PHYTOPLANKTON STUDIES OF COOTES PARADISE MARSH, ROYAL BOTANICAL GARDENS, HAMILTON

By

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Scope and contents of this thesis:

An investigation of Phytoplankton populations of the Cootes Paradise Marsh. A study of some seasonal variations, and the effect of pollution on their populations. Culture studies of four common genera found in the marsh.
Illustrated with photographs.

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INTRODUCTION

Since 1946, the Royal Botanical Gardens, Hamilton, has been interested, among many other things, in conducting investigations concerning problems related to the earth sciences and biological sciences. In particular, emphasis has been placed on the scientific interpretation of the environment of any organisms and biological communities within the limits of the Gardens. It has been found convenient to regard the Gardens with its main axis Cootes Paradise Marsh (or Dundas Marsh) as an ecological unit. This unit has already provided subject matter for various ecological problems. The present report is a contribution to these studies and deals with some of the microscopic algal flora found in the Marsh waters.

At definite times of the season, populations of algae develop

from apparent non-existence to numbers of remarkable proportions. Providing there have been suitable conditions of temperature, light, and chemical composition of the water, populations of certain organisms rise to such an extent as to color the surface of waters, producing what is called "water-blooms". However, peaks of abundance may be recognized for certain organisms even though the water-bloom phenomenon may not appear. Some organisms may have but one pulse during a season, while others may produce several.

In these investigations it is first proposed to study several common organisms with the object of determining their abundance during the greater part of the spring and summer months. Secondly, it seemed necessary to investigate the effect of pollution as a factor involved in any variations of populations of the phytoplankton organisms.

Many of the common types of phytoplankton are indices of transformation, and it seems inevitable that these organisms will need to be studied in their relation to polluted waters and ecological associations. Knowledge of facilitating specific problems of this source is frequently gained through studying the organisms under artificially controlled conditions, therefore, anticipating this, it was felt advisable to commence cultural experiments which would provide the fundamental information not only in connection with the growth comparisons, but also regarding various chemical conditions of the Marsh waters. The final objective as stated above implies that to derive an adequate understanding of any organism, a knowledge of the origin and physical structure of its environment is of great importance. In many instances, forces so remote as to appear unimportant in their environmental role

have effective results. The survey work necessary for these investigations therefore includes an account of the physical attributes of the environment of these organisms.

Physical Characteristics of Cootes Paradise Marsh

According to Coleman (1941), the development of any flora or fauna in the Great Lakes Area has taken place within the last 20-35,000 years, that is, since the period of the last ice-sheet retreat which opened up new lands for repopulation. New waterways were opened up providing for redistribution of aquatic life in wide varieties of habitats. As each new habitat was formed, so new and different communities of organisms developed. Since the last of the ice periods the habitats have changed from probable simple compositions to highly complex ones. As each habitat passed through its various cycles of complexity, similarly the production of its flora and fauna changed, each cycle developing at a different rate. Such gradual development is called ecological succession.

Besides the natural change of habitats, as a factor influencing the presence or absence of flora, there is also the highly complicated influence of man who has fundamentally changed the natural order through settlement and industrialization.

Since detailed accounts amy be consulted elsewhere, (Coleman, 1922, 1941; Radforth, 1944) a brief outline here should serve to indicate the history of this region.

Before the beginning of the Pleistocene period, i. e. in late Palaeozoic times, it is believed that the Great Lakes Region was considerably higher than it is at present. In place of the existing

lakes, the main drainage system consisted of the Laurentian River (Spencer, 1907; Coleman, 1922, 1941) which passed through some of the present lake basins.

During the Pleistocene, or Glacial period, southern Ontario was completely covered by the Labrador Ice Sheet. As the climate eventually became milder this ice cap retreated to the northeast, exposing the river valleys of the old Laurentian river system. Waters from the melting ice collected in these depressions but because of the ice barrier to the north and northeast, drainage was to the south and southwest to the Mississippi valley by way of the Fort Wayne outlet.

With continued melting of the icesheets, more of the present lake basins became exposed and the lakes increased in size, all the time bounded on the north and northeast by the ice lobes. With further retreat of the icesheet from the Ontario basin, an outlet, lower than the Fort Wayne outlet, was opened to the sea through the Mohawk-Hudson valley. With the resultant erosion by water through this outlet, the water level of the lake fell to such an extent that the Niagara cuesta was exposed and the waters from the Erie basin spilled over at Lewiston to form Lake Iroquois in the Ontario basin. With the continued melting of the Ontario ice lobe, Lake Iroquois gradually occupied an area larger than the present Lake Ontario.

As the old Laurentian river bed in the vicinity of the present St. Lawrence valley became free of ice, the land to the east became depressed and the level of Lake Iroquois fell low enough to permit an incoming marine bay to invade the Ontario basin forming Admiralty Lake. The sea continued to invade the Ontario basin until nearly the whole of the former Lake Iroquois contained marine waters. This has been named

Figure 1. An outline of Cootes Paradise Marsh showing the relation of the Gravel-Bar to the Marsh prior to industrial changes of the last century.

the Gilbert Gulf of the Champlain Sea. With the retreat of the inland sea and a rising of the land in eastern Ontario and Quebec, the present basin of Lake Ontario was established.

Geology of the Dundas Valley. The Cootes Paradise Marsh lies within the bed of the preglacial Dundas river, a tributary of the Laurentian River, which eroded through the Niagara escarpment forming precipitous walls to the north and south (See App. ii, Pl. I, Figs. 1, 2., Pl. II, Fig. 3.). The escarpment which encloses the valley in this area is underlain by Queenston red shales. This Ordovician base is overlain by Medina, Clinton, Rochester and Lockport sandstones, dolomites, shales and dolomitic limestones respectively (Caley, 1940).

The plains to the north and south of the Marsh were former Lake Iroquois beaches. The Gravel Bar (Burlington Heights) bounding the Marsh on the east (See App. ii, Pl. II, Fig. 3., Pl. III, Fig. 6., Pl. V, Fig. 10.) is of Hudson river formation built up by the action of streams coming down the Dundas Valley and meeting the waters of Lake Iroquois. Originally it was merely a spit of land running northwest from the south shore but subsequent industrialization has changed it considerably (See Maps, Figs. 1. and 2.).

Geography of Cootes Paradise Marsh. The Dundas Valley lies at the extreme western end of Lake Ontario. It is roughly triangular in shape having as its base Burlington Beach (Hamilton Beach); as its sides the escarpment and the village of Copetown as its apex. The distance from the canal at Burlington Beach to Copetown is approximately eleven miles.

Kennedy (1884) divided the valley into three parts, the lower part consisting of Burlington Bay (Hamilton Harbour), the middle part

