A STUDY OF PHYTOPLANKTON
IN
SPRING MEADOW LAKE
HELENA, MONTANA

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Brett Lee Marshall

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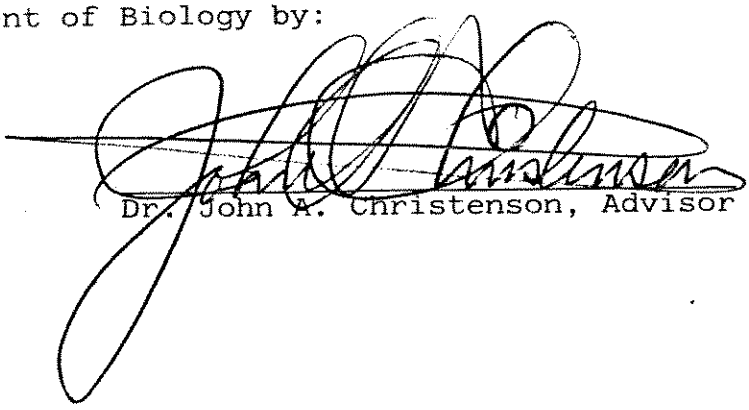
This thesis for honors recognition has been approved for the Department of Biology by:



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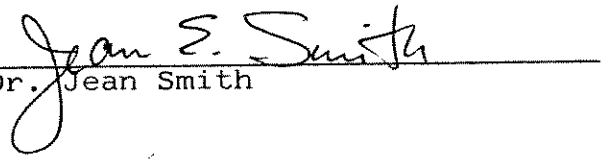
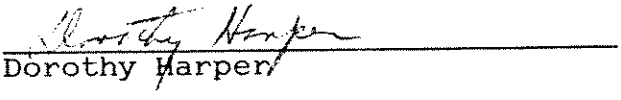


Dr. Jean Smith



Dorothy Harper

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ABSTRACT

The types of phytoplankton in Spring Meadow Lake were observed and their growth patterns recorded over a 4-month period. Algal growth peaked in mid-August and was dominated by genera of green algae (Chlorophyta). The lake did not show definite thermal stratification. The lake's nutrient situation can be described as being phosphorous-limiting early in the study period and shifting toward nitrogen-limiting during the mid-August peak.

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INTRODUCTION

Spring Meadow Lake is a small spring-fed lake just west of Helena, Montana. A one-time active gravel pit, the lake is now a state recreational park. Since the lake became a park only a few years ago, little scientific work has been done on it. Thus, any work done would be of importance for the officials concerned with the park and for the basic knowledge itself.

This study was made to determine the genera of the phytoplankton flora of the lake and the respective growth patterns over a 4-month period. Also, to help interpret results, temperature and chemical constituents of the water were determined and are included in this report.

LITERATURE REVIEW

No previous phytoplankton studies have been completed on Spring Meadow Lake. Therefore, the present work will serve as a starting point for further research. A few studies have been done on other lakes in the Helena area. One was performed on Canyon Ferry Reservoir (Rada, 1974) and another on the Helena Valley Regulating Reservoir (Bahls, 1983). These bodies of water are much larger and different from Spring Meadow Lake. Thus, different types of algae would be expected. Both reservoirs were more productive than Spring Meadow Lake, so higher densities of cells resulted. Both reservoirs tended to be dominated by blue-green algae which peaked or bloomed in late August.

The typical pattern for algal growth in temperate lakes is for an early spring bloom to occur (Fogg, 1965). By mid-winter the concentrations of nutrients in temperate waters have reached a maximum level. Chemical requirements for algal growth are present, but physical conditions are limiting. Spring brings proper physical conditions, and a bloom results. How the growth pattern continues from there is dependent on many variables. The concentration of algae found in the water tends to represent the balance between consumption and supply of nutrients (Fogg, 1965). A low concentration of a nutrient is not necessarily an indication that it is in short supply.

Light intensity and day length are important variables for algal growth. Grim found that under laboratory conditions, different species of algae grew best in light periods corresponding to the time of year that they are most abundant (cited in Round, 1968). Various species of algae have also been shown to move vertically to other water levels throughout the day (Round, 1968).

Much work has been devoted to the study of phytoplankton communities, their nutritional requirements, and distribution. See, for example, Wetzel, 1975.

Sample collection and examination techniques used in this study are described in A Treatise on Limnology by Hutchinson. Methods for chemical analysis of water samples can be found in Standard Methods for the Examination of Water and Wastewater by the American Public Health Association.

Two freshwater algae identification keys were used to identify algae observed: How to Know the Freshwater Algae (Prescott, 1975) and The Freshwater Algae of the United States (Smith, 1950).

MATERIALS AND METHODS

Phytoplankton Sample Collection

The following materials were used for this phase of the study:

- Four-man raft and oars
- Secchi disk and incremented rope
- Kemmerer water sampler and incremented rope thermometer
- 250 ml plastic bottles and caps for sample storage
- Plankton net (hole pore size-10 um)
- Small glass jar for plankton net sample storage
- Waterproof pen
- Labels for bottles and jar
- Data book

All samples were taken at the same location on the lake (Fig. 1). The sampling station was located at the center of the western portion of the lake. A small sandbar on the north shore and a tree-covered point bar on the south shore were used as reference points to position the raft. The sampling was performed every other Saturday morning between 8:30 a.m. and 10:00 a.m. from June 4 to September 10.

Water samples were taken at 3 depths. One sample was collected by submerging a 250 ml plastic bottle just under the surface. Next, the temperature of the sample was measured and recorded and labeled with the date and depth.

