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The Ecology of Periphyton in Western Lake Superior

Part I - Taxonomy and Distribution

by

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FOREWORD

This Bulletin is published in furtherance of the purposes of the Water Resources Research Act of 1964. The purpose of the Act is to stimulate, sponsor, provide for, and supplement present programs for the conduct of research, investigations, experiments, and the training of scientists in the field of water and resources which affect water. The Act is promoting a more adequate national program of water resources research by furnishing financial assistance to non-federal research.

The Act provides for establishment of Water Resources Research Institutes or Centers at Universities throughout the Nation. On September 1, 1964, a Water Resources Research Center was established in the Graduate School as an interdisciplinary component of the University of Minnesota. The Center has the responsibility for unifying and stimulating University water resources research through the administration of funds covered in the Act and made available by other sources; coordinating University research with water resources programs of local, State and Federal agencies and private organizations throughout the State; and assisting in training additional scientists for work in the field of water resources through research.

This report is the fourteenth in a series of publications designed to present information bearing on water resources research in Minnesota and the results of some of the research sponsored by the Center. In this investigation the research was directed towards providing a broader understanding of periphyton by providing a qualitative and quantitative evaluation of the nature and extent of naturally occurring periphyton growths in relatively unpolluted water, the western arm of Lake Superior. Since the periphyton is fixed in one place it reflects the quality of the water masses with which it is in contact. Using the results of this investigation as baseline data, it will be possible in the future to determine the qualitative and quantitative changes that occur in the periphyton as a result of eutrophication. It is hoped that, in this way, subtle changes in water quality brought about by chemical or thermal pollution can be detected.

INTRODUCTION

Lake Superior, with a surface area of 31,820 square miles, is the largest body of fresh water on earth.[1/] It lies at the head of the chain of Great Lakes which include, in addition to Lake Superior, Lake Michigan, Lake Huron, Lake Erie and Lake Ontario. Lake Superior is 350 miles long with a maximum breadth of 160 miles. It lies 602 feet above sea level and has a maximum depth of 1302 feet.

According to Jack Hough (1958), geologists have traced the origin of Lake Superior back more than a half a billion years, when the hard dense rocks which form the Precambrian Canadian shield cooled from the molten state. The original bedrock, depending upon its composition and degree of metamorphism, has changed to slates, quartzites, phyllites, gneisses, granite and other igneous rock types. These rocks were folded into mountain ranges by various earth forces. The mountain ranges were sculptured by stream erosion and weathering to form a large river valley. This sculpturing occurred over a period of about 180 million years. During the last million years, four distinct glacial ages occurred, during which continental ice sheets, using the river valley as a guide, invaded the region and scoured and molded the landscape, thus forming the present Lake Superior basin.

Lake Superior, despite its vast size and relatively dramatic formation, is in many ways ecologically similar to a one-half acre farm pond. Both bodies of water, for instance, depend upon the sun as their original energy source and, through a complex series of energy transfers, maintain their own characteristic ecosystem. To accomplish this, both require populations of algae, which Gilbert M. Smith (1933) defines as "simple plants with an autotrophic mode of nutrition". In an aquatic environment, algae may be either attached or free-floating. When algae are attached to aquatic plants or other surfaces projecting above the bottom, they constitute a part of the periphyton. Free-floating algae are known collectively as phytoplankton and along with minute organisms such as rotifers and crustaceans, called zooplankton, constitute the plankton. The latter term may be defined as the assemblage of microscopic or near-microscopic plants and animals which are non-motile or weakly motile and whose transport is, therefore, dependent upon the wind, waves, or current.

Since algae are ubiquitous in the euphotic zone of a body of water, their available habitats are almost endless, as are the descriptive terms applied to them. For example, when algae are found at the air-water interface, they are part of the neuston. In beach sand, they would be referred to as psammon. When periphyton algae break loose from their substratum and are found unattached as a part of the phytoplankton, they become tychoplankton. Wherever they occur, their primary function is the photosynthetic fixation of carbon. By this process of photosynthesis, algae produce organic matter from basic inorganic components and may, therefore, be referred to as primary producers. As such, they form the first link in the aquatic food chain.

[1/] According to surface area, Lake Superior is the largest fresh water lake on earth. Lake Baikal, in southern Siberia, is the largest according to volume (Encyclopedia Britannica). Its maximum depth is 6,364 ft. (Life Editors).

Algae, regardless of their habitat, are fed upon by consumers (heterotrophs), such as zooplankton and immature insects. These forms are fed upon by small fish which, in turn, may be eaten by larger fish. Ultimately, the larger fish may be fed upon by man. Each group of consumers has a definite position, or trophic level, in the so-called food pyramid. Ecologists have long used this concept. It was originally proposed by Charles Elton in 1927 as a simple graphic representation of the food chain or web. Producer organisms constitute the base of the Eltonian pyramid, consumers the remainder. Each successive tier, in units of biomass, numbers, or energy, becomes smaller and smaller. At the apex one finds man, or some other dominant carnivorous species. The precise organisms, of course, will depend on the ecosystem under scrutiny.

In addition to the free-floating or attached organisms mentioned above, producers and consumers may also be found in or on the bottom. The animals usually feed upon settled or settling organic debris and consist of forms such as nematodes, annelids, protozoans, molluscs, et cetera. The plants, consisting chiefly of algae, grow as a thin layer on the surface of the sediment.

For the proper functioning of an ecological community, organisms other than producers and consumers are needed. These are the decomposers, which consist primarily of bacteria and fungi. Such organisms are found in all habitats. Their function consists of breaking down organic matter, usually in the form of dead animals and plants, into their inorganic constituents so that they may be utilized once again by the autotrophs.

Thus, it can be seen that algae, in both the periphyton and the plankton, are the fundamental units of any aquatic environment. Lake Superior, with its approximately three thousand cubic miles of water, supports vast quantities of phytoplankton. However, its irregular shoreline area, which is even larger than the lake's breadth and width would suggest, is virtually completely covered by periphyton. While water from the open lake must be concentrated before the phytoplankton can be counted, periphyton scraped from a small rock must be diluted before a satisfactory count can be made. Periphyton organisms, due to their need for light, are most abundant near the shore. Here they are washed by shore currents and water movements induced by wind. In view of this constant exposure to ever-changing masses of water, this community should reflect certain characteristics of the lake, particularly the quality of the water. In the report which follows, this important component of the biota of Lake Superior will be defined qualitatively as well as quantitatively. In addition, certain ecological aspects of the periphyton and its possible role in the economy of Lake Superior will be considered.

Although periphyton has been briefly defined in the preceding description of an aquatic ecosystem, the confusion that exists in the literature over the precise meaning of this term points out the need for a more exact definition. Alena Sladeckova (1962), in her excellent monograph on the investigation of the periphyton community, discusses in some detail the terminology of this attached, aquatic association. Our use of the term "periphyton" follows the generally accepted definition proposed by Young (1945) and quoted by Sladeckova and Welch (1948).

> "By periphyton is meant that assemblage of organisms growing upon free surfaces of submerged objects in water, and covering them with a slimy coat. It is that slippery brown or green layer usually found adhering to the surfaces of water plants, wood, stones, or certain other objects immersed in water and may gradually develop from a few tiny gelatinous plants to culminate in a wooly, felted coat that may be slippery, or crusty with contained marl or sand."

The German word "aufwuchs" may be considered essentially synonymous with Young's definition of periphyton. Ruttner (1963) defines "aufwuchs" as those organisms that are firmly attached to a substrate but do not penetrate into it." As the translators (Frey and Fry) of Ruttner's text point out, the term "aufwuchs" has a broader connotation than does the term periphyton as used by some English-speaking authors. Prescott (1957), for example, defines periphyton as "organisms which form associations on the stems and leaves of aquatic plants." "Aufwuchs", as delineated by Ruttner, includes <u>all</u> the attached organisms except the macrophytes, as well as the unattached forms living free within the mat of attached organisms. Up to this point, "aufwuchs" and Young's definition of periphyton are synonymous. Ruttner's definition of "aufwuchs", however, does not contain the word aquatic. "Aufwuchs" may, therefore, exist in a terrestrial habitat with an adequate moisture content while periphyton, as defined by Young, is necessarily aquatic. With this exception, periphyton and "aufwuchs" are synonyms. Other authors prefer not to use either term and refer to this community as benthic algae (Blum, 1956 and Round, 1964), benthos (Lund and Talling, 1957), or other similar terms. However, the terms "benthos" or "benthic" usually refer to those unattached organisms living in or on the bottom sediments.

Strictly speaking, periphyton includes both plants and animals. Although the previously cited definitions use only the word "organisms", Odum (1959) defines periphyton as "organisms (both plant and animal) attached or clinging to stems or leaves of rooted plants or other surfaces projecting above the bottom." The vast majority of the periphyton community, however, is composed of plant material. This investigation, therefore, deals only with the members of the periphyton belonging to the plant kingdom. The term "epilithic", as used in this paper, refers to the fact that the periphyton studied was growing upon rocks.

In his book on the algae of the western Great Lakes area, G. W. Prescott (1962) states that "although convenient, the term algae has been applied to such a great variety of plant groups and has been given so many interpretations that it has no very precise meaning." It is not surprising, therefore, that basic algal taxonomy has long been, and remains, a subject of controversy among botanists. The details of algal taxonomy, therefore, will depend upon the authority consulted. Fuller and Tippo, in their 1949 textbook, for example, divide the algae into seven separate phyla under the subkingdom Thallophyta. Prescott (1962) solves the problem of taxonomy in a somewhat similar fashion, placing the algae in eight phyla, or divisions, as he calls them. Robbins, Weier, and Stocking (1967) suggest six phyla, with the blue-green algae included in the phylum Schizophyta along with the bacteria, class Schizomycetes. G. M. Smith (1933), on the other hand, divided the algae into nine classes under the phylum Thallophta. In 1950, he reorganized his algal groupings and raised most of the classes to division (phylum) status. This resulted in seven divisions. For reasons of simplicity, we have adopted in this report the conservative taxonomic system proposed by Fuller and Tippo (1949), whose seven phyla are, for practical purposes, identical to those of Smith (1950). The phyla and their distinguishing characteristics are as follows:

1. Cyanophyta or blue-green algae: The organisms in this phylum are alone among the algae in possessing no definitely organized nuclei. Their pigments, which are not localized in plastids or chromatophores,

consist of chlorophyll (green), phycocyanin (blue), and phycoerythrin (red). Their reproduction is asexual and they store their reserve food as glycogen. The plant body is single-celled, although often several cells may be held together in a gelatinous sheath or matrix to form a colony. Oscillatoria, Anabaena, and Merismopedia are examples of blue-green algae.

2. Euglenophyta: Members of this phylum have plastids containing chlorophyll and carotenoids. All genera except one reproduce asexually. Reserve food is stored as paramylum and fats. Almost all euglenoids are unicellular flagellates with one, two, and sometimes three flagellae. Many forms encyst. Examples are Euglena, Phacus, and Trachelomonas.
3. Chlorophyta or green algae: Algae belonging to this phylum have their pigments, chlorophyll and carotenoids, localized in plastids called chloroplasts. Reproduction may be either sexual or asexual. Food is stored as starch, whose formation is associated with organelles called pyrenoids. The cell walls are composed of cellulose. Most forms occur in fresh water. The plant body may be either unicellular, colonial or multicellular. Examples are Ulothrix, Scenedesmus and Pediastrum.
4. Chrysophyta: This phylum includes the yellow-green algae, the golden-brown algae, and the diatoms. They all possess plastids containing chlorophyll and yellow or brown carotenoids. Reproduction is usually asexual, but isogamous sexual reproduction may occur. Food reserves are stored as oils and as leucosin, an insoluble carbohydrate. The plant body may be unicellular, colonial, or sometimes multicellular. The cell walls of diatoms are impregnated with silica and consist of two overlapping halves. Examples of Chrysophytes are Tribonema, Synura and Achnanthes.
5. Pyrrophyta or dinoflaggelates: Organisms in this phylum, most of which are marine, usually possess yellow-green to golden-brown plastids. Some forms, however, are colorless and, therefore, saprophytic or holozoic. Reproduction is usually asexual and food reserves consist of fats or starch. Pyrrophytes are usually single-celled, having two flagellae which vary considerably from genus to genus. Examples are Peridinium and Ceratium.
6. Phaeophyta or brown algae: Plants in this phylum, with the exception of three rare species, are all marine. The pigments, localized in chromatophores, consist of chlorophyll and carotenoids. The most important golden-brown pigment is fucoxanthin. Sexual reproduction occurs in nearly all genera. The food reserves are fats and polysaccharides. The plant body is always multicellular and non-motile. The giant kelp (Macrocystis), which may be over a hundred feet long, belongs to this phylum. Ectocarpus and Laminaria are additional examples.
7. Rhodophyta or red algae: Plants in this phylum are often called sea mosses. Their pigments, consisting of chlorophyll, phycoerythrin and phycocyanin, are contained in plastids. Most red algae reproduce sexually although motile reproductive cells never occur. Food is stored as floridean starch, a carbohydrate intermediate between true starch and dextrin. The red algae may be ribbon-like, cylindrical, sheet-like, or feather-like and range in size from less that four inches to three feet in length. Examples of this primarily marine phylum are Nemalion and Dasya.

Based on observations made of Lake Superior periphyton, the majority

of the organisms belong to the phyla Chrysophyta, Chlorophyta and Cyanophyta. This is not surprising inasmuch as the Rhodophyta and the Phaeophyta are almost exclusively marine and the Pyrrophyta and Euglenophyta are ordinarily free-swimming forms.

REVIEW OF THE LITERATURE

Even though periphyton is an integral component of the aquatic environment, it has received relatively little attention in the past. G. W. Prescott (1956), in the introduction to his paper "A Guide to the Literature on the Ecology and Life Histories of the Algae", states that one of the areas in limnology in which very little work had been done was that concerned with psammon and periphyton. He indicates that although "aufwuchs" in the aquatic environment is a phase of limnology and, by nature, falls well within the field of the ecologist, the habitat of this attached community and the life history of its algal components apparently have been neglected. In his bibliography of over a thousand entries, he mentions only one (Young, 1945) which is specifically related to periphyton. Subsequently, in 1962, Alena Sladeckova in her paper "Limnological Methods for the Investigation of the Periphyton (Aufwuchs) Community" further emphasized this point by stating that work relating to the periphyton has been generally neglected. This, she pointed out, is especially noticeable when comparisons are made with the work which has been done on the plankton. Her comments relating to the bibliography of 448 references included in her paper are in general agreement with those of Prescott as relates to American publications.

In Europe, the periphyton habitat appears to have been studied a little more extensively. Even here, in comparison with the studies on plankton and benthic habitats, one discovers that very little systematic work has been carried out.

For the most part, past investigations of the periphyton community have been sporadic and relatively unrelated to each other. The reason for this is possibly the fact that this community is extremely diverse and may be strongly affected by the substratum. The reasons for studying the periphyton are almost as diverse as the community itself and the types of studies may be divided roughly into five groups.

Since ecological studies of the attached community comprise the bulk of the earlier investigations, they may be considered the first group. Best studied of the ecological factors are the relations of the periphyton to light, heat, water temperature, wind, current velocity, turbidity, chemical properties of the water, and the nature of the substratum. The bodies of water studied are likewise as varied. Abdin (1949), for example, studied the periphyton of an Egyptian reservoir while Flint (1950) related the occurrence of various species of periphyton in a British reservoir to the presence or absence of factors such as phosphate, nitrogen, silica, and sunlight. Godward (1937), likewise, related several ecological parameters to the extent of periphyton growth in Lake Windermere in Scotland. The periphyton ecology of flowing waters has been studied by Barbara Douglas (1958), who investigated a small English stream. Butcher (1932a and 1932b) and Jones (1949) have studied the ecology of several English rivers. Brook (1955) has studied the periphyton occurring in the slow sand filter beds of English water-works.

In this country, Young (1945) has investigated the periphyton of Douglas Lake, Michigan while Newcombe (1950) studied the attached algae of Sodon Lake, Michigan. In 1957, the periphyton of the Saline River, also in Michigan, was the subject of Blum's research. Gumtow (1955) studied the regrowth capabilities of the periphyton of the West Gallatin River in Montana. Williams and Mount in 1965 published a paper dealing with the influence of zinc on periphyton communities grown in the laboratory.

An excellent review of the ecology of river algae, including the periphyton, is presented by J. L. Blum (1956a). The ecological aspects of freshwater communities in static waters are discussed in some detail by Fritsch (1931).

The problems of marine and brackish water periphyton were considered by V. J. Chapman (1957). Chapman presented a comprehensive review of the work done on marine attached algal ecology and provides the reader with an extensive bibliography on the subject. The factors that affect the distribution of diatoms, usually a major component of the periphyton in both fresh and salt water, were reviewed by Ruth Patrick in 1948.

Another aspect of the ecology of periphyton, the annual succession of individual species of the attached community, has been studied by several investigators, most of whom have previously been cited as having conducted general ecological studies. Brook (1955) studied the succession, colonization and seasonal variation of periphyton growing upon glass slides placed in slow sand filters. Flint (1950) determined the seasonal variation of both the phytoplankton and the periphyton in an English reservoir while Godward (1937) determined the "periodicity" of the periphyton in Lake Windermere. In 1949, Jones, in his study of the periphyton of a river in Wales which was recovering from the effects of serious lead pollution, observed an increase in the number of species. The succession of algal species on glass slides was studied by Odum in 1957 at Silver Springs, Florida.

While the majority of the ecological reports contain taxonomic lists of the species of periphyton encountered during the course of an investigation, some researchers simply list the members of the attached community of a particular locale. Their approach is almost exclusively taxonomic. Studies of this nature comprise the second group. Butcher (1932c), for example, suspended glass slides in six English rivers for a month and subsequently was able to describe several new species of river periphyton. Fritsch (1929), while studying the encrusting species of periphyton of English streams, reported that most of the organisms were members of the phylum Cyanophyta. He discovered and described a new species. Jackson (1967) reported the genera of periphyton that occurred as regrowth on plexiglas plates suspended in the eastern end of Lake Ontario. He also determined the biomass of the accumulated growth.

Due to the tremendous photosynthetic capabilities of the periphyton, attention has been focused on its role as a primary producer. This constitutes the third type of investigation. Foerster and Schlicting (1966), for example, determined the standing crop of periphyton, which they called phyco-periphyton, growing upon several species of rooted aquatic plants in Lake Opeongo, Texas. Likewise, Odum, in 1957, studied the periphyton growing upon blades of *Sagittaria*. In 1966, Kevern *et al.* estimated the productivity of periphyton grown on plexiglas plates in a laboratory stream while Newcombe (1949) conducted a similar study using glass slides in a Michigan lake. McIntire and Phinney (1965) also used a laboratory stream to study the productivity of periphyton grown upon an artificial substratum. Instead of expressing productivity as numbers or organisms or weight of organic matter produced per unit area of substratum over a given time period, as the previously mentioned investigators did, McIntire and Phinney expressed their results as amount of oxygen produced per unit area of substratum over a certain time period. The use of a photosynthesis-respiration chamber allowed them to report their results in this manner. Cavanaugh and Tilden (1930) demonstrated the role of periphyton in productivity by showing its participation in the food web of a body of water. They

showed that the larva of the midge fly, *Tanytarsus dissimilis*, feeds entirely upon periphyton algae. Ryther, in an excellent review (1956) of the methods used for measuring primary production, presents a table showing the percentage composition of carbon, hydrogen, oxygen, nitrogen and phosphorus in organisms common to the periphyton community.

The use of the members of the periphyton as index organisms for the detection of pollution is the basis for a fourth type of study. Patrick *et al.* (1954) collected diatoms on glass slides using an instrument they call a diatometer. They sampled several rivers in the Eastern United States representing clean and polluted water. It was concluded that pollution eliminated the more sensitive diatoms while the more tolerant species proliferated and occupied a larger area of the slide. Thus, polluted water tends to have fewer species but more individuals of the pollution tolerant species. If pollution is extremely severe, the diatom community may be unable to exist at all. Neel, in 1953, studied the periphyton of the polluted North Platte River in Nebraska and Wyoming. In addition to diatoms, he found several species of Cyanophyta. In a report (1947) of his study of polluted English rivers, Butcher described the nature of the changes which occurred in periphyton communities as natural purification processes. Williams and Mount (1965), in a laboratory study of the effect of zinc on periphyton, found no species that could be considered a good indicator of zinc pollution.

Although periphyton is an integral component of the food chain of a body of water, its growth in or on various man-made structures is often of more obvious economic importance. Studies of periphyton growing upon man-made structures, therefore, constitute the subject of the fifth broad category of investigations. The majority of the studies have dealt with the undesirable aspects of growths of periphyton. Problems of this nature mentioned by Sladeckova (1962) include studies of periphyton growing upon walls of tanks and reservoirs, pipes of various materials, submerged constructions and ship bottoms, fish nets, cooling towers, irrigation tunnels and condensers. However, desirable growths of periphyton may occur in slow sand filters, clarifiers and trickling filters. These have been the subject of several studies.

Due to the inherent difficulties associated with the quantitative study of periphyton, the majority of previous investigators have used qualitative methods which usually consist of removing periphyton from the substratum with a simple scraping instrument and examining the contributing taxonomic groups under a microscope.

Quantitative results may be obtained by subjecting periphyton collected from a natural or an artificial substratum to either numerical or mass determinative methods.

Numerical methods consist of counting and identifying the individual members of the periphyton under a microscope. In addition, the numbers of organisms must be related to a specific surface area for the results to be truly quantitative. These methods are, by their very nature, laborious and time-consuming and, therefore, probably the least popular. They do, however, provide an accurate picture of the periphyton. In addition to determining the actual number of individuals of each species, the examiner is able to observe the size and physiological state of the organisms as well as components existing in their physical environment, such as sand grains, detritus, *et cetera*. The exact methodology used in numerical methods differs, depending upon the substratum on which the periphyton occurs.

When the substratum is opaque, as are most natural and some artifical materials, the periphyton must be removed in order to examine it microscopically. Young (1945) quantitatively sampled opaque natural surfaces (bulrush stems and stones) by firmly pressing a sharp edged, square, hollow instrument of known area against the objects on which the growth occurred. The surfaces outside the square were then scraped free of periphyton, leaving only the known area covered with growth and ready to be transferred to a collecting bottle. Douglas (1958), using a modification of the same procedure, scraped the periphyton directly from the area delimited by her sampling apparatus, in this case a bottomless polyethylene bottle. Another modification has been used by Gumtow (1955), who removed the periphyton from the center of a brass ring enclosing an area of one square centimeter. A rather unique method of removing periphyton from stones was proposed by Margalef in 1948. His method consisted of coating a rock covered by periphyton with dissolved collodion, after first preserving the rock in formalin and staining it. After the collodion had dried, it was peeled off, mounted in balsam, and examined microscopically. According to Margalef, a faithful image of the stone surface, including all of the epilithic vegetation, was obtained by using this procedure.

When the natural substratum is transparent, the periphyton need not be removed and may be viewed directly under a stereoscopic microscope. This procedure, however, allows for the examination of only the larger organisms. If small organisms are to be examined, the substratum must be scraped and the periphyton transferred to a counting chamber. Sladeckova (1962) mentions a study in which periphyton growing upon the thin transparent leaves of Elodea canadensis was viewed microscopically while still attached. Since most naturally occurring substrata are opaque, however, man-made substances are often employed. The predominant artifical substratum has been glass, usually in the form of standard microscope slides. The slides may be suspended in any desired position in one of several types of wooden, metal or plastic frames at a pre-determined depth or may be affixed to the bottom. Many of the frames which have been used are modifications of the original glass slide rack designed by Bissonette in 1930. He used the slides to collect bryozoans. Another advantage of the glass slide method is the fact that they may be viewed directly under a compound microscope. Gause (1937) reports that the first attempt to grow periphyton upon glass slides submerged in natural waters was made by Hentschel in 1916 in Hamburg, Germany. Gause himself was an advocate of the glass slide method and used it in studying the aquatic biological associations of a lake near Moscow. Many variations of the original method have appeared in the literature since Hentschel's time. Reynolds (1950) used submerged glass slides as a collecting device for obtaining algae to culture on agar. Butcher (1932c) used the glass slide method in his search for new species of periphyton. Odum (1957), Miller (1936), Aleem (1957), Whitford (1956), Castenholz (1960), Williams and Mount (1965), and Yount (1956) are examples of other investigators who have used glass slides to study some aspect of the attached community. Ruth Patrick and her colleagues (1954) have utilized the glass slide principle in their diatometer, an instrument buoyed by styrofoam which will float glass slides at any desired depth. The diatoms colonizing the glass may then be used as indicators of water quality.

Transparent organic plastics have also been used and offer the same advantages and disadvantages as does glass. Grzenda and Brehmer (1960) studied stream periphyton by suspending plexiglas plates as a substratum. Similar procedures were used by King and Ball (1966) in their investigation of the periphyton of the Red Cedar River in Michigan. Whitford (1956) used plastic slides for the collection of Florida spring periphyton. In his study of Lake Ontario periphyton, Jackson (1967) also used plexiglas

as a regrowth substratum.

When the artifical substratum is an opaque substance, such as clay, cement, concrete, sheet metal or asbestos, one of the previously mentioned methods for opaque natural substrata must be used. Fuller (1946), for example, used asbestos shingles in studying ship fouling by marine periphyton. Aleem (1957), in addition to using glass to study the same ship fouling organisms, used plexiglas, vinyl acetate, wood, iron, zinc, steel, brass and copper.

When information concerning the effect of the periphyton on a particular substance is desired, the use of any type of artificial substratum is, of course, justified. When one wishes to collect periphyton representative of that occurring naturally, however, care should be exercised in the selection of an artificial substratum if, indeed, one must be used at all. The possibility always exists that some or all of the artificial substrata mentioned may contain chemical components toxic to some organisms. It is stated, for instance, that "for some organisms, mostly blue-green algae, glass is not a very acceptable substratum" (Sladeckova, 1962).

The color and surface texture of the substratum may also affect the growth of periphyton. In a re-evaluation made by Hohn and Hellerman in 1963 of the diatometer, originally devised by Patrick, Hohn and Wallace in 1954, it was found that the diatom populations growing upon the glass slides of the diatometer differed from the populations growing upon the styrofoam buoy of the same diatometer. They observed that when the temperature of the water was below 16° C. glass does not support a representative growth of diatoms while styrofoam supports representative growth over a wide range of temperatures. At 3°C., there were 28 to 39.8 percent fewer species on the glass than were found on the styrofoam.

In addition to man-made artificial substrata, natural materials may be employed. Blum (1957), for example, used sterilized smooth stones obtained from a nearby moraine to study colonization by stream periphyton. His study, however, was qualitative. In a study of a Montana river, Gumtow (1955) treated cobblestones with full strength formalin before placing them in the river as a means of determining the periphyton regrowth capabilities. His brass ring sampling method has been described.

Once the periphyton sample has been collected and returned to the laboratory, the contributing species must be identified and the individuals counted. This is usually accomplished by filling a Sedgwick-Rafter counting chamber with one milliliter of the periphyton suspension and counting and identifying the organisms in a predetermined number of random microscope fields or in a number of "strips" across the chamber. Various magnifications may be used. The exact methodology is dependent upon the accuracy desired, the skill of the examiner, and the equipment available.

When the periphyton occurs on an opaque substratum or when the growth on a transparent substratum is too thick to examine microscopically, mass quantitative methods are often used. These methods are less time-consuming and usually less difficult to perform than is the numerical method. They are most useful when correlated with numerical results. In mass methods, some attribute of a large quantity of periphyton is measured. One of the most common mass determinations is that of weight, either wet, dry, or dry weight on an ash-free basis. Castenholz (1960), for example, determined the dry and ash-free dry weights of periphyton growing upon glass plates which he suspended in several lakes in the state of Washington. He used the ash-free dry weights to express productivity.

Another mass method involves the determination of the rate of photosynthesis-respiration using a Gilson differential respirometer. McIntire (1966) used this instrument in studying factors which affected periphyton respiration in a laboratory stream. He also determined the weight of the periphyton used and was thus able to express his results as the rate of respiration on an ash-free dry weight basis.

The spectrophotometric analysis of the periphyton pigments is yet another mass quantitative method. The original method, as proposed by Richards and Thompson (1952), was devised to study the pigments of phytoplankton. Several investigators have attested to the usefulness of this procedure for the estimation of primary production in the periphyton community. Waters (1961) determined the pigment content of periphyton growint upon concrete cylinders in Valley Creek, Minnesota and Duffer and Dorris (1966) conducted a similar study in the Blue River in Oklahoma. McConnell and Sigler (1959) measured the chlorophyll content of the "lithophilic algae"[2] of the Logan River in Utah. The pigments of the epipelic[3] community were analyzed by Eaton and Moss (1966), while Grzenda and Brehmer (1960) studied the periphyton pigments of a Michigan stream. A less sophisticated, as well as less expensive, method of pigment analysis may be performed by using a Klett-Summerson colorimeter. This instrument, however, cannot separately quantitate the carotenoids or the various chlorophylls.

Other mass methods include the determination of the volume of the periphyton by settling in a chamber, such as a graduated cylinder or an Imhoff cone, and the determination of the rate of photosynthesis-respiration by the light and dark bottle method. The latter method was also originally designed to be used with phytoplankton.

From the foregoing review of the literature on periphyton, several points are apparent. Most of the relatively few studies made on the periphyton of bodies of water in the United States have been qualitative in nature. Quantitative methodology, when used, has varied greatly from study to study. Artificial substrata of various compositions have been employed. Deep water sampling has rarely been attempted and the majority of the data on periphyton, therefore, pertains to bodies of shallow, flowing water. In addition, no adequate studies of the periphyton of Lake Superior were encountered in the literature.

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[2] This term is identical to epilithic periphyton.

[3] This term refers to the thin-layered community on the surface of bottom sediments.

PURPOSE OF THE STUDY

The overall objective of this study is to fill some of the gaps in periphyton research by providing a qualitative and quantitative evaluation of the nature and extent of naturally occurring periphyton growths in a relatively unpolluted and very large body of fresh water, the western arm of Lake Superior. To accomplish this objective, it was necessary to devise a method whereby the naturally occurring periphyton, in depths of up to 35 feet, could be collected, identified, counted and quantitatively related to the surface on which it originated.

Although the future role of Lake Superior in the overall water economy of this continent is presently a matter of conjecture, it will no doubt be one of far-reaching importance. This study will provide valuable baseline data which can be used as a reference in future years to measure any tendency toward eutrophication. Specifically, the study is directed toward the determination of the extent of the natural periphyton growth upon rocks in selected areas of Lake Superior as measured qualitatively and quantitatively by numerical and mass methods, the speed and phases of growth demonstrated by periphyton in re-establishing itself on an artifically denuded natural substratum, the effects of various ecological factors upon the periphyton, and the productivity potential of the periphyton in relation to the typical productivity of water in the open lake.

MATERIALS AND METHODS

The area from which the majority of samples were obtained was a small bay at the western end of Lake Superior which is known locally as Stony Point Bay. It is situated approximately fifteen miles northeast of the Duluth, Minnesota city limits and from our center of operations, the University of Minnesota Limnological Research Laboratory at Lester River. Lying two miles south of Knife River Harbor, where our thirty-foot motorized research vessel, the Oneota, is moored, the study area is bounded by the Little Sucker River on the southwest and Rocky Point on the northeast.

The investigations began during the summer of 1965 (July 19 - September 1) with a general survey of the study area. Conventional surveying techniques were employed, utilizing a baseline, stadia readings and a professional transit. For the purpose of establishing the contour of the shoreline of the bay, a base station was selected in the approximate center of the arc formed by the water's edge. This base station was located directly below a tourist observation point on a hill above the bay. A line, which extended from this station to a point on the shoreline 427 ft. away at an angle of 84°30' east of south, was then established. The transit was used to determine the angle of this baseline while a stadia rod was employed to ascertain the distance. Points along the shoreline from the Little Sucker River to Rocky Point were then marked with fluorescent paint. The exact position of each of these marked points with relation to the baseline was determined by triangulation and plotted on the master map, thus providing an accurate delineation of the water margin.

The second phase of the survey was the determination of the depth profile of the bay. The Oneota was used to place an initial reference buoy at a point 2336 feet from shore and in a southerly direction from the established base station. With the stadia rod aboard the boat and the transit ashore, it was possible, by knowing the distance of the vessel from shore and its angle from the base station, to determine the exact position of the Oneota at each sounding. Depth readings were made with an electric fathometer. At the depths encountered, the instrument was accurate to within six inches. Depth readings were relayed to shore by hand signals so that each depth determination could be related to the position of the boat as it traversed the bay.

When depth permitted, the type of bottom was determined by water glass observations. When the water was too deep for this procedure, SCUBA[4] diving procedures were employed to ascertain the bottom type.

The SCUBA equipment consisted of the following articles: single hose, two-stage, demand type regulators with air reserve mechanisms; 71.2 cubic foot capacity compressed air tanks with back packs and tank boots; 3/8 inch neoprene nylon-lined wet suits with gloves, boots and hoods; weight belts and lead weights; pitot-tube type depth gauges; fins; masks; and snorkel tubes.

A small dinghy was used to survey shallow areas less than ten feet in depth. The Oneota could not be used here due to the presence of occasional protruding boulders. The position of the dinghy at each depth reading was determined by the triangulation method used to locate the larger boat. Depth readings from the dinghy were made with a marked

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[4] Self Contained Underwater Breathing Apparatus

sounding pole. A water glass or simple visual observation was used to determine the type of bottom. The depths established by these procedures were then plotted on the master map. Points of the same depth were connected, thus providing a depth contour. Intermediate depths were established by interpolation. These contours are included in the map of the bay which also indicates the type of bottom. The bottom area not designated by the word sand was covered with rocks. It should be pointed out that small sand patches were encountered in predominantly rocky areas while the sand patch contained small areas of rock bottom.

In sampling, an imaginary line extending from the reference buoy 2336 feet from shore to the base station was used for orientation. Whenever possible, samples were collected along this line. The same line was used for the placement of the rocks used in the regrowth studies.

The study began during the summer of 1965 with an evaluation of the regrowth capabilities and the taxonomy of the periphyton. This was a qualitative study. The substrata chosen for the regrowth study were rocks already present and supporting periphyton growth in Stony Point Bay. By choosing these rocks, we hoped to minimize any deviations from the naturally occurring periphyton populations that might occur if rocks foreign to the area were used as substrata. Artificial substrata were not used for the same reason. In addition, unpublished preliminary studies made by Olson and Odlaug in which glass slides, tile, fish net, wood, and other materials were used, showed that the type of substratum material affected periphyton growth. As mentioned in the introduction, such deviations from naturally occurring populations might be produced by a variety of chemical or physical factors. For the regrowth studies, therefore, medium-sized rocks (eight to twelve inches in diameter) were taken from shallow water in the bay and returned to the laboratory in plastic buckets. There the rocks were thoroughly scrubbed with a stiff-bristled plastic fingernail brush and rinsed with tap water. A three-eighths inch hole approximately three-fourths inch deep was drilled into one side of each rock. A two inch long piece of three-eighths inch wooden dowel was driven into the hole. The rocks, with attached pegs, were then autoclaved at fifteen pounds per square inch (250°F.) for twenty minutes and after sterilization, were replaced in the lake. The rocks were lowered to the bottom by ropes attached to the pegs at designated stations and depths. Styrofoam buoys attached to the ropes marked the locations of the rocks. In water depths greater than ten feet, SCUBA diving techniques were employed to determine the nature of the bottom and to make sure that the experimental rocks were in a suitable position for regrowth to occur.

After an "incubation" period which ranged from three to twenty-seven days, the rocks were retrieved by slowly pulling them back up by the buoy ropes. This simplified technique was permissible because this was a preliminary qualitative study. At the surface, the rocks were carefully placed in individual plastic buckets which were then transported to the laboratory. There the rocks were scrubbed clean with a brush and rinsed with distilled water to remove the surface growth. A small funnel was then inverted in the periphyton-water suspension and rapidly moved in a vertical direction. During this thorough mixing, two fifty milliliter samples were removed by dipping. One of these samples was placed in a seventy-five milliliter amber bottle and preserved by bringing the aliquot to a five per cent formalin concentration. This aliquot was retained as a reference sample. The other remained unpreserved and was subjected to a prompt microscopic examination.

The microscopic examination was carried out at magnifications of 430 and 970 diameters. Drops of the sample were placed on a standard microscope slide and a standard square cover slip was used. Organisms were identified to genus and, when possible, to species. Each slide was examined until no "new" organisms were observed.

In addition to this microscopic examination of the regrowth periphyton, determinations were made of the dry weight of naturally occurring populations of periphyton. For this purpose, three rocks (four to six inches in diameter) were obtained at each of three depths. Waders were used to retrieve samples from the two foot depths near shore while rocks from depths of ten and twenty feet were obtained by SCUBA diving techniques. At these deeper depths, as determined by the fathometer aboard the <u>Oneota</u>, divers, each with his right hand and forearm in an inside-out clear plastic bag, reached out and grasped a sample rock with his right hand. With the left hand, he then pulled the bag down over his forearm and hand, entrapping the sample rock, as well as a small quantity of the surrounding water. The same plastic bag procedure was used at the two-foot depth. Each bag was knotted, brought to the surface and placed in a labelled plastic bucket with two other rocks from the same depth. The samples were returned to the laboratory within three hours.

At the laboratory, rocks were removed by slitting each bag open with a scalpel. Periphyton clinging to the bag was removed by rinsing with distilled water. The area on which growth occurred was marked by scraping an outline on each rock with a dull scalpel. Next, the periphyton was completely removed by scrubbing and rinsing with distilled water. The final sample from each depth consisted of the combined periphyton and rinse water from all three rocks. After each suspension of periphyton had been thoroughly agitated, using the funnel method described earlier, aliquots were removed, measured and filtered through Whatman filter paper. In order to insure a reasonable filtration time, the aliquot size was determined on the basis of the turbidity of each sample. In general, the sample sizes ranged from six to fifty milliliters. The filter papers were dried for one hour in an oven at 103° C., cooled in a desiccator and weighed.

In order to determine the extent of the surface upon which growth had occurred, the previously outlined area of each rock was lubricated with a thin layer of automobile grease and coated with paraffin. The paraffin was heated and applied with a paint brush until the rock was covered with a one-eighth to one-fourth inch coat. The wax was removed after it had solidified, but before it had become brittle, by cutting slits in the coating covering the vertical surfaces of the rock. The flaps created by these slits were then freed from the rock with a scalpel and the portion of the paraffin coat still attached to the horizontal surface was peeled off. By using this method, the coating could be removed as one intact piece. The paraffin was then gently pressed flat on a piece of white paper and its outline traced. A previously calibrated polar planimeter was used to determine the area enclosed by the tracing. Areas of the three rocks from each depth were combined.

During the summer of 1966 (August 9 - September 6), rocks were retrieved from depths of 2.5, 5, 10, 15, 20 and 35 feet. The depths of the deep water stations (ten feet and greater) were determined by the fathometer aboard the <u>Oneota</u>. Buoys were placed at these stations as permanent markers. The <u>Oneota</u> was used to transport divers and equipment to Stony Point Bay from Knife River Harbor and upon arrival at the bay, the vessel was anchored near the thirty-five foot buoy. Divers retrieved sample rocks using the plastic bag procedure earlier described. Again, three rocks were obtained from each depth. Laboratory procedures used for preparing the periphyton-water suspension followed those devised the previous summer.

A twenty-five milliliter aliquot to be used for counting, was removed and transferred to a seventy-five milliliter amber bottle. Twenty-five milliliters of ten percent formalin were then added. The mixture was thus preserved in five percent formalin and diluted twofold. A graduated dropper was used to transfer one milliliter of the sample into a Sedgwick-Rafter counting cell. After allowing ten minutes for settling, a binocular compound microscope was used to count ten random fields under a magnification of 200 diameters. The organisms were identified to genus. A Whipple disc, previously calibrated with a stage micrometer, was used to convert the ten random field counts into a count per milliliter. By knowing the total volume of the periphyton-water suspension, the dilution factor due to preservation and the rock area, it was possible to determine the number of organisms per square centimeter of rock surface. When the preserved sample was too turbid for accurate counting, an additional twofold dilution with distilled water was made.

For the determination of dry weights, a four milliliter sample was removed from the periphyton-water suspension, filtered through a pre-weighed Millipore membrane filter, dried for one hour in an oven at 103° C. and weighed. Results are expressed in milligrams per square centimeter of rock surface.

During the summer of 1967 (June 9 - September 15), the analysis of the naturally occurring periphyton in Stony Point Bay continued. A sampling run consisted of collecting three rocks from depths of 2.5, 5, 10, 15, 20 and 35 feet. At the time of each sampling run, light readings and water temperatures were taken. Light readings were made with a GM submersible photometer, which consists of two separate photometers, a deck and a sea cell. At the 35-foot station, readings were made at each meter from the water surface to the bottom. A standardized laboratory thermometer was used to determine the water temperature at the surface and at the bottom. A diver read the thermometer directly above the bottom at each sampling depth.

In addition to the studies of the naturally occurring periphyton of Stony Point Bay, denuded, autoclaved rocks were placed into the bay and retrieved at predetermined time intervals in order to quantitatively study the regrowth capabilities of the periphyton. Following the methods used during the summer of 1965, rocks to be denuded and autoclaved were obtained by the use of waders from shallow, near-shore areas of Stony Point Bay. As described earlier, these rocks were returned to the laboratory where they were thoroughly scrubbed with brushes and autoclaved. Since this study was to be quantitative, the methods of necessity differed somewhat from those used the first summer. Instead of inserting pegs into the rocks and raising and lowering them in the lake by buoy lines, these rocks, after being lowered in a wire basket, were carefully placed in a circular configuration directly on the bottom. SCUBA divers placed the rocks at 10, 20 and 35 feet. A buoy marked each location. After the proper time interval had elapsed, three of the rocks were picked up by divers. The plastic bag technique was employed.

During the summer of 1967, samples of naturally occurring periphyton were collected from areas other than Stony Point Bay. A 107 mile segment of the north shore of the western arm of Lake Superior was sampled at intervals of approximately ten miles. Beginning with the Lester River as the southernmost point, samples were collected as far north as Grand Marais, Minnesota. A fourteen-foot aluminum skiff with a five horsepower outboard motor was towed by car to each sampling location. Again, SCUBA diving procedures were used to collect three rocks from each depth sampled. The actual field techniques were the same as those used during the summer of 1966. Depths, however, were determined with a pitot-tube type depth gauge carried by the individual diver. These depth gauges had been calibrated against the electric fathometer aboard the Oneota. Temperatures were taken at the bottom and at the surface. Whenever possible, rocks were collected from each of the six standard sampling depths (2.5, 5, 10, 15, 20 and 35 feet) at each station. Each station was sampled on two different days. Collections were made at the locations shown below:

Periphyton Sampling Locations, North Shore, Lake Superior
(Mileages indicated are distances from Lester River)

1.	Lester River	0 miles
2.	Knife River	13.8 miles
3.	Burlington Bay	22.1 miles
4.	Split Rock River Bay	39.4 miles
5.	Beaver Bay	48.0 miles
6.	No-Name Bay (near Little Marais)	53.9 miles
7.	Sugar Loaf Cove	69.9 miles
8.	Tofte	78.8 miles
9.	Lutsen	86.3 miles
10.	Good Harbor Bay	100.9 miles
11.	Grand Marais	106.9 miles

Detailed sketch maps of each sampling area give the depth and approximate location of each sampling point. These maps were constructed by essentially the same procedures employed to establish the original shoreline contour in Stony Point Bay. A baseline was selected to include prominent landmarks which could be readily viewed by a transit. The angle that this baseline formed with a north-south line was established with the transit. Stadia readings were used to determine the length of the line. Each selected landmark on the shore was then viewed with the transit from the two ends of the baseline and the angles recorded. The baseline was drawn to a suitable scale and points on the shoreline were plotted by triangulation. All of the sampling areas except the Lester River, Tofte and Grand Marais were mapped in this manner.

