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Clarence B. Sinclair
University of Arkansas at Little Rock

Robert L. Watson
University of Arkansas at Little Rock

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Clarence B. Sinclair

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AWRRC

Arkansas Water Resources Research Center

University of Arkansas at Little Rock

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A PRELIMINARY ECOLOGICAL SURVEY OF DARDANELLE RESERVOIR PRIOR TO NUCLEAR FACILITY EFFLUENT DISCHARGE

By

Clarence B. Sinclair

and

Robert L. Watson

Principal Investigators

Arkansas Water Resources Research Center

University of Arkansas

Fayetteville, Arkansas

and

University of Arkansas at Little Rock

Little Rock, Arkansas

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ABSTRACT

A preliminary ecological survey of Dardanelle Reservoir during the construction phase of Arkansas Power and Light Company's nuclear generating facility was conducted from January 1970 through June 1974.

The reservoir is characterized by relatively shallow depths and a high flow-thru rate. A number of features were associated with these characteristics. The reservoir carried a great deal of suspended material and exhibited high turbidities throughout most of the year. Typical thermal stratification and oxygen depletion were only rarely observed.

Many of the physico-chemical parameters exhibited relatively high values in comparison to other Arkansas lakes and reservoirs, but due to absence of prolonged periods of stratification and stagnation, they did not undergo the extreme fluctuations sometimes observed in other reservoirs.

Plankton and benthic samples were collected at least nine times per year from ten stations. These stations were selected to include both shallow and deep locations and to include points both within and outside the projected area of thermal influence when the plant became operational. There were a great variety of forms in the phytoplankton with the diatoms making up a considerable portion. The level of turbidity appeared to dampen somewhat the extreme fluctuations sometimes found in "bloom" periods. In the zooplankton the rotifers *Brachionus*, *Keratella*, and *Polyarthra* predominated

followed by the microcrustaceans Cyclops and Bosmina. Both the plankton and the benthic fauna showed great seasonal variation. The benthic fauna consisted primarily of Chironomidae, Oligochaeta, and Hexagenia with the Chironomidae predominating in the shallower depths and the Oligochaeta exhibiting increased abundance and importance in the deeper stations.

A PRELIMINARY ECOLOGICAL SURVEY OF DARDANELLE RESERVOIR PRIOR TO NUCLEAR FACILITY EFFLUENT DISCHARGE

Introduction

The Arkansas River and its tributaries comprise the major drainage system for a large area in the mid-continental United States. Until recent years, the river was characterized by widely varying levels and flow rates and consequent variations in water quality. Before the recent major construction projects, the river was of little use for purposes of navigation although its waters were used extensively by industry, agriculture, municipalities and sportsmen. With the initiation and completion of the major public works projects of the "Multiple-Purpose Improvement Plan for the Arkansas River," the river underwent drastic changes in its characteristics and its potential usefulness. The River and Harbor Act of 1946 initially authorized the multiple purpose project and the McClellan-Kerr bills finally brought to completion a major public works project which was years in the making.

One of the major units in the overall project is the Dardanelle Lock and Dam and the resulting Dardanelle Reservoir. The lock has a lift of 54 feet, the highest in the river system. The lock and dam is located on the Arkansas River at mile 221.6 approximately 5 miles southwest of Russellville. The reservoir was designed for a minimum power pool elevation of 338 feet. The surface area of the reservoir is approximately 36,600 acres and it has a storage capacity of 486,200 acres feet. The reservoir has a shoreline of 315 miles, a drainage area of 153,666 (of which 22,241 square miles are probably noncontributing) and a mean stream flow of 35,980 cfs. The dam has an installed hydroelectric generating capacity of four 31,000 kw units. Commercial power generation at the dam was begun in April 1965 and the lock was completed in 1969 (U.S. Geological Survey, 1974; McGehee et.al.).

Arkansas Power and Light Company began construction of an 850 MW nuclear power plant, designated Arkansas Nuclear I Unit I, in the spring of 1968; the plant began commercial generation in December 1974. The plant is located on a peninsula extending in a southerly direction into the main body of Dardanelle Reservoir approximately seven miles upstream from the Dardanelle Lock and Dam and approximately 6 miles west northwest of the city of Russellville. The plant utilizes water from the reservoir for dissipation of heat by circulating it through a once-through condenser. The plant design requires 1700 cfs of circulating water with a maximum temperature rise of 15^{o}F as it passes through the condenser. The cooling water intake is located on the west side of the Illinois Bayou arm of the reservoir and the discharge empties into the upper end of a cove on the southern shore of the peninsula and then into the main body of the reservoir. Figure 1 shows the location of the power plant with respect to the reservoir.

The construction and operation of nuclear generating plants for the purpose of commercial generation of electric power is a relatively recent development. The demands that these plants place upon the environment, particularly the necessity for dissipating large quantities of waste heat has resulted in a great deal of concern and debate among various public and private agencies and the

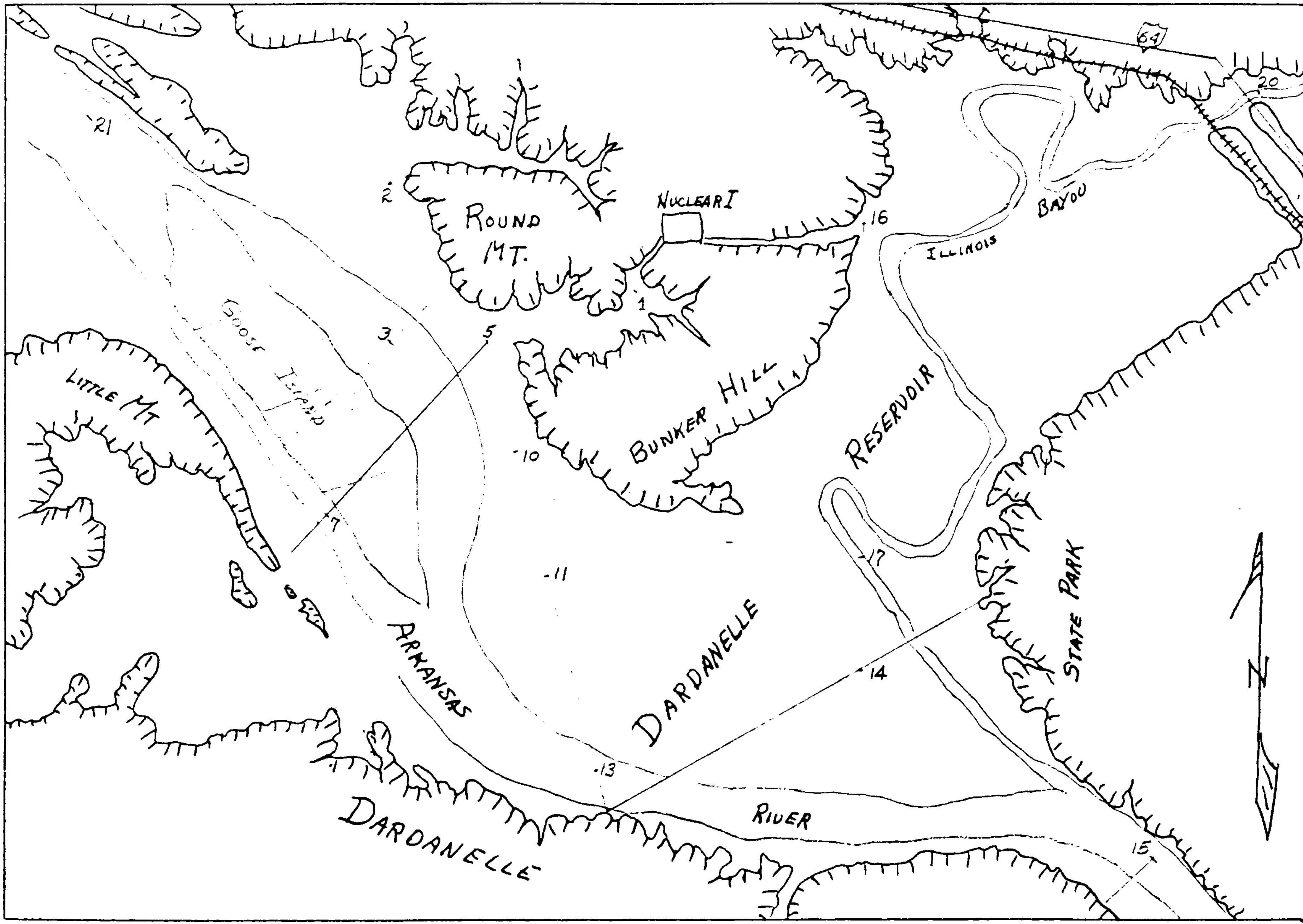

Figure 1. Diagram of the study area showing the relationship of the main body of Dardanelle Reservoir, the original Arkansas River and Illinois Bayou channels, Arkansas Nuclear I and the sampling points used during the study.

general public relative to the merits and problems of nuclear power plants. The potential for ecological problems associated with the large amounts of waste heat to be dissipated has led to the elaboration of a subdiscipline in ecology commonly referred to as thermal ecology. Within recent years, numerous scientific investigations aimed at answering some of the questions and problems have been conducted or initiated.