Another water sample was collected just above the lake bottom. This sampling depth ranged from 6 to 6.5 m. The third sample was taken at a mid-depth range

of 3 m. The latter two samples required the use of a Kemmerer water sampler which allows the user to collect a water sample at a particular depth and bring it to the surface without contaminating it with water from upper levels. The device consists of a hollow, brass tube about 0.5 meters long and 6 cm in diameter with rubber stoppers that, when in the closed position, fit over the open ends of the tube (Fig. 2). The rubber stoppers can also be locked in an open position that allows water to fill the tube.

To collect a water sample from a particular depth, the Kemmerer water sampler with the rubber stoppers in the open position was lowered to the desired depth on a rope that is marked in m. Next, a small brass cylinder called the "messenger", which fits around the rope, was dropped down the rope. When the messenger struck the top of the water sampler, it caused the locking mechanism to disengage. This allowed the rubber stoppers to snap shut capturing a water sample from that depth. The device was then pulled to the surface. The water sample within was poured through a nozzle at the bottom of the sampler into a plastic sample bottle. As before, the sample temperature was measured and the bottle labeled.

When taking a sample near the bottom of the lake, the water sampler should not be allowed to hit bottom. This causes sediment to be stirred up and contaminate the

sample. Also, to insure proper temperature data, the sample should be transferred to the plastic bottle and its temperature measured as quickly as possible.

The transparency of the water to light at the sampling site was measured using a Secchi disk. A Secchi disk is a weighted disk 20 cm in diameter with a rope attached to the center and marked in m. The top surface of the disk is divided into quadrants which are colored alternately black and white (Fig. 2). The Secchi disk was lowered into the water on the shaded side of the raft. The point at which it disappeared from sight was recorded as was the point where it reappeared upon raising it after it had been lowered beyond visibility.

Many factors can affect the Secchi disk reading. This data concerning the conditions when the readings were taken must be recorded. The following data needs to be included: time of day, water surface conditions, cloud conditions, water temperature and air temperature.

Concentrated phytoplankton samples were collected with a plankton net. The plankton net was funnel-shaped with a small length of rubber tubing attached to its tapered end. When the end rubber tubing is clamped shut, the tube provides a place for the phytoplankton to collect. The plankton net was allowed to drag behind the raft on a rope as the raft was rowed toward shore. The net retains only particles 10 um or larger. Before

reaching shore, the plankton was retrieved and the excess water allowed to stream through the net. Finally, the rubber tubing was unclamped, and its contents were emptied into the small glass jar.

Water Chemistry Sample Collection

The following materials were used:

- Four-man raft and oars
- 1 liter plastic bottles for sample storage
- 4 ml vial of nitric acid
- 4 ml vial of sulfuric acid

The same site was used for the collection of water samples. Sampling was done twice during the 4-month study period. A first sample taken on May 21 was examined for anions, cations, nutrients and heavy metals. A second sample taken on August 13 was examined for nutrients.

The samples were collected by submerging 1-liter plastic bottles. A separate sample was taken for the heavy metal scan. The 4-ml vial of nitric acid was added to this sample to lower the pH to about 2. This caused metals loosely held or absorbed by suspended particles to be released into solution. The 4-ml vial of sulfuric acid was added to the sample to be examined for anions, cations, and nutrients. The sulfuric acid killed the living organisms in the sample to prevent consumption of these components before analysis could be done.

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)TE: the sample
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Phytoplankton Sample Examination

The following materials were used:

- Stage micrometer
- Light microscope
- Sedgewick-Rafter cell and cover slip
- Depression slide and cover slip
- Plastic straws
- Freshwater algal identification keys
- Data book

To get a general idea of the organisms present, the sample collected by the plankton net was examined first. The glass jar containing the sample was shaken to evenly distribute the organisms. Using a straw as a pipette, a few drops of the sample were placed in the bottom of a depression slide and covered with a cover slip. A list of the phytoplankton genera present was made while examining the sample with a light microscope. Both 100X and 200X powers were used while scanning the sample and identifying the genera present. Fresh water algae keys were used to aid identification (Prescott, 1978 and Smith, 1950).

The next step was to estimate the amount of phytoplankton present per ml. by using a Sedgwick-Rafter counting cell. The counting cells consists of a microscope slide with a raised, rectangular border. The cell's dimensions were 50mm by 20mm and was 1mm high. When covered with a rectangular cover slip the counting cell had a volume of $1000mm^3$ or 1 ml.

The counting cell was filled with 1 ml of sample taken at one of the three depths. The cell was scanned lengthwise and the names and amount of the genera present

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were recorded. Three strips of the counting cell were examined in this fashion. The three values obtained were averaged. This gave the number of cells per strip. The cells per strip values need to be converted to cells per ml. To do this the volume of one strip has to be known. A strip was 50mm long and 1mm deep. The width was found using a stage micrometer to measure how wide the microscope's field of view is. For the particular microscope used, the field of view measured 9.57mm, giving a strip volume of 28.5mm^3. To obtain a conversion factor the volume of one strip was divided into the counting cell's total volume giving a conversion factor of 35.1. Multiplying the number of cells per strip for each genus of algae by the conversion factor gave the number of cells per ml.

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One ml from each of the three samples was examined and counted using the method described. Some of the genera grew in colonies. When these genera were found each cell making up the colony was counted.

RESULTS

The phytoplankton population of Spring Meadow Lake is composed of a wide variety of fresh water algae. Most genera of algae observed were represented by only a few individuals. A small number of genera (4 to 7) dominate the population. Table 1 lists the genera observed according to taxonomic classification.

