REGIONAL COPPER-NICKEL STUDY

LAKE PHYTOPLANKTON

Minnesota Environmental Quality Board
Regional Copper-Nickel Study

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

ABSTRACT

A survey of the phytoplankton communities in 25 lakes of northeastern Minnesota was conducted as a part of the Minnesota Regional Copper-Nickel Study in 1976 and 1977. The lakes fall into relatively narrow ranges of conductivity (26-153 umhos/cm), total alkalinity (8-71 mg/l $CaCO_3$), and hardness (10-81 mg/l). As a group they are highly colored and contain considerable amounts of dissolved organic matter. Measurements of chlorophyll a and total phosphorus indicated that most are mesotrophic or eutrophic.

Summer phytoplankton samples were almost always dominated by the Cyanophyta, Chrysophyta, or Bacillariophyta. Even the most oligotrophic of the lakes were occasionally dominated by the Cyanophyta. Seasonal patterns of dominance were quite variable not only from lake to lake, but within the same lake from year to year. With few exceptions, the Bacillariophyta was the most diverse group, followed by the Chlorophyta and then the Cyanophyta. As many as 40 to 50 species of diatoms were identified in one lake on one date. The Cryptophyta, Pyrrhophyta, and Euglenophyta were the least diverse of the algal groups and were never numerically dominant. There are clear differences between these phytoplankton communities and those of the Experimental Lakes Area of northwestern Ontario.

Phytoplankton species composition was remarkably similar in the study lakes. A group of "characteristic species" was identified based on their frequency of occurrence in the samples. These were: Bacillariophyta-*Asterionella formosa*, *Cyclotella bodanica*, *Fragilaria crotonensis*, *Melosira ambigua*, *M. distans*, *Nitzschia* sp., *Tabellaria fenestrata*; Chlorophyta-*Ankistrodesmus falcatus*, *Botryococcus Braunii*, *Oocystis* sp.; Cyanophyta-*Agmenellum quadruplicatum*, *Aphanocapsa delicatissima*, *Coelosphaerium Kuetzingianum*; Chrysophyta-*Dinobryon bavaricum*, *D. divergens*, *D. sertularia* var. *protuberans*; Cryptophyta-*Cryptomonas erosa*; Pyrrhophyta-*Ceratium hirundinella*. This list could be lengthened or shortened depending on the criteria used for inclusion of species. A number of these species are considered by other authors to be oligotrophic indicators. However, a comparison of the existing diatom flora with the diatoms of the sedimentary record from other Minnesota lakes supports the notion that these lakes are generally mesotrophic or eutrophic.

Attempts to separate the lakes into trophic subgroups using indicator species were unsuccessful, although *Melosira granulata* may have some value as an indicator of trophy. In addition, the lakes contain a number of algae characteristic of acid water, and *Binuclearia* sp. may have value as an indicator of high levels of organic matter.

Analysis of two or three samples of diatoms in sediment cores from four lakes was consistent with the analysis of surface water samples and suggested that the lakes have not changed dramatically in trophic status since human settlement in Minnesota.

The combined evidence from surface water phytoplankton samples, chlorophyll a and phosphorus data and diatom stratigraphy suggests that most of the Study Area lakes are now mesotrophic or eutrophic and have been so for some time. A few lakes, however, (e.g., Tofte, Clearwater) appear oligotrophic.

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.

PURPOSE

This regional characterization is intended to describe the dominant taxa of the region and their relationships, as well as the similarities and differences between the sites sampled. It provides a basis for assessing the potential impacts of copper-nickel development. It does not, in general, provide the baseline data necessary to detect impacts of development at particular sites. Techniques for developing such a baseline and ways in which these data might be used in planning a baseline monitoring program are discussed in a separate report, Biological Monitoring of Aquatic Ecosystems (Regional Copper-Nickel Study 1978).

INTRODUCTION

The phytoplankton algae are generally the most important primary producers of lake ecosystems. Through the process of photosynthesis they capture the energy of sunlight, transforming it into the energy of organic compounds. Thus, in spite of their microscopic size, they form the base of the lake food chain upon which fish and other aquatic animals depend for their survival. To a large extent the productivity of the phytoplankton determines the characteristics of a lake: its appearance, the kind and numbers of animals present, and even some of its chemistry. Indeed, the photosynthesis of phytoplankton algae, together with that of other aquatic plants, literally makes possible the existence of fish and the abundant invertebrate life we associate with the lake environment.

A survey of the phytoplankton communities in lakes of the Regional Copper-Nickel Study Area (Study Area) was conducted during 1976 and 1977. Its purpose was to characterize these lakes in terms of phytoplankton species composition and abundance, identifying groups of lakes having similar or differing characteristics. Since the abundance and species composition of the phytoplankton are directly related to the chemical composition of lake water, analyses of phytoplankton and water chemistry data were combined to provide a coherent picture of the trophic status of lakes. This characterization may then be used to help predict and evaluate impacts of industrial activities on lake ecosystems in the Study Area.

In addition, stratigraphic samples of pollen and diatoms from sediments of four lakes for which Cesium-137 data were available were examined to ascertain the relationship of the present diatom floras to those in the recent past and suggest how they may be changing in the absence of copper-nickel development.

In the past several attempts have been made to characterize the lakes of Minnesota on the basis of chemical characteristics, trophic status, and phytoplankton communities. Eddy (1963) summarized early attempts to classify Minnesota lakes. In the case of the soft-water lakes of northeastern Minnesota, he included three lake types:

1) Lakes with maximum depths of 20 to 60 m. These lakes are typically oligotrophic with well-defined summer stratification and no hypolimnetic oxygen depletion. They have low turbidities and relatively small littoral areas. Secchi disk values frequently approach 7 m. The phytoplankton are characterized by a scarcity of blue-green algae and an abundance of diatoms, especially *Tabellaria*, *Fragilaria*, and *Asterionella*.

2) Lakes with maximum depths of less than 15 m. These lakes are more productive than the former, and many show a tendency toward eutrophication. They have larger littoral zones and often show some hypolimnetic oxygen depletion.

3) Small acid bog lakes and ponds. These small bodies of water are dystrophic and are frequently surrounded by floating sedge mats.

Many Study Area lakes fall into Eddy's second category.

Bright (1968) discussed the surface water chemistry of Minnesota lakes in some detail. He noted that lakes of northeastern Minnesota have about equal equivalent proportions of Mg^{++} and $SO_4^{=}$, about equal equivalent proportions of carbonates and Ca^{++}, and slightly higher concentrations of Ca^{++} + carbonates than Mg^{++} + $SO_4^{=}$. These lakes have low pH, low salinity, and low residence time for ions but relatively high concentrations for some minor elements (e.g. Fe, Mn, Zn, and Cu). Nitrogen and phosphorus concentrations are also low. Tabellaria and Asterionella are the dominant planktonic diatoms, but Melosira is important in a few lakes. In terms of the ecological groups of diatoms of Hustedt (1938), lakes of northeastern Minnesota have relatively high proportions of acidophilous and indifferent species and low proportions of alkaliphilous species. These ecological groups (Hustedt 1938) are defined as:

acidophilous - most abundant in water with pH <7, especially around pH 6

indifferent - equally abundant in water above and below pH 7

alkaliphilous - having widest distribution at pH >7

The northeastern lakes studied by Bright were not chosen to be representative of this area but rather to include the widest possible range of physical, chemical, and geological lake types.

In a study of phytoplankton assemblages in Minnesota lakes, Tarapchak (1973) found that the total number of taxa, the number of desmid taxa, the relative abundance of the Araphidineae, and various indices of species diversity are higher in the northeastern lakes than in other lakes in Minnesota. The compound phytoplankton quotient (Nygaard 1949) was found to be lower in the northeastern lakes than in other lakes. Tarapchak also identified algal indicators of oligotrophic and meso-eutrophic conditions.

Other recent studies of phytoplankton ecology in Minnesota lakes include those of Bradbury (1975) who correlated diatom species composition in seven lakes to enrichment associated with human activities, and Schults et al. (1976) who compared the limnology and phytoplankton communities of Shagawa and Burntside lakes, both located in northeastern Minnesota. The latter authors found that oligotrophic Burntside Lake and eutrophic Shagawa Lake contained many of the same species and that blue-green algae and diatoms were important in both lakes. While the expected oligotrophic indicators *Tabellaria* and *Dinobryon* were conspicuously present in Burntside Lake, approximately fifty percent of the algae in late summer were blue-greens with *Chroococcum*, *Coelosphaerium*, and *Oscillatoria* dominating. In Shagawa Lake blue-green blooms dominated in mid to late summer, accounting for 60 to 80 percent of the algae. Densities of most taxa were ten times higher in Shagawa than in Burntside. However, Shagawa is not a typical eutrophic lake for this area, as it receives sewage effluent from the city of Ely.

METHODS

Study Area

The Study Area includes 2130 sq. mi. (5516 km^2) of Lake and St. Louis counties to the south and east of Ely, Minnesota. This area is divided into two major watersheds by the Laurentian Divide. Water north of the Divide flows to Hudson Bay while water south of the Divide flows to Lake Superior. Many of the lakes in the Study area are relatively shallow and contain waters which are stained brown by humic compounds. However, some deep, clear water lakes are also found in this region.

The lakes studied (Figure 1) were classified as primary or survey to indicate sampling intensity (Table 1). Five primary lakes were selected on the basis of their potential for impact; one lake with high potential for impact and one lake with low potential for impact were chosen from both north and south of the Laurentian Divide. Birch Lake was chosen as the fifth primary lake because of its high potential for impact and its importance in the Study Area. A further criterion for primary lakes was that their ecological classification by the Minnesota Department of Natural Resources (MDNR) be similar. All primary lakes were soft-water walleye lakes except for Colby Lake which was a centrarchid-walleye lake (Regional Copper-Nickel Study 1978). Two stations were located on each primary lake except Birch lake which, because of its length, had four stations. Survey lakes were selected to include lakes of varying sizes, depth, and surrounding soil types from twelve watersheds. Single stations were located on these lakes. Characteristics relating to choice of lakes are shown in Table 2.

In 1977 fourteen of the original twenty-five lakes were chosen for repeated sampling (Table 1). The lakes retained were chosen to include a range of values of pH, alkalinity, and total organic carbon (factors affecting susceptibility to impacts) and a range of morphometric types. Single stations were located on all lakes except Birch Lake where two stations were sampled.

Field collections of phytoplankton were made in conjunction with chlorophyll studies and employed a PVC integrated pipe sampler. In most cases the top four meters of the water column were sampled with this apparatus to provide a single composite sample. An integrated sampler was used so as to sample a large proportion of the euphotic zone. Spectrophotometric determinations of chlorophyll a were performed using 90 percent acetone extractions (APHA 1976). Two replicate 120 ml phytoplankton samples were preserved with Lugol's solution and shipped to Ecology Consultants, Inc., Fort Collins, Colorado, for taxonomic analysis. Laboratory analysis of sedimented samples employed the inverted microscope technique described by Utermohl (1958) and outlined by Vollenweider (1974).

Units were counted in sedimented samples at 56, 140, 280, 560, and 1400 X using Whipple grids. The counting units utilized were:

Unicells - each cell

Diatoms - each complete frustule (2 valves)

Filaments - 100 microns length

Discrete colonies - each 4, 8, 16, 32, or 64 cell colony

Indiscrete colonies - every 8 cells

Dense colonies - every 50 cells

Cells per counting "unit" were recorded for discrete and indiscrete colonies. Examples of discrete colonial forms include *Pandorina*, *Volvox*, and *Oocystis*. Indiscrete colonial forms include *Agmenellum* (*Merismopedia*), *Chroococcus*, and *Crucigenia*. Examples of dense colonies are *Microcystis*, *Aphanothece*, and other coccoid blue-greens. In 1977 the number of cells per unit was recorded whenever there were multiple cells per unit. Diatoms were subjected to sulfuric acid-potassium dichromate digestion and identified from permanent Hyrax slide mounts prepared from the sedimented material.

For calculations of dominance the mean density of each taxon (in units/ml) was calculated for all replicate samples at all stations in a lake on one date.

Methods for Stratigraphic Analyses

Stratigraphic analyses were performed by project staff using samples from cores collected by the Leaching/Pathways Study staff. Cesium-137 analyses were performed by Dr. David Edgington of Argonne National Laboratory. Pollen samples were prepared by standard methods (Faegri and Iverson 1964), and mounted in silicone oil. All grains on a coverslip 18 mm square were counted at a magnification of 400X. Sediment samples for diatom analyses were digested in cold Chromerge solution for one week and identified from permanent Hyrax slide mounts. Complete details of all analytical procedures including taxonomic criteria used in the diatom analyses of stratigraphic materials are found in the Aquatic Biology Operations Manual (Regional Copper-Nickel Study 1977).

To assure that one sample from each lake predates modern settlement, two stratigraphic levels per lake were analyzed for the percentage of *Ambrosia* (ragweed) pollen. This weed increases in abundance whenever land is broken for agricultural purposes. Its pollen can be distributed by wind for hundreds of miles; therefore, a rise in *Ambrosia* pollen is used as a time-marker reflecting the beginning of agriculture on the Great Plains as well as in the local area. Rises of a few percent are typical for northeastern Minnesota lakes (Bradbury and Megard 1972).

Depths of the two pollen samples were chosen to frame broadly the probable depth of the *Ambrosia* rise as calculated from deposition rates based on Cesium-137 data, assuming the Cesium-137 peak corresponds to 1963. Stratigraphic levels of the diatom samples were then chosen to assure at least one sample above and at least one below the *Ambrosia* rise. Stratigraphic levels of samples analyzed for pollen and for diatoms are illustrated in Figure 2 along with Cesium-137 profiles for the cores. Since not all diatom taxa preserve equally well in the sediments, one set of counts was made as near as possible to the surface sediment, which should most clearly reflect the present diatom flora. These counts of surface sediments help to separate the effects of differential breakage and corrosion from those of actual differences in floristic composition through time.

RESULTS AND DISCUSSION: SURFACE WATER SAMPLES

Water Chemistry

The Study Area lakes are listed in Table 3, together with their physical and chemical characteristics, in order of increasing values for Schindler's (1971) ratio. As a group the lakes fall into relatively narrow ranges of conductivity, alkalinity, and hardness. They are soft-water lakes (only Tofte has a total alkalinity greater than 50) with pH values generally near the neutral point (7.0). The lakes appear less similar when their sulfate (range=3-30 mg/l) and silica (range=0.4-9 mg/l) contents are examined, and it seems possible that silicon might occasionally limit diatom growth in lakes such as Triangle, Long, Turtle, Pine, and Seven Beaver. The lakes as a group are highly colored and contain considerable amounts of dissolved organic material. Three distinct subgroups of lakes may be recognized on the basis of total organic carbon content (Table 4). Since dissolved humic compounds appear to play a role in complexing metals and ameliorating their toxicity, it is likely that the phytoplankton communities of lakes in these subgroups will respond quite differently to pollution by heavy metals (e.g. see Gerhart and Davis 1978).

Vollenweider (1968) has attempted to correlate the total phosphorus content of lakes with their trophic condition. He describes the following categories:

TROPHIC CONDITION	Total P (ug/l)
ultra-oligotrophic	<5
oligo-mesotrophic	5-10
meso-eutrophic	10-30
eutrophic	30-100
hypereutrophic	>100

By applying these categories to summertime average data from the Study Area lakes (Figure 3, hatched bars), one finds that only Tofte falls in the oligo-mesotrophic range while 14 lakes are classified as meso-eutrophic and

10 as relatively eutrophic. Data from October, 1976, (Figure 3, dark bars) show the same basic pattern with Tofte as oligo-mesotrophic, 17 lakes in the meso-eutrophic category, and 4 in the eutrophic category. The greatest difference between summertime and October values appears on Clearwater Lake which was only sampled twice. This suggests that the high summer value for total phosphorus in Clearwater may have been due to sample contamination. Other data from Clearwater Lake, particularly chlorophyll data (Table 5), suggest that the October value for total phosphorus is more accurate. On this basis Clearwater Lake would be at the low end of the meso-eutrophic category. This classification of lakes by phosphorus content is tentative because it is based on so few samples.

The fact that most of these lakes do not stratify in summer, or stratify only weakly (Table 6), contributes to increased productivity since nutrients are not trapped in the hypolimnion where they are unavailable to algae. Data on dissolved inorganic nitrogen suggest that nitrogen limitation may also be important in some lakes (e.g. Tofte, Triangle, Big, Bass, Turtle, Sand, Long, and South McDougal). At the moment these sorts of conclusions must be drawn with extreme caution since the data in Table 3 were derived from only a few measurements.

