SOME LIMNOLOGICAL ASPECTS OF
SPRING VALLEY RESERVOIR

A Thesis

Presented in partial fulfillment of the requirements for the

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Douglas Willard Duff

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The thesis of Douglas Willard Duff, "Some Limnological Aspects of Spring Valley Reservoir", is hereby approved:

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BIOGRAPHICAL SKETCH OF THE AUTHOR

Douglas Willard Duff was born in Paul, Idaho on October 30, 1932. He attended the Burley High School, Burley, Idaho and received a diploma in May 1952. That September he enrolled in Idaho State College and remained there until June 1953. He was then employed as a painter until December 1958. In January 1959 he re-enrolled in Idaho State College and received the degree of Bachelor of Science in June 1962. That September he entered the Graduate School of the University of Idaho and in June 1965 completed the requirements for the Master of Science degree, of which this thesis is a part.

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INTRODUCTION

Limnological literature contains hundreds of papers on numerous phases of zooplankton biology. However, a rather obvious aspect which appears to have been neglected is information on artificial lakes. With the trend in recent years to construct more and more reservoirs for economic and recreational purposes, a need for these studies is apparent. Some publications containing discussions of limnological conditions in artificial bodies of water are those of Ward and Seibert (1963), Wright (1958, 1959, 1961), Boreckly (1956), Pennak (1941, 1946, 1949), Weib (1938, 1939), Harris and Silvey (1940), and Juday (1906, 1907).

The present investigation is an attempt to contribute to our inadequate knowledge of limnological interrelationships in an artificial body of water. Spring Valley Reservoir, a 56 acre artificial lake, was selected for study. Field work extended from May through November, 1964, but certain phases of the laboratory work were not completed until March, 1965.

Particular attention has been given to vertical and seasonal variations of zooplankton populations in reference to selected environmental factors such as temperature, transparency, dissolved oxygen, free carbon dioxide, total and calcium hardness, alkalinity, nitrogen, and phosphorus. In addition, emphasis has been given to the mean summer standing crop of zooplankton.

Although limnology has been recognized as a distinct branch of science for less than 70 years (Welch, 1952), much has been done to provide an understanding of lake productivity and the numerous factors influencing productivity. Many investigations have been conducted in an attempt to determine characteristics with which to classify the productivity of lakes. As a result, many physical, chemical, and biological measures of productivity have evolved and are now used with varying degrees of success. Some of these limnological methods have been included in the present investigation.

DESCRIPTION OF STUDY AREA

Spring Valley Reservoir (Figure 1) is located in Latah County near Troy, Idaho. It was impounded in 1961 by the Idaho Fish and Game Department as a recreational site. The dam was placed below the confluence of two intermittent streams, which now form the two arms of the reservoir. The only outlet is a spillway, effective only during the spring. The reservoir has a surface area of 21.04 hectares. Maximum depth is slightly more than 9.0 meters.

Most of the southern shoreline is wooded with mixed conifers. *Abies grandis*, *Pinus ponderosa*, *Pinus monticola*, *Pinus contorta*, *Larix occidentalis*, and *Pseudotsuga menziesii* form most of the canopy while a few *Prunus* and *Thuja* are scattered through the area. Vegetation bordering the northwest consists mostly of grasses and a few shrubs while the remainder of the shoreline is bordered by a wheat field. There is a swampy area at the north-west inlet that is intermittently wet during the spring. The original lake basin consisted of a logged-off area and grassy meadow land.

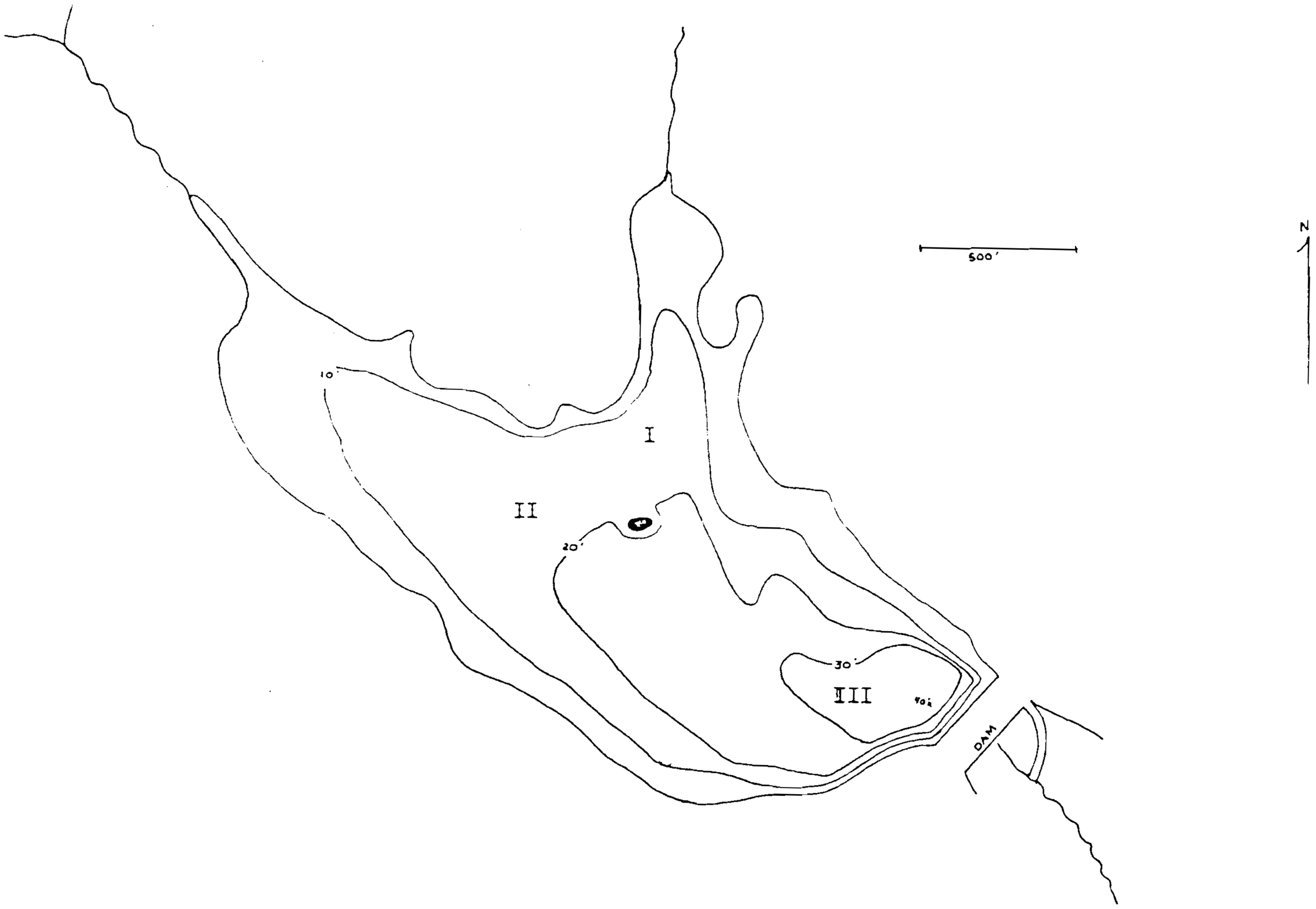

Figure 1. Hydrographic map of Spring Valley Reservoir, Idaho. Sampling stations are shown by Roman numerals.

METHODS AND MATERIALS

Physical, chemical, and biological data were collected from three stations established in the open waters of Spring Valley Reservoir (Figure 1, page 4). Normal water depths at sampling stations were: 4.5 meters at Station I; 5.0 meters at Station II; and 9.0 meters at Station III. Bimonthly visits were made for the period of May 6, 1964, through November 11, 1964.

A vertical series of temperature readings and zooplankton samples were taken at one meter intervals from each station. Secchi disc readings were taken during each visit. Dissolved oxygen and free carbon dioxide samples were taken at one meter intervals at Station III. Water samples used for analyses of total and calcium hardness, alkalinity, total iron, total and orthophosphate, nitrite and nitrate nitrogen, and pH were taken at surface, mid-depth, and near-bottom at Station III. All water samples were collected with the aid of a Kemmerer water sampler. Water for dissolved oxygen and free carbon dioxide analyses were transferred from the sampler into 300 ml. glass-stoppered bottles, using customary precautions. Water samples for other chemical determinations were placed in polyethylene bottles and returned to the laboratory for analysis. All determinations were made on the same day of collection.

An Applied Research Associates Model FT-2 electronic thermometer was employed to record temperatures.

Dissolved oxygen was determined by the Alsterberg modification of the Standard Winkler Method. A new reagent, Phenylarsene Oxide (PAO), was used in place of sodium thiosulfate according to methods of the Hach Chemical Company, Ames, Iowa. Phenylarsene oxide performs identically with sodium thiosulfate, but is completely stable thus requiring no standardization. Free carbon dioxide determinations were obtained by titrating 100 ml. of water sample with N/44 sodium hydroxide using phenolphthalein as an indicator. According to Pennak (1949) the latter method is sufficiently accurate for limnological purposes. Phenolphthalein and bromcresol green-methyl red alkalinity were determined by titrating with standard sulfuric acid (N/.02). Total hardness was determined by the Man Ver Hardness Test. Calcium hardness was determined using Cal Ver II indicator powder titrated with standard Hexa Ver solution.

Total iron, total and orthophosphate, nitrite and nitrate nitrogen were determined colorimetrically using a Bausch and Lomb Spectronic 20 colorimeter. A Leeds and Northrup pH meter was used to measure the hydrogen ion concentration.

Quantitative zooplankton samples were collected with a ten-liter Juday plankton trap. Samples were washed from the bucket of the trap into vials and preserved in 95% alcohol. In the laboratory, they were brought to suitable volumes by decanting the supernatant water from the settled sample, or by adding plankton-free water. A 1.0 ml. aliquot of the sample was placed in a Sedgewick-Rafter cell, and counts made. Appropriate calculations were made to determine the number of individuals per liter. Zooplankton organisms were identified to species only when clearly defined. All others were identified to genus. Identification was carried out with the aid of keys found in Pennak (1953) and Ward and Whipple (1959).

RESULTS AND DISCUSSION

PHYSICAL CONDITIONS

Temperature

Seasonal temperature changes recorded at Station III are shown in Figure 2. Temperature curves for Stations I and II are not included, as temperatures recorded at these stations were found to be similar to records obtained for Station III. Solid lines on the graph indicate periods of warming to the maximum summer temperature, and broken lines indicate periods of cooling from the summer maximum. Each curve is labeled as to month and day.

