A FLORISTIC STUDY OF THE ATTACHED ALGAE OF LAKE MIZE, FLORIDA

By

HELEN DAVIS BROWN

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Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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Helen Davis Brown

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A floristic survey from December, 1968, to September, 1971, provided a record of the communities of attached algae in Lake Mize, Florida. Counts and estimates of organism densities were used to determine the relative abundance of species. In all, 89 species were identified and monitored during the study period. Both quantitatively and qualitatively, desmids and filamentous Chlorophytes were usually an important part of the periphyton in Lake Mize. Several acidiophilic diatoms were abundant at certain times, while Cyanophytes generally reached high frequencies only during the July to September period.

In the course of the investigation, it was determined that algal species employing particular modes of attachment were more abundant under some conditions than others.

Generally, tightly adhering, resupinate forms attained higher densities on glass slides than filamentous and loosely associated metaplanktonic species. Conversely, the epiphytic flora of the filamentous sedge, *Websteria submersa*, contained a large number of both strong and weak attachers. Other broad-leafed macrophytes in the lake normally had an epiphytic flora composed mainly of filamentous and/or resupinate species with somewhat fewer metaplanktonic algae than the flora of *W. submersa*. However, no absolute substrate specificity could be shown for any one species or by any attaching form. A major observation to come from this investigation was that the attached flora varied not only with substrate type, but that different areas of the lake supported somewhat different periphyton communities. In calmer areas of the lake or in protected enclosures, metaplanktonic and filamentous species were more abundant on all substrates than in areas subjected to currents and turbulence.

When clean substrates (slides or plants) were submerged, the pioneering attachers were usually the most abundant resupinate and/or filamentous forms in the lake at that time. Debris became associated with the attached algae community for a period up to 5 weeks. The number of metaplanktonic species increased as well as total algal frequencies. In excess of 3 to 5 weeks, peeling ensued with a subsequent loss of debris and algae, especially debris-associated metaplanktonic forms.

Whereas the type of substrate and the amount of current appeared to be critical in determining whether weak attachers would be present in a given periphyton community, light was also important in governing the floristic composition of the community in Lake Mize. Chlorophytes were generally abundant only in the upper 6 to 18 inches of the lake. Chrysophytes, on the other hand, had a broader vertical range, frequently remaining common to a depth of 30 inches on glass and 42 inches on *W. submersa*. In the case of Cyanophytes, light requirements were variable. Some species were restricted to the upper 6 to 18 inches of the lake and others were common to a depth of 42 inches.

A comparison of the attached flora in Lake Mize, Florida, a dystrophic lake, with that of the mesotrophic Elk Lake, Minnesota, revealed a number of differences. Taxonomically, the attached floras of the two lakes were almost completely different with only three species common to both lakes. Diatoms formed the major part of the attached flora in Elk Lake, while Chlorophytes were generally the dominant algal division in Lake Mize. In Lake Mize, light was a severely limiting factor with attached algae usually restricted to the upper 30 to 42 inches of the lake and with maximum algal frequencies occurring in the upper 6 to 18 inches. In Elk Lake, attached algae were common to a depth of 4 meters. Maximum frequencies usually occurred at a depth of 3 meters.

I. INTRODUCTION

The objectives of this investigation were: (1) to analyze the composition of the attached algae communities which appeared in Lake Mize, Florida, December, 1968, to September, 1971; (2) to observe the successional tendencies among the communities of attached algae in Lake Mize; (3) to compare the attached algae communities on glass slides with those on several aquatic macrophytes; and (4) to compare the attached algae of Elk Lake, Minnesota, with those of Lake Mize.

Attached algae, which are part of the periphyton, have an important role in a lake's food web. However, studies of the periphyton in fresh-water lakes have not been as numerous as planktonic studies. To the author's knowledge, no study has been made of periphyton in a northern Florida lake. Thus, while the limnological features and the plankton of Lake Mize have been studied (Harkness and Pierce, 1941; Nordlie, 1967), no prior study has been made of its nonplanktonic algae. As a monomictic, brown-water lake, Lake Mize holds considerable interest. This investigation, together with those already made, will add to our understanding of the lake as a functioning ecosystem.

A pilot study of attached algae was first carried out at Elk Lake, Minnesota, during the summer of 1967. Elk Lake is a dimictic, mesotrophic lake. The results of this investigation provide an interesting contrast with those obtained from the summer studies in Lake Mize.

II. LITERATURE REVIEW

Terminology

The term *periphyton* has been given several meanings in the literature (Cooke, 1956). In this study, *periphyton* is used to designate "that assemblage of organisms growing upon free surfaces of submerged objects in water," as defined by Young (1945). *Aufwuchs*, a German term, carries much the same meaning (Sladeckova, 1962). Algal members of the periphyton are termed *phyco-periphyton* (Foerster, 1963) or, *attached algae* (Brook, 1955; Castenholz, 1960). Phyco-periphyton may be classified according to the nature of the substrate upon which they occur; i.e., *epiphytic algae*, those found attached to plants and *epilithic algae*, those attached to rocks and stones. *Epipelic algae* are those algae associated with lake bottom sediments (Round, 1964). The members of the *metaplankton* were first considered to be the algae lying between aquatic plants (Behre, 1956). The meaning of this term has been broadened so that the metaplankton are considered to be those algae loosely associated with a substrate, but not sessile upon it (Round, 1964). In this study the metaplankton are considered to be part of the attached algal flora when found adhering to a substrate. It is recognized that these forms are also part of the "plankton" of the lake's littoral zone.

A community is considered by Odum (1959) to be "any assemblage of populations living in a prescribed area or physical habitat." The term *community* is often used to refer to various assemblages of attached algae. With reference to the attached algae, the term denotes a group of species found together on a certain type of substrate (Castenholz, 1957). Within a community distinct groupings of species called *associations* occur (Margalef, 1953).

Succession is the orderly process of community change (Odum, 1959). With reference to the attached algae, a pioneer community occurs first on a given substrate. This pioneer community is replaced by a series of more mature communities. In most situations, whether the community of attached algae ever reaches what may be properly termed a *climax* is debatable (Blum, 1956b). In this study, when the terms *succession* or *successional tendencies* are used, reference is being made simply to the series of communities which follow each other in occupying a given substrate in the lake.

Growth Forms of Attached Algae

While the members of the plankton are adapted to flotation, those of the periphyton are adapted to attachment on a substrate. Generally, organisms in a given community tend to have certain growth forms. Both Round (1964) and Fritsch (1929) report 2 main growth forms among the attached algae: (1) species appressed to the substrate, broad surface down; and (2) species which produce a small attachment disc from which either a single cell or a filament projects. Examples of the first form include numerous diatoms and some members of the Chaetophorales. Examples of the second form include green filamentous algae, as *Oedogonium*, and diatoms attached by a mucilaginous pedicel, as *Synedra*. A third growth form is sometimes considered to occur, that of filaments within a thick mucilage, as *Nostoc* (Round, 1964). A holdfast cell or mucilage is the mode of attachment for all forms.

Substrates Used in Studying Attached Algae

In the investigation of attached algae on natural substrates, certain difficulties are encountered. Epilithic algae must be removed from their rocky substrate in order to be studied microscopically. Removal of closely adhering forms is difficult so that an extremely accurate assessment of the epilithic community is usually not possible. A method proposed by Margalef (1949a) holds promise of partially overcoming this difficulty. His method consists of applying a film of collodion to the rock or stone and then peeling the film off when it dries. To some degree, the difficulty imposed by the closely adhering forms is also met when the attached algal flora of aquatic macrophytes is studied. Sometimes, however, the epidermis of the plant may be peeled, or Margalef's method may be used (Margalef, 1949b). An additional problem in studying algal succession upon aquatic macrophytes is the problem of obtaining clean plants without epiphytes. To overcome this difficulty, Prowse (1959) grew plants in water containing silver ions. This solution acted as an algicide and a fungicide to suppress the growth of algal and fungal epiphytes on the plants. Whitford (1956) studied the succession of algal epiphytes by comparing growth on younger parts of an aquatic macrophyte with that on older parts.

Most investigations of attached algae have featured the use of artificial barren surfaces. Many different artificial barren substrates have been used: polyethylene tape (Neal, Patten, and DePoe, 1967), plastic, wood, slate, sheet metals, asbestos, and glass (Sladeckova, 1962). The use of glass slides is especially widespread.

Sladeckova (1962) reports Kny (1884) as the first to use this method for the study of zoospore attachment in the laboratory. Hentschel (1916) was the first to use the glass slide method in the qualitative and quantitative determination of periphyton. The method has been modified many times since Hentschel's work. Both smooth and scratched glass slides have been used (Castenholz, 1957). The glass slide method provides the advantage of making possible the direct microscopical observation of attached organisms.

Several investigators have attempted to compare the attached algal community found on glass slides with that found on natural substrates. The species present on glass slides appear to be almost the same as those found on aquatic macrophytes and stones (Castenholz, 1957; Dor, 1970). Blue-greens, however, do not colonize glass slides as readily as natural substrates, according to several workers (Castenholz, 1957; Sladeckova, 1962). Numerical analyses of the species present frequently yield different results with slides as compared to natural substrates (Blum, 1956a; Dor, 1970).

While differences exist between the attached algal flora of glass slides and of natural substrates, differences also exist among various forms of natural substrates.

Among aquatic macrophytes, *Carex* and *Chara* have few attached epiphytes while *Fontinalis* and *Myriophyllum* are densely populated by algal epiphytes, according to Round (1966). Some species of attached algae also grow much more readily on some plants than on others (Tiffany, 1951; Young, 1945; Prowse, 1959). Varying parts of a plant may have different attached communities (Tiffany, 1951). Also, while the epiphytic and epilithic communities share many species, stones tend to have more encrusting forms than do plants (Ruttner, 1963).

Light and ease of attachment have been theorized to be the most important factors in the distribution of algal epiphytes (Tiffany, 1951). Other factors also may account for differences in the attached algal flora of various substrates. Substrates which contain irregularities seem to make attachment easier (Blum, 1956a). Current is probably very important (Ruttner, 1963; Whitford, and Schumacher, 1963). Castenholz (1957) theorized that 1 species of *Cladophora* did not appear on glass slides due to the timing of its dispersal mechanism (zoospore production). He also found that when slides were exposed 6 weeks or longer, they developed encrusting blue-green forms not usually found on slides. A time differential may also explain some of the differences between the species composition of plants and of stones.

Many aquatic plants are short-lived and are probably populated mainly by quickly developing attached forms. Rocks allow the colonization by forms which develop slowly (Ruttner, 1963).

Vertical Zones of Periphyton Distribution

Several workers have studied the vertical distribution of periphyton in lakes or reservoirs, using artificial substrates (Maciolek and Kennedy, 1964; Neal, Patten, and Depoe, 1967; Sladeckova, 1966). Maciolek and Kennedy (1964) report that in Laurel Lake, California, attachment on glass slides was greatest at the 5-meter level. Diatoms were the chief attaching forms. Neal, Patten, and DePoe (1967) used polyethylene tape as the substrate for attachment in a polluted lake near Oak Ridge, Tennessee. Maximum biomass development was found to take about 2 weeks in the euphotic zone (upper 50.8 centimeters) and longer below the euphotic zone. Biomass accumulation was greatest in the upper 38.1 to 54.7 centimeters. Species succession continued after maximum development of biomass occurred. Succession began with blue-greens and diatoms. These pioneers were succeeded by filamentous and adhering greens.

In Polish reservoirs, Sladeckova (1966) considers periphyton distribution to be divided into 5 zones within the water column:

1. A surface zone without periphyton;
2. Zone of producers (euphotic zone), algae predominate;
3. Transition zone (compensation layer), mixture of producers and consumers present;
4. Zone of consumers, rotifers, sessile protozoans, etc., predominate;
5. Bottom zone, influenced by decomposition process in the sediments, bacteria and large benthic organisms present.

The above vertical periphyton distribution probably holds true for most water bodies with sufficient depth. At any depth, growth of periphyton is a balance between income and loss processes. Gains occur through colonization and primary productivity. Losses occur through respiration, secretion, excretion, sloughing off of the periphyton film, and grazing by consumers (Neal, Patten, and DePoe, 1967).

Successional Tendencies in the Periphyton

Ecological succession in general is characterized by a number of important features. By definition, it is an orderly process of community development that is reasonably predictable. Succession results from a modification of the habitat by the organisms present in the habitat. It is culminated by a climax community in equilibrium with the physical environment. The physical environment determines the pattern of succession, the rate of change, and how far succession may proceed (Odum, 1969).

Early stages of succession have been compared to later stages in a number of ways. Species with high rates of reproduction and growth are more likely to survive in early successional stages, while those species with capabilities for competitive survival are more likely to be present during later successional stages (Odum, 1969). Pioneer species are also better adjusted to indiscriminate dispersal. During succession, there are increases in the proportion of inert or dead matter, in biomass, in the number of niches present, and in stratification. There is frequently an increase in species diversity. Or, diversity may increase and then decrease (Margalef, 1968).

Succession is a frequent occurrence. However, orderly unidirectional succession does not *always* occur in nature. When the physical environment is extreme or subject to large-scale fluctuations, succession either does not continue or is pushed backward (Odum, 1969; Margalef, 1968).

Several studies have been made that deal with successional tendencies in the periphyton community (Whitford, 1956; Yount, 1956; Brook, 1954; Whitford and Schumacher, 1963). The use of glass slides is common.

Colonization of bare substrates placed in a lake proceeds rapidly. Within a few hours to a few days, bacteria attach (Sladeckova, 1962). According to Brook (1967) the first algal colonizers on slides in the ponds of filter plants are generally small blue-green filaments and diatom members of the Monoraphidae. Both of these groups usually appear within a week. Later, large prostrate greens, especially members of the Chaetophoraceae, appear. Competition between closely adhering diatoms and the prostrate greens may be severe with the outcome sometimes influenced by grazing. In North Carolina Piedmont streams during early spring, Whitford and Schumacher (1963) found diatoms to form the first 2 successional stages on bare substrates. The third stage was a gelatinous mat of the blue-green, *Phormidium subfuscum*, with 2 associated diatoms. This was followed by filamentous greens, such as *Microspora* and *Stigeoclonium*.

As has been pointed out previously, the actual achievement of climax by the periphyton is questioned by some investigators for many situations. Blum (1956b) doubted that the climax concept should be applied to the ephemeral algal communities of streams. However, he also reasoned that the equivalent of a "permanent" climax may be reached by algae in a single season. In North Carolina streams, Whitford and Schumacher (1963) found no perennial community of attached algae and questioned the use of such terms as *climax*, *dominant*, and *succession* for communities of attached algae. Within some Florida springs, a climax community of attached algae has been reported (Whitford, 1956; Yount, 1956). However, streams are recognized as being stable ecosystems with physical and chemical conditions rather uniform throughout the year except for light (Whitford, 1956).

III. DESCRIPTION OF THE STUDY AREAS

Lake Mize

The major part of this study was carried out at Lake Mize, Florida. Several workers have conducted extensive investigations at Lake Mize (Harkness and Pierce, 1941; Nordlie, 1967; Brezonik and Harper, 1969; Brezonik, 1970). Some aspects of their studies will be utilized in this description of Lake Mize, as well as the observations of the writer.

Lake Mize may be characterized as a limestone solution lake (Nordlie, 1967). The sedimentary rock underlying much of Florida is composed chiefly of limestone. In a limestone area, depressions or "sinks" sometimes develop due to the dissolving of carbonate deposits along fault lines. These sinks may then fill with water during subsequent Florida wet seasons and a lake is produced (Nordlie, 1967).

Location

Lake Mize is located in the Austin Cary Memorial Forest, 10 miles northeast of Gainesville, Florida, latitude 29° 44' north, longitude 82° 13' west (Harkness and Pierce, 1941).

Morphometry

Lake Mize has a surface area of 0.86 hectare and a maximum depth of 25.3 meters (Nordlie, 1967). It is generally circular in outline except for a shallow bay on the north side of the lake (Figures 1 and 2). Except for the bay area, the depth of the lake increases rapidly from the shoreline.

The littoral zone is represented by a narrow band outlining most of the lake. When the water level is high, a temporary stream carries the overflow into Hatchett Creek. The water level of Lake Mize varies considerably during any one year as the rainfall fluctuates.

Chemistry and Physics

Lakes are generally classified as to nutrient level, i.e., eutrophic, mestrophic, oligotrophic, or dystrophic. Lake Mize is a dystrophic lake. Its brown water is so colored by the leachate from the surrounding pine forest (Brezonik, 1970). According to Brezonik (1970), color values as high as 700 mg/ℓ, platinum scale, are common in the lake.

The dissolved and suspended organic materials in the lake help to produce a distinctly acid pH. Nordlie (1967) found the median pH of Lake Mize to be 4.2 for 1965. Brezonik (1970) found the median pH to be 5.2

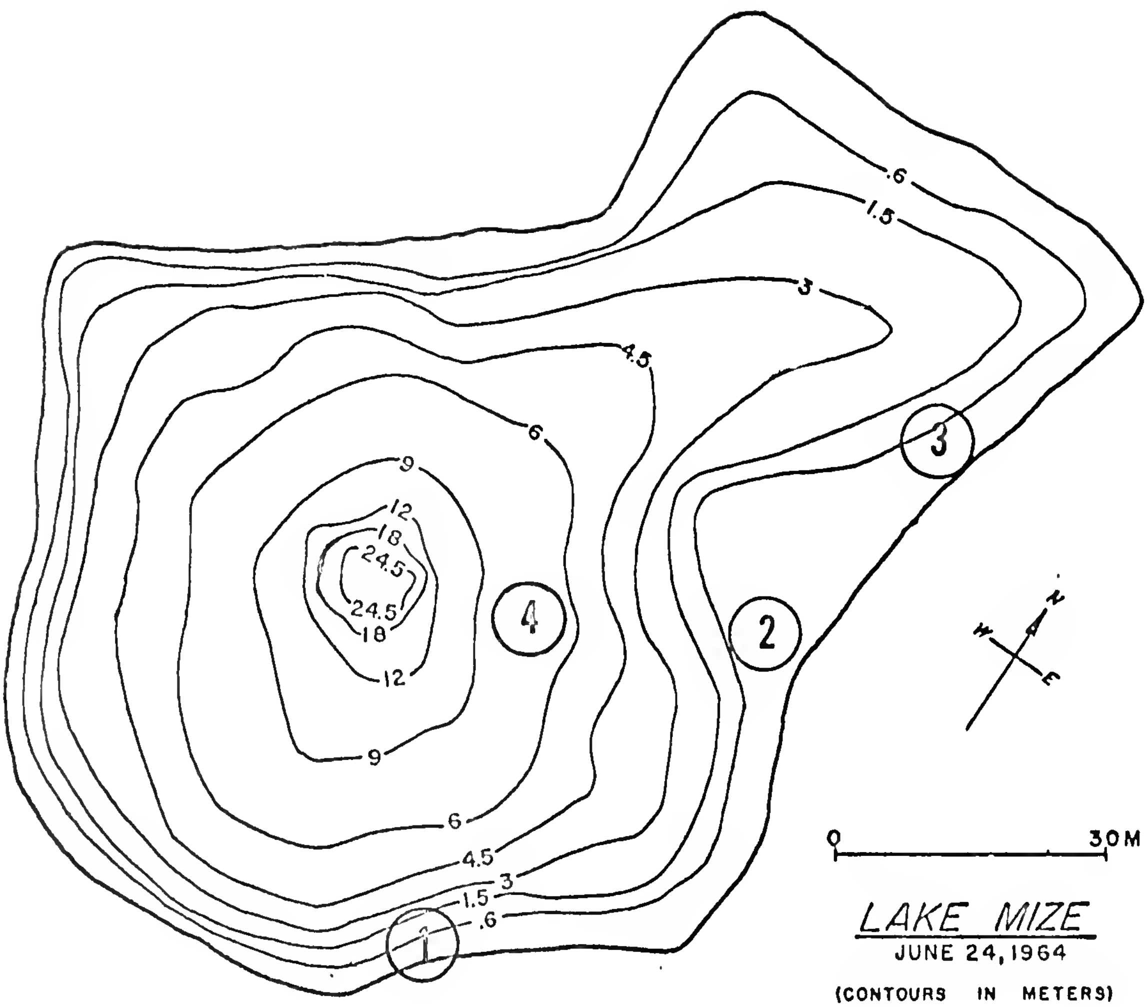

Figure 1. Bathymetric map of Lake Mize, showing sampling stations 1, 2, 3, and 4. (Courtesy of Dr. Frank Nordlie)

Figure 2. North-South view of Lake Mize, Florida.

for the period June, 1969 to June, 1970. Total acidity, as measured by Nordlie for the 1965 period, ranged from a low of 10.5 to a high of 30.0 ppm for the surface waters. Lowest values were obtained during the summer and highest values during the winter. This range in values shows that the waters of Lake Mize have a poor buffering capacity (Nordlie, 1967). Algae and other aquatic organisms in the lake are consequently exposed to fluctuations in pH and water chemistry.

The dissolved and suspended organic matter also affects the penetration of light in Lake Mize. Secchi disc readings during the period October 2, 1968, to August 13, 1970, ranged from 1 foot to 4 feet (Table 1). According to Ruttner (1953), secchi disc readings in lowland lakes generally range from a few decimeters to 10 meters. It can be seen that the secchi disc readings for Lake Mize fall in the lower part of this range. A secchi disc reading is considered to be a measure of the depth of visibility in a lake and to give some measure of the transparency of the water. Measurements made with a light meter showed light penetrating to around 3 feet December 9, 1968; to 6 feet on February 9, 1969; and to the 1 foot level on February 15, 1970 (Figure 3).

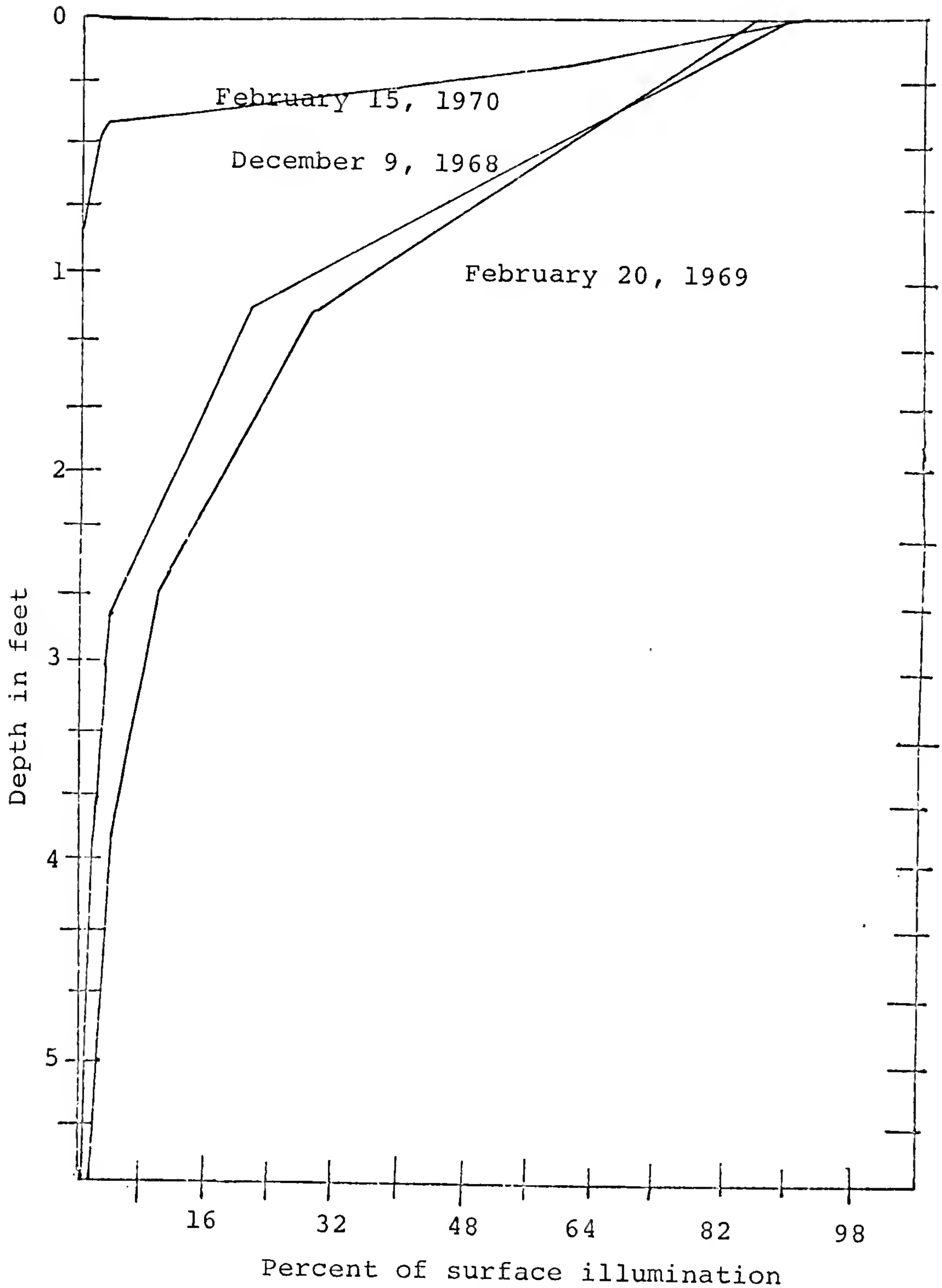

Figure 3. Light penetration in Lake Mize, Florida (Winter).

TABLE 1

Secchi Disc Measurements in Lake Mize, October 2, 1968 to August 13, 1970

Date	Hour	Secchi Reading in feet
October 2, 1968	10:30 a.m.	2-1/4
October 13, 1968	1:00 p.m.	4
December 9, 1968	11:30 a.m.	2-1/4
December 17, 1968	11:30 a.m.	3-1/2
January 9, 1969	4:00 p.m.	2-3/4
February 20, 1969	4:00 p.m.	2-1/2
April 17, 1969	3:00 p.m.	1-3/4
April 23, 1969	3:00 p.m.	1-3/4
November 29, 1969	10:00 a.m.	1
February 15, 1970	3:00 p.m.	1
July 16, 1970	7:00 p.m.	1-1/2
August 13, 1970	5:00 p.m.	1-1/2

Phosphate measurements from the epilimnion of Lake Mize ranged from nondetectable to 0.1 mg ℓ PO_4 for 1965, according to Nordlie (1967). And, for the time period of August 1, 1968, to June 12, 1970, Brezonik (1970) reported an upward trend in phosphate values with a range from 0.027 mg P/ℓ to 0.225 P/ℓ.

Nitrate-nitrogen measurements in surface samples from Lake Mize ranged from a value not detectable to 0.40 mg N/ℓ during 1965 (Nordlie, 1967). In the deep water, values occurred up to 0.83 mg N/ℓ (Nordlie, 1967). Recently, Brezonik and Harper (1969) have shown that nitrogen fixation by bacteria occurs in Lake Mize. Brezonik (1970) reported organic nitrogen values ranging from 0.55 mg N/ℓ on August 1, 1968, to 125 mg N/ℓ on June 12, 1970.

Several studies (Harkness and Pierce, 1941; Nordlie, 1967) have shown Lake Mize to be a monomictic lake, i.e., a lake having one period of circulation during the year. In Lake Mize constant circulation occurs during the winter season, generally from November through February (Brezonik, 1970). Temperature measurements by the author on December 9, 1968, showed the surface waters to be 15°C. At a depth of 1 foot, the water measured 14-1/2°C. From the 1-foot level to the bottom, the water temperature dropped only 1/4°, from 14-1/2° to 14-1/4°C. Measurements taken on February 20, 1969, indicated a slight stratification. The surface temperature was 17°C with a drop to 11.2°C at the bottom. (Surface temperatures generally ranged from 16° to 35°C throughout the year as indicated by Table 2.)

TABLE 2

Temperature Measurements from the Surface Waters of the Littoral Zone of Lake Mize, August, 1968, to August, 1970

Date	Hour	Temperature, °C.
August 16, 1968	4:00 p.m.	33
August 27, 1968	10:00 a.m.	31
September 3, 1968	1:00 p.m.	26
October 2, 1968	10:30 a.m.	24
November 8, 1968	10:00 a.m.	21
November 15, 1968	2:30 p.m.	20
December 2, 1968	2:00 p.m.	22
January 17, 1969	2:00 p.m.	16
February 20, 1969	3:30 p.m.	18
April 10, 1969	2:00 p.m.	23
May 9, 1969	2:00 p.m.	33
August 8, 1969	2:00 p.m.	35
November 29, 1969	10:00 a.m.	18
February 15, 1970	11:00 a.m.	16
February 15, 1970	3:00 p.m.	18
July 16, 1970	7:00 p.m.	35
July 21, 1970	10:00 a.m.	30
August 13, 1970	2:00 p.m.	29

Without circulation of the lake's waters, a stable thermal stratification develops. In Lake Mize, thermal stratification persists from late February or early March to late October or early November, depending upon weather conditions (Brezonik, 1970). During this period of stratification, anaerobic conditions occur below a depth of 3 to 5 meters from April or May until the end of stratification (Brezonik, 1970; Nordlie, 1967). During the period of circulation and homiothermy, oxygen is introduced into the deeper waters of the lake (Nordlie, 1967), although oxygen depletion may still exist in the deepest waters of the hypolimnion (Brezonik, 1970). Nordlie (1967) found the oxygen concentration at a depth of 70 feet to be 0.5 ppm on December 18, 1964.

Recent History of Lake Mize

The recent history of Lake Mize has included the introduction of a flock of mallard ducks for scientific study. During most of the period from August, 1968, until the present, the ducks have been confined to an enclosure on the north side of the lake in the bay area. During the spring and summer of 1970, a portion of the flock was free to roam on the lake.

