	28	0
F. construens var. pumilla	50	50	83	86	20
F. construens var. venter	50	83	67	71	40
F. pinnata	0		58	43	40
F. vancheria	0	50	42	86	100
F. viresens	25	17	33	28	60
Frustula rhomboides	50	0	42	14	0
Gomphonema spp.	75	50	58	14	0
G. angustatum	50	100	75	71	80
G. clevei	0	17	25	57	0
G. grunowii	0	17	8	14	80
G. parvulum	75	67	50	86	80
Melosira spp.	75	100	100	57	100
Meridion circulare	75	67	25	43	0
Navicula spp.	75	83	100	86	100
Nitzschia spp.	75	83	92	100	100
Pinnularia spp.	75	33	75	28	0
Synedra spp.	100	100	100	100	100
Tabellaria fenestrata	100	83	75	57	100
T. flocculosa	100	100	92	86	80

Table 17. Frequency of occurrence of diatoms by stream order in August, 1977. Taxa included have 50% frequency of occurrence in any stream order.

TAXA	STREAM ORDER 1st	2nd	3rd	4th	5th
Achnanthes flexella	0	22	33	25	60
Achnanthes lanceolata var. dubia	0	22	60	0	60
Achnanthes linearis	100	77	93	100	100
A. linearis var. pusilla	100	89	87	88	80
A. linearis var. curta	50	33	60	13	50
A. marginulata	100	56	53	25	20
A. minutissima	100	100	100	100	100
Amphora ovalis	17	11	20	63	40
Anomoeoneis vitrea	50	56	73	50	80
Anomoeoneis serians var. brachysira	35	33	47	63	60
Asterionella formosa	0	0	0	13	60
Cocconeis placentula	50	56	73	50	80
Cyclotella meneghiniana	33	33	40	50	20
Cyclotella spp.	83	78	87	38	80
Cymbella spp.	100	100	100	100	100
Eunotia spp.	100	78	93	87	60
E. curvata	67	44	80	38	80
E. pectinalis	50	33	27	0	20
E. pectinalis var. minor	67	44	33	13	0
Fragilaria construens	17	44	53	25	20
F. construens var. pumilla	83	89	93	87	100
F. construens var. venter	83	100	93	87	80
F. pinnata	100	100	100	100	60
F. vancheria	17	56	39	97	100
Frustulia rhomboides	67	33	20	0	40
Gomphonema angustatum	67	78	67	60	80
G. clevei	50	67	47	50	60
G. parvulum	67	78	80	87	80
Melosira spp.	100	89	100	100	100
Meridion circulare	67	67	7	13	0
Navicula spp.	100	89	100	100	100
Nitzschia spp.	100	100	100	100	100
Pinnularia spp.	83	47	87	38	20
Synedra spp.	100	89	100	100	100
Tabellaria fenestrata	83	67	80	38	100
T. flocculosa	100	100	100	75	100

Table 18. Mean number of acid-tolerant taxa, mean number of species and species diversity found in qualitative samples.

Stream Order	Mean Number of Acid-Tolerant Taxa August, 1977	Mean No. of Species April, 1977	Mean No. of Species August, 1977	Mean Diversity April, 1977	Mean Diversity August, 1977
1	6.5	33	31.0	5.18	8.18
2	6.2	42.6	29.6	7.72	9.00
3	6.2	45.3	34.5	11.63	9.40
4	4.3	41.9	28.5	10.2	6.70
5	6.4	42.6	35.4	9.14	6.94

Table 19. Diatom taxa which have a frequency of occurrence greater than 50% within groups from qualitative cluster (Figure 16).

SITE GROUP (See Figure 16)	STREAM ORDER	TAXA
Common	All	Achnanthes linearis
		A. linearis var. pusilla
		A. minutissima
		Anomoeneis vitrea
		Cymbella spp.
		Fragilaria construens var. pumilla
		F. construens var. venter
		F. pinnata
		Gomphonema parvulum
		Nitzschia spp.
		Navicula spp.
		Melosira spp.
		Synedra spp.
		Tabellaria flocculosa
		T. fenestrata
1	1 & 2	Achnanthes marginulata
		Eunotia pectinalis
		Frustulia rhomboides
		Gomphonema angustatum
		Meridion circulare
2	2 & 3	A. linearis var. curta
		Cocconeis placentula var. lineata
		Eunotia pectinalis var. minor
		Gomphonema angustatum
		G. gracile
3	3,4,5	Achnathes flexella
		A. linearis var. curta
		Anomoeneis serians var. brachy
		Eunotia curvata
4	3,4,5	Achnathes linearis var. curta
		Eunotia curvata
		Eunotia flexuosa
		F. leptostauron var. dubia
		Fragilaria vaucheria
		Gomphonema clevei
5	4	Amphora ovalis
		Fragilaria vaucheria
		Gomphonema angustatum
6	1,2,3	A. lanceolata var. dubia
		Achnathes marginulata
		Cocconeis placentula var. lineata
		F. construens
		F. leptostauron var. dubia
		Fragilaria vaucheria
		Gomphonema angustatum
7	4 & 5	A. exigua
		A. flexella
		Amphora ovalis
		Eunotia curvata
8	2	Achnathes linearis var. clevei
		(Anomoeneis vitrea)*
		Cocconeis placentula var. lineata
		Cyclotella meneghiniana
		Fragilaria construens
		Fragilaria leptostauron var. dubia
		Gomphonema clevei

* Absent from this group

Table 20. Comparison of productivity and diversity at impacted and unimpacted sites in the Study Area. Data from 1976 sampling season.

	Impacted Sites[1] (range)	Unimpacted Sites[2] (range)
Mean total cells (#/mm^2)	1673 (1109-2290)	1909 (385-3669)
Mean chlorophyll a (mg/mm^2)	5.62 (3.9-12.9)	6.18 (2.7-12.7)
Mean diversity	2.74 (1.8-3.9)	5.02 (2.3-6.3)
Mean number of species	59.8 (34-68)	49.4 (35-68)

[1]P-1, SL-1, D-1, P-5, BB-1.

[2]K-1, K-2, K-5, K-8, SR-1, SR-3, BI-1 KC-1, F-1, SL-3, P-2.

Table 21. Comparison of productivity and diversity at F-1, KC-1, and BB-1
Data from 1976 sampling season.

	F-1	KC-1	BB-1
Mean cells/mm^2	380	385	11.09
Mean chlorophyll a (mg/mm^2)	4.21	2.70	3.97
Mean diversity $\left(\frac{1}{\Sigma P_i^2}\right)$	7.5	8.0	3.9
Number of species	49	57	4.9

Table 22. Comparison of diatoms collected from a small creek above (Station C) and below (Stations AR and BR) a seep from the INCO exploration site. Samples collected July 5, 1977 from glass slides.

TAXA \ STATION	C	AR	BR
Achnanthes clevei	<1	0	0
A. linearis	2	<1	2
A. linearis v. curta	<1	0	0
A. marginulata	<1	0	0
A. minutissima	30	4	3
A. sp.	<1	0	0
Amphipleura pellucida	0	<1	0
Anomoneis vitrea	<1	0	0
Cocconeis placentula v. lineata	<1	0	0
Cymbella minuta	1	<1	0
Diatoma tenue v. elongatum	2	0	0
Eunotia arcus	<1	0	0
E. curvata	3	9	13
E. curvata v. capitata	0	3	<1
E. diodon	2	0	0
E. elegans	0	<4	0
E. fallax	1	<4	0
E. flexuosa	<1	7	7
E. naegelii	5	9	23
E. parallela	0	<1	0
E. pectinalis	<1	<1	0
E. pectinalis v. minor	<1	8	3
E. praeminor	0	<1	0
E. praerupta	<1	<1	0
E. praerupta v. bidens	<1	0	0
E. praerupta v. inflata	<1	<1	<1
E. rostellata	<1	0	<1
E. septentrionalis	<1	0	0
E. sp.	7	6	14
E. tenella	<1	6	2
E. vanheurckii	0	<1	0
Fragilaria construens v. pumila	<1	0	0
F. pinnata	<1	0	0
F. sp.	<1	0	0
F. vaucheria	<1	0	<1

Table 22. continued

TAXA \ STATION	C	AR	BR
Frustulia rhomboides	1	2	2
Gomphonema angustatum	1	<1	0
G. clevei	<1	0	<1
G. gracile	4	0	0
G. grunouii	2	0	<1
G. parvulum	2	<1	<1
G. sp.	<1	0	<1
Meridion circulare	1	<1	0
Navicula arvensis	0	<1	0
N. cocconeiformis	<1	0	0
N. gysingensis	<1	0	0
N. pupula v. rectangularis	0	<1	0
N. salinarum v. intermedia	<1	0	0
N. secreta v. apiculata	<1	0	0
N. seminulum	0	<1	0
N. seminulum v. hustedti	<1	<1	0
N. sp.	<1	0	0
N. tripunctata	<1	0	0
Neidium bisulcatum	<1	<1	0
Nitzschia bacata	<1	0	0
N. frustulum v. subsalina	<1	<1	<1
N. ignorata	0	<1	0
N. kutzingiana	<1	0	0
N. linearis	<1	0	0
N. paleacea	0	1	0
N. parvula	<1	0	0
N. sp.	0	<1	<1
N. sublinearis	<1	<1	0
Pinnularia abaujensis	0	<1	0
P. subcapitata v. paucistriata	<1	0	0
P. sp.	0	<1	0
P. substomatophora	0	0	<1
Surirella sp.	0	<1	0