Lakes of sufficient depth almost invariably undergo a period of temperature stratification during the summer months, resulting in the formation of temperature zones. In classic limnology these zones have been named as follows: The upper region of more or less uniformly warm, circulating, and fairly turbulent water is termed the epilimnion. Below the epilimnion a zone of rapid drop in temperature occurs with depth. This zone has been designated as the thermocline. However, in modern limnological literature the thermocline is defined as "the plane of maximum rate of decrease in temperature" (Reed, 1961). Below the thermocline is a cold, relatively undisturbed region termed the hypolimnion. Many limnological investi-

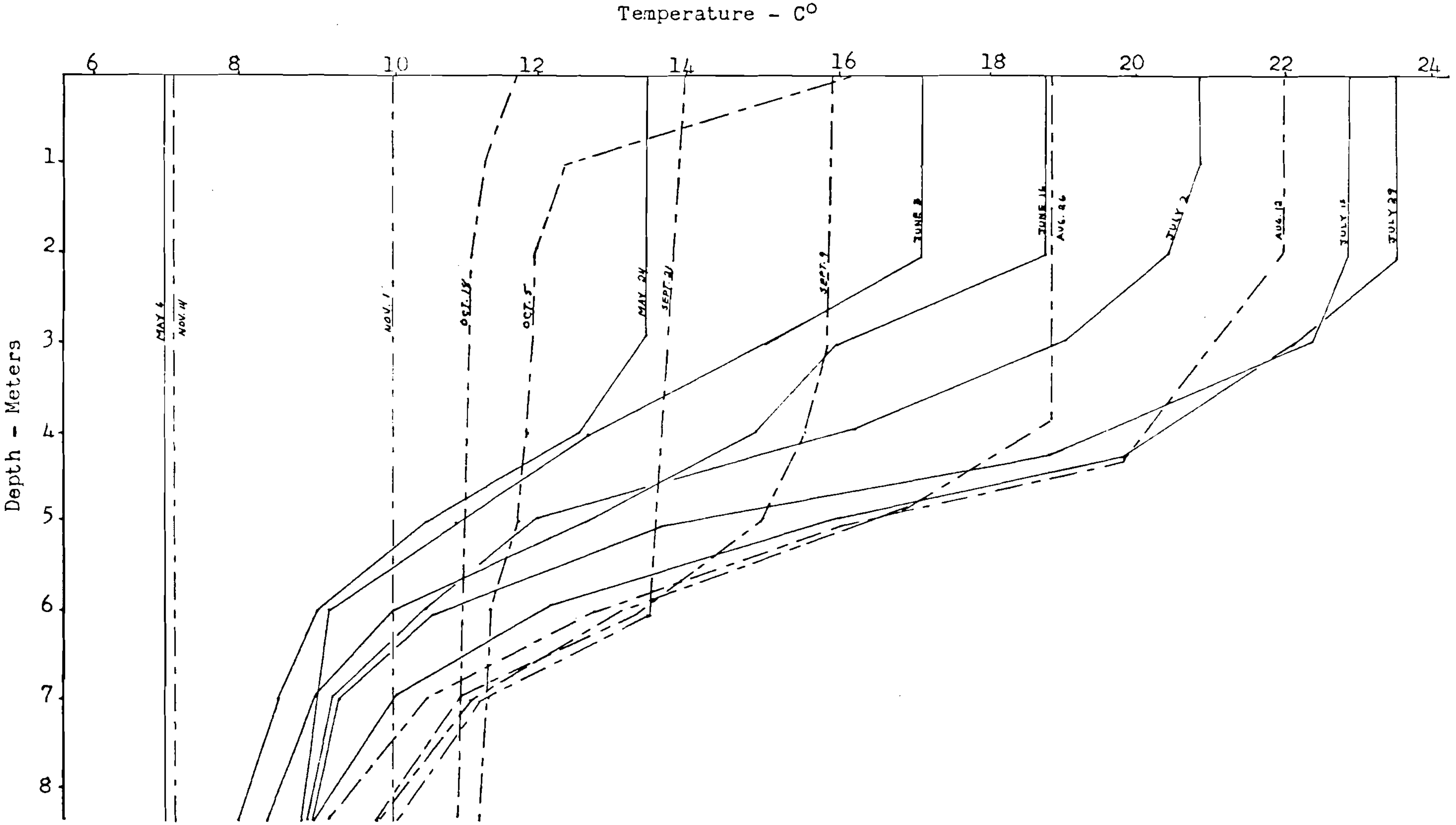

Figure 2. Vertical and seasonal temperature readings for the 1964 warm season in Spring Valley Reservoir.

gators now designate the thermocline and a gradient on either side of it as the metalimnion. The latter terminology will be employed in the following discussion of temperature.

The highest surface temperature recorded during the study occurred on July 29 (23.5° C.) and the lowest (7.1° C.) on two occasions, May 6 and November 14.

Presumably, spring overturn was occurring at the initiation of this study on May 6, and had terminated by May 24. In early June subsequent heat intake at the surface induced stratification and the development of a distinct metalimnion. The depth of the epilimnion early in the season varied from 2.0 to 4.0 meters. During June, July, and early August, stratification intensified and summer stagnation as described by Welch (1952) developed. Beginning in late August the epilimnion deepened and by early October it had disappeared.

Once the metalimnion developed it underwent a gradual change as the season progressed. During June, July, and early August the metalimnion extended about 5.0 meters in depth. In late August the surface water began to cool causing the metalimnion to sink and completely disappear by the latter part of September.

The curve for October 5 indicates the formation of a surface thermocline, a phenomenon that occurred only once during the study. The temperature dropped from 16.4° to 12.6°, a difference of 3.8° in the surface meter of water. From 1.0 meter to the bottom the temperature dropped less than 2.0°. As the day was sunny and windless and as the measurements were made in late afternoon, the surface warmed sufficiently to cause a surface thermocline.

The first indication of a fall overturn appeared on October 5 when surface to bottom temperatures were nearly homothermous. By October 18 temperatures were uniform throughout the entire water column. This homothermous condition was still evident at the close of the study.

Transparency

Since light exerts a profound influence upon a whole series of biological phenomena in water (Welch 1952), some measurement of light penetration is of value. Water transparency provides a relative index of light penetration, and this method was used to determine seasonal and inter-station differences in light. Although Secchi disc measurements provide the most practical means of measuring transparency, it must be pointed out that accuracy of readings depend to a large extent on weather conditions and time of day.

As shown in Figure 3, the waters of Spring Valley

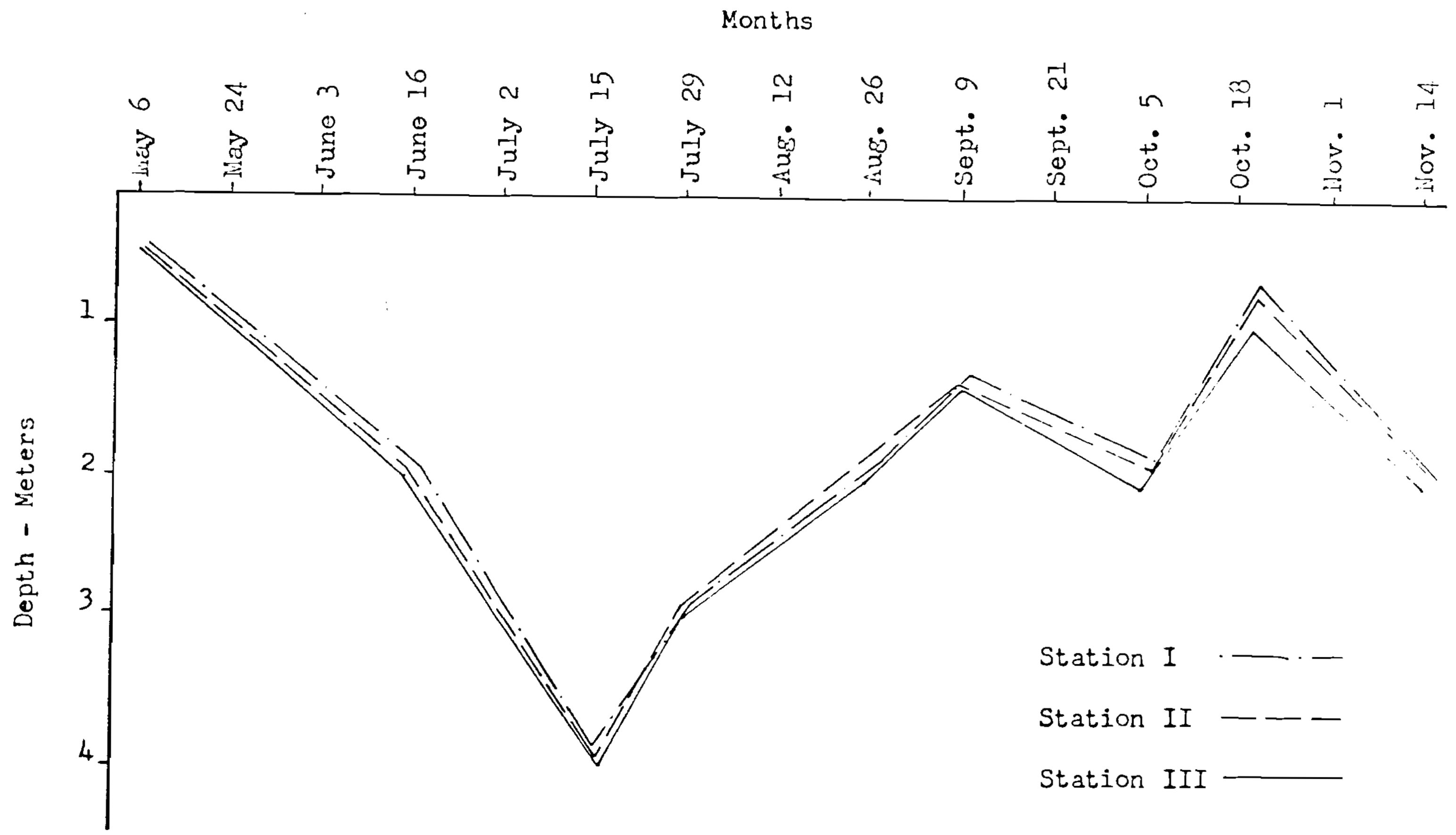

Figure 3. Secchi disc readings for the 1964 warm season in Spring Valley Reservoir.

Reservoir showed low transparencies. A maximum Secchi disc reading of 4.0 meters was recorded at Station III on July 15, 1964. Transparency readings from the three sampling stations exhibited very little variation during the study period. Thus, considering Station III as being typical, the calculated mean was 1.9 meters and the median 2.0 meters.

Viewing the curves in Figure 3, page 12, as a group, it can be seen that there was a gradual clearing from early May to mid-July. Beginning in late July a general decrease in transparency occurred until early September. For the remainder of the study period transparencies varied over a range of approximately 1.0 meter. Lowest transparencies were noted during spring and fall overturns. This marked decrease in transparency during overturn periods, when the water mass takes on a uniform character in all of its various strata, is typical of reservoir environments with high rates of sedimentation or detrital formation.

