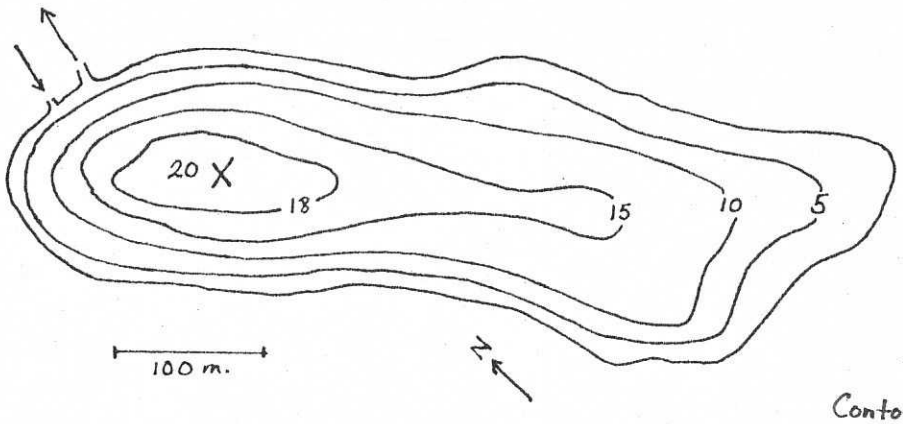
Figure 1. Bathymetric chart of Sunfish Lake. (Sreenivasa and Duthie, 1973).

Figure 2. Location map of Sunfish Lake.


20
18
15
10
5
100 m.
N

Contours (m.)

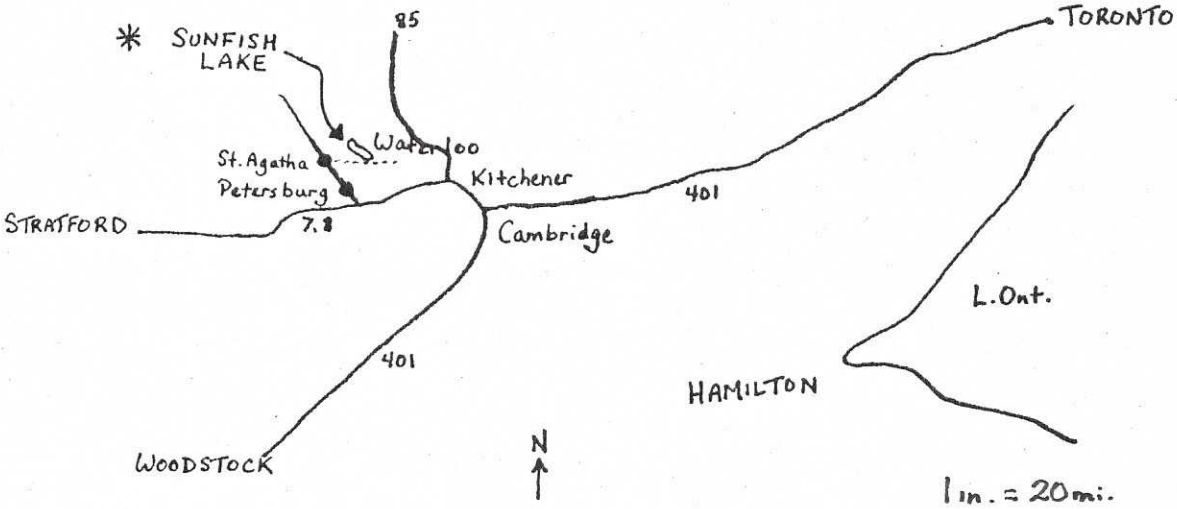

SUNFISH LAKE
85
TORONTO
Waterloo
St. Agatha
Petersburg
Kitchener
401
STRATFORD
7, 8
Cambridge
L. Ont.
401
HAMILTON
WOODSTOCK
N
1 in. = 20 mi.

Table 1. Selected Morphometric Data

(from Duthie and Carter, 1970)

Surface Area	8.3 ha
Volume	86.3 ha-m
Maximum Depth	20.0 m
Mean Depth	10.4 m
Maximum Length	577 m
Maximum Width	189 m

Figure 3. Application of limnological terms for the chemical and thermal stratification of Sunfish Lake.