Table 22. continued

TAXA / STATION	C	AR	BR
Synedra amphicephala	<1	<1	0
S. minuscula	2	0	0
S. radians	<1	0	0
S. rumpens	<1	0	<1
S. sp.	<1	0	<1
S. tenera	<1	0	0
S. ulna	0	<1	0
Tabellaria fenestrata	<1	8	5
T. flocculosa	20	30	23

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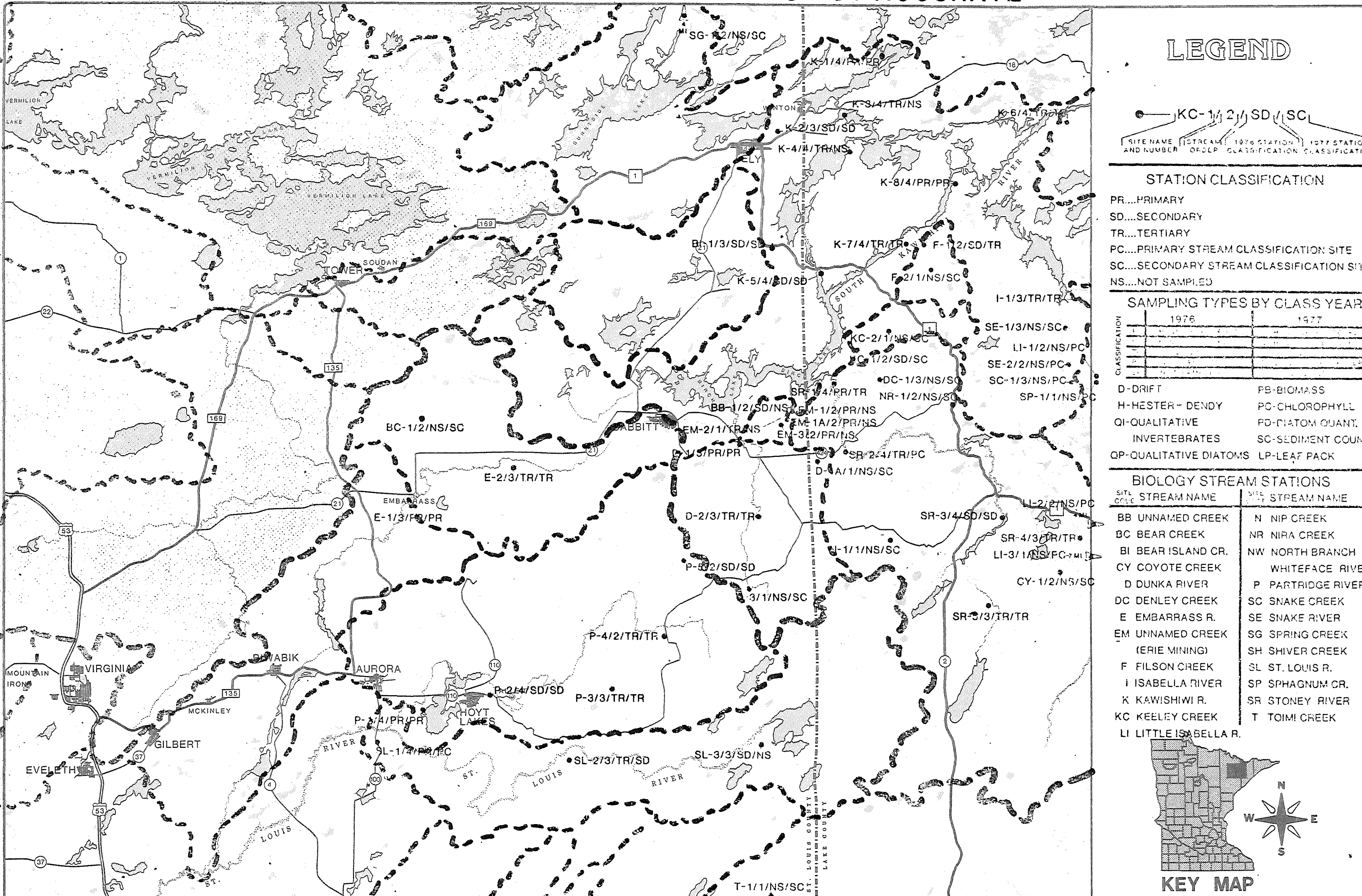


MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 1. AQUATIC BIOLOGY STREAM STATIONS

Figure 2. Relative abundance by sampling period of Achnanthes minutissima and A. linearis (including A. linearis var pusilla) at station SL-1.

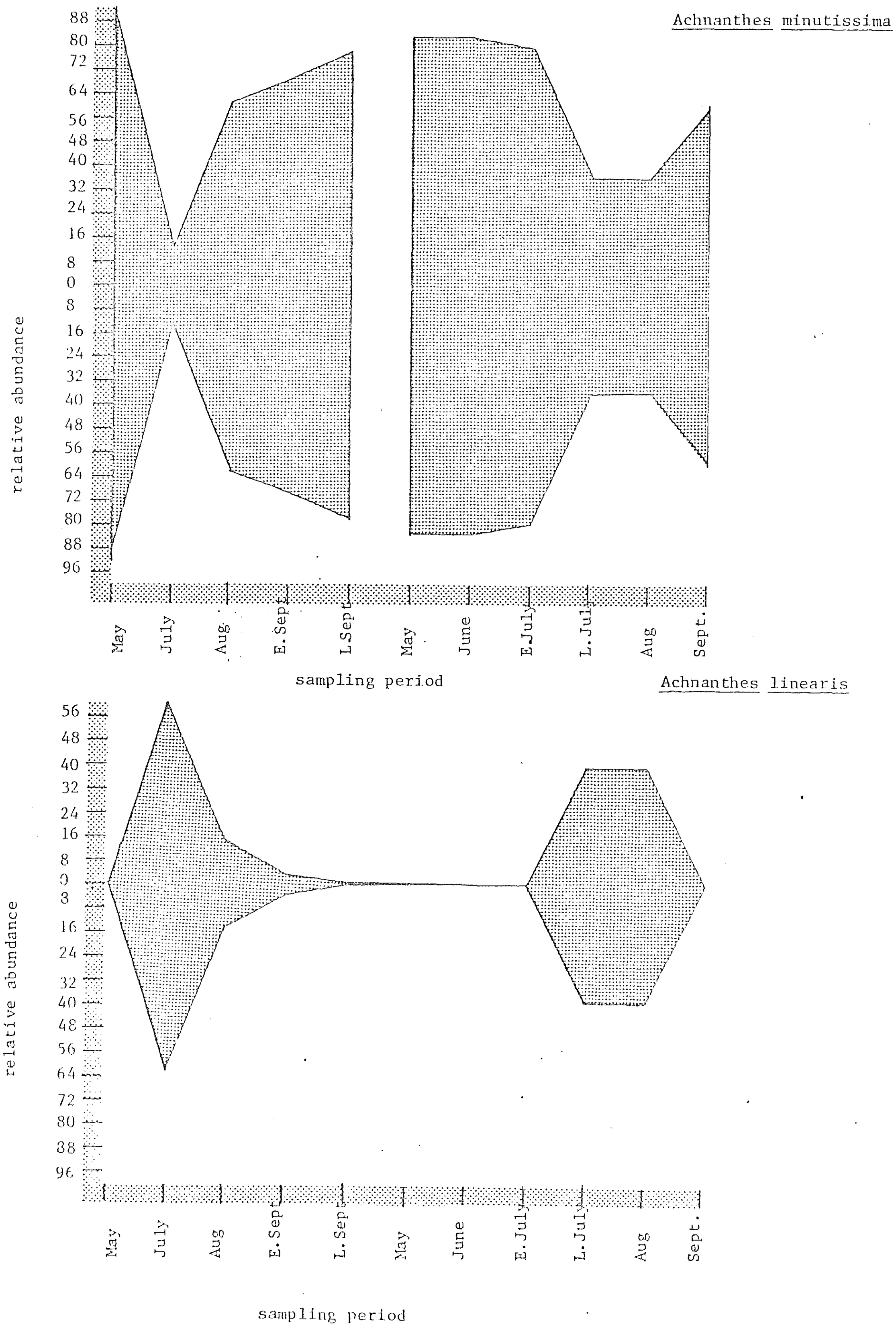


Figure 3. Relative seasonal abundance of *Cocconeis placentula* var. *lineata* at P-1 and SL-1

