Journal of the Arkansas Academy of Science

Volume 5 Article 14

1952

Limnological Studies in Arkansas. II. The Effect of Intense Rainfall on the Abundance and Vertical Distribution of Plankton in Lake Fort Smith, Arkansas

Carl E. Hoffman
University of Arkansas, Fayetteville

LIMNOLOGICAL STUDIES IN ARKANSAS*

II. The Effect of Intense Rainfall on the Abundance and Vertical Distribution of Plankton in Lake Fort Smith, Arkansas

CARL E. HOFFMAN

University of Arkansas

Lake Fort Smith, an artificial lake in northwestern Arkansas, constructed by inundating a mountain valley, is subject to the inflow of large quantities of water following rapid heavy rainfall. It has a surface area of approximately 525.5 acres, a volume of 525,598,000 cubic feet and a watershed covering about 65 square miles. The runoff water from this watershed is noticeably turbid in late winter and spring when the hills are free of green vegetation and the land is already saturated due to preceding rainfall and the slow drying of the soil during these seasons. In winter and spring large quantities of partly decayed vegetation from the previous summer and fall are carried into the lake by the runoff water.

In a study of plankton populations of Lake Fort Smith in 1939 (Hoffman and Causey, 1952) it was found that the numbers of *Kirchneriella obesa* (W. West) Schmidle virtually disappeared following intense rainfall in March and April. A similar study was made in 1949 and 1950 and special attention was given to the vertical distribution of plankton, and to the physico-chemical features occurring after heavy precipitation.

Some of the changes which rapid heavy rainfall might bring about in a lake and which in turn could influence the abundance of organisms are: increased turbidity caused by both suspended and settling materials resulting in a reduction of light and a silting down of organisms; a dilution of the organisms in the lake by large quantities being carried over the spillway; a change in the physico-chemical features which could be either harmful or beneficial to the organisms; and an addition of inorganic and organic materials which might be utilized directly or indirectly as food by the plankton.

Methods used in this investigation are discussed in Hoffman (1951) and Hoffman and Causey (1952). Samples collected in this investigation, for physico-chemical and plankton analyses, were taken at 1, 3, 5, 7, 10, 12 and 15 meters. Turbidity measurements were made with a Helige Turbidimeter.

The author is indebted to Professor Samuel Eddy of the Department of Zoology, University of Minnesota for identification of the *Peridinium* found in Lake Fort Smith; to Dr. Elbert H. Ahlstrom of the United States Fish and Wildlife Service, Scripps Institution of Oceanography, La Jolla, California for the determination of the *Dinobryon*; and to Mr. Bruce Crawford of the Arkansas Game and Fish Commission for assistance in the field.

RESULTS

The interval between May 6 and June 12, 1950 was chosen to study the effects of rapid heavy rainfall upon the abundance and vertical distribution of organisms. For the two months prior to May 6, 1950 only 0.2 of an inch of rainfall was reported in the Lake Fort Smith region, but in the 6 days previous to May 13, 1950, the second sampling date, 5.3 inches of rain fell. From May 13 through June 12, 1950 the rainfall was not heavy and the precipitation produced no evident harmful changes in the physico-chemical and biological features of the lake. The amount of rainfall in each six day period preceding each collecting date from May 19 to June 12, 1950 inclusive was as follows: May 19 (0.3 inch), May 29 (0.6 inch), June 5 (0.8 inch), and June 12 (1.3 inch). Results of this investigation are summarized in the following tables and figures: Table I gives the physico-chemical conditions; Table II and Figure 1 present the vertical distribution of turbidity, phytoplankton and zooplankton; and Table III gives

*Research Paper No. 1038 Journal Series. University of Arkansas

the averaged number of plankton and the dominant forms for 1, 3, 5, 7, 10, 12 and 15 meters.