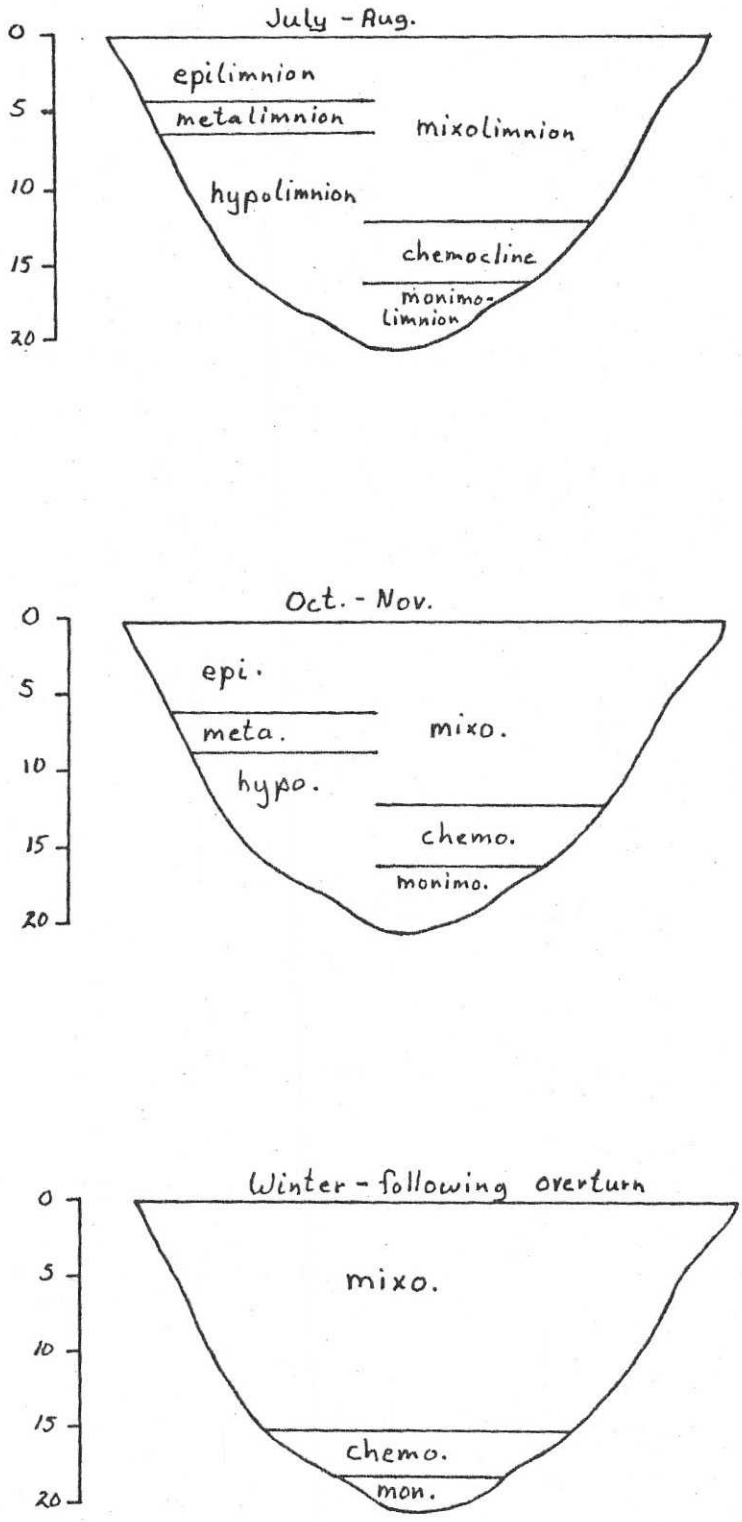
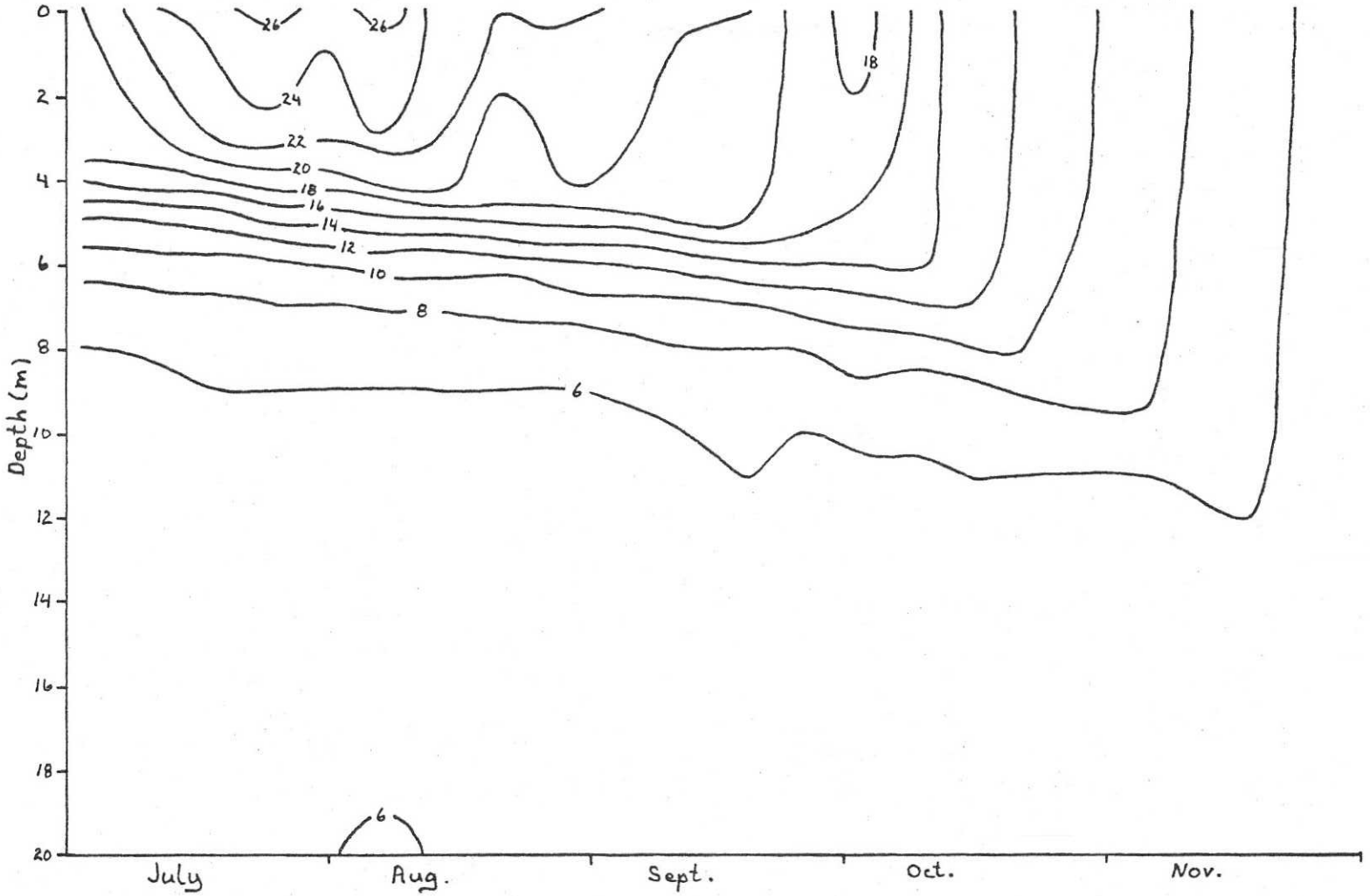

July - Aug.
0
5
10
15
20
epilimnion
metalimnion
mixolimnion
hypolimnion
chemocline
monimo-
limnion
Oct. - Nov.
Depth (m)
epi.
meta.
mixo.
hypo.
chemo.
monimo.
Winter - following overturn
mixo.
chemo.
mon.

Figure 4. Seasonal Isotherms of Sunfish Lake.


Depth (m)
0
2
4
6
8
10
12
14
16
18
20
26
26
24
22
20
18
16
14
12
10
8
6
18
6
July
Aug.
Sept.
Oct.
Nov.

Isotherms (°C)

Figure 5. Dissolved Oxygen Profiles for Sunfish Lake.