CHEMICAL CONDITIONS

Oxygen

As shown in Figures 4 and 5, dissolved oxygen in the surface water of Spring Valley Reservoir varied from a high of 10.7 p.p.m. on May 6 to a low of 7.2 p.p.m. on November 14. Oxygen content in the lowermost water varied from a

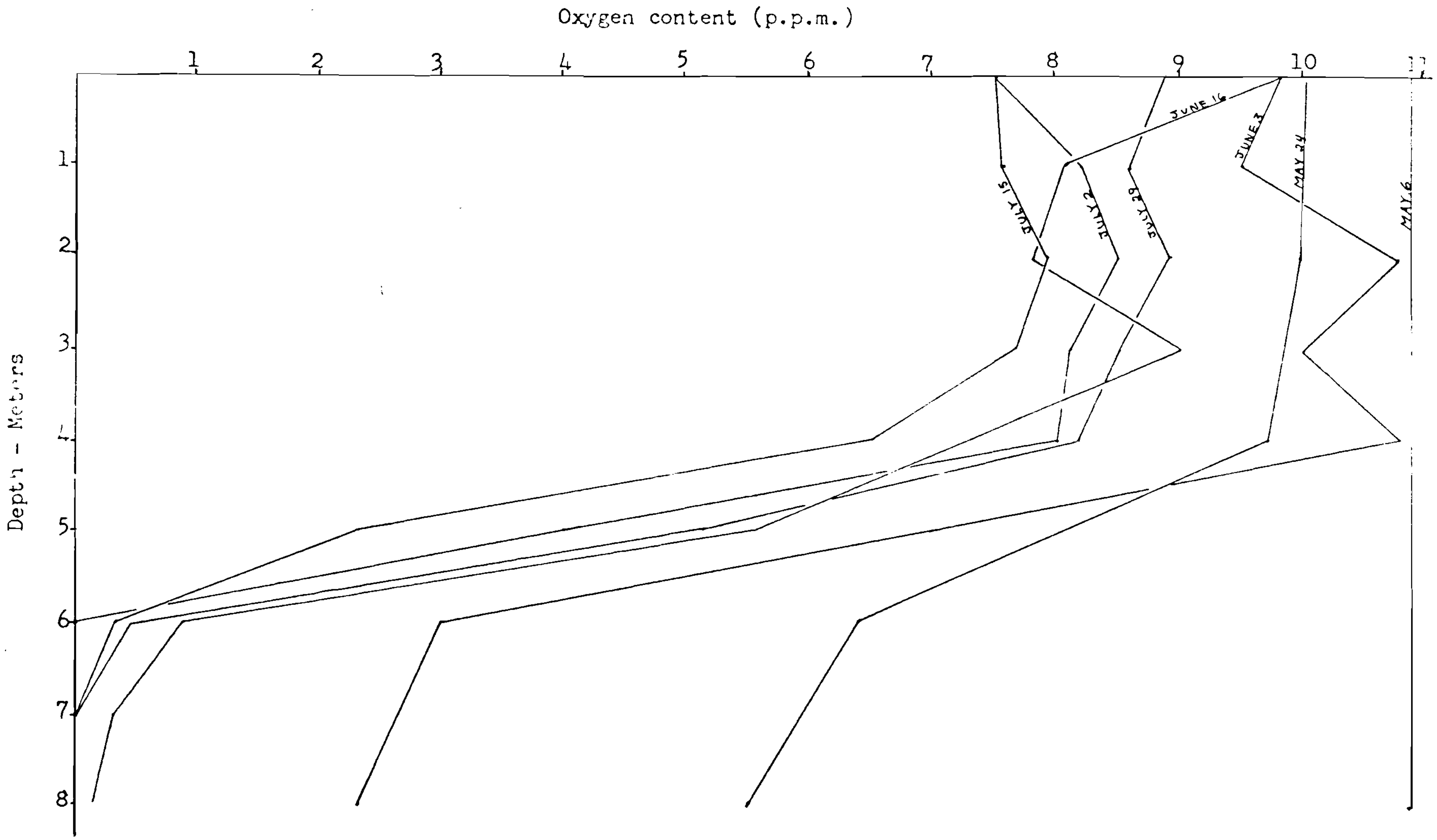

Figure 4. Dissolved oxygen (p.p.m.) at selected depths during the period of May 6 to July 29, 1964.

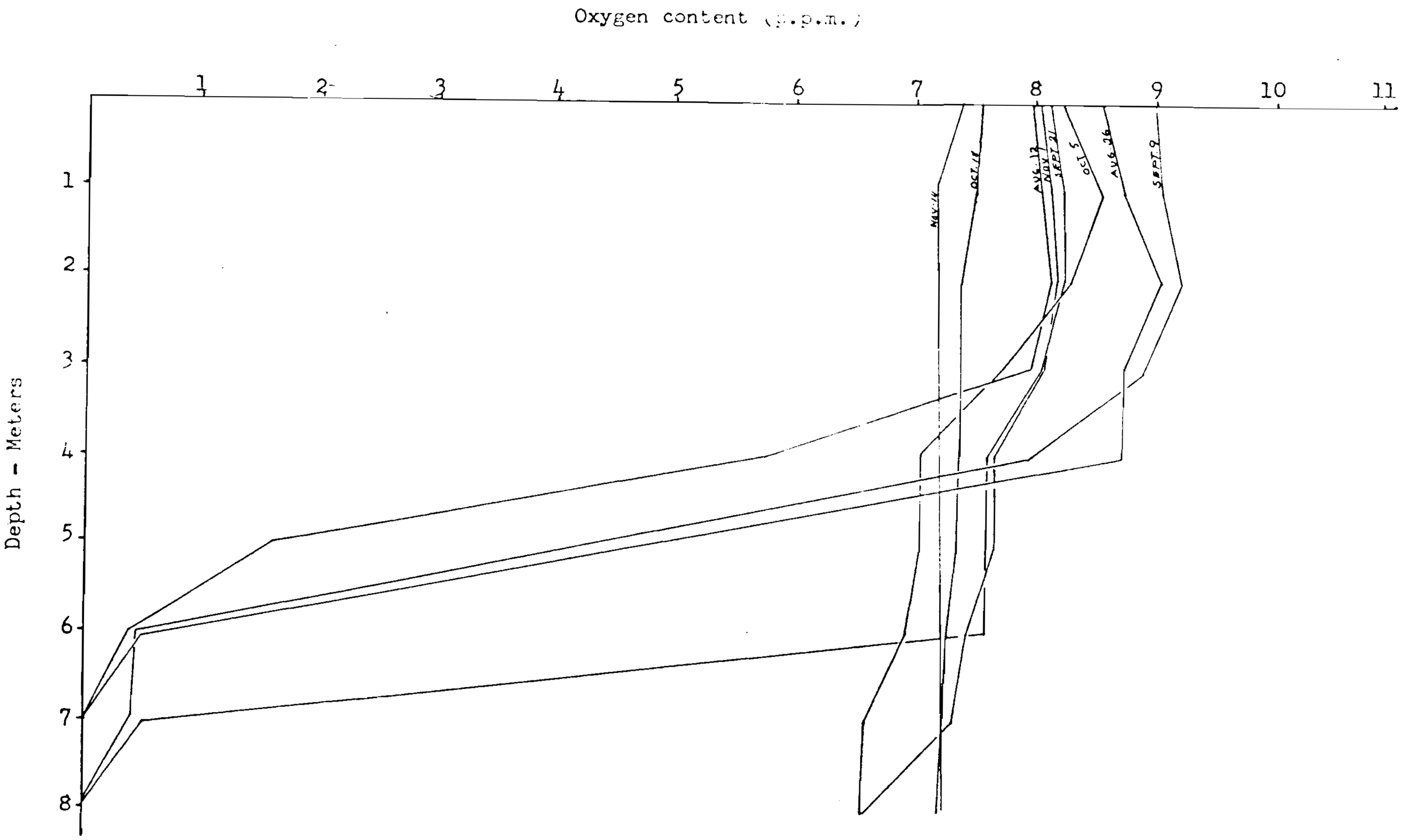

Figure 5. Dissolved oxygen (p.p.m.) at selected depths during the period of August 12 to November 14, 1964.

high of 10.7 p.p.m. on May 6 to total depletion during the months of July, August, and the early part of September. Oxygen stratification was established by May 24, and continued until the early part of October.

Based on the oxygen curves for June 3, all of July, August, and the first part of September, it is apparent that highest concentrations occurred at 2.0 meters. This condition was undoubtedly due to epilimnetic photosynthesis. On June 16, the highest oxygen concentrations occurred at the surface and at 3.0 meters. This condition could indicate two photosynthetic zones or a concentration of zooplankton (as suggested by Figures 6, 7, and 8) in the 1.0 and 2.0 meter strata.

As summer progressed, a zone of oxygen depletion developed in the lowermost portion of the hypolimnion. Probably the most important factors contributing to oxygen depletion were decomposition of organic matter and the presence of iron. According to Welch (1952), in lakes which contain iron the oxidation of soluble iron compounds to insoluble ferric hydrate plays an important role in the exhaustion of dissolved oxygen.

A fall overturn eliminated oxygen stratification by October 5.

Carbon Dioxide

Vertical and seasonal variations of free carbon dioxide content in Spring Valley Reservoir are shown in Table I. The free carbon dioxide varied from a summer low of 0.1 p.p.m. in the surface water to a maximum of 33.0 p.p.m. at 8.0 meters prior to the fall overturn. Sizable seasonal and depth variations were noted. For example, the seasonal range in free carbon dioxide in the bottom water ranged from 3.0 to 33.0 p.p.m. compared to a range of 0.1 to 4.5 p.p.m. in the surface water. The greatest surface to bottom range for any one day occurred on August 26 when a difference of 29.0 p.p.m. was noted. The smallest range occurred on October 18, again due to the fall overturn.

During summer stratification considerable decomposition takes place in the hypolimnion. Allgeier, Peterson, Juday, and Birge (1932) have shown that under laboratory conditions, carbon dioxide can be as high as 30% of the total gas evolved from decomposition. Respiration and a high decomposition rate, coupled with much reduced circulation in the hypolimnion could have been an important contributing factor to the high carbon dioxide content that occurred in the bottom waters.

No explanation, other than perhaps error, is apparent for the lower than average carbon dioxide content that was noted on July 29. It cannot be attributed to high photo-

TABLE [illegible]

CALCULATED FREE CARBON DIOXIDE CONCENTRATIONS (p.p.m.) AT SELECTED DEPTHS DURING THE PERIOD OF MAY, 1964 TO DECEMBER, 1964

Depth (meters)	May 24	June 3	June 16	July 2	July 15	July 29	August 12	August 26	September 9	September 21	October 5	October 18	November 1	November 14
0	2.0	0.8	0.8	4.5	3.0	0.1	2.0	1.0	2.5	4.0	4.5	3.5	3.0	3.5
1		0.8	0.8	4.5	2.5	0.2	1.5	1.0	2.5	4.0	4.0	3.5	3.0	3.5
2		0.8	1.5	3.0	2.0	0.1	1.5	1.0	2.0	3.5	5.0	3.5	3.0	3.5
3		1.3	0.5	4.5	2.5	0.2	2.0	1.0	3.0	4.0	5.5	3.5	3.5	3.5
4	2.5	1.5	2.5	5.5	5.5	0.4	4.0	1.0	5.0	4.3	6.0	3.5	3.8	3.5
5		2.0	3.5	10.0	11.0	1.1	8.0	6.0	7.5	4.0	6.0	3.5	4.0	3.5
6		5.0	7.5	14.0	13.0	1.7	10.5	12.0	12.5	4.5	6.5	3.5	4.3	3.0
7		7.0	8.0	14.0	13.0	3.8	15.0	17.5	18.0	22.0	7.0	3.5	4.5	3.0
8	3.0	7.5	9.0	16.0	18.0	3.9	20.0	30.0	30.0	33.0	7.0	3.5	5.0	3.0

synthesis, as plankton samples indicated a population low in phytoplankton.

Active photosynthesis never depleted carbon dioxide in the water of Spring Valley Reservoir. In contrast, there was always an excess of this gas.