The Grand Marais map was traced from a U.S. Corps of Engineers' chart (Number 97). At both Lester River and Tofte, mapping was accomplished by establishing one base station (accurately related to prominent landmarks) from which transit sightings were made to selected points along the water's edge. The angles, as well as the distances established by stadia readings, were then plotted on graph paper and the resultant points connected, thus providing the shoreline contours. This procedure was used at Lester River and Tofte because of the roughness of the terrain, which made it difficult to set up a baseline of sufficient length.

In the laboratory, all the rocks collected during 1967 were prepared for examination by our standard procedures.

An aliquot consisting of 152 milliliters was removed for counting and identification. The sample was brought to a concentration of five percent formalin by adding eight milliliters of pure formalin. The counting procedure remained the same. Organisms were identified to genus and, when possible under a magnification of 200 diameters, to species. When samples were too turbid for examination, appropriate dilutions were made with distilled water.

After the counts were made, several drops of each sample were placed on a glass microscope slide which was then placed in a muffle furnace at 300° C. for ten minutes. After cooling, the ashed sample was covered with a glass cover slip, using Hyrax as the mounting medium. The ashing process incinerated all the material except the siliceous diatom frustules which were then examined microscopically under magnifications of 430 and 970 diameters. By using this procedure, many of the diatoms could be identified to species. These permanent diatom slides, from each depth and from each station, are now on file, as are the duplicate aliquots which were preserved with formalin.

For the determination of dry weights, twenty-five milliliter portions of the suspension were filtered through pre-weighed four-centimeter filter paper. Each filter was then placed in a weighed porcelain crucible, dried for one hour in an oven at 103°C., cooled and reweighed. The samples were then ashed in a muffle furnace for fifteen minutes at 600° C. After cooling, they were again weighed in order to calculate ash-free (or organic) dry weights. Results are expressed as milligrams of total and ash-free weight per square centimeter of rock surface.

The remaining determinations, which included the pigment and the photosynthesis-respiration analyses, were made using the procedures of 1966.

RESULTS AND DISCUSSION

For the sake of simplicity, the findings are reported here in chronological order. For this reason, the results reflect certain changes made as a result of experience. To avoid repetition in a later portion of the report, the discussion and the results have been combined. In this section, therefore, one will find a summation of the data obtained for the four years of the study, 1965, 1966, 1967, and 1968.

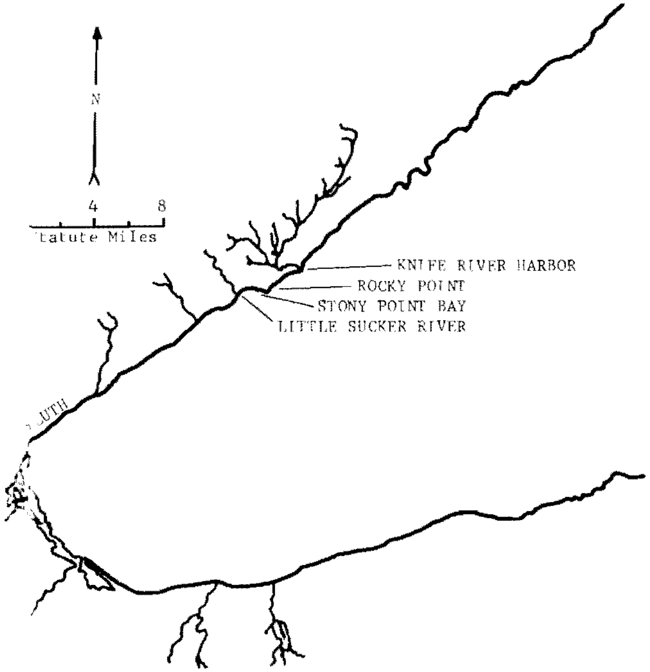
Stony Point Bay was the primary sampling area. Its location and a detailed presentation of the sampling area are shown in Figures 1 and 2. As may be seen from Figure 2, the study area is triangular, bounded by Rocky Point on the northeast, the Little Sucker River on the southwest, and a reference buoy in the lake 2,236 feet from shore. The total area enclosed by these three points is approximately 321,000 square meters. The straight line distance from Rocky Point to the Little Sucker River is about one half mile.

Initial observations made of the bay showed that the surrounding land area was very sparsely populated. The only spectators noticed during the course of our operations were an occasional tourist or commercial fisherman. Permanent cribs for holding fish were noted in the bay. One fisherman complained of the slimy growth which often fouled his nets and pointed out periphyton on some nearby rocks as the cause. Earlier unpublished studies made by one of the authors (Olson, 1960) support the hypothesis of the fisherman. In microscopic examinations of the growths on fish nets from other areas of Lake Superior, Olson found diatoms attached by gelatinous stalks. The organisms were primarily members of the genus *Cymbella*.

The water of Stony Point Bay appeared either blue, green, gray, tan, or intermediate shades, depending on the cloud cover, the nature of the bottom, and the turbidity produced by living or non-living suspended materials. Secchi disc readings likewise varied, with the maximum being about eight meters. The bottom type could usually be determined visually in depths of up to twenty feet. Maximum visibility in the bay, as reported by SCUBA divers, was about thirty feet. In general, water temperatures in the early summer were about 6°C. just under the surface and 4.5°C. at thirty-five feet.

In preparing a report on the nutrients of the western arm of Lake Superior, Putnam and Olson (1960) obtained their data from a large number of samples collected from the Larsmont-Knife River area, which is approximately two miles from Stony Point Bay. The mean values that they obtained for several chemical parameters (from July 15 - September 10, 1959) are as follows:

	Epilimnion	Hypolimnion
Silica (ppm)	2.04	2.13
Carbon dioxide (ppm)	1.28	2.33
Nitrate (ppm)	0.36	0.42
Organic nitrogen (ppm)	0.14	0.13
pH	7.9	7.7
Phosphorus, total (Microgram atoms per liter)	0.33	0.44
Oxygen saturation (%)	105	97
Alkalinity (ppm)	38.5	



gure 1. Western Arm of Lake Superior, Showing the Position of Stony Point Bay, Site of Periphyton Studies.

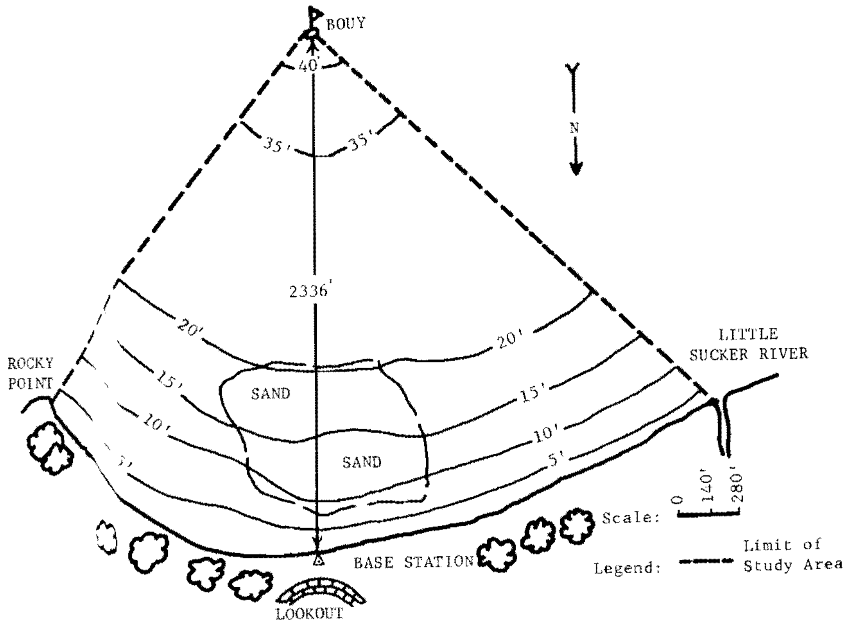


Figure 2. Detailed Map of Stony Point Bay, Lake Superior.

Routine analyses performed during the summers of 1964 to 1968 by School of Public Health students show that these values have remained essentially the same. In fact, when even slight variations from these values are obtained, the reason for them can usually be traced back to faulty laboratory technique.

In 1960, the predominant genera of phytoplankton taken in the Larsmont-Knife River area were Asterionella, Cyclotella, Fragilaria, Melosira, Synedra, Tabellaria, Dinobryon, and Ankistrodesmus (Putnam and Olson, 1961). Counts made in 1968 showed that the same organisms were predominant and that in August, Dinobryon sertularia was the most common organism in the phytoplankton.

Periphyton was apparent on the rocks through the clear bay water, appearing as a thick, tan, wooly growth containing entrapped gas bubbles. Any agitation would release the bubbles (assumed to be oxygen) and they would rise to the surface. It was observed that wave action occurring as a result of a storm would dislodge the periphyton from the rocks in the shallow areas of the bay. The resulting suspension imparted a distinct tan color to the water and sometimes reduced visibility to zero. Sculpins (genus Cottus), ranging in size from one to four inches, were the only fish observed. Occasionally, Mysis relicta, a species of minute crustacean (about seven millimeters in length) was seen swimming in groups of ten to twenty individuals near the bottom. On one occasion, several clumps of an attached, filamentous, macroscopic green alga, Nitella, were observed.

In general, the bay floor was uniformly covered with a tan mat of periphyton, on both the sand and the rocks. The rocks on which the growth occurred ranged in size from less than an inch in diameter to boulders projecting as much as six feet above the bottom. Animal forms sometimes seen in this periphyton were leeches, snails, nematodes, caddisfly larvae, and mayfly nymphs.

When the rocks were scrubbed clean in the laboratory, it was noted that they differed markedly in appearance. An analysis of one hundred representative rocks indicated that there were about twenty-two lithic types in Stony Point Bay (see Table I). The majority (fifty-six per cent) of the rocks were basalt, with twenty-four per cent of these possibly being wither andesite (sixteen per cent) or diabase (eight per cent). The next most common rock type was diabase, with fourteen positive identifications. Seven per cent of the rocks were porphyritic trachyandesite to mafic quartz latite.

The 1965 regrowth study, in which denuded, autoclaved rocks were replaced in the lake, provided the first qualitative periphyton data. Nineteen different rocks were recovered from depths of from two to nineteen feet. "Incubation" times ranged from three to twenty-seven days. The results of this study are shown in Table II. In the main, the taxonomic keys of Tiffany and Britton (1952) were used for identifying the organisms. In special instances, the texts of Prescott (1962), Smith (1950), and Hustedt (1930) were consulted. Thirty-four different genera from three phyla of algae are listed in Table II. Although not shown in the table, some genera are represented by more than one species. Of the thirty-four genera, twenty-five, or seventy-four per cent, are members of the phylum Chrysophyta and twenty-four of these are diatoms (class Bacillariophyceae). The one remaining genus, Dinobryon, belongs to the class Chrysophyceae. Next in order of abundance is the phylum Chlorophyta. Seven genera of these green algae were found. The blue-green algae (Cyanophyta) were represented by only two genera.

TABLE I

ROCK IDENTIFICATIONS, STONY POINT BAY, LAKE SUPERIOR.

Number of Samples	Lithic Description
2	medium to coarse grained granite
1	porphyritic andesite
1	massive graywacke
1	laminated hornfels, pelitic
2	fine grained, porphyritic, red granophyre
10	aphanitic to fine grained basalt, aphyric
2	very fine grained basalt with small amygdules
16	very fine grained porphyritic basalt or andesite
7	very fine grained prophyritic trachyandesite to mafic quartz latite (intermediate)
2	fine grained prophyritic trachyandesite
1	very fine grained porphyritic felsite
6	fine to medium grained amygdaloidal basalt
11	aphanitic to very fine grained ophitic basalt
3	fine grained ophitic basalt
8	fine to medium grained basalt or diabase
6	fine grained diabase
14	fine to medium grained diabase
2	anorthositic gabbro
1	anorthositic olivine gabbro
1	porphyritic gabbroic anorthosite
2	arkosic sandstone (one red, one white)
1	red siltstone
100 = Total	

Although in 1965 the study was limited to qualitative observations, it was observed that the number of genera increased with increased "incubation" time. In the shallow area, only *Cymbella*, *Diatoma*, *Gomphonema*, *Melosira*, and *Synedra* occurred. These same groups plus thirteen additional genera were observed in the sample from deeper water. Several factors may be responsible for this phenomenon. Wave action in the shallower water may make the attachment process difficult for some genera. Certain genera may be more capable of withstanding rough water. Also, waves undoubtedly knock periphyton from the rocks into the water, thereby reducing both numbers and kinds of organisms. Finally, selective grazing by insects and other organisms may also be a contributing factor in preventing the establishment of certain genera on rocks in shallow water.

The results of Douglas (1958) support the latter hypothesis. She found a negative correlation between populations of *Achnanthes* and the caddisfly larvae, *Agapetus fuscipes*, in studying the periphyton of an English stream. She stated that her findings suggest a grazing effect. In Stony Point Bay, *Achnanthes* is a common diatom and caddisfly larvae occur, especially in shallow water. Douglas also noted similar population changes in *Gomphonema* and *Synedra*, two other diatoms common in the periphyton of Stony Point Bay.

TABLE II

A CHECKLIST OF LAKE SUPERIOR PERIPHYTON OCCURRING AS REGROWTH ON ARTIFICIALLY DENUDED ROCKS, STONY POINT BAY, LAKE SUPERIOR, 1965.

Phylum Chrysophyta

Class Bacillariophyceae
- *Achnanthes microcephala* (Kuetzing) Cleve
- *Amphora ovalis* Kuetzing
- *Amphora normani* Rabenhorst
- *Asterionella formosa* Hassall
- *Ceratoneis arcus* (Ehrenberg) Kuetzing
- *Cocconeis flexella* (Kuetzing) Cleve
- *Cocconeis* spp.
- *Cyclotella* spp.
- *Cymatopleura solea* (Brebisson) W. Smith
- *Cymbella lanceolata* (Ehrenberg) Van Heurck
- *Cymbella* spp.
- *Denticula thermalis* Kuetzing
- *Diatoma elongatum* C.A. Agardh var. *tenuis* (Agardh) Van Heurck
- *Diploneis elliptica* (Kuetzing) Cleve
- *Fragilaria capucina* Desmazieres
- *Fragilaria crotonesis* Kitton
- *Gomphonema geminatum* (Lyngbye) C. A. Agardh
- *Gomphonema* spp.
- *Melosira granulata* (Ehrenberg) Ralfs
- *Melosira* sp.
- *Navicula* spp.
- *Nitzschia* spp.
- *Pinnularia* sp.
- *Rhizosolenia eriensis* H. L. Smith
- *Rhoicosphenia curvata* (Kuetzing) Grunow
- *Surirella* spp.
- *Stauroneis* spp.
- *Stephanodiscus* sp.
- *Synedra acus* Kuetzing
- *Synedra rumpens* Kuetzing
- *Synedra ulna* (Nitzsch) Ehrenberg
- *Tabellaria fenestrata* (Lyngbye) Kuetzing
- *Tabellaria flocculosa* (Roth) Kuetzing

Class Chrysophyceae
- *Dinobryon sertularia* Ehrenberg

Phylum Chlorophyta
- *Actinastrum* sp.
- *Cosmarium* sp.
- *Closterium* sp.
- *Coelastrum* sp.
- *Oedogonium* sp.
- *Scenedesmus quadricauda* (Turpin) Brebisson
- *Tetraedron minimum* (A. Brown) Hansgirg

Phylum Cyanophyta
- *Anacystis* sp.
- *Merismopedia convoluta* Brebisson

It was not felt that the varying rock types affected the growth of the periphyton in any way, inasmuch as two different types of rock from the same depth "incubated" for a like amount of time seemed to support similar numbers of the same genera of organisms. Although no specific experiments were conducted to verify this observation, later quantitative findings supported the hypothesis.

In 1965, another pertinent find was that a growth made up of eighteen genera of algae could be produced on rocks "incubated" for only three days in the lake. This information suggested that initial colonization of a denuded, autoclaved rock could take place in a very short time and provided the basis for planning future studies, in which rocks were examined as early as eight hours after being replaced in the lake.

Although quantitation was not the objective of this preliminary study, a purely subjective estimation of abundance indicated that Achnanthes and Synedra were predominant in the majority of samples.

In addition to the microscopic examination, dry weight determinations were also made on the periphyton of Stony Point Bay. Samples came from depths of two, ten, and twenty feet and weights were expressed as milligrams per square centimeter of rock surface. The results are presented in Table III. Each depth was sampled on seven different days in July and August. It will be noted that the weights are quite variable and that no obvious seasonal changes exist. In terms of mean weights for the seven days, the ten foot samples were the highest, the twenty foot samples the lowest, and the two foot samples were intermediate. Although the variation between these three means is relatively small, the figures reported are logical. For instance, it is possible that the two foot mean is lower than that for ten feet because of the fact that wave action dislodges more periphyton at the shallower depth. The lower weight at twenty feet may be explained by the fact that in deeper water there is less light penetration and therefore fewer photosynthetic organisms. Also, lower temperatures exist in deeper water and could be expected to retard growth rate.

On the basis of the mean dry weight figure for the three depths (July 27 to August 23) and the area of the bay, a rough estimate of the average total dry weight, or the standing crop, of the periphyton on the floor of Stony Point Bay is 54.4 tons (153 g/m^2).

TABLE III

NATURALLY OCCURRING PERIPHYTON DRY WEIGHTS AT SEVERAL
DEPTHS, STONY POINT BAY, LAKE SUPERIOR, 1965.
MILLIGRAMS PER SQUARE CENTIMETER
OF ROCK SURFACE.

	Depth in feet		
Date	2	10	20
7-27	12.8	28.5	25.5
8-3	39.2	18.1	6.4
8-9	3.1	10.1	3.5
8-12	8.4	8.0	8.4
8-16	17.2	14.4	20.1
8-19	20.2	36.8	19.1
8-23	5.1	5.0	13.3
Mean	15.1	17.3	13.8

The marked reductions in dry weights that occurred on August 9 and 23 (Table III) are compatible with the theory that a counterclockwise current is produced within Stony Point Bay during the time of a strong northeast wind. An east wind would have the same effect, only to a lesser degree. The current thus produced could then loosen and dissipate the periphyton, thereby reducing its volume. The depth at which the periphyton could be affected would depend on the velocity of the current. U.S. Department of Commerce climatological data, obtained from the Duluth International Airport, strongly support this hypothesis. During August of 1965, northeast winds were recorded for only three days. They occurred on August 7, 8, and 23. These dates all correspond with those on which the low weights were obtained.

In 1966, samples were examined quantitatively as well as qualitatively. From August 9 to September 6, twenty-seven samples of three rocks each were obtained from Stony Point Bay at depths of 2.5, 5, 10, 15, 20 and 35 feet. The results are presented in Figure 3 and Tables IV to VII.

Figure 3 shows the numbers of naturally occurring periphyton organisms per square centimeter of rock surface plotted against the six standard sampling depths. Numbers are means of the totals found at each depth for the five sampling days. The mean at the 2.5 foot depth was 490,000 per square centimeter, which was lower than the five foot mean of 587,000 per square centimeter. This was possibly due to the dislodgement of the organisms by wave action. The ten foot mean of 433,000 per square centimeter and the fifteen foot mean of 365,000 per square centimeter showed that there was a downward trend. This could be explained on the basis of lower temperatures and less light penetration in the deeper water. Because of these two factors, the twenty foot mean of 468,000 per square centimeter and the thirty-five foot mean of 637,000 per square centimeter were unexpectedly high. The only plausible explanation is that the unusually rough weather which occurred during the summer of 1966 dislodged the periphyton up to depths of at least twenty feet, and possibly affected growth beyond that point to a lesser degree. In discussing these counts, the numbers have been rounded off to the nearest thousand. A mean of the counts at all depths is 497,000 organisms per square centimeter of rock surface.

A checklist of the genera observed while making the counts is presented in Table IV. Of the twenty-four genera listed, nineteen, or seventy-nine per cent, are members of the phylum Chrysophyta. Only one of these, Dinobryon, is not a diatom. Four genera of green algae (Chlorophyta) were observed. The phylum Cyanophyta was represented by only one blue-green alga, Merismopedia.

It would be logical to expect more genera of organisms to be present in the naturally occurring periphyton sampled during 1966 than in the 1965 regrowth periphyton. This was not the case. In 1965, thirty-four genera were found occurring as regrowth, while only twenty-four genera were observed in the naturally occurring periphyton of 1966. This difference in the number of genera is probably a result of the differing procedures used in examining the two sets of samples. In 1965, periphyton was examined qualitatively, with the desired result being identification to species. For this reason, a good deal of time was spent on each sample and many organisms were examined. In 1966, the goal was to identify the organisms to genus and quantitate them. A ten random field counting method was used. By using this method, fewer organisms were encountered than during the 1965 examinations. In addition, the total number of samples examined during 1966 was relatively small. All but one of the genera (Ankistrodesmus) observed in the 1966 naturally occurring periphyton had been found

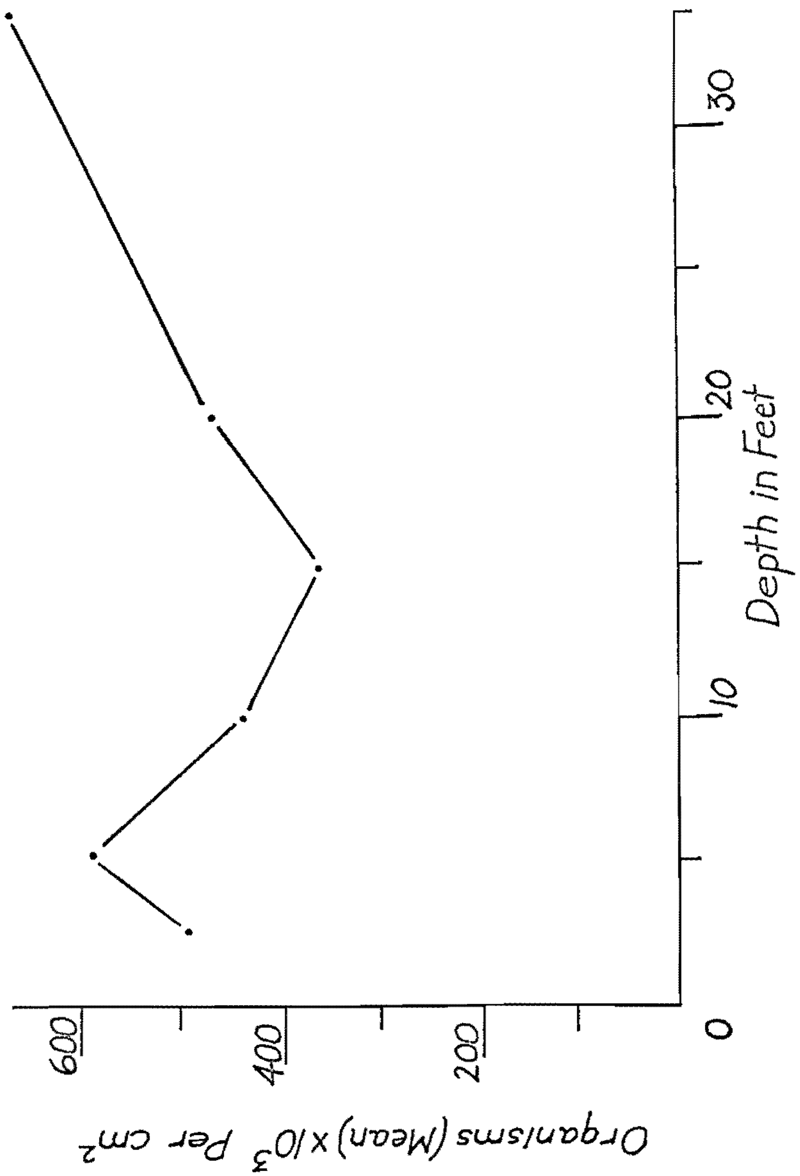


Figure 3. Mean total counts of naturally occurring periphyton at the standard sampling depths, Stony Point Bay, Lake Superior, 1966.

TABLE IV

GENERA OF ORGANISMS OBSERVED IN NATURALLY OCCURRING PERIPHYTON, STONY POINT BAY, LAKE SUPERIOR, 1966.

Phylum Chrysophyta

- Class Bacillariophyceae
  - *Achnanthes*
  - *Amphora*
  - *Asterionella*
  - *Cocconeis*
  - *Cyclotella*
  - *Cymatopleura*
  - *Cymbella*
  - *Diatoma-Denticula*
  - *Fragilaria*
  - *Gomphonema*
  - *Melosira*
  - *Navicula*
  - *Nitzschia*
  - *Rhizosolenia*
  - *Surirella*
  - *Synedra*
  - *Tabellaria*
  - Unidentified
- Class Chrysophyceae
  - *Dinobryon*

Phylum Chlorophyta

- *Ankistrodesmus*
- *Closterium*
- *Scenedesmus*
- *Tetraedron*

Phylum Cyanophyta

- *Merismopedia*

in the 1965 regrowth samples. Genera of organisms encountered during 1965 and not reported for 1966 include: Chrysophyta - *Ceratoneis*, *Diploneis*, *Pinnularia*, *Rhoicosphenia*, *Stauroneis*, and *Stephanodiscus*; Chlorophyta - *Actinastrum*, *Cosmarium*, *Coelastrum*, and *Oedogonium*; Cyanophyta - *Anacystis*.

The numbers of organisms from each of the three phyla which characterize the periphyton of Stony Point Bay and the total counts of each sample are presented in Table V. It can be seen that diatoms were found in all of the twenty-seven samples, while one or more of the genera of Chlorophyta were found in eleven samples. *Merismopedia*, the only blue-green, was observed in ten samples. *Dinobryon*, the only member of the phylum Chrysophyta that is not a diatom, was found in low numbers in thirteen of the samples. This organism, therefore, can be considered an insignificant contributor to the total numbers of Chrysophytes. The distribution of phyla according to depth is interesting, although possibly not significant. All three phyla were observed at 2.5, 5, 10, and 20 feet. At fifteen feet, however, no greens or blue-greens were found. At thirty-five feet, no greens were observed. Because of the narrow time span over which the sampling occurred and the rough weather, it would be unrealistic to intimate that these organisms were responding to seasonal changes.

A complete table (Table VI) listing all the genera and the numbers found at each depth on each sampling day is presented in the appendix (page 99). The number given below each count represents the importance of each genus in terms of percentage of the total. Table VI lists the genera of each phylum in alphabetical order. In Table VII, which is an excerpt of Table VI, seven genera, all diatoms, are listed in their order of abundance. This listing has been done on the basis of the average of the means of the percentage compositions of each organism at all six depths.

TABLE V

PHYLA AND COUNTS OF ORGANISMS OBSERVED IN NATURALLY OCCURRING PERIPHYTON, STONY POINT BAY, LAKE SUPERIOR, 1966. ORGANISMS x 10^3 PER SQUARE CENTIMETER OF ROCK SURFACE.

Depth in Feet	Phylum	Date 8-9	8-17	8-23	8-25	9-6
2.5	Chrysophyta	N.S.*	319.9	417.5	562.3	641.2
	Chlorophyta		4.6	---	---	3.4
	Cyanophyta		2.3	---	---	6.7
	Total		326.8	417.5	562.3	651.3
5	Chrysophyta	N.S.	710.1	592.3	551.0	470.8
	Chlorophyta		5.2	2.6	---	9.0
	Cyanophyta		2.6	2.6	---	---
	Total		717.9	597.5	551.0	479.8
10	Chrysophyta	568.1	271.8	523.5	419.6	360.4
	Chlorophyta	5.0	1.8	2.8	3.2	---
	Cyanophyta	5.0	---	---	---	3.4
	Total	578.1	273.6	526.3	422.8	363.8
15	Chrysophyta	703.9	172.7	N.S.	193.9	389.7
	Chlorophyta	---	---		---	---
	Cyanophyta	---	---		---	---
	Total	703.9	172.7		193.9	389.7
20	Chrysophyta	699.6	355.3	321.8	504.4	446.0
	Chlorophyta	---	2.8	5.4	---	---
	Cyanophyta	---	---	---	2.6	---
	Total	699.6	358.1	327.2	507.0	446.0
35	Chrysophyta	778.7	759.6	491.9	525.4	623.1
	Chlorophyta	---	---	---	---	---
	Cyanophyta	3.0	---	---	2.6	1.9
	Total	781.7	759.6	491.9	528.0	625.0

*N.S. means no sample was collected because of rough weather. Three dashes mean zero.

These results confirm the earlier suspicion that Achnanthes and Synedra were the most common organisms. The average of the mean percentages for all depths of Achnanthes is 32.1 per cent, while a comparable figure for Synedra is 26.4 per cent. At every depth on all sampling days, these two organisms together comprised greater than fifty per cent of the total count.

TABLE VII

COUNTS AND PERCENTAGE CONTRIBUTION TO THE TOTAL OF THE SEVEN MOST COMMON ORGANISMS OBSERVED IN THE NATURALLY OCCURRING PERIPHYTON, STONY POINT BAY, LAKE SUPERIOR, 1966. ORGANISMS x 10^3 PER SQUARE CENTIMETER OF ROCK SURFACE AND PERCENTAGE.

Organism	Depth in Feet	8-9	8-17	8-23	8-25	9-6	Mean
Achnanthes	2.5	N.S.* N.S.	128.9 42.8%	133.0 31.9%	121.5 21.6%	175.5 26.9%	139.7 30.8%
	5	N.S. N.S.	356.5 49.7%	248.7 41.6%	224.9 40.7%	172.1 35.9%	250.5 42.0%
	10	259.1 44.8%	60.4 22.1%	124.3 23.6%	123.0 29.1%	115.6 31.8%	136.4 30.3%
	15	274.1 38.9%	52.7 30.9%	N.S. N.S.	40.9 21.1%	133.1 34.2%	125.2 31.2%
	20	148.3 21.2%	147.3 41.1%	119.1 36.4%	113.0 22.3%	108.5 24.3%	127.2 29.1%
	35	323.4 41.4%	238.9 31.5%	122.9 25.0%	147.9 28.0%	129.1 20.7%	192.4 29.3%
Synedra	2.5	N.S. N.S.	76.0 25.2%	99.4 23.8%	208.0 37.0%	185.6 28.5%	142.2 28.6%
	5	N.S. N.S.	174.0 24.2%	97.9 16.4%	81.8 14.8%	96.6 20.1%	112.5 18.9%
	10	134.5 23.3%	83.5 30.5%	166.8 31.7%	116.7 27.6%	71.4 19.6%	114.5 26.5%
	15	150.9 21.4%	54.8 31.7%	N.S. N.S.	73.2 37.8%	109.7 28.1%	97.1 29.8%
	20	257.4 36.8%	78.4 21.9%	56.8 17.4%	168.0 33.1%	112.4 25.2%	134.6 26.9%
	35	206.6 26.4%	156.2 20.6%	127.7 26.0%	126.8 24.0%	177.8 28.4%	159.0 25.1%
Unidentified Diatoms	2.5	N.S. N.S.	25.3 8.4%	65.9 15.8%	78.2 13.9%	148.5 22.8%	79.4 15.2%
	5	N.S. N.S.	71.3 9.9%	84.7 14.2%	163.6 29.6%	105.7 22.0%	106.3 18.9%
	10	64.8 11.2%	33.8 12.4%	90.5 17.2%	72.5 17.1%	74.8 20.6%	67.2 15.7%
	15	73.2 10.4%	12.6 7.3%	N.S. N.S.	38.8 20.0%	79.4 20.4%	51.0 14.5%
	20	69.8 10.0%	44.0 12.3%	59.5 18.2%	95.0 18.7%	104.7 23.5%	74.6 16.5%
	35	80.9 10.3%	125.6 16.5%	78.0 15.9%	105.7 20.1%	134.7 21.6%	104.9 16.9%

* N.S. means no sample was collected. Three dashes mean zero.

TABLE VII (Continued)

Organism	Depth in Feet	8-9	8-17	8-23	8-25	9-6	Mean
Cymbella	2.5	N.S. N.S.	25.3 8.4%	25.4 6.1%	86.5 15.4%	27.0 4.1%	41.0 8.5%
	5	N.S. N.S.	7.9 1.1%	66.1 11.1%	24.5 4.4%	27.2 5.7%	31.4 5.6%
	10	34.9 6.0%	26.7 9.8%	48.1 9.1%	22.1 5.2%	27.2 7.5%	31.8 7.5%
	15	64.0 9.1%	8.4 4.9%	N.S. N.S.	17.2 8.9%	28.0 7.2%	29.4 7.5%
	20	21.9 3.1%	19.3 5.4%	16.2 5.0%	23.1 4.6%	23.3 5.2%	20.8 4.7%
	35	26.9 3.4%	33.7 4.4%	26.0 5.3%	13.2 2.5%	26.2 4.2%	25.2 4.0%
Navicula	2.5	N.S. N.S.	27.6 9.2%	42.8 10.3%	37.1 6.6%	84.4 13.0%	48.0 9.8%
	5	N.S. N.S.	29.0 4.0%	42.3 7.1%	32.7 5.9%	33.2 6.9%	34.3 6.0%
	10	34.9 6.0%	12.4 4.5%	23.2 4.4%	18.9 4.5%	27.2 7.5%	23.2 5.4%
	15	36.6 5.2%	19.0 11.0%	N.S. N.S.	6.5 3.4%	11.7 3.0%	1.8 5.7%
	20	48.0 6.9%	19.3 5.4%	N.S. 0%	28.3 5.6%	7.8 1.7%	20.7 3.9%
	35	21.0 2.7%	21.4 2.8%	35.5 7.2%	34.3 6.5%	39.9 4.8%	28.4 4.8%
Cocconeis	2.5	N.S. N.S.	2.3 .8%	1.2 .3%	4.1 .7%	6.7 1.0%	3.6 .7%
	5	N.S. N.S.	18.5 2.6%	7.9 1.3%	--- 0%	9.0 1.9%	8.9 1.5%
	10	5.0 .9%	12.4 4.5%	22.6 4.3%	12.6 3.0%	10.2 2.8%	12.6 3.1%
	15	45.7 6.5%	8.4 4.9%	N.S. N.S.	--- 0%	11.7 3.0%	16.5 3.6%
	20	91.7 13.1%	12.4 3.5%	13.5 4.1%	2.6 .5%	23.3 5.2%	28.7 5.3%
	35	24.0 3.1%	91.9 12.1%	14.2 2.9%	21.1 4.0%	43.0 6.9%	38.8 5.8%
Gomphonema	2.5	N.S. N.S.	9.2 3.1%	39.3 9.4%	16.5 2.9%	10.1 1.6%	18.8 4.3%
	5	N.S. N.S.	31.7 4.4%	18.5 3.1%	12.3 2.2%	3.0 .6%	16.4 2.6%
	10	--- 0%	1.8 .7%	10.5 2.0%	3.2 .8%	--- 0%	3.1 .7%
	15	18.3 2.6%	--- 0%	N.S. N.S.	--- 0%	2.3 .6%	4.1 .8%
	20	4.4 .6%	11.0 3.1%	18.9 5.8%	23.1 4.6%	11.6 2.6%	13.8 3.3%
	35	47.9 6.1%	15.3 2.0%	28.4 5.8%	18.5 3.5%	18.7 3.0%	23.8 4.1%

Plate 1 is a photograph of the typical species of Achnanthes found in the Stony Point Bay periphyton. All three cells are Achnanthes. According to Smith (1950), this genus is found in both salt and fresh water and is usually attached by means of a gelatinous stalk to some firm object. About a dozen species have been reported for the United States. In 1966 on August 17, Achnanthes reached its maximum in Stony Point Bay in terms of absolute numbers ($356{,}500/\text{cm.}^2$) and percentage of the total growth (49.7 per cent).

Synedra (Plates 2 and 3) was the second most commonly occurring organism and reached a maximum of 257,400 per square centimeter on August 9 at a depth of twenty feet. At five feet, the percentage contribution of Synedra to the total remained low throughout the season in comparison to the other depths. The fact that Achnanthes was higher than normal at this depth suggests an upset in the balance evidently existing between these two genera. Smith (1950) states that Synedra occurs in a variety of habitats. The smaller species are usually sessile and form a brownish-green layer on stones and woodwork in running water while the larger species are either free-floating or occur epiphytically in lakes. Twenty-five species occur in the United States. The predominant species of Synedra found in the Stony Point Bay periphyton is shown in Plate 2.

The unidentified organisms listed in Table VII include small pieces of broken organisms, atypical forms which were impractical to identify,

Plate 1. Achnanthes microcephala

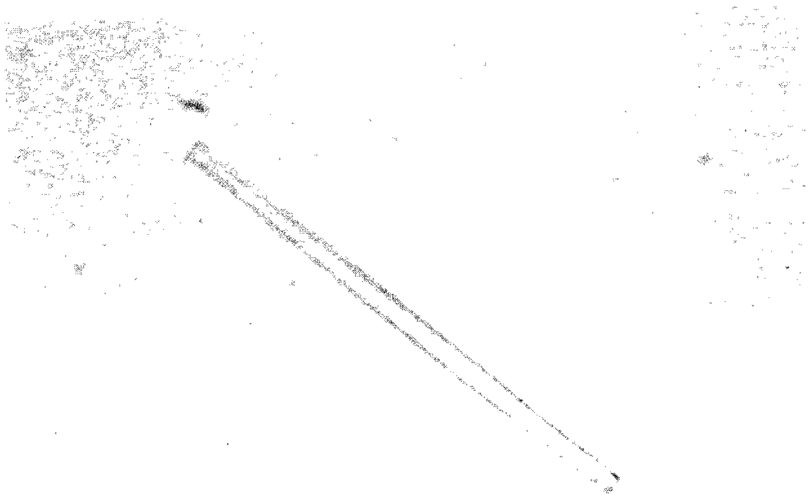


Plate 2. *Synedra acus*

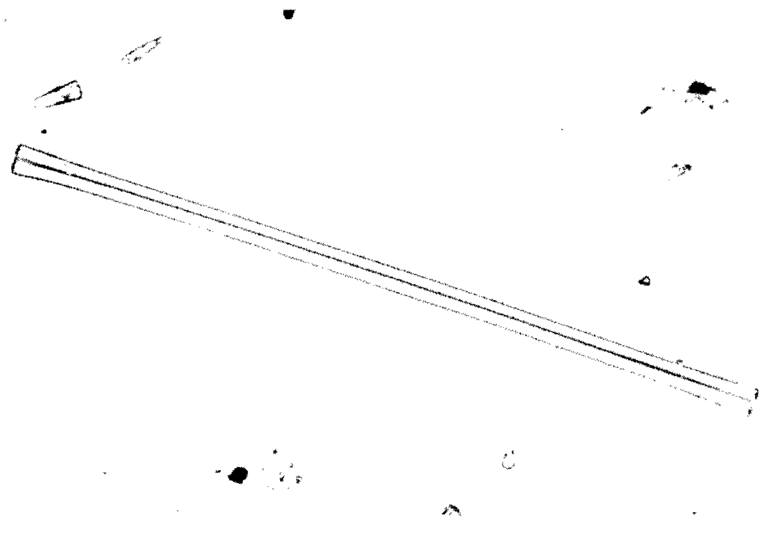


Plate 3. *Synedra ulna*

and a number of organisms which were "naviculoid" in appearance but which could not with certainty be assigned to the genus *Navicula*.

The remaining diatoms in Table VII, *Cymbella*, *Navicula*, *Cocconeis*, and *Gomphonema*, each comprise an average of less than seven per cent of the total at all depths. Plates 4 through 11 are photomicrographs of common species from these four genera.

Cymbella, with an average mean percentage for all depths of 6.3 per cent, was the fourth most common organism. Smith (1950) states that this organism may be either free-floating or sessile. The sessile species may be found singly at the tip of a stout gelatinous stalk or may occur grouped seriately within branched gelatinous tubes. A typical *Cymbella ventricosa* tube and its included organisms are shown in Plate 4. *Cymbella lanceolata* (Plate 5) typically grows at the tip of a stalk, which, in this case, has been incinerated. *Cymbella*, like *Navicula*, *Cocconeis*, and *Gomphonema*, shows no marked seasonal variations in Stony Point Bay. However, the means of the numbers and percentages at each depth indicate that *Cymbella* decreases with increasing depth.

Navicula (Plates 6 and 7) comprises on the average 6.1 per cent of the total at all depths and is the only one of the seven organisms listed which is usually free-floating. *Navicula* is motile and probably moves at will among the other members of the attached periphyton. Strictly speaking, organisms that are not attached but live with the periphyton constitute a part of the merophyton. *Navicula*, like *Cymbella*, seemed to decrease as the depth of the water increased.

Cocconeis, with an average mean percentage at all depths of 3.7 per cent, was the sixth most abundant organism. Four species of this predominantly marine genus occur in fresh water. All grow attached, with the hypotheca flattened against the substratum.. Plates 8 and 9 show two species commonly found in Stony Point Bay. *Cocconeis*, unlike *Cymbella* and *Navicula*, was more common in samples from deeper water.

Gomphonema comprised on the average 2.6 per cent of the total count at all depths. According to Smith (1950), the frustules "are usually epiphytic and borne at the tips of a dichotomously branched system of gelatinous stalks." This method of attachment is illustrated by Plate 10. Here, the organisms appear in girdle view. Plate 11 represents the valve view. *Gomphonema* occurred in highest percentages at 2.5 and thirty-five feet. The minimum occurred at ten and fifteen feet.