Five of the nine fresh water algal divisions (or phyla) are represented in Spring Meadow Lake. They are as follows: Chlorophyta -- the green algae, Phrrhophyta -- the dinoflagellates, Cryptophyta -- the cryptomonads, Chrysophyta -- the yellow-green or yellow-brown algae, and Cyanophyta -- the blue-green algae. Fig. 3 shows the number (in cells per ml) of algae grouped by division, present throughout the sampling period. Samples were collected every 2 weeks from June 6 to September 10 of 1983. An extra grouping, called microplankton is a catch-all group that includes phytoplankton that is smaller than 10um. The Division Chrysophyta was divided into two groupings: the Bacillariophyta or diatoms, and the Chrysophyceae or non-diatom yellow-green algae. The green algal division dominated the phytoplankton population. Their numbers peaked during mid-August.

When the data from the three different sampling depths was examined, it showed the same peak period during mid-August (Fig. 4). The numbers plotted in Fig. 4 represent the total number of individuals of all genera counted (in cells per ml) on each sampling

date. The three lines graphed represent the three sampling depths. During the mid-August peak the mid-depth level had the highest number of phytoplankton.

Fig. 5 is similar to Fig. 4 except that only the sampling date totals of the green algae (Chlorophyta) are plotted. As before, a mid-August peak is seen and the mid-depth had the greatest number of these organisms.

Of all the algae types recorded only seven genera multiplied to relatively high numbers. Table 2 lists these genera and their average number of cells per ml for the whole sampling period. Only genera having an average of at least 50 cells/ml in two of the three sampling levels are listed. Of the seven genera listed five are green algae. Table 2 also shows the distribution of each genus in the three sampling depths.

Temperature was not constant over the sampling period (Fig. 6). The values ranged from 11°C to 21.5°C (Fig. 6). The mean temperature values of the three depths for the entire sampling period were 16.7°C at surface, 16.5°C at mid-depth, and 15.1°C at bottom. The largest temperature difference between the three depths was 3°C on August 13. On three occasions (5-21, 7-16, 9-10) the values for the three depths were within 1°C of each other.

The Secchi disk data for the sampling period is plotted in Fig. 7. The values are the average of the depth of disappearance and reappearance of the Secchi disk. The values ranged from a high of 7.8 m (7-2)

to a low of 3.05 m (8-13). The mean value over the sampling period was 5.55 m.

The results of the chemical analysis on a sample taken from the surface on May 21 are presented in Table 3. A second surface sample collected on August 13 was analyzed for nutrients only. Table 4 compares the nutrient levels of the two samples. A heavy metal scan was done on the May 21 sample. The scan revealed that heavy metal levels were very low if present at all. Table 5 compares important ions from three sites near Spring Meadow Lake, with the May 21 sample from the lake.

TABLE 1

TAXONOMIC LIST OF ORGANISMS OBSERVED

DIVISION: Chlorophyta
- ORDER: Tetrasporales
  - FAMILY: Gloeocystaceae
    - *Gloeocystis*
- ORDER: Chlorococcales
  - FAMILY: Chlorococcaceae
    - *Planktosphaeria*, *Schroederia*
  - FAMILY: Oocystaceae
    - *Ankistrodesmus*, *Oocystis*, *Quadrigula*
  - FAMILY: Dictyosphaeriaceae
    - *Botryococcus*
  - FAMILY: Scenedesmaceae
    - *Scenedesmus*
  - FAMILY: Hydrodictyaceae
    - *Pediastrum*
- ORDER: Chaetophorales
  - FAMILY: Chaetophoraceae
    - *Stigeoclonium*
- ORDER: Zygnematales
  - FAMILY: Desmidiaceae
    - *Closterium*

DIVISION: Pyrrhophyta
- CLASS: Dinophyceae
  - ORDER: Dinokontae
    - FAMILY: Peridiniaceae
      - *Peridinium*
    - FAMILY: Ceratiaceae
      - *Ceratium*

DIVISION: Cryptophyta
- FAMILY: Cryptochrysidaceae
  - *Rhodomonas*
- FAMILY: Cryptomonadaceae
  - *Cryptomonas*

DIVISION: Chrysophyta
- SUB-DIVISION: Chrysophyceae
  - ORDER: Chromulinales
    - FAMILY: Chromulinaceae
      - *Chromulina*
    - FAMILY: Chrysococcaceae
      - *Chrysococcus*
  - ORDER: Ochromomadales
    - FAMILY: Dinobryaceae
      - *Dinobryon*
    - FAMILY: Synuraceae
      - *Mallomonas*
- SUB-DIVISION: Bacillariophyta
  - ORDER: Centrales
    - FAMILY: Coscinodiscaceae

Cyclotella, Stephanodiscus
ORDER: Pennales
FAMILY: Fragilariaceae
Asterionella, Diatoma, Fragilaria, Synedra
FAMILY: Achnanthaceae
Achnanthes, Cocconeis, Rhoicosphenia
FAMILY: Naviculaceae
Navicula
FAMILY: Gomophonemaceae
Gomphonema
FAMILY: Cymbellaceae
Amphora, Cymbella
FAMILY: Epithemiaceae
Denticula
FAMILY: Nitzschiaceae
Nitzschia
FAMILY: Surirellaceae
Cymatopleura

DIVISION: Cyanophyta
ORDER: Chroococcales
FAMILY: Chroococcaceae
Anacystis
ORDER: Oscillatoriales
FAMILY: Oscillatoriaceae
Oscillatoria
ORDER: Nostocales
FAMILY: Nostocaceae
Anabaena

