THE PHYTOPLANKTON AND SOME PHYSICAL-CHEMICAL DATA OF THE COTTONWOOD AND UPPER NEOSHO RIVERS IN KANSAS, 1959

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INTRODUCTION

The comparative survey of the Neosho and Cottonwood rivers at Emporia included determining some physical and chemical conditions and sampling the phytoplankton and zooplankton populations of each stream. Qualitative and quantitative phytoplankton populations and the physical and chemical features are discussed in this paper.

Emporia is situated between the Neosho and Cottonwood rivers approximately seven miles above their confluence in Lyon County, Kansas (Fig. 1). The Cottonwood River originates primarily in the flint hills of Marion and Chase counties while the headwaters of the Neosho River drain parts of Wabaunsee and Morris counties (Fig. 3). The drainage area of the Neosho is predominantly cropland and the Cottonwood drains some cropland and a large area of grassland. It is estimated that 72 per cent of Chase County is grassland. It was also known from samples taken earlier that the water from the Cottonwood is harder than that of the Neosho. These are some of the primary factors which stimulated this investigation.

Several other features added local interest to this study. According to records examined at the office of the City Manager,

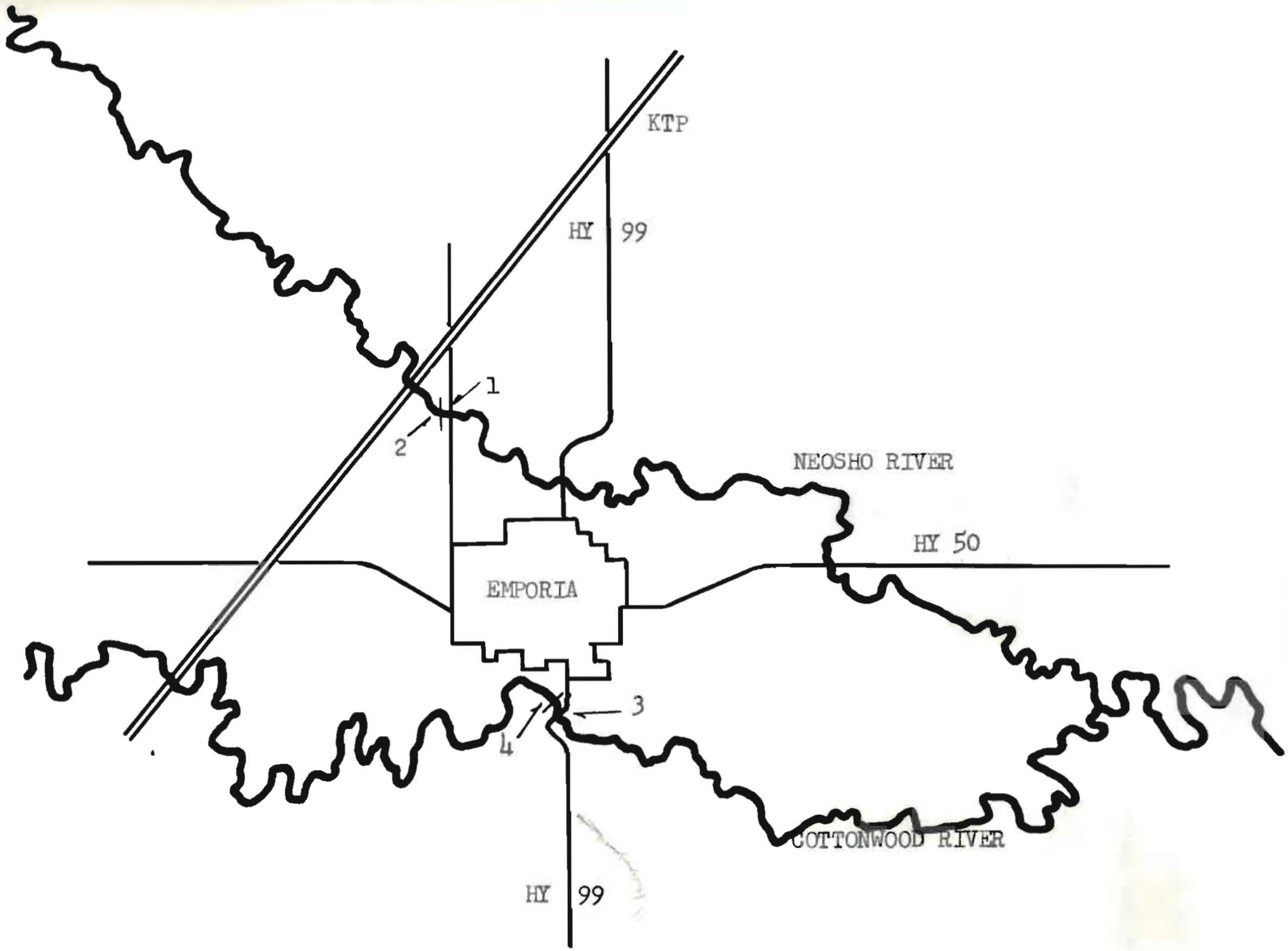


Fig. 1. Map of the rivers at Emporia showing the location of the collecting stations.

an average of 1.5 million gallons of water were pumped from the rivers daily for domestic and industrial use at Emporia during 1958 and approximately three million gallons were needed daily during hot summer days. Local fishermen were present near the stations at one or both rivers on all collecting trips indicating that the streams were consistently utilized for recreational purposes. Frequent heavy thunderstorms during spring and summer months in the upper watershed area of both rivers resulted in excessive runoff and intermittent flooding of lowlands. Flooding occurred in May of 1959 and high water conditions existed again during July although overflow was very limited.

The Neosho River watershed which extends from northern Oklahoma to central Kansas was being impounded (1960) to control flooding. Several dams were under construction or had been completed below the area of this study. Reservoirs were also to be formed upstream to control the headwaters of both the Neosho and Cottonwood rivers (Fig. 2). This study was made before such measures were in effect and consequently might serve as a reference to help indicate the changes which occur in the limnology of the rivers after completion of the reservoirs.

Published reports of studies of the phytoplankton of rivers and streams with accompanying data of the physical and chemical conditions include primarily the larger rivers (Damaan, 1951, Berner, 1951, Allen, 1920). Welch (1952) stated that only one extensive, long term investigation of the limnology of rivers has been undertaken in the United States. The comprehensive study of the Illinois River

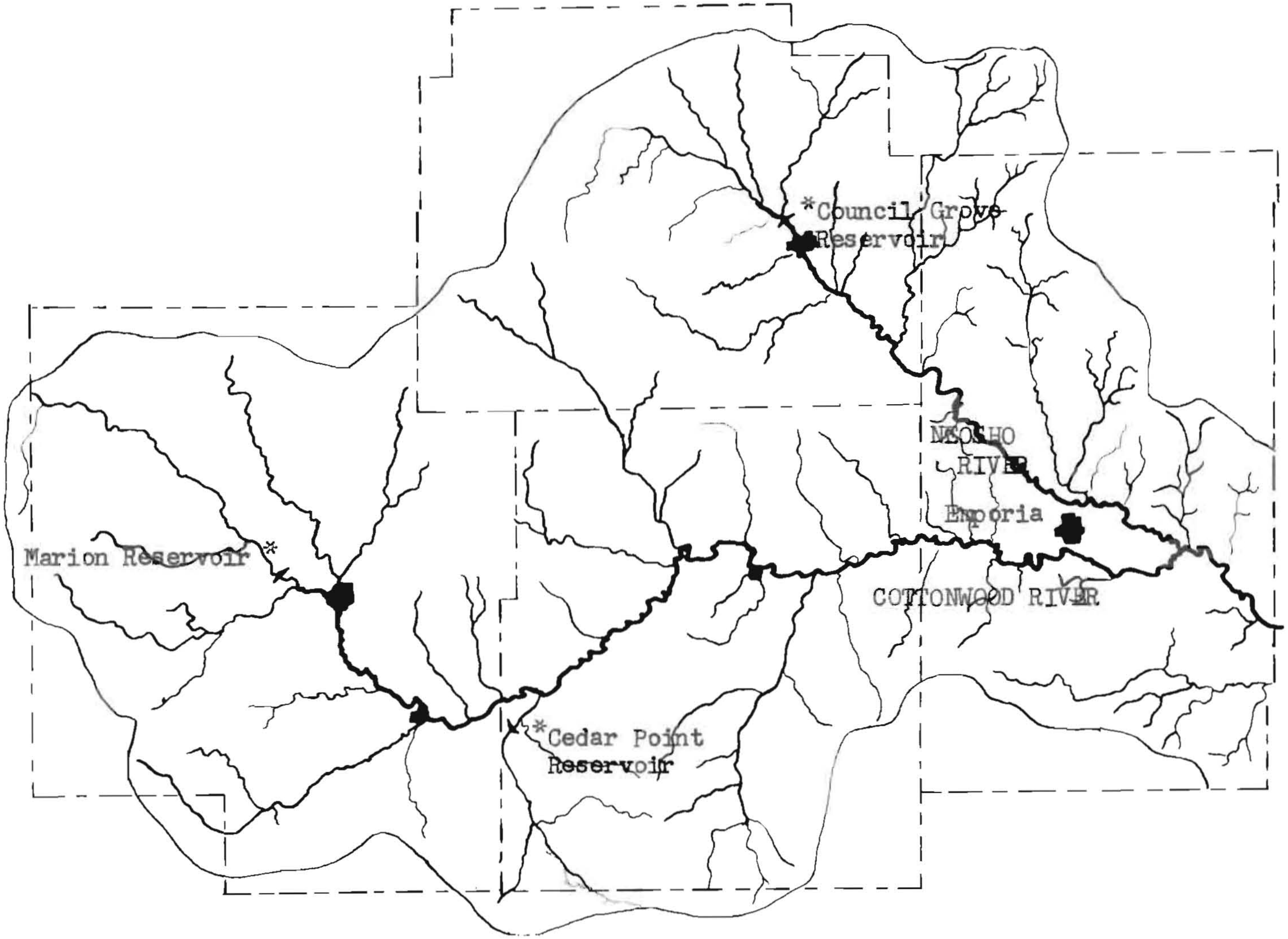


Fig. 2. Watersheds of the Cottonwood River and the upper Neosho River showing proposed flood control dam sites. * Proposed dams (1960).

resulted in publications which include several by Kofoid (1903, 1908). Although these studies are important, it should be recognized that the small rivers and streams are much more numerous in Kansas than large rivers and affect a large drainage area. Approximately 1500 rivers and streams in Kansas have been named (Schoewe, 1951) but the limnology of only a few of these has been investigated (Prophet, 1957, Goulden, 1959). Dowell (1952) has indicated that limnology in Kansas is still in the pioneering stages of development. Phytoplankton of rivers with accompanying chemical and physical data have apparently not been included in published literature in Kansas.

DESCRIPTION

The water from Kansas streams drains into two larger rivers (Fig. 2). The Arkansas River drainage basin includes the area south of a line through the following Kansas cities: Leoti, Scott City, Utica, LaCrosse, Holyrood, McPherson, to south of Herington (Schoewe, 1951). An arc from south of Herington through Alta Vista and Reading circumscribes the northernmost edge of its watershed. A line extending from Reading southeast through Pittsburg indicates the eastern boundary of the Arkansas River drainage area. The part of Kansas to the north and east of the line is part of the Missouri River drainage basin. The Neosho and Cottonwood rivers are part of the Arkansas River drainage basin.

The headwaters of the Neosho River originate in the Flint Hills of Morris and southwestern Wabaunsee counties. The course of the river is generally southeastward along a path 180 miles long when measured in a straight line or 281 miles along its channel. It joins the Arkansas River about ten miles northeast of Muskogee, Oklahoma. In the area of its headwaters above Council Grove, the Neosho has an average gradient of 15 feet per mile (Kansas State Board of Agriculture, 1947). From Cottonwood Falls to Emporia the average gradient is three feet per mile and below the point of confluence with the Cottonwood River to its mouth in Oklahoma, it is reduced to 1.35 feet per mile.