In Table 5 the lakes are grouped into three categories based on their summertime chlorophyll a concentrations. Again, most of the lakes fall into mesotrophic/eutrophic categories. It is likely that there is some correlation between summer chlorophyll levels and Schindler's ratio, but the chlorophyll data are too few to warrant a detailed analysis. The classification of the lakes presented in Table 5 must be viewed as a very tentative one since only one or two summertime chlorophyll measurements were made on the survey lakes. It should also be noted that the use of an integrated pipe sampler on stratified lakes may pose problems in the interpretation of chlorophyll results if this sampler extends into the metalimnion or hypolimnion. During summer stratification sedimenting cells may concentrate in the metalimnion or hypolimnion, or blooms may occur in the metalimnion.

In 1976 chlorophyll measurements on the primary lakes were made more frequently (Table 7). Chlorophyll maxima generally occurred in August and September in these lakes, and concentrations were similar in all of the primary lakes during these months. In contrast, several of the survey lakes (Bear Island, Triangle, Perch, Bass, and Turtle) had significantly higher chlorophyll concentrations in October than in July. With the exception of Turtle, all of these lakes stratify during the summer, and the fall blooms are probably related to the breakdown of stratification and subsequent mixing of nutrients or cells from the hypolimnion.

Phytoplankton Cell Counts

Dominance and Diversity of Algal Groups--The summer phytoplankton samples were generally dominated (in terms of total units counted) by the Cyanophyta, Chrysophyta, and Bacillariophyta. Only a few lakes were dominated by the Chlorophyta (Table 8). There was no clear relationship between the dominant groups and the trophic condition of the lakes. For example, Tofte, Clearwater, and Bass lakes, probably the most oligotrophic of the Study Area lakes, were all occasionally dominated by blue-green algae. This finding contradicts generally accepted ideas about oligotrophic lakes but is in agreement with the information on oligotrophic Burntside Lake reported by Schults et al. (1976).

In 1976 five samples were collected from the primary lakes during the ice-free season, providing some information regarding the seasonal succession of algal groups in these lakes. In spite of the presence of similar species and other limnological similarities among the primary lakes, no consistent pattern of succession emerges from the data. In Birch and White Iron lakes large midsummer populations of blue-green algae declined in the autumn and were replaced by blooms of diatoms. Gabbro Lake was dominated by diatoms throughout the summer, while blue-greens and flagellates increased in abundance in September and October. Colby Lake was dominated by Chrysophytes (Dinobryon) until October when blue-green algae become dominant. Autumn data are not available for Seven Beaver Lake, but blue-greens and diatoms were dominant during the summer. It is likely that patterns of dominance are quite variable not only from lake to lake, but within the same lake from year to year. For example, of the fourteen lakes sampled in July, 1977, only six had the same dominant algal group that was present when the lakes were sampled in July or August, 1976.

In most cases dominance was shared by several or many algal species, but occasionally a single algal genus or species showed exceptionally strong dominance. This was especially true of the Chrysophyte Dinobryon (e.g.

Pine, Colby, and Bearhead lakes, summer 1976) and the green alga *Chlorococcum humicoli* (Wynne and White Iron lakes, summer 1977).

An examination of species diversity (number of species found) within algal groups yields a much clearer picture for the Study Area lakes than the analysis of dominant groups (Table 9). With few exceptions, the diatoms were the most diverse group, followed by the greens and then the blue-greens. As many as 40 to 50 species of diatoms were identified in one lake on one date. The green algae, while usually quite diverse, were usually not dominant in these lakes; the reverse was true of the Chrysophytes. Extremely low species diversity in Wynne and Perch lakes during the summer of 1977 was accompanied by the presence of *Chlorococcum humicoli* as a dominant green alga in both cases. The Cryptophyta, Pyrrhophyta, and Euglenophyta were the least diverse of the algal groups and were never numerically dominant.

Characteristic Algae--The dominant species within each algal group for all summer and October samples are tabulated in appendix A, with densities (units/ml) given only when a taxon is dominant on a date. The total density of each group is also tabulated. Dominant species are defined as the five most abundant species in the groups Bacillariophyta, Chlorophyta, Cyanophyta, and Chrysophyta, and two most abundant in Cryptophyta and Pyrrhophyta. The species composition of the phytoplankton samples were remarkably similar in the lakes studied and it is possible to identify a group of "characteristic species" based on their frequency of occurrence in the samples (Table 10). This similarity of algal communities is likely due in part to the relatively similar conditions of alkalinity, hardness, and pH found in these lakes, although many of the species listed in Table 10 are widely distributed. This list is an arbitrary one in that it includes only those species present in more than two-thirds of the lakes during at least two sampling seasons. This criterion could be made either more or less restrictive, thus shortening or expanding the list. For example, if the two-thirds criterion were relaxed to, say, one-half, species such as the following would be included: Bacillariophyta-*Rhizosolenia eriensis*, *Synedra delicatissima*, *Achnanthes* spp.; Chlorophyta-*Cosmarium* sp., *Crucigenia tetrapedia*, *Scenedesmus quadricauda*; Cyanophyta-*Anabaena* spp., *Aphanocapsa elachista*, *Coelosphaerium Naegelianum*; Chrysophyta-*Synura uvella*, *Centritractus belanophorus*, *Dinobryon cylindricum* and *sociale*, *Mallomonas akrokomos*, *Mallomonas* sp. However, for the purpose of identifying future changes in species composition in this region, the shorter list in Table 10 is probably more useful.

In examining Table 10 it becomes apparent that the percentages in both the "Dominant" and "Present" columns are generally higher in 1976 than in the same sampling season in 1977. The reason for this phenomenon is not known, but it may be worth noting that the two years were very different in terms of precipitation. The year 1976 was extremely dry and many lakes experienced low water levels; precipitation in 1977 was more typical for the region. Precipitation may affect phytoplankton communities by providing plant nutrients through runoff and from rain falling directly on a lake's surface; and, especially in small lakes, it may have a considerable effect on a lake's flushing time. It seems possible that the lake environments, and hence phytoplankton communities, may be more similar in dry years. Contributing to the difference between the frequency of species presences in 1976 and 1977 is the difference in sampling intensity; in 1976 two replicate samples were analyzed from two or more stations in primary lakes. Rare species were thus more likely to be sampled in 1976 than in 1977 in primary lakes.

Indicator Species--Although an exhaustive study of indicator species was not made, attempts to separate the Study Area lakes into trophic subgroups using indicators were generally unsuccessful. This is perhaps not surprising since most of the lakes appear to fall near the middle of the trophic spectrum. Thus, the eutrophic indicators *Anabaena flos-aquae* and *Aphanizomenon flos-aquae* were present in lakes from all three of the chlorophyll categories in Table 5. The same was true of *Aphanocapsa elachista*, which Tarapchak (1973) considers an oligotrophic indicator in Minnesota lakes, and of *Chroococcus dispersus*, which he considers a mesotrophic-eutrophic indicator. An attempt to separate the lakes based on the number of desmid species also proved futile. The only species which appeared to have some value as an indicator of trophy was the diatom *Melosira granulata*. In the summers of 1976 and 1977 this species was present only in Colby, Birch, Seven Beaver, White Iron, Gabbro, Long, Fall, Wynne, Sand, and Bear Island lakes. It is a generally accepted indicator of eutrophy (e.g. Lowe 1974).

A number of species characteristic of acid waters are found in these lakes. These include *Ankistrodesmus falcatus*, *Binuclearia* sp., *Cyclotella* bodanica, Centritractus belanophorus, and Aphanocapsa delicatissima. Binuclearia sp. may have value as an indicator of organic matter (Prescott 1962). In the summers of 1976 and 1977 it was present as a dominant only in Cloquet, Greenwood, Pine, South McDougal, Slate, Big, and Bearhead lakes. It was also observed in several other lakes but was absent in lakes of the lowest TOC category in Table 4.

Comparisons With Other Regional Lake Studies

A number of regional lakes studies have been conducted which include attempts to classify algae according to their trophic distribution. Unfortunately, the results of these studies are rarely consistent. Tarapchak (1973) listed thirteen species as characteristic of oligotrophic Minnesota lakes. Of these, Aphanocapsa elachista, Chrysosphaerella longispina, Synura uvella, and Cyclotella comta (=bodanica?) are common in the lakes discussed in the present study. Since most of these lakes are definitely not oligotrophic, the use of these species as oligotrophic indicators may be questioned. Similarly, Rawson (1956), in his study of lakes of western Canada (including the Great Lakes), presented lists of oligotrophic and mesotrophic algal species. Asterionella formosa, Tabellaria fenestrata, Dinobryon divergens, and Melosira granulata were all considered oligotrophic species, while Fragilaria crotonensis, Ceratium hirundinella, Coelosphaerium Naegelianum, Anabaena spp., and Aphanizomenon flos-aquae were considered mesotrophic. Although his mesotrophic category is consistent with the results from the present study, his oligotrophic category is not. Based on species occurrences in the Great Lakes, Stoermer

(1978) found the distributions of Melosira distans, Chrysosphaerella longispina, Dinobryon bavaricum, and Cyclotella comta (=bodanica?) to be primarily oligotrophic, while the distributions of Melosira granulata, Ankistrodesmus falcatus, Cryptomonas erosa, and Aphanizomenon flos-aquae were primarily eutrophic. Ubiquitous forms included Asterionella formosa, Fragilaria crotonensis, Rhizosolenia eriensis, Botryococcus Braunii, Dinobryon divergens, and Anabaena flos-aquae. Finally, in studies of Finnish lakes Jarnefelt (1952) classified Agmenellum quadruplicatum, Dinobryon divergens, and Dinobryon bavaricum as oligotrophic indicator species. Clearly, there is much disagreement on this subject, especially with regard to oligotrophic indicators. Many species considered oligotrophic by these authors are common or even characteristic of the moderately productive lakes of the Study Area. Rawson (1956) discussed the problems of identifying reliable oligotrophic indicator species and suggested that most of the species in oligotrophic lakes are not distinctive of that condition but in fact are widely tolerant forms. An alternative explanation, also considered by Rawson, is that many physiological varieties of algae have developed which we are unable to distinguish morphologically.

In spite of these problems concerning specific indicator algae, it is possible to distinguish the phytoplankton communities of lakes of the Study Area from those of other geographical regions. Bright (1968) and Tarapchak (1973) have indicated differences in species composition between lakes of northeastern Minnesota and those of central and southwest Minnesota.

Bright, for example, points out that while Tabellaria, Asterionella, and Melosira are important diatoms of the northeast lakes, the nutrient-rich lakes of southwestern Minnesota are characterized by Fragilaria, Synedra, and Melosira.

It is perhaps not surprising that such differences occur when comparing lakes of the paririe with those of the northeastern forests. However, the Study Area lakes also differ in species composition from lakes of the Experimental Lakes Area (ELA) of northwestern Ontario, Canada (Schindler and Holmgren 1971). These Canadian lakes have considerably lower conductivities (10-35 umhos/cm) and bicarbonate concentrations (0.2-9.9 mg/l HCO_3^-) than lakes of the Study Area. Most of the ELA lakes were dominated by the Chrysophyta. The Cyanophyta and Bacillariophyta appear to be less abundant in the Canadian lakes than in Study Area lakes, while the Chrysophyta, Cryptophyta, and Pyrrhophyta appear to be more abundant. In terms of number of species, diatom diversity may be somewhat less, while dinoflagellate, cryptomonad, and chrysophyte diversity are clearly greater in ELA lakes. Some species are common to both lake groups (e.g. Coelosphaerium Kuetzingianum, Crucigenia tetrapedia, Dinobryon spp., Asterionella formosa, Tabellaria fenestrata, Rhizosolenia eriensis, and Botryococcus Braunii), but many of the important ELA algae are rare or absent in the Study Area lakes.

A preliminary survey of diatom communities in nineteen lakes of the Sylvania Recreation Area of the Ottawa National Forest, Michigan, was made by Crumrine and Beeton (1975). Important diatoms included Asterionella *formosa*, *Tabellaria flocculosa*, *Fragilaria pinnata*, and *Fragilaria crotonensis*. Non-diatoms were also important, but these were not examined quantitatively. Based on the occurrence of *Tabellaria flocculosa* (Stockner 1971) and the relatively high secchi disk values for these lakes (average=4.3 m), it is likely that they are significantly less productive than those of the Study Area. The same may be said for the ELA lakes.

RESULTS AND DISCUSSION: STRATIGRAPHIC ANALYSES OF FOUR LAKES

Pollen

Work completed to date suggests that an *Ambrosia* rise is present in the following three lakes between the listed depths (Figure 2):

Clearwater - between 7-8 cm and 28-29 cm

Gabbro - between 7-8 cm and 29-30 cm

White Iron - between 15-16 cm and 30-31 cm

Ambrosia pollen in Birch Lake is constant at 0.6 percent at depths of 8 to 9 cm and 26-27 cm. A Cesium-137 peak at 3 cm suggests a deposition rate of 0.2 cm per year in Birch Lake. This suggests a rise in *Ambrosia* pollen (presumably around 1900) should occur at 12-13 or 13-14 cm (Bradbury and Megard 1972). However, the pollen does not show a rise above this level. Birch Lake behaves very much like a river, with a flushing rate of 5.5 times/year. Prior to impoundment (between 1895 and 1905) the water level was six feet lower than at present. The dam was washed out in 1952, allowing the water to drop to its previous level, but has since been repaired. The high flushing rate and the washout may have modified the sedimentary record, accounting for the anomalous pollen data.

Diatoms

Comparison of Water and Surface-Sediment Samples

The percentage of dominant diatom taxa in water samples was averaged to compensate for seasonal population peaks and this average was compared with percentages of the same taxa in surface sediment samples (Figure 4). In this discussion the term "dominant diatoms" refers to the ten most abundant diatoms in any sample under discussion. All species that occur in the list of ten most abundant taxa in any of the averaged surface water samples or surface sediment samples are listed in Figure 4. The top ten diatom species account for between 60 and 70 percent of all frustules in the surface sediments of all four lakes and between 80 and 97 percent of all frustules in the water samples (Table 11). (The integrated water samples include only planktonic forms, while sediments include benthic forms as well.) Thus the dominant diatoms comprise the bulk of the diatom communities.

All the dominant species in the water samples (except for *Rhizosolenia* in Clearwater Lake) are among the dominant species in the surface sediment samples, though the relative abundances vary considerably between water samples and surface sediment samples. Most of the dominants occur in higher percentages in the water than in the sediment because of the benthic forms included in the sediments. *Melosira italica* and *M. granulata v.*

angustissima are exceptions to this trend and are much more abundant in the surface sediments than the water samples, probably because they are better preserved in the sediments than other taxa. Two taxa appear particularly under-represented in the surface sediments: Rhizosolenia spp. (especially in Clearwater Lake), and Asterionella formosa. Rhizosolenia is well known for its poor preservation in sediments (Tarapchak, personal communication) and Asterionella also appears to be poorly preserved in these slightly acidic lakes.

Despite the differences in preservation between species, 6 of 7 diatom species characteristic of the region (Table 10) are included in the dominant diatom species found in the cores (Figure 5). The only characteristic diatom species found in water samples but not sediments was Nitzschia, which was never dominant in water samples from the four lakes sampled for stratigraphic analysis.

Present status of the four lakes

In general, sediments of the four lakes are dominated by Melosira italica, Melosira ambigua, Tabellaria fenestrata, Melosira distans and Melosira granulata. M. distans and T. fenestrata are considered by some authors (Rawson 1956, Stoermer 1978, Tarapchak 1973) to indicate oligotrophic conditions, and Melosira granulata is generally considered an indicator of eutrophy. M. granulata never appeared in the water samples of the less productive Study Area lakes. The importance of M. granulata and its varieties in Birch, Gabbro, and White Iron is consistent with the surface chlorophyll data (Tables 5 and 7) and the phosphorus data (Figure 3) in placing these lakes in a meso-eutrophic category. Study Area lakes appear to be acidic as suggested by the presence at low percentages of one or more species of Eunotia in sediments of all four lakes. Members of this genus are acidophilic littoral forms.

Examination of figures 4 and 5 reveals that Clearwater Lake differs from the other three lakes both in species composition and relative abundance of certain species. The difference shows specifically in the presence in Clearwater of Rhizosolenia and the importance of Tabellaria fenestrata, Cyclotella glomerata, and Cyclotella bodanica along with the absence of Melosira granulata, Stephanodiscus astraea and Fragilaria capucina and unimportance of Fragilaria crotonensis. Together these differences suggest that Clearwater Lake is more oligotrophic than the others. Table 11 shows that Clearwater Lake also has a much higher percentage of frustules of littoral species among the dominant forms than do the other lakes. Since the other lakes have a much greater shoreline development than Clearwater, it seems likely that the higher percentage of littoral diatoms in the sediment represents a lower planktonic production of diatoms in Clearwater. This is consistent with the chlorophyll a data from water samples (Table 5) which shows Clearwater Lake in the least productive group, and Gabbro, White Iron, and Birch in the most productive group.

