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A study of the algal flora phytoplankton and chemistry of Rainbow Lake Sanders County Montana

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A STUDY OF THE ALGAL FLORA,

PHYTOPLANKTON, AND CHEMISTRY OF RAINBOW LAKE,

SANDERS COUNTY, MONTANA

by

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A STUDY OF THE ALGAL FLORA, PHYTOPLANKTON, AND CHEMISTRY OF RAINBOW LAKE, SANDERS COUNTY, MONTANA

Introduction

Montana has many small lakes, but only a few of these have received concentrated study with respect to their algal flora, algal distribution and periodicity, or their chemistry.

Lakes of western Montana commonly exhibit algal blooms. These blooms are frequently accompanied by unpleasant odors and often cause the water to be colored blue-green to red depending on the particular alga responsible for the blooms. Blooms are known to be toxic to certain animals such as fish.

Rainbow Lake was selected for study because of the presence of *Nitella sp.* which is an indicator of soft water, and because of the blooms that occur in the lake. These conditions made Rainbow Lake appear biologically and chemically unique among the lakes in this section of Montana.

It is the purpose of this study to: (1) study the algal flora; (2) make a quantitative analysis of the phytoplankton; (3) describe the vertical distribution of the phytoplankton; (4) determine the periodicity of the phytoplankton; and (5) characterize the lake chemically.

Information of this sort is lacking for most lakes of the Pacific Northwest, including Montana.

Literature Review

Pardee (1942) studied the geology of the area submerged by Glacial Lake Missoula and included an explanation of the formation of

Rainbow Lake and Flathead Lake.

Several texts were used for the taxonomic classification of the algae of Rainbow Lake. The Cyanophyta, Chlorophyta, and some Cyrysophyta were classified by the use of the following publications: Prescott (1962, 1964); Smith (1920, 1924, 1950); Irenee-Marie (1939); West and West (1904, 1905, 1908, 1912); West and Carter (1923); and Wolle (1887). The diatoms were classified using Patrick and Reimer (1966), Hustedt (1923), and Vinyard (1964). Ecological notes and distributions of the organisms are included in most of these works.

Welch (1952), Ruttner (1963), and Hutchinson (1967) review and summarize the literature on phytoplankton ecology. Hutchinson (1967) is especially valuable for the limnologist. Welch (1948) is a standard text of methods used in limnological investigations.

Prescott (1962), Hutchinson (1967), Patrick and Reimer (1966), and Krieger (1927) review the literature on the subject of algal associations that are indicators of lake types. William and Scott (1962) list the diatoms most commonly found in flowing water in the United States.

Seasonal periodicity has been described by Pearsall (1932), Young (1935), Patrick and Reimer (1966), Hutchinson (1967), Morgan (1968), and others. Flathead Lake succession was first described by Young (1935), and recently by Morgan (1968).

The factors that cause phytoplankton succession are listed by Hutchinson (1967). Droop (1962) concluded that rough correlations between pulses of specific genera and environmental requirements such as light, water movement, temperature, and mineral nutrients have been made, but exact correlation defies analysis.

Fitzgerald (1964) attributes the succession of the phytoplankton to organic substances such as extracellular secretions, metabolites, vitamins, and amino acids in the water.

Akehurst (1931) explained succession on the basis of one group producing substances which were toxic to themselves but stimulatory to another species. In the case of diatoms, Talling (1957) found no evidence that extracellular substances were produced by either of the two species, Asterionella formosa or Fragilaria crotonensis, which affected the growth of the other.

Morgan (1968) reviewed the pertinent papers regarding phytoplankton ecology and the physiological requirements of phytoplankton.

In an early report on the results of the use of rotenone in Potter's Lake, Smith (1940) concluded that there was no evidence that rotenone acted upon the plant life of the lake. Species of algae belonging to the genera Aphanocapsa, Anabaena, Dinobryon, Staurastrum, Tabellaria, and others common to the phytoplankton, were plentiful before and after the rotenone was added to the water. Smith's conclusions were based on observations only and were not supported by quantitative data.

Brown and Ball (1942) collected bi-monthly net samples at 10 foot intervals in a lake treated with 0.5 ppm of 5% rotenone. They reported that the dinoflagellate, Peridium, disappeared for the entire year. The crustaceans, Daphnia, Diaptomus, Cyclops, and Epischura were absent for as long as 5 weeks after treatment. Corethra was affected immediately, and the rotifers were reduced.

Bonn and Holbert (1961) reported increased plankton and bacterial counts after treatment of 5 coves of Lake LaVan, a small lake in northern Texas.

Kiser, Donaldson, and Olson (1963) reported that rotenone is commonly used and that little is known of its effect on zooplankton.

Young (1935) and Morgan (1968) studied the phytoplankton of Flathead Lake. Morgan (1968) concluded that little change has taken place in the phytoplankton of the lake since the study by Young. He reported similar phytoplankton succession. These studies are used to compare the phytoplankton of Flathead Lake with that of Rainbow Lake.

Fragilaria crotonensis, a common phytoplankter of both lakes, appears to have its pulse at similar temperatures in the two lakes. Wesenberg and Lund (1904) and Kofoid (1908) have also reported that the pulses of this organism appear to be correlated with temperature.

Materials and Methods

Field collections were made as follows: November 12, 1966, and during the year 1967, on January 6, February 3, April 1, April 28, May 15, June 22, July 5, July 18, July 25, and August 8. Winter conditions prevented December collections, and the study area was closed in September and October because of severe forest fire danger.

Twenty-four hour and weekly samplings were made during the summer of 1965 for chemical analyses. Quantitative samples were also collected; they were of a limited nature for preliminary counts.

Vertical distributions and seasonal succession of the phytoplanktonic algae were studied via samples collected from stations 1 and 2 indicated on the accompanying map (Fig. 1). Occasional samples were taken from feeder streams and random locations that appeared worthy of observation.

Qualitative phytoplankton samples were made by towing a #20 mesh

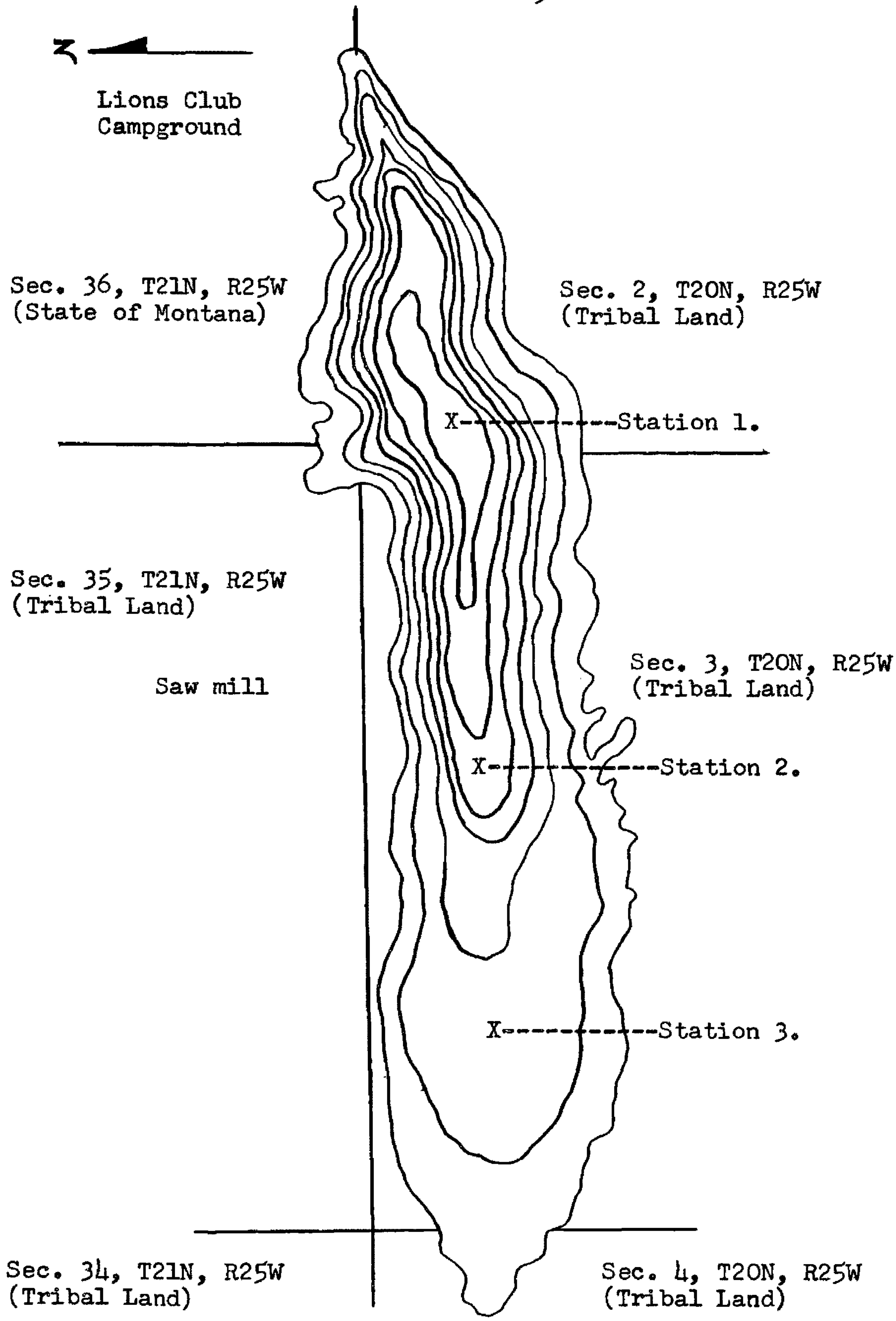

Figure 1. Rainbow (Dog) Lake, Sanders County, Montana. Contour interval - 5 feet. Surface area - 207 acres.

net. A one liter Juday bottle was used to collect quantitative samples. these samples were then poured through a nanno-plankton net, concentrated, and preserved in Transeau solution (6-3-1). These samples were then centrifuged and adjusted to a known volume. Plankton counts were made using a Sedgewick-Rafter counting chamber calibrated as described by Welch (1948). Permanent mounts of diatoms were made as described by Patrick and Reimer (1966), and photomicrographs made of all diatoms found. Camera lucida drawings were made of the green and blue-green algal species.