The Neosho River drains an area of 825 square miles above

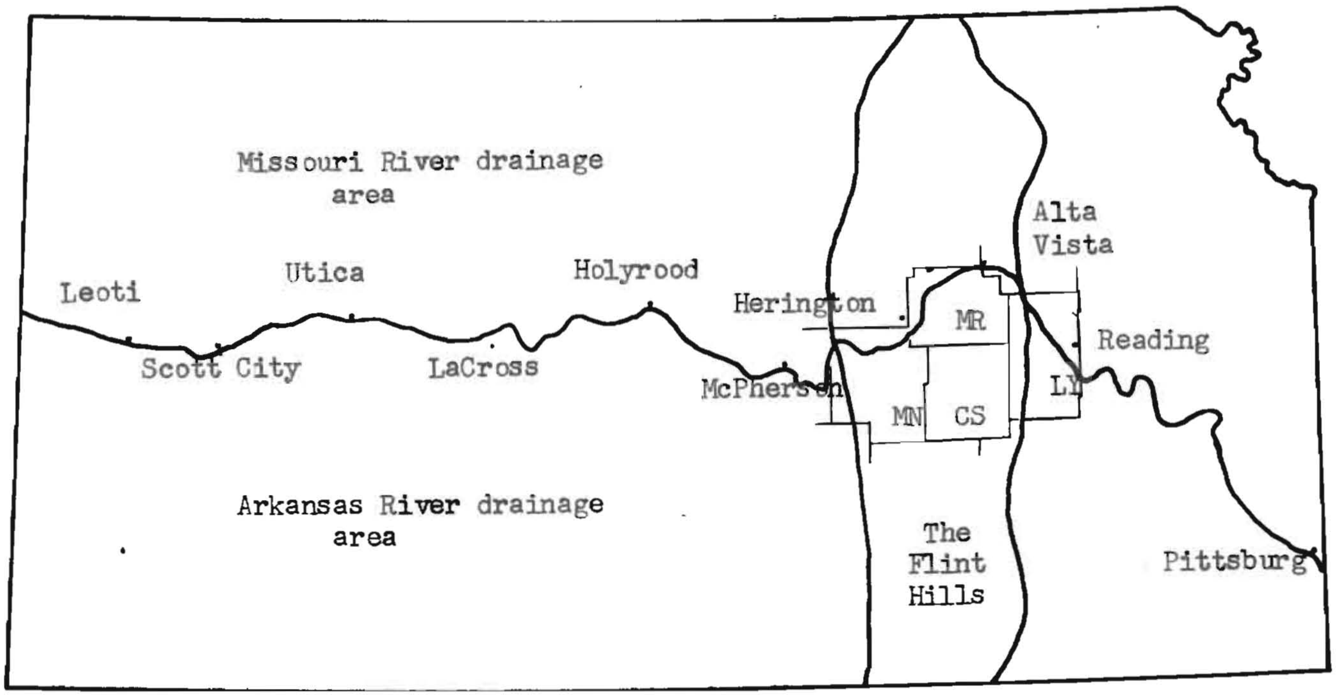


Fig. 3. Map of Kansas showing the Flint Hills Region and the watersheds of the Missouri and Arkansas rivers.

its junction with the Cottonwood. The area is composed of mostly limestone and shales of the Wabaunsee, Admire, Council Grove and Chase groups (Schoewe, 1951).

A series of three dams has been constructed upstream from Emporia. One of these is located an estimated 19.5 river miles above the confluence with the Cottonwood River and is 70 feet long and 10 feet high. Records from the office of the City Engineer state that it was constructed in 1885 with an approximate reservoir capacity of 100,000,000 gallons. It is located just north of the Emporia city limits and its reservoir is tapped heavily for the city's water supply. Records also indicate that during periods of drought water does not flow over the dam and conversely during high water in July of 1959 the dam was completely submerged so that its location could only be estimated.

The banks of the Neosho support a dense vegetation including the following plants: Ulmus americana (American elm), Salix nigra (black willow), Celtis occidentalis (hackberry), Rhus radicans (poison ivy), Fraxinus sp. (ash), Morus alba (white mulberry), Morus rubra (red mulberry), Polygonum sp. (smartweed), Quercus macrocarpa (bur oak) and Acer negundo (boxelder) (Fernald, 1950).

Station I is in a pool area about 75 feet below the dam (Fig. 4). During high water it becomes part of a large whirlpool area. During normal river flow it is about 90 feet wide and 150 feet long with a maximum depth of approximately 6 feet. Immediately below the pool and extending about 100 yards downstream is a riffle

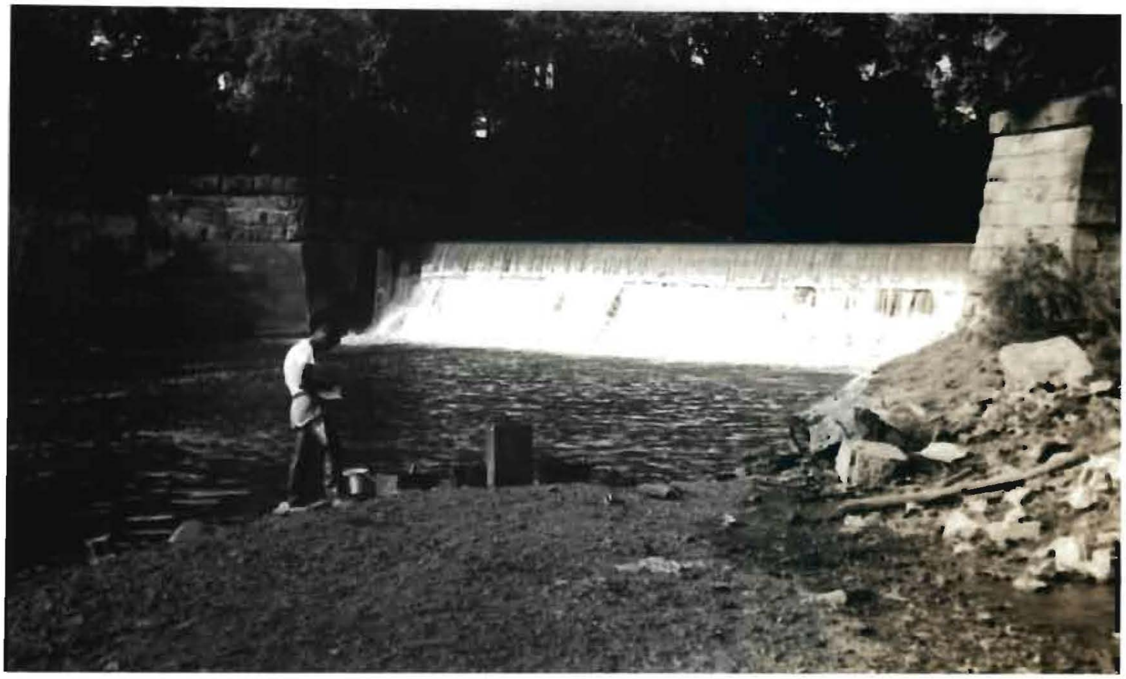


Fig. 4. Station I looking upstream at the site of Station II above the dam.

Fig. 5. Station II looking upstream over the pool area above the dam.

area. Seepage from the bank at the station added a steady flow of water, colored with diatoms, to the stream.

Collections at Station II were taken from a cement abutment approximately 100 feet above the dam on the right hand side of the stream (Fig. 5). The bottom was composed of gravel covered with detritis in the pool region. The river was quite sluggish upstream from the pool area and steep banks kept the stream well defined. The pool was about 90 feet wide and had a maximum depth of about 8 feet.

The Cottonwood River is a right hand tributary of the Neosho (Fig. 2). From its origin in Marion County, Kansas it flows 137 miles by way of its channel in a general eastward direction. Its watershed covers an area of 1830 square miles with approximately 58,000 acres of it subject to periodic flooding after heavy rains (Schoewe, 1951). A gradient of 10 feet per mile in Marion County decreases to an average of 2.5 feet per mile near its mouth in Lyon County (Kansas State Board of Agriculture, 1947). Rock strata in the watershed are composed mostly of Wabaunsee, Admire, Council Grove and Chase groups as in the Neosho watershed (Schoewe, 1951). In addition, there is Wellington shale in the upper drainage area. The river drains about the same area of limestone as the Neosho above the point of their junction but in its headwaters it also drains an area which is composed partly of gypsum (O'Connors, 1959). This is apparently the source of the sulfate ions which were greatly responsible for the difference in hardness of the waters of the Neosho

Fig. 6. Looking downstream from station I at the riffle area.

Fig. 7. Field equipment in use at station III.

and Cottonwood rivers.

An old mill dam 112 feet long and nine feet high crosses the river near Emporia. According to the city manager it was constructed about 1856-1860 and was repaired during a period of drought in 1956. Oscillatoria coated the face of the dam during the entire study and Cladophora was found growing on top of the dam in August.

Vegetation on the banks of the river included Populus deltoides (cottonwood), Morus rubra (red mulberry), Gleditsia triacanthos (honey locust), Platanus occidentalis (sycamore), Ulmus americana (american elm), Fraxinus sp. (ash), Acer negundo (boxelder maple), Salix sp. (willow) and Polygonum sp. (smartweed) (Fernald, 1950).

Station III below the dam on the Cottonwood River had a rocky bottom (Fig. 8). Cladophora grew abundantly on these rocks during normal stream flow in July and again in August. At this time the stream flowed rapidly at this station and the water was approximately three feet deep. It was about 150 feet wide and extended several hundred feet downstream. Collections were made an estimated 150 feet below the dam on the left hand side of the stream.

Station IV (Fig. 9), approximately 60 feet above the dam on the left hand side of the stream, was a pool area about 125 feet wide and 200 feet long. The bottom was rocky and covered with detritus. Maximum depth was about seven feet during normal stream flow. During July and August slightly submerged rocks along the banks were covered with diatoms.

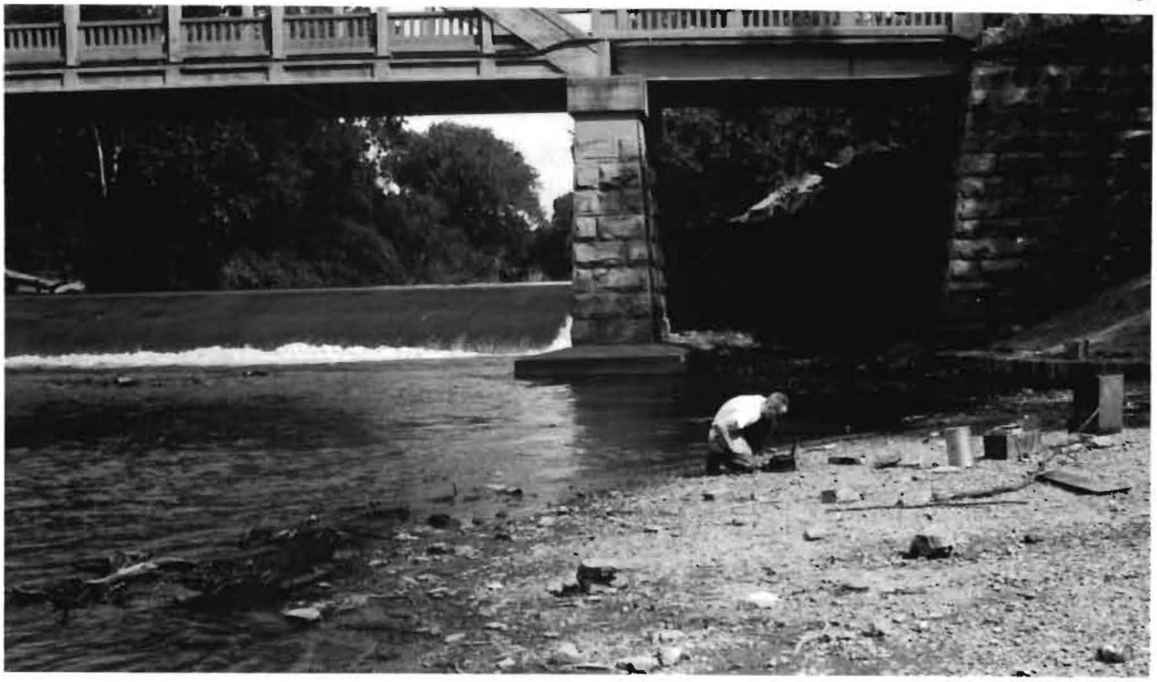


Fig. 8. Station III looking upstream at the pool area above the dam.