The dry weights of the 1966 samples are presented in Table VIII. Results are expressed as milligrams of dry weight per square centimeter of rock surface. Because the samples used for counting and those used for the weight determinations were taken from the same periphyton-water suspension, each weight is representative of a corresponding count. The weights, according to the mean weight at each depth, were lowest at 2.5 feet and gradually reached their peak at fifteen feet. The variations of the weights, if viewed alone, would be expected on the basis of the factors already discussed, namely, dislodgment of the periphyton by waves in the shallow water and lower numbers due to the decrease in light and temperature in the deeper water. The fact that the counts (Figure 3 and Table V) do not correlate with their corresponding dry weights (Table VIII) may be due to the variation in the sizes of the individual organisms at each depth. Thus, if the total count at a particular depth is high and the corresponding dry weight is low, one could surmise that the individual organisms were of a small size. By the same token, larger organisms in smaller numbers could cause a higher dry weight. This disparity might also be explained by the presence of varying amounts of sand in the periphyton-

Plate 4. Cymbella ventricosa

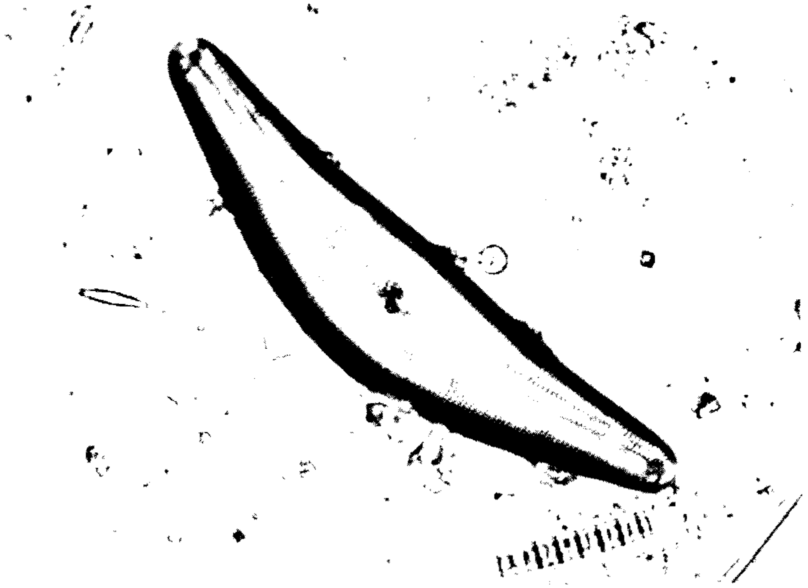


Plate 5. Cymbella lanceolata

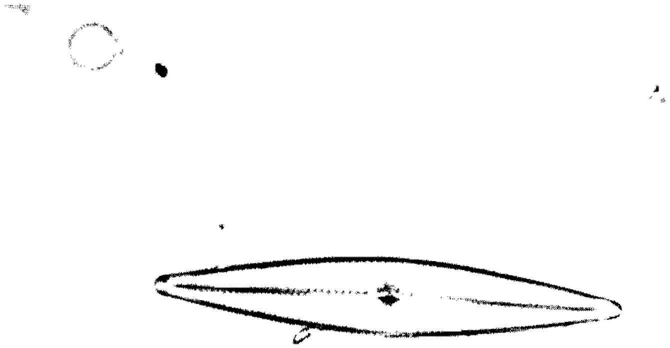


Plate 6. Navicula radiosa

Plate 7. Navicula reinhardtii

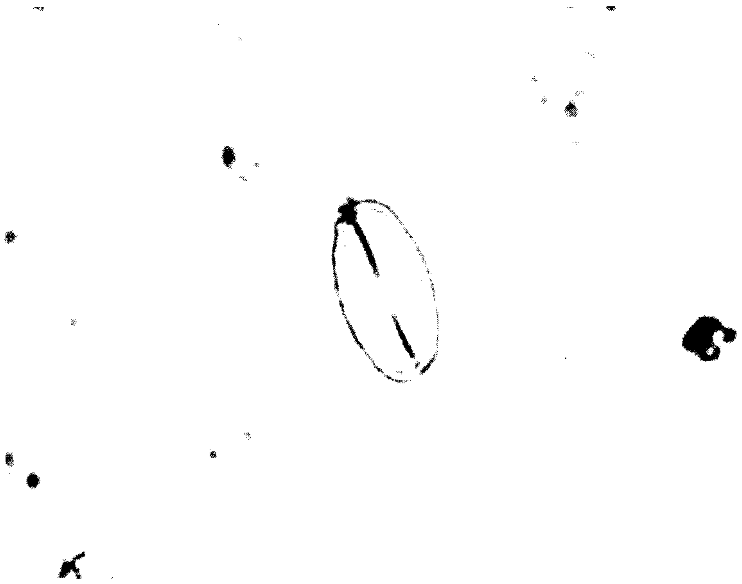


Plate 8. Cocconeis flexella

Plate 9. Cocconeis placentula

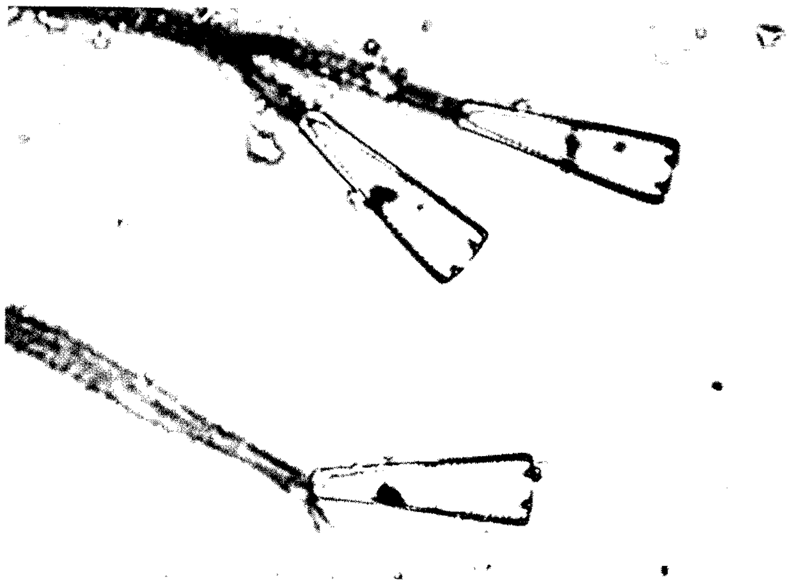


Plate 10. Gomphonema sp.

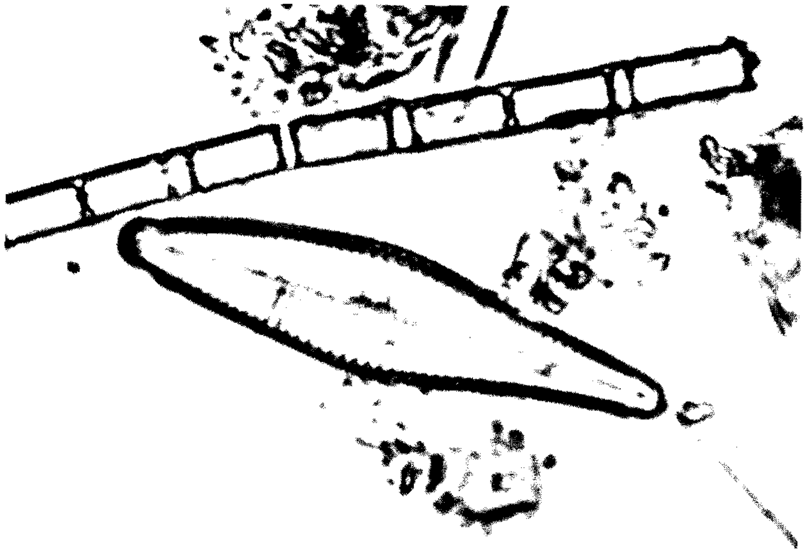


Plate 11. Gomphonema sp.

water suspensions or by the presence of empty diatom frustules. Both of these factors could cause fluctuations in the dry weights.

It is most probably that rough water dislodged and suspended both periphyton and sand in Stony Point Bay. The sand, of course, would settle rapidly on the rocks and is probably included in the dry weights, while some of the periphyton, which would take longer to settle out, was carried away by the current. This theory explains why the weights were high when the counts were low and vice versa. In an attempt to determine why the counts did not correlate with the dry weights, the methods were modified in 1967. In that year, the ash-free dry weight, or organic weight, of the periphyton was determined.

On the basis of the average of the 1966 mean dry weights for all of the depths, the total biomass, or standing crop, of the Stony Point Bay periphyton was calculated to be 37.1 tons (104 g./m.^{2}). The fact that this figure is lower than the comparable figure (54.4 tons or 153 g./m.^{2}) for 1965 is probably due to the rough weather of 1966. Even though six depths were sampled during 1966, as compared to three for 1965, the average depth sampled was just about the same for the two years.

The results of 1967 are presented in three sections. The first deals with the naturally occurring periphyton of Stony Point Bay. The second section is concerned with regrowth studies made in the same area while the third includes the results of studies conducted in areas other than Stony Point Bay along Lake Superior's north shore.

TABLE VIII

NATURALLY OCCURRING PERIPHYTON DRY WEIGHTS AT THE STANDARD DEPTHS, STONY POINT BAY, LAKE SUPERIOR, 1966. MILLIGRAMS PER SQUARE CENTIMETER OF ROCK SURFACE.

	Depth in Feet					
Date	2.5	5	10	15	20	35
8-9	N.S.*	N.S.	19.7	30.0	32.0	9.9
8-17	7.5	15.1	5.1	6.0	12.4	24.3
8-23	2.5	4.8	7.3	N.S.	2.1	5.3
8-25	10.0	3.1	6.0	10.0	11.0	9.2
9-6	6.0	5.4	13.0	10.2	9.5	9.7
Mean	6.5	7.1	10.2	14.0	13.4	11.6

*N.S. means no sample was collected.

Naturally occurring periphyton, Stony Point Bay.

During 1967, routine sampling was carried on between July 11 and September 15. An additional sampling trip was made on November 10. From July 11 to November 10, samples were collected on seventeen days. On each day, three rocks were obtained from each of the six standard sampling depths (2.5, 5, 10, 15, 20 and 35 feet). A total of 306 rocks was collected.

The numbers of organisms found at each depth are presented in Figure 4. Each point represents the mean count of seventeen samples collected from one particular depth during the sampling season. The means, rounded off to the nearest ten thousand, range from a maximum of 2,116,000 per square centimeter at 2.5 feet to a minimum of 1,034,000 per square centimeter at thirty-five feet. The downward trend in the counts as the depth increases is logical in view of certain facts. With increasing depth, light penetration is diminished and the temperature drops. The decrease in these two factors results in the generally lower periphyton populations which are shown by Figure 4. A mean of the counts at all depths is 1,470,000 organisms per square centimeter of rock surface. The mean of the 1967 counts for all depths was three times as high as the comparable figure for 1966. This threefold differential did not hold true at each depth, thus accounting for the difference in the shape of the curves. The greatest differences occurred in shallow water. At 2.5 feet, the 1967 mean count was more than four times as high as the 1966 mean count at the same depth. At five and ten feet, the 1967 means were greater than three times those of the comparable 1966 means. At fifteen and twenty feet, the 1967 mean counts were less than three times those of 1966, while the 1967 count at thirty-five feet was less than twice as high as the 1966 thirty-five foot mean count. These findings further substantiate the hypothesis that bad weather adversely affects periphyton growth, particularly in shallow water. The summer of 1967 was characterized by ideal weather conditions. High numbers of organisms were present that year because violent storms did not dislodge the periphyton nor stir up the bottom to produce deleterious tubidity. Climatological records show that during the 1967

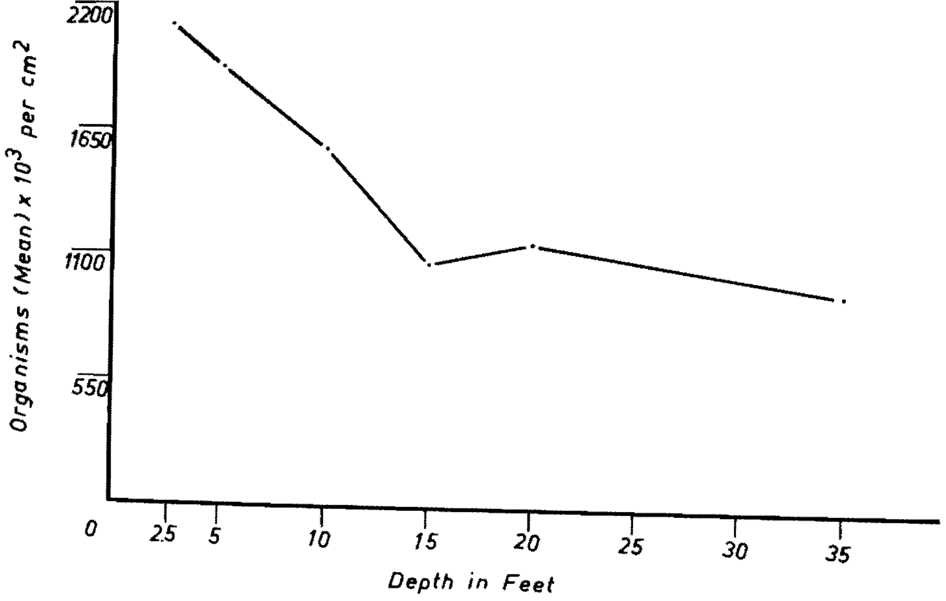


Figure 4. Mean total counts of naturally occurring periphyton at the standard sampling depths, Stony Point Bay, Lake Superior, 1967.

sampling season (sixty-seven days) east winds occurred on only eleven days, or sixteen per cent of the time. No northeast winds occurred. In contrast, east and northeast winds occurred during thirty-nine per cent of the 1966 sampling season. While it is felt that the differing weather conditions which occurred during the two years are primarily responsible for the variations in the counts, the twofold decrease in the counts at thirty-five feet may have been caused by factors other than, or in addition to, the weather.

The variations in the total counts of organisms according to date are presented in Figures 5 through 10. Since, in this case, each count is an actual count and not a mean these curves show greater variation than does Figure 4. These figures (Figures 5-10) reflect the general decrease with depth shown by Figure 4. This can readily be seen if the graphs are superimposed and the area below each curve is inspected. The greatest variation is shown in the counts from samples obtained from shallow water.

While it is impossible to explain precisely the causes for each dip and rise in these six curves, it is possible to surmise the reason for the similarity between the curves for the four relatively shallow depths (2.5, 5, 10, and 15 feet). A plausible explanation can also be offered for the similarity between the twenty and the thirty-five foot curves. The variability exhibited by the shallower water counts (Figures 5-8) is probably due to the effect of wave action upon the periphyton. Each peak represents a renewal of growth or settling of organisms that took place after some climatic disturbance. The high mean of the counts in the shallow water show that the growth was never seriously reduced by the effects of waves or currents. The fact that the peaks and dips correspond, in general, at the different depths supports this weather hypothesis. The progressive increases exhibited by Figures 9 and 10 (twenty and thirty-five feet) are probably indicative of a true rising seasonal trend, which reached a maximum on September 5. The minor hydraulic disturbances causing deviations in the counts of the shallow water samples were probably not strong enough to affect growth in the deeper water. The dip in the counts at twenty and thirty-five feet on August 28 may have been caused by a deep current, which may have also been responsible for the periphyton reduction in the shallower water (2.5 and 10 feet) on the same date. Such a current could be produced in a number of ways. In this instance, it could be that strong shifting winds produced water movement which swept away part of the periphyton. Weather data during the period in question tend to support this view. Intermittent rainstorms with attendant winds of twenty-five miles an hour or greater were recorded on August 24 through August 26. At the onset, the winds were from the south. There was then a gradual shift to the southwest and finally, to the northwest. However, the lower count at twenty feet on August 17, which was not accompanied by coincidental decreases at thirty-five feet and at the shallow water stations, must be ascribed to a local current of unknown origin.

A checklist of the organisms encountered while making the above counts is presented in Table IX. The total number of genera observed was thirty-eight. Sixty-eight per cent, or twenty-six genera, belong to the phylum Chrysophyta. Only one of these twenty-six genera, Dinobryon, is not a diatom. There were seven genera of green algae and five blue-green algae. Only these three phyla were represented. The checklist can be broken down further into sixty-one recognized species. Of the sixty-one species, forty-seven (seventy-seven per cent) were diatoms. Eight species of Chlorophyta and five species of Cyanophyta are reported.

Fourteen more genera of naturally occurring periphyton were encountered during 1967 than were found in the 1966 samples. In both years,

Figure 5. Naturally occurring periphyton, total counts at 2.5 feet, Stony Point Bay, Lake Superior, 1967.

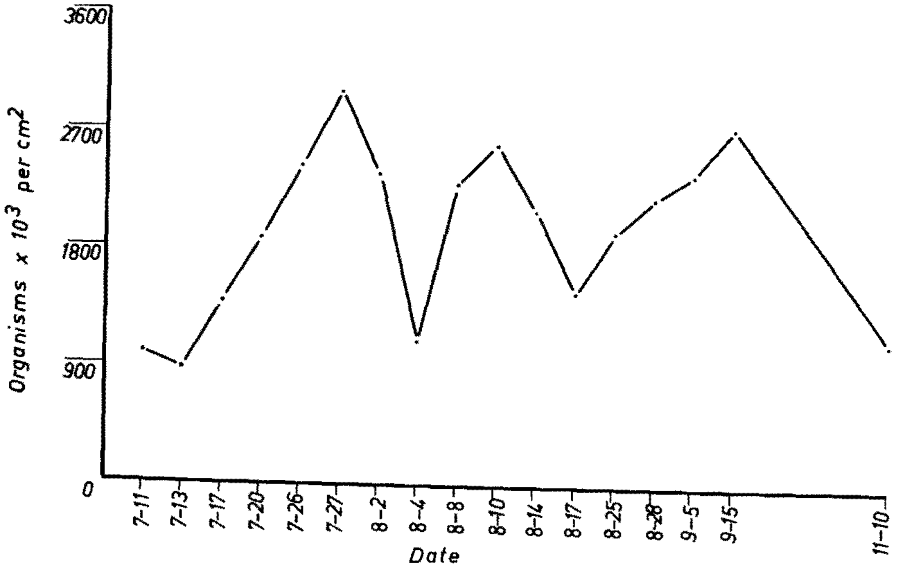


Figure 6. Naturally occurring periphyton, total counts at 5 feet, Stony Point Bay, Lake Superior, 1967.

Figure 7. Naturally occurring periphyton, total counts at 10 feet, Stony Point Bay, Lake Superior, 1967.

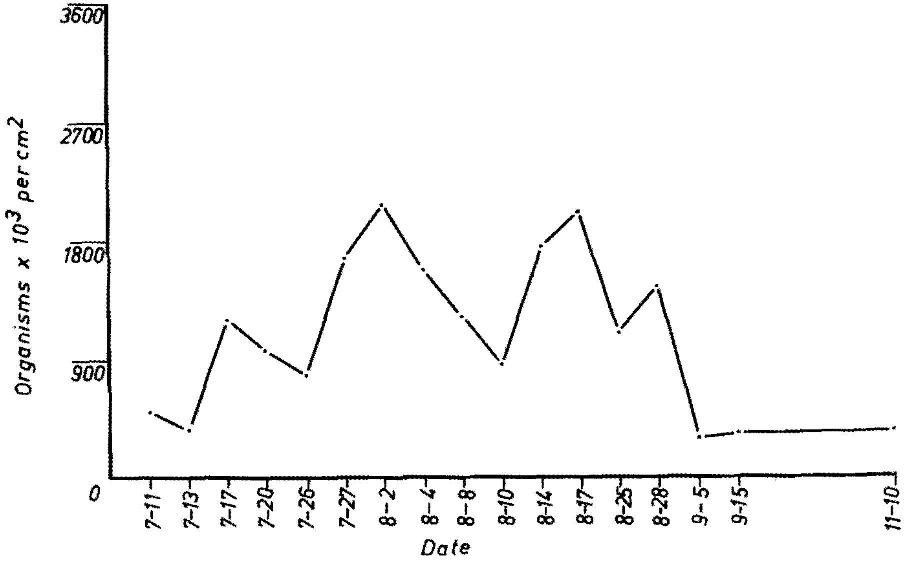


Figure 8. Naturally occurring periphyton, total counts at 15 feet, Stony Point Bay, Lake Superior, 1967.

Figure 9. Naturally occurring periphyton, total counts at 20 feet, Stony Point Bay, Lake Superior, 1967.

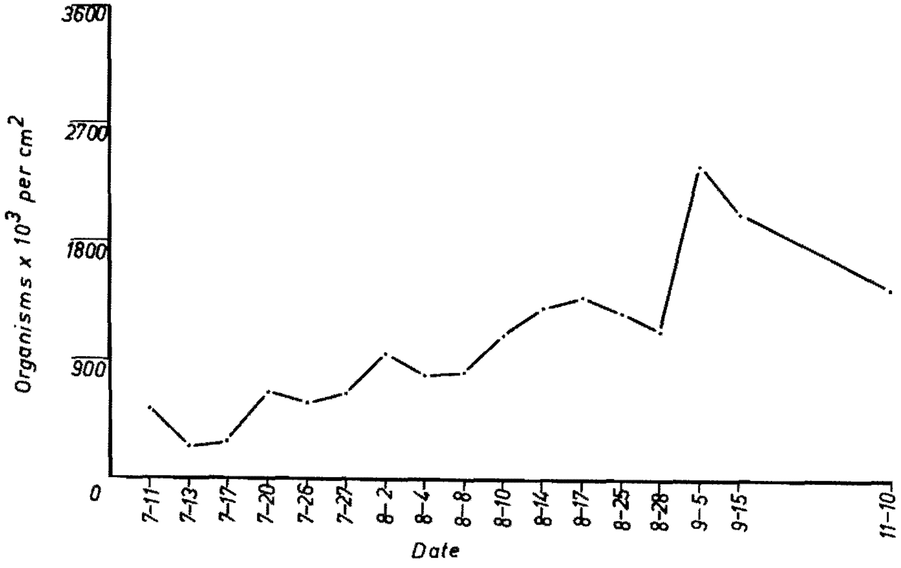


Figure 10. Naturally occurring periphyton, total counts at 35 feet, Stony Point Bay, Lake Superior, 1967.

TABLE IX

ORGANISMS OBSERVED IN NATURALLY OCCURRING PERIPHYTON, STONY POINT BAY, LAKE SUPERIOR, 1967.

Phylum Chrysophyta

Class Bacillariophyceae
Achnanthes microcephala
(Kuetzing) Cleve +
Amphora ovalis
Kuetzing *+
Amphora normani
Rabenhorst *
Asterionella formosa
Hassall +
Ceratoneis arcus
(Ehrenberg) Kuetzing +
Cocconeis group:
C. flexella
(Kuetzing) Cleve +
C. pediculus
Ehrenberg
C. placentula
Ehrenberg +
Cyclotella antiqua
Wm. Smith * +
Cyclotella group:
C. bodanica
Eulenstein var.
michiganensis Skvortzow +
C. meneghiniana
Kuetzing
C. michiganiana
Skvortzow
Cymatopleura solea
(Brebisson) Wm. Smith * +
Cymbella group A:
C. cistula
(Hemprich) Grunow
C. lanceolata
(Ehrenberg) Van Heurck +
Cymbella group B:
C. ventricosa
Kuetzing +
C. amphicephala
Naegeli
Denticula thermalis
Kuetzing +

Diatoma elongatum
C. A. Agardh var. tenuis
(Agardh) Van Heurck
Fragilaria capucina
Desmazieres +
Fragilaria crotonensis
Kitton * +
Fragilaria harrisonii
(Wm. Smith) Grunow * +
Frustulia viridula
(Brebisson) DeToni +
Gomphoneis herculeana
(Ehrenberg) Cleve * +
Gomphonema group +
Gyrosigma attenuatum
(Kuetzing) Cleve * +
Melosira granulata
(Ehrenberg) Ralfs +
Melosira varians
C. A. Agardh * +
Navicula group:
N. dicephala
(Ehrenberg) Wm. Smith
N. radiosa
Kuetzing +
N. reinhardtii
(Grunow) Van Heurck +
N. rhyncocephala
Kuetzing
Nitzschia denticula
(Grunow) *
Nitzschia palea
(Kuetzing) Wm. Smith * +
Nitzschia sigmoidea
(Nitzsch) Wm. Smith *
Nitzschia vermicularis
(Kuetzing) Hantzsch +
Pinnularia viridis
(Nitzsch) Ehrenberg * +
Rhizosolenia eriensis
H. L. Smith +
Rhoicosphenia curvata
(Kuetzing) Grunow * +
Stauroneis producta
Grunow *

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*Organisms found on less than eight of the seventeen sampling days

+Refer to List of Plates in Table of Contents for location of photomicrograph of this organism.

TABLE IX (continued)

Surirella group:
S. angusta
Kuetzing +
S. ovalis
Brebisson
S. ovalis
Brebisson var. pinnata
Wm. Smith +
Synedra acus
Kuetzing +
Synedra ulna
(Nitzsch) Ehrenberg +
Tabellaria fenestrata
(Lyngbye) Kuetzing +
Tabellaria flocculosa
(Roth) Kuetzing +

Class Chrysophyceae
Dinobryon sertularia
Ehrenberg

Phylum Chlorophyta

Ankistrodesmus falcatus
(Corda) Ralfs *
Cladophora glomerata
(Linnaeus) Kuetzing*
Closterium sp. *
Pediastrum duplex
Meyen *
Scenedesmus acuminatus
(Lagerheim) Chodat *
Scenedesmus quadricauda
(Turpin) Brebisson
Spirogyra sp. *
Tetraedron sp. *

Phylum Cyanophyta

Anabaena sp.
Lyngbya sp.
Merismopedia convoluta
Brebisson
Oscillatoria sp.
Raphidiopsis curvata
Fritsch *

however, the proportion of diatom genera to greens and blue-greens remained constant. The twenty-four genera encountered during 1966 (Table IV) were also present in 1967. The fourteen additional genera found in 1967 were: Chrysophyta - Ceratoneis, Frustulia, Gomphoneis, Gyrosigma, Pinnularia, Rhoicosphenia, and Stauroneis; Chlorophyta - Cladophora, Pediastrum, and Spirogyra; Cyanophyta - Anabaena, Lyngbya, Oscillatoria, and Raphidiopsis.

The numbers of organisms from each of the three phyla and the total counts of each sample are shown in Table X. It will be noted that the mean of the totals at each depth are the points of the curve in Figure 4 while the total figures for each day at each depth are plotted in Figures 5 through 10. The figures in Table X have been rounded off to the nearest one hundred. In all cases, the Chrysophytes are by far the most abundant phylum, ranging from a minimum of 88.2 per cent of the total at twenty feet on September 15 to one hundred per cent of the total of the samples collected on November 9 at 2.5,15, and 35 feet and on July 17 at 2.5 feet. With the one exception above, the Chrysophytes always comprised at least ninety per cent of the total. It should also be noted that they occurred in all samples.

Chlorophytes, or green algae, were found in only seventy-three of 102 samples, or seventy-one per cent of the time. Blue-greens were more abundant and occurred in eight-seven per cent of the samples.

In comparing the results of 1966 and 1967 (Tables V and X), it will be seen that the Chrysophytes were by far the most abundant organisms during both years. This was true for every sample from every depth for both

TABLE X

PHYLA AND COUNTS OF ORGANISMS OBSERVED IN NATURALLY OCCURRING PERIPHYTON, STONY POINT BAY, LAKE SUPERIOR, 1967. ORGANISMS X 10^3 PER SQUARE CENTIMETER OF ROCK SURFACE.

DEPTH in feet	PHYLUM	DATE																	MEAN
		Jul 11	Jul 13	Jul 17	Jul 20	Jul 26	Jul 27	Aug 2	Aug 4	Aug 8	Aug 10	Aug 14	Aug 17	Aug 25	Aug 28	Sep 5	Sep 15	Nov 9	
2.5	Chrysophyta	2188.7	1977.2	1030.9	3025.8	3170.1	3378.4	1739.4	1768.8	1485.7	1482.6	2520.7	2936.2	2058.1	1416.5	2324.7	2665.4	426.3	2093.9
	Chlorophyta		3.3		10.0		7.0		18.6	25.9		12.1	36.5						6.7
	Cyanophyta	7.2	3.3		3.3	13.4	20.9	9.0	6.2	6.5	10.9	36.2	21.9	17.8	7.3	46.0	55.2		15.6
	TOTAL	2195.9	1983.8	1030.9	3039.1	3183.5	3406.3	1748.4	1793.6	1518.1	1493.5	2569.0	2994.6	2075.9	1423.8	2370.7	2720.6	426.3	2116.2
5	Chrysophyta	1001.6	842.4	1375.5	1850.5	2281.6	2881.7	2265.1	1084.3	2231.5	2531.3	2021.3	1415.0	1891.3	2098.8	2207.3	2688.5	1079.5	1867.5
	Chlorophyta	3.2	7.3		16.1	31.3	12.3	10.0	7.4		8.1	4.7	7.1	13.6	7.1	7.0		13.7	8.7
	Cyanophyta		4.6	26.6	10.7	106.3	80.0	79.8		42.8	48.5	60.6	46.1	20.3	78.3	146.6	78.2		48.8
	TOTAL	1004.8	854.3	1402.1	1877.3	2419.2	2974.0	2354.9	1091.7	2274.3	2587.9	2086.6	1468.2	1925.2	2184.2	2360.9	2766.7	1093.2	1925.0
10	Chrysophyta	609.9	538.5	1007.1	1307.5	1973.9	1700.1	3248.8	1435.9	1077.2	2228.1	1053.9	2157.9	2990.1	887.8	1455.6	1165.5	1005.0	1520.2
	Chlorophyta		13.3	18.1	13.8	12.9	15.3	34.8	4.0	18.1	13.8		24.4	8.3		18.4		5.1	11.8
	Cyanophyta	11.0	1.7	33.2	41.4	77.4	71.5	292.1	23.9	13.6	46.8	19.5	97.7	82.8	34.0	92.1	36.4		57.4
	TOTAL	620.9	553.5	1058.4	1362.7	2064.2	1786.9	3575.7	1463.8	1108.9	2288.7	1073.4	2280.0	3081.2	921.8	1566.1	1201.9	1010.1	1589.4
15	Chrysophyta	496.3	355.2	1148.1	926.1	751.6	1571.2	1943.6	1512.3	1169.9	816.8	1697.2	1932.4	1056.5	1366.5	270.8	312.4	327.7	1038.5
	Chlorophyta	1.9	3.3	22.9	16.4	3.6		41.4	11.0	20.4	3.7	4.2	11.9		8.8	3.0			9.0
	Cyanophyta	2.5		28.6	24.6	18.0	100.0	63.3	38.5	24.5	29.8	46.3	60.2	25.5	74.0	6.0	5.4		32.5
	TOTAL	500.7	358.5	1199.6	967.1	773.2	1671.2	2048.3	1561.8	1214.8	850.3	1747.7	2004.5	1082.0	1449.3	279.8	317.8	327.7	1080.0
20	Chrysophyta	439.0	460.5	721.6	562.4	814.2	927.6	1015.9	1023.0	1032.8	976.9	2017.4	1338.1	2308.6	695.6	2478.9	1102.4	325.5	1073.0
	Chlorophyta	11.9	4.4	13.7	6.5	11.7	14.4	18.1			14.5	26.9	22.4	5.0	11.4	13.2		2.4	10.4
	Cyanophyta		2.2	24.7	28.2	14.7	36.1	72.3	28.7	15.8	28.9	145.5	114.4	164.6	18.9	317.3	63.6		63.3
	TOTAL	450.9	467.1	760.0	597.1	840.6	978.1	1106.3	1051.7	1048.6	1020.3	2189.8	1474.9	2478.2	725.9	2809.3	1166.0	327.9	1146.7
35	Chrysophyta	523.7	234.4	269.7	643.6	543.0	613.5	923.9	760.9	783.3	1077.3	1188.0	1314.1	1238.2	1099.8	1871.2	1844.3	1351.0	959.4
	Chlorophyta	8.3	1.7	4.2	7.2	4.6	8.5		7.3	3.1		19.6	14.8	8.7	13.5		9.0		6.4
	Cyanophyta		9.4	7.0	21.5	20.6	23.4	39.3	21.8	25.0	23.3	98.1	59.0		18.0	166.3	165.3		41.1
	TOTAL	532.0	245.5	280.9	672.3	568.2	645.4	963.2	790.0	811.4	1100.6	1305.7	1387.9	1246.9	1131.3	2037.5	2018.6	1351.0	1006.9

years. They never dropped below eighty-eight per cent of the total of any one sample. In many cases, diatoms comprised the entire population and Dinobryon was the only genus of Chrysophyta observed that was not a diatom.

The phyla Chlorophyta and Cyanophyta showed some variations in frequency of occurrence for the two year period. In 1966, greens were found in forty per cent of the samples, as contrasted with sixty-seven per cent in 1967. A similar rise in the blue-greens occurred during 1967. In 1966, the Cyanophytes were represented only by Merismopedia, which was present thirty-seven per cent of the time, whereas five genera of blue-greens occurred in 1967. Cyanophytes, in that year, were seen in eighty-seven per cent of the samples.

A table (Table XI) listing all the organisms which were found on eight or more of the seventeen sampling days in 1967 is presented in the Appendix. With the listing are the individual counts of each of these organisms and the relative importance of each in terms of percentage of the total. Organisms not included in the table occurred on less than eight of the sampling days and, when they did occur, comprised less than one per cent of the total. Such organisms are marked with an asterisk in the 1967 checklist (Table IX).

For easy reference, the eight organisms whose average mean percentage composition at all depths was greater than one per cent were tabulated (Table XII). These eight organisms, on the average, comprised ninety-three per cent of the total counts at all depths. With the exception of the category "unidentified blue-greens", all were diatoms. The blue-greens could have been very small species of Oscillatoria. Synedra acus and Achnanthes microcephala were by far the most common organisms. The average of the mean percentages at all depths for Synedra acus was 47.2 per cent, while a comparable figure for Achnanthes microcephala was 28.1 per cent. On the average, therefore, these two diatoms comprised seventy-five per cent of any one sample.

Synedra acus (Plate 2) reached its maximum of 2,523,000 per square centimeter at a depth of 2.5 feet on July 27. On the basis of mean counts, it can be seen that Synedra acus, in both absolute numbers and percentages of the total, decreased as the depth increased. In general, however, the counts at the twenty and thirty-five foot depths rose seasonally.

Achnanthes microcephala (Plate 1), the second most common organism of 1967, reached its maximum (1,002,000/cm.^{2}) on August 25 at a depth of twenty feet. As with Synedra acus, a marked variation according to depth occurred. In this case, however, the means of Achnanthes microcephala rose with increasing depth.

In comparing the per cent contribution to the total at each depth on each day for Achnanthes microcephala and Synedra acus, it can be seen that a balance exists between these two organisms. When the percentage of one is low, the other is high, and vice versa. In most instances, the combined percentage of these two diatoms is somewhere between seventy and eighty per cent.

In 1966, the genus Achnanthes was the predominant organism, with an average mean percentage contribution to the total of 32.1 per cent, while Synedra was second with a comparable figure of 26.4 per cent. Together, therefore, they averaged about fifty-nine per cent of the total. In 1967, on the other hand, these two diatoms comprised seventy-five per cent of the total, with Synedra acus averaging 47.2 per cent of the total and Achnanthes microcephala 28.1 per cent. The changes that occurred in the individual order of predominance of these two and their combined contribution to the total in 1967 are probably due to several interrelated factors. The genus Achnanthes grows at the tips of gelatinous stalks which are attached to rocks by means of specialized holdfasts. Synedra, on the other hand, attaches itself with a small amount of adhesive material secreted from one end of its frustule. These organisms are often found free-floating, while Achnanthes is rarely found unattached. The rough weather that had occurred during 1966, therefore, probably dislodged a proportionately greater number of Synedra than Achnanthes because of Achnanthes' superior mode of attachment. The counts reflected this in showing more Achnanthes than Synedra.

TABLE XII

EIGHT MOST COMMON ORGANISMS IN THE NATURALLY OCCURRING PERIPHYTON, EXPRESSED AS COUNTS AND PER CENT CONTRIBUTION TO THE TOTAL, STONY POINT BAY, LAKE SUPERIOR, 1967. ORGANISMS X 10^3 PER SQUARE CENTIMETER OF ROCK SURFACE OVER PERCENTAGE.

Organism	Depth in feet	Jul 11	Jul 13	Jul 17	Jul 20	Jul 26	Jul 27	Aug 2	Aug 4	Aug 8	Aug 10	Aug 14	Aug 17	Aug 25	Aug 28	Sep 5	Sep 15	Nov 9	Mean
Synedra acus	2.5	[illegible]	1392	[illegible]	[illegible]	[illegible]	2525	[illegible]	[illegible]	[illegible]	[illegible]	1668.4	[illegible]	1507.5	795	1555	2205	560	[illegible]
		73.0	70.5	67.4	78.4	[illegible]	76	70.9	51.0	52	66	[illegible]	64.5	67.8	55	65	62	33.4	64
	5	568.6	659.5	870.3	1173.4	1456	1932	1631.8	577	1288.9	1552.8	1201	890.2	1206.5	1240	1170	1677	361	1145
		56.6	58.5	62.3	62.5	60.2	65.5	60.8	57.9	56.7	60.0	57.5	60.8	62.1	57.7	55.9	60.6	51.8	58.5
	10	331.8	180.9	511.7	741	1083.6	888.5	1956.6	697.9	602.8	627.7	558	1085	1780.8	496.7	688	490.1	415.4	760
		55.6	12.2	58.5	55.6	52.5	46.2	56.3	67.2	36.5	27.4	52.0	47.5	57.8	51.9	61.9	60.8	61.1	46.7
	15	282.9	187.5	555.0	450.8	102.1	603.6	292.8	626.9	456.0	319.5	226.4	788.7	669.1	381.0	92.5	127.7	48.9	425.8
		55.9	52.5	29.6	46.6	39.1	36.3	38.9	40.3	37.4	39.9	41.4	39.1	43.6	40.2	36.8	40.2	14.9	39.4
	20	132.6	246.8	260.7	179.5	788.1	128.2	165.2	388.6	474.8	154.6	872.7	540.1	673.5	290.8	780.1	480.6	62.6	407.6
		30.5	52.8	14.1	10.1	14.5	31.8	13.0	16.9	45.5	36.8	19.9	36.6	15.4	40.0	27.8	41.2	19.6	35.8
	35	242.5	127.9	511.3	266.7	210.7	272.0	401.0	120.4	293.6	625.1	610.3	441.0	584.2	350.1	685.8	750.1	412.5	371.4
		45.6	52.2	39.8	16.7	37.1	42.9	41.6	40.8	36.2	38.8	11.0	37.9	66.9	30.9	11.7	37.2	29.9	38.5
Achnanthes microcephala	2.5	178.8	212.6	105.1	111.8	696.7	403.2	256.7	478.7	361.7	712.6	611.1	495.4	278.0	341.2	193.0	761.7	152.6	360.1
		8.1	10.7	10.2	10.9	15.5	11.8	14.6	23.8	21.8	16.2	16.0	16.5	11.6	24.1	8.1	8.9	35.8	15.7
	5	305.2	202.9	288.8	338.2	436.3	566.2	508.9	340.5	567.7	549.9	512.7	195.1	291.5	384.6	279.4	360.9	185.7	372.8
		30.4	21.8	20.6	18.0	18.8	19.0	21.6	11.2	25.0	21.2	24.5	13.3	15.1	17.6	11.8	13.0	17.0	20.1
	10	151.6	202.1	272.0	349.9	541.8	656.4	717.1	516.5	686.3	380.0	131.8	667.8	629.5	197.1	313.1	266.3	301.9	406.6
		24.6	51.0	25.7	25.7	26.2	25.6	20.6	35.1	61.7	16.6	30.9	29.3	20.6	21.4	20.0	22.2	30.1	22.6
	15	118.9	86.6	569.7	327.8	327.2	652.3	818.1	612.6	441.7	120.6	699.1	718.5	300.8	513.6	70.1	100.5	173.8	404.3
		23.5	23.6	41.5	31.9	62.3	39.3	60.0	40.5	16.6	17.2	40.1	35.7	27.8	35.4	25.1	31.6	33.0	36.1
	20	196.6	117.6	115.6	268.2	361.5	458.0	630.1	910.1	312.6	421.5	227.3	488.3	1082.2	192.6	876.6	114.5	115.5	410.1
		63.2	26.1	61.5	44.9	63.0	46.8	58.9	40.9	11.7	41.5	11.2	31.2	40.8	26.5	28.7	27.0	35.2	36.5
	35	181.9	30.5	79.6	250.1	206.2	170.4	281.9	234.0	302.8	386.6	311.7	610.4	414.3	199.5	720.3	495.6	496.2	340.0
		34.2	12.4	28.3	17.2	16.1	26.4	30.2	29.5	37.3	34.8	34.1	46.0	35.2	55.3	35.6	24.6	35.9	32.6
Navicula group	2.5	28.6	29.4	5.7	19.9	26.8	27.8	27.0	55.9	32.3	65.5	94.6	206.0	96.6	16.6	266.3	276.2	38.8	77.5
		1.3	1.5	0.6	0.7	0.8	0.8	1.5	3.1	2.1	4.4	3.5	6.8	4.6	1.0	12.0	10.2	9.1	4.7
	5	19.3	6.1	34.2	40.5	62.5	50.7	54.9	15.8	96.6	22.8	55.9	132.0	128.8	128.2	272.4	306.7	126.0	93.6
		1.9	0.7	2.4	2.1	2.8	1.7	2.3	1.6	6.2	2.8	2.7	8.0	6.7	5.9	11.5	11.0	11.5	4.7
	10	15.4	10.0	27.2	27.8	116.1	33.7	69.6	47.9	40.7	60.5	19.3	130.1	132.5	54.6	202.7	200.0	182.4	80.7
		2.5	1.8	2.6	2.0	5.6	2.0	1.9	1.1	3.2	2.6	1.8	5.7	4.3	5.9	17.9	16.6	18.1	5.5
	15	13.0	14.9	25.8	26.6	21.6	36.0	62.2	88.0	49.1	37.5	46.3	120.4	81.6	82.7	54.8	24.5	47.1	44.8
		2.6	4.2	2.7	2.5	2.8	2.2	3.0	5.6	4.0	4.4	2.6	6.0	7.5	5.7	19.6	7.7	14.4	5.7
	20	28.5	30.9	30.2	15.1	20.6	23.2	39.8	56.1	61.1	21.7	140.1	116.6	129.6	86.9	536.1	109.5	67.1	82.0
		6.3	6.6	4.0	2.5	2.5	2.6	1.6	5.1	6.0	2.1	6.4	7.8	5.2	12.0	15.5	9.4	16.6	6.6
	35	31.1	25.8	16.8	47.9	18.3	29.8	51.1	41.7	40.6	34.0	78.6	68.9	64.4	121.2	325.1	267.9	155.6	83.5
		6.2	10.5	6.0	6.4	3.2	4.4	5.3	5.3	5.0	3.2	6.0	5.0	5.2	10.7	16.0	13.3	11.3	7.1
Cymbella Group B	2.5	93.0	114.4	71.8	122.8	120.6	236.3	98.9	229.3	206.7	147.2	187.6	218.6	167.8	116.8	124.6	262.4	36.1	152.2
		4.2	5.6	3.2	4.0	3.8	6.9	5.7	12.8	13.6	9.9	7.3	7.3	7.1	8.2	7.6	9.6	8.5	7.6
	5	19.3	52.3	64.6	158.5	168.0	129.2	104.8	70.3	150.0	194.1	135.0	106.6	155.9	178.1	153.7	192.5	92.9	125.1
		1.9	6.1	4.6	8.4	7.0	4.3	4.5	6.4	6.6	7.5	6.5	7.2	8.1	8.2	6.5	7.0	8.5	6.4
	10	65.9	13.3	76.6	87.5	135.4	158.5	224.5	115.7	61.6	52.3	39.0	116.0	149.1	67.6	86.0	90.9	35.5	92.6
		10.6	3.1	7.7	6.4	6.6	9.4	6.4	7.6	5.7	2.3	3.6	5.0	4.8	5.2	5.5	7.6	3.5	5.9
	15	27.9	14.9	32.7	36.8	50.3	121.6	62.2	66.0	61.3	26.1	71.6	150.5	66.1	43.5	15.2	24.5	10.9	52.2
		5.5	4.2	3.1	3.8	6.5	7.3	3.0	4.2	5.0	3.1	4.1	7.5	6.1	3.0	5.4	7.7	3.3	4.9
	20	7.1	13.2	24.7	28.1	52.9	46.9	47.0	38.2	47.5	32.6	70.0	69.9	114.7	30.2	105.8	70.7	16.5	48.0
		1.6	2.8	3.3	4.7	6.3	4.8	4.2	3.6	4.5	3.2	3.2	4.7	4.8	4.2	3.8	6.1	5.0	4.2
	35	5.5	11.7	5.6	46.5	16.0	23.4	39.3	21.8	12.5	46.6	58.8	44.3	8.7	35.9	70.0	75.9	41.8	33.2
		1.0	4.8	2.0	6.9	2.8	3.6	4.1	2.8	1.5	4.2	4.5	3.2	0.7	3.2	3.4	3.8	3.0	3.3
Gomphonema group	2.5		45.7	51.1	34.8	20.1	20.9	11.5	37.2	25.8	31.8	10.2	16.6	23.7	14.6	38.8	41.4	17.0	27.8
			2.3	5.0	1.3	0.6	0.6	1.8	2.1	1.7	1.5	1.2	0.5	1.1	1.0	1.6	1.5	6.0	1.6
	5	9.6	24.6	53.7	51.0	18.8	43.1	29.9	21.0	42.8	48.5	27.9	26.4	8.8	12.2	34.9	30.1	6.6	28.2
		1.0	2.9	3.8	2.7	0.8	1.4	1.3	1.0	1.9	1.9	1.3	1.9	0.4	0.6	1.5	1.1	0.6	1.5
	10	8.8	16.6	24.2	23.0	6.5	30.6	41.7	19.9	18.1	16.5	7.8	16.3	8.3	13.4	12.5	12.1	10.1	16.8
		1.4	3.0	2.3	1.7	0.1	1.7	1.2	1.3	1.6	0.7	0.7	0.7	0.3	1.5	0.8	1.0	1.0	1.2
	15	13.0	16.6	105.9	16.4	16.0	27.0	88.5	38.5	49.1	29.8	21.1	12.0	30.6	26.1	8.1	5.4	21.7	29.8
		2.4	4.6	8.8	1.7	2.1	1.6	3.3	2.5	4.0	3.5	1.2	0.6	2.8	1.8	2.2	1.7	6.6	3.0
	20	16.4	13.2	24.7	19.5	29.6	21.6	54.2	31.9	15.8	50.2	63.1	19.1	39.9	3.8	26.6	11.6	21.3	27.2
		3.7	2.8	3.3	3.3	3.5	2.2	4.9	1.0	1.5	5.0	2.0	1.3	1.6	0.5	0.9	3.7	6.5	2.4
	35	13.8	12.9	11.2	25.0	29.8	49.0	59.0	32.8	31.2	104.8	7.8	44.3	36.9	80.6	110.8	67.0	131.1	49.8
		2.6	5.3	4.0	3.7	5.2	7.6	6.1	4.2	3.6	9.5	0.4	3.2	2.8	7.1	5.4	3.3	9.5	4.9
Cocconeis group	2.5		3.3		3.3	6.7	7.0	4.5	6.2	6.5				23.7	36.5			7.3	6.2
			0.2		0.1	0.2	0.2	0.3	0.3	0.4				1.1	2.6			1.7	0.4
	5	9.6	6.1				24.6	5.0	7.4	10.7	24.3	4.7	3.5	13.6	14.2		12.0	6.6	8.4
		1.0	0.7				0.8	0.2	0.7	0.5	0.9	0.2	0.2	0.7	0.7		0.4	0.6	0.4
	10	2.2	10.0	16.1	23.0	12.9	5.1	7.0	4.0	18.3	33.0	15.6	8.1	33.1	20.4	24.6	18.2		16.9
		0.4	1.8	1.2	1.7	0.6	0.3	0.2	0.3	1.6	1.4	1.5	0.4	1.1	2.2	1.6	1.5		1.1
	15	18.6	5.0	2.9	20.5	7.2	40.5	46.6	22.0	53.2	22.4	25.3	36.1	5.1	17.4	3.0	21.7	9.1	21.0
		3.7	1.4	0.2	2.1	0.9	2.4	2.3	1.4	4.4	2.6	1.4	1.8	0.5	1.2	1.1	6.8	2.8	2.2
	20	11.9	4.4	24.7	19.5	26.3	18.0	3.6	15.9	23.7	39.8	37.7	28.6	10.0	11.3	52.9	35.3	21.2	22.6
		2.6	0.9	1.3	3.1	3.2	1.8	0.1	1.5	2.3	3.9	1.7	1.9	0.4	1.6	1.9	3.0	6.5	2.4
	35	2.8	7.0		10.7	16.0	25.6	27.5	24.1	28.1	34.9	11.8	34.5	21.8	35.9	48.5	53.6	23.9	24.2
		0.5	2.9		1.6	2.8	4.0	2.9	3.7	3.5	3.2	0.9	2.5	1.7	3.2	2.6	2.7	1.7	2.4
Unidentified Blue-greens	2.5		3.3		5.3	13.4	20.9	9.0	6.7		10.9	30.2		17.8	3.3		55.2		10.4
			0.2		0.1	0.4	0.6	0.5	0.3		0.7	1.2		0.9	0.5		2.0		0.4
	5		4.4	26.8	10.7					42.8	48.5		46.1	20.3	78.3	118.7	78.2		27.9
			0.5	1.9	0.8					1.9	1.9		3.1	1.1	3.6	5.0	2.8		1.3
	10			27.2	38.8				23.9		46.8		89.6	74.5	34.0	92.1	30.3		26.8
				2.6	2.7				1.6		2.0		3.9	2.4	1.7	3.9	2.5		1.6
	15			28.6	20.5		40.5		27.5	20.4	22.4		34.2	23.5	69.6	3.0	2.7		18.5
				2.4	2.1		2.4		1.8	1.7	2.6		2.7	2.4	4.8	1.1	0.8		1.5
	20		2.2	19.2	26.0		36.1	22.3	20.7	15.8	21.7		108.0	34.9	18.9		60.1		26.1
			0.5	2.5	4.4		3.7	6.5	0.7	1.5	2.1		7.1	1.4	2.6		5.2		2.3
	35			7.0	14.3		23.4	27.5	30.9	15.6	23.3		34.1		18.0		136.1		20.6
				2.5	2.1		3.8	2.9	1.4	1.9	2.1		3.9		1.6		7.7		1.7
Unidentified Diatoms	2.5	35.8	9.8	22.7	6.6			9.0		6.5		48.4		11.8		9.2	20.7	2.4	10.8
		1.6	0.5	2.2	0.2			0.5		0.4		1.9		0.6		0.4	0.8	0.6	0.6
	5	28.2	7.9	3.8	8.1			10.0	7.4		24.3	4.7	7.1	20.3		7.0	24.2		9.0
		2.8	0.9	0.1	0.4			0.4	0.7		0.9	0.2	0.5	1.1		0.3	0.9		0.6
	10	6.6		9.3	13.8	6.5	10.2	55.6		4.5	8.7	11.7	16.3	16.6		18.4	8.7	5.1	12.2
		1.1		0.9	1.0	0.3	0.6	1.6		0.4	0.4	1.1	0.7	0.5		1.2	0.7	0.5	0.6
	15	7.4	5.0	20.0			13.5	25.9		4.1	7.5	25.3	12.0	5.1	4.4	3.0		5.4	8.2
		1.5	1.4	1.7			0.8	1.3		0.3	0.9	1.4	0.6	0.5	0.3	1.1		1.6	0.8
	20	21.4	15.4	8.7	6.5	5.9	3.6	1.6	25.5	4.0	3.6	16.2	6.4	5.0	9.0	33.1	10.6		10.5
		4.7	3.3	1.1	1.1	0.7	0.4	0.3	2.4	0.4	0.4	0.7	0.4	0.2	1.2	1.2	0.9		1.1
	35	35.8	3.5	16.8	10.7	9.2	10.7	23.6	10.9	15.6	17.5	19.6	29.5	32.4		20.8	26.8	29.9	17.5
		6.7	1.4	6.0	1.6	1.6	1.7	2.5	1.4	1.9	1.6	1.5	2.1	4.4		1.0	1.3	2.2	2.1