Dissolved O_2, CO_2, OH^-, $CO_3^{=}$, and HCO_3^- were analyzed according to Standard Methods for the Examination for Water, Sewage, and Industrial Wastes (1955). Common lots of test chemicals, such as phenophthalein and NaOH, were used throughout the study. The pH was determined with a Beckman meter and a Dr-El. Submerged, vertical, one-meter interval temperatures were taken with a Foxburo portable indicator. Surface temperatures were taken with a 76mm immersion thermometer.

History and Description of the Study Area

Rainbow Lake is located on Montana state highway #28 between Plains and Hot Springs, in T.20N., R.25W., Sections 2, 3, 4, and T.21N., R.25W., Sections 35 and 36, on the Flathead Indian Reservation. The lake is approximately 2 miles in length, and has an area of 2,670 square feet (unpublished report of the Montana Fish and Game Commission, 1958). The maximum depth is 30 feet, and the morphometry has been studied by the Montana Fish and Game Commission (Fig. 1).

Pardee (1942) studied the geology of the Rainbow Lake area and arrived at the following conclusions. Rainbow Lake was formed as a result of a catastrophic failure of an ice dam that blocked Glacial Lake Missoula. Glacial Lake Missoula submerged an area that included several intermountain basins and connecting valleys, or "narrows", that drain to the Clark Fork River. It is theorized that a sudden break of an ice dam that blocked the entire valley near the present Idaho-Montana state line was responsible for large quantities of water moving through the valleys and narrows in the partially submerged rim of the Camas Prairie Basin. Direct evidence for the large and rapid currents is found in the rocky channels and unique giant ripple marks found on the Camas Prairie valley floor. At its highest level the lake was estimated to have had a volume of 500 cubic miles of water. Three-fourths of this was stored above a constricted part of the Clark Fork valley called the Eddy Narrows. An estimate of the flow based on incomplete data indicated that a flow of 9.46 cubic miles per hour occurred through the Eddy Narrows at its high point.

It is not known whether or not Glacial Lake Missoula was completely drained when the ice dam broke. However, evidence based on geological observations of a later set of beaches indicates that the basin contained a new lake soon after the rapid outflow. It is suggested that the final outflow of the new lake was gradual.

Rainbow Lake Pass shows evidence of this catastrophic action. There are two passes on the east end and one on the west end of the lake area. The eastern entrance which is traversed by the Plains-Elmo highway #28 is approximately a half-mile wide. The western entrance is narrower. Both passes are about 3,650 feet, approximately 700 feet above the valley floor. The pass is nearly 6 miles in length.

Rainbow Lake fills a gouge in a narrow stretch of the pass. The surface elevation is 3,600 feet. There are small seasonal fluctuations in the level of the lake.

The lake is fed by two small streams and several streams of an intermittent nature. There is no visible outlet. However, early in the spring one can observe water escaping at the west end of the lake into an apparently underground outlet.

Rainbow Lake Pass exhibits the effects of a former large and rapid westward flowing current. The floors of both branches above the lake have been severely scoured and the bedrock exposed. The bedrock still remains bare except for a layer of rubble loosened by recent weathering. There are many channel depressions which contain ponds and marshes. Prominent knobs are rounded in a manner effected by the action of water. The side slopes are bare to a height of 200 feet or more; farther up the slopes are covered. The area occupied by Rainbow Lake is similar to a hollow or "plunge pool" that would be formed below a rapids by combined currents of two stream branches (Pardee, 1942). The lake, therefore, can best be described as a "scour" lake. Course gravel deposited at the west end of the lake supports the above theory. A complete discussion of the geology is included in Pardee's paper cited above.

In 1958, a small dam at the west end of the lake was removed, resulting in a drop of the water level of the lake of approximately 2 feet. The lake is easily accessible because a paved highway passes within 100 to 200 feet of the lake on the south and east sides, and an old logging road leads around the north and west sides, nearly encircling the lake. The watershed consists of an area of approximately 10 square miles. The drainage is covered by second-growth mixed coniferous timber. The species represented are <u>Pinus ponderosa</u>, <u>Pinus contorta</u>, Pseudotsuga taxifolia var. glauca, and Larix occidentalis. Populus deltoides and Populus tremuloides occur near the edge of the lake and in wet areas in the drainage. At the present time the drainage area is used as pasturage for cattle.

The lake is surrounded by campsites which receive considerable use. There are numerous outside toilets near the lake. The soil and rocks that make up the lake bed are very porous and evidence of this can be observed at the west end of the lake where the outlet disappears into the ground. There are also several homesites on the south side of the lake that are occupied periodically. Toilets, homes, campsites, and cattle contribute various nutrients to the lake.

The watershed was logged in 1943-1945 and a saw mill was located near the lake on the north side. Old logs and logging debris are still abundant along the edge of the lake. Sawdust from the mill operation was dumped into the lake and the bottom still contains quantities of old sawdust. Upon completion of the logging, a placer mining operation started in 1945 one-half mile above the lake and approximately $50,000. worth of gold was removed by hand shovel.

The lake was poisoned to remove unwanted fish in September, 1957, and May, 1966, by the Montana Fish and Game Commission. Pro-Nox, containing rotenone, at the concentration of one gallon per 3 acre feet, was used as the poison. in 1957, a total of 1,455 gallons of the poison was used, and in 1966, the amount was 896 gallons.

The Montana Fish and Game Commission has done a limited chemical study, and the results are summarized in Table 1. To my knowledge, this is the extent of the chemical information available for Rainbow Lake.

Table 1

Results of the
Montana Fish and Game Commission Chemical Studies

Date and Station	D.O. ppm	pH	total alkalinity ppm P.R.	total alkalinity ppm M.P.	Temp. deg. F.	Conductance	Std. C.
Feb. 18, 1965.							
2: surface	11.2	6.7	0	20	3' 33.5	45/68°F	51
bottom	5.7	6.8	0	23	38	50/68°F	56
1: surface	11.2						
12'	9.0						
bottom	1.8			27		58/68°F	65
May 17, 1965.							
1: surface		6.9		16	53	38/74°F	39
13'		7.0		21	53		
bottom		6.9		18	53		
Lions Club Inlet		6.8		10	44	24/74°F	25
Saw Mill Inlet		6.8		25	52	57/74°F	59

Results

A. Algal Flora of Rainbow Lake

The algae found are listed in Table 2.

B. Vertical Distribution of the Phytoplankton

The phytoplankton of Rainbow Lake is distributed vertically, which is best illustrated by the diatoms. Populations of *Asterionella formosa* reached their maximum between March and June. During this period the highest concentration of the organisms was found in the bottom samples on April 1. On April 28, May 13, and June 22, the maximum number occurred in the surface samples.

Melosira spp. greatest populations were found on the surface April 1 and April 28. However, on May 13, the greatest numbers occurred in the bottom samples.

Rhizosolenia spp. greatest numbers occurred at mid depth (5 meters) in January and February, bottom depth in the April 1 collection, and in surface samples of April 22. In May the greatest numbers were found at mid depth, and finally, at the surface in June.

Fragilaria vaucheria occurred in greatest numbers at the mid depth on February 3, at the surface on April 1 and April 28, and at mid depth again in May.

Synedra spp. occurred in greatest numbers between February and June. The greatest populations occurred at mid depth in February and in the bottom sample of April 1. On April 28, May 5, and June 6, the greatest numbers were found at the surface.

Fragilaria crotonensis was found in greatest abundance in surface samples on November 12, February 3, April 1, and April 28. In May,

Table 2

A check list of the genera and species of the algae of Rainbow Lake determined according to families, orders, and phyla after Prescott (1964), except for the diatoms, which follow Patrick and Reimer (1966).

I. Phylum (Division) Chlorophyta
- A. Sub-division Chlorophyceae
  - Order Volvocales
    - Family Volvocaceae
      - Eudorina sp.
      - Pandorina morum
  - Order Tetrasporales
    - Family Palmellaceae
      - Gloeocystis ampla
      - Sphaerocystis ampla
  - Order Ulotrichales
    - Family Ulotrichaceae
      - Ulothrix sp.
    - Family Chaetophoraceae
      - Draparnaldia sp.
      - Stigeoclonium fasiculare
    - Family Protococcaceae
      - Protococcus sp.
  - Order Oedogoniales
    - Family Oedogoniaceae
      - Bulbochaete sp.
      - Oedogonium sp.
  - Order Chlorococcales
    - Family Botryococcaceae
      - Botryococcus braunii
    - Family Hydrodictyaceae
      - Pediastrum duplex
      - Pediastrum duplex var. clathratum
    - Family Oocystaceae
      - Ankistrodesmus faleatus
      - Dictyosphaerium pulchellum
      - Oocystis sp.
      - Tetraedron regulare
      - Tetraedron limneticum
    - Family Scenedesmaceae
      - Crucigenia sp.
      - Scenedesmus sp.
  - Order Zygnematales
    - Family Zygnemataceae
      - Mougeotia sp.
      - Sirogonium sp.
      - Spirogyra sp.
      - Zygnema sp.

Table 2, continued.