Period Preceding Intense Rainfall

An average of 453 organisms per liter, present on May 6, 1950, was the largest number of plankton encountered since November 3, 1949. Using the criterion as presented in Welch (1935, p. 48) to delimit the thermocline, the lake was stratified as of April 29, 1950. Turbidity on May 6 was low, the amount ranging from 11 to 16 parts per million. The dominant organisms present on this date were: *Dinobryon cylindricum* Imhof, *Synedra* sp., *Codonella cratera* (Leidy), and an unidentified *free swimming* zooid belonging to the order Peritricha, suborder Sessilia, tribe Aloricata. Also present, but in small numbers, were: *Trachelomonas volvocina* Ehr., *Peridinium wisconsinense* Eddy, 4 species of rotifers, a variety of members belonging to the Chlorophyta and a few individuals belonging to the crustacea. *Kirchneriella obesa*, a dominant form in the winter of 1938-1939, appeared in numbers no greater than 1 per liter in 1949-1950.

Effect of Intense Rain

During the six days preceding May 13, 1950 a rainfall of 5.3 inches fell on the lake and its watershed; on May 7 and May 11, 2.68 and 1.27 inches respectively, were recorded. This rainfall changed the transparency, as measured by the Secchi disc, from 60 centimeters on May 6 to 13 centimeters on May 13. On the latter date the turbidity also increased over that of May 6. Turbidity on May 13 ranged from 51 to 57 parts per million in the upper 12 meters (figure 1). On May 13 the turbid materials had not reached the fifteenth meter as evidenced by a low reading of 21 parts per million (figure 1). The surface temperature, following the rain, changed from 19.0°C. to 16.2°C. and the lake which was stratified the week before now showed no thermocline. Chemical changes were: increased carbon dioxide content from the surface to the bottom, a change in pH from 6.6 to 6.4 in the upper 12 meters, a lowering of the bicarbonate content, and a reduction of dissolved oxygen in the upper levels with a rise in content in the lower water levels (table I).

The phytoplankton, following this heavy precipitation, were greatly reduced in numbers from the surface through 15 meters (table II and figure 1). Of the few that occurred on this date the largest numbers were found near the surface. Since *Dinobryon cylindricum* and *Synedra* sp. were the only abundant phytoplankters collected on May 6, 1950 significant comparisons can only be made of these. Both *Dinobryon* and *Synedra* were greatly reduced when compared to the records of May 6. However, it should be indicated that the Chlorophyta, even though the numbers were not large on May 6, were completely absent on May 13 (table III).

Numbers of zooplankton following this heavy rainfall were only slightly altered. Figure 1 shows that the largest numbers of zooplankton on May 13 were found between the seventh and twelfth meters. The number occurring in the upper five meters was noticeably reduced. The averaged number of Peritricha for all meters was slightly greater on May 13 than it was on May 6 (table III). *Codonella cratera* were reduced in numbers and the rotifers, with the exception of *Synchaeta*, disappeared. Because of the small numbers of crustacea present at this time no conclusions can be drawn regarding this group.

The Recovery Period

From May 19 through June 12 the surface water lost turbidity while the lowest meters became more turbid. This probably was due to a slow settling of the temporary suspended materials. By May 19 the water had warmed and the lake was again stratified. On this date the effects of the rainfall were still evident in that the pH of the bottom had dropped from 6.6 to 6.4, the dissolved oxygen from the top to the bottom was greatly reduced and carbon dioxide showed an increase in the lower meters (table I). Following the advent of permanent stratification, May 19, the lake showed the expected changes in the chemical nature of the water: the amount of carbon dioxide was greater at the bottom than in the surface waters; pH readings were lower at the bottom than at the surface; and dissolved oxygen near the bottom was being expended.

Journal of the Arkansas Academy of Science, Vol. 5 [1952], Art. 14

Along with the above physico-chemical changes of the period from May 19 through June 12, 1950 the phytoplankton increased in numbers. The zooplankton numbers increased through May 29 and then began to decline. Figure 1 shows that as the water cleared in the upper levels organisms again began to concentrate here. Three of the dominant plankters of May 6, namely, *Dinobryon*, *Synedra* and the representative of the Peritricha were found in increased numbers again on May 19 but were virtually gone by June 12. These three forms have never been found to be abundant summer plankters in Lake Fort Smith. The other species, *Codonella cratera*, found in moderate numbers before the heavy rainfall, again increased on May 29 and occurred in small to moderate numbers throughout the summer. Along with the four forms mentioned above the general increase in numbers beginning May 29 can be attributed to species which formed the dominant plankters during the summer of 1950, such as *Sphaerocystis schroeteri* Chod., *Peridinium wisconsinense* Eddy, *Polyarthra* sp., and members of the crustacea.