In a study to determine the influence of the ducks on Lake Mize, as well as to evaluate any possible potential disruptive effects on the lake's ecosystem, Brezonik (1970) found a trend of gradually increasing phosphate and nitrate values during the period of August 1, 1968, to June 12, 1970 (cf. p. 20). He also found chlorophyll *a* values during 1969 to be almost twice as high as the values Nordlie found for 1965. Primary productivity values also increased (Brezonik, 1970; Nordlie, 1967). Brezonik theorized that from 50 to 90% of the duck food being added to Lake Mize was not utilized by the ducks. This unused duck food represents a significant portion of the nitrogen and phosphorus entering Lake Mize at present, according to his calculations and those of Shannon (1970).

Aquatic Macrophytes of Lake Mize

Some changes in the populations of aquatic macrophytes also occurred in the 1968-1970 period. During April, 1968, the following species of floating, submerged, and emergent aquatic plants were common in Lake Mize: *Panicum hemitomon*, *Leersia oryzoides*, *Websteria submersa*, *Utricularia olivacea*, *Sphagnum macrophyllum*, and *Mayaca aubletii*. *Potamogeton floridanus* also occurred in the bay area of the lake, but was not common or widespread. Several of the common species gradually decreased over the 2-year period. A survey taken during April, 1970, showed the following to be absent: *S. macrophyllum*, *L. oryzoides*, and *M. aubletii*. The population of *P. hemitomon* had increased greatly and surrounded the lake, growing both in shallow water and on shore. *W. submersa* was present in reduced amounts, as compared to the 1968 survey.

Some of the aquatic macrophytic species of Lake Mize occasionally grow both submerged and as shore plants. During periods of low water, submerged aquatic macrophytes are left stranded on the sloping shore. Such conditions usually bring desiccation to the aquatic plants. However, *S. macrophyllum*, *W. submersa*, and *M. aubletii* grow both as submerged plants in Lake Mize and as terrestrial plants on shore during low water. This is also a common occurrence at other soft-water lakes of northern Florida and Georgia. Sculthorpe (1967) comments that while it is common for floating aquatic plants to have land forms, few land forms of submerged plants have been described.

Floating plants also occur to a limited degree in Lake Mize. Masses of *W. submersa*, usually mixed with *U. olivacea*, are sometimes present on the surface of the lake. The floating plant *Lemna minor* is sporadically present in Lake Mize.

Surrounding Vegetation of Lake Mize

Besides the land forms of some of the submerged plants of Lake Mize, there are a number of herbaceous and shrubby plants around the lake. The herbaceous species include: *Polygonum hirsutum*, *Hypericium myrtifolium*, *Panicum hemitomon, Fuirena scirpoidea, Rynchospora* sp., *Cyperus* sp., *Ericaulon decangulare, Xyris ambigua, Ludwigia alata, Rhexia mariana, Diodia hirsuta, Pluchea rosea, Polypremum procumbens, Elephantopus tomentosus, Eupatorium capillifolium, E. compositifolium, Osmunda cinnamonea, Pteridium aquilinum, Hydrocotyle umbellata, Sagittaria graminea, Diodia virginiana, D. teres, Andropogon* sp., *Conyza canadensis*, and *Lyonia lucido.* A number of woody plants, trees, shrubs, and vines border the lake on the south and west sides. These include: *Diospyros virginiana, Magnolia virginiana, Myrica cerifera, Ilex glabra, Serenoa repens, Vaccinium stamineum, Cephalanthus occidentalis, Quercus hemisphaerica, Q. geminata, Q. laevis, Q. incana, Callicarpa americana, Smilax glauca, S. laurifolia*, and *S. bona-nox.*

Lake Mize is situated within the body of a pine forest which surrounds the lake. Important tree species in the forest include: *Pinus palustris, P. taeda, P. elliotii, Quercus nigra*, and *Q. laurifolia.* The understory consists largely of *Serenoa repens, Ilex glabra* and *Vaccinium* spp.

The forest, in addition to its influence on the lake's chemistry and coloring, also provides some measure of protection from wind.

Elk Lake

In order to compare the perphyton of Lake Mize with a different kind of lake, a portion of this study was carried out at Elk Lake, Minnesota. Elk Lake is located at Itasca Biology Station, Minnesota. It has a single outflow stream, Chambers Creek, by which it is also connected to Lake Itasca. Several springs and streams run into Elk Lake.

Elk Lake has a surface area of 102 hectares, a maximum depth of 29 meters, a volume of 1.13 × 107 cubic meters, and a shoreline length of 4.78 × 103 meters (Baker and Davison, 1966).

Elk Lake may be characterized as a mesotrophic lake. It is dimictic, having overturn periods in the spring and fall. During the winter season it is generally covered by ice.

The water of Elk Lake is green in color. During the summer of 1967 light penetrated generally to a depth of around 10 meters (Figure 4). During the study period, temperature was fairly uniform for the top meters, 24°C on July 24, 1967. Below the 4-meter level, there was a rapid decline in the thermocline to 8°C at the 10-meter level. At the 29-meter level, temperature registered around 6°C.

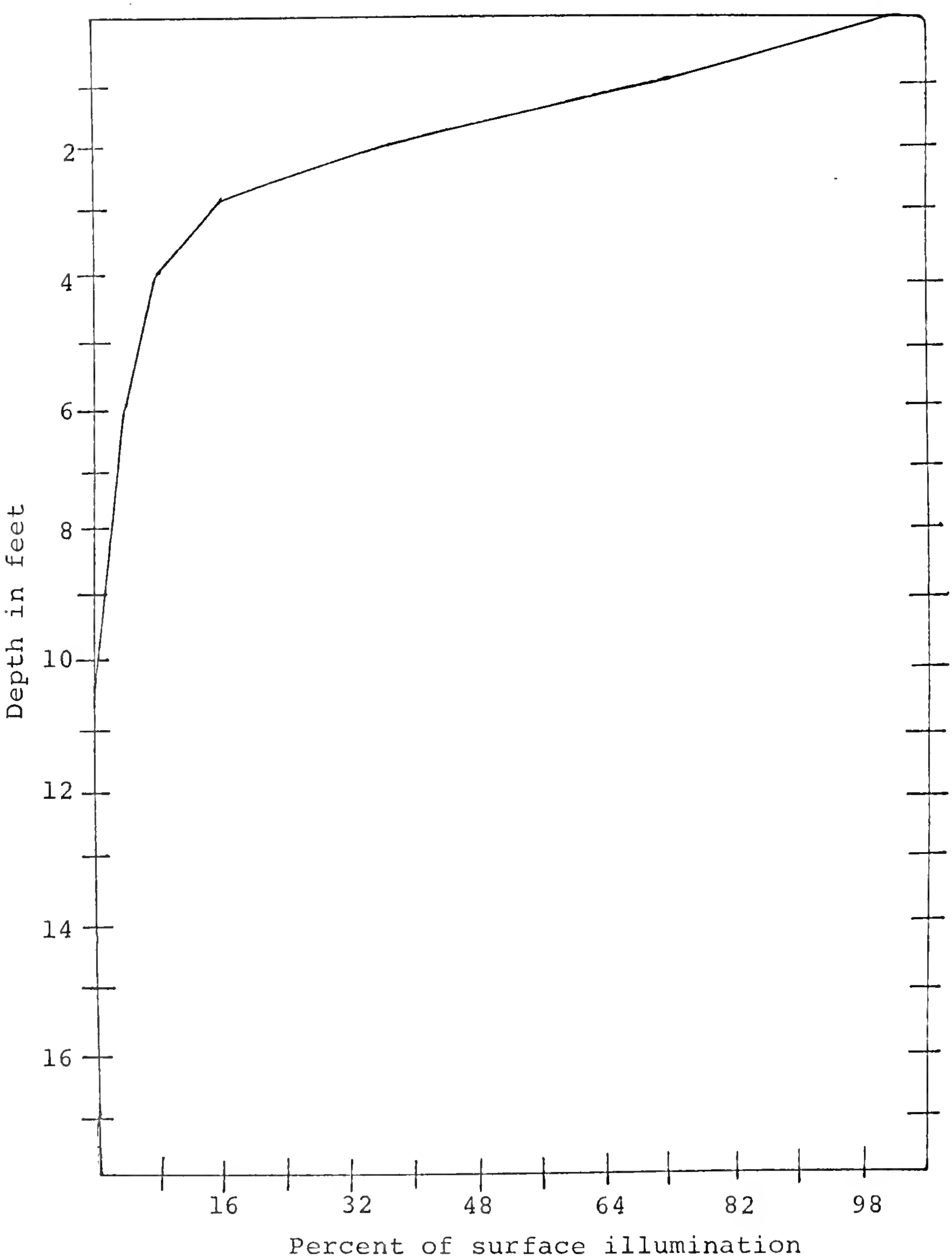

Figure 4. Light penetration in Elk Lake on August 14, 1967.

The littoral area of Elk Lake is populated by a number of aquatic plants, including several species of *Scirpus*. Except for the southwest corner, it is surrounded by deciduous forest, which provides some protection from winds.

IV. MATERIALS AND METHODS

General Sampling

The attached algae of Lake Mize, Florida, were first studied during December, 1968. The study was concluded in September, 1971. During this study period, collections were made of the attached algae present in the littoral area during May, 1969; July, 1969; August, 1969; August, 1970; April, 1971; July, 1971; and September, 1971. Studies of the attached algal species present in the limnetic area were made during December, 1968; January, 1969; February, 1969; August, 1969; September, 1969; and August, 1970. Three stations were maintained in the littoral area and 1 in the limnetic area (Figure 1, p. 16).

At Elk Lake, Minnesota, glass slides were used to study attached algal forms present in both the littoral and limnetic areas during August, 1967. This timing permitted comparison with the August studies in Lake Mize. At Elk Lake, 1 station was maintained in the limnetic area and 1 in the littoral area.

Use of Substrates

A number of substrates were used in studying the attached algal flora of Lake Mize. Among inert substances, glass slides were the most commonly used (Figure 5). Pieces of plastic were also submerged in the lake for attachment by the phyco-periphyton. The aquatic macrophytes which were sampled for epiphytic growth during the study included: *Sphagnum macrophyllum*, *Websteria submersa*, *Panicum hemitomon*, *Leersia oryzoides*, *Mayaca aubleti*, *Polygonum hirsutum*, and *Utricularia olivacea*. As previously mentioned, some of these aquatic macrophytes found at Lake Mize are amphibious, i.e., found growing at time of low water on the shore as well as submerged in the lake. The shore forms of these plants were gathered and grown in closed glass containers in the laboratory. These plants, assumed to be without epiphytes, were submerged in the lake in order to study the progressive growth of epiphytic communities. Because of its frequent occurrence and physiological hardiness, *W. submersa* was the plant most commonly used in this way. Other amphibious plants so used were *M. aubleti*, *S. macrophyllum*, *F. scirpoidea*, and *Bacopa caroliniana*.

Littoral Area Methods

In the littoral area of Lake Mize, slides and plants were submerged in rectangular plastic baskets at a depth of 18 inches (Figure 6). The baskets had a loosely woven framework. A few were lined with plastic screening

Figure 5. Glass slide showing periphyton present after 3 weeks' exposure in Lake Mize (× 1).

Figure 6. Plastic enclosure used in Lake Mize littoral studies (× 1/10).


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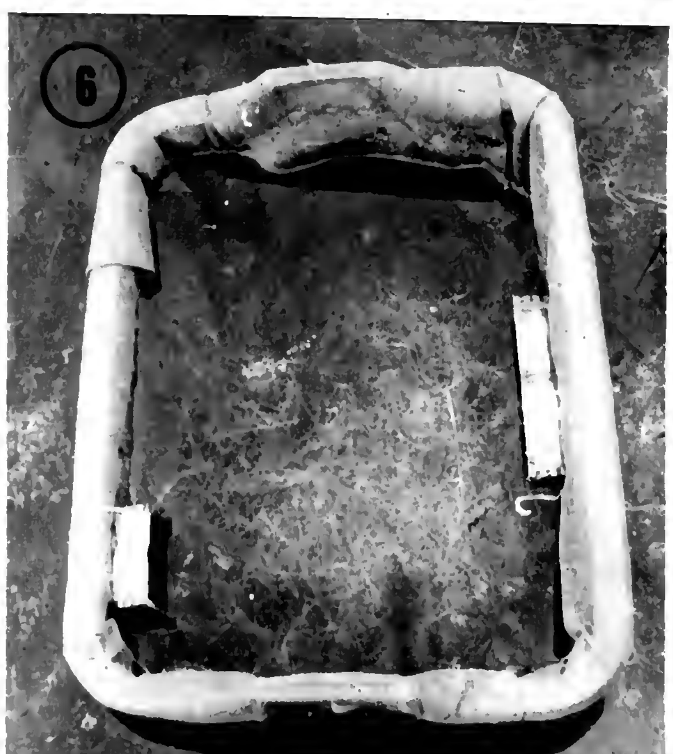
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to provide protected enclosures. Aquatic macrophytes were planted in sand at the bottom of the baskets. Vertically positioned glass slides were also placed in the baskets. The slides were placed in wooden slide boxes which had the bottoms removed and the boxes were then attached to the sides of the baskets. The basket enclosures with plants and slides were generally left in place for varying periods up to 6 weeks. Occasionally large glass jars were also used as enclosures for macrophytes. Outside the enclosures slides in boxes were sometimes attached to upright poles or to ropes secured by an anchor and buoy. Plants occurring naturally in the littoral area were also sampled.

Specific methods, collection dates, and exposure periods differed in the various littoral studies. Details concerning aspects of each separate study are included in Chapter V.

Limnetic Area Methods

Comparative studies were made at Lake Mize, Florida, and Elk Lake, Minnesota, of the attached algae present in the limnetic areas. In August, 1967, the attached algal flora on vertical glass slides placed in the limnetic area of Elk Lake, Minnesota, was studied. Slides were attached to wooden blocks in which slits had been cut. The blocks were attached to a rope. The rope was then attached to a buoy at the surface of the lake and to an anchor at the lake's bottom. Slides were suspended at the surface, at 1-meter intervals to the 5-meter level, and at 2-meter intervals from the 7-meter level to the 15-meter level.

In Lake Mize, 3 similar studies were conducted during the following time periods: December, 1968, to February, 1969; July to August, 1969; and July to August, 1970. Slides were placed in wooden slide boxes with the bottom sections removed. In an arrangement similar to that carried out at Elk Lake, the boxes were attached to a rope. The rope was then attached to a buoy and an anchor and suspended in the middle of the limnetic area of the lake near the deepest. Since Lake Mize is a brown-water lake with limited light penetration, slides were placed nearer the surface than at Elk Lake, Slide racks were generally attached to the rope at levels of 6, 18, 30, and 42 inches. In the 1968-1969 winter study and the August to September, 1969, study, slide racks were also placed at deeper depths (see p. 50 and p. 63).

In August, 1970, the sedge, *Websteria submersa*, was also suspended on a rope-buoy system during the same time as the suspension of glass slides. As indicated earlier, this macrophyte occurred naturally from time to time in the lake as floating mats, so that its retention on an artificial rope-buoy approximated the floating state. Suspensions were made at levels of 6, 18, 30, and 42 inches with groups of the plants tied to the rope at these levels. The suspended plants remained alive throughout the study period. Considerable plant growth occurred at the first 2 levels.

Various exposure periods were used for slides and plants during the study, ranging from 6 hours to 6 weeks. Exposure periods and collection dates are enumerated for each part of the study in Chapter V.

Collecting Procedures

After collecting, plants and slides (Figure 5) were placed in liquid preservative prepared according to the following formula.*

Dioxan	50 cc
Formalin	6 cc
Acetic Acid	5 cc
Water	40 cc

This solution preserved most algae so that plastid color was retained. Algae which were alive at the time of collection could be distinguished from dead forms.

Species Composition Method

In the Lake Mize limnetic studies and in the August, 1970, littoral study, proportions and frequency of

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*McWhorter and Weier, 1936.

the various species present on glass slides and on some plants were calculated. With the glass slides, after 1 side of the slide was wiped clean, algae on the unwiped side were examined directly. Species were usually identified before any cell counts were made. Counts were made in 2 prescribed areas of the slide, since observation indicated that algal populations were not evenly distributed on the slides. On most slides, heavier concentrations of algae were generally present near the edges of the slides. Counts were therefore made in 2 areas extending as lines, as indicated by Figure 7. Along these 2 lines, counts were made of the algae present in randomly selected fields, using a 43× objective and a 10× ocular.

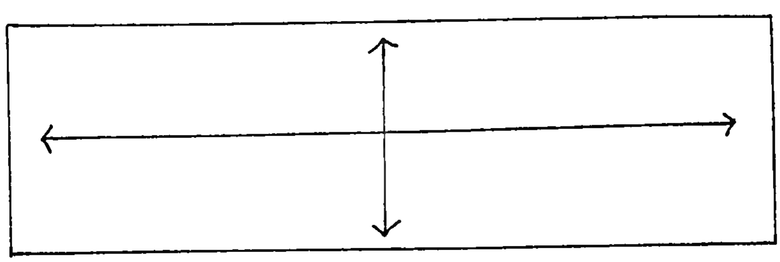


Figure 7. Areas counted, indicated by lines, on glass slides in Lake Mize studies.

In his study of attached algae, Castenholz (1957) found that counting 300 individuals in randomly selected microscopic fields gave reasonable statistical accuracy.

In the writer's Lake Mize study, Castenholz's counting procedure was generally followed with the first 300 individuals recorded. Sometimes on sparsely populated slides, it was necessary to count only 100 individuals. And, on heavily populated slides, 500 to 1000 individuals were counted. Frequencies per square centimeter for individual species and for the total algae present were calculated. Relative abundance as presented in Table 42 of the Appendix was based on these calculations. Proportions of the various species among the 300 attached forms counted were also calculated.

Among the aquatic macrophytes, it was possible to examine directly the attached flora of *S. macrophyllum*. However, the attached algae of most aquatic plants were observed by scraping off the epidermis with its attached organisms from a prescribed portion of the plant. Scrapings were placed on a slide, a drop of water added, and the mixture stirred. Counts were then made with the first 300 individuals recorded. Proportions of the various species among the 300 recorded were calculated. In the case of the linear plant, *W. submersa*, plant area was measured before the epidermis was scraped so that frequency could be calculated for comparison with glass slides.

With the Elk Lake study and with some of the collections made from the Lake Mize littoral areas, species proportions and frequency were not calculated. Identification was made of the species present and dominants were noted.

Based on frequency calculations or estimates, several terms are used throughout this study in order to describe relative abundance of an algal taxon. These terms and the meaning ascribed to them by the writer are listed as follows:

1. *Very Abundant:* Over 5000 cells, filaments, or colonies per square centimeter
2. *Abundant:* 2000 to 5000 cells, filaments, or colonies per square centimeter
3. *Common:* 500 to 2000 cells, filaments, or colonies per square centimeter
4. *Infrequent:* 100 to 500 cells, filaments, or colonies per square centimeter
5. *Rare:* 10 to 100 cells, filaments, or colonies per square centimeter
6. *Dominant:* Algal species present in largest numbers (numerical dominance)

Physical Measurements

A Whitney light meter was used to measure light penetrance in Lake Mize. For temperature measurements, a precision oxygen analyzer was used in the limnetic area and a pocket thermometer in the littoral area.

V. OBSERVATIONS AND RESULTS

The results of the Lake Mize and Elk Lake studies are organized chiefly according to: (1) the period of the observation (month and year) and (2) the site of the observations in the lake, i.e., whether in the littoral or limnetic area of the lake. Data relating to the statistical reliability of the observations of this study are also presented. A master list of the species found in Lake Mize, Florida, is included in the Appendix (Table 38) as well as photographs of selected species identified during the study. A list of species identified from Elk Lake, Minnesota, is also included in the Appendix (Table 39). In addition, a third table (Table 40) is included which presents comparative frequencies of a number of algae identified during the limnetic studies.

Limitations of the Study

In determining the relative abundance of species of attached algae under various conditions in Lake Mize, 2 sources of error deserve consideration. One source of error in making comparisons is derived from the unavoidable loss of attached material from the substrate while collecting. This loss of material could be observed both in the lake during collection and at the bottom of the collecting jar after preservation. In making this study, it was assumed that the amount of material lost from various substrates while collecting was the same. Precautions were taken while collecting so that the loss of material was minimal. The material at the bottom of the collecting jars was also periodically examined for species which might not appear in the material still attached to the substrate. Proportions of species in the material at the bottom of collecting jars were also checked. These proportions were similar to those proportions of species remaining attached to the substrate except for slightly higher losses of metaplanktonic species. The factors contributing to these losses are discussed in Chapter VI.

Another source of error is the statistical error found in the counts which provide the basis for some of the comparisons in this study. Brook (1953) in a study of bottom-living algae of sand filter beds in waterworks, found that sampling error for 1 filter bed was around 23% when 10 collections were made. However, because changes in time were so marked, he still found it possible to make valid comparisons in his successional study.

The sampling errors in the present study were also high. For a given algal species, counts made from replicate substrates frequently showed a variation as high as that of Brook's study. Occasionally the variation was even higher (Table 3). However, significant differences in frequencies and in proportions among species did commonly occur under different environmental conditions. Differences with time were also sometimes marked.

The variation present among counts from replicate substrates was due to a complex interaction of factors and will be elaborated upon in Chapter VI.

Lake Mize Studies

Eighty-nine species of algae were identified as part of the periphyton in Lake Mize or as planktonic forms associated with the periphyton. Thirteen other species were present but could not be identified to species, chiefly due to the lack of reproductive structures in the Zygnematales and Oedogoniales collected. Of the 102 species present, 63 were Chlorophytes, 2 were Euglenophytes, 22 were Chrysophytes, 2 were Pyrrophytes, 1 was a Xanthophyte, and 1 was a Chloromonadophyte.

Colonization of Substrates by Algae

Glass slides placed in the lake and removed after 6 hours were populated by a variety of forms. Many bacteria were attached to these slides. Planktonic algae were common on those slides exposed for a short period of time. Epiphytic algae common natural substrates in the lake at the time were also present.

TABLE 3

Representative Sampling Errors as Experienced in the Proportions and Frequencies of *Mougeotia* sp., Diatoms, and Algae on Replicate Glass Slides Exposed at a Depth of 6 Inches for 4 Weeks During the 1968-1969 Winter Study.

Taxon	No. of plates	Median % of periphyton	SD	C as %	Frequency per centimeter^2	SD	C as %
Mougeotia sp.	4	19.4	3.2	16.5	2,544	506	19.9
Diatoms	4	11.9	4.8	40.3	1,545	659	42.7
Total Algae	4	97.5	3.4	3.4	12,965	651	5.0

Note: SD = standard deviation
C = coefficient of variation

Slides submerged in the lake for 1 week retained a clear appearance. However, microscopic examination of slides from depths of 6 to 18 inches indicated that several thousand organisms per square centimeter were present. Slides collected after 2, 3, 4, 5, or 6 weeks' exposure were partially covered by a film of brown debris. Accumulation and loss of this debris continued throughout the exposure period. Several other changes with time were evident in the periphyton when glass slides exposed for 1 week were compared with those exposed for several weeks. The periphyton community on slides exposed from 2 to 4 weeks showed an increase in algal frequency and in species diversity when compared with that of slides submerged for one week during the same season. Slides exposed for periods longer than 3 to 5 weeks sometimes showed a loss of both debris and associated algae.

Dominant algae present on slides collected after 1 week were usually of the same species as those dominant on slides collected several weeks later. In the 1968-1969 winter study, *Mougeotia* sp. made up 23% by count of the periphyton on slides collected at the 6-inch level on December 17, 1968. On January 9, 1969, slides collected at the same level after 4 weeks' exposure showed higher algal frequencies and greater species diversity. However, *Mougeotia* sp. remained as a dominant, making up 20% of all the organisms counted.

Colonization of submerged plants followed the same trends as those of glass slides. During a time period up to 3 or 4 weeks debris accumulated, algal frequency increased, and species diversity increased. On some plants, sharper increases over a period of time were recorded in algal frequency and species diversity than on glass slides.

Dispersal or "seeding" units of algae which colonized submerged slides were generally zoospores, single vegetative cells, akinetes, or hormogones. Germlings of *Oedogonium* and *Bulbochaete* which had developed from zoospores were frequently observed on slides and plants. Single vegetative cells were the seeding units for most diatoms, desmids, and members of the Zygnemataceae. During seasons when blue-green algae were abundant, germinating akinetes were common on submerged substrates. Hormogones of several species of the Oscillatoriales were also common then.

The epiphytic algae of Lake Mize showed several methods of attachment. Many single-celled and filamentous algae attached along their broad side to the substrate. This type was represented by such forms as the diatom, *Eunotia*, several species of the desmid, *Cosmarium*, and several filamentous blue-greens. Other filamentous forms, as *Mougeotia* and *Oedogonium* developed a terminal cell modified into a holdfast. Attachment to the substrate was by means of this holdfast with the remainder of the filament free of the substrate and extending vertically above it. The single-celled diatom, *Gomphonomena lanceolatum*, also extended vertically above the substrate, attaching by means of a button of mucilage on 1 end of the cell. Other algae, termed the meta-plankton, generally did not attach directly to submerged slides and plants, but were found floating in the debris associated with submerged substrates. These forms associated with debris included a number of single-celled and filamentous desmids and several filamentous blue-green algae.

Spatial Variation in the Periphyton in Lake Mize

During the study period both dominance and species composition varied considerably in the communities of attached algae present in Lake Mize. At any given point in time, algal species were generally the same in the periphyton communities located in separate areas of the lake. However, proportions of the algal species present varied on similar substrates in different areas. Slides placed for a measured period of time at the same depth in the limnetic area and at various points in the littoral area had somewhat different algal communities.

Generally, there were some dominant species common on all slides at all locations. Other species assumed a dominant role at some locations but not at others. Several examples may be cited. Prostrate greens such as *Protoderma viride* and *Coleochaete irregularis* were occasionally common on slides submerged at some littoral stations. However, during the same period they were generally rare or absent on slides exposed at other littoral stations and in the limnetic area. Conversely, the heterotrophic alga, *Rhipidodendron splendidum*, was common only on slides suspended in the limnetic area during August, 1970. Its occurrence was rare on littoral area slides suspended at the same depth.

Natural substrates in different areas of the lake also had epiphytic communities of different floristic compositions. As a rule filamentous Chlorophytes were the dominant epiphytes on grass culms in the littoral area, especially several species of *Oedogonium*. Collections of *Panicum hemitomon* from 3 stations in the littoral zone on the same date generally all contained *Oedogonium* as an abundant or very abundant epiphyte. The co-dominants were usually not the same at the 3 stations. The filamentous macrophyte, *Websteria submersa*, also showed horizontal variations at separate stations in the lake in regard to its epiphytic flora. *W. submersa* frequently supported an epiphytic flora of many desmids. Generally, some desmids were more abundant on *W. submersa* in some areas of the lake than in others. The epiphytic algal communities on other aquatic macrophytes in Lake Mize also showed the same trends toward horizontal variation as did the epiphytic communities on *P. hemitomum* and *W. submersa*.

Vertical differences as well as horizontal differences were also apparent in the communities of attached algae in the lake. Light undoubtedly is a severely limiting factor in Lake Mize. This was reflected generally in the paucity of attached algae on slides submerged below a depth of 30 inches. In contrast, the maximum number of attached algae generally occurred on slides suspended at a depth of 3 meters in Elk Lake, Minnesota. In general, slides suspended at various depths in Lake Mize showed the following patterns of vertical distribution with reference to the periphyton:

1. Six-inch depth—desmids and other Chlorophytes abundant or very abundant, Cyanophytes and Chrysophytes occasionally abundant, species diversity high.

2. Eighteen and 30-inch depths—Chrysophytes, especially species of the diatom *Eunotia*, dominant, cell frequency common to very abundant, Cyanophytes and Chlorophytes occasionally common, species diversity lower than at 6-inch depth.

3. Forty-two and 54-inch depths—Few attaching algae present, attached protozoans usually the dominant component of the periphyton.

4. Depths below 54 inches—Attaching forms generally rare.

An exception to the general pattern of vertical distribution in the periphyton did occur during the 1968-1969 winter season with respect to one species of *Euglena*. This alga was abundant to very abundant on slides suspended at all depths. (Slides were suspended to a depth of 6-1/2 feet.) Planktonic algae were also occasionally found on slides suspended at depths below 54 inches.

Seasonal Variation in the Periphyton in Lake Mize

From season to season and from year to year, the magnitude of variation in the periphyton was even greater than in different areas of the lake within the same season. As could be anticipated, both species composition and dominance changed from one season to another. Considerable differences were recorded in communities of attached algae present in the same season during different years. These differences occurred mainly at the species level. Few seasonal changes occurred at the divisional level. During most of the year, Chlorophytes were usually dominant in the upper 6 to 18 inches of the lake. As a rule Chrysophytes assumed a secondary role to Chlorophytes in this upper vertical layer of the lake.

The most obvious seasonal change in the relative abundance of the various algal divisions occurred during the warmer months of late summer and early fall. During this period (late July—late September), Cyanophytes became an important component of the epiphytic flora in Lake Mize. Conversely, few Cyanophytes occurred during the winter months in the communities of attached algae.

Attached Algae Present in the Limnetic Area of Lake Mize, Winter, 1968-1969

During the 1968-1969 winter study of attached algae, frames of vertically positioned glass slides were suspended in the limnetic area of Lake Mize at depths of 80 and 104 inches in addition to the suspensions made near the surface (see p. 35, Methods). Slides were exposed from December 9 to 17 (1 week); from December 17 to January 9 (4 weeks); and from February 6 to February 13 (1 week).

Dominant algae on slides during the winter study included a species of the filamentous Chlorophyte, *Mougeotia*, and a species of *Euglena*. Several species of the diatom, *Eunotia*, were also occasionally common on slides. During this period, species diversity among the algal communities on slides was high as contrasted with the two August studies (see Table 40, Appendix). Many of the species present during the winter study were Chlorophytes (Tables 4, 5, 6, and 7). Generally, on upper level slides (6 to 18 inches) suspended during this period, Chlorophytes were abundant to very abundant; Chrysophytes were somewhat common, but not as numerous as Chlorophytes; and Cyanophytes occurred only rarely (Figure 8 and Tables 5 and 7).