Stratigraphy

Diatom assemblages in the sediments of all four lakes are dominated by Melosira italica and Melosira ambigua to a depth of 30 cm (Figure 5). The presence of Melosira granulata and its variety angustissima in both the surface and basal sediment samples of Birch and White Iron lakes suggests that they have always been more eutrophic than Gabbro and Clearwater lakes. The increase of these two species of Melosira and of Fragilaria crotenensis in the surface sediment of Gabbro lake may indicate a recent trend toward eutrophication, but a more detailed analysis of the core would be necessary before any conclusion could be drawn. Clearwater Lake appears oligotrophic at all three stratigraphic levels examined.

These data are too sketchy to allow much generalization about the history of these four lakes. However, aside from the possible indication of a shift to enrichment in Gabbro Lake, it appears that White Iron and Clearwater lakes have not undergone any dramatic shifts in diatom flora since human settlement. In Birch Lake Melosira italica and Melosira ambigua were difficult to distinguish; hence more weight should be placed on the nearly constant percentage of Melosira granulata as an indication of little change. In any case since no clear Ambrosia rise could be detected in Birch Lake, the sediments may have been disturbed.

One other stratigraphic study has been done in the Study Area, on Shagawa and Burntside lakes (Bradbury 1978). Shagawa Lake was undoubtedly mesotrophic or eutrophic in its natural condition. Its presettlement diatom communities were dominated by Fragilaria capucina, Melosira ambigua, and other Melosira species, including M. granulata. All of these species are characteristic of relatively high nutrient conditions. As cultural enrichment became progressively more severe, beginning in the late 1800s, the diatom flora became dominated first by Melosira ambigua, then by Fragilaria crotonensis, and finally by Stephanodiscus hantzschii under conditions of severe eutrophy. After 1954 when sewage treatment facilities were improved, dominance returned to species such as Fragilaria crotonensis, Asterionella formosa, and Melosira spp. In contrast the pre-settlement diatom flora of Burntside Lake was dominated by Tabellaria flocculosa and Cyclotella spp. Although this lake has remained largely unaffected by human activities, significant and consistent increases in the spring and fall maxima of Asterionella formosa have occurred since 1949. Bradbury believes this change is related to cultural enrichment. (In this regard, care must be taken not to confuse the occurrence of a species in a lake with its presence as a dominant. Asterionella formosa occurs regularly under quite oligotrophic conditions but seldom exhibits strong population peaks in oligotrophic lakes. Indeed, this species was present throughout the sedimentary history of Burntside Lake.)

In the Study Area lakes, the most abundant diatom species in water samples are Asterionella formosa, Fragilaria crotonensis, Melosira ambigua, and Tabellaria fenestrata. Thus, the observations of Bradbury in Shagawa and Burntside lakes are consistent with the idea that Study Area lakes generally fall into mesotrophic and eutrophic categories.

SUMMARY

Surface water samples from 25 lakes in the Study Area showed most lakes to be meso-eutrophic, primarily on the basis of total phosphorus concentrations, summer chlorophyll concentrations, and phytoplankton species composition. The presence of Melosira granulata was associated with the more productive lakes. Stratigraphic analysis confirmed that Clearwater Lake was less productive than White Iron, Birch, and Gabbro lakes and indicated little evidence of change in these lakes since human settlement. Clearwater, Tofte, and Burntside are examples of more oligotrophic lakes in the Study Area.

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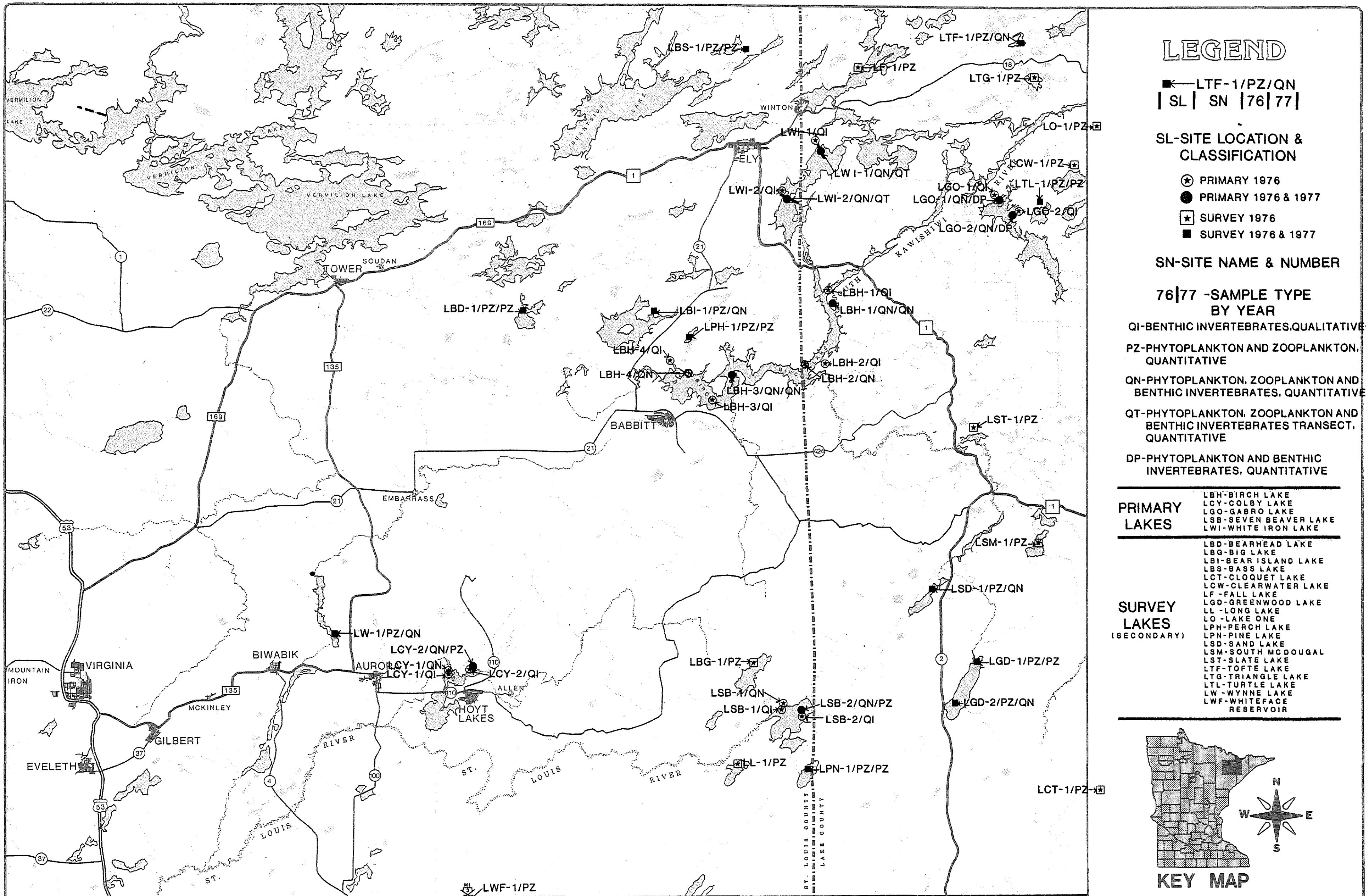
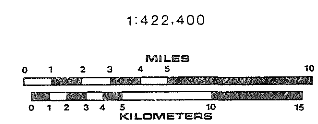




MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 1. AQUATIC BIOLOGY LAKE STUDY SITES

FIGURE 2.

Stratigraphic position of samples analyzed. Arrows represent samples analyzed for diatoms. Cesium-137 generally peaks in 1963.

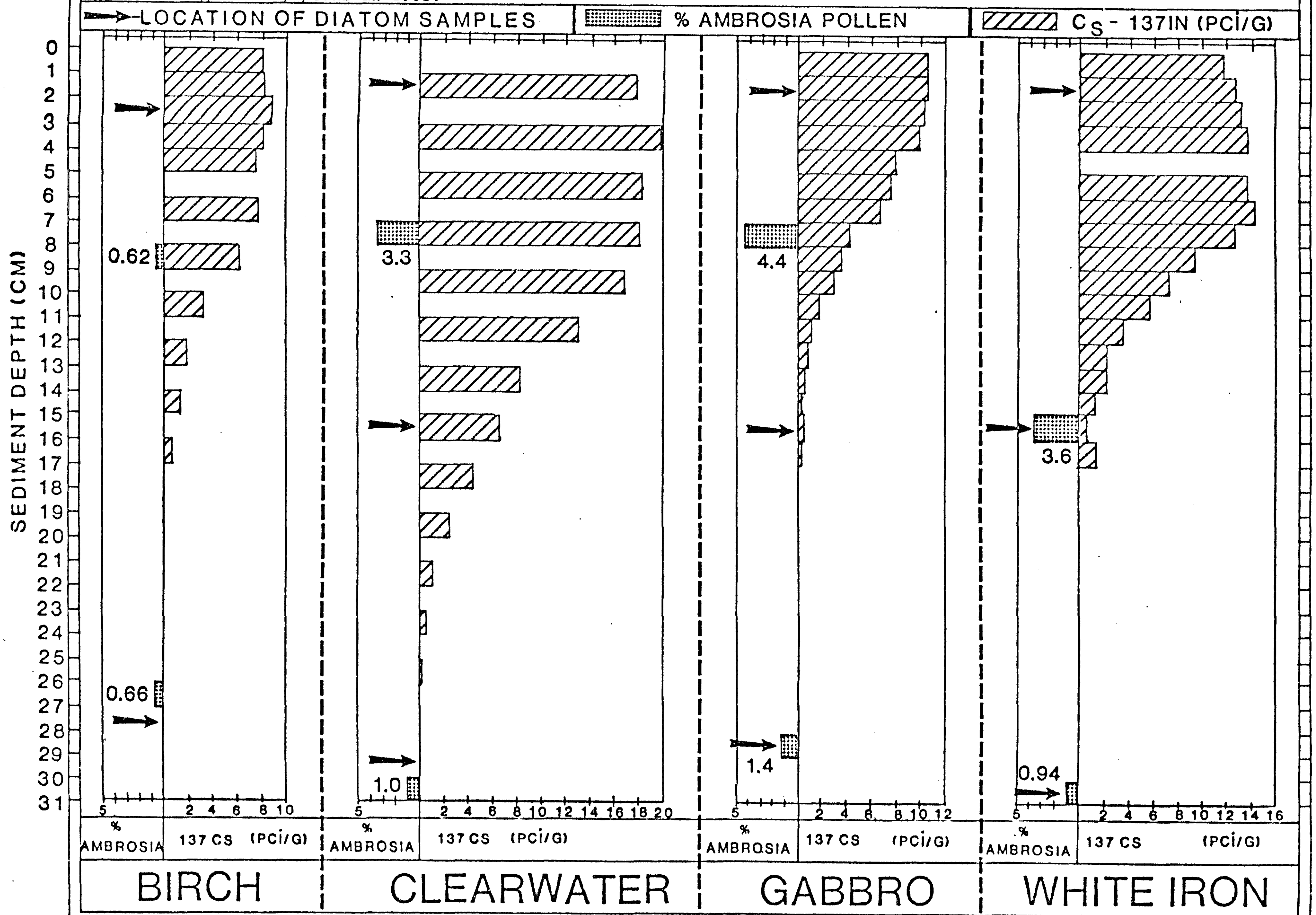
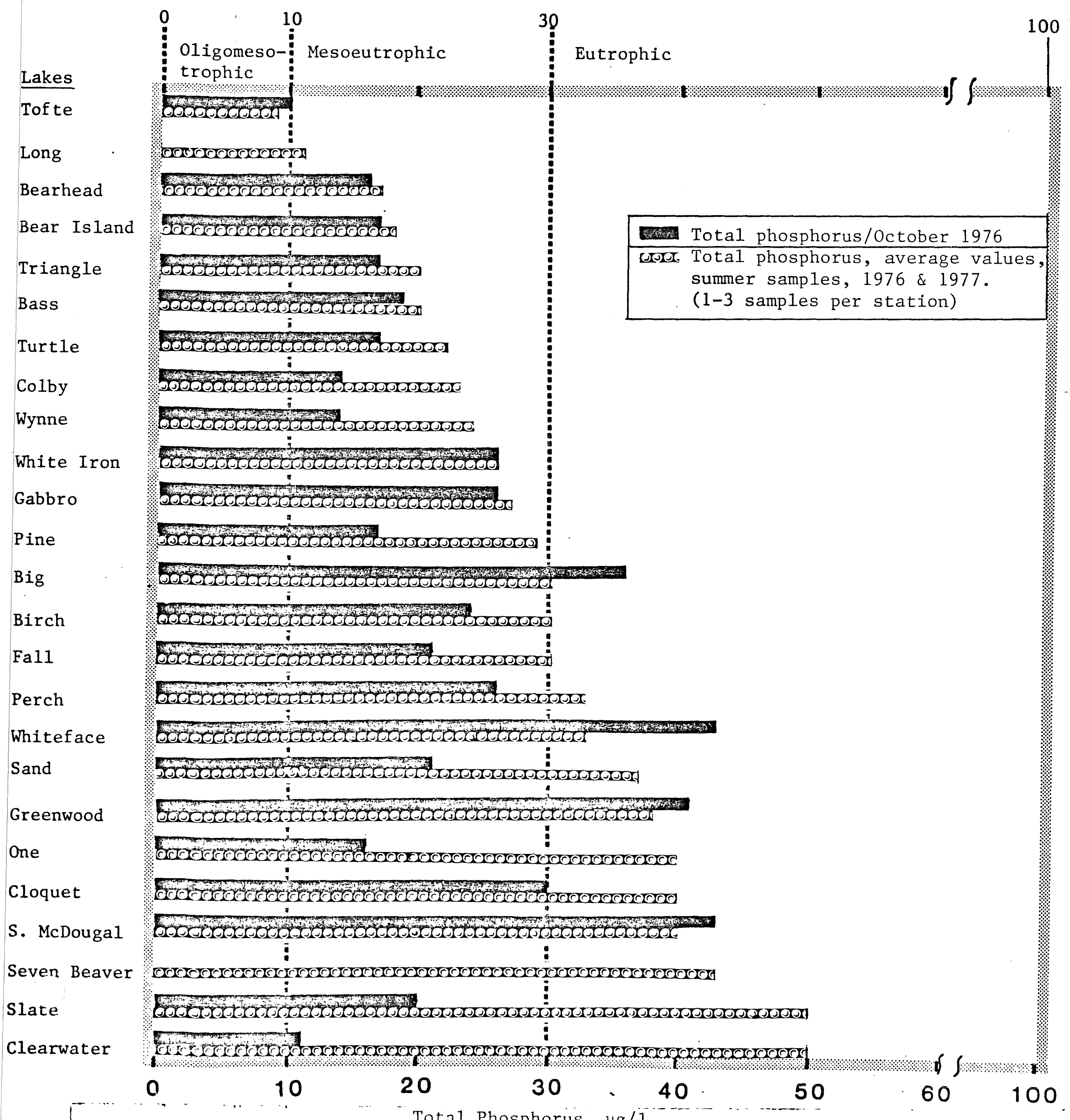


Figure 3. Classification of study lakes based on total phosphorus concentration. (after Vollenweider, 1968)