The results of many of these investigations are presented in Thermal Ecology (Gibbons and Sharitz Eds. 1974) and Thermal Ecology II (Esch and McFarlane eds. 1976). The scope and diversity of investigations reported in these volumes is indicative of the widespread interest and concern in the scientific community for this relatively new field.

In some of the earlier programs of siting and constructing nuclear generating plants, one of the factors which had to be dealt with was lack of background data on the environment which would be affected and a limited amount of time to gather such data. In a few instances, extensive studies prior to operation of a nuclear generating facility have been conducted. Taylor (1974) and Rankin et. al. (1974) have reported on two such studies. At the time of planning and initiation of construction of ANO unit 1, very little ecological data was available for the area to be impacted by the plant. This was especially true for Dardanelle Reservoir. The reservoir itself had just been formed and, although water quality studies for the Arkansas River covering a considerable period of years were available, almost no data was available pertaining to the ecological characteristics of the newly formed reservoir. ANO unit 1 was the first nuclear generating plant to be built in the State of Arkansas and also the first in the entire southwest. Fortunately, there was a considerable period of time available in which to acquire background ecological data on the newly formed reservoir prior to the beginning of operations for ANO unit 1. In addition to this study, several additional investigations were conducted during the period of construction. These include those of Sinclair (1969) and Palko (1970, 1972). General hydrological and water quality data on the Arkansas River Systems was obtained from the U. S. Geological Survey (1964-1974).

Investigations conducted on other Arkansas reservoirs were utilized for comparison of some of the findings as well as for information on techniques. The studies of Mullen and Applegate (1965), Applegate and Mullen (1967), Aggus and Warren (1965), Aggus (1971), Iovino (1967), and Meyer (1971) proved useful.

The purpose of this investigation was to augment and expand a monitoring study which Arkansas Power and Light had initiated in response to requirements by the regulatory agencies involved in regulating and licensing such facilities. This study was described by Sinclair (1969). The present study provided for a more complete ecological background survey by increasing the sampling frequency and adding a number of parameters being measured to the minimum required program in progress.

The stated objectives of this project were to:

(1) determine baseline values for physico-chemical parameters of the reservoir including (a) chemical oxygen demand, (b) chloride ion, (c) conductivity, (d) dissolved oxygen, (e) pH, (f) nitrate

ion, (g) phosphate ion, and (h) temperature.

(2) establish quantitative and qualitative baseline data for the benthic fauna including species composition and level of benthic production.

(3) establish quantitative and qualitative baseline data for net plankton.

(4) accumulate data concerning the productivity of selected areas of the lake and correlate the chemical and biological data obtained so that future trends in the productivity of the lake water may be properly evaluated.

The starting date of this project was January 1970, and the completion date was June 1974.

Description of Study Area

The study area involved in this project consisted of a series of sampling sites located in Dardanelle Reservoir. The area of the reservoir which would receive heated discharge from ANO unit 1 and the associated flow patterns had been determined by a hydraulic model investigation (Bechtel Corp. 1969).

Most of the sampling sites had been previously selected by the company, in consultation with various regulatory agencies, for a separate monitoring program (Sinclair 1969). The sites included representative areas in the vicinity of the intake canal, the discharge canal, in the projected thermal plume and control sites. The location of the sampling sites and their relation to the plant is shown in Figure 1. Some of the sampling sites were marked with permanent marker buoys while others were identified by locating specific depths along transect lines whose ends were marked with shore markers. There were a total of 12 sampling stations of which 10 were within the area of predicted influence and two were control stations outside the area of predicted influence.

In the area of predicted influence, five stations were shallow water stations and five were deep water stations. Stations number 5, 10, 11, 14 and 16 were shallow water stations with depths ranging from 9 to 14 feet. Stations number 3, 7, 13, 15 and 17 were deep water stations, located in the old river channels with depths ranging from 32 to 52 feet.

The reservoir differed considerably from most of the man-made reservoirs in Arkansas because of its shallow average depth and the high flow-through rate. The combined effect of wind action on the extensive shallow portion of the lake and the large volume of water flowing through the lake generally resulted in more or less thorough mixing of the water in the reservoir and only occasional, localized stratification. The bottom substrate for most of the sampling sites was generally a muck of fine clay to silt although a few of the sites (numbers 10 and 11) tended toward sandy composition. There was some shifting of substrate conditions during the study, undoubtedly due to current shifts during periods of high and low flows.

Materials and Methods

Sampling was conducted 10 times per year, with the months of November and February usually omitted. Adverse weather or water conditions occasionally resulted in incomplete sampling in other months. An 18 ft. Monark Belle workboat with a 40 h.p. engine was utilized for on-site work. Water samples were taken by means of a 2 liter

VanDorn water sampler. As much on-site testing was done as was practical. Any water samples that had to be returned to the laboratory for testing were placed in sterile plastic bags, stored and transported in an ice chest. They were kept refrigerated until processed in the laboratory. Specific methodology for determining each parameter being monitored follows.

Temperature and dissolved oxygen readings were made at each site using a YSI Model 54 oxygen meter. The meter was calibrated each month before use using the Azide modification of the Winkler Method (Standard Methods, 1974, 218B). Readings were made at depths of 1 foot, 2 feet, 7 feet and at each succeeding 5 foot interval to the bottom. In the AP & L monitoring program readings were taken at a depth of 5 feet starting in September 1973, and readings at this depth were also incorporated into this study as of that date. Temperature was recorded as degrees fahrenheit and dissolved oxygen as ppm or mg/lt.

Hydrogen ion concentration was also measured on site by use of a Taylor pH color comparator. This instrument was checked a number of times against electronic pH meters and found to be quite dependable. The danger of breaking the glass electrodes and the difficulty in getting a stable meter reading in a rocking boat made use of the electronic pH meter undesirable. Determinations of pH were made for water samples taken at 2 ft., at the mid-point and at the bottom for the same depths.

Determination of chemical oxygen demand was made in the laboratory using the dichormate reflex method (Standard Methods, 1974, 220). In most cases the alternate procedure for diluted samples was used. The results are reported as mg/l COD.

Measurements for chloride ion were made in laboratory using an Orion Research model 401 specific ion meter with the solid state chloride ion electrode. Results were recorded as ppm or mg/l.

Conductivity determinations were made in the laboratory by use of a Lab-line Lectro MHO-Meter Model MC-1, Mark IV. The conductance measurements are reported as microohms/cm.

Measurements for nitrate ion were made in the laboratory using the ultraviolet Spectrophotometric Method as described in Standard Methods. The colorimetric determinations were made on a B & L Spectronic 700 meter. The data was recorded as mg/l. The water samples are filtered through a Millipore filter prior to use in this procedure.

Several methods for detection of phosphate ion were tried. A great deal of variation in results was found depending on the age of the sample and other factors. It was finally determined that the Hach Phosyer III Method for orthophosphate made on site with fresh water samples was as dependable as any. A Hach Model DC-DR Colorimeter was used on the boat for making these measurements.

Plankton samples were taken monthly, or a minimum of nine times a year, weather permitting. The following ten stations were sampled at each collection date: 1, 2, 3, 5, 10, 11, 14, 15, 16, and 21. The sample was a composite 10 lt. sample with 2 lt. from the bottom, 2 lt. from midpoint, 2 lt. from 2 ft. and 4 lt. from the surface. The water was obtained by use of a VanDorn sampler and was poured through a standard Wisconsin style plankton net and bucket. The net and bucket were of No. 20 mesh nylon bolting cloth woven 173 threads to the inch. The sample was then washed from the bucket with 10 ml. of water into a bottle containing 1 ml. of M^3 Iodine fixative (Meyer, 1971). The plankton were then counted in the laboratory using a Nikon Model MS inverted microscope with a Sedgewick-Rafter counting cell. Since the study was a monitoring inventory, 2 types of counts were made. First a field count using 10 random fields was made without regard to kind of organism. Then a strip count was made identifying and counting the specific organisms. Identification was generally made to Genus. In making the field count it was frequently noted that large size plankton were seen that did not get included in strip enumeration. Since this study was a survey type study and there was interest in the total picture, the enumeration method was augmental as follows: After making the strip enumeration, the entire slide was examined rapidly and the obvious organisms not included in the strip count were named and counted. These data were then included in the total identification counts.

