A QUANTITATIVE SURVEY OF THE PHYTOPLANKTON AND WATER QUALITY OF THE LA CROSSE, "BLACK" AND MISSISSIPPI RIVERS

by

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ABSTRACT

A seven-month study of the phytoplankton populations and water quality of the La Crosse and Mississippi Rivers and the back water slough of the old Black River channel below navigation pool #7, hereafter referred to as the "Black" River, was initiated on May 19, 1971 and terminated on November 20, 1971. Nine sampling stations were chosen in such a manner as to monitor the different channels above and below their point of convergence. Phytoplankton samples were collected at 3 depths, while samples used in the determination of chemical parameters were obtained at the 2 m depth.

Six major groups of algae were found in the study area. These were the Chrysophyceae, Pyrrophyta, Euglenophyta, Bacillariophyceae, Chlorophyta and Cyanophyta. The latter three made up the major portion of the phytoplankton, both in numbers and diversity.

The "Black" and Mississippi Rivers were found to be similar with regard to phytoplankton composition. The chemical parameters of the two study areas were also similar, with the exception of total hardness. It was observed that the total hardness concentration was lower in the "Black" River than in the Mississippi River.

The La Crosse River presented a seemingly unfavorable set of conditions for the maintenance of phytoplankton populations. The major organisms of this river were various species of *Ulothrix*. This was also the only genus to occur in bloom proportions in the La Crosse River. The La Crosse River, besides being distinct from the "Black" and Mississippi Rivers with regard to phytoplankton composition, was also distinct from the latter two on the basis of turbidity and settleable matter.

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INTRODUCTION

In 1878, a 4½ foot minimum channel was authorized by Congress for the Mississippi River between St. Louis, Missouri and St. Paul, Minnesota. In 1907, due to an increase in the amount of competition from railroads, a 6 foot channel was authorized in order to accommodate larger barges and again facilitate more economical water transport. In 1930, the Army Corps of Engineers assured Congress that a 9 foot channel could be engineered in order to handle the larger tows and tugs which were coming into use. The 9 foot channel was formed by the construction of 28 locks and dams from the mouth of the Missouri River to Minneapolis-St. Paul. In conjunction with raising the water level, the Corps dredged many parts of the existing channel.

The purpose of this study was to monitor chemical parameters and enumerate and identify the phytoplankton of the La Crosse, "Black" and Mississippi Rivers. It was also anticipated that certain correlations could be obtained regarding periodicity of the major divisions of phytoplankton and the effect of water quality on the different algal populations.

The area selected presents an ideal situation for study because the three rivers converged within 200 m of each other before the initiation of the 9 foot channel. With the construction of lock and dam #7, the waters of the Black and Mississippi Rivers became impounded to form Lake Onalaska. The section of the old Black River channel which was studied became a back water slough whose main source of water is Lake Onalaska, and will be referred to as the "Black" River for convenience. The majority of the water entering this lake comes from the Mississippi

River, thus chemical characteristics of the Black River entering the lake (soft water containing tannins) are lost due to an approximately 6:1 dilution ratio. During periods of flooding, this ratio is much greater. The retention time of the water in the lake during periods of normal water level is approximately 5 or 6 days (Claflin, personal communication). This time is greatly extended for those parts of the lake which are sheltered from winds and currents. The Mississippi River, though contributing to the water of the lake, is largely confined to the navigation channel which runs along the west shoreline. This situation resulted from channelization and the confinement of the Mississippi's waters by large weed beds and islands which reduce mixing. Thus at the point of study, the waters of the "Black" River represent the waters of Lake Onalaska. The waters of both the Black and Mississippi River, as they flow through the lake, undergo changes which are common to lake environments. The Mississippi River at the point of study maintains its individuality, as does the La Crosse River.

LITERATURE SEARCH

The role of phytoplankton in lakes and reservoirs has been well documented and much work continues to be done on this subject. Rivers, however, present a more difficult study habitat because of the constantly changing conditions which occur throughout their length. Much of the information concerning rivers is from major works produced during the early 1900's. Kofoid's (1903-1908) monumental work on the Illinois River represents a five-year investigation of the composition and seasonal distribution of the plankton in this river. It also encompasses many of the chemical parameters and a detailed study of the hydrography of the river. Allen (1913) produced a quantitative and statistical study of the plankton of the San Joaquine River and its tributaries. The effects of pollution on planktonic organisms and the role of natural purification in the Ohio River was studied by Purdy (1922). Galsoff (1924) and Wiebe (1927) performed limnological and biological surveys of the Upper Mississippi River. Again, these works included sections on the effects of domestic pollution on aquatic organisms. Chandler (1932) studied the effect which stream environments have on lake plankton. The Maple River and a number of other Michigan streams were monitored in order to determine the fate of lake plankton which were subjected to streams having different flow rates, different river bed characteristics and varying amounts of aquatic vegetation. Eddy (1932) performed a quantitative and qualitative summer survey of the plankton of the Sangamon River. Roach (1932) studied the ecology of the plankton in the Hocking River. Unlike many other river studies, Roach sampled the entire length of the river. Brinley (1942) studied the effects of pollution on plankton populations in the White

River and Hupp (1942) performed similar studies on the White River Canal. This canal was a bypass of the White River and received domestic wastes from the city of Indianapolis. The effect of calcium on the growth rate of algae in highly calcareous streams was studied by Butcher (1946).

After the mid-1940's the literature reveals sporadic studies on the ecology of river phytoplankton. Blum (1957) did work on the ecology of the phytoplankton in the Saline River. This included the quantitative and qualitative composition of the phytoplankton and the determination of chemical parameters. Woodson (1960) worked on the qualitative determination of the Chlorophyceae in the James River. Leake and Leake (1962) performed ecological studies on the algae in the spring-fed streams of the Ozarks. Hohn and Hellerman (1963) identified and enumerated the diatom populations from three eastern North American rivers and Whitford's and Schumacher's (1963) work on the seasonal relationships of algal communities in streams added additional information on plankton ecology.

Most of the works represent studies of sections of the individual rivers or streams, but by obtaining information at strategic points, a characterization of a river can be obtained. With the increased influx and diversity of pollutants currently entering the nations waterways, renewed interest in river ecology is imperative.

METHODS AND MATERIALS

Nine sampling stations (Figure 1) were chosen on the "Black", La Crosse and Mississippi Rivers, while one station was established at the convergence of the "Black" and Mississippi Rivers. All samples were taken between 8:00 A.M. and 12:00 P.M. and collection was facilitated by the use of a 19 foot Kayot pontoon boat equipped with a Johnson 40 horsepower motor. The location of these stations may be summarized as follows:

Station 1: A point on the "Black" River approximately 2.2 km upstream from the junction of the "Black" and Mississippi Rivers was selected. This station was situated 100 m from the east bank at the upper end of an oil storage depot and 150 m from the point of the peninsula. The depth of the river at this station was approximately 3.5 m.

Station 2: This station was located 0.6 km upstream from the junction of the "Black" and Mississippi Rivers where the water was 3.5 m in depth. Collections were made approximately 150 m from the west bank of the river and 100 m below a small, partially submerged island.

Station 3: A point 20 m north of the mouth of the La Crosse River and 25 m from the east bank was chosen for the location of this station. Water depth was 3 m.

Station 4: This station was situated at midstream at a point approximately 4 m from the mouth of the La Crosse River. The depth of the water at this station was 1 m.

Station 5: This station was situated 0.3 km upstream from the mouth of the La Crosse River where further boat traffic was prevented by a railroad tressel. A point 1 m from the north bank was chosen for sampling because this location had a water depth of 1 m. This was the deepest part of the river.

Station 6: This station was at the junction of the "Black" and Mississippi Rivers. A buoy marking a partially removed wing dam was used as a point of reference. Collections were made approximately 100 m from the tip of the island; a point exposed to the currents of both rivers. Water depth averaged 4.5 m.

Station 7: Situated in the main channel of the Mississippi River, this station was approximately 0.8 km upstream from the junction of the "Black" and Mississippi Rivers. A point was chosen 125 m from the east bank of the river and in line of sight between two wing dam buoys. The water was 8.0 m in depth and a turbulent current prevailed.

Station 8: This station was located 0.6 km south of the mouth of the La Crosse River. A point was chosen at the end of the State Street entrance to Riverside Park and 10 m from the east bank where the water depth averaged 11.0 m.

Station 9: The last station was located on the west bank of the main channel of the Mississippi River, at a point 0.8 km south of the mouth of the La Crosse River and 100 m offshore. Water depth was 1.5 m.

