from Ph.D. thesis of Waldo Johnson 1954

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A COMPARISON OF THE LAKES WITH RESPECT TO THE BIOLOGICAL EFFECTS OF LIME-TREATMENT

Introduction

Lake Peter and Lake Petrea have received treatment with lime throughout the course of these studies and the general physical and chemical effects of such treatment have been described above. (see page 114 of insert)

A unique part of these field studies has been the use of Lakes Peter and Paul, which were orginally one lake consisting of two basins. The two basins were separated by an earthen barrier to form the two separate lakes; Lake Peter then receiving lime-treatment with Lake Paul serving as the untreated natural control. It is unfortunate that thorough pretreatment studies were not conducted; but the original plan for these lakes was that they serve as a field demonstration for the clearing effect of lime-treatment, and it was not known until later that it would be possible to carry out detailed investigations on them. All indications from preliminary surveys indicate that the two basins were similar in all respects previous to separation and alkalization of Lake Peter. In the comparisons made below, it is assumed that this was the case, and that Lake Paul is a good natural control representing conditions similar to those which would have persisted in Lake Peter had it not been for additions of lime.

Although Lake Peter responded to lime-treatment with a clearing of the water, which had been previously noted as a usual response by Professor Hasler and his students, Lake Petrea did not respond to lime-treatment in this respect. This indicates that such clearing on application of lime is not a general phenomenon.

Considering Lake Paul as representative of untreated lakes of this type, and lime-treated Lake Peter similar to lime-treated Lake Petrea except for the effect of clearing of the water, some interesting comparisons can be made.

Such comparisons are based principally on the data used above in the analysis of the dynamics of trout-growth, and on studies of the phytoplankton. Data for the phytoplankton are given below.

The Phytoplankton

It is generally believed that the greatest role in the basic elaboration of organic matter in lakes is taken by the phytoplankton. This would seem especially true in lakes of this type where there is such a sparce development of higher aquatic plants. Assuming this to be true, any basic changes in productivity as a result of lime-treatment should be reflected in the phytoplankton.

With this in mind, samples of the phytoplankton of Lakes Peter, Paul and Petrea were taken periodically throughout the course of these investigations.

Methods: Samples of the phytoplankton from each lake were taken periodically during 1951 and 1952, and at more frequent intervals during 1953, using a simple cone net of number 20 standard silk bolting cloth (68 meshes/cm.). The ring to which the net was attached had an inside diameter of 25 cm. and the straining cone had a slant height of 19 cm. Each sample was obtained by making one vertical haul at the deepest station of the lake. Each vertical haul consisted of lowering the net so that it was collecting both on the descent and the ascent; the ascending haul was made at the rate of one-half meter per second. Hauls were made from the following depths to the surface: Lake Petrea - 6 meters, Lake Paul - 10 meters, and Lake Peter - 14 meters. The samples were preserved by addition of formalin immediately after collection.

This method of sampling of the phytoplankton has many limitations which have been discussed by Ricker (1937). However, assuming random horizontal distribution and constant efficiency of the net, it is felt that these samples are sufficient to serve in comparing the quality and relative quantity of the number 20 net phytoplankton of these lakes.

Concentrates from each sample were examined with the compound microscope to identify the different genera present. All samples were diluted to equal volume (70 cc.) and counts were made to determine the relative quantity using the Utermohl sedimentation method and the inverted microscope. Thirty fields, chosen at random, were counted for each sample and the number of cells or colonies of each genera recorded. In this way it was possible to calculate the total number of cells or colonies in each sample and the percentage composition for the dominant forms. Duplicate counts made showed little variation; Loeffler (unpubl. MS), using the same method, has found a mean coefficient of variation of 5.8% in duplicate counts when using 30 fields for each count.

Results: The number of cells or colonies per net haul, the number of different genera present in each net haul, and the dominant genera and the percent of the total number of cells or colonies counted which these dominant forms represent, for each sample are given in Fig. 2-4. Table 6 lists the different genera encountered in all of the samples from each of the lakes.

Discussion of these results is restricted to general features obvious in the comparison of the three lakes.

In untreated Lake Paul, Fig. 2, Peridinium completely dominated in nearly all samples except during the late fall and winter period, the only other form which occurred in quantity being Mallomonas in two samples as noted. Synura was the dominant form found during the late fall and winter period, the only other form appearing in number during this time of year being Dinobryon. The summer pattern of abundance for both 1952 and 1953 was similar except for the low in August of 1952. The maximum calculated number of cells or colonies per net haul for

Fig. 2. Lake Paul. The number 20 net phytoplankton. The total number of cells or colonies per net haul, the number of different genera in each sample, and the dominant genera expressed as the percent of the total number of cells or colonies counted. 1951-1954.

Fig. 3. Lake Peter. The number 20 net phytoplankton. The total number of cells or colonies per net haul, the number of different genera in each sample, and the dominant genera expressed as the percent of the total number of cells or colonies counted. 1951-1954.

Fig. 4. Lake Petrea. The number 20 net phytoplankton. The total number of cells or colonies per net haul, the number of different genera in each sample, and the dominant genera expressed as the percent of the total number of cells or colonies counted. 1951-1954.