Gravimetric analysis was also done on the samples. A 5 ml. sample was oven dried at 60°C and this weight recorded as wet weight (Welch 1948, Lagler, 1956). This sample was then put into a muffle furnace at a temperature of 600°C and fired for 30 minutes. The example was then cooled and weighed, and the weight loss was recorded as ash weight (Welch, 1948).

The bottom fauna was sampled on the same schedule and at the same stations as the plankton. The samples were taken with either a standard or tall form Eckman dredge using the standard methods as described by Welch (1948). Hudson (1970) found the Eckman dredge to be an efficient sampling device in soft substrates. The substrate in this study area was almost all of this type. After a sample was procured using the dredge, it was washed in a standard 30 mesh bucket and the organisms, along with some of the substrate, were placed in a plastic container and refrigerated until they were returned to the lab and processed. The samples were sorted by hand and the specimens preserved in 80% alcohol. Identification was as low a taxonomic level as practical in the lab. Various keys were used in identification of the specimens obtained. These include those of Pennak (1953), Edmondson (1959), Eddy and Hodson (1962), Mason (1973), and Usinger, *et al*. (1956).

RESULTS AND DISCUSSION

PHYSICO-CHEMICAL DATA

All physico-chemical data from January 1969 through October 1972 was punched onto computer cards for statistical analysis. Since only one sample per station per depth was taken for each month, there simply was insufficient numerical information to make valid statistical tests for much of the data. By combining station and depth readings and testing the area under surveillance as a whole, some statistical analyses were possible.

The dissolved oxygen data was used by averaging the D. O. at 1, 2 and 7 feet at each station. An average over all the stations was also used to get an average over the reservoir area under consideration. Averaging was also done for the shallow water stations (5, 10, 11, 14, 16, 20) and deep stations (3, 7, 13, 15, 17, 21). Kendall's test for correlation (Kendall 1955) was used as a test for monatonic trend, letting one of the variables represent time. The Null hypothesis of no trend was tested against the alternative of an increasing or decreasing trend. On the basis of our data, no trend was indicated for the lake as a whole, for the shallow stations and deep stations, or for any of the seasons.

Using Noether's test for cyclical trend (Noether 1956), the Null hypothesis of no trend was tested against the alternative of a cyclic trend. While this is not a highly efficient test, it was found on the basis of our data that a cyclic trend did exist for the whole lake and for the shallow and deep water stations. This would be as expected.

These data tend to demonstrate that the nominal seasonal variations anticipated from water bodies of this geographic location do occur. Since it is a flow through reservoir the influences exerted by flow input tend to overshadow the normal cyclic modifications found in a closed body of water. Simple visual observations of the reservoir during low water periods when the dam gates were closed and there was an extremely swift current are confirmed by the findings of the statistical data.

These data do give a statistical basis for determining whether the increased temperature for the thermal plume after operation begins produces a noticeable change in the test area of the reservoir.

A check of these chemical data against data found in various previous records for the state indicated no unusual findings (USGS 1965-1974). The general findings for the major parameters measured follow.

Temperature and D.O.

The records of the temperature and dissolved oxygen at the various depths at the designated sampling stations are presented in the appendix.

One of the striking features about the temperature data for the reservoir is the indication that the reservoir undergoes typical thermal stratification only rarely and only for limited periods of time. The large volume of water flowing through the reservoir (avg. discharge 35, 980 ft^3/s)(USGS 1974) undoubtedly contributes to the thorough mixing of the reservoir. Also, there is a considerable amount of wind action on the lake over much of the year and this coupled with the shallow depth of the non-channel portion of the reservoir, contributes to the mixing. When stratification does occur it often occurs only in localized parts of the reservoir and generally only in warmer parts of the year during periods of low stream flow; and little wind action. During 1970 there was some stratification and some oxygen depletion at many of the stations in May, June and July. In August only two of the deep stations, #13, and #17, showed appreciable lowered D.O. values at deeper depths indicating that there had been a general mixing of most of the reservoir. The generally low D.O. values for all depths of all the stations during August may indicate that a complete mixing had just occurred prior to these readings. In September a pattern of partial stratification again became evident with average D.O. readings for the upper 5-10 feet and a rapid decline to 2.5-4.5 ppm at greater depths. Any appreciable differences for temperature readings or D.O. values between any of the depths had disappeared by the date of the October samples and a return to the more homogenous conditions prevailed.

If there is any trend or pattern to be noted concerning temperature or dissolved oxygen conditions in the reservoir, it is a tendency toward homogeneity of conditions both between the various depths of individual stations and between the various sapmling stations over the lake.

The graphical presentation of the temperature and D.O. data would seem to indicate that stagnation of the water at lower depths had begun in most parts of the reservoir in late May, and that mixing had occured in much of the reservoir by the time of the June reading with some stratification persisting (Stations #15, 16, 17 and 20). July shows a general lowering of the D.O. with surface to bottom differentials in both temperature and D.O. being most pronounced in Stations 15, 16, 17 and 20. August readings indicated a general mixing except below 40 feet (Station 13) and at Station 17 near the bottom. In September the water temperatures were generally high in the upper 7 feet of the water column and the D.O. values had increased to normal levels with lower values (2½ to 4½ ppm) at depths below 20 feet.

It is interesting to note that stagnation of the water started earlier or was more pronounced earlier in the station in the Illinois Bayou area of the reservoir (Stations #16, 17 and 20). In August the only place where appreciable lower oxygen values remained was Station 17, the Illinois Bayou channel near the junction with the main portion of the reservoir and the very deep portion of Station 13 (the deepest portion of the reservoir). It is apparent that station 15, a deep station downstream from the point where the Illinois Bayou joins the main stem of the reservoir, is influenced by the mixing of the flow from the two different sources.

In general, the 1971 data show more limited and more transient instances on stagnation with concurrent lower D.O. values at greater depth and sharper temperature differentials in the water column. In April Station 17 showed some slope in the temperature and D. O. curve. In May the seasonal warming and high phytoplankton productivity gave a considerable slope to the temperature and D. O. curve but there was no evidence of true stratification. In June there was some indication of stagnation at least in most of the deep stations, particularly Stations 13, 15 and 17 and in shallow Station 20. This had all been wiped out in July except for some remnant of stagnant water at Station 17 below 20 feet. In August a pattern of thermal stratification and lowered D.O. values at depth was established at all the stations. This pattern had disappeared by the time of the September readings and for the remainder of the year the typical homogeneous conditions prevailed.

During 1972 the previously established pattern was again seen for the temperature and D.O. records. In April, Station 17 showed some depressed oxygen values at depth and was the only station to do so. There was some surface warming of the water at various stations but, in general, uniform temperatures prevailed at most of the stations. The water temperature in the Illinois Bayou areas were somewhat lower than the rest of the lake as evidenced by the temperature data at Station 20 (about 2½ degrees lower) and at the deeper portions of Station 17. It is interesting to note that this carried over to a slight extent in the readings downstream at Station 15. By May there was considerable slope to the temperature and D.O. curves with most of the deep stations and some of the shallow stations having D.O. curves with most of the deep stations and some of the shallow stations having D.O. values below 4.0 over the bottom. Station 17 had the lowest value with D.O. values down to 1.0 at the greater depths. This pattern persisted for the deeper stations during June and there was definite stratification in the D.O. values with almost complete oxygen depletion (generally less than 1.0 on down to 0.15 ppm) below the 22 ft. depth. The temperature curve is generally similar to the D.O. curve but is never as pronounced in its decline as the D.O. curve. All evidence of stratification was wiped out in July. The D.O. values were somewhat low throughout the water column. In August some stagnation was evident again. Temperature showed only gradual slope from top to bottom but near oxygen depletion was evident at the greater depths in all the deep stations. The shallower stations had some lower values near the bottom but did not approach the depleted values of the deeper stations. Any indication of stagnation or stratification was gone by the time of the September reading (September 22-23) and thorough mixing of the reservoir water was evident for the rest of the year.