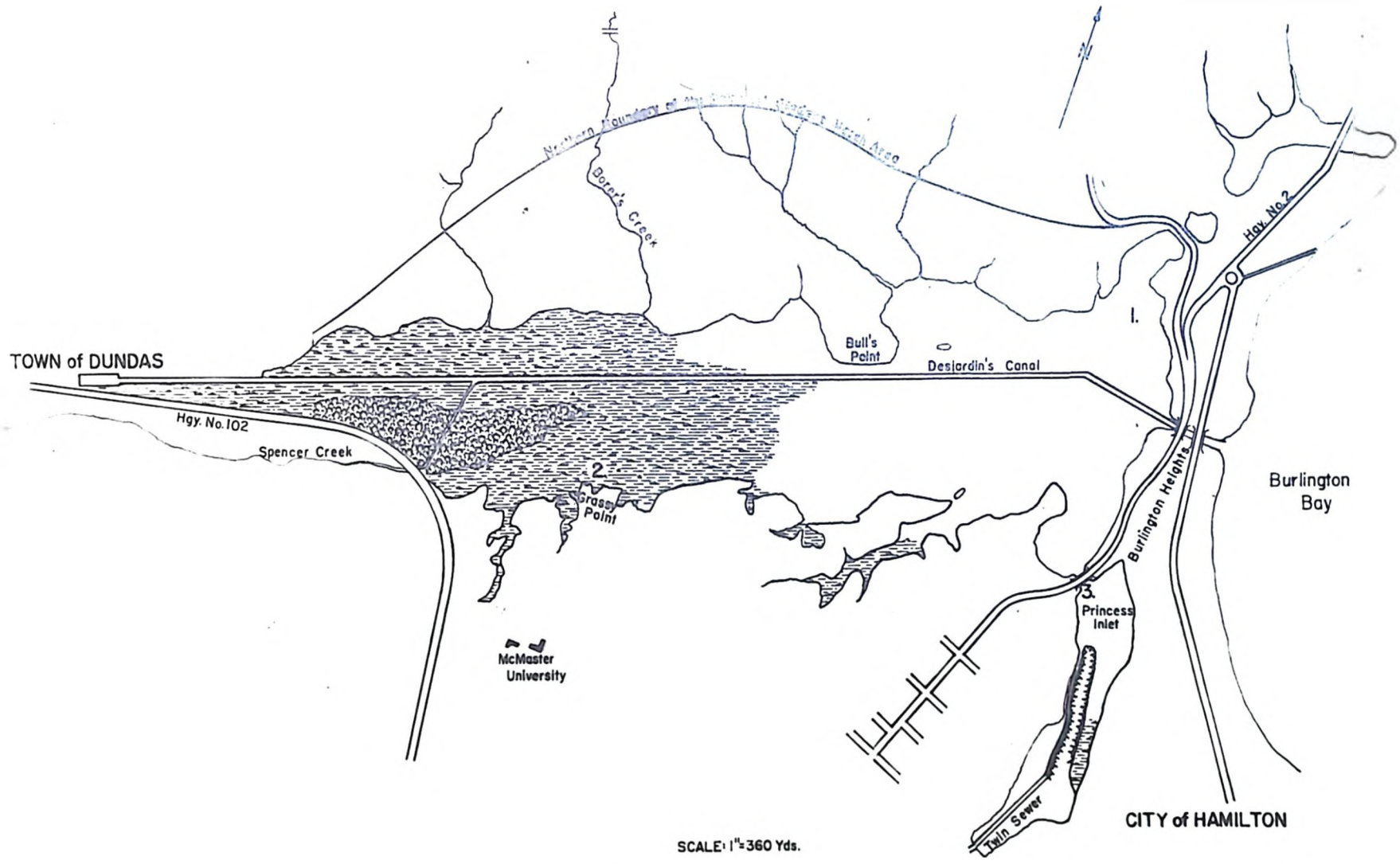

Figure 2. Cootes Paradise Marsh, Royal Botanical Gardens, Hamilton
Numerals indicate positions of stations.

enclosing the Dundas Marsh (See Map, Fig. 2.) and the upper part occupied by rolling morainic hills extending from the town of Dundas westerly to the village of Copetown where the height of land divides the Grand River and Lake Ontario watersheds.

The location of Cootes Paradise Marsh is 79°54' longitude west and 43°16'30" latitude north in the County of Wentworth, Townships of Barton and mainly West Flamborough. The axis lies in a position north 70° east; the altitude is 245 feet above sea level. All of the Marsh comprises a part of the Royal Botanical Gardens forming the heart of the undeveloped areas.

The Marsh too is roughly triangular in shape, $2\frac{3}{4}$ miles at its greatest length and about 1 mile wide at its base. Although the Marsh covers an area of approximately 700 acres, of which some 350 are open water, the shoreline, due to numerous inlets, has a length of about 9 miles.

To the east the Marsh is bounded by the gravel and conglomerate bar (Burlington Heights), some 110' in height, (See Pl. II, Fig. 3., Pl. III, Fig. 6., Pl. IV, Fig. 10.) which consists of rounded gravel pebbles. The soils of the lacustrine plain on the south are mainly silty loam, with the southeastern border consisting predominantly of sand. The north shore soils of the Royal Botanical Gardens area show different composition varying from clays to loams.[1.]

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1. Data obtained from Mr. L. Laking, Hort., R. B. G.

The Dundas Valley watershed begins to the north in Lockport formation which constitutes the top strata of the escarpment. One stream, Borer's Creek, enters the Marsh on the north shore, (See Map, Fig. 2.) but this dries up during the summer months. Several smaller streams draining the area below the escarpment are similarly of no importance in the summer months.

The most important part of the watershed, Beverly Swamp, lies in the Guelph formation and is situated north westerly from the Marsh. This swamp is the source of the largest stream flowing into the Marsh - the Lindsay Creek. Further south the Lindsay Creek joins the Spencer Creek and falls over the escarpment at Webster Falls, flows through the town of Dundas, is joined by the Ancaster Creek and enters the western end of the Marsh by the Desjardin's Canal (See Map, Fig. 2.). This creek flows throughout the summer.

With the exception of a storm sewer and creek that enters Princess Inlet to the south east (See Map, Fig. 2.), there are no streams of importance on the south shore.

The only outlet for the Marsh waters is the canal cut through Burlington Heights into Burlington Bay. The water at this point is approximately 12 feet in depth, varying considerably with seasonal fluctuations of the lake level. While no depth soundings relative to this problem have been made, it is understood from other investigators (E. R. M. Kay and E. Turner) that the deepest part of the Marsh proper is by the Longwood Road bridge over the outlet of Princess Inlet (7 feet). The next deepest part of the Marsh is the mouth of the former rivulet

that was the exit of the Marsh waters before the Desjardin's Canal was cut through Burlington Heights (See Map, Fig. 1.). Elsewhere the Marsh is somewhat shallower. In the western parts during slight drops in water levels, only thin films of water remain (See App. ii, Pl. IV, Fig. 7.).

The bottom of most of the Marsh is mud and muck. The bottom of the western half consists of thick layers of organic material and decaying plants.

The water is unstratified, freezing almost to the bottom during winter and ranging from 17°C. to 33°C. during the summer months of 1949 with but a drop of one degree Centigrade for bottom readings.

The water is consistently murky brown in color in those portions that have no vegetation. This does not filter out during processing of water samples and is very likely due to clay suspensions. In the western end of the Marsh where there is much marsh vegetation (See App. ii, Pl. II, Fig. 4., Pl. III, Figs. 5., 6., Pl. IV, Figs. 7., 8.), the water is inclined to be considerably clearer since it is not disturbed with wind action.

Pollution enters the Marsh at two places. A sewage outlet from the town of Dundas empties into the western end of the Desjardin's Canal. A disposal lot for untreated domestic garbage is situated in Princess Inlet (See App. ii, Pl. V, Figs. 9., 10.). A storm sewer also empties into this inlet (See Map, Fig. 2.), as well as untreated sewage and industrial wastes from parts of West Hamilton.

The vegetation of the surrounding shores is mainly Maple-Oak with a few White Pine. Crack willow (Salix fragilis L.) is very common

at the western end of the Marsh (See App. ii, Pl. IV, Figs. 7., 8.). While the eastern half is almost all open water (See App. ii, Pl. I, Figs. 1., 2., Pl. II, Fig. 3.), the rest, being considerably shallower, is filled with Typha, Glyceria, Carex, Lemna, Ceratophyllum, Lythrum, Utricularia, etc. Provisional lists of aquatic plants may be obtained from records of Judd (1946), Brown and Sims (1947) and Pase (1948).

I PHYTOPLANKTON PERIODICITIES

Review of Literature Much has been written concerning the prime importance of phytoplankton in relation to the balance of nature (Mann. 1921; Allen, 1921, 1934; Tilden, 1937; et al). Several authors have made large scale studies on the distribution of algae of North America and Canada (Kemp, 1848; West & West, 1896; Tilden, 1910; Bailey, 1925; Boyer, 1926; and Smith, 1933). More locally contributions have been made as applied to the Great Lakes Region (Snow, 1902; MacClemont, 1915; Smith, 1921; Lowe, 1928; Tiffany, 1934; Daily, 1938; Irenee-Marie, 1938, 1940, 1942, 1943, 1944; Damann, 1941; Chandler, 1940, 1942, 1945). Relatively little is known about the algae of Lake Ontario in particular. Mackenzie, in 1890, and Faull in 1913 recorded various algae that were taken from Lake Ontario in the Toronto region, and Kindle in 1915 mentioned a few that he had encountered in his dredging work. However, little knowledge has been added in the interval.