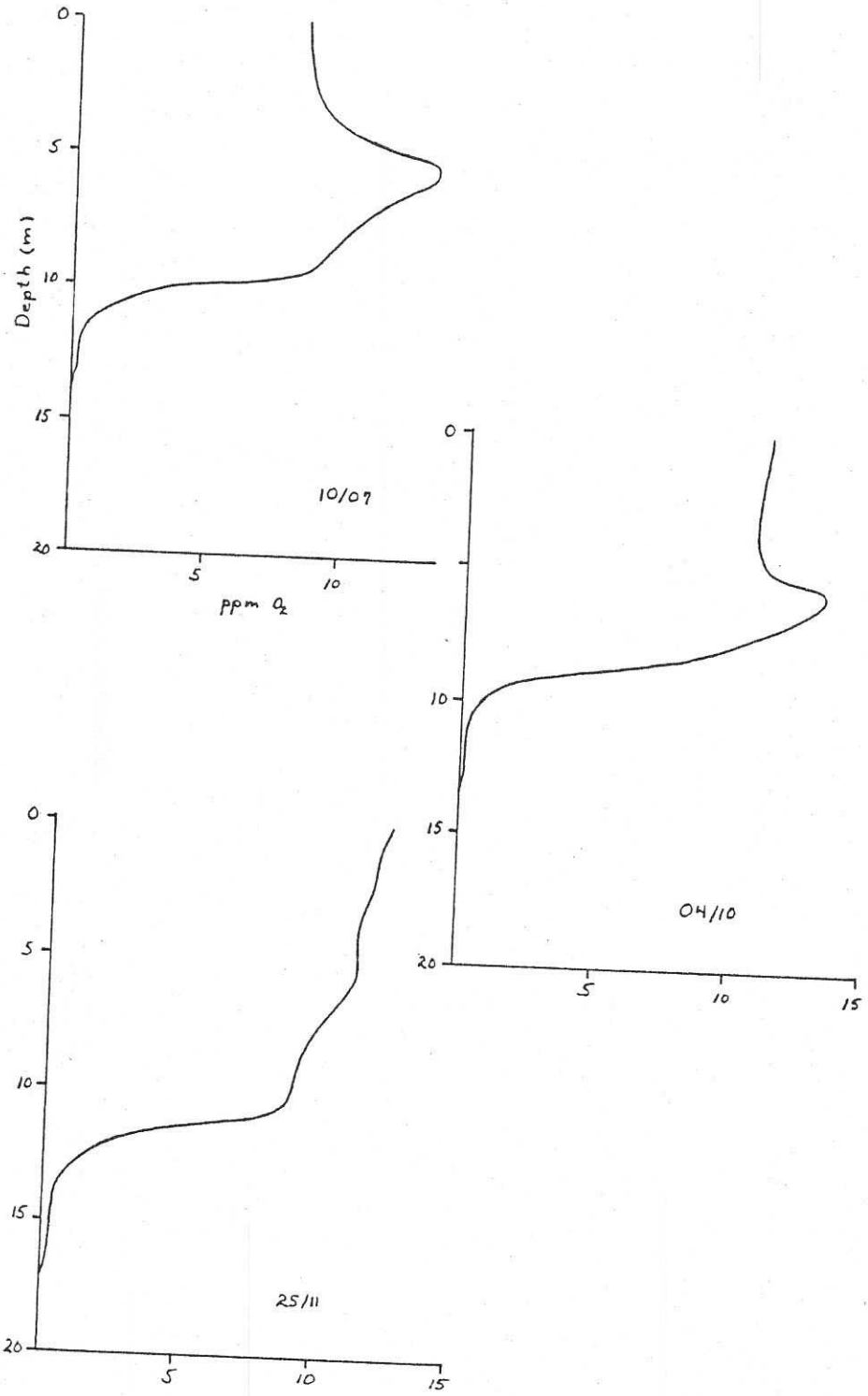
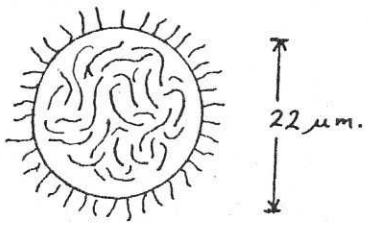

0
5
10
15
20
Depth (m)
10/07
5
10
ppm O_2
0
10
15
04/10
20
5
10
15
0
5
10
15
25/11
20
5
10
15

Figure 6. Sketches of 3 temporarily unidentified algae of Sunfish Lake.

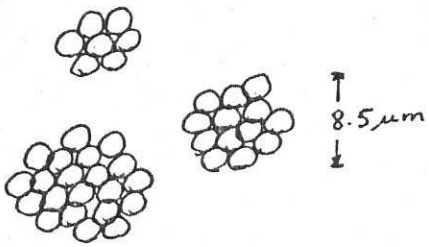
A. Sun

B. R.S.

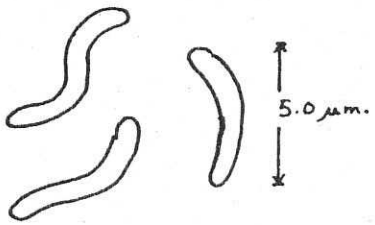
C. Lenores



A. Sun



B. R.S.



C. Lenores

METHODS AND MATERIALS

Sunfish Lake was sampled weekly from the third week in July until the end of August and then once in early October and again in late November following overturn. An additional zooplankton sample was collected in the first week of July. Phytoplankton and zooplankton samples were collected at the deep end of the lake where the water depth was 20 metres (figure 1), and were always collected between 1100 - 1500 hours.

Zooplankton samples were collected with a 22.4 l. Schindler trap and were obtained from the lake surface to the bottom at one metre intervals. A 40% formaldehyde-5% sucrose solution was used to preserve the zooplankton for laboratory analysis.

Phytoplankton samples were collected by obtaining whole water samples using a 1.5 l plastic VanDorn sampler. Samples were taken at 1 metre intervals from the surface to a depth of 14 m and at ½ m intervals from depths of 6 to 10 m where the *Oscillatoria* layer is concentrated. The plankton samples were transferred to 300 ml bottles, fixed immediately with a 1% Lugols Iodine solution and stored for laboratory analysis.

The phytoplankton were identified and enumerated using a Wild (Heerbrugg) inverted microscope. Identifications were made at a magnification of 400 x using the Upsalla Fytoplankton key and enumerations were made at a magnification of 200 x. Each sample was thoroughly but gently mixed by inversion and subsampled by pipetting from top to

bottom to enhance the integration. Samples were diluted to ½ concentration and allowed to settle for no less than eight hours in a 50 ml settling chamber. Enough cells were counted in total for each sample for a ± 20% accuracy according to Lund's (1958) criteria.

The average cell volume of each algal species cell, filament or colony was obtained from Munro (1978), or was calculated using an optical micrometer, in order to present the data in units of biomass.

Three algal species could not be identified and were termed Suns, Lenores, and R.S. Sketches of these alga are presented in figure 6.

Zooplankton samples were identified at a magnification of 64 x and enumerated at 25 x using a Wild dissecting microscope and a petri dish with a grid bottom. The entire concentrated sample from the Schindler trap was enumerated with the same degree of error as was present in the phytoplankton counts (± 20%). The samples were diluted only when algae concentrations were sufficient to impede the zooplankton counting.

Dissolved oxygen was measured in the field using a Y.S.I. combination oxygen-temperature meter and probe on the October and November sampling dates. As well, one oxygen profile was obtained early in July before any plankton samples were obtained. Specific conductivity was measured with a Beckman conductivity meter and probe on the November sampling date. An annual $CaCo_3$ profile compiled by Duthie and Carter (1970) is used to aid in locating the position of the chemocline.

Temperature profiles were recorded by Mr. J. Hutchison, a cottage owner on Sunfish Lake, using a thermistor on a weekly basis throughout the entire sampling period.

RESULTS

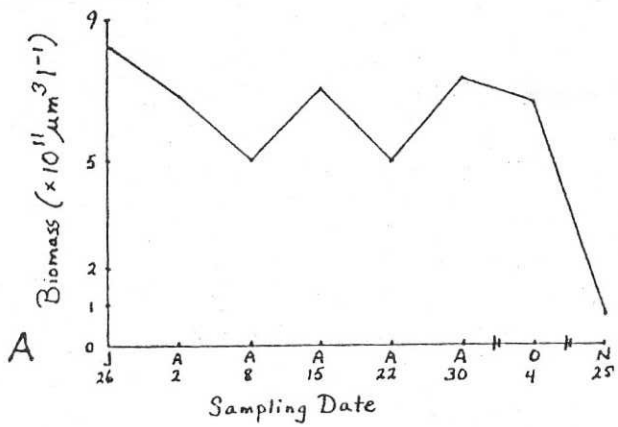
Figure 7. Seasonal distribution of major algal groups.