Plankton samples were collected at 1, 2, and 3 meter depths at each station with the exception of stations 4, 5, and 9, where the water was less than 2 m in depth. Samples were obtained by lowering a garden hose to the desired depth. This hose was graduated in increments of 1 m and was attached to a 12 volt D.C. pump. Five 1 liter samples were accurately measured in a graduated cylinder and were poured through a #20 silk plankton net. After lowering the hose to the next depth, water was allowed to run through it for 30 seconds in order to flush it of water from the previous depth. The outside of the net was washed three times with river water from the hose and the collection bottle was removed after all the water had been drained. The samples were placed in labeled

50 ml test tubes and fixed immediately with FAA[1]. The tubes were then sealed with cork stoppers and stored in the dark until they were ready to be evaluated.

A Whipple Disc and a Sedgwick-Rafter cell (Standard Methods, 1965) were used in the examination of the plankton samples. Instead of the normal cover glass which accompanies the Sedgwick-Rafter cell, a 24 x 60 cover slip (#1), rounded at the corners, was used. This procedure facilitated identification of smaller organisms with the 45x objective. A 1 ml pipette was used to fill the cell and three minutes were allowed to elapse before examination, thus allowing time for the contents of the cell to settle. Ten field counts and one strip count were made for each sample, with a quantitative record of each genus being kept. In all cases the 20x objective of the microscope was used to make the counts.

A stage micrometer was used to calibrate the Whipple Disc for the 20x objective. The entire grid of the Whipple Disc covered 0.35^{-2} mm and the diameter of the entire field of view for the 20x objective was 0.915 mm. From this information the number of organisms per liter was determined by multiplying the total number of organisms in each genus by the factors obtained from the equations in Standard Methods (1965).

Samples for the determination of nitrates, phosphates, turbidity, pH and total hardness were collected from the 2 m depth by means of the water pump. A DR-EL Hach Kit[2] was used to ascertain these chemical parameters within 4 hours after collection of the samples. When possible, a 25 ml volumetric pipette was used to measure aliquots of the river water for use in the chemical tests.

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[1] 90 ml of 50% EtOH; 5 ml of 40% formaldehyde; 5 ml of glacial acetic acid.
[2] Hach Chemical Company, Ames, Iowa.

The dissolved oxygen content of the water was also determined from samples collected from 2 m. However, these samples were collected with a Kemmerer bottle and were transferred, with as little agitation as possible, to clean BOD bottles. Once in these latter bottles, the water was fixed immediately and each was appropriately labeled. Dissolved oxygen was determined spectrophotometrically[3] at 450 mμ by using a free iodine standard curve of the azide modification of the iodometric method (Standard Methods, 1965).

Water temperature was obtained from each depth by placing a thermometer in a 2 gallon pail and allowing river water to run into it for 5 minutes. The thermometer was then withdrawn just far enough from the water to take a reading.

Settleable matter was determined by using an Imhoff cone (Standard Methods, 1965).

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[3]Bausch & Lomb, Spectronic 20.

RESULTS AND DISCUSSION

Plankton samples were taken weekly from May 19 to July 3. After the latter date, bimonthly samples were taken until November 20, at which time the study was terminated.

The generic circumscription of the phytoplankton was of major concern in this study, but species identifications were made when possible. However, because of the time limitations, the majority of the Centrales and Pennales were only recorded numerically under the heading of diatoms. Organisms found during this study are listed in Table 1.

WATER QUALITY

Temperature: A marked similarity in temperature was observed for the three study areas throughout the sampling period. However, the La Crosse River remained one or two degrees lower than the "Black" or Mississippi Rivers. The lowest water temperature for any of the rivers was 3.5 C, which occurred in the La Crosse River on November 6 (Figure 2). The highest water temperature was 26.2 C on the "Black" River. On two separate occasions, June 5 and July 19, a temperature of 25.5 C was recorded.

Sudden fluctuations in air temperature usually do not have any immediate effects on the water temperature of lakes, due to the lack of water movement and the establishment of a thermocline (Hutchinson, 1967). However, the water temperature of turbulent streams that are relatively narrow and shallow, are influenced by rapid changes in air temperature (Reid, 1961). Figure 2 indicates that the water temperature of all three study areas was influenced by air temperature. Although the "Black" and Mississippi Rivers do not conform to the characteristics of a narrow shallow stream, their water temperatures nevertheless were influenced by the air temperature. These water temperature fluctuations may be attributed to the lack of thermal stratification and the turbulence produced as the water passes over submerged wing dams.

Dissolved Oxygen: This parameter is one of the most important factors used in determining the quality of a body of water (Odum, 1956). Figure 2 shows that there is a great variance between the rivers in the amount of dissolved oxygen that is found during any given time. Although water samples were only collected at the 2 m depth, it is assumed that the dissolved oxygen content of each river was not significantly influenced by water depth due to the lack of thermal stratification (Reid, 1961). The "Black" and Mississippi Rivers were usually synchronous in their fluctuations even though they contained different amounts of dissolved oxygen. There were a number of instances when the La Crosse River deviated from the synchronous fluctuations of the other two rivers. The lowest recording (mg/liter) for the "Black", Mississippi and La Crosse Rivers were 5.9, 6.07, and 5.41, respectively. These readings occurred at the end of August and the first week in September. The high for the "Black" River was 10.85 which occurred on November 6. On October 23 the La Crosse River had a high of 9.82. The Mississippi River reached a high concentration of 11.41 on June 3.

Turbidity: Turbidity is usually more prevalent in a stream situation than in large lakes. The major causes of turbidity are surface water runoff and the characteristics of the river basin (Reid, 1961). The degree to which turbidity will persist in a river is largely dependent upon the velocity and turbulence of the river. Turbidity appeared to be very cyclic in all three study areas (Figure 2). Since no record of rainfall was kept during the period of observation, it can only be hypothesized that the cycles were the result of seasonal rainfall. Because of the narrow, shallow and turbulent nature of the La Crosse River, repeatedly higher readings were recorded for this river than for the "Black" or Mississippi Rivers, since the latter are large, deep rivers in which settling and dilution reduces the amount of turbidity. On July 3 and 17 the "Black" and Mississippi Rivers had turbidity readings of 0 JTU's. It is known that suspended material was present, but for some unexplainable reason it was not detected by the Hach Kit. The La Crosse River had a low reading of 21 JTU's on two separate occasions, May 26 and November 6. High readings were: La Crosse River, 112 JTU's on May 6; "Black" River, 77 JTU's on November 6; Mississippi River, 97 JTU's on November 6. The increase in turbidity at this time may be the result of an increased discharge rate.

Phosphate: In many aquatic systems the limiting nutrient is often phosphate. This is especially true of lakes and stagnant bodies of water (Hutchinson, 1967). In streams whose course takes them through terrain made up of farm land and residential areas, phosphates can be expected to be found in higher concentrations than those that drain non-agricultural areas (Reid, 1961). This is the result of surface water runoff and the lack of thermal stratification. As surface water runoff enters a stream it carries a silt load and inorganic phosphates which are washed from the soil. This appears to be the case for the peaks in phosphate concentrations (Figure 3) which are almost in unison with the peaks observed for turbidity (Figure 2).

The "Black" River had a high reading of 1.90 ppm on September 11 and a low of 0.13 ppm on May 26 (Figure 3). For the La Crosse River the high was 2.60 ppm on September 11 and a low of 0.22 ppm on May 26. A high of 1.90 ppm on September 11 and 25 and a low of 0.15 ppm on May 26 was recorded for the Mississippi River.

Nitrates: From the graph (Figure 3), nitrates appear to be quite variable during May, June and July. During the remainder of the summer, nitrate concentrations declined to approximately 1 ppm and then remained below 0.5 ppm until October; the La Crosse River being an exception. The lower detectable limits of the Hach-Kit were exceeded for the "Black" and Mississippi Rivers on two separate occasions, the 19th and 26th of June. Again there may be a possible connection between nitrates and surface water runoff (Reid, 1961). Although the peaks for nitrates are just the opposite of those for turbidity, this may represent a time lag between the introduction of nitrogenous organic material and the deaminization by bacteria which convert the organic nitrogen back to nitrates. Other possibilities such as sewage from domestic and agricultural sources may also be an influence, with the resulting time lag being a coincidence. High concentrations were: "Black" River, 6.30 ppm on July 3; La Crosse River, 2.50 ppm on July 3; Mississippi River, 12.80 ppm on July 12. On August 28 the La Crosse River contained a low of 0.33 ppm.