Hardness

Total hardness and the portion of hardness due to calcium are given in Tables II and III. It can be seen that there was a seasonal as well as a vertical increase in total and calcium hardness until the fall overturn period. Total hardness exhibited a seasonal range from a minimum of 16 p.p.m. in the surface water to a maximum of 44 p.p.m. in the bottom water. The greatest vertical range was noted in September and late August with a surface to bottom range of 14 p.p.m. Seasonal and vertical comparisons for calcium hardness are not given due to a lack of values for hypolimnetic water. Samples taken from water in the hypolimnion during all of July, August, and September, were impossible to analyze for calcium hardness with the proceedure used. Apparently, stagnant water in the hypolimnion contained some substance(s) which interfered with the indicators.

Alkalinity

Alkalinity of water is a result of the presence of

TABLE II

TOTAL HARDNESS (p.p.m.) AT SELECTED DEPTHS DURING THE PERIOD OF MAY, 1964 TO DECEMBER, 1964

Depth (meters)	May 6	May 24	June 3	June 16	July 2	July 15	July 29	August 12	August 26	September 9	September 21	October 5	October 18	November 1	November 14
0	18.0	32.0	18.0	16.0	16.0	18.0	18.0	22.0	18.0	16.0	20.0	20.0	20.0	20.0	22.0
4	18.0	34.0	18.0	18.0	20.0	16.0	18.0	18.0	20.0	18.0	24.0	20.0	20.0	20.0	22.0
8	18.0	38.0	20.0	22.0	28.0	30.0	30.0	32.0	32.0	40.0	44.0	24.0	20.0	20.0	22.0

TABLE III

CALCIUM HARDNESS (p.p.m.) AT SELECTED DEPTHS DURING THE PERIOD OF MAY, 1964 TO DECEMBER, 1964

Depth (meters)	May 6	May 24	June 3	June 16	July 2	July 15	July 29	August 12	August 26	September 9	September 21	October 5	October 18	November 1	November 14
0	8.0	10.0	10.0	10.0	10.0	10.0	10.0	14.0	12.0	14.0	16.0	14.0	14.0	14.0	14.0
4	9.0	10.0	10.0	10.0	10.0	10.0	12.0	12.0	14.0	16.0	16.0	14.0	14.0	14.0	14.0
8	10.0	12.0	12.0	----	----	----	----	----	----	----	----	18.0	14.0	14.0	14.0

bicarbonates, carbonates, and hydroxides of calcium, magnesium, and other metals. Alkalinity has little or no relation to pH of water: it refers to the acid neutralizing capacity of the water.

As can be seen in Table IV, alkalinity was due entirely to bicarbonate with the exception of a small amount of carbonate present in the surface waters on July 29, 1964. The greatest variation in the concentration of bicarbonate was indicated during August, 1964, when bicarbonate concentration ranged from a maximum of 50.0 p.p.m. at 8.0 meters on August 26 to 11.0 p.p.m. minimum at the surface on August 12. The total bicarbonate content at all measured depths was highest during the fall period and lowest in the summer. Average alkalinity values at surface, mid-depth, and bottom were 19.5, 20.4, and 29.9 p.p.m., respectively.

Bicarbonate seasonal variation in the bottom water was nearly three times that of the surface water. Surface and mid-depth waters exhibited a much more homogeneous seasonal variation than that of the bottom water. With the exception of August 12, seasonal variation in surface bicarbonate concentration ranged from 16.0 to 26.0 p.p.m., whereas the bottom water ranged from 18.0 to 50.0 p.p.m.

A comparison of average alkalinities from various depths of the reservoir indicated only minor difference

TABLE IV

BICARBONATE ALKALINITY CONCENTRATIONS (p.p.m.) AT SELECTED DEPTHS DURING THE PERIOD OF MAY, 1964 TO DECEMBER, 1964

Depth (meters)	May 6	May 24	June 3	June 16	July 2	July 15	July 29	August 12	August 26	September 9	September 21	October 5	October 18	November 1	November 14
0	22.0	20.0	18.0	20.0	16.0	16.0	17.0	11.0	18.0	18.0	22.0	22.0	22.0	24.0	26.0
4	22.0	18.0	18.0	18.0	18.0	18.0	22.0	20.0	20.0	16.0	22.0	22.0	22.0	24.0	26.0
8	22.0	18.0	20.0	22.0	28.0	24.0	38.0	32.0	50.0	46.0	50.0	26.0	22.0	24.0	26.0

between surface and mid-depth. However, the average alkalinity of bottom water was considerably higher than those for surface and mid-depth. Homogeneous alkalinities at all depths occurred during spring and fall overturn periods.

A seasonal relationship appeared to exist between hardness and total alkalinity. As the water became progressively harder, there was an increase in total alkalinity, a relationship that was also observed by Tucker (1958).

Nitrogen

Nitrogen occurs in lake water as a gas, in organic compounds, and in the form of inorganic nitrogen compounds such as ammonia, nitrite, and nitrate. According to Reed (1961) all organic forms of nitrogen can be utilized by most green plants, particularly by various algae in their role of primary producers of enery-containing mass that can enter the aquatic food web.

Nitrite.

This form of inorganic nitrogen occurs in very minute quantities, if at all, in unpolluted waters. The water of Spring Valley Reservoir proved to be no exception. As can be seen in Table V, nitrite content was low, ranging from an absolute minimum of zero on several occasions to a maximum of 0.024 p.p.m. in the surface water on May 6. It is generally held that the seasonal variation in in concentration of nitrite nitrogen somewhat follows that

TABLE V

NITRITE NITROGEN CONCENTRATIONS (p.p.m.) AT SELECTED DEPTHS DURING THE PERIOD OF MAY, 1964 TO DECEMBER, 1964

Depth (meters)	May 6	May 24	June 3	June 16	July 2	July 15	July 29	August 12	August 26	September 9	September 21	October 5	October 18	November 1	November 14
0	.024	.001	.003	.001	.005	.005	.002	.000	.003	.000	.001	.000	.003	.001	.000
4	.015	.001	.005	.002	.003	.003	.000	.002	.003	.000	.000	.000	.001	.004	.003
8	.020	.011	.003	.001	.001	.000	.000	.002	.002	.000	.002	.018	.003	.001	.003

of nitrate from which the nitrite is probably formed (Reed, 1961 and Hutchinson, 1957). However, variation in nitrite concentrations in the water of Spring Valley Reservoir appeared to have no correlation to variations in nitrate concentrations.

Nitrate. Nitrate nitrogen occurs in relatively small concentrations in unpolluted waters. Nitrate is one of the nutritive substances necessary for the production of chlorophyll, and according to Rodhe (1948) formation of chlorophyll ceases very quickly in the presence of nitrate deficiency.

As shown in Table VI, nitrate nitrogen varied from a maximum of 1.3 p.p.m. to a low of 0.0 p.p.m. The seasonal range of nitrate in the surface water varied from 0.0 to 1.3 p.p.m., at mid-depth 0.0 to 0.6 p.p.m., and in the bottom water 0.06 to 0.9 p.p.m. There is no evidence of nitrate stratification. However, nitrate content of mid-depth water was often less than that of the surface and bottom waters. This lower nitrate content of mid-depth could be due in part to a higher assimilation of nitrate by planktonic organisms which usually occurred in greater numbers in this stratumof water than in either surface or bottom waters.

TABLE VI

NITRATE NITROGEN CONCENTRATIONS (p.p.m.) AT SELECTED DEPTHS DURING THE PERIOD OF MAY, 1964 TO DECEMBER, 1964

Depth (meters)	May 6	May 24	June 3	June 16	July 2	July 15	July 29	August 12	August 26	September 9	September 21	October 5	October 18	November 1	November 14
0	0.07	....	0.40	0.00	0.10	1.30	0.20	0.10	0.10	0.80	0.30	0.00	0.50	0.30	0.30
4	0.07	....	0.30	0.02	0.10	0.60	0.00	0.30	0.10	0.40	0.20	0.00	0.50	0.20	0.30
8	0.06	....	0.10	0.11	0.10	0.90	0.10	0.50	0.60	0.90	0.60	0.03	0.50	0.30	0.30

Phosphorus

In ecological thinking phosphorus is often considered the most critical single factor in the maintenance of biogeochemical cycles (Reed, 1961 and Hutchinson, 1957). Orthophosphate in the trophogenic zone of lakes is continually taken up and released by plankton, the turnover time of this fraction being as short as 3.6 minutes (Rigler, 1956 and 1964). Therefore, a deficiency in phosphorus is more likely to limit the productivity of a biological system.

Both total and orthosphosphate determinations were taken during the study. However, since total phosphate is a measure of both soluble and organic phosphate and the fact that soluble phosphorus occurs in the inorganic form as orthophosphate, only orthophosphate results are discussed.

As can be seen in Table VII, orthophosphate was detected in quantities greater than 1 p.p.m. only in samples taken on September 9 and 21. All remaining samples taken during the investigation contained less than 1 p.p.m. The seasonal distribution of orthophosphate varied with a mean of 0.29 p.p.m. and a range of 0.04 to 1.10 p.p.m. Much greater variation was exhibited by the water of the hypolimnion than either the surface or mid-depth. During the summer stagnation period, orthophosphate concentration

TABLE VII

ORTHO PHOSPHATE CONCENTRATIONS (p.p.m.) AT SELECTED DEPTHS DURING THE PERIOD OF MAY, 1964 TO DECEMBER, 1964

Depth (meters)	May 6	May 24	June 3	June 16	July 2	July 15	July 29	August 12	August 26	September 9	September 21	October 5	October 18	November 1	November 14
0	0.19	0.19	0.09	0.21	0.32	0.32	0.26	0.14	0.21	0.07	0.11	0.07	0.14	0.34	----
4	0.23	0.07	0.12	0.21	0.14	0.09	0.34	0.09	0.04	0.11	0.28	0.09	0.12	0.40	----
8	0.23	0.09	0.14	0.19	0.32	0.95	0.74	0.66	0.95	1.01	1.10	0.16	0.16	0.44	----

in the hypolimnion increased. This increase in phosphorus content in the hypolimnion has amply been illustrated in other lakes studies by Mortimer (1941 and 1942), Hutchinson (1941), and Rigler (1964). This increase during the stagnation period could be due in part to the iron content and the absence of oxygen. Investigation has shown that phosphorus can be released from a ferric iron phosphorus complex which is insoluble in the presence of oxygen (Reed, 1961). However, in the absence of oxygen the ferric compound is reduced to a soluble ferrous form, thus liberating phosphorus.

Total Iron

As shown in Table VIII, iron was present in the water of Spring Valley Reservoir throughout the entire period of investigation. Total iron ranged from a low of 0.03 p.p.m. in the surface water to a maximum of 9.96 p.p.m. in the bottom water. There was a constant increase in the concentration of total iron in the hypolimnion during the period of summer stratification. The greatest surface to bottom range was noted on August 26 with a range of 9.90 p.p.m. On two occasions, during spring and fall overturn, the waters exhibited homogeneous iron content from surface to bottom.