DISCUSSION

From the results of this investigation and another carried on in 1939 (Hoffman and Causey, 1952) it is evident that following concentrated precipitation there is a reduction in numbers of certain types of phytoplankton in Lake Fort Smith, namely, *Dinobryon cylindricum*, *Synedra* sp. and *Kirchneriella obesa*. It has also been shown that a *free swimming* zooid, a member of the Peritricha, is not eliminated but is instead found in the deeper levels of the lake. This study also reveals that these Peritricha find the period after heavy precipitation in spring a favorable environment since their numbers are the greatest then.

During the six days previous to May 13 (a period of heavy precipitation) a number of environmental features were changed which independently or collectively could have reacted unfavorably on the phytoplankton. It is the author's opinion that turbidity, precipitation, and dilution were the major factors in the reduction of the phytoplankton at this time. Phytoplankters and zooplankters found on May 13 had minute particles adhering to their body surfaces which could have accounted for the transporting of the Peritricha to the lower levels and the phytoplankton to the bottom of the basin. If this conclusion is correct then the survival of the Peritricha might be explained in their swimming ability in contrast to that of the phytoplankton. If the phytoplankters were carried down by settling materials one would expect to find them at the lower level of the turbid water. In studying Lake Fort Smith, from time to time, over a period of 13 years the author has found that a sample taken a day or two after heavy rainfall does not reveal the true nature of all the material washed into the lake. A sample taken directly after rainfall will often have fragments of shale, limonite and quartz grains large enough that each particle can be distinguished with the naked eye. If a sample is taken a day or two after a heavy precipitation these larger particles have found their way to the bottom and only the slow settling and suspended materials remain to produce the turbidity of the water. It is possible that these larger particles, found directly after rainfall, carry quantities of phytoplankton down with them and in this way reduce the numbers soon after the turbid materials enter the lake. Another factor in relation to turbidity to be considered which evidently plays an important role is the reduction of light, which interferes with photosynthesis and eventually eliminates the phytoplankter. A number of other investigators (e.g., Chandler, 1940, 1942; Verduin, 1951) have found turbidity a limiting factor to phytoplankton numbers.

Five inches of rain falling over a watershed of 65 square miles and flowing into a lake with a surface area of 525.5 acres will add large quantities of water to the lake. One important factor to be considered here is that not all of the precipitation on the watershed in May 1950 reached the lake, and as the rainfall was spread over a period of six days, all of the runoff water did not reach the lake at once. Since it is the water near the surface of the lake which flows over the spillway it can be assumed that phytoplankters which are concentrated in the upper levels continue to move toward the spillway as long as washing currents carry them; this could also explain the reduction of Peritricha in the upper meters at this time. It therefore appears that each liter of water that passes over the spillway carries plankters with it, but this does not entirely account for the rapid reduction of phytoplankton in the lower levels following heavy rainfall.

The total number of Peritricha for all meters on May 13 was slightly greater than the total for the same meters on May 6. The Peritricha present in the deeper levels on May 6 may have found the conditions in the lower levels from May 6 to May 13 very favorable and increased in numbers while those in the upper levels were carried over the spillway. But, the adherence of foreign materials to the bodies of these Peritricha strongly suggests that many were carried down to the lower levels. In conclusion, it appears that three major factors in Lake Fort Smith following rainfall which influence the productivity and distribution of plankters are: (1) a sinking or settling of materials carrying organisms to the deeper levels, (2) turbidity with a reduction of light, and (3) a dilution of the water in the upper meters by water coming in from the watershed and flowing over the spillway.