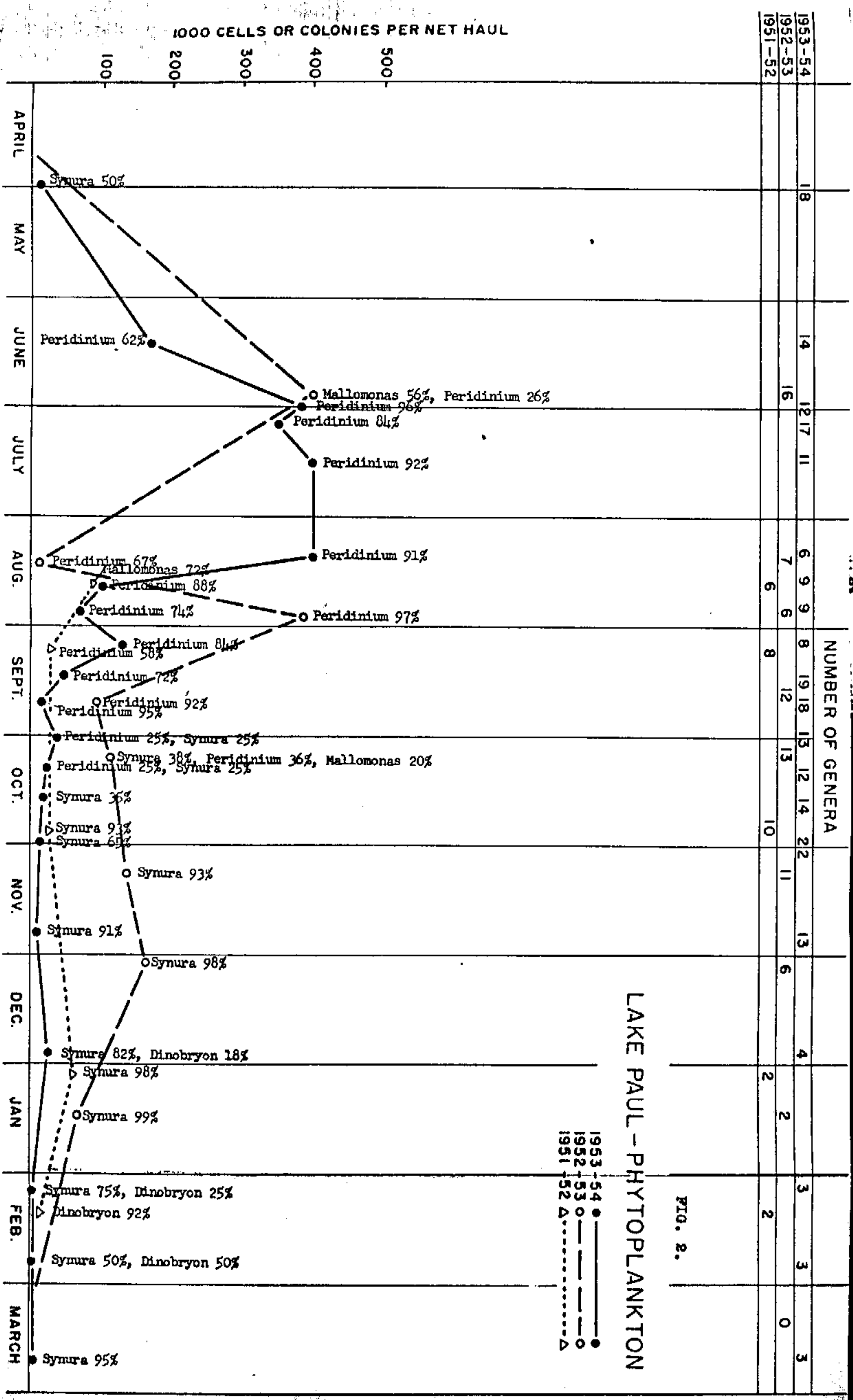

1000 CELLS OR COLONIES PER NET HAUL
100
200
300
400
500
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN
FEB.
MARCH
Synura 50%
Peridinium 62%
Mallomonas 56%, Peridinium 26%
Peridinium 96%
Peridinium 84%
Peridinium 92%
Peridinium 91%
Peridinium 67%
Mallomonas 72%
Peridinium 88%
Peridinium 74%
Peridinium 97%
Peridinium 84%
Peridinium 58%
Peridinium 72%
Peridinium 92%
Peridinium 95%
Peridinium 25%, Synura 25%
Synura 38%, Peridinium 36%, Mallomonas 20%
Peridinium 25%, Synura 25%
Synura 36%
Synura 93%
Synura 65%
Synura 93%
Synura 91%
Synura 98%
Synura 82%, Dinobryon 18%
Synura 98%
Synura 99%
Synura 75%, Dinobryon 25%
Dinobryon 92%
Synura 50%, Dinobryon 50%
Synura 95%
1951-52
1952-53
1953-54
NUMBER OF GENERA
18
14
16
12
17
11
7
6
6
9
9
6
9
8
8
19
12
18
13
13
12
14
10
22
11
13
6
4
2
2
3
2
3
0
3
LAKE PAUL-PHYTOPLANKTON
1953-54 ●———
1952-53 ○— — —
1951-52 △·········

FIG. 2.

each of the two years was 400,000. In all of the samples from Lake Paul, 34 different genera were identified.

In comparison, the phytoplankton of lime-treated Lake Peter, Fig. 3, is very different. Peridinium is present only as a rarity. Asterionella and Dinobryon dominate the spring and early summer pulse which reaches a much higher level than that in Lake Paul. Beginning in late July, a number of other forms take a dominant role; these include, Oocystis, Chrysosphaerella, Mallomonas and Ceratium, Oocystis, Eudorina, Asterionella, Aphanizomenon, and Synura in that order during 1953, and a quite similar pattern during 1952. The only similarity in the compostion of the phytoplankton of the two lakes appears in winter, when Lake Peter is dominated by Synura the same as Lake Paul. The summer pattern of abundance for the two years 1952 and 1953 was quite similar. This pattern of abundance differed from that of Lake Paul in that the pulse came earlier and reached a much higher level as far as numbers are concerned. In all the samples from Lake Peter a total of 50 different genera were identified as compared to 34 for Lake Paul.

Lime-treated Lake Petrea, Fig. 4, also lacks the monotonous domination of the phytoplankton by one genus that was shown for Lake Paul. Asterionella and Dinobryon dominated the spring pulse in 1953, and Dinobryon in 1952, giving way to a dominance by Gloeocystis in late June during

TABLE 6. Genera of phytoplankton taken in vertical cone net hauls during the period of investigation.