According to Reed (1961) the iron centent in

TABLE VIII

TOTAL IRON CONCENTRATIONS (p.p.m.) AT SELECTED DEPTHS DURING THE PERIOD OF MAY, 1964 TO DECEMBER, 1964

Depth (meters)	May 6	May 24	June 3	June 16	July 2	July 15	July 29	August 12	August 26	September 9	September 21	October 5	October 18	November 1	November 14
0	1.15	0.27	0.33	0.22	0.18	0.03	0.16	0.16	0.27	0.24	0.42	0.77	0.73	0.71	0.29
4	1.15	0.31	0.44	0.31	0.18	0.08	0.20	0.42	0.22	0.31	0.40	0.94	0.50	0.31	0.29
8	1.15	0.55	0.68	1.79	2.98	3.40	4.71	9.96	5.26	3.79	3.94	1.89	0.55	0.31	0.31

epilimnetic regions is ordinarily quite low, usually less than 0.2 p.p.m. The epilimnetic water of Spring Valley Reservoir had an average iron content of 0.36 p.p.m., somewhat above the average indicated by Reed.

Iron concentrations in the hypolimnion appeared to vary with oxygen content. As oxygen content decreased iron content increased. Iron is more soluble under anaerobic conditions, thus an increase in iron content within the hypolimnion would not be unusual.

According to Ruttner (1953) conditions which promote high amounts of dissolved iron are: (1) water that is free of oxygen, (2) adequate amounts of carbon dioxide, (3) a pH that is under 7.5, and (4) the presence of organic substances arising from decomposition. All these conditions were present in the hypolimnion and certainly contributed to the high iron content of these waters.

Hydrogen-ion Concentration

As illustrated in Table IX, the hydrogen-ion concentration in the waters of Spring Valley Reservoir remained within a pH range of 6.30 to 7.20 during the period of study. A surface maximum of 7.20 occurred on July 29 and a minimum of 6.30 occurred on October 5. At 8.0 meters pH values were slightly lower than at the surface throughout the period of thermal stratification. At mid-depth and

TABLE IX

HYDROGEN-ION CONCENTRATIONS (pH) AT SELECTED DEPTHS DURING THE PERIOD OF MAY, 1964 TO DECEMBER,1964

Depth (meters)	May 6	May 24	June 3	June 16	July 2	July 15	July 29	August 12	August 26	September 9	September 21	October 5	October 18	November 1	November 14
0	6.5	7.0	7.0	7.1	6.8	6.7	7.2	7.1	6.8	6.8	6.4	6.3	6.7	6.6	6.6
4	6.6	7.0	7.2	6.9	6.7	6.6	6.7	6.9	6.9	6.8	6.5	6.4	6.9	6.6	6.5
8	6.9	6.9	6.8	6.4	6.5	6.4	6.5	6.5	6.5	6.5	6.3	6.5	6.9	6.6	6.6

bottom, pH readings remained relatively more uniform than those of the surface waters.

As surface waters gained heat they became slightly more alkaline. However, seasonal pH variation never exceeded one pH unit. Most of the pH fluctuation in the upper water could be attributed to photosynthesis (Boreckly, 1956). Hypolimnetic waters tended to become more acid prior to fall overturn. Liberation of large amounts of free carbon dioxide in the hypolimnetic waters were probably responsible for the lowering of pH (Hutchinson, 1957). With the onset of fall overturn and complete circulation of the water, the hydrogen-ion concentration became fairly homogeneous at all depths.

BIOLOGICAL CONDITIONS

Vertical Distribution of Zooplankton

All samples obtained for the present study were taken during daylight hours, usually in the morning. As would be expected, there were consistent differences in zooplankton numbers at the various depths. Many factors determine the vertical distribution of zooplankton making it difficult to generalize on the causes for these distribution patterns as described below. However, Armitage (1962) suggests light as an important factor.

As seen in Figure 6, there is no obvious seasonal

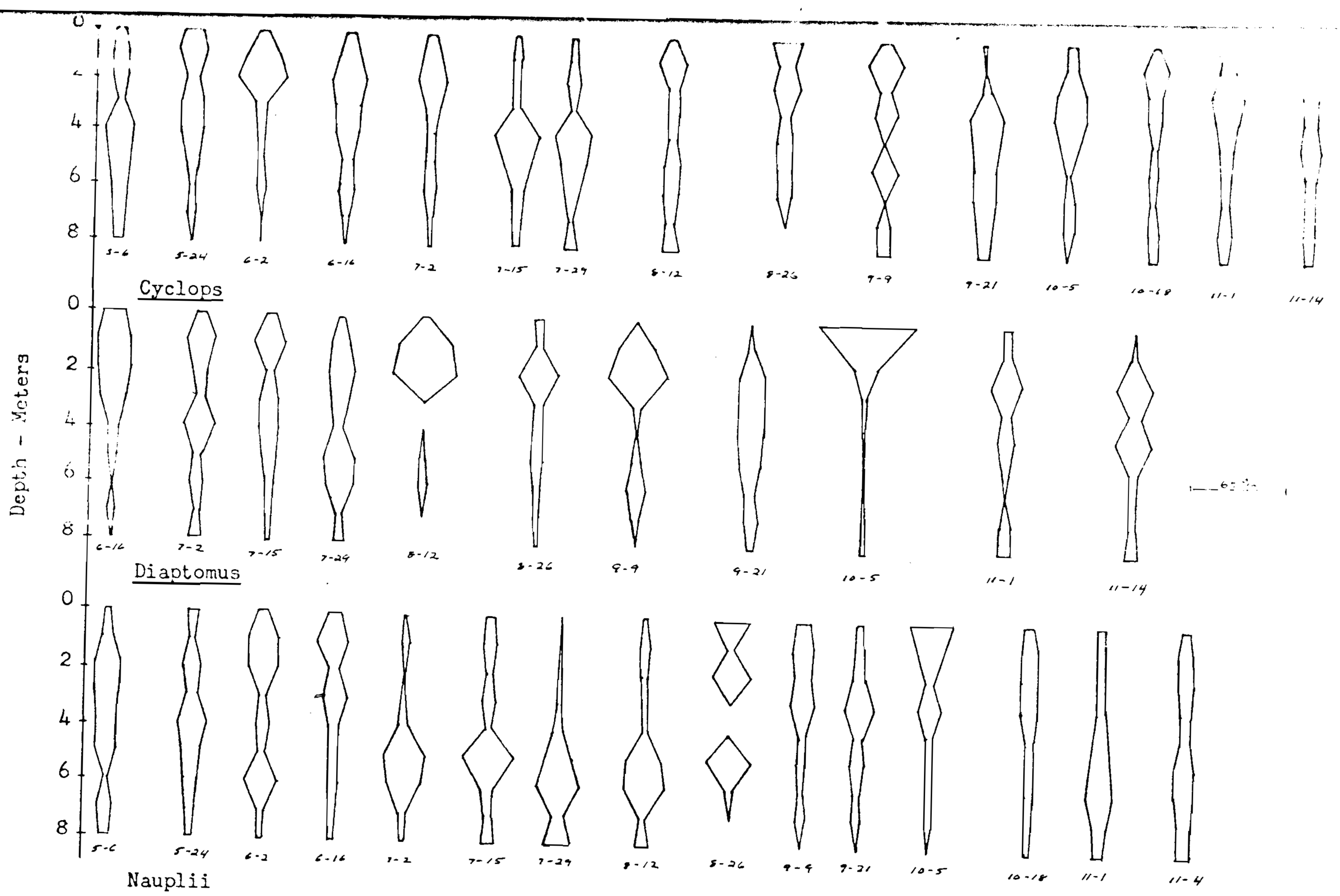

Figure 6. Vertical distribution of Copepoda on selected dates in Spring Valley Reservoir.

pattern to the vertical distribution of copepods. However, Cyclops and nauplii showed some correlation with light penetration. They were concentrated at greater depths during July when light penetration was maximum. Diaptomus showed a tendency to favor the upper 3 meters throughout most of the study. Nauplii tended to favor the upper 2 meters of the water as often as deeper water. This would appear to be an exception to the general belief that nauplii have a tendency to concentrate in deeper waters.

As shown in Figure 7, the cladocerans (Daphnia) were present only in small numbers at the surface. They appeared to show a slight correlation with light penetration. Daphnia were concentrated near the surface on June 16, September 9, and October 18, during periods of low Secchi disc readings (Figure 3, page 12).

As seen in Figure 7, the rotifers Kellicottia and Polyarthra showed a tendency to favor somewhat deeper water during the warmer summer months and the surface water during the fall. The other genera of rotifers, which occurred sporadically throughout the period of study, were not constantly more abundant in one layer of water than in another.

Ceratium first appeared more concentrated in the upper water but from mid-July to mid-August they favored deeper water (Figure 8). During fall overturn, zooplankton

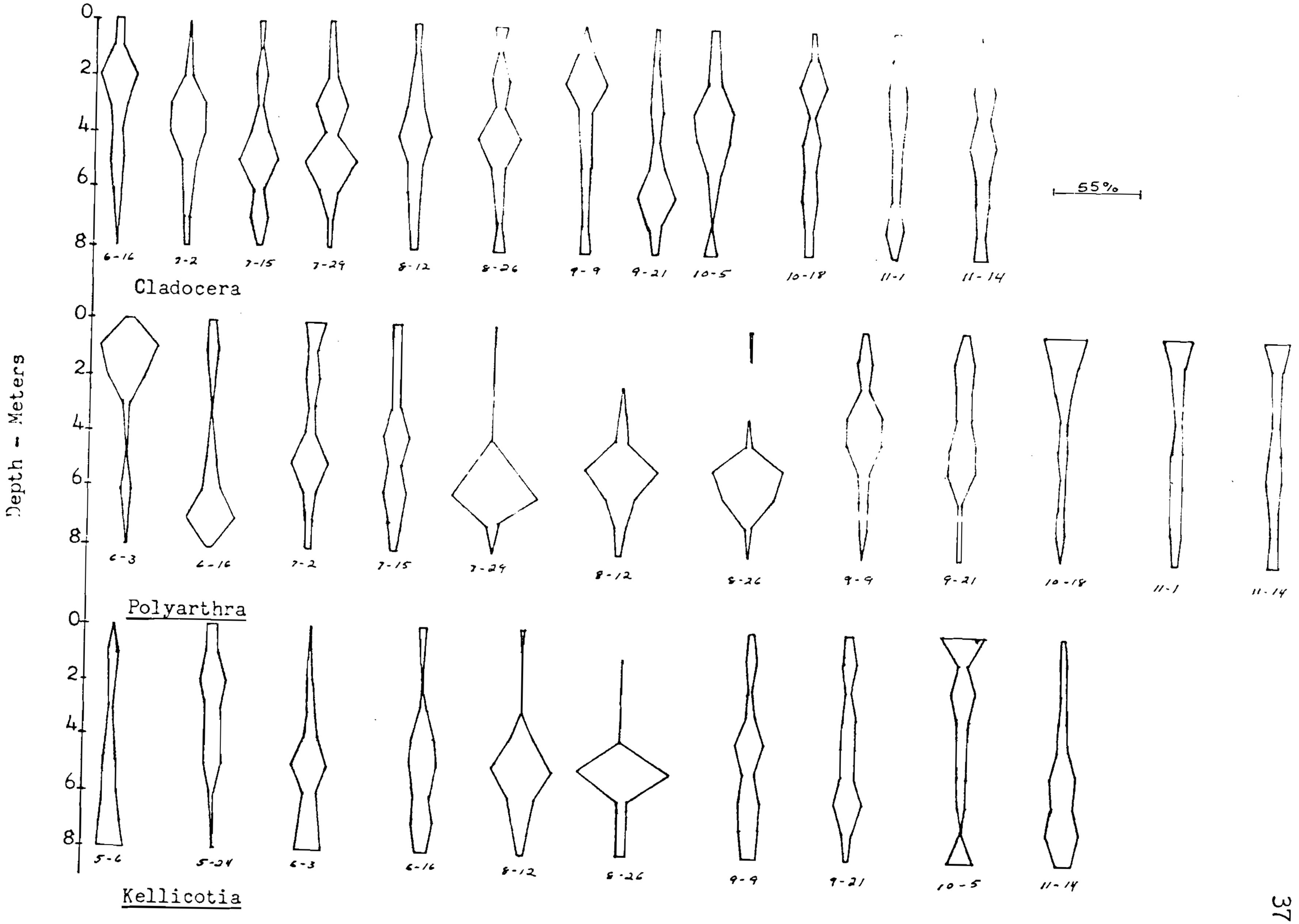

Figure 7. Vertical distribution of Cladocera and Rotatoria on selected dates in Spring Valley Reservoir.