Family Desmidiaceae
- *Closterium maculentum* var. *substriatum*
- *Cosmarium bioculatum*
- *Cosmarium granatum*
- *Euastrum sp.*
- *Hyalotheca sp.*
- *Micrasterias mahabulleshwarensis* var. *dichotana*
- *Micrasterias radiata*
- *Pleurotaenium trabecula*
- *Sphaerozosma exiguum*
- *Staurastrum arctison*
- *Staurastrum arctison* var. *glabrum*
- *Staurastrum Johnsonii*
- *Staurastrum mucronatum*
- *Staurastrum furcatum*
- *Xanthidium antilopean* var. *polymazum*

B. Sub-division Characeae
- *Nitella sp.*

II. Phylum (Division) Chrysophyta

A. Sub-division Xanthophyceae (Heterokontae)

Order Heterotrichales

Family Heterotrichaceae
- *Tribonema atriculosum*

B. Sub-division Chrysophyceae

Family Ochromonadaceae
- *Dinobryon divergens*
- *Dinobryon bavaricum*

C. Sub-division Bacillariophyta

Order Fragilariales

Family Fragilariaceae
- *Tabellaria quadrisepta*
- *Tabellaria fenestrata*
- *Tabellaria floculosa* var. *floculosa*
- *Diatoma hiemale* var. *grande*
- *Diatoma vulgare* var. *mesodon*
- *Diatoma anceps* var. *anceps*
- *Meridion circulare* var. *circulare*
- *Meridion circulare* var. *constrictum*
- *Asterionella formosa*
- *Fragilaria crotonensis*
- *Fragilaria brevistriata*
- *Fragilaria brevistriata* var. *brevistriata*
- *Fragilaria brevistriata* var. *inflata*
- *Fragilaria lepastauron* var. *dubia*
- *Fragilaria construens*
- *Fragilaria construens* var. *construens*
- *Fragilaria vaucheria* var. *capitata*
- *Fragilaria vaucheria* var. *vaucheria*
- *Fragilaria vaucheria*

Table 2, continued.

Fragilaria pinata
Fragilaria pinata var. pinata
Fragilaria virescens
Hannaea arcus var. arcus
Synedra arcus
Synedra delicatissima var. angustissima
Synedra ulna var. ulna
Order Eunotiales
Family Eunotiaceae
Eunotia sp.
Eunotia indica var. indica
Eunotia formica var. formica
Eunotia pectinalis var. minor
Eunotia flexuosa var. flexuosa
Order Achnanthales
Family Achnanthaceae
Cocconeis placentula var. lineata
Cocconeis sp.
Cocconeis disculus
Achnanthes sp.
Achnanthes exigua var. exigua
Achnanthes exigua var. heterovalva
Achnanthes coarctata var. coarctata
Achnanthes lanceolata
Achnanthes clevei var. clevei
Achnanthes lemmermannii
Achnanthes hungarica var. hungarica
Achnanthes pinnata
Achnanthes linearis var. linearis
Rhoicosphenia curvata
Order Naviculales
Family Naviculaceae
Diatomella balfouriana var. balfouriana
Mastogloia sp.
Frustulia rhomboides var. amphipleuroides
Frustulia vulgaris var. vulgaris
Gyrosigma acuminatum var. acuminatum
Stauroneis phoenicenteron var. phoenicenteron
Stauroneis phoenicenteron var. gracilis
Stauroneis anceps
Stauroneis anceps var. gracilis
Stauroneis acuta var. acuta
Stauroneis smithii var. smithii
Stauroneis Kriegeri var. kriegeri
Neidium iridis var. amphigomphus
Neidium ampliatum
Neidium affine var. affine
Neidium sp.
Diploneis elliptica
Navicula semen

Table 2, continued.

Navicula cuspidata var. obtusa
Navicula americana var. americana
Navicula laevissima var. laevissima
Navicula pupula var. rectangularis
Navicula pupula var. capitata
Navicula pupula var. mutata
Navicula mutica
Navicula mutica var. mutica
Navicula mutica var. undulata
Navicula mutica var. nivalis
Navicula semenoides
Navicula elginensis var. rostrata
Navicula explanata
Navicula minutissima
Navicula simula var. simula
Navicula radiosa
Navicula flotowii
Navicula secreati
Navicula pseudoscultiformis
Navicula pseudoscultiformis var. pseudoscultiformis
Navicula cascadensis var. cascadensis
Navicula capitata var. capitata
Caloneis limosa var. limosa
Caloneis ventricosa var. subundulata
Caloneis hyalina
Pinnularia sp.
Pinnularia mesolepta
Pinnularia biceps
Pinnularia brounii
Pinnularia subcapitata var. pausistriata
Pinnularia brebissonii
Pinnularia viridis var. viridis
Pinnularia borealis var. borealis
Pinnularia borealis var. rectangularis
Pinnularia balfouriana
Pinnularia abaujensis
Pinnularia abaujensis var. undulata
Pinnularia brevicostata var. brevicostata
Pinnularia streptoraphe var. streptoraphe
Pinnularia acrosphaeria var. acrosphaeria
Cymbella sp.
Cymbella ventricosa
Cymbella prostata
Cymbella naviculiformis
Cymbella cesati
Cymbella Hauckii
Cymbella chembergii
Cymbella cistula
Cymbella helvetica
Cymbella pusilla

Table 2, continued.

Cymbella aspera
Gomphonema sp.
Gomphonema constrictum
Gomphonema constrictum var. capitata
Gomphonema acuminatum var. coronata
Gomphonema lanceolatum
Gomphonema parvulum
Gomphonema angustatum
Amphora ovalis
Amphora ovalis var. pediculus
Order Epithemiales
Family Epithemiaceae
Epithemia trugida var. granulata
Epithemia zebra var. porcellar
Order Nitzschiales
Hantzschia amphioxys var. virax
Hantzschia virgata
Hantzschia virgata var. capitella
Nitzschia sp.
Nitzschia gracilis
Order Surirellales
Surirella sp.
Surirella angistatum
Cymatopleura solea
Stenopterobia intermedia
Rhopalodia parrarella
Rhopalodia gibba var. ventricosa
Order Eupodiscales
Melosira islandica
Melosira rosea
Melosira granulatum
Cyclotella sp.
Stephanodiscus astraea
Order Rhizosoleniales
Rhizosolenia eriensis

III. Phylum (Division) Pyrrhophyta
Sub-division Dinophyceae
Order Dinokontae
Family Peridiniaceae
Peridinium sp.
Family Glenodiniaceae
Glenodinium sp.
Family Ceratiaceae
Ceratium hirudinella

IV. Phylum (Division) Cyanophyta
Sub-division Myxophyceae
Order Chroococcales
Family Chroococcaceae

Table 2, continued.

- *Aphanocapsa sp.*
- *Coelosphaerium naegelianum*
- *Microcystis sp.*

Order Hormogonales

- Family Oscillatoriaceae
  - *Oscillatoria sp.*
  - *Spirulina major*
- Family Nostocaceae
  - *Anabaena spiroides*
  - *Anabaena flos-aquae*
  - *Nostoc palludosum*
  - *Aphanizomenon flos-aquae*
- Family Scytonemataceae
  - *Desmonema Wrangelii*
  - *Tolypothrix distorta*
- Family Rivulariaceae
  - *Gloeotrichia echinulata*

approximately twice as many were found at the bottom depth than were found at the surface. On June 22 and July 5, the greatest numbers were found in the bottom samples. In the July 18, 25, and August 8 collections the greatest numbers were found in the surface samples.

Dinobryon spp. occurred in greatest numbers in the bottom samples on April 1, and surface samples on April 28, May 13, and June 22. Dinobryon spp. are included with the diatoms because they have a similar population pulse.

Table 3 illustrates the vertical distribution of diatoms and of Dinobryon spp. in number of organisms per liter from surface (S), mid depth (M), and bottom (B) samples.

The green and blue-green algae were also distributed vertically. Sphaerocystis sp. illustrates this best of the green algae that are represented. In November, the greatest numbers of this organism were found at the mid depth. Staurastrum Johnsonii was found primarily in the surface samples and at mid depth. Green colonies, the identifications of which were difficult, were grouped together as colonies unknown. On April 28, four times as many of these colonies were found in the surface samples as in the mid depth samples. Twice as many were found in the bottom samples as at the mid depth. Other species were distributed vertically but were not considered to be found in great enough numbers for significant data. However, some of these organisms are included in Table 4 which illustrates vertical distribution of the green algae.

The vertical distribution of the blue-green algae is depicted in Table 5.

Anabaena spp. occurred in greatest numbers during April 28 to June 22. They also appeared in the August collections. The greatest popu-

Table 3

Vertical Distribution of the Phytoplankton (organisms per liter).

Chrysophyta		1966: 11/12	1967: 1/6	2/3	4/1	4/28	5/13	6/22	7/5	7/18	7/25	8/8
Asterionella formosa	S	490	0	1,960	21,070	7,667,520	163,660	140,630	4,704	0	0	0
	M	0	1,960	0	13,230	2,284,380	94,050	77,420	1,960	0	6,860	1,960
	B	0	0	490	24,010	1,111,320	95,550	81,340	0	3,920	0	0
Melosira sp.	S	6,370	0	0	12,740	299,880	0	1,960	392	1,470	490	0
	M	1,470	0	0	490	32,340	2,450	980	0	1,470	490	0
	B	490	0	490	6,860	0	56,350	980	0	3,920	980	0
Rhizosolenia sp.	S	0	4,900	0	10,490	490,980	2,940	9,310	0	0	0	0
	M	0	5,880	9,800	2,450	226,380	5,880	7,840	0	0	0	0
	B	0	4,410	6,860	119,560	70,560	490	1,470	0	0	0	0
Fragilaria vaucheria	S	980	0	980	6,370	41,160	2,640	0	0	0	0	31,850
	M	0	0	25,480	3,920	38,220	8,820	980	0	0	0	0
	B	0	6,860	20,580	2,940	8,820	5,390	980	0	0	0	0
Synedra sp.	S	490	0	490	2,450	155,820	28,420	2,450	392	0	0	0
	M	490	0	4,900	1,470	49,980	21,560	980	0	0	0	0
	B	980	0	2,940	11,760	4,740	12,740	0	490	0	0	980
Fragilaria crotonensis	S	18,130	0	1,470	5,880	105,840	36,260	0	0	2,940	17,150	299,390
	M	1,960	0	0	0	76,440	33,810	2,450	0	0	0	247,210
	B	0	0	0	490	97,020	76,930	5,390	6,370	0	0	137,200
Dinobryon spp.	S	6,370	0	0	12,740	299,880	0	1,960	392	1,470	490	0
	M	1,470	0	0	490	32,340	2,450	980	0	1,470	490	0
	B	490	0	490	6,860	0	56,350	980	0	3,920	980	0

Table 4

Vertical Distribution of the Phytoplankton (organisms per liter).