Fig. 9. Station IV looking upstream at the pool area above the dam.

METHODS AND MATERIALS

Physical-Chemical Conditions

Observation of existent plankton and limnological conditions were made from June 5, 1959 to October 10, 1959. Weekly collections were made from June 5 to August 19 and the stations were again visited on September 12 and October 10. Collections were made at all stations each time they were visited except when high water inundated the stations. Only one set of samples was taken from each river on July 16 and on July 23 only one station was visited on the Neosho because of high water.

Limnological conditions recorded at each station included air and water temperatures, turbidity, hardness, dissolved oxygen, carbon dioxide, hydrogen-ion concentration (pH), seston, and phenolphthalein and methyl orange alkalinities (Table I). A qualitative phytoplankton sample from a tow net and a 100-liter quantitative phytoplankton sample, concentrated to 35 milliliter (ml), were brought into the laboratory for examination.

Temperatures were recorded in degrees Centigrade (^{o}C) with a Whitney underwater transistor thermometer. The temperature difference between surface and bottom was considered insignificant and only one temperature at a depth of one to two feet was recognized.

Turbidity, a measurement of suspended matter, was determined as parts per million (ppm) with a United States Geological Survey turbidity rod.

Total hardness, measurement of the sum of concentrations of cations in solution, was determined by the soap titration method as outlined in Standard Methods for the Examination of Water, Sewage and Industrial Wastes, (1955). The hardness of Neosho water is caused primarily by carbonate and bicarbonate ions but the Cottonwood in addition carries varying amounts of sulfate ions in significant quantity according to reports obtained from the city water department. Sulfate hardness was not derived at this time.

Dissolved oxygen in parts per million was determined by the unmodified Winkler method (Welch, 1948) with suitable adjustments in concentration of reagents to accommodate a 135 ml water sample. Oxygen in parts per million was converted to per cent of saturation from the monograph by Welch (1948).

Free carbon dioxide, and phenolphthalein and methyl orange alkalinities were determined as outlined in Welch (1948). Phenolphthalein alkalinity was not found in samples from these rivers.

Inorganic and organic seston was concentrated from 500 ml of water with a Foerst centrifuge operating at a speed of about 20,000 rpm. The centrifugate was dried at 42-44 degrees Centigrade for about 72 hours or longer. Then it was cooled in a desiccator and weighed. It was burned over a carbon-free flame for 20 minutes and weighed again after cooling. Results were converted to milligrams per liter (mg/liter) and per cent organic and inorganic seston.

Qualitative Phytoplankton

One qualitative and one quantitative sample were taken at each station. A cone-shaped tow net constructed of number 20 bolting silk was used to collect qualitative samples. The diameter of the net opening at the inflowing end measured 15 centimeters (cm) and a 37 ml screw cap bottle with an opening of 2.3 cm was attached at the smaller end of the net. A sample was collected by throwing the net into the stream to about 45-50 feet from shore and retrieving it. The depth at which the sample was taken was controlled by how fast the net was drawn toward the shore. Several casts were made to include samples from different depths of the stream and care was exercised to include only floating organisms.

Water samples were returned to the laboratory shortly after they were collected and cooled in a refrigerator to four °C. Many of the motile organisms become sluggish and settle to the bottom when they are cooled sufficiently. After an hour or more wet mounts were examined with a microscope at a magnification of 100 diameters (X). High power (430X) was used to make more accurate identification. Three or four mounts from each sample were made to insure more complete sampling. A binocular American Optical microscope equipped with a mechanical stage and a Whipple's ocular micrometer was used for all quantitative examinations. Fresh-water Algae of the United States (Smith, 1950), The Algae of Illinois (Tiffany and Britton, 1952), Algae of the Western Great Lakes Area (Prescott, 1951), Structure and Reproduction of the Algae (Fritsch, 1935 and 1945) were used to identify the algae.

Quantitative Phytoplankton

A 10-liter bucket was used to pour 100 liters of water through a partially submerged dip net to get a quantitative sample. A larger opening of 75 cm made this net more convenient for quantitative sampling than the tow net described on the preceding page. A 35 ml bottle was attached to the net to receive the concentrated sample. Enough formalin was added to the sample to make a three to five per cent solution for preservation. The quantitative portion was not examined until specimens in the tow sample were identified. Then the 35 ml quantitative aliquot was further concentrated to about four to six ml depending upon the amount of suspended matter it contained. A part of it was then transferred in a dropper to a Sedgwick-Rafter cell for counting under the binocular microscope previously described. Counts were confined to the area outlined by the Whipple field through a 10X ocular and a 10X objective.

Algae were examined at 40 different locations in each Sedgwick-Rafter sample. Four rows of 10 fields each were examined at 135, 140, 144, and 148 millimeters (mm) on the vertical component of the mechanical stage. Horizontal components were selected at five mm intervals from 20 mm to 65 mm. The counting cell was refilled until the entire sample was examined. By calculation the conversion factor 0.5 was derived to obtain the number of algal units per liter of river water.

From the literature studied it seems that there is a lack of standardization of the unit for counting algae. The unit as found in this paper refers to the definition as outlined by Lund (1957).

Unit - (a) a single-celled alga such as *Synedra*, *Euglena*, *Ceratium*.

(b) a colony of cells like *Pediastrum*, *Scenedesmus* or *Eudorina*.

(c) a filament crossing the field or entering the field each time that it contacts the prescribed area.

REVIEW OF LITERATURE

Available reports of Kansas algae date back to 1884. Wolle (1884, 1885, 1886 and 1889) listed 53 species of algae which he collected near Topeka. Smyth (1891) included three genera of algae, among other flora, in his report to the Kansas Academy of Sciences and in 1889 Curtis added descriptions and plates of 16 genera of diatoms from central Kansas. Specimens were taken from Reno and McPherson counties and Gage's Pond at Topeka. These are apparently the only published reports of algae before 1900.

In 1918 McNaught published a list of 51 genera of algae composed of diatoms, Chlorophyceae, Myxophyceae, Heterokontae and Flagellata. He indicated they were forms which were troublesome in surface water supplies for cities. This was followed by another publication (McNaught, 1920) which included 13 additional genera of algae from reservoirs. It included a key for identifying algae and a description of a method for applying copper sulfate to reservoirs for the control of algal growth. Mannoni (1932) included drawings of 52 species of Chlorophyceae in his preliminary survey of Crawford County algae and Bailey (1932) reported 20 species of filamentous green algae in a similar study in Labette County. Thompson (1938) made a preliminary survey of the fresh water algae of eastern Kansas. He included 116 genera collected from pools and streams from several counties. Although it was not confined to plankton algae, it apparently represents the greatest contribution to phytoplankton surveys in the state. Limnological records to accompany these collections were not included.

Two recent, unpublished reports at Kansas State Teachers College of Emporia, Kansas include some data on algae. Davies (1958) collected 29 genera of winter phytoplankton from a slough near Emporia and included the physical-chemical data in his report. He correlated the occurrence of the genus Cyclops with the order Zygnematales and found a relationship between the occurrence of the genus Diaptomus and the order Volvocales. Jantzen (1959) collected nine genera of algae and recorded some limnological data from a boggy marsh in Stafford County, Kansas.

There are in the state related limnological reports not specifically concerned with phytoplankton. Andrews and Breukelman (1952) surveyed 19 Kansas state lakes and recorded physical and chemical data along with zooplankton over a period of ten months. A survey of six roadside ditches in Chase and Lyon counties by Ratzlaff (1952) was also restricted to the zooplankters and physical and chemical conditions. Burner and Leist (1953) studied a strip-mine lake in southeastern Kansas for a period of ten months. Tiemeier (1951) investigated the turbidity and plankton of Kanapolis Reservoir, and Tiemeier and Moorman (1957) surveyed the limnology of ponds around Manhattan, Kansas with emphasis on classification of lakes by their turbidity. Tiemeier and Elder (1957) studied ponds in the Flint Hills to determine the physical and chemical relationships to the kinds of zooplankton.

Several studies of smaller lotic waters in the state are recorded. Walton (1949) determined the physical and chemical conditions in the Verdigris River in southeastern Kansas and Prophet (1957) and Goulden (1959) included zooplankton and physical-chemical conditions for both the Fall and Verdigris rivers.

Among several studies of larger rivers in other states, Allen (1920) studied the plankton of the San Joaquin River near Stockton, California. He utilized the Sedgwick-Rafter cell for quantitative counting. Bacillariophyceae were dominant among the 90 genera of algae identified. A shift in dominance from zooplankters in the rivers to algal dominance in a polluted channel is also noted. Temperature was responsible for seasonal dominance of plankton forms. Lackey and Hupp (1956) reported sampling the White River in Indiana near the headwaters at a point 41 miles from its source. Many pool areas in the headwaters allowed the water to age and resulted in good phytoplankton growth. According to Lackey (1958) pollution of the stream served to fertilize it and increased the productivity. Phosphorus (Lackey and Hupp, 1958) is seldom present in small enough amounts in rivers to limit the growth of algae.

Among studies of phytoplankton productivity in the United States, Hutchinson (1944) in the study of lakes and Blum (1956) in studying rivers indicated there is no simple formula to indicate algal periodicity by chemical and physical determination. Pennak (1946) stated that most quantitative phytoplankton studies on smaller streams and rivers are not available in the literature. By the study of several small Colorado lakes he showed that the seasonal pulses are not always found in smaller bodies of water and that they may occur during any season of the year. He also pointed out that seston is a good index of plankton production. Hartman and Graffius (1960) supported the view of Pennak by positively correlating seston with populations in Pymatuning Reservoir. Armitage (1958) found alkalinity a chief determinant of the standing crop of a stream and Wallen (1955) refers to alkalinity as an indicator of productivity.

Several recent studies have indicated specific limiting factors of phytoplankton populations. Fish (1956) pointed to the sulfate ion as a limiting factor in Lake Victoria. Neel (1951) suggested that oxygen was limiting the population in the North Platte River and Berner (1951) found temperature and turbidity as limiting factors in the Missouri River. Temperature is also referred to by Wallen (1955) as important in Oklahoma ponds. Turbidity according to Blum (1956) reduces light penetration in river waters. He supported this with studies which show that shaded regions of rivers are lower in productivity in the beech-maple communities of northeastern United States than in well lighted areas in the same rivers. He also suggested that high turbidity would limit algal growth when it prevents light from penetrating the water.

Phytoplankton reports are available from several states surrounding Kansas. In Oklahoma, Wallen (1949) identified 67 genera of phytoplankton from a pond fertilized with sewage sludge. Zooplankton at no time during the study outnumbered the phytoplankton.

Procter (1951) included limnological and phytoplankton information in an unpublished report on three central Missouri farm ponds.