This survey deals with the phytoplankton only, no attempt having been made to include the unpigmented planktonts. With the exception of a provisional list that is included, the organisms have been listed to genus only, since the species of many small forms could not be determined by using a 16mm. objective. However, such identifications that have been made are reasonably accurate since before and after all counts slide examinations were made to key down unknown planktonts. Results are expressed in terms of "organisms per liter of marsh water" instead of "standard units" in which the size of organisms is determined, or "cubic standard units" in which the cubic centimeters

of plankton per cubic meter of water is expressed (Whipple, 1947). Major environmental factors such as chemical composition, pH., or dissolved oxygen of the water were not studied, the temperature of the water being the only data obtained. Further limitation includes the time limit: the investigation being carried on during August, September and October in 1948, and April to August in 1949 for one station and shorter periods of time for two other stations; the fact that samples were collected only once a week; the fact that sampling was done at only three locations. The time limit has been curtailed to more favorable seasons, due to weather conditions during the winter of 1948-49 which made it impossible to get to the stations on thin ice.

Samples were taken at the surface of the water only, since no appreciable difference in either quantity or quality of organisms was noted in any records for surface and bottom samples.

Methods and Equipment

The procedure followed in the investigation consisted in (1) collection of samples; (2) concentration by filtration; (3) examination of the concentrate, and enumeration of the phytoplankton; (4) calculation of the number of organisms per liter of water.

Three stations for collecting water samples were chosen to present as close to representative sampling as thought could be possible.

It is known that the marsh is polluted, but the extent of pollution has not been recorded on a quantitative chemical basis. The qualitative aids, sight and smell, were used to determine the presence

or absence of pollution without difficulty, and it was on this basis that the sampling stations were established as follows:

Station 1. In the open portion of the Marsh, where the water averages 5 feet in depth, the first station was established to collect plankton that would be least affected by pollution. (See App. ii, Pl. I, Fig. 1., Pl. II, Fig. 3.) While the Marsh at this place is sufficiently open that wind action can carry surface waters from great distances, it is not in direct line with the out-flowing currents from Princess Inlet that would pollute the waters to any greater extent. Of course, the term pollution can be used only loosely in connection with the Marsh, since no part could be called pure, let alone clean. Suffice it to say, here the water did not seem to be as relatively polluted as elsewhere.

Plankton flora collected at this station are not as likely to be affected by littoral associations of higher plants, since the station is approximately 100 yards from the nearest shore.

Station 2. is situated at the end of Grassy Point, (See Map, Fig. 2.) in a typical marsh vegetation of Typha, Glyceria maxima (Judd, 1946), various Duckweeds: Lemna minor, L. trisulca, Spirodela polyrhyza, Wolffia columbiana, W. punctata, Ceratophyllum demersum, and Utricularia. Prior to mid-summer, the water level is such that all Marsh land is covered, but in August, only a thin film of water persists, with but a few pools connected by drainage ditches and muskrat runs. (See App. ii, Pl. IV, Fig. 7.) It was from this station that it was hoped that a population more closely related to a littoral vegetation could be obtained, since there is but very little current or wind action that could

bring other waters in from the rest of the Marsh.

Station 3. Prior to 1935, Princess Inlet (See Map, Fig. 2.) was dry ground and was used as community gardens as a part of a relief campaign. The land was very fertile, with much organic matter present. With ensuing higher water levels, this land was flooded to a depth of 1 to 3 feet. During recent years, the inlet has been used as a disposal lot for untreated household garbage. (See App. ii, Pl. V, Fig. 10.) A stream which serves an an effluent for untreated domestic, industrial and storm sewage from the western portion of the city of Hamilton also enters the inlet at the south end, (See Map, Fig. 2.) and flows into the Marsh under a concrete bridge, from which point water samples were taken. Since this inlet presents the main source of pollution it was felt that organisms collected from these waters would show the effect of pollution better than elsewhere in the Marsh.

A collection was made every week at each of the three stations, between 9:30 and 10:00 A. M. in June, July, and the first two weeks of August, 1949. Prior to that time, only two monthly collections were made at Station 1., and one at Station 3. Surface sampling consisted in dipping three 200 ml. jars to a depth not exceeding 4 inches.

The samples were taken immediately to the laboratory and concentrated. The method of concentration used was the Sedgwick-Rafter method (Whipple, 1947) in which 500 ml. of the sample were filtered in a 500 ml. Sedgwick-Rafter filtering funnel, fitted with a one-hole rubber stopper with a U-tube inserted. 15 to 20 mm. of 60-120 mesh banding sand were separated from the tube and stopper by a 200 mesh silk bolting cloth about 12 mm. in diameter. Suction was used at all times to

hasten the period of filtration which was usually two hours. The inner surface of the funnel was washed down several times with distilled water to remove organisms and debris. The surface of the sand was intermittently broken by careful use of a finely drawn glass tipped rod in order to hasten filtration.

Following filtration, the sand and residue were washed four times with 5 ml. each of distilled water, and decanted into a small beaker.

To obtain aliquot samples, air was blown through a pipette into the beaker of concentrate, distributing the organisms uniformly. One ml. sample was then drawn up and transferred to a counting cell of 1 ml. capacity. From each concentrate, counts for each sample were obtained in the following manner: three fields were counted for each of two cell quantities, and four from a third, making a total of ten counts per sample. The counts were then averaged, and the following formula (Welch, 1948) used to convert them to average numbers of plankters per liter: $N = \frac{a(1000)c}{L}$

where N = the number of plankters per liter of sample water.

a = the average number of plankters in all counts in counting cell of 1 ml. capacity.

c = the volume of original concentrate in millilitres.

L = the volume of original water sample in liters.

For use of the Lehmann charts (Whipple, 1947) N has been converted by use of the following formula: $R = \sqrt[3]{\frac{1}{4}V}$

where R = the radius

V = the average number of plankters per liter.

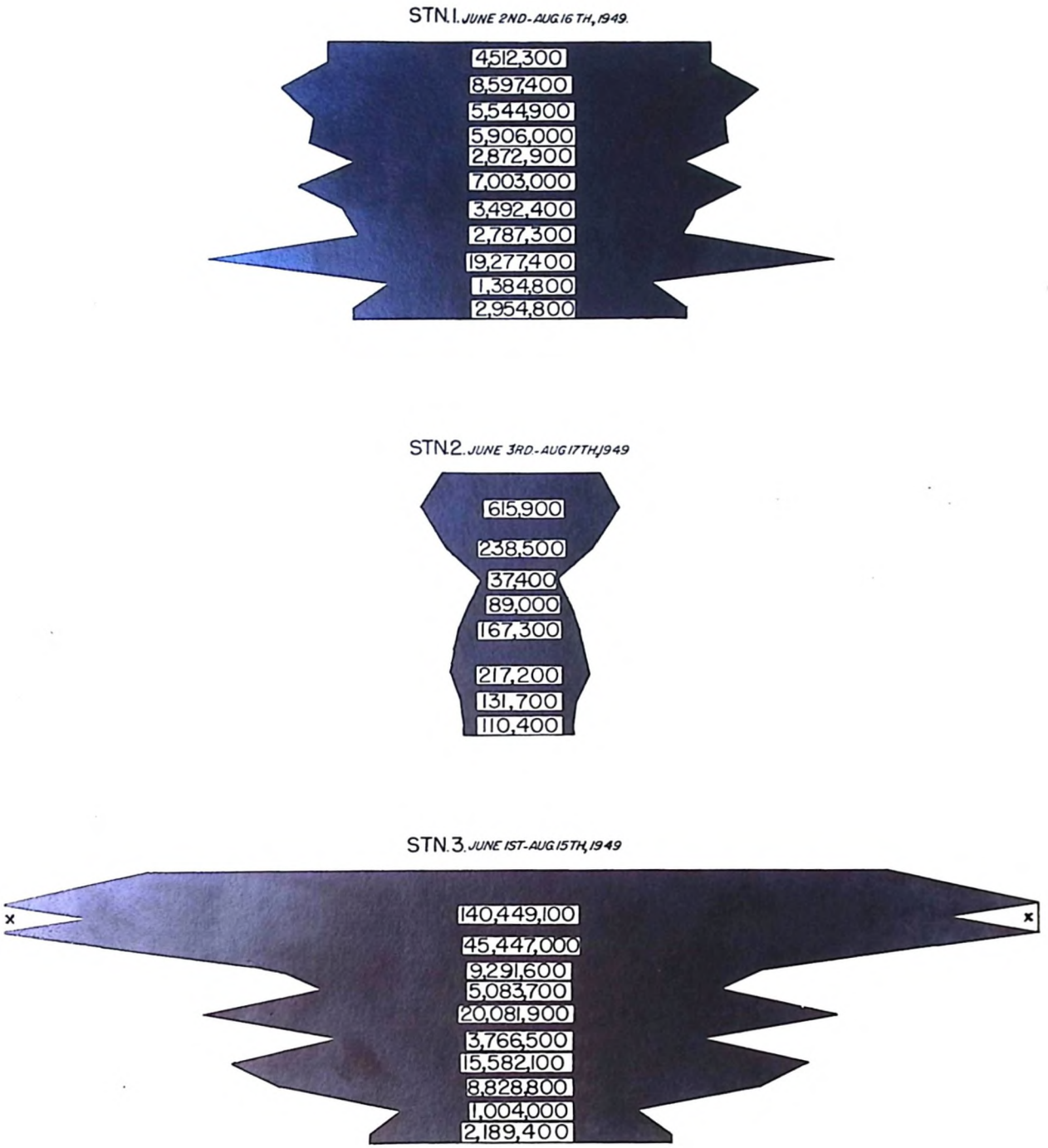

Figure 3. Diagrams showing the quantitative changes of total phytoplankton numbers at three selected stations in Cootes Paradise Marsh. The numbers set within the black areas indicate total numbers per liter of water.
x Folded over.