A. filamentous Cyanophyceae

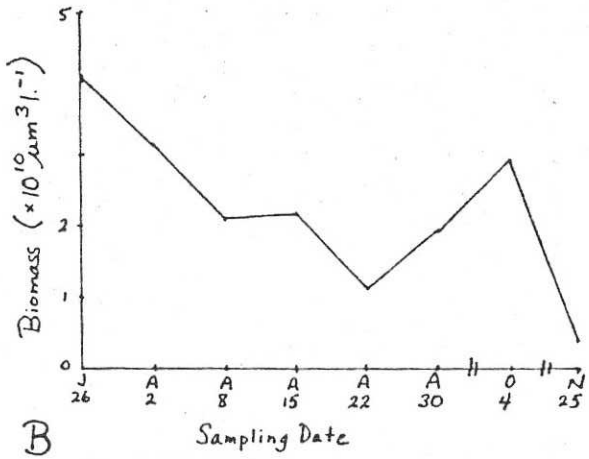
B. colonial Cyanophyceae

C. Chrysophyceae

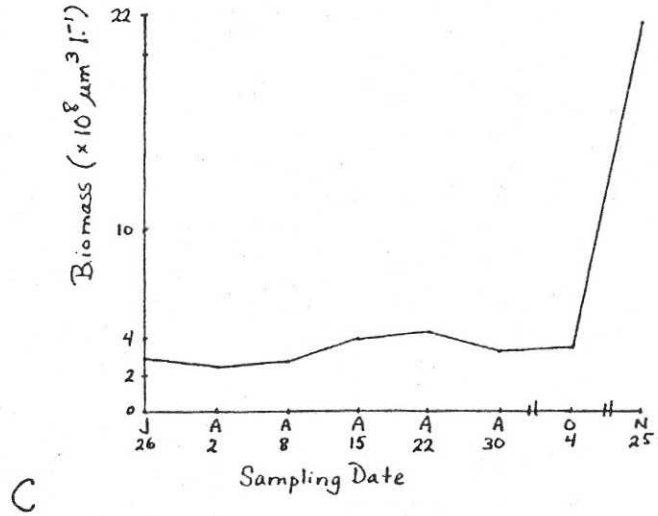
D. Chlorophyceae



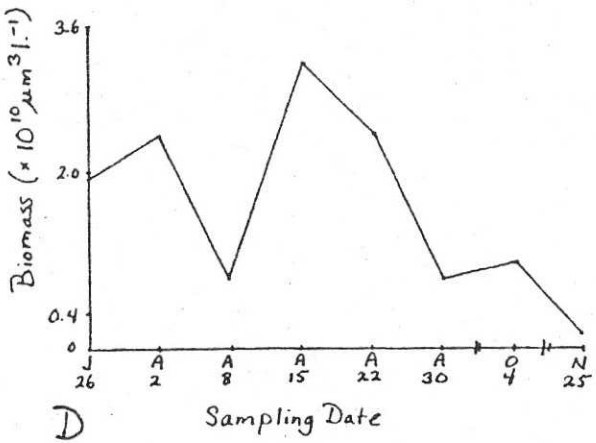
Filamentous Cyanophyceae



Colonial Cyanophyceae



Chrysophyceae



Chlorophyceae

Figure 8. Vertical distribution of *Oscillatoria agardhii*.

Figure 9. Vertical distribution of R.S.

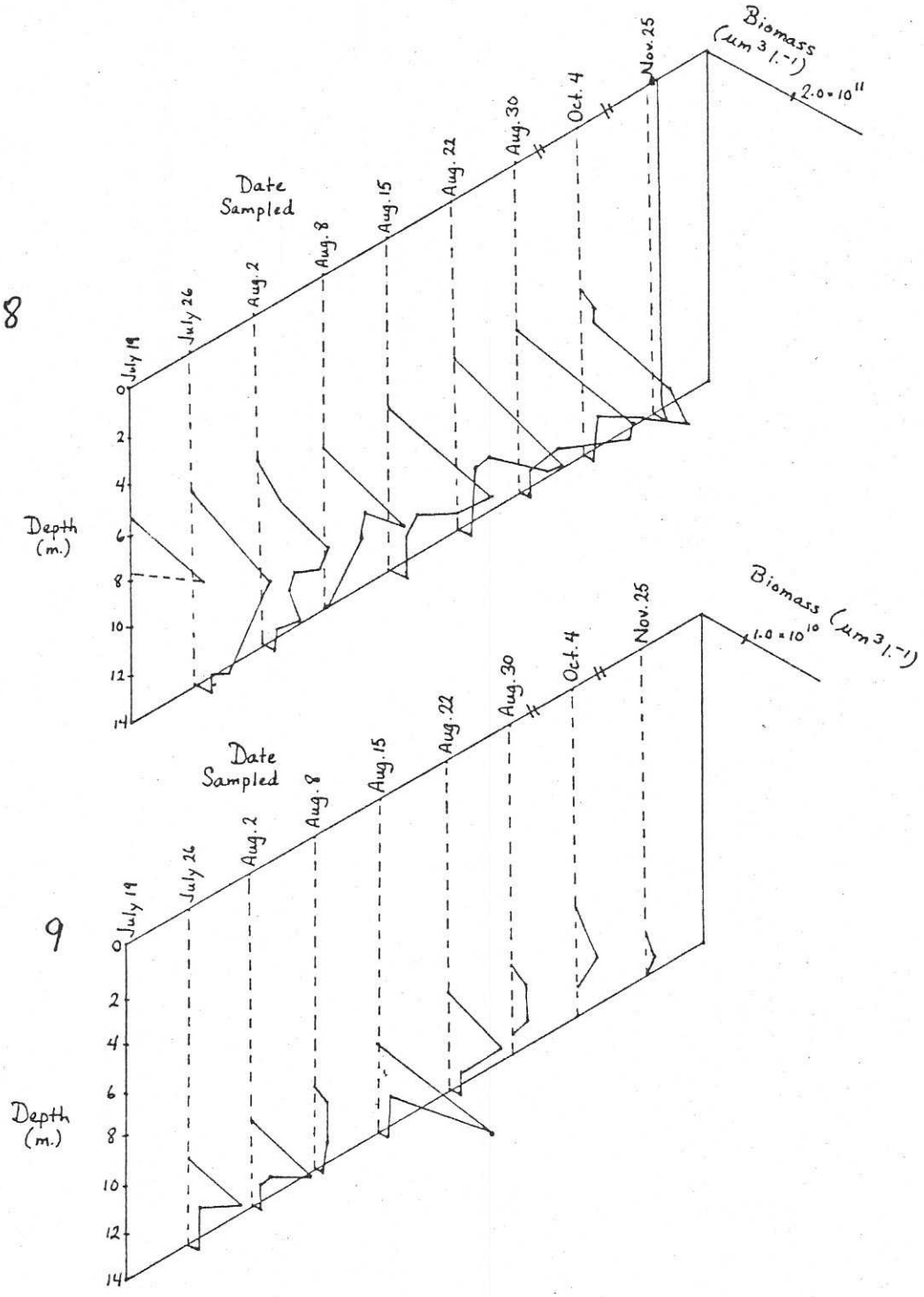
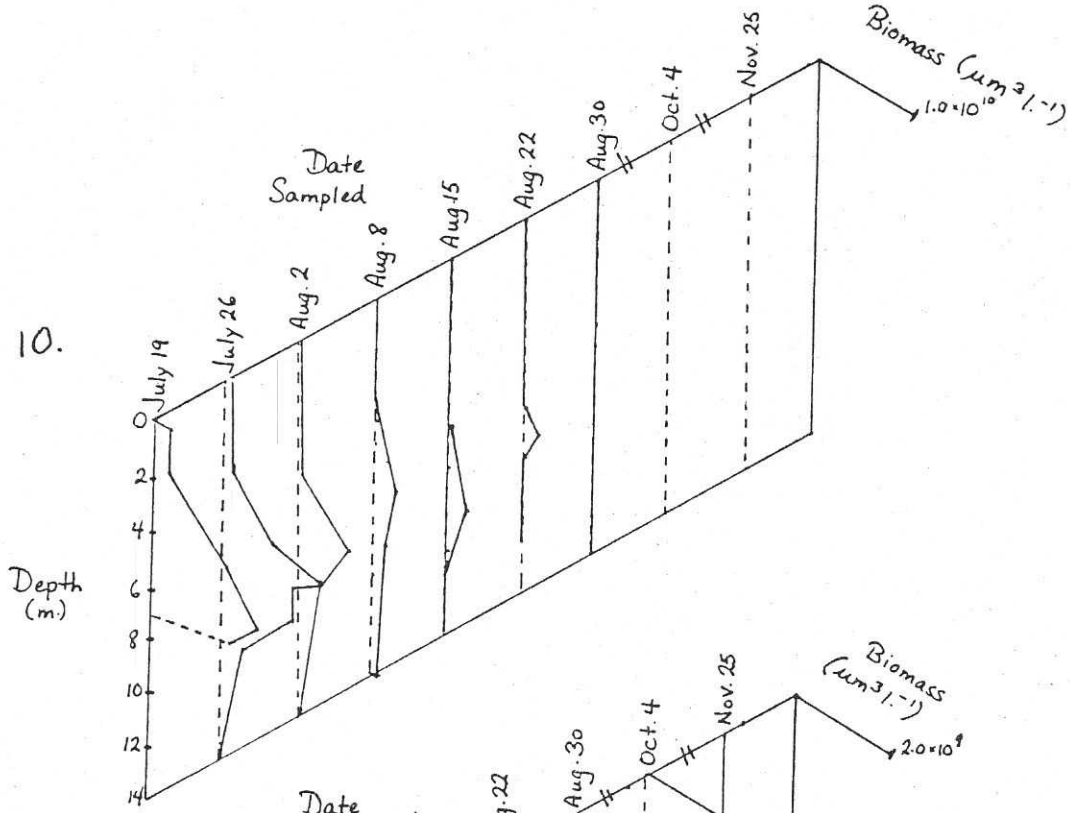