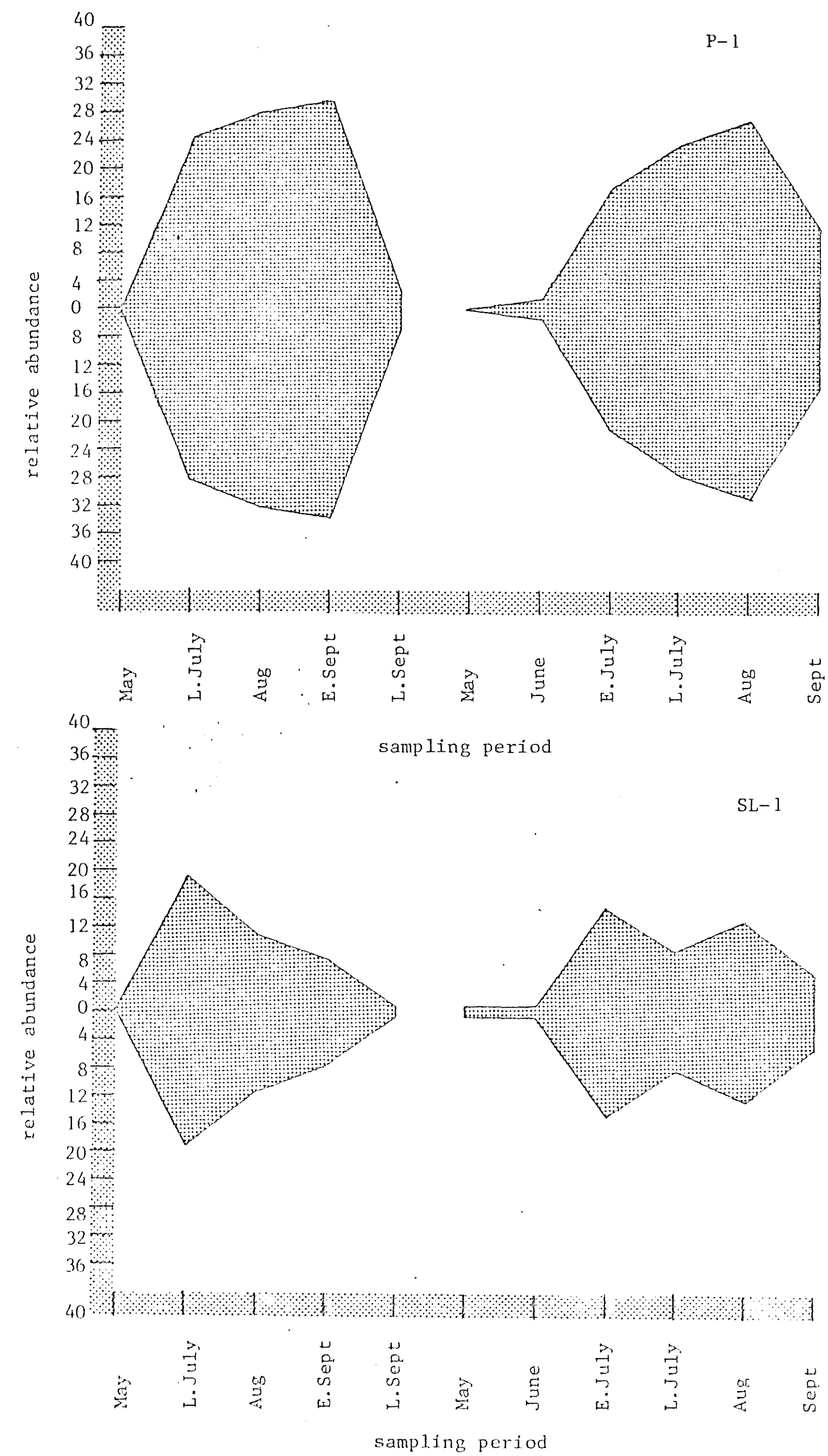


Figure 4. Relative seasonal abundance of <u>Synedra</u> spp at P-1 and SL-1

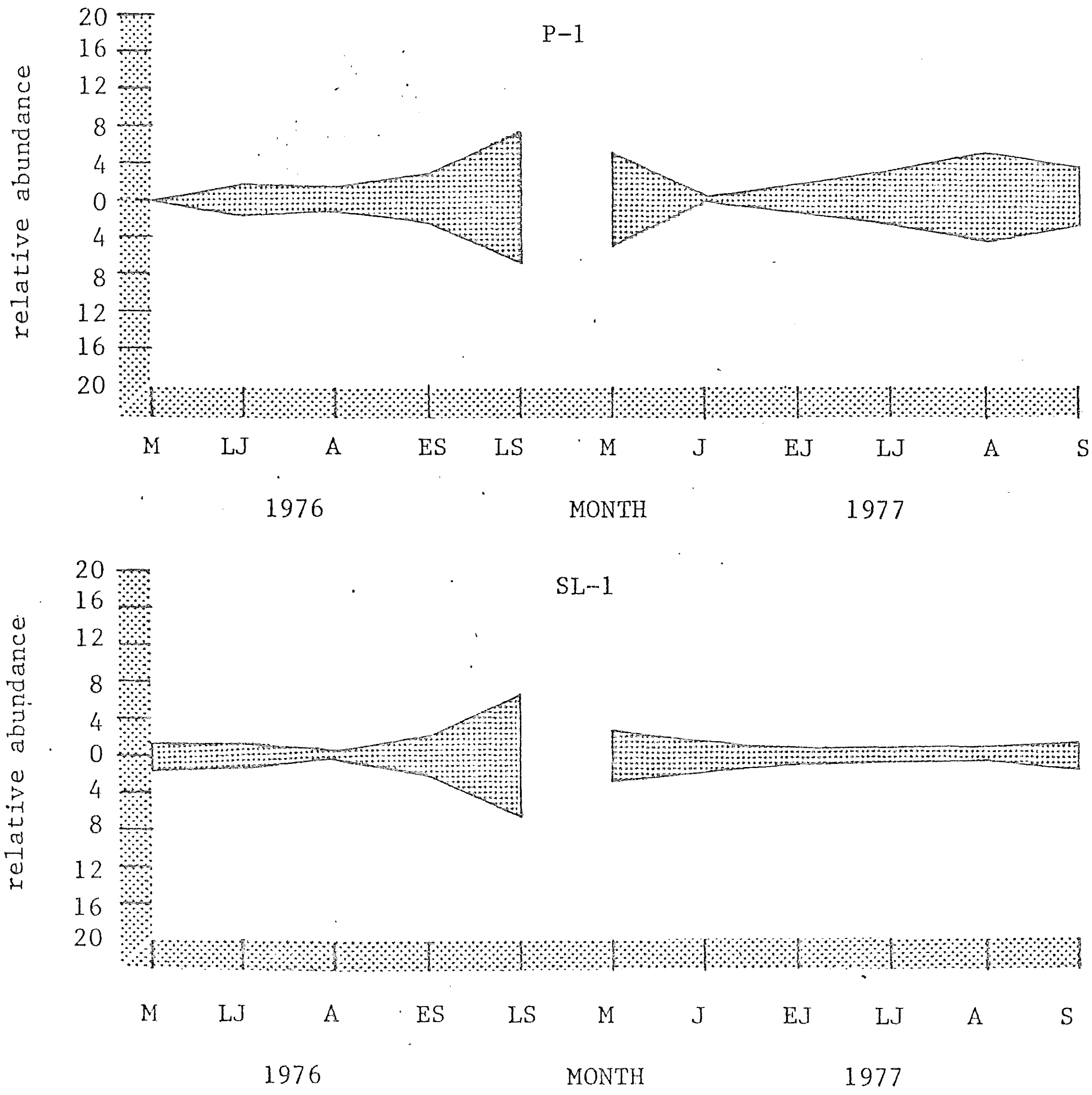


Figure 5. Species diversity $\left(\frac{1}{\Sigma(Pi^2)}\right)$ at five primary sites in 1976 and 1977.