Other factors which may have contributed to the reduction in numbers of phytoplankton are the lowering of temperature and the change in hydrogen-ion concentration. Since both carbon dioxide and dissolved oxygen are used in the life processes of these organisms, and since neither was changed to extremes, it is difficult to comprehend how these could be major factors here. *Dinobryon* could have been influenced by the sudden temperature change because it was not found in numbers in the winter plankton of Lake Fort Smith and it had just made its appearance, at a higher temperature, on May 6. *Synedra* sp., although never found in large numbers in Lake Fort Smith, appears throughout the winter and is probably not influenced by a lowering of temperature alone.

A study of the data presented in this report reveals that it is necessary to take plankton samples from the deeper levels in Lake Fort Smith in order to obtain a reliable estimation of the zooplankton present in spring. Collections taken during this investigation from the first five meters give a relatively accurate measurement of the phytoplankton but give an erroneous picture of zooplankton abundance. Table III shows that the average number of zooplankton for all meters does not differ greatly between May 6 and May 13, 1950; however, table II and figure 1 show that these zooplankton were found in the deeper levels on May 13.

SUMMARY

1. Lake Fort Smith, Arkansas, with a watershed of 65 square miles and a lake surface area of 525.5 acres, has large quantities of turbid water flowing into it following rapid heavy rainfall in late winter and spring.
2. This investigation deals with the period from May 6 through June 12, 1950. In the two months previous to May 6 only 0.2 inches of rainfall was reported while in the 6 days previous to May 13, 5.3 inches fell.
3. Rainfall, in the 6 days prior to May 13, brought about the following physico-chemical changes: reduced transparency, as measured by the Secchi disc; increased turbidity down through the twelfth meter; lowered water temperature and disturbed stratification; increased carbon dioxide content from the surface to the bottom; lowered pH in the upper twelve meters; lessened bicarbonate content; and reduced dissolved oxygen content in the upper meters.
4. Organisms found in significant numbers on May 6, just before the heavy rainfall, were: *Dinobryon cylindricum* Imhof, *Synedra* sp., *Codonella cratera* (Leidy) and a *free swimming* zooid belonging to the order Peritricha, suborder Sessilia, tribe Aloricata.
5. On May 13, after the heavy rainfall, the numbers of phytoplankton were reduced from the surface to the bottom. Zooplankters were concentrated in the 7 to 12 meter level and reduced in the surface waters. The total number of Peritricha present on May 13 was slightly greater than on May 6.
6. In the period after May 13, as the surface water cleared, organisms again appeared here. The Peritricha reached their highest numbers for the year during the last two weeks in May.
7. In Lake Fort Smith turbidity, precipitation, and dilution, following rapid heavy rainfall, appear to be major factors in the reduction of Phytoplankton.