* See Table IX for the species included in the groups given in this table. Gomphonema was identified only to genus.

In 1967, calm weather prevailed and both organisms were subjected to optimal growth conditions. The results of 1967 show that Synedra acus "prefers" shallow water, for here the greatest numbers accurred. Achnanthes, in contrast, was proportionately more common in the deep water. Since bad weather in 1966 caused a great amount of turbulence in the shallow water, Synedra was adversely affected and, in that year, was exceeded in numbers by Achnanthes.

In 1967, the third most commonly occurring organism in the naturally occurring periphyton of Stony Point Bay was Navicula, with an average mean percentage of the total of 5.8 per cent. Two of the commonly occurring species are shown in Plates 6 and 7. The species included in this group are presented in Table IX. In general, it was observed that Navicula increased with increasing depth. The maximum reached by this organism was 436,000 per square centimeter. In 1966, Navicula was the fifth most abundant organism and comprised, on the average, 6.1 per cent of the total at all depths.

The fourth most numerous organism in 1967 was Cymbella (group B, Table IX). This group is made up of the smaller species of Cymbella and was most frequently represented by Cymbella ventricosa (Plate 4). The average mean percentage contribution to the total for all depths was 5.4 per cent. If all the species of Cymbella observed in 1967 had been grouped together, as they were in 1966, their average mean percentage contribution to the total would have been 6.0 per cent. In 1966, the genus Cymbella averaged 6.3 per cent of the total and was the fourth most common genus. In both 1966 and 1967, Cymbella decreased, in absolute numbers and percentage of the total, with increasing depth. The 1967 maximum for Cymbella group B was 262,000 per square centimeter.

Numerically, the fifth most common organism in 1967 was Gomphonema (Plates 10 and 11), which constituted an average of 2.5 per cent of the total at all depths. In 1966, this genus ranked seventh and averaged 2.6 per cent of the total. In the first year, no definite depth "preference" was noted for this organism, although the highest percentages occurred at 2.5 and thirty-five feet. In 1967, the thirty-five foot counts were the highest, in both absolute numbers and percentage of the total.

The sixth most abundant organism for both years was Cocconeis (Plates 8 and 9). It averaged 3.7 per cent of the total for all depths in 1966 and 1.5 per cent in 1967. In both years, this organism was more common in the deeper water.

The last two groups of organisms in Table XII are the unidentified blue-greens and diatoms, which were, respectively, the seventh and eighth most abundant organisms found in the 1967 periphyton. The average mean percentage contribution to the total was 1.5 per cent for the blue-greens and 1.0 per cent for the diatoms.

The photomicrographs in the appendix (Plates 12 through 37) show representative species of diatoms found as a part of the 1967 naturally occurring periphyton in Stony Point Bay. The photomicrograph of Rhizosolenia eriensis (Plate 32) is somewhat unusual, inasmuch as its delicate frustules usually do not survive the incineration process used in preparing the permanent slides.

The dry and ash-free (organic) dry weights of all the 1967 Stony Point Bay samples are presented in Tables XIII and XIV. The ash-free dry weights are shown graphically by Figures 11 through 16 in the appendix. Each weight is representative of a corresponding count, since samples for both determinations were taken from the same periphyton-water suspension. The dry weights (Table XIII), in terms of mean weights for each depth, were highest at 2.5 feet and lowest at thirty-five feet. With the exception of the fifteen and twenty foot means, which were almost identical, the dry weights decreased with increasing depth. The mean ash-free dry weights (Table XIV) were highest at 2.5 feet and dropped regularly to their minimum at fifteen feet.

On the basis of the average of the 1967 mean dry weights for all depths, the total dry weight of the Stony Point Bay periphyton was calculated to be 55.5 tons (156 g./m.^{2}). The corresponding figure for the ash-free dry weights is 4.4 tons (12 g./m.^{2}) or 7.9 per cent of total dry weight.

When the means for the dry and ash-free dry weights are compared to the mean total counts for the six depths (Figure 4), it can be seen that both the dry and the ash-free dry weights, with one exception, vary with depth as do the mean counts. This apparent correlation between counts and weights is in distinct contrast to the situation observed in 1966. In that year, the relationship between the mean dry weights and the mean counts at the standard depths was inverse. When the counts rose, the weights dropped, and vice versa. The lack of correlation was attributed to the presence of sand in the samples. The 1967 data support this hypothesis, for in that year storm-caused turbulence was at a minimum and the mean ash-free and dry weights, in general, varied directly with the mean counts at each depth. The factors causing variations in the counts, therefore,

TABLE XIII

NATURALLY OCCURRING PERIPHYTON DRY WEIGHTS AT THE STANDARD SAMPLING DEPTHS, STONY POINT BAY, LAKE SUPERIOR, 1967. MILLIGRAMS PER SQUARE CENTIMETER OF ROCK SURFACE.

	Depth in Feet					
Date	2.5	5	10	15	20	35
7-11	28.8	7.4	9.0	7.8	3.3	6.0
7-13	30.0	8.7	4.4	6.2	9.2	7.9
7-17	19.7	26.1	9.6	6.1	7.4	--*
7-20	33.3	10.7	10.5	10.8	4.7	8.1
7-26	39.8	18.4	16.5	14.5	8.1	8.4
7-27	38.9	17.2	17.7	15.2	7.2	7.3
8-2	28.9	14.4	16.2	17.6	8.5	11.0
8-4	14.8	5.9	12.7	18.8	13.8	9.0
8-8	21.2	19.8	10.4	11.3	27.8	10.5
8-10	12.5	20.3	9.0	10.6	11.5	10.4
8-14	27.9	11.7	9.2	16.7	15.8	10.9
8-17	21.4	13.6	14.3	17.9	12.1	10.5
8-25	21.9	36.0	44.3	14.0	20.3	13.9
8-28	23.3	29.6	10.5	14.8	9.3	13.6
9-5	52.0	21.5	12.1	4.8	13.7	19.6
9-15	39.5	28.8	10.7	3.1	17.5	17.2
11-10	21.3	20.3	17.5	13.4	17.0	13.8
Mean	27.9	18.2	13.8	11.9	12.1	10.4

TABLE XIV

NATURALLY OCCURRING PERIPHYTON ASH-FREE DRY WEIGHTS AT THE STANDARD SAMPLING DEPTHS, STONY POINT BAY, LAKE SUPERIOR, 1967. MILLIGRAMS PER SQUARE CENTIMETER OF ROCK SURFACE.

	Depth in Feet					
Date	2.5	5	10	15	20	35
7-11	2.58	1.44	1.23	1.02	0.64	1.14
7-13	1.86	0.97	0.58	0.63	0.63	0.63
7-17	0.72	1.38	0.98	0.46	0.84	--*
7-20	1.95	1.26	1.03	0.85	0.47	0.69
7-26	3.43	2.64	2.00	1.22	1.05	1.07
7-27	1.99	1.60	1.38	1.11	0.30	0.96
8-2	1.66	1.50	2.07	1.29	0.97	1.09
8-4	0.85	0.70	1.12	1.22	0.97	1.04
8-8	1.71	1.88	1.19	1.10	1.97	1.58
8-10	0.68	1.36	0.71	0.55	0.72	0.80
8-14	1.15	0.88	0.52	0.93	1.08	0.82
8-17	1.46	1.02	1.01	0.77	0.72	1.61
8-25	1.39	1.92	2.25	1.01	1.66	1.18
8-28	1.90	2.35	1.38	1.81	1.04	1.48
9-5	3.48	2.37	1.50	0.88	1.82	2.32
9-15	1.90	1.82	0.81	0.33	1.25	1.65
11-10	0.33	0.73	0.85	0.44	0.55	1.17
Mean	1.70	1.51	1.21	0.91	0.98	1.20

* Sample was lost

can also be cited as causing variations in the weights. These factors were primarily the weather, temperature, and light intensity. The optimal weather conditions of 1967 probably explain why the total weight figure (55.5 tons or 156 g./m.^{2}) for that year was higher than the 1966 figure (37.1 tons or 104 g./m.^{2}).

Determinations of ash-free dry weights were made during 1967 in order to eliminate inconsistencies caused by the presence of sand, although this factor was minimal in 1967. By comparing Figures 11 through 16 to Figures 5 through 10, it can be seen that the individual ash-free dry weights and the counts show an apparent positive correlation over the entire sampling season at each depth. To test this theory, regression lines were constructed (Figures 17 through 22) using the least squares method. Counts (y axis) were plotted against ash-free dry weights (x axis). The correlation coefficients (r) and probability values (P) are presented with the regression lines. The correlation coefficients were positive for all depths, ranging from .492 at fifteen feet to .775 at ten feet. Probability values ranged from 0.05 at fifteen feet to 0.001 at ten and thirty-five feet. From these figures, it can be stated that to predict total counts from ash-free dry weights, one would be safest in choosing samples from ten and thirty-five feet. At these two depths, the correlations were the best and the probability values were lowest. The other depths also showed positive correlations between counts and weights, but were accompanied by slightly higher probability values.

It has been mentioned several times that as the depth of the water increases, the temperature drops and the amount of light reaching the bottom decreases. Table XV and Figure 23 substantiate these assumptions. Table XV shows the water temperatures of Stony Point Bay on all the collection days at each sampling depth (just above the bottom) as well as immediately below the surface. Two trends are obvious. The water temperatures decreased with increasing depth and increased at all depths as the summer progressed, reaching a maximum around August 14. For the whole season, the highest temperature (19.5°C.) was recorded at the surface and the coldest water (4.5°C.) was encountered by SCUBA divers at a depth of thirty-five feet on July 11, twenty and thirty-five feet on July 13, and thirty-five feet on November 10.

The light intensities reaching depths of water corresponding to the sampling depths are presented in Figure 23. Each point on the curve is an average of the light intensities in foot candles recorded at that particular depth on the seventeen sampling days. The average intensity of the sunlight striking the deck photometer was 7,275 foot candles. This figure was reduced to 5,600 foot candles by six inches of water. As expected, the intensity of the sunlight diminished gradually with depth, reaching a minimum of 265 foot candles at thirty-five feet. In general, readings were made near mid-day.

The hypothesis that decreased light intensity is responsible for the fact that the counts were lower in deeper water is supported by results reported by Ryther (1956b). In studying the effect of light on cultures of marine diatoms (Skeletonema costatum, Nitzschia closterium, and Navicula sp.), Ryther found that these organisms photosynthesized most effectively at light intensities of 1,000 to 2,200 foot candles. Below 1,000 foot candles, photosynthesis dropped rapidly. At 500 foot candles, for instance, a fifty per cent reduction occurred. From Figure 23, it can be seen that in Stony Point Bay at depths greater than about seventeen feet the light intensity is less than 1,000 foot candles. The minimum readings were taken at thirty-five feet and averaged 265 foot candles. At thirty-

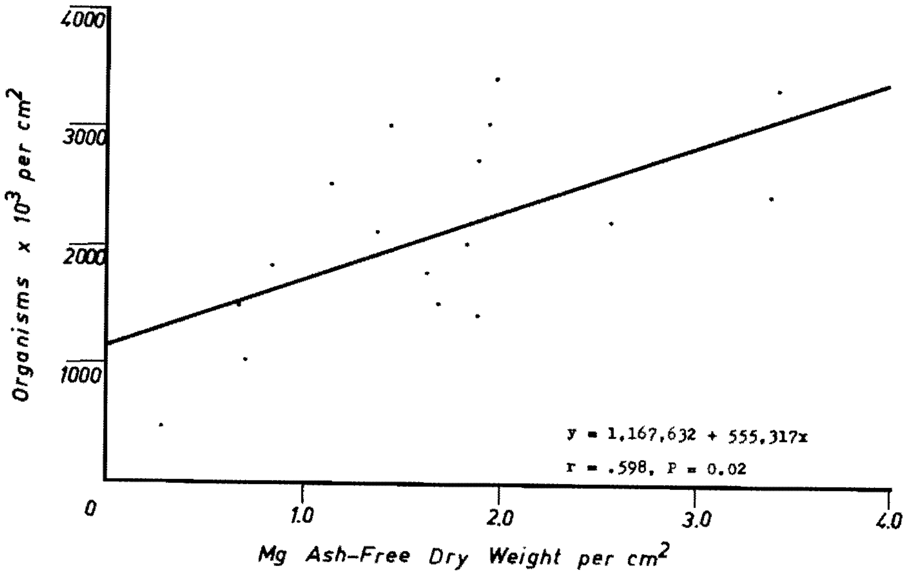

Figure 17. Counts versus ash-free dry weights, naturally occurring periphyton, 2.5 foot samples, Stony Point Bay, Lake Superior, 1967.

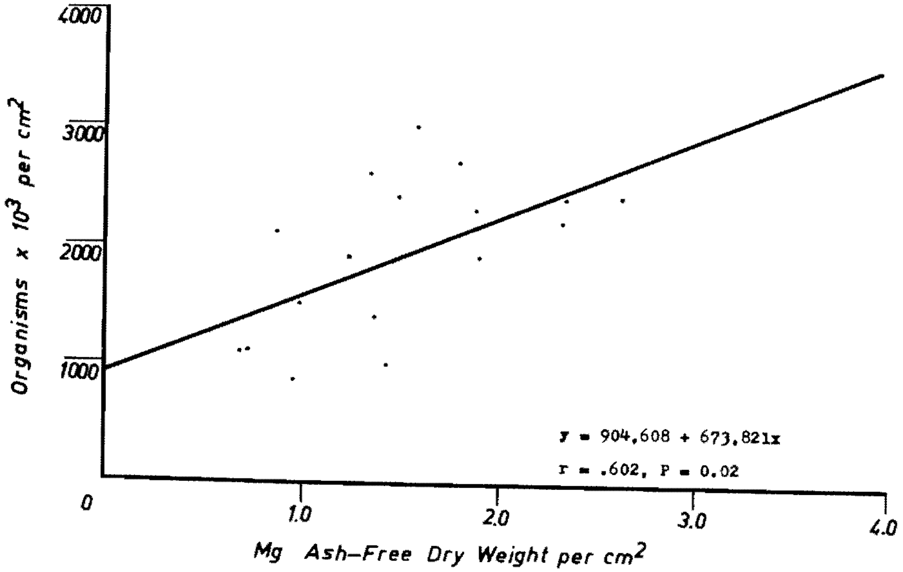

Figure 18. Counts versus ash-free dry weights, naturally occurring periphyton, five foot samples, Stony Point Bay, Lake Superior, 1967.

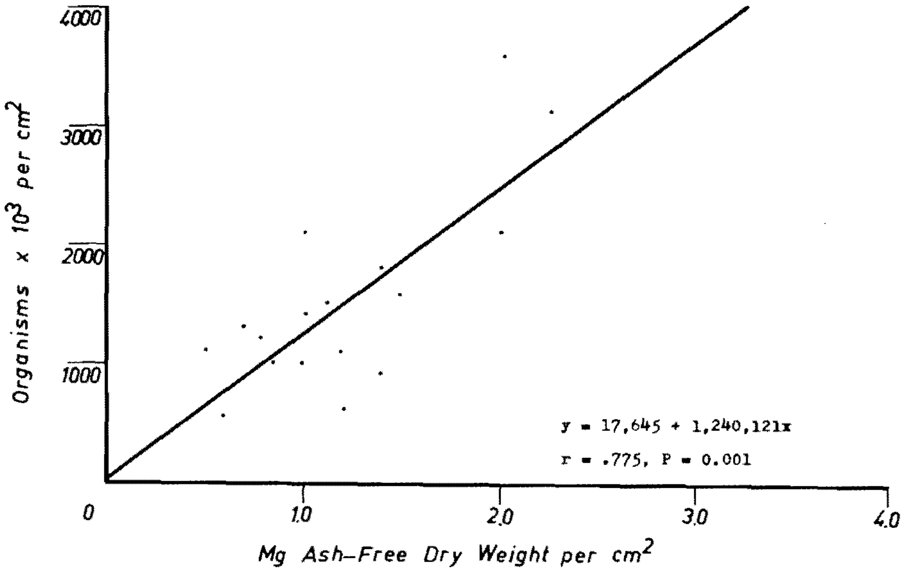

Figure 19. Counts versus ash-free dry weights, naturally occurring periphyton, ten foot samples, Stony Point Bay, Lake Superior, 1967.

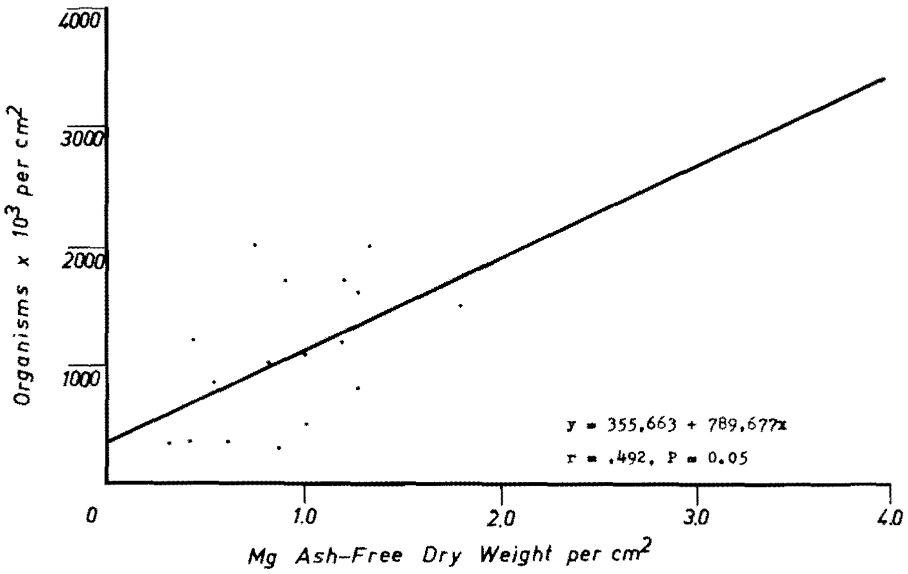

Figure 20. Counts versus ash-free dry weights, naturally occurring periphyton, fifteen foot samples, Stony Point Bay, Lake Superior, 1967.

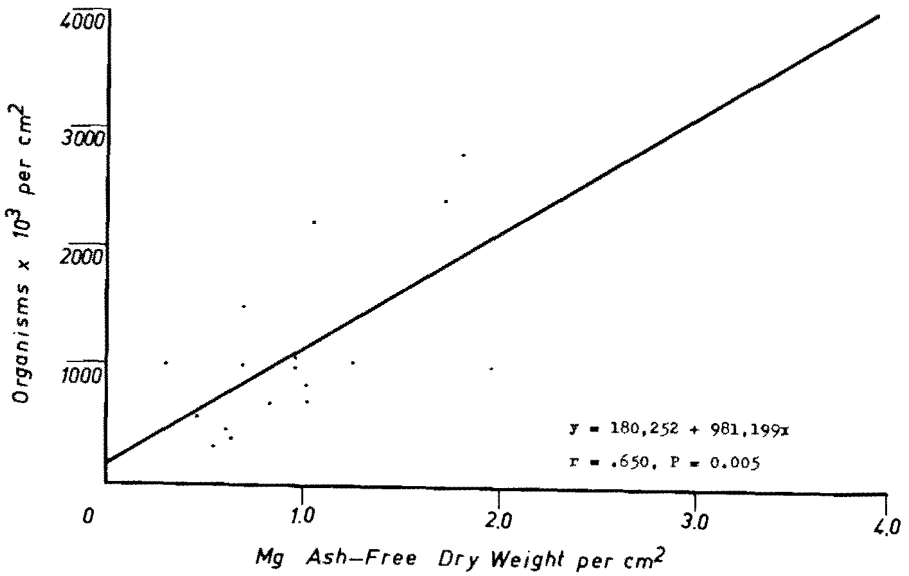

Figure 21. Counts versus ash-free dry weights, naturally occurring periphyton, twenty foot samples, Stony Point Bay, Lake Superior, 1967.

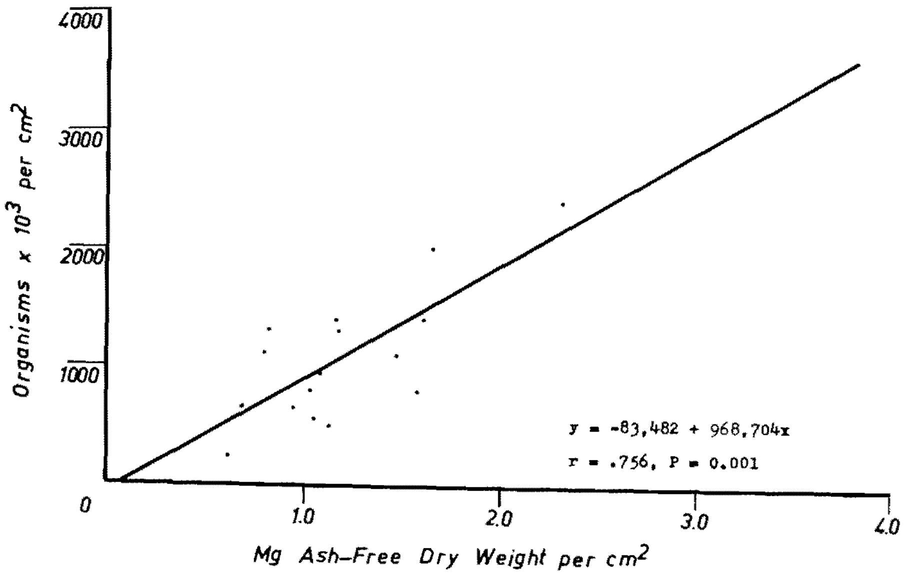

Figure 22. Counts versus ash-free dry weights, naturally occurring periphyton, thirty-five foot samples, Stony Point Bay, Lake Superior, 1967.

TABLE XV

WATER TEMPERATURES AT THE SURFACE AND THE BOTTOM AT THE STANDARD SAMPLING DEPTHS, STONY POINT BAY, LAKE SUPERIOR, 1967. DEGREES CENTIGRADE.

Date	Depth in Feet						
	0.5	2.5	5	10	15	20	35
7-11	6.5	6.5	6.0	5.5	5.5	5.0	4.5
7-13	6.0	6.0	6.0	6.0	5.0	4.5	4.5
7-17	6.5	6.5	6.5	5.5	5.5	5.5	5.0
7-20	7.5	7.5	7.0	7.0	6.0	5.5	5.0
7-26	8.0	8.0	7.5	6.5	5.5	5.0	5.0
7-27	9.5	9.5	9.0	7.5	6.0	5.0	5.0
8-2	11.0	10.5	10.5	10.5	9.5	6.5	5.5
8-4	12.5	12.5	12.5	12.0	10.0	8.0	7.0
8-8	16.5	16.0	15.0	15.0	15.0	10.0	8.5
8-10	18.0	18.0	17.5	15.0	14.5	13.5	9.5
8-14	19.5	19.5	19.0	17.5	16.0	14.0	9.5
8-17	17.7	17.0	17.0	16.0	11.0	11.0	8.3
8-25	16.5	16.0	15.5	15.5	12.0	11.0	9.5
8-28	15.5	15.5	15.5	15.0	13.5	12.5	9.5
9-5	16.0	15.5	15.0	15.0	14.0	13.5	9.5
9-15	15.5	15.0	14.5	14.5	14.5	14.0	7.0
11-10	7.5	6.5	5.5	5.0	4.5	4.5	4.5

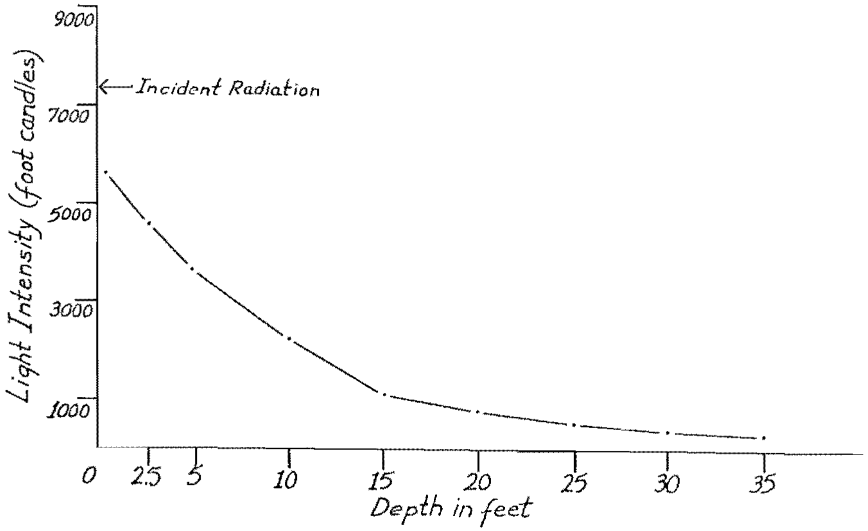

Figure 23. Average light intensity near mid-day, Stony Point Bay, Lake Superior, 1967.

five feet, the total counts were, on the average, fifty per cent of the counts from 2.5 feet. Whether or not a reduction in photosynthesis is directly related to reduction of total counts was not determined. It seems logical to assume, however, that a reduction in photosynthesis would retard growth rate and, over a period of time, result in populations consisting of fewer organisms. In his study, Ryther also found that light intensities greater than 2,200 foot candles had an inhibitory effect on the photosynthesis of the diatoms. The deleterious effect of high light intensity on photosynthesis was less marked than the low intensity effect. At 5,000 foot candles, relative photosynthesis was reduced fifty per cent. The high counts of organisms from the shallow depths of Stony Point Bay, where light intensity was probably the greatest, do not indicate that Lake Superior periphyton is inhibited by high light intensity. One explanation is that near shore, where the samples were taken, wave-caused turbidity probably filtered out harmful light.

The kinds and numbers of organisms found in the naturally occurring periphyton of oligotrophic waters have been determined only infrequently. Foerster and Schlicting (1965) studied the epiphytic periphyton growing upon leaves of rooted aquatic plants in an oligotrophic Texas lake. Their methods were similar to those used in this study. SCUBA diving procedures were employed to snip leaves from submerged plants. The leaf surfaces were washed free of periphyton and measured for area. Foerster and Schlicting found that most of the organisms growing on the leaves were diatoms, although five phyla of algae were represented. On the average, the counts obtained were from 300,000 to 500,000 organisms per square centimeter of leaf surface. These counts are comparable to those found for Lake Superior periphyton, especially those made in 1966, when a relatively lower growth level occurred. The diatoms found by Foerster and Schlicting included many genera observed in Lake Superior periphyton. Examples are Achnanthes, Synedra, Navicula, Nitzschia, Gomphonema, and Diatoma. The phyla they encountered were the three found in Lake Superior (Chrysophyta, Chlorophyta, and Cyanophyta), as well as Euglenophyta and Pyrrophyta.

Douglas (1958), whose bottomless plastic bottle sampling technique was described earlier, also made a quantitative study of naturally occurring periphyton. Her study dealt with the periphyton of a stream in England. She concluded that her sampling apparatus was practical only for the collection of diatoms. Since this was a stream study, the organisms found could be expected to differ from those found in Lake Superior. This was not so, for the diatoms Douglas found were primarily Achnanthes, which usually varied in numbers from 100,000 to 500,000 per square centimeter of permanent rock surface. She recorded over a million per square centimeter several times. On stones in the stream, however, the maximum Achnanthes count was 270,000 per square centimeter. The other commonly occurring genera were Synedra, Gomphonema, Cocconeis, Eunotia, Ceratoneis, and Cymbella. Douglas concluded that the substratum and the weather affect the number of organisms that occur. More diatoms were present on permanent rock than on stones. Rainstorms caused high water which scoured the substratum and removed the periphyton. The latter finding was also made by McIntire (1966), who observed that increased velocity adversely affects the periphyton growth in a laboratory stream. Lake Superior findings indicate that currents produced by storm winds scour the rocks, particularly in shallow water, and thereby reduce periphyton populations. Additional findings of Douglas showed that there did not seem to be a relationship between temperature or light intensity and growth of diatoms. In a shallow stream, however, light and temperature are not reduced by depth as they are in Lake Superior.

The general similarity between Douglas' findings and ours indicate that the periphyton environment in Lake Superior is not entirely unlike that of a stream. Moving masses of lake water constantly supply the attached growth with nutrients and flush away harmful metabolic by-products. The analogy is especially valid for the shallow water area of Lake Superior, for here the temperature and light intensity probably approach levels found in streams.

Duffer and Dorris (1966), like Douglas, concluded that the substratum affects the amount of periphyton growth that is produced. In studying the Blue River in Oklahoma, they found that "aufwuchs" productivity was higher on a granite substratum than it was on limestone or sand. They concluded that a major factor in determining the magnitude of a stream's productivity is a favorable attachment surface for "aufwuchs". Genera of organisms found in Blue River periphyton included Leptodictyon, Diatoma, Melosira, Synedra, Spirogyra, Rhizoclonium, Schizothrix, and Cladophora. Duffer and Dorris also point out the fact that high productivity is not limited to organically enriched waters. The Blue River, Florida artesian springs, and Pacific coral reefs are examples of oligotrophic areas with high productivity.

The fact that the bodies of flowing water just discussed support genera of periphyton identical to Stony Point Bay genera emphasizes the ecological similarity between the bay and a stream. Furthermore, the findings of Douglas (1958) and Duffer and Dorris (1966) were not atypical. In her 1948 article, Ruth Patrick states that "in fast flowing streams only those forms which can attach themselves by gelatinous mass[es] or stalks can survive. Thus the typical genera of such habitats are Achnanthes, Cocconeis, Cymbella, and Gomphonema. Ceratoneis arcus is also considered a typical stream species." All of these organisms were found in Stony Point Bay periphyton, some in quite high numbers.

To classify a lake solely on the grounds of its algal components (either phytoplankton or periphyton) would be, at best, risky. The status of many of the so-called indicator species is uncertain. Rawson (1956), in a paper dealing with the phytoplankton of the Great Lakes and large oligotrophic lakes in western Canada, discusses several of these and questions species generally thought to be indicative of eutrophy. Patrick (1948), for instance, calls Asterionella formosa an indicator of eutrophic water while Rawson places the same species at the head of his list of indicators of oligotrophic waters. Often, the absence of certain groups of organisms may be as, or more, indicative of water quality than the presence of others. Thus, in Lake Superior, the fact that large numbers of Cyanophytes are not present is indicative of oligotrophy, for blue-greens grow best in water with a high nutrient content.

Many of the species of diatoms have a wide range of requirements and may occur under almost any conditions. Neel (1953), for instance, found Diatoma, Navicula, Gomphonema, Rhoicosphenia, Synedra, and Cymbella in the the periphyton of what he considered a polluted irrigation stream. All these forms are also present in Lake Superior periphyton. It might be added that Neel also found large numbers of blue-greens.

As long as it is realized that the presence or absence of particular species of organisms is the result of a great variety of physical, chemical and biological factors, biological indicators may be used to draw certain conclusions regarding a particular body of water. The validity of the conclusions depends a great deal on the number of physical and chemical factors known. The similarity between the abundant forms in Lake Superior periphyton and the forms present in oligotrophic streams and lakes suggests that the water of Stony Point Bay is relatively clean. Rawson (1956) lists species of the following genera as being indicators of oligotrophy: Asterionella, Tabellaria, Dinobryon, Fragilaria, Stephanodiscus, Staurastrum, and Melosira. In the oligotrophic lakes he studied, diatoms comprised eighty to ninety per cent of the phytoplankton populations. Rawson concludes by stating that only a few algal species can be used to indicate oligotrophy, whereas many species are limited to eutrophic waters. Thus, some organisms need, while others only prefer, high concentrations of nutrients. Very few, however, prefer low nutrient concentrations. This latter group would be indicators of oligotrophy. It is not surprising that there are so few of them. Although Rawson was discussing only phytoplankters, it seems logical to assume that his conclusions would also apply to organisms in the periphyton.

Regrowth, Stony Point Bay

The 1967 regrowth study was conducted from July 31 to November 9. During this time interval, eighty-four denuded, autoclaved rocks that had been replaced in the lake were recovered from depths of ten, twenty, and thirty-five feet. "Incubation" times ranged from eight hours to 101 days. The total counts at the time of each collection for all three depths is shown in Figure 24. In general, the counts increased with increased "incubation" times. Counts of samples from ten feet were higher than counts of twenty foot samples "incubated" for the same amount of time. Accordingly, the twenty foot counts were higher than the thirty-five foot counts. At ten feet, the counts reached 30,000 per square centimeter after eight hours and climbed to 370,500 per square centimeter after forty-six days of "incubation". These ten foot counts always remained higher than counts of samples from the other two depths "incubated" for the same period of time. In the same forty-six day time interval, the twenty foot counts went from 16,000 per square centimeter to 340,600 per square centimeter. The thirty-five foot samples ranged from 8,000 organisms per square centimeter after eight hours of "incubation" to 215,500 per square centimeter after forty-six days. By November 9, the count had dropped to 129,200 per square centimeter. In general, the counts rose fairly regularly with time at all depths.

A checklist of the organisms occurring as regrowth is given in Table XVI. A total of at least forty-seven species representing thirty genera and three phyla were found. Forty of the species (eighty-five per cent) and twenty-three of the genera (seventy-seven per cent) were diatoms. Dinobryon sertularia was the only "non-diatom" Chrysophyte observed. Two species of greens and four species of blue-greens were found.

The numbers of organisms in each of the three phyla, as well as the total counts of all the regrowth samples, are shown in Table XVII. No averages are presented, for they would be meaningless in this type of study. In all but one of the samples, the phylum Chrysophyta comprised over ninety per cent of the total number of organisms. The vast majority of the Chrysophytes were diatoms, for Dinobryon sertularia was present in low numbers and appeared only near the end of the sampling season. Since most of the organisms were diatoms, their variation may be seen graphically in Figure 24, which shows the total counts for each depth versus "incubation" time.

By looking at Table XVII, it can be seen that the greens and blue-greens do show a rising trend with increased "incubation" times. Because of the fact that they occurred in such small numbers, however, any conclusions that might be drawn by looking at these figures would be highly

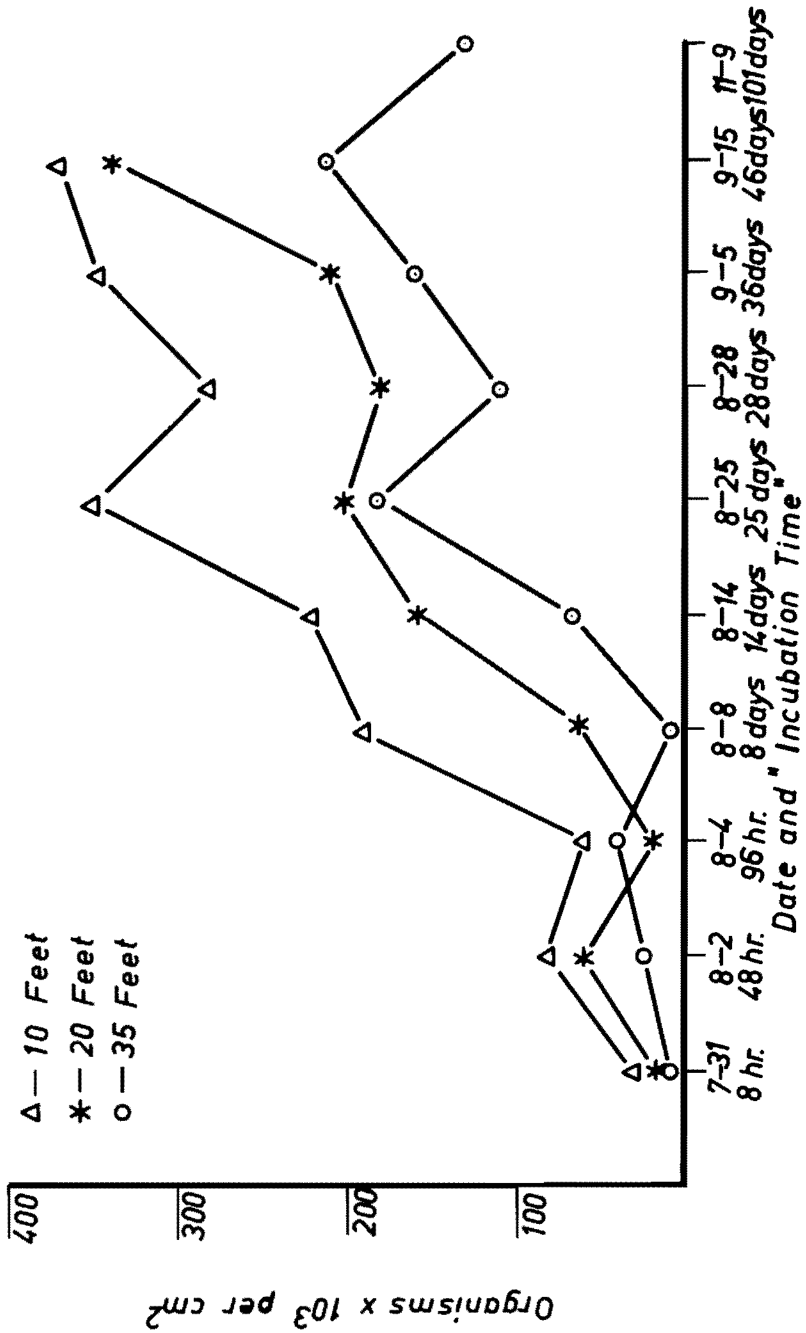

Figure 24. Total counts of periphyton appearing as regrowth, Stony Point Bay, Lake Superior, 1967.