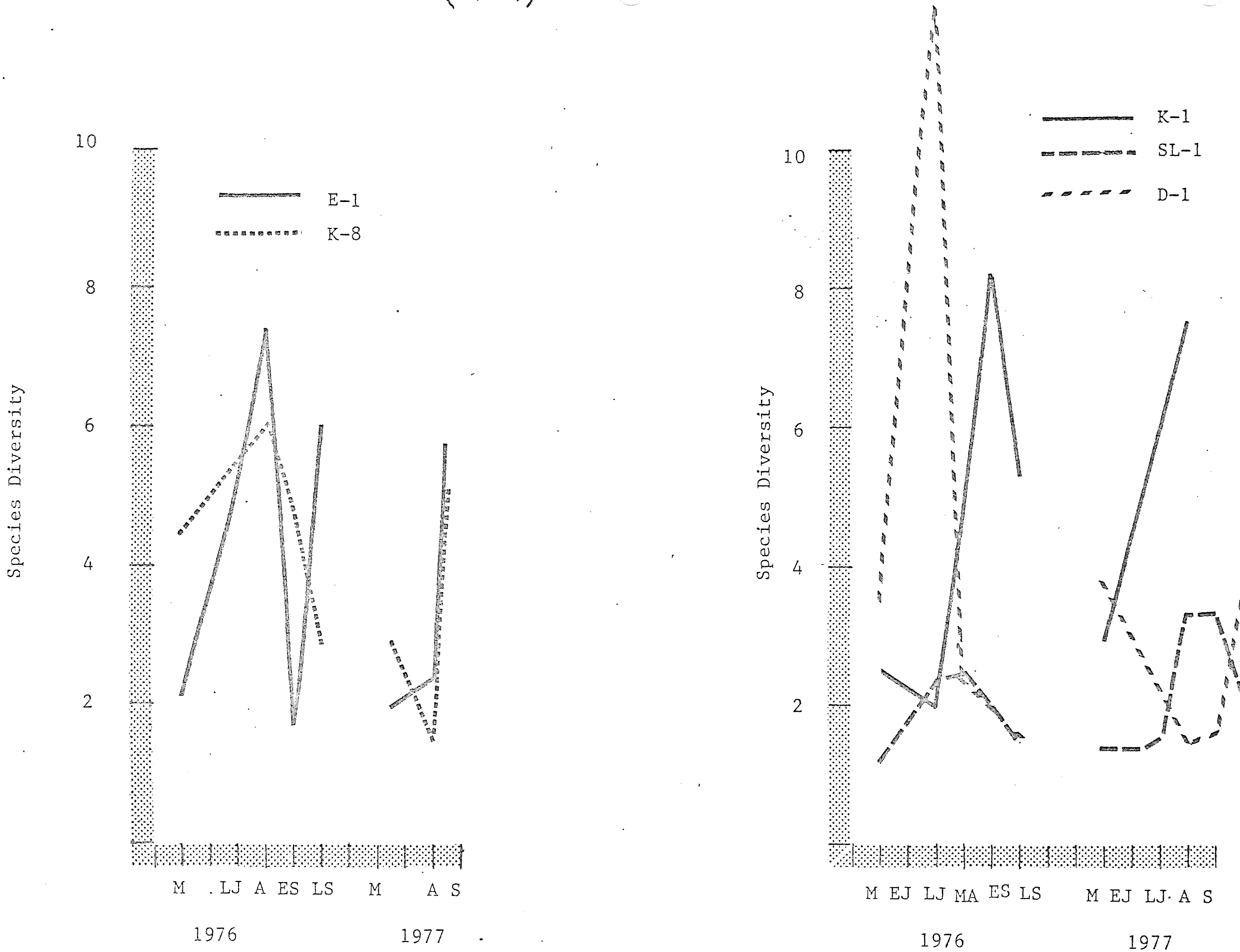
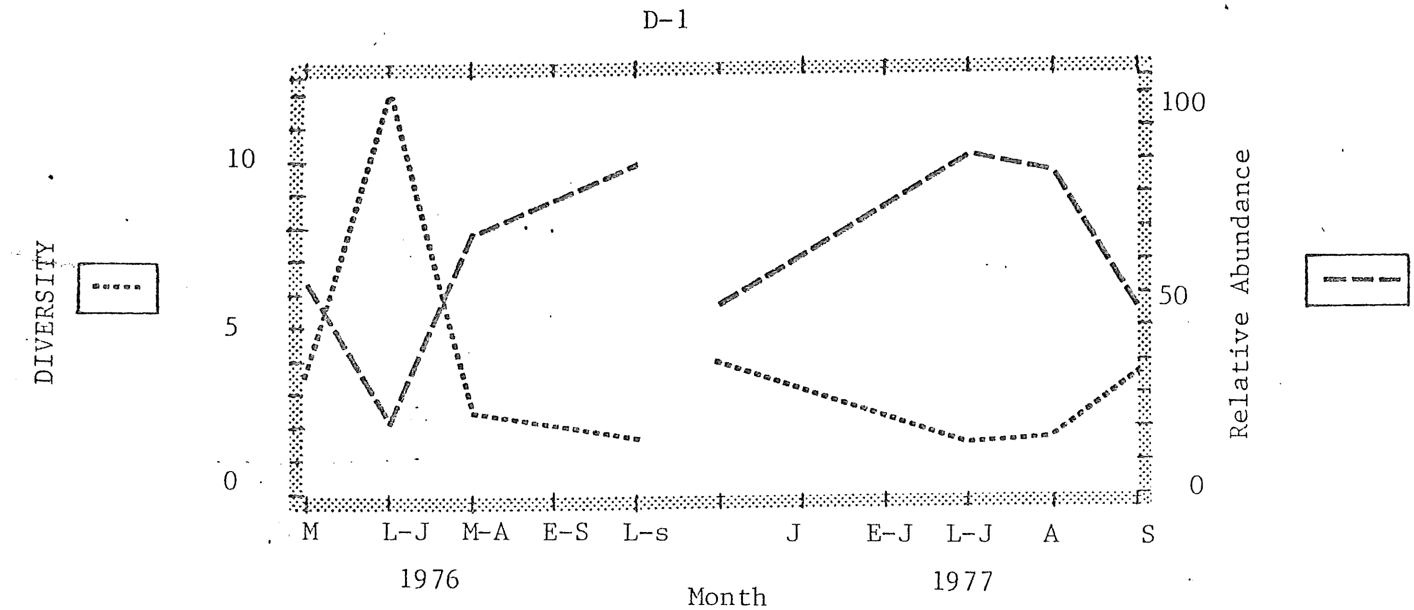
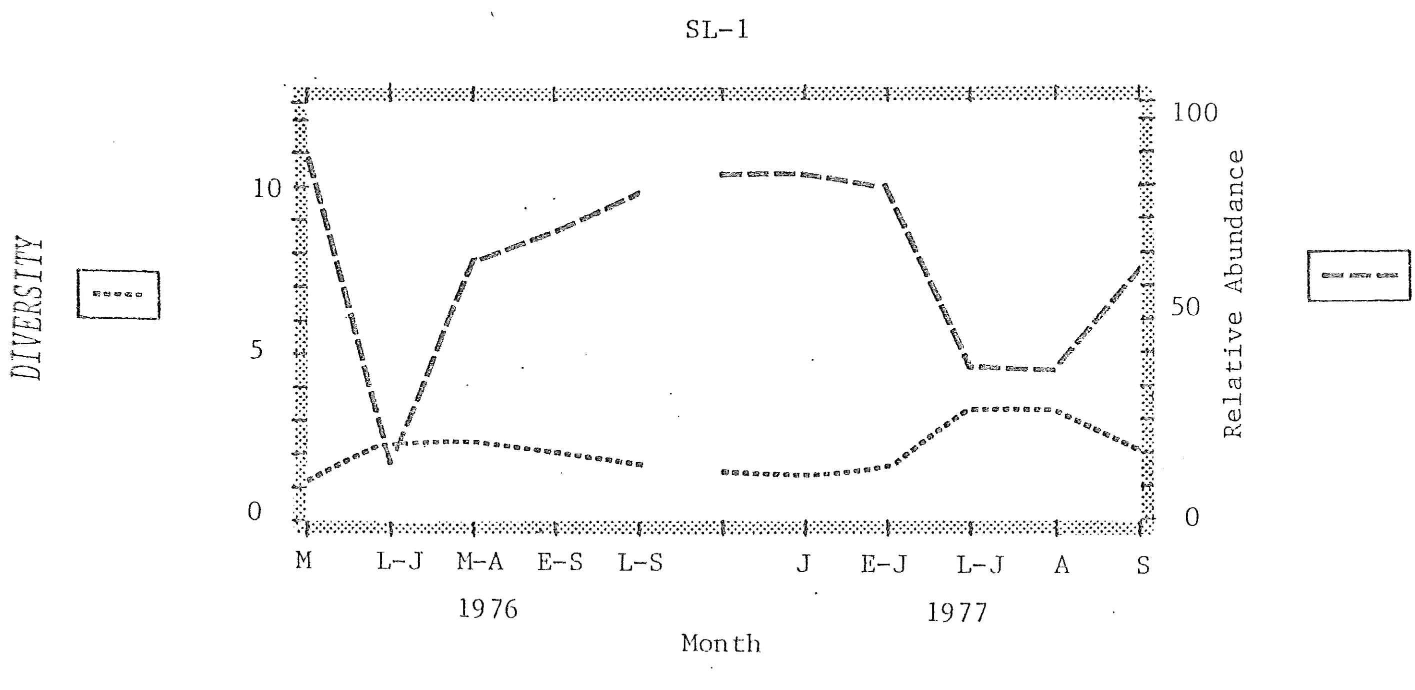


Figure 6. Species diversity $\frac{1}{\Sigma P_i^2}$ and relative abundance of Achnanthes minutissima at stations D-1 and SL-1.