Genera	Lake Peter	Lake Paul	Lake Petrea
CHLOROPHYTA			
Eudorina	x	x	
Volvox	x	x	
Gloeocystis	x	x	x
Spirogyra	x	x	
Ulothrix	x	x	
Dictyosphaerium		x	x
Kirchneriella	x	x	
Quadrigula	x	x	x
Mougeotia	x	x	x
Zygnema	x	x	
Radiofilum	x		
Scenedesmus	x		
Hormidium	x		
Oedogonium	x		
Micractinium	x		
Pediastrum	x		
Oocystis	x		x
Eremosphaera	x		
Crucigenia	x		
Tetraedron	x		
Cordinella			x
Schroederia			x
Microthamnion			x
Cladophora			x
Ankistrodesmus			x
Desmids:			
Gonatozygon	x	x	
Closterium	x	x	x
Euastrum	x	x	
Staurastrum	x	x	x
Spondylosium	x	x	
Desmidium	x	x	
Gymnozyga	x	x	
Hyalotheca	x	x	
Triploceras	x		
Sphaerozosma	x		
Onychonema	x		
Micrasterias	x		
Arthrodesmus	x		
Cosmarium	x		

TABLE 6. (cont'd)

	Lake Peter	Lake Paul	Lake Patron
CHRYSOPHYTA			
Mallomonas	x	x	x
Chrysosphaerella	x	x	
Synura	x	x	x
Dinobryon	x	x	x
Diatoms:			
Diatoma	x	x	
Tabellaria	x	x	x
Asterionella	x	x	x
Synedra	x		x
Navicula	x		
PYRROPHYTA			
Peridinium	x	x	x
Ceratium	x	x	x
Glenodinium	x	x	
Gymnodinium			x
CYANOPHYTA			
Chroococcus	x	x	
Coelosphaerium	x	x	
Dactylococcopsis		x	
Oscillatoria	x	x	x
Anabaena	x	x	
Aphanizomenon	x	x	x
Total number of Genera:	50	34	23

both years. Later, Mallomonas became a dominant form, this genus reaching a very high level in September 1952. As in both the other lakes, Synura was the dominant winter form. In contrast to Lakes Peter and Paul, the summer pattern of abundance in Lake Petrea was very different for the two years, 1952 and 1953. This great difference seems completely unexplainable from any data at hand. For the summer of 1953, the pattern of abundance was quite similar to Lake Peter inasmuch as the summer pulse came at an earlier time and reached a much greater height, as far as numbers are concerned, than in Lake Paul. In all the samples from Lake Petrea a total of only 23 different genera were identified, as compared to 50 for Lake Peter and 34 for Lake Paul.

With regard to the general effect of lime-treatment on the phytoplankton, little can be said with certainty from the data at hand. If Lake Paul is a perfect control, then it would appear that lime treatment has resulted in a much more varied flora as far as the number of different genera which play a dominant role. Also, it appears that liming has resulted in a greater standing crop of phytoplankton, as far as numbers of cells or colonies is concerned. Standing crop, expressed as numbers of cells has often been used as an index of production. However, with the great variety of genera involved, and differences in size, their numbers are hardly an index of standing crop, much less of production, which would require knowledge of rates of growth and reproduction for each form as well.

The Zooplankton

Again considering unlimed Lake Paul as a perfect control, some interesting comparisons can be made regarding the zooplankton.

Qualitatively, all three lakes were similar during the two years 1952 and 1953 inasmuch as Daphnia longispina was the dominant form of Zooplankton. In 1953 (Tables 2-4) this species accounted, on the average, for the following percentages of the total number of zooplankton organisms in the samples: Lake Peter 92.8%, Lake Petrea 79.8%, Lake Paul 60.2%. In Lake Petrea, a species of Diaptomus constituted an average of 17.2% of the total number of organisms, this form and Daphnia longispina being the only two zooplankters encountered in the samples from this lake. In Lake Paul, a species of Cyclops accounted for an average of 22.8% of the number of organisms in the samples, and Holopedium gibberum for an average of 7%. A species of Bosmina occured in the spring samples. In Lake Peter, Cyclops, Diaptomus and Bosmina played minor roles. In all three lakes, Chaoborus and water mites were of rare occurrence in the zooplankton samples.

— B.S. D. pulex

The differences noted in the quality of the zooplankton are not great and may or may not be related to the lime-treatment. The absence of Holopedium gibberum in the samples from limed lakes has been noted previously by Hasler and Brynildson (unpubl. MS) and appears to be a general result of alkalization.

Results from the quantitative studies of the zooplankton are more consistant.

Average standing crop of zooplankton
(Gms./Sq. Meter - dry weight)