Settleable Matter: Figure 3 shows the graph for the settleable matter in the La Crosse River. The only time when settleable matter was recorded for the "Black" and Mississippi Rivers was on July 3, when readings of 0.3 ml/l and 0.2 ml/l were recorded. Again, settleable matter may be attributed to surface water runoff, for the peaks for settleable matter coincide with the peaks for turbidity (Figure 2).

pH: Figure 4 shows the graph for pH. Recordings for all three study areas closely coincided at any given time and all three fluctuated in unison. These fluctuations also coincide with the fluctuations shown in the graph for turbidity. As the turbidity increased, there was a corresponding shift in the hydrogen ion concentration towards the alkaline range. The La Crosse area is in a region of soluble geologic formations, thus calcium and magnesium are found as carbonates. The result is that as surface water runoff passes over these formations the carbonic acid in the water makes the carbonates more soluble and thus they can be carried along with the surface water runoff into aquatic systems (Reid, 1961). The lowest recording was a pH of 8.03 for the "Black" River and a high reading of pH 8.86 for the La Crosse River.

Total Hardness: This parameter and pH are functions of each other. As pH increases, total hardness increases (Ruttner, 1953). This might also be attributed to the type of geologic substrate around the La Crosse area. Figure 4 indicates that total hardness increased early in the summer, diminished, and then became quite variable for each river. As autumn approached, a decrease in total hardness was observed. The "Black" River had a high concentration on June 11 of 185 ppm and a low of 101 ppm on November 6. The high for the La Crosse River was on June 5, when a concentration of 228 ppm was reached. The low of 140 ppm was recorded on September 25. The Mississippi River reached a high of 210 ppm on June 5 and 11 while its low of 114 ppm was taken on November 6.

Discharge Rates: Except during the flood period in the spring, the discharge rate for the "Black" River remains at a relatively constant 1500 cu. ft./sec. The discharge rates for the La Crosse and Mississippi Rivers is controlled by the U. S. Army Corps of Engineers and a Price Current Meter is used to determine the volume. Figure 5 shows the discharge rates for the La Crosse and Mississippi Rivers[4]. Surface water runoff in connection with flow rates was a more important factor in

[4]Data obtained from U. S. Army Corps of Engineers Lock and Dam 7, Dresbach, Minnesota.

producing turbidity than was the amount of water discharged by the locks and dams. The maximum discharge rate for the Mississippi River was 63,000 cu. ft./sec., which occurred on May 26. On November 6, the discharge rate again increased when 60,300 cu. ft./sec. was discharged from Lock and Dam 7. The rate of discharge for the Mississippi River was at a low on August 14 when 10,600 cu. ft./sec. was discharged. The La Crosse River's high discharge rate was 383 cu. ft./sec. on May 19 and a low of 136 cu. ft./sec. on June 5.

PHYTOPLANKTON

Total Phytoplankton: Total phytoplankton (Figure 6) for each study area was obtained by averaging the total number of phytoplankton present at each depth, thus giving an average for each station. The average for each river in turn, was obtained by taking the average for the stations on that river. Station 6 was not used in averaging total phytoplankton in either the "Black" or Mississippi Rivers because the degree of mixing was not known. The "Black" and Mississippi Rivers had low phytoplankton counts in the beginning of the summer, but near the 11th of June the phytoplankton increased sharply with peaks being observed between June 26 and July 3. After a short decline, the population reached a stable level from July 17 until the end of September. As autumn approached, there was another peak which was observed to decline on October 23. The population remained relatively low for the remainder of November.

The La Crosse River, on the other hand, presented a different situation. While the populations were increasing on the other two rivers, the total phytoplankton in the La Crosse River was not increasing to such an appreciable extent. From the middle of June to the end of August, the populations fluctuated between 20,000 - 50,000 organisms/l. The population reached a peak which exceeded 100,000 organisms/l. The fall peak observed in the "Black" and Mississippi Rivers was not observed in the La Crosse River.

Station Phytoplankton: Because of the similarity between stations in each individual river, a representative station from each of the study areas was used to typify the succession of the phytoplankton.

The size of the populations for each station has been categorized on the basis of the following groups: Chlorophyta, Cyanophyta, Bacillariophyceae, Euglenophyta, Chrysophyceae and Pyrrophyta.

Station 2 (Figure 7) was chosen as the representative of the "Black" River. The phytoplankton present during May and the first half of June was composed primarily of diatoms and members of the Chlorophyta, while the Cyanophyta were not abundant. During the early part of June this latter division was dominated by Oscillatoria spp., but this alga was not detected throughout the remainder of the summer. However, this organism again became prevalent during late fall. On approximately June 11 conditions became optimal for the growth of the blue-greens and a very rapid development occurred for three weeks with the population reaching its peak on July 3. The dominant organism during this period was Aphanizomenon flos-aquae L. with a maximum concentration of over 3.18×10^5 organisms/liter. The Cyanophyta remained the dominant group almost to the end of July. At the time of dominance by the Cyanophyta, the diatoms and Chlorophyta remained at a uniform concentration, with the Chlorophyta being more prevalent than the diatoms. During the rest of the summer and autumn, when other groups became dominant, Microcystis spp. and Aphanocapsa spp. were the dominant blue-greens.

The next group of organisms attaining dominance was the Chlorophyta. As the Cyanophyta were declining in numbers, conditions became favorable for the emergence of the Chlorophyta. The increase in numbers of this group started in the middle of July and continued in most cases until the end of the month, at which time a plateau was reached. At a number of stations a peak was observed at the 1 m and 2 m depths in the early part of August, while at other stations at the same depths, a 2 week plateau was exhibited with the peak occurring in the middle of the month. At the 3 m depth the plateau continued during the entire summer and a slight peak was observed around the middle of September.

Ulothrix spp. was the dominant member of the Chlorophyta throughout the study period. Next in order of abundance were Scendesmus spp. and Pediastrum spp. Those Chlorophyceae which seemed to have required the most specific requirements for development were Quadrigula chodatii Smith, Errerrella bornhemiensis Conrad, Elakatothrix gelatinosa Wille, Echinosphaerella limnetica Smith, and Polyedriopsis spinulosa Schmidle. These organisms were found only in the samples of August 14.

Dominance by the Chlorophyta in all depths started to decline in early October. At this time the diatoms, which had remained at a relatively constant level throughout the summer, became dominant. A peak in the diatom population was observed on October 23. The greatest abundance of diatoms occurred near the surface, while the concentration of the diatoms at the 2 m and 3 m depths appeared to be very uniform. The larger peak of diatoms near the surface may reflect the fall conditions in which less light is able to penetrate the surface of the water due to the angle of incidence of the sun, thus raising the depth of the euphotic zone.

In the Centrales, various species of Stephanodiscus and Cyclotella were dominant. In the Penales, Fragilaria sp. and Asterionella sp. were the most prominant members.

The latter peak in number of organisms marks the end of conditions which were favorable for the growth of the major groups of organisms in the study area. Often the dominant groups of organisms under the ice during the winter are the diatoms and in the early spring these organisms will peak and the cycle will start over again (Hutchinson, 1967).

Figure 7A shows the graphs for the Pyrrophyta, Chrysophyceae and Euglenophyta. The Pyrrophyta were most abundant during the middle of the summer and the population continued until the end of September when they were no longer detectable. *Ceratium hirundinella* was the most prevalent member of this group.

In the Euglenophyta, *Phacus* sp. was found to be more dominant than *Euglena* sp. These algae were most abundant during the end of May and the beginning of June, although they did occur briefly at other times.

The only organisms representing the Chrysophyceae were *Dinobryon* sp., *Synura uvella*, *Mallomonas alpina* and *Chrysosphaerella longispina*. The latter two were not abundant, and of the first two, *Dinobryon* sp. was found both in the spring and fall, while *Synura uvella* was found only in the fall.

Depth does not seem to be an influencing factor in determining the distribution of the populations in a large river as it does in a lake environment. Due to the amount of turbulence and the lack of thermal stratification, it appears to the author that the number of organisms at each depth are quite close, however, higher concentrations were found at the 3 m depth than at the surface.

The La Crosse River is represented by station 4 (Figure 10). Since the river is very shallow, only one depth could be sampled. The La Crosse River represents a situation which is found in those rivers which are characterized by being turbulent and having a high amount of turbidity and settleable matter. The peak in the Cyanophyta that was so prevalent in the "Black" and Mississippi Rivers was completely absent in the La Crosse River. Phytoplankton populations remained relatively low throughout the major portion of the summer. The only major concentration of organisms found in the river were the Chlorophyta. The major component of this group was Ulothrix spp. which occurred in almost unialgal proportions. The remaining Chlorophyta comprised approximately 0.6% of the population. In the La Crosse River, Ulothrix spp. increased in density almost a month later than in the "Black" or Mississippi Rivers. A peak in the population was observed on September 25 and there was no characteristic plateau as in the other two rivers. The population declined just as rapidly as it rose and it remained constant during October and November.