TABLE 2

LIST OF DOMINANT PHYTOPLANKTON GENERA

GENUS	Cells Per ml SURFACE	MID-DEPTH (3M)	BOTTOM (6M)
Planktosphaeria (G)	992	567	246
Scenedesmus (G)	357	680	342
Gloeocystis (G)	136	177	149
Cryptomonas (C)	149	59	57
Ankistrodesmus (G)	51	58	85
Asterionella (B)	42	59	73
Schroederia (G)	37	59	50

(G) = Belongs to Division Chlorophyta (Green algae)

(C) = Belongs to Division Cryptophyta

(B) = Belongs to Division Chrysophyta (subdivision Bacillariophyta)

TABLE 3

CHEMICAL ANALYSIS OF SURFACE SAMPLE

Date Sampled - 5/21/83

Laboratory pH 8.36

Total hardness - 181

Total Alkalinity - 152

Silica (dissolved as SIO_2) 13 mg/1

IONS	mg/1	meq/1
Calcium	44.1	2.201
Magnesium	17.2	1.415
Sodium	21.4	0.931
Potassium	4.1	0.105
Bicarbonate plus carbonate	185.4	3.039
Chloride	13.1	0.369
Sulfate	54.0	1.124
Fluoride	0.70	0.037

mg/1 = Milligram per liter

meq/1 = Milliequivalents per liter

TABLE 4

COMPARISON OF NUTRIENT LEVELS

Nutrient	5/21/83 SAMPLE mg/l	8/13/83 SAMPLE mg/l
Phosphate (PO4 as P)	0.005	0.016
NO_3 + NO_2 (Total as N)	0.56	0.090
Phosphorous, Total	0.01	0.02
Ammonia, Total (as N)	0.10	0.02
TIN/TP	66	5.5
TIN/phosphate as P	132	6.9

TABLE 5

COMPARISON OF IMPORTANT IONS

	SITE I		SITE II		SITE III		SITE IV	
ION	Mg/L	Meg/L	Mg/L	Meg/L	Mg/L	Meg/L	Mg/L	Meg/L
Calcium	44.1	2.201	1.0	0.050	21.2	1.060	23.5	1.173
Magnesium	17.2	1.415	1.0	0.082	2.7	0.219	13.4	1.105
Sodium	21.4	0.931	162.0	7.047	6.2	0.159	49.6	2.158
Bicarbonate	185.4	3.039	209.8	3.439	31.0	0.510	210.	3.439
Chloride	13.1	0.369	26.0	0.733	1.2	0.034	8.5	0.240
Sulfate	54.0	1.124	145.0	3.019	53.0	1.103	32.0	0.666