In January 1973, there was some surface warming of the reservoir due to some warm and fair weather. The reservoir remained uniformly mixed until July at almost all the stations. Station 17 showed just the beginning of stagnation near the bottom in May and Station 17 and 20, both in the Illinois Bayou continued this in June. In July there was a great deal of slope to the temperature and D.O. curves, but this was apparently due to relatively calm conditions and a great deal of surface heating and high level of phytoplankton activity. The D.O. values were quite high over the surface and were fairly high throughout the water column except for the deep portion of Staions 15 and 17. In August some of the other stations showed lowered D.O. values below a depth of 7 feet, but only Stations 15, 17 and 20 had values below 3 ppm. The lake was thoroughly mixed at the time of the September reading (September 21-22) and remained so for the rest of the year. The graphical data in October shows that some water considerably warmer than the rest of the lake was entering the lake from the Illinois Bayou.

During the first half of 1974, there was no general condition of stagnation found in the lake. Station 17 shows its tendency to resist mixing at the lower depth in March and continues this along with Station 20 through April, May and June but does not actually show oxygen depletion until July.

pH

The pH shows a seasonal cycle and, during the warmer months of higher plankton activity, it also shows a considerable top to bottom differential. In January, 1970, the pH was fairly uniform throughout the reservoir at all depths. It ranged from 7.7 to 7.9 for most stations. Station 16 was lower at 7.5. The uniform readings continued through March at 7.7 for almost all stations. April's were still uniform with some increase in values over the prior month, being in the 7.9-8.1 range with 8.0 the predominant value. In May there began to be some difference in the values between the various stations and between the various depths in the water column at each station. The 2 ft. values ranged from 7.9 to 8.5. The values for the bottom of shallow stations and middle sample for deep stations (10-27 ft.) were quite uniform (7.7 to 7.9) except for Station 17 where this value was 7.1. The values for the bottom water at stations in the main stem of the reservoir were only slightly lower, 7.5 to 7.3, the latter for Station 15. In the case of Station 17, where near oxygen depletion existed, the pH had dropped to 6.9. In June the pH was more uniform from top to bottom after more mixing, as evidenced by the uniformity of temperature and D.O. values. The values for 2 ft. ranged from 7.9 to 8.1 except for Station 16 where it was 8.7. For mid and bottom depths 7.7 and 7.8 were common except for Station 17 were these values were 7.5 and 7.1 respectively and station 15 where the bottom value was 7.5. Station 15 obviously receives water from the deeper portion of Station 17 and is influenced by it. In July the gradient from top to bottom was evident again with the top values mostly in the 8.3 to 8.5 range (Station 16 was 8.8) and the bottom values 7.7-7.8 except for Station 17 where it was 7.2.

In August, there was again uniformity in the values at different levels for most of the stations. Station 13, which was still stratified, has a low value for the bottom and Stations 14, 17 and 7 had high 2 ft. pH values. Both Stations 14 and 17 had high D.O. values also, indicating that photosynthetic activity was high. September showed the sharp vertical gradient associated with calm water and high phytoplankton activity. pH values ranged from 8.1-8.7 at 2 ft. to 7.5-7.7 at the bottom of the deep stations.

In October top-to-bottom uniformity had returned with most readings in the 7.7 to 7.9 range. Station 16 was an exception with 6.9. In December the readings were the same, 7.7-7.9, except for Station 16 which now showed a reading of 7.5.

In 1971, the pH again showed the seasonal cycle. It was uniform and ranged from 7.5-7.7 in January. In March it had increased to 7.7-7.9 at most stations and was still uniform. In April it had further increased to the 8.1 to 8.3 range and showed vertical uniformity except at the bottom sample for Station 17 where it was 7.2, a full unit below the middle samples. In May almost all the deep stations showed vertical uniformity with only a 0.2 difference from top to bottom (7.6-7.8, 7.7-9.9, 7.5-7.7). All the shallow stations showed a differential of 0.4 or more (7.9-8.5, 7.7-8.1, 7.6-8.5). The Illinois Bayou stations reversed this with 16 (shallow) exhibiting uniformity and 17 (deep) exhibiting a gradient (8.5-7.5). In June there was a great deal of variability with some of the stations showing very little vertical difference and some having a great deal. Station 17 and 15, where D.O. depletion was evident at the greater depths, ranged from 7.1 or greater to 8.7 and 8.3 respectively. In July most stations were fairly uniform at the bottom and middle depths with some higher readings on top.

In August a vertical gradient again appeared with most readings in the 7.7 - 7.9 range, middle and bottom, and 8.3 - 8.8 range on top. This continued into September with some narrowing of the range-the lower part of the range coming up - all 7.9 - and the top end lowering somewhat, 8.1 - 8.3. October readings had returned to general uniformity throughout with all readings 7.7 to 7.9. December's readings were also uniform with all values at 7.9.

In January 1972, all readings had dropped to the 7.5 - 7.7 range and were uniform (except for Station 16 where 7.4 and 7.5 were obtained). The seasonal pattern was again similar to prior years with rising values in March and some slight vertical differentiation. April was uniform. May showed the higher readings characteristic of warmer months at the upper levels. June was similar but with less vertical differentiation except where low values occured at the bottom of deep stations in conjunction with oxygen depletion.

In July uniform values prevailed in the 7.7 - 7.9 range. In August a steep vertical gradient existed with some of the upper values for the surface reaching very high levels (8.9 - 9.0). September and October were uniform with values in the 7.9 - 8.1 range. There was a rapid decline in the 7.2 - 7.5 range in December. Station 16 was again low with a reading of 7.0.

In January 1973, the pH values were uniformly 7.5 except for the Illinois Bayou values of 7.2 at Station 16 and the surface of Station 17 and the 7.3 values at Station 14 which is just downstream from Station 17. March values were uniform in the 7.2 - 7.4 range except for Stations 16 and 17 where 7.0 values were recorded at all depths except 42 feet. April values were still uniform at 7.4-7.5

except for Station 16 with 7.0 and the upper two readings at Station 17 with values of 7.1 and 7.2. By May the readings had increased to the 7.5 to 7.9 range for all except the bottom at Stations 16 and 17 where they were 7.0 and 6.9 respectively. In June they were fairly uniform with most at 7.7 (range 7.6 - 7.9) except for the bottom at Stations 16 and 17 again where they were 7.1 and 6.9, respectively.

In July there was again the vertical gradient seen frequently in warmer months with 8.2 to 8.6 readings at the 2 feet level. Station 17 at the bottom had apparently still not mixed as its reading was again 6.9. This trend continued into August but some rise in both pH and D. O. at the bottom of Station 17 indicated some mixing had occurred.

In September general uniformity had returned to the lake with values in the 7.9 - 8.3 range and a few 2 foot values of 8.4 and 8.5. October readings were uniform but dropped off to 7.4 to 7.6. November values were uniform but up slightly to 7.7 to 7.9. December values were also uniform with most at 7.5 and 7.6. Station 16 had slightly lower values.

In January 1974, pH values were uniform and in the range of 7.5 to 7.7 except for the Illinois Bayou area where 7.3, 7.4 and 7.5 were recorded.

In March they were still uniform at 7.9 except for the Illinois Bayou where Station 16 showed 7.5 and Station 17 at the bottom showed 7.3. In April a slight vertical gradient appeared with most values at 7.9 at the bottom and 8.1 at the top except for the Illinois Bayou and downstream from it. Station 17 had 7.2 on bottom, Station 16 read 7.7 on bottom and Station 15 read 7.5 on bottom. The May pattern was almost identical to April's. In June there was a general top to bottom uniformity and some lowering of the values (to 7.5). Again Stations 16 and 17 were different with values at Station 16 of 6.7 bottom and 8.2 top and Station 17 with 6.9, 6.9, and 7.6 bottom, middle and top, respectively.

In summary, there is a seasonal trend in pH values. This trend seems to be lower values in the winter months followed by a gradual rise in the spring and summer then a decline again in the fall. There is a considerable vertical gradient present in some but not all of the warmer weather months, being most acute in the upper 2 or 3 feet when phytoplankton activity is high and in the lower few feet in periods of oxygen depletion, especially in the deeper stations.

CHEMICAL OXYGEN DEMAND

The COD values obtained up until the end of 1970 were quite variable and probably unreliable. In December 1970, improved procedures and techniques were initiated and the values were considered to have more accuracy and precision. Values in the range of 20 mg/1 to 70 mg/1 were obtained. There did not appear to be appreciable differences between the stations. The data for 1971 does not appear to indicate any pettern with respect to differences between stations or differences between depths. The values range from 0 to 80 mg/1 with most values in the 20 to 60 range. Some problems with technique resulted in a determination of the June readings of all 0 which were apparently in error. This recurred to some extent in the latter part of the year. The COD data in 1972 again does not indicate any apparent trends or comparison. The COD for the reservoir is, in general, low and no detectable seasonal cycle can be found. In 1973 the COD values again were low generally in the 10 to 25 range and did not reveal any apparent trends or obvious differences between areas of the lake or between different depths. This same pattern continued in 1974 and if anything showed a slightly lower COD than the previous year.

