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Studies on the periodicity of certain Plankton species of Salem Lake

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STUDIES ON THE PERIODICITY OF CERTAIN PLANKTON SPECIES OF SALEM LAKE

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Of Science

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This thesis by Gene A. Pratt is accepted in its present form by the Thesis Committee as satisfying the thesis requirements for the degree of Master of Science. August, 1957.

Signed:

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CHAPTER I

INTRODUCTION

SCOPE OF THE PROBLEM

The intent of this study has been to examine the periodicity of certain kinds of plankton in Salem Lake and the factors affecting their periodicity.

Our understanding of plankton is limited. This is especially true concerning plankton periodicity and the factors affecting this periodicity. Brown (p. 223) noted as early as 1908 that in order to understand the fluctuations seen in algal populations, one must study the algal growth at frequent intervals throughout the year, noting such attending factors as the different species present, their relative abundance, amount of light, temperature, etc. "But," he stated, "little careful and systematic study has been devoted to this subject." In 1931 Prescott (p. 5) stated that "the algae of a given region, in any event, are usually the least known plants of its flora." These statements might be expanded to include the total plankton community.

It is hoped that the present study will contribute to our understanding of the factors affecting the fluctuations of plankton organisms and the extent of their influences.

HISTORICAL BACKGROUND

Victor Hensen first used the term "plankton" in 1887 to include all minute animals, plants, and debris suspended in natural waters

(Ruttner, 1952, p. 94; Welch, 1935, p. 4). Ruttner (1952, pp. 94-105) restricts the definition to include only those organisms which are free-floating, which have the ability to carry on metabolism and reproduction, and which are either producers (autotrophic plants) or consumers of organic matter, or both. It is this restricted usuage which is employed in this study.

According to Ruttner (1952, p. 93), the first plankton studies resulted from the examination of the stomach contents of animals or of accidental findings of forms that had wandered into the littoral zone. Johannes Müller made the first detailed studies of plankton in 1845 when he gathered plankton by means of a fine-meshed net and studied his samples microscopically (Ruttner, 1952, p. 93; Welch, 1935, p. 4). Although techniques have improved greatly since the time of Müller, our knowledge of plankton communities is still limited.

SALEM LAKE

Salem Lake is located along U. S. Highway 91 just southwest of the business center of Salem, Utah. The main body of the lake lies to the south of the highway and is connected to Lower Pond on the north of the highway by a canal (see Figure 1). The present lake is fed by numerous springs, especially evident at the extreme south end, and by drainage from the surrounding foothills. The lake was formed in 1856 by damming the spring-fed stream then present (Faux, 1955, p. H19; Huff, 1947, p. 460; Taylor, 1954, p. 2). The dam was expanded and strengthened during the following years and became the highway in the 1860's. In the late 1930's U. S. Highway 91 was built across the lake just south of the original dam. It now serves as the dam.

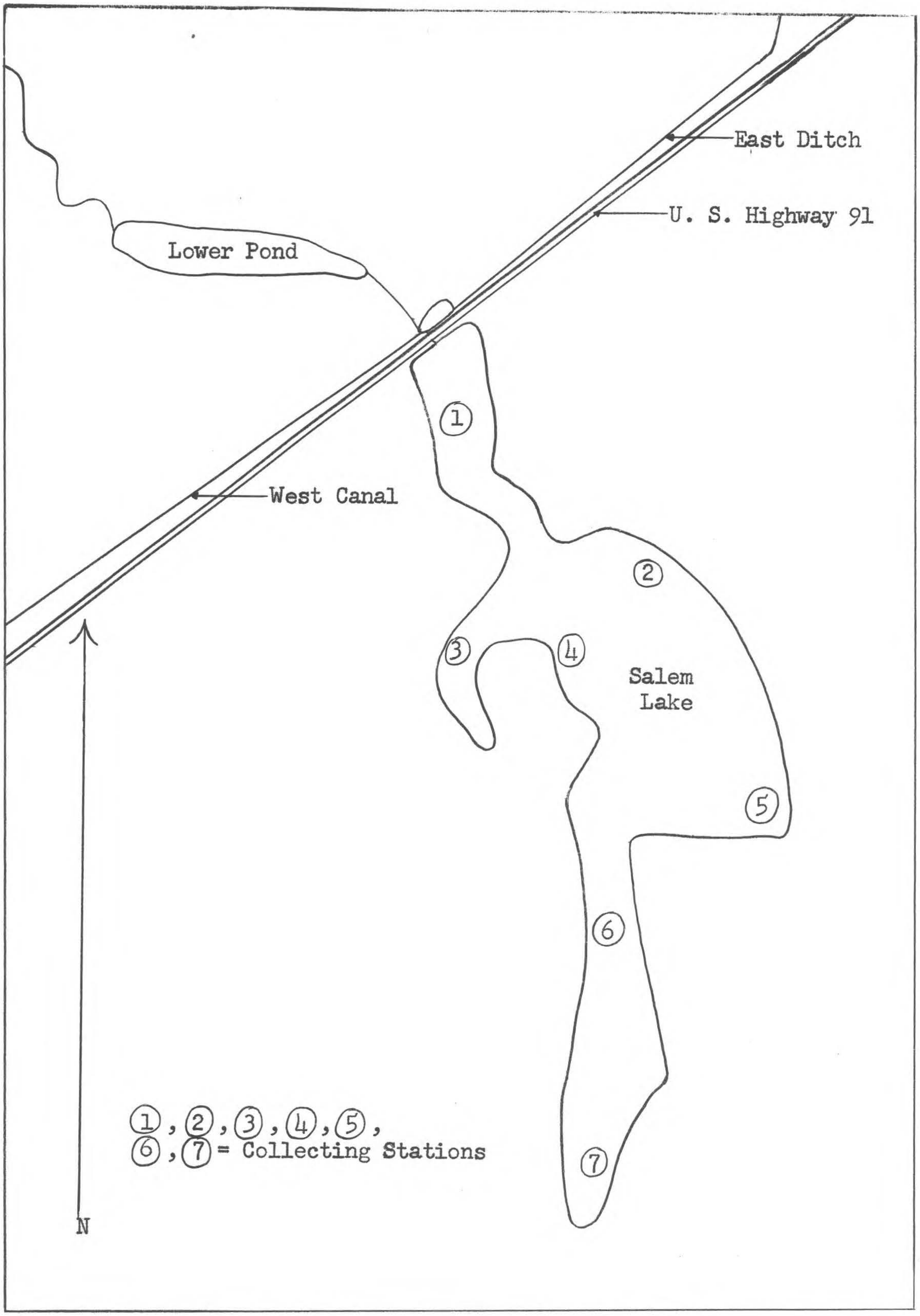


Figure 1.-Map of Salem Lake, Salem, Utah

Two irrigation canals on the north of the highway drain the lake. West Canal is the larger of the two and leaves from the west end of the lake. East Ditch, which is smaller, leaves from the east end of the lake. A third canal drains in a northwesterly direction from the west end of Lower Pond.

The Salem Lake was chosen for study because of the variety of conditions offered, the abundant algal growth, the ease and convenience of access, and the limited amount of information available regarding plankton cycles of the lake. No published accounts of detailed plankton studies from this lake were found. Only one unpublished account was found (Thomas, 1941).

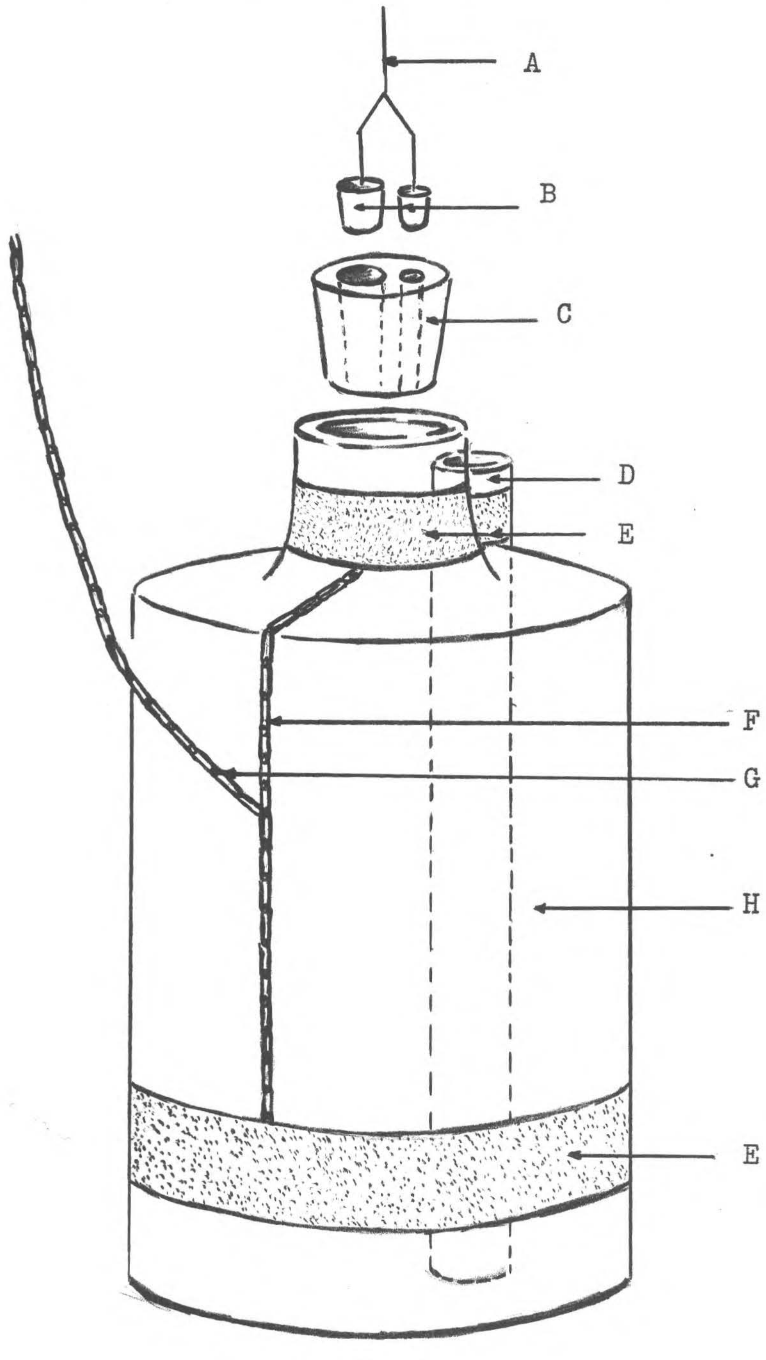
CHAPTER II

METHODS AND MATERIALS

Seven collecting stations were located at different sites throughout the lake (see Figure 1). Detailed study was restricted to Station #1, which was located in a narrow portion of the lake and which had an average depth of about eight feet. A slight current flowed through this station toward the northwest.

Collections were made periodically from the fall of 1955 through the winter of 1957 from the surface and bottom waters of Station #1. Surface samples were collected by means of a plankton net equipped with a 110 ml. jar. The net was thrown from the boat and drawn across the surface waters for approximately twenty feet. Bottom samples were obtained by use of the special collecting jar illustrated in Figure 2. This collection jar was made from a 500 ml. bottle which was weighted with a piece of iron pipe to insure sinking. A two-hole stopper was placed in the mouth of the jar and was fitted with two corks, which were attached to a cord. A graduated chain was fastened to a smaller chain attached to the jar. A sample was obtained by lowering the jar by the chain to the desired depth and pulling the corks, thus allowing the water to enter the jar. When the jar was filled, it was pulled to the surface and emptied into a 110 ml. collecting jar.

The samples thus obtained were brought into the laboratory and were first tested by means of a Beckman pH meter to determine the pH.



A = Cord
B = Corks
C = Two-hole rubber stopper
D = Iron pipe
E = Tape
F = Chain attached to bottle
G = Chain to suspend jar to desired depth
H = 500 ml. bottle

Figure 2.-Collection jar used for obtaining samples from bottom stations

The samples were then centrifuged at 3000 r.p.m. for two minutes. The concentrated samples were preserved in a 4 percent formalin solution, one of the better plankton preservatives according to West and Fritsch (1927, p. 14) and Welch (1948, p. 271). Each preserved sample was mixed thoroughly at the time of examination. Two drops were placed in a depression slide and covered with a circular cover slip having a diameter of 22 mm. This amount of sample filled the depression and extended to the edges of the cover slip. The entire sample under the cover slip was examined microscopically, and density counts were taken of the more common species and of the total population. Duplication in counting was avoided by using a mechanical stage to scan each sample. Density in this study refers to the actual number of individuals of each species present in a given sample as determined from single-slide examinations. Total population refers to the total number of individuals present in the species studied. Percent density calculations were made from the density data of each sample. Percent density as used in this study refers to that percent of the total population which is made up of a given species or phylum. Density and percent density calculations were also made for the different phyla studied. They include only the species considered in this report. The density counts were made on the following basis: (1) each individual cell of Anuraea cochlearis Gosse, Ceratium hirundinella (O. F. M.) Schrank, Navicula sp., and Cosmarium sp. was counted as one individual; (2) each colony of Pediastrum boryanum (Turp.) Meneghini, Scenedesmus quadricauda (Turp.) de Brebisson, Asterionella formosa Hassall, Merismopedia elegans A. Br., Oscillatoria limosa Ag., and Dinobryon sertularea Ehr. was counted as one individual.

Percent frequency data were recorded for both species and phyla. The term percent frequency in this study refers to the percent of samples in which a species or phylum was present out of the total number of samples taken. Sixteen surface samples and sixteen bottom samples were collected.

The dissolved oxygen content of surface and bottom waters was estimated periodically by means of the Rideal-Stewart modification of the Winkler Method (Welch, 1948, pp. 207-211).

The temperature of the water of each sample was recorded at the time of collection by means of a Taylor maximum-minimum Fahrenheit thermometer. The temperature of the air was also taken at the time of each collection by the same device. These readings were then converted to degrees centigrade and recorded.

Turbidity was taken by means of a Secchi Disk. This instrument records the depth to which light can be seen to penetrate the water. Actually it records the limit of visibility of light (Welch, 1948, p. 159) rather than the depth to which light penetrates.

The depth from which the bottom samples were taken was recorded in feet and inches at the time of each collection. The depth of the surface collections included approximately the first foot of surface water.

The date and time of day were recorded by standard means. The brightness of the day was recorded on an arbitrary scale especially established for this purpose. The sky conditions prevalent at the time of the collections were given the numerical ratings of (1) stormy, (2) very overcast or cloudy, (3) overcast or cloudy, (4) bright though cloudy, (5) bright and clear with very high and very thin overcast, (6) bright and clear, and (7) extremely bright and clear.

Other biological and physical data such as unusual disturbances, wind, etc. were gathered by personal observations and contact with local residents. Local histories provided the necessary historical background.

CHAPTER III

DATA

HYDROGEN ION CONCENTRATION

The pH of the surface station varied from 7.7 to 8.4 (see Graph 1). The pH was above 8.0 during the fall, winter, and spring and below 8.0 during the summer months. The pH was slightly lower in the bottom waters than in the surface waters in most instances, although it followed a cycle of variation similar to that in the surface waters (see Graph 1). It was low in the summer and higher during the fall, winter, and spring. There was one exception. In February the pH dropped in the bottom waters while it rose in the surface waters.

DISSOLVED OXYGEN

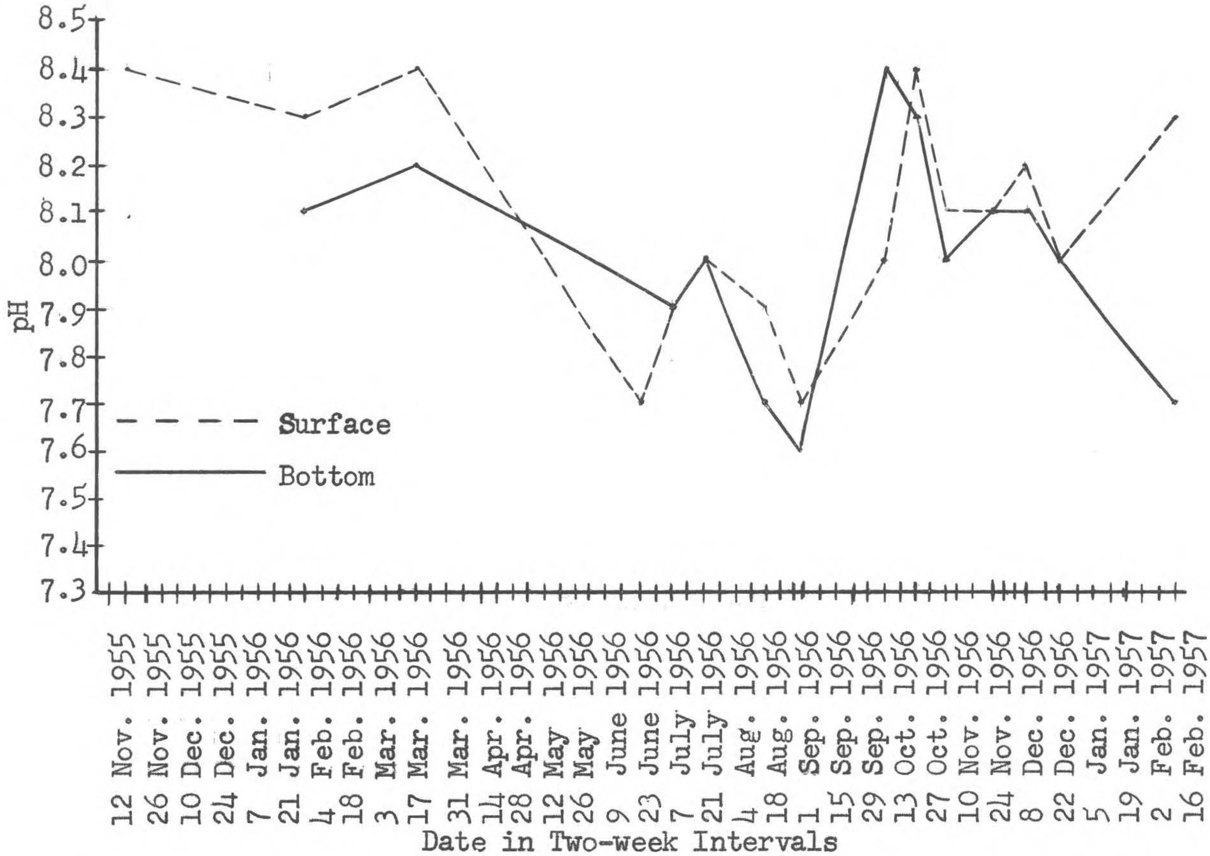
Dissolved oxygen content was taken from late summer of 1956 through late winter of 1957 (see Table 1). There was a slight, but steady increase from late summer through late winter in both surface and bottom waters. The dissolved oxygen content of the bottom waters was slightly lower than that of the surface waters in most instances.