8
Biomass (µm³ l.⁻¹)
2.0 × 10¹¹
Date Sampled
July 19
July 26
Aug. 2
Aug. 8
Aug. 15
Aug. 22
Aug. 30
Oct. 4
Nov. 25
Depth (m.)
0
2
4
6
8
10
12
14
9
Biomass (µm³ l.⁻¹)
1.0 × 10¹⁰
Date Sampled
July 19
July 26
Aug. 2
Aug. 8
Aug. 15
Aug. 22
Aug. 30
Oct. 4
Nov. 25
Depth (m.)
0
2
4
6
8
10
12
14

Figure 10. Vertical distribution of *Gomphosphaeria* X.

Figure 11. Vertical distribution of *Gomphosphaeria aponina*.

10.


Biomass (um3 l.-1)
1.0×10^10
Nov. 25
Oct. 4
Aug. 30
Aug. 22
Aug. 15
Aug. 8
Aug. 2
July 26
July 19
Date Sampled
Depth (m.)
0
2
4
6
8
10
12
14

11.

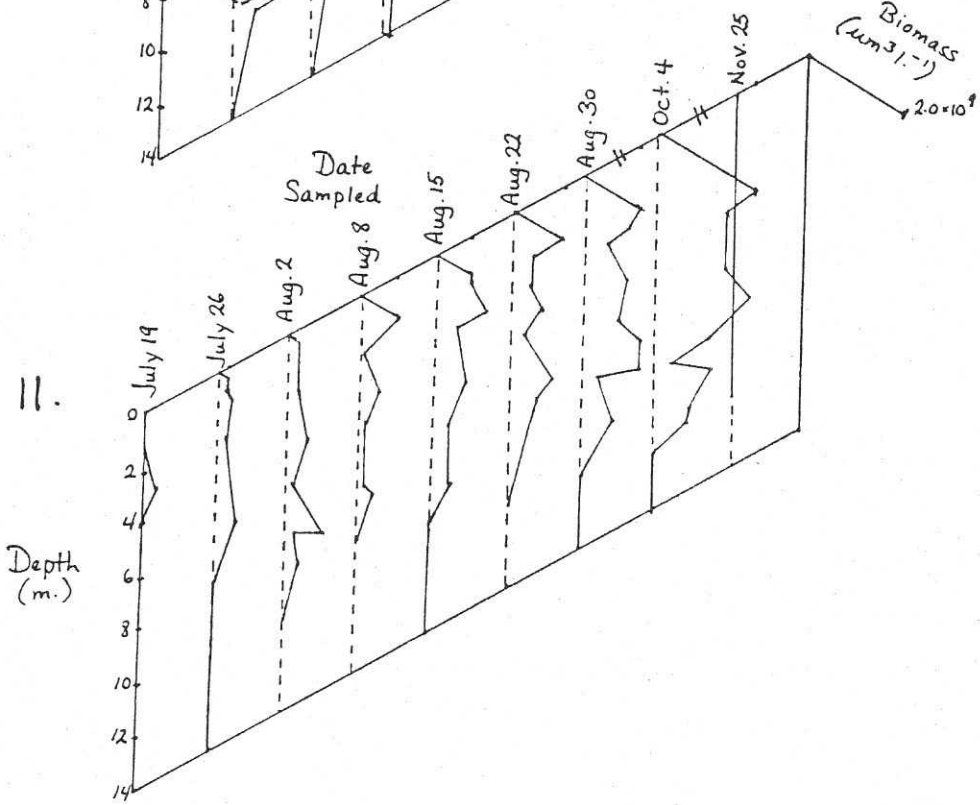
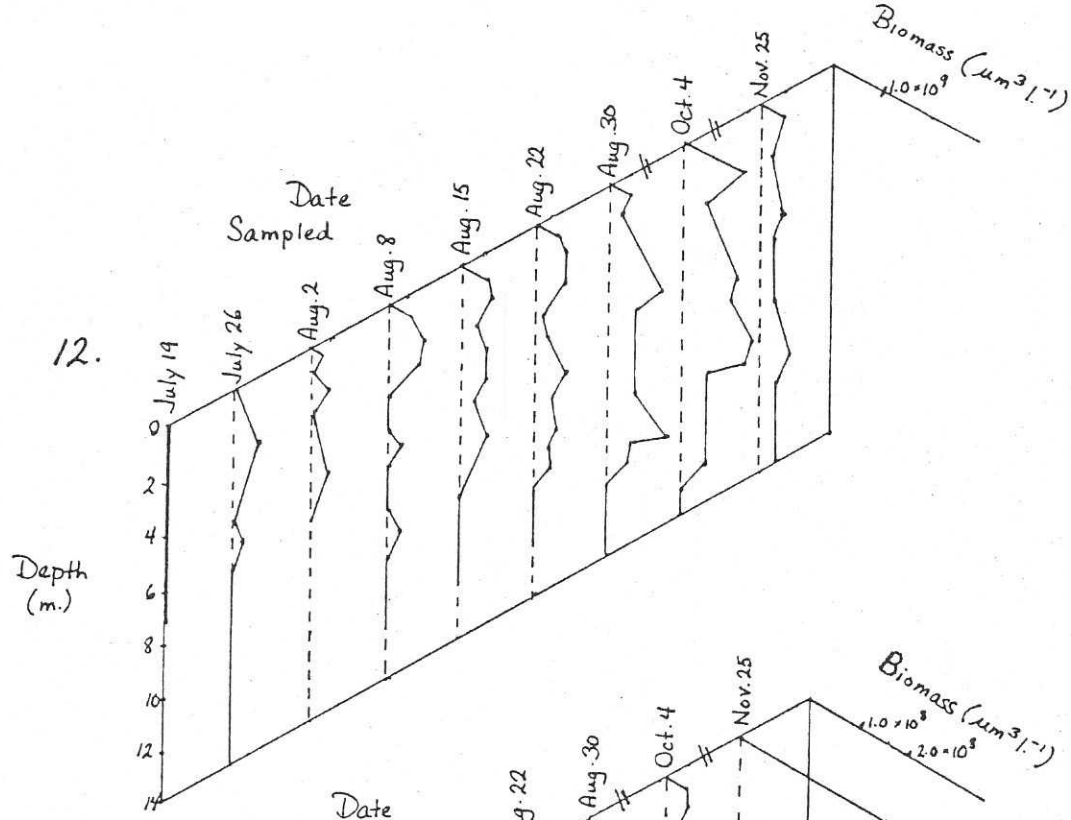