TABLE XVI

ORGANISMS OCCURRING AS REGROWTH ON ARTIFICIALLY DENUDED ROCKS, STONY POINT BAY, LAKE SUPERIOR, 1967.

Phylum Chrysophyta

Class Bacillariophyceae
- *Achnanthes microcephala* (Kuetzing) Cleve
- *Amphora ovalis* Kuetzing
- *Amphora normani* Rabenhorst
- *Asterionella formosa* Hassall
- *Ceratoneis arcus* (Ehrenberg) Kuetzing
- *Cocconeis* group*
- *Cyclotella* group*
- *Cymatopleura solea* (Brebisson) Wm. Smith
- *Cymbella* group A*
- *Cymbella* group B*
- *Denticula thermalis* Kuetzing
- *Diatoma elongatum* C.A. Agardh var. *tenuis* (Agardh) Van Heurck
- *Fragilaria capucina* Desmazieres
- *Fragilaria harrisonii* (Wm. Smith) Grunow
- *Frustulia viridula* (Brebisson) DeToni
- *Gomphoneis herculeana* (Ehrenberg) Cleve
- *Gomphonema* group
- *Melosira granulata* (Ehrenberg) Ralfs
- *Navicula* group*
- *Nitzschia palea* (Kuetzing) Wm. Smith
- *Nitzschia vermicularis* (Kuetzing) Hantzsch
- *Pinnularia viridis* (Nitzsch) Ehrenberg
- *Rhizosolenia eriensis* H. L. Smith
- *Stauroneis producta* Grunow
- *Surirella* group*
- *Synedra acus* Kuetzing
- *Synedra ulna* (Nitzsch) Ehrenberg
- *Tabellaria fenestrata* (Lyngbye) Kuetzing
- *Tabellaria flocculosa* (Roth) Kuetzing

Class Chrysophyceae
- *Dinobryon sertularia* Ehrenberg

Phylum Chlorophyta
- *Cosmarium* sp.
- *Scenedesmus quadricauda* (Turpin) Brebisson

Phylum Cyanophyta
- *Anabaena* sp.
- *Lyngbya* sp.
- *Merismopedia convoluta* Brebisson
- *Oscillatoria* sp.

*See Table IX for the species comprising this group.

TABLE XVII

PHYLA AND COUNTS OF ORGANISMS OBSERVED IN REGROWTH PERIPHYTON, STONY POINT BAY, LAKE SUPERIOR 1967.
ORGANISMS X 10^3 PER SQUARE CENTIMETER OF ROCK SURFACE.

Depth in Feet	Phylum	*Date and "Incubation Time"									
		Jul 31 8 hrs.	Aug 2 48 hrs.	Aug 4 96 hrs.	Aug 8 8 days	Aug 14 14 days	Aug 25 25 days	Aug 28 28 days	Sep 5 36 days	Sep 15 46 days	Nov 9 101 days
10	Chrysophyta	28.8	76.0	55.7	184.7	212.5	345.7	278.1	338.7	368.3	N.S.
	Chlorophyta	0.5	1.0	4.5	2.7	3.7	5.9	0.9	5.1	---	
	Cyanophyta	1.0	3.0	---	---	12.3	5.9	5.5	7.7	2.2	
	TOTAL	30.3	80.0	60.2	187.4	228.5	357.5	284.5	351.5	370.5	
20	Chrysophyta	16.1	60.1	21.4	57.0	146.9	190.8	177.1	193.4	314.2	N.S.
	Chlorophyta	---	---	---	3.4	5.3	3.9	0.7	0.6	1.8	
	Cyanophyta	---	0.7	1.6	---	8.4	9.6	4.8	20.5	24.6	
	TOTAL	16.1	60.8	23.0	60.4	160.6	204.3	182.6	214.5	340.6	
35	Chrysophyta	8.0	25.3	38.4	8.4	66.0	173.6	102.2	149.9	208.3	123.9
	Chlorophyta	---	---	1.1	1.4	---	3.3	4.2	1.0	2.4	---
	Cyanophyta	---	---	---	----	---	5.5	3.4	6.9	4.8	5.3
	TOTAL	8.0	25.3	39.5	9.8	66.0	182.4	109.8	157.8	215.5	129.2

*Dash indicates zero; N.S. indicates no sample was collected.

speculative. It can only be pointed out that greens and blue-greens did appear as regrowth, but in relatively low numbers.

All of the organisms appearing as regrowth, their counts, and their per cent contribution to the total are shown in Table XVIII (see the Appendix). In this table, the organisms are listed in alphabetical order. In all cases, the two predominant organisms were Synedra acus and Achnanthes microcephala. Together, these two diatoms comprised an average of sixty-eight per cent of the total counts at all three depths. They were the only organisms which were found on all days at all depths. In terms of percentage contribution to the total, Achnanthes microcephala climbed regularly at all depths with increasing "incubation" time, as did Synedra acus. For the whole study, Synedra acus was predominant. Among the initial colonizers, on the other hand, Achnanthes microcephala was the predominant form. In terms of percentage of the total, Achnanthes microcephala, with one exception, was higher than Synedra acus after eight and forty-eight hours of "incubation" at all depths. The exception was at ten feet after eight hours. Graphically, the order of predominance (in absolute numbers and percentage contribution to the total) of Achnanthes microcephala (A) and Synedra acus (S) according to incubation time and depth may be presented as follows:

	8 hrs.	48 hrs.	96 hrs.	8 days	14-46 days
10 feet	S	A	S	S	S
20 feet	A	A	S	S	S
35 feet	A	A	A	A	S

The fact that Achnanthes microcephala was the initial colonizer supports the earlier conclusion that one of the reasons Achnanthes was predominant in 1966, when rough weather occurred, was its superior mode of attachment.

The two other primary colonizers at all depths in the 1967 regrowth study appeared to be Navicula spp. and Gomphonema spp. Fairly substantial numbers of Cymbella spp. (group B) appeared early at ten feet. After a week of regrowth, Asterionella formosa, Cocconeis spp., Cyclotella spp., Cymbella spp. (group B), Melosira granulata and the unidentified blue-greens appeared regularly at all depths.

The dry and the ash-free dry weights of the regrowth periphyton are shown in Table XIX. In general, the weights increased with prolonged "incubation" time and decreased with depth. Since the weights of two groups of samples collected after different "incubation" times are not comparable, means for these weights are not presented. When the weights obtained on the last regular day of sampling (September 15) are divided by their "incubation" time (forty-six days), a daily production rate can be calculated. For the dry weights at ten, twenty, and thirty-five feet the rates are 5.76, 2.26, and 2.77 grams per square meter per day. On the basis of the ash-free dry weights, comparable figures for the three depths are 0.09, 0.05, and 0.06 grams per square meter per day.

Figures 25 through 27 show the regression lines obtained when one attempts to predict total counts from ash-free dry weights. Correlation coefficients and probability values are presented with the regression lines. The best correlation coefficient (.803) and the lowest probability value (0.01) were obtained with the data from ten feet. Although the correlation coefficients for the twenty and thirty-five foot data (.574 and .605) were not exceedingly low, their corresponding probability values were quite high (0.1 for both) because of the low number of samples.

TABLE XIX

DRY AND ASH-FREE DRY WEIGHTS OF PERIPHYTON OCCURRING AS REGROWTH, STONY POINT BAY, LAKE SUPERIOR, 1967. MILLIGRAMS PER SQUARE CENTIMETER OF ROCK SURFACE.

Dry Weight				Ash-Free Dry Weight			
	Depth in Feet				Depth in Feet		
Date	10	20	35	Date	10	20	35
7-31	.68	.28	.62	7-31	.06	.02	.04
8-2	.54	.27	.30	8-2	.17	.01	.09
8-4	1.65	.80	.59	8-4	.23	.18	.17
8-8	1.92	1.83	.78	8-8	.45	.18	.13
8-14	5.03	6.96	5.36	8-14	.64	.57	.54
8-25	13.18	7.49	12.82	8-25	1.21	.52	.77
8-28	16.53	11.71	6.10	8-28	.49	.37	.26
9-5	7.97	9.48	4.22	9-5	1.03	.40	.75
9-15	26.49	10.41	12.75	9-15	.43	.24	.29
11-9	N.S.*	N.S.	7.02	11-9	N.S.	N.S.	.13

* N.S. means no sample was collected.

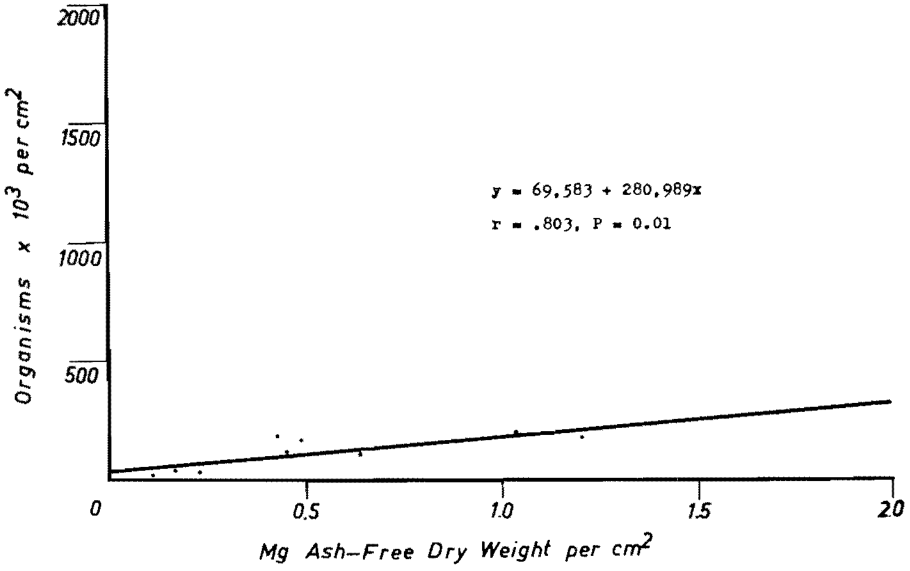

Figure 25. Counts versus ash-free dry weights, regrowth study, ten foot samples, Stony Point Bay, Lake Superior, 1967.

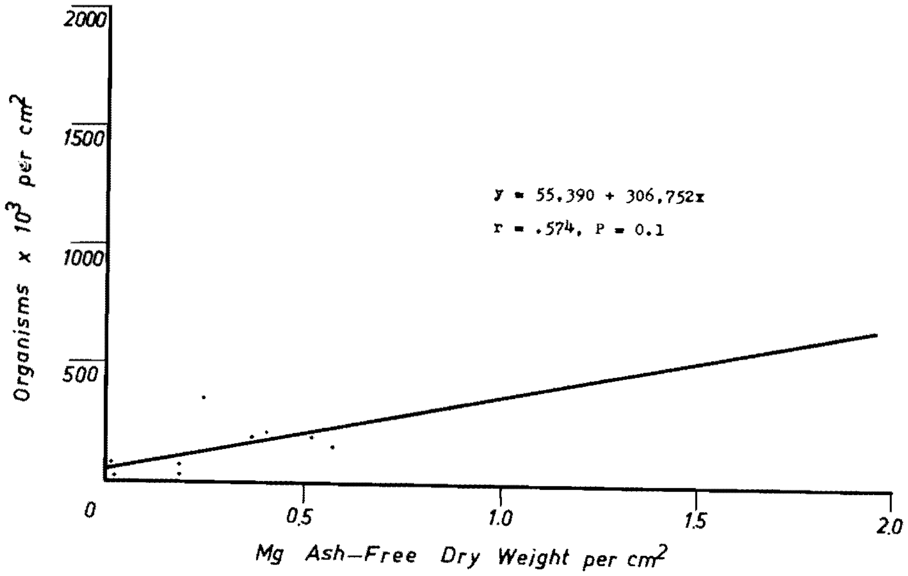

Figure 26. Counts versus ash-free dry weights, regrowth study, twenty foot samples, Stony Point Bay, Lake Superior, 1967.

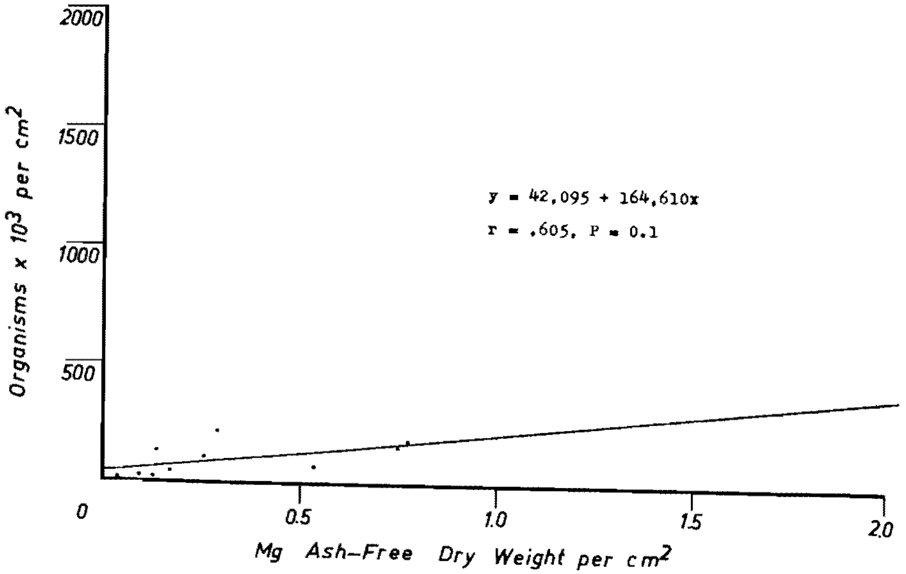

Figure 27. Counts versus ash-free dry weights, regrowth study, thirty-five foot samples, Stony Point Bay, Lake Superior, 1967.

Since only qualitative regrowth data was obtained during 1965, quantitative comparisons to the 1967 data cannot be made. The organisms in the checklists for these two summers, however, are comparable. In 1965 (Table II), thirty-four genera of Chrysophytes, Chlorophytes, and Cyanophytes were found. In 1967, the same three phyla were represented by thirty genera. Genera observed in 1965 and not seen in the 1967 regrowth samples were: Chrysophytes - Diploneis, Rhoicosphenia, and Stephanodiscus; Chlorophytes - Actinastrum, Closterium, Coelastrum, Oedogonium, and Tetraedron. The four genera observed in the 1967 counts not seen in 1965 included one diatom, Gomphoneis, and three blue-greens: Anabaena, Lyngbya, and Oscillatoria. With these exceptions, the genera on both checklists were seen both summers. From this comparison, it can be seen that the organisms in the regrowth for 1965 and 1967 were quite similar, at least qualitatively.

In order to see how close the 1967 regrowth approximated the naturally occurring growth, the following comparison was made. The regrowth counts reached their maximum at all depths after forty-six days of "incubation". If the September 15 regrowth counts are compared to the 1967 naturally occurring counts for the same date, it will be seen that the regrowth level reached was approximately fourteen per cent of the naturally occurring growth level at ten feet, twenty-eight per cent at twenty feet, and eleven per cent at thirty-five feet. From this comparison, it is clear that the quantity of regrowth that occurs after forty-six days of "incubation" is far below the amount of naturally occurring periphyton.

In the forty-six day growth period, thirty genera of algae appeared on the rocks. In contrast, thirty-eight genera were found in the naturally occurring periphyton in 1967. The only genus that appeared as regrowth and was not seen in the naturally occurring periphyton was Cosmarium, which appeared in very low numbers in only one sample. Genera of naturally occurring periphyton that did not appear in the regrowth in 1967 were: Chrysophyta - Gyrosigma and Rhoicosphenia; Chlorophyta - Ankistrodesmus, Cladophora, Closterium, Pediastrum, Spirogyra, and Tetraedron: Cyanophyta - Raphidiopsis. All of these genera, most of which are greens, appeared in relatively low numbers. The fact that they did not appear as regrowth is probably not significant. The most common genera in the naturally occurring periphyton of 1967 were also the most numerous regrowth forms. On the basis of the means of the September 15 counts from the three depths for each organism, the most abundant forms in the regrowth, in order, were Synedra acus, Achnanthes microcephala, Navicula spp., Cymbella spp. (group B), and Gomphonema spp. These were also the five most commonly occurring organisms in the 1967 naturally occurring periphyton. Even the order of abundance was almost identical. In the naturally occurring periphyton, Gomphonema spp. was more common than Cymbella spp. (group B). The naturally occurring periphyton populations and those occurring as regrowth both showed a preponderance of diatoms in all samples; low numbers of greens and blue-greens that showed no marked trends, either seasonally or according to depth, and; a decrease in counts with increasing water depth. The primary difference between the two communities was one of quantity.

Most of the past studies encountered in the literature have dealt with periphyton occurring as regrowth on some artificial substratum. Gumtow (1955) was one of the few workers who used a natural substratum in studying periphyton regrowth. He cleaned cobblestones taken from the bank of the West Gallatin River in Montana by rinsing them in formalin. After placing them in the river for varying periods of time, he found that the most common genera of diatoms appearing as regrowth were Navicula, Diatoma, Cymbella, Cocconeis, Synedra, and Ceratoneis.

Plexiglas and glass have been the most common materials used as artificial substrata. Jackson (1967) used plexiglas plates in studying the periphyton of the eastern end of Lake Ontario. He identified the organisms occurring as regrowth to genus and estimated their abundance. He also determined their monthly biomass in terms of organic weight per square decimeter of plate surface. The most common organisms found were diatoms. Of the seventeen genera recorded, Melosira and Stephanodiscus were always common. The most abundant of the ten genera of greens observed was Cladophora, an organism which has created nuisance problems in Lakes Erie and Ontario since the early nineteen-thirties (Neil and Owen, 1964). None of the five genera of Cyanophytes were considered abundant by Jackson. All of the diatom genera reported were also observed in Lake Superior periphyton.

Kevern et al. (1966) and King and Ball (1966) also used plexiglas plates as a substratum for regrowth. Kevern et al. used this method to determine the periphyton production in a laboratory stream. Their average estimate for daily net production was 0.6 grams of organic (ash-free dry) weight per square meter per day. King and Ball arrived at a comparable figure of about 0.3 grams per square meter per day. In their study of the Red Cedar River in Michigan, they found that almost all the organisms occurring as regrowth were diatoms. The most common genera were Gomphonema, Navicula, Fragilaria, Cymbella, Cyclotella, and Synedra.

Castenholz (1960) used glass slides as a substratum in studying the periphyton of lakes in the state of Washington. Common diatoms appearing as regrowth were Achnanthes, Amphora, Cocconeis, Cymbella, Gomphonema, Navicula, Nitzschia, and Stephanodiscus. A typical high production rate was 0.5 grams per square meter per day of organic weight. Castenholz felt that glass was not unduly selective and that a two week period of submergence was sufficient for determining production rates. Foerster and Schlicting (1965), on the other hand, came to a different conclusion. After comparing the natural periphyton growth in a Texas lake to regrowth on glass slides, they stated that "the artificial barren surface gave a false impression of the productivity trends and indicated only some of the significant genera present in the ecosystem."

In looking at these regrowth results from other bodies of water, most of which were streams, it can be seen that the genera of organisms found are remarkably similar to those found in Lake Superior periphyton. The production figures, however, are a good deal higher than those found for Lake Superior periphyton. The average daily production rate for the three depths sampled in Stony Point Bay was 0.066 grams per square meter while others reported figures from streams of as high as 0.6 grams per square meter per day. Whether or not regrowth on glass or other artificial substrata is comparable to regrowth on a natural substratum is debatable, as has been shown. It must also be remembered that the Lake Superior regrowth study was conducted at depths of ten, twenty, and thirty-five feet. Had regrowth production rates been determined for the very shallow water area of Stony Point Bay, figures comparable to those reported for streams may have resulted.

Naturally occurring periphyton, north shore stations

The eleven north shore sampling areas and the distance of each from the Lester River are presented in Table XX. The geographic relationship of each of these sampling stations to the north shore of the western arm of Lake Superior is shown by Figure 28. Figures 29 through 39 are the detailed sketch maps of each sampling location.

A summary of the north shore findings is presented in Table XXI. In constructing this table, counts from all depths on the two sampling days for each station were averaged to give the mean total count. This figure is rounded off to the nearest ten thousand organisms per square centimeter of rock surface. The individual total counts for all depths on the two sampling days for each north shore station are shown in Figures 40 through 50. In Table XXI, the dry and ash-free dry weights, expressed as milligrams per square centimeter of rock surface, are also expressed as means. Individual weights are shown in Table XXII.

The five most common organisms in Table XXI were calculated on the basis of their total numbers per square centimeter of rock surface at a particular station, regardless of depth or day collected. They are presented in their order of abundance.

The water temperatures recorded while sampling the north shore stations are shown in Table XXIV.

The 1967 total counts, with only a few exceptions, were higher at the north shore stations than were counts for the same year at Stony Point Bay (1,470,000 per square centimeter). The exceptions were samples from the Lester River area, the Knife River area, and Sugar Loaf Cove. These stations were similar to Stony Point Bay.

The lowest mean count (1,466,000/cm.^{2}) was recorded at Sugar Loaf Cove. This area has been and still is the site of a large logging operation. At times, the entire cove was filled with floating logs, which undoubtedly diminished the sunlight reaching the bottom. Also, large amounts of wood chips were noted covering the rocks, again, causing a reduction in available sunlight.

Counts of over three million organisms per square centimeter were recorded at Split Rock River Bay, Good Harbor Bay, and Grand Marais. Only the Grand Marais sampling area was near a relatively large population center. It is possible that sewage effluent found its way into Grand Marais Bay. Rather extensive growths of *Ulothrix* sp. were noted in very shallow water. This green alga also appeared in the counts. Split Rock River Bay and Good Harbor Bay, on the other hand, were quite isolated and their high counts cannot be explained on the same basis as those of Grand Marais.

Neil and Owen (1964), in their paper on *Cladophora* in the Great Lakes, state that this green alga causes nuisance problems in Lake Erie and Lake Ontario. In this study, *Cladophora* was observed only at the Lester River. This growth may have been stimulated by the intermittent discharges of raw sewage directly into the lake near the sampling area. Such discharges have been observed following storms. Neil and Owen feel that increased nutrient levels, often as a result of added sewage, cause excessive growths of *Cladophora*. At Lester River, however, the growth could not be considered to be of nuisance proportions.

At Beaver Bay, which is close to the taconite operation at Silver Bay, black magnetic particles (ten to twenty microns in diameter) were observed. These did not seem to interfere with periphyton growth, for the counts were quite high (2,964,000/cm.^{2}). Interestingly enough, the highest periphyton productivity, in terms of weight, occurred at Beaver Bay.

At all eleven stations, four of the five most common organisms were *Synedra acus*, *Achnanthes microcephala*, *Cymbella* spp., and *Navicula* spp. The predominant organisms were always *Synedra acus* and *Achnanthes microcephala*. At the Lester River and at Sugar Loaf Cove, *Achnanthes microcephala* was the most common. At all other points, *Synedra acus* predominated. Occasionally appearing among the five most common organisms were *Nitzschia* spp., an unidentified blue-green (probably a small species of *Oscillatoria*),

TABLE XX

PERIPHYTON SAMPLING LOCATIONS,
NORTH SHORE, LAKE SUPERIOR.

1.	Lester River	0 miles
2.	Knife River	13.8 miles
3.	Burlington Bay	22.1 miles
4.	Split Rock River Bay	39.4 miles
5.	Beaver Bay	48.0 miles
6.	No-Name Bay (near Little Marais)	53.9 miles
7.	Sugar Loaf Cove	69.9 miles
8.	Tofte	78.8 miles
9.	Lutsen	86.3 miles
10.	Good Harbor Bay	100.9 miles
11.	Grand Marais	106.9 miles

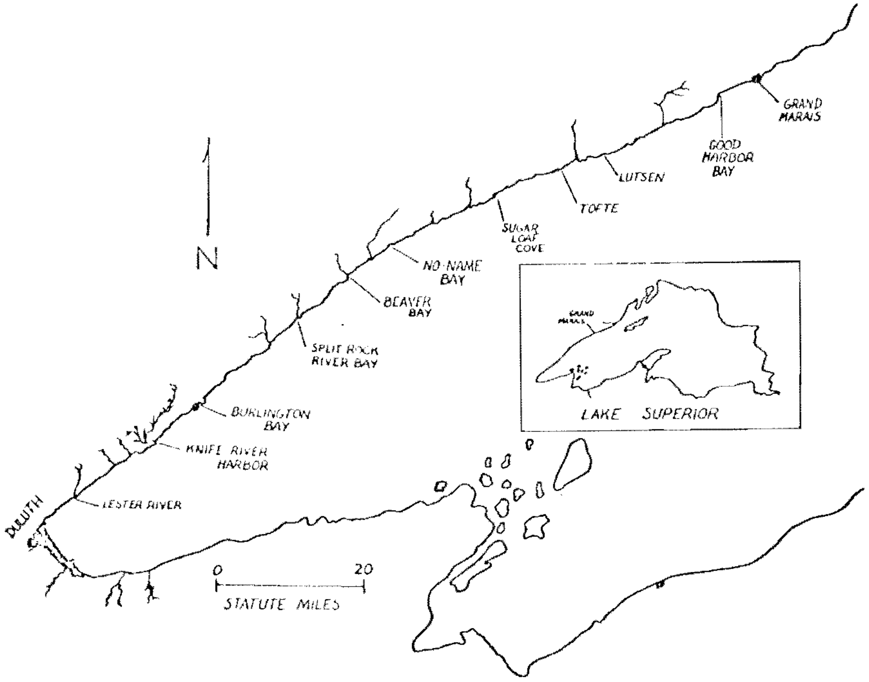

Figure 28. North shore sampling stations and the western arm of Lake Superior.

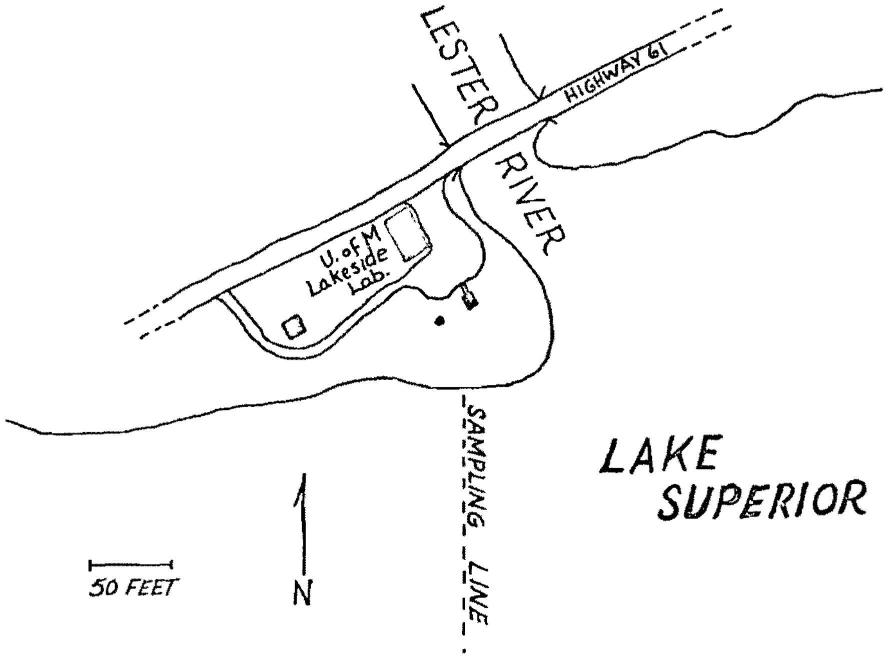

Figure 29. Lester River area, north shore, Lake Superior.

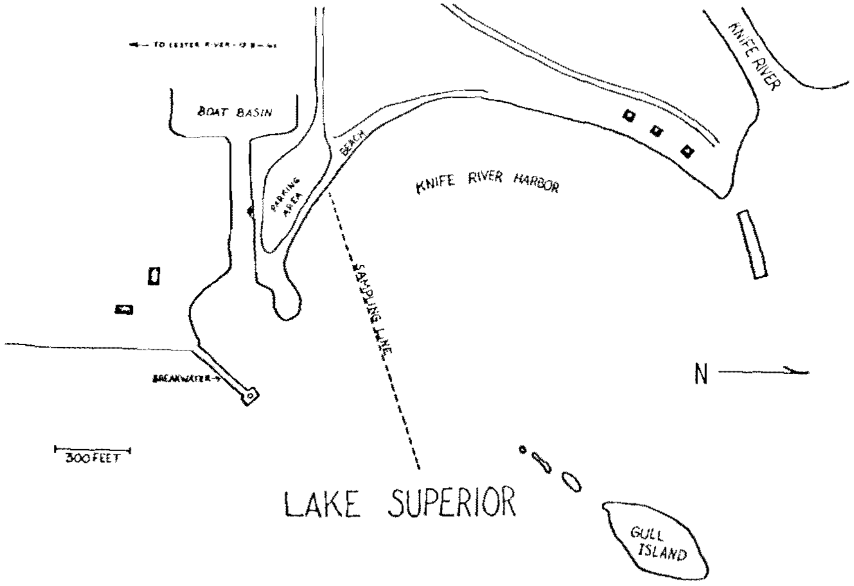

Figure 30. Knife River area, north shore, Lake Superior.

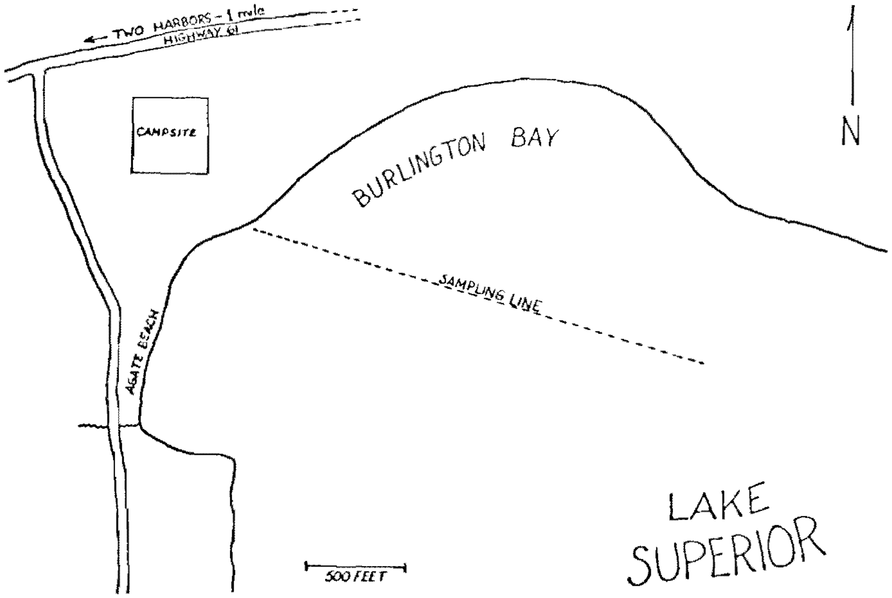

Figure 31. Burlington Bay, north shore, Lake Superior.

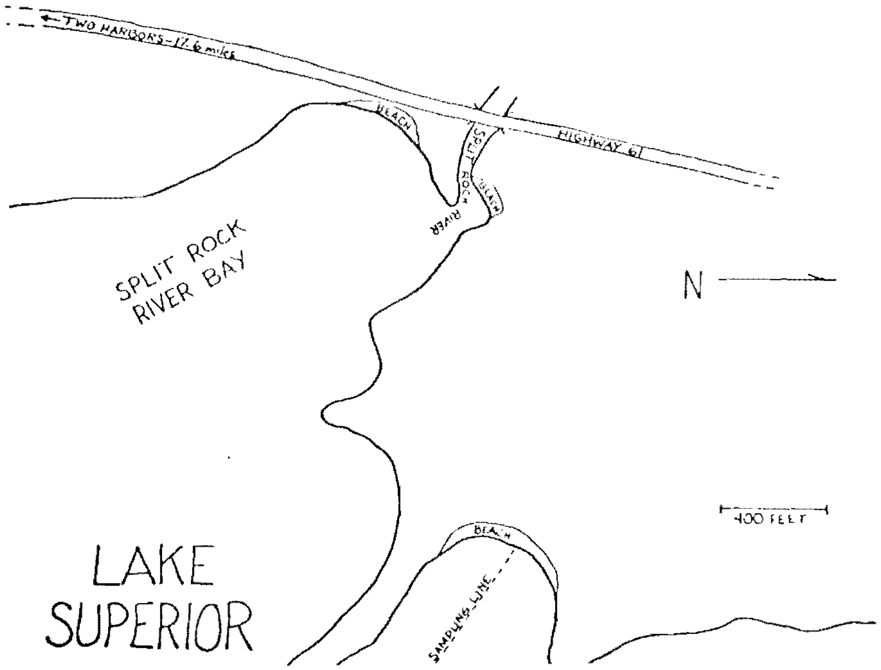

Figure 32. Split Rock River Bay, north shore, Lake Superior.

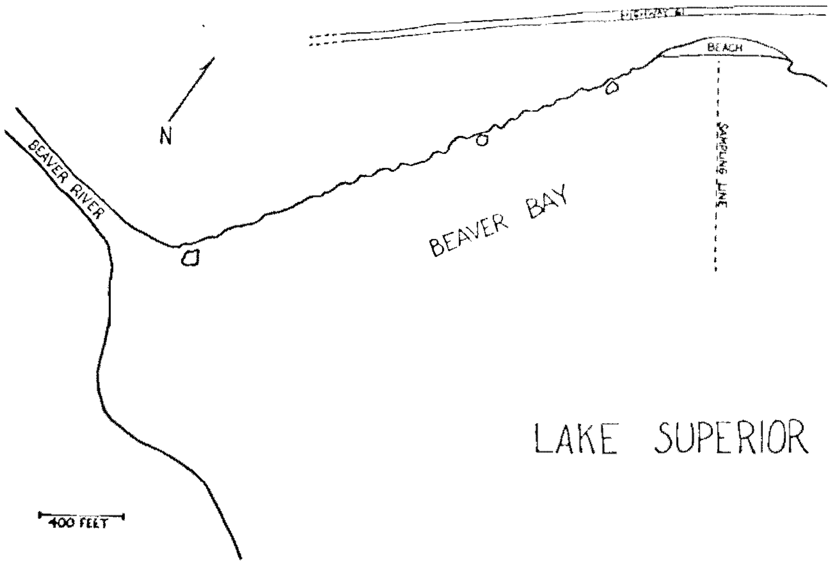

Figure 33. Beaver Bay, north shore, Lake Superior.

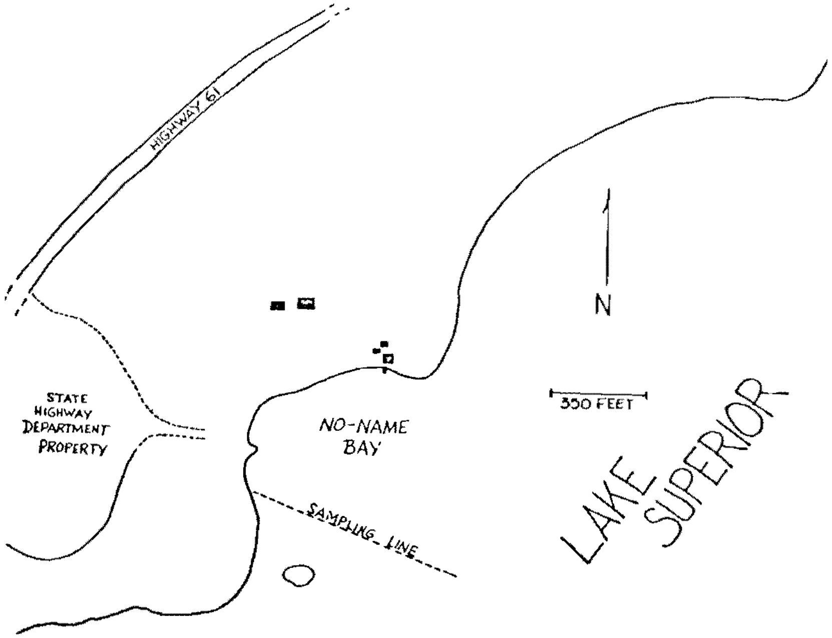

Figure 34. No-Name Bay, north shore, Lake Superior.

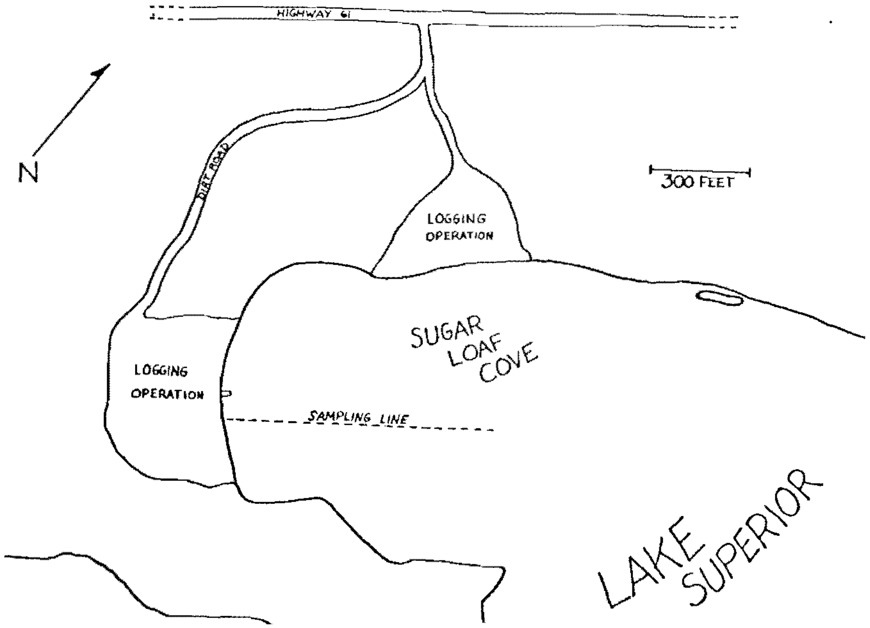

Figure 35. Sugar Loaf Cove, north shore, Lake Superior.

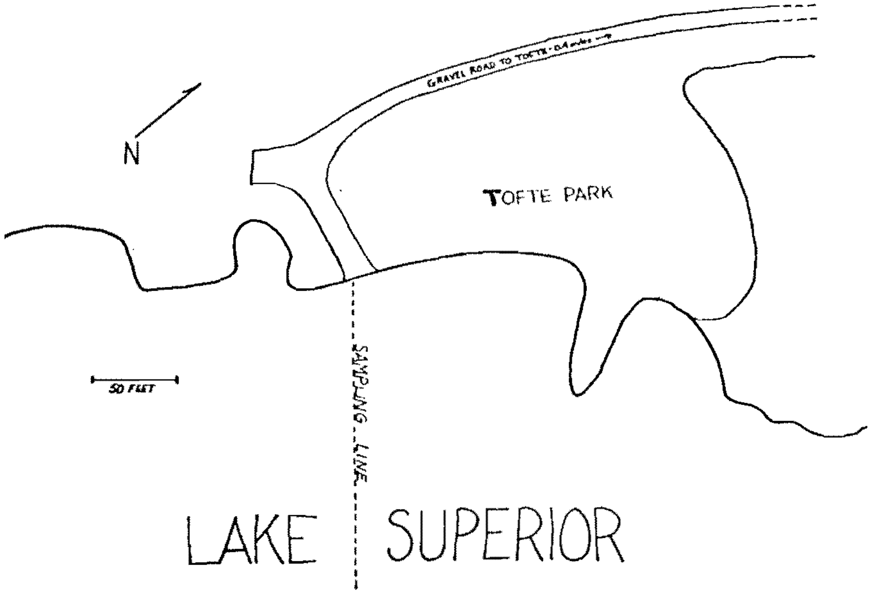

Figure 36. Tofte area, north shore, Lake Superior.

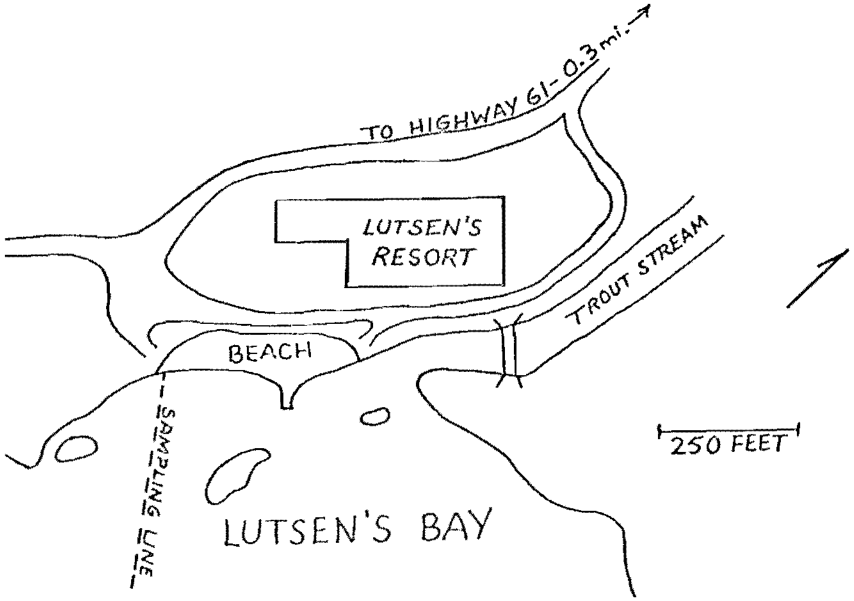

Figure 37. Lutsen area, north shore, Lake Superior.

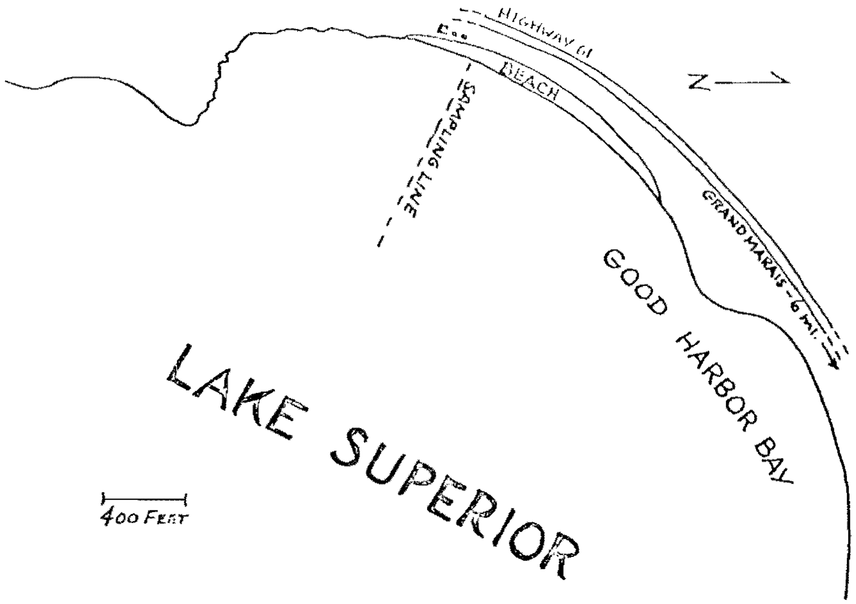

Figure 38. Good Harbor Bay, north shore, Lake Superior.