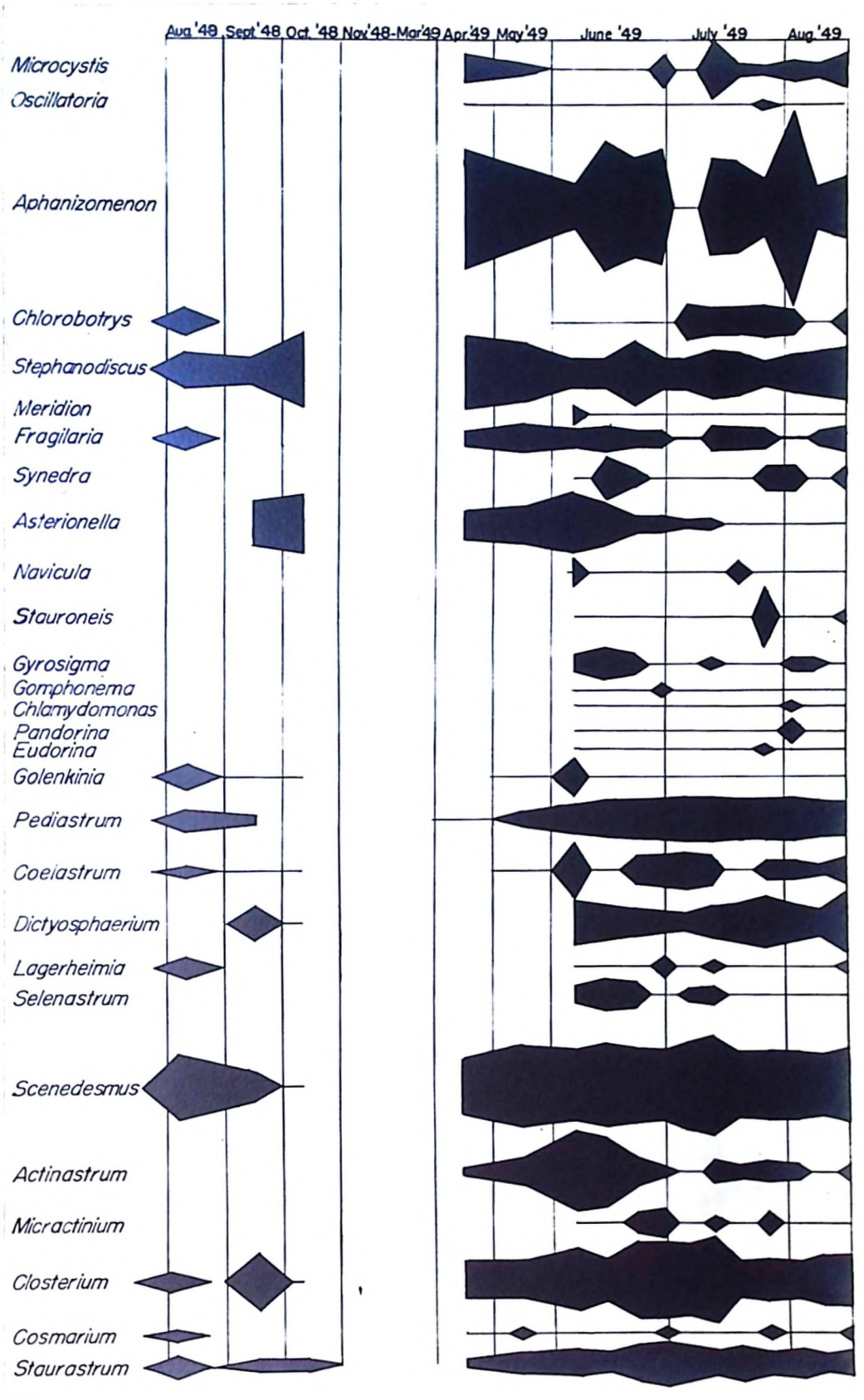

Figure 4. Diagrams showing the quantitative changes of various phytoplankton organisms at Station 1.

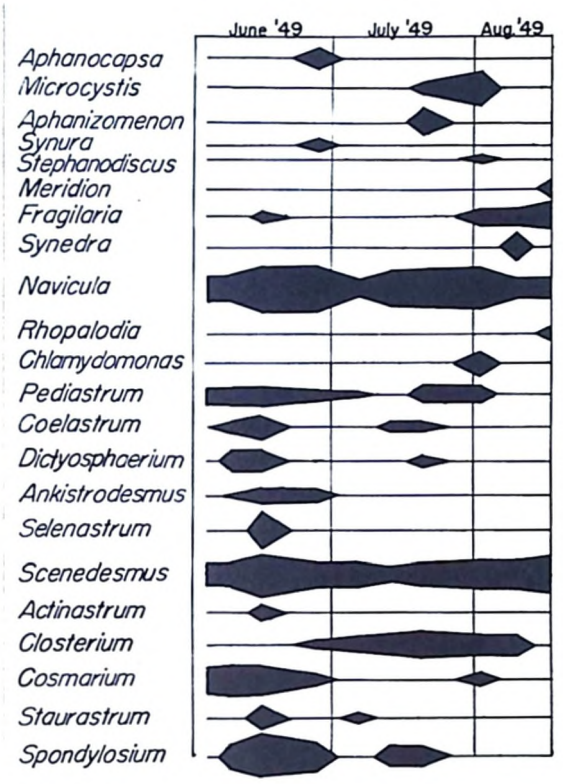

Figure 5. Diagrams showing the quantitati
changes of various phytoplankto
organisms at Station 2.