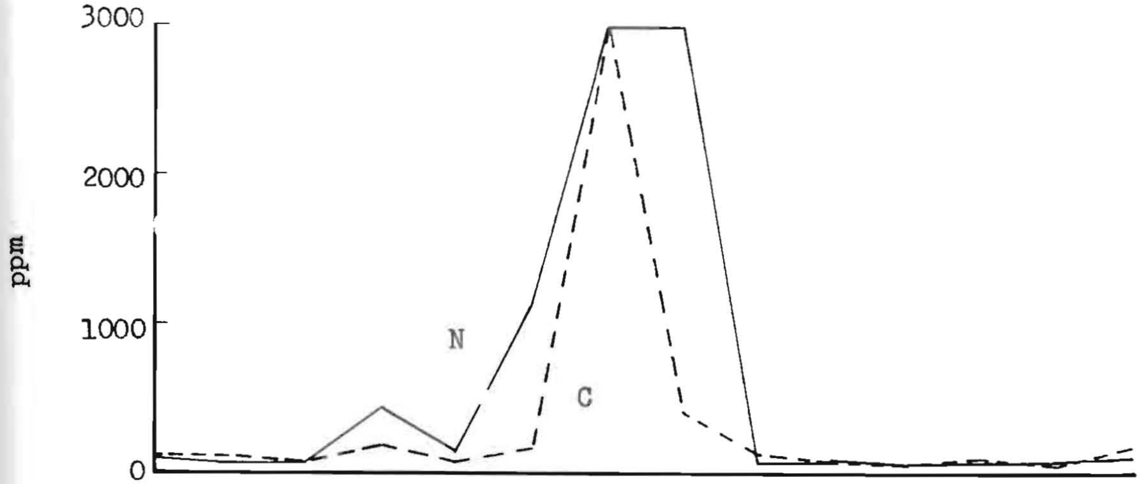
Lund and Talling (1957) reviewed the methods of limnology with specific reference to algae. They emphasized the need for simplicity of methods and made recommendations for procedure in phytoplankton field and laboratory work. Some investigators, including Chandler (1940), have used a centrifuge to concentrate algal samples for quantitative microscopic examination. Hartman (1958) discussed the effectiveness of this method in separating algae from liquids. Apparently phytoplankton cannot all be equally well retained by centrifugation except by repeated processing. It is found that generally blue greens are more difficult to concentrate by this method than other algal groups. A technique using a transparent filter for concentrating and counting algae was described by McNabb (1960). The Sedgwick-Rafter cell as a practical means for counting algal cells in city water supplies was reviewed by Palmer (1959).

RESULTS AND DISCUSSION

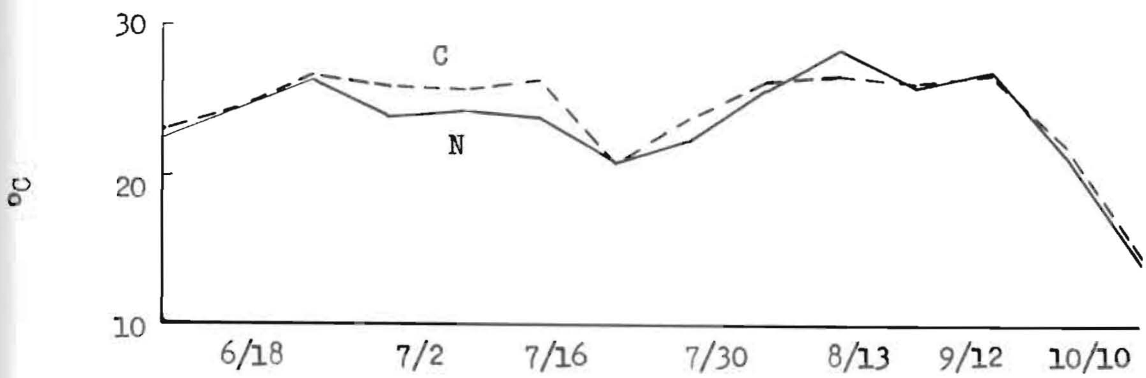
Physical-chemical Conditions

From observation it became apparent that intermittent heavy rains in the watershed area caused rapid rise and fall of the water level in both rivers. City records showed that the Cottonwood River crested at 25.05 feet at Emporia on May 19 and both rivers again had high water levels on June 25. On July 15, the Neosho River crested at 23.4 feet after a series of heavy rains in the upper watershed of that river. Blum (1956) stated that there was a physical difference between slow and fast flowing water which had not been identified. Very few fragmentary parts of algae were encountered even during times of high water. Apparently the steep gradient in the watershed above the stations subjected the plankton to continual adverse physical and mechanical conditions so that the effect was not noticeable at any one time. Pennak (1946) reviewed the effects of current on algae in rivers. He stated that qualitatively there is no difference between the plankton of running and standing water but quantitatively the populations are greatly reduced in running water.

Heavy runoff in the Neosho and Cottonwood caused a wide fluctuation in turbidity (Fig. 10). Chandler (1937) indicated that high turbidity decreases light penetration. The extremes of turbidity of the Neosho were 72 ppm on August 13 and 3000 ppm on July 16 and 23, and the mean was 608 ppm. Turbidity in the Cottonwood ranged from 52 ppm on September 12 to 3000 ppm on July 23 with a mean of 351 ppm. The high reading of 3000 ppm for both rivers on July 16 corresponds

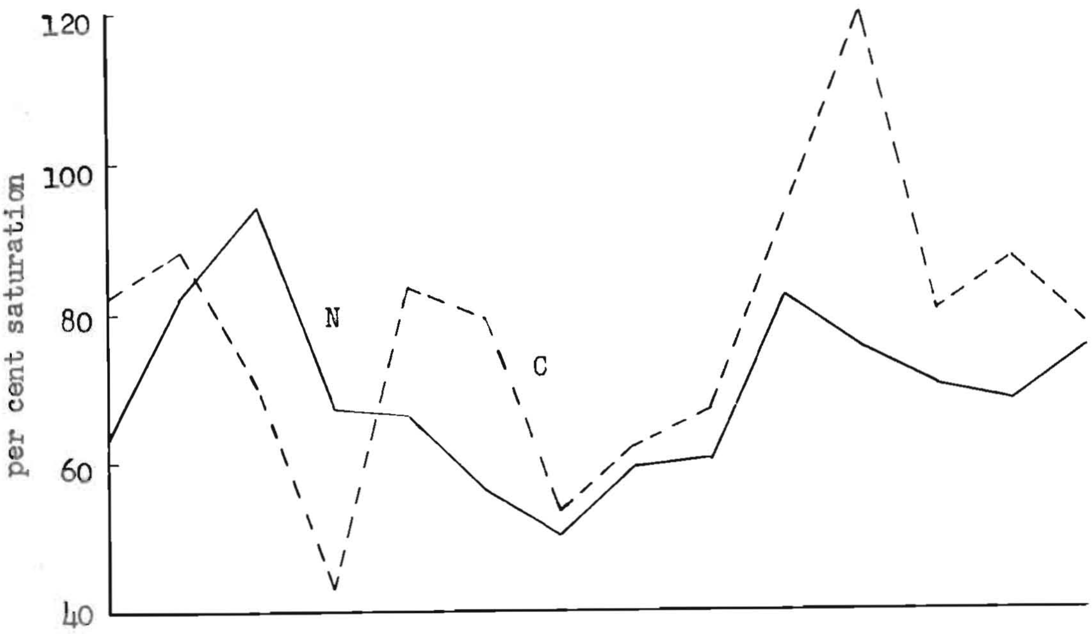


Turbidity in parts per million (ppm).

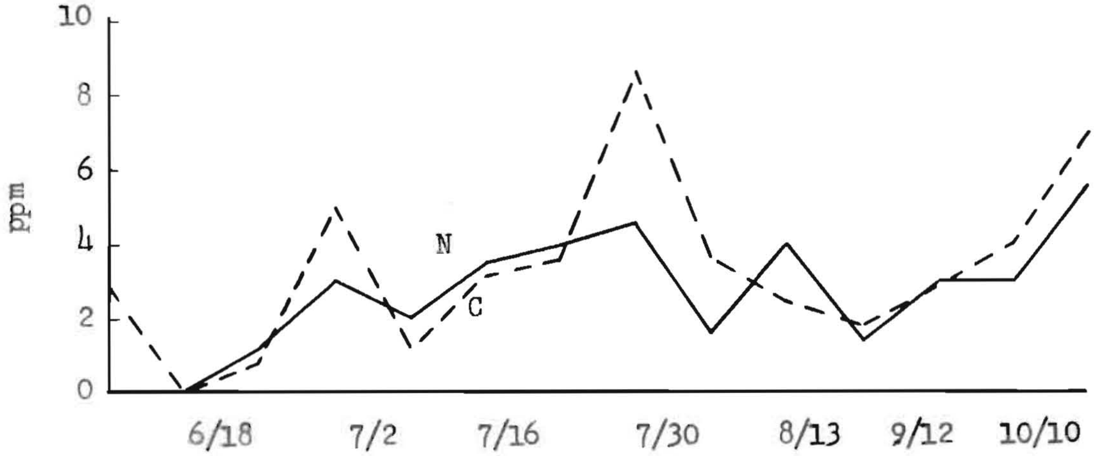


Temperature in degrees Centigrade (°C).

Fig. 10. Graphs showing some physical and chemical features for the Neosho (N) and Cottonwood (C) rivers on each date of collection.

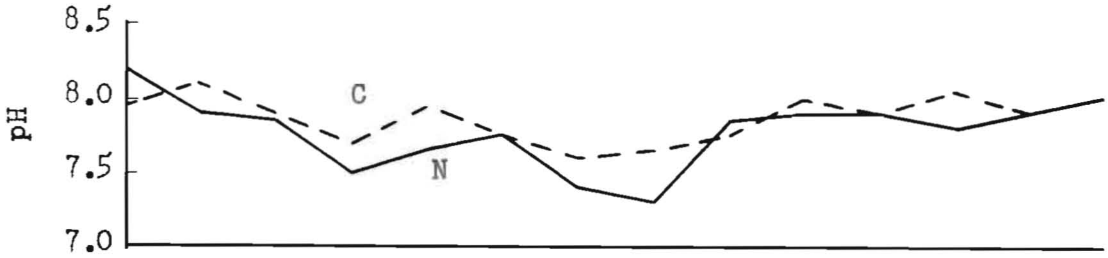


Oxygen in per cent saturation

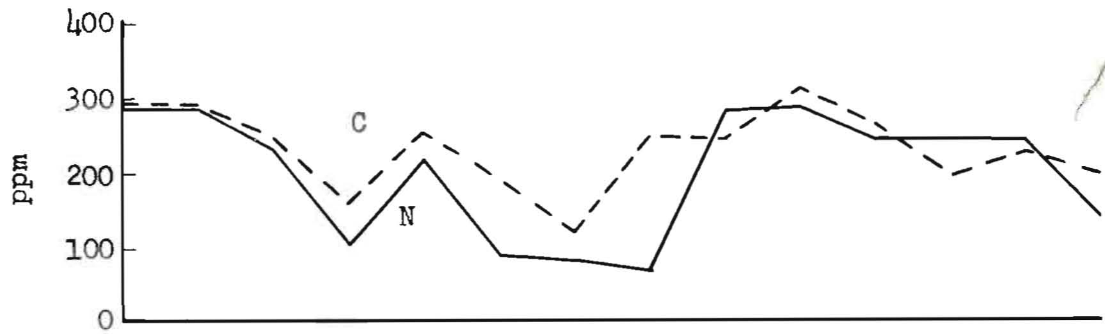


Carbon dioxide in parts per million (ppm).

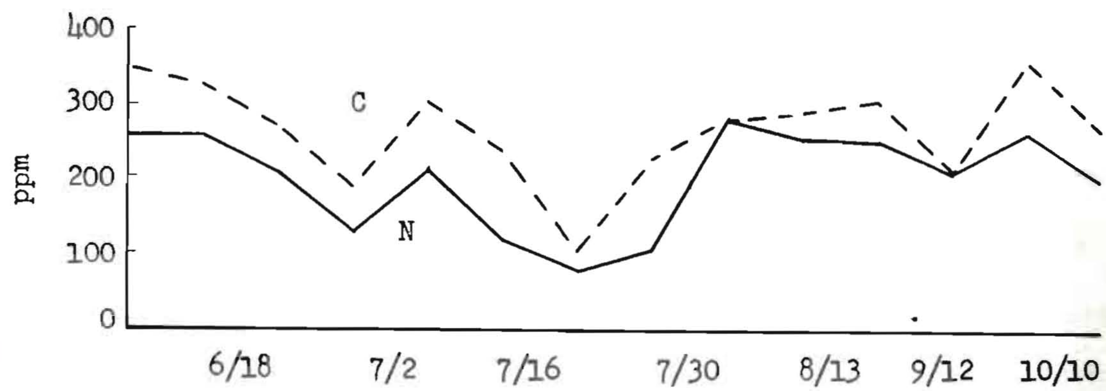
Fig. 10. (continued).