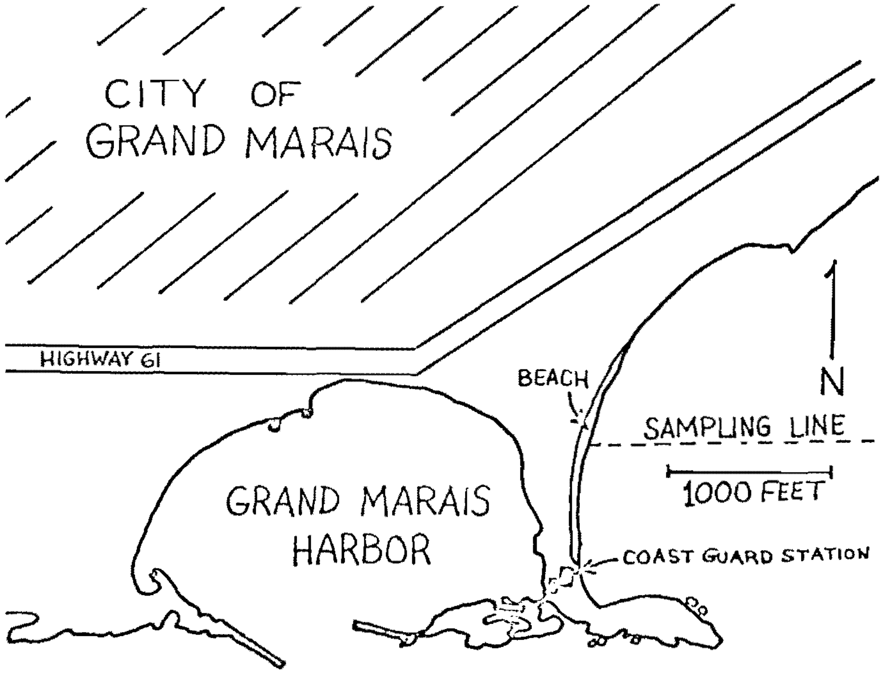

Figure 39. Grand Marais area, north shore, Lake Superior.

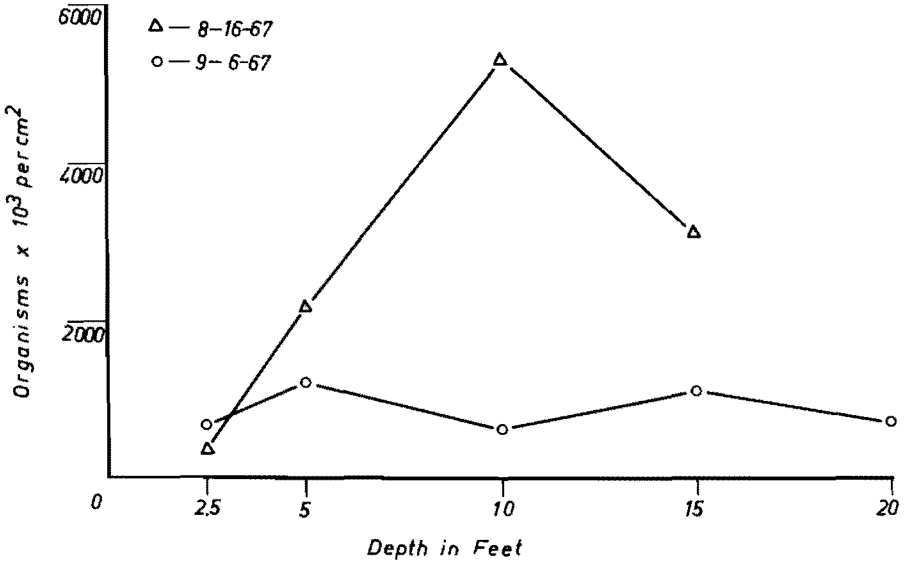

Figure 40. Naturally occurring periphyton, total counts, Lester River area, north shore, Lake Superior, 1967.

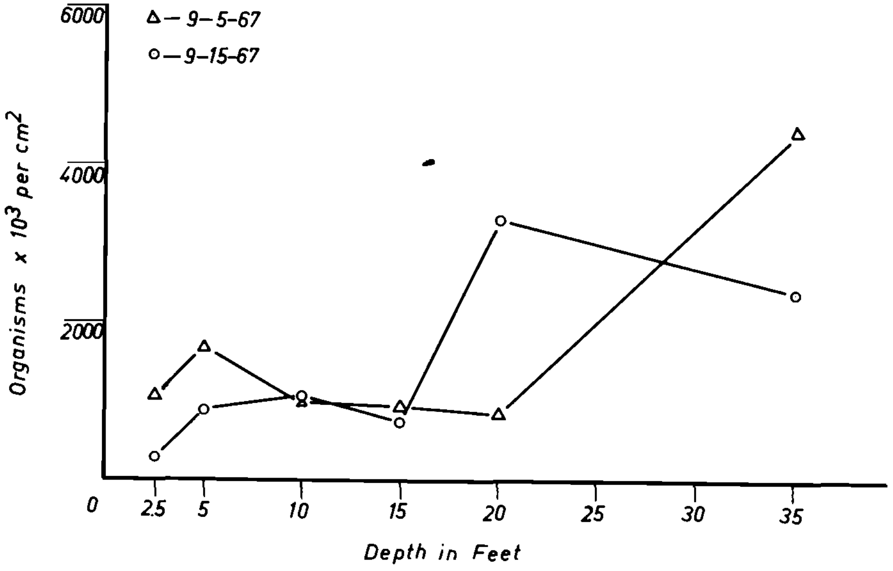

Figure 41. Naturally occurring periphyton, total counts, Knife River area, north shore, Lake Superior, 1967.

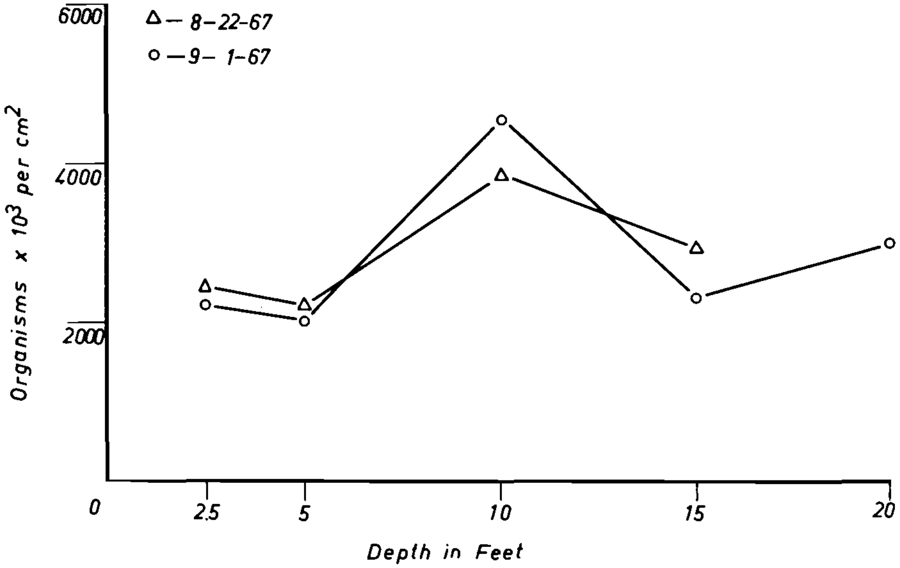

Figure 42. Naturally occurring periphyton, total counts, Burlington Bay, north shore, Lake Superior, 1967.

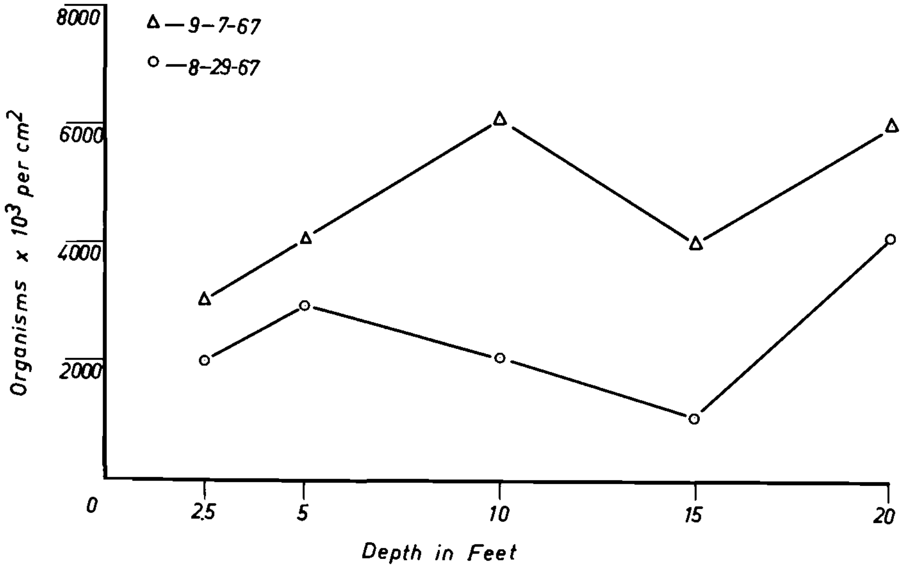

Figure 43. Naturally occurring periphyton, total counts, Split Rock River Bay, north shore, Lake Superior, 1967.

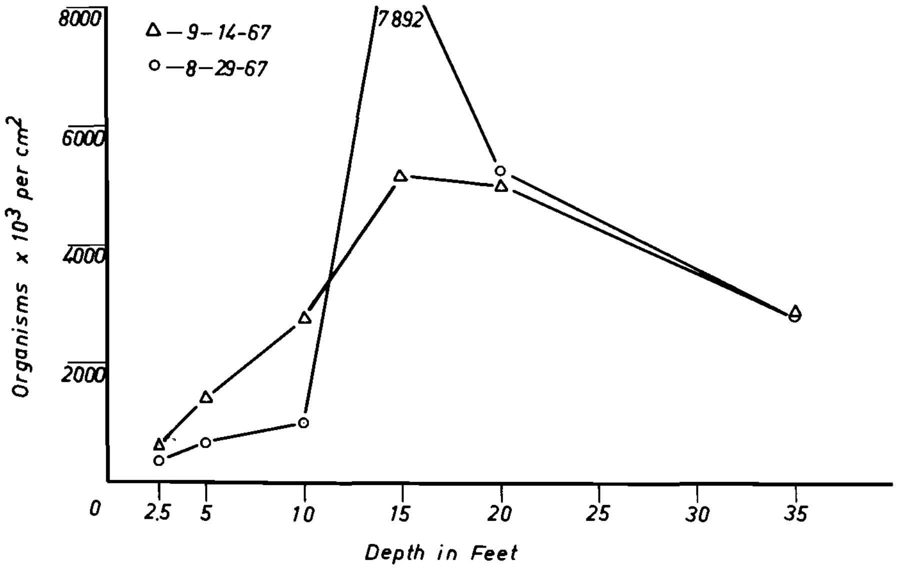

Figure 44. Naturally occurring periphyton, total counts, Beaver Bay, north shore, Lake Superior, 1967.

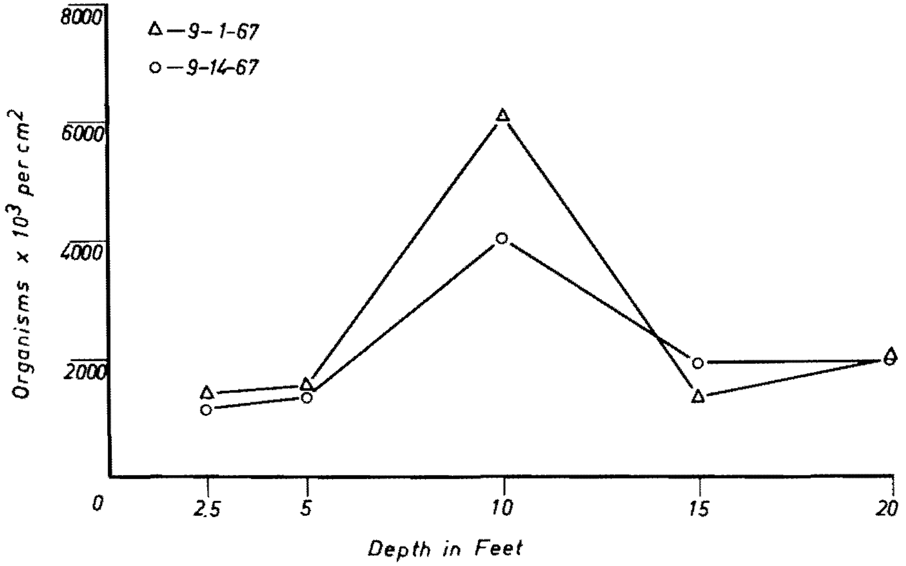

Figure 45. Naturally occurring periphyton, total counts, No-Name Bay, north shore, Lake Superior, 1967.

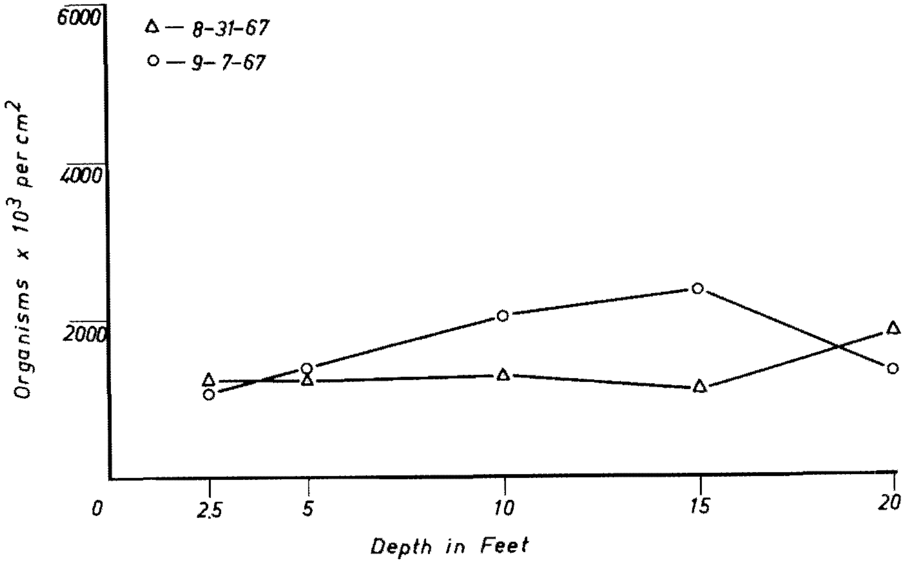

Figure 46. Naturally occurring periphyton, total counts, Sugar Loaf Cove, north shore, Lake Superior, 1967.

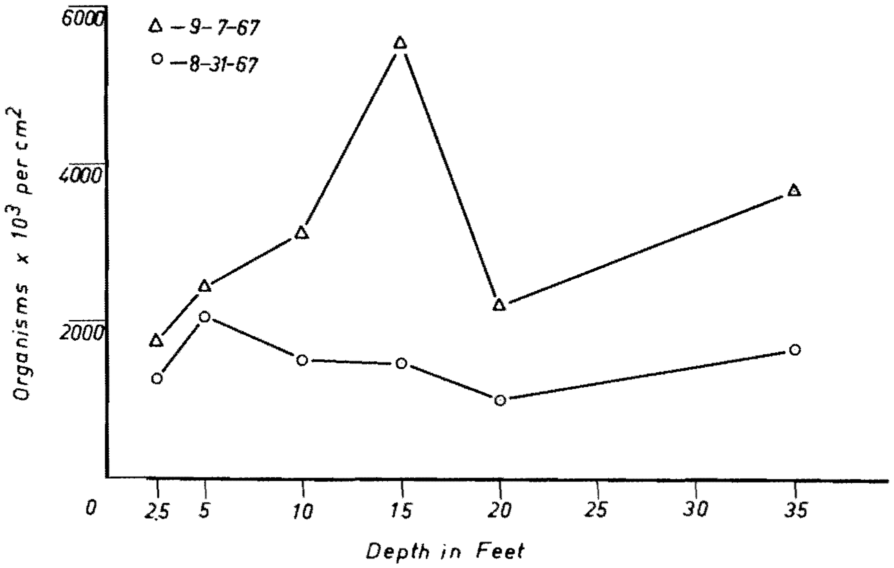

Figure 47. Naturally occurring periphyton, total counts, Tofte area, north shore, Lake Superior, 1967.

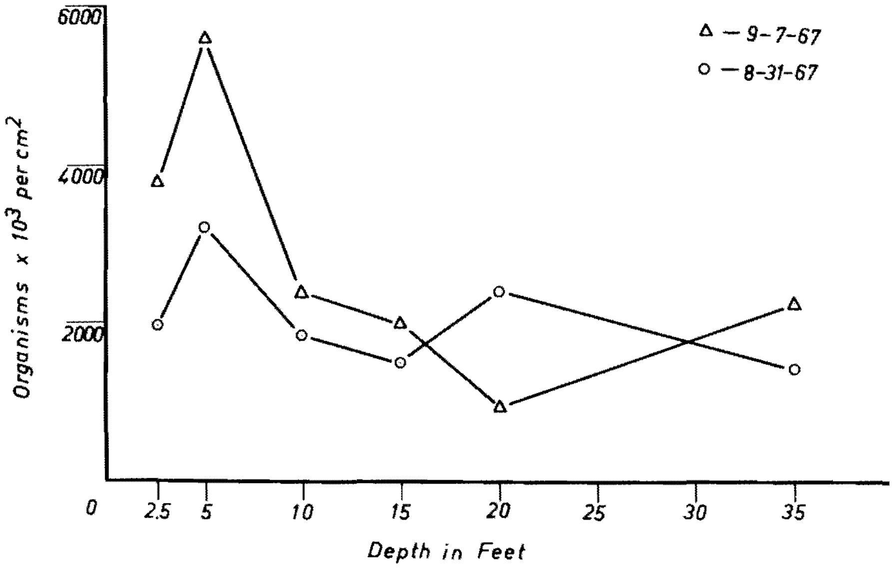

Figure 48. Naturally occurring periphyton, total counts, Lutsen area, north shore, Lake Superior, 1967.

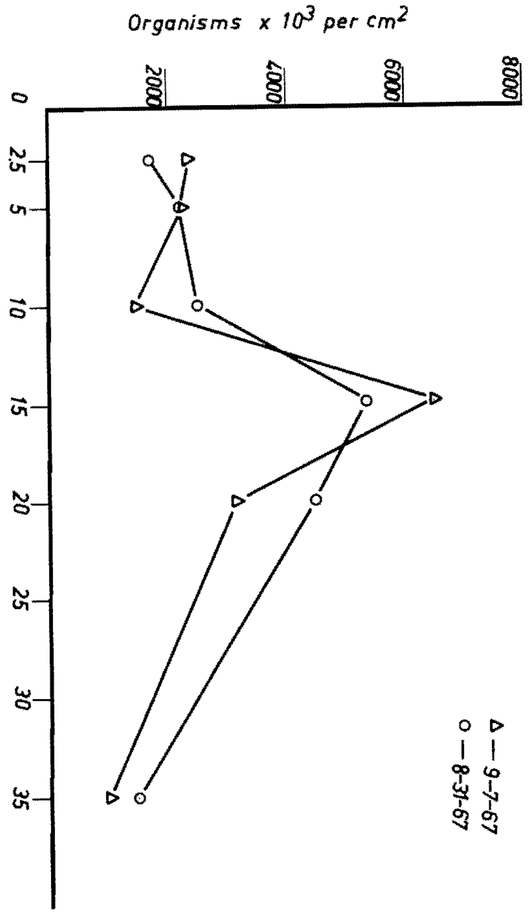

Figure 49. Naturally occurring periphyton, total counts, Good Harbor Bay, north shore, Lake Superior, 1967.

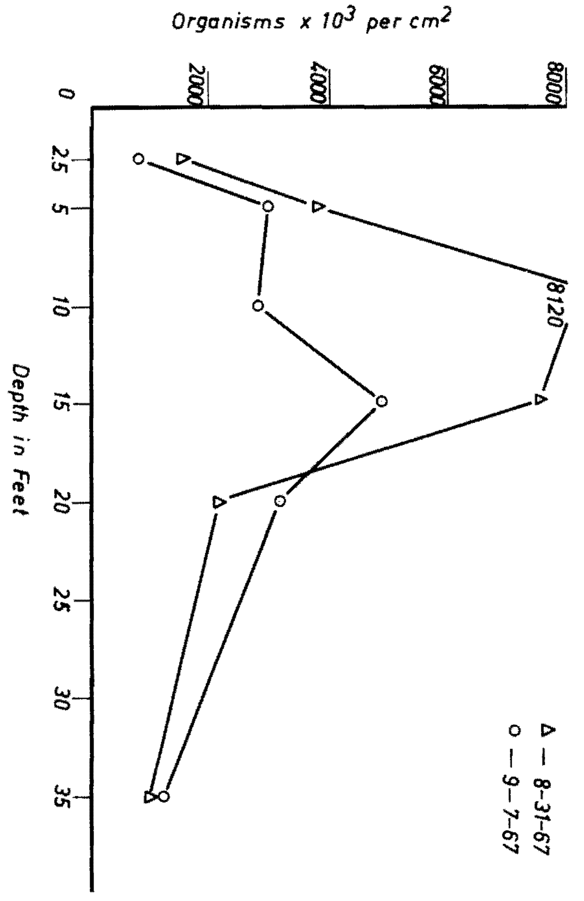

Figure 50. Naturally occurring periphyton, total counts, Grand Marais area, north shore, Lake Superior, 1967.

TABLE XXI

SUMMARY OF RESULTS, NORTH SHORE STATIONS, LAKE SUPERIOR, 1967

Study Area	Mean Total Count*	Mean Weights**		Five Most Common Organisms
		Dry	Ash-Free	
Lester River	1,693,000	19.5	1.46	Achnanthes microcephala, Synedra acus, Cymbella spp., Navicula spp., Nitzschia spp.
Knife River	1,526,000	9.5	1.16	S. acus, A. microcephala, Navicula spp., Cymbella spp., unidentified blue-green
Burlington Bay	2,890,000	16.6	1.50	S. acus, A. microcephala, Navicula spp., unidentified blue-green, Cymbella spp.
Split Rock River Bay	3,798,000	12.5	1.35	S. acus, A. microcephala, Cymbella spp., Navicula spp., Synedra ulna
Beaver Bay	2,964,000	31.5	2.31	S. acus, A. microcephala, Cymbella spp., Navicula spp., Gomphonema spp.
No-Name Bay	2,294,000	5.65	0.84	S. acus, A. microcephala, Navicula spp., Cymbella spp., Gomphonema ssp.
Sugar Loaf Cove	1,466,000	2.72	0.61	A. microcephala, S. acus, Cymbella spp., Navicula spp., Gomphonema spp.
Tofte	2,291,000	5.5	0.97	S. acus, A. microcephala, Cymbella spp., Navicula spp., Gomphonema spp.
Lutsen	2,497,000	9.5	0.89	S. acus, A. microcephala, Cymbella spp., Navicula spp., unidentified blue-green
Good Harbor Bay	3,020,000	10.5	1.51	S. acus, A. microcephala, Cymbella spp., Navicula spp., Synedra ulna
Grand Marais	3,309,000	16.0	1.60	S. acus, A. microcephala, Cymbella spp., Navicula spp., Ceratoneis arcus

*Organisms per square centimeter of rock surface

**Milligrams per square centimeter of rock surface

TABLE XXII

PERIPHYTON DRY WEIGHTS AT SEVERAL DEPTHS, NORTH SHORE STATIONS, LAKE SUPERIOR, 1967. MILLIGRAMS PER SQUARE CENTIMETER OF ROCK SURFACE.

	Depth in Feet					
Date	2.5	5	10	15	20	35
			Lester River			
8-16	2.9	10.1	47.5	76.5	---	---
9-6	2.6	5.0	5.4	11.6	13.9	---
			Knife River			
9-5	2.8	5.0	3.6	4.3	6.8	36.3
9-15	1.1	1.1	3.5	3.2	35.8	9.8
			Burlington Bay			
8-22	7.7	3.7	13.9	20.5	---	---
9-1	17.8	9.5	35.2	19.6	22.0	---
			Split Rock River Bay			
8-29	4.8	7.6	7.6	22.6	25.1	---
9-7	7.7	9.6	13.8	9.7	14.4	14.9
			Beaver Bay			
8-29	4.5	11.0	9.4	13.1	49.8	42.8
9-14	15.1	29.9	45.4	56.4	51.8	48.6
			No-Name Bay			
9-1	4.5	2.8	13.2	3.2	4.1	---
9-14	3.6	3.3	12.6	5.7	3.5	---
			Sugar Loaf Cove			
8-31	2.0	1.9	1.7	1.5	5.5	---
9-7	3.5	1.9	4.5	2.4	2.3	---
			Tofte			
8-31	2.7	4.3	3.6	3.9	2.6	8.4
9-7	4.1	3.7	4.9	10.5	2.6	14.4
			Lutsen			
8-31	9.5	7.5	6.2	8.0	11.3	10.6
9-7	8.9	13.5	8.4	7.5	2.5	9.6
			Good Harbor Bay			
8-31	4.0	9.1	6.1	17.5	16.7	15.4
9-7	8.4	9.1	6.2	19.4	11.1	2.8
			Grand Marais			
8-31	4.9	19.3	12.9	22.2	28.6	5.8
9-7	2.1	21.7	21.1	21.9	24.7	7.8

TABLE XXIII

PERIPHYTON ASH-FREE DRY WEIGHTS AT SEVERAL DEPTHS, NORTH SHORE STATIONS, LAKE SUPERIOR, 1967. MILLIGRAMS PER SQUARE CENTIMETER OF ROCK SURFACE.

	Depth in Feet					
Date	2.5	5	10	15	20	35
			Lester River			
8-16	0.38	1.23	3.33	3.54	----	----
9-6	0.90	1.25	0.63	0.91	0.95	----
			Knife River			
9-5	0.34	0.70	0.73	0.66	0.90	3.84
9-15	0.23	0.42	0.59	0.31	2.81	2.40
			Burlington Bay			
8-22	1.03	0.63	1.47	1.95	----	----
9-1	1.39	0.98	2.45	1.54	2.07	----
			Split Rock River Bay			
8-29	0.55	0.81	1.04	1.02	2.04	----
9-7	0.57	0.87	2.13	1.64	2.27	1.88
			Beaver Bay			
8-29	0.50	0.82	0.72	2.32	4.25	2.80
9-14	0.84	2.62	4.07	3.75	3.55	3.58
			No-Name Bay			
9-1	0.76	0.46	1.75	0.56	0.60	----
9-14	0.59	0.42	1.75	0.80	0.69	----
			Sugar Loaf Cove			
8-31	0.27	0.14	0.42	0.60	0.94	----
9-7	0.29	0.41	1.04	1.17	0.79	----
			Tofte			
8-31	0.43	0.72	0.66	0.89	0.57	1.24
9-7	0.76	0.82	1.14	1.80	0.50	1.95
			Lutsen			
8-31	0.49	0.49	0.27	0.65	1.22	0.91
9-7	1.43	1.89	0.97	1.14	0.39	1.13
			Good Harbor Bay			
8-31	0.53	0.97	1.16	2.44	2.67	1.32
9-7	0.81	0.98	0.67	3.21	1.85	0.59
			Grand Marais			
8-31	0.65	1.61	2.09	3.74	0.91	0.55
9-7	0.31	1.90	1.76	2.73	2.50	0.57

TABLE XXIV

WATER TEMPERATURES AT THE SURFACE AND THE BOTTOM AT THE STANDARD SAMPLING DEPTHS, NORTH SHORE STATIONS, LAKE SUPERIOR, 1967. DEGREES CENTIGRADE.

	Depth in Feet						
Date	0.5	2.5	5	10	15	20	35
			Lester River				
8-16	21.5	21.5	20.0	9.0	8.0	----	----
9-6	23.0	22.5	21.0	20.0	11.0	9.0	----
			Knife River				
9-5	15.0	15.0	14.5	14.0	11.0	6.0	6.0
9-15	15.5	15.5	14.5	14.0	8.0	7.5	7.0
			Burlington Bay				
8-22	13.0	13.0	12.5	12.0	10.0	----	----
9-1	13.0	13.0	13.0	13.0	13.0	13.0	----
			Split Rock River Bay				
8-29	10.0	10.0	10.0	10.0	10.0	10.0	----
9-7	8.0	8.0	8.0	7.0	6.5	6.0	----
			Beaver Bay				
8-29	8.0	8.0	7.5	7.0	6.5	5.5	5.5
9-14	12.5	12.5	12.5	12.5	12.5	12.5	8.5
			No-Name Bay				
9-1	11.0	11.0	11.0	10.5	9.5	9.5	----
9-14	13.0	13.0	13.0	13.0	13.0	13.0	----
			Sugar Loaf Cove				
8-31	7.0	7.0	6.5	6.0	6.0	5.5	----
9-7	7.5	7.5	7.5	6.5	6.5	6.1	----
			Tofte				
8-31	11.0	11.0	11.0	9.5	9.5	9.0	8.5
9-7	10.8	10.8	10.5	10.5	9.5	8.6	8.0
			Lutsen				
8-31	12.5	12.5	12.5	12.0	11.5	11.5	10.0
9-7	13.0	13.0	12.5	12.5	10.0	10.0	9.0
			Good Harbor Bay				
8-31	11.5	11.5	11.0	9.0	8.5	8.5	7.8
9-7	11.5	11.5	11.0	10.0	10.0	9.5	9.5
			Grand Marais				
8-31	9.5	9.5	9.5	9.0	9.0	8.5	8.5
9-7	10.5	10.5	10.0	10.0	10.0	9.2	9.0

Synedra ulna, *Gomphonema* spp., and *Ceratoneis arcus*.

The five most common organisms in 1967 samples from Stony Point Bay were, in order, *Synedra acus*, *Achnanthes microcephala*, *Navicula* spp., *Cymbella* spp., and *Gomphonema* spp. Thus it can be seen that the organisms comprising the periphyton remain practically the same for a 107 mile segment of the north shore.

It is felt that the same factors which affect periphyton growth in Stony Point Bay influence growth at any other point in the lake. These are primarily water movement (regardless of cause), light intensity, temperature, available nutrients, and the type of substratum. While it is true that all of these factors are variable, the similarity found between the periphyton at Stony Point Bay and the eleven north shore stations indicate that these factors do not differ drastically in the stretch of Lake Superior shoreline studied.

SUMMARY AND CONCLUSIONS

1. In this study, the plant portion of the epilithic periphyton of the western arm of Lake Superior was found to consist solely of representatives from three phyla of algae, the Chrysophyta, the Chlorophyta, and the Cyanophyta.

2. Members of the phylum Chrysophyta were the most abundant organisms. The diatoms (class Bacillariophyceae) comprised over ninety per cent of the total number of organisms.

3. The predominant genera were found to be Synedra, Achnanthes, Navicula, Cymbella, and Gomphonema.

4. The mean total counts of organisms in the naturally occurring periphyton of Stony Point Bay, the primary sampling area, ranged from 497,000 per square centimeter of rock surface in 1966 to 1,470,000 per square centimeter in 1967.

5. The biomass of the naturally occurring Stony Point Bay periphyton, in terms of dry weight, was 153 grams per square meter in 1965, 104 g./m.^{2} in 1966, and 156 g./m.^{2} in 1967.

6. After forty-six days of regrowth on artificially denuded rocks in Stony Point Bay, the growth level was approximately eighteen per cent of that occurring naturally.

7. The daily regrowth production rate in Stony Point Bay averaged 3.6 grams of dry weight per square meter and 0.067 grams of organic weight (ash-free dry) per square meter.

8. Mean total counts of organisms from the eleven north shore stations ranged from 1,466,000 organisms per square centimeter at Sugar Loaf Cove to 3,798,000 per square centimeter at Split Rock River Bay.

9. It is felt that the interrelated factors which affect periphyton growth are light intensity, water movement, depth, temperature, nutrient levels, and type of substratum.

10. The periphyton of Lake Superior was found to be similar, in many respects, to attached growths found in streams.

It is concluded that the organisms found in the periphyton of the western arm of Lake Superior are indicative of clean water. The extensive shallow water area of Lake Superior supports large quantities of attached algae, which, as primary producers, form the first link in the food chain. It is felt that the results of this study will be of practical value in the future. Since the periphyton is fixed in one place, it reflects the quality of water masses with which it comes into contact. By using the results of this study as baseline data, it will be possible in the future to determine the qualitative and quantitative changes that occur in the periphyton as a result of eutrophication. It is hoped that, in this way, subtle changes in water quality brought about by chemical or thermal pollution can be detected.

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APPENDIX

TABLE VI

GENERA OF NATURALLY OCCURRING PERIPHYTON, EXPRESSED AS COUNTS AND PER CENT CONTRIBUTION TO THE TOTAL, STONY POINT BAY, LAKE SUPERIOR, 1966. ORGANISMS X 10^3 PER SQUARE CENTIMETER OF ROCK SURFACE OVER PERCENTAGE.

Organism	Depth in feet	8-9	8-17	8-23	8-25	9-6	Mean	Organism	Depth in feet	8-9	8-17	8-23	8-25	9-6	Mean
Phylum Chrysophyta Class Bacillariophyceae *Achnanthes*	2.5	NS	128.9	133.0	121.5	175.5	139.7	*Cyclotella*	2.5	NS		2.3	2.1		1.1
			42.8	31.9	21.6	26.9	30.8					0.6	0.4		0.3
	5	NS	356.5	248.7	224.9	172.1	250.5		5	NS		2.6	4.1	3.0	2.4
			49.7	41.6	40.7	35.9	42.0					0.4	0.7	0.6	0.4
	10	259.1	60.4	124.3	123.0	115.6	136.4		10	14.9	8.9	8.5	6.3	6.6	9.1
		44.8	22.1	23.6	29.1	31.8	30.3			2.6	3.3	1.6	1.5	1.9	2.2
	15	274.1	52.7	NS*	40.9	133.1	125.2		15	4.6		NS	8.6	2.3	3.9
		38.9	30.5		21.1	34.2	31.2			0.7			4.4	0.6	1.4
	20	148.3	147.3	119.1	113.0	108.5	127.2		20	18.7	1.4	5.4	2.6	23.3	10.3
		21.2	41.1	36.4	22.3	24.3	29.1			2.7	0.4	1.7	0.5	5.2	2.1
	35	323.4	238.9	122.9	147.9	129.1	192.4		35	12.0	12.3	21.3	29.1	20.6	19.1
		41.4	31.5	25.0	28.0	20.7	29.3			1.5	1.6	4.3	5.5	3.3	3.2
Amphora	2.5	NS	4.6				1.2	*Cymatopleura*	2.5	NS					
			1.5				0.4								
	5	NS		2.6			0.7		5	NS					
				0.4			0.1								
	10			3.5			0.7		10						
				0.7			0.1								
	15			NS					15			NS			
	20								20		1.4				0.3
											0.4				0.1
	35		6.1				1.2		35						
			0.8				0.2								
Asterionella	2.5	NS		2.3			0.6	*Cymbella*	2.5	NS	25.3	25.4	86.5	27.0	41.0
				0.6			0.2				8.4	6.1	15.4	4.1	8.3
	5	NS				3.0	0.8		5	NS	7.9	66.1	24.5	27.2	31.4
						0.6	0.2				1.1	11.1	4.4	5.7	5.6
	10		3.3	6.5	3.2	3.4	3.7		10	34.9	26.7	48.1	22.1	27.2	31.8
			1.3	1.6	0.8	0.9	0.9			6.0	9.8	9.1	5.2	7.5	7.5
	15			NS		2.3	0.6		15	64.0	8.4	NS	17.2	28.0	29.4
						0.6	0.2			9.1	4.9		8.9	7.2	7.5
	20	4.4	2.8	2.7	2.6		2.5		20	21.9	19.3	16.2	23.1	23.3	20.8
		0.6	0.8	0.8	0.5		0.5			3.1	5.4	3.0	4.6	5.2	4.7
	35	9.0	21.4	9.5	2.6	7.5	10.0		35	26.9	33.7	26.0	13.2	26.2	25.2
		1.2	2.8	1.9	0.5	1.2	1.5			3.4	4.4	5.3	2.5	4.2	4.0
Cocconeis	2.5	NS	2.3	1.2	4.1	6.7	3.6	*Diatoma-Denticula*	2.5	NS	2.3	3.5	2.1		2.0
			0.8	0.3	0.7	1.0	0.7				0.8	0.8	0.4		0.5
	5	NS	18.5	7.9		9.0	8.9		5	NS	10.6	7.9	4.1		5.7
			2.6	1.3		1.9	1.5				1.5	1.3	0.7		0.9
	10	5.0	12.4	22.6	12.6	10.2	12.6		10			5.7	3.2	13.6	4.5
		0.9	4.5	4.3	3.0	2.8	3.1					1.1	0.8	3.7	1.1
	15	45.7	8.4	NS		11.7	16.5		15		2.1	NS	2.2	2.3	1.7
		6.5	4.9			3.0	3.6				1.2		1.1	0.4	0.7
	20	91.7	12.4	13.5	2.6	23.3	28.7		20		5.5	2.7	7.7	7.6	4.7
		13.1	3.5	4.1	0.5	5.2	5.3				1.5	0.8	1.5	1.7	1.1
	35	24.0	91.9	14.2	21.1	43.0	38.8		35	6.0	6.1	4.7	2.6	3.7	4.6
		3.1	12.1	2.9	4.0	6.9	5.8			0.8	0.8	1.0	0.5	0.6	0.7

*NS means no sample was taken. A blank space indicates zero.