Chlorophyta		1966: 11/12	1967: 1/6	2/3	4/1	4/28	5/13	6/22	7/5	7/18	7/25	8/8
Sphaerocystis	S	7,350	0	0	0	0	490	980	0	0	5,390	0
sp.	M	23,520	0	0	0	0	0	0	0	0	0	0
	B	2,940	490	0	0	0	0	0	0	0	0	2,940
Staurastrum	S	1,960	0	0	0	0	0	980	0	2,940	3,430	3,430
Johnsonii	M	0	0	0	0	0	0	0	4,900	980	1,960	2,950
	B	0	0	0	0	0	0	0	0	490	490	1,960
Colonies	S	0	0	0	0	32,340	1,470	490	0	0	2,450	1,350
unknown	M	980	0	0	0	8,820	0	0	0	4,900	0	1,470
	B	0	0	0	0	17,640	0	0	0	2,450	0	3,430
Staurastrum	S	0	0	0	0	5,880	490	490	0	0	0	0
mucronatum	M	980	0	0	0	2,940	980	0	0	0	0	2,360
	B	0	0	0	0	5,880	0	1,470	0	0	0	490
Staurastrum	S	0	0	0	0	0	0	0	0	0	0	0
florida	M	980	0	0	0	0	0	0	490	0	0	0
	B	490	0	0	0	0	0	0	0	0	490	0

Table 5

Vertical Distribution of the Phytoplankton (organisms per liter).

Cyanophyta		1966: 11/12	1967: 1/6	2/3	4/1	4/28	5/13	6/22	7/5	7/18	7/25	8/8
Anabaena spp.	S	0	0	0	0	2,940	1,470	24,010	0	980*	1,470	3,430** 980*
	M	0	0	0	0	5,880	1,960	21,560	0	0	0	1,960** 1,470*
	B	0	0	0	0	8,820	2,940	3,430	0	0	0	980**
Aphanizomenon flos-aquae	S	0	0	0	0	0	0	26,950	0	2,940	3,430	490
	M	9,800	0	0	0	0	1,470	4,410	0	6,370	3,430	490
	B	5,880	0	0	0	0	0	490	980	24,010	2,940	3,430
Microcystis sp.	S	490	0	0	0	0	0	0	0	3,920	8,330	14,700
	M	1,960	0	0	490	0	980	490	3,920	490	1,470	10,480
	B	0	0	0	0	0	0	0	0	1,470	8,330	15,680
Gloeotrichia echinulata	S	0	0	0	0	0	0	490	0	0	5,390	11,270
	M	0	0	0	0	0	0	0	0	0	980	3,430
	B	0	0	0	0	0	0	0	0	0	0	0

* = colonies
** = filaments

lation occurred in the bottom samples in the April 28 and May 13 collections, decreased at the mid depth, and still further decreased at the surface. In June the greatest number occurred in surface samples and the least in bottom samples. The samples of August 8 also had the greatest number in the surface and the least in the bottom.

Aphanizomenon flos-aquae occurred in the June 22 sample but was absent in the July 5 samples. It reappeared in the July 18, 25, and August samples. The maximum population occurred in the surface sample of June 22. The greatest number was found in the bottom samples on July 18, in surface samples on July 25, and bottom samples on August 8.

Microcystis sp. occurred in greatest numbers in the July 25 and August 8 surface samples.

C. Seasonal Succession of the Phytoplankton

The genera and species that reached concentrations sufficient to become the dominant species periodically during the study were as follows: Sphaerocystis sp., Fragilaria vaucheria, Asterionella formosa, Dinobryon spp., Aphanizomenon flos-aquae, Microcystis sp., and Fragilaria crotonensis. They occurred as dominants in the following chronological order: Sphaerocystis sp., Rhizosolenia spp., Fragilaria vaucheria, Rhizosolenia spp., Asterionella formosa, Dinobryon spp., Asterionella formosa, Aphanizomenon flos-aquae, Fragilaria vaucheria, Microcystis sp., and Fragilaria crotonensis.

The green colonial alga, Sphaerocystis sp., reached a peak in the November collections. It was the dominant organism at this time.

Rhizosolenia sp. appeared first in the January collections and then increased in numbers in the February and April collections and decreased in numbers in May. It rose again in the June samples and disappeared completely thereafter.

Fragilaria vaucheria (on the basis of single cells) had 5 peaks in its concentration. It was the dominant species in the February and July 18 collections. Another peak in its population was apparent in the August 8 collection in which higher numbers were reached but it was not the dominant species at that time. Peaks also occurred in January and April during which times the organism occupied a subdominant position.

Asterionella formosa was present in all collections except those of November, July 18, and August. Its pulse occurred during the period from February to early July. It attained its greatest abundance in the April 28 collections and was the dominant species at this time. Following its dominant phase, there was a decrease in the May 13 sample, a slight increase in June, a decline in the July 5 samples, no organisms counted in the July 18 samples, and finally, a small number of organisms in the July 25 samples.

Aphanizomenon flos-aquae reached its highest concentrations in the June collection but was the dominant in the July 18 samples. It then declined in the next 2 collections. It also appeared in the November collections.

Microcystis sp. (colonies) reached its peak during the summer months.

The interaction of the dominant and subdominant genera, and in some cases, species, is illustrated in Fig. 2.

Table 6 illustrates the relationships of the major phyla of the lake in organisms per liter during the period of the study. All of these phyla are present for the entire year in the phytoplankton. The Chrysophyta dominate spring and late summer. In numbers of organisms per

Table 6

<u>Relationships of the major phyla of Rainbow Lake</u>
<u>(organisms per liter)</u>

Phylum:	1966: 11/12*	1967: 1/6**	2/3*	4/1	4/28	5/13	6/22*	7/5*	7/18	7/25	8/8
Cyanophyta	36,330	490	9,800	8,820	26,460	18,110	248,310	102,306	91,530	142,540	133,780
Chlorophyta	50,980	490	980	5,390	149,940	8,820	28,420	25,382	48,510	37,240	38,960
Chrysophyta	62,230	37,240	490	96,040	17,731,140	1,295,780	548,420	53,022	111,720	67,130	2,224,560
Total Organisms:	149,540	38,220	11,270	110,250	17,907,540	1,322,710	825,150	180,710	251,760	246,910	2,397,300

* = data missing for bottom samples, Station 2.
** = data are from Station 1 only.

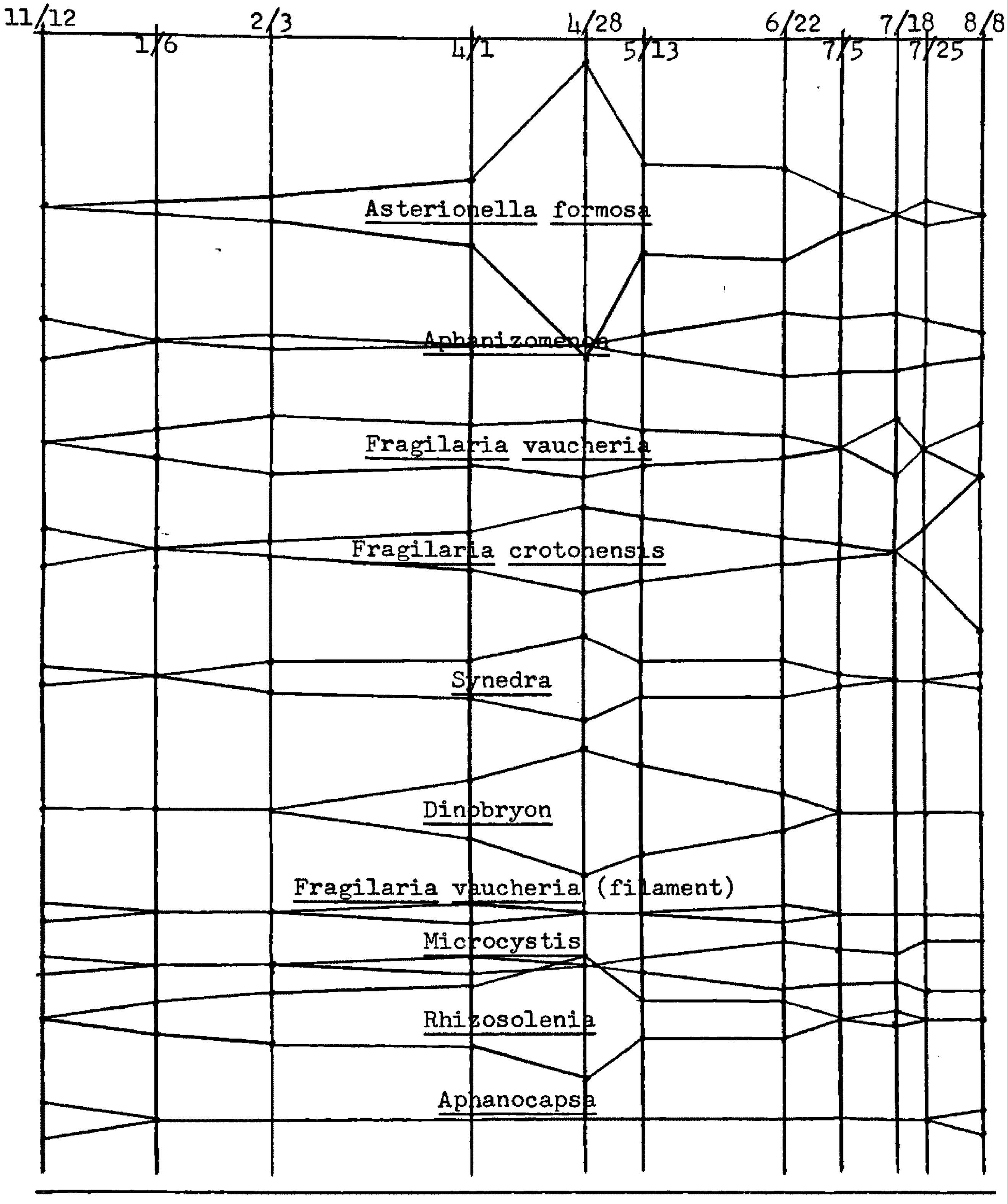

Figure 2. Seasonal variation of the phytoplankton of Rainbow Lake, Sanders County, Montana, 1966-1967; relative abundance plotted in proportion to the cube roots of the organisms per liter.