In the La Crosse River it was observed that a slight peak in the Bacillariophyceae did occur during July, but the autumnal peak that occurred in the "Black" and Mississippi Rivers was absent in the La Crosse River.

Throughout most of the summer, euglenoids were more prevalent in the La Crosse River than in either of the other two study areas. In the La Crosse River this population was more abundant near the mouth of the river (station 4) than at the upstream station (station 5). This might be due to the fact that a large holding pond receiving effluent (fecal material, fish pellets, etc.) from a federal facility utilizing large numbers of fish has its outfall between station 4 and station 5. These materials may be a source of nutrients for euglenoids, but since no data was taken from this pond, it is only a possible answer for the maintenance of the population at station 4.

The Pyrrophyta in the La Crosse River were found throughout the major portion of the summer. The peak for this group occurred in early August.

There were no observations of members of the Chrysophyceae in the La Crosse River during the entire period of the study.

Station 6 (Figure 9 and 9A), at the junction of the "Black" and Mississippi Rivers and station 7 (Figure 10 and 10A), which is representative of the Mississippi River, show curves which are very similar to those of the "Black" River. The peaks for the Cyanophyta appear to taper off more slowly than on the "Black", while the emergence of the Chlorophyta appears to take place at the same time as on the "Black" River. On the Mississippi River, at stations 7 and 9, where mixing of the "Black" and Mississippi's water does not occur, there was a more prevalent population of euglenoids. This population started in May and lasted through August. Also at these stations, the Pyrrophyta did not appear to be as abundant as on the "Black" River.

DATA CORRELATIONS

An attempt to correlate the biological and chemical parameters was made, but no significant correlations existed.

CONCLUSIONS

PHYTOPLANKTON

Bacillariophyceae: It is assumed that the diatoms developed a vernal maximum, though none was observed due to the time of year in which the study began. Hutchinson (1967) and Birge and Juday (1922) have shown this to true for many temperate lakes. Because the "Black" and Mississippi Rivers showed such a divergence in species and a cyclic effect of the different groups, it is assumed that a spring maximum did occur. This assumption is further supported by the fact that an autumnal maximum did occur and the conditions which were favorable for their development would again be prevalent during the early spring.

It was observed that a small spring peak in the diatom population occurred in the "Black" and Mississippi Rivers. The population then remained relatively low for the remainder of the summer and on October 2 the autumnal peak was observed. In the La Crosse River the peak in density was observed during July and the autumnal peak was completely absent.

Cyanophyta: In the "Black" and Mississippi Rivers this division was dominated from the beginning of the study until the middle of June by Oscillatoria spp. During the period of dominance of the Cyanophyta, which occurred from June 11 to July 31, this group was composed primarily of Aphanizomenon flos-aquae. It was during this period that a total blue-green concentration of 31.9×10^5 organisms/liter was observed. The organisms which were most prominent during the remainder of the study period were Microcystis spp. and Aphanocapsa spp.

In the La Crosse River this division, like the Bacillariophyceae, was not a major component of the phytoplankton. Kofoid (1908) and Chandler (1932) have shown that these groups become less prevalent as current increases. The peaks which were observed for the "Black" and Mississippi Rivers were not detected in the La Crosse River.

Chlorophyta: The major component of this group in all three study areas was various species of *Ulothrix*. In the La Crosse River this genus occurred in almost unialgal proportions.

Dominance by this group started in the middle of July and lasted until the end of September. In the "Black" and Mississippi Rivers a plateau either preceded or followed a peak in the population. In the La Crosse River the Chlorophyta increased in density almost a month later than the populations in the other two study areas.

The organisms which followed *Ulothrix* spp. in their order of abundance were *Scendesmus* spp. and *Pediastrum* spp. Five genera (*Quadrigula*, *Errerrella*, *Elakatothrix*, *Echinosphaerella*, and *Polyedriopsis*) were found only on August 14.

Pyrrophyta: This division did not contribute significantly to the numerical composition of the phytoplankton. The greatest concentrations occurred during the middle of the summer and *Ceratium hirundinella* was the most prevalent representative.

Euglenophyta: *Phacus* sp. was the dominant genus in each of the study areas. The Mississippi River contained a more prevalent population of euglenoids than did the "Black" River. The highest density was observed at the end of May and the beginning of June. In the La Crosse River, station 4 maintained a higher level of euglenoids than did station 5. This may have been the result of a holding pond effluent, which received metabolic fish wastes, entering the river between the two stations.

Chrysophyceae: This group of organisms was detected only in the "Black" and Mississippi Rivers. Dinobryon sp. was detected in the spring and fall while Synura uvella could only be found in the fall. In the spring, the population appeared to be declining from some unknown value and then in the fall, it appeared to be on the increase, though this increase could not be followed due to the termination of the study.

THE RIVERS

The Mississippi River, through channelization and confinement by weed beds and islands, remains relatively independent of the waters of Lake Onalaska. In spite of this, the "Black" and Mississippi Rivers, at the point of study, are quite similar to each other in their phytoplankton populations. The phytoplankton of both rivers resembles the phytoplankton of a eutrophic lake, both in numbers and diversity. The rivers differ from the latter in the lack of thermal stratification and a greater input and availability of nutrients.

The physical characteristics of the "Black" River, which contributes to the waters of Lake Onalaska, are lost through dilution. The "Black" River at the point of study represents the waters of navigation pool 7. The waters of both the "Black" and Mississippi Rivers undergo changes common to a lake environment. This is seen at the point of study on the "Black" River where the total hardness remains at a level which is 20-30 ppm lower than the hardness of the Mississippi River. This difference is brought about by the removal of calcium ions by rooted vegetation in Lake Onalaska.

The La Crosse River is characterized by having little diversity in its phytoplankton. This is probably the result of a fast flow rate and a high amount of turbidity (Hynes, 1969).

The individuality of the La Crosse and "Black" Rivers could not be detected at stations 8 or 9. This is due to dilution by the waters of the Mississippi River. It is believed by the author, however, that after periods of heavy rainfall the La Crosse River may maintain its identity at station 8. This is the result of direct observations in which the silt load carried by the La Crosse River, after periods of rainfall, was seen to be segregated from the waters of the Mississippi River. Unfortunately, these observations were made at times between sampling periods.

This study is by no means conclusive. A more detailed study of the physical, chemical and biological interactions occurring in the plankton of rivers should be undertaken. With the complexity of the different types of pollutants entering the waterways, a more thorough understanding of their effects should be obtained. This is, of course, a massive undertaking, a task which should not be ignored.