TURBIDITY

The turbidity of the water ranged from one foot eleven inches to five feet nine inches (see Graph 2). The turbidity was highest in August and lowest in January of 1957.

DEPTH

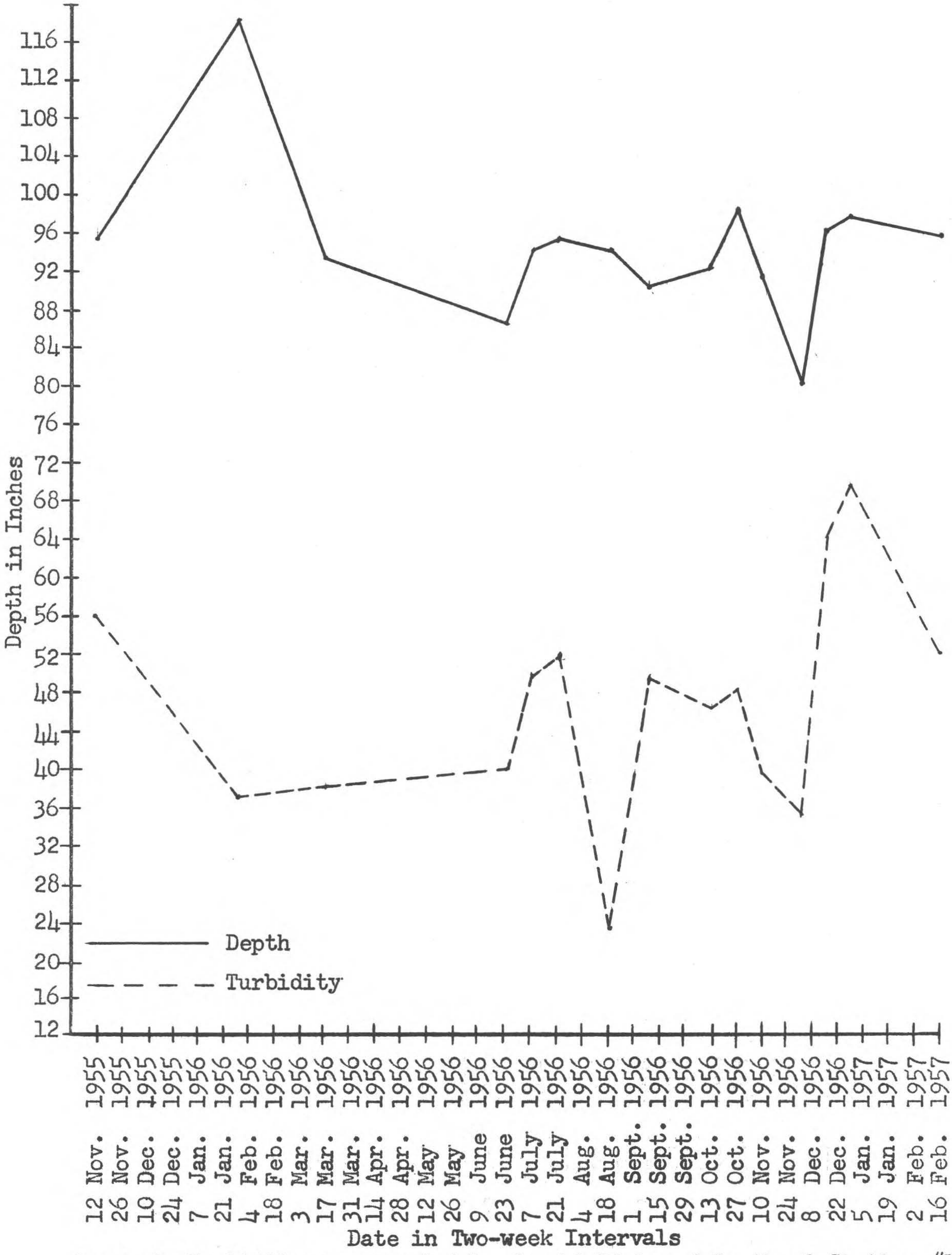
All surface samples were taken from the first foot of water.



Graph 1.-pH of surface and bottom waters at Station #1, Salem Lake

Date	Surface Station		Bottom Station	
	ppm	cc/l	ppm	cc/l
18 Aug. 1956	4.5	3.14	4.1	2.83
13 Oct. 1956	6.2	3.46	5.2	2.90
27 Oct. 1956	6.1	3.32	5.6	3.05
10 Nov. 1956	6.6	3.69	7.3	4.08
1 Dec. 1956	7.0	6.45	6.8	6.27
15 Dec. 1956	6.1	3.41	6.3	3.49
1 Jan. 1957	7.4	3.82	7.5	3.87
16 Feb. 1957	8.9	5.56	7.7	4.81

Table 1.-Dissolved oxygen content of surface and bottom waters at Station #1, Salem Lake



Graph 2.-Turbidity as recorded by Secchi Disk and Depth of Station #1, Salem Lake

Bottom samples were taken from directly below the boat at the same time that the surface samples were being taken. The depth ranged from six feet eight inches to nine feet eleven inches (see Graph 2). The average depth was seven feet ten inches. The average depth of the other stations investigated (see Figure 1) but not reported here were (1) Station #2, four feet four inches; (2) Station #3, eight feet one inch; (3) Station #4, nine feet two inches; (4) Station #5, five feet one inch; (5) Station #6, five feet two inches; (6) Station #7, seven feet.

TIME OF COLLECTIONS

The time of day at which the collections were taken as well as the date of each collection are presented in Table 2. Most of the collections were made in the afternoon. Two were made in the late morning.

BRIGHTNESS OF DAY

The brightness of the day at the time of each collection is indicated in Graph 3. Most of the days were bright; a few in late summer and fall were dark.

FREQUENCY OF COLLECTIONS

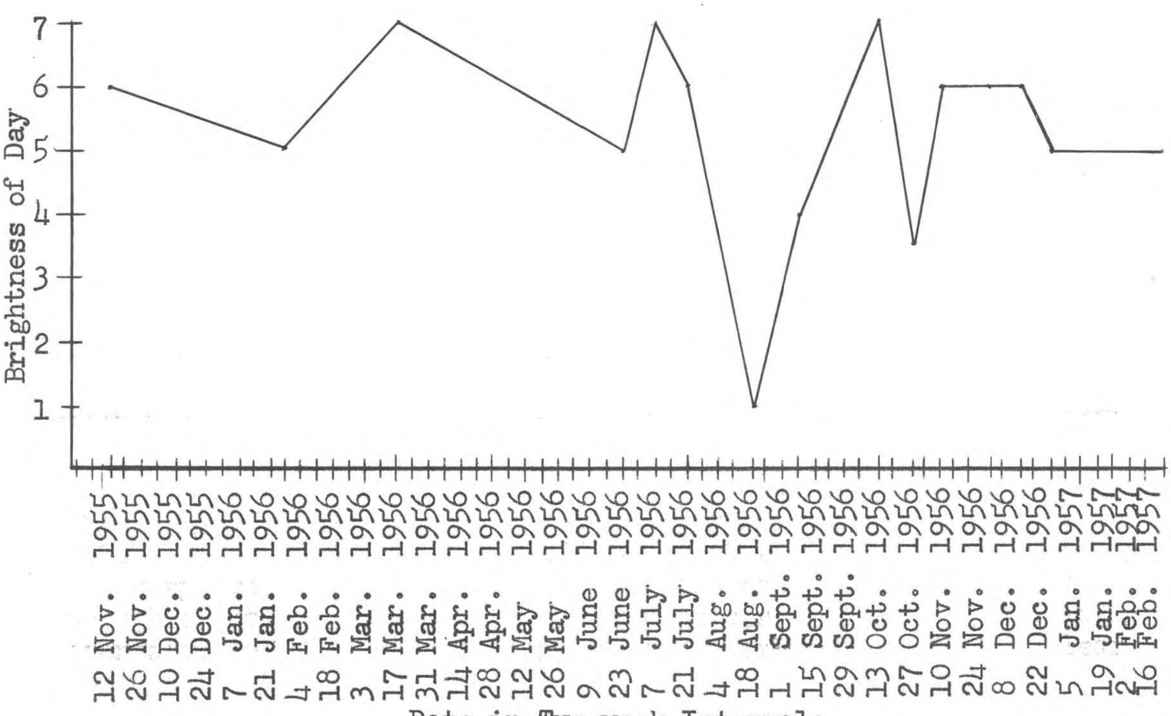
Collections were taken on the average of every four weeks. The actual lapse of time between each collection is indicated in Table 3

TEMPERATURE

Temperature proved to be the most variable factor of the physical environment (see Graph 4). The temperatures of air and water exhibited the same general cycles of variation. The temperature of the surface waters was usually slightly lower than that of the air. Likewise the

Date	Time of Day	Date	Time of Day
12 Nov. 1955	1:00 p.m.	15 Sept. 1956	2:00 p.m.
26 Jan. 1956	3:00 p.m.	13 Oct. 1956	2:15 p.m.
17 Mar. 1956	1:15 p.m.	27 Oct. 1956	11:00 a.m.
23 June 1956	1:30 p.m.	10 Nov. 1956	10:00 a.m.
7 July 1956	1:30 p.m.	1 Dec. 1956	2:45 p.m.
21 July 1956	4:00 p.m.	15 Dec. 1956	2:30 p.m.
18 Aug. 1956	2:00 p.m.	1 Jan. 1957	2:15 p.m.
8 Sept. 1956	. . . . .	16 Feb. 1957	2:30 p.m.

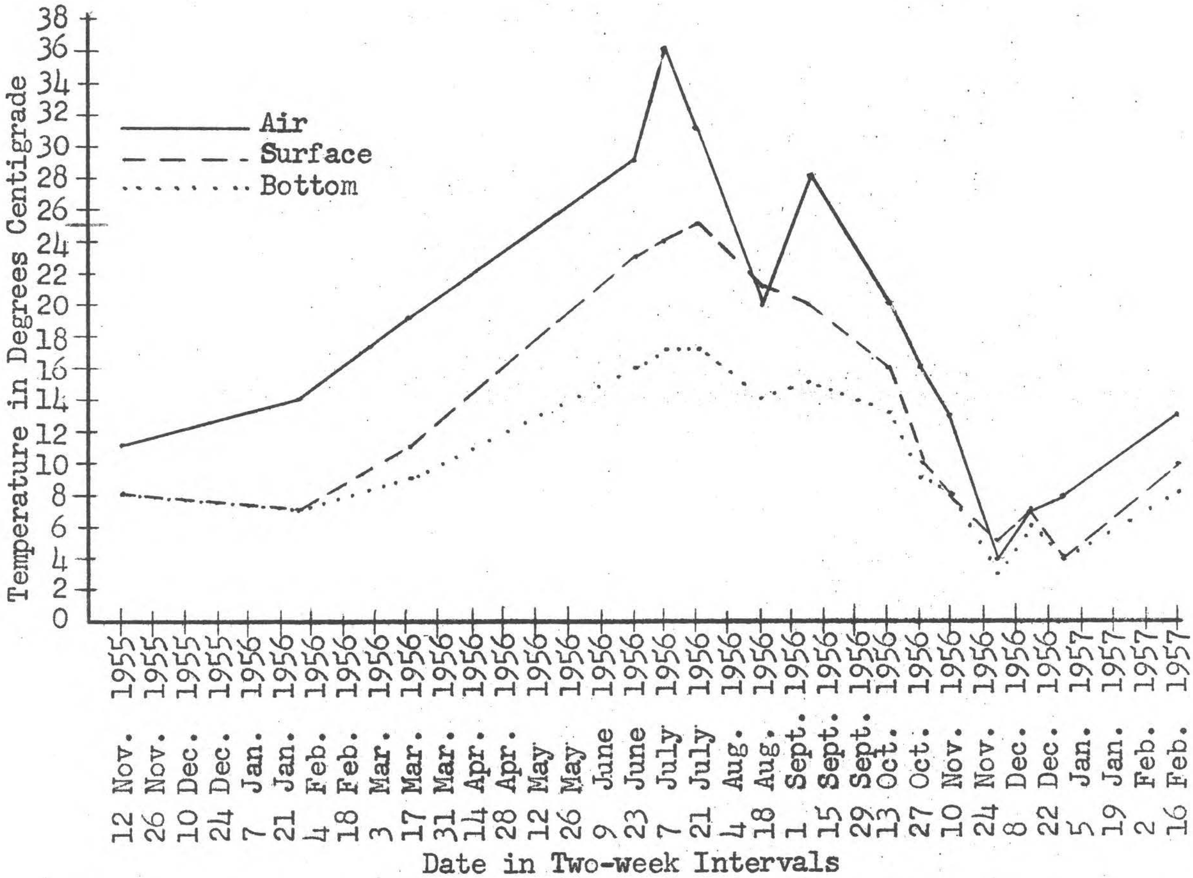
Table 2.-Time of day at which collections were taken at Station #1, Salem Lake



Graph 3.-Brightness of day at time of collections in Station #1, Salem Lake, according to the following arbitrary scale: (1) stormy, (2) very overcast or cloudy, (3) overcast or cloudy, (4) bright though cloudy, (5) bright and clear with very high and very thin overcast, (6) bright and clear, and (7) extremely bright and clear

from	to	# weeks	from	to	# weeks
12 Nov. 1955	26 Jan. 1956	10	15 Sept. 1956	13 Oct. 1956	4
26 Jan. 1956	17 Mar. 1956	7	13 Oct. 1956	27 Oct. 1956	2
17 Mar. 1956	23 June 1956	13	27 Oct. 1956	10 Nov. 1956	2
23 June 1956	7 July 1956	2	10 Nov. 1956	1 Dec. 1956	3
7 July 1956	21 July 1956	2	1 Dec. 1956	15 Dec. 1956	2
21 July 1956	18 Aug. 1956	4	15 Dec. 1956	1 Jan. 1957	2
18 Aug. 1956	8 Sept. 1956	3	1 Jan. 1956	16 Feb. 1957	6
8 Sept. 1956	15 Sept. 1956	1	Average		4

Table 3.-Dates of plankton collections and intervals in weeks between collections



Graph 4.-Temperatures of air and of surface and bottom waters at Station #1, Salem Lake

temperature of the bottom waters was usually slightly lower than that of the surface waters. The temperatures of the air and those of the surface and bottom waters were more nearly equal during the colder months but were more dissimilar during the warmer months. There was one exception. In August the air temperature was one degree below that of the surface waters while the difference between surface and bottom temperatures was about the same as that found during the other summer months. This was presumably due to the cloudiness of the day at the time of collection.

PLANKTON

The density of each species and of the total population for each sample is given in Tables 4 and 5 for the surface and bottom waters respectively. The total population in the surface waters showed three density maxima as opposed to four in the bottom waters (see Graph 5). In the surface waters the maxima occurred in spring, midsummer, and late fall. In the bottom waters the maxima occurred in early spring, early summer, midsummer, and late fall. With the exception of spring, the total population in the surface waters was greater than that in the bottom waters.

Each of the different species reached its maximum density at about the same time that the total populations reached one of its peak densities.

The species responsible for the spring peak density in the surface waters were *Navicula* sp., *Oscillatoria limosa*, *Ceratium hirundinella*, and *Dinobryon sertularia* (see Graph 6). The spring peak density in the bottom waters was due to *Navicula* sp. and *Oscillatoria limosa*.