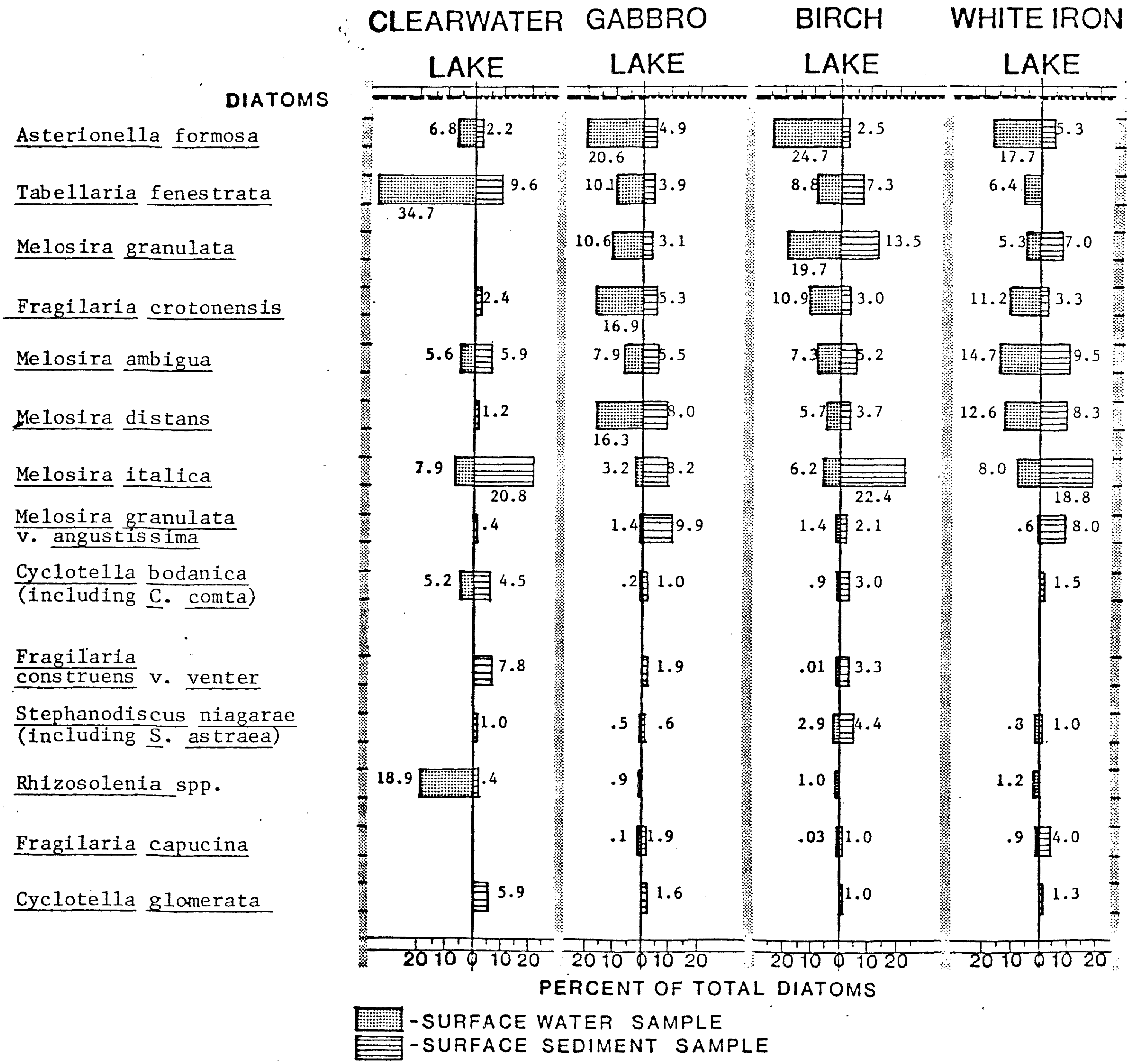


Figure 4 Comparison of Surface Sediment Samples with Average Composition of Water Samples, Based on Percent of all Frustules Belonging to Dominant Taxa. Missing Columns Mean the Taxon is Absent.

Figure 5. Stratigraphy of Selected Dominant Diatom Taxa in Four Study Lakes

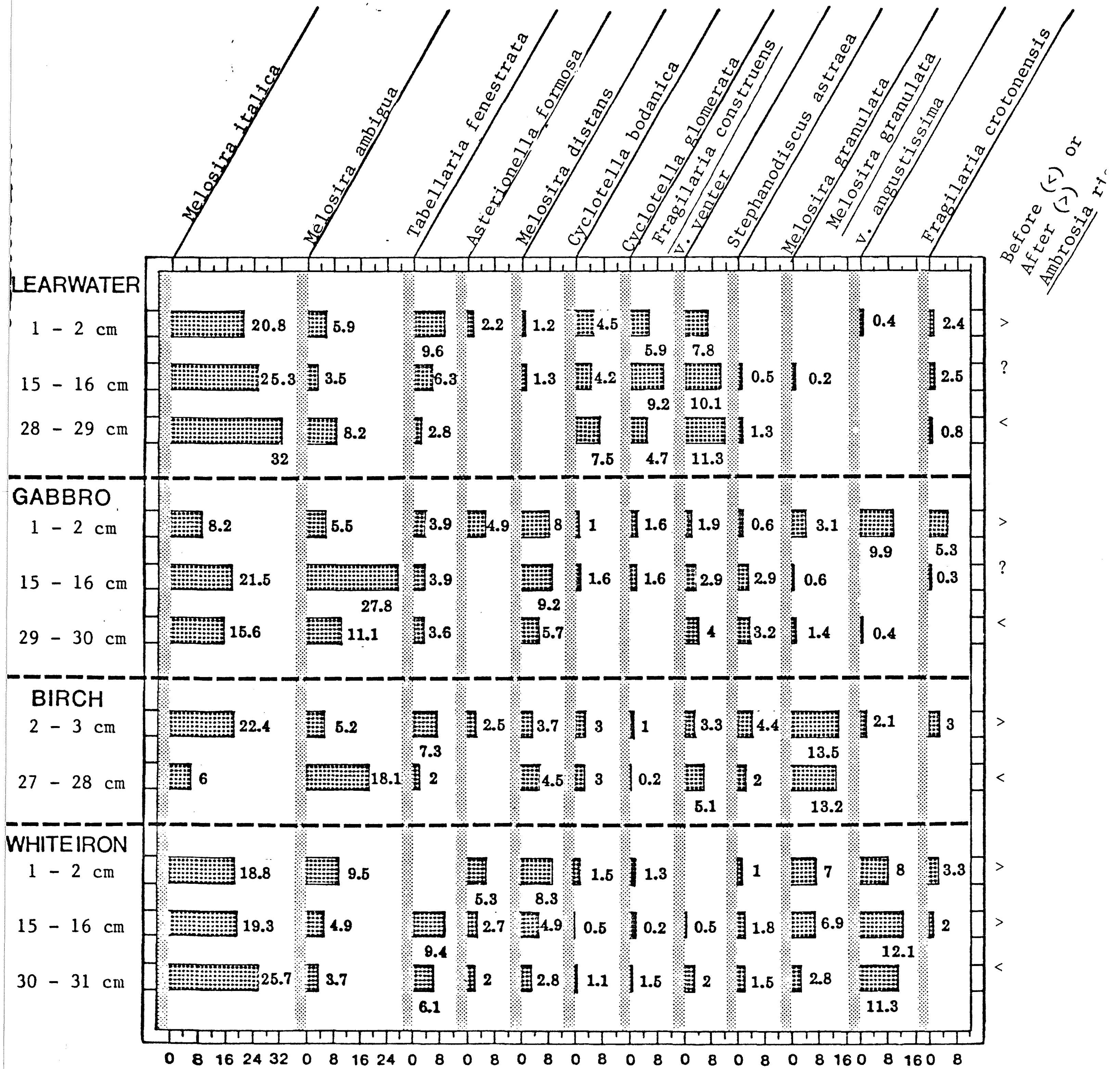


Table 1. Frequency of collection of phytoplankton samples.

Lake	YEAR: 1976					1977		
	MONTH: May	June/July	Aug.	Sept.	Oct.	April	July	Oct.
Primary:								
Birch	X	X	X	X	X	X	X	X
Seven Beaver	X	X	X			X	X	X
White Iron	X	X	X	X	X	X	X	X
Colby	X	X	X	X	X	X	X	X
Gabbro	X	X	X	X	X			
Survey:								
Pine		X			X	X	X	X
Bass		X			X	X	X	X
Bearhead		X			X	X	X	
Perch		X			X	X	X	
Sand		X			X	X	X	X
Greenwood		X			X		X	X
Tofte		X			X	X	X	X
Turtle		X			X	X	X	X
Wynne		X			X	X	X	X
Bear Island		X			X	X	X	X
Fall		X			X			
Long		X						
Big		X			X			
Slate		X			X			
So. McDougal		X			X			
One		X			X			
Cloquet		X			X			
Triangle		X			X			
Whiteface					X			
Clearwater		X			X			

Table 2. Physical and chemical characteristics of lakes sampled biologically and reasons for sampling.

LAKE	WATERSHED	SURFACE AREA-Km^2	DEPTH (m)	pH[a]	COLOR[a]	ALKALINITY[a]	CONDUCTIVITY[a]	TSI[b] (P)	POTENTIAL FOR CU-NI IMPACTS DIRECT[c]	INDIRECT[d]	REASON FOR SAMPLING[e]
Birch	Birch	25.62	4.15	7.1	54.9	23.4	68.6	49	high	high	1
Colby	Partridge	2.24	3.13	7.1	133.75	33.0	152.65	51			
Gabbro	Isabella	3.63	3.66	7.25	100.25	17.75	48.25	48	low	low	2, 10
Seven Beaver	St. Louis	5.63	1.46	6.5	172.5	13.67	47.75	54	med	med	1, 3
White Iron	Kawishiwi	13.85	6.00	6.95	73.75	17.15	51.25	49	high	med	1
Bass	Range	.68	5.51	8.15	6.5	32.0	79.5	47	low	low	3
Bearhead	Vermilion	2.74	4.49	7.85	26.0	23.5	68.0	40	low	low	3, 9
Bear Island	Bear Island	8.64	8.74	7.4	39.5	15.5	44.25	47	low	low	3
Big	Partridge	3.21	--	7.6	14.0	25.0	62.0	61	med	med	3, 4, 7
Clearwater	Kawishiwi	2.61	7.44	6.7	2.0	16.0	39.0	54	low	low	4, 7
Cloquet	Cloquet	0.74	.85	7.2	90.0	21.0	54.0	55	low	low	3
Fall	Fall	8.93	3.99	6.7	45.0	16.0	43.0	51	med	low	3, 5
Greenwood	Stony	5.06	1.27	6.65	170.0	8.0	50.0	60	low	med	3
Long	St. Louis	1.79	.50	7.1	30.0	14.0	46.0	46	low	med	4, 7
One	Kawishiwi	3.55	3.14	6.7	27.0	15.0	27.0	52	low	low	3, 4
Perch	Bear Island	0.44	2.30	6.5	82.5	7.5	28.5	51	low	low	4, 7
Pine	St. Louis	1.77	2.34	7.8	102.5	18.0	59.5	52	low	med	4, 7
Sand	Stony	2.05	1.45	7.25	80.0	21.5	63.5	60	low	med	3
Slate	Stony	0.93	1.51	6.8	180.0	21.0	51.0	--	low	med	4
South McDougal	Stony	1.12	.51	6.7	260.0	11.0	36.0	55	low	med	4
Tofte	Moose Lake	0.47	10.73	8.55	3.0	70.5	147.5	38	low	low	4, 9, 10
Triangle	Moose Lake	1.32	3.99	7.7	2.0	34.0	65.0	46	low	low	9
Turtle	Isabella	1.36	1.13	6.85	30.0	8.5	26.0	50	low	low	4, 9
Whiteface Res.	Whiteface	17.22	3.15	7.05	137.5	19.75	57.5		low	low	1, 3, 5
Wynne	Embarrass	--	11.1	7.2	110.0	42.5	139.0	43	low	low	3

Table 2 (contd.)

[a]Summertime averages (June, July, and August data) from Water Quality Programs.

[b]TSI (P) = Carlson's Trophic State Index based on median total phosphorus concentrations.

[c]Potential direct impact: Lake may receive effluents either directly from mining operation or tailings basin, or receives water from a directly impacted watershed.

[d]Potential indirect impact: Lake may receive impacted water "second hand," or is in area likely to receive air-borne contaminates.

[e]1. Likely to be impacted by copper-nickel development
2. Not likely to be impacted ("control")
3. Represents a particular watershed
4. Chosen because of a prevailing soil type and/or percent predominant slope
5. Receives water from large watershed
6. Receives water from small watershed
7. No inlet
8. No outlet
9. Neither inlet nor outlet
10. Chosen because of greater maximum depth

Table 3. Physical and chemical characteristics of study area lakes. Lakes are arranged in order of increasing values for Schindler's (1971) ratio $A_d + A_o/V$. (A_d = area of terrestrial portion of lake's drainage; A_o = surface area of lake; V = volume of lake.) Water chemistry values are averages for summertime samples, 1976 and 1977. For survey lakes only one or two measurements were made.

Lake	$\frac{A_d + A_o}{V}$ (rel.)	A_o (km^2)	Max. Depth (m)	Color (Pt-Co units)	Secchi Disk (m)	pH	Cond. (µmhos/cm)	Total Alkalinity (mg/1 $CaCO_3$)	Total Hardness (mg/1)	TOC (mg/1)	Total P (ug/1)	NO_3-N + NO_2-N (mg/1)	NH_4-N (mg/1)	SO_4 (mg/1)	Dissolved Silica (mg/1)
Tofte	0.4	0.47	22	3	5.3	8.6	148	71	31	6	9	0.009	0.01	8.4	0.8
Clearwater	0.6	2.61	14	2	4.0	6.7	39	16	24	7	50*	0.050	0.03	4.0	0.5
Bear Island	1.2	8.64	22	40	2.9	7.4	45	16	24	12	18	0.027	0.04	6.2	3.6
Bearhead	1.3	2.74	14	26	1.8	7.9	68	24	31	11	17	0.030	0.03	8.9	5.8
Triangle	1.3	1.32	12	2	3.8	7.7	65	34	81	7	20	0.010	0.03	4.3	0.4
Big	2.5	3.21	5	14	3.0	7.6	62	25	22	11	30	0.010	0.01	8.1	2.7
Perch	3.6	0.44	9	83	1.3	6.5	29	8	12	16	33	0.017	0.01	4.2	1.9
Bass	3.6	0.68	11	7	5.0	8.2	80	32	41	6	20	0.010	0.02	11.0	3.4
Pine	4.0	1.77	4	103	1.4	7.8	60	18	25	29	29	0.050	0.01	7.8	1.6
Turtle	5.0	1.36	3	30	1.8	6.9	26	9	11	13	22	0.010	0.01	3.1	1.0
Whiteface	6.5	17.22	9	138	1.0	7.1	58	20	42	30	33	0.089	0.09	9.1	6.2
Cloquet	10.4	0.74	2	90	-	7.2	54	21	32	22	40	0.020	0.02	11.0	8.7
Sand	14.4	2.05	12	80	1.4	7.3	64	22	-	28	37	0.009	0.01	8.0	6.0
Greenwood	17.2	5.06	2	170	1.1	6.7	50	8	-	31	38	0.024	0.01	9.8	2.5
One	19.3	3.55	17	27	2.4	6.7	27	15	10	11	40	0.010	0.04	4.2	3.9
Seven Beaver	19.6	5.63	2	168	0.8	6.5	49	13	23	28	43	0.042	0.06	5.4	1.6
Birch	23.6	25.62	8	55	1.9	7.1	69	23	37	14	30	0.073	0.10	8.9	4.9
Long	26.0	1.79	2	30	2.6	7.1	46	14	18	14	11	0.008	-	-	1.6
Wynne	29.4	1.15	16	110	1.9	7.2	139	43	-	25	24	0.130	0.02	29.0	8.6
White Iron	32.6	13.85	15	72	1.7	7.0	52	17	22	14	26	0.031	0.10	8.6	5.2
Colby	47.7	2.24	11	136	2.4	7.1	153	33	60	22	23	0.022	0.09	29.8	6.5
So. McDougal	67.6	1.12	2	260	0.9	6.7	36	11	17	23	40	0.010	-	6.0	5.2
Gabbro	78.2	3.63	15	100	1.4	7.3	48	18	25	15	27	0.037	0.05	4.3	7.3
Fall	106.4	8.93	10	45	1.8	6.7	43	16	24	13	30	0.030	0.06	5.4	4.5
Slate	322.8	0.96	3	180	-	6.8	51	21	22	27	50*	0.060	0.02	5.6	5.8

*contaminated?

Table 4. Lake groups based on total organic carbon and color. (TOC values are mg/l; color values are Pt-Co units.)

TOC = 6 - 7 Color = 2 - 7	TOC = 11 - 16 Color = 14 - 100	TOC = 22 - 31 Color = 80 - 260
Tofte	One	Colby
Bass	Bearhead	Cloquet
Clearwater	Big	So. McDougal
Triangle	Bear Island	Wynne
	Turtle	Slate
	Fall	Seven Beaver
	White Iron	Sand
	Long	Pine
	Birch	Whiteface
	Gabbro	Greenwood
	Perch	

Table 5. Lake groups based on summertime measurements of chlorophyll a. (No data are available for Whiteface Reservoir.)