Site I - Spring Meadow Lake

Site II - Private Well Near Spring Meadow Lake

Site III - Ten Mile Creek

Site IV - Top water from Green Meadow Country Club

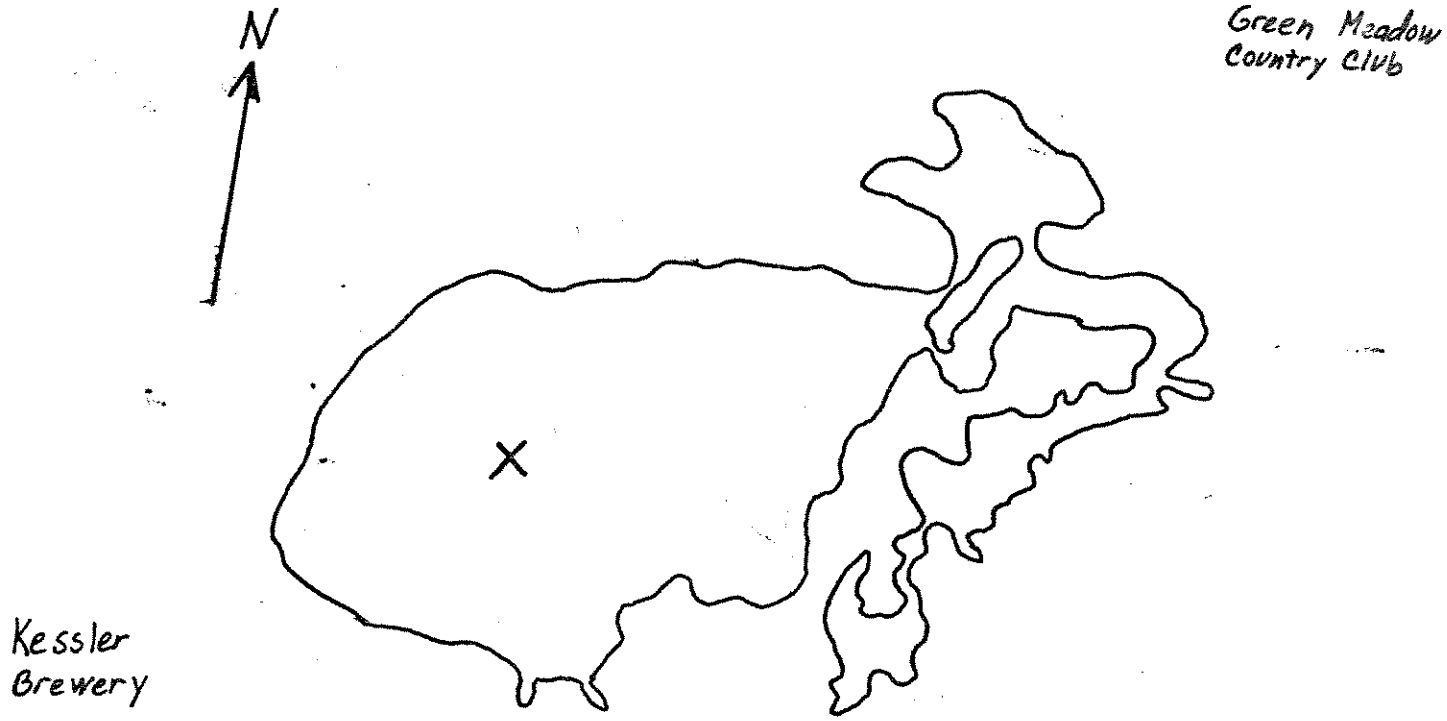

Fig. 1 MAP OF SPRING MEADOW LAKE

x - denotes sampling site

Fig. 2 KEMMERER WATER SAMPLER AND SECCHI DISK

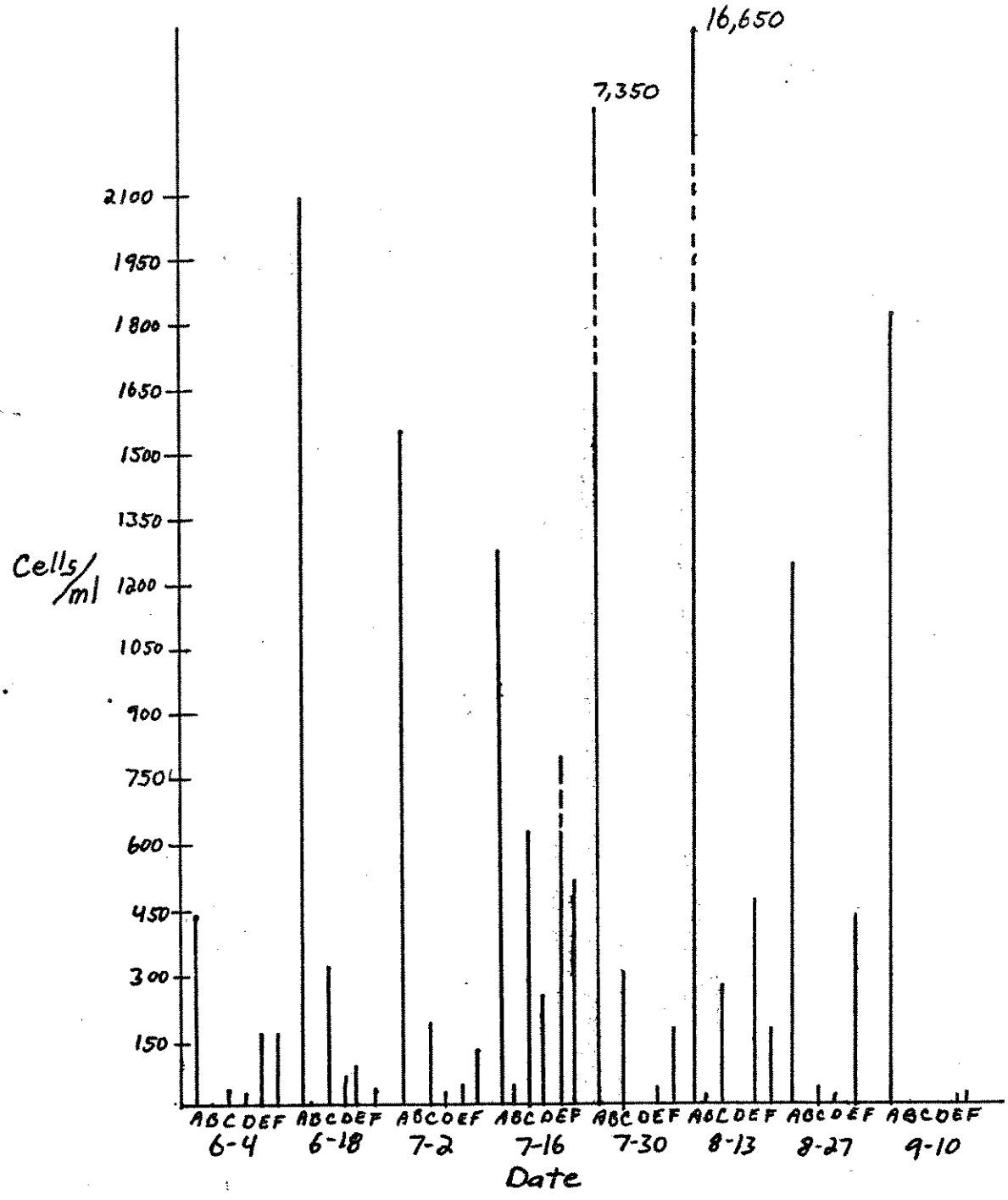

Fig. 3 DENSITY OF PHYTOPLANKTON GROUPED BY DIVISION

A - Chlorphyta
B - Pyrhophyta
C - Cryptophyta
D - Chrysophyta, Chrysophyceae
E - Chrysophyta, Bacillariophyta
F - Microplankton