Species	Density															
Date of Collection	12 Nov. 1955	26 Jan. 1956	17 Mar. 1956	23 June 1956	7 July 1956	21 July 1956	18 Aug. 1956	8 Sept. 1956	15 Sept. 1956	13 Oct. 1956	27 Oct. 1956	10 Nov. 1956	1 Dec. 1956	15 Dec. 1956	1 Jan. 1957	16 Feb. 1957
Anuraea cochlearis	0	5	3	4	0	4	2	1	1	29	0	0	1	0	1	0
Asterionella formosa	1	2	4	14	1	4	0	9	0	3	210	1706	593	7	8	8
Ceratium hirundinella	0	0	0	311	65	117	89	55	1390	787	45	2	4	5	2	1
Cosmarium sp.	0	0	0	0	0	17	113	19	1	0	0	0	0	0	0	0
Dinobryon sertularea	0	0	0	61	24	65	45	43	16	25	210	232	8	0	0	0
Merismopedia elegans	0	0	0	0	0	12	25	0	0	0	0	0	0	0	0	0
Navicula sp.	0	2	85	1	0	76	29	705	3	5	5	6	16	20	22	18
Oscillatoria limosa	0	0	84	0	0	0	0	371	5	0	0	0	0	0	0	4
Pediastrum boryanum	0	0	1	1	1	72	126	26	4	1	0	1	0	1	1	0
Scenedesmus quadricauda	0	0	1	9	16	626	1810	189	28	3	10	5	0	1	1	1
Total	1	9	178	401	107	993	2239	1418	1448	853	480	1952	622	34	35	32

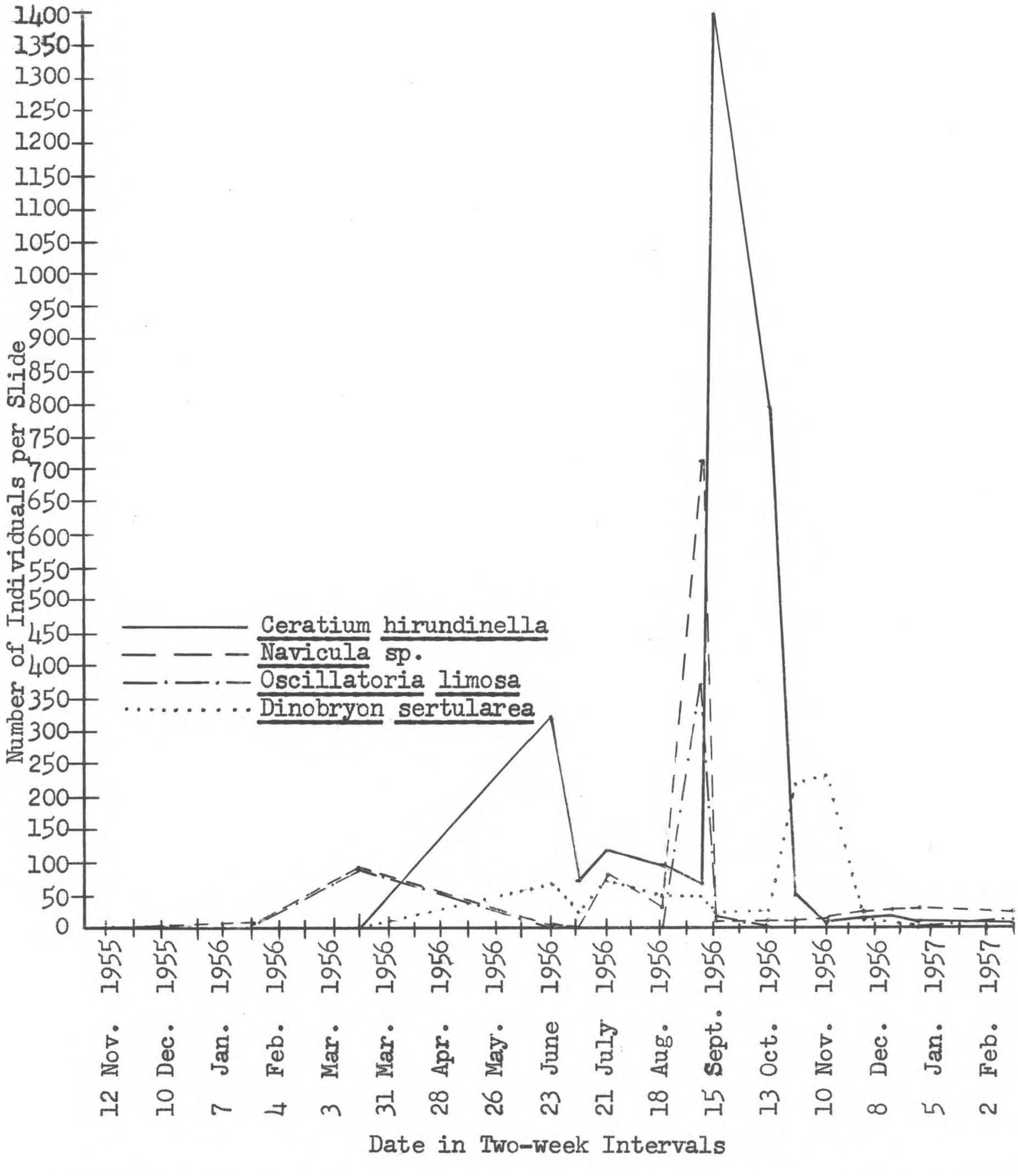
Table 4.-Densities of ten plankton species of the surface waters of Station #1, Salem Lake

Species	12 Nov. 1955	26 Jan. 1956	17 Mar. 1956	23 June 1956	7 July 1956	21 July 1956	18 Aug. 1956	8 Sept. 1956	15 Sept. 1956	13 Oct. 1956	27 Oct. 1956	10 Nov. 1956	1 Dec. 1956	15 Dec. 1956	1 Jan. 1956	16 Feb. 1956
	Density															
Anuraea cochlearis	1	0	0	0	4	1	1	2	0	0	0	1	0	4	00	0
Asterionella formosa	2	1	4	9	1	8	66	22	2	4	92	834	100	5	3	1
Ceratium hirundinella	2	0	0	9	19	4	195	5	1	7	0	0	0	0	0	0
Cosmarium sp.	0	0	0	0	9	6	5	2	1	1	0	0	0	0	0	0
Dinobryon sertularea	0	0	0	10	53	205	167	192	27	169	80	65	3	0	0	0
Merismopedia elegans	0	0	0	0	11	0	0	0	0	1	0	0	0	0	0	0
Navicula sp.	14	11	633	10	64	52	42	31	53	39	10	8	49	73	19	77
Oscillatoria limosa	0	1	93	0	0	0	1	3	0	0	0	1	0	0	0	4
Pediastrum boryanum	1	0	7	1	57	15	23	14	13	5	0	1	2	9	0	1
Scenedesmus quadricauda	1	0	13	22	779	140	217	192	194	73	23	22	15	3	0	10
Total	21	13	750	61	997	431	717	463	291	299	205	932	169	94	22	93

Date of Collection

Table 5.-Densities of ten plankton species of the bottom waters of Station #1, Salem Lake

Graph 5.-Total population densities of surface and bottom waters of Station #1, Salem Lake



Graph 6.-Densities of four species which represent the spring maximum in surface waters, and which also have a fall peak period

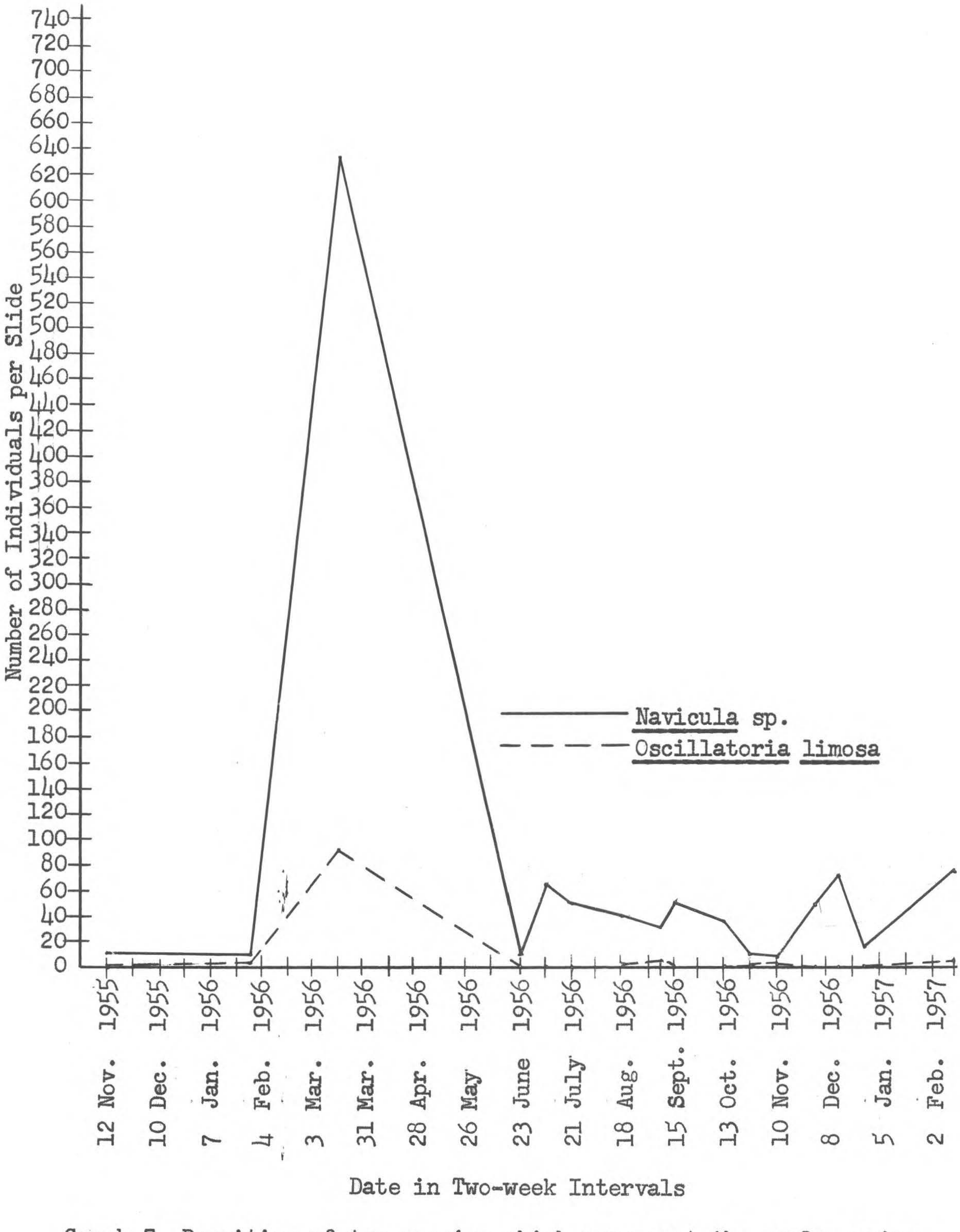
This is shown in Graph 7. All those species forming maxima in the surface waters in the spring also formed maxima in the fall. The fall maximum reached by each of these species was greater than that reached in the spring. Navicula sp. and Oscillatoria limosa, which formed peak densities in the bottom waters in the spring, did not form peak densities again in the fall, although Navicula sp. was fairly high in numbers throughout most of the fall and winter. Ceratium hirundinella and Dinobryon sertularia were low in numbers in the bottom waters in spring but formed a small peak density in the fall.

An early summer maximum density was reached in the bottom waters but not in the surface waters. Those species which participated in this maximum were Scenedesmus quadricauda and Pediastrum boryanum (see Graph 8), and Cosmarium sp., Anuraea cochlearis, and Merismopedia elegans (see Graph 8A).

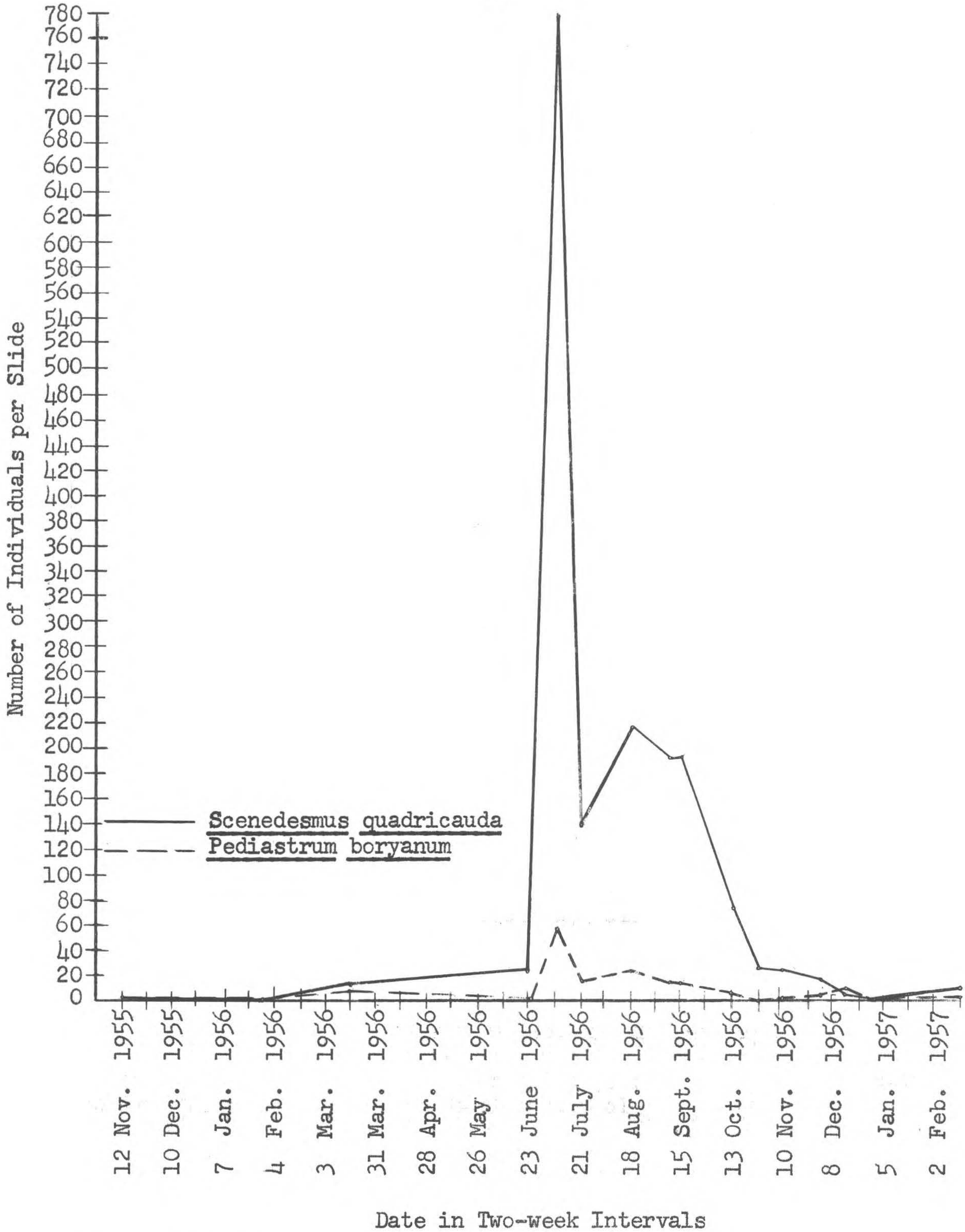
Scenedesmus quadricauda, Cosmarium sp., Pediastrum boryanum, and Merismopedia elegans all reached a midsummer peak density in the surface waters (see Graph 9), but not in the bottom waters. Asterionella formosa, Ceratium hirundinella, and Dinobryon sertularia all reached peak densities at the same time in the bottom waters (see Graph 10).

Anuraea cochlearis and Asterionella formosa reached maximum densities in the late fall in the surface waters (see Graph 11), while Asterionella formosa reached a maximum in the bottom waters at the same time (see Graph 12).

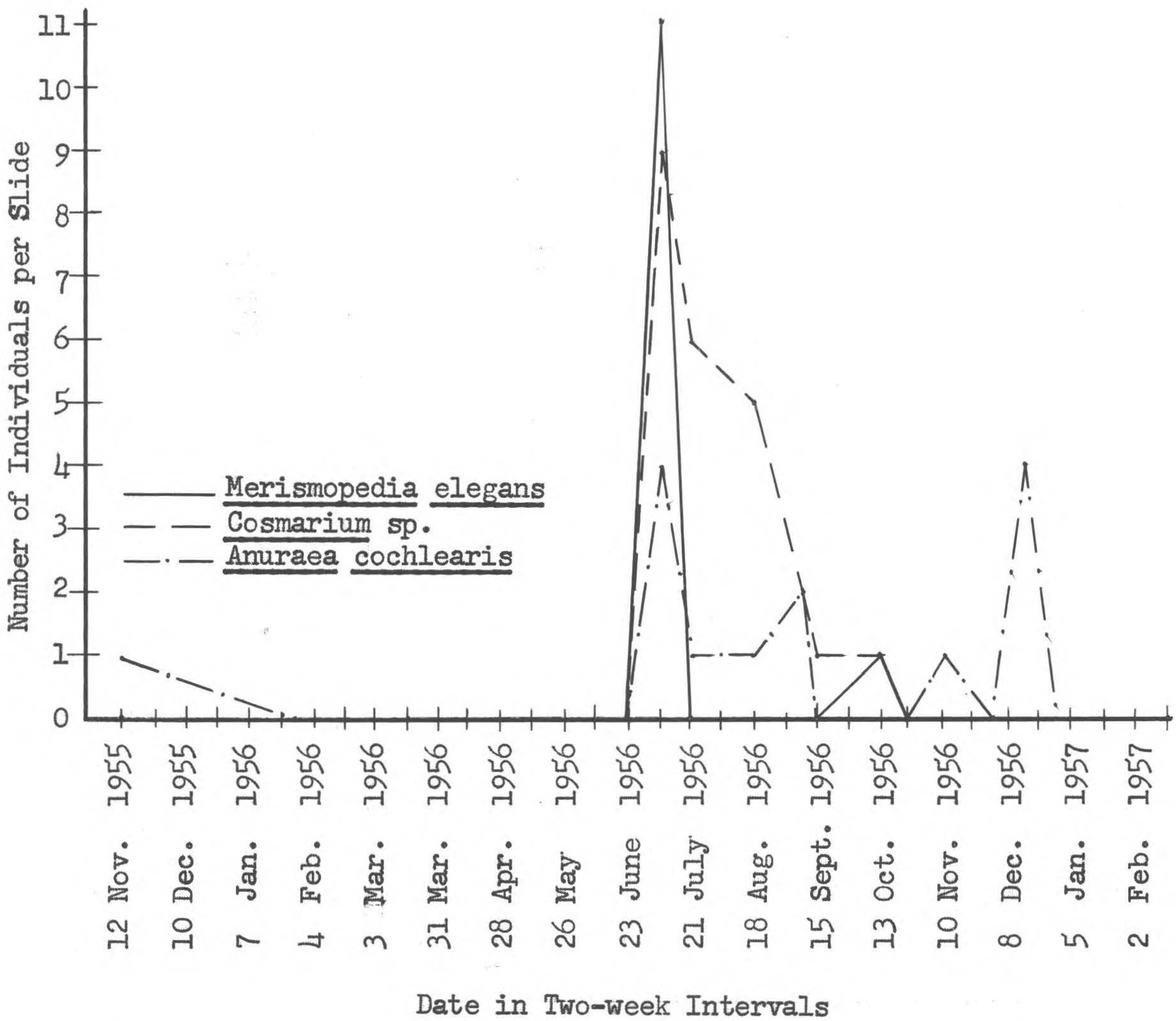
Most of the species studied showed differences in periodicity in the surface and bottom waters. Anuraea cochlearis reached its greatest density, 29, in the surface waters in the fall, but it was insignificant