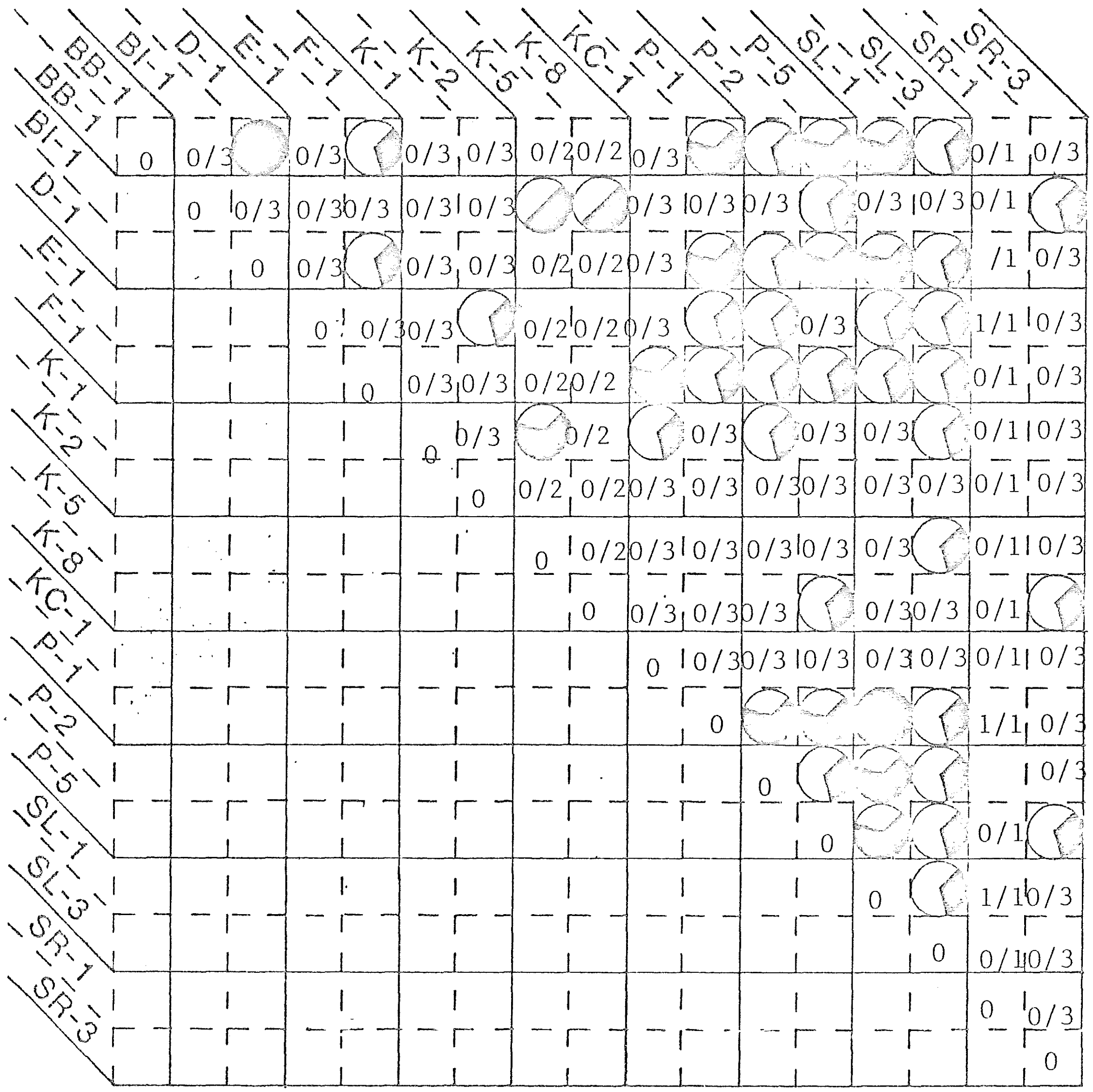


Figure 7. Percent of time stations occurred in clusters at the .5 level of similarity

Figure 8. Mean relative abundance of the Achnanthes minutissima, A. lineuris (including A. linearis var pusilla), Cocconeis placentula (including C. placentula var. lineata), Tabellaria flocculosa, and Synedra spp. at primary and secondary stations in 1976. Stations are ordered according to the abundance of A. minutissima.

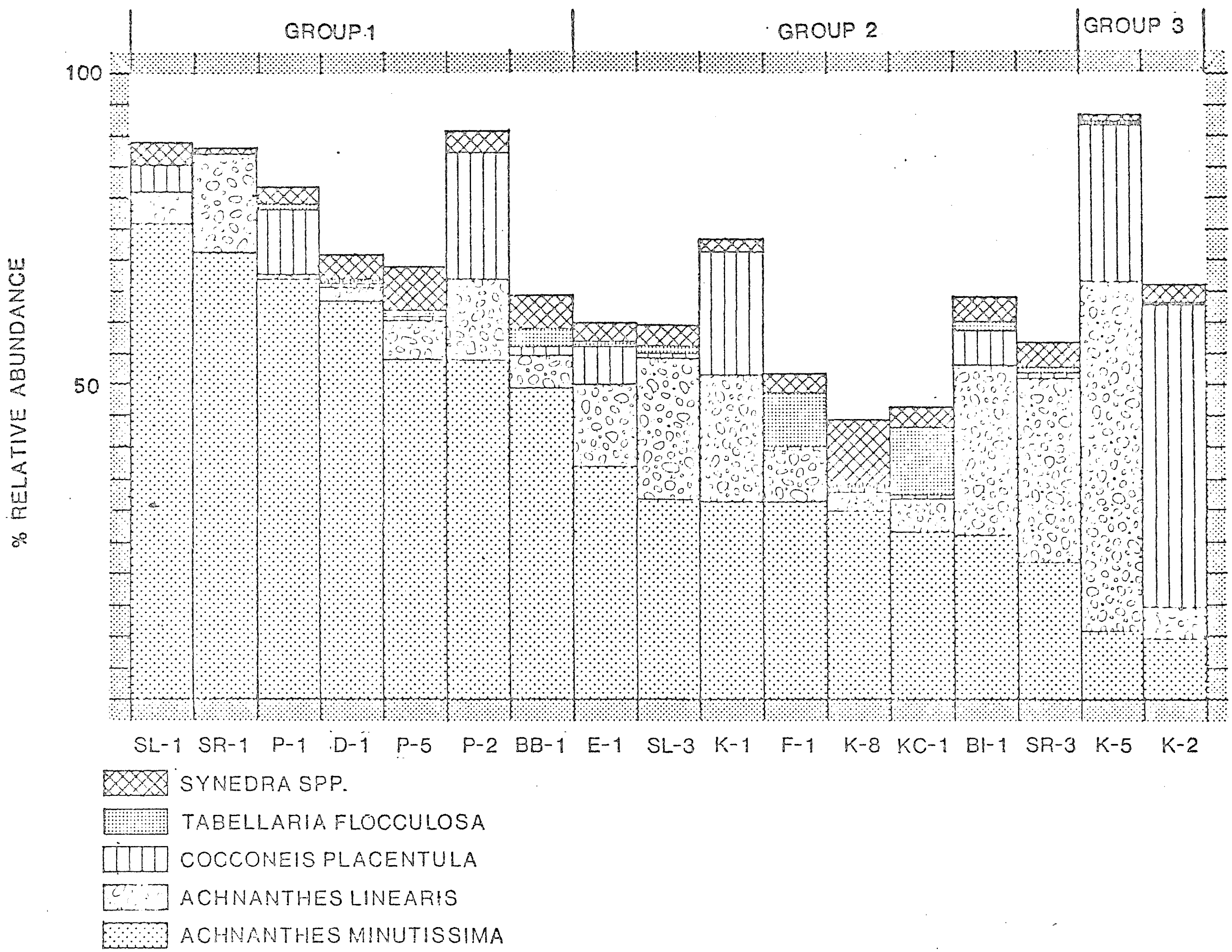


Figure 9. Mean relative abundance of the taxa Achnanthes minutissima, A. linearis (including A. linearis var. pusilla), Cocconeis placentula (including C. placentula var. lineata), and Synedra spp. at primary and secondary stations in 1977. Stations have been ordered according to the abundance of A. minutissima.

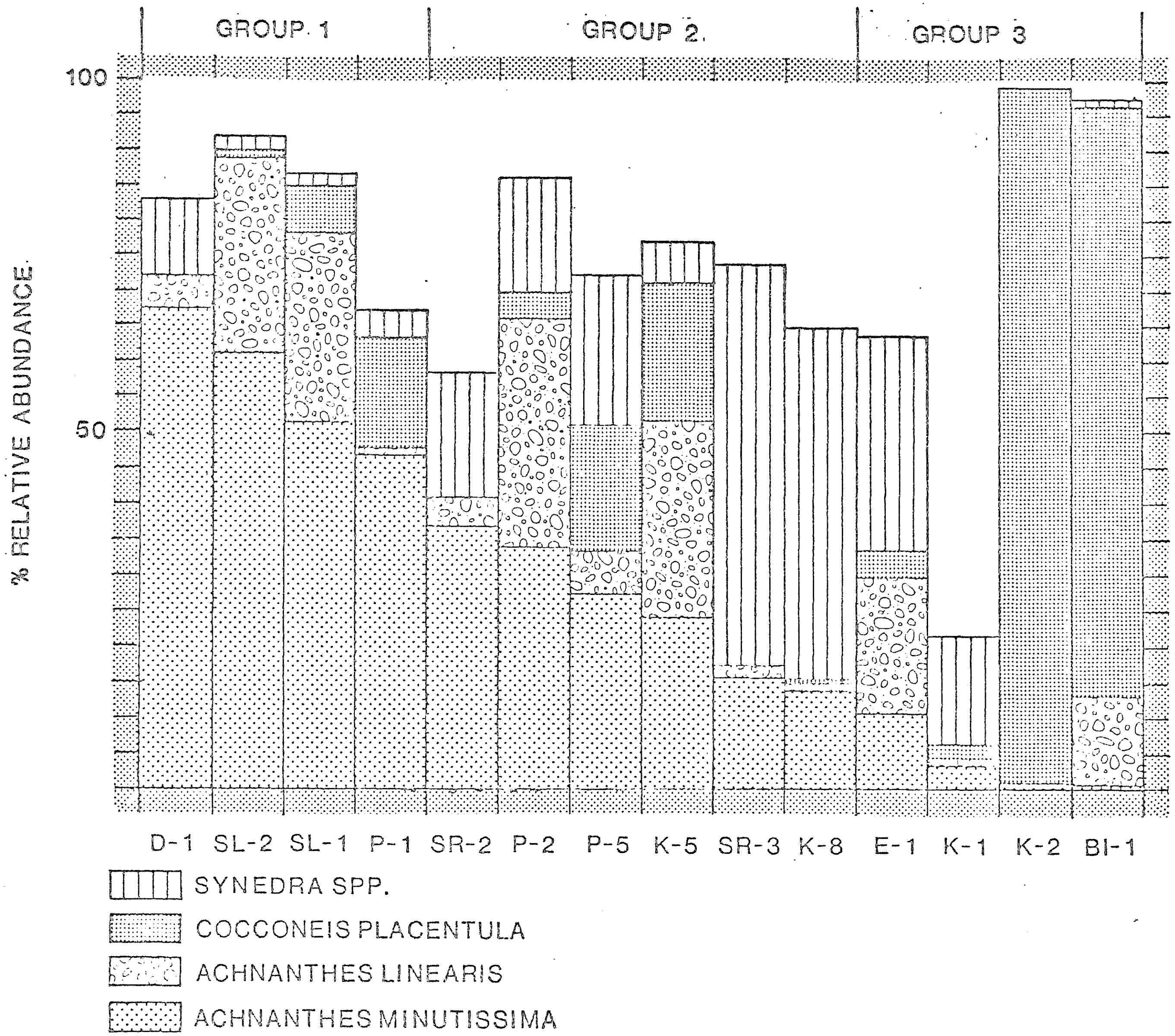


Figure 10. Mean chlorophyll a in 1976 and 1977 averaged over all stations sampled in each sampling period.