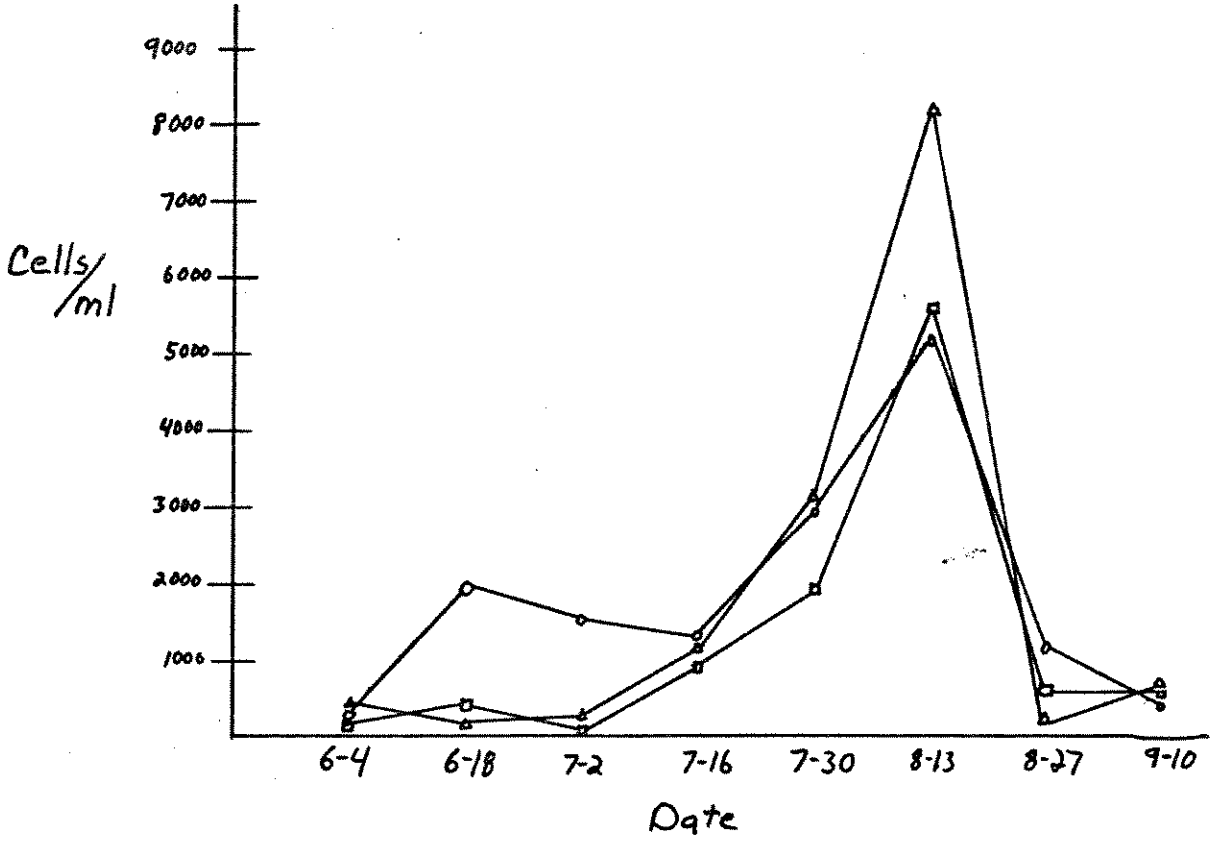

Fig. 4 PHYTOPLANKTON DENSITY OF ALL GENERA AT SAMPLING DEPTHS

o - surface

Δ - mid-depth (3m)

□ - bottom (6m)

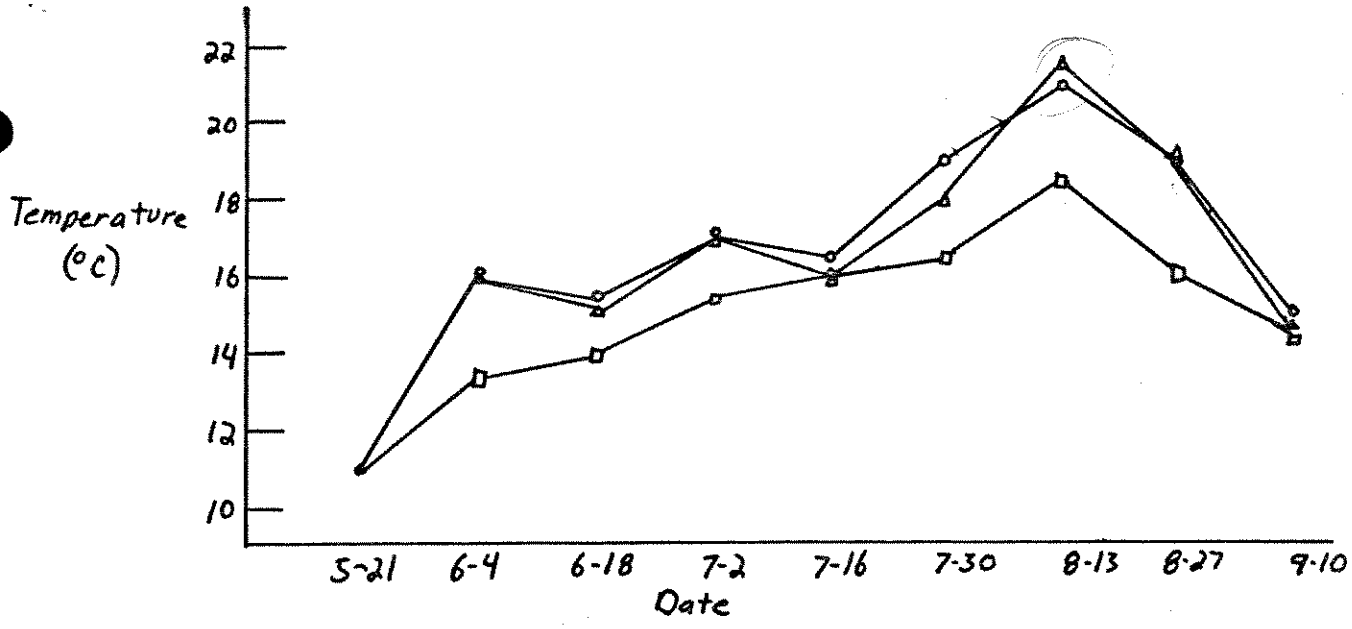

Fig. 6 TEMPERATURE OF SAMPLING DEPTHS

o - surface

Δ - mid-depth (3m)