Vertical Distribution of Attached Algae on Glass Slides, December, 1968 to February, 1969

Varying patterns of vertical distribution were observed among the algal species on glass slides suspended during the 1968-1969 winter period. *Euglena* sp. was abundant to very abundant on all exposed slides. The vertical distribution of this alga was unusual in that these frequencies occurred on all slides suspended from a depth of 6 inches to a depth of 6-1/2 feet (Figure 8). Most other attached algae achieved such frequencies only in the top 6 to 30 inches of the lake. A general increase in frequency for this alga did occur on slides exposed for 4 weeks as compared to those exposed for 1 week. However, the abundant frequencies of *Euglena* sp. on slides exposed for 1 week were much higher than those of most other algae after a similar exposure period.

In contrast to the broad vertical range over which *Euglena* sp. occurred abundantly, *Mougeotia* sp. was abundant

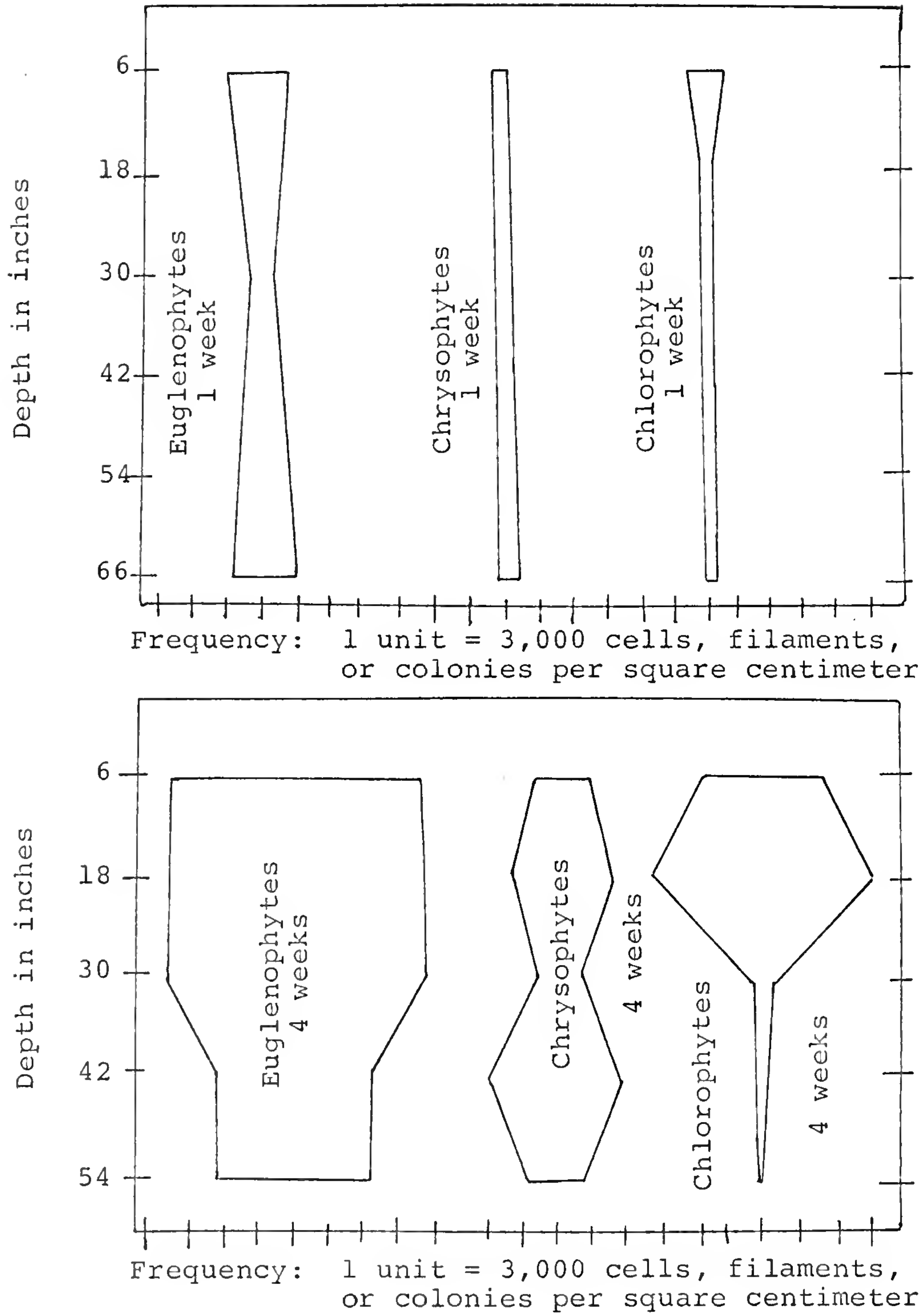


Figure 8. Frequencies of 3 algal divisions present on glass slides suspended in the limnetic area of Lake Mize for 1 week, December 9 to December 17, 1968, and for 4 weeks, December 17, 1968, to January 9, 1969.

TABLE 4

Dominant Algal Species Found on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 1 Week, December 7 to December 17, 1968

	Percent of the Total Number of Attached Organisms			
	6-inch depth (%)	18-inch depth (%)	42-inch depth (%)	104-inch depth (%)
Chlorophytes				
Mougeotia sp.	23	10	10	4
Chrysophytes				
Eunotia spp.	3	4	6	10
Euglenophytes				
Euglena sp.	54	70	70	68

TABLE 5

Proportions of Algal Divisions and Attached Protozoa Present on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 1 Week, December 9 to December 17, 1968

	Percent of the Total Number of Attached Organisms			
	6-inch depth (%)	18-inch depth (%)	42-inch depth (%)	104-inch depth (%)
Algae				
Chlorophytes	26	10	11	4
Chrysophytes	12	10	13	18
Cyanophytes	2	1	1	1
Euglenophytes	54	70	70	68
Xanthophytes	3	4	3	6
Pyrrophytes	1	1	1	1
Attached Protozoans	ab.	3	2	ab.

Note: ab. = absent

TABLE 6

Dominant Algal Species Found on Glass Slides Suspended in the Limnetic Area of Lake Mize for 4 Weeks, December 17, 1968, to January 9, 1969

	Percent of the Total Number of Attached Organisms				
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)	80-inch depth (%)
Chlorophytes					
Mougeotia sp.	20	21	4	1	1
Chrysophytes					
Mallomonas sp.*	2	2	6	18	40
Eunotia spp.	5	2	3	1	ab.
Nitschia palea	2	6	3	ab.	1
Euglenophytes					
Euglena sp.	54	52	66	72	52

Note: ab. = absent

*planktonic

TABLE 7

Proportions of Algal Divisions and Attached Protozoa Present on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 4 Weeks, December 17, 1968, to January 9, 1969

	Percent of the Total Number of Attached Organisms				
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)	80-inch depth (%)
Algae					
Chlorophytes	26	28	9	1	1
Chrysophytes	12	11	15	19	41
Cyanophytes	3	3	1	3	1
Euglenophytes	54	52	66	72	52
Xanthophytes	2	2	4	4	2
Pyrrophytes	1	1	1	ab.	ab.
Attached Protozoans	1	2	2	1	3

Note: ab. = absent

only on slides exposed for 4 weeks which were suspended at depths of 6 and 18 inches. At 30 inches, the frequency of this alga dropped, although it was still common. At depths below 30 inches, the occurrence of *Mougeotia* sp. on slides was rare. However, this was a greater range of depths than was the case for dominant Chlorophytes on slides during the summer studies.

Other Chlorophytes which were common on slides at one or both of the upper two depths included several species of *Oedogonium* and a number of desmids. The most common desmid was *Closterium intermedium*, although *Cosmarium ornatum* and *Closterium setaceum* were also somewhat common on slides at the two upper levels.

Several Chrysophytes also occurred on slides during the 1968-1969 winter season. The most numerous diatoms were *Eunotia pectinalis* and *Nitschia palea*. The former was common on slides suspended at a depth of 6 inches after 4 weeks' exposure and rare or absent at depths below 6 inches. The latter was common on slides suspended at a depth of 6 inches and became abundant on slides suspended at a depth of 18 inches. It was infrequent on slides suspended at a depth of 30 inches and rare at depths below 30 inches.

Several diatoms reached their greatest abundance during the winter period. These included *Eunotia curvata* and *Frustulia rhomboides*. *E. curvata* was common on slides suspended at a depth of 18 inches for 4 weeks and was infrequent or rare on slides suspended at other depths during the winter study. During other seasons it was usually absent in the communities of attached algae found on plants and slides. Only an occasional cell appeared in some collections. *F. rhomboides* occurred regularly in the periphyton during all seasons of the year. Its occurrence on slides and on plants was always rare to infrequent, attaining its greatest frequency during the 1968-1969 winter period.

Few Cyanophytes occurred on winter slides. The adhering filaments of *Phormidium tenue* were infrequent on slides suspended at a depth of 6 inches and were rare or absent at other depths. In addition to *P. tenue* several other Cyanophytes appeared at the 6-inch depth. However, they were rare even at this level and were generally absent at still deeper levels.

Several planktonic species were also present on winter slides. These included the Pyrrophyte, *Peridinium limbatum*. Slides suspended during this period were littered with dead cells of this dinoflagellate, although some living cells were also present. This alga was the dominant component of the winter plankton, occurring exclusively during the cooler months in Lake Mize. A small species of *Mallomonas* also appeared on the winter slides. This planktonic Chrysophyte was common to infrequent on slides suspended at a depth of 30 inches or less, becoming abundant on slides suspended at depths of 42 inches and 80 inches (6-1/2 feet). The increase in *Mallomonas* sp. with increasing depth accounts for the somewhat "hour-glass" frequency profile for the Chrysophyta (Figure 8). Most Chrysophytes at upper levels were diatoms as discussed previously.

Variation in Algal Flora on Glass Slides with Time, Winter, 1968-1969

When slides collected at various depths on December 17, 1968, after 1 week's exposure were compared with those collected on January 9, 1969, after 4 weeks' exposure, two changes with time were apparent. At all depths, the frequency of attached organisms was greater on slides exposed for 4 weeks than on slides exposed for 1 week. The number of species also was greater on slides exposed for 4 weeks. Twenty species were found on slides exposed for 1 week as compared to 40 species found on slides exposed for 4 weeks. Most of this increase in species diversity occurred at the upper levels (Tables 8 and 9). At the lower levels, little increase in species

TABLE 8

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Area of Lake Mize for 1 Week, December 9 to December 17, 1968

	Number of Species			
	6-inch depth	18-inch depth	42-inch depth	104-inch depth
Chlorophytes	12	5	4	2
Chrysophytes	6	6	5	6
Cyanophytes	1	1	1	2
Euglenophytes	1	1	1	1
Xanthophytes	1	1	1	1
Pyrrophytes	1	1	1	1
Total Number of Species	22	15	13	13

TABLE 9

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Area of Lake Mize for 4 Weeks, December 17, 1968, to January 9, 1969

	Number of Species				
	6-inch depth	18-inch depth	30-inch depth	42-inch depth	80-inch depth
Chlorophytes	23	21	10	3	3
Chrysophytes	10	9	11	3	3
Cyanophytes	4	4	2	1	2
Euglenophytes	1	1	1	1	1
Xanthophytes	1	1	1	1	1
Pyrrophytes	1	1	1	ab.	ab.
Total Number of Species	40	37	26	9	10

Note: ab. = absent

number occurred over a 4-week period. Much of the increase in species diversity at the upper levels was due to the increase in desmid species.

Similarities, especially in the proportions of some dominants, were also apparent when proportions of *Mougeotia* sp. on slides collected on December 17, 1968, after 1 week's exposure were not significantly different from that on slides collected on January 9, 1969, except at the 18 inch level where an increase occurred (Tables 4 and 6). At any given depth where slides were exposed, proportions of *Euglena* sp. were also similar on the two dates.

Total desmid frequency did increase between the two dates, as did the number of species. *Closterium intermedium* was the only individual desmid to show a significant numerical increase between 1 week and 4 weeks at the upper two levels. No increase occurred at the lower levels.

The number of diatom species were generally the same at comparable depths on slides exposed for 1 week as on slides exposed for 4 weeks. Frequency increases were recorded for *Eunotia pectinalis* and *Nitschia palea.*

Several Chlorophyte and Chrysophyte species were present on slides collected during February which were not present on slides collected during December or January.

Most of the new Chlorophyte species were desmids. None of the species which first appeared in February were abundant. As in the two previous months, *Mougeotia* sp. and *Euglena* sp. were the dominant genera.

Attached Algae Present in the Limnetic Area of Lake Mize, August to September, 1969

During the August-September study, the general methods used in limnetic studies were modified in that slides were suspended at depths of 54, 66, 120 and 240 inches in addition to the standard suspensions in the upper 42 inches of the lake. Collections were made on August 14, 1969, after 1 week's exposure; on August 28, 1969, after 3 weeks' exposure; and, on September 11, 1969, after 6 weeks' exposure.

Twenty-seven species of algae were identified on glass slides during the August-September study, 15 Chlorophytes, 6 Chrysophytes, and 6 Cyanophytes. Seven of the Chlorophytes were desmids, a smaller number of desmid species than had appeared during the 1968-69 winter study. The total number of species was also less in the August to September, 1969, study than in the 1968-1969 winter study. However, the highest organism frequency recorded on glass slides in the limnetic area of Lake Mize occurred during August, 1969.

Dominants appearing at upper levels on slides were chiefly Cyanophytes. These included *Phormidium tenue*, *Oscillatoria tenuis*, and *Aphanocapsa delicatissima*. The diatoms *Eunotia pectinalis* and *Navicula minima* sometimes reached abundant to very abundant frequencies on slides, as did the planktonic Chrysophyte, *Mallomonas caudata*. *Gleocystis vesiculosa* was a dominant on slides exposed for 1 week from August 7 to August 14.

Vertical Distribution of Attached Algae and Other Periphyton on Glass Slides, August to September, 1969

The dominant algal species present on slides during the August to September, 1969, limnetic study showed several varied patterns of vertical distribution. The Chlorophyte, *Gleocystis vesiculosa*, made up a large proportion of the periphyton on slides exposed for 1 week (Table 10). On this group of slides, *G. vesiculosa* reached its highest frequencies at depths of 30 and 42 inches. The colonies of this alga were common on slides suspended at depths of 6 inches and 18 inches, becoming abundant at depths of 30 and 42 inches. Below this depth, *G. vesiculosa* was infrequent to rare on slides exposed for 7 days.

On slides exposed for 3 weeks, *G. vesiculosa* had a different vertical distribution from that recorded from

TABLE 10

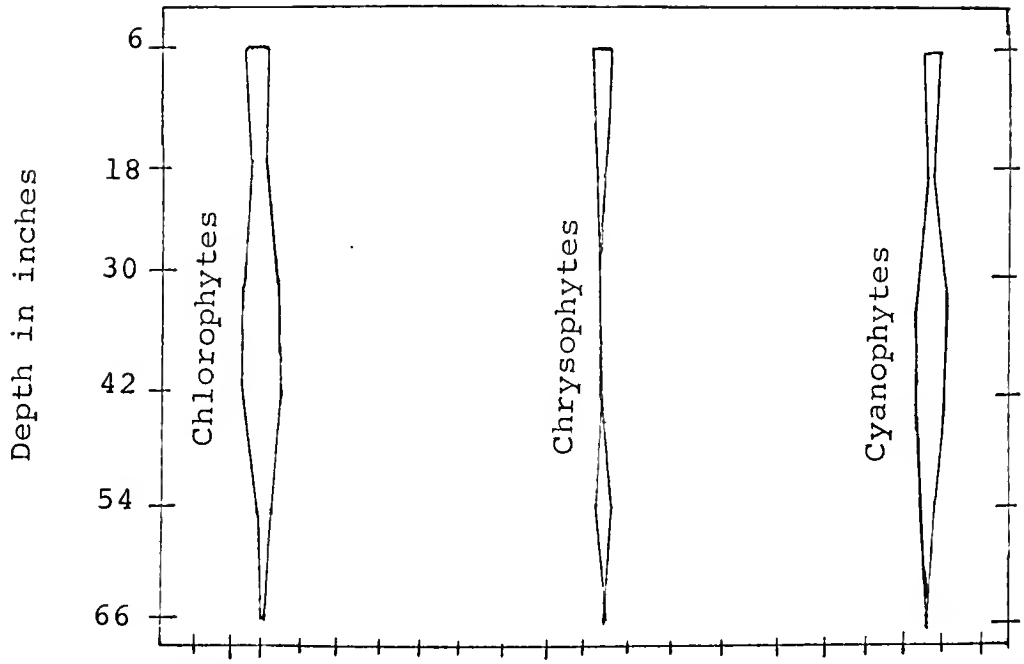
Dominant Algal Species Found on Glass Slides Suspended in the Limnetic Area of Lake Mize, for 1 Week, August 7 to August 14, 1969

	Percent of the Total Number of Attached Organisms							
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)	54-inch depth (%)	66-inch depth (%)	126-inch depth (%)	240-inch depth (%)
Chlorophytes								
Gleocystis vesiculosa	27	28	49	33	31	25	15	8
Cyanophytes								
Oscillatoria tenuis	2	7	13	12	7	8	3	4
Phormidium tenue	13	2	5	4	5	10	6	33

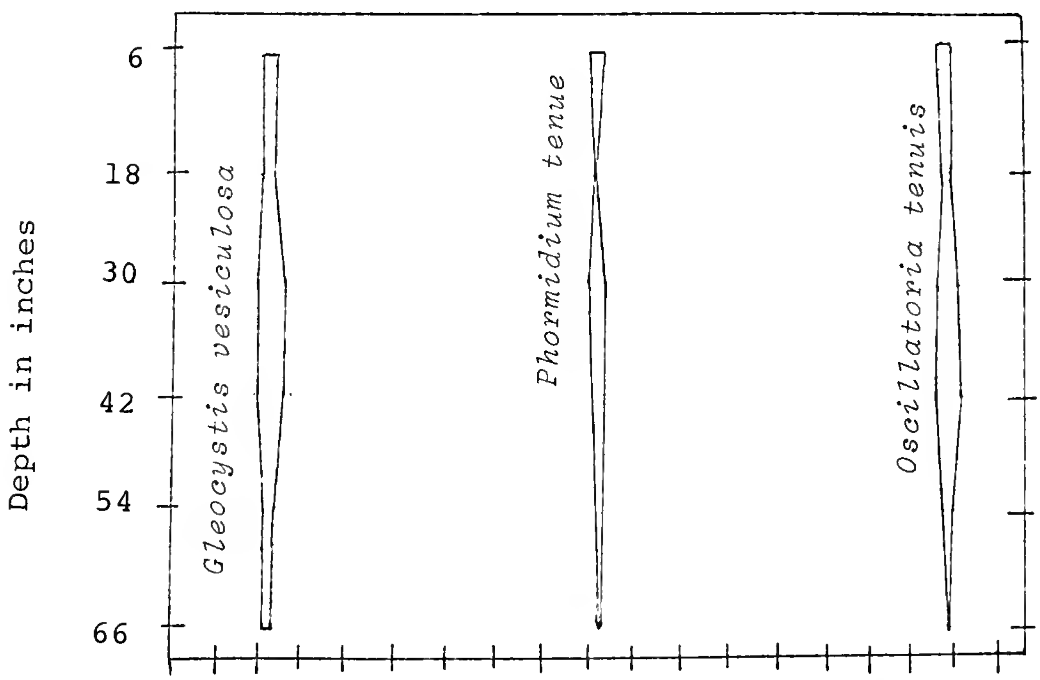
slides exposed for 1 week (see Figures 9 and 10). On slides exposed for 3 weeks highest frequencies occurred at a depth of 6 inches. *G. vesiculosa* was abundant at this depth and then common to rare at all other depths.

Other Chlorophytes present included several species of *Oedogonium*, *Ankistrodesmus falcatus*, *Cosmarium* sp., *Protoderma viride*, *Scenedesmus dimorphus*, *Closterium intermedium*, and the planktonic *Helicodictyon planctonicum*. All were rare to infrequent. Most of these Chlorophytes were restricted to slides suspended at 30 inches or above (Tables 11, 12, 13). However, the desmid, *Cosmarium* sp., occurred rarely on slides to a depth of 20 feet, and germlings of *Oedogonium* sometimes occurred infrequently on slides to a depth of 10-1/2 feet. The planktonic alga, *H. planctonicum*, was also recorded, though rarely, to a depth of 20 feet.

Among the three dominant Cyanophytes present were two shade-tolerant species, *Phormidium tenue* and *Oscillatoria tenuis*, which occurred to a depth of 5-1/2 feet. Both species displayed a broad limnological tolerance, occurring on slides near the surface as well as at much greater depths. The highest recorded frequency for any alga on glass slides during the entire study period occurred in *P. tenue*. These exceptionally high counts were taken from slides submerged to a depth of 6 inches

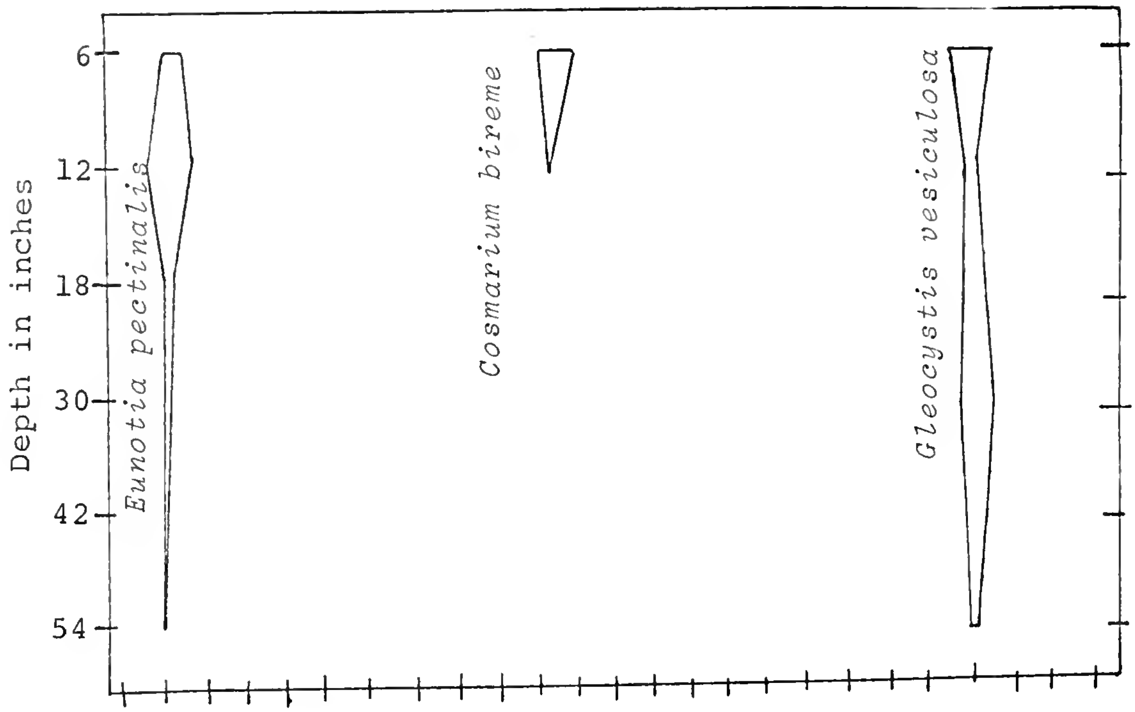


Frequency: 1 unit = 3,000 cells, filaments, or colonies per square centimeter

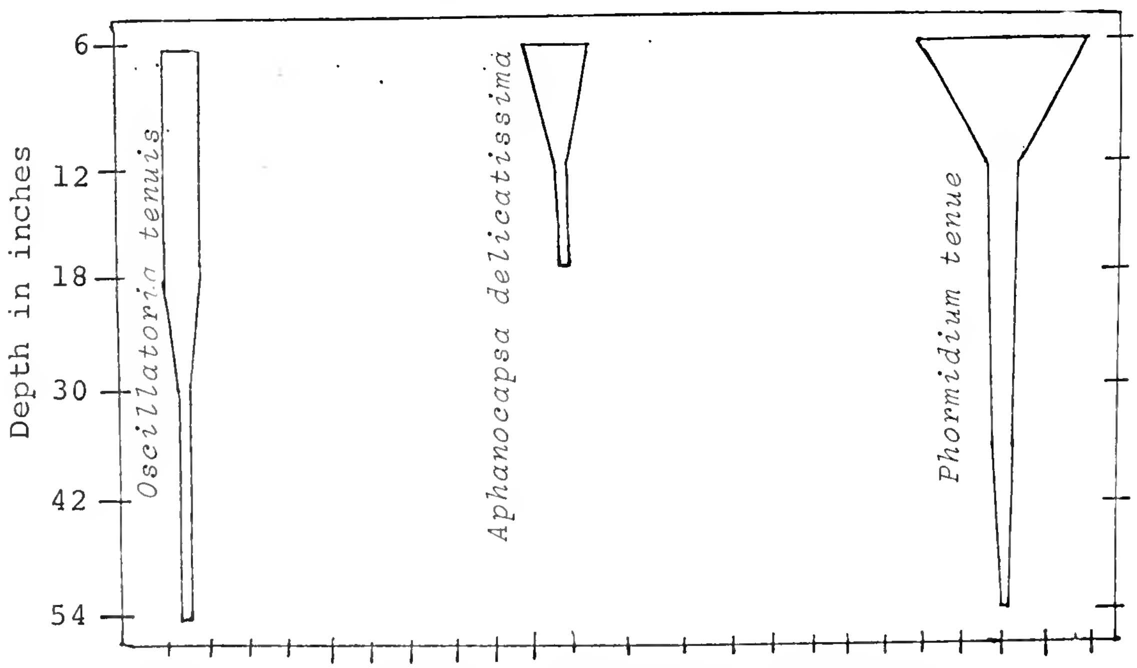


Frequency: 1 unit = 3,000 cells, filaments, or colonies per square centimeter

Figure 9. Frequencies of 3 algal division and of the dominant algal species present on glass slides suspended in the limnetic area of Lake Mize for 1 week, August 7 to August 14, 1969.



Frequency: 1 unit = 3,000 cells, filaments, or colonies per square centimeter



Frequency: 1 unit = 3,000 cells, filaments, or colonies per square centimeter

Figure 10. Frequencies of the dominant algal species present on glass slides suspended in the limnetic area of Lake Mize for 3 weeks, August 7 to August 28, 1969.

TABLE 11

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Area of Lake Mize for 1 Week, August 7 to August 14, 1969

	Number of Species							
	6-inch depth	18-inch depth	30-inch depth	42-inch depth	54-inch depth	66-inch depth	126-inch depth	240-inch depth
Chlorophytes	8	6	5	5	5	2	3	3
Chrysophytes	6	6	1	2	2	2	2	2
Cyanophytes	5	6	3	3	2	4	3	2
Euglenophytes	ab.	1	ab.	ab.	1	1	ab.	ab.
Xanthophytes	ab.	ab.	ab.	ab.	ab.	1	1	ab.
Total Number of Species	25	19	9	10	10	6	9	7

Note: ab. = absent

TABLE 12

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 3 Weeks, August 7 to August 28, 1969

	Number of Species							
	6-inch depth	18-inch depth	30-inch depth	42-inch depth	54-inch depth	66-inch depth	126-inch depth	240-inch depth
Chlorophytes	10	9	4	5	3	4	5	
Chrysophytes	5	4	3	4	2	4	3	2
Cyanophytes	5	4	5	4	3	2	2	1
Euglenophytes	ab.	ab.	ab.	ab.	ab.	ab.	1	ab.
Xanthophytes	ab.	ab.	ab.	1	1	1	1	ab.
Total Number of Species	20	17	12	14	9	11	12	3

Note: ab. = absent

TABLE 13

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 6 Weeks, August 7 to September 11, 1969

	Number of Species						
	6-inch depth	18-inch depth	30-inch depth	42-inch depth	54-inch depth	66-inch depth	120-inch depth
Chlorophytes	11	5	3	4	1	1	3
Chrysophytes	4	5	3	3	3	2	3
Cyanophytes	6	5	6	5	6	3	1
Euglenophytes	ab.	ab.	ab.	1	ab.	ab.	ab.
Xanthophytes	1	1	1	1	1	1	1
Total Number of Species	22	16	13	14	11	7	8

Note: ab. = absent

and exposed for 3 weeks. (Higher frequencies for other algae were recorded on plants.) Frequencies of *P. tenue* were also comparatively high at other depths after the same 3-week exposure period. It was very abundant on slides exposed at a depth of 18 inches, although a decrease in numbers from the upper level did occur (see Figure 10). A gradual decrease of the frequency of this alga then occurred at lower depths. It was common on slides suspended at 30 inches, infrequent at 42 inches, and rare at 54 inches. On slides exposed for 3 weeks at a depth of 54 inches, *P. tenue* made up a large proportion of the periphyton (Table 14). Although it was rare at this depth, the numbers of other organisms were comparatively lower. The frequencies of this alga were not as high on slides exposed for either 1 week or 6 weeks as on slides exposed for 3 weeks. Slides exposed for 1 week on which colonization had recently begun had frequencies for *P. tenue* which ranged from common (6-inch depth) to rare (54-inch depth). Losses of *Phormidium* filaments from slides exposed for periods in excess of 3 weeks accounted for its decreased frequency (see Figures 10 and 11).