Biomass (um3 l.-1)
2.0×10^9
Nov. 25
Oct. 4
Aug. 30
Aug. 22
Aug. 15
Aug. 8
Aug. 2
July 26
July 19
Date Sampled
Depth (m.)
0
2
4
6
8
10
12
14

Figure 12. Vertical distribution of *Gomphosphaeria lacustris*.

Figure 13. Vertical distribution of *Ochromonas* spp.

12.


Biomass ($\mu m^3 l^{-1}$)
1.0×10^9
Nov. 25
Oct. 4
Aug. 30
Aug. 22
Aug. 15
Aug. 8
Aug. 2
July 26
July 19
Date Sampled
Depth (m.)
0
2
4
6
8
10
12
14

13.

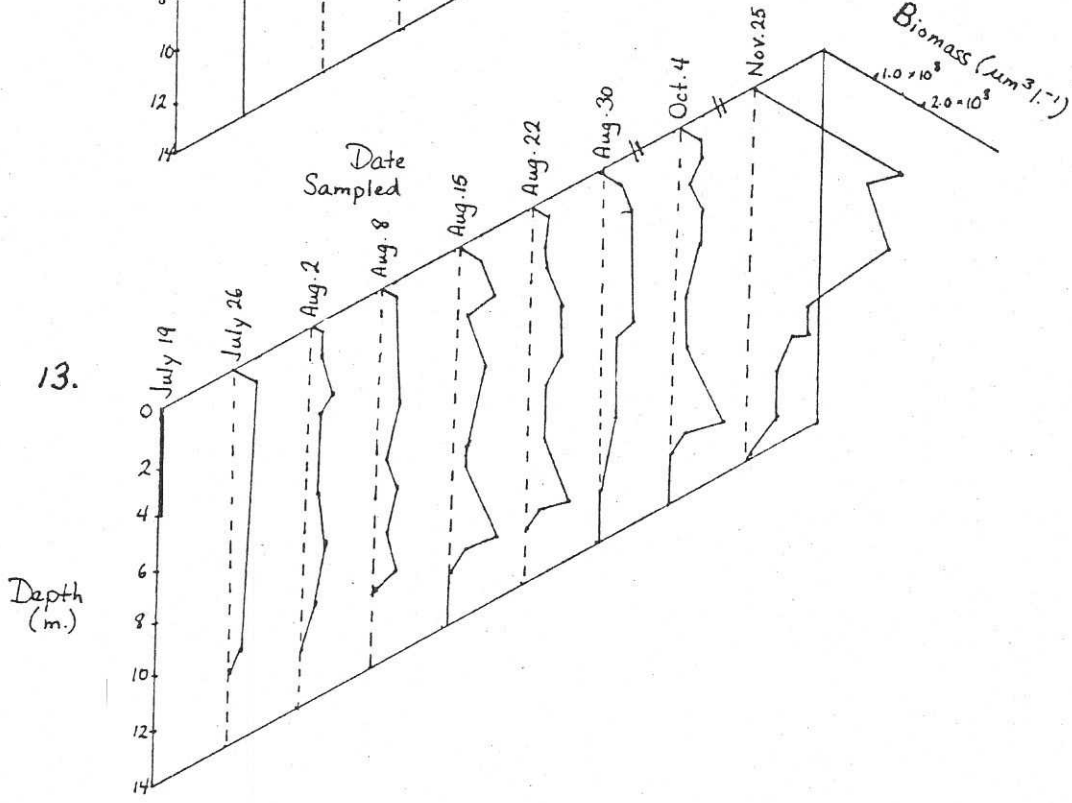
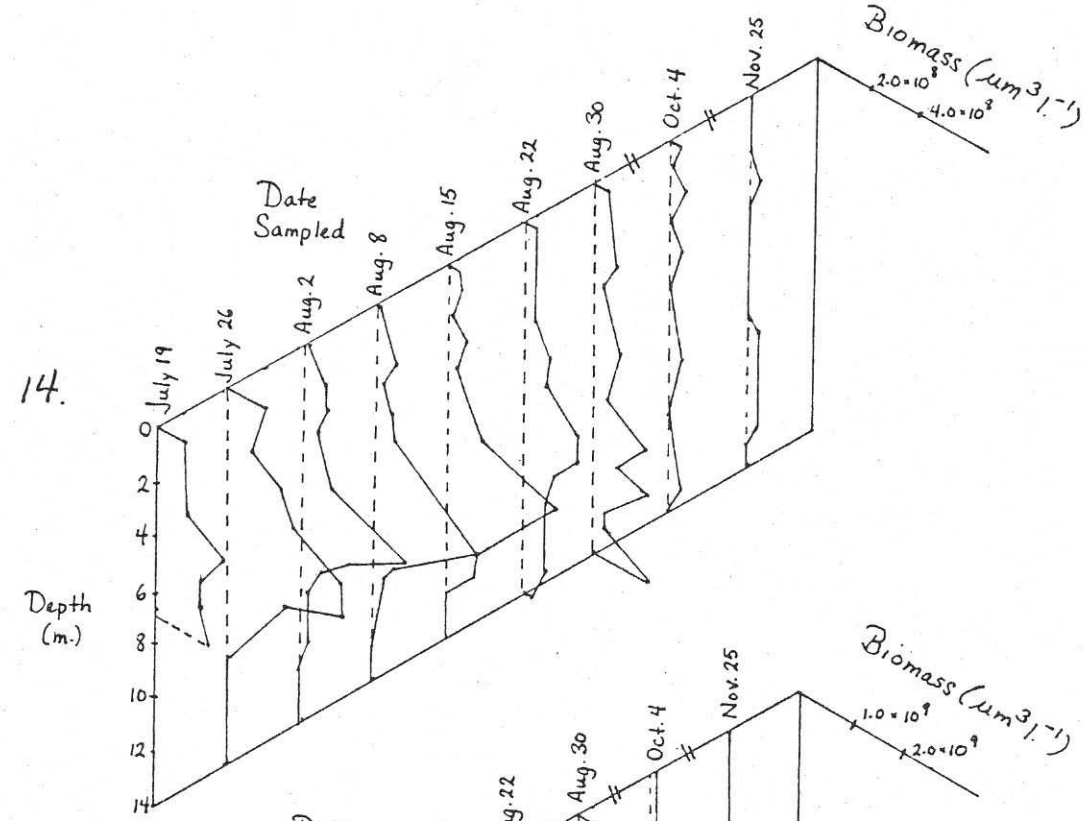