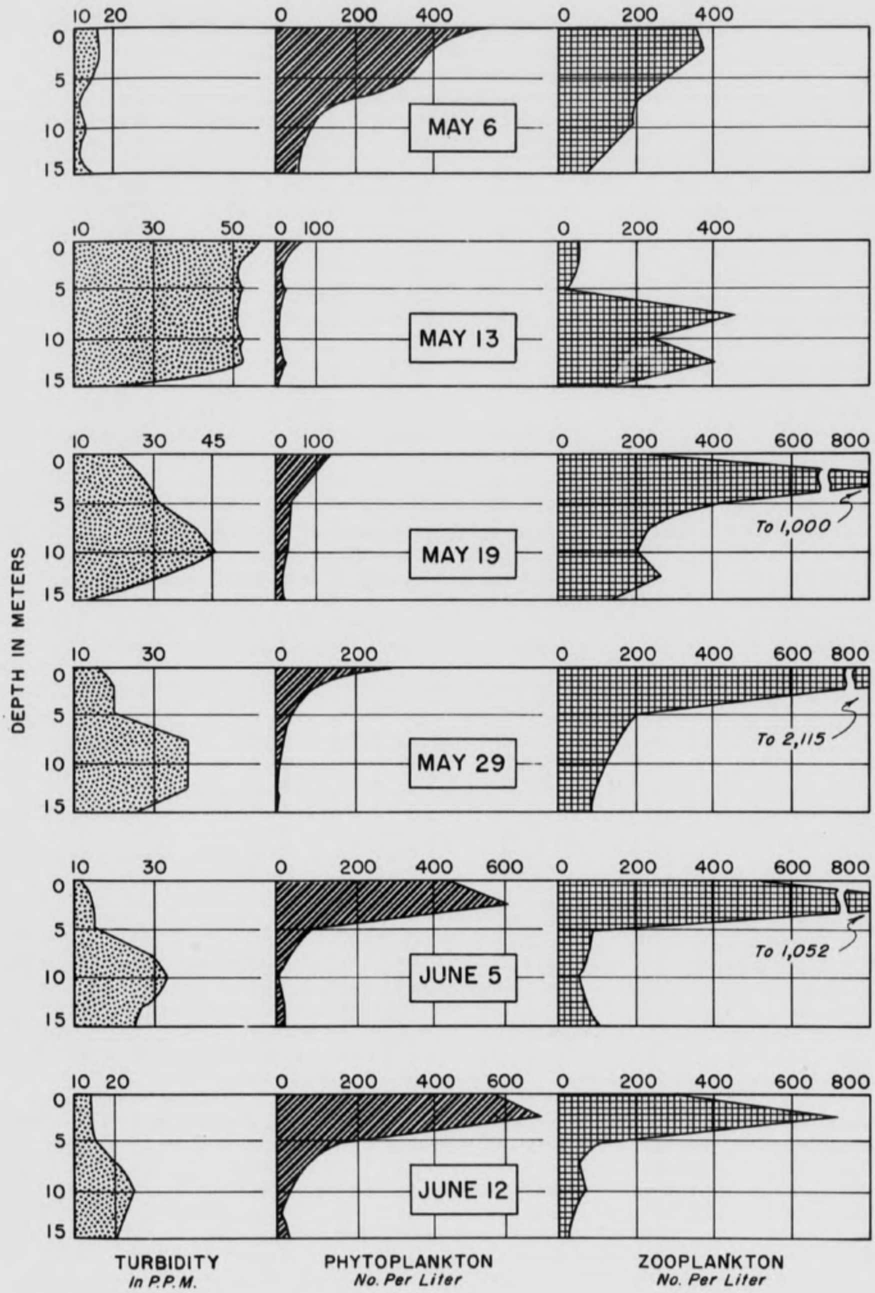

Figure 1. A graphic representation of the vertical distribution of turbidity, phytoplankton and zooplankton from May 6 through June 12, 1950 in Lake Fort Smith, Arkansas. May 6 shows the normal spring vertical distribution, May 13 shows the effects of 5.3 inches of rainfall, and the period from Mav 19 through June 12 shows the recovery period.

TABLE I. Summary of Some Physico-Chemical Conditions in Lake Fort Smith, Arkansas, from May 6 through June 12, 1950.

	May 6	May* 13	May 19	May 29	June 5	June 12
Transparency in cm.	60.0	13.0	30.0	59.0	68.0	80.0
Surface Temp. in °C.	19.0	16.2	20.4	22.6	22.8	26.8
Stratified	yes	no	yes	yes	yes	yes
Bottom Temp. in °C.	12.0	12.1	12.2	11.2	12.4	12.4
Surface CO_2 in ppm.	2.5	5.0	2.5	2.0	2.0	2.0
Bottom CO_2 in ppm.	2.5	3.0	4.0	6.0	5.0	5.0
Surface M.O. Alk. in ppm.	20.0	11.0	16.0	17.0	19.0	23.0
Bottom M.O. Alk. in ppm.	18.0	11.0	15.0	17.0	19.0	23.0
Surface O_2 in ppm.	9.0	8.4	6.8	8.6	7.8	7.0
Bottom O_2 in ppm.	6.6	8.2	6.6	5.8	5.0	4.3
Surface pH	6.6	6.4	6.6	6.7	7.2	7.2
Bottom pH	6.6	6.6	6.4	6.4	6.6	6.6

*Following intense rainfall

TABLE II. Vertical Distribution of Turbidity, Phytoplankton and Zooplankton in Lake Fort Smith, Arkansas, from May 6 through June 12, 1950.