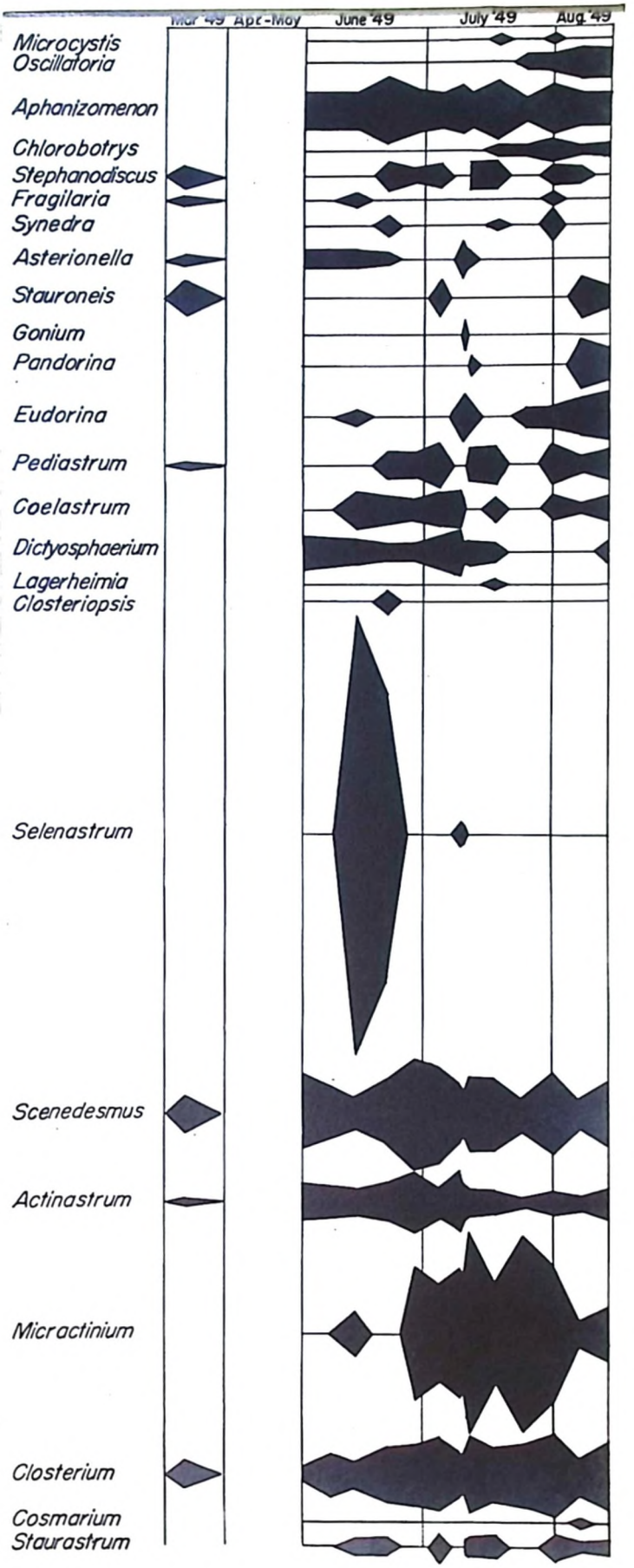

Figure 6. Diagrams showing the quantitative changes of various phytoplankton organisms at Station 3.

Observations

In all collections taken from the Marsh, 55 genera of algae, representing 6 classes were recorded (See App. i). Of these, 36 genera representing 5 classes were studied individually for this investigation. The results have been set out in charts, Figs. 3-6.

It will be noted in Fig. 3. that average counts at Station 1. are five times greater than at Station 2. which has flora of very similar constitution.

Myxophyceae: Aphanocapsa was observed on one occasion at Station 2. (Fig. 5.). Microcystis appeared at all three stations, but in greatest quantities at Station 1. (Fig. 4.) in July and August. Oscillatoria appeared once in late July at Station 1. A pulse at approximately the same period also appeared at Station 3. (Fig. 6.). Aphanizomenon showed great variations at Station 1., with similar peaks of abundance at Station 3., and one at Station 2.

Heterokontae: The only genus, Chlorobotrys, appeared with pulses at approximately the same period of time at Stations 1., and 3.

Chrysophyceae: The only genus noted in this class, Synura, appeared once in small quantities at Station 2. in late June.

Bacillarieae: Of the ten genera studied, Stephanodiscus, Fragilaria, Asterionella and Navicula appeared in greatest numbers. Stephanodiscus appeared consistently throughout all periods of the investigation at Station 1. Its one appearance at Station 2. in early August does not coincide with pulses found at Station 1., but does with one pulse noted at Station 3. With exception of two occasions, when none was noted, Fragilaria appeared in similar quantities at Station 1.

Pulses noted at Stations 2. and 3. coincide as to times of appearance. Asterionella appeared with similar peaks of abundance at Stations 1. and 3. but the quantities were much greater at Station 1. It was not noted at Station 2. Navicula appeared at Station 2. only, in consistent numbers, however, two pulses at Station 1. coincide with peaks noted at Station 2.

Chlorophyceae: A small pulse of Chlamydomonas was noted in early August at both Stations 1. and 2. Pandorina and Eudorina appeared with peaks of abundance at approximately the same periods of time at Stations 1. and 3., but were not noted at Station 2. Pediastrum has shown a remarkable steadiness in numbers at Station 1. with a peak of abundance that might be said to occur in July. At Station 2. the quantities were not nearly as great, with two pulses in June, and late July. Pulses were erratic at Station 3., occurring in early July, mid-July, and early August. At all three stations Coelastrum also has been inconsistent with regards peaks of abundance. There may be a certain degree of consistency if it is noted that one similar peak appears in early July. Dictyosphaerium appeared with three pulses at Stations 1. and 3. with the same interval of time. Two peaks noted at Station 2. appeared at similar times to two at the other stations. Selenastrum appeared with peaks of abundance in mid-June at all three stations. The quantities of Scenedesmus seem to indicate small pulses that occured near the middle of the months at Station 1., while only two were noted in mid-June and August at Station 2. The quantities, while differing greatly at the two stations, were fairly consistent, in marked contrast to those noted at Station 1. The peaks of abundance for Actinastrum

at Stations 1. and 2. appeared both near mid-June. Micractinium was inconsistent at Station 1. with small peaks of abundance in late June, mid-July, and late July. It was noted at Station 2. At Station 3. pulses occurred similar to those of Station 1., but the quantities were by far greater. Closterium has shown fairly consistent numbers at all three stations, with a broad pulse period in July. Staurastrum was also consistent at Station 1. with a peak appearing in late June. Peaks of abundance at Station 2. appeared before and after that at Station 1. Quantities at Station 3. were rather inconsistent. Spondylosium appeared with two peaks of abundance in mid-June and July at Station 2. only.

II THE RELATION OF POLLUTION TO PHYTOPLANKTON

Total plankton counts at Station 3., where waters are to be considered more highly polluted than elsewhere, are considerably greater than those of the other two stations (See Chart, Fig. 3.) For the period June-August, 1949, the weekly average is 5 times greater than that at Station 1., and 125 times greater than that at Station 2. Although the flora at Station 3. is overall similar to that found elsewhere in the Marsh, there are a few constituent differences. Bacillarieae is represented few in quality and quantity. There are greater numbers of the Volvocales, and in general, greater quantities of the Chlorophyceae.

III RESPONSE OF SELECTED PHYTOPLANKTERS IN ARTIFICIAL MEDIA

During the period of time when it was impractical or difficult to visit the sampling stations, culture studies were made on some of the more common types of organisms found in the Marsh waters to determine favourable conditions for population increase and maintenance.

Methods

On October 7th, 1948, one sample of water was taken from Station 1. 500 ml. were centrifuged, and the concentrate diluted with distilled water to 200 ml. This was placed in a soft-glass jar, and left in a south exposure window with other samples, to serve as stock for future cultures. Water was added when necessary to replace water lost by evaporation. All organisms that were cultured were taken from this one jar.

At first, considerable difficulty was encountered with bacterial and fungal contaminants, however, a technique of Bold's (1942) with some modifications, was used to obtain pure cultures. A drop of the stock culture was placed on a microscope slide, and using a 32 mm. objective, any organism that was desired for culture purposes was picked up in a micro-pipette. The water and organism was then transferred to a clean slide by means of a micro-pipette bulb. The procedure was repeated three times, using sterile slides, distilled water, and pipettes. Following the third transfer into sterile water, the organism was placed in a selected medium, and left for one week in a light chamber, after which time it was thought that any growth that should appear would be evident.

Bold (1936) described an artificial light source for algal cultures, and one similar to that outlined was set up. In addition, a black cloth, to prevent all excess light from getting to the cultures was placed over a frame covering the culture tubes. Racks were placed inside the frame to hold the various dishes and tubes. The light source (100 watt tungsten lamp) was time controlled so that light was available only from 8:00 P. M. to 6:00 A. M., a total of ten hours each day. Temperature was maintained at 20°C. ±2°.

Ordinary distilled water was originally used for the various media, but when satisfactory results were not obtained, two different techniques were used to rid the water of the probable toxic copper ions that are lethal to algal organisms. It is known that colloids remove free ions, and with this in mind, 20 grams of fine agar were added to each liter of distilled water, the container vigorously shaken, and the agar removed by suction filtration through No. 2. Whatman paper. The water was then sterilized in an autoclave for 20 minutes at 15 pds. pressure.

A second method for obtaining purer distilled water was used: 15 grams of Dowex-50, a coarse grained synthetic resin, were added to each liter of distilled water, the container was shaken vigorously and the resin allowed to settle. The decanted water was then autoclaved as above.

All media were made up under sterile conditions. Knop's, Beyerinck's (Bold, 1942) and Soil Extract solutions (Bold, 1936) were used with distilled water, agar and distilled water, and Dowex and distilled water.