	1952	1953
Lake Paul	0.64	0.70
Lake Peter	0.81	0.82
Lake Petrea	0.77	0.80

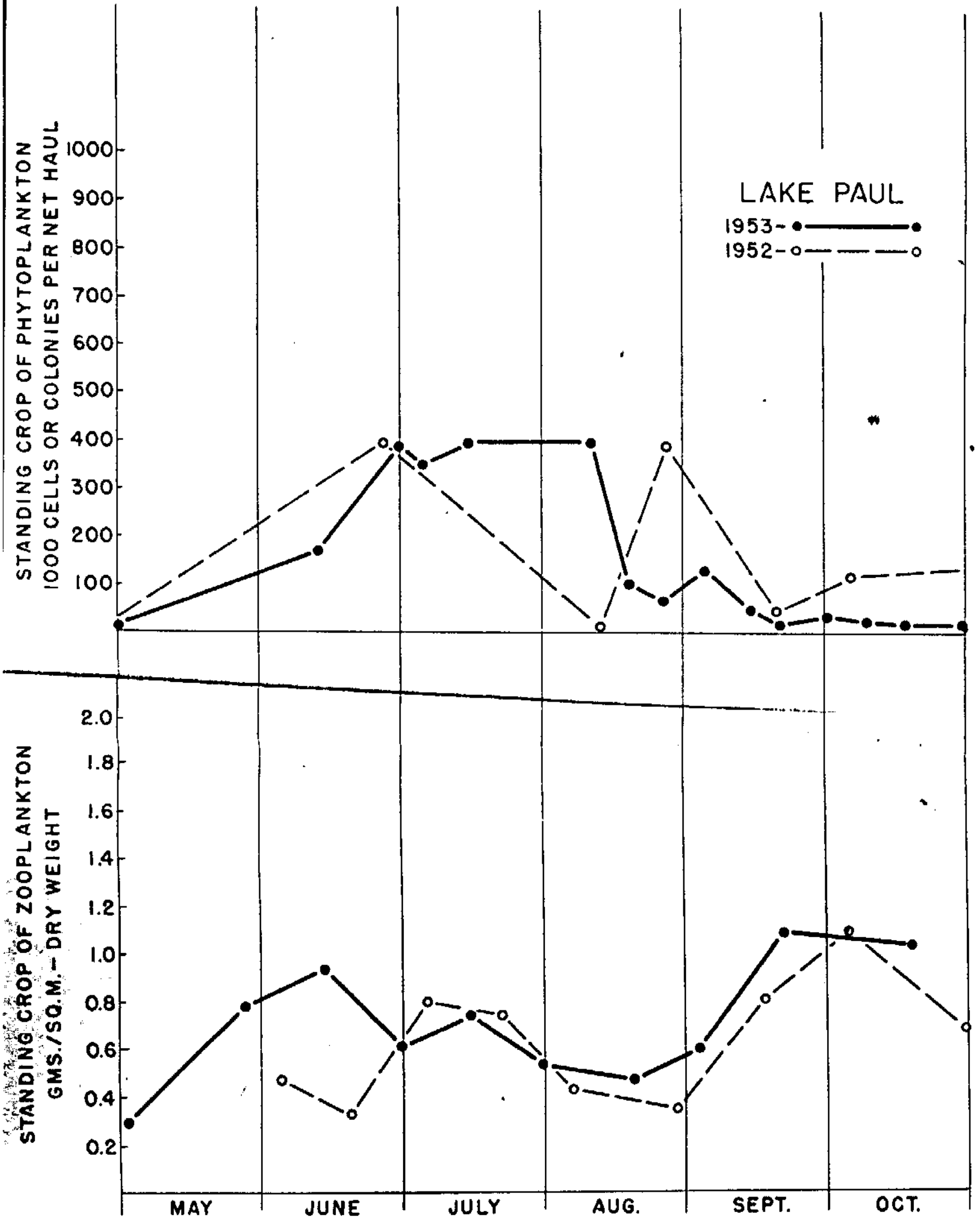
The average standing crop of zooplankton was greater in the lime-treated lakes in both years than in untreated Lake Paul. This would seem to indicate that lime-treatment has resulted in a slightly greater production of zooplankton. However, it must be remembered that these figures are for the standing crop, which may or may not have any relation to the actual production. Here as with the phytoplankton there is a lack of knowledge about rates of growth and reproduction.

The seasonal patterns of standing crop of zooplankton together with that of the phytoplankton are presented for each of the three lakes for 1952 and 1953 in Figs. 5-7. The pattern of fluctuation in standing crop of zooplankton followed the same general pattern during both years in all three of the lakes. As noted earlier, the standing crop of phytoplankton expressed as the number of cells or colonies followed the same general pattern during the two years in Lakes Peter and Paul but not in Lake Petrea. Although

Fig. 5. Lake Paul. The standing crop of zooplankton and the standing crop of phytoplankton. 1952 and 1953.

Fig. 6. Lake Peter. The standing crop of zooplankton and the standing crop of phytoplankton. 1952 and 1953.

Fig. 7. Lake Petrea. The standing crop of zooplankton and the standing crop of phytoplankton. 1952 and 1953.



LAKE PAUL
1953 –●——●
1952 –○— —○
STANDING CROP OF PHYTOPLANKTON
1000 CELLS OR COLONIES PER NET HAUL
1000
900
800
700
600
500
400
300
200
100
STANDING CROP OF ZOOPLANKTON
GMS./SQ.M. – DRY WEIGHT
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
MAY
JUNE
JULY
AUG.
SEPT.
OCT.

FIG. 5.