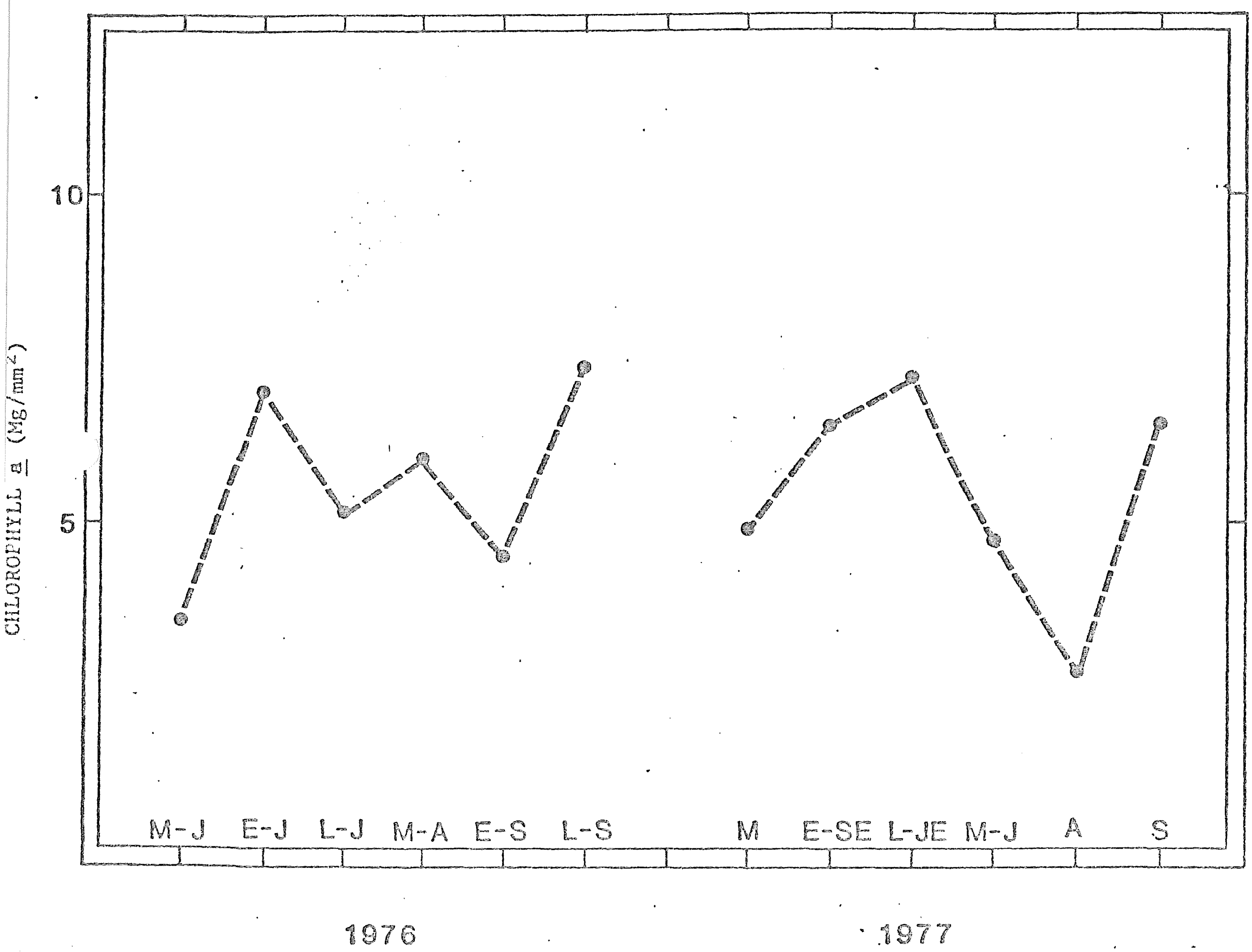


Figure 11. Seasonal changes in chlorophyll a and total cell counts averaged over primary sites.

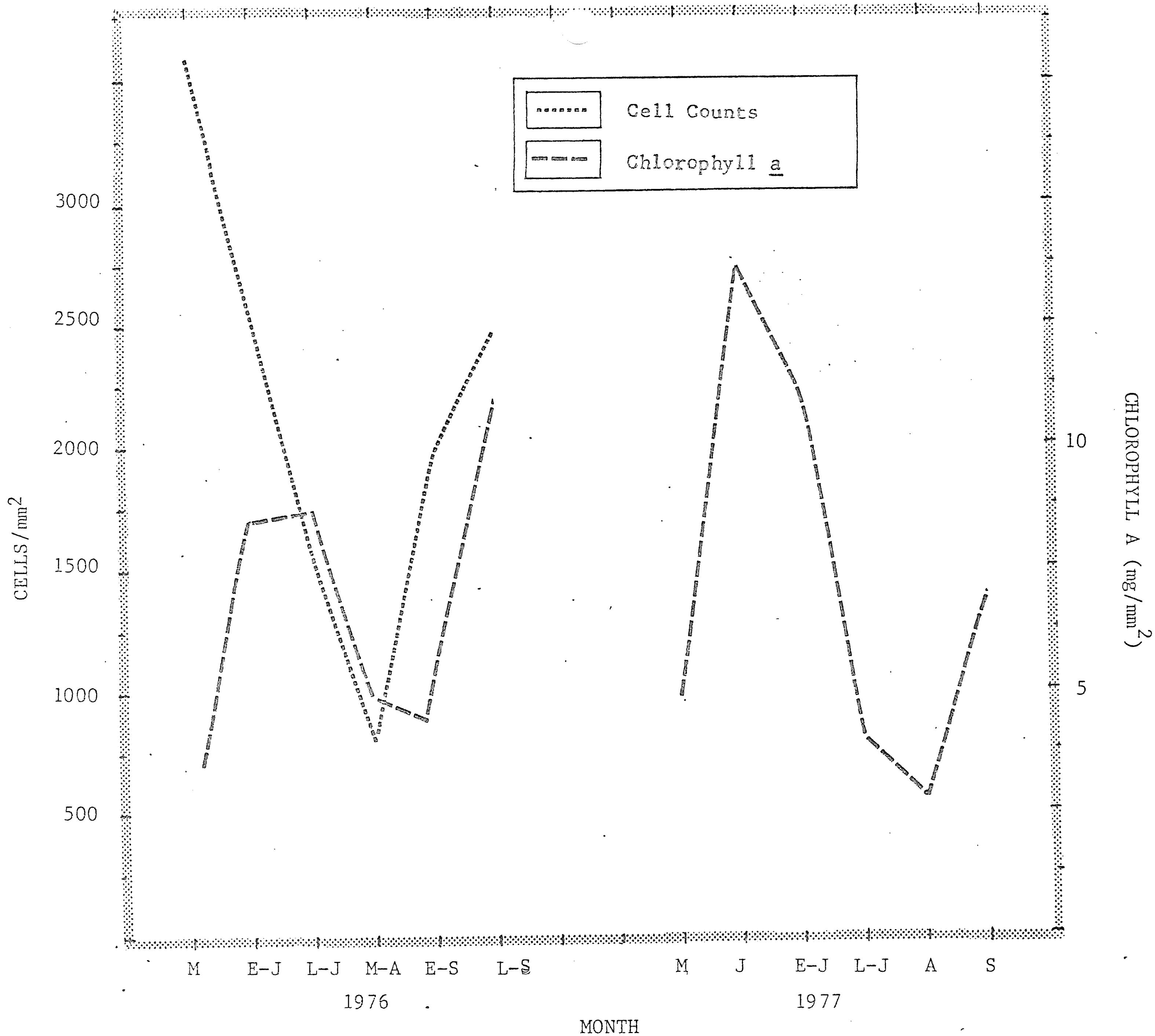


Figure 12. Mean chlorophyll a averaged over all sites within each stream order in 1976 and 1977.