O. tenuis did not occur as frequently on slides during the 1969 summer study as *P. tenue*. In the case of slides exposed for 3 weeks, maximum frequency occurred

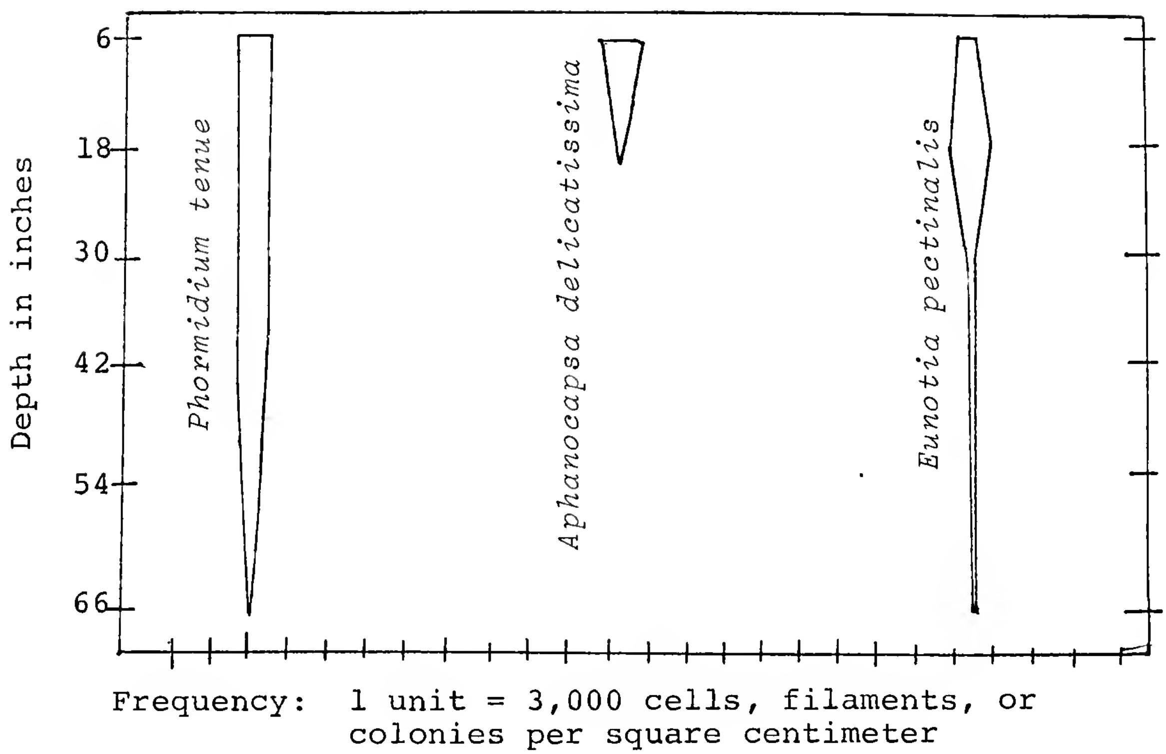


Figure 11. Frequencies of dominant algal species present on glass slides suspended in the limnetic area of Lake Mize for 6 weeks, August 7 to September 11, 1969.

TABLE 14

Dominant Algal Species Found on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 3 Weeks, August 7 to August 28, 1969

	Percent of the Total Number of Attached Organisms							
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)	54-inch depth (%)	66-inch depth (%)	126-inch depth (%)	240-inch depth (%)
Chlorophytes								
Gleocystis vesiculosa	6	2	9	11	5	2	2	ab.
Cosmarium bireme	5	1	ab.	ab.	ab.	ab.	ab.	ab.
Chrysophytes								
Eunotia spp.	5	22	1	4	1	1	20	45
Cyanophytes								
Aphanocapsa delicatissma	16	12	1	1	ab.	ab.	ab.	ab.
Oscillatoria tenuis	11	11	20	8	12	5	ab.	ab.
Phormidium tenue	42	32	40	16	12	10	10	55

TABLE 14—*Continued*

	Percent of the Total Number of Attached Organisms							
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)	54-inch depth (%)	66-inch depth (%)	126-inch depth (%)	240-inch depth (%)
Xanthophytes								
Stephanoporas regularis	ab.	ab.	ab.	1	30	25	35	ab.

Note: ab. = absent

at the 6-inch depth, although this alga remained common at successively deeper levels (18, 30, and 42 inches). With slides exposed for 7 days *O. tenuis* attained maximum frequencies at the 42-inch depth. When slides were left submerged for periods of 5 to 6 weeks, sloughing of the periphyton layer reduced the counts for most species. *O. tenuis*, for example, was recorded only rarely from slides exposed for 6 weeks regardless of depth.

Unlike *P. tenue* and *O. tenuis*, *Aphanocapse delicatissima* occurred only on slides suspended in the upper 18 inches of the lake with most of its growth on 6-inch slides. It was very abundant at 6 inches and rare at 18 inches on 3-week slides (Figure 10). Maximum frequencies also occurred at 6 inches on 6-week slides (Figure 11).

Other Cyanophytes found on slides during August and September, 1969, included *Calothrix epiphytica* and *Anabaena oscillarioides*. Both of these species occurred only on slides suspended at the depth of 6 inches. *C. epiphytica* was common at this depth and *A. oscillarioides* was infrequent at the end of the 3-week exposure period.

A number of Chrysophytes appeared on slides during the August to September, 1969, study. While not abundant on slides exposed for only 1 week, *Eunotia pectinalis* was a dominant species on slides exposed for both 3 weeks and 6 weeks (Tables 14 and 15). After both exposure periods,

TABLE 15

Dominant Algal Species Found on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 6 Weeks, August 7 to September 11, 1969

	Percent of the Total Number of Attached Organisms						
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)	54-inch depth (%)	66-inch depth (%)	126-inch depth (%)
Chlorophytes							
Gleocystis vesiculosa	1	3	5	13	ab.	2	3
Chrysophytes							
Eunotia spp.	11	19	2	5	12	4	7
*Mallomonas caudata**	8	1	4	11	1	12	6
Cyanophytes							
Aphanocapsa delicatissma	18	2	ab.	ab.	ab.	ab.	ab.
Phormidium tenue	2	1	14	17	5	ab.	ab.
Oscillatoria tenuis	1	1	11	8	2	2	ab.
Xanthophytes	2	1	1	1	20	16	51

Note: ab. = absent

*Planktonic

frequencies of this diatom were highest on slides suspended 18 inches from the surface, although it was abundant on slides suspended near the surface at a depth of 6 inches. A dramatic drop in the numbers of *E. pectinalis* occurred between 18 and 30 inches. Very abundant frequencies were recorded on slides suspended at 18 inches while only rare occurrences were noted at a depth of 30 inches (see Figures 10 and 11).

While *E. pectinalis* was the Chrysophyte present in largest numbers, several other Chrysophytes were rare to abundant. These included *Mallomonas caudata*, *Frustulia rhomboides*, *Navicula minima*, *Gomphonema lanceolatum*, and *Nitschia palea*. This period marked the only recorded occurrence of *G. lanceolatum* on slides in Lake Mize. Except for *M. caudata*, the vertical distribution of Chrysophytes was mainly limited to the upper 18 inches of the lake as was the case with *E. pectinalis*.

A coccoid Xanthophyte, *Stephanoporos regularis*, was also present on the August to September slides. The vertical distribution of this alga was unusual in that it occurred chiefly on deeper slides.

Attached protozoans made up a high proportion of the periphyton on slides exposed for 6 weeks during the 1969 summer study (see Table 16). Maximum abundance occurred at the 6-inch level with a gradual decline in frequency occurring at greater depths. A maximum frequency

TABLE 16

Proportions of Algal Divisions and Other Groups of Organisms Present on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 6 Weeks, August 7 to September 11, 1969

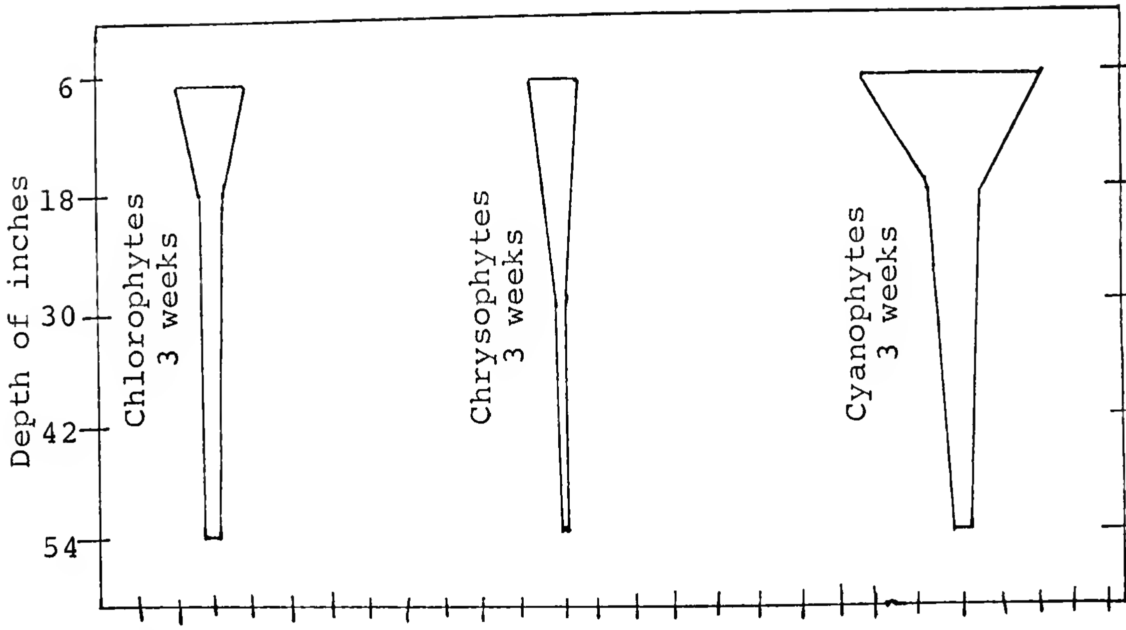
	Percent of the Total Number of Attached Organisms						
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)	54-inch depth (%)	66-inch depth (%)	120-inch depth (%)
Algae							
Chlorophytes	6	6	10	15	4	2	15
Chrysophytes	23	24	11	18	15	15	14
Cyanophytes	24	22	33	38	55	45	30
Xanthophytes	2	1	1	1	20	16	51
Euglenophytes	ab.	ab.	ab.	1	ab.	ab.	ab.
Attached Protozoans	41	30	33	35	10	20	ab.
Filamentous Oomycete	4	8	11	2	1	4	ab.

Note: ab. = absent

of attached algae for the 1969 summer study occurred on slides exposed for 3 weeks which were collected August 28. Vorticelloids occurred infrequently on these slides at most depths, although they were abundant on slides suspended at the depths of 42 inches (Table 17).

Changes in the Algal Flora on Glass Slides with Time, August to September, 1969

Glass slides collected on each of three dates during August to September, 1969, were populated by several Cyanophyte species. Slides collected on August 14 after 1 week's exposure were dominated by the green alga, *Gleocystis vesiculosa* (Tables 10 and 18). After 3 weeks' exposure the populations of *G. vesiculosa* showed a marked decrease. Instead, three Cyanophytes were dominant: *Oscillatoria tenuis*, *Phormidium tenue*, and *Aphanocapsa delicatissima* (Table 14). Debris covered parts of the slides, giving them a brown appearance. A significant increase in algal frequency occurred. Slides collected on September 11, 1969, after 6 weeks' exposure had lost most of the debris observed on August 21. Dominance also had shifted somewhat, so that Cyanophytes and Chrysophytes were present at upper levels in almost equal proportions (Tables 16 and 17 and Figure 12). In addition, a decrease in algal frequency since August 28 had occurred.



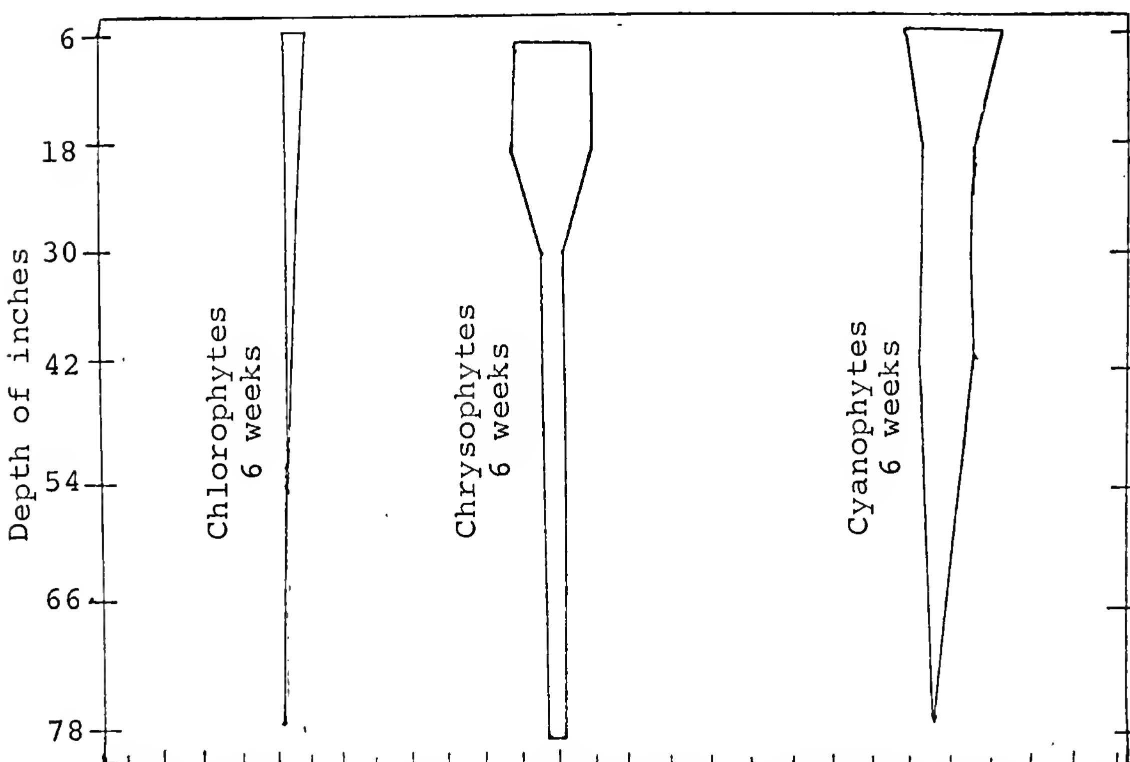


Figure 12. Frequencies of 3 algal divisions on glass slides suspended in the limnetic area of Lake Mize for 3 weeks, August 7 to August 28, 1969, and for 6 weeks, August 7 to September 11, 1969.

TABLE 17

Proportions of Algal Divisions and Attached Protozoa Present on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 3 Weeks, August 7 to August 28, 1969

	Percent of the Total Number of Attached Organisms							
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)	54-inch depth (%)	66-inch depth (%)	120-inch depth (%)	240-inch depth (%)
Algae								
Chlorophytes	14	5	10	16	14	5	12	ab.
Chrysophytes	14	28	3	6	28	30	35	45
Cyanophytes	68	60	62	26	8	15	13	55
Euglenophytes	ab.	ab.	ab.	ab.	ab.	ab.	2	ab.
Xanthophytes	ab.	ab.	ab.	1	30	25	35	ab.
Attached Protozoans	1	1	23	50	20	20	2	ab.

Note: ab. = absent

TABLE 18

Proportions of Algal Divisions and Attached Protozoans Present on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 1 Week, August 7 to August 14, 1969

	Percent of the Total Number of Attached Organisms							
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)	54-inch depth (%)	66-inch depth (%)	120-inch depth (%)	240-inch depth (%)
Algae								
Chlorophytes	75	36	50	34	33	45	20	18
Chrysophytes	10	8	1	1	12	14	66	38
Cyanophytes	11	11	22	33	15	20	10	40
Euglenophytes	ab.	1	ab.	ab.	1	ab.	ab.	ab.
Xanthophytes	ab.	ab.	ab.	ab.	ab.	4	3	ab.
Attached Protozoans	3	3	15	39	35	15	ab.	ab.

Note: ab. = absent

Adaptive Algal Forms Present, August to September, 1969

Attached forms present during the August 14 to September 11, 1969, period on glass slides tended to be resupinate, firmly attached along their broadsides. These included sheathed filaments of *Phormidium tenue*, colonies of *Aphanocapsa delicatissima*, plus those of several other blue-greens. Some resupinate single-celled forms also occurred. These included the diatom, *Eunotia pectinalis*, and the desmid, *Cosmarium bireme*. All of these resupinate forms had a distinct tendency to occur in areas of the slides which were free of debris. Frequencies for these forms were also usually higher for the edges than for the middle portion of slides. (The slide edges were generally free of debris.) The tendency of the coccoid colony of *A. delicatissima* to appear only on cleared edges of slides was especially notable.

Whereas the resupinate forms were associated with cleared areas of slides, other forms were present which tended to float in the debris that was associated with slides submerged for several weeks or longer. Many desmids tended to be associated with this debris. The filamentous blue-green, *O. tenuis*, was the most numerous of the debris-associated forms during the 1969 summer study. In his study of the communities of algae in a Michigan river, Blum (1957) also comments upon the tendency of *O. tenuis* communities to be associated with silt, with these communities generally occurring only on silted stream bottoms during the summer season. He also notes an apparent light sensitivity by *O. tenuis* in that it occurred mainly in shaded areas of the stream.

Attached Algae of the Littoral Area, August, 1969

On August 14 and 24, 1969, collections were made of aquatic macrophytes in the littoral area for determination of their epiphytic flora. *Fuirena scirpoidea*, *Polygonum hirsutum*, and *Panicum hemitomon* were collected on the earlier date from a depth of 18 inches at station 2. On all macrophytes the epiphytic flora was dominated by several unidentified species of *Oedogonium*. On *P. hemitomon* a co-dominant was *Oscillatoria tenuis*. In addition, the following attached species were recorded from the leaf sheath: *Pleurataenia subcoronulatum*, *Gleocystis vesiculosa*, *Mougeotia* sp., *Spirogyra* sp., *Phormidium tenue*, *Eunotia pectinalis*, *Frustulia rhomboides*, and *Anabaena oscillarioides*. A fresh water sponge was also present on some areas of the sheath and leaves.

In addition to *Oedogonium* spp., *Coleochaete irregularis* was a common attached form on the vertical sheaths of *F. scirpoidea*. Present on this sedge, but not as common,were the following species: *G. vesiculosa*, *Bulbochaete* sp., *Helicodictyon planctonicum*, *Stephanoporos regularis*, *E. pectinalis*, *A. oscillarioides*, *Oscillatoria tenius*, and *Hapalosiphon fontinalis*.

The sheath of *Polygonum hirsutum* was populated mainly by *Oedogonium* spp. and *Oscillatoria tenius* with *Oedogonium* spp. the more abundant of the two. Present also were: *G. vesiculosa, F. rhomboides,* and *A. oscillarioides.*

On August 24, 1969, collections were made from station 1 of *S. macrophyllum* and of *Fuirena scirpoidea* and from station 3 of *W. submersa. S. macrophyllum* and *F. scirpoidea* were collected from an open area of the littoral zone while *W. submersa* was harvested from a protected plastic enclosure (Figure 6). All substrates were taken from depths of 18 inches.

Little similarity was seen between the ephiphytic communities of the 3 macrophytes. Nor did the species composition of the communities of attached algae in the limnetic area resemble that of the aquatic macrophytes, although the seeding units which populated limnetic area slides undoubtedly came from epiphytic and epipelic communities in the littoral area.

The dominant epiphytes present on *S. macrophyllum* were *Spirogyra* sp., *Oscillatoria tenuis, A. oscillarioides,* and *Frustulia rhomboides.* Many aseriate packets of Cyanophyte cells, a morphological form assumed to be a number of the Nostocaceae, were also present. Other less numerous epiphytes present included: *Oedogonium* sp., *Mougeotia* sp., *Euastrum binale*, *Eunotia pectinalis*, and *H. fontinalis*.

Fewer species were present on *Fuirena scirpoidea* (station 1) than on *S. macrophyllum* (station 1). Scrapings from the sheath encircling the stem contained mainly the coccoid Chlorophyte, *G. vesiculosa*. Other epiphytes present were *Oedogonium* spp., *Mougeotia* sp., *Coleochaete irregularis*, *Staurastrum paradoxum*, *Staurastrum* sp., and *Microspora tumidula*. A fresh water sponge was also attached in some areas of the sheath.

A number of species were present as epiphytes on *W. submersa*, many of which were desmids. Desmids, in fact, dominated the epiphytic flora and included: *Closterium intermedium*, *Cl. intermedium* var. *hibernicum*, and *Cl. libellula* var. *angusticeps*. In addition several desmids occurred which were not dominants. In this latter group were: *Closterium incurvum*, *Cl. navicula*, *Desmidium baileyi*, *Actinotaenium cruciferum*, *Arthrodesmus incus*, *A. octocornis*, *Netrium digitus*, *Euastrum ciastonii*, *Xanthidium antilopaeum* var. *minneapoliense*, *Cosmarium ornatum*, *C. bireme*, *C. blyttii*, *C. pyramidatum* and *Pleurotaenium minutum*. Besides desmids, other epiphytes on *W. submersa* were *Bulbochaete* sp., *Oedogonium* spp., *Coleochaete irregularis*, *G. vesiculosa*, *E. pectinalis*, and *Nitschia palea*.

Planktonic Algae, August to September, 1969

Two vertical plankton tows were made in the limnetic area of Lake Mize at station 4 during the 1969 summer studies. From a tow made on August 28, the following species were identified: *Eudorina elegans*, *Peridinium westii*, and *Gonyostomum semen*. *P. westii* was the most abundant of the three. On September 11, the most abundant planktonic species was *G. semen*. *Mallomonas caudata* and *P. westii* were also present. In addition to planktonic algae, a number of copepods, cladocerans, and rotifers were also present in the two plankton samples.

Attached Algae Present in the Limnetic Area of Lake Mize, August, 1970

Glass slides and the aquatic macrophyte, *Websteria submersa*, were used to study the attached algae of the limnetic area of Lake Mize during August, 1970. Collections of slides and plants were made on August 13, after 3 weeks' exposure and on August 19, after 4 weeks' exposure.

Seventeen species were identified on glass and 25 on *W. submersa*. On both substrates, the majority of species present were Chlorophytes. A desmid, *Cosmarium regnellii*, and a diatom, *Eunotia pectinalis*, were the dominant species present on glass. These two species were also among the dominants present on *W. submersa*.

In addition, *Mougeotia* sp., *Oedogonium* spp., *Anabaena oscillarioides*, and *Hapalosiphon fontinalis* were abundant as epiphytes on *W. submersa* at one or more depths.

Vertical Distribution of Attached Algae and Other Periphyton on Glass Slides, August, 1970

During the summer study, as in previous studies, the different algal divisions and species had different vertical ranges in Lake Mize. These vertical ranges were frequently overlapping, however, as was the case with *Cosmarium regnellii* and *Eunotia pectinalis*. These two algae were commonly found together on slides suspended at 6 and 18 inches, sometimes reaching abundant frequencies at these depths. The vertical range of *E. pectinalis* generally extended deeper than that of *C. regnellii*.

Although it was either rare or absent in collections made during most of the study period, *C. regnellii* was one of the most abundant epiphytes in Lake Mize during August, 1970. Unlike most desmids, which are debris-associated forms of the metaplankton, *C. regnellii* attached broadside to the substrate. On slides exposed for 3 weeks, the highest frequencies of *C. regnellii* occurred on slides suspended at a depth of 18 inches. At this level, *C. regnellii* was abundant and made up a larger proportion of the periphyton than any other alga (see Table 19). *C. regnellii* occurred

TABLE 19

Dominant Algal Species Present on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 3 Weeks, July 23 to August 13, 1970

	Percent of Total Attached Organisms			
	6-inch depth	18-inch depth	30-inch depth	42-inch depth
Chlorophytes				
Cosmarium regnellii	6	15	3	ab.
Chrysophytes				
Eunotia pectinalis	33	6	2	1
Rhipidodendron splendidum (heterotrophic)	ab.	2	12	1
Pyrrophytes				
Peridinium westii	6	6	9	11
Other Algae	6	7	3	1

Note: ab. = absent

only infrequently on slides suspended at 6 inches, the depth at which maximum frequencies of Chlorophytes on glass slides usually occurred. This species was rare at 30 inches and absent at 42 inches on 3-week slides.

The frequency pattern of *C. regnellii* at various depths was altogether different on slides exposed for 4 weeks as compared to those exposed for 3 weeks. While maximum frequencies occurred at 18 inches on slides exposed for 3 weeks, the maximum occurred at 6 inches on slides exposed for 4 weeks (Figures 13 and 14). Proportionally, *C. regnellii* also made up a large share of the periphyton on 6-inch slides. At other levels, it made up comparatively little of the periphyton (Table 20).

In addition to *Cosmarium regnellii*, six other Chlorophytes were also present. These included: *Staurastrum setigerum*, *Closterium navicula*, *Protoderma viride*, *Coleochaete irregularis*, *Staurastrum* sp., and *Oedogonium* sp. All were rare on slides at 6 and 18 inches and were generally absent at depths below 18 inches.

During August, 1970, *E. pectinalis* was the most frequently occurring Chrysophyte at most depths. On slides exposed for 3 weeks it was common at 6 and 18 inches, with its frequency dropping to rare at depths of 30 and 42 inches. The frequency pattern of *E.*

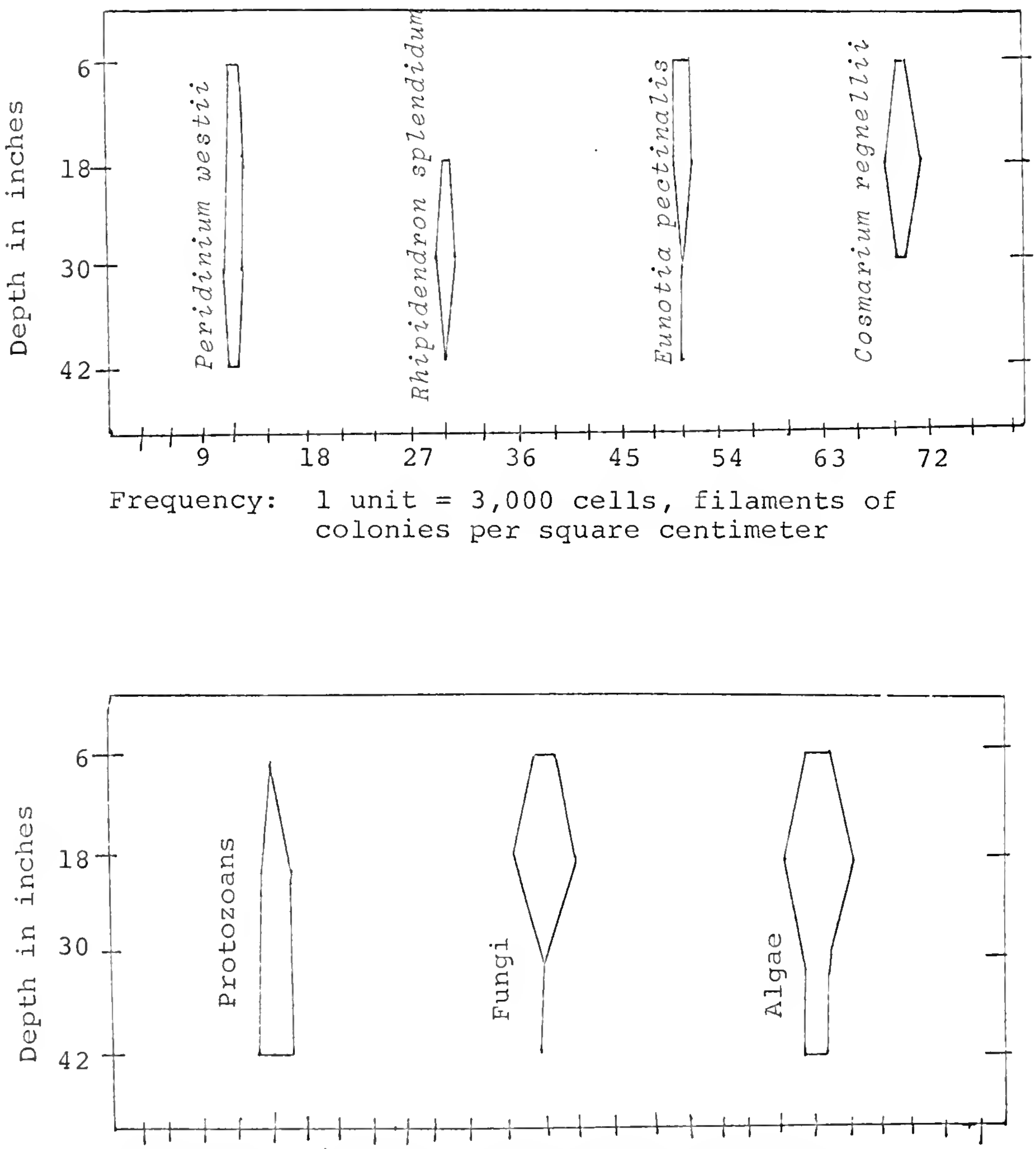
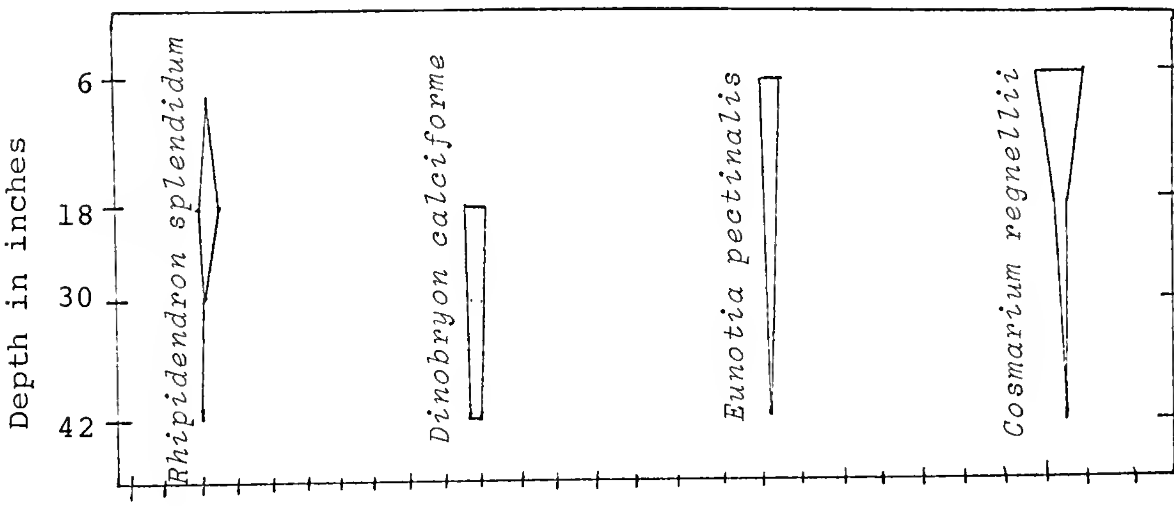
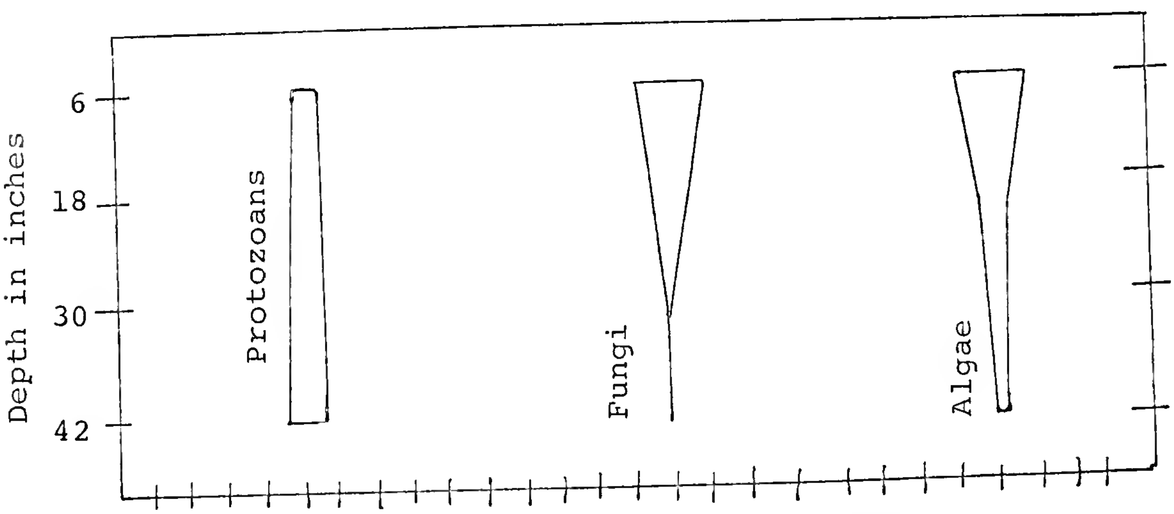


Figure 13. Frequencies of dominant algal species and the major groups of attached organisms present on glass slides suspended in the limnetic area of Lake Mize for 3 weeks, July 23 to August 13, 1970.