□ - bottom (6m)

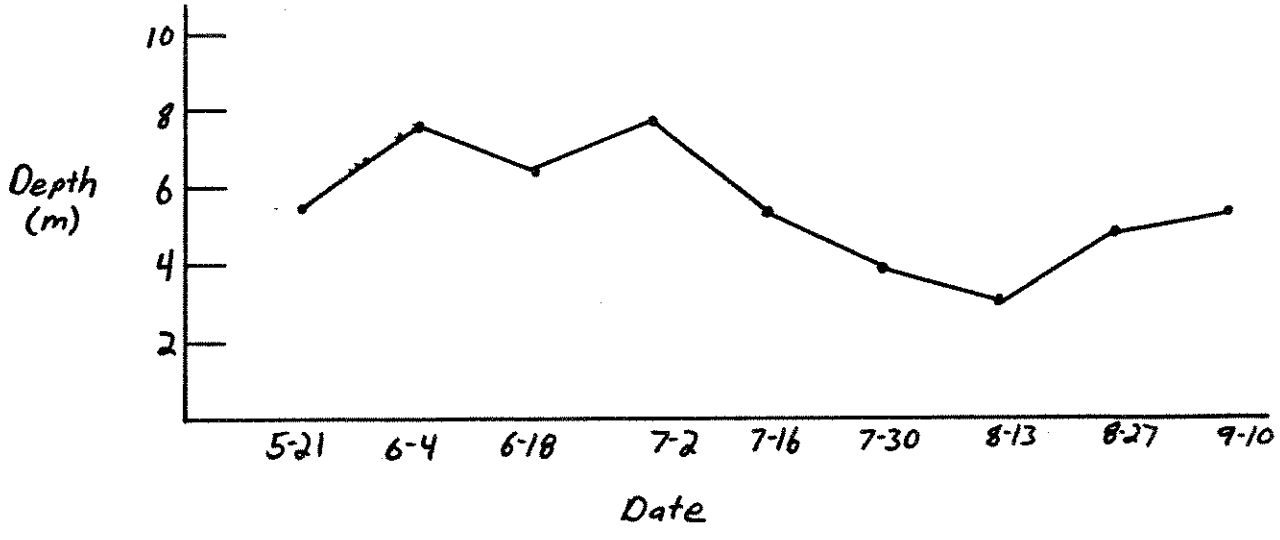

Fig. 7 SECCHI DISK MEASUREMENTS

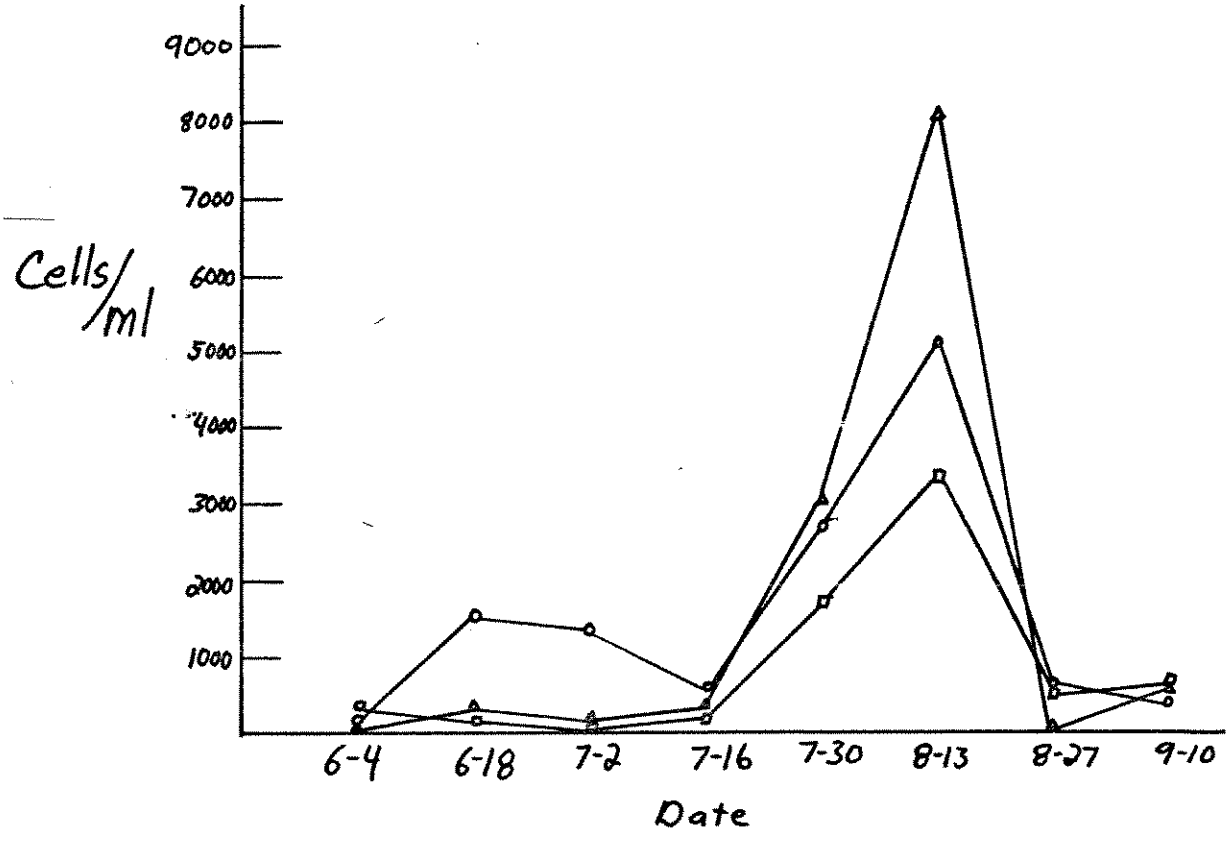

Fig. 5 DENSITY OF CHLOROPHYTA AT SAMPLING DEPTHS

o - surface

Δ - mid-depth (3m)

□ - bottom (6m)

DISCUSSION AND CONCLUSIONS

Although Spring Meadow Lake has a wide variety of algae comprising the phytoplankton, the population is clearly dominated by green algae (Chlorophyta). Three genera of green algae were most prevalent during the study period. They were Planktosphaeria, Scenedesmus, and Gloeocystis. The former two were responsible for the large population bloom during mid-August (Fig. 4).

The Secchi disk data (Fig. 7) correlates well with this peak. As the number of cells per ml sharply increased in mid-July, the Secchi disk readings began to decrease. The lowest Secchi disk reading occurred on the mid-August peak. This shows that the Secchi disk is a quick and fairly accurate tool for measuring the relative amounts of phytoplankton present. The observer must be careful to take into consideration the conditions at the time the disk is used (such as time of day, cloud cover, and water surface conditions).

Comparing the temperature data with the algal peak, another good correlation is evident. Beginning in mid-July the water temperature steadily rose to a high in mid-August. As this occurred, the number of cells/ml of algae also increased to a peak. This temperature increase seemed to favor the three previously mentioned genera of green algae. Although other factors probably contributed to the multiplication of the algae, the temperature increase probably played a major role.

When I began this study I expected to see a definite temperature stratification in the lake. I thought the warmer summer temperatures would raise the temperature of upper water levels while the lower ones would remain cooler, however the temperature from surface to bottom never differed more than 3°C (Fig. 6). This is not enough to be considered stratified. Maybe the higher density of cells in the upper depths contributed to the lower temperature of the bottom depth by reducing light penetration. Perhaps the lake's small size allowed water of different levels to mix more readily than in a larger lake. Also, the lake is fed by springs at the bottom which would facilitate water mixing.

The amount of algae in Spring Meadow Lake was generally evenly distributed in the three sampling levels. Early in the study the surface had a somewhat higher number of cells/ml. At the mid-August peak the mid-depth level had the highest concentration of cells. When the patterns of individual genera are examined it shows that Planktosphaeria favored the surface level, while Scenedesmus grew better at the mid-depth level. Throughout the study the diatoms were more abundant at the bottom level. This could have been caused by the different nutrients and physical conditions present in the three levels. Or the algae may have been migrating vertically through different levels, and the particular sampling time may have favored finding them at those levels.