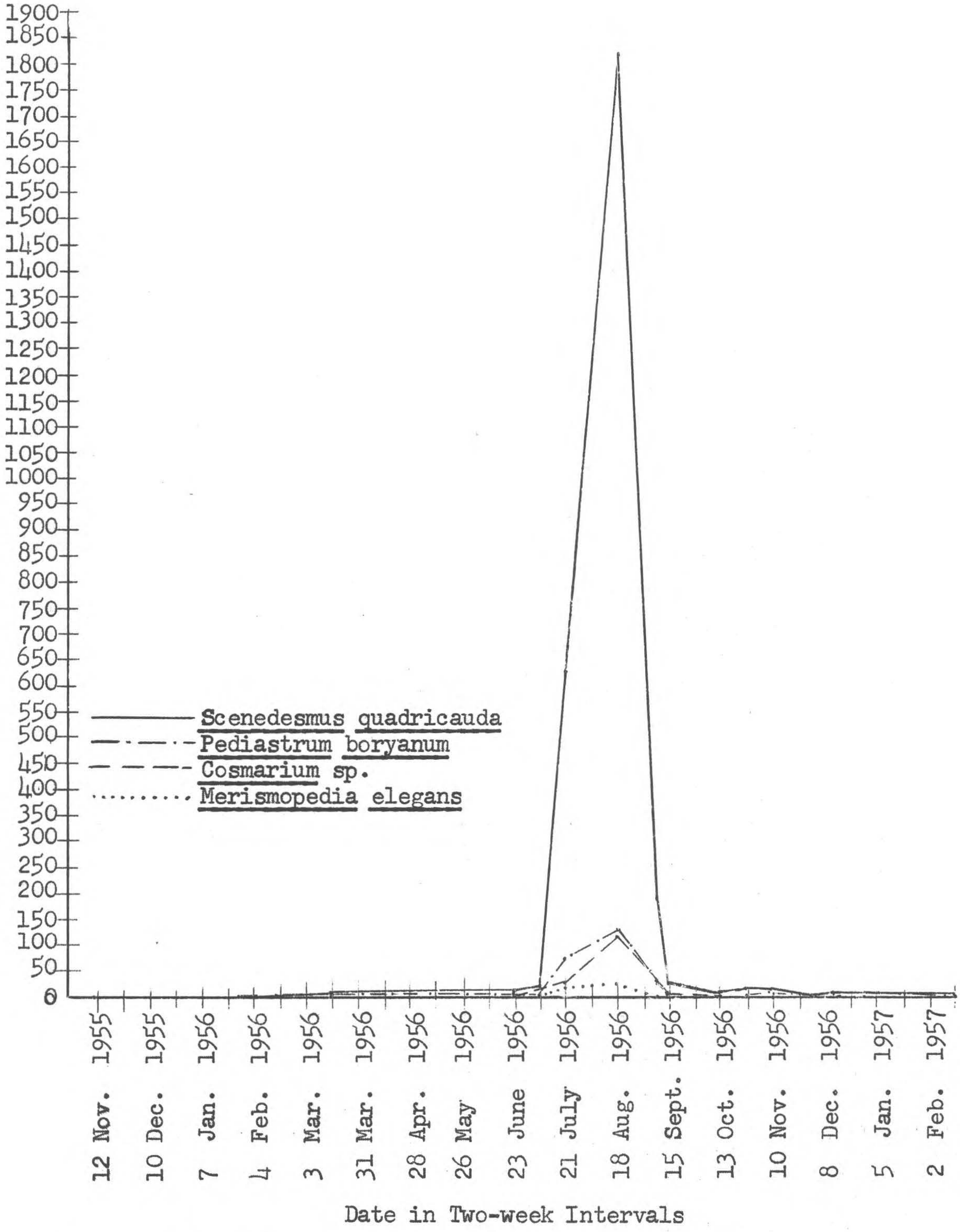
Graph 7.-Densities of two species which represent the early spring maximum in bottom waters of Station #1, Salem Lake



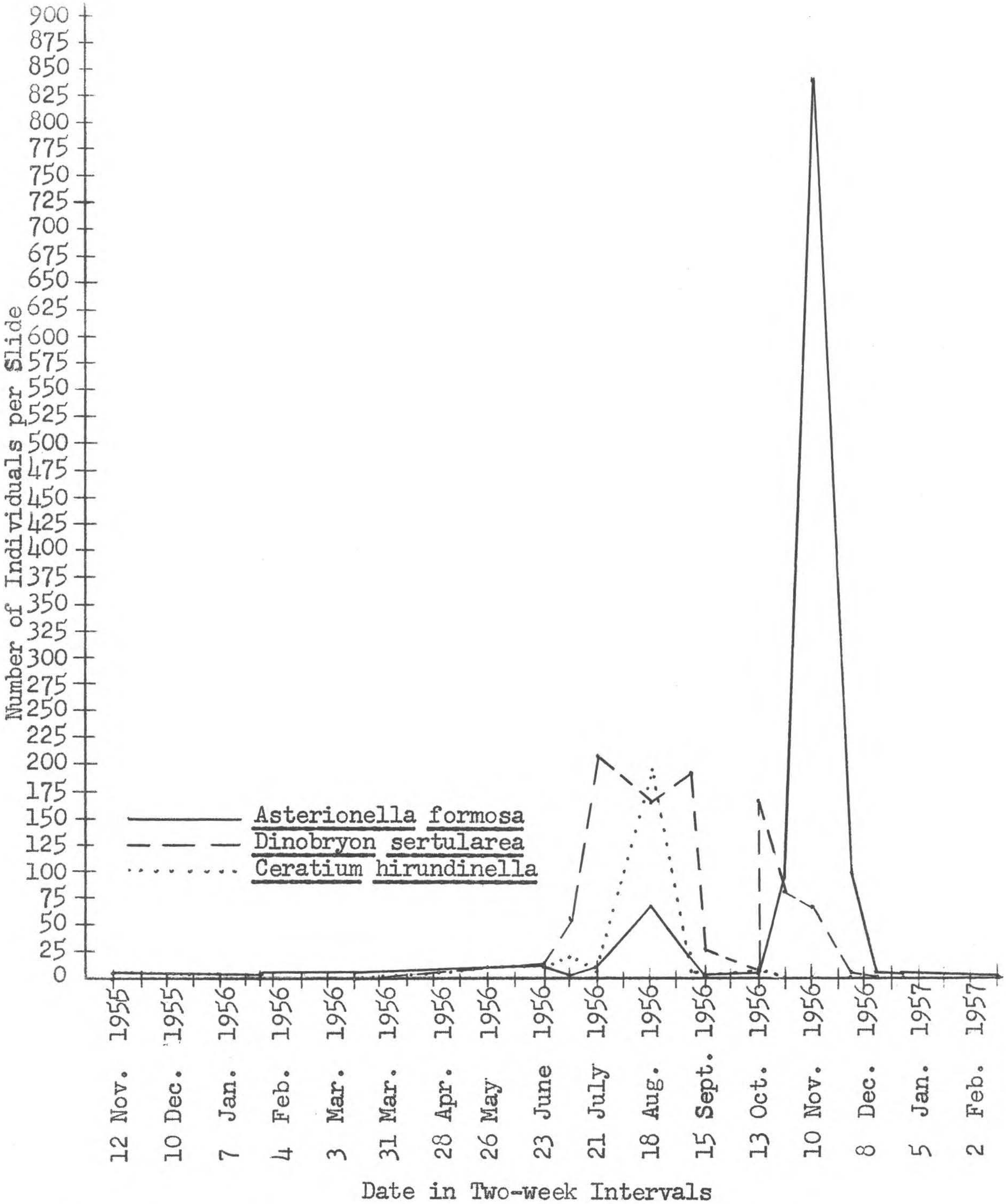
Graph 8.-Densities of two species which represent the early summer maximum in bottom waters of Station #1, Salem Lake



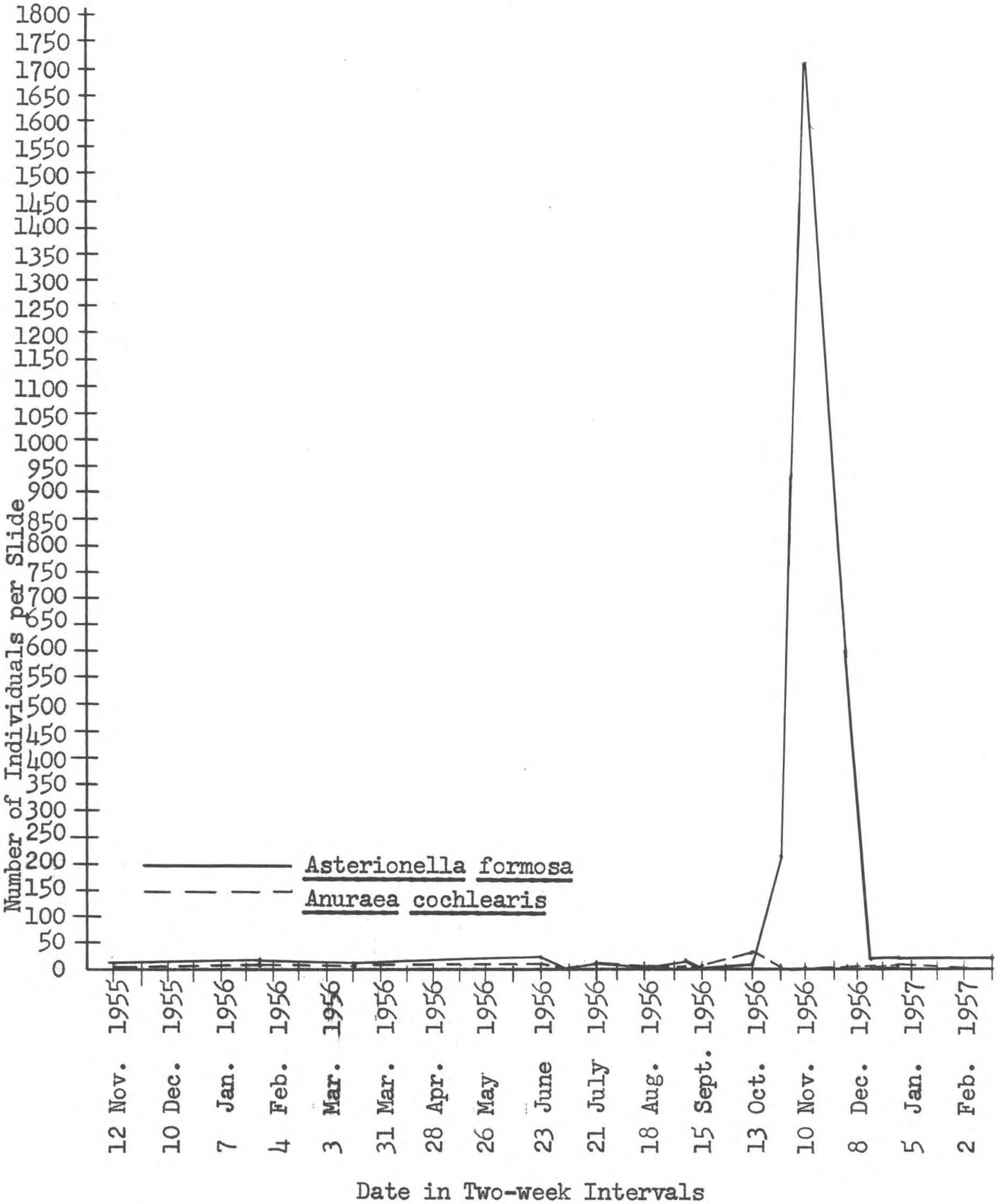
Graph 8A.-Densities of three species which represent the early summer maximum in bottom waters of Station #1, Salem Lake.



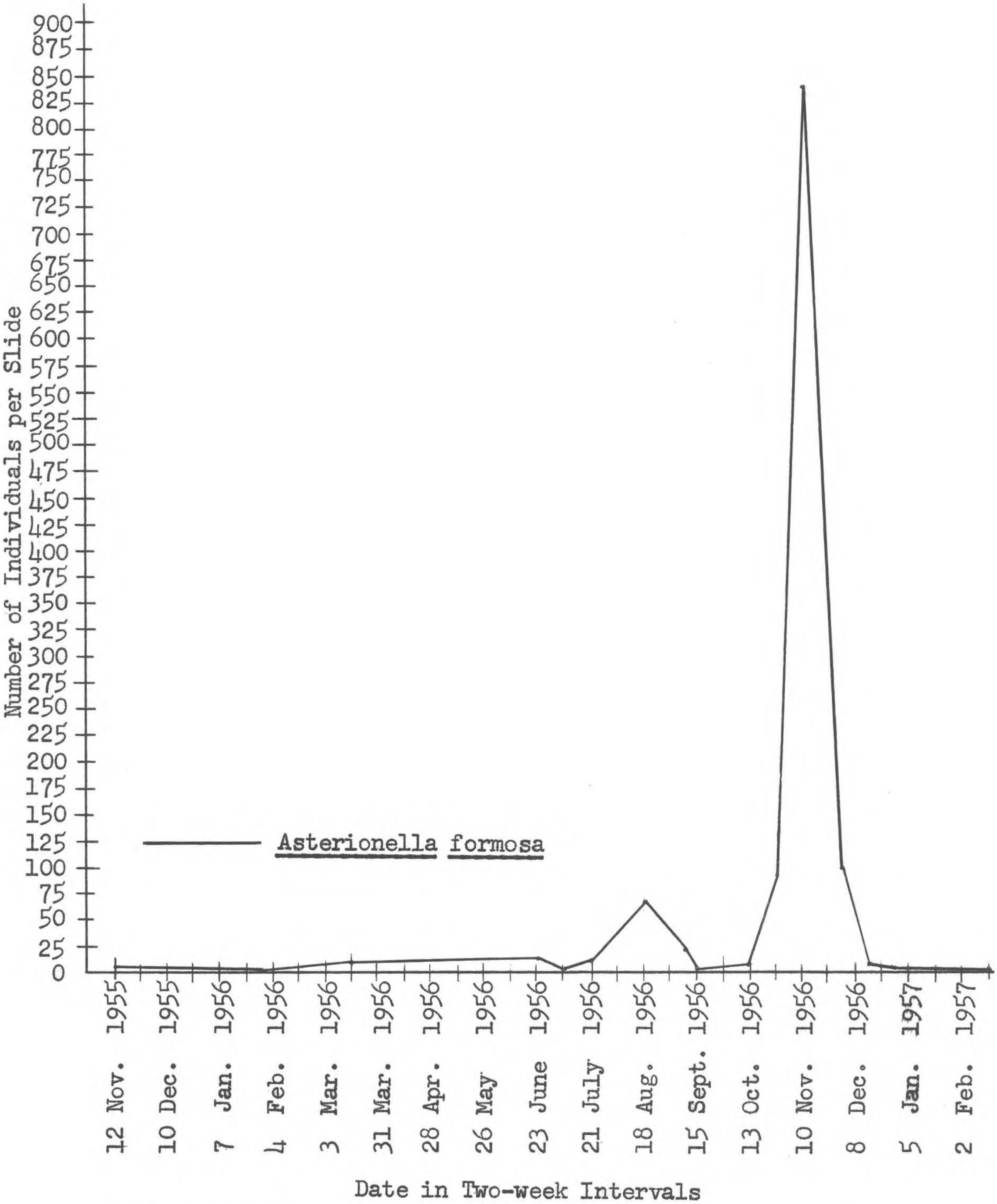
Graph 9.-Densities of four species which represent the midsummer maximum in surface waters of Station #1, Salem Lake



Graph 10.-Densities of three species which represent the midsummer maximum in bottom waters of Station #1, Salem Lake



Graph 11.-Densities of two species which represent the late fall maximum in surface waters of Station #1, Salem Lake



Graph 12.-Density of the one species which represents the late fall maximum in bottom waters of Station #1, Salem Lake

in the bottom waters (see Graph 13). Its greatest densities there were 4 in July and 4 in December.

Asterionella formosa reached its greatest density in the late fall in both surface and bottom waters (see Graph 14). The numbers were 1706 in the surface waters and 834 in the bottom waters. It also reached a slight peak density of 66 in the midsummer in the bottom waters.

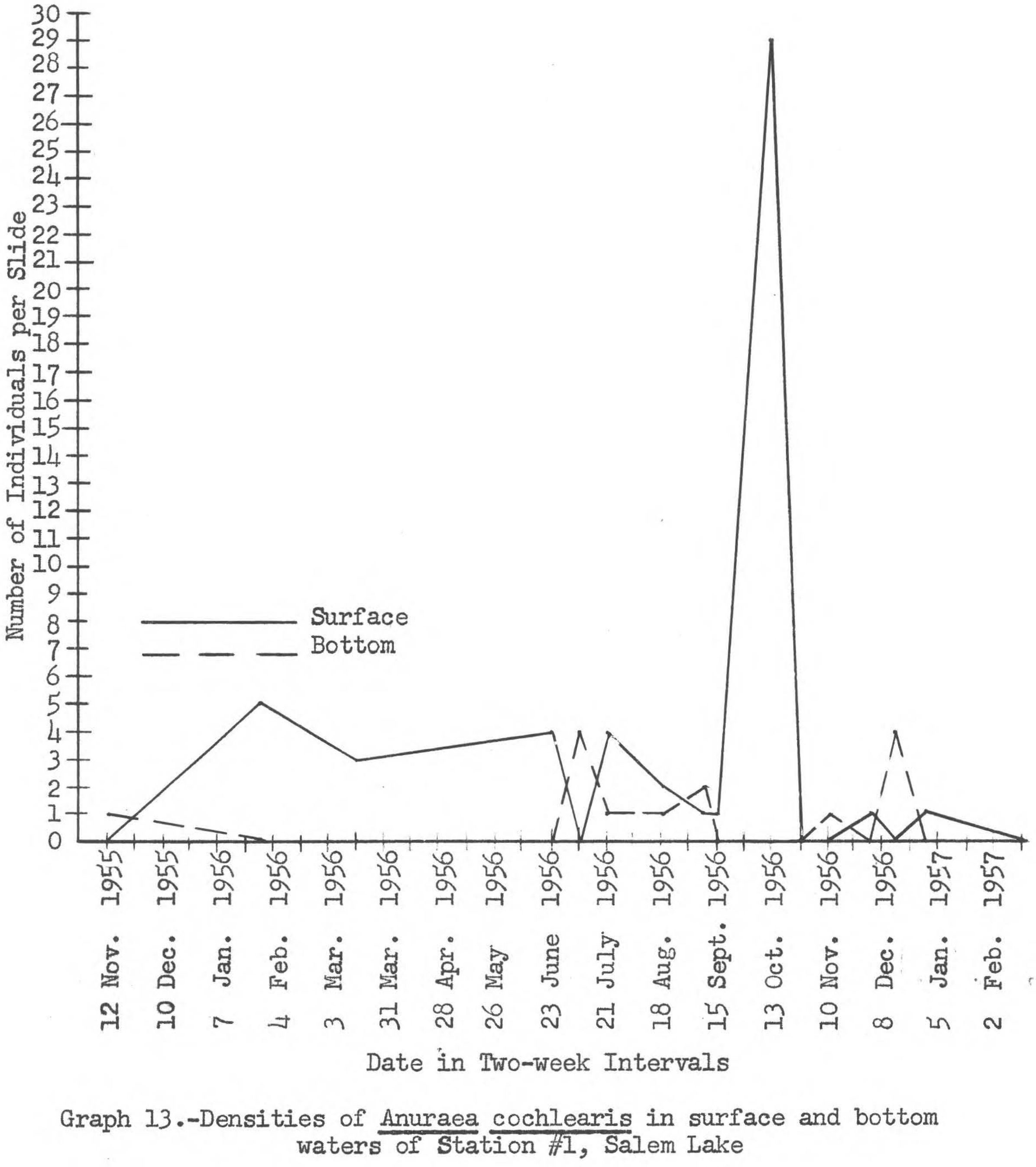
Ceratium hirundinella reached peak densities of 311 in the spring and 1390 in the fall in the surface waters and a single peak density of 195 in midsummer in the bottom waters (see Graph 15).