APPENDIX

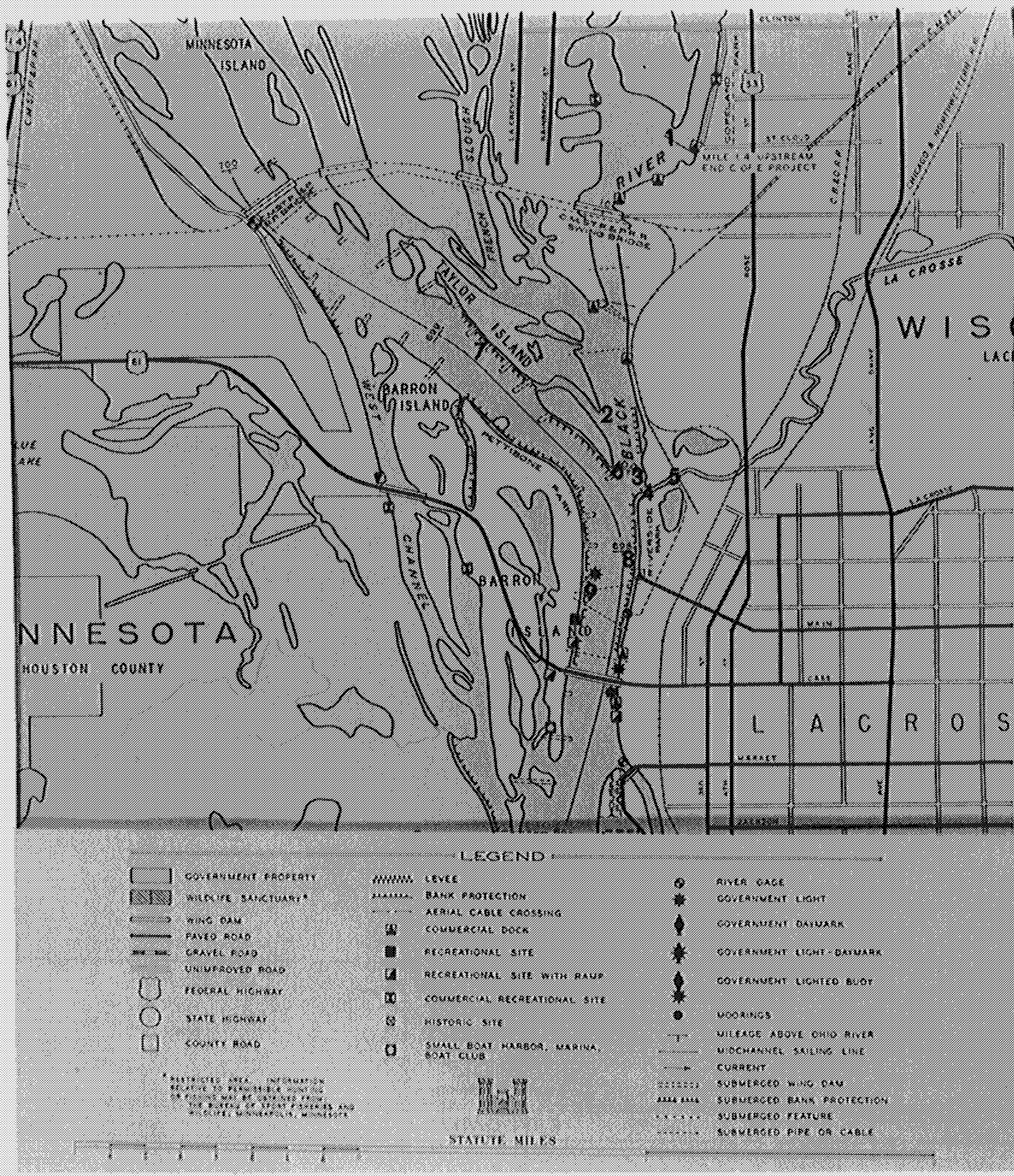

Figure 1: Map depicting the three river system and the location of the sampling sites.

Table 1: Phytoplankton found in the "Black", La Crosse and Mississippi Rivers. Classification according to Prescott, 1962.

CHLOROPHYTA

Class Chlorophyceae
Order Volvocales
Family Volvacaceae
Eudorina elegans Ehrenberg
Gonium pectorale Mueller
Pandorina morum (Muell.) Bory
Platydorina caudatum Kofoid
Volvox aureus Ehrenberg

Order Tetrasporales
Family Coccomyxaceae
Elakatothrix gelatinosa Wille
Family Palmellaceae
Sphaerocystis schroeteri Chodat

Order Ulotrichales
Family Ulotrichaceae
Ulothrix cylindricum Prescott
Ulothrix zonata (Weber & Mohr) Kuetzing
Family Chaetophoraceae
Draparnaldia sp.

Order Cladophorales
Family Cladophoraceae
Cladophora fracta (Dillw.) Wille

Order Chlorococcales
Family Chlorococcaceae
Acanthosphaera zachariasi Lemmermann
Golenkinia radiata (Chod.) Wille
Family Characiaceae
Characium ambiguum Hermann
Family Hydrodictyaceae
Hydrodictyon reticulatum (L.) Lagerheim
Pediastrum boryanum (Turp.) Meneghini
Pediastrum boryanum var. undulatum Wille
Pediastrum duplex Meyen
Pediastrum simplex (Meyen) Lemmermann
Family Coelastraceae
Coelastrum microporum Naegeli

Table 1: Continued

Family Oocystaceae
Ankistrodesmus falcatus (Corda) Ralfs
Cerasterias stuarastroides West & West
Chlorella sp.
Chlorella vulgaris Beyerinck
Dictyosphaerium pulchellum Wood
Echinosphaerella limnetica G. M. Smith
Polyedriopsis spinulosa Schmidle
Quadrigula chodatii (Tan.-Ful.) G. M. Smith
Selenastrum gracile Reinsch
Treubaria setigerum (Archer) G. M. Smith
Family Scenedesmaceae
Actinastrum hantzschii Lagerheim
Actinastrum hantzschii var. *fluviatile* Schroeder
Crucigenia tetrapedia (Kirch.) West & West
Errerella bornhemiensis Conrad
Micractinium pusillum var. *elegans* G. M. Smith
Scenedesmus quadricauda (Turp.) de Brebisson
Scenedesmus quadricauda var. *maximus* West & West
Scenedesmus quadricauda var. *Westii* G. M. Smith

Order Zygnematales
Family Zygnemataceae
Mougeotia sp.
Spirogyra sp.
Family Desmidiaceae
Closterium sp.
Cosmarium sp.
Staurastrum sp.

EUGLENOPHYTA
Order Euglenales
Family Euglenaceae
Euglena sp.
Phacus sp.

PYRRHOPHYTA
Class Dinophyceae
Order Dinokontae
Family Ceratiaceae
Ceratium hirundinella (O. F. Muell.) Dujardin

Order Dinococcales
Family Dinococcaceae
Cystodinium cornifax (Schill.) Klebs

CHRYSOPHYTA
Class Chrysophyceae
Order Chrysomonadales
Family Mallomonadaceae
Chrysosphaerella longispina Lauterb.
Mallomonas alpina Pascher & Ruttner
Family Synuraceae
Synura uvella Ehrenberg
Family Ochromonadaceae
Dinobryon sp.

Class Bacillariophyceae
Order Centrales
Family Coscinodiscaceae
Coccinodiscus sp.
Cyclotella sp.
Stephanodiscus sp.
Family Rhizosoleniaceae
Rhizosolenia sp.

Order Pennales
Family Tabellariaceae
Tabellaria sp.
Family Fragilariaceae
Asterionella sp.
Fragilaria sp.
Family Naviculaceae
Navicula sp.

CYANOPHYTA
Class Myxophyceae
Order Chroococcales
Family Chroococcaceae
Aphanocapsa spp.
Chroococcus sp.
Coelosphaerium spp.
Gloeocapsa spp.
Gomphosphaeria spp.
Marssoniella elegans Lemm.
Merismopedia glauca (Ehrenb.) Naegeli
Microcystis spp.

Order Hormogonales
Family Oscillatoriaceae
Oscillatoria spp.
Spirulina laxa G. M. Smith
Family Nostocaceae
Anabaena spp.
Aphanizomenon flos-aquae (L.) Ralfs
Nostoc spp.
Family Rivulariaceae
Rivularia haematites (D. C.) C. A. Agardh