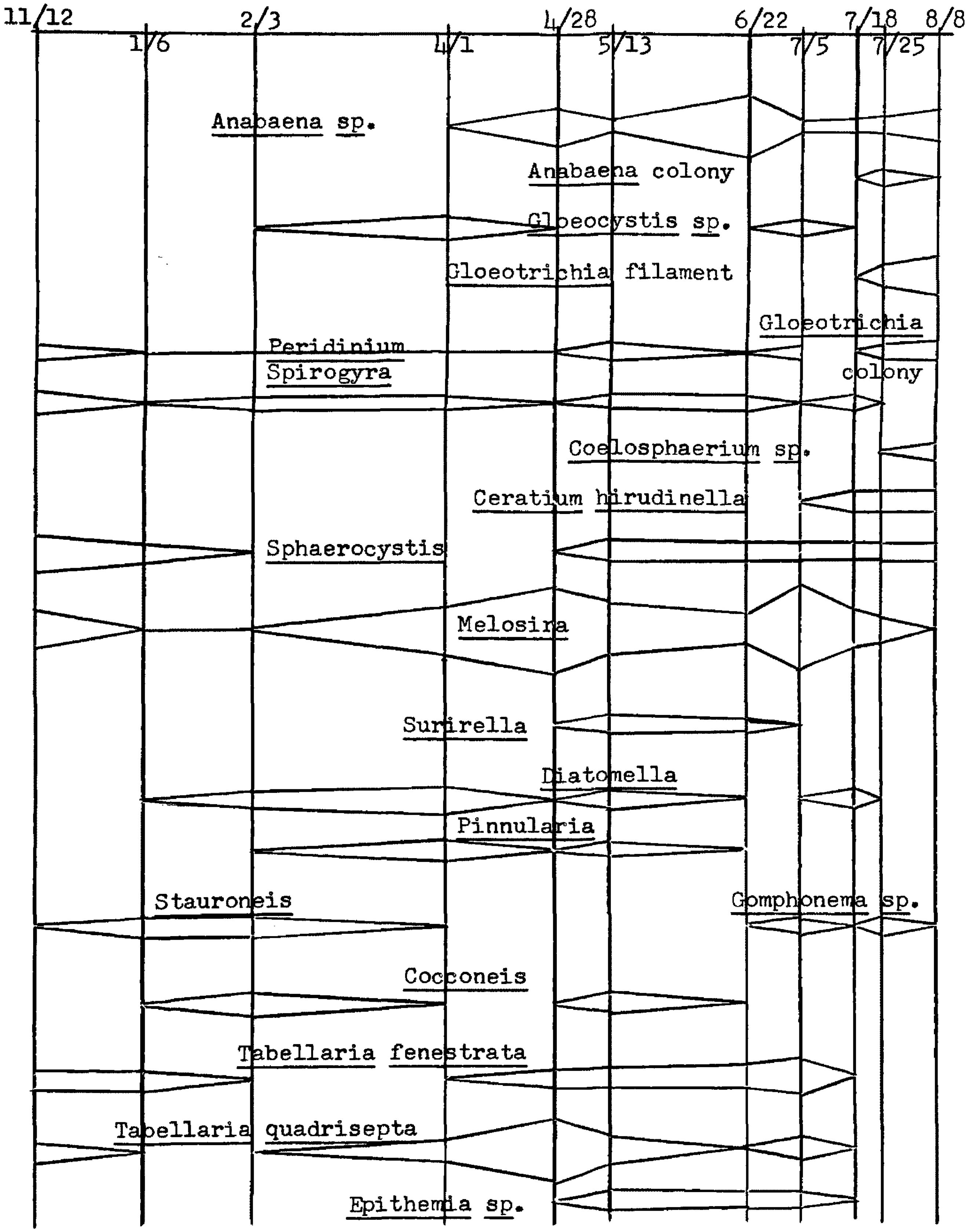

Figure 2, continued.

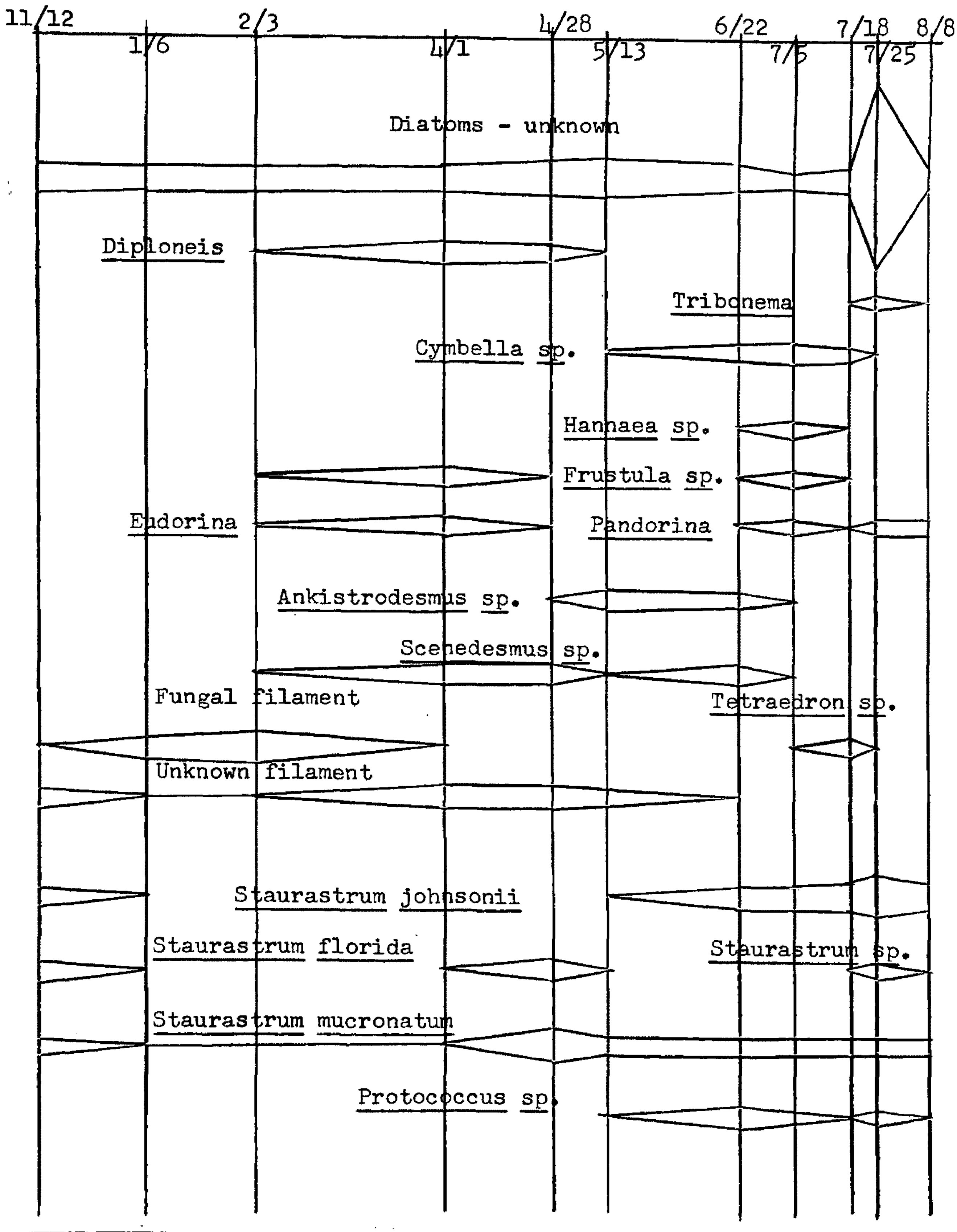

Figure 2, continued.