Hydrogen ion concentration (pH).



Alkalinity in parts per million (ppm).



Hardness in parts per million (ppm) for both rivers.

Fig. 10. (continued).

to the high water level readings from the Neosho River. Goulden (1959) reported high turbidity readings to 3000 ppm during periods of rising water levels on the Fall and Verdigris rivers. He also reported low turbidity readings of less than 10 ppm on the same rivers during normal stream flow. Common high readings of 3000 ppm were reported by Berner (1951) in his survey of the Missouri River. He further indicated that turbid water affected all features of the Missouri either directly or indirectly. Roy (1955) noted that phytoplankton production varied inversely with turbidity.

All temperatures were taken in surface water near the shore. Welch (1952) stated that temperatures of streams are generally nearly uniform at all depths. They ranged from 29.4°C in the Cottonwood and 28.7°C in the Neosho on August 6 to a low of 14.2°C in the Neosho and 14.8°C in the Cottonwood on October 10 (Table I). During a high water season on July 16 the temperature in both rivers was 20.7°C, a low reading for the months of June, July, August and September. The mean temperature was 23.7°C in the Neosho and 24.6°C in the Cottonwood (Fig. 12). Slack (1955) reported that a difference in the amount of shaded area in the stream probably caused a higher temperature at some stations than others in his Indiana studies. This apparently did not explain the temperature difference between streams in our study. Although there were trees along the banks of both rivers in the collecting areas they did not perceptably shade one river more than the other during the early part of the day. Berner (1951) recorded temperatures as high as 82°Fahrenheit (27.7°C) in the Missouri River. Welch (1952) stated that small streams follow air temperatures more closely than large rivers. Pennak (1946) said, "plankton populations are undoubtedly determined to a large extent by temperature characteristics of lakes and streams".

Per cent saturation of dissolved oxygen is emphasized more in this investigation than parts per million because it reflects its solubility. Greater variation in per cent saturation of oxygen in the Cottonwood was indicated by low readings of 43 per cent on June 25 and 53 per cent on July 16 in the Neosho and Cottonwood, respectively, with corresponding high readings of 94 per cent on June 18 and 120 per cent on August 16 (Fig. 12). A mean of 70 per cent for the Neosho and 77 per cent for the Cottonwood indicated a somewhat greater amount of available oxygen in the Cottonwood. The 120 per cent saturation in the Cottonwood on August 13 is the only recording of super saturated oxygen conditions during the study. Comparatively low readings of 50 and 53 per cent on July 16 correspond to the high water season and the low water temperature for both rivers. According to Pennak (1946) the dissolved oxygen is never a limiting factor in unpolluted streams.

There was no free carbon dioxide detected in the Neosho on June 4 and none in either river on June 11 (Fig. 10). A high of 7 ppm in the Neosho on October 10, 8.5 ppm in the Cottonwood on July 23 and a mean of 2.6 ppm for the Neosho and 3.2 ppm for the Cottonwood were determined. A gradual increase in carbon dioxide resulted from the first collections to the last in both rivers and greater weekly variations in the Cottonwood in June are apparent.

Our records showed a general inverse relationship between dissolved oxygen and free carbon dioxide (Fig. 10). Davies (1959) reported that no clear relationship existed between oxygen and carbon dioxide in his study of a slough. Welch (1952) stated that agitation is a very effective method of eliminating free carbon dioxide in water. Prophet (1957) found no free carbon dioxide in either the Fall or Verdigris rivers and Goulden (1959) reported an increase in carbon dioxide corresponding to an increase in stream flow. Records from our study in general indicated similar results.

There was a slight, gradual increase in hydrogen-ion concentration to July 16 (Fig. 10). From this date to the last collecting date the trend was reversed as the pH showed a gradual increase to near 8.0. A high of 8.2 on June 11 and a low of 7.3 on July 25 were recorded for the Neosho and a high of 8.1 to a low of 7.6 showed less variation in pH in the Cottonwood. A 7.8 mean pH reading in the Neosho and 7.9 in the Cottonwood showed little difference between the two rivers. Prophet (1957) reported a range in pH of 7.2 to 8.2 in the Verdigris River and 7.3 to 8.0 in the Fall River. Streams are probably more acid near their Headwaters and reach neutrality downstream according to Blum (1956). In agreement with the trend indicated, low pH during a high water level indicates that aging the water is necessary to reach an equilibrium in pH. Moulton (1939) related low pH to low phytoplankton numbers.

No phenolphthalein alkalinity was detected. A mean of 198 ppm of methyl orange alkalinity in the Neosho was 21 ppm lower than the mean of 229 ppm in the Cottonwood (Fig. 10). There was a low of 67 ppm recorded for the Neosho and 115 ppm for the Cottonwood and highs of 285.5 ppm and 310 ppm respectively. Total alkalinity was higher in the Cottonwood than in the Neosho until July 23. Tests indicated low alkalinities during high water seasons and showed an inverse relationship to the turbidity. Coopey (1953) relates low alkalinities to overflow seasons in rivers. Armitage (1958) in his studies of the Firehole River pointed out that alkalinity might be the chief factor which determines the standing crop in a stream. Such a relationship was supported by a comparison of the total alkalinity with total algal abundance (Figs 10 and 12). Prophet (1957) reported ranges of 53 ppm to 202 ppm and 106 ppm to 182 ppm for the Verdigris and Fall rivers. Results of the present study indicated higher alkalinity in both rivers.

It was known from earlier unpublished reports that the water of the Cottonwood River was harder than that of the Neosho River. The average difference in hardness between the two streams during the study was 60 ppm. The mean hardness for the Cottonwood was 264 ppm and for the Neosho it was 204 ppm. The Neosho varied in hardness from 80 ppm to 282 ppm and the Cottonwood varied from 104 ppm to 358 ppm (Table I). The hardness of the Neosho was never higher than the Cottonwood (Fig. 10). In a general way, it varied inversely with the turbidity. In two rivers in southeastern Kansas, Prophet (1957) reported a range of 98 ppm to 438 ppm in the Verdigris River and 109 ppm to 336 ppm in the Fall River.

Variation in mg/liter of total seston was considerable (Table I). The Neosho water samples yielded a low of 33.8 mg/liter, a high of 1044.2 mg/liter and a calculated mean of 215.8 mg/liter. Corresponding values for the Cottonwood were 40.3 mg/liter, 711.2 mg/liter and 163.1 mg/liter. The mean for the Neosho was 52.7 mg/liter higher than the mean for the Cottonwood. The per cent organic seston showed less variation (Fig. 10) than the organic seston in ppm. The extremes for the Neosho were 9.0 per cent and 25.8 per cent and the Cottonwood extremes were 8.5 per cent and 23 per cent. Respective means for the two rivers were 16.6 and 16.0 per cent. Pennak (1946) and Andrews (1953) have both supported the importance of seston as a valuable and reliable index of comparative plankton abundances. Pennak (1946) specified three to 60 mg/liter (dry weight) total dissolved organic matter or four to eight times the weight of the total plankton and detritus as a normal range for most fresh waters.

Table 1. Physical-chemical data and total algae from the Neosho (N) and Cottonwood (C) rivers tabulated for each collection date.

Date of collection	June 4	June 11	June 18	June 25	July 2	July 9	July 16	July 23	Rivers
Water temp. in °C	22.4 23.1	24.6 24.6	26.5 26.8	24.1 26.1	24.5 26.0	23.9 26.5	20.7 20.7	22.4 24.1	N C
Turbidity in ppm	95 130	80 122	75 95	450 205	155 82	1150 185	3000 3000	3000 425	N C
Hardness in ppm	262 352	262 328	212 272	132 188	212 304	120 240	80 104	104 214	N C
Dissolved O_2 in ppm	5.4 7.1	6.9 6.6	7.7 5.7	5.7 3.5	6.0 6.8	4.8 6.4	4.6 4.8	4.0 5.3	N C
O_2 per cent saturation	62 81	82 88	94 70	67 42	66 83	56 79	50 53	64 62	N C
Free CO_2 in ppm	0.0 2.7	0.0 0.0	1.2 0.7	3.0 5.0	2.0 1.6	3.5 3.2	4.0 3.5	4.5 8.5	N C
Methyl orange alkal., ppm	285 289	284 292	227 248	104 154	215 252	88 191	80 115	67 248	N C
Seston, total in mg/liter	24.8 45.3	53.1 94.2	49.8 73.6	207.8 91.9	108.4 61.6	408.6 86.1	800.2 711.2	1044.2 633.0	N C
Seston, organ. in mg/liter	6.5 6.5	11.5 14.1	14.3 14.8	18.9 12.3	10.5 10.1	57.7 12.8	92.8 80.8	117.4 60.0	N C
Seston, organ. per cent	26.8 16.5	21.7 14.9	29.0 20.2	9.0 13.3	9.7 16.3	11.9 13.4	11.6 11.4	11.3 9.8	N C
pH	8.2 7.9	7.9 8.1	7.9 7.9	7.5 7.7	7.6 8.0	7.5 7.8	7.4 7.6	7.3 7.6	N C
Total algae units/liter	22.6 12.5	41.8 10.5	70.0 36.5	12.2 42.5	27.7 40.0	21.3 6.7	23.0 9.0	13.5 34.5	N C

Table 1. (continued)

Date of collection	July 30	Aug. 6	Aug. 13	Aug. 20	Sept 14	Oct. 10	Mean	Rivers
Water temp. in °C	25.9 26.2	28.7 29.2	26.1 26.2	27.1 27.0	21.8 23.2	14.2 14.8	23.8 25.3	N C
Turbidity in ppm	72 140	77 85	72 65	82 120	77 52	120 200	608 351	N C
Hardness in ppm	282 282	258 292	256 304	212 212	264 358	200 268	204 264	N C
Dissolved O_2 in ppm	5.5 5.6	6.2 7.2	6.3 9.4	5.7 6.2	6.0 7.6	7.7 8.0	6.2 6.5	N C
O_2 per cent saturation	65 67	82 93	82 120	70 80	68 87	75 78	70 77	N C
Free CO_2 in ppm	1.6 3.7	4.0 2.5	1.4 1.9	3.0 2.7	7.0 5.5	3.0 4.0	2.6 3.2	N C
Methyl orange alkal., ppm	278 243	285 310	239 257	241 193	240 224	136 193	198 229	N C
Seston, total in mg/liter	63.1 105.1	34.1 42.3	48.6 45.2	45.7 47.3	47.0 43.0	86.5 203.3	215.8 163.1	N C
Seston, organ. in mg/liter	8.2 15.5	6.6 8.9	8.3 8.1	8.0 9.1	10.7 9.9	9.3 17.0	27.2 18.9	N C
Seston, organ. per cent	13.0 14.8	19.8 21.3	18.8 22.5	17.0 18.0	23.0 23.0	10.5 8.5	16.6 16.0	N C
pH	7.8 7.7	7.9 8.0	7.9 7.9	7.8 8.1	7.9 7.9	8.0 8.0	7.8 7.9	N C
Total algae units/liter	119 84.5	51 77	51 72	338 89	112 56	11 13	65.3 45.8	N C