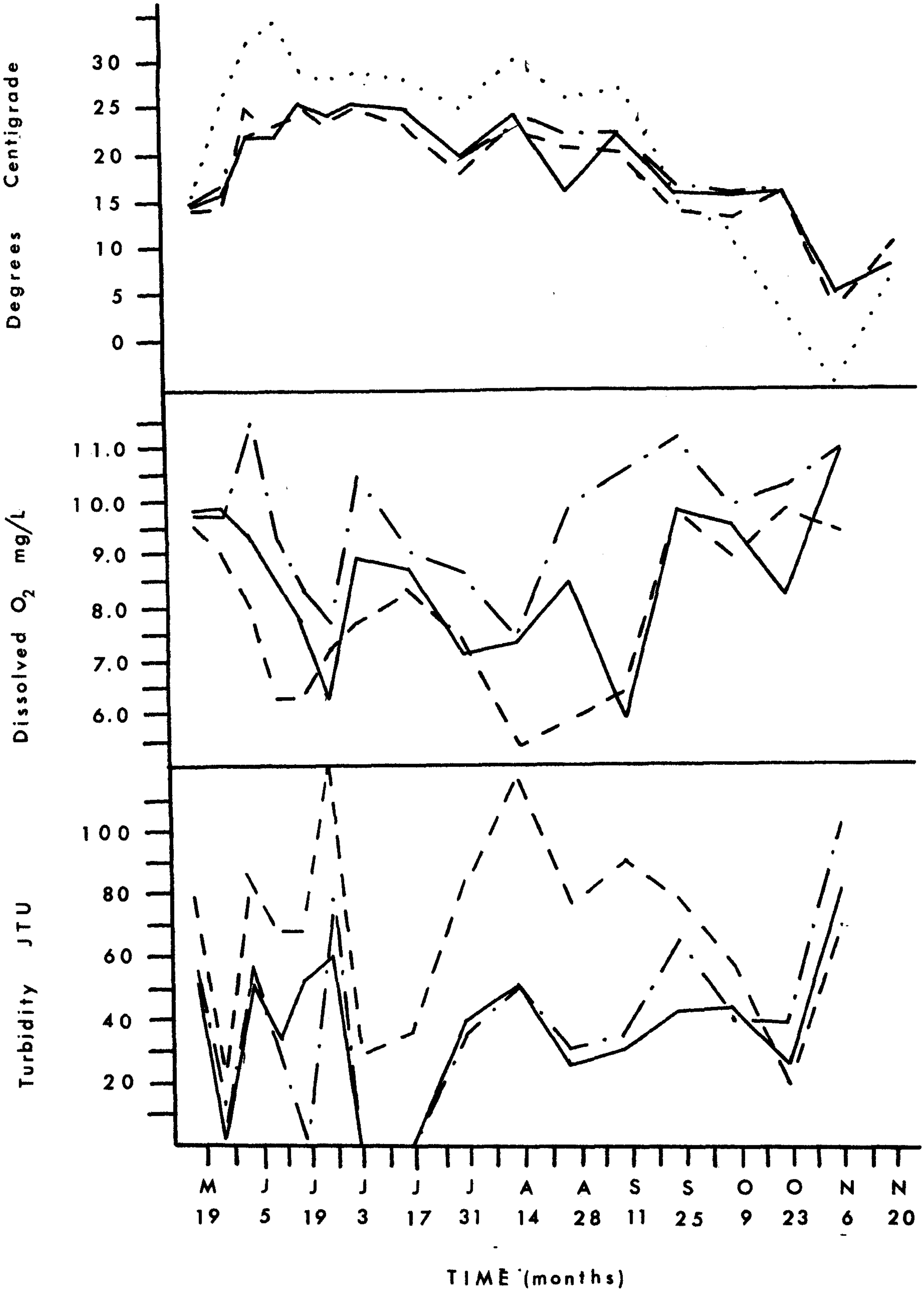

Figure 2: Temperature, oxygen and turbidity for the three study areas, "Black" ——— , LaCrosse — — — , Mississippi ——— . ———Air . . . . . .

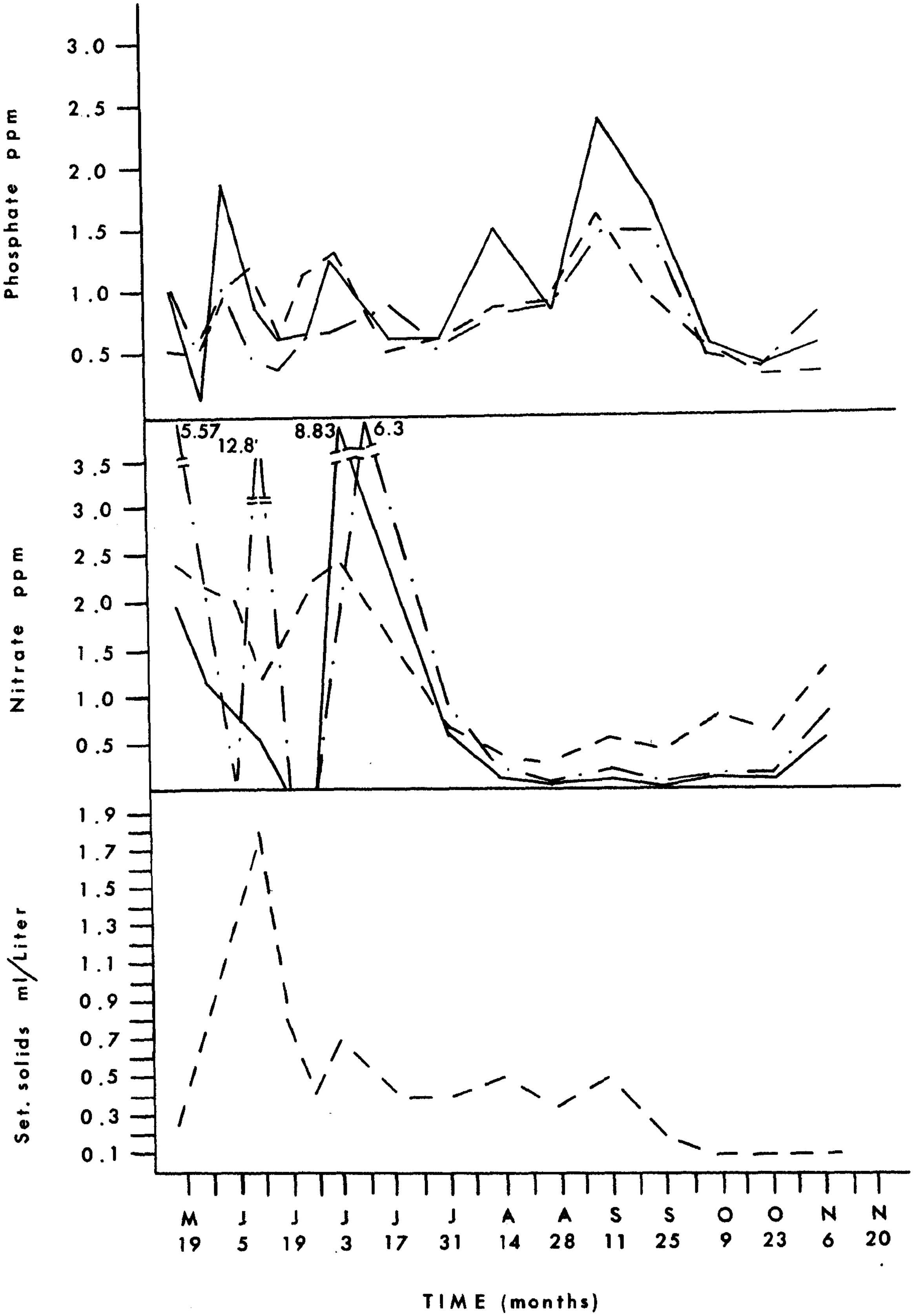

Figure 3: Phosphates, nitrates and settleable matter for the three study areas, "Black" ______ , LaCrosse _ _ _ , Mississippi ___ . ___

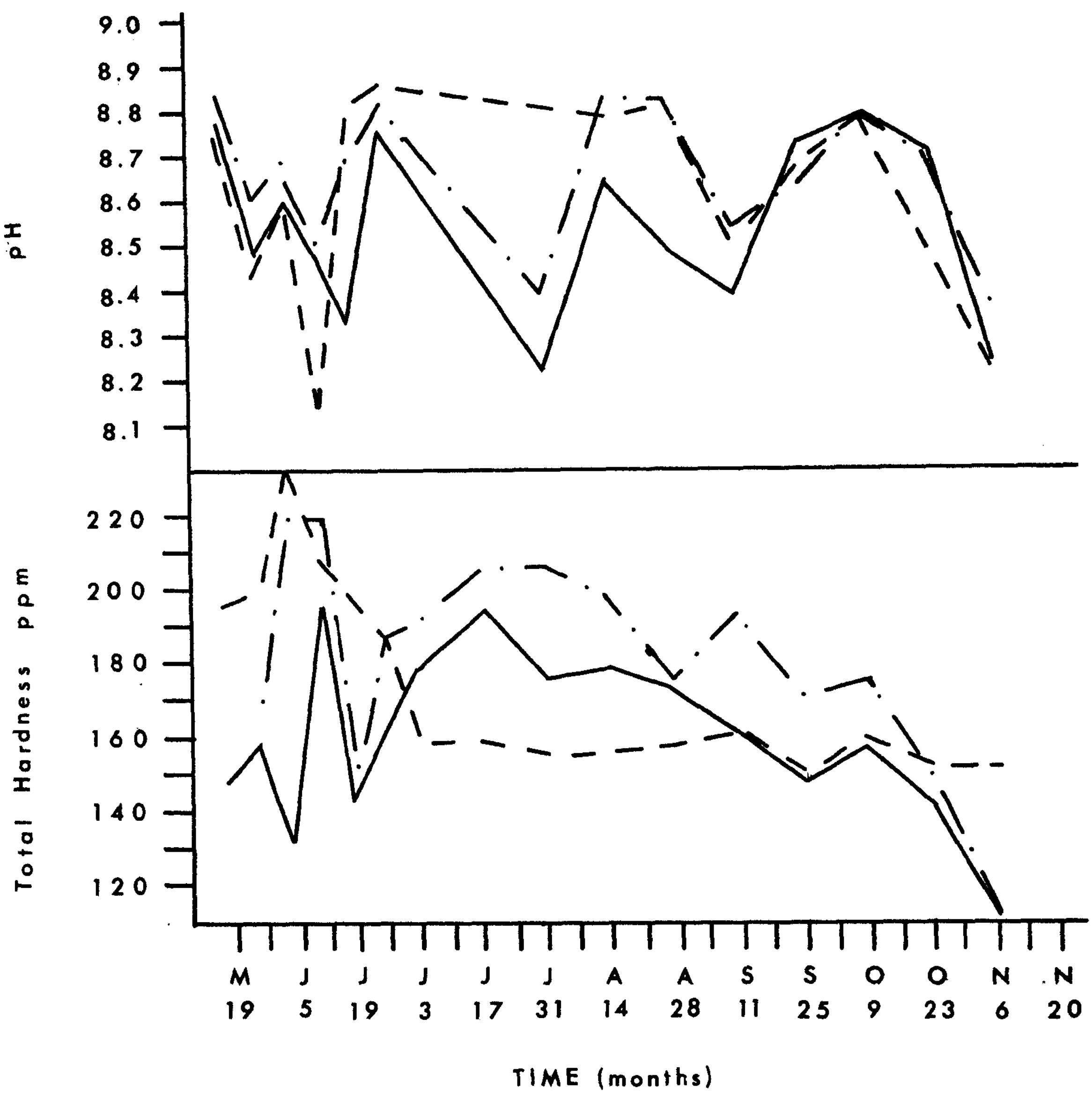

Figure 4: pH and Total Hardness for the three study areas, "Black" ——, LaCrosse — — —, Mississippi —— . ——