Max. Chlorophyll a (µg/l)		
0 - 4	5 - 10	11 - 20
Tofte	Bear Island	Greenwood
Clearwater	Bearhead	Seven Beaver
Bass	Triangle	Birch
	Big	White Iron
	Pine	Colby
	Turtle	Gabbro
	Cloquet	Slate
	Sand	Perch
	One	
	Long	
	Wynne	
	So. McDougal	
	Fall	

Table 6. Thermal stratification of study area lakes, 1976.

	June-July			August		
	Strong	Weak	None	Strong	Weak	None
Primary Lakes		White Iron (Sta. 1) Colby	Seven Beaver Gabbro White Iron (Sta. 2) Birch	Colby	White Iron (Sta. 1)	Gabbro Birch White Iron (Sta. 2) Seven Beaver
Survey Lakes	One Bass Tofte Triangle Wynne Bear Island	Fall Big Bearhead Perch Whiteface Reservoir	Clearwater Cloquet Pine Long Slate So. McDougal Sand Greenwood Turtle		No Data	

Table 7. Chlorophyll a concentrations (μg/l) in primary lakes, 1976.

Lake	Station	May	June	August	September	October
Birch	1	5.6	6.0	10.5	12.0	-
	2	5.3	6.5	14.0	11.4	11.0
	3	6.0	7.6	14.0	10.9	12.5
	4	7.4	8.0	11.1	11.4	14.7
White Iron	1	4.9	4.4	11.4	13.4	13.6
	2	4.9	6.7	12.9	15.4	7.1
Gabbro	1	6.2	8.7	10.4	11.1	10.0
	2	4.0	8.0	14.4	15.3	6.5
Seven Beaver	1	9.6	12.0	12.3	-	-
	2	8.5	8.5	11.8	-	-
Colby	1	4.9	3.3	11.1	11.1	7.3
	2	3.3	4.4	12.9	12.3	5.3

Table 8. Dominance for algal groups in summer samples from study lakes. Data for primary lakes during 1976 are from August samples.

Algal Group	Number of Lakes Showing Dominance by Each Algal Group*	
	1976	1977
Cyanophyta	9	5
Chrysophyta	7	5
Cabillariophyta	7	2
Chlorophyta	1	2
Total number of lakes sampled	24	14

*Dominance is based on total unit concentrations, not cell concentrations, for each group in each sample.

Table 9. Phytoplankton species diversity (number of species observed) in study lakes, summer samples, 1976 and 1977. Data for primary lakes during 1976 are from August samples. No summer samples were collected for Whiteface Reservoir.

Lake		Number of Species							
		Bacillario-phyta	Chloro-phyta	Cyano-phyta	Chryso-phyta	Crypto-phyta	Pyrrho-phyta	Eugleno-phyta	Total
Primary:									
Birch	'76	31	32	21	7	1	2	3	97
	'77	16	8	9	5	1	3	1	43
Seven Beaver	'76	45	37	19	6	1	1	5	114
	'77	22	22	11	4	1	1	0	61
White Iron	'76	26	19	18	6	2	1	0	72
	'77	10	6	6	7	0	1	0	30
Colby	'76	28	12	10	6	2	3	0	61
	'77	28	9	5	4	1	1	1	49
Gabbro	'76	27	16	16	6	2	2	2	71
Survey:									
Pine	'76	26	11	5	7	1	3	1	54
	'77	12	14	4	6	0	3	1	40
Bass	'76	11	10	9	4	1	1	0	36
	'77	12	9	8	0	1	1	1	32
Bearhead	'76	15	12	3	7	2	5	0	44
	'77	11	13	7	4	1	2	1	39
Perch	'76	18	11	1	7	1	3	2	43
	'77	0	7	2	3	0	0	0	12
Sand	'76	29	9	4	7	2	4	0	55
	'77	10	7	2	3	1	1	0	24
Greenwood	'76	11	16	5	4	1	1	2	40
	'77	18	13	5	6	0	0	1	43
Tofte	'76	12	1	4	3	1	0	0	21
	'77	12	9	7	1	1	0	0	30
Turtle	'76	22	16	8	2	1	6	1	56
	'77	24	16	12	4	0	4	0	60
Wynne	'76	19	7	5	4	3	1	0	39
	'77	3	3	1	1	0	0	0	8
Bear Island	'76	19	13	12	4	2	2	2	54
	'77	12	19	7	4	1	0	2	45
Fall	'76	22	15	6	7	2	2	0	54
Long	'76	44	12	4	7	1	2	0	70
Big	'76	20	24	14	4	3	3	1	69
Slate	'76	50	7	2	2	3	2	1	67
So. McDougal	'76	46	11	5	3	2	1	2	70
One	'76	16	11	8	11	1	3	0	50
Cloquet	'76	33	25	12	4	3	4	2	83
Triangle	'76	14	6	9	4	1	3	0	37
Clearwater	'76	11	14	9	6	1	2	0	43

Note: Where samples were collected at several stations in a lake, these were pooled. Apparent differences in species diversity between 1976 and 1977 in primary lakes are artifacts since they result from pooling different numbers of samples.

Table 10. Characteristic phytoplankton algae of study lakes. Algae included in the table are those which were present in more than two-thirds of the lakes during at least two sampling seasons and which were present as dominants on at least one occasion. For the Bacillariophyta, Chlorophyta, Cyanophyta, and Chrysophyta dominant species are defined as the 5 most abundant species in each group in a given sample. For the Cryptophyta and Pyrrhophyta dominant species are defined as the 2 most abundant species. The number of units (not cells) of a species was taken as the measure of its abundance.

Species	Percent of Lakes in which Species was Dominant or Present							
	Summer 1976 (24 lakes sampled)		Summer 1977 (15 lakes sampled)		Fall 1976 (23 lakes sampled)		Fall 1977 (12 lakes sampled)	
	Dominant	Present	Dominant	Present	Dominant	Present	Dominant	Present
Bacillariophyta								
Asterionella formosa	75	96	53	80	96	100	83	92
Cyclotella bodanica	33	75	13	60	13	78	0	17
Fragilaria crotonensis	71	96	67	93	48	87	33	67
Melosira ambigua	29	79	27	53	74	91	58	83
Melosira distans	50	71	27	67	39	70	8	25
Nitzschia sp.	46	88	27	67	17	87	33	58
Tabellaria fenestrata	67	96	47	100	61	83	75	100
Chlorophyta								
Ankistrodesmus falcatus including varieties acicularis & mirabilis	75	96	40	87	61	91	50	75
Botryococcus Braunii	21	88	27	40	4	87	8	8
Oocystis sp.	54	88	20	87	43	87	8	42
Cyanophyta								
Agmenellum quadrupli-catum (= Merismopedia glauca)	71	79	67	87	43	70	17	17
Aphanocapsa delicatissima	88	92	60	80	78	83	58	67
Coelosphaerium Kuetzing-ianum	50	88	20	27	43	91	8	17
Chrysophyta								
Dinobryon bavaricum	92	92	60	73	70	87	33	33
Dinobryon divergens	75	75	60	60	70	87	50	58
Dinobryon sertularia var. protuberans	58	71	60	67	30	65	17	25
Cryptophyta								
Cryptomonas erosa	79	83	60*	67*	74	78	92	92
Pyrrhophyta								
Ceratium hirundinella	50	88	7	47	17	74	8	8

*Cryptomonas spp.

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Table 11. Proportion of Diatoms in Surface Water Phytoplankton and Proportion of Dominants within Diatom Samples.

	Clearwater	Gabbro	Birch	White Iron
Diatoms as percentage of total phytoplankton cells in surface water samples, July or August and October, 1976.	6.4%	7.6%	13.0%	11.4%
Percentage of frustules contributed by top 10 diatoms				
- in surface water samples	81%	89%	98%	84%
- in surface sediment samples	69%	63%	68%	62%

Table 12. Summary of percentages of planktonic and benthic species contributed by the top 10 diatoms in surface sediment samples.

	CLEARWATER	GABBRO	BIRCH	WHITE IRON
Planktonic dominants	44.1%	49.9%	62.0%	53.4%
Benthic dominants	24.9%	13.1%	6.3%	8.8%
Total percent contributed by top 10 diatoms	69.1%	63.0%	68.3	62.2%

Appendix A

Tables 1 through 20 summarize the abundance of 'dominant' taxa in each of the algal divisions in lakes sampled for the Regional Study in summer and fall, 1976 and 1977. Dominants are defined as the five most abundant taxa in each of the group Bacillariophyta, Chlorophyta, Cyanophyta, and Chrysophyta, and the two most abundant taxa in Cryptaphyta and Pyrrhophyta. Taxa are included in the tables if they appeared as dominant in any of the lakes in the sample period tabulated. The abundance of dominant taxa is given in units/ml.

Counting units utilized were:

Unicells - each cell
Diatoms - each complete frustule (2 valves)
Filaments - 100 microns length
Discrete colonies - each 4,8,16,32, or 64 cell colony
Indiscrete colonies - every 8 cells
Dense colonies - every 50 cells

Cells per counting 'unit' were recorded for discrete and indiscrete colonies. Examples of discrete colonial forms include Pandorina, Volvox, and Oocystis. Indiscrete colonial forms include Agmenellum (Merismopedia), Chroococcus and Crucigenia. Examples of dense colonies are Microcystis, Aphanothece, and other cocoid blue-greens.

For taxa present but not dominant in a lake on that date, the entry is a P. For 1976, when 2 samples were analyzed from more than one station per lake for many lakes, the numbers given are averages of all samples collected and analyzed from that lake, that date.

TOTALS GIVEN ARE TOTAL UNITS FOR THE GROUP, INCLUDING ALL TAXA, NOT JUST IN THE TABLE.

Samples were collected with a 4 meter integrated sampler tube during the time intervals shown below:

All Lakes

Sample Period	Primary Lakes ('76)	Survey Lakes ('76)
Summer, 1976	June 15 - June 24	July 7 - July 15
October, 1976	October 5 - October 14	October 18 - October 25
Summer, 1977	July 6 - July 12	
October, 1977	October 12 - October 14	

Table 1. Diatoms (Bacillariophyta)
Sampled in June or July, 1976, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes \ TAXA	Achnanthes sp.	Asterionella formosa	Cyclotella bodanica	Cyclotella stelligera	Cymbella naviculiformis	Fragilaria capucina	Fragilaria construens	Fragilaria crotonensis	Melosira ambigua	Melosira distans	Melosira granulata	Melosira italica	Navicula cryptocephala	Navicula pupula	Navicula scutelloides	Navicula sp.	Nitzschia sp.	Pinnularia sp.	Rhizosolenia eriensis	Rhizosolenia longiseta	Stephanodiscus astraea	Synedra delicatissima	Synedra sp.	Tabellaria fenestrata	TOTAL
Greenwood	-	218	-	-	-	-	-	42	P	26	-	-	-	-	-	-	42	-	P	-	-	-	-	48	413
Colby	3	7	-	-	-	-	-	P	P	P	P	P	-	P	-	P	P	P	P	-	P	-	2.0	3.0	33
Bass	-	P	19	-	4	-	-	276	21	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	330
Bear Island	P	4	12	P	-	-	-	P	P	P	P	9	-	-	-	-	4	P	P	-	-	-	-	12	73
Birch	P	27	P	P	-	-	-	P	-	46	100	-	-	P	-	P	P	-	P	P	26	-	P	18	501
Bearhead	-	-	P	4	-	-	-	4	9	-	-	-	-	-	-	P	10	-	-	-	-	-	P	4	50
Seven Beaver	-	153	P	P	P	-	-	173	P	P	166	-	P	P	-	58	P	P	-	-	P	-	P	230	1054
Pine	-	53	11	P	P	-	-	P	P	-	-	P	P	-	-	-	27	-	32	-	-	-	-	11	171
Perch	-	76	P	P	P	-	-	P	P	21	-	-	-	-	-	-	13	-	60	100	-	-	-	P	434
Tofte	-	5	-	-	-	-	-	106	-	-	-	-	-	5	5	P	P	-	-	-	-	-	-	P	136
Sand	-	P	P	P	-	-	-	82	21	107	P	P	P	-	-	-	56	P	33	P	-	-	-	P	431
Wynne	P	P	-	P	P	-	-	5	-	P	P	P	5	-	-	3	5	-	-	5	-	-	-	P	37
White Iron	P	74	P	P	-	P	-	7	P	51	45	-	P	P	-	P	P	P	P	P	P	-	P	22	250
Turtle	P	9	12	-	P	-	-	4	P	-	-	-	-	P	-	-	5	P	P	-	-	-	-	142	193
Gabbro	P	175	P	P	-	-	-	58	P	400	215	-	-	P	-	P	P	P	P	P	P	-	P	85	1102
Triangle	-	79	3	-	-	-	-	76	P	-	-	-	-	P	-	-	P	-	18	P	-	-	-	24	224
Fall	P	P	P	-	-	-	-	147	55	P	281	P	P	P	-	-	P	-	52	-	-	-	-	139	912
Long	-	244	-	P	-	-	-	63	63	P	39	-	P	P	-	P	34	P	P	P	-	-	P	P	719
One	P	42	21	P	-	-	-	-	P	42	-	P	-	-	-	-	-	-	26	90	-	-	P	P	348
Cloquet	P	8	-	-	-	-	-	8	76	P	-	-	P	P	-	P	34	10	-	-	-	-	-	P	227
Clearwater	P	2	12	-	-	-	-	P	-	-	-	-	-	4	-	P	-	-	47	-	-	-	P	65	136
S. McDougal	-	45	P	P	P	P	-	34	P	26	-	P	P	-	-	P	3	P	-	-	-	-	-	37	261
Slate	P	P	P	P	-	16	38	P	52	10	-	P	-	P	-	P	P	P	-	-	-	-	-	10	142
Big	-	77	49	P	-	-	-	146	-	58	-	-	-	-	-	-	P	-	P	-	P	-	P	140	523

TAXA	Big	Slate	S. McDougal	Clearwater	Cloquet	One	Long	Fall	Triangle	Gabbro	Turtle	White Iron	Wynne	Sand	Tofte	Perch	Pine	Seven Beaver	Bearhead	Birch	Bear Island	Bass	Colby	Greenwood
Ankistrodesmus falcatus	P	-	-	12	P	P	P	P	8	P	12	-	P	P	-	13	P	P	18	5	P	P	4	P
Ankistrodesmus falcatus var. acicularis	P	8	P	56	-	16	P	29	5	40	-	26	13	21	-	3	32	11	P	-	18	-	P	P
Ankistrodesmus falcatus var. mirabilis	-	P	-	-	-	-	29	21	-	-	-	5	9	32	-	-	-	P	-	P	P	P	-	P
Ankistrodesmus spirales	-	P	P	P	-	-	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	-
Arthrodesmus ralfsii	-	-	P	-	-	-	P	-	P	-	-	P	-	-	-	-	-	P	4	-	-	-	P	-
Arthrodesmus triangularis	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-
Bambusina brebissonii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Binuclearia sp.	21	14	32	-	121	-	P	-	-	-	P	-	-	-	-	P	11	-	-	-	-	-	-	159
Botryococcus braunii	P	-	5	P	P	P	P	P	8	P	11	P	P	-	P	3	P	P	P	-	5	P	-	P
Chlamydomonus sp.	-	-	-	-	-	P	-	P	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	P
Cosmarium sp.	P	-	-	P	P	P	-	P	P	P	P	P	-	P	P	5	-	P	P	P	P	P	-	P
Crucigena apiculata	-	P	P	7	P	-	-	-	-	P	P	-	-	-	-	-	-	P	-	-	-	-	-	21
Crucigenia irregularis	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35	-	-
Crucigenia sp.	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	P	-	-	3	-
Crucigenia tetrapedia	P	4	8	-	81	27	8	P	10	P	P	P	-	7	-	-	P	P	-	-	P	-	-	74
Crucigenia truncata	-	-	P	-	-	-	-	-	-	20	-	P	-	-	-	P	-	P	-	-	-	-	-	-
Crucigenia quadrata	26	-	P	-	50	P	-	21	-	-	P	-	-	P	-	-	P	-	-	-	-	-	-	P
Dictyosphaerium pulchellum	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	P	-	P	-	P	P	-
Gleoystis gigas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	62	-	P	-	-	10	-
Gleocystis sp.	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-
Golenkinia radiata	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	16	-	-	P	-	-	-	-
Kirchneriella contorta	P	-	-	-	P	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Micractinium pusillum	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-
Oocystis sp.	16	5	16	23	P	P	8	P	5	18	P	P	5	5	P	-	-	40	P	20	23	-	P	37
Pediastrum tetras	-	-	-	-	-	-	-	-	-	253	-	P	-	-	-	-	-	P	-	P	-	-	P	-

Table 2. Chlorophyta
Sampled in June or July, 1976, by RCNS
Numbers represent abundance of dominants in units/ml.