Frequency: 1 unit = 3,000 cells, filaments, or colonies per square centimeter



Frequency: 1 unit = 3,000 cells, filaments, or colonies per square centimeter

Figure 14. Frequencies of dominant algal species and the various groups of attached organisms present on glass slides suspended in the limnetic area of Lake Mize for 4 weeks, July 23 to August 20, 1970.

TABLE 20

Dominant Algal Species Present on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 4 Weeks, July 23 to August 20, 1970

	Percent of Total Attached Organisms			
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)
Chlorophytes				
Cosmarium regnellii	33	3	2	1
Chrysophytes				
Eunotia pectinalis	7	3	4	4
Dinobryon calciforme	ab.	22	17	4
Rhipidodendron splendidum (heterotroph-ic)	1	11	<1	<1
Other Algae	2	8	12	8

Note: ab. = absent

pectinalis changed somewhat on slides exposed for 4 weeks where decreases in frequencies occurred at each of the 3 lower levels as compared to slides exposed for 3 weeks. *E. pectinalis* was infrequent on slides at each of these depths. At 6 inches beneath the surface *E. pectinalis* had a frequency comparable to that observed for the optimum period of 3 weeks (Figures 13 and 14).

Other Chrysophytes present included *Frustulia rhomboides*, *Dinobryon calciforme*, *Rhipidodendron splendidum*, and *Synura sphagnicola* (planktonic). Both the attached form, *F. rhomboides*, and the planktonic form, *S. sphagnicola*, showed comparable vertical distributions on slides in the upper 42 inches of the lake, tending to occur rarely on all slides at all depths. *D. calciforme* and *R. splendidum* had higher frequencies at some depths than at others. The heterotrophic alga, *R. splendidum*, had a distinctive frequency curve which showed maximum frequencies at 30 inches on slides exposed for 3 weeks and at 18 inches on slides exposed for 4 weeks. *R. splendidum* was infrequent on the former (30 inches/3 weeks) and common on the latter (18 inches/4 weeks). In slide samples collected from other depths on both dates, this alga was only rarely present. These frequencies during August, 1970, were also the highest recorded during the study period for *R. splendidum*. Only an occasional specimen was found in collections made at other times.

D. calciforme was infrequent on slides exposed for 3 weeks at the 30-inch depth and was absent at other depths. However, by the end of the 4-week exposure period, *D. calciforme* had become abundant on 18-inch slides where it was present in greater numbers than any other alga (see Table 20). The individually attached cells of *D. calciforme* also occurred infrequently at 30 and 42 inches.

Proportionally, Cyanophytes were only a small part of the algal flora of limnetic area slides during August, 1970 (Tables 21 and 22). Two species were present, *Anabaena oscillarioides* and *Hapalosiphon fontinalis*. Both occurred rarely to infrequently on 6- and 18-inch slides with 3 weeks' exposure. A few filaments of *A. oscillarioides* were also present at 30 inches. On slides exposed for 4 weeks, *A. oscillarioides* and *H. fontinalis* occurred infrequently at the 6-inch level. *A. oscillarioides* was also rare on 18- and 30-inch slides. A planktonic dinoflagellate, *Peridinium westii*, appeared on slides occurring commonly at all depths.

Heterotrophs formed a conspicuous part of the periphyton on upper level limnetic slides during the

TABLE 21

Proportions of Algal Divisions and Other Groups of Organisms Present on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 3 Weeks, July 23 to August 13, 1970

	Percent of Total Attached Organisms			
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)
Algae				
Chlorophytes	15	19	3	<1
Chrysophytes	36	7	11	3
Cyanophytes	19	4	1	ab.
Pyrrophytes	5	6	9	11
Filamentous Oomycete	36	42	<1	ab.
Attached Protozoans	1	20	56	70
Rotifers	ab.	1	6	14

Note: ab. = absent

TABLE 22

Proportions of Algal Divisions and Other Groups of Organisms Present on Glass Slides Suspended for 4 Weeks in the Limnetic Zone of Lake Mize, July 23 to August 20, 1970

	Percent of Total Number of Attached Organisms			
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)
Algae				
Chlorophytes	42	6	2	2
Chrysophytes	7	39	25	13
Cyanophytes	3	1	3	<1
Filamentous Oomycete	37	10	1	1
Attached Protozoans	11	42	67	81

summer of 1970 (Tables 21 and 22). An unidentified filamentous Oomycete was abundant on 6- and 18-inch slides exposed for 3 weeks. After the 4-week exposure period, it became very abundant on 6-inch slides, remaining abundant at 18 inches. On slides exposed for both 3 and 4 weeks it was rarely seen at 30 inches and was entirely absent at 42 inches.

Several genera of Vorticelloids were also prominent on slides during this period. These generally had frequencies which increased with depth in the upper 42 inches of the lake with the largest increase occurring between 6 and 18 inches.

Variations with Time in the Algal Flora Present on Limnetic Area Slides, August, 1970

When slides collected on August 13, 1970, after 3 weeks' exposure, were compared with those collected on August 20, 1970, after 4 weeks' exposure, the species present and the dominants were much the same. At some depths differences in proportions at the specific level occurred between the two dates. Generally, the frequency of Chlorophytes decreased between August 13 and August 20 on slides suspended at 18 inches or below, while Chrysophytes increased slightly at depths of 30 and 42 inches.

Vertical Distribution Patterns of Attached Algae and Other Periphyton on Websteria submersa, August, 1970

Two general types of algal communities were present on *Websteria submersa*. The epiphytes on upper level *W. submersa* (6 and 18 inches) were organized into a complex, somewhat stratified community. In this community, closely adhering, resupinate forms made up the level closest to the macrophyte. Filaments projecting above the resupinate forms made up the second level. Debris and debris-associated species were then intermingled with the filaments. The communities present at 30 and 42 inches were less stratified, dominated by resupinate forms and resembling the communities found on glass slides suspended at 6 and 18 inches.

Generally, *W. submersa* was much more densely populated by attached forms than in the case of glass slides. Counts of individual organisms were 6 to 20 times higher on *W. submersa* than on glass slides at the same depth. Maximum frequency of organisms on *W. submersa* occurred on plants submerged at either 18 or 30 inches as compared to 6 to 18 inches for glass slides. Species diversity was greatest at the 6- and 18-inch levels for *W. submersa*, as with glass (Tables 23, 24, 25, and 26).

A large variety of Chlorophytes, especially desmids, appeared as epiphytes on *W. submersa* (Tables 25

TABLE 23

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Zone of Lake Mize for 3 Weeks, July 23 to August 13, 1970

	Number of Species			
	6-inch depth	18-inch depth	30-inch depth	42-inch depth
Chlorophytes	1	5	1	1
Chrysophytes	4	5	4	4
Cyanophytes	2	2	1	0
Pyrrophytes	1	1	1	1
Total Algal Species	8	13	7	6

TABLE 24

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Area of Lake Mize for 4 Weeks, July 23 to August 20, 1970

	Number of Species			
	6-inch depth	18-inch depth	30-inch depth	42-inch depth
Chlorophytes	7	6	2	3
Chrysophytes	4	5	5	6
Cyanophytes	3	1	1	1
Total Number of Species	14	12	8	10

TABLE 25

Number of Algal Species Present at Various Depths on *Websteria submersa* Suspended in the Limnetic Zone of Lake Mize for 3 Weeks, July 23 to August 13, 1970

	Number of Species			
	6-inch depth	18-inch depth	30-inch depth	42-inch depth
Chlorophytes	16	12	4	1
Chrysophytes	4	4	6	4
Cyanophytes	4	4	3	2
Total Number of Species	24	20	13	7

TABLE 26

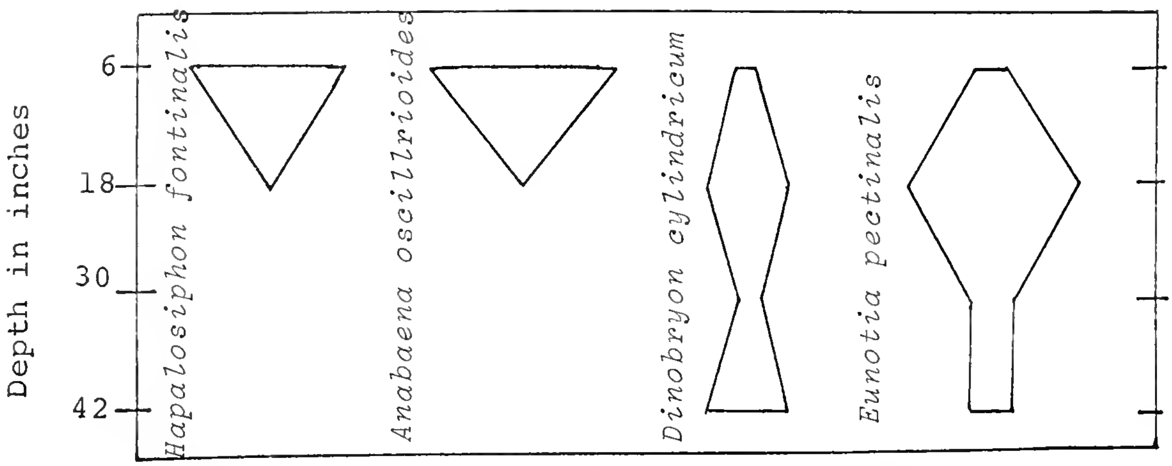
Number of Algal Species Present at Various Depths on *Websteria submersa* Suspended in the Limnetic Zone of Lake Mize for 4 Weeks, July 23 to August 20, 1970

	Number of Species			
	6-inch depth	18-inch depth	30-inch depth	42-inch depth
Chlorophytes	16	12	2	3
Chrysophytes	3	8	2	2
Cyanophytes	4	3	1	2
Total Number of Species	24	23	5	7

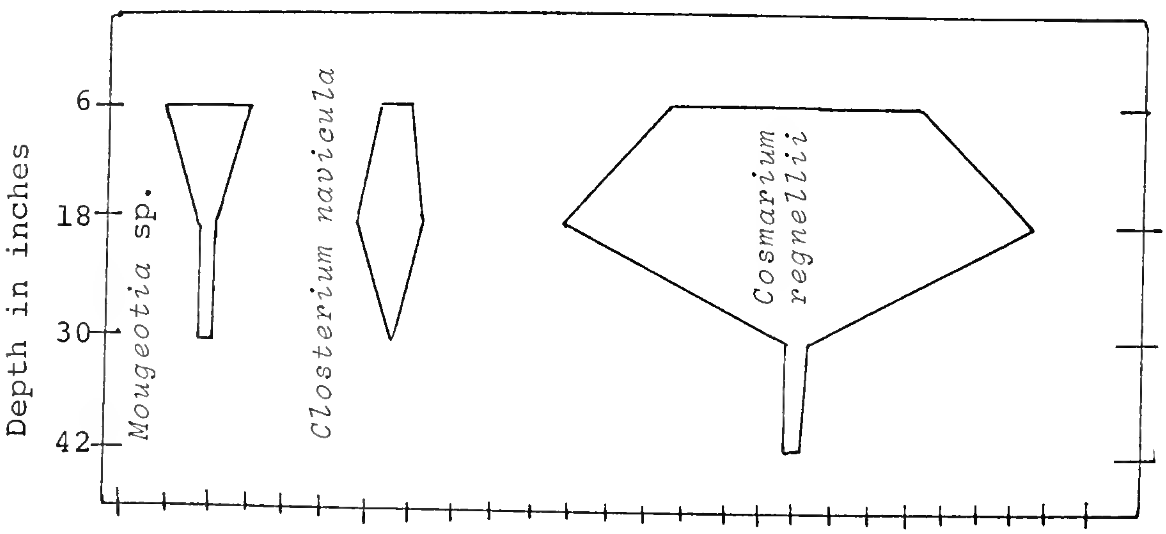
share of the periphyton (Tables 27 and 28, Figure 15). The most abundant Chlorophyte was the desmid, *Cosmarium regnellii* (Tables 28 and 29). This desmid, also abundant on glass slides, had a tendency to form short chains while adhering closely to the substrate.

Maximum frequencies of *C. regnellii* occurred at a depth of 18 inches after both 3- and 4-week exposure periods (see Figures 15 and 16). This alga was also very abundant in samples taken from the 6-inch depth on both August 13 and August 20. With plants exposed for 3 weeks, a sharp decline in the numbers of cells of *C. regnellii* occurred between 18 inches (point of maximum frequency) and 30 inches. Considerable growth of *C. regnellii* occurred at the 30-inch depth between August 13 and August 20 so that on *W. submersa* exposed for weeks at this depth, *C. regnellii* was very abundant. Frequencies then dropped to rare at 42 inches.

A second desmid which was sometimes present as an epiphyte on *W. submersa* was *Closterium navicula*. While the frequencies of this alga did not approach those of *Cosmarium regnellii*, it was nevertheless abundant at some depths. Generally, highest frequencies occurred at 18 inches, as in the case of *Cosmarium regnellii*. At 6-inch depths, *Closterium navicula* was also abundant.

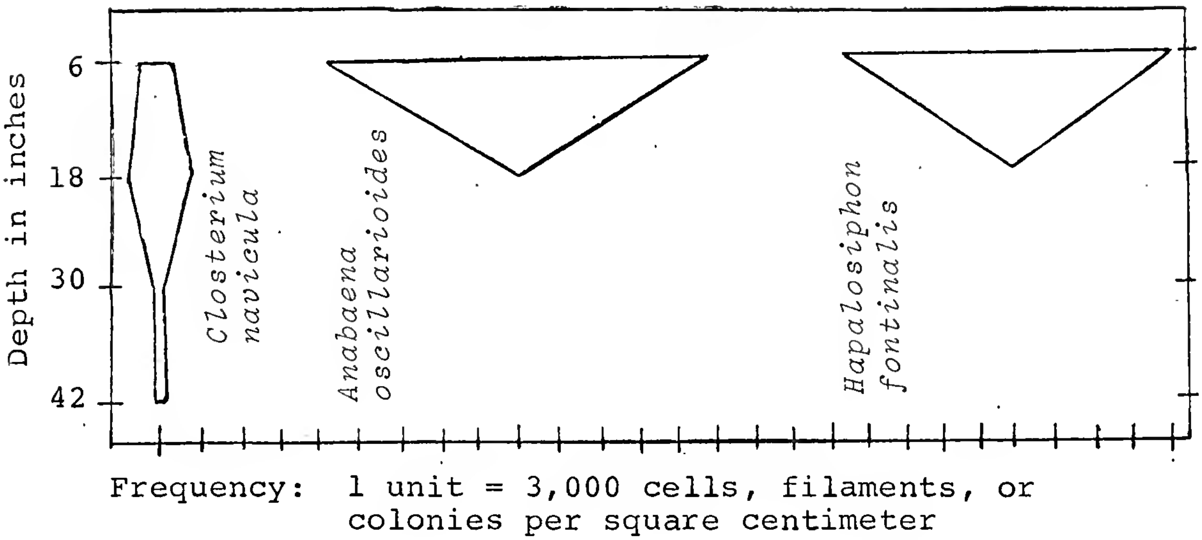


Frequency: 1 unit = 3,000 cells, filaments, or colonies per square centimeter



Frequency: 1 unit = 3,000 cells, filaments, or colonies per square centimeter

Figure 15. Frequencies of dominant algal species present on *Websteria submersa* suspended in the limnetic area of Lake Mize for 3 weeks, July 23 to August 13, 1970.



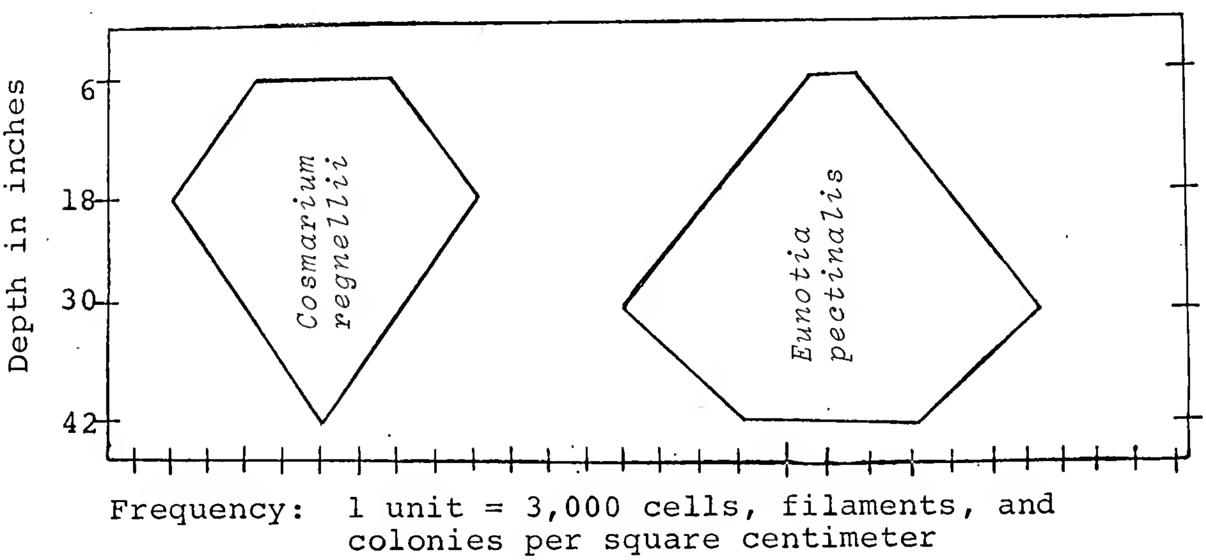


Figure 16. Frequencies of dominant algal species present on *Websteria submersa* suspended in the limnetic area of Lake Mize for 4 weeks, July 23 to August 20, 1970.

TABLE 27

Proportions of Algal Divisions Present on *Websteria submersa* Suspended in the Limnetic Zone of Lake Mize for 3 Weeks, July 23 to August 13, 1970

	Percent of the Total Number of Attached Organisms			
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)
Chlorophytes				
Chlorophytes	65	46	15	1
Chrysophytes	9	17	14	16
Cyanophytes	24	9	3	2

TABLE 28

Proportions of Algal Divisions and Attached Protozoa Present on *Websteria submersa* Suspended in the Limnetic Zone of Lake Mize for 4 Weeks, July 23 to August 20, 1970

	Percent of Total Attached Organisms			
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)
Algae				
Chlorophytes	44	68	27	2
Chrysophytes	7	30	72	57
Cyanophytes	45	2	1	1
Attached Protozoans	<1	<1	<1	1

TABLE 29

Dominant Algal Species Found on *Websteria submersa* Suspended in the Limnetic Zone of Lake Mize for 3 Weeks, July 23 to August 13, 1970

	Percent of the Total Number of Attached Organisms			
	6-inch depth (%)	12-inch depth (%)	30-inch depth (%)	42-inch depth (%)
Chlorophytes				
Cosmarium regnellii	40	36	12	<1
Mougeotia sp.	11	3	<1	ab.
Chrysophytes				
Eunotia pectinalis	5	13	14	7
Cyanophytes				
Anabaena oscillarioides	11	3	1	1
Hapalosiphon fontinalis	10	1	ab.	ab.
Other Algae	21	11	9	14
Attached Protozoans	2	25	62	75

Note: ab. = absent

TABLE 30

Dominant Algal Species Found on *Websteria submersa* Suspended in the Limnetic Zone of Lake Mize for 4 Weeks, July 23 to August 20, 1970

	Percent of the Total Number of Attached Organisms			
	6-inch depth (%)	18-inch depth (%)	30-inch depth (%)	42-inch depth (%)
Chlorophytes				
Cosmarium regnellii	27	48	26	1
Chrysophytes				
Eunotia pectinalis	5	27	72	52
Cyanophytes				
Anabaena Oscillarioides	33	<1	ab.	ab.
Hapalosiphon fontinalis	11	<1	ab.	ab.
Other Algae	12	11	1	9

Note: ab. = absent

At 30 and 42 inches, it was rare or absent (see Figures 15 and 16). This desmid was usually a resupinate form which appeared to adhere closely to the substrate. Sometimes it was associated loosely with the substrate or with debris.

In addition to *Cosmarium regnellii* and *Closterium navicula*, many other desmids were also present in the limnetic area on *W. submersa*. These included: *Cosmarium amoenum*, *C. pyramidatum*, *C. bireme*, *Staurastrum setigerum*, *S. orbiculare*, *Closterium libellula*, *Euastrum binale*, *Onchyonema laeve* var. *latum*, and *Bambusiana brebissonnii*. All of these were metaplanktonic forms which were loosely associated with the substrate or with debris, rather than closely adhering to a surface. *C. pyramidatum*, *S. setigerum*, and *S. orbiculare* were all common epiphytes of *W. submersa* at the 6-inch level, after 3 weeks' exposure of the macrophytes. Each of the three desmids was infrequent at 18 inches and rare or absent at deeper levels. The other desmids listed above were all rare to infrequent at depths of 6 and/or 18 inches.

Filamentous Chlorophytes which attached to *W. submersa* included an undetermined species of *Mougeotia* and three undetermined species of *Oedogonium*. Numerically, filamentous Chlorophytes did not form as large a proportion of the periphyton as did several of the single-celled desmids. However, the tangled mass of filaments had an important structural role in the epiphytic communities by providing a means of entrapment and retention for loosely associated desmids and blue-greens.

Mougeotia sp. was the most abundant of the filamentous Chlorophytes. It was very abundant at the 6-inch level after both 3 and 4 weeks' exposure. At other levels, *Mougeotia* sp. was rare to infrequent. *Oedogonium* spp. occurred infrequently at 6 and 18 inches after 3 and 4 weeks. These species of *Oedogonium* were totally absent at greater depths.

Two large prostrate Chlorophytes, *Protoderma viride* and *Coleochaete irregularis*, also occurred rarely on *W. submersa* suspended at 6 or 18 inches. These algal epiphytes were never found to be abundant on the filamentous *W. submersa*, although high frequencies sometimes occurred on littoral area slides and on broad-leaved aquatic macrophytes.

Eunotia pectinalis was the dominant Chrysophyte present on *W. submersa* during August, 1970. Maximum frequencies of this alga occurred at the 18-inch depth on plants exposed for 3 weeks with common frequencies recorded for 6, 30, and 42 inches. On plants exposed for

4 weeks, maximum frequencies were at the 30-inch depth. *E. pectinalis* was then very abundant at 18 and 42 inches and common at 6 inches. It was, by far, the dominant alga on plants submerged at 30 and 42 inches with a vertical range extending deeper than that of desmids, filamentous Chlorophytes, or blue-greens.

Other Chrysophytes which were epiphytes or were associated with *W. submersa* included: *Dinobryon cylindricum* (planktonic), *Synura sphagnicola* (planktonic), *Frustulia rhomboides*, *Dinobryon calciforme*, and *Rhipidodendron splendidum*. *D. calciforme* and the planktonic *S. sphagnicola* occurred rarely throughout the entire vertical range of 42 inches. *R. splendidum* was absent from all depths except 42 inches, where it was a rare epiphyte with frequencies much below those which had been recorded from glass slides. *F. rhomboides* occurred irregularly (rare to common) on *W. submersa* at all depths. Occasionally it was absent. The planktonic, *D. cylindricum*, was associated with *W. submersa* exposed for 3 weeks at all depths. This species was rare to abundant.

It was not unusual for planktonic forms to become associated with or trapped by communities of attached algae. For such planktonic forms, bimodal or "hourglass-type" frequency diagrams were representative, e.g., Figure 15. (A few attached forms, as *F. rhomboides*, also sometimes had bimodal frequency diagrams.)

Planktonic dinoflagellates, frequently found on submerged glass slides, were not usually associated with *W. submersa* and other aquatic macrophytes in Lake Mize.

During August, 1969, the vertical range of the dominant Cyanophytes on glass slides (*Phormidium tenue* and *Oscillatoria tenuis*) extended to a depth of 66 inches. During August, 1970, the vertical range of the dominant blue-green epiphytes of *W. submersa* was quite reduced in comparison. Both *Hapalosiphon fontinalis* and *Anabaena oscillarioides* occurred almost exclusively at the 6-inch depth on *W. submersa*. At the 6-inch depth they were each abundant to very abundant. At 18 inches, only a few specimens were found (Figures 15 and 16). Both species were absent at 30 and 42 inches. (They also occurred mainly at the 6-inch depth on glass slides where they were much less abundant than on *W. submersa*, cf. p. 94).

The attaching forms of these two blue-greens were usually different. The branched filaments of *H. fontinalis* were tightly attached to the substrate. In contrast, the filaments of *A. oscillarioides* were usually locsely associated or intermingled with the vertical filaments of both *Mougeotia* sp. and other Chlorophytes.

A. oscillarioides was also observed at times adhering to the substrate in a prostrate position.

Variations with Time in the Algal Flora Present on Websteria submersa, August, 1970

When the *Websteria submersa* collected on August 13, 1970 (3 weeks' exposure) was compared with that collected on August 20, 1970 (4 weeks' exposure), certain differences became apparent, particularly at the depths of 6 and 30 inches. At 6 inches, an increase in Cyanophytes occurred especially in the number of filaments of *Anabaena oscillarioides*. Many of the filaments on August 20 were short, the product of a recently germinated akinete. There were also a number of akinetes present. The increase in *A. oscillarioides* was accompanied also by an increase in *Cosmarium regnellii*. At 30 inches, an increase in populations of *Eunotia pectinalis* occurred between August 13 and August 20 (see Figures 15 and 16).

At other depths, frequencies and proportions of most algae showed little change over the 7-day period. Nor did frequencies of *Mougeotia* sp. and *E. pectinalis* change significantly at the 6-inch depth. The number of species at all depths was also similar on August 13 and August 20 (Tables 25 and 26), although some of the rare species were different. At the upper levels (6 and 18 inches), these rare species were mainly desmids.

Comparison: Algal Flora of Glass Slides and of Websteria submersa, August, 1970

The community of attached algae on glass slides and on *Websteria submersa* during August, 1970, contained many of the same species. Some dominants were also the same. However, marked differences were observed in the proportions and frequencies of algal species on the two substrates. Higher frequencies were recorded for most species of algae on *W. submersa* than on glass slides. Desmids, filamentous Chlorophytes, and blue-green algae also formed larger proportions of the periphyton on *W. submersa* than on glass slides.

The desmid, *Cosmarium regnellii*, was a major component in the algal flora of both glass slides and *W. submersa*. At all depths higher frequencies of this desmid were recorded on *W. submersa* than on glass slides (Table 31). These differences were especially evident on substrates submerged at depths of 18 and 30 inches. On August 20, 1970, there were approximately 100 times as many cells of *C. regnellii* present on *W. submersa*, suspended at a depth of 6 inches, as on glass slides. And, at 30 inches, there were over 150 times as many cells of this alga on *W. submersa* as on glass slides.