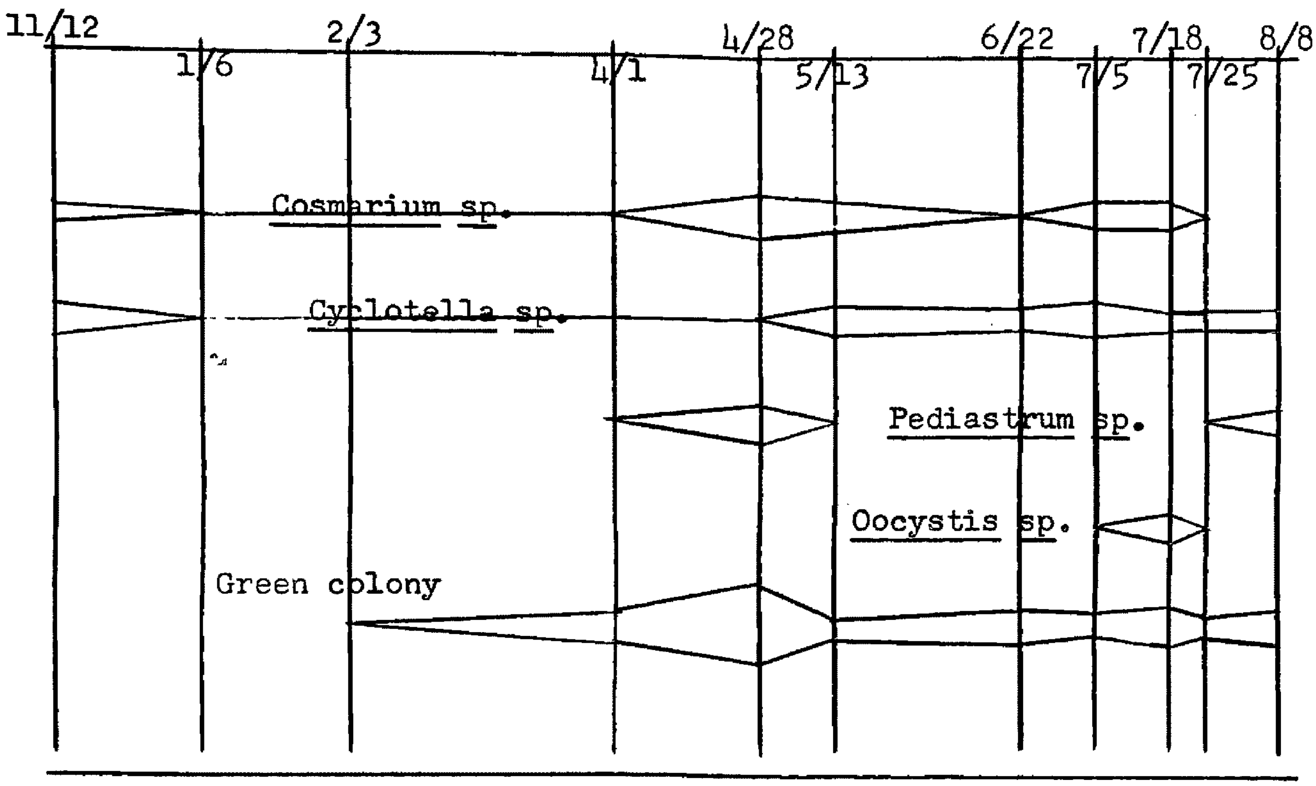

Figure 2, continued.

liter, the Cyanophyta became the dominant phylum during the summer months. The Chlorophyta appears to be the least important phylum, based on organisms per liter, represented in the phytoplankton. Fig. 3 illustrates the interrelationship of these phyla.

D. Chemical Results

The dissolved oxygen followed the typical diurnal variation early in the year as would be expected in a lake in which plants are the main utilizers and producers of oxygen. The diurnal variation was less pronounced later in the season (Table 7). The dissolved oxygen varied from a high of 13 ppm to a low of 1.6 ppm. The dissolved oxygen was usually above 8 ppm.

The phosphates decreased gradually during the study period. Early studies found them to be between 0.1 and 0.23 ppm. They declined to 0.1 ppm on July 15. An increase was noted from July 15 to July 22 to 0.2 ppm.

The NO_3^- declined gradually from 2.9 ppm on June 3 to 0.9 ppm on July 22. NO_2^- was essentially absent during the investigation (Table 8).

The water became more alkaline early in the afternoon, particularly at Stations 2 and 3. The bicarbonate alkalinity varied from 12 ppm at 4 P.M. to 63 ppm at 1 P.M. (Table 7). On the basis of alkalinity, and also on the conductance from a low of 25 to a high of 65 (Table 1), the water of Rainbow Lake is considered to be relatively soft.

The Montana Fish and Game Commission found that the pH varied from 6.7 to 7.0 (Table 1). In this study the pH was found to fluctuate widely in different sections of the study area.

Tests were carried out for other anions and cations. The results of these tests are found in Table 10.

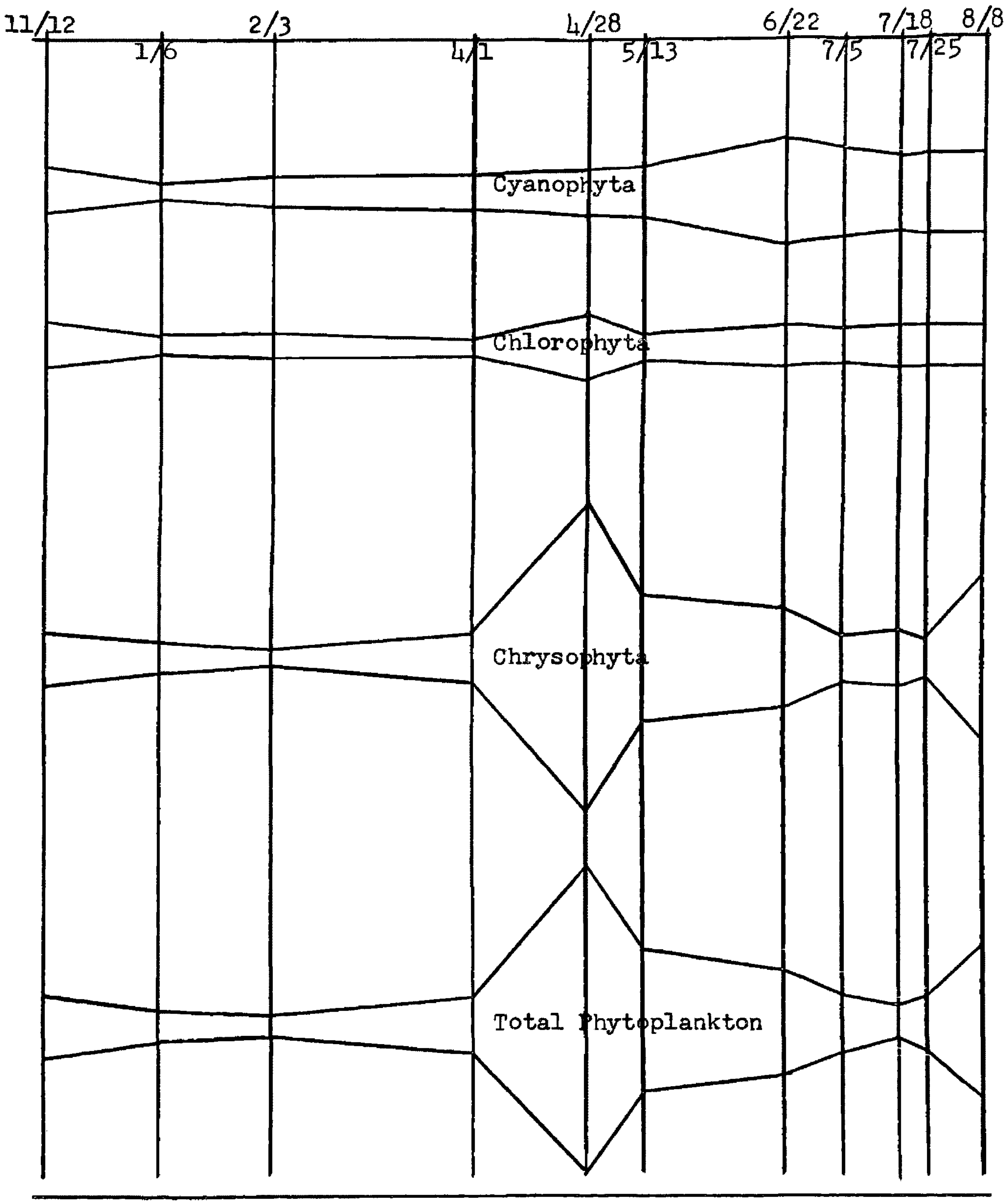

Figure 3. Seasonal variation of the phytoplankton of Rainbow Lake; relative abundance of phyla plotted in proportion to the cube roots of the organisms per liter.

Table 7

Chemical Data from Rainbow Lake, June 30, 1965.
(ppm)

Station and Time	Temp. °C.	D.O.	CO_2	OH^-	$CO_3^=$	HCO_3^-	NO_3^-	$PO_4^{\equiv}$	NO_2^-	$SO_4^=$
Station 1:										
11:00/PM	18	9.6	4.0	0	0	21	2.8	0.1	0	5
2:00/AM	17	8.3	0.5	0	0	21	2.1	0.15	0	5
5:00/AM	17	10.1	0	0	0	14	2.3	0.1-	0	5
9:00/AM	18	10.2	0.5	0	0	18	2.5	0.1+	0	5
1:00/PM	19	11.0	0	0	2	16	1.4	0.15-	0	5
4:00/PM	20	9.4	0	0	2	24	2.0	0.2	0	5
7:00/PM	20	4.7	-	-	-	-	1.4	0.15+	0	5
Station 2:										
11:00/PM	18	8.7	1.0	0	6	14	2.1	0.1	0	5
2:00/AM	17	9.3	0.5	0	0	20	2.4	0.1	0	5
5:00/AM	17	10.7	0	0	2	13	2.6	0.5	0	5
9:00/AM	17	10.1	0.5	0	4	22	1.8	0.2	0	5
1:00/PM	19	9.5	1.5	0	0	44	1.5	0.2	0	5
4:00/PM	21	1.6	0.5	0	12	14	3.3	0.2+	0	5
7:00/PM	21	9.3	-	0	-	-	1.6	0.1	0	5
Station 3:										
11:00/PM	19	13.0	0	0	7	18	2.2	0.15	0	6
2:00/AM	18	8.1	0	0	2	16	1.9	0.15+	0	-
5:00/AM	17	9.6	0.5	0	0	15	2.2	0.1-	0	-
9:00/AM	17	10.0	0	0	4	22	1.4	0.15-	0	-
1:00/PM	21	10.2	0	0	2	63	2.0	0.15-	0	-
4:00/PM	21	9.9	0	0	6	12	1.2	0.15+	0	-
7:00/PM	22	9.6	-	-	-	-	1.6	0.15	0	-

Table 8

Chemical Data from Rainbow Lake, July 22, 1965.
(ppm)