Table 3. Cyanophyta
Sampled in June or July, 1976, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes \ TAXA	Agmenellum quadriduplicatum	Anabaena circinalis	Anabaena flos-aquae	Anabaena planctonica	Anabaena spiroides	Anabaena spiroides var. crassa	Anabaena sp.	Aphanizomenon flos-aquae	Aphanocapsa delicatissima delicatissima	Aphanocapsa sp.	Aphanothece nidulans	Aphanothece sp.	Chroococcus dispersus	Chroococcus limneticus	Coelosphaerium kuetzingianum	Coelosphaerium naegelianum	Gloeotrichia sp.	Lyngbya lageheimii	Phormidium angnstissima	Aphanocapsa elachista	Total
Greenwood	414	-	-	-	-	-	32	-	117	-	-	-	-	-	875	-	-	-	-	-	1443
Colby	P	45	95	-	P	-	30	86	P	-	-	-	-	-	P	-	-	-	-	-	448
Bass	-	-	30	18	-	-	P	26	53	-	-	P	-	P	21	P	-	-	-	-	158
Bear Island	95	P	19	P	-	-	P	-	55	-	-	P	35	19	P	P	-	-	-	9	257
Birch	144	P	P	P	P	P	P	1727	1394	P	-	P	-	-	P	675	-	-	-	-	9231
Bearhead	60	-	-	-	-	-	5	2	-	-	-	-	-	-	-	P	-	-	-	-	67
Seven Beaver	2820	P	-	P	-	-	P	P	37500	P	8363	P	P	P	P	1938	-	-	-	-	58409
Pine	127	-	-	-	-	-	5	-	27	-	-	-	-	5	21	-	-	-	-	-	185
Perch	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	3
Tofte	-	-	-	-	-	-	26	-	80	P	-	-	-	-	5	-	-	-	366	?	477
Sand	98	-	-	19	-	-	-	-	40	-	-	-	-	-	P	2	-	-	-	-	159
Wynne	-	-	21	-	-	-	-	8	3	-	-	-	3	-	5	P	-	-	-	-	40
White Iron	P	115	-	P	55	-	P	76	275	P	-	-	-	-	P	P	-	-	-	-	1844
Turtle	63	-	P	-	-	-	-	-	23	P	-	-	179	P	-	-	-	14	-	67	360
Gabbro	178	P	P	P	305	P	P	P	763	950	-	P	P	P	P	P	-	-	-	-	8649
Triangle	-	-	24	P	-	-	P	10	10	P	-	-	10	-	P	P	32	-	-	10	109
Fall	34	-	-	-	29	-	-	26	60	P	-	-	-	P	63	P	-	-	-	10	222
Long	218	-	-	-	-	-	10	-	92	-	-	-	-	-	32	-	-	-	-	-	352
One	175	-	-	-	-	-	P	-	32	-	-	69	P	P	133	P	-	-	-	-	429
Cloquet	220	-	-	-	-	-	P	-	83	-	-	-	P	16	108	P	-	-	-	5	493
Clearwater	207	-	P	-	-	-	P	-	93	-	26	-	-	-	19	-	-	-	-	77	446
S. McDougal	375	-	8	-	-	-	3	-	37	-	-	-	-	-	129	-	-	-	-	-	552
Slate	3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	4
Big	121	P	-	-	-	-	-	P	184	-	-	P	-	123	P	51	-	-	-	202	804

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Table 2 (cont.) Chlorophyta

Lakes \ TAXA	Pediastrum tetras var. tetraodon	Quadrigula pfitzeri	Scenedesmus abundans	Scenedesmus denticulatus	Scenedesmus quadricauda	Scenedesmus sp.	Sphaerozosma sp.	Schroederia judayi	Schroederia setigera	Sphaerocystis schroeteri	Spondylosium planum	Staurastrum paradoxum	Tetraedran minimum	Xanthidium subbastiferum	Total
Greenwood	P	-	-	-	P	-	P	-	-	32	P	-	-	P	435
Colby	-	-	P	-	P	P	-	-	2	-	-	-	-	-	56
Bass	-	P	-	P	-	-	-	18	-	12	23	-	P	P	133
Bear Island	4	P	-	P	P	P	-	-	-	-	P	-	P	-	74
Birch	-	P	P	-	P	P	-	-	7	42	-	-	-	-	165
Bearhead	4	5	-	10	-	-	-	-	-	-	-	-	-	-	55
Seven Beaver	-	-	-	-	77	-	-	-	-	P	P	P	-	-	589
Pine	P	11	11	P	P		-	-	-	-	P	-	P	P	111
Perch	21	-	-	-	-	-	-	-	-	-	-	-	-	3	63
Tofte	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
Sand	P	-	-	-	5	-	-	-	-	-	-	-	P	-	82
Wynne	-	-	-	P	-	-	-	-	-	P	-	-	-	-	39
White Iron	-	-	-	-	9	P	-	-	P	P	P	-	-	-	192
Turtle	P	7	-	19	P	-	-	-	-	-	-	-	P	-	94
Gabbro	-	-	-	-	-	P	-	-	-	P	P	-	-	P	481
Triangle	-	-	-	P	-	-	-	-	-	-	P	-	-	-	39
Fall	P	-	-	-	P	-	P	-	-	71	P	-	-	P	229
Long	P	8	P	-	P	-	-	-	10	-	-	-	P	-	94
One	P	16	-	-	P	-	-	-	-	-	P	-	-	-	92
Cloquet	68	197	P	P	P	P	P	-	-	-	-	-	P	-	784
Clearwater	P	P	-	-	-	-	P	-	-	-	12	-	P	-	149
S. McDougal	P	-	-	P	P	-	-	-	-	-	-	-	-	5	93
Slate	-	-	-	-	P	-	-	-	-	-	-	-	-	-	34
Big	P	P	-	P	P	-	44	-	P	-	-	-	81	-	277

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Lakes \ TAXA	Centritractus belanophorus	Chrysosphaerella longispina	Dinobryan bavaricum	Dinobryan cylindricum	Dinobryan divergens	Dinobryan sociale	Dinobryan sociale var. americanum	Dinobryan sertulia var. protuberans	Dinobryan sp.	Mallomonas akrokomonas	Mallomonas pseudcornata	Mallomonas sp.	Ophiocytinum bicuspididatum	Ophiocytinum cupitatum var. longisoninum	Ophiocytinum sp.	Stipitacoccus apiculatis	Synura adamsii	Synura uvella	Synura sp.	Tribonema sp.	Total
Greenwood	11	-	42	-	-	-	-	-	-	-	-	21	-	5	-	-	-	-	-	-	79
Colby	P	-	13	-	330	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	344
Bass	2	-	-	P	4	2	-	18	-	-	-	-	-	-	-	-	-	-	-	-	26
Bear Island	-	-	12	5	-	-	-	-	-	7	-	-	-	-	-	-	-	67	-	-	91
Birch	P	-	P	-	P	-	-	24	-	-	-	P	-	-	-	-	-	184	-	-	237
Bearhead	P	-	86	7	225	-	-	51	-	-	-	4	-	-	-	-	-	4	-	-	379
Seven Beaver	-	-	7	-	164	16	-	-	-	-	-	P	9	-	-	-	-	-	-	-	189
Pine	5	-	5	-	1289	-	-	5	5	-	-	5	-	5	-	-	-	-	-	-	1319
Perch	-	-	165	-	26	-	-	-	3	-	-	P	-	5	-	-	-	39	-	-	242
Tofte	-	-	11	-	-	700	-	-	-	5	-	-	-	-	-	-	-	-	-	-	716
Sand	7	-	177	-	5	-	-	46	12	-	-	-	-	P	-	-	-	4	-	-	255
Wynne	-	-	116	-	-	-	-	P	8	-	-	63	-	-	-	-	-	5	-	-	192
White Iron	P	-	4	-	5	P	-	56	-	-	-	4	P	-	P	-	-	496	-	-	568
Turtle	-	-	7	-	-	-	-	44	P	-	-	-	-	-	-	-	-	-	-	-	51
Gabbro	-	-	P	P	6	-	-	72	-	-	-	11	P	-	P	12	-	1792	-	-	1896
Triangle	-	-	533	-	186	10	-	-	-	-	-	P	-	-	-	-	-	16	-	-	745
Fall	P	-	152	-	42	-	-	13	13	-	-	13	-	-	-	-	-	42	-	-	278
Long	P	-	16	144	3	-	-	P	3	-	-	3	-	13	-	-	-	94	-	-	276
One	P	P	64	P	42	-	-	578	P	-	-	P	-	P	-	-	37	493	-	-	1310
Cloquet	5	-	-	-	5	-	-	P	5	-	-	5	-	-	-	-	-	-	-	-	20
Clearwater	2	-	51	-	53	-	70	2	-	-	-	5	-	-	-	-	-	-	-	-	183
S. McDougal	-	-	5	-	373	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	386
Slate	-	-	10	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	26
Big	-	-	9	-	7	7	-	14	-	-	-	-	-	-	-	-	-	-	-	-	37

Table 4. Chrysophyta
Sampled in June or July, 1976, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes	CRYPTOPHYTES: Chroemonas sp.	Cryptomonas erosa	Cryptomonas erosa var. reflexa	Cryptomonas marsonii	Cryptomonas ovata	Total	DINOFLAGELLATES: Ceratium hirundinella	Cystodinium iners	Glenodinium penardinforme	Glenodinium oculatum	Glenodinium sp.	Gymnodinium sp.	Peridinium inconspicuum	Peridiniuum wisconsinense	Peridinium sp.	Total	EUGLENOPHYTA: Euglena sp.	Phacus acuminatus	Phacus sp.	Trachelomonas volvocina	Trachelomonas sp.	Total
Greenwood	-	48	-	-	-	48	5	-	-	-	-	-	-	-	-	5	5	-	5	-	-	10
Colby	-	-	49	-	15	64	-	-	-	-	-	-	-	-	1	1	P	-	-	-	-	0
Bass	-	60	-	-	-	60	5	-	-	-	-	-	-	-	-	5	-	-	-	-	-	0
Bear Island	-	99	-	P	9	108	2	-	-	-	-	3	-	-	-	5	-	-	P	-	5	8
Birch	-	-	60	-	42	102	P	-	-	-	-	-	-	-	-	1	P	1	P	-	P	1
Bearhead	-	16	-	7	-	23	P	P	-	-	19	P	105	P	P	151	-	-	-	-	-	0
Seven Beaver	-	-	17	-	7	24	P	-	-	-	4	-	-	-	-	4	P	-	-	-	2	3
Pine	-	11	-	-	-	11	P	-	-	-	11	-	5	5	-	21	-	-	-	-	5	5
Perch	-	37	-	-	-	37	P	-	-	-	-	-	328	60	-	391	P	-	-	26	-	29
Tofte	-	16	-	-	-	16	P	-	-	-	-	-	-	-	-	0	-	-	-	-	-	0
Sand	-	21	2	-	-	23	P	-	-	-	-	-	16	P	-	22	-	-	-	-	-	0
Wynne	-	47	18	-	8	73	P	-	-	-	-	-	10	-	-	10	-	-	-	-	-	0
White Iron	-	-	32	-	60	92	P	-	1	-	3	-	-	-	-	4	-	-	-	-	-	0
Turtle	-	4	P	-	-	4	-	-	-	-	5	-	P	12	-	25	2	-	-	-	-	2
Gabbro	-	-	54	-	76	130	-	-	-	-	1	-	-	-	-	1	1	P	-	-	-	1
Triangle	-	39	-	-	-	39	3	-	-	3	-	-	10	P	-	16	P	-	-	-	-	0
Fall	-	118	-	-	18	136	3	-	-	-	13	-	-	-	-	16	-	-	-	-	-	0
Long	-	18	-	-	-	18	P	-	-	-	-	-	-	P	10	13	-	-	P	-	P	0
One	-	96	-	-	-	96	11	-	-	-	-	-	-	P	48	64	P	-	P	-	-	0
Cloquet	-	13	5	13	-	31	P	-	-	-	5	5	-	-	21	34	-	-	-	3	3	6
Clearwater	-	2	-	-	-	2	-	2	-	-	9	-	-	-	-	11	-	-	-	-	-	0
S. McDougal	-	18	3	-	-	21	5	-	-	-	-	-	-	-	-	5	P	-	P	-	5	8
Slate	-	54	-	-	122	177	-	-	-	-	10	-	4	-	-	14	3	-	-	-	-	3
Big	-	7	14	-	4	25	P	5	-	-	-	-	-	7	-	14	-	-	2	-	-	2

Table 5. Cryptophyta, Pyrrophyta, Euglenophyta
Sampled in June or July, 1976, by RCNS
Numbers represent abundance of dominants in units/ml.

Table 6. Diatoms (Bacillariophyta)
Sampled in October, 1976, by RCNS -
Numbers represent abundance of dominants in units/ml.

Lakes / TAXA	Achnanthes sp.	Asterionella formosa	Cyclotella bodanica	Cymbella minuta	Cymbella sp.	Diploneis sp.	Fragilaria capucina	Fragilaria construens	Fragilaria crotonensis	Melosira ambigua	Melosira distans	Melosira granulata	Melosira italica	Nitzschia linearis	Navicula pupula	Navicula subhamulata	Nitzschia sp.	Rhizosolenia longiseta	Rhizosolenia eriensis	Stephanodiscus niagarae	Tabellaria fenestrata	Total
Greenwood	-	186	-	-	-	P	-	-	P	54	10	-	-	-	-	-	5	-	P	P	44	330
Colby	P	50	P	P	P	P	29	-	81	53	P	8	-	-	P	-	P	-	-	P	P	254
Bass	-	159	16	P	-	-	P	-	80	212	P	-	-	-	-	-	P	-	P	P	122	647
Bear Island	P	144	P	P	P	P	71	-	P	80	P	134	P	-	-	-	P	-	P	P	P	628
Birch	P	2538	P	P	P	P	-	P	P	371	170	P	-	-	-	-	P	P	P	102	89	3462
Bearhead	-	1092	P	-	5	-	-	-	P	29	-	-	-	-	-	-	P	-	-	3	16	1158
Seven Beaver										NOT	SAMPLED											
Pine	-	121	P	P	-	P	-	-	34	P	-	-	16	-	P	P	P	P	39	P	32	299
Perch	-	133	53	-	-	-	-	-	P	32	P	-	-	-	-	-	P	P	186	-	483	945
Tofte	-	172	P	P	-	-	-	-	86	P	P	-	-	-	-	-	P	-	11	-	11	289
Sand	-	P	P	P	-	5	-	-	992	P	11	P	11	-	-	-	P	P	P	P	159	1193
Wynne	p	50	-	-	-	-	-	-	312	-	5	10	P	-	-	-	-	P	P	P	16	420
White Iron	P	1042	P	P	P	P	P	-	P	859	100	P	-	P	P	-	P	62	-	P	62	2316
Turtle	-	48	11	-	-	-	-	-	122	-	-	-	-	-	11	-	-	-	P	-	281	473
Gabbro	P	298	P	P	P	-	P	P	34	47	134	P	-	-	P	-	P	18	P	P	P	602
Triangle	5	467	-	-	-	-	-	-	159	58	-	-	-	-	-	-	-	-	-	P	117	807
Fall	P	173	P	-	-	P	-	-	P	P	147	P	236	-	P	-	P	-	94	P	74	1047
Whiteface Res.	-	10	-	-	-	-	-	-	16	76	-	3	-	-	-	-	P	-	-	-	16	142
One	P	144	P	-	P	-	-	-	-	321	68	P	118	-	-	-	P	P	123	-	P	915
Cloquet	P	368	P	13	-	-	-	-	58	113	P	-	-	P	P	-	47	-	-	-	P	860
Clearwater	P	80	P	-	-	-	-	-	P	74	-	-	106	-	P	-	P	P	16	P	143	664
S. McDougal	P	313	P	P	-	P	-	64	P	64	80	P	P	P	P	P	P	-	-	-	58	876
Slate	-	160	-	-	-	-	-	-	-	3	-	-	-	3	-	3	5	-	-	-	-	188
Big	-	158	P	P	P	-	-	-	128	148	P	P	P	-	-	-	112	P	P	P	244	1129

PRELIMINARY DRAFT SUBJECT TO MAJOR REVISION DO NOT QUOTE

Table 7. Chlorophyta. Sampled in October, 1976, by RCNS. Numbers represent abundance of dominants in units/ml.