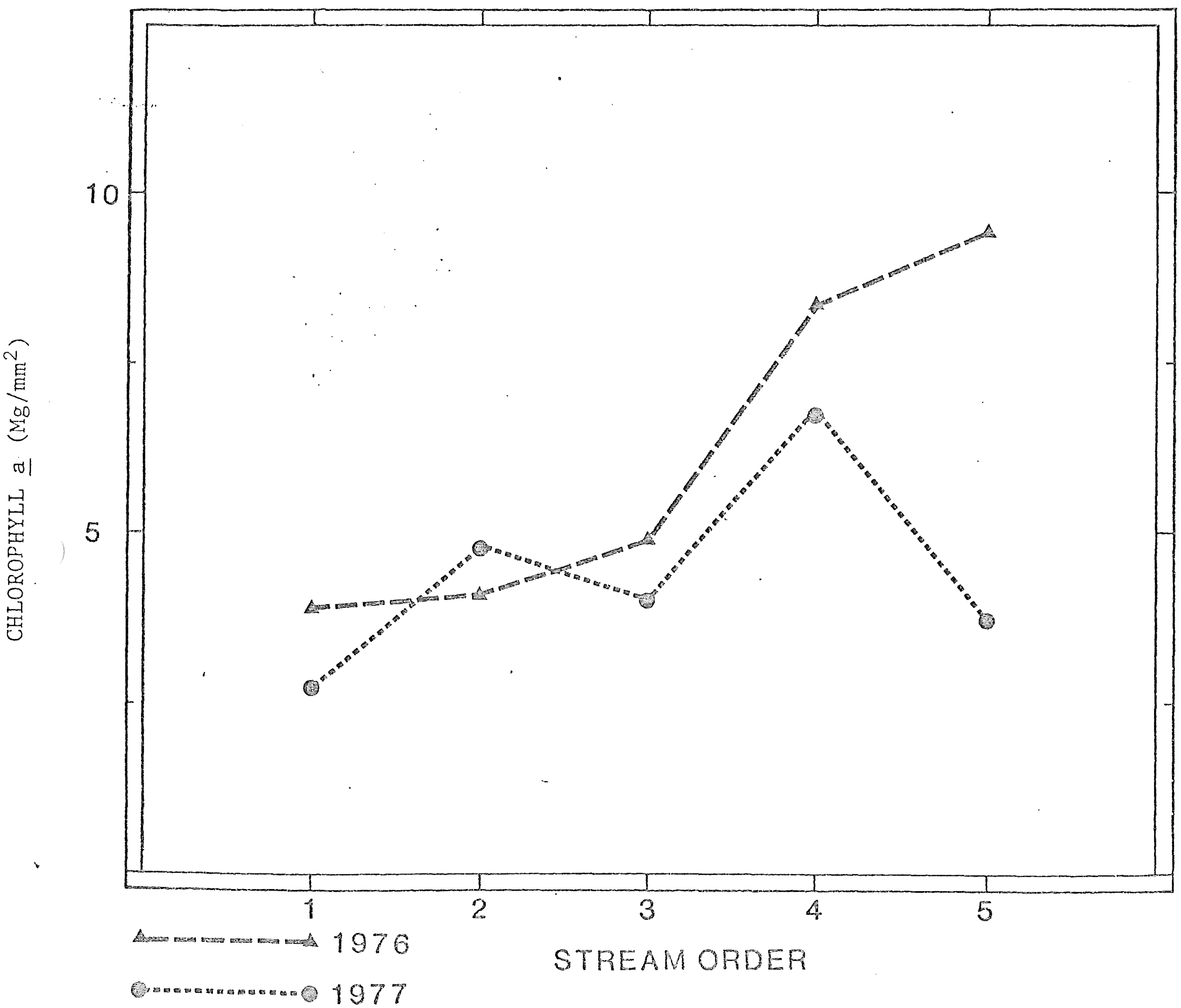


Figure 13. Average percent relative abundance by stream order of acidophilous diatoms collected on glass slide artificial substrates in 1976 and average pH by stream order

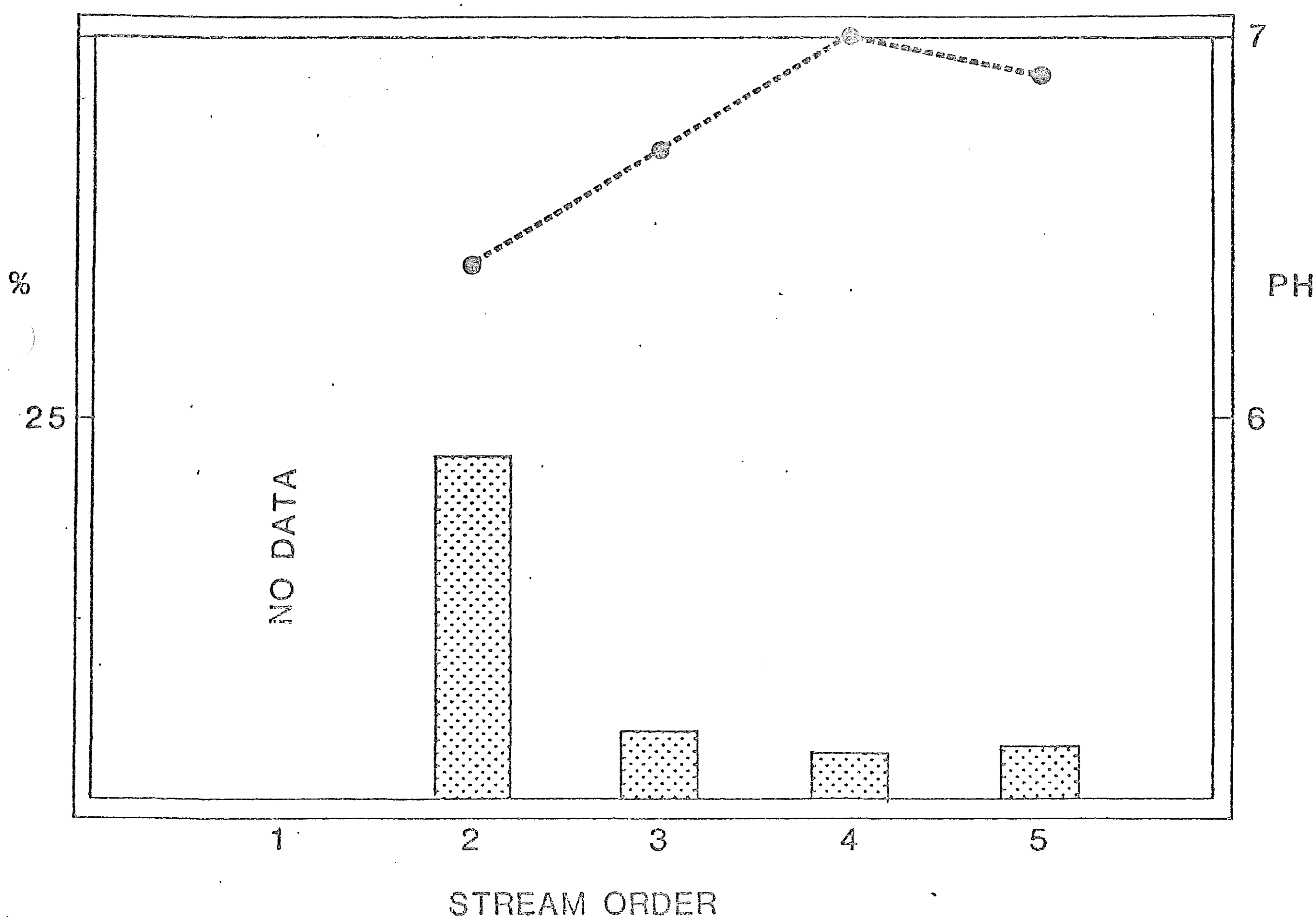
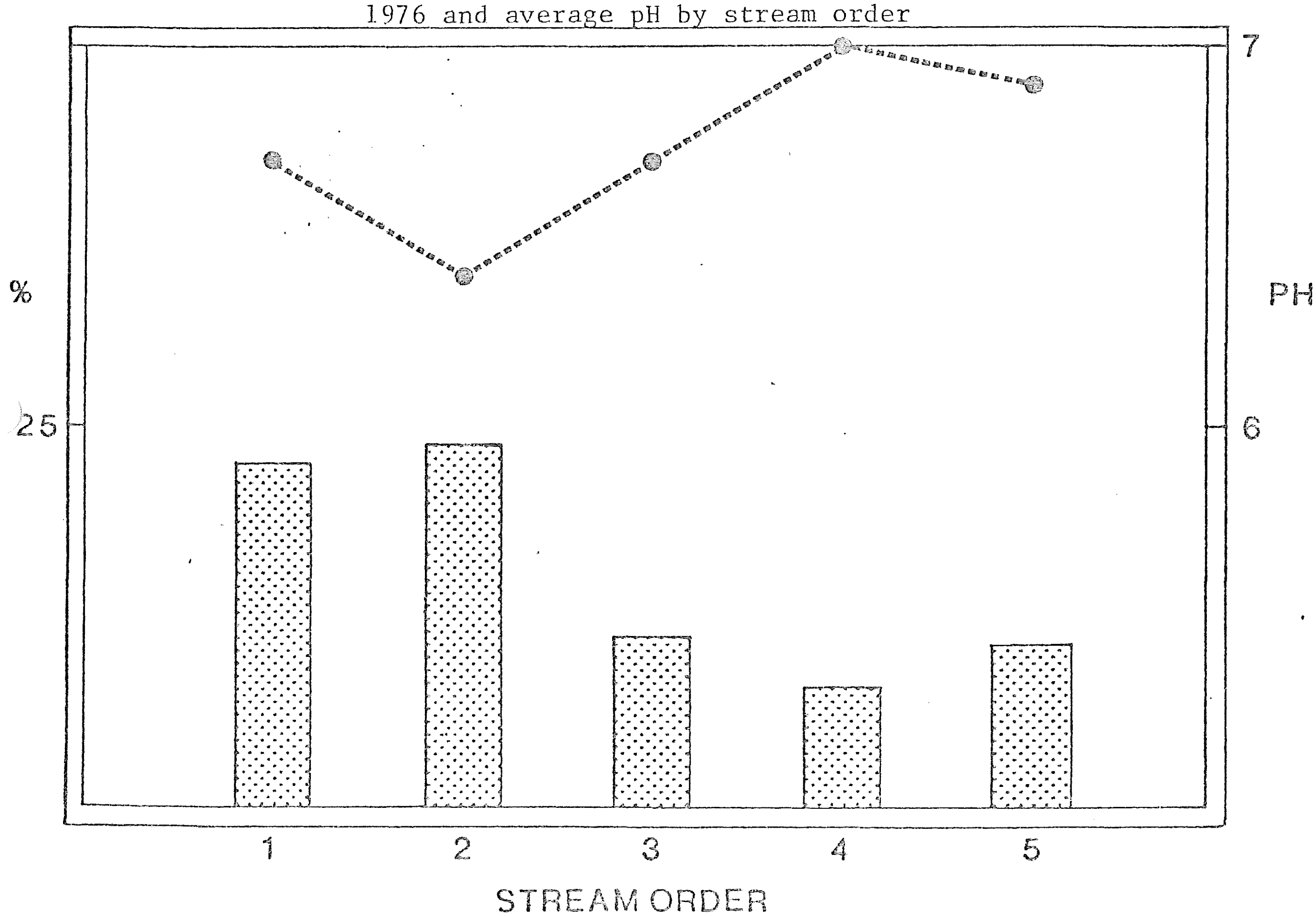