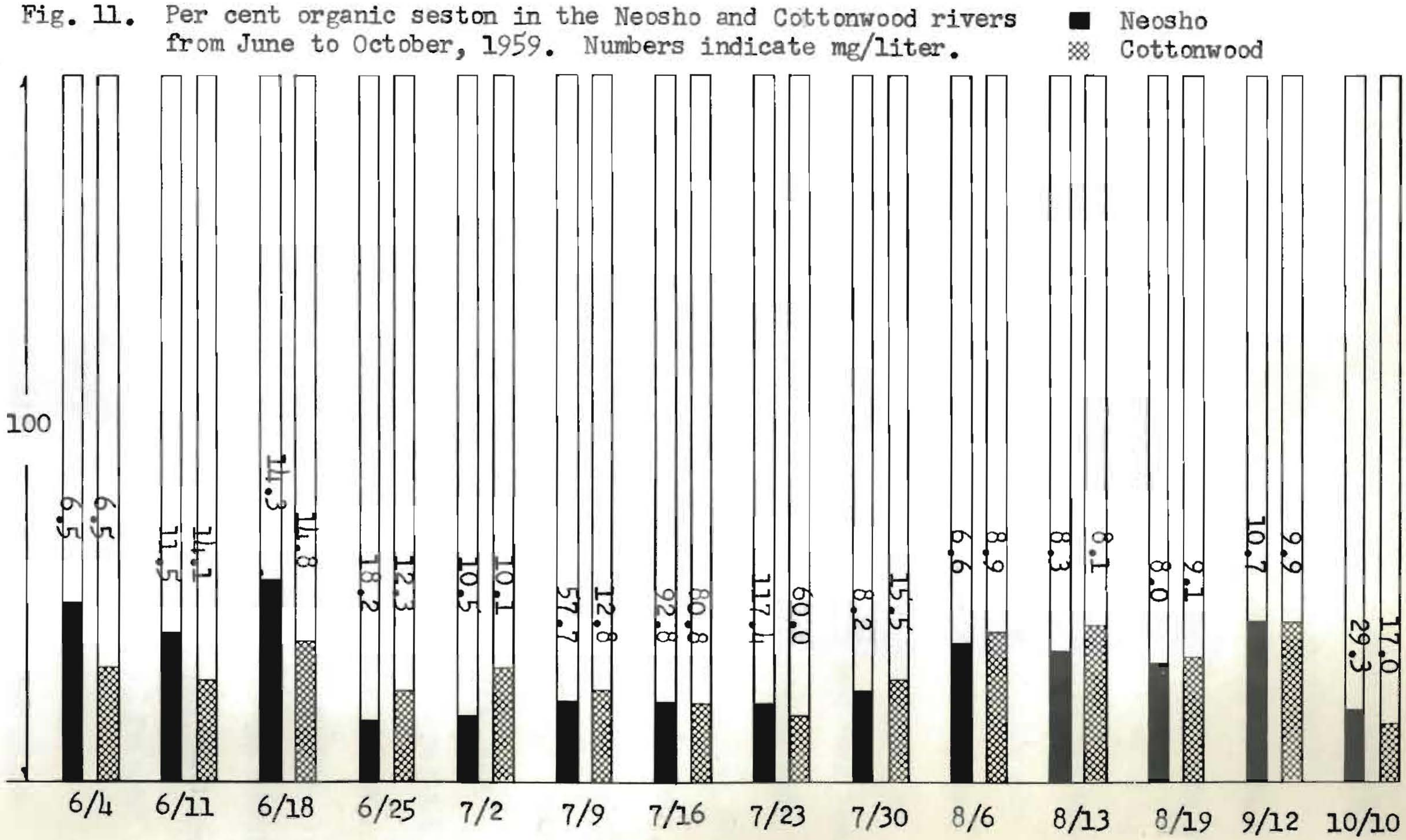


Fig. 11. Per cent organic seston in the Neosho and Cottonwood rivers from June to October, 1959. Numbers indicate mg/liter.

Phytoplankton Data

It was obvious early in this investigation, after comparing our results with those of other investigators of larger rivers (Berner, 1951, Kofoid, 1903 and Allen, 1920) that the phytoplankton counts were low in both rivers. Chandler (1937) found a definite decrease in phytoplankton as they moved from a lake into a running water environment. Kofoid (1903) indicated that the age of the water in a river was important in determining the population of plankton and Welch (1952) pointed out that water which had been in a stream for less than 15 hours was very young. Our study was conducted on rivers in which the water would be considered young on the same basis.

A total of 59 genera were identified from collections made during this study (Table II). Fifty-three genera were collected from the Neosho River and 46 genera were collected from the Cottonwood River. An average of 20.7 genera were identified from the Neosho on each collecting date. Only 15 genera were identified from the Neosho on July 23 in contrast to 29 genera collected on August 19. The Cottonwood yielded similar results. An average of 20.6 genera were classified on each collecting date. This river yielded 26 genera on July 9 and on June 11 only 15 genera were identified. Davies (1959) collected 18 genera of algae from a slough in March and April and only 4 genera on October 12. Pennak (1946) pointed out that one can expect 40 to 150 genera of algae in a river or lake if regular weekly samples are taken for one year.

During July, the number of units of total algae per liter

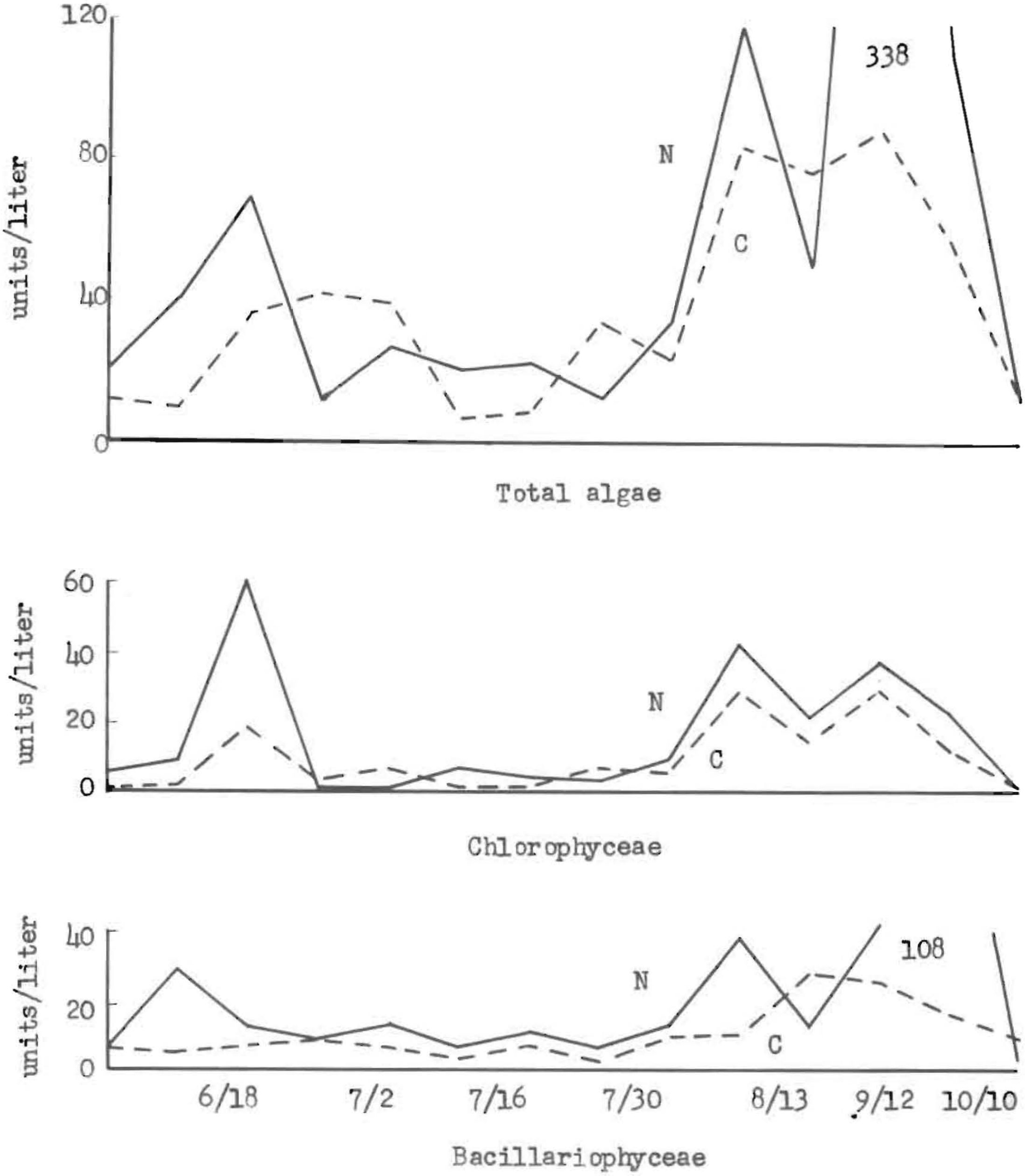


Fig. 12. Graphs showing the abundance of algae in each class represented in the collections for both the Neosho (N) and Cottonwood (C) rivers on each date of collection.

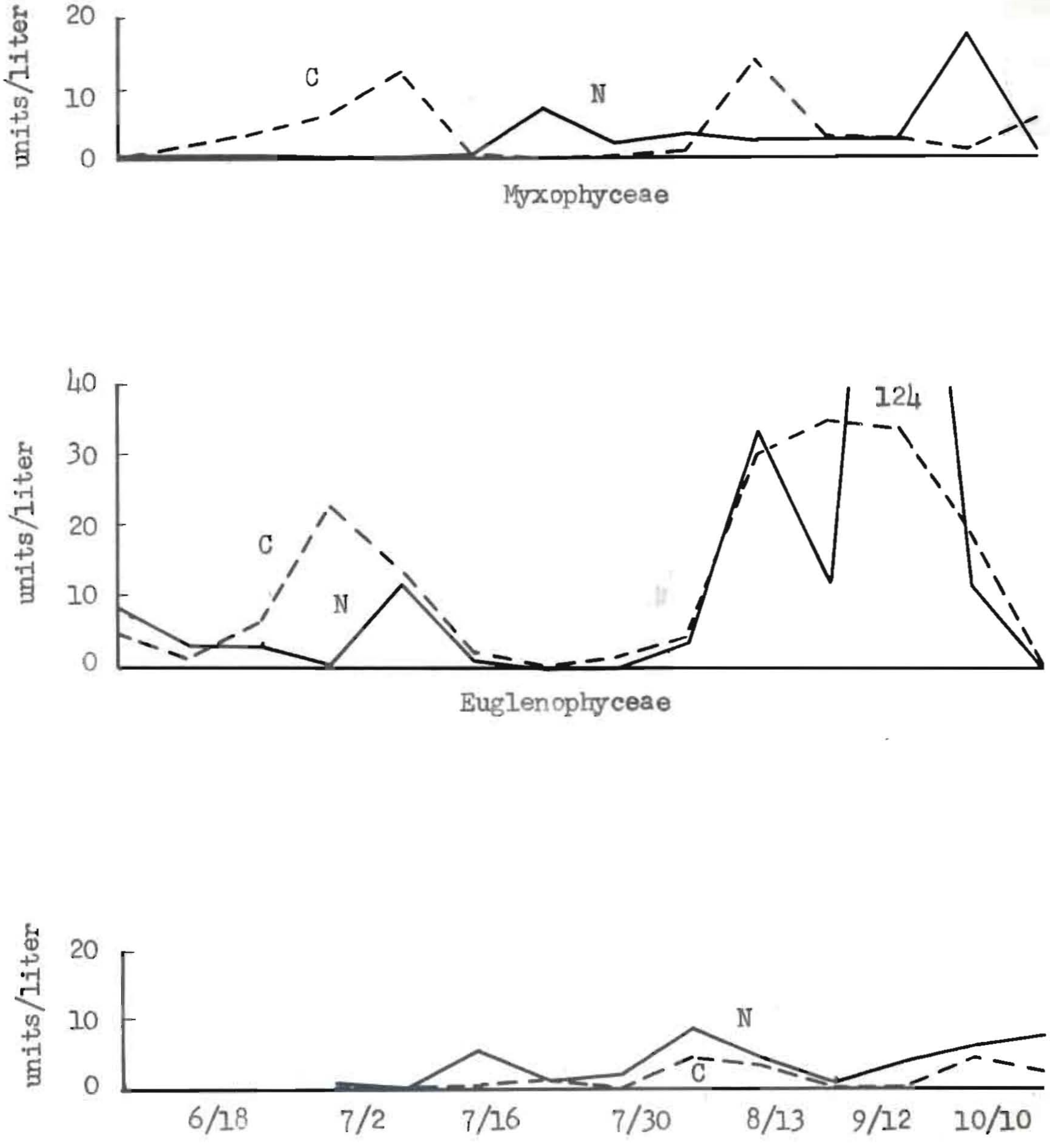


Fig. 12. (continued).

was generally lower than during June and the last part of the study (Fig. 12). On August 19, 338 units per liter of algae were collected from the Neosho compared to 11.5 units per liter collected from the same river on October 10. On July 9, 6.7 units/liter were identified from the Cottonwood and 178 units/liter were identified from the collections of August 19.