Biomass ($\mu m^3 l^{-1}$)
1.0×10^9
2.0×10^9
Nov. 25
Oct. 4
Aug. 30
Aug. 22
Aug. 15
Aug. 8
Aug. 2
July 26
July 19
Date Sampled
Depth (m.)
0
2
4
6
8
10
12
14

Figure 14. Vertical distribution of *Oocystis* spp.

Figure 15. Vertical distribution of *Microcystis* spp.


14.
Biomass ($\mu m^3 l^{-1}$)
2.0×10^8
4.0×10^8
Date Sampled
July 19
July 26
Aug. 2
Aug. 8
Aug. 15
Aug. 22
Aug. 30
Oct. 4
Nov. 25
Depth (m.)
0
2
4
6
8
10
12
14

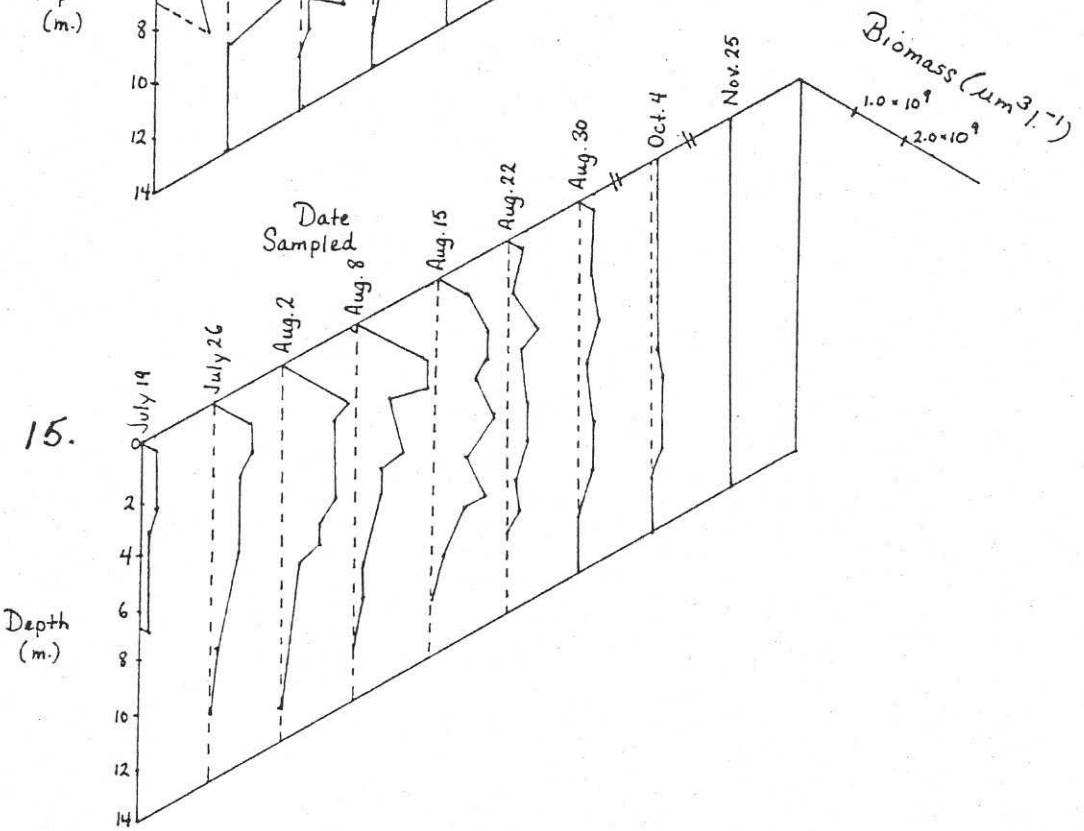

15.
Biomass ($\mu m^3 l^{-1}$)
1.0×10^9
2.0×10^9
Date Sampled
July 19
July 26
Aug. 2
Aug. 8
Aug. 15
Aug. 22
Aug. 30
Oct. 4
Nov. 25
Depth (m.)
0
2
4
6
8
10
12
14

Table 2. Phytoplankton of Sunfish Lake.

Phytoplankton Present	Group	Average filament colony or cell volume (μm^3)
Oocystis spp.	Chlorophyceae	2,010
Microcystis spp.	Cyanophyceae (c)	3,925
Mallomonas spp.	Chrysophyceae	8,860
Gloeocystis spp.	Chlorophyceae	1,345
Anabaena spp.	Cyanophyceae (f)	1,570
Gomphosphaeria aponina	Cyanophyceae (c)	10,750
Gomphosphaeria lacustris	Cyanophyceae (c)	21,000
Gomphosphaeria X	Cyanophyceae (c)	10,750
Sun	---	5,765
Cosmarium spp.	Chlorophyceae	5,250
Aphanothece spp.	Cyanophyceae (c)	565
Neidium spp.	Diatom	395
Synedra spp.	Diatom	45
Ochromonas spp.	Chrysophyceae	125
Cryptomonas spp.	Pyrrophyceae	2,545
Aphanocapsa spp.	Cyanophyceae (c)	565
Chroococcus spp.	Cyanophyceae (c)	1,345
Ankistrodesmus spp.	Chlorophyceae	50
Oscillatoria agardhii	Cyanophyceae (f)	157,000
Coelosphaerium spp.	Cyanophyceae (c)	565
Oscillatoria limnetica	Cyanophyceae (f)	80
Scenedesmus spp.	Chlorophyceae	80
Lenore	---	15
R.S.	Chlorophyceae (?)	330
Cyclotella spp.	Diatom	4,535
Tabellaria spp.	Diatom	630