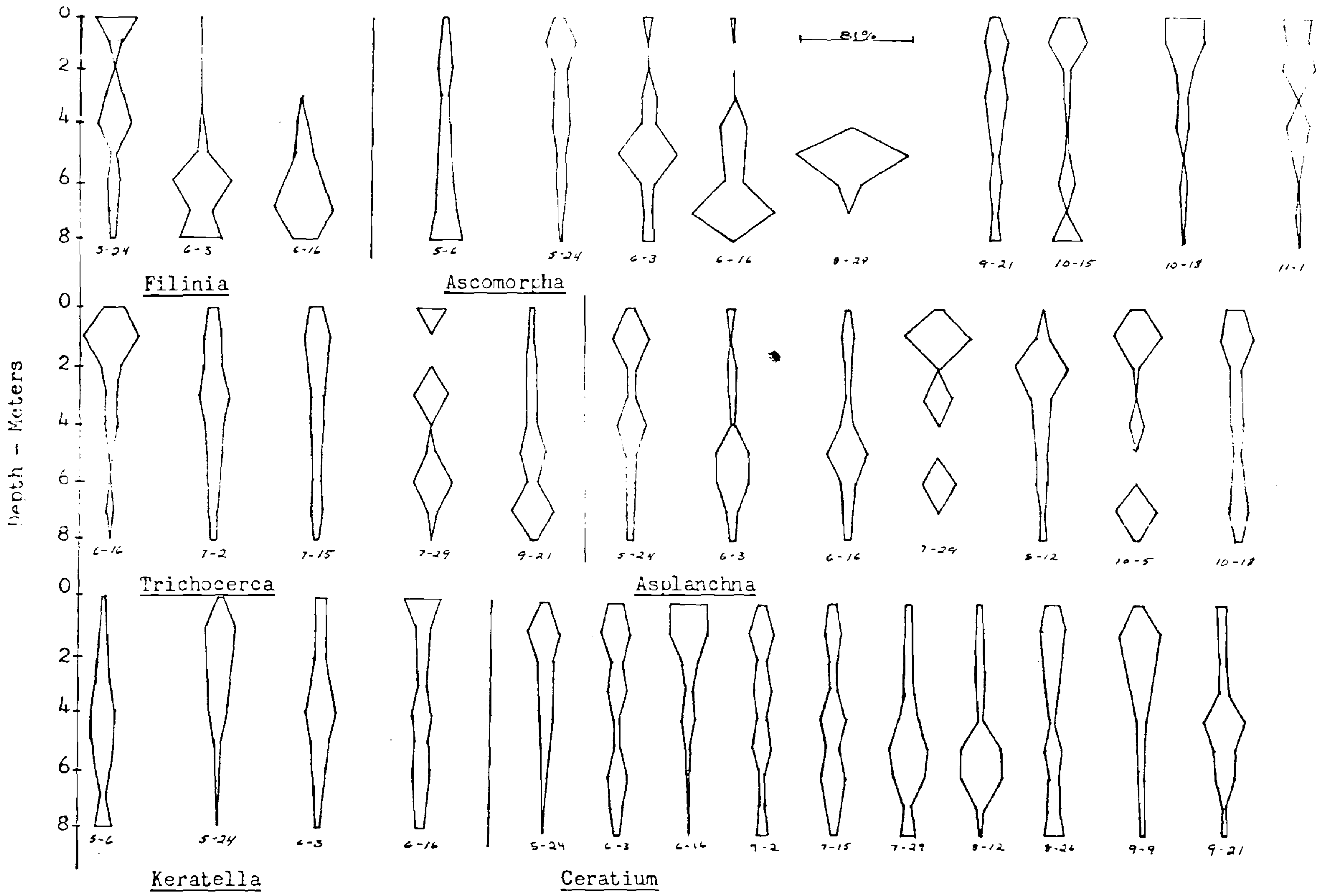

Figure 8. Vertical distribution of Rotatoria and Ceratium on selected dates in Spring Valley Reservoir.

distribution became more uniform throughout various depths, with some tendency for concentration near the surface. This particular pattern of vertical distribution, during fall overturn, was also noted by Armitage (1962).

Seasonal Distribution of Zooplankton

For convenience and ease of discussion, zooplankton results are given in four groups: Copepoda, Cladocera, Rotatoria, and Protozoa (Ceratium). Population values for each sampling day were determined by averaging the vertical samples for each station.

Copepoda. Two genera, Cyclops and Diaptomus occurred regularly in the waters of Spring Valley Reservoir. General features on seasonal variation in abundance of Copepoda are shown in Figure 9. It is seen that for the most part copepods increased at about the same time throughout the reservoir. Therefore, it may be concluded that copepod distribution is of a homogeneous nature, a situation that could be expected in a body of water as small as Spring Valley Reservoir.

Copepod zooplankters were present in relatively small numbers at the start of the investigation in early May. They increased to what apparently was a summer pulse in late June and early July, after which their numbers decreased until late autumn. On November 14, at the

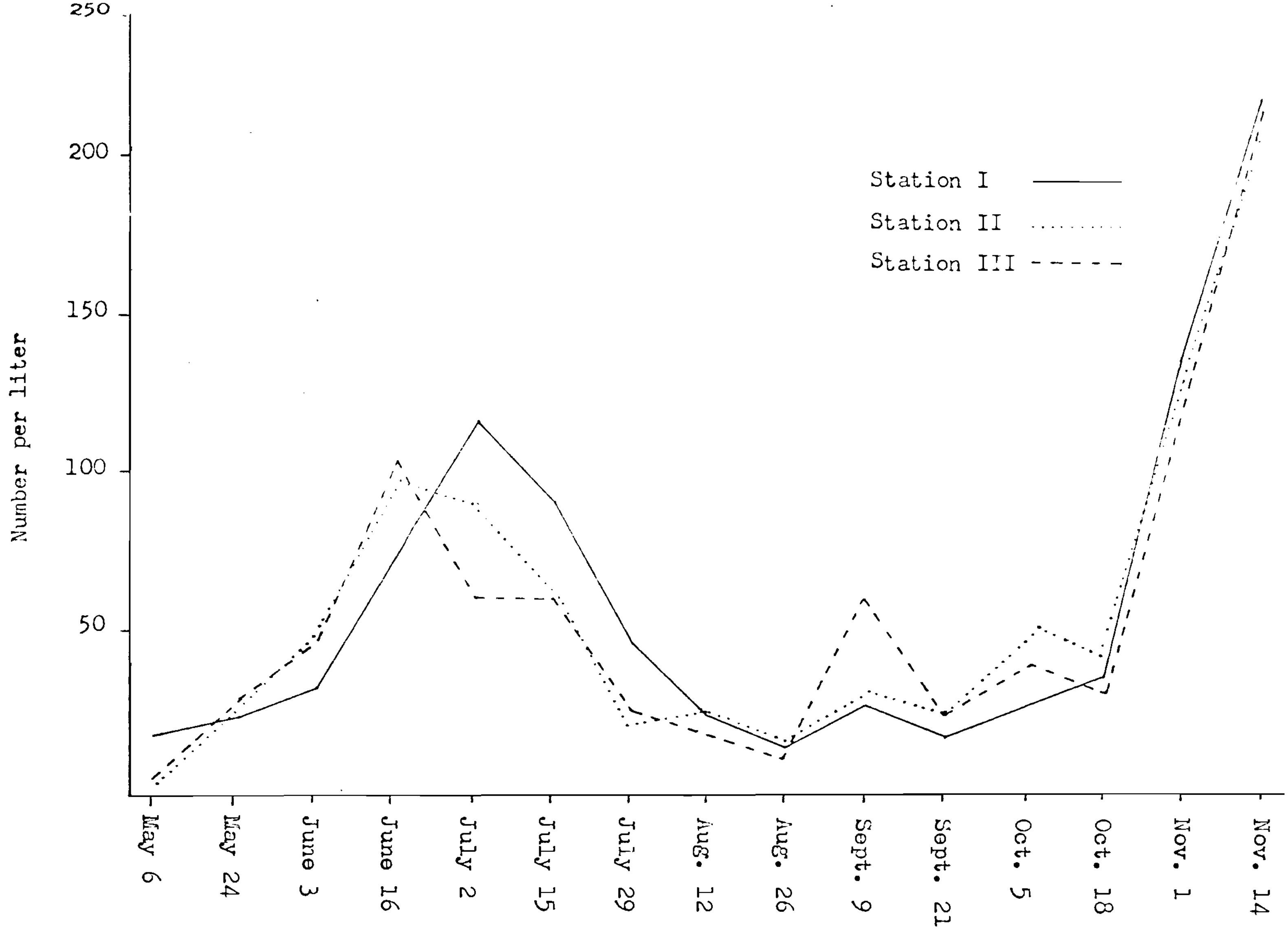

Figure 9. Seasonal and inter-station variation (average no./liter) in total Copepoda on selected dates.

termination of the study, a second pulse occurred when the numbers had risen to the highest value of the entire study, with an average of 221 organisms per liter. This large number was primarily due to the quantity of nauplii present in the zooplankton samples. It is interesting to note that copepods were more abundant during the second pulse and at a time when waters were coolest.

Table X illustrates the variation in number of dominant copepod constituents during sampling periods. Since copepod numbers varied at about the same rate at all sampling stations, values are based on an average for the various sampling stations.

Cyclops sp. was the most abundant constituent of the adult copepod complex throughout the period of investigation. Cyclops comprised almost the entire number of adult copepods during the two pulses. In these two pulses, maxima were 28 and 75 organisms per liter, respectively.

Diaptomus sp. occurred regularly but were never present in large numbers. The greatest numbers were recorded on July 15, with a maximum of 17 organisms per liter.

Nauplii were the most abundant constituent of the total copepod zooplankton population. A maximum of 121 organisms per liter occurred during the fall pulse.