Cosmarium sp. reached a minor peak density of 9 in the bottom waters in early summer and a peak density of 113 in the surface waters in midsummer (see Graph 16).

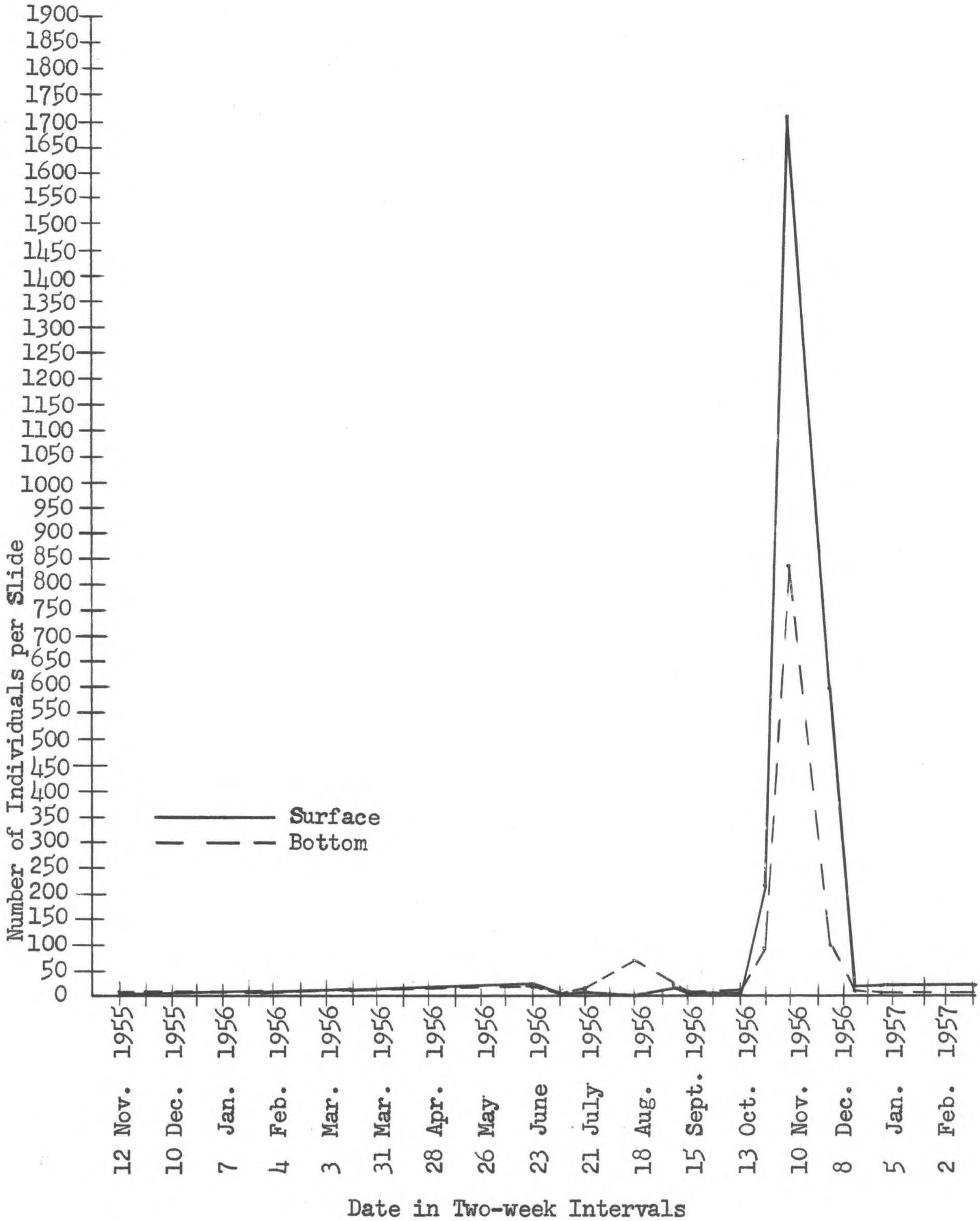
Dinobryon sertularea reached a fairly high density level of about 65 in the late spring and early summer and a definite peak density of 232 in the late fall in the surface waters. It reached a high density level of about 200 in the summer and a peak density of 169 in the fall in the bottom waters. The summer maximum density in the bottom waters was slightly behind that in the surface waters. The fall maximum density in the bottom waters was slightly ahead of that in the surface waters (see Graph 17).

Merismopedia elegans attained a peak density of 11 in the bottom waters in early summer and a peak density of 25 in the surface waters in midsummer (see Graph 18).

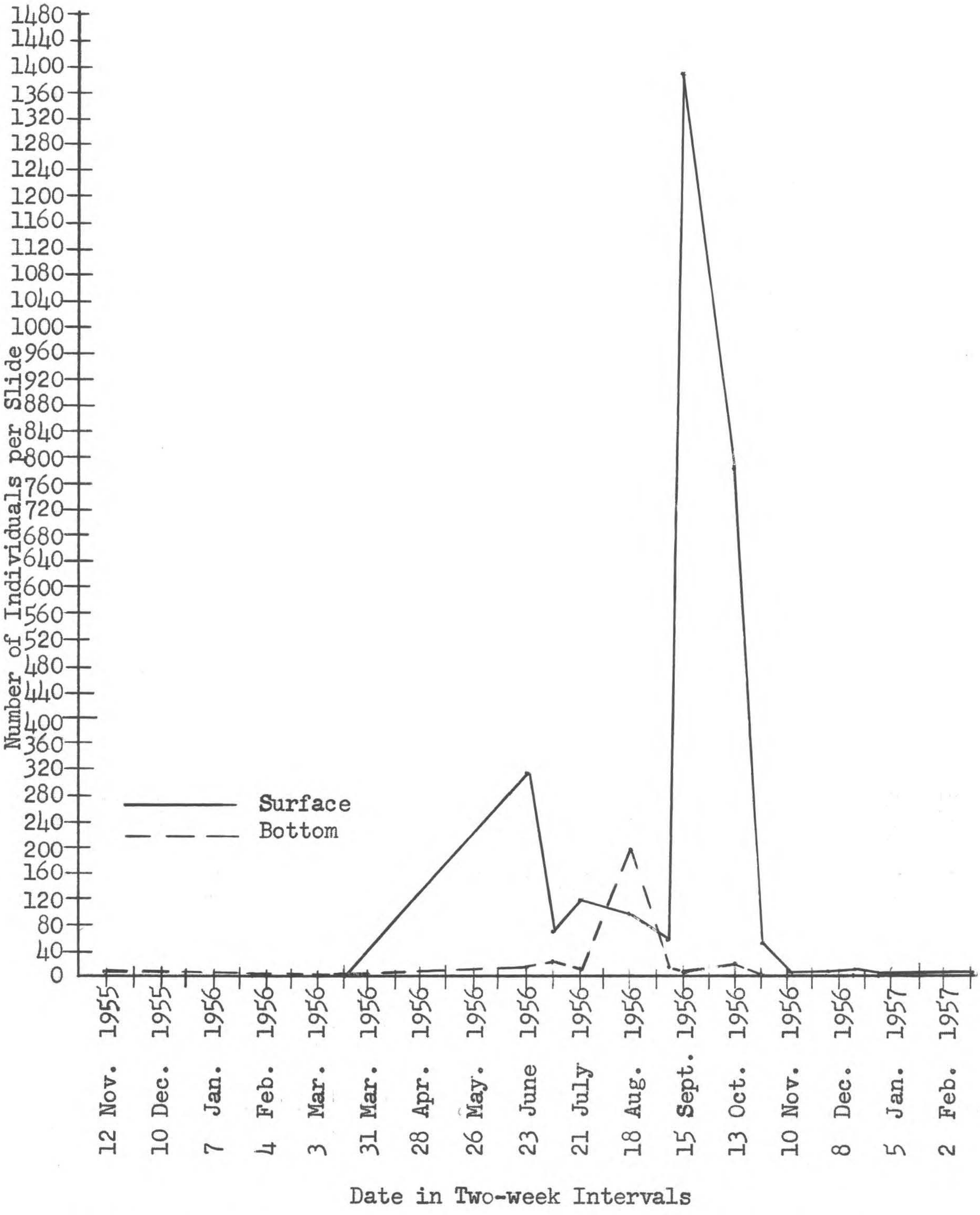
Navicula sp. reached a minor peak density in the spring and a major peak density in the fall in the surface waters (see Graph 19). The numbers were 85 in the spring and 705 in the fall. In the bottom



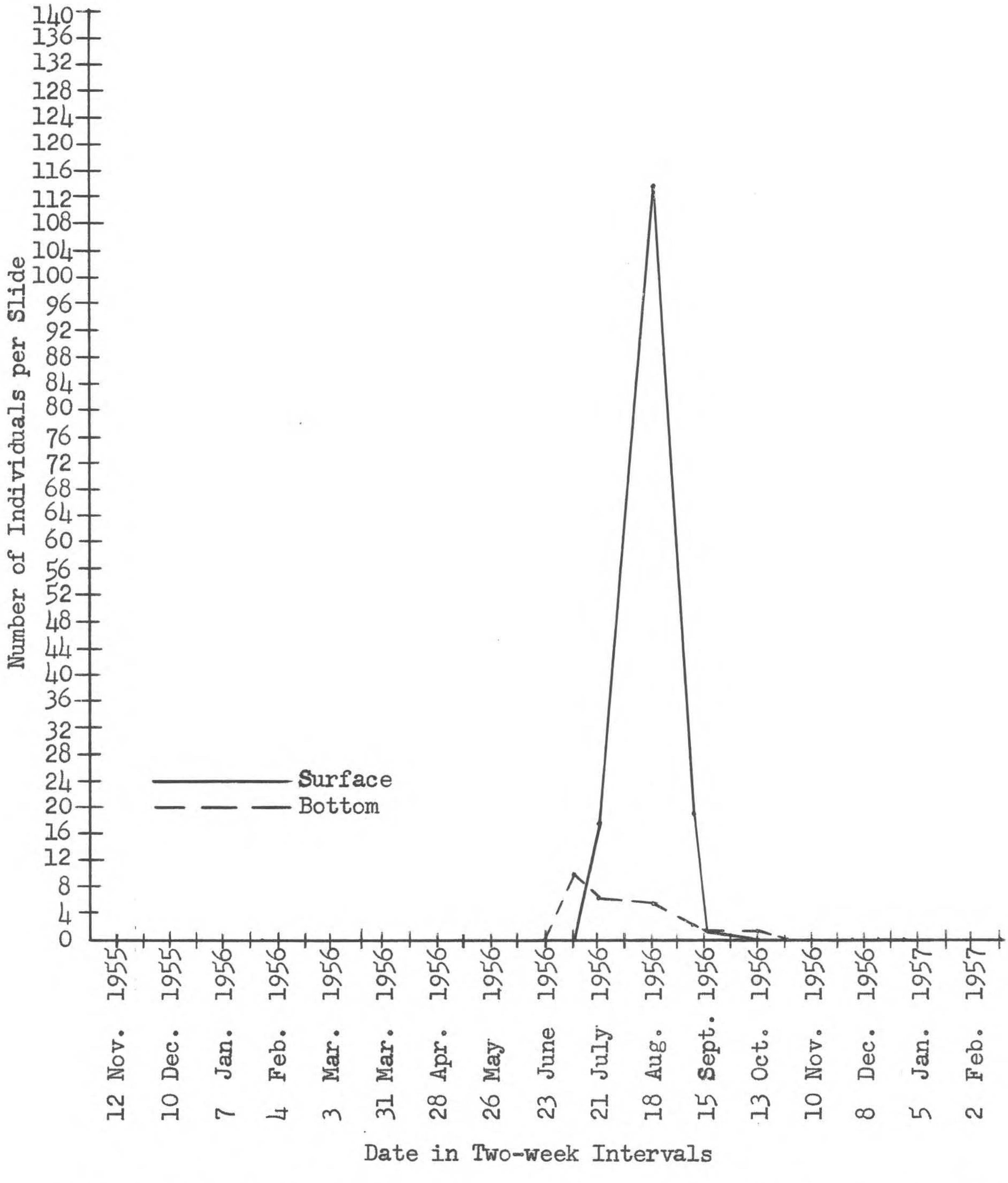
Graph 13.-Densities of <u>Anuraea cochlearis</u> in surface and bottom waters of Station #1, Salem Lake



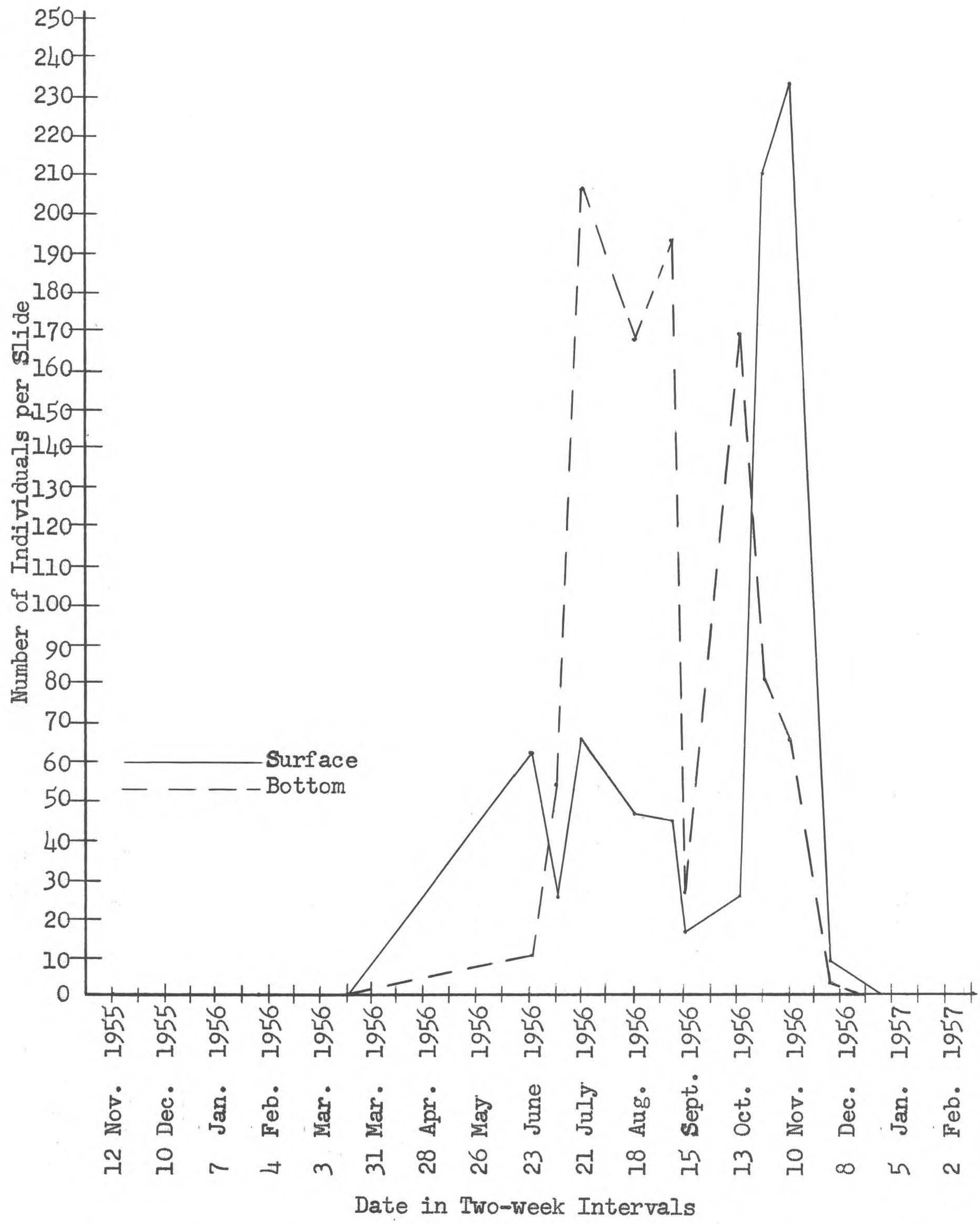
Graph 14.-Densities of Asterionella formosa in surface and bottom waters of Station #1, Salem Lake