Lakes \ TAXA	Ankistrodesmus falcatus	Ankistrodesmus falcatus v. acicularis	Ankistrodesmus falcatus v. mirabilis	Botryococcus braunii	Cosmarium sp.	Crucigenia apiculata	Crucigenia irregularis	Crucigenia quadrata	Crucigenia tetrapedia	Crucigenia truncata	Elakatothrix gelatinosa	Eudorina elegans	Kirchmeriella lunaris	Mougoetia sp.	Oedogonium sp.	Oocystis sp.	Quadrigula pfitzeri	Scenedesmus abundans	Scenedesmus denticulatus	Scenedesmus quadricauda	Schroederia setigera	Schroederia judayi	Sphaerozosma sp.	Spondlyosium planum	Staurastrum sp.	Tetraedron minimum	Westella botryoides	Total
Greenwood	P	P	-	P	P	18	-	P	16	-	P	-	-	P	-	18	-	-	-	5	25	-	-	P	-	-	-	92
Colby	-	-	4	P	-	-	-	-	P	-	-	1	-	-	-	P	-	P	P	-	2	-	-	-	-	P	-	24
Bass	P	-	P	P	P	-	P	-	P	-	P	-	-	-	-	P	P	-	P	-	P	P	-	P	P	P	-	5
Bear Island	P	4	P	8	P	P	1	23	P	-	-	-	-	-	-	11	P	P	P	P	P	-	-	-	P	P	-	66
Birch	P	P	25	P	-	P	-	-	P	P	-	P	P	P	-	P	4	P	-	7	24	-	-	-	-	-	-	116
Bearhead	P	8	-	P	P	-	-	P	-	-	-	-	-	-	-	3	P	-	P	P	P	-	-	-	3	P	-	28
Seven Beaver	NOT SAMPLED																											
Pine	P	P	-	P	P	P	-	P	16	-	P	-	21	-	-	26	P	P	P	P	-	-	32	P	P	P	58	221
Perch	32	26	-	P	P	16	-	P	-	-	P	-	-	-	16	-	16	-	P	P	-	-	-	P	P	-	-	153
Tofte	20	45	-	P	P	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	P	9	-	-	-	-	-	78
Sand	5	11	P	P	P	-	-	P	P	-	P	-	P	-	-	11	-	-	-	P	-	-	-	-	-	P	-	32
Wynne	13	3	-	-	-	-	-	-	-	-	P	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	21
White Iron	28	-	18	P	P	-	12	-	P	P	-	-	-	P	-	P	P	-	P	15	P	-	-	-	-	-	-	163
Turtle	P	-	-	P	P	-	-	P	P	-	-	-	-	-	-	P	P	-	26	P	-	-	11	P	-	-	-	82
Gabbro	-	-	P	-	-	-	-	-	P	3	-	P	-	75	2	-	-	-	P	3	P	-	-	-	-	-	-	180
Triangle	-	11	-	P	-	-	-	-	-	-	5	-	-	-	-	26	P	-	-	-	-	-	-	P	-	-	-	47
Fall	P	P	39	P	P	P	-	29	P	50	P	-	P	45	-	24	P	-	P	P	P	-	P	P	P	-	-	347
Whiteface Res.	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	16	-	-	-	-	-	26
One	P	21	P	P	8	-	-	P	8	-	P	-	-	60	-	P	P	-	P	P	-	-	-	13	P	-	-	130
Cloquet	P	P	-	P	P	68	P	126	60	-	P	-	-	-	-	63	P	P	P	39	-	-	P	-	P	P	-	465
Clearwater	11	26	-	P	P	P	-	P	-	-	P	-	-	-	-	P	P	-	P	P	-	-	P	P	P	P	-	88
S. McDougal	21	5	-	P	-	-	-	P	-	-	P	-	-	-	-	5	-	-	-	-	16	-	-	-	-	-	-	47
Slate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	3	-	-	3	11	-	-	-	-	-	17
Big	P	P	P	P	P	-	-	25	P	P	10	-	P	14	P	P	-	P	P	P	P	-	100	-	P	11	-	238

Table 9. Chrysophyta
Sampled in October, 1976, by RCNS

Lakes / TAXA	Centritractus belanophorus	Dinobryon bavaricum	Dinobryon cylindricum	Dinobryon divergens	Dinobryon sociale	Dinobryon sertularia v. protuberans	Dinobryon vanhoffenii	Dinobryon sp.	Mallomonas akrokomus	Mallomonas sp.	Ophiocytium mucronatum	Synura adamsii	Synura uvella	Total
Greenwood	2	47	-	-	-	-	-	-	-	28	-	-	7	84
Colby	-	8	1	27	-	2	-	-	-	-	-	-	-	37
Bass	P	P	P	P	P	P	-	-	-	5	-	-	-	5
Bear Island	-	P	2	P	-	-	-	-	17	-	-	-	16	66
Birch	1	24	P	24	-	-	-	-	-	1	1	-	-	51
Bearhead	8	8	108	228	-	299	-	-	34	P	-	-	P	690
Seven Beaver						NOT SAMPLED								
Pine	8	45	5	121	-	21	-	5	-	5	-	-	5	215
Perch	5	133	-	21	-	5502	-	-	-	16	-	-	P	5677
Tofte	3	P	-	138	12	-	-	-	5	20	-	-	-	176
Sand	P	P	-	P	-	P	-	P	-	-	-	5	37	42
Wynne	-	-	-	102	-	-	-	-	-	P	-	-	446	548
White Iron	1	76	-	8	-	-	-	-	-	P	-	-	-	85
Turtle	-	361	-	1618	-	11	318	32	-	-	-	-	-	2340
Gabbro	P	9	4	71	30	P	-	-	-	3	-	-	-	120
Triangle	-	32	-	1040	-	P	-	-	53	-	-	-	16	1141
Fall	3	184	-	26	-	P	-	P	10	-	-	-	24	247
Whiteface Res.	-	-	-	-	-	-	-	-	16	-	-	-	-	16
One	P	50	18	76	-	P	P	P	-	8	-	P	16	176
Cloquet	8	47	-	P	-	P	-	-	129	P	-	-	5	189
Clearwater	P	11	11	32	-	707	154	P	-	P	-	-	P	920
S. McDougal	42	-	-	-	-	-	-	-	16	-	-	-	-	58
Slate	3	8	-	291	-	P	-	-	58	8	-	-	3	371
Big	-	79	-	12	104	39	-	-	-	P	-	-	-	234

Numbers ... dominant units/ml

Table 8. Cyanophyta
Sampled in October, 1976, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes \ TAXA	Agmenellum quadriduplicatum	Anabaena flos-aquae	Anabaena planctonica	Aphanizomenon flos-aquae	Aphanocapsa delicatissima	Aphanocapsa elachista	Aphanothece nidulans	Coelosphaerium kuetzingianum	Coelosphaerium naegelianum	Chroococcus limneticus	Chroococcus dispersus	Lyngbya lagerheimii	Oscillatoria geminata	Oscillatoria sp.	Phormidium sp.	Rhaphidiopsis curvata	Total
Greenwood	5	-	P	-	9	-	-	7	P	2	-	-	-	-	-	-	23
Colby	-	P	-	190	6	-	-	P	P	-	-	-	-	P	5	P	239
Bass	P	11	138	1284	P	-	-	P	P	P	-	-	-	-	-	-	1433
Bear Island	90	P	P	-	61	P	-	65	33	P	P	-	-	-	P	-	324
Birch	42	-	-	P	169	-	-	10	P	-	-	-	-	-	52	P	364
Bearhead	P	P	-	P	18	3	-	34	P	-	-	-	-	-	-	-	55
Seven Beaver							NOT	SAMPLED									
Pine	3	-	-	-	3	P	-	P	P	P	-	-	-	P	-	-	6
Perch	53	-	-	-	32	-	-	16	-	-	-	-	-	P	-	-	106
Tofte	-	24	P	236	268	P	-	P	-	53	-	-	-	-	29	-	642
Sand	P	5	P	-	16	-	-	16	P	-	-	-	-	-	-	-	37
Wynne	-	P	-	18	-	-	-	P	P	-	-	-	-	P	-	-	18
White Iron	62	-	P	40	33	61	P	P	P	-	-	-	-	P	P	P	491
Turtle	58	-	-	-	32	69	-	74	-	P	P	26	-	-	-	-	280
Gabbro	P	P	P	322	101	-	-	P	P	-	-	-	-	58	-	18	606
Triangle	-	37	5	292	26	P	-	P	5	-	-	-	-	P	-	-	365
Fall	116	-	P	58	184	P	1	P	68	P	P	-	87	-	-	-	620
Whiteface Res.	-	-	-	501	-	-	-	-	5	-	-	-	-	-	-	-	506
One	P	-	P	P	10	-	-	10	3	P	3	-	-	3	-	-	29
Cloquet	105	-	-	-	158	26	-	45	P	18	P	-	-	P	-	-	399
Clearwater	P	P	-	-	26	37	16	16	P	16	P	-	-	-	-	-	148
S. McDougal	-	5	-	-	-	-	-	P	-	-	-	-	-	-	-	-	16
Slate	-	5	18	-	-	-	-	-	-	-	-	-	-	-	-	-	23
Big	37	-	24	23	150	60	P	P	P	P	-	-	-	P	-	-	310

PRELIMINARY DRAFT SUBJECT TO MAJOR REVISION DO NOT QUOTE

Table 10. Cryptophyta, Pyrrhophyta, Euglenophyta
Samples in October, 1976 by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes \ TAXA	CRYPTOPHYTES Cryptomonas erosa	Cryptomonas erosa v. reflexa	Cryptomonas marssonii	Cryptomonas nordstedii	Cryptomonas vata	Cryptomonas reflexa	Total	DINOFLAGELLATES	Ceratium hirundinella[a]	Cystodinium iners	Glenodinium	Gymnodinium	Peridinium inconspicuum	Peridinium willei	Total	EUGLENOPHYTES	Phacus sp.	Trachelomonas volvocina	Trachelomonas sp.	Total
Greenwood	54	-	28	-	-	-	82		P	-	-	-	-	-	0		P	-	-	0
Colby	-	4	-	-	14	-	18		-	-	-	-	-	-	0		-	-	-	0
Bass	64	-	-	-	5	5	74		5	-	-	-	-	-	5		P	16	P	16
Bear Island	50	-	-	-	2	-	52		P	-	P	-	-	-	0		P	16	P	21
Birch	-	10	-	-	53	-	62		1	-	-	-	-	-	1		P	-	-	0
Bearhead	26	-	39	-	-	26	109		P	P	P	P	P	-	0		-	-	-	0
Seven Beaver		NOT SAMPLED									NOT SAMPLED							NOT SAMPLED		
Pine	58	-	13	-	-	-	71		P	P	5	-	3	-	8		-	-	P	0
Perch	11	-	P	-	-	-	11		P	-	-	-	P	P	0		-	P	-	0
Tofte	17	35	P	-	-	11	70		5	-	-	2	-	-	7		-	-	3	3
Sand	P	21	-	-	-	5	26		P	-	-	-	P	-	0		P	-	-	0
Wynne	60	26	-	-	-	-	86		P	-	-	-	P	-	0		-	-	3	3
White Iron	-	1	-	1	14	-	16		P	-	-	-	-	-	0		-	-	-	0
Turtle	74	26	-	-	16	-	116		-	-	-	-	90	P	9		-	-	P	0
Gabbro	-	8	-	13	46	-	67		-	-	-	-	-	-	0		-	-	-	0
Triangle	85	58	-	-	-	P	159		P	-	-	-	-	5	5		-	5	-	5
Fall	44	3	-	-	45	-	92		3	-	-	-	-	-	3		-	-	5	5
Whiteface Res.	-	-	79	-	-	10	89		-	-	-	-	-	-	0		-	3	-	3
One	21	-	-	-	-	3	24		P	-	-	-	-	-	0		P	-	13	13
Cloquet	10	P	3	-	-	-	13		P	-	P	P	-	-	0		-	P	P	0
Clearwater	32	-	-	-	-	P	32		P	P	P	-	-	-	0		P	-	-	0
S. McDougal	90	-	42	-	-	P	132		-	-	-	-	-	-	0		-	-	-	0
Slate	84	-	74	-	-	3	161		-	-	-	-	-	-	0		-	-	-	0
Big	32	10	-	-	16	P	67		P	2	2	-	-	P	4		P	-	18	20

Lakes \ TAXA	Achnanthes minutissima	Asterionella formosa	Cyclotella bodanica	Diatoma tenue v. elongatum	Fragilaria crofonensis	Fragilaria vancheriae	Gomphonema angustatum	Melosira ambigua	Melosira distans	Melosira granulata	Melosira italica	Nitzschia spp.	Pinnularia acrosphaeria	Rhizosolenia eriensis	Synedra delicatissima	Tabellaria fenestrata	Synedra ulna	Total
Greenwood	P	31	-	203	23	P	-	-	P	-	P	34	-	-	-	23	P	411
Colby	78	-	-	P	36	-	P	P	P	P	P	15	-	-	-	P	20	222
Bass	-	P	34	83	36	P	-	-	-	-	-	P	-	-	-	P	45	236
Bear Island	-	P	42	28	P	-	-	17	P	P	-	-	-	P	-	80	-	235
Birch-3	-	171	P	P	99	-	-	94	P	39	P	P	-	P	-	216	-	689
Birch-1	-	P	P	-	78	-	-	-	28	44	34	P	-	P	-	28	-	286
Bearhead	-	13	P	-	16	-	-	-	-	-	-	P	-	10	-	10	-	93
Seven Beaver	-	166	P	P	P	-	-	171	P	-	42	36	-	P	-	42	-	641
Pine	-	6	-	6	21	-	-	P	P	-	-	16	-	-	-	P	-	75
Perch	-	P	-	-	-	P	-	-	-	-	-	-	-	-	-	P	-	0
Tofte	P	-	-	4	P	16	3	-	-	-	-	P	3	-	-	P	P	36
Sand	P	P	P	-	134	-	-	P	60	P	12	-	-	-	8	P	-	265
Wynne	-	174	-	P	P	-	-	-	75	-	-	-	-	-	-	-	-	251
White Iron	P	214	P	-	445	-	-	71	214	P	71	-	-	-	-	P	-	1123
Turtle	-	83	8	-	21	P	-	-	-	-	-	-	-	P	-	249	P	365

Table 11. Diatoms (Bacillariophyta)
Sampled in July, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes \ TAXA	Ankistrodesmus falcatus v. acicularis	Ankistrodesmus falcatus v. mirabilis	Arthrodesmus sp.	Binuclearia sp.	Botryococcus braunii	Chlorococcum numicola	Closterium ceratium	Crucigenia apiculata	Crucigenia guadrata	Crucigenia rectangularis	Crucigenia tetrapedia	Dictyosphaerium pulchellum	Elakatothrix gelatinosa	Mougeotia sp.	Oocystis parva	Oocystis sp.	Pediastrum tetras v. tetraodron	Quadrigula pfitzeri	Selenastrum spp.	Scenedesmus balatonius	Scenedesmus denticulatus	Scenedesmus quadricauda	Scenedesmus serratus	Scenedesmus sp.	Sphaerocystis schroeteri	Sphaerozosma spp.	Total
Greenwood	-	-	-	36	-	-	-	31	P	-	21	-	-	-	-	P	-	-	-	-	-	P	P	-	16	16	275
Colby	P	-	-	-	-	-	-	-	-	-	-	-	-	2	-	P	-	-	-	-	1	1	2	-	-	-	14
Bass	19	-	-	-	2	-	-	-	-	7	-	-	P	-	-	P	-	P	1	-	-	-	-	-	29	P	70
Bear Island	P	-	P	-	2	-	-	-	P	-	P	-	P	P	21	-	P	16	-	-	P	-	-	-	6	P	104
Birch-3	36	-	-	-	-	-	8	-	-	-	-	-	P	-	-	P	-	-	-	-	8	5	-	-	18	-	95
Birch-1	117	P	-	-	10	-	-	5	P	-	5	-	-	-	-	P	P	-	-	-	P	P	-	-	5	-	148
Bearhead	P	-	P	5	-	-	-	-	-	-	P	-	-	10	16	-	P	P	-	-	8	-	-	-	P	5	60
Seven Beaver	P	-	68	P	P	-	-	-	215	-	83	P	P	-	-	68	P	52	-	-	P	P	P	-	-	P	650
Pine	22	-	-	P	-	-	-	-	P	-	9	-	P	-	-	P	P	10	-	-	P	-	-	P	P	P	114
Perch	P	-	-	P	-	2117	-	-	25	-	25	-	-	-	P	-	-	75	-	-	P	-	-	-	50	-	2342
Tofte	P	-	-	-	-	-	-	-	-	7	-	-	P	P	-	18	-	P	-	1	-	-	-	P	4	-	38
Sand	8	P	-	-	-	-	-	-	-	-	2	-	-	-	-	P	P	-	-	-	-	-	P	4	4	-	28
Wynne	P	-	-	-	-	74,812	-	-	-	-	-	-	25	-	-	P	-	-	-	-	P	-	-	-	150	-	74,987
White Iron	71	18	-	-	P	74,729	-	-	18	-	-	18	-	-	-	P	P	P	-	-	18	-	P	-	-	P	74,872
Turtle	-	-	-	P	2	-	-	P	-	-	P	-	P	-	-	P	18	21	-	-	21	-	P	-	5	P	126