TABLE X

AVERAGE ABUNDANCE OF THE MAJOR COPEPOD CONSTITUENTS (EXPRESSED AS NUMBER PER LITER) DURING SELECTED PERIODS FROM MAY, 1964 TO DECEMBER, 1964

Period	Diaptomus	Cyclops	Nauplii
May 6	0.0	5.0	5.0
May 24	1.0	9.3	16.0
June 3	1.0	17.3	18.0
June 16	2.0	28.3	62.0
July 2	5.6	24.0	59.3
July 15	17.0	13.3	43.0
July 29	8.3	7.0	10.3
August 12	7.0	4.3	10.0
August 26	4.0	7.0	4.0
September 9	4.6	2.3	29.3
September 21	3.0	4.0	17.0
October 5	7.6	14.6	17.0
October 18	4.6	15.3	17.0
November 1	6.0	40.0	68.0
November 14	7.6	75.0	121.3

Cladocera. During the period of investigation only a single genus, Daphnia, occurred in Spring Valley Reservoir. Further, this water flea rarely constituted a large element of the plankton. As shown in Figure 10 Cladocara exhibited a single pulse during the study with a maximum development of 72 organisms per liter recorded in mid-July. At the time of maximum development, summer phytoplankton populations were at a minimum.

Stations I and II exhibited slightly higher maxima during the July pulse than Station III. However, no interstation differences in the time of occurrence of plankton pulse peaks were noted, all three stations attaining maxima on the same date, July 15. After the July pulse there was a gradual decline in Cladoceran populations. The usual autumn pulse typical of many Cladoceran populations did not develop (Pennak, 1946).

Rotatoria. Seven genera of rotifers were identified in Spring Valley Reservoir during the course of this investigation. Of the genera represented, Filinia and Trichocerca occurred only for a short period in early summer. Ascomorpha, Asplanchna, Keratella, Kellicottia, and Polyarthra were present throughout the entire period of study.

Sizable variations in abundance of total rotifers

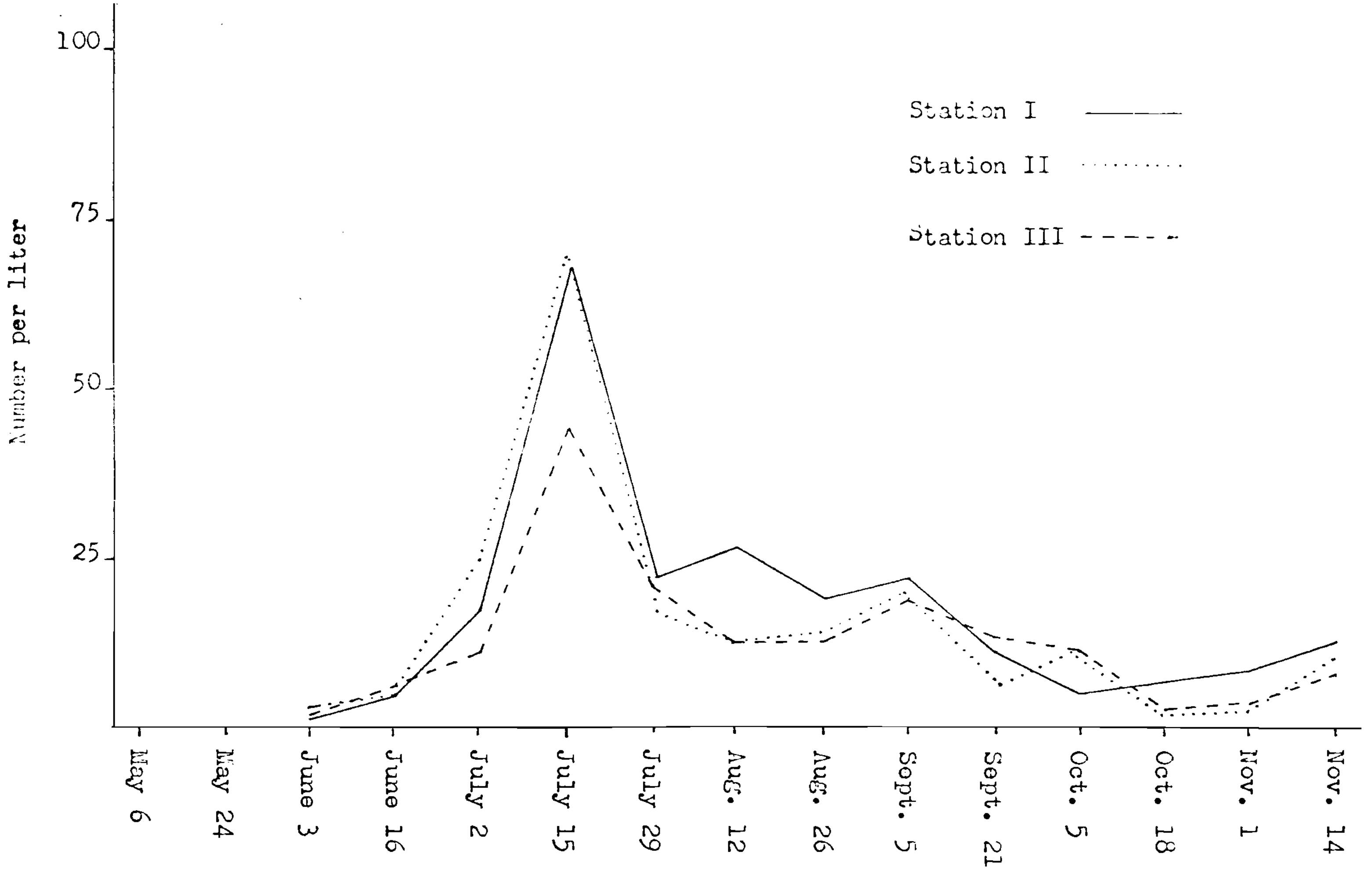

Figure 10. Seasonal and inter-station variation (average no./liter) in total Cladocera on selected dates.

were noted. Figure 11 gives the seasonal curves for total Rotatoria. It can be seen that four distinct pulses occurred during the study. The first pulse involved a heterogeneity of genera with Keratella and Kellicottia constituting nearly 90 per cent of the population in this June pulse. Rotifers belonging to two genera, Polyarthra and Trichocerca, were responsible for the second pulse. The third pulse, occurring in September, involved only one predominant genus (Kellicottia) although most other genera also occurred. The fourth and final pulse occurred in mid-October. Two genera, Ascomorpha and Asplanchna, were responsible for this pulse. However, Ascomorpha was the more important of the two genera with a maximum of 614 individuals per liter.

For the most part, rotifer numbers at the collecting stations varied at the same time and had similar population peaks. However, during the October pulse there were considerable inter-station differences in numbers, especially between Stations I and III. This difference was primarily due to the presence of larger numbers of Ascomorpha at Station III.

Each rotifer genus identified in the plankton samples is discussed briefly in the following section. Many individuals could not be identified even to genus because they were strongly contracted and contorted by alcohol preservative.

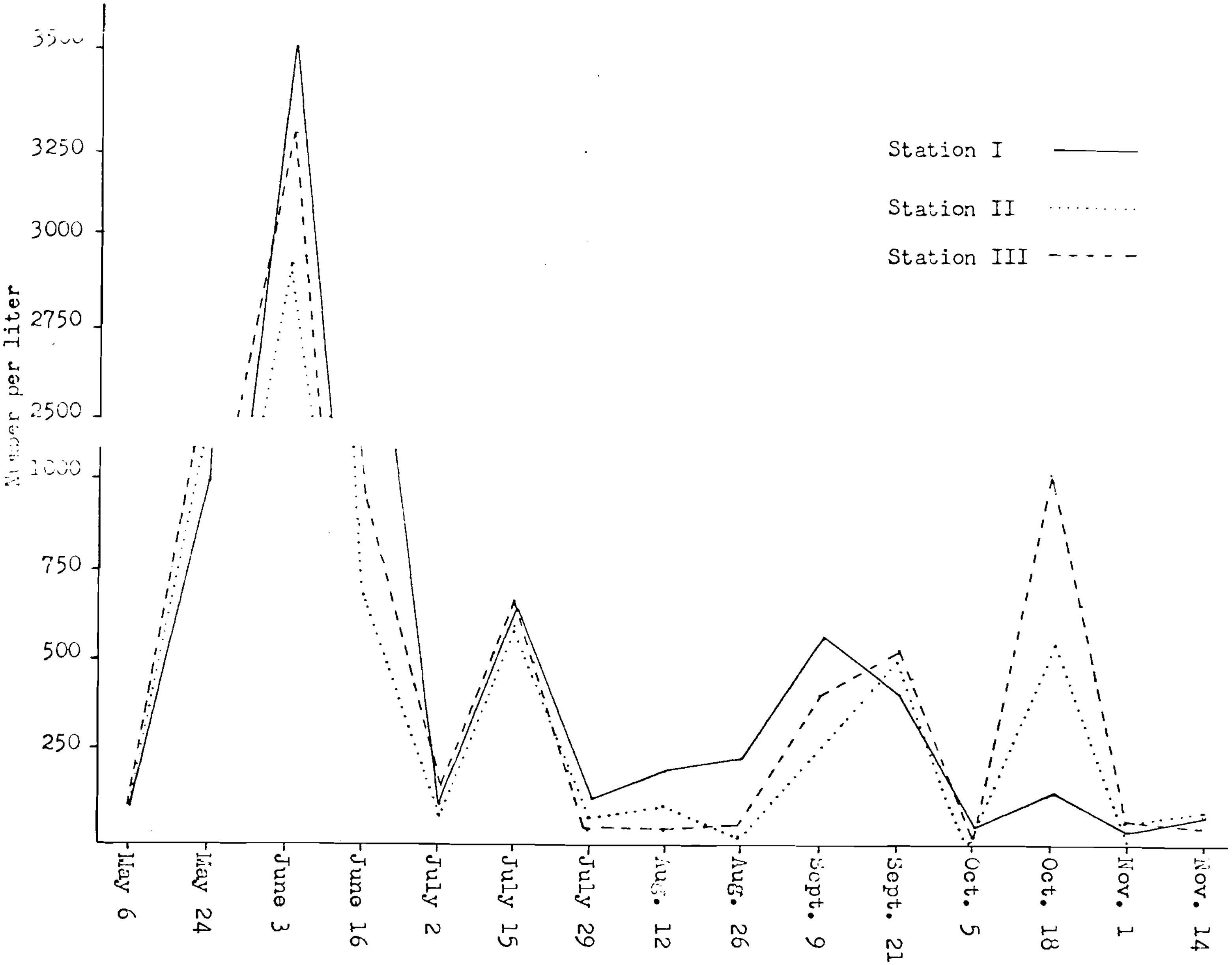

Figure 11. Seasonal and inter-station variation (average no./liter) in total Rotatoria on selected dates.

Ascomorpha sp. occurred sporadically throughout the period of study. A maximum of 614 individuals per liter occurred during the October pulse and in somewhat more limited numbers during the June pulse.

Asplanchna sp. occurred abundantly only during June and again in limited numbers in the October pulse.

Filinia longiseta was never a very important constituent of the rotifer population. It occurred only during June collections and never in large numbers.

Keratella cochlearis was present in abundance only during the June pulse when a maximum of 1840 individuals per liter occurred.

Kellicotta longispina was the most abundant of all rotifers, constituting a major portion of the early June pulse and nearly all of the September rotifer population. A maximum of 2230 individuals per liter occurred in early June.

Poyarthra sp. occurred regularly throughout the period of investigation. The greatest numbers were encountered during the mid-July pulse when a maximum of 335 individuals per liter were recorded.