(c) - colonial

(f) - filamentous

(?) - tentative

DISCUSSION

The trophic status of a lake can be classified with the aid of a variety of indices including phytoplankton quantity and quality. Rawson (1956) presented several ways in which algae could be used as indicators of trophic lake status. Eutrophic lakes have a rich quantity of phytoplankton, a small species diversity, and an algal distribution occurring mainly in the trophogenic layer. Algal blooms are frequent and the characteristic algal groups are the Cyanophyceae and several diatom species including *Melosira, Fragilaria, Stephanodiscus* and *Asterionella.* Rawson (1956) characterized oligotrophic lakes as containing smaller algal biomass but larger diversity than eutrophic lakes, with an algal distribution occurring to great depths. Algal blooms in oligotrophic lakes are rare and the characteristic algae are the Chlorophyceae and the diatom species: *Tabellaria* and *Cyclotella.*

One difficulty with classifying the trophic status of a lake lies in the exact positioning of the value of any one indicator onto a continuum of values observed when studying the differences between oligotrophy and eutrophy. Another difficulty is that different indicators often classify one lake into varying trophic states.

The algal composition of Little Round Lake, a meromictic, oligotrophic lake in southern Ontario was analyzed by Karen Munro (1978). Sunfish Lake has a much greater algal biomass than Little Round Lake thus indicating the status as being mesotrophic or eutrophic. Productivity appears to be so high in Sunfish Lake that it may be

regarded as a continuous bloom. This is a characteristic of eutrophic lakes (Davis, 1964). By analyzing the presence of various diatom species in Sunfish Lake, the lake can be classified as mesotrophic. The lack of significant quantities of any diatom species is an indication that the lake is in a transition period from oligotrophy to eutrophy termed mesotrophy (Rawson, 1956). Core samples have shown that diatoms previously existed in abundance in Sunfish Lake (Sreenivasa and Duthie, 1973) and thus the present absence of significant quantities of diatoms does not appear to be due to any nutrient limitation.

The presence of distinctly stratified algal blooms in lakes was first reported by Lund (1959). Since then researchers began searching for these stratified blooms and reports indicate that they are now recognized as a common phenomenon (Davidson, 1979). Stratified algal populations typically occur in small well sheltered mesotrophic to highly eutrophic lakes which are subject to intense thermal stratification (Skulberg, 1978; Fogg and Walsby, 1971). The stratified bloom will normally occur in the metalimnion and in most cases these blooms are heavily dominated by blue-green algae, particularly *Oscillatoria* species (Wholer and Hartman, 1973). The presence of such a bloom is indicated in figure 8 which illustrates the depth distribution of *Oscillatoria agardhii* throughout the sampling period. The bloom reached its maximum between 8 and 9 meters and this maximum gradually moved deeper in the water column in the summer and fall until late November when the *Oscillatoria* distribution became more uniform due to the mixing effect of overturn. It is interesting to note that the depth of the *Oscillatoria* maximum is very similar to the depth of the 6-8° C

temperature range in the water column before overturn (figure 4). Thus, there may be some form of temperature preference exhibited by the *Oscillatoria*. The fact that the *Oscillatoria* layer is below the metalimnion is an occurrence which has also been observed in Lake-on-the-Mountain (Davidson, 1979).

The distribution of the alga R.S., which has been tentatively identified as a green alga (Chlorophyceae) also is stratified at a depth between 10 and 14 meters through the entire sampling period (figure 9). This is an important phenomenon as according to Dr. S.R. Brown (personal communication), to the best of his knowledge there are no reports of any existing stratification of a microplanktonic algal form. The occurrence of this alga so deep in the water column may be explained by the possibility that the R.S. is heterotrophic, i.e., it can remain viable in bacteria-free culture by chemo-organotrophic uptake of dissolved organic compounds without requiring the presence of light (Wetzel, 1975). Another possible explanation is that the photosynthesis of R.S. is inhibited by oxygen and thus the R.S. can only exist at greater depths where the oxygen concentrations are smaller.

Gomphosphaeria species probably occupy a special environmental niche, within which seasonal succession between three species is observed. Between July 19 and October 4, there is a succession in which *Gomphosphaeria X* is replaced by *Gomphosphaeria aponina* and *Gomphosphaeria lacustris* (figures 10, 11 and 12).

The presence of large numbers of *Oocystis* at depths of 4 to 6 meters in the summer (figure 14) is one possible means of explaining the supersaturation of oxygen at this depth. The maintenance of large

oxygen tensions would be one of the goals for a management program for the lake. Thus, further studies should be carried out in order to indicate to what degree, if any, the *Oocystis* contributes to these high oxygen levels.

A large number of *Ochromonas* were present in Sunfish Lake through the entire sampling period (figure 13). These algae did not demonstrate any marked vertical stratification until November when they occurred most abundantly in the top 4 m of water. *Ochromonas* was also found in large numbers throughout the year in Little Round Lake where it also showed no noticeable stratification (Munro, 1978). The bloom of *Ochromonas* in Sunfish Lake after overturn is an occurrence which is not common in most lakes at this time of year. One possible explanation for this bloom is that the *Ochromonas* species present in the lake is phagotrophic. The phagotrophic ingestion of a blue-green alga by *Ochromonas* has been previously observed (Daley, Morris and Brown, 1973). Another possibility for the occurrence of the bloom at this time in the season is the requirement of the *Ochromonas* species for some organic supplement, possibly a vitamin, which was limiting before overturn.

The seasonal succession of the major algal groups is shown in figure 7. The only distinct trend occurs in the late fall after overturn when there is a large decrease in the abundance of the Chlorophyceae and both the colonial and filamentous Cyanophyceae, and a large increase in the Chrysophyceae biomass.

At this point it should be mentioned that during the algal sample analysis what appeared to be a variety of plant or fungal fragments were observed in extremely large numbers in every sample taken from depths of

12 to 14 m throughout the entire sampling period. These fragments have been tentatively identified as conidia and conidiophore fragments of aquatic hyphomycetes as illustrated in diagrams from Hudson (1972). It appears that the presence of these fragments at this depth is due to the density differences associated with the chemocline. It was noted that those fragments with large surface areas were most abundant in the samples obtained from 12 m, while the smaller fragments were more abundant at 14 m.

The distribution of algal biomass with depth results from the interaction of a number of factors including light penetration, temperature, depth of mixing, nutrient concentration and the organisms present. Thus, to determine why one algal species is more abundant at a particular depth is very complex although several possible associations can usually be drawn. Due to the limited amount of data concerning such variables as nutrient concentrations in Sunfish Lake, the purpose for the acquisition of data examining both the seasonal and depth variation for each algal species is to illustrate the trends present as well as to indicate possible contributing factors causing these trends. With subsequent studies perhaps enough information will be obtained to clearly indicate which factors are most influential in the causation of these trends.

Having determined the composition of the phytoplankton, and obtained an indication of their productivity from changes in biomass the next obvious step is to use ^{14}C or Winkler techniques to measure actual rates of oxygen evolution. Maintenance of large oxygen tensions may be regarded as of equal importance as trophic contribution of the algae in this lake ecosystem.

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