Figure 14. Average percent relative abundance by stream order of acidophilous diatoms collected qualitatively in 1976 and average pH by stream order



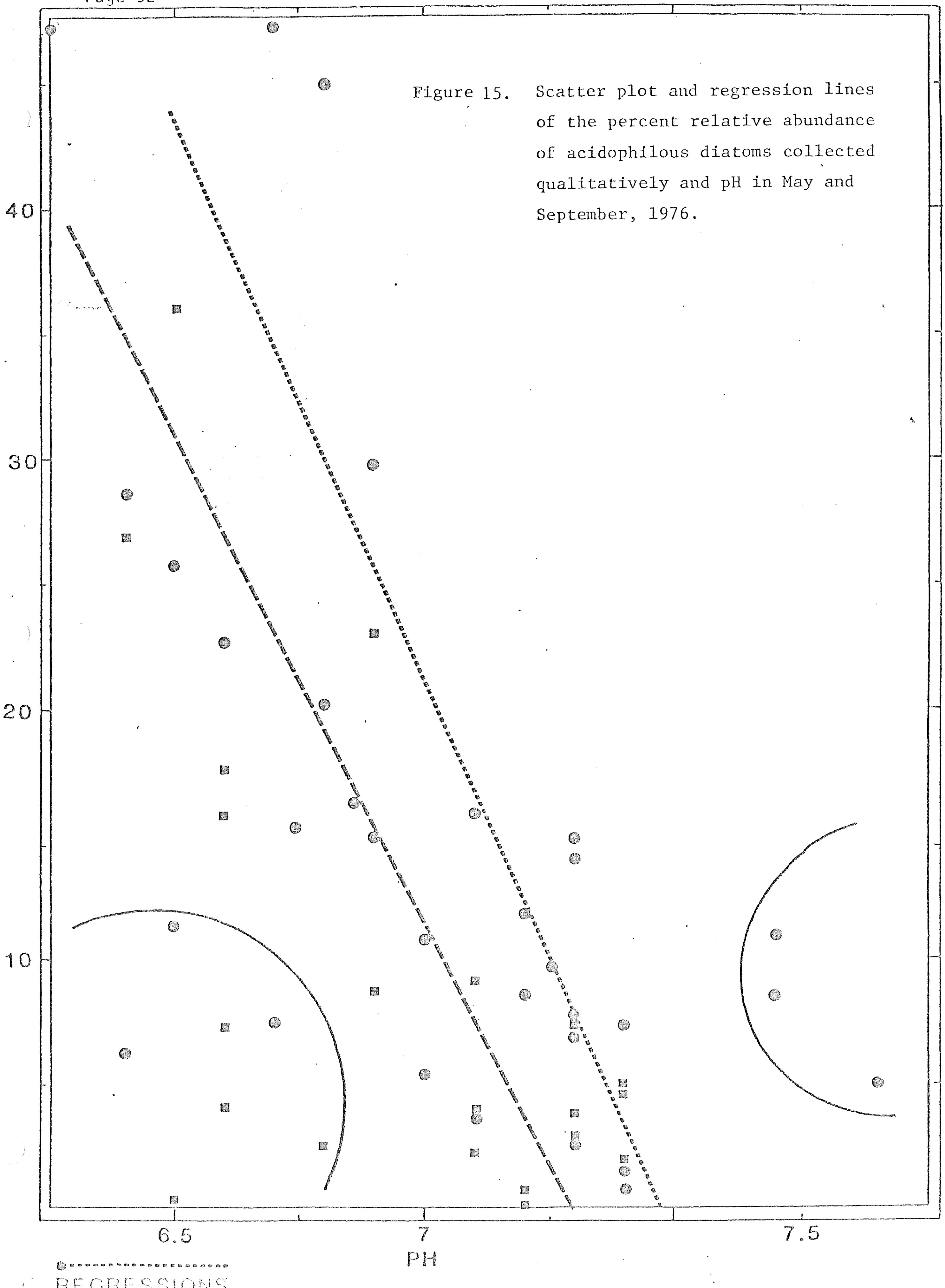


Figure 15. Scatter plot and regression lines of the percent relative abundance of acidophilous diatoms collected qualitatively and pH in May and September, 1976.

Figure 16 . Dendrogram for diatom species collected qualitatively during August 1977.

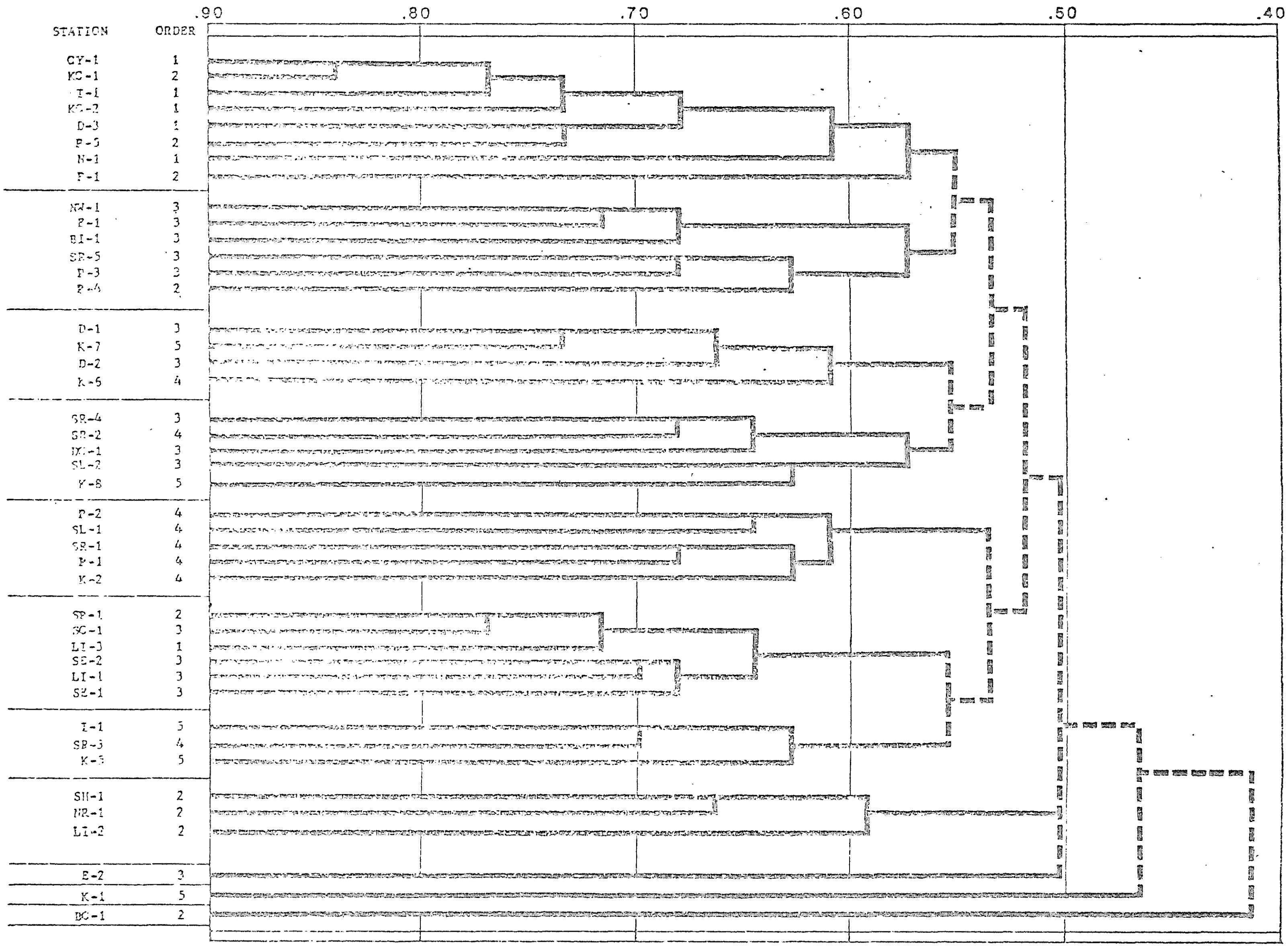


Figure 17. Shift in dominant species between unimpacted sites (SR-1 and KC-1) and impacted sites (SC-1 and P-5) within 4th order and 2nd order streams.