TABLE 31

Comparison of Algal Flora Present on Vertically Positioned Glass Slides and on the Aquatic Plant, *Websteria submersa*, on August 13, 1970, after 3 Weeks' Suspension in the Limnetic Zone of Lake Mize, Florida (VA = Very Abundant, A = Abundant, C = Common, I = Infrequent, and R = Rare)

	6 Inches		18 Inches		30 Inches		42 Inches	
	Glass	*Websteria*	Glass	*Websteria*	Glass	*Websteria*	Glass	*Websteria*
Chlorophytes								
Microspora tumidula		I		I				
Oedogonium spp. (3 species)		VA	R	I				
Mougeotia sp.		A	R	C		R		
Coleochaete irregularis Pringsheim				R				
Protoderma viride Kutzing			R					
Closterium navicula (Breb.)		A	R	A		I		R
Closterium intermedium		I	R	R				
Euastrum binale (Turp.) Ehrenberg		I		I				

TABLE 31—*Continued*

	6 Inches		18 Inches		30 Inches		42 Inches	
	Glass	*Websteria*	Glass	*Websteria*	Glass	*Websteria*	Glass	*Websteria*
Cosmarium regnellii var. *pseudoregnellii* (Messikommer) Krieger & Gerloff	I	VA	A	VA	R	A		I
Cosmarium bireme Nordstedt		I						
Cosmarium pyramidatum Breb.		C				I		
Cosmarium amoenum Ralfs		I		I		R		
Cosmarium sp.		I						
Staurastrum setigerum Cleve		C		I				
Staurastrum orbiculare Ralfs		A		I				
Staurastrum sp.		I		R				
Onchyonema laeve var. *latum* West & West				R				
Bambusiana brebissonii Kutzing		R						
Chrysophytes								

TABLE 31—*Continued*

	6 Inches		18 Inches		30 Inches		42 Inches	
	Glass	*Websteria*	Glass	*Websteria*	Glass	*Websteria*	Glass	*Websteria*
Dinobryan calciforme (Bachmann) Hilliard & Asmund	R	I		I	R			I
Dinobryan eurystoma (Lemm.) Hilliard & Asmund	R	C		A	I	C		A
Synura sphagnicola			R		I		R	
Rhipidodendron splendidum Stein			I	R	I		R	
Eunotia pectinalis (Kutz.) Rabenhorst	C	C	A	VA	R	A	R	A
Frustulia rhomboides var. *saxonica* (Rabh.) de Toni	R	I	R			R	R	C
Pyrrophytes								
Peridinium westii Lemmermann	I		C		I		I	
Cyanophytes								
Phormidium tenue (Menegh) Gomont		I		C		I	I	

TABLE 31—*Continued*

	6 Inches		18 Inches		30 Inches		42 Inches	
	Glass	*Websteria*	Glass	*Websteria*	Glass	*Websteria*	Glass	*Websteria*
Anabaena oscillarioides Bory	I	A	I	C	R	I	I	
Hapalosiphon fontinalis (Ag.) Bornet		A	R	C		I		
Total Number of Species	6	23	12	20	9	11	7	6

**Very Abundant* (VA) represents a frequency of over 5,000 per square centimeter.
Abundant (A) represents a frequency of 2,000 to 5,000 per square centimeter.
Common (C) represents a frequency of 500 to 2,000 per square centimeter.
Infrequent (I) represents a frequency of 100 to 500 per square centimeter.
Rare (R) represents a frequency of 10 to 100 per square centimeter.

A number of other desmids, rare or absent on glass, were also associated with *W. submersa* (Table 31). *Staurastrum setigerum* was a common epiphyte on 6-inch *W. submersa* on August 13. It was rarely present on glass slides. Also, on August 13, *Cosmarium pyramidatum* was abundant on *W. submersa* but was absent from glass. Altogether, 13 desmid species occurred as epiphytes on *W. submersa* while 5 species were associated with glass slides on August 13. Data for August 20 were similar.

Filamentous Chlorophytes also occurred more frequently on *W. submersa* than on glass slides. *Mougeotia* sp. was absent on glass slides during August, 1970. Yet, on both August 13 and August 20, 1970, this species was very abundant on *W. submersa* at 6 inches. (*Mougeotia* sp. did occur on glass slides during January, 1969, cf. p. 57).

Differences were also observed in the frequency of blue-green algae on glass slides and on *W. submersa* as has been mentioned previously. At 6 inches, blue-green algae were infrequent on glass slides; however, *Hapalosiphon fontinalis* was abundant and *Anabaena oscillarioides* was very abundant on *W. submersa* suspended at 6 inches.

As with Chlorophytes and Cyanophytes, higher numbers of most Chrysophyte species occurred on *W.*

submersa than on glass slides (Table 31). These differences were especially obvious at depths of 18, 30, and 42 inches. One common species on both glass and on *W. submersa* was the diatom, *Eunotia pectinalis*. This species always had higher frequencies on *W. submersa* than on glass slides. This difference may be illustrated by two examples. On August 20, 1970, 65 times as many cells of *E. pectinalis* occurred on *W. submersa* as on glass at 18 inches. And, at 30 inches, the difference in cell density, *Websteria*/glass increased to 200/1.

While higher diatom frequencies occurred on *W. submersa*, in contrast, the heterotrophic Chrysophyte, *Rhipidodendron splendidum*, reached a higher frequency on glass. This alga was only rarely found at 42 inches as an epiphyte on *W. submersa*. However, it was a common attached form on glass slides suspended at some depths.

Several other categories of organisms were more abundant on glass slides than on *W. submersa*. Most planktonic algae were more abundant on glass, and a filamentous Phycomycete was abundant to very abundant on upper level slides (6 and 18 inches) but was rare on *W. submersa*.

Planktonic Algae, August 13, 1970

Two algal species were identified from a vertical plankton tow in the limnetic area of Lake Mize on August, 1970. These were *Peridinium westii* and *Stephanoporos regularis*, the former being more abundant than the latter. Both of these species were also sometimes present in the periphyton during August, 1970.

As previously mentioned, planktonic species in Lake Mize were more commonly trapped by the periphyton of slides than that of aquatic macrophytes.

Attached Algae of the Littoral Area, August, 1970

A study of the attached algae present in the littoral area of Lake Mize was undertaken during August, 1970, to parallel the limnetic area studies carried out at the same time. Slides and aquatic macrophytes were collected from glass and plastic enclosures at station 1 on August 15. On August 20, collections of slides and plants were also made from a glass enclosure at station 2. In each case, substrates were submerged at a depth of 18 inches and collected after an exposure period of 4 weeks. Plants and slides from open areas of the littoral zone were also gathered on these two dates. In addition, collections were made of glass and plastic slides suspended in an area of the littoral zone near station 1 which was exposed to currents. These slides were submerged at the depth of 18 inches from April 30, 1970, to August 20, 1970.

As during previous littoral studies, diverse communities of attached algae were found on the different plants and slides collected during August, 1970. Floristic composition varied from one area of the lake to another and even from one slide to another in the same area.

While some species were broadly distributed over the lake, others were confined to specific locations or were more abundant in some parts of the lake than in others. Although no substrate specificity by any algal species could be demonstrated, frequencies and relative proportions of various algae were dissimilar on different plants and on artificial substrates used, e.g., glass and plastic. (Some harvested plants were exposed for a measured period. For others, which grew naturally in the lake, recording of the exposure period was not possible.)

Several differences were evident in comparing the periphyton on slides at stations 1, 2, and 4 submerged at the same depth (18 inches). Slides in the littoral area (stations 1 and 2) showed a total organism frequency which differed little from the organism frequency on slides at the 18-inch level in the limnetic area (station 4). However, 40% of the organisms on slides in the limnetic area were protozoans and fungi. In the littoral area, most attaching forms were algae. Protozoans and fungi together constituted less than 1% of the attached biota. Other differences were also apparent. The spreading, prostrate alga, *Protoderma viride*, was common on slides at both stations in the littoral area. It did not appear on glass slides in the limnetic area. Another prostrate alga, *Coleochaete irregularis*, was common on glass slides at station 2. It was rare to infrequent on plastic slides submerged in the limnetic area, but was not present on glass slides at either station 1 (littoral) or station 4 (limnetic).

Chlorophytes were generally more abundant on littoral area slides than on limnetic area slides, although many of the species present were the same. *Cosmarium regnellii* was a widely distributed attached species in Lake Mize during August, 1970. At 18 inches in the limnetic area, it was infrequent on glass slides. It was over 10 as times abundant on glass slides in a protected enclosure at station 1 than on 18-inch limnetic area slides. At station 2, frequencies of *C. regnellii* were not as high as at station 1, although it remained abundant.

Blue-greens were also more abundant on littoral area slides than on limnetic area slides. As with the prostrate green species, differences also occurred between stations 1 and 2. One species, *Anabaena oscillarioides*, occurred rarely on 18-inch slides in the limnetic area. This species was also rare at station 1. It did not appear on slides at station 2. At station 1, two closely adhering, filamentous forms, *Lynbya nordgaardii*, and *Hapalosiphon fontinalis*, were common on slides. At station 2, *L. nordgaardii* was rare while *H. fontinalis* was abundant. Both *L. nordgaardii* and *H. fontinalis* were absent on limnetic area slides at this depth. *Dinobryon calciforme* and *Rhipidodendron splendidum* were rare on slides at both littoral stations. On 18-inch slides in the limnetic area the former was abundant and the latter common.

Attached Algae on Glass and Plastic Slides, Littoral Area, August, 1970

The glass and plastic slides submerged at a depth of 18 inches in an exposed area of the littoral zone from April 30, 1970, to August 15, 1970, had a flora dominated by diatoms. *Eunotia pectinalis*, *E. vanheurckia* var. *intermedia*, and *E. zygodon* were the most abundant species. A significant difference occurred in the frequency of these 3 diatoms on glass and plastic. Collectively, they were 5 times as frequent on plastic as on glass. Total organism frequency, as well as the number of species, was also higher on plastic (see Tables 32 and 33). However, species diversity on neither

TABLE 32

Number of Algal Species Present on Glass and Plastic Slides Exposed in the Littoral Area of Lake Mize at a Depth of 18 Inches, Collected August 15 and 20, 1970

	Number of Species		
	Glass Slides Protected Area July 18 to August 15, 1970	Glass Slides Exposed Area April 30 to August 20, 1970	Plastic Slides Exposed Area April 30 to August 20, 1970
Chlorophytes	13	2	3
Chrysophytes	5	4	4
Cyanophytes	3	1	2
Xanthophytes	1	1	1
Total Number of Species	22	8	10

TABLE 33

Frequencies of Dominant Algal Species Present on Glass and Plastic Slides Exposed in the Littoral Area of Lake Mize at a Depth of 18 Inches, Collected August 15 and 20, 1970

	Frequency per Square Centimeter		
	Glass Slides Protected Area July 18 to August 15, 1970	Glass Slides Exposed Area April 30 to August 20, 1970	Plastic Slides Exposed Area April 30 to August 20, 1970
Chlorophytes			
Cosmarium regnellii	2,600 cells	20 cells	100 cells
Chrysophytes			
Eunotia spp.	7,300	5,300 cells	28,800 cells
Cyanophytes			
Lynbya nordgaardii	1,650 filaments	absent	absent
Total Organism Frequency	13,300 organisms	6,000 organisms	29,400 organisms

plastic nor glass in the area exposed to currents was as high as that on glass in protected areas at stations 1 and 2. Total organism frequency on glass in the 3 areas was similar.

The macrophytes submerged in a plastic enclosure for 4 weeks at station 1 included *W. submersa* and *S. macrophyllum*. Several naturally growing plants were also collected on August 15 from a depth of 18 inches. These included *Utricularia olivacea*, *Panicum hemitomon* and *Polygonum hirsutum*.

The most abundant epiphytic species appearing on *W. submersa* at station 1 after 4 weeks' exposure were *Cosmarium regnellii*, *Closterium navicula*, *Mougeotia* sp., and *Eunotia pectinalis*. Frequencies of the two tightly adhering dominants, *C. regnellii* and *E. pectinalis*, and the filamentous *Mougeotia* sp. were comparable to those on 18-inch limnetic *W. submersa* while frequencies of the loosely associated *Cl. navicula* and *Anabaena oscillarioides* were not the same on 18-inch limnetic and littoral *W. submersa*. *Cl. navicula* was 5 times more abundant and *A. oscillarioides* was 20 times more abundant in the littoral area at 18 inches than in the limnetic area at the same depth.

All five dominants had higher frequencies on littoral *W. submersa* than on vertically positioned glass slides in the same enclosure. *C. regnellii* was over 10 times as abundant on *W. submersa* as on glass while *Cl. navicula* was 70 times more frequent on *W. submersa* as on glass slides. *A. oscillarioides* and *Mougeotia* sp. were both abundant on *W. submersa* while occurring only rarely on glass.

The other epiphytic algae present from the littoral area are listed in Table 34. Generally, the broad, prostrate greens common on glass were rare on *W. submersa*. Several other algae, including the small Chrysophyte, *Peroniella planctonica*, were also more abundant on glass than on the filamentous *W. submersa*.

Sphagnum macrophyllum had a reduced algal flora as compared to that of *W. submersa* in the same plastic enclosure. The number of algal species appearing on the two macrophytes, however, was about the same (see Table 33). The most abundant species occurring on *S. macrophyllum* were *Cosmarium regnellii*, *Closterium navicula*, *Anabaena oscillarioides*, and *Eunotia pectinalis*. These four species were also dominants on *W. submersa* where frequencies were several times greater than on *S. macrophyllum*.

During August, 1970, tangled masses of the bladderwort, *Utricularia olivacea*, occupied much of the

TABLE 34

Attached Algae Found on Glass Slides, *Websteria submersa*, and *Sphagnum macrophyllum* Placed in the Littoral Area of Lake Mize (Station 1), 18 Inches Below the Surface for 4 Weeks, July 21, August 15, 1970

	Percent of the Total Number of Attached Organisms		
	Sphagnum macrophyllum (%)	*Websteria submersa* (%)	Glass Slides (%)
Chlorophytes			
Gleocystis vesiculosus	> 1	2	ab.
Microspora tumidula	ab.	2	< 1
Oedogonium sp. 1	ab.	1	1
Oedogonium sp. 2	2	1	1
Bulbochaete sp.	1	< 1	< 1
Protoderma viride	ab.	ab.	4
Coleochaete irregularis	ab.	< 1	< 1
Spirogyra sp.	ab.	ab.	1
Mougeotia sp.	5	3	< 1
Cosmarium regnellii	17	38	28
Cosmarium bireme	2	ab.	< 1
Cosmarium amoenum	1	ab.	ab.
Closterium navicula	9	21	1
Euastrum binale	1	< 1	< 1
Staurastrum setigerum	1		
Micriasterias fimbriata	1		
Number of Species	11	10	12

TABLE 34—*Continued*

	Percent of the Total Number of Attached Organisms		
	Sphagnum macrophyllum (%)	*Websteria submersa* (%)	Glass Slides (%)
Chrysophytes			
Dinobryon calciforme	1	1	ab.
Dinobryon acuminatum	ab.	< 1	ab.
Synura sphagnicola	1	ab.	< 1
Rhipidodendron splendidum	ab.	ab.	< 1
Eunotia pectinalis	15	6	61
Frustulia rhomboides	4	2	1
Pinnularia biceps	4	ab.	ab.
Nitschia palea	1	ab.	ab.
Number of Species	6	4	4
Cyanophytes			
Aphanocapsa delicatissma	5	ab.	< 1
Anabaena oscillaroides	7	5	< 1
Oscillatoria tenuis	ab.	ab.	2
Lynbya nordgaardii	1	ab.	6
Hapalosiphon fontinalis	2	< 1	1
Number of Species	4	2	5

Note: ab. = absent

littoral area at station 1, extending several feet below the surface and into the perforated plastic enclosure. Usually, this macrophyte was observed only in the floating state. Samples of this filamentous aquatic plant taken from outside the plastic enclosure had a flora unlike that of other macrophytes or of glass slides at station 1. The dominants present were *Eunotia zygodon*, *E. pectinalis*, *Coleochaete irregularis*, and *Protoderma viride*. During the study period, *E. zygodon* was recorded as abundant only on *U. olivacea*, although it was sometimes rare to infrequent on other substrates. Other epiphytes which occurred on *U. olivacea* were *Aphanochaete repens*, *Oedogonium* spp., *Gleocystis vesiculosa*, *Cosmarium regnellii*, *Mougeotia* sp., *Stephanoporos regularis*, *Lynbya nordgaardii*, and *Hapalosiphon fontinalis*.

Samples of *U. olivacea* taken from inside the plastic enclosure had an aquatic flora similar to that of the *W. submersa*, also inside the enclosure. The most abundant species on *U. olivacea* were *Cosmarium regnellii*, *Cl. navicula*, *Mougeotia* sp., and *A. oscillarioides*. The other species present were *Euastrum binale*, *Protoderma viride*, *G. vesiculosa*, *Microspora tumidula*, *Onchyonema laeve* var. *latum*, *Oedogonium* sp., *Bulbochaete* sp., and *L. nordgaardii*.

Both leaf and stem sheaths of *Panicum hemitomon* and *Polygonium hirsutum* were examined for epiphytes.

Oedogonium spp. was a dominant on both areas of *Panicum hemitomon* with *Cosmarium regnellii* also a common epiphyte on the leaves, but not on the vertical, hairy sheath where it was infrequent. Most algal species occurring on *P. hemitomon* were present on both leaves and sheaths. These included: *Closterium navicula*, *S. regularis*, *Mougeotia* sp., *Bulbochaete* sp., *Spirogyra* sp., *G. vesiculosa*, *Nitschia palea*, *Frustulia rhomboides*, *E. pectinalis*, *E. zygodon*, and *A. oscillarioides*.

The hirsute leaves of *Polygonum hirsutum* were covered by a mucilaginous layer containing *L. nordgaardii* and an unidentified filamentous Oomycete. The other epiphytes present on the submerged leaves of *P. hirsutum* were: *Cl. navicula*, *Staurastrum setigerum*, *Cosmarium regnellii*, *G. vesiculosa*, *Bulbochaete* sp., *E. pectinalis*, and *H. fontinalis*.

Sheaths of *Polygonum hirsutum*, which are also hirsute, were not covered by the mucilaginous layer containing *L. nordgaardii* and the filamentous fungus, although a few specimens of *L. nordgaardii* were present. *Oedogonium* spp. and *H. fontinalis* were the most abundant epiphytes with the following also recorded: *O. laeve* var. *latum*, *Closterium navicula*, *Cosmarium regnellii*, *C. amoenum*, *G. vesiculosa*, *Euastrum binale*, *Bulbochaete* sp., *Frustulia rhomboides*, *Eunotia pectinalis*, *E. zygodon*, *N. palea*, and *H. fontinalis*.

At station 2, located in a protected area of the lake, the following macrophytes were submerged at 18 inches for 4 weeks in a glass enclosure: *Sphagnum macrophyllum*, *Bacopa caroliniana*, *Mayaca aubleti*, and *Fuirene scirpoidea*. The floating angiosperm, *U. olivacea*, was also gathered from the surface of the lake near the glass enclosure.

S. macrophyllum had an epiphytic flora at station 2 which was dominated by *C. regnellii*, *Oedogonium* spp., and *A. oscillarioides*. Two of these algae (*C. regnellii* and *A. oscillarioides*) were among the dominants on *S. macrophyllum* at station 1. The other epiphytes present also included a number of desmids as observed at station 1. These were: *Cosmarium bireme*, *C. pyramidatum*, *Onchyonema laeve* var. *latum*, and *Closterium navicula*. In addition, the following epiphytes were also present: *Bulbochaete* sp., *Coleochaete irregularis*, *Protoderma viride*, *Mougeotia* sp., *N. palea*, *E. pectinalis*, *A. oscillarioides*, and *H. fontinalis*.

The lower leaves of *B. caroliniana* at station 2 had an epiphytic flora not clearly dominated by any one alga. The most numerous species included *Coleochaete* *irregularis*, *Protoderma viride*, *Cosmarium regnellii*, *C. bireme*, *Oedogonium* sp., *E. pectinalis*, and *H. fontinalis*. Except for *Oedogonium* sp., all were resupinate forms which adhered closely to the surface of the broad, horizontally oriented leaves of *B. caroliniana*. Nineteen species of algae were present. In addition to the above, records show the presence of *Mougeotia* sp., *Closterium navicula*, *Euastrum binale*, *Cosmarium amoenum*, *Staurastrum setigerum*, *Desmidium baileyi*, *N. palea*, *F. rhomboides*, and *L. nordgaardii*.

The upper leaves of *B. caroliniana* were sparsely populated with only a few attached forms present. No one species was dominant as a pioneering attacher on the new leaves.

Seven species of attached algae were present on *M. aubleti*. *Oedogonium* spp., and *Coleochaete irregularis* were the most common epiphytes. The other species present were *Mougeotia* sp., *Eunotia pectinalis*, *A. oscillarioides*, and *L. nordgaardii*.

The dominant epiphytes were *Cosmarium regnellii*, *E. pectinalis*, and *A. oscillarioides* on the vertical stems of *F. scirpoidea* at station 2. These were all common attached species at this time on many of the aquatic macrophytes present at stations 1 and 2 and on *W. submersa* artificially suspended in the limnetic area. In addition, the following were recorded from *F. scirpoidea:* *Cosmarium bireme*, *C. amoenum*, *Mougeotia* sp., *Oedogonium* sp., *Protoderma viride*, *E. pectinalis*, *F. rhomboides*, *H. fontinalis*, and *A. oscillarioides*.

Other Littoral Studies, May, 1969; July, 1969; April, 1971; July, 1971; and September, 1971

In addition to the observations of littoral algae made during August, 1969, and August, 1970, collections of aquatic macrophytes and their epiphytes were also made during May, 1969; July, 1969; April, 1971; and July, 1971. In addition, glass slides were exposed at littoral stations during the periods April to May, 1969, and August to September, 1971.

Collections were made on May 9 and May 20, 1969. On May 9, collections were made from two plastic enclosures at station 2 of glass slides, of *Mayaca aubletii*, of *Websteria submersa*, and of *Sphagnum macrophyllum*. All were exposed at a depth of 18 inches for 2 weeks.

In the first plastic enclosure, glass slides were covered by bryozoans. Attached to the bryozoans, but not directly to the slide, was the blue-green alga, *Hapalosiphon fontinalis*. The dominant alga present on slides was *Phormidium tenue* which occurred mainly in areas of the slides near the bryozoans. In addition, a number of desmids were present. These included *Cosmarium bireme*, *C. ornatum*, *C. pyramidatum*, *Euastrum ciastonii*, *E. affine*, *Micrasterias fimbriata*, *Tetmemorus brebissonii*, *Closterium navicula*, *Cl.intermedium*, and *Netrium digitus*. Other epiphytes included *Protoderma viride*, *Oedogonium* sp., *Neidium ladogense* var. *densestriatum*, *Eunotia pectinalis*, *E. vanheurckia* var. *intermedia*, *Nitschia palea*, and the planktonic dinoflagellate, *Peridinium limbatum*.

S. macrophyllum was populated by seven algal species, none of which were abundant or dominant. These included: two unidentified species of *Oedogonium*; the desmids, *Spirotaenia condensata*, *Cosmarium regnellii*, *C. bireme*, and *Closterium intermedium*; and the diatom, *Eunotia pectinalis*.

The diatoms, *E. pectinalis* and *E. vanheurckia* var. *intermedia* were abundant on *W. submersa* at station 2. In addition, the following epiphytes were present: *Cosmarium bireme*, *C. regnellii*, *Oedogonium* spp., and *Frustulia rhomboides*.

Glass slides taken from the second plastic enclosure at station 2 were more densely populated than those taken from the first enclosure. Also, bryozoans were not present as in the first enclosure. The dominant species on slides taken from the second enclosure were *N. palea* (diatom) and *Stephanoporos regularis* (Xanthophyte). On the edges of the slides, three resupinate species, *Aphanocapsa delicatissima*, *P. viride*, and *E. pectinalis*, were abundant. The other attached species recorded from the slides were *Micrasterias fimbriata*, *Closterium intermedium*, *Cl. incurvum*, *Gleocystis vesiculosa*, *Oedogonium* sp., *Spirogyra* sp., *F. rhomboides*, *Pinnularia gibba*, and *Phormidium tenue*.

S. macrophyllum and *M. aubleti* removed from the second enclosure were sparsely populated with infrequent epiphytes. The following were recorded on *S. macrophyllum*: *Oedogonium* spp., *Bulbochaete* sp., *Stephanoporos regularis*, *Closterium incurvum*, *Cosmarium bireme*, *F. rhomboides*, *N. palea*, *E. pectinalis*, and *A. delicatissima*. *M. aubleti* was even more sparsely populated than *Sphagnum macrophyllum*, having *Micrasterias fimbriata*, *Mougeotia* sp., and *Spirogyra* sp. as the only epiphytes. In his study of the phyco-periphyton in several oligiotrophic lakes, Foerster (1964) observed that colonization of glass slides by attached algae proceeded faster in earlier successional stages than on aquatic macrophytes. In later stages production on aquatic macrophytes exceeded that on glass slides. The present writer's study tends to confirm these observations. Algal frequencies were greater on slides after 2 weeks' exposure during April to May, 1969, than on macrophytes. Foerster's second observation was also confirmed for the filamentous aquatic macrophytes which were present. For example, substantially greater algal frequencies were found on *Websteria submersa* after 3 to 4 weeks' exposure than on glass slides (cf. p. 116).

On May 20, 1969, a number of collections were made from station 3. From a glass enclosure after 6 weeks' exposure at 18 inches, *W. submersa*, *M. aubleti*, and *Sphagnum macrophyllum* were collected. The following naturally growing species were also collected from a depth of 18 inches at station 3: *Panicum hemitomon*, *M. aubleti*, *Leersia oryzoides*, and *Utricularia olivacea*.

W. submersa, collected from the enclosure, had the following epiphytes: *Oedogonium* sp., *Spirogyra* sp., *Bulbochaete* sp., *Gleocystis vesiculosa*, *Coleochaete irregularis*, *Mougeotia* sp., *Cosmarium bireme*, *C. pyramidatum*, *Desmidium baileyi*, *E. pectinalis*, and *Rhipidodendron splendidum*. None were abundant.

M. aubleti, also collected from the enclosure, had a somewhat different flora from that of *W. submersa*. Several closely appressed forms were common to abundant: *Cosmarium bireme*, *C. regnellii*, *Coleochaete irregularis*, and *E. pectinalis*. Other epiphytes included: *Oedogonium* sp., *Bulbochaete* sp., *Spirogyra* sp., *M. fimbriata*, *Onchyonema laeve* var. *latum*, *E. zygodon*, and *A. oscillarioides*.

The *S. macrophyllum* from the enclosure had a still somewhat different algal flora. The appressed species, *Cosmarium bireme* and *H. fontinalis*, and the filamentous *Oedogonium* spp. were abundant. Also present were: aseriate packets of an unidentified member of the Nostocaceae, *Cosmarium ornatum*, *Actinotanium cruciferum*, *Closterium intermedium*, *G. vesiculosa*, *Mougeotia* sp., *Bulbochaete* sp., *R. splendidum*, *Eunotia pectinalis*, and *F. rhomboides*. The small Chrysophyte, *Lagynion scherffellii*, was also present as an epiphyte on a single *Oedogonium* species.

The leaves and stems of the naturally growing grasses, *Panicum hemitomon* and *Leersia oryzoides* taken from station 3 on May 20, 1969, were covered by a filamentous mat composed of several unidentified species of *Oedogonium*. The other epiphytes present on the leaves of *P. hemitomon* were: *Pleurataenia subcoronulatum*, *Cosmarium pyramidatum*, *C. blylii*, *C. regnellii*, *Closterium intermedium*, *Cl. incurvum*, *Cl. libellula*, *Cl. setaceum*, *Coleochaete irregularis*, *Gleocystis vesiculosa*, *Mougeotia* sp., *E. pectinalis*, *A. oscillarioides*, and *H. fontinalis*.

In addition to the leaves, several of the adventitious roots of *P. hemitomon* were also examined for epiphytes. These roots were filamentous, extending into the water rather than anchoring the plant. The epiphytic community present was unlike that on the leaves. *Oedogonium* spp. remained dominant but was not as abundant as on the broad leaves of this macrophyte. The filamentous *Mougeotia* sp. and several closely adhering species, *Cosmarium regnellii*, *C. bireme*, *Coleochaete irregularis*, and *H. fontinalis*, were also abundant. The other species recorded were: *Pleurataenia subcoronulatum* and *E. pectinalis*. *L. oryzoides* had few epiphytes besides *Oedogonium* spp. The other species present were *Coleochaete irregularis*, *Mougeotia* sp., and *H. fontinalis*.

The floating macrophyte, *U. olivacea*, also had an epiphytic flora dominated by *Oedogonium* spp. The filamentous desmid, *Pleurataenia subcoronulatum*, was a subdominant. The other epiphytes recorded were: *Mougeotia* sp., *Coleochaete irregularis*, and *H. fontinalis*.

At station 3, the naturally growing *M. aubleti* had a unique epiphytic flora as compared with the other macrophytes sampled on May 20, 1969. Two closely adhering forms *Protoderma viride* (Chlorophyte) and *Aphanocapsa delicatissima* (Cyanophyte) were co-dominants. Also present, but not as abundant were *Oedogonium* spp., *G. vesiculosa*, *Cosmarium bireme*, *Aphanochaete repens*, *E. pectinalis*, and *E. zygodon*.

On July 26, 1969, *Panicum hemitomon* (natually growing) was collected from each of the three littoral stations. In each case the portion of the plant sampled was the vertical leaf sheath. Sheaths were collected from a depth of 18 inches.