Station and Time	Temp. °C	D.O.	CO_2	OH^-	$CO_3^=$	HCO_3^-	NO_3^-	$PO_4^\equiv$	NO_2^-	$SO_4^=$	pH
Station 1:											
7:00/PM	19	12.0	-	0	22	0	1.3	0.4	-	5-	9.7
10:00/PM	19	8.6	-	0	8	10	0.9	0.2	-	5-	9.4
1:00/AM	18	8.3	-	0	12	6	0.8	0.3	-	5	9.4
4:00/AM	19	9.4	-	0	6	7	1.6	0.3	-	5	9.4
7:00/AM	17	8.9	-	-	-	-	0.8	0.1	-	5	9.4
10:00/AM	20	8.4	-	0	12	8	1.0	0.1	-	5-	9.2
1:00/PM	20	8.1	-	0	10	12	1.1	0.1+	-	5-	9.4
5:00/PM	20	5.3	-	-	26	0	1.2	0.3-	-	5-	9.6
Station 2:											
7:00/PM	20	9.6	-	0	14	6	1.4	0.3	-	5-	9.6
10:00/PM	18	8.3	-	0	10	8	0.9	0.2	-	5	9.2
1:00/AM	18	8.9	-	0	8	11	1.1	0.3-	-	5-	9.4
4:00/AM	18.5	8.3	-	0	12	6	1.0	0.2	-	5-	9.4
7:00/AM	18	7.9	-	-	-	-	0.8	0.1	-	5-	9.5
10:00/AM	19	8.4	-	0	6	6	1.1	0.1	-	5-	9.4
1:00/PM	21	8.3	-	0	8	6	1.2	0.2	-	5-	9.3
5:00/PM	23	7.9	-	0	10	6	1.1	0.2	-	5-	9.9
Station 3:											
7:00/PM	20	9.7	-	0	12	8	1.6	0.2	-	5	9.6
10:00/PM	19	8.2	-	0	8	12	1.2	0.2	-	5	8.9
1:00/AM	18	6.1	-	0	2	19	1.3	0.3+	-	7.5	8.9
4:00/AM	18	6.7	-	0	0	17	1.2	0.35	-	5+	8.8
7:00/AM	19	7.6	-	0	0	20	1.1	0.1	-	7.5	9.0
10:00/AM	21	8.1	-	0	6	17	1.4	0.1	-	5+	8.9
1:00/PM	21.5	8.6	-	0	6	17	1.4	0.2-	-	5	9.0
5:00/PM	25	-	-	0	12	7	1.2	0.15+	-	5	9.5
Stream, east end:											
7:00/PM	11	8.1	-	0	0	18	1.0	0.2	-	2.5	8.7
10:00/PM	11	13.3	-	0	0	21	0.8	0.2	-	5-	8.8
1:00/AM	11	8.8	-	0	0	20	1.3	0.3-	-	5-	8.6
4:00/AM	10	8.8	-	0	0	21	0.6	0.2	-	5-	8.6
7:00/AM	10	9.0	-	0	0	20	0.6	0.1	-	5-	8.5
10:00/AM	12	8.7	-	0	0	21	1.0	0.1	-	5-	8.5
1:00/PM	12.5	8.9	-	0	0	21	0.6	0.15+	-	5-	8.5
5:00/PM	11.5	7.5	-	0	0	19	0.5	0.2-	-	5-	8.6

Table 9

Chemical Data Based on Weekly Samples

Date and Station	Temp. °C	D.O.	CO_2	OH^-	$CO_3^=$	HCO_3^-	NO_3^-	$PO_4^{\equiv}$	NO_2^-	$SO_4^=$	pH
June 29											
Station 2:	16	9.0	-	0	0	10	0	0.1	-	5	-
July 8											
Station 1:	21	9.7	0	0	10	7	1.8	-	2.8	-	8.0
Stream:	13	8.9	0	0	0	20	1.3	-	0.1	5	9.4
Station 2:	24	10.3	0	0	10	7	2.5	-	0.1	5	8.9
Station 3:	24	7.1	0	0	12	6	1.8	-	0.1	5	9.2
July 15											
Station 1:	21	9.8	0	2	18	0	2.1	0.1	-	-	-
Station 2:	21	10.0	0	0	14	4	1.8	0.1	-	7	-
Station 3:	22	7.2	0	0	10	0	1.6	0.1	-	5	-
Stream:	10	8.6	-	0	0	17	1.3	0.1	-	4	-

Table 10

Anions and Cations in Lake Water

	ppm
$SO_4^=$	5.0
NO_2^-	0
Cl^-	0.2
Ca hardness..................	10.0
Mg hardness..................	10.0
Cu^{++}	0
Fe^{+++}	0.3
Mn^{++}	1.8

Discussion

Rainbow Lake has changed considerably since its origin. Factors that have contributed to this change are as follows: 1) the high ratio of shallow water to deep water; 2) placer mining of one of the streams entering the lake; 3) removal of timber from the drainage area around the lake; 4) removal of a man-made dam at the west end of the lake; 5) the presence of homesites and campgrounds which contribute nutrients to the lake; 6) poisoning of the lake with rotenone, which reduces grazing and also contributes nutrients from killed organisms.

The lake bed itself contributes few nutrients as it consists mainly of quartzitic argillite, quartzite, and carbonate rocks, mostly dolomitic limestone (Pardee, 1942). These rocks are reported to erode slowly, and thus contribute little nutrient to the lake (Morgan, 1968).

Rainbow Lake is dimictic, as are many lakes of the temperate region, having an overturn twice a year. Thermal stratification occurred between May and August. Wind action probably slows stratification of the lake. However, the colder streams entering the lake probably aid in setting up the thermocline.

The effect of thermal stratification on the phytoplankton population is difficult to interpret. It would appear that the pulse of the diatoms that occurred in April may have been correlated with the overturn of the lake. The concentration of many of the phytoplanktonic organisms was found in the bottom samples in February. In April, the greatest numbers of the phytoplankton were found in the surface samples. The increase in the numbers of phytoplanktonic organisms which occurred in April may have been correlated with a release of chemicals from the hypolimnion.

A slight chemocline would appear to have been established. The dissolved oxygen was above 8.0 ppm at the surface with a low of 7.9 ppm below the thermocline in August. A concentration of CO_2 of 0 ppm was found at the surface and 8.5 ppm was found at the 5 meter depth.

The pH, which is a controlling factor in the solubility of dissolved nutrients in water, was found to fluctuate widely in the study areas. The chemical data obtained are included in Tables 7, 8, and 9.

The flora of Rainbow Lake was found to be of many different lake types. The flora can best be described as a diatom-cyanophyte association which is reported to be characteristic of hard water lakes (Prescott, 1962). Nitella sp. occurs in the lake and is reported to be typical of soft water or water rich in humic acids (Prescott, 1962). Members of the family Zygnemataceae are found in the lake. They are reported to be characteristic of semi-hard or hard water (Prescott, 1962). On the basis of the chemical data, the lake is probably best described as a soft water lake.

The following genera are reported to be typical of dystrophic water: Frustulia, Stenopterobia, and Pinnularia (Patrick and Reimer, 1966). These genera are represented in the flora of Rainbow Lake.

William and Scott (1962) reported the following genera to be most common in the rivers of the United States: Melosira, Cyclotella, Stephanodiscus, Fragilaria, Tabellaria, and Synedra. These have been found in Rainbow Lake; they do not appear to enter from the streams.

A study of the flora also reveals indicators that are reported to be typical of eutrophic and oligotrophic conditions; i.e., Cymbella, Epithemia, Gomphonema, Navicula, and Nitzschia are reported to be typical of eutrophic waters (Krieger, 1927). All of these genera are found in abundance in Rainbow Lake.

Rawson (1956) concluded from a survey of data that in large lakes of North America, Asterionella, Tabellaria, and Melosira often associated with Dinobryon sp. are the most usual phytoplankters in oligotrophic water. This association is found in Rainbow Lake which may be an indication of oligotrophic conditions in the lake, or that the association occurs in smaller oligotrophic lakes also.

Patrick and Reimer (1966) stated that the type of water determines the species that are present. They reported that eutrophic waters are often characterized by the following: Stephanodiscus hinderanus, Cyclotella dubia, and Asterionella formosa. Members of the genera Stephanodiscus and Cyclotella have been reported from Rainbow Lake, but they were not abundant. Asterionella formosa was abundant. Further work should reveal more information about this association in Rainbow Lake.

Welch (1952) concluded that the plankton, in general, gives an indication of the nutritive condition of the water; i.e., a high plankton count indicates high nutrients. Rainbow Lake would appear to be nutrient poor because of low phosphates, nitrates, and nitrites. However, poor nutrient levels in the water may be due to minerals and nutrients being bound in the biota of the lake.

Oligotrophic conditions are reported to occur in eutrophic lakes. Patrick and Reimer (1966) reported Melosira granulata to be an oligotrophic organism which often follows a pulse of Synedra. An increase in the populations of Melosira spp. was noted after a population peak of Synedra in Rainbow Lake.

The appearance and increase in numbers of desmids, and possibly the presence of green algae in the summer, may be associated with the low $N:NO_3::P:PO_4$ ratio which occurs in the summer in Rainbow Lake. Hutchinson (1967) reported that green algae occur in the summer when the nutrient content is low.

From the foregoing it appears that the flora of a lake will depend largely on its geographical location; i.e., northwest Montana or Michigan. The progression from oligotrophic to eutrophic conditions probably is never complete in the sense that all of the oligotrophic species will be eliminated from the flora as the lake approaches the eutrophic condition. This probably has occurred in Rainbow Lake. This fact will make classification on the basis of the flora difficult if not impossible, except, perhaps, on a local basis. Because of the variety of niches in each lake, classification even on a local basis may be difficult.

Seasonal periodicity of the phytoplankton has been described by Pearsall (1932), Young (1935), Patrick and Reimer (1966), Hutchinson (1967), and Morgan (1968). The factors involved in seasonal succession are summarized by Hutchinson (1967).

Droop (1962) stated that rough correlations between pulses of specific genera and environmental requirements, e.g., light, water movement, temperature, and mineral nutrients, have been made but that exact correlation defies analysis. Fitzgerald (1964) attributed the succession of the phytoplankton to organic substances such as extra-cellular secretions, metabolites, vitamins, and amino acids in the water. Akehurst (1931) explained succession on the basis of one group producing substances which are toxic to itself but which may be stimulating to another species. This may be the case with respect to the blue-green algae in Rainbow Lake; however, several of the diatoms appeared to bloom simultaneously. Their maximum numbers varied, but this could be accounted for by their genetic ability for reproduction; i.e., some were able to divide faster than others. Asterionella, Rhizosolenia, Fragilaria, Dinobryon, and Melosira all had a peak in their populations in April. Collections made at closer intervals may have shown their actual peaks to vary. Talling (1957) studied Asterionella formosa and Fragilaria crotonensis and found no evidence that either species produced extracellular substances that modified the growth of the other. This would indicate that the peaks of the above species could indeed occur at the same time.