CHLORIDE

The chloride values for the reservoir are generally quite high, which is to be expected as this value is usually high in the Arkansas River due to the fact that several of its tributaries in Oklahoma contribute a heavy salt load to the water. There is a general seasonal cycle evident in the chloride values recorded with the higher values recorded in the late spring correlating with high river flows. This cycle is variable, however, as the high river flows which generally are seasonal are, of course, subject to variation in timing and duration in different years. In 1970 the chloride values were somewhat lower for Station 16. This was particularly true during periods of high values for the rest of the reservoir, as in April when the major part of the reservoir had values of 190-330 ppm and Station 16 had values of 70 and 74. The values dropped considerably in May, however, and did not pick up again until August. They remained relatively high until October when they again dropped to below 100 ppm. Station 16 had very low readings at this time. The readings remained low until June of 1971 when they again exceeded 100 ppm at all the stations. They remained high through August and then in September dropped below 100 ppm again. They were up above 100 again in October and back below 100 in December. This illustrates the variable nature of this parameter which in this situation is highly influenced by the amount and source of the inflowing water.

This general pattern was followed in 1972 with some very high readings (above 200 ppm) being recorded in May. In August some even higher readings (above 300 ppm) were recorded. These generally high levels persisted through October but had dropped sharply by the time of the December readings.

In 1973 the fluctuations continued with January readings exceeding 200 ppm, followed by lower levels through June. Very low values (below 50 ppm) were recorded for June. In August and September the levels returned above 100, mostly in the 150 range. They declined in October, increased in November and declined in December. Again Station 16 and sometimes Station 17 showed considerably lower readings indicating the different source of water influencing these stations.

In most instances, these do not appear to be appreciable differences between stations except for the Illinois Bayou stations previously mentioned and in most cases there does not appear to be any significant differences in chloride content at different levels in the vertical water column. There is occasionally some apparent vertical gradient at stations where there has not been thorough mixing. These stations may show a "lag" effect where the readings at the greater depths are closer to the previous months readings than they are to the other readings at shallower depths for the current month.

January through June 1974 showed fluctuating values for chloride with the readings usually lower than in prior years. May had the highest values with readings in the 120 to 152 ppm range, except for Station 16 and 17 in the Illinois Bayou.

Specific Conductance

This parameter is a measure of a water's capacity to convey an electric current. It is related to the total concentration of ionized substances in a water sample at a given temperature. Most raw and finished waters in the United States exhibit a specific conductance 50 to 500 micromhos/cm (Std. Methods, 1971). Specific conductance measurements can serve to quickly reveal variation in the dissolved mineral concentration of a body of water or water source.

The values obtained for this parameter exhibited a great deal of variability, similar to those for the chloride measurements. Like chloride, they showed distinct differences correlated with the water source. In January 1970, the readings were in the 200-280 range which was about middle level. Station 16 with values of 150 and the surface of Station 17 with a 175 reading were well below the rest of the reservoir. The March readings were lower than the January readings, generally in the 150-175 range with Station 16 again lower than the others. In April the readings reached high levels with most readings in the 400-500 range except for Station 16 again which had readings of 130 and 140. The readings were back down in May to the 200 ± range with Station 16 and the bottom readings at Station 17 only slightly lower. June readings were very similar to May with all of the readings at Stations 16 and 17 somewhat lower. In July the readings were elevated back to the 275-300 range with Stations 16 and 17 at the bottom only very slightly lower. In August all were high in the 350± range and very little difference in Station 16. September was similar to August, in the 300-350 range except for lower readings at the bottom of some of the deep stations and somewhat elevated readings (355-370) at Stations 16 and 17. In October there was a general lowering back to the 225-250 range except for much lower readings at Station 16 and an intermediate reading on the surface at Stations 17 and 15. In December the values were in the 130-150 range except for Station 16 at 100. In 1971 the overall pattern was similar to that of the previous year, except that the April surge in readings was less, only reaching the 200-250 range (Station 16 and bottom sample of Station 17 were again lower). In June they rose to the 350-400 range for most stations and depths with a slight decline for July. In August very high readings in the 650-700 range occurred. This increased in September to figures in the 680-750 range except for Stations 16 and 17 which declined slightly. High readings continued through October then declined back to the 425-490 range for December.

In 1972 the January readings were at a high level, in the 680-710 range, except for significantly lower readings at Station 16 (455-475) and surface at Station 17 (525). There was a slight lowering in March to the 550-585 range. The April readings were very similar to those of March with Station 16 and the surface of Station 17 and Station 15 again lower. In May the readings were up slightly but Station 16 and the bottom of Stations 17 and 15 were considerably lower than the rest of the reservoir. In June the readings were back down slightly with values in the 550$\pm$ range except for the bottom readings at Station 17 at 160. In July readings were only slightly lower, mostly in the 500-550 range. August saw greatly elevated readings with a range of 920-1050 except for Station 16 with 858 and 860, top and bottom. September showed approximately a 50 point decline with almost complete uniformity throughout the lake. In October the decline continued with another 50$\pm$ point drop. In December the values had dropped from the 840-950 range of October to values of 388 to 408 for the main stem stations and much lower values for Stations 16, 17, 14 and the surface of Station 15.

In 1973, the January values were in the range of 628-690 except for Station 16 and the surface of Stations 17, 14 and 15 (intermediate). In March there was a general drop into the 400's except for the Illinois Bayou stations which were less. This level continued into April, May and June. In June the Illinois Bayou stations were near the rest of the stations in values recorded except for the bottom reading at Station 17. In July most of the readings increased by value of 50-100 points. In August there was a considerable increase into the 700± range for most stations. This increase continued into September and carried readings into the 800± range. By October the readings had fallen back into the 500's and the decline continued into November. Station 16 was considerably lower both months. In December there was a further drop to the 300 level.

January 1974 readings were back up to the 540-630 range except for Station 16 and the surface of Stations 17, 14, and 5. This lowered surface value at Station 5 was also evident at the surface of Station 10 with a 60 point difference from surface to bottom. In March the readings were in the 600-690 range except for Stations 16 and 17. In April, these had declined to 418-440 except for the Illinois Bayou stations or those downstream from them (Stations 16, 17, 14 and 15).

In May there was a drastic rise to the low 700's for most stations. Station 16 was quite high for that station (500-520) but the bottoms at Station 17 (235) and at 7 (418) were lower. In June the readings were back to the 300-380 range except for Stations 16, 17 and surface of 15. The readings for the lower depths at Stations 16 and 17 were quite low.

PHOSPHATE

Phosphorous is an essential element for the growth of organisms and can often be a limiting factor in the growth of aquatic organisms. Phosphorous occurs in natural waters almost entirely in the form of various types of phosphate (Std. Methods, 1971). The most common and abundant form is Orthophosphate and this is the form for which the measurements were taken during this study.

The measurement of phosphate began in March 1970 using the Hach procedure as described previously. The readings in March were generally low, in the .1 to .15 ppm range, except for one abnormally high reading which was probably due to a procedural error. In April the readings were higher with readings ranging from .15 to .55 ppm. The May readings continued at a similar level to those of April with some readings higher, although Station 16 was somewhat lower than the prior month. The June readings continued at about the same level except for one high reading at Station 15. In July the readings were quite variable with some high readings but some were also lower than the prior months. In August the readings were more uniform over the lake, generally in the .2 to .7 range, but there were a few high readings (2.4 to 3.8) which did not seem to fit any predictable pattern of distribution. September saw a return to fairly uniform readings throughout with readings in the .15 to .70 range. The readings in October were generally the same. In December the readings were quite variable but generally low.

In January 1971 the readings were low, in the 0 to .30 ppm range with most less than .2 ppm. The March readings were similar but there were occasional high readings. April readings were uniform and generally low. May readings were in the same range as the April readings. This was true of the June and July readings also. The August readings were somewhat higher with the values at Station 16 remaining somewhat low.

There was a general decline in September although the values at greater depth for some of the stations remained somewhat higher. In October the values rose slightly and in December there was a further rise at most stations.