The method used to determine degree of growth in the culture tubes was as follows: First the tubes were shaken vigorously to distribute the organisms uniformly throughout. Immediately some of the liquid was drawn up a pipette, and one drop placed on a microscope slide. Ten fields were then counted and the following enumeration system used:

0 - 10 organisms	-
10 -150 "	x
150 -250 "	xx
250 and over	xxx

Statistical results derived in accordance with this method are given in Tables I-III, page 22.

Observations

It is obvious from examination of Tables I-III that Knop's solution did not favour successful growth. Beyerinck's solution did prove to be a better medium.

Successful growth also depended on the source of the distilled water. Water distilled over copper gave the results expressed in Table I, columns 1 and 2. Here, Beyerinck's solution which offered good results as presented in Tables II and III did not support increases in population to a successful degree. Removal of copper ions by the methods suggested on page 20 promoted better results.

Contrary to observations made by Bold (1942) and Pringsheim (1946) that direct sunlight does not favour successful growth, throughout the winter months, the stock jars, especially that one collected on October 7th, persisted in producing heavy masses of algae, both microscopic and

Table I

Degree of population increase and maintenance using nutrients in distilled water.

	Knop's	Beyerinck's	Soil Extract			
	0.7%	1%	5%	15%	25%	35%
Microcystis	-	-	x	xx	xx	xx
Pediastrum	-	-	xx	-	xxx	xxx
Scenedesmus	-	-	-	xxx	xx	xx
Closterium	-	-	xx	xxx	xxx	xxx

Table II

Degree of population increase and maintenance using nutrients in Agar-distilled water.

	Knop's	Beyerinck's	Soil Extract			
	0.7%	1%	5%	15%	25%	35%
Microcystis	-	x	x	-	xx	xx
Pediastrum	-	x	xx	xx	xx	xx
Scenedesmus	-	xx	xx	x	xx	✱
Closterium	-	xxx	xx	-	xxx	x

Table III

Degree of population increase and maintenance using nutrients in Dowex-distilled water.

	Knop's	Beyerinck's	Soil Extract			
	0.7%	1%	5%	15%	25%	35%
Microcystis	-	xx	x	x	✱	xx
Pediastrum	-	x	xx	xx	xx	xx
Scenedesmus	-	xx	xx	x	-	xx
Closterium	x	xxx	xx	xxx	xxx	xx

✱ Culture accidently destroyed.

macroscopic. Spirogyra often threatened to completely fill the bottle and was on several occasions picked out. The contents of the jar thrived even when tap water and distilled water was added to replace evaporated water. When transfers were made into nutrient salt solutions in which water distilled over copper was a constituent and when the culture tubes were kept in the same window, no growth was apparent.

DISCUSSION AND CONCLUSIONS

In the case of each genus, periodicity for all stations occurred approximately the same times. The effect of pollution did not interfere with periodicities nor with the fact that these peaks occurred at similar times as those for elsewhere.

Reasons for small peaks of abundance of the littoral flora might possibly be found in the following factors: (1) poor light penetration because of heavy mats of higher vegetation, (2) difference of pH from that of the rest of the Marsh, (3) less wind action to oxygenate the waters, (4) fewer inorganic materials in solution. Confirmation of proof is beyond the scope of this investigation, the object being simply to discover whether there are differences, and the extent.

It is difficult to account for the differences in lengths of intervals (See Charts, Figs. 4-6.). As this phenomenon was discovered, an attempt was made to correlate it to wind direction and velocity, air and water temperatures, and sky conditions, but the author feels that this would be in the nature of a different set of problems which must be exploited if the periodicity pattern is to be properly understood. Again it must be emphasized that the prime importance of this problem was to establish the periodicity patterns.

It is to be noted that Chlorophyceae, which is a very marked class in the polluted zone, is the predominating class in general for all three stations. High overall incidence of Chlorophyceae may suggest a degraded condition as regards pollution for the Marsh in general.

Smith (1933) makes reference to plankton flora designated as either Baltic or Caledonian type phytoplankton. The Cootes Paradise Marsh may

carry the designation Baltic type phytoplankton because of the scarcity of desmids, predominance of Chlorophyceae and the fact that the Marsh area is more recent in age than the Carboniferous period. It seems pertinent in this respect to note that an assemblage of features, such as represented by the geological account in the introduction of this report, should not be disregarded because of their role of environmental factors acting on a biological community.

The relatively high populations in plankter crops at Station 3 have probably much significance. This station was chosen as a region of great pollution. The results may suggest a high density of plankters as an indication of this pollution. Whipple (1947) suggests confirmation of this, that chlorophyllaceous organisms take part in a mesosaprobic zone.

At the time information concerning periodicity peaks was being collected, the significant algae noted in the peak patterns were not known. It will be instructive to discover whether the culture media conducive to successful growth will be useful in the cultivation of the index types. Whether they are or not, it remains that a set of suggested media and techniques has been derived which supports growth in numbers of some of the plankter organisms. Among these Soil Extract, which by reason of its nature is copper free, offers best results. Not only has Beyerinck's solution turned out to be a favourable medium, it also obtains optimum conditions of pH. that compare favourably with those of the Marsh.

Consistency in growth response, regardless of the genus in the

case of the best media, suggests that the media might be successful for other genera. This has not been exploited as yet.

SUMMARY

1. A quantitative study of the phytoplankton of Cootes Paradise Marsh during the spring and summer months of 1949 was made by filtering weekly samples of Marsh water through sand and observing measured amounts of the concentrate.

2. The study revealed a marked periodicity of the total phytoplankton and of the genera.

3. Chlorophyceae predominated in waters at three stations.

4. Littoral type flora was not abundant.

5. The effect of pollution was noted to produce greater quantities of phytoplankton with fewer Bacillarieae and considerably greater quantities of the Chlorophyceae, but produced no marked effect on the times of periodicity.

6. The Cootes Paradise Marsh algal flora might be typed as "Baltic Type Plankton".

7. In Vitro studies were conducted on four common Marsh organisms to find favourable conditions for growth.

8. Knop's solution was found to be an unsuccessful medium for Marsh phytoplankton.

9. Beyerinck's solution and Soil Extract solutions were excellent media for Marsh organisms.

10. Methods of removing copper ions from distilled water (colloidal adsorption and free-ion exchange) proved successful for purposes of culturing phytoplankton.

11. 116 species of phytoplankton representing 55 genera and 6 classes have been recorded.

ACKNOWLEDGEMENTS

Initial support for this investigation was given by the Research Council of Ontario to which I am very grateful for financial assistance. The program was conducted under the direction of Dr. N. W. Radforth, Director, Royal Botanical Gardens, and Head, Department of Botany, McMaster University, Hamilton, at whose suggestion the problem was undertaken. I wish to express my sincere appreciation for his advice and criticism throughout the course of the investigation. I am also indebted to members of the staff of the Department of Botany, McMaster University, for their helpful suggestions at times when advice concerning photographic and biological techniques was needed.

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APPENDIX i

Provisional List of Phytoplankton of Cootes Paradise Marsh

The following references were used for identification purposes: Boyer, 1926; Irenee-Marie, 1938, 1942, 1943; Smith, 1916, 1920, 1924, 1933; Tilden, 1910; Ward & Whipple, 1918; West 1916; West & Fritsch, 1932; Whipple, 1947.

The list has been arranged according to the classification of Smith (1933).

Myxophyceae

Chroococcales

Aphanocapsa Castagnei (Breb.) Rab.

Microcystis incerta Lemm.

M. pulvera (Wood) Migula

Coelosphaerium Kuetzingianum Näg.

C. Naegelianum Unger

Hormogonales

Oscillatoria limosa Ag.

O. splendida Grev.

Aphanizomenon flos-aquae (L.) Ralfs.

Heterokontae

Heterococcales

Chlorobotrys regularis (West) Bohlin.

Chrysophyceae

Chrysomonadales

Synura uvella Ehr.

Cyclonexis annularis Stokes.

Bacillarieae

Centrales

Melosira varians Ag.

Stephanodiscus niagarae Ehr.

Rhizosolenia eriensis H. L. Smith

Pennales

Tabellaria flocculosa (Roth) Kütz.

T. fenestrata (Lyngb.) Kütz.

Meridion circulare (Grev.) Ag.

Fragilaria crotonensis Kitton

F. construens (Ehr.) Grun.

Synedra pulchella (Ralfs.) Kütz.

Synedra sp.

Asterionella formosa Hass.

Navicula rhyncocephala Kütz.