TABLE VI (Continued)

Organism	Depth in feet	8-9	8-17	8-23	8-25	9-6	Mean
Fragilaria	2.5	NS	9.2				2.3
			3.1				0.8
	5	NS			4.1	3.0	1.8
					0.7	0.6	0.3
	10	5.0	5.3	5.7	3.1	3.4	4.5
		0.9	1.9	1.1	0.7	0.9	1.1
	15		2.1	NS		2.3	1.1
			1.2			0.6	0.5
	20	4.4	2.8	2.7		3.9	2.8
		0.6	0.8	0.8		0.9	0.6
	35	6.0	9.2	2.4	2.6	1.9	4.4
		0.8	1.2	0.5	0.5	0.3	0.7
Gomphonema	2.5	NS	9.2	39.3	16.5	10.1	18.8
			3.1	9.4	2.9	1.6	4.3
	5	NS	31.7	18.5	12.3	3.0	16.4
			4.4	3.1	2.2	0.6	2.6
	10		1.8	10.5	3.2		3.1
			0.7	2.0	0.8		0.7
	15	18.3		NS		2.3	4.1
		2.6				0.6	0.8
	20	4.4	11.0	18.9	23.1	11.6	13.8
		0.6	3.1	5.8	4.6	2.6	3.3
	35	47.9	15.3	28.4	18.5	18.7	23.8
		6.1	2.0	5.8	3.5	3.0	4.1
Melosira	2.5	NS	4.6		4.1		2.2
			1.5		0.7		0.6
	5	NS		5.3		3.0	2.8
				0.9		0.6	0.4
	10	5.0	7.1	2.8	9.5		4.9
		0.9	2.6	0.5	2.2		1.2
	15	9.1	4.2	NS	4.3		4.4
		1.3	2.4		2.2		1.5
	20	8.7	1.4	10.8	15.4	3.9	8.0
		1.2	0.4	3.3	3.0	0.9	1.8
	35	9.0	12.3	11.8	15.8	20.6	13.9
		1.2	1.6	2.4	3.0	3.3	2.3
Navicula	2.5	NS	27.6	42.8	37.1	84.4	48.0
			9.2	10.3	6.6	13.0	9.8
	5	NS	29.0	42.3	32.7	33.2	34.3
			4.0	7.1	5.9	6.9	6.0
	10	34.9	12.4	23.2	18.9	27.2	23.3
		6.0	4.5	4.4	4.5	7.5	5.4
	15	36.6	19.0	NS	6.5	11.7	1.8
		5.2	11.0		3.4	3.0	5.7
	20	48.0	19.3		28.3	7.8	20.7
		6.4	5.4		5.6	1.7	3.9
	35	21.0	21.4	35.5	34.3	29.9	28.4
		2.7	2.8	7.2	6.5	4.8	4.8
Nitzschia	2.5	NS	2.3				0.6
			0.8				0.2
	5	NS					
	10				3.2		0.6
					0.8		0.2
	15	4.6		NS			1.2
		0.7					0.2
	20				5.1		1.0
					1.0		0.2
	35						
Rhizosolenia	2.5	NS					
	5	NS					
	10	5.0					1.0
		0.9					0.2
	15			NS			
	20	4.4			5.1		1.9
		0.6			1.0		0.3
	35			2.4			0.5
				0.5			0.1
Synedra	2.5	NS	76.0	99.4	208.0	185.6	142.2
			25.2	23.8	37.0	28.5	28.6
	5	NS	174.0	97.9	81.8	96.6	112.5
			24.2	16.4	14.8	20.1	18.9
	10	134.5	83.5	166.8	116.7	71.4	114.5
		23.3	30.5	31.7	27.6	19.6	26.5
	15	150.9	54.8	NS	73.2	109.7	97.1
		21.4	31.7		37.8	28.1	29.8
	20	257.4	78.4	56.8	168.0	112.4	134.6
		36.8	21.9	17.4	33.1	25.2	26.9
	35	206.6	156.2	127.7	126.8	177.8	159.0
		26.4	20.6	26.0	24.0	28.4	25.1
Surirella	2.5	NS		1.2			0.3
				0.3			0.1
	5	NS	5.3	2.6			1.9
			0.7	0.4			0.3
	10	3.0	7.1		6.3	3.4	4.4
		0.9	2.6		1.5	0.9	1.2
	15	9.1	6.3	NS		2.3	4.4
		1.3	3.6			0.6	1.4
	20	13.1	4.1	5.4	7.3	3.4	6.8
		1.9	1.1	1.2	1.5	0.4	1.4
	35		6.1			7.5	2.7
			0.8			1.2	0.4

TABLE VI (Continued)

Organism	Depth in feet	8-9	8-17	8-23	8-25	9-6	Mean (#/ℓ)
Tabellaria	2.5	NS		1.2	2.1	3.4	1.7
				0.3	0.4	0.5	0.3
	5	NS	5.3	2.6		6.0	3.5
			0.7	0.4		1.1	0.6
	10		7.1		3.2	3.4	2.7
			2.6		0.8	0.9	0.9
	15	9.1	2.1	NS		2.3	1.4
		1.3	1.2			0.6	0.8
	20		2.8	5.4	5.1	11.6	4.9
			0.8	1.7	1.0	2.6	1.2
	35	3.0	3.1	7.1	2.6	1.9	3.5
		0.4	0.4	1.4	0.5	0.3	0.6
Unidentified Diatoms	2.5	NS	25.3	65.9	78.2	148.5	79.4
			8.4	15.8	13.9	22.8	15.2
	5	NS	71.3	84.2	163.6	105.7	106.3
			9.9	14.2	29.6	22.0	18.9
	10	64.8	33.8	90.5	72.5	74.8	67.2
		11.2	12.4	17.2	17.1	20.6	15.7
	15	73.2	12.6	NS	38.8	79.4	51.0
		10.4	7.3		20.0	20.4	14.5
	20	69.8	44.0	59.5	95.0	104.7	74.6
		10.0	12.3	18.2	18.3	21.5	16.5
	35	80.9	125.6	78.0	105.7	134.7	104.9
		10.3	16.5	15.9	20.1	21.6	16.9
Class Chrysophyceae Dinobryon	2.5	NS	2.3				0.6
			0.8				0.2
	5	NS		2.6		6.0	2.1
				0.4		1.3	0.4
	10		1.8	2.8	12.6		3.4
			0.7	0.5	3.0		0.8
	15	4.6		NS	2.2		1.7
		0.7			1.1		0.5
	20	4.4	1.4	2.7			1.7
		0.6	0.4	0.8			0.4
	35	3.0			2.6		1.1
		0.4			0.5		0.2
Phylum Chlorophyta Ankistrodesmus	2.5	NS					
	5	NS				3.0	0.8
						0.6	0.2
	10						
	15			NS			
	20						
	35						
Closterium	2.5	NS	4.6				1.2
			1.5				0.4
	5	NS					
	10						
	15			NS			
	20						
	35						
Scenedesmus	2.5	NS				3.4	0.9
						0.5	0.1
	5	NS	2.6	2.6		6.0	2.8
			0.4	0.4		1.3	0.5
	10	5.0	1.8	2.8	3.2		2.3
		0.9	0.7	0.5	0.8		0.6
	15			NS			
	20		2.8				0.6
			0.8				0.2
	35						
Tetraedron	2.5	NS					
	5	NS	2.6				0.7
			0.4				0.1
	10						
	15			NS			
	20			5.4			0.2
				1.7			0.3
	35						
Phylum Cyanophyta Merismopedia	2.5	NS	2.3			6.7	2.3
			0.8			1.0	0.5
	5	NS	2.6	2.6			1.3
			0.4	0.4			0.2
	10	3.0				3.4	1.7
		0.9				0.9	0.4
	15			NS			
	20				2.6		0.5
					0.5		0.1
	35	3.0			2.6	1.4	1.5
		0.4			0.5	0.3	0.2

TABLE XI

ORGANISMS IN THE NATURALLY OCCURRING PERIPHYTON, EXPRESSED AS COUNTS AND PER CENT CONTRIBUTION TO THE TOTAL. STONY POINT BAY, LAKE SUPERIOR, 1967. ORGANISMS X 10^3 PER SQUARE CENTIMETER OF ROCK SURFACE OVER PERCENTAGE.*

Organism	Depth in feet	Jul 11	Jul 13	Jul 17	Jul 20	Jul 26	Jul 27	Aug 2	Aug 4	Aug 8	Aug 10	Aug 14	Aug 17	Aug 25	Aug 28	Sep 5	Sep 15	Nov 9	Mean
Phylum Chrysophyta Class Bacillariophyceae *Achnanthes microcephala*	2.5	178.8	212.4	105.1	331.8	494.7	403.2	256.2	428.2	361.7	212.6	411.1	495.4	278.0	343.2	193.0	241.7	152.6	[illegible]
		8.1	10.7	10.2	10.9	15.5	11.8	14.6	23.8	23.8	14.2	16.0	16.5	13.4	24.1	8.1	8.9	35.0	15.7
	5	305.2	202.9	288.8	338.2	456.3	566.2	508.9	340.5	567.7	549.9	512.2	195.1	291.5	304.6	279.4	[illegible]	185.7	372.6
		30.4	23.8	20.6	18.0	18.9	19.0	21.6	31.2	25.0	21.2	24.5	13.3	15.1	17.6	11.8	13.0	17.0	20.1
	10	151.6	282.1	272.0	349.9	341.8	454.4	737.3	514.5	454.3	380.0	331.8	667.8	629.5	197.3	313.3	[illegible]	[illegible]	[illegible]
		24.4	51.0	25.7	25.7	26.2	25.4	20.6	35.1	43.7	16.6	39.9	29.3	20.4	21.4	20.0	22.2	30.1	27.7
	15	118.9	84.6	569.7	327.8	327.2	657.3	818.3	632.4	441.7	320.8	699.1	716.5	300.8	513.4	70.1	190.5	173.6	464.3
		23.5	23.6	47.5	33.9	42.3	39.3	40.0	40.5	36.6	37.7	40.1	35.7	27.8	35.4	25.1	31.6	53.0	36.1
	20	194.6	112.4	315.6	268.2	361.5	458.0	430.3	430.1	332.4	423.4	727.3	489.3	1002.2	192.6	[illegible]	314.5	115.5	[illegible]
		43.2	24.1	41.5	44.9	43.0	46.8	38.9	40.9	31.7	41.5	33.2	33.2	40.4	26.5	28.7	27.0	35.2	36.5
	35	181.9	30.5	79.6	250.3	206.2	170.4	290.9	233.0	302.8	384.4	513.7	610.4	414.1	339.5	720.5	495.6	495.2	340.0
		34.2	12.4	28.3	37.2	36.3	26.4	30.7	29.5	37.3	34.9	39.3	44.0	33.2	35.3	35.4	24.6	35.9	32.6
Asterionella formosa	2.5	7.2																	0.4
		0.3																	<.05
	5				2.7		6.2	5.0				4.7	3.5				6.0		1.7
					0.1		0.2	0.2				0.2	0.2				0.2		0.1
	10					6.5	5.1				2.0	7.8		16.6	3.4	6.1	6.1	6.6	3.6
						0.3	0.3				0.1	0.7		0.5	0.4	0.4	0.5	0.7	0.2
	15		1.7	5.7			13.5			4.1		4.2	6.0	15.3	8.7				3.5
			0.5	0.5			0.8			0.3		0.2	0.3	1.4	0.6				0.3
	20				4.3			10.8	3.2			5.4	6.4	5.0	15.1	26.4	3.5		4.7
					0.7			1.0	0.3			0.2	0.4	0.2	2.1	0.9	0.3		0.6
	35			1.4		9.2	2.1	11.8	10.9	6.2		3.9		4.4	4.5	20.8	8.9		5.2
				0.5		1.6	0.3	1.2	1.4	0.8		0.3		0.4	0.4	1.0	0.4		0.5
Ceratoneis arcus	2.5	21.5	6.5		3.3	6.7	7.0												2.6
		1.0	0.3		0.1	0.2	0.2												0.1
	5				2.7	12.5	12.3	5.0											1.9
					0.1	0.5	0.4	0.2											0.1
	10	3.4			4.6	6.5		7.0											1.3
		0.5			0.3	0.3		0.2											0.1
	15			2.9			9.0												0.7
				0.2			0.5												<.05
	20					5.9	3.6	3.6			3.6								1.0
						0.7	0.4	0.3			0.4								0.1
	35																		
Cocconeis group**	2.5		3.3		3.3	6.7	7.0	4.5	6.2	6.5				23.7	36.5			7.3	6.2
			0.2		0.1	0.2	0.2	0.3	0.3	0.4				1.1	2.6			1.7	0.4
	5	9.6	6.1				24.6	5.0	7.4	10.7	24.3	4.7	3.5	13.6	14.2		12.0	6.6	8.4
		1.0	0.7				0.8	0.2	0.7	0.5	0.9	0.2	0.2	0.7	0.7		0.4	0.6	0.4
	10	2.2	10.0	18.1	23.0	12.9	5.1	7.0	4.0	18.1	33.0	15.6	8.1	33.1	20.4	24.6	18.2		14.9
		0.4	1.8	1.7	1.7	0.6	0.3	0.2	0.3	1.6	1.4	1.5	0.4	1.1	2.2	1.6	1.5		1.1
	15	18.6	5.0	2.9	20.5	7.2	40.5	46.6	22.0	53.2	22.4	25.3	36.1	5.1	17.4	3.0	21.7	9.1	21.0
		3.7	1.4	0.2	2.1	0.9	2.4	2.3	1.4	4.4	2.6	1.4	1.8	0.5	1.2	1.1	6.8	2.8	2.2
	20	11.9	4.4	24.7	19.5	26.5	18.0	3.6	15.9	23.7	39.8	37.7	28.6	10.0	11.3	52.9	35.3	71.2	22.6
		2.6	0.9	3.3	3.3	3.2	1.8	0.3	1.5	2.3	3.9	1.7	1.9	0.4	1.6	1.9	3.0	6.5	2.4
	35	2.8	7.0		10.7	16.0	25.6	27.5	29.1	28.1	34.9	11.8	34.5	21.8	35.9	48.5	53.6	23.9	24.2
		0.5	2.9		1.6	2.8	4.0	2.9	3.7	3.5	3.2	0.9	2.5	1.7	3.2	2.4	2.7	1.7	2.4
Cyclotella group	2.5			2.8						6.5				5.9					0.9
				0.3						0.4				0.3					0.1
	5					6.2		5.0		10.7						7.0	6.0	6.6	2.4
						0.3		0.2		0.5						0.3	0.2	0.6	0.1
	10			3.0	4.6		15.3	7.0	4.0	4.5				33.1		6.1		5.1	4.4
				0.3	0.3		0.9	0.2	0.3	0.4				1.1		0.4		0.5	[illegible]
	15			5.7	4.1	3.6					3.7		6.0		8.7			1.8	2.0
				0.5	0.4	0.5					0.4		0.3		0.6			0.5	[illegible]
	20					2.9	3.6	3.6		19.8			3.2		1.8	26.4		2.4	[illegible]
						0.3	0.4	0.3		1.8			0.2		0.5	0.9		0.7	0.3
	35		2.3	4.2	1.6	11.5	6.4	3.9	7.3	6.2	5.8	11.8	4.9	4.4	4.5	6.9		29.9	[illegible]
			0.3	1.5	0.5	2.0	1.0	0.4	0.9	0.8	0.5	0.9	0.4	0.4	0.4	0.1		2.2	[illegible]

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TABLE XI (Continued)

Organism	Depth in feet	Jul 11	Jul 13	Jul 17	Jul 20	Jul 26	Jul 27	Aug 2	Aug 4	Aug 8	Aug 10	Aug 14	Aug 17	Aug 25	Aug 28	Sep 5	Sep 15	Nov 9	Mean
Cymbella Group A	2.5	21.5	29.4	5.7	[illegible]	13.4	34.8	22.5	6.2	32.9		6.0			21.9		13.8	[illegible]	14.7
		1.0	1.5	0.6	0.9	1.0	1.0	1.3	0.3	0.8		0.2			1.5		[illegible]	[illegible]	0.8
	5	1.2	3.1	19.0	13.4	12.5	12.3	14.9	3.7			4.7	7.1	6.8	14.2	7.0		33.7	[illegible]
		0.1	0.5	1.4	0.7	0.5	0.4	1.5	0.1			0.2	[illegible]	0.6	0.7	0.3		3.0	0.6
	10	4.4	3.3	6.0	13.8		20.4		4.0	9.1	5.5	19.5	16.3	8.3	10.2			20.1	[illegible]
		0.7	0.6	0.6	1.0		1.1		0.3	0.8	0.2	1.8	0.7	0.3	1.1			2.0	0.7
	15	1.9	1.7	2.9	4.3	7.2	13.5	10.4		4.1	3.7	25.3	6.0	5.1				1.6	[illegible]
		0.4	0.5	0.2	0.4	0.9	0.8	0.5		0.3	0.4	1.4	0.3	0.5				1.1	[illegible]
	20			5.5	4.3	8.8	1.6	7.2			3.6	10.8	6.5		7.6	11.2	7.1		5.6
				0.7	0.7	1.0	0.4	0.7			0.4	0.5	0.5		1.0	0.5	0.6		0.5
	35			4.2	3.6	2.3	2.1	7.9	3.6	6.2	5.8	11.8		17.4		31.9	[illegible]	6.0	[illegible]
				1.5	0.5	0.4	0.3	0.8	0.5	0.8	0.5	0.9		1.4		0.7	0.2	0.4	[illegible]
Cymbella Group B	2.5	93.0	114.4	73.8	122.8	120.4	236.3	98.9	229.7	206.7	147.2	187.4	218.6	147.8	116.8	[illegible]	[illegible]	16.3	[illegible]
		4.2	5.8	7.2	4.0	3.8	6.9	5.7	12.8	13.6	9.9	7.3	7.3	7.1	8.2	7.4	9.6	8.5	7.6
	5	19.3	52.3	64.6	158.5	168.8	129.2	104.8	70.3	150.0	194.1	135.0	106.4	155.9	178.1	151.7	192.5	92.9	[illegible]
		1.9	6.1	4.6	8.4	7.0	4.3	4.5	6.4	6.6	7.5	6.5	7.2	8.1	8.2	6.5	7.0	8.5	6.4
	10	65.9	17.3	76.6	87.5	135.4	168.5	229.5	111.7	63.4	52.3	39.0	114.0	149.1	47.6	86.0	90.9	35.5	92.4
		10.6	3.1	7.3	6.4	6.6	9.4	6.4	7.6	5.7	2.3	3.6	5.0	4.8	5.2	5.5	7.6	3.5	5.9
	15	27.9	14.9	37.2	36.8	50.3	121.6	62.2	66.0	61.3	26.1	71.6	150.5	66.3	43.5	15.2	24.5	10.9	52.2
		5.5	4.2	3.1	3.8	6.5	7.3	3.0	4.2	5.0	3.1	4.1	7.5	4.1	3.0	5.4	7.7	3.3	4.9
	20	7.1	13.2	24.7	28.1	52.9	46.9	47.0	38.2	47.5	32.6	70.0	69.9	114.7	30.2	105.8	70.7	16.5	48.0
		1.6	2.8	3.3	4.7	6.3	4.8	4.2	3.6	4.5	3.2	3.2	4.7	4.6	4.2	3.8	6.1	5.0	4.2
	35	5.5	11.7	5.6	46.5	16.0	23.4	39.3	21.8	12.5	46.6	58.8	44.3	8.7	35.9	30.0	75.9	41.8	33.2
		1.0	4.8	2.0	6.9	2.8	3.6	4.1	2.8	1.5	4.2	4.5	3.2	0.7	3.2	3.4	3.8	3.0	3.3
Denticula thermalis	2.5		16.3	25.6	3.3			9.0			5.4		7.3	5.9				4.8	4.6
			0.8	2.5	0.1			0.5			0.4		0.2	0.3				1.1	[illegible]
	5	16.1	18.4	22.8		12.5				5.4		4.7	3.5		7.1		6.0		[illegible]
		1.6	2.2	1.6		0.5				0.2		0.2	0.2		0.3		0.2		0.4
	10	4.4	8.3	15.1		12.9	5.1	11.9	4.0		2.8	3.9	12.6	24.8	6.8	6.1		5.1	8.6
		0.7	1.5	1.4		0.6	0.3	0.4	0.3		0.1	0.4	1.4	0.8	0.7	0.4		0.5	0.6
	15		8.3		8.2			10.4		8.2	3.7	4.2	6.0	5.1	4.6	3.0			3.6
			2.3		0.8			0.5		0.7	0.4	0.2	0.3	0.5	0.3	1.1			0.4
	20	14.2	4.4	8.2	4.3		3.6	18.1		19.8	3.6	16.2	3.2	19.9		33.1		11.8	[illegible]
		3.1	0.9	1.1	0.7		0.4	1.6		1.9	0.4	0.7	0.2	0.8		1.2		3.6	[illegible]
	35		3.5	2.8			4.3						4.9	8.7		13.9	4.5		2.5
			1.4	1.0			0.7						0.4	0.7		0.7	0.2		0.3
Diatoma elongatum	2.5	50.1			3.3	26.8		9.0	18.6	12.9	16.1	24.2	51.0	5.9	7.3	9.2	6.9	[illegible]	[illegible]
		2.3			0.1	0.8		0.5	1.0	0.8	1.1	0.9	1.7	0.3	0.5	0.4	0.3	1.7	0.7
	5				10.7	12.5	36.9	15.0	22.2	26.8	8.1	14.0	21.3		7.1	7.0	6.0	19.9	12.2
					0.6	0.5	1.2	0.6	2.0	1.2	0.3	0.7	1.5		0.3	0.3	0.2	1.8	0.7
	10			6.0	4.6		15.3	7.0	4.0		5.5	7.8	16.3	8.3			6.1	5.1	[illegible]
				0.6	0.3		0.9	0.2	0.3		0.2	0.7	0.7	0.3			0.5	0.5	[illegible]
	15	3.7	5.0				4.5				3.2	8.4	6.0						1.8
		0.7	1.4				0.3				0.4	0.5	0.3						0.2
	20			2.7	2.2	5.9				4.0			3.2		3.8	6.6		7.1	[illegible]
				0.4	0.4	0.7				0.4			0.2		0.5	0.2		2.2	0.3
	35		2.3						7.3										0.6
			0.9						0.9										0.1
Fragilaria capucina	2.5	14.3										18.1	7.3			9.2	6.9		3.3
		0.7										0.7	0.2			0.4	0.3		0.1
	5			3.8			6.2	5.0	1.7	10.7		4.7						5.6	2.4
				0.1			0.2	0.2	0.3	0.5		0.2						0.6	0.1
	10	2.2		3.0				13.9			2.8	3.9		8.3					2.0
		0.4		0.3				0.4			0.1	0.4		0.3					0.1
	15	1.9	3.7										6.0	5.3					0.9
		0.4	0.5										0.3	0.5					0.1
	20		4.4						3.2				6.4			11.2			1.6
			0.9						0.3				0.4			0.5			0.1
	35			1.4															0.1
				0.5															< .05
Frustulia viridula	2.5			2.8				13.5	6.2	12.9		12.1	58.3	17.8	43.8		41.4	[illegible]	12.4
				0.3				0.8	0.3	0.8		0.5	1.9	0.9	3.1		1.5	0.6	0.6
	5			3.8					11.1		24.3	14.0	10.6	27.1	42.2	48.9	18.0	13.3	12.6
				0.1					1.0		0.9	0.7	0.7	1.4	2.0	2.3	0.7	1.2	0.6
	10			6.0	4.6		5.1		8.0	4.5	2.8	7.8	8.1	33.1	3.4	30.7	6.1	10.1	7.7
				0.6	0.3		0.3		0.5	0.4	0.1	0.7	0.6	1.1	0.4	2.0	0.5	1.0	0.5
	15		3.3			3.6	4.5	5.2	5.5	4.1	3.7	12.6	6.0	10.2	4.4	3.0	2.7	1.8	4.2
			0.9			0.5	0.3	0.3	0.4	0.3	0.4	0.7	0.3	0.9	0.3	1.1	0.8	0.5	0.5
	20					2.9	7.2	3.6		7.9	7.2	5.4		15.0	3.8			2.4	3.3
						0.3	0.7	0.3		0.8	0.7	0.2		0.6	0.5			0.7	0.3
	35		2.3	5.6			2.1		3.6					4.4		41.6	8.9	29.9	5.8
			0.9	2.0			0.3		0.5					0.4		2.0	0.4	2.2	0.5

TABLE XI (Continued)

Organism	Depth in feet	Jul 11	Jul 13	Jul 17	Jul 20	Jul 26	Jul 27	Aug 2	Aug 4	Aug 8	Aug 10	Aug 15	Aug 17	Aug 25	Aug 28	Sep 5	Sep 15	Nov 9	Mean
Gomphonema group	2.5		45.7	51.1	34.8	20.1	20.9	11.5	17.2	25.8	21.8	20.2	15.6	25.1	15.6	16.8	[illegible]	17.6	22.8
			2.3	5.0	1.1	0.6	0.6	1.8	2.1	1.7	1.5	1.2	0.5	1.1	1.0	1.8	[illegible]	[illegible]	1.6
	5	9.6	24.6	51.2	51.0	18.8	43.1	29.9	11.0	42.8	48.5	27.9	28.4	4.8	12.2	14.9	40.1	6.6	28.2
		1.0	2.9	3.8	2.7	0.8	1.4	1.3	1.0	1.9	1.9	1.3	1.9	0.4	0.8	1.5	3.3	0.4	1.4
	10	8.8	16.6	24.2	23.0	4.5	30.6	41.7	19.9	18.1	14.3	7.8	16.3	8.3	11.6	12.3	12.1	10.1	16.8
		1.4	3.0	2.1	1.7	0.1	1.7	1.2	1.3	1.6	0.7	0.7	0.7	0.3	1.5	0.8	1.0	1.0	1.2
	15	11.0	16.6	105.9	16.4	18.0	27.0	68.5	38.5	49.1	29.8	21.1	12.0	30.6	26.1	4.1	5.5	21.7	29.8
		2.6	4.6	8.8	1.7	2.1	1.6	3.3	2.5	4.0	3.5	1.2	0.6	2.8	1.8	2.2	1.7	6.6	3.0
	20	16.6	13.2	26.7	19.5	29.6	21.6	54.2	31.9	15.8	50.7	43.1	39.1	39.9	3.8	26.4	31.8	21.2	27.2
		3.7	2.8	3.3	1.3	3.5	2.2	4.9	3.0	1.5	5.0	2.0	1.3	1.6	0.5	0.9	2.2	6.5	2.9
	35	13.8	12.9	11.2	25.0	29.8	49.0	39.0	32.8	231.2	104.8	7.8	44.3	34.9	80.8	110.8	67.0	131.5	49.8
		2.6	5.3	4.0	3.7	5.2	7.6	6.1	4.2	3.8	9.5	0.6	3.2	2.8	7.1	5.4	3.3	9.5	4.9
Navicula group	2.5	28.6	29.4	5.7	19.9	26.8	27.8	22.0	55.9	32.3	65.4	84.6	204.0	94.5	14.6	784.1	276.2	38.8	77.5
		1.3	1.5	0.6	0.7	0.8	0.8	1.5	3.1	2.1	4.4	3.4	6.8	4.6	1.0	17.0	10.2	4.1	4.7
	5	19.3	4.1	34.2	40.3	62.5	50.7	55.9	16.8	94.4	32.8	55.9	117.0	128.8	128.2	272.4	306.7	176.0	93.4
		1.9	0.7	2.4	2.1	2.6	1.7	2.3	1.4	4.2	2.8	2.7	8.0	6.7	5.9	11.5	11.0	11.5	4.2
	10	15.4	10.0	27.2	27.6	116.1	35.7	49.6	47.9	40.7	60.5	19.5	130.3	132.5	54.4	207.7	200.0	182.4	80.7
		2.5	1.8	2.6	2.0	5.6	2.0	1.9	3.3	3.7	2.6	1.8	5.7	4.3	5.9	12.9	16.6	18.1	5.5
	15	13.0	14.9	25.8	24.6	21.6	36.0	62.2	88.0	49.1	37.3	46.3	120.4	81.6	82.7	54.9	24.5	47.1	48.8
		2.6	4.2	2.2	2.5	2.8	2.2	3.0	5.6	4.0	4.4	2.6	6.0	7.5	5.7	19.6	7.7	14.4	5.7
	20	28.5	30.9	30.2	15.1	20.6	25.2	39.8	54.1	63.3	21.7	140.1	114.4	129.6	86.9	436.3	109.5	47.1	82.0
		6.3	6.6	4.0	2.5	2.5	2.6	3.6	5.1	6.0	2.1	6.4	7.8	5.2	12.0	15.5	9.4	14.4	6.6
	35	33.1	25.8	16.8	42.9	18.3	29.8	51.1	43.7	40.6	34.9	78.4	68.9	64.4	121.2	325.1	267.9	155.4	83.5
		6.2	10.5	6.0	6.4	3.2	4.6	5.3	5.5	5.0	3.2	6.0	5.0	5.2	10.7	16.0	13.3	11.3	7.3
Nitzschia vermicularis	2.5														7.3				0.4
															0.5				<.05
	5					6.3	6.2	5.0	3.7										1.2
						0.3	0.2	0.2	0.1										0.1
	10					12.9			4.0				8.1			6.0			1.8
						0.6			0.3				0.4			0.4			0.1
	15						4.5		5.5	8.2					4.4	3.0			1.5
							0.1		0.4	0.7					0.3	1.1			0.2
	20							3.6				5.4				6.6		2.4	1.1
								0.1				0.2				0.2		0.7	0.1
	35														4.5				0.3
															0.4				<.05
Melosira granulata	2.5	7.2			3.3		13.9		6.2			6.0	21.9			18.4			4.5
		0.3			0.1		0.4		0.3			0.2	0.7			0.8			0.2
	5				5.4	12.5	6.2				8.3	4.7	3.5	6.8	14.2	7.0	6.0		4.4
					0.3	0.5	0.2				0.1	0.2	0.2	0.4	0.7	0.3	0.2		0.2
	10	2.2				12.9	5.1	62.6		9.1	2.8	7.8		8.3	6.8	6.1	30.3		9.1
		0.4				0.6	0.3	1.8		0.8	0.1	0.7		0.3	0.7	0.4	2.5		0.5
	15		1.7		12.3	3.6	13.5	20.7	16.5		7.5	12.6	24.1		17.4		2.7	1.8	7.9
			0.5		1.3	0.5	0.8	1.0	1.1		0.9	0.7	1.2		1.2		0.8	0.5	0.6
	20		2.2	2.7	2.2			14.5	12.7	4.0	21.7	32.3	19.1	15.0	3.8	19.8			8.8
			0.5	0.4	0.4			1.3	1.2	0.4	2.1	1.5	1.3	0.6	0.5	0.7			0.6
	35	2.8	3.5	4.2	3.6	4.6		7.9	10.9	18.7	17.5	19.6	4.9	8.7	13.5	34.6	40.2	12.0	12.2
		0.5	1.4	1.5	0.5	0.8		0.8	1.4	2.3	1.6	1.5	0.4	0.7	1.2	1.7	2.0	0.9	1.1
Rhizosolenia eriensis	2.5																		
	5					12.5													0.7
						0.5													<.05
	10											3.9							0.2
												0.4							<.05
	15			5.7						4.1									0.6
				0.5						0.3									<.05
	20											5.4	3.2	5.0	3.8				1.0
												0.2	0.2	0.2	0.5				0.1
	35					4.6	2.1		7.3					4.4					1.1
						0.8	0.3		0.9					0.4					0.2
Surirella group	2.5																13.8		0.8
																	0.5		<.05
	5											4.7					6.0		0.6
												0.2					0.2		<.05
	10	2.2	1.7	4.0			5.1	7.0			5.5						12.1	5.1	2.3
		0.4	0.3	0.6			0.3	0.2			0.2						1.0	0.5	0.2
	15							5.2	5.5							3.0		1.8	0.9
								0.3	0.4							1.1		0.5	0.1
	20	2.4	2.2					3.6	6.4			10.8		5.0	3.8	19.8	10.6	2.4	3.4
		0.5	0.5					0.3	0.6			0.5		0.2	0.5	0.7	0.9	0.7	0.3
	35						2.1		3.6	3.1		7.8			6.5	4.4	4.5		1.9
							0.3		0.5	0.4		0.6			0.4	0.3	0.2		0.2

TABLE XI (Continued)

Organism	Depth in feet	Jul 11	Jul 13	Jul 17	Jul 20	Jul 26	Jul 27	Aug 2	Aug 4	Aug 8	Aug 10	Aug 14	Aug 17	Aug 25	Aug 28	Sep 5	Sep 15	Nov 9	Mean
Synedra acus	2.5	1602.7	1392.1	600.5	2188.2	2134.3	2121.3	1250.1	942.0	796.1	997.2	1658.4	[illegible]	1607.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		21.4	20.3	67.0	78.8	74.6	74.8	30.9	51.6	32.5	66.5	65.1	[illegible]	67.4	55.7	[illegible]	[illegible]	[illegible]	[illegible]
	5	368.6	499.5	870.1	1173.8	1456.4	932.1	1431.0	577.4	1288.9	1552.4	1201.4	890.2	1206.3	1760.4	1120.3	1672.8	561.8	[illegible]
		56.6	38.5	62.1	62.1	60.2	65.0	60.8	52.9	56.7	60.0	57.6	60.6	67.2	57.2	55.9	60.4	51.9	[illegible]
	10	331.8	180.9	513.7	741.7	1083.0	888.5	1954.6	697.9	402.6	627.7	558.3	1081.1	1780.8	496.7	688.4	490.1	413.4	[illegible]
		53.4	32.2	48.5	54.4	52.5	49.2	54.7	47.7	36.3	27.4	52.0	47.5	57.8	51.9	41.9	40.8	41.1	[illegible]
	15	282.5	187.5	355.0	450.8	302.1	603.1	397.6	626.9	454.0	339.5	224.4	388.7	469.1	583.0	97.5	127.2	48.9	[illegible]
		55.9	32.1	29.6	46.6	39.1	36.1	38.9	40.1	37.4	39.9	41.4	39.1	43.4	40.7	34.8	40.2	16.5	[illegible]
	20	137.6	246.8	260.7	179.5	288.1	328.2	365.2	588.6	474.8	354.6	872.7	540.1	877.5	290.8	780.1	480.6	61.6	407.4
		30.5	52.8	34.3	30.1	34.3	33.6	33.0	36.9	45.3	34.8	39.9	36.6	35.4	40.0	27.8	41.2	19.4	35.6
	35	242.5	127.9	111.2	248.7	210.2	277.0	401.0	120.4	293.4	425.1	431.3	441.0	584.2	350.1	685.8	750.1	412.5	371.4
		43.6	32.2	39.8	36.7	27.1	42.9	41.6	40.6	36.2	38.6	33.0	31.9	46.9	30.9	33.7	17.2	29.9	38.5
Synedra ulna	2.5	128.7	111.7	45.6	69.7	53.5	104.3	18.0	6.2		16.3	12.1	14.6	17.8	7.3	36.6	20.7	2.4	39.5
		5.9	5.9	4.4	2.3	1.7	3.1	1.0	0.3		1.1	0.5	0.5	0.9	0.5	1.6	0.8	0.6	1.8
	5	22.5	21.5	11.4	40.3	31.3	43.1	39.9	7.4	21.4	16.2	14.0	14.2	13.6	21.4	14.0	30.1	5.1	27.6
		2.2	2.5	0.8	2.1	1.3	1.4	1.7	0.7	0.9	0.6	0.7	1.0	0.7	1.0	0.8	1.1	0.5	1.2
	10	8.8	5.0	18.1		12.9	30.6	27.8	8.0	18.1	19.1		8.1	41.6	3.4	24.6	6.1		13.6
		1.4	0.9	1.7		0.6	1.7	0.8	0.5	1.6	0.8		0.4	1.3	0.4	1.6	0.5		0.8
	15	3.7	3.1	2.9	20.5	7.2	9.0	10.4	5.5	12.3	3.7	8.6	30.1	10.2	4.4		2.7		7.9
		0.7	0.9	0.2	2.1	0.9	0.5	0.5	0.4	1.0	0.4	0.5	1.5	0.9	0.3		0.8		0.7
	20		8.8	11.0	6.5			3.6	6.4	11.8	7.2	7.8	6.4	19.9	7.6	26.4	10.6	4.7	8.2
			1.9	1.4	1.1			0.3	0.6	1.1	0.7	0.4	0.4	0.8	1.0	0.9	0.9	1.4	0.1
	35	3.3				4.6	4.1		7.1	4.4			9.8	8.7	4.3	68.5		6.0	6.4
		1.0				0.8	0.7		0.9	1.2			0.7	0.7	0.4	2.4		0.4	0.5
Tabellaria fenestrata	2.5												7.1	5.9					0.6
													0.2	0.3					<.05
	5						6.6							6.8	7.1				1.2
							0.2							0.4	0.5				0.1
	10																		
	15													5.1					0.3
														0.5					<.05
	20								3.2									2.4	0.1
									0.1									0.7	
	35								3.6	1.1							4.5		0.7
									0.5	0.4							0.2		0.1
Tabellaria flocculosa	2.5																		
	5				2.7											27.9			1.8
					0.1											1.2			0.1
	10												8.1						0.3
													0.4						<.05
	15						4.5							5.1		3.0			0.7
							0.1							0.5		1.1			0.1
	20		2.3										3.2	5.0		13.2	3.5	2.4	1.7
			0.5										0.2	0.2		0.5	0.3	0.7	0.1
	35											3.9		5.4			13.4	6.0	1.7
												0.3		0.4			0.7	0.4	0.1
Unidentified Diatoms	2.5	35.8	9.8	22.7	6.6			9.0		6.5		48.4		11.8		9.2	20.7	2.4	10.8
		1.6	0.5	2.2	0.2			0.5		0.4		1.9		0.6		0.4	0.8	0.6	0.8
	5	24.2	7.9	3.8	8.1			10.0	7.4		24.3	4.7	7.1	20.3		7.0	24.2		9.0
		2.8	0.9	0.3	0.4			0.4	0.2		0.9	0.2	0.5	1.1		0.3	0.9		0.6
	10	6.6		9.1	13.8	6.5	10.2	55.6		4.5	8.3	11.7	16.3	16.6		18.4	6.2	5.1	11.2
		1.1		0.9	1.0	0.3	0.6	1.6		0.4	0.4	1.1	0.7	0.5		1.2	0.7	0.5	0.6
	15	7.4	5.0	20.0			13.5	25.9		4.1	7.5	25.3	12.0	5.1	4.4	3.0		5.4	8.3
		1.5	1.4	1.7			0.8	1.3		0.1	0.9	1.4	0.6	0.5	0.3	1.1		1.6	0.8
	20	21.4	15.4	8.2	6.5	5.9	3.6	3.6	25.5	4.0	3.6	16.2	6.4	5.0	9.0	33.1	10.6		10.5
		4.7	3.3	1.1	1.1	0.7	0.4	0.3	2.4	0.4	0.4	0.7	0.4	0.2	1.2	1.2	0.9		1.1
	35	33.8	3.5	18.8	10.7	9.2	10.7	23.6	10.9	15.6	17.5	19.6	29.5	17.4		20.2	24.8	29.9	17.5
		6.7	1.4	6.0	1.6	1.6	1.7	2.5	1.4	1.9	1.6	1.5	2.1	1.4		1.0	1.3	2.2	2.1
Class Chrysophyceae *Dinobryon sertularia*	2.5								6.2	6.5		12.1		11.8	7.3				2.6
									0.3	0.4		0.5		0.6	0.5				0.1
	5							5.0			8.1	9.3	7.1		14.2	21.0			3.8
								0.2			0.3	0.4	0.5		0.7	0.9			0.2
	10							7.0				3.9	24.4	49.7	20.4	17.3			4.9
								0.2				0.4	1.1	1.6	2.2	0.8			0.4
	15										3.7	4.3		36.7	39.2	3.0			5.1
											0.4	0.2		3.4	2.7	1.1			0.5
	20										3.6	5.4	3.2	29.9	15.1	24.4			4.9
											0.4	0.2	0.2	1.2	2.1	0.9			0.3
	35									3.1		2.8	4.9	26.2	33.9	20.8	4.5		5.1
										0.4		0.8	0.4	2.1	1.2	1.0	0.2		0.5

TABLE XI (Continued)

Organism	Depth in feet	Jul 11	Jul 13	Jul 17	Jul 20	Jul 26	Jul 27	Aug 2	Aug 4	Aug 8	Aug 10	Aug 14	Aug 17	Aug 25	Aug 28	Sep 5	Sep 15	Nov 9	Mean
Phylum Chlorophyta *Scenedesmus quadricauda*	2.5									6.5			15.6						1.2
										0.4			0.5						0.1
	5					12.5								6.8	7.1	7.0	8.0	8.6	2.7
						0.5								0.4	0.1	0.1	0.2	0.8	0.1
	10										2.8		8.1	8.3		12.3	12.3		2.6
											0.1		0.4	0.3		0.8	1.0		0.2
	15							15.5					5.9		4.4				1.5
								0.8					0.3		0.3				0.1
	20					2.9						5.4			5.8	6.5			1.1
						0.3						0.2			0.5	0.2			0.1
	35																		
Unidentified Greens	2.5		3.3		10.0		7.0		18.6	19.4		12.1	21.9						5.5
			0.7		0.3		0.2		1.0	1.3		0.5	0.7						0.2
	5	3.2	6.1		16.1	18.8	12.3	10.0	3.7		8.1	4.7	7.1	6.8				6.6	6.1
		0.3	0.7		0.9	0.8	0.6	0.4	0.3		0.1	0.2	0.5	0.4				0.6	0.3
	10		13.3	18.1	13.8	12.9	10.2	14.8	4.0	18.1	11.0		16.3			6.1			9.1
			2.4	1.7	1.0	0.6	0.6	1.0	0.3	1.6	0.5		0.7			0.4			0.4
	15	1.9	3.3	22.9	16.4	3.6		25.9	11.0	20.4	3.7	4.2	6.0		4.4	3.0			7.3
		0.4	0.9	1.9	1.7	0.5		1.3	0.7	1.7	0.4	0.2	0.3		0.3	1.1			0.7
	20	11.9	4.4	13.7	6.5	8.8	14.9	18.1			14.5	21.5	22.4	5.0	7.6	6.8			9.1
		2.6	0.9	1.8	1.1	1.0	1.5	1.6			1.4	1.0	1.5	0.2	1.0	0.2			0.9
	35	8.3		4.2	3.2	2.3	4.3		7.3	3.1		19.6	14.8	8.7	13.5		4.5		5.8
		1.6		1.5	1.1	0.4	0.7		0.9	0.4		1.5	1.1	0.7	1.2		0.2		0.7
Phylum Cyanophyta *Anabaena sp.*	2.5												14.6			36.8			3.0
													0.5			1.6			0.1
	5					106.3	71.8	79.8				55.9							18.5
						4.4	2.5	3.4				2.7							0.8
	10					27.4	71.5	292.1		13.6		19.5							27.9
						3.7	4.0	8.2		1.2		1.8							1.1
	15					18.0	27.5	61.3				46.3							9.1
						2.3	1.6	3.1				2.6							0.6
	20					14.7						140.3		124.7		297.5			33.9
						1.7						6.4		5.0		10.6			1.4
	35		9.4			18.3						70.6				166.3			15.6
			3.8			1.2						5.4				8.2			1.2
Lyngbya sp.	2.5									6.5						9.2		4.8	1.2
										0.4						0.4		1.1	0.1
	5						6.2												0.4
							0.2												<.05
	10																6.1		0.4
																	0.5		<.05
	15						4.5			4.1					4.4				0.8
							0.3			0.3					0.3				0.1
	20										7.2					19.8	3.5	2.1	2.2
											0.7					0.7	0.3	2.2	0.2
	35				3.6	2.3		7.9	7.3	9.4		15.7					4.5	29.9	6.7
					0.5	0.4		0.8	0.9	1.2		1.2					0.2	2.2	0.4
Merismopedia convoluta	2.5																		
	5															27.9		6.6	2.0
																1.2		0.6	0.1
	10				4.6								8.1						0.7
					0.3								0.4						<.05
	15				4.1				5.5		3.7					3.0		3.6	1.2
					0.4				0.4		0.4					1.1		1.1	0.2
	20			5.5	2.2							5.4	6.4	5.0					1.4
				0.7	0.4							0.2	0.4	0.2					0.1
	35				3.6			3.9					4.9						0.7
					0.5			0.4					0.4						0.1
Oscillatoria sp.	2.5	7.2										6.0	7.1					7.3	1.6
		0.3										0.2	0.2					1.7	0.1
	5																	26.5	1.6
																		2.4	0.1
	10	11.0	1.7	6.0														13.2	2.0
		1.8	0.3	0.6														1.5	0.2
	15	5.6					27.5						6.0					5.6	2.6
		1.1					1.6						0.3					1.6	0.3
	20																	2.4	0.1
																		0.7	<.05
	35								3.6			11.8						17.9	2.0
									0.5			0.9						1.1	0.2

TABLE XI (Continued)

Organism	Depth in feet	Jul 11	Jul 13	Jul 17	Jul 20	Jul 26	Jul 27	Aug 2	Aug 4	Aug 8	Aug 10	Aug 14	Aug 17	Aug 25	Aug 28	Sep 5	Sep 15	Nov 9	Mean
Unidentified Blue-greens	2.5		3.1		5.1	13.4	20.9	9.0	6.2		10.9	30.2		17.8	7.3		55.2		[illegible]
			0.2		0.1	0.4	0.6	0.5	0.1		0.7	1.2		0.9	0.5		2.8		[illegible]
	5		4.8	26.6	10.7					42.8	48.5		46.3	20.3	78.3	118.7	78.2		[illegible]
			0.5	1.9	0.6					1.9	1.9		3.3	1.1	3.6	5.0	2.8		[illegible]
	10			27.2	46.8				21.9		46.8		89.6	74.5	34.6	92.1	80.1		26.8
				2.4	2.7				1.6		2.0		3.9	2.4	3.7	5.9	[illegible]		[illegible]
	15			28.6	20.5		40.5		27.5	20.4	22.4		54.2	25.5	69.6	1.0	2.7		[illegible]
				[illegible]	3.1		2.4		1.8	1.7	2.6		2.7	2.4	4.8	1.1	[illegible]		[illegible]
	20		2.2	19.2	26.0		36.1	72.3	28.7	15.8	21.7		[illegible]	14.9	18.9		80.1		[illegible]
			0.5	[illegible]	[illegible]		3.7	6.5	0.7	1.5	2.1		7.3	1.6	2.6		5.2		[illegible]
	35			7.0	14.3		23.4	27.5	10.9	15.6	23.3		54.1		38.0		[illegible]		20.9
				2.5	2.1		3.6	2.9	1.4	1.9	2.1		3.9		1.6		7.3		1.7

* This table includes only those organisms found on eight or more of the seventeen sampling days included.

** See Table IX for the species included in the groups given in this table. Gomphonema was identified only to genus.

TABLE XVIII

ORGANISMS OCCURING AS REGROWTH ON ARTIFICIALLY DENUDED ROCKS, STONY POINT BAY, LAKE SUPERIOR, 1967.
EXPRESSED AS COUNTS AND PER CENT CONTRIBUTION TO THE TOTAL.
ORGANISMS X 10^3 PER SQUARE CENTIMETER OF ROCK SURFACE OVER PERCENTAGE.