In January 1972 the readings were back in the medium range (.25 to .5). In March they were considerably lower at all stations. The values were up slightly in April and then remained about the same in May except for abnormally high readings at Station 3. The readings continued at about the same level except for abnormally high values at Station 16. July values were up slightly. August values were lower except for Station 16 which was somewhat higher. September values were about the same as those of August and generally uniform. October readings were approximately the same to slightly lower for most stations but higher at Station 14 and the middle depth at Station 17. December readings were low to medium and uniform.

In January 1973 the readings were fairly uniform and were in the medium range (.12 to .35). In March most of the readings were missed due to poor weather conditions but the ones obtained were slightly lower. The April readings were low but variable. In May the readings were up slightly with some high readings in the Illinois Bayou section. In June they were similar with only Station 16 showing very high readings. In July the values were about the same as June except for the surface value at Station 17 which was 3.4. In August the readings were higher and some were quite high with Station 3, bottom of Station 10 and top of Station 14 showing values of 2.1 to 3.0. They continued high at most stations in both September and October. The November readings were also high with several above 2.0 ppm. The December readings were not obtained.

The values for January 1974 were in the medium range except for

2.0+ readings at two stations in the Illinois Bayou area of the reservoir. March readings were high with several from various parts of the lake in the 1.0 to 2.5 range. April readings were generally lower but several scattered readings were above 1.0. In May the readings were high again with several above 2.0 ppm in the main reservoir but those in the Illinois Bayou area were in the medium range. June readings were slightly lower but several remained above 1.0 ppm.

There appeared to be no definite pattern in the phosphate readings in relation to location of sampling station and very little, if any, in regard to seasonal trends. In three of the four years the August readings were high but did not appear to represent a seasonal upswing.

NITRATE

Suitable methodology and equipment for determining nitrate values was not obtained until July of 1970. The readings for July 1970 ranged from 1.5 to 3.4 ppm. Most were within the range of 1.8 to 2.1 ppm. The 3.4 Reading at Station 10 is out of line with the rest of the values. No Particular patterns as to station or depths are apparent in the range of values. In August the values range from 1.5 to 3.25 ppm. All except one were less than 2.5. In September the values were 1.0 to 4.3. All the values above 2.0 were at the bottom of the deeper stations. In October the values were all quite high with readings in the 4.2 to 5.0 range. The December readings had declined somewhat, back into the 2.7 to 3.4 range. In January 1971 the readings were in the range of 2.6 to 4.4 and most were 4.0 or above. This general level of values continued through the March readings. In April there was a drop to the 1.4 to 2.1 range. There was a slight increase in May for most stations although the range was 1.3 to 2.7. The readings for Station 16 and the surface of Station 14 and surface and middle of Station 17 were low as was the surface of Station 5. The June values were very similar with a range of 1.0 to 3.0 with most in the 2.0 to 2.5 range. July values were similar ranging from 1.4 to 3.35. August readings also were quite similar. The September values fell slightly to 1.4 to 2.8 ppm but in October there was a sharp increase with the levels going up to a range of 4.8 to 5.6 except for lower values at Station 16 and the surface of Station 17. By December the values had declined sharply to less than 1.0.

In January 1972, the readings were up slightly but still generally in the 1.0± range. In March and April the readings were all below 1.0. There was a general rise in the values in May with readings in the 0.4 to 3.8 range. The higher readings generally occurred at the deeper depths. The Illinois Bayou stations (16 and 17) had the lowest readings. In June 1972 the readings were all back under 1.0. In July they continued to be low with the range 0.7 to 1.0. In August they declined further to the 0.4± range. In September they continued low, in the 0.4 to 0.8 range. In October the readings were 0.4 to 1.0. In December the values rose again to a range of 1.1 to 2.0.

In 1973 the NO_3 readings started off in January at a relatively high level, 2.0 to 2.6, except for Station 16 and the surface of Stations 17 and 14 where they were 1.3 to 1.5. In March they were slightly higher except for the Illinois Bayou stations (16 and 17) and the upper and middle of Station 15.

The May readings continued at about the same level as for March. In June the values declined somewhat, ranging from 1.3 to 2.2 but with most under 2.0. In July they had all fallen to less than 1.0. There was a further decline in August at most sample sites and the readings remained at a very low level through September. There was a marked increase in October to the 1.8 to 2.7 range for most of the stations. The Illinois

Bayou stations and station 14 and the surface of Station 15 remained low. In December the values ranged from 2.0 to 2.6 for all stations except Station 16 (the sample from Station 17 was lost).

In January of 1974 the readings declined to the range of 1.6 to 2.6 (except for Station 16 and surface of Stations 17 and 14 where they were lower). They had risen again in March to the 1.8 to 2.5 range for all stations except 16 which was slightly lower. In April there was a decline to 1.3 to 2.2 (except for 16 which was less then 1.0). May's readings were almost identical except that a low reading was obtained at the bottom of Station 17. In June there was a further decline to a range of 1.0 to 1.7 for all stations except the Illinois Bayou stations which had very low levels.

There seemed to be no definite trends in the NO_3 values. The Illinois Bayou stations were generally different, usually lower than the main stem stations. There was some seasonal fluctuation with the highs occurring late in the year (October to December) and in mid to late winter (January - March) with a surge in May in some years. The summer months (June - September) were the months in which the lowest readings were ordinarily obtained.

PHYTOPLANKTON

As previously detailed, an attempt to make a computerized analysis of this data for trend gave little positive information due to sampling procedures. A less highly sophisticated examination by graphs and charts does tend to show some of the type of information spoken of in the literature.

A numerical tabulation, made from the differential phytoplankton survey lists, groups the organisms into the general categories of Bacillariophyceae (diatoms), Cyanaochloronta (blue-green algae) and Chlorophycophyta (green algae) (Bold, 1973). A percent of genera value was obtained by dividing the number of genera per group by the total genera, and a percent of numbers value was obtained by dividing the number of organisms per groups by the total number of organisms. The data are shown in Figures 2 to 4. These data show the increase-decrease trends of season and water temperature. The large increase in blue-green algae during warm water periods is clearly evident as is the genera dominance of diatoms during colder water periods.

Due to the method of enumeration, the identification of plankton was made only to genus. It was recognized that this may lump some of the more minute organisms into a single group for this report. With several of the algae, i.e. *Pediastrum* and *Scenedesmus*, more than one species was observed on several occasions. At the magnification level used in the enumeration process the determination of diatoms even to the correct genus was also highly speculative. Phytoplankton