At station 1, the most abundant epiphytes on the leaf sheat of *P. hemitomon* were the metaplanktonic *Pleurataenia subcoronulatum* and four unidentified species of *Oedogonium*. (Many *Oedogonium* germlings were present.) *Coleochaete irregularis*, *Cosmarium regnellii*, and *Oscillatoria tenuis* were common epiphytic species. Other species with rare to infrequent occurrences were *Mougeotia* sp., *Cosmarium bireme*, *Netrium digitus*, *Onchyonema laeve* var. *latum*, *Hyalotheca dissiliens*, *Closterium incurvum*, *Cl. navicula*, *Frustulia rhomboides*, *E. pectinalis*, *E. zygodon*, *Nitschia palea*, *Stephanoporos regularis*, and *Anabaena oscillarioides*.

At station 2, *Panicum hemitomon* also had an algal flora dominated by *Oedogonium* spp. Again, many of the specimens present were germlings. Two other filamentous greens, *Mougeotia* sp. and *Spirogyra* sp., were sub-dominants. Additional epiphytes present were: *Closterium incurvum*, *Cl. navicula*, *Cosmarium bireme*, *C. amoenum*, *G. vesiculosa*, *Bulbochaete* sp., *F. rhomboides*, and *E. pectinalis*. The filamentous desmid, *Pleurataenia subcoronulatum*, abundant at station 1, was absent at station 2.

The *Panicum hemitomon* gathered from station 3 supported an epiphytic flora dominated by *Oedogonium* spp., as observed at stations 1 and 2. As at station 1, *Pleurataenia subcoronulatum* was a co-dominant. The other members of the epiphytic community at station 3 were: *G. vesiculosa*, *Staurastrum paradoxum*, *Cosmarium ornatum*, *Closterium incurvum*, and *Onchyonema laeve* var. *latum*.

On April 30, 1971, spring winds had uprooted a portion of the aquatic macrophyte, *W. submersa*, so that it was present both in the rooted and floating states. Collections were made of this plant from stations 1 and 2 and at several intermediate points between the two stations. At station 1, collections were made of rooted plants from a depth of 6 inches. At station 2, floating plants were gathered as well as rooted plants from depths of 6 and 9 inches. Macrophytes collected from intermediate points were taken from depths of 6 or 9 inches.

At station 1, a microscopic examination of *W. submersa* (depth of 6 inches) showed the macrophyte to be covered by the Xanthophyte, *Stephanoporos regularis*, and by the diatom, *E. pectinalis*. Both of these epiphytes were very abundant. A limited number of other species were present including: *Cosmarium pyramidatum*, *Helicodictyon planctonicum*, *E. zygodon*, and *Neidium ladogense*.

E. pectinalis was also the dominant epiphyte on *W. submersa* at station 2 (6-inch depth) with *Aphanocapsa delicatissima* as a sub-dominant. The other epiphytes included: *Closterium intermedium*, *Cl. navicula*, *Spondylosium pulchellum* var. *bambusinoides*, *Staurastrum paradoxum*, *C. regnellii*, *Oedogonium* sp., *Protoderma viride*, *Scendesmus dimorphus*, and *E. zygodon*. The desmid, *Spondylosium pulchellum* var. *bambusinoides*, was present only in the collections made on April 30, 1971.

The floating *W. submersa* at station 2 had presumably drifted into the area from other parts of the lake. On these plants the epiphytic community was not the same as that on the *W. submersa* rooted at a depth of 6 inches. *G. vesiculosa* was the dominant species present. Sub-dominants (frequency "common") were: *Mougeotia* spp., *Phormidium tenue*, *Closterium navicula*, *E. vanheurckia* var. *intermedia*, and *E. pectinalis*. Other species with rare to infrequent occurrences included: *Cosmarium bireme*, *C. regnellii*, *Spondylosium pulchellum* var. *bambusinoides*, *Micrasterias fimbriata*, *Staurastrum paradoxum*, *Oedogonium* sp., *Coleochaete irregularis*, *F. rhomboides*, *Nitschia palea*, and *Peridinium limbatum* (planktonic).

E. pectinalis (diatom) and *Closterium navicula* (desmid) were the dominant species on *W. submersa* collected from a depth of 9 inches between stations 1 and 2. A number of desmids other than *Cl. navicula* were also present. These included: *Cosmarium bireme*, *C. regnellii*, *C. blyttii*, *C. pyramidatum*, *C. amoenum*, *Closterium intermedium*, *Arthrodesmus incus*, and *Spondylosium pulchellum* var. *bambusinoides*. Epiphytes, other than desmids, were *Oedogonium* sp., *Mougeotia* sp., *Scendesmus dimorphus*, *Stephanoporos regularis*, *F. rhomboides*, *E. pectinalis*, *E. vanheurckia* var. *intermedia*, *E. curvata*, *Dinobryon euryostoma*, *Oscillatoria tenius*, and *Aphanocapsa delicatissima*.

W. submersa was collected from a depth of 6 inches at a second intermediate point between stations 1 and 2. As on most samples of this macrophyte gathered on April 30, 1971, *E. pectinalis* was abundant. Co-dominant with *E. pectinalis* were two other species, *Protoderma viride*, and *A. delicatissima*. Other epiphytes were: *Staurastrum paradoxum*, *Cosmarium pyramidatum*, *C. bireme*, *C. blyttii*, *Closterium navicula*, and *Spondylosium pulchellum* var. *bambusinoides*.

On July 31, 1971, *W. submersa*, gathered from a depth of 12 inches at station 1, was densely populated by epiphytes. Both *Mougeotia* spp. and *Anabaena oscillarioides* were very abundant. *Microspora pachyderma* was common. Other species with densities ranging from rare to infrequent were: *Spirogyra* sp., *Bulbochaete* sp., *Aphanochaete repens*, *Staurastrum paradoxum*, *G. vesiculosa*, *Closterium intermedium*, *Cl. setaceum*, *Dinobryon bavaricum*, *E. pectinalis*, *Oscillatoria tenius*, and *H. fontinalis*.

For 5 weeks, from August 6 to September 3, 1971, 6-inch slides were exposed at station 2. At the time of collection approximately 50% of the slide area was covered by a fresh-water sponge, *Spongilla* sp. The remaining areas of the slides were thickly populated by attached algae, especially blue-greens. Several Cyanophycean species appeared for the first time in collections on September 3, 1971.

The blue-green, *Anabaena oscillarioides*, was one of the dominants on slides. Filaments of this alga were attached directly to the substrate. Such a manner of attachment in this species contrasts sharply with that observed at other times during the period of study when *A. oscillatarioides* was part of the metaplankton. Other blue-greens present included aseriate packets of an unknown member of the Nostocaceae, *Anabaena lapponica*, *A. variabilis*, *Aphanocapsa delicatissima*, *Lynbya nordgaardhii*, *O. tenius*, and *H. fontinalis*.

The small diatom, *Navicula minima*, was very abundant on slides during September, 1971. This alga showed a distinctly clumped distribution, covering some areas of a slide while being absent from other portions. Other attached diatoms were *Neidium ladogense*, *Nitschia palea*, *E. pectinalis*, and *F. rhomboides*. Attached members of the Chrysophyceae were *Dinobryon bavaricum* and *D. calciforme*.

The most abundant Chlorophyte present was the loosely associated desmid, *Staurastrum leptocladum*. Other Chlorophytes included *S. paradoxum*, *Euastrum binale*, *Cosmarium regnellii*, *C. bireme*, *Closterium navicula*, *Protoderma viride*, *Coleochaete irregularis*, *Characium ambigium*, *Schoederia setigera*, *Mougeotia* sp., *Oedogonium* sp., and *Spirogyra* sp.

A Xanthophyte, *Stephanoporos regularis*, which sometimes appeared in the attached flora of Lake Mize, was also present on slides during September, 1971.

Planktonic Algae, September 3, 1971

On September 3, 1971, a bloom of the green alga, *Helicodictyon planctonicum*, occurred in some areas of the lake. This alga occasionally appeared in the plankton. At times it was also trapped by the periphyton, although it did not appear on slides during September, 1971.

Elk Lake Studies

The attached algae of Elk Lake, Minnesota, were studied during a 6-week period in the summer of 1967, from July 1 to August 4. Results differed from the July to August studies at Lake Mize, Florida, and are presented here for comparative purposes.

Twenty-five species of algae were identified during the study period. Several other species present could not be identified, due, in some cases, to a lack of reproductive structures. Of the 34 species present, 19 were diatoms, 7 were Cyanophytes, and 8 were Chlorophytes. Generally, diatoms dominated the attached flora in both the limnetic and littoral areas, although a few Chlorophytes and Cyanophytes were sometimes abundant. This domination by diatoms was in striking contrast to Lake Mize, where desmids and other Chlorophytes generally dominated the attached flora. The majority of the species present in Lake Mize were also Chlorophytes.

Collections of slides were made from littoral and limnetic stations on July 28 after one week's exposure, on

August 4 after 2 weeks' exposure, and on August 14 after 3-1/2 weeks' exposure. Collections were also made of some slides in the limnetic area on August 14 after 6 weeks' exposure and of *Scirpus* sheaths from the littoral area.

As in the Lake Mize limnetic studies, colonization patterns that appeared on slides were studied from a comparative view with regard to: (1) *time*—the succession of attached forms that appeared from week to week at a given depth in the lake; (2) *space*—differences in the types of attached algae that appeared on slides in the different vertical layers of the lake. Dominance on slides was determined by counts and estimates. One slide from each level per week was examined.

Vertical Patterns of Attached Algae and Other Periphyton on Glass Slides in Elk Lake, July to August, 1967

On each of the three collections dates, the greatest number of organisms attached to slides suspended at depths of 1 and 3 meters. Organism frequency was also high on slides suspended at the depth of 2 meters. A substantial reduction in organism frequency occurred on slides submerged at a depth of 4 meters. Below the depth of 4 meters, organism frequency was low on slides. At these lower levels, most attaching algae occurred on that protected portion of the slides near the wooden rack.

Fourteen diatom species, 1 Chlorophyte species, and 1 Cyanophyte species appeared on limnetic area slides on July 28.

Several attaching diatoms had high frequencies on slides collected on July 28, 1967, after 1 week's exposure. Colonization patterns were similar on slides submerged at each of the upper 4 levels. The diatoms, *Achnanthes minutissima* and *Cocconeis placentula*, were the most abundant species present. Other diatoms which were somewhat numerous included: *Synedra radians*, *Epithemia zebra*, *Epithemia turgida*, *Gomphonema lanceolata*, and *Cymbella affinis*. At meter 4, the blue-green, *Oscillatoria quadripunctulata*, was also an important component of the algal flora.

Slides collected on July 28, 1967, below the depth of 4 meters had a sparse algal flora. The algae present in limited numbers at these lower levels were chiefly *Tabellaria flocculosa*, *A. minutissima*, and *C. placentula*.

The algal flora of slides collected on August 4, 1967, after 2 weeks' exposure, was dominated by the diatom, *A. minutissima* at the upper 3-meter levels. Large numbers of this small diatom were present, attached broadside to the slides. Sixteen diatom species, 2 Chlorophyte species, 5 Cyanophyte species, and 1 species of *Euglena* were present on slides in the limnetic area.

On slides at the 1-meter level, *A. minutissima* made up 90% of the attached flora. At meter 2, dominance was shared by *A. minutissima* and *G. lanceblatum*. At a depth of 3 meters, *A. minutissima* and *O. quadripunctulata* were the most abundant algae. At a depth of 4 meters, the diatom, *C. placentula*, and the green algae, *Mougeotia* sp., *Oocystis* sp., and *Radiococcus nimbatus*, were the most important components of the algal flora. *A. minutissima*, abundant at the upper levels, was present only in limited numbers.

Below meter 4, algal frequency was low with *Tabellaria flocculosa* and *Cyclotella bodin* present in low frequencies.

The communities of attached algae present on slides at the 3-meter depth in the limnetic area of Elk Lake on August 14, 1967, after 3 weeks' exposure, showed more variation than on earlier dates (Tables 35, 36, and 37). At the upper two levels, species diversity was comparatively low and *A. minutissima* continued to be a dominant, making up 51% of the attached flora on slides at meter 1 and 86% at meter 2. *O. quadripunctulata* was also abundant on slides at the 1-meter level. Both of these algae attached broadside to the slides, adhering closely to the substrate.

TABLE 35

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Area of Elk Lake, Minnesota, for 1 Week, July 21 to July 28, 1967

	Number of Species				
	1-Meter depth	2-Meter depth	3-Meter depth	4-Meter depth	6-Meter depth
Chlorophytes	1	ab.	ab.	ab.	ab.
Chrysophytes	9	11	13	11	8
Cyanophytes	ab.	1	ab.	2	ab.
Total Number of Species	10	12	13	13	8

Note: ab. = absent

TABLE 36

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Area of Elk Lake, Minnesota, for 2 Weeks, July 21 to July 28, 1967

	Number of Species				
	1-Meter depth	2-Meter depth	3-Meter depth	4-Meter depth	6-Meter depth
Chlorophytes	ab.	ab.	ab.	2	1
Chrysophytes	13	11	11	9	6
Cyanophytes	1	ab.	5	1	ab.
Euglenophytes	ab.	ab.	ab.	1	ab.
Total Number of Species	14	11	16	13	7

Note: ab. = absent

TABLE 37

Number of Algal Species Present at Various Depths on Glass Slides Suspended in the Limnetic Area of Elk Lake, Minnesota, for 3-1/2 Weeks, July 21 to August 14, 1967

	Number of Species				
	1-Meter depth	2-Meter depth	3-Meter depth	4-Meter depth	6-Meter depth
Chlorophytes	ab.	ab.	2	2	1
Chrysophytes	10	8	14	8	2
Cyanophytes	3	ab.	5	2	ab.
Euglenophytes	ab.	ab.	1	1	ab.
Total Number of Species	13	8	22	13	3

Note: ab. = absent

Two protozoans, *Vorticella* and *Actinophyrs*, were numerous on slides at the upper two levels.

Slides submerged at a depth of 3 meters were covered by a thick film of brown debris. Dominance was shared by four algal species. Two of these, *A. minutissima* and *O. quadripunctulata*, were forms which attached directly to the substrate. Two others, *Gomphosphaeria lacustris* and *Synedra radians*, were associated with the debris and did not adhere closely to the slides. Species diversity was also higher on slides at meter 3 than at other levels (see Table 37). The attached protozoan, *Vorticella*, was the chief grazer present.

Slides at the 4-meter level did not have the thick film of debris which had been present on slides at meter 3. *A. minutissima* and *S. radians* were the most abundant algae on slides. The protozoans, *Vorticella* and *Actinophyrs*, were abundant on slides at the 4-meter level.

Again, slides suspended at levels below 4 meters were only sparsely populated by algae and other attached forms.

Slides were also collected from the 3-meter level on August 14, 1967, after 6 weeks' exposure. These slides were covered by a thick coat of debris. The dominant algae were forms which tended to drift in the debris rather than attach firmly to the substrate. *Gomphosphaeria lacustris* made up 46%, *Rhopalodia gibba* made up 30%, and *Cymbella affinis* made up 18% of the algae associated with meter 3 slides after 6 weeks' exposure. At this time, the blue-green, *G. lacustris*, and one of the diatoms, *R. gibba*, were also present in the plankton (Baker, 1967). Both were also found on the sediments and as epiphytes on *Scirpus* in the littoral area.

Variation with Time in the Algal Flora Present on Glass Slides, Elk Lake Limnetic Area, August, 1967

Resupinate forms were the pioneers in colonizing glass slides at the upper 4 levels. The diatoms, *A. minutissima* and *C. placentula*, were prominent on slides after 1 week's exposure. Both of these species were examples of the resupinate type.

Prostrate forms continued to be abundant on slides after 2 weeks' exposure during August, 1967. At 3 of the 4 upper levels, *A. minutissima* continued to be abundant. A closely adhering blue-green, *O. quadripunctulata*, became abundant also on slides at a depth of 3 meters. And, the colonial greens, *Radiococcus nimbatus* and *Oocystis* sp., became abundant on slides at the 4-meter level. Both of these colonial algae were embedded in mucilage which also adhered to the substrate.

On slides at each of the upper 3-meter levels, *Gomphonema lanceolatum* became abundant. This alga represented a second attaching form to become abundant on slides in Elk Lake. Cells of *G. lanceolatum* attached vertically to the substrate via a button of mucilage on one end of the cell. The green filamentous species, *Mougeotia* sp., also became abundant on slides at a depth of 4 meters. This species attached vertically to the substrate as did *G. lanceolatum*. Attachment for *Mougeotia* sp. was by means of a holdfast.

After 3 weeks' exposure, resupinate forms remained dominant on slides at meter levels 1 and 2. At meter 3, a thick film of debris had formed. Two of the prostrate species remained abundant. However, 2 other abundant species, *Gomphosphaeria lacustris* and *Synedra radians*, were forms associated with the debris on slides. *S. radians* was also the most abundant species at meter 4. Slides exposed for 6 weeks at meter 3 carried the successional tendency further. Three species, *G. lacustris*, *Rhopalodia gibba*, and *Cymbella affinis*, were abundant. All 3 were species which loosely associated with the substrate, tending to float in debris rather than attach directly to the slide.

Round (1964) in commenting upon the communities of attached algae which make up successional stages on glass slides, states that slides primarily attract a mixture of species from epiphytic and epilithic habitats. After this initial colonization, he observed that slides secondarily trap species from the epipelic and planktonic habitats. Slides exposed at the depth of 3 meters in Elk Lake during August, 1967, for 3 or 6 weeks, did secondarily trap planktonic species. This trapping occurred after the accumulation of debris on the slides.

Attached Algae of the Littoral Zone, Elk Lake, August, 1967

Colonization of slides placed at depths of 5 meters and 1 meter in the littoral area of Elk Lake was similar to the colonization of slides placed in the limnetic area at the upper 2-meter levels. *Achnanthes minutissima* was a dominant on slides at each weekly collection period. Other major species, *Cocconeis placentula*, *Gomphonema lanceolatum*, *Cymbella affinis*, *Synedra radians*, and *Epithemia zebra*, were also found on limnetic area slides. The differences which did exist between littoral area slides and upper level limnetic slides included the appearance of a prostrate green alga, *Coleochaete orbicularis*. Grazers were also more diverse on slides in in the littoral zone. *Actinophrys* appeared on slides during the first week with hypotrichs, attaching rotifers, ciliates, and gastrotrichs appearing the second week.

Gastrotrichs and rotifers were also present during the third week, moving easily about in the debris attached to slides. Except for the hypotrichs, which fed on *Achnanthes minutissima*, the feeding habits of these invertebrates were not observed.

The epiphytic algae of the aquatic macrophyte, *Scirpus* sp., in the littoral area of Elk Lake were also examined. Epiphytes which were present on both *Scirpus* and on glass slides included *E. zebra*, *E. turgida*, *Rhopalodia gibba*, *Amplipleura pellucida*, *Cymbella affinis*, *Nitschia palea*, *Amphora ovalis*, *Gomphosphaeria lacustris*, and *Radiococcus nimbatus*. The chief epiphyte, not present on glass slides, which was present in large quantities on *Scirpus* was a species of *Oedogonium*. *Achnanthes minutissima*, *Cocconeis placentula*, and *Oscillatoria quadripunctulata* were not detected on *Scirpus*. However, this was probably due to the difficulty of obtaining the closely adhering forms in scrappings from *Scirpus*, not to their absence.

Comparison: Attached Algae of Lake Mize, Florida, and Elk Lake, Minnesota

Few of the species of attached algae found in the dystrophic Lake Mize, Florida, and the mesotrophic, Elk Lake, Minnesota, were the same. Two diatoms, *Nitschia palea* and *Gomphonema lanceolatum*, and 1 Chlorophyte, *Protoderma viride*, were the only species common to both lakes. The chemical differences in Lake Mize and Elk Lake were reflected in an almost completely different alga flora in the two lakes. Some of the floristic differences in the two lakes may be elaborated on as follows:

1. A large number of desmids were present in Lake Mize whereas only single specimens of a few species were found in Elk Lake.

2. Diatoms formed the majority of the attached flora in Elk Lake while diatoms were generally subdominant to Chlorophytes in Lake Mize.

3. The most common diatoms in Lake Mize were several species of the genus, *Eunotia*. In contrast, *Achnanthes minutissima* was the most frequently appearing diatom in the flora of Elk Lake.

General similarities between the attached flora of the two lakes should also be cited. Closely adhering filamentous Cyanophytes appeared on the slides of both lakes during the month of August, although the species were different. In Elk Lake, *Oscillatoria quadripunctulata* was sometimes abundant on limnetic area slides, while the closely adhering *Phormidium tenue* was abundant in Lake Mize during August, 1969. Large, prostrate Chlorophytes appeared on littoral area slides in both lakes. In Elk Lake, *Coleochaete orbicularis* was common on slides while *Protoderma viride* and *Coleochaete irregularis* were frequently common to abundant on littoral area slides in both lakes. Prostrate greens were also absent or rare on limnetic area slides in both Elk Lake and Lake Mize.

In both lakes, closely adhering, resupinate forms made up many of the pioneering species which attached to recently submerged substrates. In Lake Mize, filamentous species were also sometimes included among the first attachers to a bare substrate. These were rare on Elk Lake slides except at the depth of 4 meters. Conversely, few stalked diatoms appeared in Lake Mize while such forms were common on Elk Lake slides.

In Elk Lake, a large film of debris collected on slides submerged at the depth of 3 meters after 3 weeks. A number of metaplanktonic and planktonic species became associated with this debris, becoming more abundant than the closely adhering and stalked diatoms. The layer of debris on 6-to 30-inch slides in Lake Mize never became as thick as that in Elk Lake. (Because most of the light was absorbed by upper layers of the lake, slides submerged at 3 meters in Lake Mize had a very sparse flora.) Fewer metaplanktonic species were also associated with Lake Mize slides in the latter stages of succession than on the 3-meter Elk Lake slides.

VI. DISCUSSION

As could be anticipated, the species composition and relative frequencies of organisms within the communities of attached algae in Lake Mize were dependent upon a number of factors.

Losses Due to Peeling

Losses due to peeling from an established periphyton community had a major influence upon the species diversity and the relative abundance of species within the community. Peeling—the detachment of portions of the periphyton from a substrate—may be caused by current, by decomposition gases (Neal, Patten, and DePoe, 1967), or by movements of fish and other animals.

Examination of periphyton dislodged from the substrate by slight movements in the water and of species falling to the bottom of collecting jars indicated that losses of individual species were not in proportion to the relative frequencies of the species within the part of the community left adhering to the substrate. Slightly greater losses of the loosely associated species of the metaplankton occurred than of tightly appressed species. Most of these metaplanktonic species in Lake Mize were desmids which were frequently rare species in the periphyton. Two blue-greens, *Oscillatoria tenuis* and *Anabaena oscillarioides*, at times were also part of the loosely associated metaplankton. At such times, losses by peeling were accompanied by substantial decreases in frequencies of these two algae. Peeling was responsible for the frequency decrease in *O. tenuis* on glass slides between August 20 and September 11, 1969.

Peeling due to decomposition gases within the debris or to currents was of rather irregular occurrence on a given substrate with respect to time. Nor did peeling take place at the same rate on replicate substrates subjected to the same limnological conditions. This peeling and subsequent recolonization by tightly adhering forms on portions of the substrate undergoing peeling sometimes caused a great deal of variation between closely situated periphyton communities on replicate substrates. Such variation, however, was not nearly as large as that encountered in different seasons, at different localities in the lake, on different substrates at a particular time, or at different depths.

Changes with Time: Colonization and Succession

Although metaplanktonic species have a slightly higher rate of loss from the periphyton than tightly adhering forms, the members of a given attached species of any form in the open waters of the lake may be presumed to be a function of the relative abundance of the species within the periphyton and of the turbulence in the lake at that time. Such species when present in plankton samples are generally referred to as tychoplankters.

Colonization of a clean substrate introduced into the lake was initiated within hours by drifting tychoplankters. Most pioneer attaching species were not the same at different seasons or during the same year. Instead, pioneer attachers on a bare substrate were generally those species which were the most abundant in the lake (or area of the lake) at the time that the substrate was submerged. After attachment to a substrate by an individual cell or other unit of dispersal, subsequent cell divisions occurred if environmental conditions were suitable. A scattering of single-celled forms then developed from the original point of attachment while filament or colony formation took place for those forms. Microscopic examination of slides exposed for 7 days in the upper 6 to 18 inches of the lake generally showed considerable variation in the frequencies of attached species which were capable of rapid divisions, e.g., diatoms. Chance apparently dictated the numbers of such tychoplankters which made contact with a clean substrate during the first days after submergence. Subsequent rapid divisions on a substrate to which many tychoplankters chanced to attach resulted in higher frequencies of the species than on replicate substrates where fewer tychoplankters made contact.

Pioneering attaching species in Lake Mize were generally either tightly adhering, resupinate forms or filamentous and secured to the substrate by a holdfast. With the passing of time (up to 3 to 5 weeks generally) debris collected on the substrate. This accumulation of debris was accompanied by an increase in the number and frequency of metaplankters present. Metaplanktonic forms also occurred intermingled with filamentous forms, apparently requiring an association with either debris or filaments if they were to be retained on a substrate subjected to light currents.

This retention of the metaplankton was by no means absolute. After a period of time, generally exceeding 3 to 5 weeks, the layer of debris accumulated was usually great enough so that peeling ensued with a loss of many members of the periphyton. Secondary succession then proceeded to take place on cleared areas of the substrate.

Influence of the Substrate

Authorities are of divergent opinions regarding the degree and nature of the selectivity exerted by different types of substrates for various attached species (Godward, 1937; Castenholz, 1957; Sladeckova, 1962). In Lake Mize no absolute substrate specificity by any species of attached algae could be observed. However, the epiphytic communities on various macrophyte species at the same depth in the same area of the lake were usually significantly different. These differences existed with both naturally growing plants and those submerged for identical submergence periods in plastic or glass enclosures. The macrophytes involved were apparently exposed to the same environmental conditions so that substrate differences would appear to be the cause of variation in the epiphytic communities. However, if the same macrophytic species was collected at the same littoral station over a period of several years, the epiphytic species which were prevalent on it in time disappeared or sometimes appeared on another vascular aquatic species at the same or different littoral stations. It follows logically that the influence of the substrate is part of a complex interaction of factors acting upon the epiphytic communities. A few references exist in the literature to this interaction of the substrate and other environmental conditions. After reviewing several papers by Pearsall (1917, 1920, 1921, 1933) on rooted vegetation and the distribution of animals in English lakes, Macan (1970) concluded that on any one type of substrate, conditions for attachment by algae are different in different areas of a lake.

Current and its interaction with different types of substrates seem to be of critical importance in Lake Mize. During August, 1970, the filamentous sedge, *Websteria submersa*, was placed in the limnetic area of the lake, a part of the lake which is subject to currents. A stratified community of epiphytes with many meta-planktonic species soon developed. Limnetic area glass slides, however, had few metaplanktonic species and lower overall frequencies of all attached species. In littoral areas of the lake, the filamentous macrophytes, *W. submersa* and *Utricularia olivacea*, were generally more densely populated than the broader leaf blades and leaf sheaths of other macrophytes. The greatest differences existed when epiphytic communities on filamentous macrophytes were compared with the periphyton of glass slides.

At least one reference has been made in the literature stating that aquatic macrophytes with finely divided leaves tend to be more heavily populated by many epiphytes, including desmids, than macrophytes without such leaves (Sculthorpe, 1967). It may be hypothesized that the morphology of finely divided leaves makes for easier attachment and/or more protection for epiphytes. The filamentous morphology of *W. submersa* and *U. olivacea* appears to do likewise.

Glass slides are a convenient means of studying attached algae and are commonly used for such research. Regarding the effectiveness of this method, the point has been made earlier that both population density and the number of species were lower on glass slides than on the aquatic macrophyte, *W. submersa*, in Lake Mize. This was the case both in the open waters of the limnetic area and in protected enclosures in the littoral zone. However, inside protective enclosures, the periphyton communities of glass slides and *W. submersa* more nearly resembled each other quantitatively and qualitatively. On littoral area slides, frequencies of most species of both firm attachers and metaplankters were greater than on limnetic area slides at the same depth. Comparisons between the attached communities on glass slides and on nonfilamentous macrophytes such as *Sphagnum macrophyllum* and *Mayaca aubleti* showed somewhat comparable frequencies of attached algae. However, macrophytes of any morphological form were more likely to support metaplanktonic forms and certain species of adhering blue-greens than were glass slides. Conversely, other blue-green species were more likely to appear on glass.

Except for some metaplanktonic desmids, all species of attached algae which were present in Lake Mize appeared at some time during the study on glass slides. Both Castenholz (1967) and Sladeckova (1962) have commented upon the relative absence of blue-greens recovered from glass slides. In Lake Mize, blue-greens did occur on glass slides, especially in more protected portions of the littoral area.

During August, 1970, the blue-greens, *Hapalosiphon fontinalis* (prostrate, filamentous) and *Anabaena oscillarioides* (loose, filamentous), were rare and infrequent, respectively, on glass slides submerged 6 inches in the limnetic area. In contrast, these same species were very abundant on *W. submersa* submerged to a comparable depth in the limnion of the lake. These two blue-greens were also common to abundant on other aquatic macrophytes during August, 1970.

While this observation tends to agree with those of Castenholz and Sladeckova, other observations from Lake Mize do not. Under certain conditions, blue-greens had high frequencies on glass slides. Both *H. fontinalis* and *A. oscillarioides* were sometimes abundant on slides submerged at station 2. This station was located behind a projecting arm of the shoreline which protected it from north-south and south-north currents. During August, 1969, two blue-green species, *Oscillatoria tenuis* and *Phormidium tenue*, were also common and very abundant, respectively, on limnetic area slides.

It seems likely that some blue-greens, e.g., *H. fontinalis* and *A. oscillarioides*, are weak attachers, especially as compared to the diatom, *Eunotia*. Lake Mize is surrounded by trees which act as a wind buffer. This added protection from the wind, which diminishes the magnitude of currents, probably allows weakly adhering blue-greens to attach to glass, although losses of blue-greens from glass were higher than from most macrophytes. In quieter areas of the lake (station 2), even glass slides had a diverse and abundant blue-green flora.