Trichocerca cylindrica constituted a major portion of the rotifer population only during July. The greatest average number attained was 372 individuals per liter recorded on July 15.

Protozoa. Although the waters of Spring Valley Reservoir undoubtedly contain many plankton protozoa, the only protozoan of sufficient size to be taken with the sampling method used was Ceratium hirundinella. Seasonal and inter-station variation of Ceratium are shown in Figure 12. Ceratium was by far the most abundant of all zooplankters, with a high of 6795 organisms per liter recorded from Station I on July 29. It can be seen that there was a gradual increase in Ceratium, from a minimum of 3 organisms per liter of May 6, to a pulse of 1297 organisms per liter recorded at Station I on June 16. This pulse was followed by a much more pronounced pulse on July 29 when a maximum of 6795 organisms per liter were recorded at Station I.

Even though Ceratium increased at about the same time throughout the reservoir, quantitatively there were considerable inter-station differences in total numbers during the late July pulse. Differences between the two extremes were: 6795 organisms per liter at Station I and 4041 organisms per liter at Station III. This represents a difference of 2754 organisms per liter.

Ceratium decreased markedly after the late July pulse. By late September they had almost disappeared from

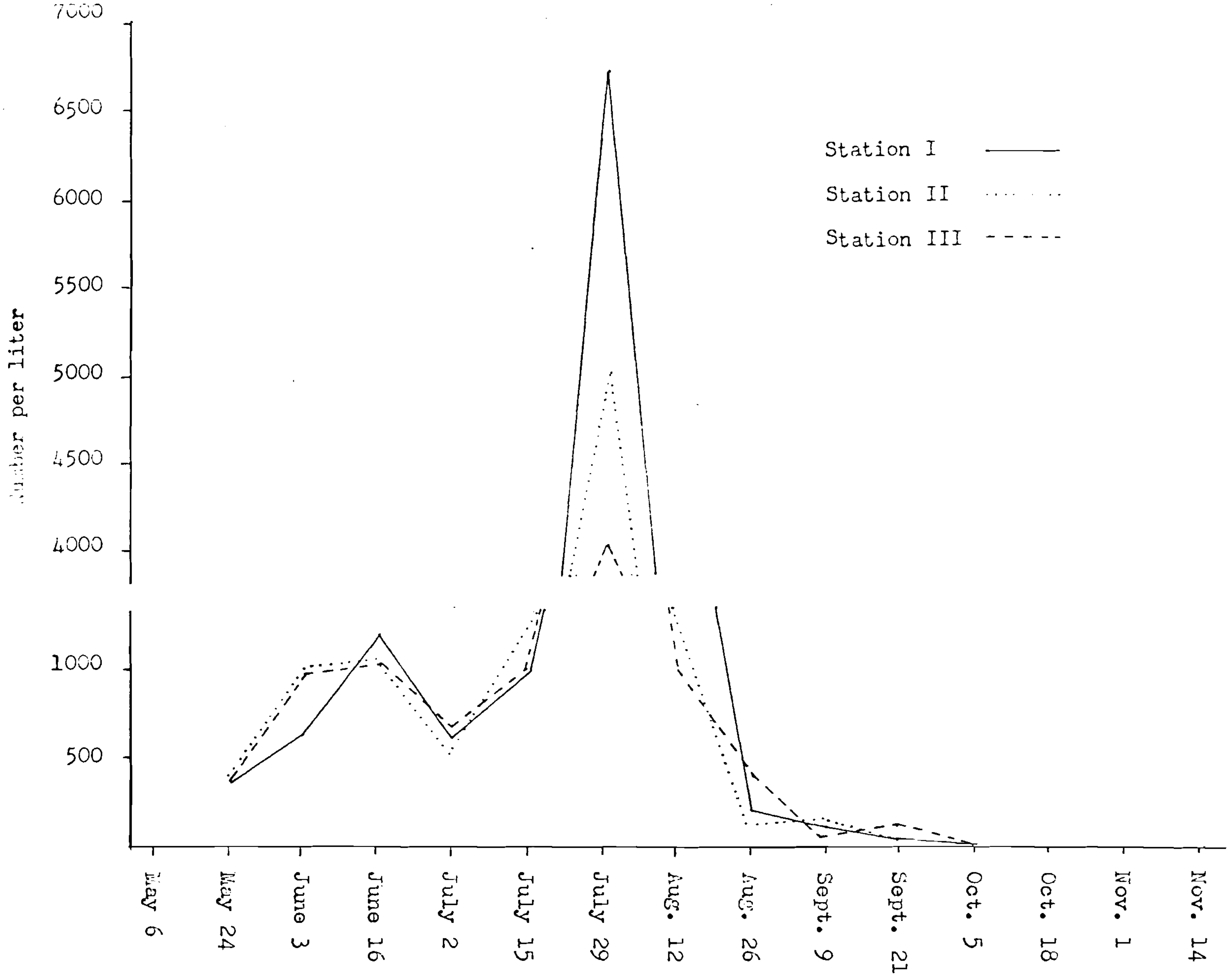

Figure 12. Seasonal and inter-stational variation (average no./liter) in total Ceratium on selected dates.

the plankton populations.

THE STANDING CROP

The average summer standing crop of zooplankton for Spring Valley Reservoir was arrived at by averaging all vertical samples for each station independently, and then combining and averaging these totals for an over-all warm season average for the entire reservoir. The mean calculated summer standing crop of total zooplankton was 505 organisms per liter.

Standing crop represents an instantaneous quantity of organisms, and is visible evidence of the degree of success of the nutritional chain concerned (Welch, 1952). One of the best studies in this field is that of Juday (1942) on the standing crop of four Wisconsin lakes. However, his results were determined gravimetrically, thus no comparisons between the two studies can be made as similar data are not available on Spring Valley Reservoir.

Buscemi (1964) has expressed zooplankton abundance as average number of organisms per liter for three Idaho lakes. Pennak (1949) extensively studied seven northern Colorado reservoirs, computing the mean annual standing crop for each. Tressler, Tiffany, and Spencer (1940) have expressed zooplankton abundance as average number of organisms per liter for Buckeye Lake, Ohio. Chandler (1940) and Davis (1962) have published comparable data on zooplankton for two different areas in Lake Erie. Stross (1954) extensively studied Lake Pend Oreille in northern Idaho and reported his results as average number of organisms per liter. Young (1935) published comparable data for Flathead Lake, Montana.

For purposes of comparison, differences in summer standing crop from the above mentioned studies, except that of Juday, have been calculated from respective tables and graphs and presented along with similar data for Spring Valley Reservoir. It should be noted that all calculations represent the average standing crop from approximately June 1 to September 15 unless otherwise indicated.

As seen in Table XI rather high numbers of Rotatoria were found in Spring Valley Reservoir when compared with other lakes. Spring Valley Reservoir with an average of 773 organisms per liter was exceeded only by Gaynor Lake, Colorado, with 1772 individuals per liter. However, several of the compared lakes exceeded the numbers of copepod and cladocerans found in Spring Valley Reservoir. Ceratium, the only protozoan of sufficient size to be taken with the collecting method used, averaged 1224 per liter, while this protozoan averaged 7,133 per liter in Buckeye Lake, Ohio.

Spring Valley Reservoir's standing crop ranged

TABLE XI

MEAN STANDING CROP OF ZOOPLANKTON (EXPRESSED AS NO./LITER) FOR SEVERAL SELECTED LAKES

Lake	Protozoa	Rotatoria	Copepod	Cladocera	Reference
Spring Valley Res., Idaho	1224	773	47	17	Duff
Allens Lake, Colo.	106,000	168	86	26	Pennak (1949)
Baseline Lake, Colo.		662	74	83	
Beasley Lake, Colo.	43,000	259	158	129	
Boulder Lake, Colo.	128,000	215	29	45	
Gaynor Lake, Colo.	1,050,000	1772	482	141	
Haydens Lake, Colo.	39,000	225	41	73	
Kossler Lake, Colo.		30	25	5	
Buckeye Lake, Ohio	7133	158	75	11	Trossler (1940)
Bass Island Lake Erie	30	30	39	4	Chandler (1940)
Cleveland Harbor, L. Erie		200	17	33	Davis (1962)
Lake Pend Oreille, Idaho		44	25	5	Stross (1954)
Flathead L., Montana	58	34	16	1	Young (1935)
Kelso Lake, Idaho		378	24	35	Buscemi (1964)
Fernan Lake, Idaho		54	138	12	
Stanley Lake, Idaho		35	3	10	

considerably higher in quantity than most of the lakes compared in Table XI, but several of the Colorado lakes exceeded that of Spring Valley Reservoir. However, it must be remembered that standing crop represents an instantaneous quantity of organisms but does not include the time (rate) factor concerned with the development of the crop. According to Reed (1961), a high standing crop does not necessarily mean that the ecosystem has a high rate of production.

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LITERATURE CITED

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NOTICE OF RESEARCH PROJECT
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SUPPORTING AGENCY:

OFFICE OF WATER RESOURCES RESEARCH
DEPARTMENT OF THE INTERIOR

TITLE OF PROJECT:

Effects of stream sedimentary deposits on the distribution and metabolic activity of the bottom fauna in Coeur d'Alene Lake, Idaho

Give names, departments, and official titles of PRINCIPAL INVESTIGATORS and ALL OTHER PROFESSIONAL PERSONNEL engaged on the project.

Dr. Philip A. Buscemi, Assistant Professor
Aquatic Biology Laboratory, Department of Biological Sciences

NAME AND ADDRESS OF INSTITUTION:

University of Idaho
Moscow, Idaho

SUMMARY OF PROPOSED WORK — (200 words or less.) — In the Science Information Exchange summaries of work in progress are exchanged with government and private agencies supporting research, and are forwarded to investigators who request such information. Your summary is to be used for these purposes.

Two shallow-water transects will be established in Coeur d'Alene Lake, extending from the river mouths to an area of typical lake bottom deposits. Quantitative bottom fauna samples will be collected at regular monthly and spatial intervals along these transects during the warm season. Samples will be sieved through 0.2 and 0.4 mm mesh screens and the debris + organisms preserved in 10% neutral formalin. Organisms will be removed from the debris by a flotation process. All organisms collected will be classified and counted. A map will be constructed which duplicates the bottom contours of the lake in the area of the transects, and the horizontal distribution of bottom fauna plotted thereon. Growth rates of certain larvae will be determined by weighing selected organisms and measuring hard parts. Respiration rates of those organisms collected from St. Joe River deposits will be compared with those collected from Coeur d'Alene River deposits, the two being compared to respiration rates determined for the natural lake fauna. These determinations will be carried out with the aid of a Warburg respirometer. Core samples of bottom deposits will be collected along the transects and an analysis made for total volatile matter by the method of loss-on-ignition. The vertical distribution of such volatile matter will be determined for comparison with the vertical distribution of organisms in the sediments.

* Limnology
Lakes

Period for this NRP
FY - 66 to __ - __
mo yr mo yr
Sub-group A

SIGNATURE OF PRINCIPAL INVESTIGATOR

PROFESSIONAL SCHOOL (medical, graduate, etc.) [illegible]

Proj. No.	Period	Amount	Proj. No.	Period	Amount
GUW 332	ACTIVE FY66	UNKNOWN			