Station I on the Neosho had a mean population of 76.3 units/liter and Station II had 69.3 units/liter (Table II). Station III on the Cottonwood yielded 52.0 units/liter and station IV yielded 39.2 units/liter. On both rivers the stations above the dams yielded fewer plankton than those below the dams. Berner (1951) found reservoirs behind dams in the Missouri River basin consistently less productive than stations downstream.

The mean number of genera identified from the tow net sample showed that 14.5 genera were collected from station I, 14.2 genera were collected from Station II, 16.5 genera were collected from station III and 14.1 genera were collected from station IV. Qualitative sampling yielded varying results from one collecting date to another and remained quite constant in the average number of genera collected (Fig. 12).

The algae collected represented seven algal classes. There were 5 Cyanophyceae, 3 Chrysophyceae, 3 Xanthophyceae, 18 Bacillariophyceae, 23 Chlorophyceae, 3 Dinophyceae and 3 Euglenophyceae (Table II). Among the Cyanophyceae only Oscillatoria was collected more than five times. It was the only one of the 59 genera collected that

Table II. The genera of algae collected at the Neosho (N) and Cottonwood (C), grouped into classes and tabulated for each collecting date.

Date of Collection	June 4		June 11		June 18		June 25		July 2		July 9		July 16		July 23	
Rivers	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
CYANOPHYCEAE																
Anabaena															x	
Lyngbya															x	
Merismopedia														x		
Microcystis				x		x		x		x		x				
Oscillatoria	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Nostoc																
CHRYSOPHYCEAE																
Mallomonas								x	x	x						
Synura					x											
Rhizochrysis													x			
XANTHOPHYCEAE																
Characiopsis													x			
Ophiocytium							x		x	x	x	x				
Tribonema														x	x	x
BACILLARIOPHYCEAE																
Asterionella									x		x					
Cocconeis							x	x	x	x						
Cymatopleura														x		x
Cymbella	x		x	x	x		x	x	x	x	x					
Diatoma																
Fragilaria	x	x	x			x		x	x	x		x		x		x
Gomphonema			x	x	x	x	x	x	x	x	x	x	x		x	x
Gyrosigma	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Melosira	x	x	x	x	x	x	x		x		x	x				x
Meridion												x				
Navicula	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Nitschia				x		x	x	x	x	x	x	x	x		x	x
Pinnularia																
Pleurosigma														x		x
Rhoicosphenia													x			
Stephanodiscus																
Surirella														x		x
Synedra	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Total. N	7		8		9		10		13		10		9		9	
C		6		8		9		11		12		11		10		12

Table II. (continued)

Date of Collection	July 30		Aug. 6		Aug. 13		Aug. 19		Sept 12		Oct. 10		Genera per class		No. times collected
Rivers	N	C	N	C	N	C	N	C	N	C	N	C	N	C	
CYANOPHYCEAE															
Anabaena	x														2
Lyngbya															1
Merismopedia							x								2
Microcystis															5
Oscillatoria	x	x	x	x	x	x	x	x	x	x	x	x			32
Nostoc	x														1
													5	3	
CHRYSOPHYCEAE															
Mallomonas	x														4
Synura															1
Rhizochrysis															2
													3	1	
XANTHOPHYCEAE															
Characiopsis															1
Ophiocytium															5
Tribonema	x	x	x	x	x	x	x				x	x			12
													3	2	
BACILLARIOPHYCEAE															
Asterionella															2
Cocconeis															4
Cymatopleura	x	x										x			5
Cymbella		x			x	x	x	x	x	x					16
Diatoma								x		x		x			3
Fragilaria		x					x		x	x	x				15
Gomphonema	x	x	x	x	x	x	x	x	x	x	x	x			25
Gyrosigma	x	x	x	x	x	x	x	x	x	x	x	x			27
Melosira	x	x	x	x		x	x		x						18
Meridion										x					2
Navicula	x	x	x	x	x	x	x	x	x	x	x	x			28
Nitschia	x	x	x	x	x		x				x	x			19
Pinnularia							x								1
Pleurosigma															2
Rhoicosphenia															1
Stephanodiscus							x	x							2
Surirella					x										3
Synedra	x	x	x	x	x	x	x	x	x		x	x			27
													14	15	
Total. N	12		8		9		13		8		8		53		
C		11		8		9		8		8		9		46	

Table II. (continued

Date of collection	June 4		June 11		June 18		June 25		July 2		July 9		July 16		July 23	
Rivers	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
CHLOROPHYCEAE																
Actinastrum	x	x	x	x	x	x		x	x	x		x				
Ankistrodesmus																
Chlamydomonas	x	x			x											
Closterium	x	x	x	x	x	x	x	x	x	x		x	x	x		x
Cladophora					x	x	x	x	x	x	x	x	x	x		x
Closteriopsis						x										
Coelastrum	x	x	x	x	x	x		x	x	x		x				
Cosmarium					x	x		x	x	x						
Errerella											x					
Eudorina					x	x					x	x	x	x	x	x
Gonium			x		x	x										
Microspora							x				x	x	x	x		
Oocystis																
Pandorina		x			x	x		x	x	x	x	x				x
Pediastrum	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Penium				x												
Platydorina											x					x
Pteromonas									x							
Scenedesmus	x	x	x	x	x	x	x	x	x	x		x		x		
Sphaerocystis	x															
Spirogyra						x							x		x	x
Staurastrum	x											x	x			x
Ulothrix									x				x		x	
DINOPHYCEAE																
Ceratium					x	x	x	x	x	x	x	x	x	x	x	x
Glenodinium			x									x			x	
Peridinium																
EUGLENOPHYCEAE																
Euglena	x	x	x	x	x	x	x	x	x	x	x	x	x			x
Phacus		x	x		x	x	x	x	x	x	x	x				x
Trachelomonas	x	x	x	x	x	x	x	x	x	x	x	x				x
Total. N	10		10		14		8		13		11		10		6	
C		10		7		15		12		12		15		7		12
Total genera for each date N	17		18		23		18		26		21		19		15	
C		16		15		24		23		24		26		17		24

Table II. (continued)

Date of collection	July 30		Aug. 6		Aug. 13		Aug. 19		Sept 12		Oct. 10		Genera per class		No. times collected
Rivers	N	C	N	C	N	C	N	C	N	C	N	C	N	C	
CHLOROPHYCEAE															
Actinastrum	x	x	x	x		x		x							16
Ankistrodesmus				x			x	x							3
Chlamydomonas															3
Closterium	x	x	x	x	x		x	x	x	x	x	x			25
Cladophora	x	x		x	x	x	x	x	x		x	x			21
Closteriopsis	x	x	x	x							x				6
Coelastrum	x		x	x	x	x	x	x		x					18
Cosmarium				x			x								7
Errerella															1
Eudorina	x		x	x	x	x	x		x						15
Gonium															3
Microspora															5
Oocystis						x	x								2
Pandorina	x	x	x	x	x	x	x	x	x						18
Pediastrum	x	x	x	x	x	x	x	x	x	x	x				27
Penium															1
Platydorina	x		x	x	x	x	x		x						9
Pteromonas			x	x			x								4
Scenedesmus	x		x	x	x	x	x	x	x	x					21
Sphaerocystis															1
Spirogyra															4
Staurastrum	x	x		x		x			x	x	x	x			12
Ulothrix															3
													22	19	
DINOPHYCEAE															
Ceratium				x	x		x		x		x	x			14
Glenodinium							x								4
Peridinium									x	x					2
													3	3	
EUGLENOPHYCEAE															
Euglena	x	x	x	x	x	x	x	x	x	x	x	x			26
Phacus	x	x	x	x	x	x	x	x	x	x	x				22
Trachelomonas	x	x	x	x	x	x	x	x	x	x	x				24
													3	3	
Total. N	14		13		12		16		13		8		53		
Total. C		10		18		13		11		9		6		46	
Total genera for each date N	26		21		21		29		21		16				
Total genera for each date C		21		26		22		19		17		15			

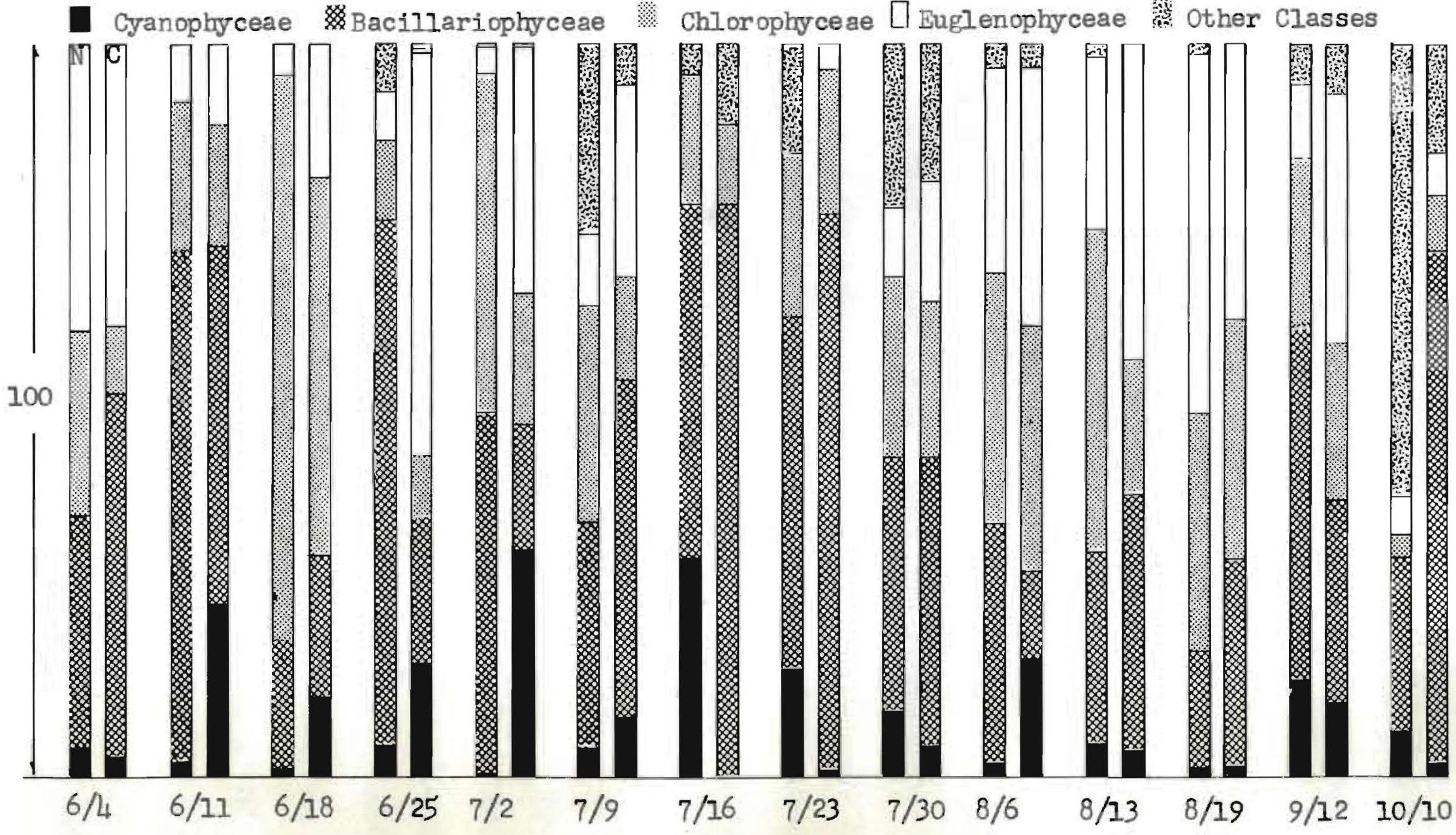
was found in each river on each collecting date. Davies (1959) collected Oscillatoria four times from October to May. Chrysophyceae were encountered only a few times during the study and Tribonema of the Xanthophyceae was collected a total of 12 times in August and October. Among the Bacillariophyceae, Synedra, Navicula, Gyrosigma and Gomphonema were found in more than 75 per cent of the collections. The Chlorophyceae were qualitatively more abundant than any of the other classes. Closterium, Cladophora, Pediastrum and Scenedesmus were the most often collected genera in this class. Davies (1959) found 13 genera of Chlorophyceae in his slough study. This was the largest number of genera identified from any of the classes in his investigation. Dinophyceae were found intermittently throughout this investigation. Ceratium was collected 14 times and represented the dominant qualitative genus in this group and it was the only genus from the Dinophyceae identified by Davies (1959) as a phytoplankton. Euglenophyceae represented by Euglena, Phacus and Trachelomonas were collected quite consistently. However, on July 16 Euglena was the only genus of Euglenophyceae represented in the Neosho and none were collected from the Cottonwood on that date.