Influence of Physical Factors—Current

The influence of the current in Lake Mize has already been alluded to in the discussion of substrates. One additional observation about current should be made. When slides were placed in an area subject to the fastest currents (just above the outflow ditch during a time of high water), the slides became covered by several species of the diatom, *Eunotia*, i.e., *Eunotia pectinalis*, *E. vanheurckia*, and *E. zygodon* with few other algae present (Table 33).

In Lake Mize, therefore, only firmly attaching, resupinate forms were able to remain attached to slides in relatively fast currents, and, 95-98% of these were diatoms. Due to the absence of filamentous and metaplanktonic species, diversity was low.

Unlike Lake Mize, Elk Lake, Minnesota, was only partially surrounded by trees and as such was more exposed to wind. In Elk Lake, when slides were submerged at meter intervals in the top 4 meters of the lake, most of the attached species found in the upper 2 meters were tightly adhering, resupinate forms, e.g., *Achnanthes minutissima*. Surface currents presumably did not penetrate to the depth of 3 meters where slides supported a number of planktonic and metaplanktonic species.

Influence of Physical Factors—Light

Light was a severely limiting factor for attached algae in Lake Mize due to the darkly colored waters. Only in the upper 6 to 30 inches of the lake was light not reduced to a critically low level. The degree of humolimnic acid coloration of the water fluctuated from time to time, so that the vertical range of the producers varied somewhat as a function of the amount of coloration. The vertical range of producers also varied with different substrates, extending deeper on *Websteria submersa* than on glass slides. The depth of maximum algal frequencies was also different on these 2 substrates, generally occurring at 6 inches for glass and at 18 inches for *W. submersa*. An interaction of several factors probably accounted for these differences. Losses due to peeling from both plants and slides were probably greatest at 6 inches due to surface currents in the lake. At all depths, losses were presumably greater from slides than from *W. submersa*. Only near the surface of the lake was photosynthesis sufficient to maintain a rapidly increasing algal density while also replacing losses from slides. With fewer losses on *W. submersa* at 18 and 30 inches than at 6 inches, greater population growth occurred despite the decreased photosynthesis. In the green-colored waters of Elk Lake, light became limiting for the attached flora of slides only below a depth of 3 meters.

Influence of Physical Factors—Temperature

An increase in temperature in Lake Mize during late summer and early fall was accompanied by an increase in the frequency of Cyanophytes among the attached flora during the 3 years of the study period. In late July or early August, 2 Cyanophyte species generally became abundant to very abundant on some substrates in the lake. These species were not always the same from year to year. In 1969, high frequencies were recorded for *Oscillatoria tenuis* and *Phormidium tenue* while *Anabaena oscillarioides* and *Hapalosiphon fontinalis* became abundant in both 1970 and 1971 during the warmer months.

Seasonal Influences

The seasonal variation in the periphyton of Lake Mize was not as great as that reported for lakes in the state of Washington (Castenholz, 1967) or for plankton (Fogg, 1966). Other than the influence of high temperatures associated with summer and fall, the effect of wind and storms seemed to be the chief seasonally related factor influencing the diversity and abundance of the attached algae. Slides placed in the limnetic area of the lake during the comparatively calm 1968-1969 winter season had a flora characterized by a number of species of metaplanktonic desmids and by high frequencies (abundant) of filamentous greens. Slides placed in the limnetic area during the periods August to September, 1969, and July to August, 1970, when the lake's waters were occasionally turbulent from the action of summer storms, had a flora dominated by tightly adhering, resupinate forms. Few filamentous or metaplanktonic forms were present.

An exception was *Oscillatoria tenuis* which in August, 1969, was common on limnetic area slides. Large losses from slides of this alga occurred between August 20 and September 11. In July, 1970, similar losses from slides of the metaplanktonic *Gleocystis vesiculosa* also occurred. At these times, summer thunderstorms were common and probably accounted for the large losses of algae from slides.

Conversely, many filamentous and metaplanktonic forms were abundant in some areas of the littoral zone during the summer and fall months where waters were presumably calmer and the area more protected. There the periphyton persisted through turbulent periods caused by rains and wind. This relatively restricted occurrence and frequent losses of filamentous and metaplanktonic forms during the summer and fall seasons may be contrasted with the winter season when such forms were widespread in all parts of the lake. Losses during December, January, and February (1968-1969) were also minimal.

A number of algal species were sporadically abundant in the periphyton of Lake Mize. Except for warmer summer and fall months, one or more Chlorophytes were dominant components of the periphyton. However, the pulses of individual species could not be predicted as to month or season. The occurrence of particular species in the periphyton during the December, 1968, to September, 1971, was noncyclic.

VII. SUMMARY

A floristic survey from December, 1968, to September, 1971, provided a record of the communities of attached algae in Lake Mize, Florida. Eighty-nine algal species were identified and monitored during the study period. Thirteen other unidentified species were also present. Of the 102 species distinguished, 63 were Chlorophytes, 2 were Euglenophytes, 22 were Chrysophytes, 2 were Pyrrophytes, 11 were Cyanophytes, 1 was a Xanthophyte, and 1 was a Chloromonadophyte. Both quantitatively and qualitatively, desmids and filamentous Chlorophytes were usually an important part of the periphyton in Lake Mize. Several acidiophilic diatoms were abundant at certain times while Cyanophytes generally reached high frequencies only during the July to September period.

Counts and estimates were used to determine the relative abundance and frequencies of the species present under different environmental conditions. Such analyses indicated that at any given time, and place, a number of factors influenced the composition of the periphyton. The most important conclusions drawn from this study regarding the influence of certain seasonal and environmental factors upon the phyco-periphyton are:

1. Algae employing particular modes of attachment were more abundant under some conditions than in others. Generally, tightly adhering, resupinate forms attained higher densities on glass slides than filamentous and loosely associated metaplanktonic species. Conversely, the epiphytic flora of the filamentous sedge, *Websteria submersa*, contained a large number of both strong and weak attachers. Substrates of any type exposed to a moderate current were populated almost exclusively by tightly adhering, resupinate forms.

2. At any given time, different areas of the lake supported somewhat different periphyton communities. In calmer areas of the lake or in protected enclosures, metaplanktonic and filamentous species were more abundant on all substrates than in areas subjected to currents and turbulence.

3. Light was an important environmental factor in determining the taxonomic composition of the periphyton community. Chlorophytes were generally abundant only in the upper 6 to 18 inches of the lake. Attached Chrysophytes had a broader vertical range, frequently remaining common to a depth of 30 inches on glass and 42 inches on *Websteria submersa*. Light requirements for Cyanophytes were variable with some species restricted to the upper 6 to 18 inches of the lake and other remaining common to a depth of 42 inches.

4. Seasonal influences upon the attached algae of Lake Mize were not as pronounced as those reported for northern lakes. During the study period pulses of individual species occurred in the periphyton but their occurrence could not be predicted as to month or season. Desmids and filamentous Chlorophytes were generally abundant throughout the year while maximum frequencies of Cyanophytes occurred during the warmer summer and fall months. The lack of turbulence from winds and storms during the winter season also influenced the periphyton, permitting metaplanktonic and filamentous species to become widespread in the lake.

5. When clean substrates (slides or plants) were submerged in the lake, the pioneering attachers were usually the most abundant resupinate and/ or filamentous forms in the lake at the time. With time, frequencies of the early attachers increased. Under proper conditions, species diversity also increased as metaplanktonic forms became associated with the substrate. Peeling and a loss of metaplanktonic and other attached species generally occurred with exposure periods exceeding 3 to 5 weeks or under conditions of sudden turbulence, e.g., storms.

6. The attached flora of the dystrophic Lake Mize, Florida, was very unlike that of the mesotrophic Elk Lake, Minnesota. Whereas Chlorophytes were the most important component of the periphyton in Lake Mize, diatoms formed the majority of the attached flora in Elk Lake.

APPENDIX

TABLE 38

Master List of the Attached Algae of Lake Mize, Florida, and Planktonic Species Associated with Communities of Attached Algae, December, 1968, to September, 1971

Chlorophyta

Volvocales

Eudorina elegans Ehrenberg*

Tetrasporales

Gleocystis vesiculosa Naegeli

Ulotrichales

Microspora tumidula Hazen
Microspora pachyderma (Wille) Lagerheim
Protoderma viride Kutzing
Aphanochaete repens A. Braun
Helicodictyon planctonicum (Whit.) Whitford & Schumacher*
Coleochaete irregularis Pringsheim.
Dicranochaete reniformis Hieronymus

Oedogoniales

Oedogonium reinschii Roy
Oedogonium spp.
Bulbochaete spp.

Chlorococcales

Characium ambicuum Hermann.
Schoederia setigera (Schroed.) Lemmermann
Coelastrum sphaericum Nageli
Ankistrodesmus falcatus (Corda.) Ralfs
Scenedesmus dimorphus (Turp.) Kutzing.

Zygnematales

Spirogyra spp.
Mougeotia spp.
Spirotaenia condensata Breb.
Netrium digitus (Ehren.) Itzigsohn and Rothe

TABLE 38—*Continued*

Closterium incurvum Brebisson
Closterium intermedium Ralfs
Closterium libellula Focks
Closterium navicula (Breb.) Lutkem.
Closterium setaceum Ehrenberg
Pleurotaenium minutum (Ralfs) Delponte
Pleurotaenium subcoronulatum var. *detum* (Turner) West & West
Triploceras gracile Bailey
Tetmemorus brebissonii (Menegh.) Ralfs
Euastrum affine Ralfs
Euastrum binale (Turp.) Ehrenberg
Euastrum ciastonii Racib.
Micrasterias fimbriata Ralfs
Actinotaenium cruciferum (De Bary) Teiling
Cosmarium amoenum Ralfs
Cosmarium bireme Nordstedt
Cosmarium blytii Wille
Cosmarium ornatum Ralfs
Cosmarium pygaeum Archer
Cosmarium pyramidatum Brebisson
Cosmarium regnellii var. *pseudoregnellii* (Messikommer) Krieger & Gerloff
Arthrodesmus incus (Breb.) Hassall
Arthrodesmus octocornis Ehrenberg
Xanthidium antilopaeum var. *minneapoliense* Wolle
Xanthidium subhastiferum var. *towerii* (Cushman) G. M. Smith
Staurastrum leotocladum Nordstedt
Staurastrum paradoxum Meyen
Staurastrum pyramidatum West
Staurastrum spp.
Onchyonema laeve var. *latum* West & West
Hyalotheca undulata Nordstedt
Hyalotheca dissiliens (Smith) Brebisson
Desmidium baileyi (Ralfs) Norstedt
Bambusiana brebissonii Kutzing
Spondylosium pulchellum var. *bambusinoides* (Wittr.) Lundell
Euglenophyta
Euglena sp.
Phacus lemmermannii (Swkr.) Skvortzow

TABLE 38—*Continued*

Xanthophyta

Stephanoporos regularis (Pasch.) Bourrelly

Chrysophyta

Chrysophyceae

Dinobryon bavaricum Imhof
Dinobryon calciforme (Bachmann) Hilliard & Asmund
Dinobryon cylindricum Imhof*
Dinobryon euryostoma (Lemm.) Hilliard & Asmund
Mallomonas caudata Conrad*
Mallomonas sp.*
Synura sphagnicola Korsch*
Lagynion scherffellii Pascher
Rhipidodendron splendidum Stein

Bacillariophyceae

Asterionella formosa Hassal.*
Eunotia curvata (Kutz.) Lagerheim
Eunotia pectinalis (Kutz.) Rabenhorst
Eunotia vanheurckia var. *intermedia* (Kras. ex. Hust.) Patrick
Eunotia zygodon Ehrenberg
Frustulia rhomboides var. *saxonica* (Rabh.) de Toni
Neidium ladogense var. *densestriatum* (Oestrup) Foged
Navicula minima Grunow
Gomphonema lanceolatum Ehrenberg
Nitschia palea (Kutz.) W. Smith
Surirella biseriata var. *constricta* Grunow
Surirella robusta var. *splendica* (Ehr.) Van Heurck.
Pinnularia gibba Ehrenberg

Pyrrophyta

Peridinium limbatum (Stokes) Lemmermann*
Peridinium westii Lemmermann*

Chloromonadophyta

Gonyostomum semen (Ehr.) Diesing.*

TABLE 38—*Continued*

Cyanophyta

Chroococcales

Aphanocapsa delicatissima West & West

Oscillatoriales

Oscillatoria tenuis Ag.
Phormidium angustissimum West & West & West
Phormidium tenue (Meneg.) Gomont
Lynbya nordgaardii Wille
Anabaena oscillarioides Bory
Anabaena variabilis Kuetzing
Anabaena lapponica Borge
Anabaena flos-aquae (Lyngh.) Brebisson*
Hapalosiphon fontinalis (Ag.) Bornet.
Calothrix epiphytica West & West

*Planktonic species.

Figure 17. Germlings of *Bulbochaete* sp. on *Websteria submersa* (×400), Lake Mize.

Figure 18. Colony of *Protoderma viride*, a prostrate Chlorophyte, with diatoms, *Nitschia palea* and *Frustulia rhomboides* (×1,400), Lake Mize.

Figure 19. *Oscillatoria tenuis* filaments (×1,300), Lake Mize.

Figure 20. *Anabaena oscillarioides* (×1,000), Lake Mize.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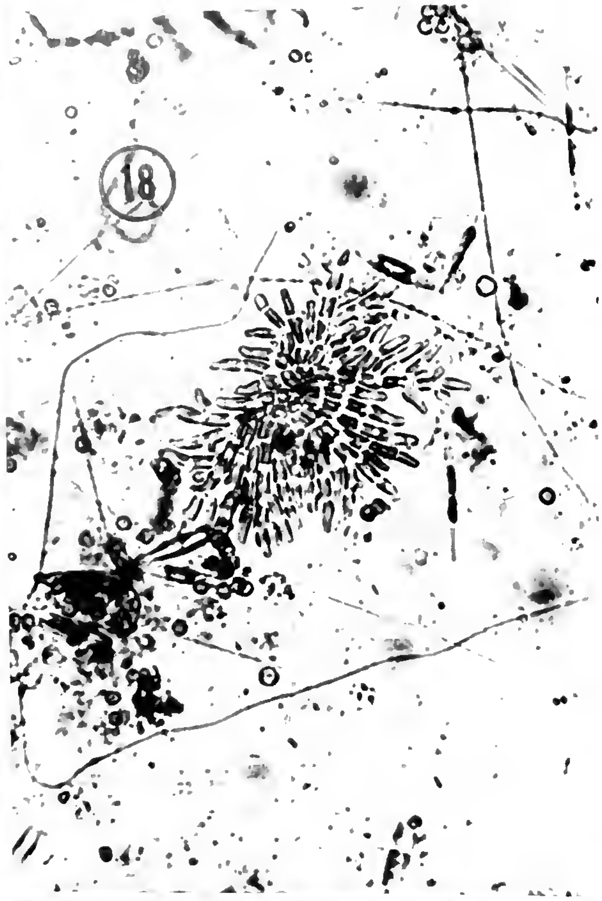
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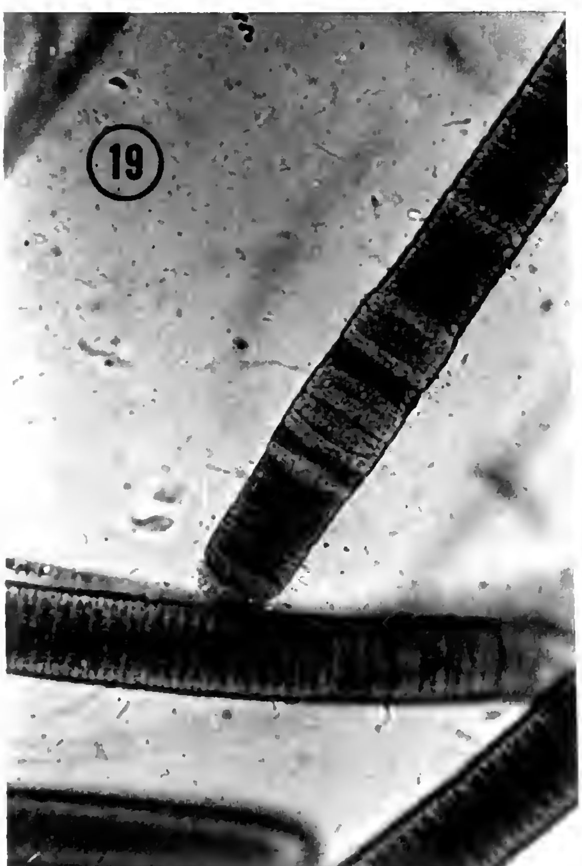
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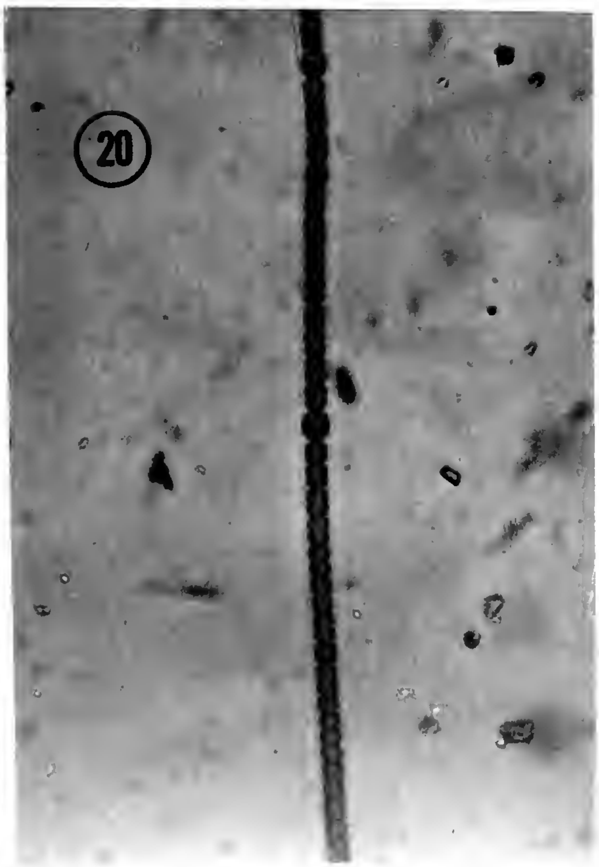
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Figure 21. *Closterium setaceum* (×320), Lake Mize.

Figure 22. *Closterium navicula* (×600), Lake Mize.

Figure 23. *Oedogonium* sp., showing holdfast (×400), Lake Mize.

Figure 24. Branched filaments of *Hapalosiphon fontinalis* (×500), Lake Mize.

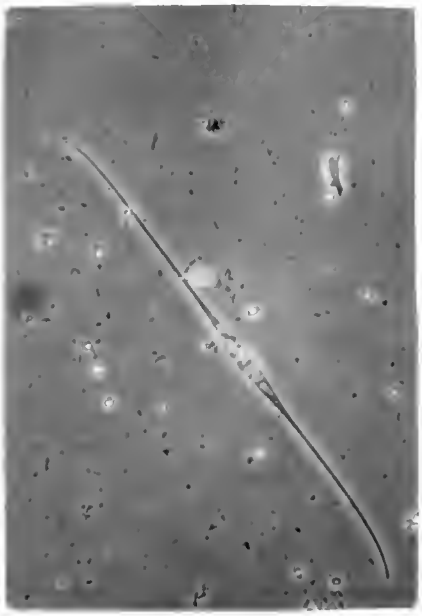

Figure 21

Figure 22

Figure 23

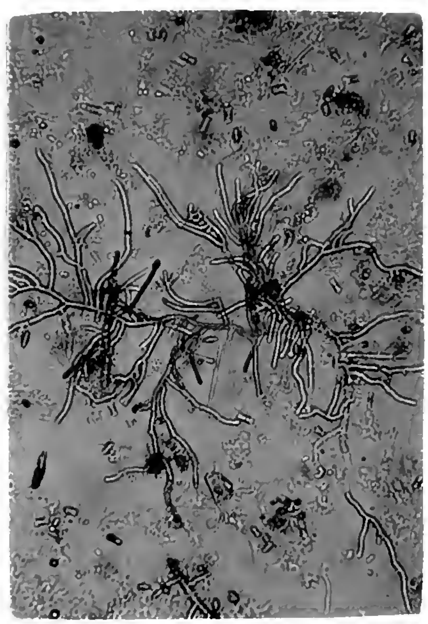

Figure 24

Figure 25. Portion of the attached community of a glass slide, showing *Cosmarium regnellii* *Eunotia* sp., and a filamentous Oomycete (×600), Lake Mize.

Figure 26. *Frustulia rhomboides* var. *saxonica* (×750), Lake Mize.

Figure 27. *Rhipidodendron splendidum*, a heterotrophic Chrysophyte (×300), Lake Mize.

Figure 28. *Epithemia zebra* (×400), Elk Lake.

Figure 25

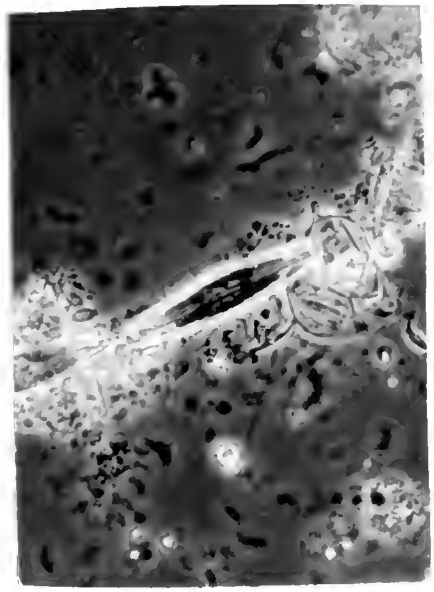

Figure 26

Figure 27

Figure 28

TABLE 39

Master List of the Attached Algae and Planktonic Species Associated with Attached Algae in Elk Lake, Minnesota, August, 1967

Chlorophyta

Ulotrichales

Protoderma viride Kutzing
Coleochaete orbicularis Pringsheim

Chlorococcales

Radiococcus nimbatus (de Wild.) Schmidle
Oocystis sp.

Oedogoniales

Oedogonium sp.
Bulbochaete sp.

Zygnematales

Mougeotia sp.
Spirogyra sp.

Euglenophyta

Euglena sp.

Chrysophyta

Bacillariophyceae

Cyclotella bodin var. *affinis* O. Mull.
Tabellaria flocculosa (Roth.) Kutzing.
Synedra radians Kutzing.
Synedra ulna (Nitz.) Ehrenberg
Synedra actinastroides Lemmerman
Achnanthes minutissima Kutzing
Cocconeis placentula Ehrenberg
Amplipleura pellucida Kutzing
Gomphonema lanceolatum Ehrenberg
Gomphonema acuminatum var. *coronata* (ehr.) W. Smith

TABLE 39—*Continued*

Gomphonema intricatum var. *pumila* Grun.
Amphora ovalis Kutzing.
Cymbella affinis Kutzing
Cymbella cistula (Hemprich) Grun.
Epithemia turgida (Ehr.) Kutzing
Epithemia zebra (Ehr.) Kutzing
Rhopalodia gibbia (Ehr.) O. Muller*
Nitschia palea (Kutz.) W. Smith
Nitschia gracilis Hantzsch.

Cyanophyta

Chroococcales

Merismopedia sp.
Coelosphaerium sp.
Gomphospaeria aponina Kutzing
Gomphospaeria lacustris Chordat*

Oscillatoriales

Oscillatoria quadripunctulata Bruhl & Biswas
Lyngbya sp.
Spirulina sp.

*Planktonic species.

TABLE 40

The Algal Flora Present on Vertically Positioned Glass Slides Suspended in the Limnetic Zone of Lake Mize during January, 1969; August, 1969; and August, 1970 (VA = Very abundant, A = Abundant, C = Common, I = Infrequent, R = Rare)

	January 1969	August 1969	August 1970
Chlorophyta			
Protoderma viride Kutzing	A	R	
Coleochaete irregularis Pringsheim		R	
Ankistrodesmus falcatus (Corda.) Ralfs		R	
Helicodictyon planctonicum		I	R
Oedogonium spp.	I	I	R
Bulbochaete sp.	R	R	
Spirogyra spp.	R		
Mougeotia spp.	A	R	
Closterium setaceum Ehrenberg	R		
Closterium intermedium Ralfs	P	R	
Closterium navicula (Breb.) Lutkem.	R	R	R
Pleurotaenium subcoronulatum var. *detum* (Turner) W. & G. S. West	R	R	
Triplocerus gracile Bailey	R		
Euastrum affine Ralfs	R		

TABLE 40—*Continued*

	January 1969	August 1969	August 1970
Euastrum ciastonii Racib.	R		
Euastrum binale (Turp.) Ehrenb.			
Micrasterias fimbriata Ralfs	R		
Cosmarium amoenum Ralfs	R		
Cosmarium ornatum Ralfs	R	R	
Cosmarium regnellii var. *psuedoregnellii* (Messikommer) Krieger & Gerloff	R	I	
Cosmarium pygmaeum Archer		R	
Cosmarium bireme Nordstedt	R	A	R
Cosmarium pyramidatum Breb.			
Xanthidium antilopaeum var. *minneapoliense* Wolle	R		
Staurastrum leptocladum Nordstedt.			
Staurastrum gladiosum Turner			R
Staurastrum orbiculare Ralfs			
Staurastrum paradoxum Meyen	R	R	
Staurastrum sp. *1*	R		
Staurastrum sp. *2*	R		
Arthrodesmus incus (Breb.) Hassall	R		

TABLE 40—*Continued*

	January 1969	August 1969	August 1970
Arthrodesmus octocornis Ehrenberg	R		
Hyalotheca dissiliens (Smith) Brebisson	R		
Hyalotheca undulata Nordst.	R		
Desmidium baileyi (Ralfs) Nordstedt.	R		
Chrysophyta			
Dinobryon calciforme (Bachmann) Hilliard & Asmund			I
Dinobryon eurystoma (Lemm.) Hilliard & Asmund			R
Mallomonas caudata Conrad	R	I	
Rhipidodendron splendidum Stein			I
Eunotia curvata (Kutz.) Lagerheim	I		
Eunotia pectinalis (Kutz.) Rabenhorst	I	A	C
Eunotia vanheruckia var. *intermedia* (Krasske ex. Hustedt) Patrick			
Frustulia rhomboides var. *saxonica* (Rabh.) de Toni	I	R	R
Neidium ladogense var. *densestriatum* (Oestrup) Foged	R		R

TABLE 40—*Continued*

	January 1969	August 1969	August 1970
Navicula minima Grunow.	R	C	
Gomphonema lanceolatum Ehrenberg		C	
Nitzschia palea (Kutz.) W. Smith	I	C	
Surirella biseriata var. *constricta* Grunow.	R		
Asterionella formasa var. *gracillima* (Hantz.) Grunow.	R		
Pyrrophyta			
Peridinium limbatum (Stokes) Lemmermann	R		
Peridinium westii Lemmermann		R	I
Cyanophyta			
Anacystis marina Crouet & Daily		A	
Oscillatoria tenuis Ag.		A	
Phormidium angustissimum West & West	I		
Phormidium tenue (Menegh.) Gomont	I	VA	
Phormidium tenue (Meneg.) Gomont	R	R	
Anabaena Oscillarioides Boay		R	I
Hapalosiphon fontinalis (Ag.) Bornet.			R
Calothrix epiphytica West & West		R	

TABLE 40—*Continued*

	January 1969	August 1969	August 1970
Euglenophyta			
Euglena sp.	VA		
Total Number of Species	40	27	15

Note: Frequencies given here represent the maximum population occurring on glass slides placed in the limnetic zone of Lake Mize. This maximum frequency may have occurred on slides at any of the following levels: 6 inches, 18 inches, 30 inches, or 42 inches. Depending upon the species, cells, filaments, or colonies may have been counted.

Very Abundant (VA) represents a frequency of over 5,000 per square centimeter.

Abundant (A) represents a frequency of 2,000 to 5,000 per square centimeter.

Common (C) represents a frequency of 500 to 2,000 per square centimeter.

Infrequent (I) represents a frequency of 100 to 500 per square centimeter.

Rare (R) represents a frequency of 10 to 100 per square centimeter.

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BIOGRAPHICAL SKETCH

Helen Davis Brown was born in Charlotte, North Carolina, on March 23, 1934. She graduated from North Mecklenberg High School in 1952. Her undergraduate eduation was obtained at Mars Hill Junior College (A.A., 1954) and Appalachian State Teachers College (B.S., 1956). The M.A. degree was also awarded her in 1959 by Appalachian State Teachers College after study during successive summers from 1957 to 1959. During the 1966-1967 academic year, graduate study in botany was begun at the University of Minnesota. A doctoral program in botany with a specialization in phycology was then initiated at the University of Florida in 1967, continuing through 1972.

As a teacher in secondary schools prior to the majority of her graduate work, Helen Davis Brown held the following positions: Arlington Junior High, Gastonia, North Carolina (1956-1962); Woodbridge Junior High, RAF Woodbridge, England (1962-1964); and DeLaura Junior High, Satellite Beach, Florida (1964-1966).

While at the University of Florida, she held a graduate assistantship from the Botany Department during the years 1967-1968 and 1971-1972 and a Graduate School

Fellowship during the 1968-1969 academic year. From 1969-1971 she also served in an interim appointment as an assistant professor of biology at Augusta College in Augusta, Georgia.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Dana G. Griffin III

Dr. Dana G. Griffin, III, Chairman
Assistant Professor of Botany

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Leland Shanor

Dr. Leland Shanor
Professor and Chairman, Botany

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Henry C. Aldrich

Dr. Henry C. Aldrich
Associate Professor of Botany

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Dr. James W. Kimbrough
Associate Professor of Botany

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Dr. Frank G. Nordlie
Associate Professor Zoology

This dissertation was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1972

Asst. Dean, College of Agriculture

Dean, Graduate School