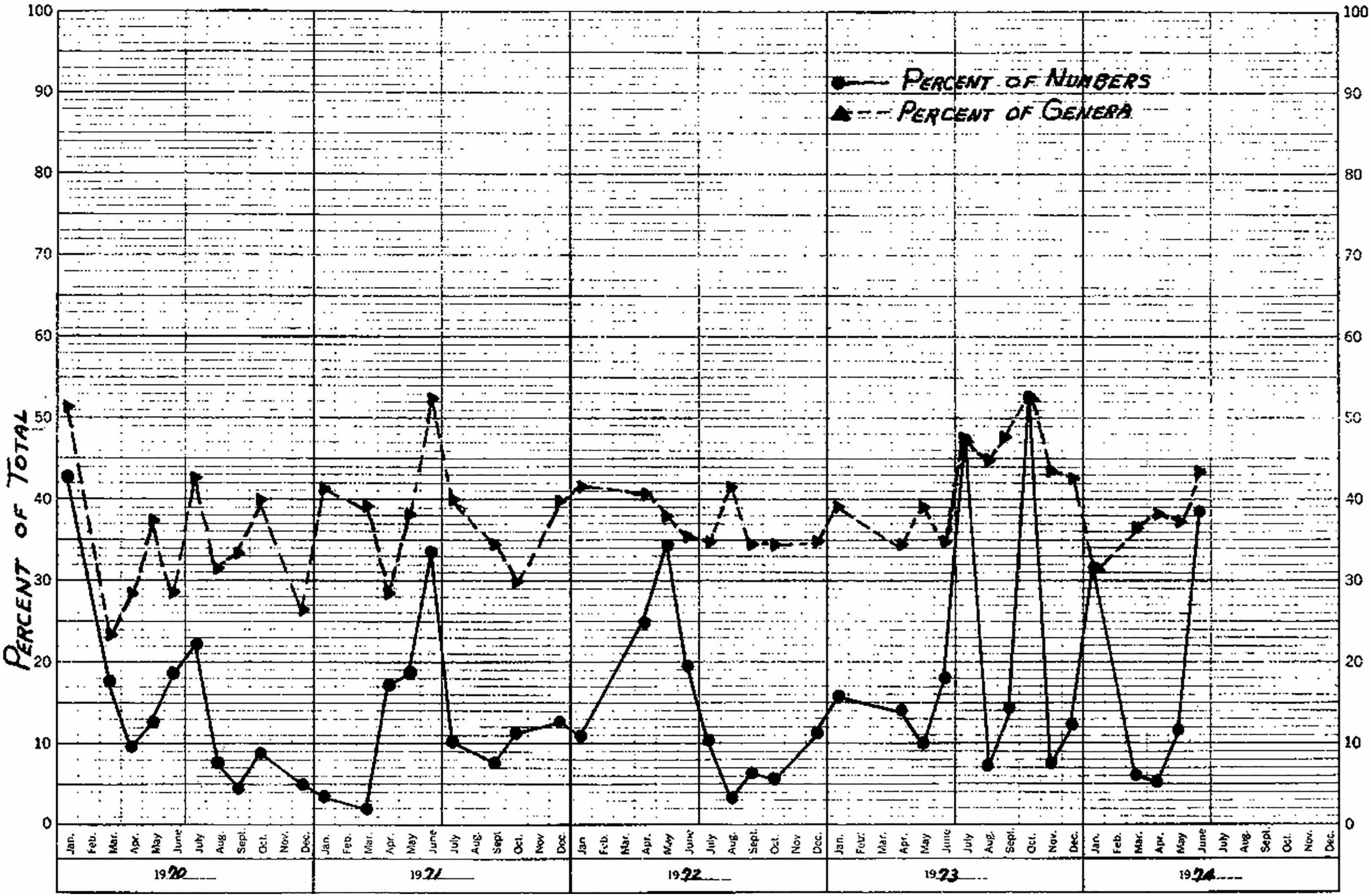

Figure 2. Percentages of Chlorophycophyta by genera and numbers for the project dates.

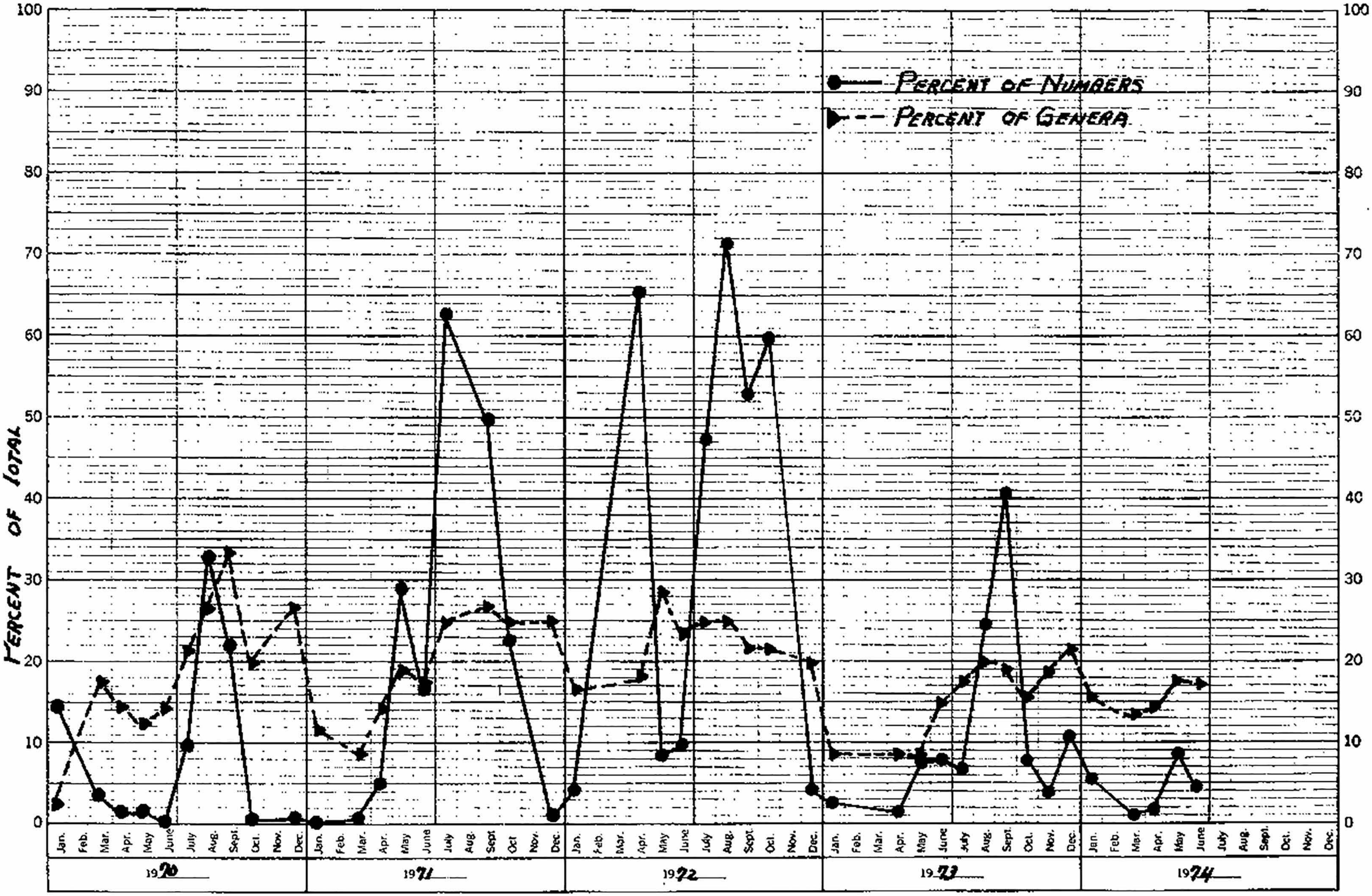

Figure 3. Percentages of Cyanochloranta by genera and numbers for the project dates.

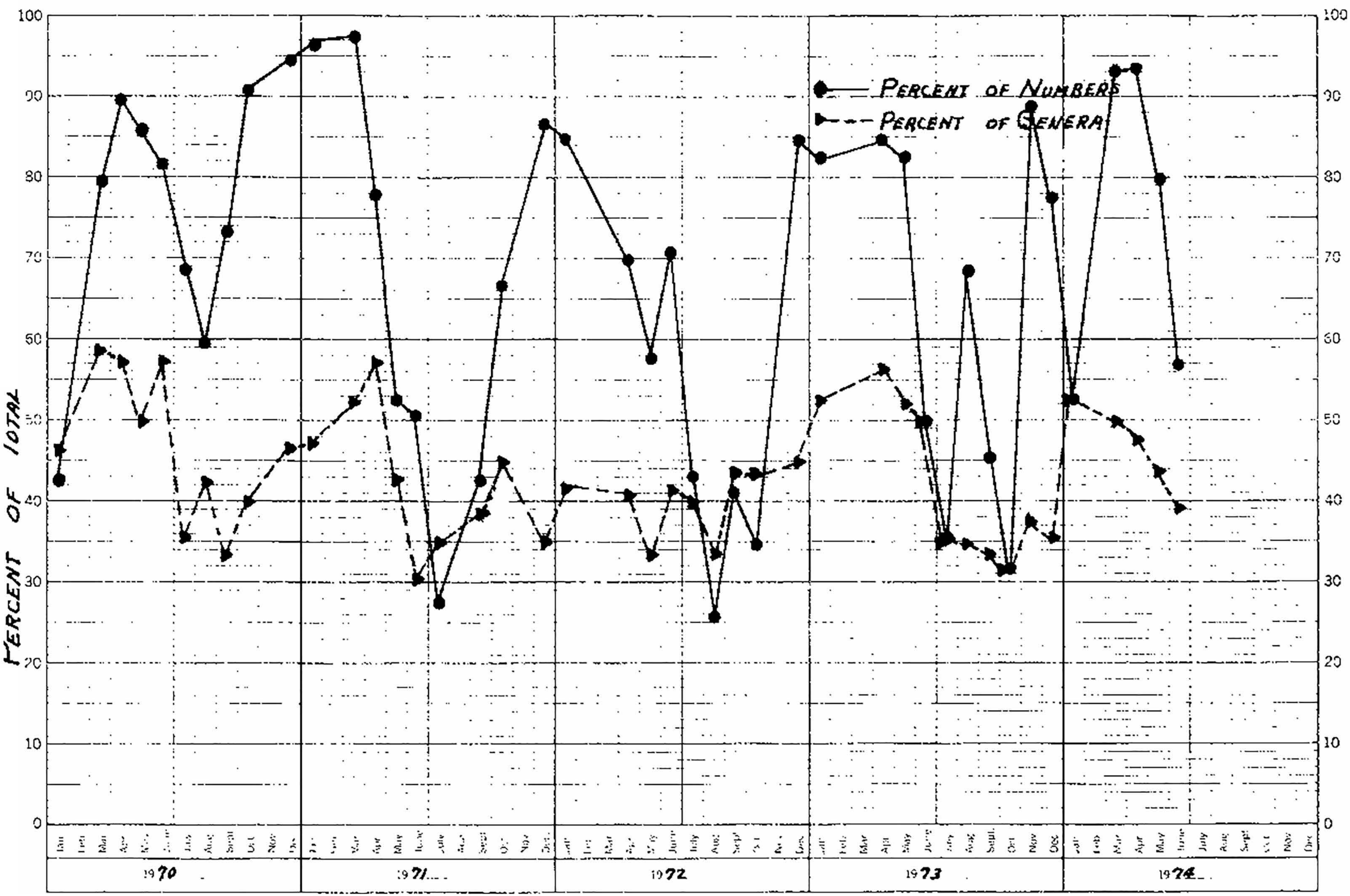

Figure 4. Percentages of Bacillariophyceae by genera and numbers for the project dates.

genera ranged from a genera count of 16 for April and July of 1970 to a high of 34 for May of 1973.