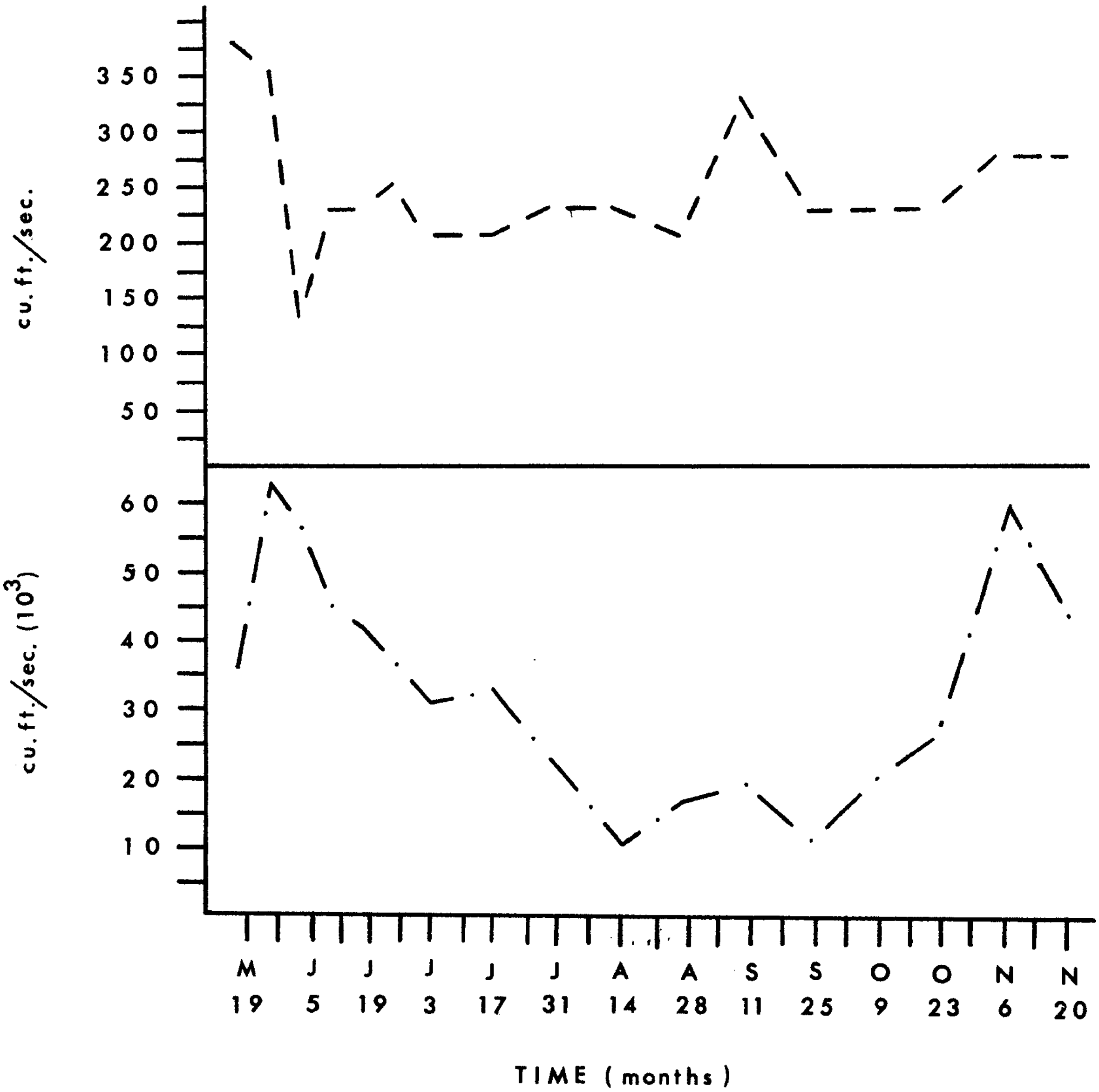

Figure 5: Discharge rates for the La Crosse and Mississippi Rivers, La Crosse — — —, Mississippi —— . ——

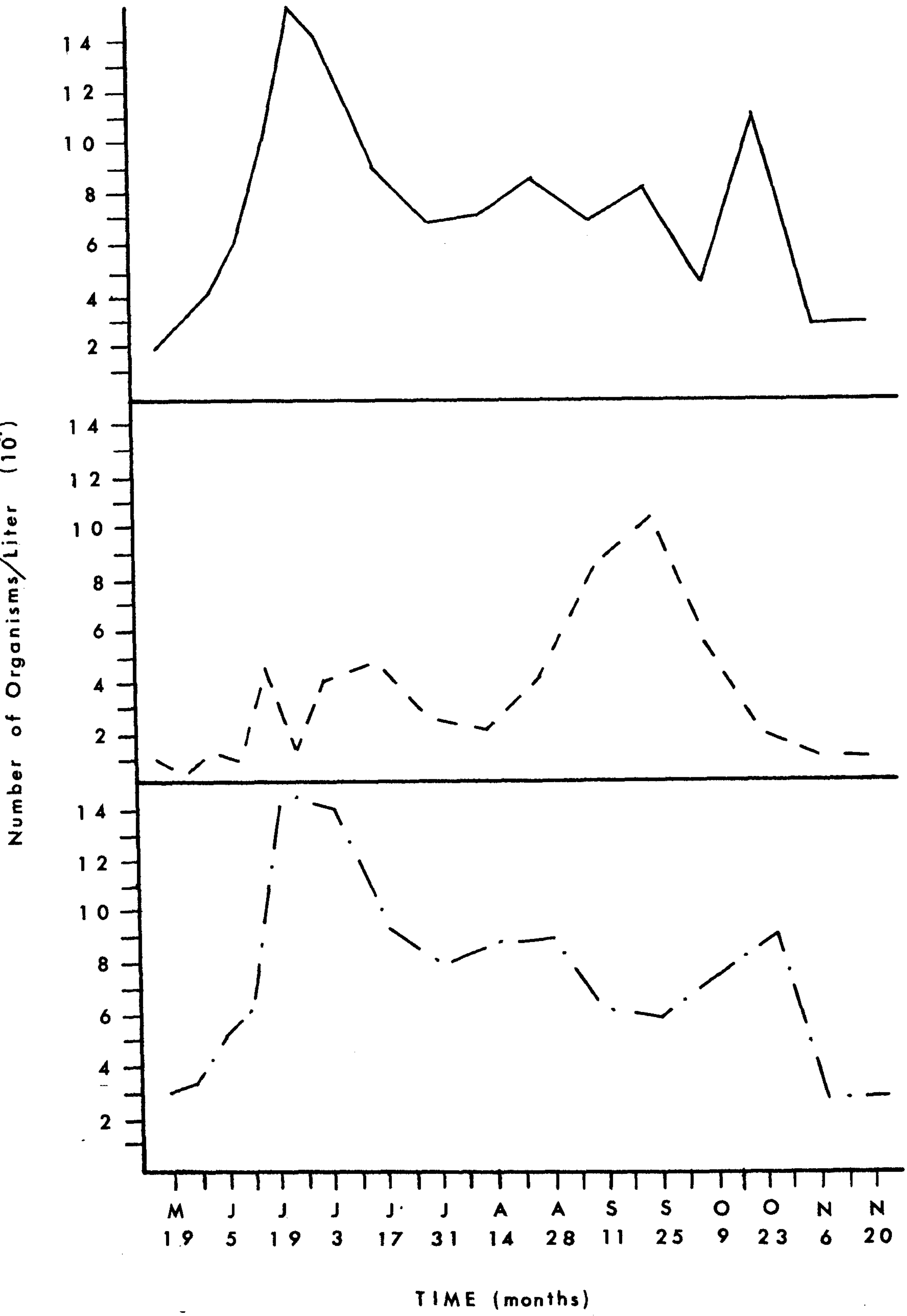

Figure 6: Total phytoplankton for the three study areas, "Black" ____ , La Crosse _ _ _, Mississippi __ . __