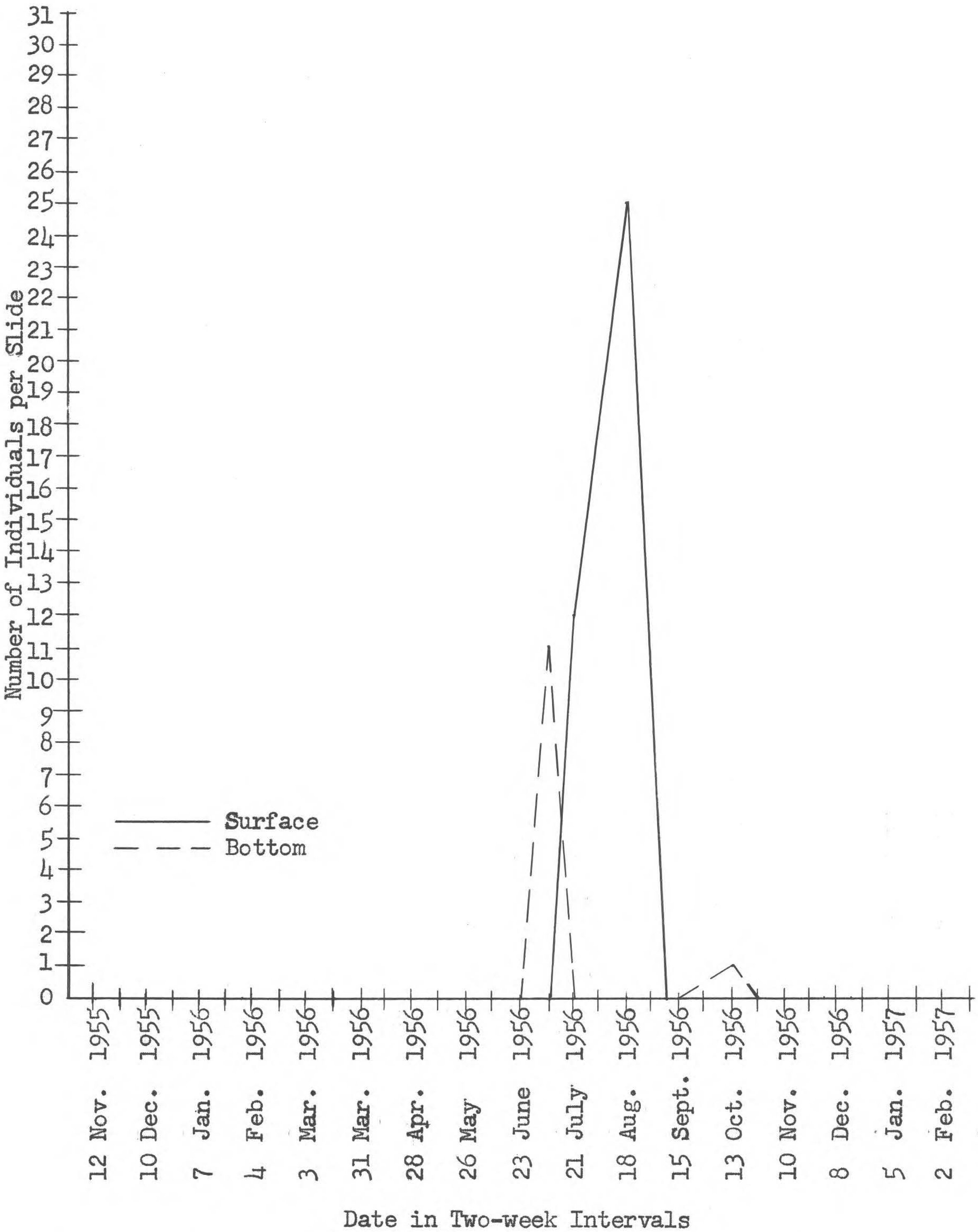
Graph 15.-Densities of Ceratium hirundinella in surface and bottom waters of Station #1, Salem Lake



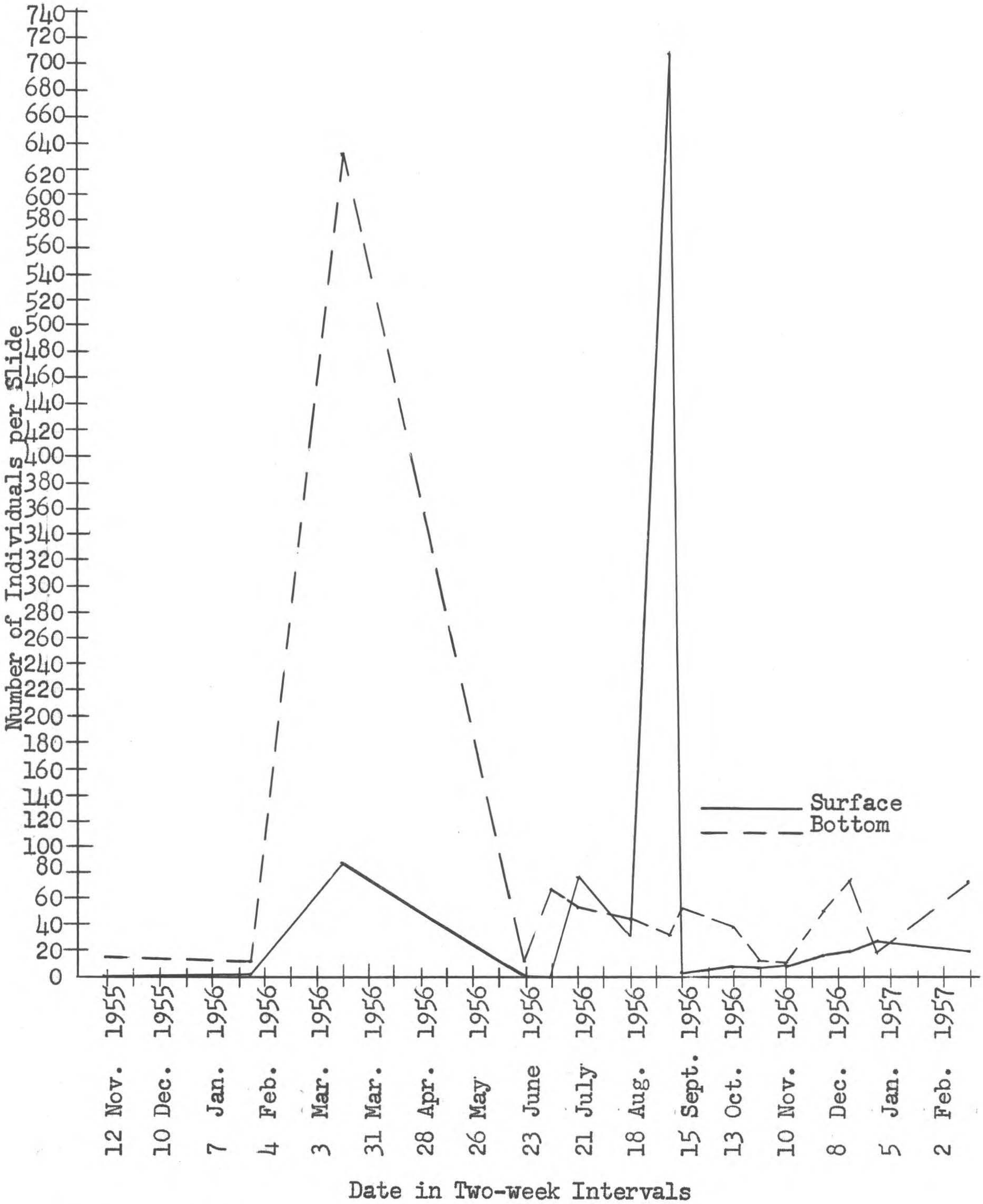
Graph 16.-Densities of Cosmarium sp. in surface and bottom waters of Station #1, Salem Lake



Graph 17.-Densities of Dinobryon sertularea in surface and bottom waters of Station #1, Salem Lake



Graph 18.-Densities of Merismopedia elegans in surface and bottom waters of Station #1, Salem Lake



Graph 19.-Densities of Navicula sp. in surface and bottom waters of Station #1, Salem Lake

waters Navicula sp. attained a minor peak density of 64 in the early summer and a major peak density of 633 in the spring. A fairly high level of about 50 was maintained throughout the winter.

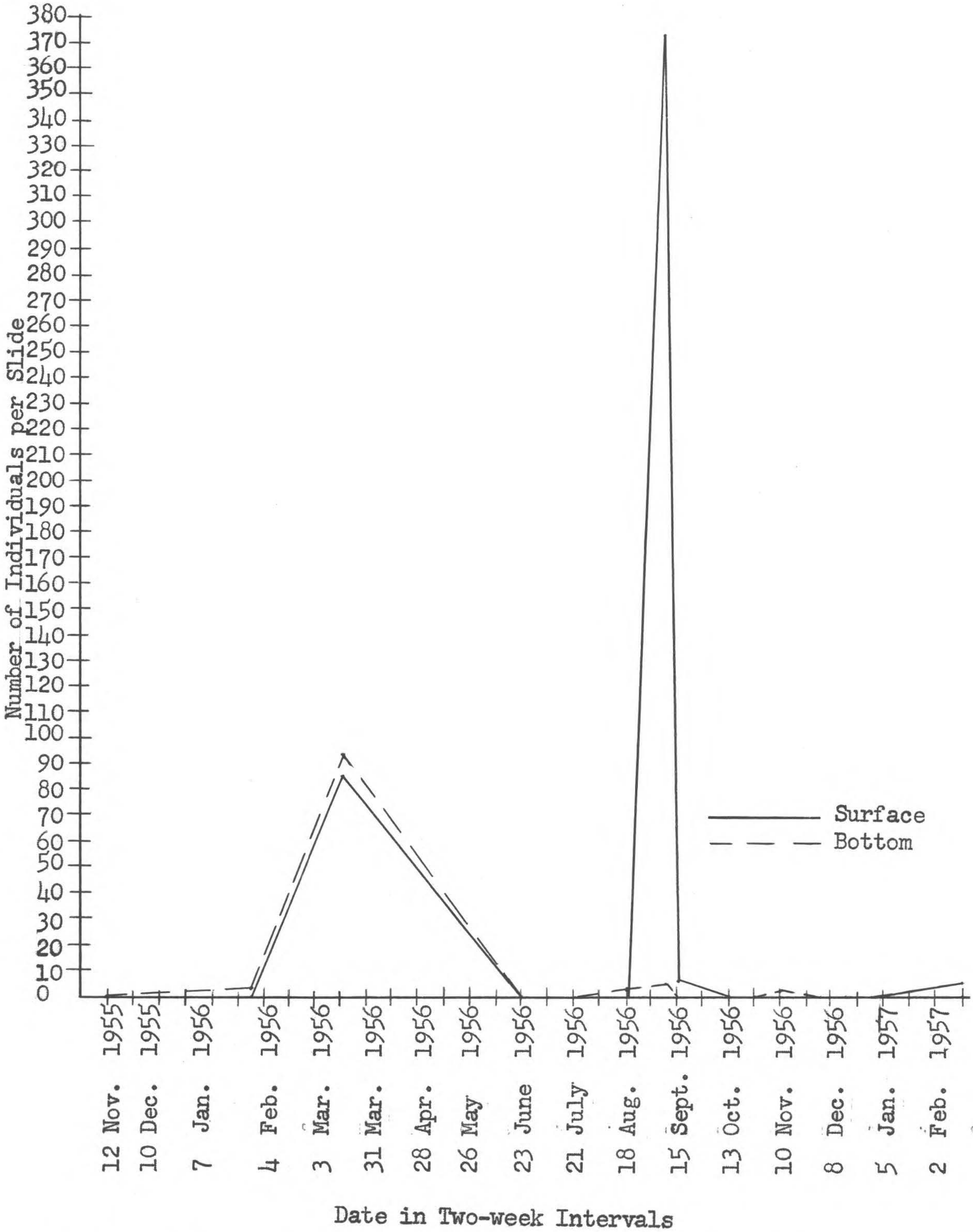
Oscillatoria limosa reached peak densities of 84 and 93 in surface and bottom waters respectively in the spring. It reached a major peak density of 371 in the surface waters in the fall, but no peak density was attained in the bottom waters. However, it was present again in the bottom waters at that time after being absent during the summer months (see Graph 20).

Pediastrum boryanum attained a peak density of 57 in the bottom waters in the early summer and a peak density of 126 in the surface waters in midsummer (see Graph 21).

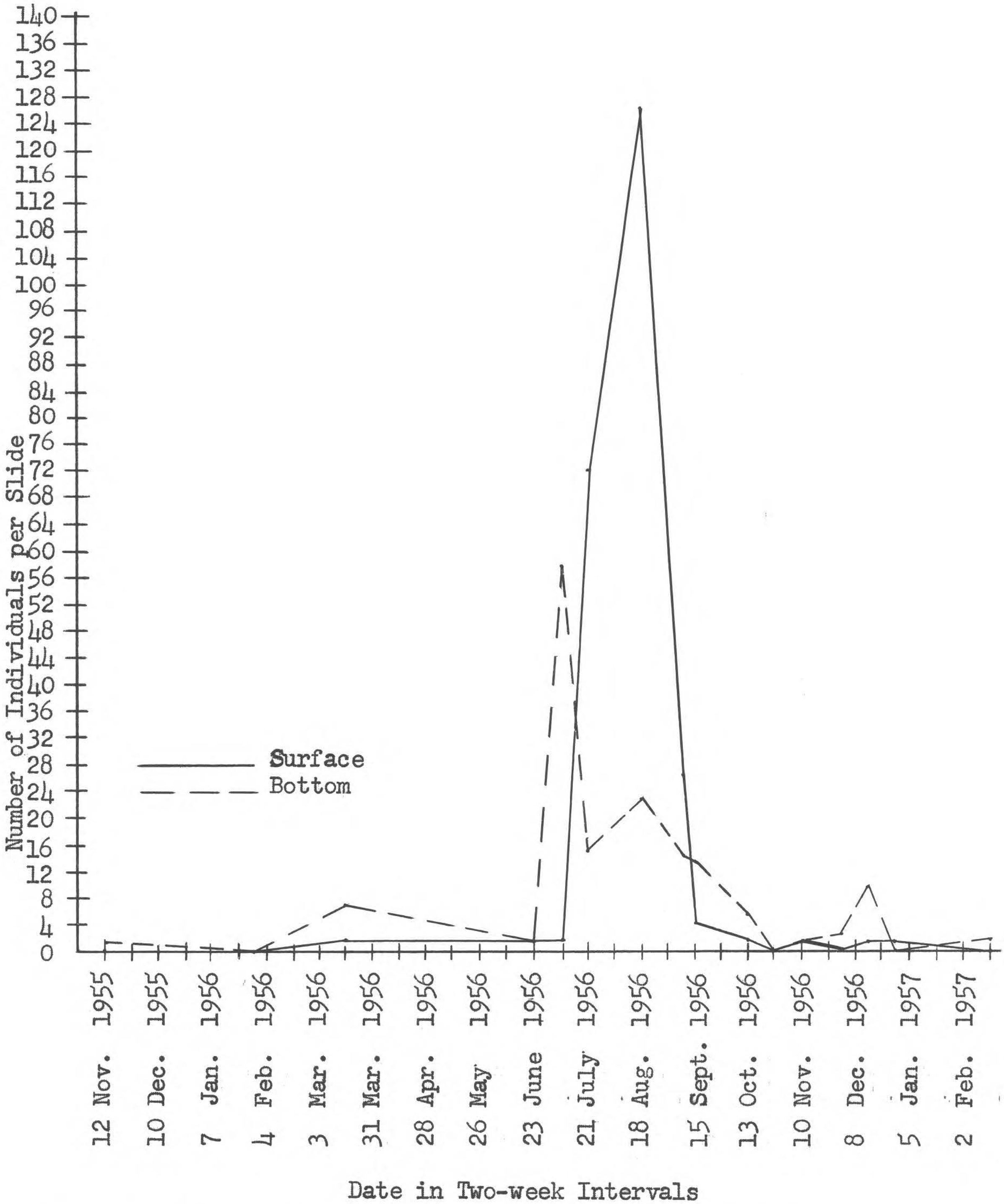
Scenedesmus quadricauda followed the same pattern as Pediastrum boryanum, reaching a peak density of 779 in the bottom waters in early spring and a peak density of 1810 in the surface waters in midsummer (see Graph 22).

Certain species were present throughout a large portion of the year (see Tables 6 and 7). Navicula sp. and Asterionella formosa were present all year in the bottom waters and were missing from surface samples only twice. Navicula sp. was usually present in greater abundance. Ceratium hirundinella was abundant from spring through fall in the surface waters only. Dinobryon sertularea was fairly abundant from spring through fall in both surface and bottom waters. Pediastrum boryanum and Scenedesmus quadricauda were both present nearly all year in the bottom waters, although in high numbers only during the summer.

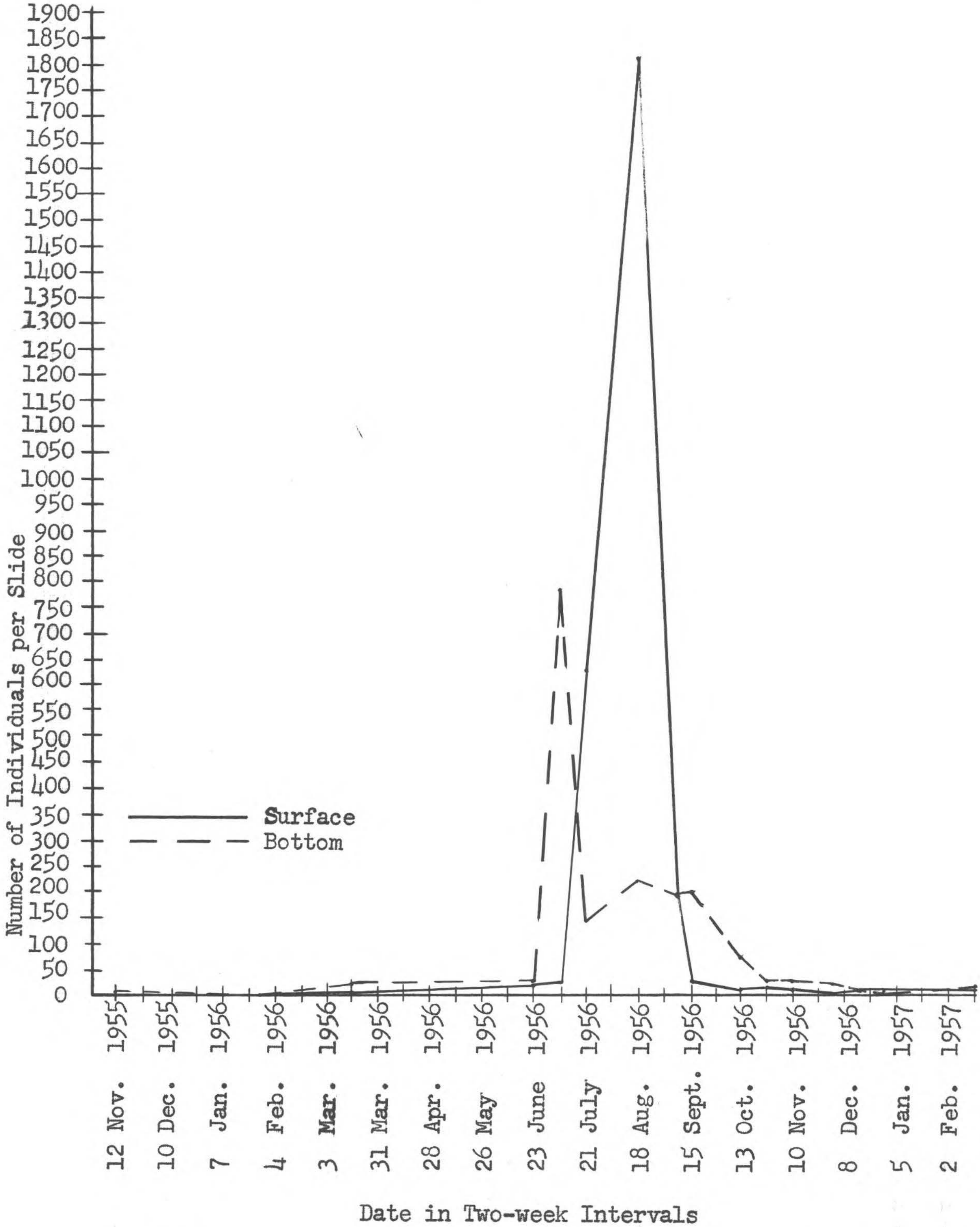
The percent density and percent frequency data for the surface