On numerous occasions aquatic fungi, including bacteria, helicoids, and various fungal spores, were observed. These, along with several unusual phyto- and zooplanktonic forms, would tend to support the idea that a detailed study of these groups from the water of the reservoir would be a very worthwhile study.

The marker buoys have had a heavy circle of Cladophora growing around them at the water line since shortly after their installation. Only rarely have specimens of it been picked up in the plankton samples. This growth occurs very heavily in the early spring and again in the late fall, but nearly dies out during the heat of mid summer.

Identification of the phytoplankton was made using Forest (1954), Palmer (1962), Patrick et al. (1966), Prescott (1962), Smith (1950), Weber (1971), and Whitford and Schumacher (1969).

Zooplankton

The zooplankton identification was made with the aid of Eddy and Hodson (1962), Pennak (1953) and Edmondson (1959). A summary of the data giving the major genera identified at the time of their peak abundance is given in Table I.

No major differences in trends between stations or areas of the reservoir were detected. There were, of course, seasonal cycles in most of the forms present. Eggs of various forms were present throughout the year but were most abundant during the period from

	1970		1971		1972		1973		1974	
	Peak	Rank	Peak	Rank	Peak	Rank	Peak	Rank	Peak	Rank
Asplanchna	May	6	Jun	5	May	8	May	11	Oct	6
Bosmina	Mar	3	Apr	6	Apr	6	Jun	5	May	4
Brachionus	Jul	1	Jun	1	May	1	Sep	3	May	1
Cyclops	Jul	2	Apr	3	Apr	7	Sep	6	Apr	5
Daphnia	Jul	9	May	9	May	11	Aug	7	Jul	10
Filina	Mar	6	Mar	11	Apr	9	Jul	8	Aug	8
Keratella	Jul	4	Mar/Oct	2	May	3	Sep	1	Apr	2
Polyarthra	Dec	10	Sep	4	Jun	2	Sep	4	Jul	3

Table I. Major genera of zooplankton showing month of peak abundance and relative rank in abundance.

December through April or May. They declined to lower levels in mid to late summer in most of the years. Crustacean naupli were most abundant in April or May except for 1973--a year in which several of the forms recorded showed an unusual pattern of late abundance. The peak abundance of Asplanchna was May or June. Bosmina reached its greatest abundance in the period March to June. Brachionus had high populations throughout much of the year and reached peaks at varying times ranging from May in 1972 and 1974 to September in 1973. Cyclops was present in considerable numbers through much of its warm season and also showed varying times of peak abundance, varying from April to September. Keratella was present in abundance over much of the year with peaks occurring from March to October. The rotifer genus Polyarthra appeared to be a late-season group, reaching peak abundance in the period of June to October.

As mentioned previously, data from 1973 show an unusual lateness in the time of peak abundance for many of the most important genera. The genera Bosmina, Brachionus, Cyclops, and Keratella all exhibit peaks later in the season than is apparently normal for these groups.

With the exception of eggs and naupli which were very abundant in most of the samples, the rotifer genus Brachionus was most abundant of the zooplankton groups. The only year that it was not the most abundant genus recorded was 1973 when it was surpassed by Keratella The rotifer Keratella was second in abundance overall followed by Polyanthra. The crustaceans Cyclops and Bosmina were next in relative abundance followed by another rotifer, Asplanchna. Several other genera, including the rotifer genus Filina and the crustacean genus Polyphemus, were numerous at various times but did not reach the sustained high population levels exhibited by the genera previously mentioned.

BENTHOS

Due to the limited number of samples taken at each station on each date a statistical analysis of the data from the benthic sampling was not done. Even though the number of replicates was not sufficient for statistical analysis, it was possible to establish the patterns of relative abundance between various taxa and between various sampling stations.

During 1970 specimens of Chaoborus were taken at all the stations at various times, although their distribution was erratic during some of the sampling periods. The numbers per sample varied widely also. They were abundant in July and August and reached very abundant levels in September and October. Chironomid larvae were present at all of the stations sampled in every sampling period. They were usually the most abundant component of the bottom fauna. Oligochaete worms were present at most of the stations in widely varying quantities. They were usually more abundant or made up a greater percentage of the fauna, at the deeper stations, i.e., Stations 3, 15 and 21. Members of the genus Hexagenia made up almost all of the mayfly component. They were fairly consistent as a part of the benthos at each station. They were more consistently found and usually more abundant at Stations 5, 10, 11 and 16, all of which are shallow stations. Of the deeper stations, they were most often taken from Station 21. As can be seen from the tables, the other taxa in the bottom fauna were generally sporadic and limited in their occurence.

The 1971 bottom sampling data showed similar trends to that of the previous year. Chaoborus was abundant in July and August, again with specimens then in almost all of the samples. This group persisted at an abundant but somewhat irregular level into December.

The Chironomidae were present at all of the stations on almost every sampling date. They were taken in greatest numbers during June, July and August. The Oligochaetes were abundant throughout much of the year but were definitely more abundant at the deeper stations (Station 3, 15 and 21). Specimens of Hexagenia were again most often taken at Stations 5, 10, 11 and 16 and only occasionally from several of the other stations.

In 1972 the January counts showed a high level of abundance for Chaoborus and Chironomidae. The Oligochaeta was somewhat sporadic and Hexagenia was present at almost all the stations and was especially numerous at Station 14 as was the case the previous month. Chaoborus declined in abundance in April and May but in June there was a marked upsurge in numbers which remained high for the rest of the year. They were very abundant in August. The numbers obtained at Station 1 were especially high. Chironomids were fairly uniformly abundant at all stations throughout the year. The oligochaeta were again present at almost all stations throughout the year but again were most abundant at the deeper stations. The Hexagenia were very abundant at Station 16 in January. They were relatively abundant at most of the stations in April and May and at Stations 10, 11, 14 and 16 in June. After that, they were rather sporadic for the remainder of the year.

In 1973 the Chaoborus were abundant at most stations in January, especially at Station 1. Stations 10, 11 and 16 showed much less abundance. In April the numbers were down at most stations, although Station 1 was an exception and remained high. The numbers continued low in May, June and July, then rose slightly in August. Station 2 was somewhat higher than the average in July, August and September. Numbers at most stations were higher in October, then declined in November and December. The Chironomidae were again abundant at all stations throughout the year. Oligochaeta were abundant at most stations most of the year and the deeper stations again had higher numbers than did the shallower stations. However, Stations 10 and 11 appear to be maintaining higher populations than the other shallower stations. Hexagenia populations were at low levels at most stations throughout the year. They were most abundant at Stations 1 and 16.

In 1974 Chaoborus were only moderately abundant in January, then declined somewhat in March and were at low levels in April, May and June. The Chironomidae were generally abundant at all the stations for the entire period of January through June. The Oligochaeta were present at most of the stations throughout the period but were abundant only at the deeper stations and also at Stations 10 and 11. This relative abundance at Stations 10 and 11 continued a trend which had appeared the prior year. The population of Hexagenia was fairly low and uniform throughout the period with the exception of Station 1 in March.

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APPENDICES

NOTE: In order to conserve publication costs, the appendices containing graphs and tables of the raw data have been omitted. Interested parties may obtain copies of the appendices by requesting copies from:

Water Resources Research Center
University of Arkansas
223 Ozark Hall
Fayetteville, AR 72701