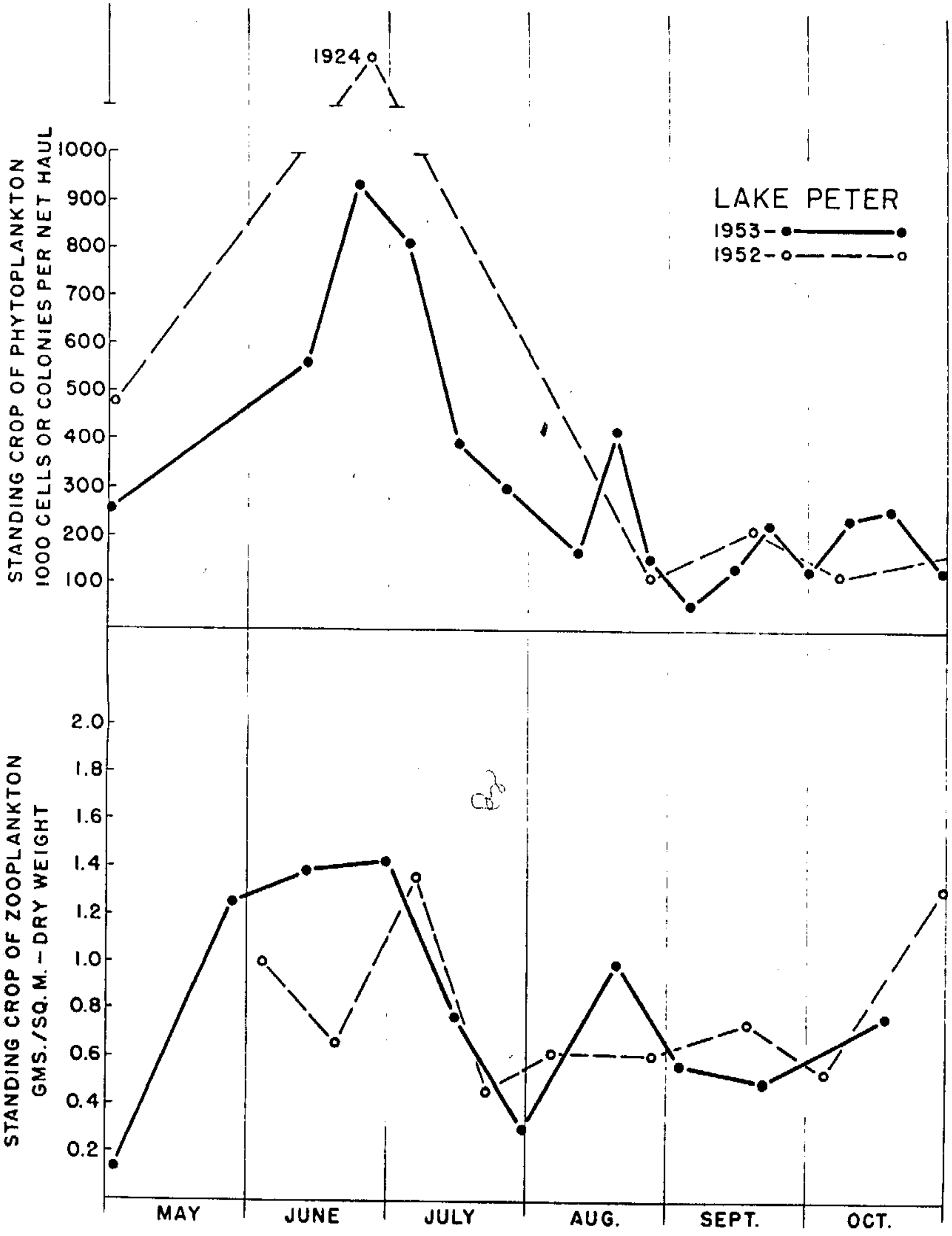

1924
LAKE PETER
1953
1952
STANDING CROP OF PHYTOPLANKTON
1000 CELLS OR COLONIES PER NET HAUL
1000
900
800
700
600
500
400
300
200
100
STANDING CROP OF ZOOPLANKTON
GMS./SQ.M.–DRY WEIGHT
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
MAY
JUNE
JULY
AUG.
SEPT.
OCT.

FIG. 6

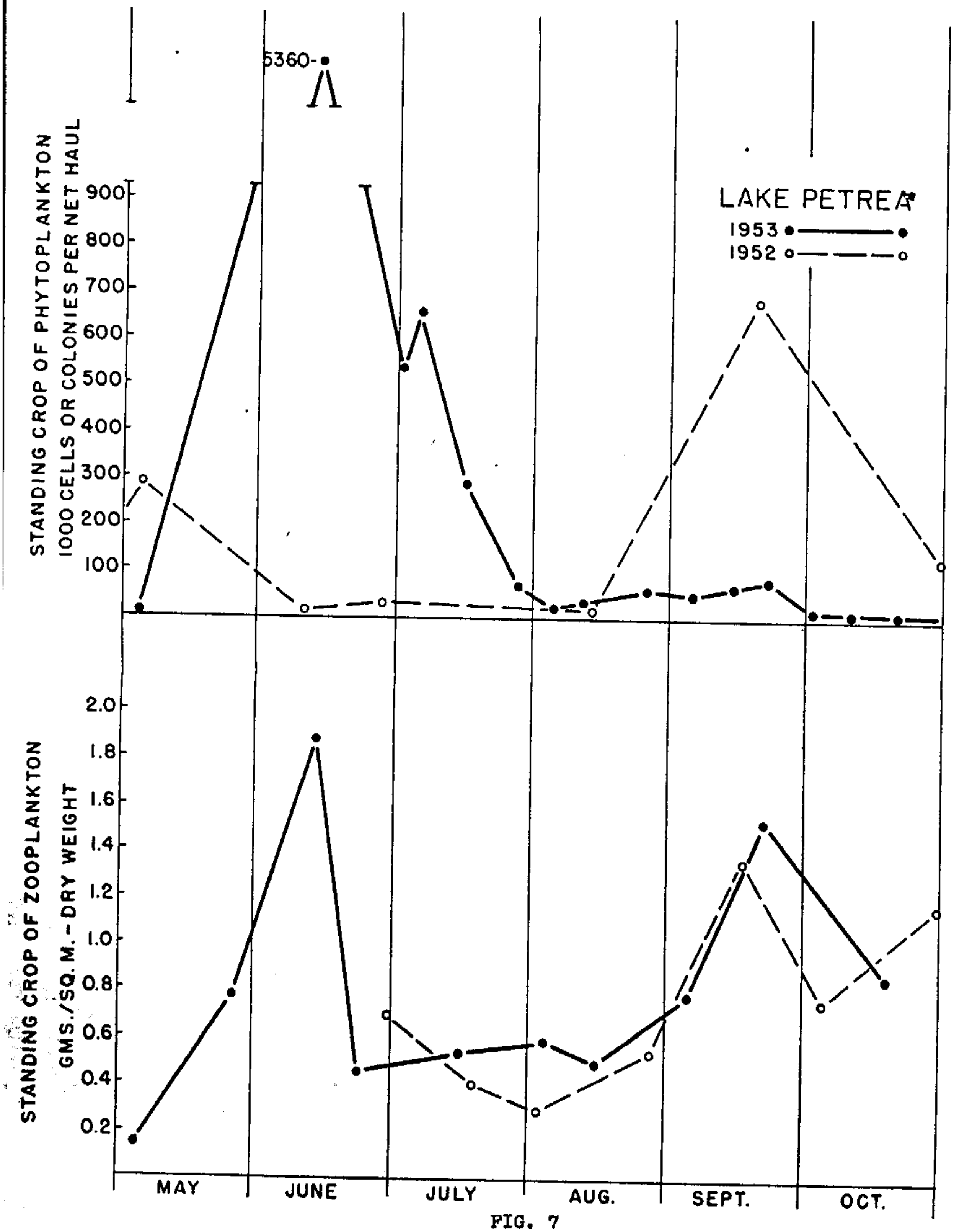

LAKE PETREA
1953 ●——●
1952 ○— —○
5360-●
STANDING CROP OF PHYTOPLANKTON
1000 CELLS OR COLONIES PER NET HAUL
900
800
700
600
500
400
300
200
100
STANDING CROP OF ZOOPLANKTON
GMS./SQ.M.- DRY WEIGHT
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
MAY
JUNE
JULY
AUG.
SEPT.
OCT.

FIG. 7

there appears to be a general correspondence of high pulses of both phytoplankton and zooplankton in early summer, However this is no sign of a cause-result relationship and Figs. 5-7 give no real evidence for such. As noted earlier, the standing crop of phytoplankton is likely a poor indication of phytoplankton production. Furthermore, this standing crop of phytoplankton represents only the number 20 net phytoplankton which may have no relation to the total phytoplankton. Considering this, and the possibility of organic matterial of allothonous origin---to say nothing of such things as food preferences and feeding habits of the zooplankters---any statements concerning the relationships between the phytoplankton and the zooplankton from this data are impossible.