Graph 20.-Densities of Oscillatoria limosa in surface and bottom waters of Station #1, Salem Lake



Graph 21.-Densities of Pediastrum boryanum in surface and bottom waters of Station #1, Salem Lake



Graph 22.-Densities of Scenedesmus quadricauda in surface and bottom waters of Station #1, Salem Lake

Species	12 Nov. 1955	26 Jan. 1956	17 Mar. 1956	23 June 1956	7 July 1956	21 July 1956	18 Aug. 1956	8 Sept. 1956	15 Sept. 1956	13 Oct. 1956	27 Oct. 1956	10 Nov. 1956	1 Dec. 1956	15 Dec. 1956	1 Jan. 1957	16 Feb. 1957	Percent Frequency
	Percent Densities																
Anuraea cochlearis	0	59.6	1.7	1.0	0	0.4	0.1	0.1	0.1	3.4	0	0	0.2	0	2.9	0	62
Asterionella formosa	100	22.2	2.2	3.5	0.9	0.4	0	0.6	0	0.4	43.8	87.4	95.3	20.6	22.9	25.0	88
Ceratium hirundinella	0	0	0	77.6	60.7	11.8	4.0	3.9	96.0	92.3	9.4	0.1	0.6	14.7	5.7	3.1	81
Cosmarium sp.	0	0	0	0	0	1.7	5.0	1.3	0.1	0	0	0	0	0	0	0	25
Dinobryon sertularea	0	0	0	15.2	22.4	6.5	2.0	3.0	1.1	2.9	43.8	11.9	1.3	0	0	0	62
Merismopedia elegans	0	0	0	0	0	1.2	1.1	0	0	0	0	0	0	0	0	0	13
Navicula sp.	0	22.2	47.8	0.2	0	7.7	1.3	49.7	0.2	0.6	1.0	0.3	2.6	58.8	62.9	56.3	88
Oscillatoria limosa	0	0	47.2	0	0	0	0	26.2	0.3	0	0	0	0	0	0	12.5	25
Pediastrum boryanum	0	0	0.6	0.2	0.9	7.3	5.6	1.8	0.3	0.1	0	0.1	0	2.9	2.9	0	69
Scenedesmus quadricauda	0	0	0.6	2.2	15.0	63.0	80.8	13.3	1.9	0.4	2.0	0.3	0	2.9	2.9	3.1	81

Date of Collection

Table 6.-Percent densities and percent frequencies of ten plankton species of the surface waters of Station #1, Salem Lake

Species	12 Nov. 1955	26 Jan. 1956	17 Mar. 1956	23 June 1956	7 July 1956	21 July 1956	18 Aug. 1956	8 Sept. 1956	15 Sept. 1956	13 Oct. 1956	27 Oct. 1956	10 Nov. 1956	1 Dec. 1956	15 Dec. 1956	1 Jan. 1957	16 Feb. 1957	Percent Frequency
	Percent Densities																
Anuraea cochlearis	4.8	0	0	0	0.4	0.2	0.1	0.4	0	0	0	0.1	0	4.3	0	0	44
Asterionella formosa	9.5	7.7	0.5	14.8	0.1	1.9	9.2	4.6	0.7	1.3	44.9	89.5	59.2	5.3	13.6	1.1	100
Ceratium hirundinella	9.5	0	0	14.8	1.9	0.9	27.2	1.1	0.3	2.3	0	0	0	0	0	0	50
Cosmarium sp.	0	0	0	0	0.9	1.4	0.7	0.4	0.3	0.3	0	0	0	0	0	0	37
Dinobryon sertularea	0	0	0	16.4	5.3	47.6	23.2	41.5	9.3	56.5	39.0	7.0	1.8	0	0	0	62
Merismopedia elegans	0	0	0	0	1.1	0	0	0	0	0.3	0	0	0	0	0	0	13
Navicula sp.	66.7	84.6	84.4	16.4	6.4	12.1	5.9	6.7	18.2	13.0	4.9	0.8	29.0	77.7	86.4	82.8	100
Oscillatoria limosa	0	7.7	12.4	0	0	0	0.1	0.6	0	0	0	0.1	0	0	0	4.3	37
Pediastrum boryanum	4.8	0	0.9	1.6	5.7	3.5	3.2	2.9	4.5	1.7	0	0.1	1.2	9.3	0	1.1	81
Scenedesmus quadricauda	4.8	0	1.7	36.1	78.1	32.5	30.3	41.5	66.7	24.4	11.2	2.4	8.9	3.2	0	10.8	88

Date of Collection

Table 7.-Percent densities and percent frequencies of ten plankton species of the bottom waters of Station #1, Salem Lake

and bottom stations showed that most of the species studied reached their greatest density and greatest percent density at about the same time (see Tables 6 and 7). There were certain notable exceptions. *Anuraea cochlearis* reached its greatest density in the fall but reached its greatest percent density in the winter when its numbers were reduced. The same appears to be true of *Anuraea cochlearis* in the bottom waters, but its numbers there were not significant. Similarly *Navicula* sp. attained its greatest densities in spring and fall in surface waters, but it reached its greatest percent density in the winter months when its numbers were greatly reduced. *Navicula* sp. followed a similar pattern in the bottom waters, although it attained higher numbers in the winter which parallel the higher percent density at the same time. *Dinobryon sertularea* reached its greatest density in late October and early November. Its greatest percent density occurred in late October, but dropped abruptly in November while its density was still high. In the bottom waters *Dinobryon sertularea* attained its greatest densities in July and September, but reached its greatest percent density in July and October. *Pediastrum boryanum* attained its greatest density in early July and its greatest percent density in mid-December.

The organisms studied were classified according to the systems of Smith (1950) and Pratt (1935) (see Table 8). The phyla density data are presented in Table 9, and the phyla percent density and percent frequency data are given in Table 10. They indicate that the Chrysophyta are present in the highest frequency and in the greatest numbers in both the surface and bottom waters. They are followed in

Chlorophyta
    Chlorococcales
        Hydrodictyaceae
            Pediastrum boryanum (Turp.) Meneghini
        Scenedesmaceae
            Scenedesmus quadricauda (Turp.) deBrebisson
        Desmidiaceae
            Cosmarium sp.

Chrysophyta
    Chrysomonadales
        Ochromonadaceae
            Dinobryon sertularea Ehr.
    Pennales
        Fragilariaceae
            Asterionella formosa Hassall
        Naviculaceae
            Navicula sp.

Pyrrophyta
    Peridiniales
        Ceratiaceae
            Ceratium hirundinella (O. F. M.) Schrank

Cyanophyta
    Oscillatoriales
        Oscillatoriaceae
            Oscillatoria limosa Ag.
    Chroococcales
        Chroococcaceae
            Merismopedia elegans A. Br.

Trochelminthes
    Monogononita
        Brachionidae
            Anuraea cochlearis Gosse

Table 8.-Classification of the species studied according to Smith (1950) and Pratt (1935)

Phylum	Chlorophyta		Chrysophyta		Cyanophyta		Pyrrophyta		Trochelminthes		Total
Date	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	
12 Nov. 1955	0	2	1	16	0	0	0	2	0	1	22
26 Jan. 1956	0	0	4	12	0	1	0	0	5	0	22
17 Mar. 1956	2	20	89	637	84	93	0	0	3	0	928
23 June 1956	10	23	76	29	0	0	311	9	4	0	462
7 July 1956	17	745	25	118	0	11	65	19	0	4	1104
21 July 1956	715	161	145	265	12	0	117	4	4	1	1424
18 Aug. 1956	2049	245	74	275	25	1	89	195	2	1	2956
8 Sept. 1956	234	208	757	245	371	3	55	5	1	2	1881
15 Sept. 1956	33	208	19	82	5	0	1390	1	1	0	1739
13 Oct. 1956	4	79	33	212	0	1	787	7	29	0	1152
27 Oct. 1956	10	23	425	182	0	0	45	0	0	0	685
10 Nov. 1956	6	23	1944	907	0	1	2	0	0	1	2884
1 Dec. 1956	0	17	617	152	0	0	4	0	1	0	791
15 Dec. 1956	2	12	27	78	0	0	5	0	0	4	128
1 Jan. 1957	2	0	30	22	0	0	2	0	1	0	57
16 Feb. 1957	1	11	26	78	4	4	1	0	0	0	125

Table 9.-Densities of five plankton phyla of the surface and bottom waters of Station #1, Salem Lake

Phylum	Chlorophyta		Chrysophyta		Cyanophyta		Pyrrophyta		Trochelminthes	
Date	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
12 Nov. 1955	0	9.6	100.0	76.2	0	0	0	9.5	0	4.8
26 Jan. 1956	0	0	44.4	92.3	0	7.7	0	0	59.6	0
17 Mar. 1956	1.2	2.6	50.0	84.9	47.2	12.4	0	0	1.7	0
23 June 1956	2.4	37.7	18.9	47.6	0	0	77.6	14.8	1.0	0
7 July 1956	15.9	84.7	23.3	11.8	0	1.1	60.7	1.9	0	0.4
21 July 1956	72.0	37.4	14.6	61.6	1.2	0	11.8	0.9	0.4	0.2
18 Aug. 1956	91.4	34.2	2.4	38.3	1.1	0.1	4.0	27.2	0.1	0.1
8 Sept. 1956	16.4	44.8	53.3	52.8	26.2	0.6	3.9	1.1	0.1	0.4
15 Sept. 1956	2.3	71.5	1.3	28.2	0.3	0	96.0	0.3	0.1	0
13 Oct. 1956	0.5	26.4	3.9	70.8	0	0.3	92.3	2.3	3.4	0
27 Oct. 1956	2.0	11.2	88.6	88.8	0	0	9.4	0	0	0
10 Nov. 1956	0.4	2.5	99.6	97.3	0	0.1	0.1	0	0	0.1
1 Dec. 1956	0	10.0	99.2	90.0	0	0	0.6	0	0.2	0
15 Dec. 1956	5.8	12.5	79.4	83.0	0	0	14.7	0	0	4.3
1 Jan. 1957	5.8	0	85.8	100.0	0	0	5.7	0	2.9	0
16 Feb. 1957	3.1	2.9	81.3	83.9	12.5	4.3	3.1	0	0	0
Average	13.7	24.3	52.9	69.8	5.5	1.7	23.7	3.6	4.3	0.6
% Frequency	81	88	100	100	44	50	88	50	69	44

Table 10.-Percent densities and percent frequencies of five phyla of the surface and bottom waters of Station #1, Salem Lake

order by the Pyrrophyta, Chlorophyta, Cyanophyta, and Trochelminthes. In the bottom waters the Chlorophyta and Pyrrophyta have exchanged places in the sequence.

CHAPTER IV

DISCUSSION

HYDROGEN ION CONCENTRATION

Prescott (1951, p. 6) states that a substrate low in calcium would result in an aquatic environment with a pH below 7.0, while a substrate of shale and limestone, being high in calcium, would result in an aquatic environment with a pH above 7.0. In a later report (1956, p. 177) he states that basic waters are the result of drainage through sedimentary rock, especially limestone. These statements are in agreement with the data obtained from Salem Lake. The pH was basic throughout the duration of this study, ranging from 7.7 to 8.4 in the surface waters and from 7.6 to 8.35 in the bottom waters. This is undoubtedly due to the nature of the substratum in the surrounding hills through which the water passes before it reaches the lake. The mountains in this area are principally limestone and calcareous shale. Filtration of water through such rocks would account for the basicity noted.

Basic waters are known to be high in dissolved minerals and to support a rich algal growth composed largely of diatoms and blue-green algae (Prescott, 1939, p. 66; 1951, p. 18; 1956, p. 176; Riley, 1940, p. 282; Smith, 1950, p. 20). In his study of the plankton of Linsley Pond, Riley (1940, p. 282) states that basic waters produce a considerably lesser growth of green algae than of diatoms and blue-green algae. This view is supported by Prescott (1939, p. 66). In general the data derived from the Salem Lake in this study support the observations of these authors. This can be seen by analysis of the density, percent density, and percent frequency data for each phylum. An abundance of diatoms was present, as indicated by the data for the Chrysophyta. These attained percent frequencies of 100% in both surface and bottom waters and average percent densities of 52.9% and 69.8% in the surface and bottom waters respectively. These are the highest frequencies and densities attained by any of the phyla studied. Most published accounts refer to the diatoms as a group separate from the other Chrysophyta. However, in this study Dinobryon sertularea as well as the two diatoms Navicula sp. and Asterionella formosa are included in the Chrysophyta. This is in keeping with the classification of Smith (1950).

The Cyanophyta found in Salem Lake are not as abundant as one might expect, exhibiting only 50% frequency and 44% frequency in the surface and bottom waters respectively and 5.5 and 1.7 average percent densities in the surface and bottom waters. Oscillatoria limosa is the more abundant of the two species of the Cyanophyta studied. Merismopedia elegans is present only for a short period of time and then in very small numbers.

The Chlorophyta are perhaps more abundant than one might expect in basic waters. They show a percent frequency of 81% in the surface waters and 88% in the bottom waters and an average percent density of 13.7% in the surface waters and 24.3% in the bottom waters. Cosmarium sp. is one of the desmids commonly found in basic waters, but it does not contribute greatly to the total population of the Chlorophyta as far as numbers of individuals are concerned.

Smith (1950, p. 16) and Needham and Lloyd (1937, p. 52) agree that basic waters are producers of more abundant algal growth than are acid waters. Smith (1950, p. 16) attributes this observation directly to the utilization of dissolved bicarbonates of magnesium and calcium as an additional source of carbon dioxide for photosynthesis. Prescott (1951, p. 15) lists the following additional factors which may contribute to the greater algal abundance noted in basic waters: (1) the high nitrogen and phosphorus content of the waters, (2) the higher temperature of the total amount of water present, (3) the shallowness, and (4) the greater proportion of water in contact with the bottom.

The lower pH values recorded for Salem Lake during the summer are in contradiction to the statements of Prescott (1939, p. 69; 1951, p. 30) that the pH should be higher in the late summer because of the removal of much of the half-bound carbon dioxide from the bicarbonates by photosynthesis. The pH did tend to rise slightly at approximately the same times that the total population maxima were reached, but the relationship was not so close as might be expected if the above condition existed in Salem Lake. Especially difficult to explain on the above basis are the higher pH values recorded in the winter months when the plankton growth was greatly reduced. In this regard it should be remembered that only a very narrow range of pH was recorded. It is possible that, in contrast to a larger lake, the shallowness of Salem Lake facilitated the absorption of carbon dioxide from the atmosphere in great enough quantities that the carbon dioxide was not depleted to a great enough extent to cause the pH to increase.

The pH of the surface waters was generally slightly higher than that of the bottom waters. The range of the difference between the pH of the surface waters and the pH of the bottom waters was from 0.0 to 0.6 pH units, and the average difference was 0.16 pH units. These differences were not considered significant, but might be accounted for by the oxidative processes of decomposition and respiration and the reduced amount of photosynthesis taking place in the bottom waters.

Philip (1927, p. 88) suggests that because of the great variety of physical and biological factors operating at any one time, a single pH reading per day is not a sufficient index of the hydrogen ion activity of an aquatic environment. This type of error could conceivably result in the very small variation recorded in the pH of Salem Lake throughout the year.

DISSOLVED OXYGEN

One might expect the dissolved oxygen content to increase greatly in the summer due to the increased photosynthetic activity taking place. This was not borne out by the data collected on Salem Lake. There was only a narrow range of variation exhibited by the dissolved oxygen and it increased slightly from summer through winter. Such an increase in the colder months could have been due to the greater ability of water to absorb oxygen at lower temperatures (Needham and Lloyd, 1937, pp. 43-44).

Prescott (1951, p. 333) and Ruttner (1952, p. 67) agree that there is usually a greater quantity of dissolved oxygen in the upper layers of water than in the lower layers. The results of this study indicated a slightly lower dissolved oxygen content in the bottom waters than in the surface waters. This would be in agreement with the above views and could probably be explained on the basis of greater photosynthetic activity in the surface waters throughout most of the year and greater decomposition rates in the bottom waters. Welch (1935, p. 333) indicates that the circulation of oxygen from surface to bottom is facilitated by shallow depth of water. This was probably true in the case of the station studied in Salem Lake. One might still expect a higher dissolved oxygen content in the surface waters due to direct exposure to the atmosphere.

Smith (1950, p. 26) states that it is not possible to correlate the seasonal changes in dissolved oxygen and carbon dioxide with the periodicity of the various components of the algal flora. It is likely that dissolved oxygen was not limiting in Salem Lake due primarily to the shallow depth of water.

TURBIDITY AND DEPTH

The turbidity as determined by the Secchi Disk is actually a measure of the penetration of light; therefore, the brightness of the day at the time of each measurement might be expected to affect the turbidity directly. That this was so, was evident in the August collection in which the penetration of light was greatly reduced due to cloudiness (see Graphs 2 and 3). The turbidity is also an index of the amount of matter suspended in the water (Needham and Lloyd, 1937, p. 27). The suspended matter is principally inorganic in nature, but organic matter, including the plankton, may contribute to the turbidity (Chandler, 1942, p. 43). Chandler (1942, p. 45) from his study of Western Lake Erie indicates that the turbidity was greatest in the summer and autumn and least in the winter and spring. The same was generally true in Salem Lake, the lowest turbidity readings being recorded in the winter and the highest being recorded in the summer. Since the total plankton population was also highest in the summer and lowest in the winter, the indication is that the plankton population did have an effect on the turbidity of the water at this station in Salem Lake. Because of this, light transmission was also lowest in the summer and fall and highest in the winter and spring. This reduced penetration of light might be expected to reduce the amount of photosynthesis that could occur in the lowermost waters and thus affect the kinds of organisms and the total number of organisms able to survive there. Chandler (1942, p. 41) states that changes in the transparency of natural waters, or turbidity, may be far more important in determining the quantity of light at a given depth than seasonal changes in illumination reaching the surface of the water. Buell (1938, p. 231) says that the low transparency of shallow ponds affects the light enough to produce a condition comparable to that in deep-water regions of European lakes. The high turbidity recorded in August did not seem to restrict the number of species present in the lowermost waters of Station #1, due probably to the shallowness of the lake. The same organisms present in the surface waters were present in the bottom waters. It is felt that the statement of Chandler refers to deeper waters and that of Buell refers to more shallow waters. As a result the effects of high turbidity were not so great on Salem Lake. However, there were fewer organisms present in the bottom than the surface waters. This reduced number of organisms in the lower waters was likely due to turbidity.