On the basis of previous discussion, Spring Meadow Lake would be classified as an oligotrophic lake. That is, the lake is not very productive in terms of phytoplankton, and the algae produced is evenly distributed throughout the different levels. In comparison the Helena Valley Reservoir and Canyon Ferry Reservoir produce peaks of much higher amounts of phyroplankton per unit of water sampled (Bahls 1983, Rada 1974). Thus the phytoplankton of Spring Meadow Lake can be described as oligotrophic and green algal dominated.

Examination of Table 5 gives an idea of the water sources that fill Spring Meadow Lake. It appears that the lake's water is a mixture of Ten Mile Creek water and ground water from the surrounding area. The ion concentrations tend to support this with the exception of calcium and magnesium. For some reason(s) these ions are more abundant than expected. It is likely that the underlying rock of the lake is limestone and/or dolostone which contain calcium and magnesium. This probably accounts for the elevated levels of these ions.

Using the data from Table 4 we can get an idea of which nutrients are limiting factors for growth. First the nutrient weight ratios (R) must be calculated. R is equal to the concentration of total inorganic nitrogen present divided by the concentration of orthophosphate (Mills et al, 1982). Orthophosphate is the concentration of total phosphorous minus the amount of phosphate present.

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If R is greater than ten, then phosphorous is more likely to be a limiting factor. If R is less than five, then nitrogen is more likely to be a limiting factor. If R falls between five and ten, a determination cannot be made (Mills et al, 1982).

OTE: should be 6.9, ot 27.5 LLB

R values for the two samples taken were 132 for the May 21 sample and 27.5* for the August 13 sample. Thus, early in the study period the lake was high in nitrogen, and phosphorus was the limiting nutrient. Later the lake begins to progress toward nitrogen being the limiting factor during the mid-August bloom. Perhaps it was these chemical conditions coupled with the rise in temperature that favored the peak in growth of colonial green algae genera like Planktosphaeria, Scenedemus, and Gloeocystis.

Overall this study has given insight to the type of algae present in Spring Meadow Lake and their growth patterns. If this study were to be continued, I would make a few changes. First, it would probably be beneficial to take samples more often, say weekly. Also, a second sampling station might be included at another site on the lake. I would also examine more than just one milliliter from each sample to get a better representation of the algal population present. Finally, if money was available, it would be interesting to analyze samples for nutrients more often and possibly at different levels.

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