The most obvious difference in a comparison of these lakes has been the difference in the vertical distribution of the zooplankton. The zooplankton of the three lakes appear to be concentrated near the surface in inverse relation to the light conditions.

	Average depth to which 1% of the surface light is transmitted. (Meters)	Average percent of zooplankton in the surface meter.
Lake Petrea	2.2	53.3
Lake Paul	2.7	42.8
Lake Peter	4.3	27.9

If this difference in vertical distribution of the zooplankton is related to light conditions, then the lesser degree of concentration of zooplankton near the surface in Lake Peter as compared to the other lakes is a result of lime-treatment through its effect of clearing the water. If this is a result of lime-treatment, it is actually a deleterious effect at lower levels of standing crop of zooplankton, as was indicated by differences in zooplankton density and corresponding differences in trout growth which were noted earlier. On the other hand, it could concievable be advantageous when food is plentiful as it would tend to reduce any tendency toward a crowding of the trout in space. The differences in zooplankton distribution as noted in these lakes suggests the existance of a complex food-space relationship which might be of considerable importance. However, the data available offers nothing in solution. Fig. 8 gives a graphic presentation of the different degrees of zooplankton concentration noted in the three lakes.

In comparing Lakes Peter and Paul, two other changes have been noted. Brasenia, formerly present in both lakes, is still found in Lake Paul but has disappeared from Lake Peter since treatment with lime. Hasler and his students have noted this previously as a result of alkalization. In Lake Peter, dense beds of <u>Chara Braunii</u> have developed since the lime-treatment, especially on the new bottom created by the barrier separaing this lake from Lake Paul. There has been no appearance of this species in Lake Paul--- on the new bottom created by the same barrier or elsewhere. This development of Chara did not begin until late in the second summer after the first applications of lime, and

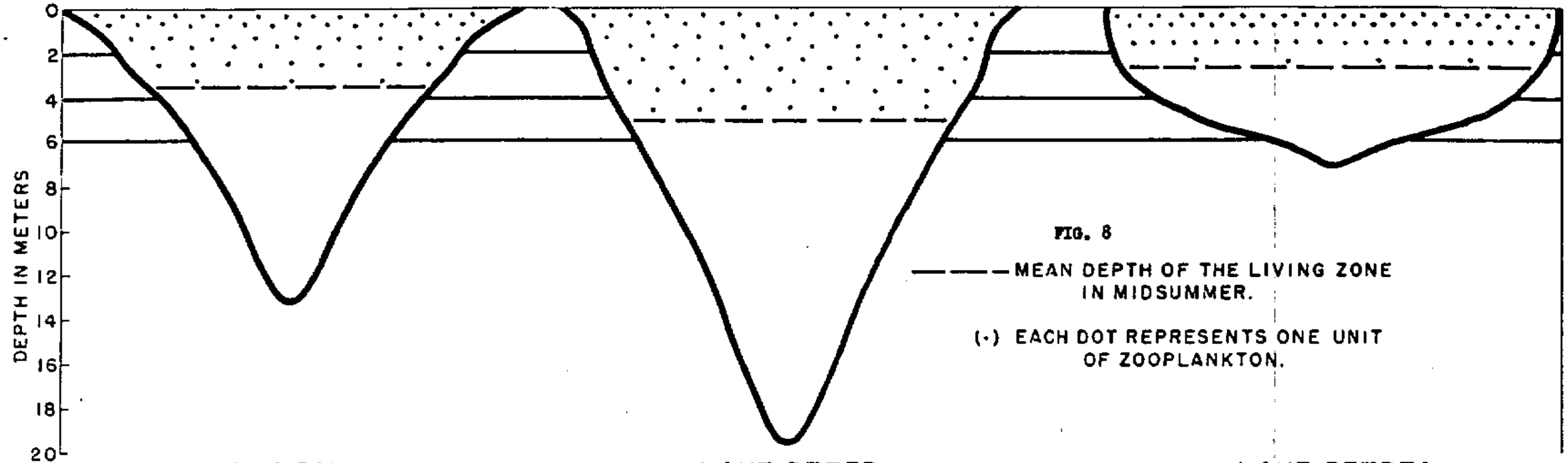
Macrophyte
ΔS

suggests that some effects of lime-treatment may be very slow in expressing themselves.

Fig. 8 summarizes a comparison of the three lakes under consideration with respect to the biological effects of lime-treatment. Little more can be said than is shown in that figure, and much of that only when Lake Paul is considered as a perfect control.

Fig. 8. Profiles of Lakes Paul, Peter and Petrea, showing the vertical distribution of the zooplankton and the mean depth of the living zone in midsummer; and a tabulation of various factors useful in a comparison with respect to the biological effects of lime-treatment.

FIG. 8



	LAKE PAUL UNTREATED CONTROL	LAKE PETER LIME TREATED	LAKE PETREA LIME TREATED
pH	5.9	7.3	7.2
Methyl orange alkalinity. (ppm)	5.8	19.5	17.0
Mean depth to which 1% of surface light is transmitted. (Meters)	2.7	4.3	2.2
Mean standing crop of zooplankton. 1953. (Gms./Sq. M. - dry weight)	.71	.81	.81
Mean density of zooplankton. 1953. (index)	.22	.16	.31
Phytoplankton	Monotonous flora dominated by Peridinium	Flora richer in dominant forms and in quantity.	Flora richer in dominant forms and in quantity.
Other features	Brasenia present.	Brasenia disappeared. Appearance of <u>Chara Braunii</u>.	