From the quantitative collections, algae were separated into the Cyanophyceae, Chlorophyceae, Bacillariophyceae and the Euglenophyceae. Other classes were not represented in the collections until June 23 (Fig. 12). Tribonema from the class Xanthophyceae and Ceratium from the Dinophyceae were the genera present in significant numbers in the remaining classes. In Figure 12 it was noted that the phytoplankton in the Cottonwood was comparatively uniform in abundance and the Neosho phytoplankton was sporadic in abundance. The greatest phytoplankton concentration during June and July was 40 units per liter except for an increase on June 18 in the Neosho collection. Eudorina was found in abundance only on that date and no Eudorina colonies were encountered in the preceding collection of June 11 or the succeeding collection of June 25. A special tow net sample on June 20 after a heavy rainstorm yielded only two Eudorina colonies. August 6 and 19 and September 12 again showed increased numbers in the Neosho. A gradual increase in the algal abundance of the Cottonwood was noted from June 11 to 25. An increase in August and September corresponded in time to an increase in numbers in the Neosho on those dates. It yielded an approximate average of 80 units per liter.

Cyanophyceae were significantly present in collections from the Cottonwood River during the early part of the investigation and increased gradually until July 2. During this same period, Cyanophyceae were almost completely absent from the Neosho. From July 16 to August 19 approximately three to five units/liter of Cyanophyceae were present in the Neosho. On August 6 the Cottonwood yielded 14 units/liter and on September 12 a similar increase in the Neosho to 17 units/liter was encountered. The Eudorina pulse previously referred to was the only significant abundance of algae represented by the Chlorophyceae until an increase on August 6. Up to this time Chlorophyceae represented approximately five units/liter for both rivers. The increase in August and September corresponds in time to the increase in total algae previously discussed. The concentration of Chlorophyceae in the Neosho during this period averages approximately ten units/liter above the Cottonwood. The increase resulted in a total algal abundance of approximately 30 units/liter for the Neosho and 20 units/liter in the Cottonwood. The October collection marked almost a complete absence of Chlorophyceae. Bacillariophyceae were less numerous in Cottonwood collections than in the Neosho, except on August 13 when the diatoms in the Cottonwood exceeded those in the Neosho. Approximately ten units/liter were identified from the Neosho collections through June and July and the Cottonwood had a slightly lower average. An increase is apparent in August and a recession marks the October collections. On September 12 a sharp increase of Bacillariophyceae was evident in the Neosho as 108 units/liter was encountered while a decline from the previous collections was noted in the Cottonwood. Euglenophyceae in the Neosho showed a recovery in numbers after the May flooding. On June 25, 23 units/liter were counted in the collection from the Cottonwood and on this date the Neosho yielded one unit/liter of Euglenophyceae. Low _Euglena_ numbers were noted in July but on August 6 and 19 an increase to 33 and 124 units/liter were counted in Neosho collections. Similar increased counts of 30, 35 and 34 units/liter were identified in Cottonwood collections on August 6, 13 and 20, respectively. A sharp decline was noted in September and October. Xanthophyceae and Dinophyceae furnished small numbers to accompany the greater abundance of other classes already discussed. _Ceratium_ was collected periodically from the Neosho River and _Tribonema_ furnished the only other significant quantity in this group from July 30 to September 12.

The quantitative percentage distribution of each class in the collections is shown in Figure 13. Only four classes are represented in the Cottonwood on July 23 and August 13 and 19. Cyanophyceae were never the most abundant in any collection and they were completely absent from the Cottonwood on July 16. Chlorophyceae became the dominant class in the Neosho on June 18 when 81 per cent of the collections were composed of members from this group. The Cottonwood River collections on June 18 were composed of 50.6 per cent Chlorophyceae. Algae from this class were found in both rivers on all collecting dates. Bacillariophyceae represented the greater percentage of the algae on several dates. In the Neosho, high percentages of populations were recorded from June 11 and 25. On June 11, 70.9 per cent of the population was diatoms and on June 25, 72 per cent was diatoms. In the Cottonwood, on July 16 and 25 and October 10 Bacillariophyceae represented 78, 76 and 70 per cent of the total number of algae. On July 2, 45 per cent of the algae collected from the Neosho were Euglenophyceae and on August 19, 49 per cent were classified as Euglenophyceae. Between these two dates on July 16 and 23 no Euglenophyceae were collected from this river. In the Cottonwood collections on June 25, 55 per cent of the algae were Euglenophyceae and on August 13, 43.2 per cent showed a similar representation. Euglenophyceae from this river were not encountered on July 16. Two genera of the remaining classes represented appreciable quantities of the total number of algae. Predominantly <u>Ceratium</u> and <u>Tribonema</u> composed 62 per cent of the collection in the Neosho on October 10. From the Cottonwood the highest percentage composition represented by this group was 18.8 per cent of the total units of algae on July 30.

Fig. 13. Percentage distribution of the abundance of algae by classes for the Neosho (N) and the Cottonwood (C) on each date of collection.



SUMMARY

1. A survey was made of the phytoplankton and physical-chemical conditions of the Neosho and Cottonwood rivers near Emporia, Kansas, from June 4 to October 10, 1959.

2. A tow net phytoplankton sample and a 100-liter quantitative phytoplankton sample were taken. Air and water temperature, turbidity, hardness, dissolved oxygen, carbon dioxide, pH, seston and phenolphthalein and methyl orange alkalinities were recorded.

3. There were 53 genera of algae identified from the Neosho River and 46 genera from the Cottonwood River. The lowest number of algae genera in either river on a particular collecting date was 15 and the highest number was 29 for the Neosho and 26 for the Cottonwood.

4. The population of algae varied from 6.7 units per liter to 89 units per liter in the Cottonwood and from 11 units per liter to 338 units per liter in the Neosho. The greatest total algae count occurred on August 19 in both rivers. The abundance of the classes Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae were discussed.

5. The ranges of physical-chemical conditions in the Neosho were recorded as follows: turbidity, 72 ppm to 3000 ppm; temperature, 14.2°C to 28.7°C; hardness, 80 ppm to 282 ppm; oxygen saturation, 50 per cent to 94 per cent; carbon dioxide, 0.0 ppm to 7.0 ppm; methyl orange alkalinity, 67 ppm to 285 ppm; seston, 9.0 per cent to 29.0 per cent; pH, 7.3 to 8.2.

6. The ranges of physical-chemical conditions in the Cotton-

wood were recorded as follows: turbidity, 52 ppm to 3000 ppm; temperature, 14.8°C to 29.2°C; hardness, 104 ppm to 358 ppm; oxygen saturation, 42 per cent to 120 per cent; carbon dioxide, 0.0 ppm to 8.5 ppm; methyl orange alkalinity, 115 ppm to 310 ppm; seston, 9.8 per cent to 22.5 per cent; pH, 7.6 to 8.1.

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APPENDIX

Appendix A: Checklist of the Algae. (Smith, 1950).

Division Chlorophyta
- Class Chlorophyceae
  - Order Volvocales
    - Family Chlamydomonadaceae
      - Chlamydomonas
    - Family Phacotaceae
      - Ptermonas
    - Family Volvocaceae
      - Gonium
      - Pandorina
      - Eudorina
      - Platydorina
  - Order Ulotrichales
    - Suborder Ulotrichineae
    - Family Ulotrichaceae
      - Ulothrix
    - Family Microsporaceae
      - Microspora
  - Order Cladophorales
    - Family Cladophoraceae
      - Cladophora
  - Order Chlorococcales
    - Family Micractinaceae
      - Errerella
      - Micractinium
    - Family Hydrodictyaceae
      - Pediastrum
    - Family Coelastraceae
      - Coelastrum
    - Family Oocystaceae
      - Oocystis
      - Ankistrodesmus
      - Closteriopsis
    - Family Scenedesmaceae
      - Scenedesmus
      - Actinastrum
  - Order Zygnematales
    - Family Zygnemataceae
      - Spirogyra
    - Family Desmidiaceae
      - Closterium
      - Penium
      - Cosmarium
      - Staurastrum

Division Euglenophyta
    Class Euglenophyceae
        Order Euglenales
            Family Euglenaceae
                <u>Euglena</u>
                <u>Phacus</u>
                <u>Trachelomonas</u>

Division Chrysophyta
    Class Xanthophyceae
        Order Heterococcales
            Family Characiopsidaceae
                <u>Characiopsis</u>
            Family Chlorotheciaceae
                <u>Ophiocytium</u>
        Order Heterotrichales
            Family Tribonemataceae
                <u>Tribonema</u>
    Class Chrysophyceae
        Order Chrysomonadales
            Family Mallomonadaceae
                <u>Mallomonas</u>
            Family Synuraceae
                <u>Synura</u>
        Order Rhizochrysidales
            Family Rhizochrysidaceae
                <u>Rhizochrysis</u>
    Class Bacillariophyceae
        Order Centrales
            Family Coscinodiscaceae
                <u>Melosira</u>
                <u>Stephanodiscus</u>
        Order Pennales
          Suborder Fragilarineae
            Family Meridionaceae
                <u>Meridion</u>
            Family Diatomaceae
                <u>Diatoma</u>
            Family Fragilariaceae
                <u>Fragilaria</u>
                <u>Synedra</u>
                <u>Asterionella</u>
          Suborder Achnanthineae
            Family Achnanthaceae
                <u>Rhoicosphenia</u>
                <u>Cocconeis</u>

Suborder Naviculineae
Family Naviculaceae
Navicula
Pinnularia
Gyrosigma
Pleurosigma
Family Gomphonemataceae
Gomphonema
Family Cymbellaceae
Cymbella
Suborder Surirellineae
Family Nitschiaceae
Nitschia
Family Surirellaceae
Cymatopleura
Surirella

Division Pyrrophyta
Class Dinophyceae
Order Peridiniales
Family Glenodiniaceae
Glenodinium
Family Peridiniaceae
Peridinium
Family Ceratiaceae
Ceratium

Division Cyanophyta
Class Myxophyceae (Cyanophyceae)
Order Chroococcales
Family Chroococcaceae
Merismopedia
Order Oscillatoriales
Suborder Oscillatorineae
Family Oscillatoriaceae
Oscillatoria
Lyngbya
Family Nostocaceae
Anabaena
Nostoc

LIMNOLOGY - RIVER DATA - PHYTOPLANKTON

Station ________ Date _____ River ___________ Collector ______________

Temp °C		Turb	Oxygen		CO_2	Alkal.		Hard	pH	Seston inorganic		Seston organic		total
Air	H_2O	ppm	ppm	% sat	ppm	Phth	M.O.	ppm		mg/l	%	mg/l	%	mg/l

Tow Genus count

1 ____
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____
8 ____
9 ____
10 ____
11 ____
12 ____
13 ____
14 ____
15 ____
16 ____
17 ____

Tot. genera ____ units %

Cyanophyceae ____ ____
Chlorophyceae ____ ____
Bacillariophyceae ____ ____
Chrysophyceae ____ ____
Euglenophyceae ____ ____
Others ____ ____
Total ____ u/l

18 ____
19 ____
20 ____
21 ____
22 ____
23 ____
24 ____
25 ____

Quant. Genus Count

Genus Count