Chytrids may have been a factor in the decline of Asterionella formosa in Rainbow Lake, as they were observed on Asterionella formosa during its maximum pulse. Further study along these lines might show fungi, bacteria, and viruses important in the succession of the plankton.

Treatment of the lake with rotenone may have reduced the grazers of certain species of phytoplankton and hence, account for the high numbers of some species. Brown and Ball (1942) collected bimonthly net samples at 10 foot intervals in a lake treated with 0.5 ppm of 5% rotenone. They reported that the dinoflagellate, Peridinium, disappeared for an entire year. The crustaceans Daphnia, Diaptomos, Cyclops, and Epischura were absent for as long as five weeks. Corethra was affected immediately, and the numbers of rotifers were reduced.

Bonn and Holbert (1961) reported increased plankton and bacterial counts in five coves of Lake LaVan during and after treatment with rotenone. Kiser, Donaldson, and Olson (1963) reported that rotenone is commonly used but that little is known of its effects on zooplankton. They reported that open water species were completely removed, and remained absent for over three months. Organisms near the shore resisted the effects of rotenone, but eventually disappeared for several weeks. They reported that during 1959, 8,577 lakes in the United States with a combined area of 290,000 acres, had been rehabilitated for more profitable sport fishing. Trout waters treated totaled 563 lakes with a surface area of 128,902 acres. It would appear that further studies concerned with the use of rotenone should be made before its use is continued.

Temperature is important in the periodicity of plankton. Wesenberg and Lund (1904) found that *Fragilaria crotonensis* did not flourish at temperatures above 16°C. Kofoid (1908) reported *Fragilaria crotonensis* apparently did not do well at temperatures in access of 15.5°C. Temperatures below this would occur in Rainbow Lake in the spring and possibly in the late summer when the pulse of *Fragilaria crotonensis* occurred.

It would appear that thermal races or ecotypes occur among the phytoplankton of Rainbow Lake. *Fragilaria vaucheria* in the spring collections appeared to be of a different size than those collected in the late summer. The two sizes of organisms may have represented different varieties or physiological races of the species. This emphasizes the need for a counting method that would enable the investigator to identify organisms to species. The Sedgewick-Rafter counting chamber does not permit this. In this study, *Asterionella formosa*, *Synedra*, and *Melosira* appeared to have physiological races or varieties. Culture work will be required to determine whether or not ecotypes or races do exist in their populations.

Melosira spp. appeared to have different sinking rates which affected their numbers in the phytoplankton. Further work, in which bottom samples are taken and correlated with phytoplankton samples, would probably aid in determining the effect that sinking has on the occurrence of these organisms in the bottom samples. Lund (1955) studied *Melosira italica* var. *sub-arctica* and found that its growth was curtailed by sinking. He also showed that it sank from three to five times the rate of *Asterionella formosa*, and that its sinking was correlated with turbulence of the water. He reported that it disappeared completely during stratification. *Melosira spp.* were absent from the January collections made in this study, which indicates that this genus disappears during the period in which Rainbow Lake is stratified. A study of the genus *Melosira* in Rainbow Lake would make an interesting investigation and might shed some light on this subject.

Many of the genera represented in Fig. 2 are considered to be temporary residents of the phytoplankton in Rainbow Lake. *Surirella*, *Diatomella*, *Pinnularia*, *Gomphonema*, *Cocconeis*, *Stauroneis*, *Diploneis*, *Frustulia*, *Cymbella*, and *Epithemia* are typically found on the bottom growing among the higher aquatics or attached to the higher plants or rocks of the lake. They are considered to occur in the phytoplankton because of disturbances of their natural habitat. There are many natural disturbances of the environment such as wind causing wave action that dislodges these organisms, causing them to become temporarily suspended in the phytoplankton in large numbers. They would remain suspended until turbulence decreased or until their physiological condition could not keep them among the phytoplankton. In Rainbow Lake, some diatoms of the phytoplankton were difficult to classify to genus. Many of these belonged to the genera mentioned above. The greater abundance of these organisms in the July collections probably was the result of wind or of the activity of swimmers and summer visitors to the lake.

Some of the green algae are probably forced into the phytoplankton in the manner described above. Desmids and *Tetraedron sp.* appeared to be found naturally among the higher aquatic plants. Their occurrence in the phytoplankton was probably the result of disturbances to their natural environment. Filaments of *Spirogyra* and *Tribonema* are also considered to occur naturally in the shallow waters among the higher plants. The occurrence of these organisms in the phytoplankton also is probably the result of disturbances to their natural environment.

Flathead Lake was formed by the same processes as Rainbow Lake. Both lakes were at one time part of Glacial Lake Missoula. A comparison of the flora of the two lakes is made because of this fact.

Young (1935) and Morgan (1968) reported that the phytoplankton of the pelagic zones of Flathead Lake are almost entirely diatoms of the following genera: *Asterionella*, *Fragilaria*, *Melosira*, *Rhizosolenia*, *Synedra*, and *Tabellaria*, with an occasional admixture of *Cyclotella*, *Navicula*, *Cymbella*, *Campylodiscus*, *Surirella*, *Gyrosigma*, *Sphinctocystis*, and *Eunotia*. They reported that other algae occur, but are rare; i.e., green algae entering much less frequently were *Oocystis*, *Sphaerocystis*, *Pediastrum*, *Cosmarium*, and *Staurastrum*. A few desmids and a few blue-green algae have been found in the shallow north and south ends of the lake. Most of these same genera are represented in Rainbow Lake. Only two of the above genera, Campylodiscus and Sphinctocystis, have not been found in Rainbow Lake. These two genera may be found there in the future. The greatest difference between the two lakes appears to be the development of the blooms of blue-greens in the summer months in Rainbow Lake.

Young (1935) and Morgan (1968) found Melosira, Tabellaria, and Synedra had their highest peaks in April and June with minor peaks in the autumn. These genera also had peaks in Rainbow Lake in April. Melosira spp. had a peak in April and again in July. This may have been because a different species was involved.

A prominent member of the phytoplankton of Rainbow Lake, Fragilaria crotonensis, had a major peak in April and a minor pulse in August. This pulse may have continued to increase into a maximum in the autumn. Fragilaria crotonensis in Flathead Lake had a pulse in the summer or autumn and a minor peak in the spring. Temperature appears to be a factor involved in the explanation of the pulses of Fragilaria crotonensis. Temperatures from both lakes which could be correlated to the pulses of Fragilaria crotonensis would give valuable information regarding the cycles of this organism.

Rhizosolenia was reported to have concentrations of 51,000 organisms per liter at the 18 meter depth by Young (1935) during the latter part of July, its numbers then diminishing gradually in September. It reappeared in November. Morgan (1968) reported a similar pattern. Rhizosolenia in Rainbow Lake had a maximum in April and a minor peak in July. Further investigation, including comparisons of the chemical and physical factors of the two lakes that are responsible for the pulses of this organism, would provide insight into its ecological relationships.

Ceratium hirudinella occurred late in the summer in both lakes. It is reported to appear late in the summer in similar studies.

Dinobryon sertularia in Flathead Lake was the dominating genus from the middle of July to the end of the study. Morgan (1968) concluded that the low nutrient requirements of *Dinobryon* undoubtedly are the reason for its dominance during the last four weeks of his study. The nutrient levels gradually increased in the final three weeks and numbers of *Dinobryon* per liter decreased correspondingly. In Rainbow Lake, *Dinobryon spp.* had their peak in April, at which time several other genera had peaks in their populations. It would appear that the conclusion reached by Morgan would not be applicable to Rainbow Lake, since the nutrient level would probably be high in this lake in April. Further work is needed to either support or refute this conclusion.

Comparisons of chemical, physical, and biological information from the two lakes would make an interesting and fruitful study.

Rainbow Lake also offers a unique opportunity for a study of phytoplankton ecology. It apparently is an oligotrophic lake that is actually quite productive. Many of the phytoplankton of the lake are common to Flathead Lake, a large oligotrophic lake which was formed by the same geological phenomenon. There are many differences, chemical, physical, and biological, between the two lakes. A study of these differences and similarities would provide insight regarding phytoplankton ecology and possibly, into the future evolution of Flathead Lake. One can hypothesize that the future flora of Flathead Lake might eventually be similar to the flora that currently exists in Rainbow Lake.

A study of core samples from the two lakes would provide information regarding the diatom flora of Glacial Lake Missoula. This information could be used to support the geological evidence regarding their common origin.

In the future, the Montana Fish and Game Commission should provide the universities with information regarding the rehabilitation of lakes which would allow study before and after rehabilitation. This type of information is lacking, as is information on the chemicals being used for rehabilitation purposes.

Summary and Conclusions

Rainbow Lake is a remnant of the prehistoric Glacial Lake Missoula. The lake is a productive oligotrophic lake.

The lake covers an area of 207 acres. The depth varies from 5 to 10 feet in the shallow west end and near the shore line of the lake. Its maximum depth is 30 feet in the deep eastern end. A considerable portion of the lake is less than 10 feet deep.

The flora of the lake can best be described as a diatom-cyanophyte association. A total of over 200 algae was identified to the generic level. Many of these were identified to species and to variety. The phytoplankters are similar to those found in Flathead Lake, which is also a remnant of Glacial Lake Missoula. The seasonal succession of the phytoplankton, also, has many similarities to the succession of the phytoplankton of Flathead Lake.

Rainbow Lake provides a unique opportunity for future studies of algal flora, phytoplankton ecology, and lake chemistry. It also presents an opportunity for comparisons with Flathead Lake.

In conclusion, the lake provides future studies in all its limnological facets.

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