Diffuse light penetrates beyond the depth at which the Secchi Disk disappears (Needham and Lloyd, 1937, p. 28). The average depth at which it disappeared in this study, which was recorded as turbidity, was three feet ten and one-half inches. It is entirely feasible that light could have penetrated effectively to the bottom but the data indicate that the bottom waters may have been deep enough for light to be a limiting factor, especially under conditions of high turbidity. Table 5 indicates that the bottom waters usually supported an abundant plankton growth. That it was generally less than that of the surface waters, however, suggests that light may have been partially limiting at such a depth, especially under turbid conditions.

According to Andrews (1948, p. 502) the most obvious effect of a strong wind is the increased turbidity of the water. Chandler (1942, p. 42) also states that high wind velocities favor high turbidity. The unexpected high turbidity which occurred in January of 1956 can be traced to an extreme wind during the time of the collection.

According to one historical news account (Faux, 1955, p. H19) Salem Lake averages ten feet in depth. Station #1 had an average depth of seven feet ten inches. Mr. Albert Peterson, Game Warden in Salem, states that the lake is not nearly so deep as it used to be. Although this is a general statement which could not be verified, the condition is typical of small lakes. It is an expression of the lentic society of the lake-to-pond-to-swamp-to-dry land succession reviewed by Welch in 1935 (pp. 9, 13).

TIME OF DAY

Diurnal fluctuations of certain zooplankters were noted by Plew and Pennak (1949, p. 30). Such fluctuations may also be true for certain phytoplankters. The brightness of the day, the temperature, the dissolved oxygen content, the pH, and the plankton population could vary with the time of day. The range of time at which collections were made in this study was six hours during the middle of the day (see Table 2). It is felt that fluctuations in the above factors within this range of time were not great enough to have altered the end products of a study such as this. The two collections that were taken in the morning showed no marked differences in the data obtained which could be correlated with the time of day.

BRIGHTNESS OF DAY

The brightness of the day may have limited the number of organisms present in the bottom waters. This was not due to the light intensity except as it affected or was affected by the turbidity. Light became limiting presumably due to the depth and the turbidity of the water.

The brightness of the day affects the water indirectly in another important way. Heating of the water is accomplished through the radiation of the sun (Ruttner, 1952, p. 24; Lind, 1938, p. 270). This is reflected in the temperature cycles.

DAY LENGTH

The duration of the daily illumination may have notable effects on the plankton population. One might expect a great similarity in the spring and fall populations due to the similarity of the light-duration and the temperature curves at these seasons. That this is not always true is emphasized by Ruttner (1952, p. 140) and was indicated by the peak densities of certain species in this study. Ruttner (1952, p. 140) states that because the water-temperature curve lags behind the light-illumination curve, there is a selection in the spring for a population which can utilize cold water temperatures and longer periods of illumination; whereas, in the fall, there is a selection for a population which can utilize warm water and shorter days. He illustrates this with a chart from Fundenegg (1947) which is reproduced below:

	weak-light forms	strong-light forms
cold water forms	winter plankton	spring plankton
warm water forms	fall plankton	summer plankton

Plankton groups according to their response to day length and temperature (after Fundenegg)

Certain of the species studied and reported here fit into these categories. This will be discussed later in greater detail.

It should be noted that along with the variation in day length, there is an attending variation in the light intensity. The light intensity is less during the shorter days of fall and winter and greater during the longer days of spring and summer. This in effect produces the temperature differences of the different seasons.

TEMPERATURE

Because of the shallowness of Salem Lake, no stratification was evident such as is seen in deeper lakes. The bottom waters were slightly colder throughout the year until winter when the surface and bottom waters were of essentially the same temperature. In such shallow waters there is no "turnover" as found in deeper lakes, again because of lack of stratification.

Ruttner (1952, p. 123) states that the mean temperatures at which the population maxima occur are, within certain limits, almost constant for the individual species. However, he regards the effect of day length as equal to or more important than the effect of temperature on periodicity. There were certain species in this study, however, which seemed to be limited by temperature alone, or at least by temperature more than by day length. Even some of those species which seemed to be related to day length were either restricted to or prevented from growing at certain temperatures. Winter seemed to be one of the periods when temperature was limiting for all species. This was indicated by the stability and low numbers of the population during the winter months.

PLANKTON

The plankton periodicity seemed to be influenced most by day length and temperature. These are the factors which showed the most variation throughout the year. Certain of the species studied here seemed to fit into the classification of Fundenegg mentioned above; others did not. _Asterionella formosa_ belonged to the fall plankton group in density in both the surface and bottom waters. It was low in numbers all through winter, spring, and summer, and then attained its maximum in the early fall when the water was still warm and the days were shorter. Its numbers were reduced again in the winter when the water cooled and the days were short. Essentially the same was true of _Anuraea cochlearis_ which reached its maximum in the fall only. It was important only in the surface waters in this regard. Neither of these two species reached a peak density again in the spring when the day length or temperature were similar. They seemed not to be controlled primarily either by temperature or day length, but by a combination of the two factors.

Smith (1950, p. 24) states that the development of certain algae, including the diatoms, in the spring is correlated with their ability to grow vigorously at low temperatures. Evidently this was true for _Navicula_ sp. in both surface and bottom waters, but it also reached a peak density in the fall in the surface waters when the water temperature was much higher, but when the day length was similar. This would imply that _Navicula_ sp. was limited by day length primarily, but within a certain temperature range. _Oscillatoria limosa_ followed the same pattern as _Navicula_ sp. It was, however, less abundant.

Merismopedia elegans, _Cosmarium_ sp., _Pediastrum boryanum_, and _Scenedesmus quadricauda_ were good examples of Fundenegg's summer plankton group. They were present in abundance only when the days were long and the temperature was high. They seemed to be controlled primarily by temperature since they did not reach another maximum in the spring when the day length was similar. These species reached an early summer peak density in the bottom waters which was not paralleled by a similar peak density in the surface waters. The same species all reached their maximum densities in the surface waters later in midsummer. At that time they were all reduced in numbers in the bottom waters. A discussion by Fritsch (1931, p. 245) might help to explain this migration.

He states that many organisms probably overwinter in the bottom or in the littoral zone. Assuming that the above-named species overwintered on the bottom, their early abundance in the bottom waters and later migration to the surface could have been in response to temperature. They likely began growth from their overwintering stages on the bottom when the temperature was warmer than it had been through the winter and spring. This would account for their early abundance on the bottom. The production of oxygen from their photosynthetic activity could have been sufficient to account for their rise to the surface. These species, then, seemed to be primarily limited by temperature.

Ceratium hirundinella was present from spring through fall. It reached peak densities in the spring and fall in the surface waters and in summer in the bottom waters. This was probably a function of temperature. The temperature on the bottom in the summer was similar to that on the surface in the spring and fall. Dinobryon sertularea followed approximately the same pattern. It was found in the surface waters when the temperature was lower and in the bottom waters when the temperature was high in the summer. These two species seemed to be primarily temperature controlled.

Most of the species studied reached their greatest density and their greatest percent density at the same time. Pearsall (1932, p. 242) also found this to be true in his studies of plankton in English lakes. He stated that this was true except at the end of the diatom phase in the fall when the diatom numbers fell off tremendously but their percent density remained very high. The diatom Navicula sp. showed the same trend in this study. It reached its greatest density in the fall and spring, but reached its greatest percent density in the winter months when its numbers were greatly reduced. Essentially the same was true for Anuraea cochlearis in the surface waters. It reached its greatest density in the fall, but reached its greatest percent density in the winter. This would imply that these species were comparatively hardy, being able to continue on in importance in the population through the winter months even though reduced in numbers. Dinobryon sertularea was another exception. In the surface waters it attained its greatest numbers in late October and early November and its greatest percent density in late October. Even though it maintained its high numbers in November, it fell off abruptly in its percent density. This was due to the tremendous increase in numbers of Asterionella formosa which was reaching its peak density at that time. In the bottom waters Dinobryon sertularea reached its greatest density in July and September and its greatest percent density in July and October. It was only slightly less important in September than in October. Its decreased percent density in September was due primarily to an increase of Scenedesmus quadricauda colonies. Pediastrum boryanum was also an exception in the bottom waters. It reached its greatest percent density in Mid-December rather than in July when it was at its greatest density. This was due to the great decrease in the total population and to a slight increase in its numbers.

Two of the species studied showed a definite preference for surface waters over bottom waters. They were Anuraea cochlearis and Ceratium hirundinella. Dinobryon sertularea, Merismopedia elegans, and Scenedesmus quadricauda showed no particular preference for either surface or bottom waters, at least in this shallow lake. Asterionella formosa, Cosmarium sp., Oscillatoria limosa, Navicula sp., and Pediastrum boryanum showed greater numbers present in the surface waters but a higher percent frequency in the bottom waters. These generalizations were drawn primarily from the percent frequency data in Tables 6 and 7, but also from the density and percent density data in Tables 4 and 5, and 6 and 7, respectively. In general the population at any one time was greater in the surface waters than in the bottom waters. This could be a result of the method of sampling. It might be expected that the surface samples would be more concentrated. However, in the spring and early summer the bottom samples showed a greater number of organisms present. Had the bottom samples been as concentrated as the surface samples, there might have been an even greater difference. The total population in the bottom waters in the early summer was greater than that in the surface samples because of the greater abundance of the Chlorophyta there at that time.

There seemed to be little, if any, correlation between the different species in a phylum in regards to their periodicity. Only in the Chlorophyta did all the species studied reach their peak densities at the same time. Only one species of the Pyrrophyta and one of the Trochelminthes were studied, so no comparison could be made.

The different phyla reached their peak densities at different times of the year. The Chrysophyta, and especially the diatoms, reached their greatest density and percent density in the fall, winter, and early spring, in both surface and bottom waters. Similar results were found by Prescott (1951, p. 18), Langlois (1954, p. 89), Needham and Lloyd (1937, p. 303), and Greenbank (1945, p. 383). The Chrysophyta were more abundant in the summer in the bottom waters than in the surface waters. This may have been in response to the temperature, which was lower in the bottom waters than in the surface waters, and which was similar to that temperature at which they reached their peak densities in the surface waters in the spring and fall. The Cyanophyta, and especially <u>Oscillatoria limosa</u>, reached their greatest importance in the early spring and early fall. Prescott (1951, p. 18) also found this to be so in his studies of the western Great Lakes. The Cyanophyta were more abundant in the surface waters than in the bottom waters, especially in the fall. The Pyrrophyta were most important in the late spring and early fall in the surface waters. They were not significant in the bottom waters. The Chlorophyta were most important during the summer months in the surface waters. Prescott (1951, p. 18) and Langlois (1954, p. 90) also found this to be true in their studies. The Chlorophyta reported here were most important in the bottom waters in the early and late summer. This could have been the result of their reactivation from overwintering in the early summer and their settling in the late summer previous to overwintering again. <u>Anuraea cochlearis</u> in the Trochelminthes, was most important in the late winter, rather than in the late spring as reported by Carl (1940, p. 68) and Needham and Lloyd (1937, p. 302).

The plankton population, though reduced in numbers, seemed to be more stable during the winter months than in the summer months. This paralleled the results of studies by Anand (1937, p. 356) on cliff algae. The presence of so few species in such small numbers with the restricted photosynthetic and reproductive activities could account for the stability of the population.

CHAPTER V

SUMMARY

1. The periodicity of selected plankton species in the Salem Lake and the physical factors of the environment which affect their periodicity have been studied.
2. Plankton samples were collected periodically over a period of sixteen months from surface and bottom waters of one station in Salem Lake. The samples thus obtained were analyzed microscopically and density counts were made of certain of the more common species present.
3. Among the most common plankton species at the station studied were *Anuraea cochlearis* Gosse, *Asterionella formosa* Hassall, *Ceratium hirundinella* (O. F. M.) Schrank, *Cosmarium* sp., *Dinobryon sertularea* Ehr., *Merismopedia elegans* A. Br., *Navicula* sp., *Oscillatoria limosa* Ag., *Pediastrum boryanum* (Turp.) Meneghini, and *Scenedesmus quadricauda* (Turp.) deBrebisson.
4. The waters of Salem Lake were found to be basic. They supported a plankton flora typical of basic waters, except that the Cyanophyta were less abundant and Chlorophyta were more abundant than might be expected.
5. The variations recorded in the pH were not considered to be great enough to influence significantly the periodicity of the organisms studied.

6. The dissolved oxygen content of the waters varied only slightly during the period studied. The variation recorded was not considered to be sufficient to influence greatly the periodicity noted.
7. The turbidity and the depth of the water together tended to reduce the total number of organisms present in the bottom waters, but not the number of species present.
8. Neither the time of collection nor the brightness of the day were considered as significant factors affecting the periodicity of the organisms studied.
9. Length of day and temperature seemed to have the greatest influence on the periodicity of the organisms studied. Oscillatoria limosa and Navicula sp. seemed to be controlled primarily by day length. Merismopedia elegans, Cosmarium sp., Pediastrum boryanum, Scenedesmus quadricauda, Dinobryon sertularea, and Ceratium hirundinella seemed to be controlled primarily by temperature. Asterionella formosa and Anuraea cochlearis seemed to be controlled by a combination of day length and temperature.
10. Three peak densities were reached in the surface waters. Oscillatoria limosa, Navicula sp., Ceratium hirundinella, and Dinobryon sertularea attained peak densities in the spring and fall. Cosmarium sp., Merismopedia elegans, Pediastrum boryanum, and Scenedesmus quadricauda reached peak densities in the summer. Anuraea cochlearis and Asterionella formosa reached peak densities in the fall only.
11. Four peak densities were attained in the bottom waters. Navicula sp. and Oscillatoria limosa reached their peak densities in the early

spring. Scenedesmus quadricauda, Anuraea cochlearis, Cosmarium sp., Pediastrum boryanum, and Merismopedia elegans attained their greatest densities in the early summer. Those species which reached their peak densities in midsummer were Asterionella formosa, Ceratium hirundinella, and Dinobryon sertularea. Asterionella formosa also reached a peak density in the late fall.

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STUDIES ON THE PERIODICITY OF CERTAIN PLANKTON SPECIES OF SALEM LAKE

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By

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STUDIES ON THE PERIODICITY

OF CERTAIN PLANKTON SPECIES OF SALEM LAKE

AN ABSTRACT

Plankton samples were taken periodically from one station in Salem Lake from the fall of 1955 through the winter of 1957. Other data including the pH, dissolved oxygen content, turbidity, brightness of day, temperature, and time of day were recorded at the time of each collection. The plankton samples were centrifuged and preserved in a 4% formalin solution. They were later examined microscopically, and density, percent density, and percent frequency calculations were made from them for ten selected species and for the five phyla which they represent.

The waters of the station studied were found to be basic. The pH varied only from 7.7 to 8.4 during the period studied. The basicity of the waters is likely due to the nature of the substrate through which the water passes before reaching the lake, since the mountains around the area studied are primarily limestone and calcareous shale. This would account for the basicity noted. This station in the lake supported plankton flora typical of basic waters except that the Cyanophyta were less abundant and the Chlorophyta were more abundant than might be expected. The slight variations in the pH recorded could not be correlated with the periodicity of the species studied.

The dissolved oxygen content varied only from 3.14 to 6.45, showing a slight increase from summer through winter. The narrow

range exhibited by the dissolved oxygen could not be correlated with the periodicity noted.

The turbidity of the water, as recorded by a Secchi Disk, varied considerably. The combination of the depth of the water and high turbidity was likely responsible for the total population of fewer numbers in the bottom waters than in the surface waters. This could have been the result of a decrease in the amount or the intensity of light reaching the organisms on the bottom. The average depth of the station was seven feet ten inches.

The time of day at which the collections were taken varied only within a range of six hours in mid-day. A comparison of these data with the plankton data showed no direct correlation between the two.

The brightness of the day did not seem to affect the periodicity of the organisms studied directly, but it did influence the turbidity and thus the number of organisms able to survive in the bottom waters.

Temperature and day length seemed to exert the greatest influence on the periodicity of the species studied.

There were three maximum densities reached by the total population in the surface waters and four in the bottom waters. The three maximum densities in the surface waters were in the spring, midsummer, and late fall. In the bottom waters the maximum densities occurred in the early spring, early summer, midsummer, and the late fall.

Navicula sp., *Oscillatoria limosa*, *Ceratium hirundinella*, and *Dinobryon sertularea* were responsible for the spring peak density in the surface waters. These species also reached peak densities in the fall in the surface waters. *Navicula* sp. and *Oscillatoria limosa* were responsible for the spring peak density in the bottom waters also, but did not reach peak densities in the fall. They reached their maximum densities in the surface waters in the spring and fall at times when the temperatures were different but when the day length was similar. This would imply that they were limited by day length.

The early summer maximum in the bottom waters was the result of the peak densities of *Scenedesmus quadricauda*, *Cosmarium* sp., *Pediastrum boryanum*, and *Merismopedia elegans*. These same species all reached a maximum density in the surface waters later in midsummer, suggesting that they are limited by temperature. This also might indicate that they overwintered on the bottom of the lake and were thus abundant first in the bottom waters and later migrated to the surface, where light and temperature conditions were perhaps more desirable.

The temperature of the bottom waters in the summer was similar to that of the surface waters in the fall and spring. *Ceratium hirundinella* and *Dinobryon sertularea* were most abundant in the bottom waters in the summer and in the surface waters in the spring and fall. This suggests that they are both temperature limited.

Asterionella formosa and *Anuraea cochlearis* reached their greatest densities in the fall only. This suggest that they are limited by a combination of day length and temperature. They are most abundant when the days are short and the water is warm.

Ceratium hirundinella and *Anuraea cochlearis* showed a definite preference for surface waters over bottom waters. The other species studied showed no particular preference.

The plankton population, though reduced in numbers, seemed to be more stable during the winter months than in the summer months.