N. major (Kutz.) W. Smith

N. viridis (Nitzsch) Ehr.

Stauroneis anceps Ehr.

S. acuta W. Smith

Gyrosigma sp.

Gomphonema Vibrio Ehr.

G. olivaceum (Lyngb.) Kütz.

Rhopalodia gibba (Ehr.) O. Müller

Chlorophyceae

Volvocales

Chlamydomonas globosa Snow.

Volvocales (Cont'd.)

Gonium formosum Pascher

Pandorina morum Bory.

Eudorina elegans Ehr.

Tetrasporales

Sphaerocystis Shroeteri Chod.

Asterococcus limneticus G. M. Smith

A. superbus (Cienk.) Scherffel.

Schizochlamys gelatinosa A. Br.

Chlorococcales

Golenkinia radiata Chod.

Pediastrum simplex var. duodenarium (Bailey) Rab.

P. sculptatum G. M. Smith

P. Boryanum (Turp.) Menegh.

P. duplex Meyen

P. duplex var. clathratum (A. Braun) Lagerh.

P. duplex var. reticulatum Lagerh.

P. duplex var. gracillimum W. & G. S. West

P. tetras (Ehr.) Ralfs.

P. tetras var. tetraödon (Corda) Hansgirg.

Pediastrum sp.

Sorastrum americanum var. undulatum G. M. Smith

Coelastrum microporum Näg.

C. cambricum Archer

Dictyosphaerium pulchellum Wood

Planktosphaeria gelatinosa G. M. Smith

Chlorococcales (Cont'd.) .

Echinosphaerella limnetica G. M. Smith

Pachycladon umbrinus G. M. Smith

Oöcystis lacustris Chod.

Lagerheimia subsala Lemm.

L. longiseta var. major var. nov. G. M. Smith

L. ciliata (Lagerh.) Chodat.

Ankistrodesmus falcatus (Corda) Ralfs

A. falcatus var. acicularis (A. Braun) G. S. West

A. spiralis (Turner) Lemm.

Closteriopsis longissima var. tropica W. & G. West.

Selenastrum gracile Reinsch.

S. minutum (Näg.) Collins

S. Bibraianum Reinsch.

Tetraëdon minimum (A. Br.) Hansg.

T. regulare Kütz.

T. trigonum (Näg.) Hansg.

T. limneticum Borge.

Scenedesmus obliquus (Turp.) Kütz.

S. dimorphus (Turp.) Kütz.

S. Bernardii G. M. Smith

S. acuminatus (Lagerh.) Chodat.

S. arcuatus Lemm.

S. acutiformis Schröder.

S. denticulatus Lagerh.

S. longus var. brevispina Smith

Chlorococcales (Cont'd.)

Scenedesmus abundans (Kirchner) Chodat.

S. quadricauda (Turp.) Breb.

S. quadricauda var. parvus G. M. Smith

S. quadricauda var. quadrispina (Chodat.) G. M. Smith

S. quadricauda var. longispina (Chodat.) G. M. Smith

S. quadricauda var. Westii G. M. Smith

S. opoliensis P. Richt.

Crucigenia rectangularis (Näg.) Gay

C. quadrata Morren.

Tetrastrum elegans Playfair

Actinastrum gracillimum G. M. Smith

A. Hantzschi Lagerh.

Micractinium pusillum Fresenius

Zygnematales

Closterium acutum (Lyngb.) Breb.

C. Ehrenbergii Menegh.

C. moniliferum (Bory) Ehr.

C. acerosum (Shrank) Ehr.

C. Kuetzingii Breb.

C. decorum Breb.

C. praelongum Ehr.

C. rostratum

Cosmarium Botrytis (Bory) Menegh.

C. reniforme (Ralfs.) Archer

C. protractum (Näg.) De Bary.

Zygnematales (Cont'd.)

C. punctatum Breb.

Staurastrum muticum Breb.

S. cerastes Lundell.

S. curvatum W. West

S. paradoxum Meyen.

Arthrodesmus phimus Turner

Sphaerozosma exiguum Turner

Spondylosium planum (Wolle) W. & G. S. West

S. papillatum W. & G. S. West

Dinophyceae

Dinoflagellatae

Glenodinium cinctum Ehr.

Peridinium tabulatum Clap. & Lach.

APPENDIX ii

Explanation of Photographs

Figure 1. A westerly view of Cootes Paradise Marsh, taken from a position at the north end of Burlington Heights. The Niagara escarpment is at the horizon. Station 1. is at the right hand side.

Figure 2. A westerly view of Cootes Paradise Marsh, taken from a south position on Burlington Heights. The town of Dundas is in the background, and the Niagara escarpment at the horizon.

PLATE I

Figure I

Figure 2

Explanation of Photographs

Figure 3. Another view of the open waters, taken from a height of land at the south-east corner of the Marsh, with Station 1. in the left background, and Burlington Heights at the right horizon. Niagara escarpment is on the left. Note the rubbish floating from Princess Inlet, which is situated to the right of this portion of the Marsh.

Figure 4. A westerly view taken from Bull's Point, on the north shore showing the open waters, and marsh vegetation. The Desjardin's Canal is in the center-right foreground.

PLATE II

Figure 3

Figure 4

Explanation of Photographs

Figure 5. A second view taken from Bull's Point indicating the types of vegetation to be found at the western end of the Marsh. Station 2. is situated near the center background.

Figure 6. An easterly view of the Marsh taken from Grassy Point, showing the Typha, Glyceria and beds of Lemna surrounding Station 2., and Burlington Heights in the right background.

PLATE III

Figure 5

Figure 6

Explanation of Photographs

Figures 7. & 8. North and west views respectively of Cootes Paradise Marsh, taken from the same position as in the preceding figure (6) to show the mud flats caused by receding water levels, and the tree cover, typical of the western end of the Marsh.

PLATE IV

Figure 7

Figure 8

Explanation of Photographs

Figure 9. The bridge at Station 3. Note the rubbish and oily scum at the bottom right.

Figure 10. A view of Princess Inlet with the household garbage at center-right background. Burlington Heights is to the left.

PLATE V

Figure 9

Figure 10

APPENDIX iii

Explanation of Photographs

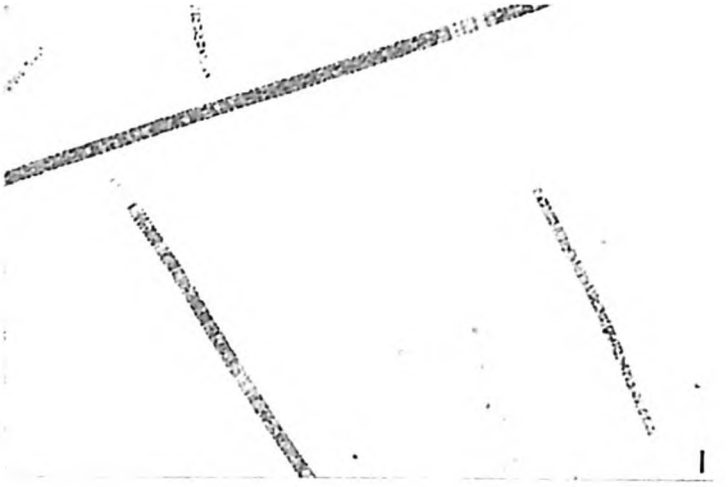
Figure 1. Field of Aphanizomenon flos-aquae (l.) Ralfs
Magnification : 430X

Figure 2. Chlorobotrys regularis (West) Bohlin.
Magnification: 430X

Figures 3-4. Stephanodiscus Ehr. Girdle and valve views respectively. Magnification: 430X

Figure 5. Asterionella formosa Hass. Girdle view.
Magnification: 430X

PLATE I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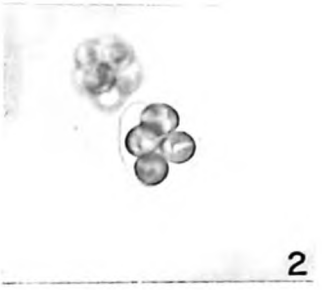
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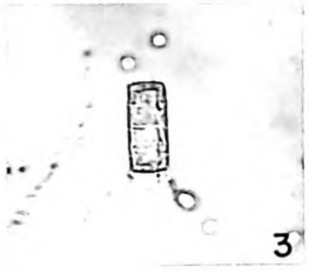
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Explanation of Photographs