Organism	Depth in feet	* Date and "Incubation Time"									
		Aug 1 8 hrs.	Aug 2 48 hrs.	Aug 4 96 hrs.	Aug 8 8 days	Aug 15 15 days	Aug 25 25 days	Aug 28 28 days	Sep 5 36 days	Sep 15 46 days	Nov 10 101 days
* Phylum Chrysophyta Class Bacillariophyceae *Achnanthes microcephala*	10	10.9	11.0	9.9	21.6	27.2	56.6	31.3	86.2	62.4	N.S.
		56.0	41.3	16.6	11.5	11.9	11.8	18.0	25.5	16.8	
	20	10.2	47.0	6.1	18.1	32.7	68.8	39.3	29.8	23.7	N.S.
		61.6	28.3	27.4	30.0	20.6	14.7	21.5	15.9	21.6	
	35	3.2	15.2	24.3	2.8	11.5	24.0	28.1	25.8	39.4	51.8
		40.0	60.1	61.0	28.6	17.4	11.2	21.8	16.7	18.3	50.3
Amphora ovalis	10										N.S.
	20										N.S.
	35							0.8			
								0.7			
Amphora normani	10									2.2	N.S.
										0.6	
	20					1.1					N.S.
						0.7					
	35					1.1					
						0.7					
Asterionella formosa	10	0.5		0.9			1.2	1.8	1.1	8.6	N.S.
		1.7		1.5			0.3	0.6	0.4	2.3	
	20						1.0	1.4	5.6	10.5	N.S.
							0.3	0.8	2.6	3.1	
	35					1.4	7.6	2.5	7.9	4.8	
						2.1	4.2	2.3	5.0	2.2	
Ceratoneis arcus	10								1.1		N.S.
									0.4		
	20										N.S.
	35										
** *Cocconeis* group	10				0.7	2.4	8.3	8.2	16.7	4.3	N.S.
					0.4	1.1	2.3	2.9	4.8	1.2	
	20				2.6	4.3	7.7	4.7	18.0	14.0	N.S.
					4.3	3.3	1.8	2.6	8.4	3.1	
	35	0.7				2.9	10.9	6.7	12.8	9.5	4.4
		8.8				4.6	6.0	6.1	8.1	4.4	3.4
Cyclotella group	10				0.7		2.4	1.8	2.6	2.2	N.S.
					0.4		0.7	0.6	0.7	0.6	
	20				1.7	2.1	1.0	1.4	3.7	5.3	N.S.
					2.8	1.1	0.5	0.8	1.7	1.6	
	35			1.1		2.9	3.3	4.2	1.0	6.0	6.1
				2.8		4.4	1.8	3.8	0.6	2.8	4.7
Cymatopleura solea	10										N.S.
	20				0.9						N.S.
					1.5						
	35					1.4					
						2.1					
Cymbella Group A	10				2.0	1.2	4.7	1.8	3.9	6.5	N.S.
					1.1	0.5	1.3	0.6	1.1	1.8	
	20							0.7		1.8	N.S.
								0.4		0.5	
	35							0.8			0.9
								0.7			0.7
Cymbella Group B	10	1.5	4.0	6.3	15.5	8.7	27.1	31.1	33.5	25.8	N.S.
		5.0	5.0	10.5	8.5	3.8	7.6	10.9	9.5	7.0	
	20				0.9	10.6	2.9	5.4	9.9	19.3	N.S.
					1.5	6.6	1.4	3.0	4.6	5.7	
	35	0.4				7.2	13.1	6.7	2.0	6.0	1.8
		5.0				10.9	7.2	6.1	1.1	2.8	1.4

TABLE XVIII (Continued)

Organism	Depth in feet	Date and "Incubation Time"									
		Aug 1 8 hrs.	Aug 2 48 hrs.	Aug 4 96 hrs.	Aug 8 8 days	Aug 15 15 days	Aug 25 25 days	Aug 28 28 days	Sep 5 36 days	Sep 15 46 days	Nov 10 101 days
Denticula thermalis	10						1.7	1.8	1.9	5.1	N.S.
							0.3	0.6	1.1	1.2	
	20						1.0		2.5	1.8	N.S.
							0.5		1.2	0.7	
	35						1.1	1.7	1.0		
							0.6	1.5	0.6		
Diatoma elongatum	10				0.7	3.7	3.4		5.1	2.2	N.S.
					0.4	1.6	1.0		1.5	0.6	
	20				0.9		1.0	1.4	1.2		N.S.
					1.5		0.5	0.8	0.6		
	35										
Fragilaria capucina	10						2.4				N.S.
							0.7				
	20										N.S.
	35										
Fragilaria harrisonii	10										N.S.
	20									1.8	N.S.
										0.5	
	35										
Frustulia viridula	10				2.0	1.2		6.4	2.6	6.5	N.S.
					1.1	0.5		2.7	2.7	1.8	
	20							0.7			N.S.
								0.4			
	35										
Gomphoneis herculeana	10										N.S.
	20							0.7			N.S.
								0.4			
	35										
Gomphonema group	10	1.5	4.0	2.7	3.4		10.6	8.2	15.4	36.6	N.S.
		5.0	5.0	4.5	1.8		3.0	2.9	4.4	9.9	
	20	1.5	2.2	0.8		5.3	7.7	1.4	6.7	7.0	N.S.
		9.3	3.6	3.5		3.3	3.8	0.8	2.9	2.1	
	35	0.4	1.9	6.6	2.1	4.3	5.5	0.8	3.0	16.1	4.6
		5.0	7.5	16.7	21.4	6.5	3.0	0.7	1.9	7.5	3.6
Melosira crenulata	10				1.3	1.2	1.2	3.7	1.3	10.8	N.S.
					0.7	0.5	0.3	1.3	0.4	2.9	
	20				2.6	2.1	1.0	1.4	1.9	3.5	N.S.
					4.3	1.3	0.5	0.8	0.9	1.0	
	35						2.2	0.8	1.0	6.0	
							1.7	0.7	0.6	2.8	
Navicula group	10	1.5	3.0	2.7	8.1	7.4	24.8	16.5	41.2	43.0	N.S.
		5.0	3.8	4.5	4.3	3.2	6.9	5.8	11.7	11.6	
	20	1.5	0.7			13.7	9.7	10.8	19.8	45.6	N.S.
		9.3	1.2			8.5	4.7	5.9	9.2	13.4	
	35	0.4		2.2	0.7	1.4	9.8	1.7	12.8	13.1	7.9
		3.0		5.6	7.1	2.1	5.4	1.5	8.1	6.1	6.1
Nitzschia palea	10								1.3	2.2	N.S.
									0.4	0.6	
	20										N.S.
	35										
Nitzschia vermicularis	10				0.7		1.2				N.S.
					0.4		0.3				
	20							1.4	0.6		N.S.
								0.8	0.3		
	35										

TABLE XVIII (Continued)

Organism	Depth in feet	Date and "Incubation Time"									
		Aug 1 8 hrs.	Aug 2 48 hrs.	Aug 4 96 hrs.	Aug 8 8 days	Aug 14 14 days	Aug 21 21 days	Aug 28 28 days	Sep 5 36 days	Sep 15 46 days	Nov 9 101 days
Pinnularia viridis	10					1.2	1.2				N.S.
						0.5	0.3				
	20										N.S.
	35										
Rhizosolenia eriensis	10						2.4		1.3		N.S.
							0.7		0.4		
	20			0.8	0.9		1.0	0.7	0.6		N.S.
				3.5	1.5		0.5	0.4	0.3		
	35				0.7		2.2	0.8	3.9	1.2	
					7.1		1.2	0.7	2.3	0.4	
Stauroneis producta	10						2.6		1.3		N.S.
							0.7		0.4		
	20										N.S.
	35										
Surirella group	10										N.S.
	20		0.7								N.S.
			1.2								
	35							0.8			0.9
								0.7			0.7
Synedra acus	10	11.9	29.0	31.2	118.5	153.3	180.4	139.1	114.6	137.7	N.S.
		19.1	36.1	55.3	61.2	67.1	50.5	48.9	32.6	37.7	
	20	2.4	7.4	12.7	27.5	68.6	71.6	90.8	82.5	121.1	N.S.
		14.5	12.2	55.2	45.5	42.7	36.0	49.7	38.5	35.6	
	35	2.5	7.6	5.3	1.4	31.6	77.5	40.3	75.9	101.4	33.4
		31.1	10.0	8.4	14.3	47.9	42.5	36.7	46.8	47.1	25.9
Synedra ulna	10				6.1		1.5	2.7		2.2	N.S.
					3.3		1.0	0.9		0.6	
	20					1.1	1.0	0.7	2.5		N.S.
						0.7	0.5	0.4	1.2		
	35						3.3	0.8		1.7	2.4
							1.8	0.7		0.6	7.0
Tabellaria fenestrata	10						1.2		2.6	7.2	N.S.
							0.3		0.7	0.4	
	20						1.0	2.0	0.4		N.S.
							0.5	1.1	0.3		
	35								1.0		
									0.9		
Tabellaria flocculosa	10					1.2					N.S.
						0.5					
	20				0.9				0.6	5.3	N.S.
					1.5				0.3	1.6	
	35				0.7					1.2	5.3
					7.1					0.6	4.1
Unidentified diatoms	10	1.0	3.0		3.6	2.5	9.4	3.7	2.6	6.6	N.S.
		1.3	3.8		1.8	1.0	2.6	1.3	0.7	2.1	
	20	0.5	1.5	0.8		3.2	3.9	3.4	3.7	3.5	N.S.
		3.1	2.3	3.5		2.0	1.9	3.0	1.7	1.0	
	35	0.4	0.6	1.1		1.4	4.4	0.8	2.0	1.2	3.5
		5.0	2.4	2.8		2.1	2.4	0.7	1.3	0.4	2.3
Class Chrysophyceae *Dinobryon sertularia*	10					1.2					N.S.
						0.5					
	20					1.1	8.7	6.8	1.7		N.S.
						0.7	4.3	3.7	1.7		
	35						7.6	5.9	2.0	1.7	
							6.2	5.4	1.3	0.4	
Phylum Chlorophyta *Cosmarium* sp.	10										N.S.
	20					1.1					N.S.
						0.7					
	35										

TABLE XVIII (Continued)

Organism	Depth in feet	Date and "Incubation Time"									
		Aug 1 8 hrs.	Aug 2 48 hrs.	Aug 4 96 hrs.	Aug 8 8 days	Aug 14 14 days	Aug 21 21 days	Aug 28 28 days	Sep 5 36 days	Sep 15 46 days	Nov 9 101 days
Scenedesmus quadricauda	10						1.2	0.9	5.1		N.S.
							0.3	0.3	1.5		
	20						1.0				N.S.
							0.5				
	35										
Unidentified greens	10	0.5	1.0	4.5	0.7	3.7	4.7				N.S.
		1.7	3.8	7.5	0.4	1.6	3.3				
	20				3.4	4.2	2.9	0.7	0.6	1.8	N.S.
					5.6	2.6	1.4	0.4	0.3	0.5	
	35			1.1	1.4		3.3	4.2	1.0	2.6	
				2.8	14.3		1.8	3.8	0.6	1.1	
Phylum Cyanophyta *Anabaena* sp.	10	1.0	1.0			9.9					N.S.
		1.3	1.1			4.3					
	20			1.6						22.8	N.S.
				7.0						6.7	
	35										5.3
											4.1
Lyngbya sp.	10					1.2					N.S.
						0.5					
	20		0.7								N.S.
			1.2								
	35										
Merismopedia convoluta	10					1.2	1.2			2.2	N.S.
						0.5	0.3			0.6	
	20						1.9	0.7			N.S.
							0.9	0.4			
	35						1.1				
							0.6				
Oscillatoria sp.	10										N.S.
	20										N.S.
	35									1.2	
Unidentified blue-greens	10						4.7	5.5	7.7	1.8	N.S.
							1.3	1.9	2.2	0.5	
	20					8.4	7.7	4.1	20.5		N.S.
						5.2	3.8	2.2	9.6		
	35						4.4	3.4	7.0	3.6	
							2.4	3.1	4.4	1.7	

* N.S. indicates no sample was taken; a blank space indicated zero.

** See Table IX for the species included in the groups given in this table. Gomphonema was identified only to genus.

Figure 11. Naturally occurring periphyton ash-free dry weights at 2.5 feet, Stony Point Bay, Lake Superior, 1967.

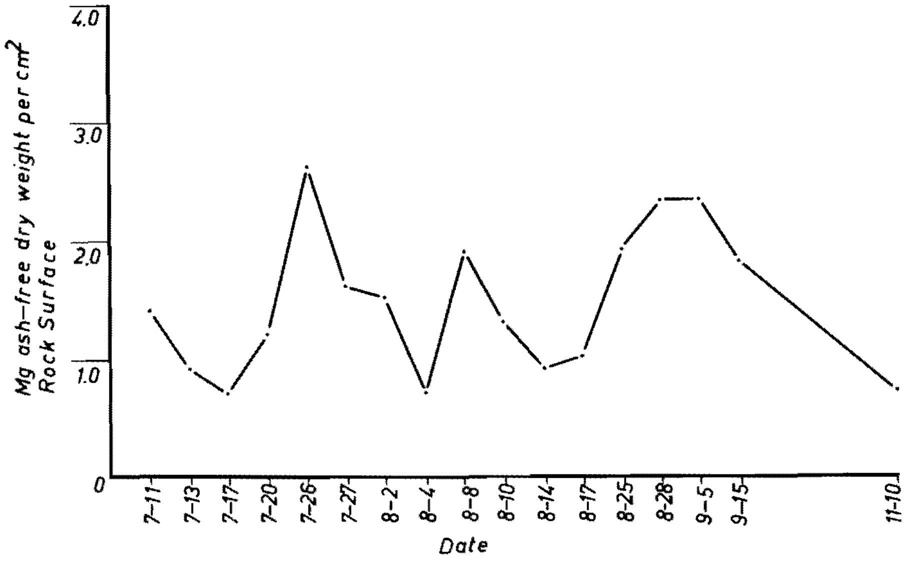

Figure 12. Naturally occurring periphyton ash-free dry weights at five feet, Stony Point Bay, Lake Superior, 1967.

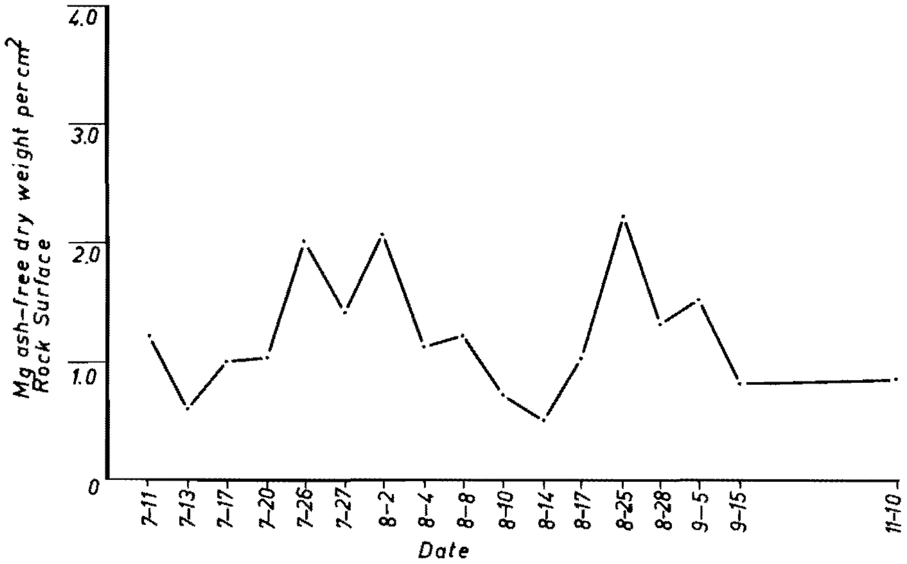

Figure 13. Naturally occurring periphyton ash-free dry weights at 10 feet, Stony Point Bay, Lake Superior, 1967.

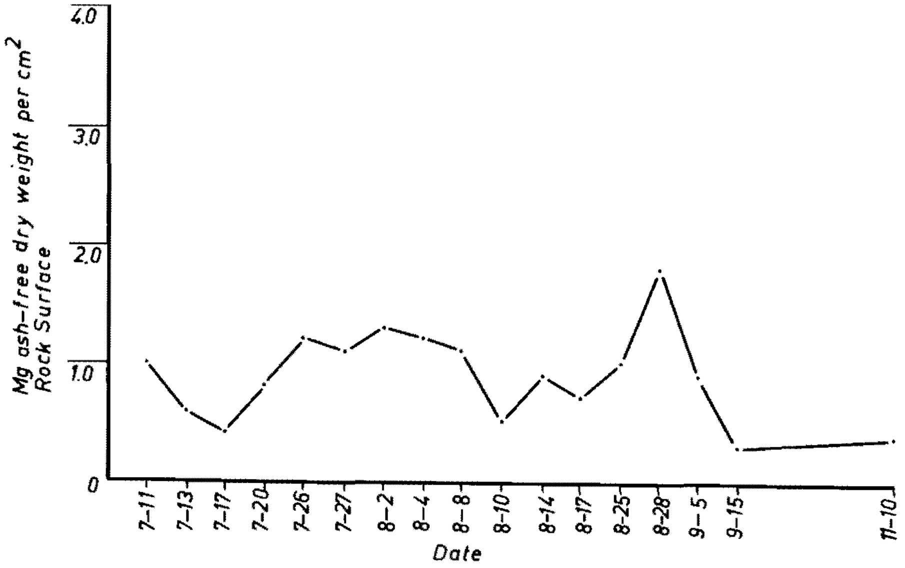

Figure 14. Naturally occurring periphyton ash-free dry weights at 15 feet, Stony Point Bay, Lake Superior, 1967.

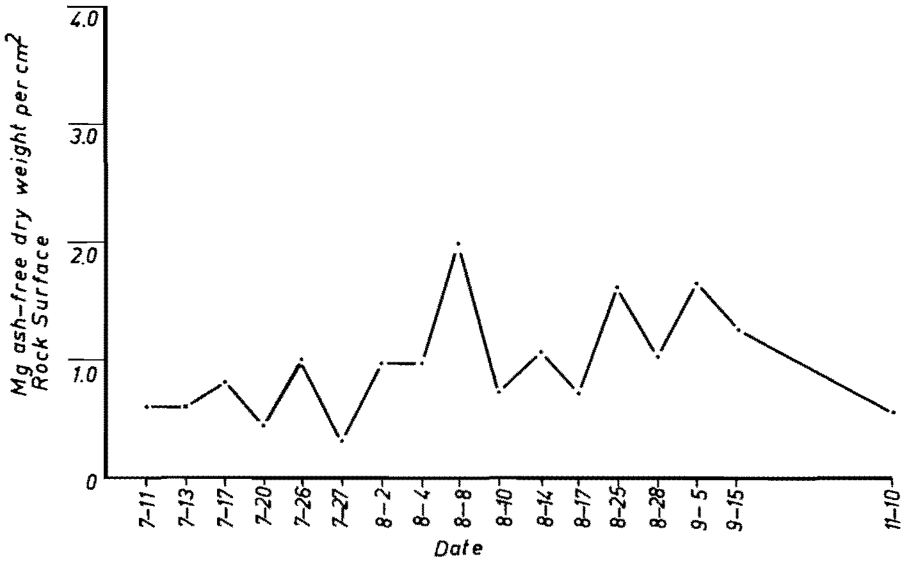

Figure 15. Naturally occurring periphyton ash-free dry weights at 20 feet, Stony Point Bay, Lake Superior, 1967.

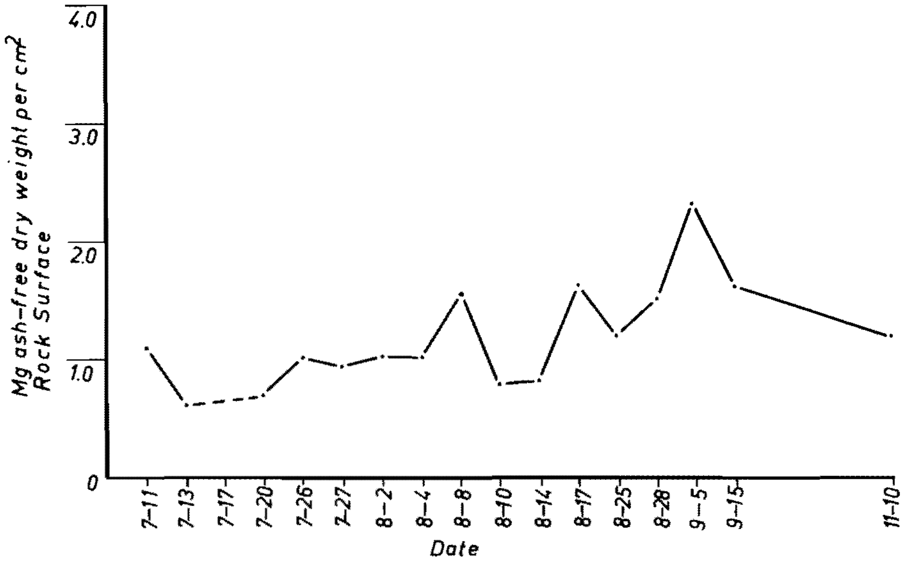

Figure 16. Naturally occurring periphyton ash-free dry weights at 35 feet, Stony Point Bay, Lake Superior, 1967.

Plate 12. Amphora ovalis

Plate 13. Asterionella formosa

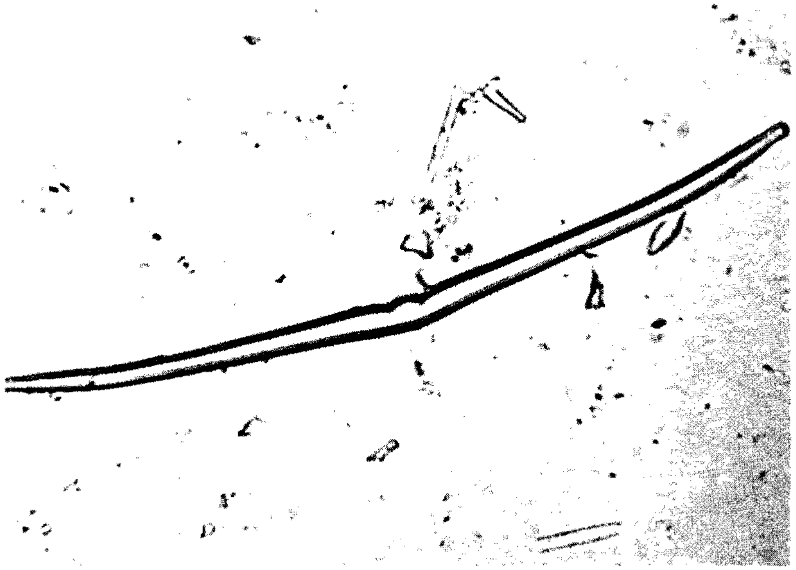

Plate 14. Ceratoneis arcus

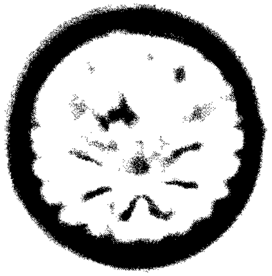

Plate 15. Cyclotella antiqua

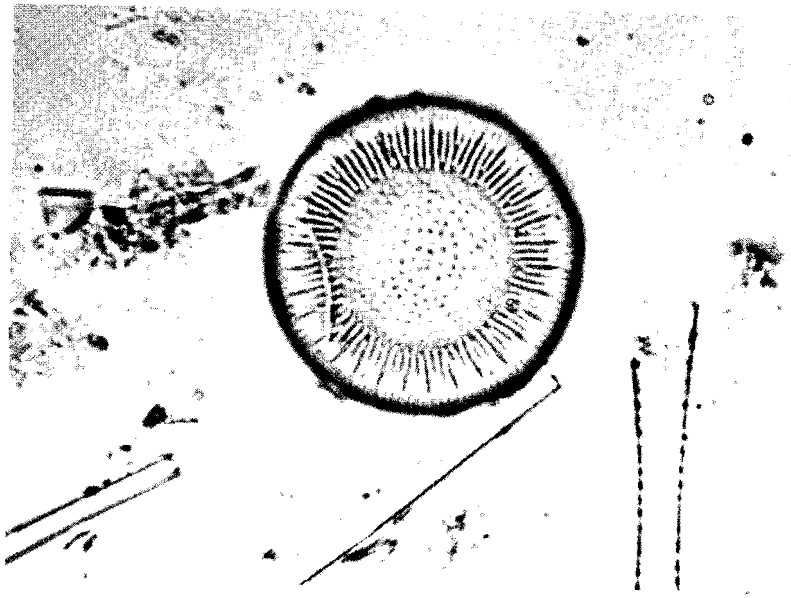

Plate 16. Cyclotella bodanica

Plate 17. Cymatopleura solea

Plate 18. Denticula thermalis

Plate 19. Diatoma vulgare

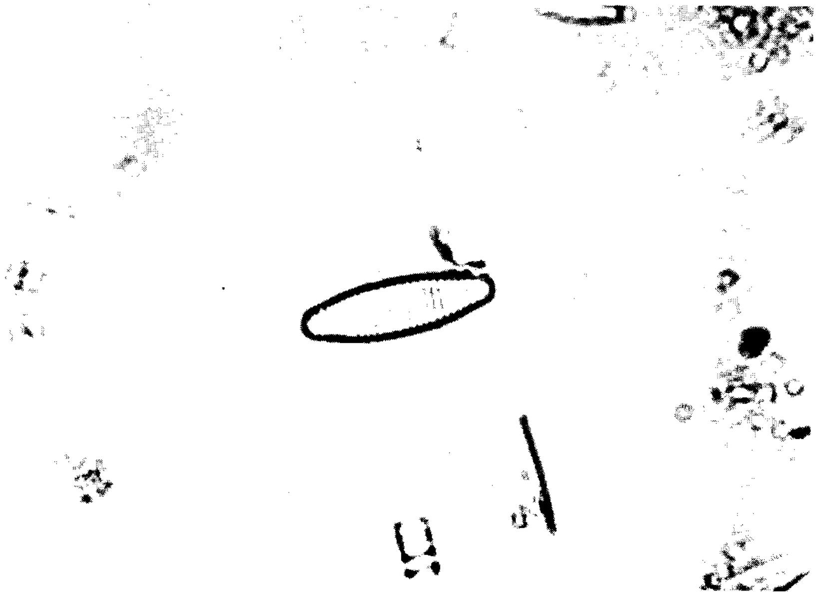

Plate 20. Diatoma vulgare

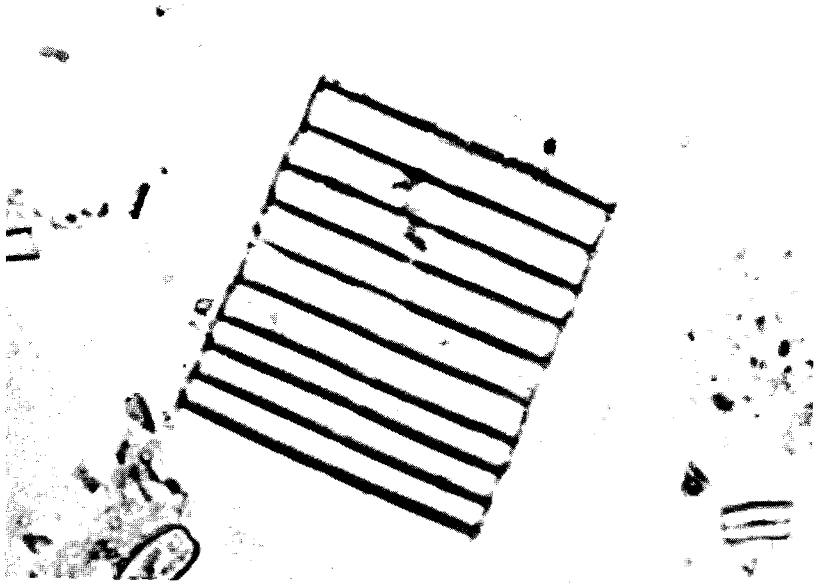

Plate 21. Fragilaria capucina

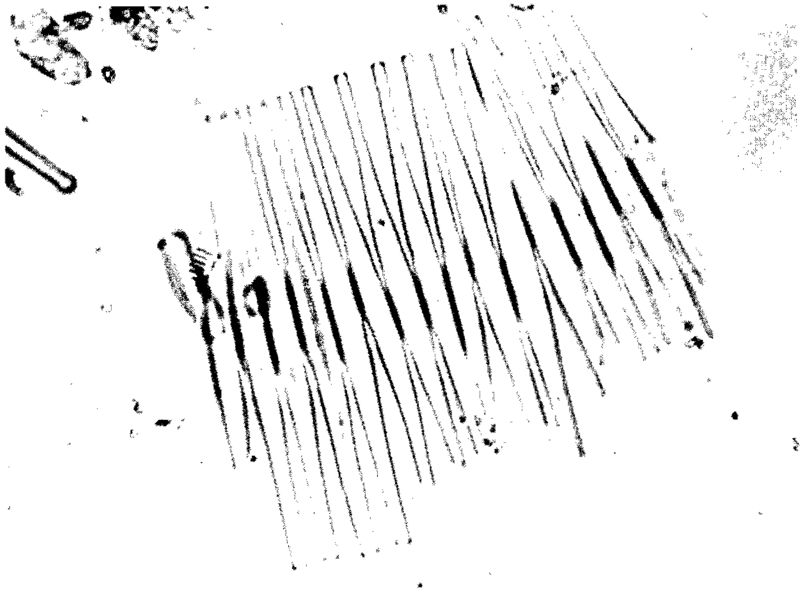

Plate 22. Fragilaria crotonensis

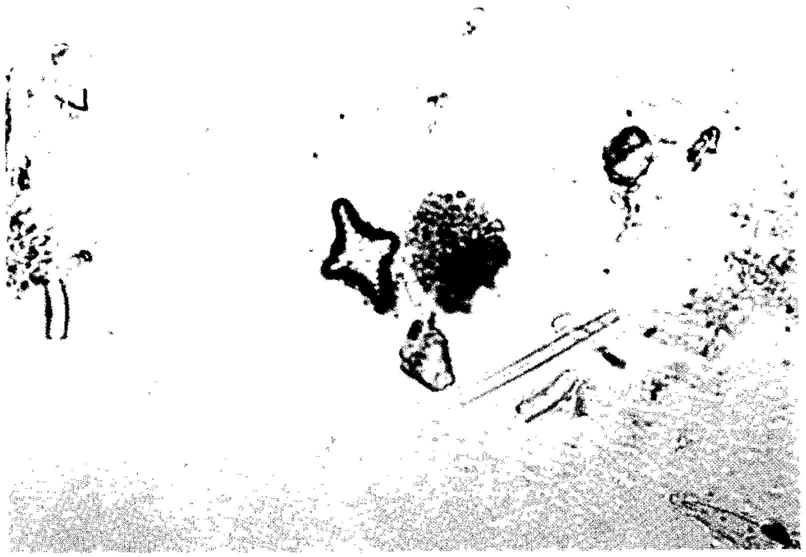

Plate 23. Fragilaria harrisonii

Plate 24. Frustulia viridula

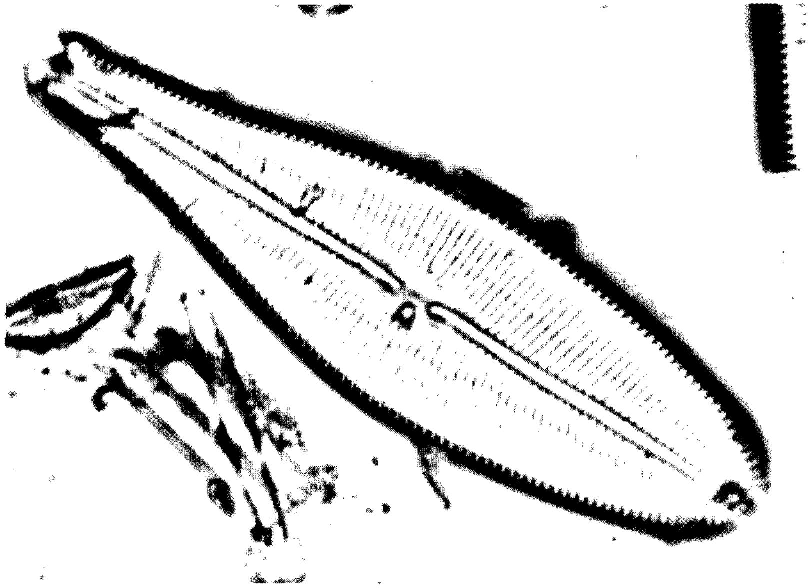

Plate 25. Gomphoneis herculeana

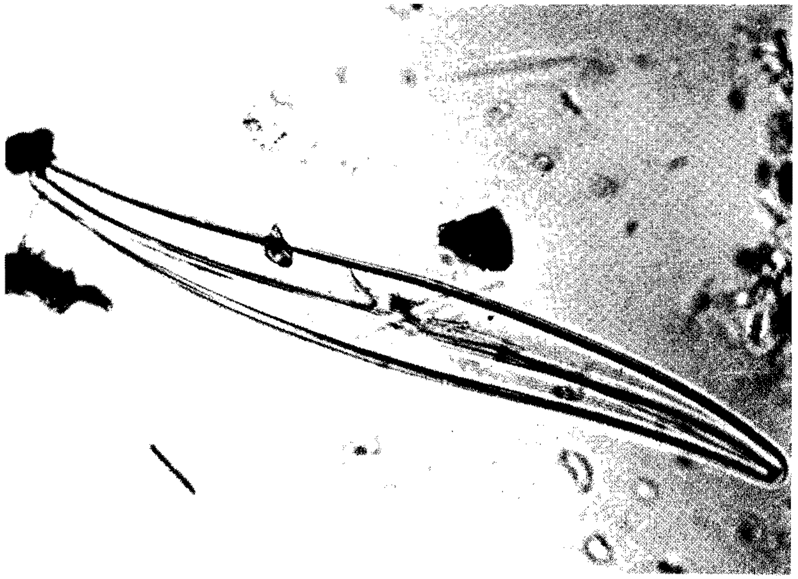

Plate 26. Gyrosigma attenuatum

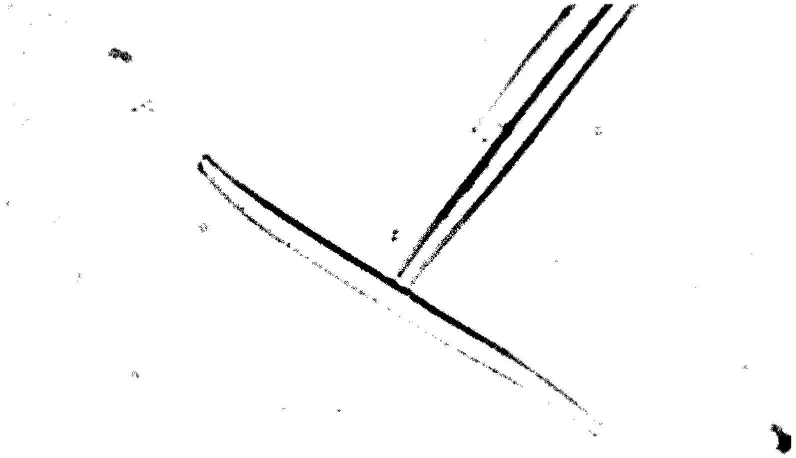

Plate 27. Nitzschia vermicularis

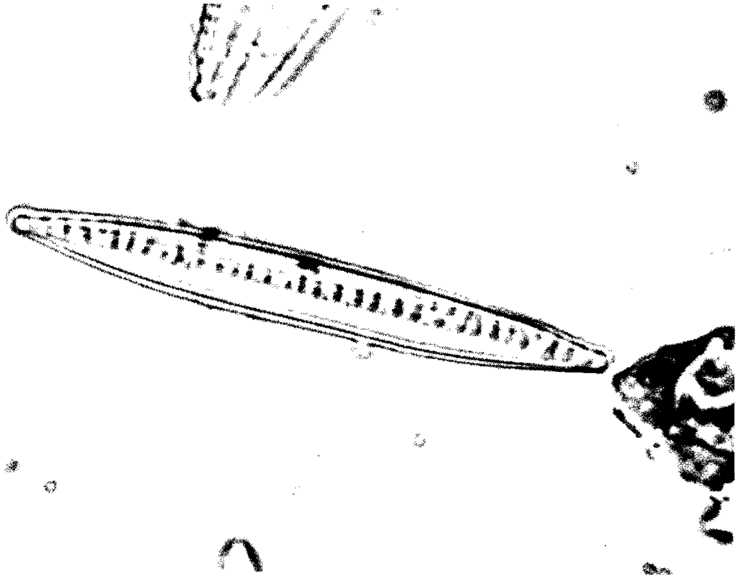

Plate 28. Nitzschia palea

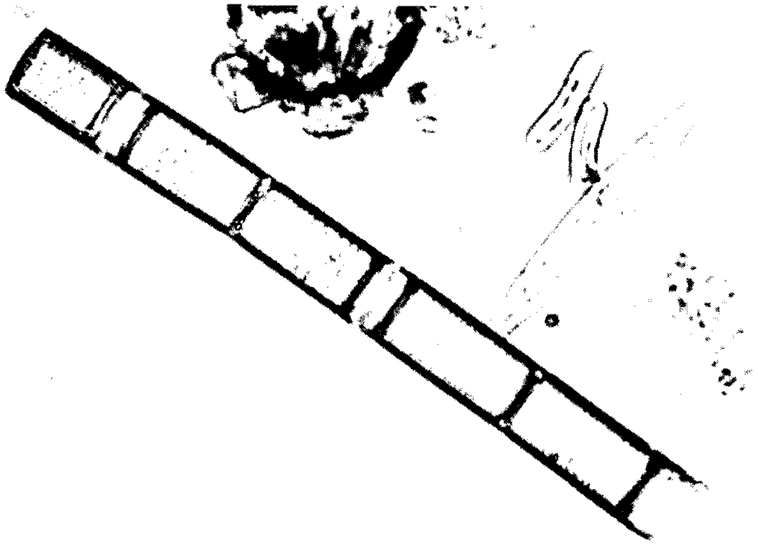

Plate 29. Melosira granulata

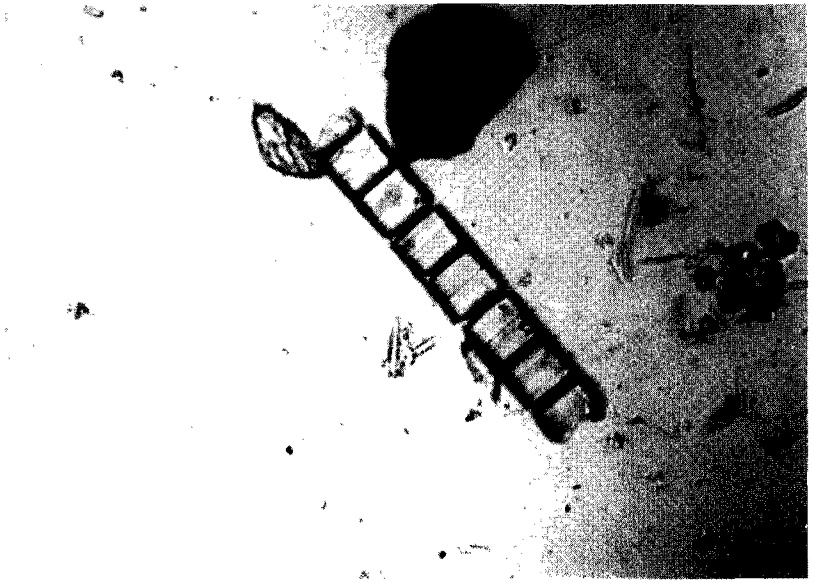

Plate 30. Melosira varians

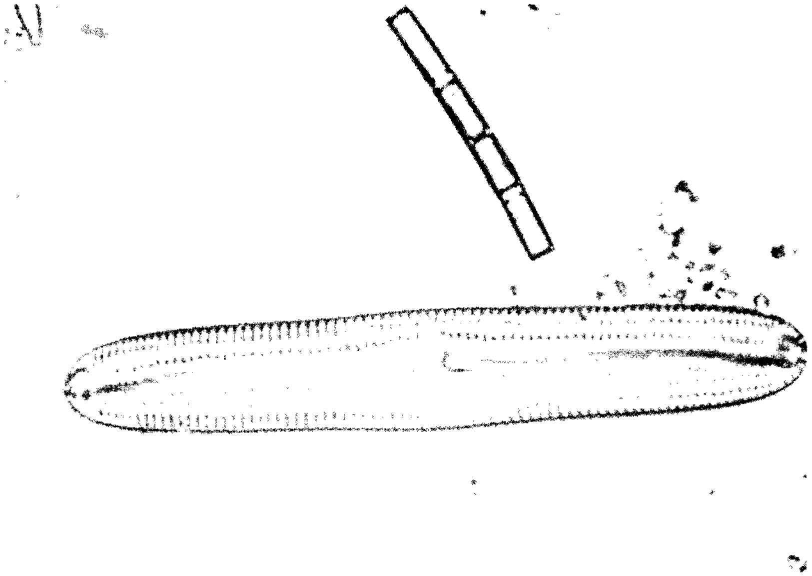

Plate 31. Pinnularia viridis

Plate 32. Rhizosolenia eriensis

Plate 33. Rhoicosphenia curvata

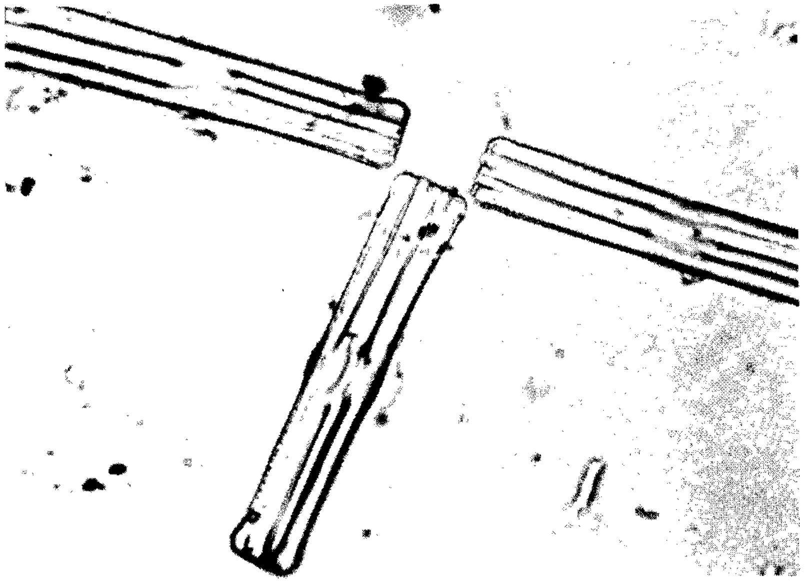

Plate 34. *Surirella angusta*

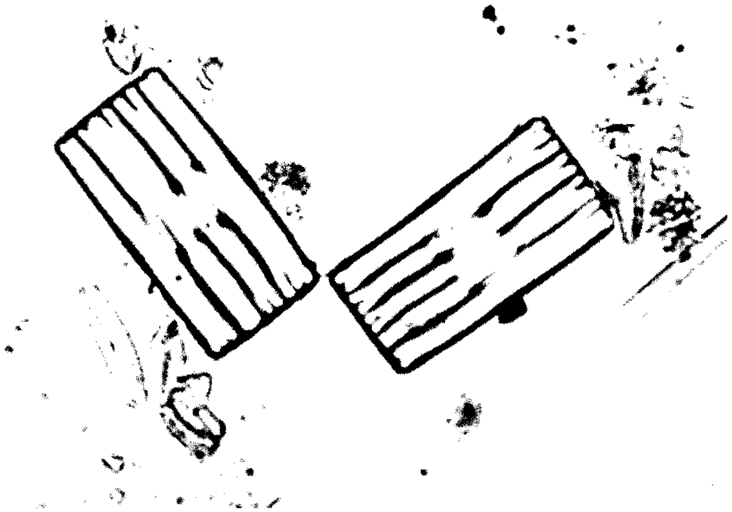

Plate 35. *Surirella ovalis* var. *pinnata*

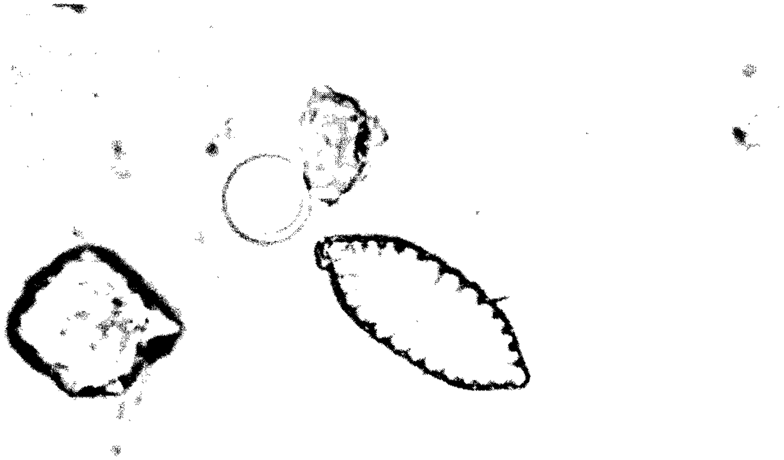

Plate 36. *Tabellaria fenestrata*

Plate 37. *Tabellaria flocculosa*