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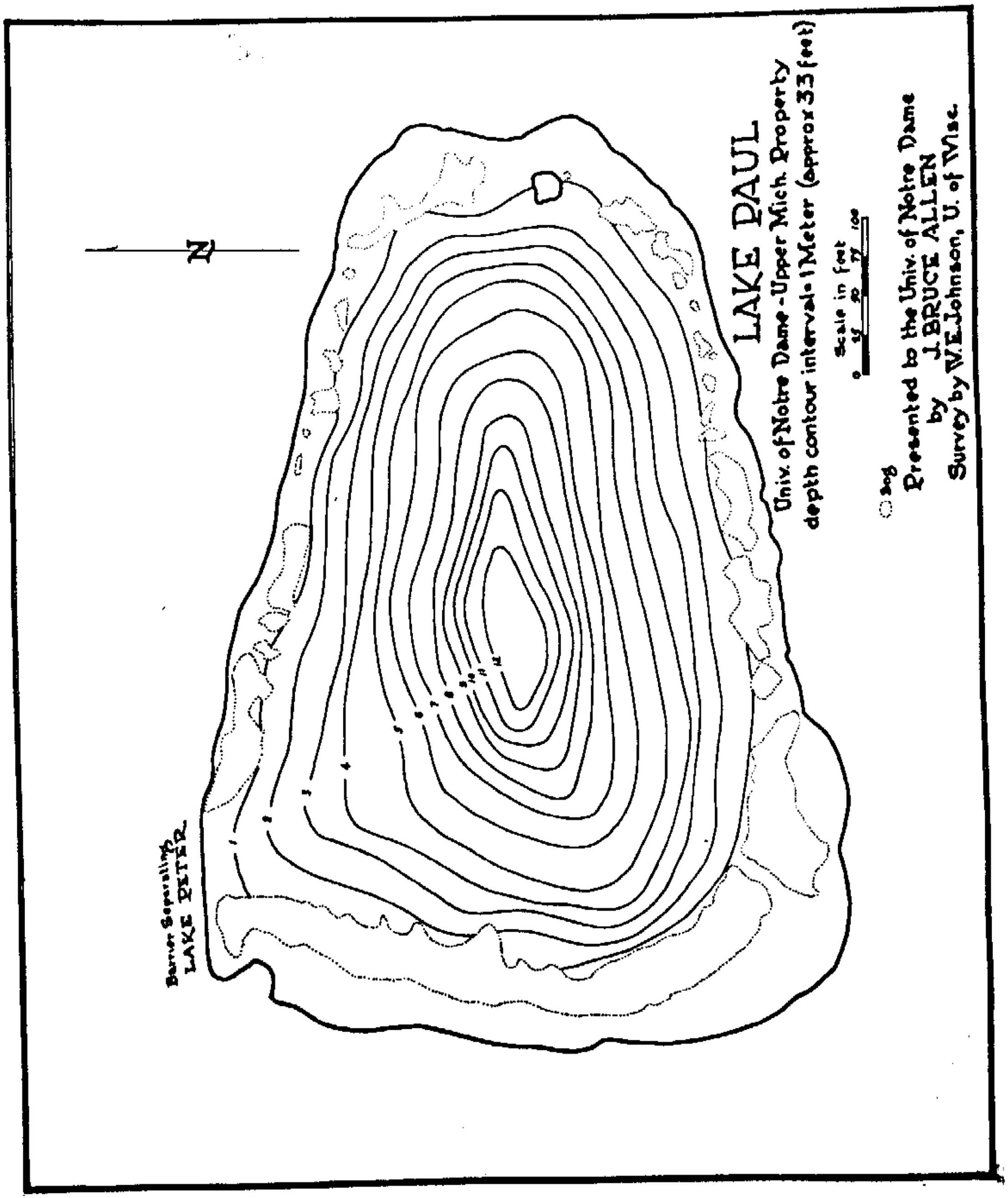
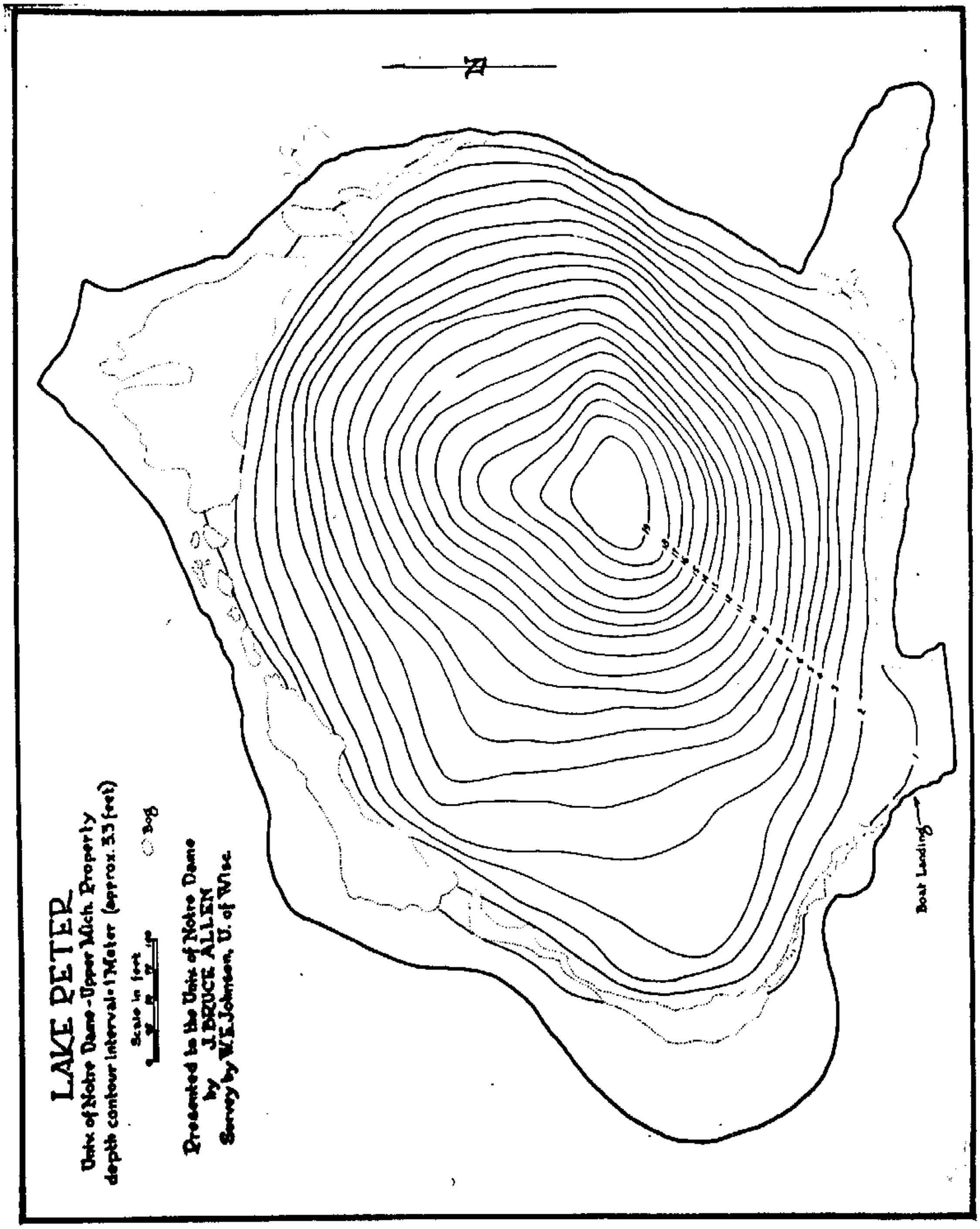
APPENDIX OF MAPS.