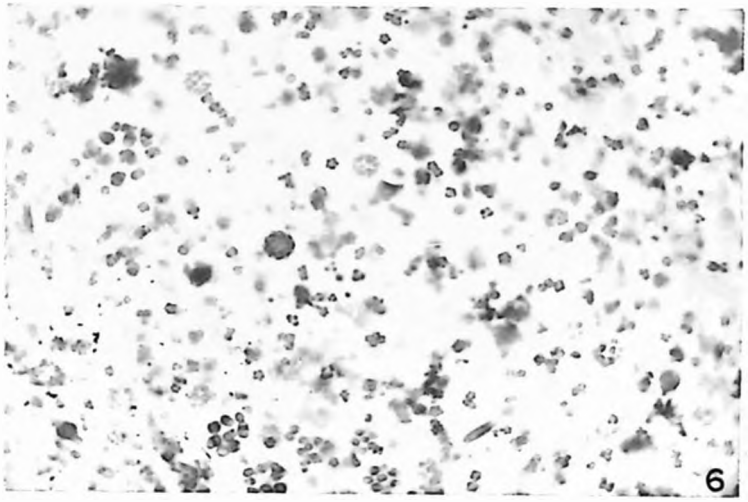
Figure 6. A typical field of the counting cell at a time of great abundance of Micractinium pusillum Fresenius. Pandorina and Eudorina are also present. The field is 1 mm. in depth, therefore the lack of detail. Magnification: 100X

Figure 7. Eudorina elegans Ehr. Magnification: 430X

Figure 8. Asterococcus limneticus. G. M. Smith
Magnification: 430X

Figure 9. Coelastrum microporum Näg.
Magnification: 430X

PLATE II



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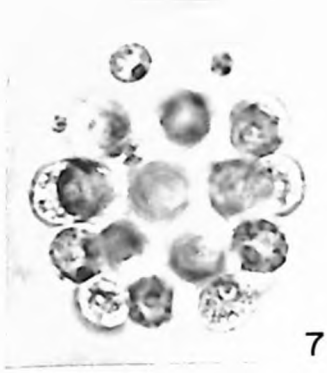

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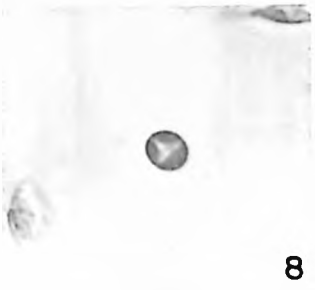

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Explanation of Photographs

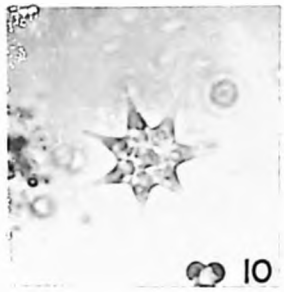
Figures 10-12. Pediastrum simplex var. duodenarium (Bailey) Rab. Magnification: 430X

Figures 13-14. P. duplex Meyen. Magnification: 430X

Figure 15. P. Boryanum (Turp.) Menegh. Magnification: 430X

Figure 16. Dictyosphaerium pulchellum Wood Magnification: 430X

PLATE III



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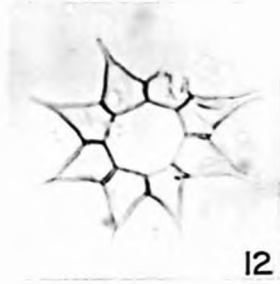

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Explanation of Photographs

Figure 17. Lagerheimia longiseta var. major var. nova
Magnification: 430X

Figure 18. Ankistrodesmus spiralis (Turner) Lemm.

Figure 19. Selenastrum gracile Reinsch. Magnification: 430X

Figure 20. S. Bibraianum Reinsch. Magnification: 430X

Figure 21. Scenedesmus opoliensis P. Richt.
Magnification: 430X

Figure 22. Scenedesmus sp. Magnification: 430X

Figure 23. S. quadricauda var. quadrispina (Chodat) G. M. Smith
Magnification: 430X

Figure 24. Scenedesmus sp. Magnification: 430X

Figure 25. S. dimorphus (Turp.) Kütz.

Figure 26. S. dimorphus (Turp.) Kütz.

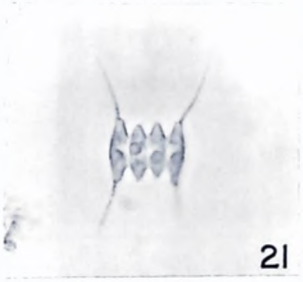
PLATE IV


17


18


19


20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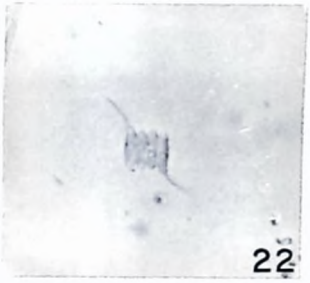
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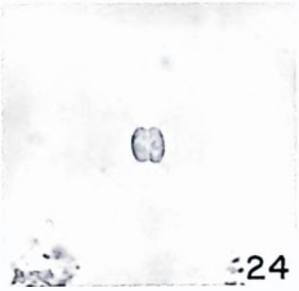
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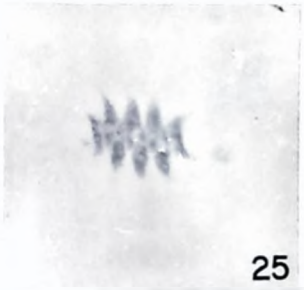
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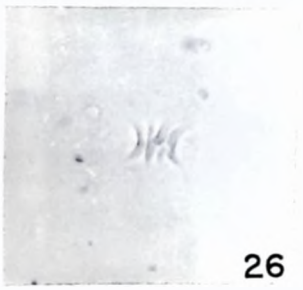
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Explanation of Photographs

Figure 27. Crucigenia rectangularis (Näg.) Gay
Magnification: 430X

Figure 28. Actinastrum Hantzschii Lagerh. Magnification: 430X

Figure 29. Micractinium pusillum Fresenius Magnification: 430X

Figure 30. Closterium acutum (Lyngb.) Breb. Magnification: 430X

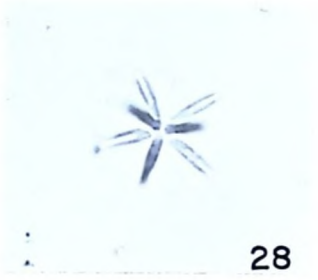
Figure 31. C. Kuetzingii Breb. Magnification: 430X

Figure 32. Closterium sp. Magnification: 430X

Figure 33. C. moniliforme (Bory) Ehr. Magnification: 100X

PLATE V


27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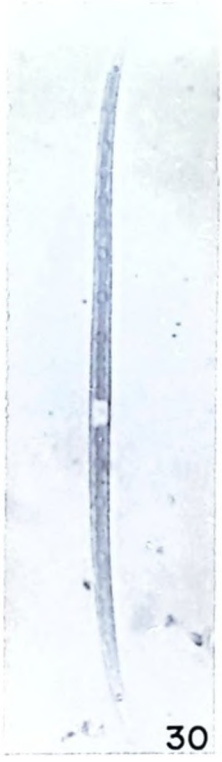
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Explanation of Photographs

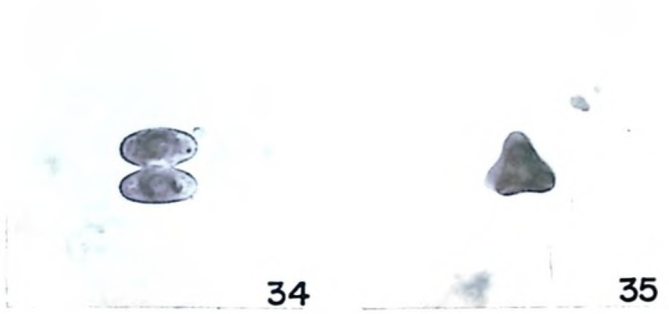
Figures 34-35. Staurastrum muticum Breb. Lateral and end views respectively. Magnification: 430X

Figure 36. Staurastrum sp. End view. Magnification: 430X

Figures 37-39. Staurastrum spp. Lateral views. Magnification: 430X

Figure 40. Spondylosium planum (Wolle) W. & G. S. West Magnification: 430X

PLATE VI



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