Table 12. Chlorophyta
Sampled in July, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes \ TAXA	Agmenellum quadriduplicatum	Anabaena flos-aquae	Anabaena spiroides var. crassa	Anabaena sp.	Aphanizomenon flos-aquae	Aphanocapsa delicatissima	Aphanocapsa elachista	Aphanotheca clathratum	Aphanothece spp.	Chroococcus dispersus	Coelosphoerium kuetzingianum	Coelosphaerium naegelianum	Coelosphaerium pallidum	Comphosphaerium lacustris	Oscillatoria geminata	Oscillatoria tenuis	Chrococcus limneticus	Total
Greenwood	36	-	-	-	-	205	5	-	-	2	-	-	361	-	-	-	-	609
Colby	7	-	-	-	-	-	1	-	-	2	-	-	-	-	1	1	-	12
Bass	P	59	-	P	227	P	-	-	43	P	14	-	55	-	-	-	P	418
Bear Island	17	-	P	-	-	16	30	10	-	P	-	-	P	22	-	-	-	109
Birch-3	P	203	-	65	73	P	-	-	-	P	382	-	127	-	-	-	-	869
Birch-1	31	23	P	-	P	P	-	-	-	P	10	2	8	-	-	-	-	94
Bearhead	28	-	-	P	P	8	10	2	-	-	-	-	5	-	-	-	-	60
Seven Beaver	1548	-	-	P	-	494	73	-	94	P	-	P	364	-	-	-	-	2712
Pine	6	-	-	-	-	26	P	-	-	14	-	-	1	-	-	-	-	47
Perch	6651	-	-	-	-	75	-	-	-	-	-	-	-	-	-	-	-	6726
Tofte	-	1	1	-	3	74	21	-	-	44	-	-	-	-	-	-	-	145
Sand	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2
Wynne	-	-	-	P	P	-	-	-	-	-	-	-	-	-	-	25	-	25
White Iron	18	-	-	53	P	36	P	-	-	-	P	-	18	-	P	-	18	161
Turtle	P	P	-	-	-	260	184	-	301	158	-	-	192	-	-	-	P	1256

Table 13. Cyanophyta
Sampled in July, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes \ TAXA	Chrysosphaera sp.	Chrysoshaerella longispina	Diceras chodati	Dinobryon bavaricum	Dinobryon cyclindricum	Dinobryon divergens	Dinobryon sertularia v. protuberans	Dinobryon sociale	Dinobryon sociale v. americanum	Dinobryon sp.	Mallomonas akrokomas	Ophiocytium capitatum v. longispinium	Synura uvella	Mallomonas sp.	Total
Greenwood	-	-	P	18	P	13	13	-	-	-	-	-	5	-	53
Colby	-	-	-	34	-	22	-	11	-	-		-	-	1	68
Bass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Bear Island	-	-	-	36	-	13	94	-	-	-	P	-	34	-	177
Birch-3	-	-	-	44	-	34	P	73	-	-		-	-	8	159
Birch-1	-	-	-	47	-	49	530	553	-	-	-	P	10	-	1189
Bearhead	-	-	2	104	-	312	-	-	-	2	-	-	-	-	420
Seven Beaver	-	-	P	21	-	-	47	-	-	-	-	10	5	-	83
Pine	-	-	-	-	103	P	131	-	-	-	1	2	1	-	239
Perch	8644	523	-	P	-	-	797	-	-	-	P	-	-	-	9964
Tofte	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Sand	-	-	-	1	-	1	1	-	-	-	-	P	-	-	3
Wynne	-	-	-	-	50	-	-	-	-	-	-	-	P	-	50
White Iron	-	-	P	P	P	124	89	142	107	-		-	P	18	586
Turtle	-	-	2	262	-	-	452	-	-	21	-	-	-	-	737

Table 14. Chrysophyta
Sampled in July, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.

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Lakes / TAXA	CRYPTOPHYTA Cryptomonas spp.	Total	PYRRHOPHYTA	Ceratium hirundinella	Glenodinium gymnodinium	Glenodinium sp.	Peridinium aciculiferum	Peridinium inconspicium	Peridinium willei	Peridinium wisconsinonse	Total	EUGLENOPHYTA	Euglena sp.	Phacus caudatus	Phacus pyrum	Trachelomonas volvocina	Trachelomonus spp.	Total
Greenwood	-	0		-	-	-	-	-	-	-	0		P	2	-	-	-	2
Colby	11	11		-	-	3	-	-	-	-	3		1	-	-	-	-	1
Bass	7	7		2	-	-	-	-	-	-	2		-	3	-	P	-	3
Bear Island	7	7		-	-	-	-	-	-	-	0		-	-	-	1	1	2
Birch-3	5	5		P	-	-	-	-	2	-	2		P	-	-	-	5	5
Birch-1	26	26		-	-	13	-	21	P	-	36		P	2	-	-	-	2
Bearhead	5	5		P	2	2	-	-	-	P	4		P	-	-	10	-	10
Seven Beaver	21	21		-	-	-	P	5	-	-	5		-	-	-	-	-	0
Pine	-	0		-	-	-	4	21	-	5	30		-	-	1	-	-	1
Perch	-	0		P	-	-	-	-	-	-	0		-	-	-	P	-	0
Tofte	26	26		P	-	-	-	-	-	-	0		-	-	-	-	-	0
Sand	4	4		-	-	4	-	-	-	-	4		-	-	-	-	P	0
Wynne	-	0		P	-	-	-	-	-	-	0		-	-	-	-	P	0
White Iron	-	0		P	-	18	-	-	P	-	18		-	-	-	-	-	0
Turtle	-	0		-	P	5	-	P	P	5	14		P	-	-	-	-	0

Table 15. Cryptophyta, Pyrrhophyta Euglenophyta
Sampled in July, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes / TAXA	Achnanthes linearis	Achnanthes minutissima	Achnanthes sp.	Amphipleura lindheimeri	Asterionella formosa	Cocconeis placentula	Fragilaria crotonensis	Gomphonema olivaceum	Melosira ambigua	Melosira distans	Melosira granulata	Melosira italica	Navicula cryptocephala	Navicula sp.	Nitzschia sp.	Rhizosolenia eriensis	Synedra sp.	Stauroneis sp.	Stephanodiscus niagarae	Stephanodiscus sp.	Synedra delicatissima v. angustissima	Tabellaria fenestrata	Cyclotella bodanica	Total
Greenwood	16	-	-	P	76	P	P	-	18	-	P	-	P	P	20	-	-	-	-	P	-	71	-	305
Colby	P	P	P	-	P	P	6	-	P	3	-	3	P	7	7	-	-	P	-	-	-	P	-	55.6
Bass	-	-	-	-	31	10	P	P	62	-	78	-	-	-	-	P	-	-	P	-	10	P	-	196
Bear Island	-	-	-	-	57	-	P	-	88	-	18	-	-	P	-	-	-	-	18	54	-	119	-	393
Birch	-	35	-	-	287	P	P	-	65	P	17	P	-	P	P	P	P	-	P	P	90	P	P	710
Seven Beaver	-	P	-	-	302	-	36	-	120	-	-	-	P	P	94	-	-	P	-	P	-	49	-	776
Pine	P	-	-	-	83	-	-	-	-	-	-	-	P	-	P	34	34	-	P	P	44	16	-	256
Tofte	-	-	-	8	-	-	94	-	146	-	-	-	-	-	-	-	-	-	-	8	-	34	-	296
Sand	P	-	-	-	52	-	80	-	P	P	-	-	-	-	P	-	-	-	8	5	-	93	P	242
Wynne	P	-	2	-	2	-	-	P	P	-	6	-	2	P	-	-	-	-	-	2	-	2	-	23.4
White Iron	-	P	-	-	26	P	-	P	73	-	P	-	P	-	13	-	-	-	-	86	-	28	-	269
Turtle	-	-	-	-	3363	-	-	5	-	-	-	-	-	-	-	5	-	5	99	-	-	244	-	3721

Table 16. Diatoms (Bacillariophyta)
Sampled in October, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes / TAXA	Ankistrodesmus falcatus	Ankistrodesmus falcatus v. acicularis	Ankistrodesmus falcatus v. mirabilis	Arthrodesmus triangulus v. subtriangularis	Botryococcus braunii	Chlamydomonas sp.	Cosmarium sp.	Crucigenia tetrapedia	Crucigenia truncata	Desmidium grevelii	Elakatothrix gelatinosa	Euastrum sp.	Nephrocytium agardhianum	Oocystis lacustris	Oocystis parva	Oocystis pusilla	Oocystis sp.	Pediastrum boryanum	Pediastrum tetras v. tetraodon	Quadrigula pfitzeri	Scenedesmus abundans	Scenedesmus opoliensis	Scenedesmus quadricauda	Schizochlamys sp.	Schroederia setigera
Greenwood	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	3	-	-
Colby	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-
Bass	-	-	21	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bear Island	P	P	31	-	-	-	-	12	P	-	P	-	-	-	-	-	P	-	P	P	P	P	P	-	-
Birch	P	13	-	P	-	P	-	18	P	-	P	-	-	P	-	-	P	P	-	-	31	13	8	-	-
Seven Beaver	23	-	-	18	-	-	P	P	-	-	-	-	-	-	-	-	5	-	P	-	-	-	5	-	-
Pine	91	-	-	-	-	-	2	-	-	-	-	-	-	13	8	-	-	2	-	-	-	-	-	-	-
Tofte	-	P	P	-	-	-	-	8	-	-	-	-	-	-	-	-	P	-	8	-	-	-	-	-	2
Sand	-	0.3	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-
Wynne	P	-	P	-	-	-	-	-	18	10	-	-	2	-	-	2	-	-	-	-	-	-	2	-	-
White Iron	-	-	-	-	31	-	P	441	-	-	36	-	-	-	-	-	-	-	P	57	-	-	P	-	-
Turtle	P	-	P	-	-	-	-	P	-	-	8	-	-	-	-	13	-	-	-	-	-	2	-	18	-

Table 17. Chlorophyta
Sampled in October, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes / TAXA	Spondylosium planum	Staurastrum lunatum v. planctonicum	Stylosphaeridium stipitatum	Tetraedron minimum	Tetrastrum staurogeniaeforme	Trochiscia granulata	Trochiscia sp.	Westella botryoides	Total
Greenwood	-	2	-	-	-	1	-	-	9
Colby	-	-	-	-	-	-	-	-	0.3
Bass	-	-	-	-	-	-	-	-	21
Bear Island	-	-	6	-	-	-	-	-	218
Birch	-	-	-	-	P	-	-	-	113
Seven Beaver	-	-	-	10	P	-	-	-	69
Pine	-	-	-	-	-	-	-	31	147
Tofte	-	-	-	-	-	-	-	-	18
Sand	-	-	-	-	-	-	-	-	0.6
Wynne	-	-	-	-	2	-	-	-	56
White Iron	31	-	-	-	P	-	-	-	705
Turtle	-	-	-	-	2	-	2	-	57

Table 17 (cont.)

PRELIMINARY DRAFT SUBJECT TO MAJOR REVISION DO NOT QUOTE

Lakes / TAXA	Anabaena flos-aquae	Anabaena planctonica	Anabaena sp.	Anacystis sp.	Agmenellum quadriduplicatum	Aphanizomenon flos-aquae	Aphanocapsa delicatissima	Aphanocapsa elachista	Chroococcus minor	Coelosphaerium kuetzingianum	Gomphosphaeria aponina	Gomphosphaeria lacustris	Lyngbya nordguardii	Oscillatoria geminata	Oscillatoria tenuis	Oscillatoria sp.	Phormidium sp.	Rhabdoderma lineare	Coelosphaerium naegelianum	Total
Greenwood	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	5	-	-	7
Colby	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	0
Bass	-	379	10	-	-	887	-	-	-	-	-	-	-	-	-	-	-	-	-	1261
Bear Island	-	-	2	5	2	-	2	-	-	-	-	-	-	-	-	-	2	-	-	13
Birch	-	P	P	-	-	38	P	-	27	P	-	-	-	P	43	7	-	-	67	193
Seven Beaver	-	-	-	-	16	-	-	-	5	-	2	-	-	-	-	-	-	-	-	23
Pine	-	-	-	-	-	-	21	-	-	-	-	2	-	-	-	-	-	-	-	23
Tofte	-	-	2	-	-	-	161	10	-	-	-	-	5	2	-	-	-	-	-	180
Sand	5	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	7
Wynne	-	-	-	-	-	-	-	-	-	-	-	-	3	0.3	8	-	-	-	-	11.3
White Iron	-	-	-	-	-	-	5	-	-	2	2	10	-	5	18	2	-	-	-	44
Turtle	-	-	-	-	-	-	384	-	21	-	-	135	-	-	-	-	-	150	-	690

Table 18. Cyanophyta
Sampled in October, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes / TAXA	Chrysolykos planctonica	Derepyxis sp.	Diceras chodati	Dinobryon bavaricum	Dinobryon divergens	Dinobryon sertularia	Dinobryon sertularia v. protuberans	Dinobryon sociale	Dinobryon tabellariae	Gloeobotrys sp.	Mallomonas akrokomos	Microspara crassier	Ophiocytium parvulum	Pseudokephurion entzii	Synura uvella	Total
Greenwood	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Colby	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	0
Bass	-	-	-	47	-	-	10	-	-	-	P	-	-	-	P	62
Bear Island	-	-	2	-	2	-	-	-	-	-	31	-	-	-	-	35
Birch	-	-	2	3	1	7	P	-	-	2	12	-	-	-	P	27
Seven Beaver	-	-	-	-	-	-	-	-	-	-	-	-	8	2	-	10
Pine	2	-	26	223	106	-	-	31	-	-	-	-	-	-	-	338
Tofte	-	-	8	-	62	-	-	-	-	18	-	-	-	-	-	88
Sand	-	-	2	-	-	-	-	-	-	-	62	-	-	-	5	69
Wynne	-	0.3	-	-	0.3	-	-	-	-	-	-	-	-	-	-	0.6
White Iron	-	-	16	-	-	-	16	-	-	-	2	-	-	-	-	34
Turtle	-	-	10	5	32	-	-	-	62	-	-	5	-	-	285	399

Table 19. Chrysophyta
Sampled in October, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.

Lakes / TAXA	CHRYPTOPHYTA	Chroomonas acuta	Chroomonas sp.	Cryptomonas erosa	Cryptomonas sp.	Stelexomonas dichotoma	Total	DINOFLAGELLATES	Ceratium hirundinella	Gymnodinium sp.	Peridinum sp.	Total	EUGLENOPHYTA	Euglena sp.	Lepocinetis acuta	Phacus sp.	Trachelomonas cylindrica	Trachelomonas verrucosa	Trachelomonas volvocina	Total
Greenwood		-	-	47	-	1	48		-	-	-	0		-	-	-	-	1	1	2
Colby		-	-	-	2	-	2		-	-	-	0		-	-	-	-	-	-	0
Bass		104	83	124	-	-	311		-	-	-	0		-	-	-	-	-	-	0
Bear Island		304	67	2	-	-	373		-	-	-	0		-	-	-	-	-	2	2
Birch		214	38	74	-	P	327		-	-	-	0		P	6	-	-	-	P	8
Seven Beaver		-	-	8	16	-	24		-	-	-	0		-	-	-	-	-	5	5
Pine		392	143	80	-	P	617		-	-	2	2		-	-	-	-	-	-	0
Tofte		263	83	52	-	-	398		2	-	-	2		2	-	2	2	-	-	6
Sand		319	-	44	-	P	363		-	-	-	0		-	-	-	-	-	-	0
Wynne		12	P	3	35	-	51.3		-	0.3	-	0.3		-	-	-	-	-	-	0
White Iron		340	70	49	-	-	459		-	-	-	0		2	-	2	-	-	2	6
Turtle		36	-	31	26	197	290		-	-	5	5		-	-	-	-	-	-	0

Table 20. Cryptophyta, Pyrrhophyta, Euglenophyta
Sampled in October, 1977, by RCNS
Numbers represent abundance of dominants in units/ml.