Meters	May 6	May* 13	May 19	May 29	June 5	June 12
			Turbidity in PPM.			
1.	16.0	57.0	21.0	15.0	11.0	14.0
3.	16.0	52.0	29.0	20.0	15.0	14.0
5.	15.0	52.0	31.0	20.0	15.0	14.5
7.	11.0	51.0	41.0	38.0	29.0	20.5
10.	12.0	52.0	46.0	38.0	33.0	24.5
12.	11.0	52.0	36.0	38.0	28.0	22.5
15.	15.0	21.0	15.0	26.0	25.0	20.5
			Phytoplankton in Organisms per Liter			
1.	535	54	132	290	442	560
3.	375	7	75	75	605	692
5.	350	7	35	37	77	180
7.	172	2	27	20	35	60
10.	80	5	30	5	12	27
12.	60	7	17	5	17	7
15.	45	2	20	2	17	22
			Zooplankton in Organisms per Liter			
1.	345	45	185	2115	510	250
3.	355	52	987	717	1052	712
5.	282	22	452	197	87	110
7.	200	447	242	160	75	50
10.	192	232	212	130	62	57
12.	117	402	270	100	70	27
15.	67	157	147	87	102	25

*Following intense rainfall

TABLE III. Averaged Number of Net Plankters Per Liter for 1, 3, 5, 7, 10, 12 and 15 Meters in Lake Fort Smith, Arkansas, from May 6 through June 12, 1950.

Groups and Plankters	May 6	May* 13	May 19	May 29	June 5	June 12
All Chlorophyta	15	0	1	5	17	36
All Euglenophyta	7	2	9	7	3	13
Dinobryon	94	3	16	36	19	1
Mallomonas	2	0	0	0	109	128
Other Chrysophyceae	0	0	0	0	0	0
Synedra	100	6	17	3	1	1
Other Bacillariophyceae	6	0	2	3	1	16
Peridinium	7	1	0	7	20	26
Other Pyrrophyta	0	0	0	1	2	0
Total Phytoplankton	231	12	45	62	172	221
Codonella	20	5	7	22	5	15
Peritricha	177	185	323	355	30	6
Other Protozoa	0	0	0	0	0	0
Conochilus	7	0	1	2	16	100
Keratella	3	0	0	1	3	1
Polyarthra	6	0	0	85	180	29
Synchaeta	3	1	1	27	3	1
Other Rotifera	0	0	0	2	2	7
Daphnia	1	1	1	0	12	1
Other Cladocera	2	0	0	3	6	0
Nauplii	2	2	0	3	19	11
Other Copepoda	1	0	0	1	4	4
Total Zooplankton	222	194	333	501	280	175
Total Plankton	453	206	378	563	452	396

*Following intense rainfall

LITERATURE CITED

Chandler, David C. 1940. Limnological studies of western Lake Erie. 1. Plankton and certain physical-chemical data of the Bass Islands region, from September, 1938, to November, 1939. Ohio Jour. Sci., 40 (6): 291-336.

__________ 1942. Limnological studies of western Lake Erie. II. Light penetration and its relation to turbidity. Ecology 23: 41-52.

Hoffman, Carl E. 1951. Limnological Studies in Arkansas. Temperature and turbidity records for Lake Fort Smith. Ark. Acad. Sci., 4: 91-95.

Hoffman, Carl E. and Causey, David. 1952. Limnological Studies in Arkansas. I. Physico-chemical and net plankton studies of Lake Fort Smith in its fourth year of impoundment. Ark. Acad. Sci., 5: In press.

Verduin, J. 1951. Comparison of spring diatom crops of western Lake Erie in 1949 and 1950. Ecology 32: 662-668.

Welch, P. S. 1935. Limnology. McGraw-Hill Book Company, Inc. New York.