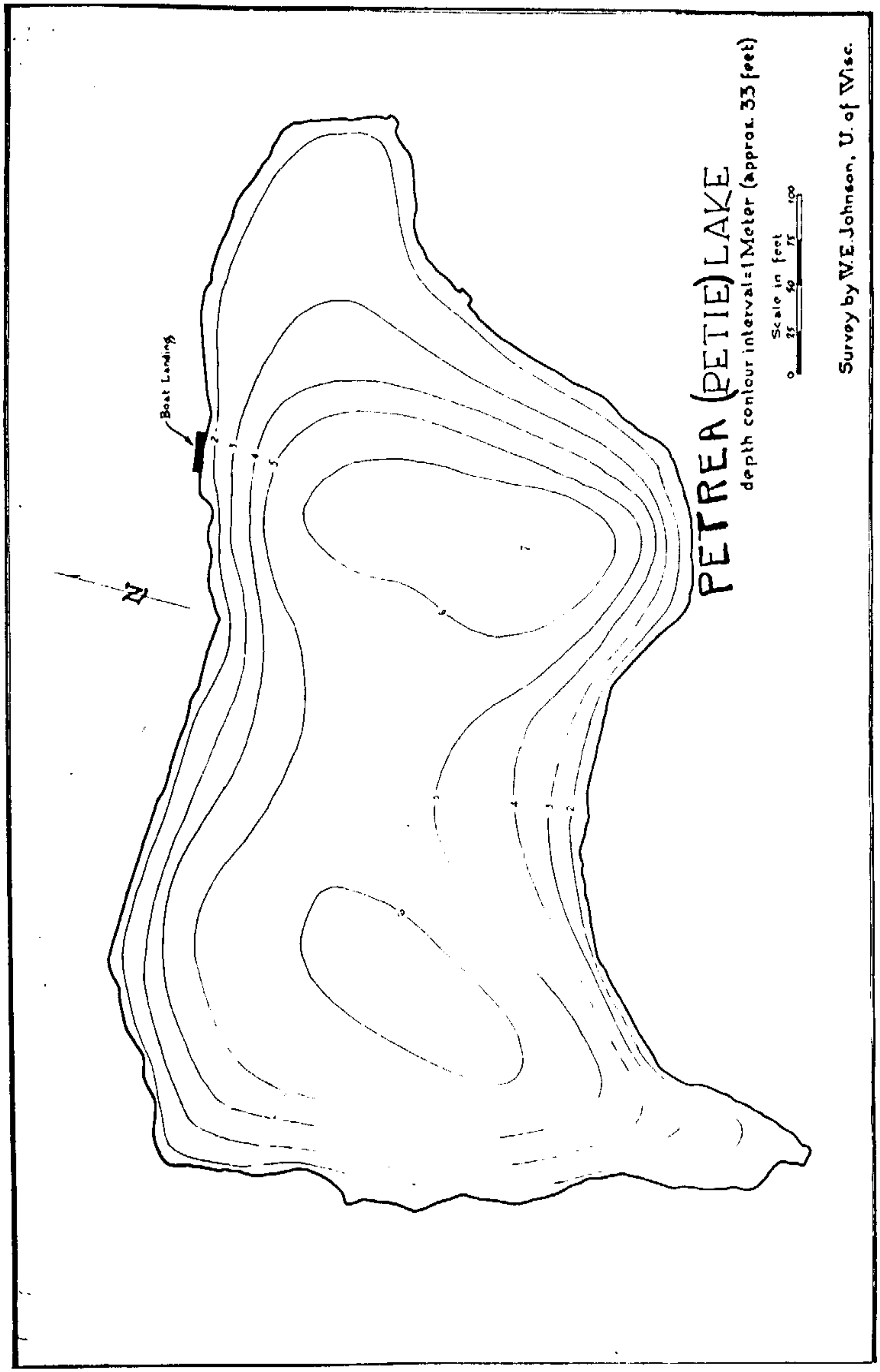
Fig. 9. Map of Lake Paul.

Fig. 10. Map of Lake Peter.

Fig. 11. Map of Lake Petrea.


LAKE PAUL
Univ. of Notre Dame - Upper Mich. Property
depth contour interval = 1 Meter (approx 3.3 feet)
Scale in feet
0 25 50 75 100
Bog
Presented to the Univ. of Notre Dame
by
J. BRUCE ALLEN
Survey by W. E. Johnson, U. of Wisc.
N
Barrier Separating
LAKE PETER
1
2
3
4
5
6
7
8
9
10
11
12


LAKE PETER
Univ. of Notre Dame - Upper Mich. Property
depth contour interval = 1 Meter (approx. 3.3 feet)
Scale in feet
Bog
Presented to the Univ. of Notre Dame
by J. BRUCE ALLEN
Survey by W.E. Johnson, U. of Wisc.
Boat Landing
N



PETREA (PETIE) LAKE

depth contour interval=1 Meter (approx. 3.3 feet)

Survey by W.E. Johnson, U. of Wisc.