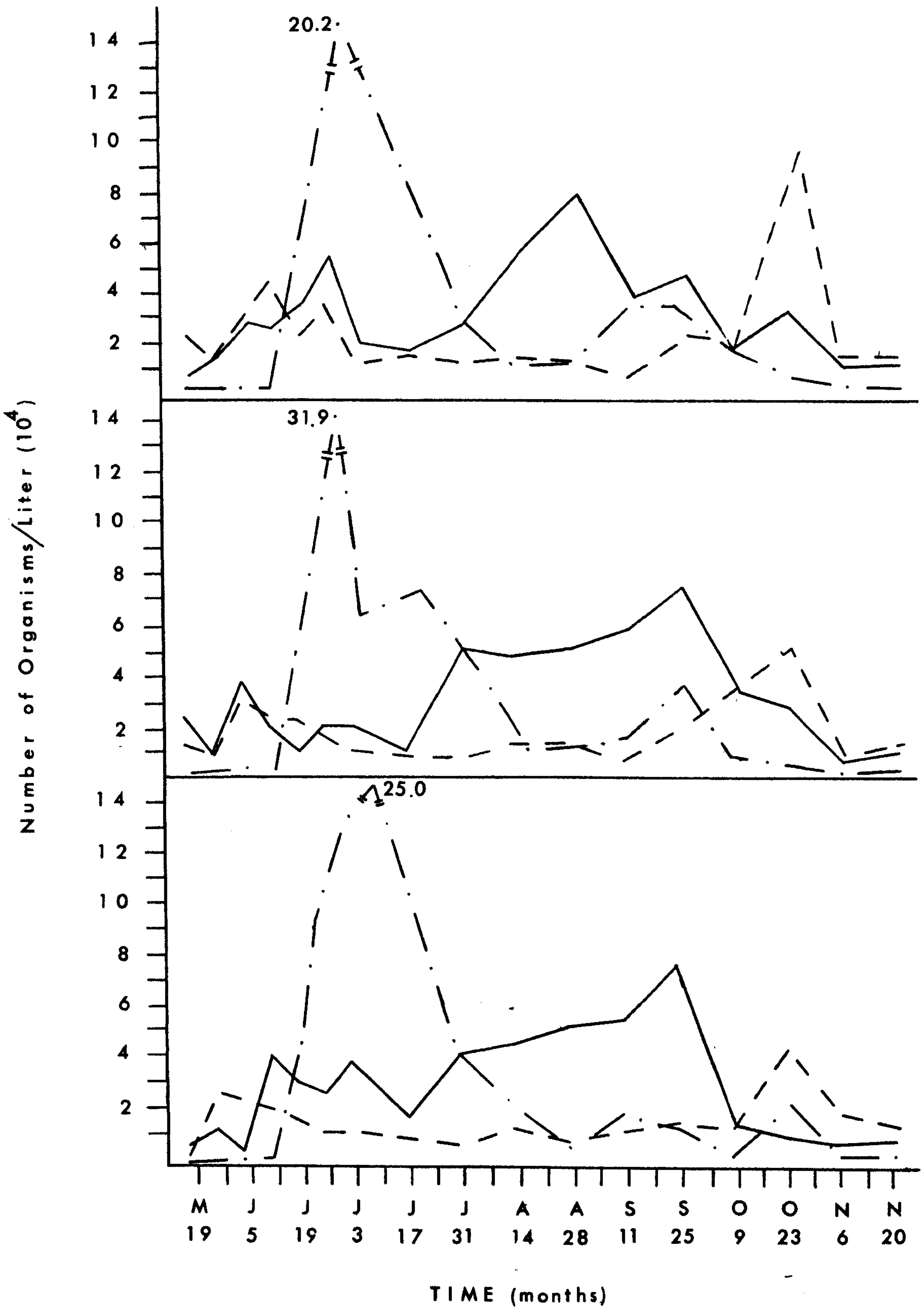

Figure 7: Station 2 "Black" River, 1m, 2m, & 3m. Chlorophyta ——— Cyanophyta —— · ——, Bacillariophyceae — — —

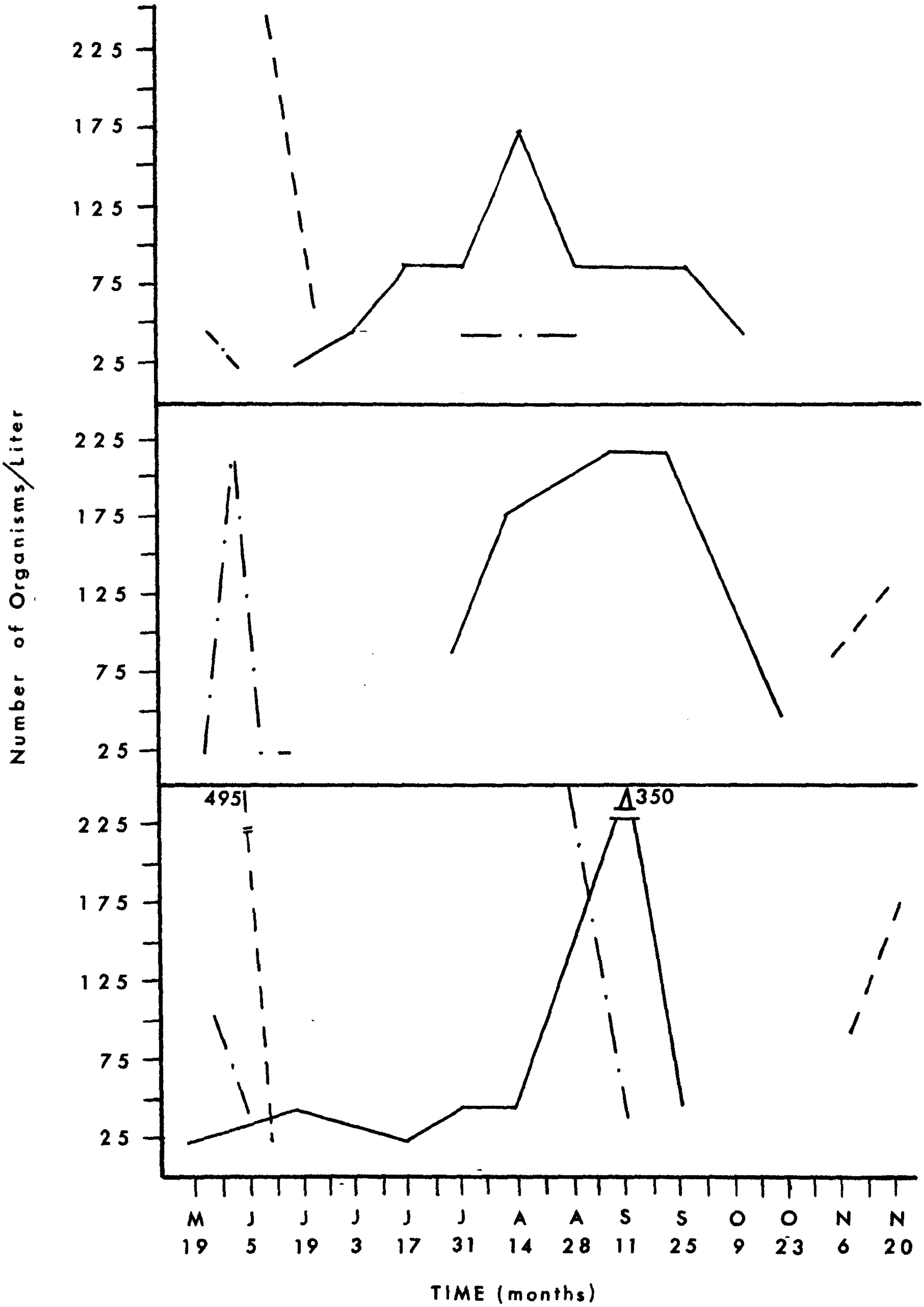

Figure 7A: Station 2 "Black" River, 1m, 2m, & 3m. Pyrrophyta ——, Euglenophyta —— . ——, Chrysophyceae — — —

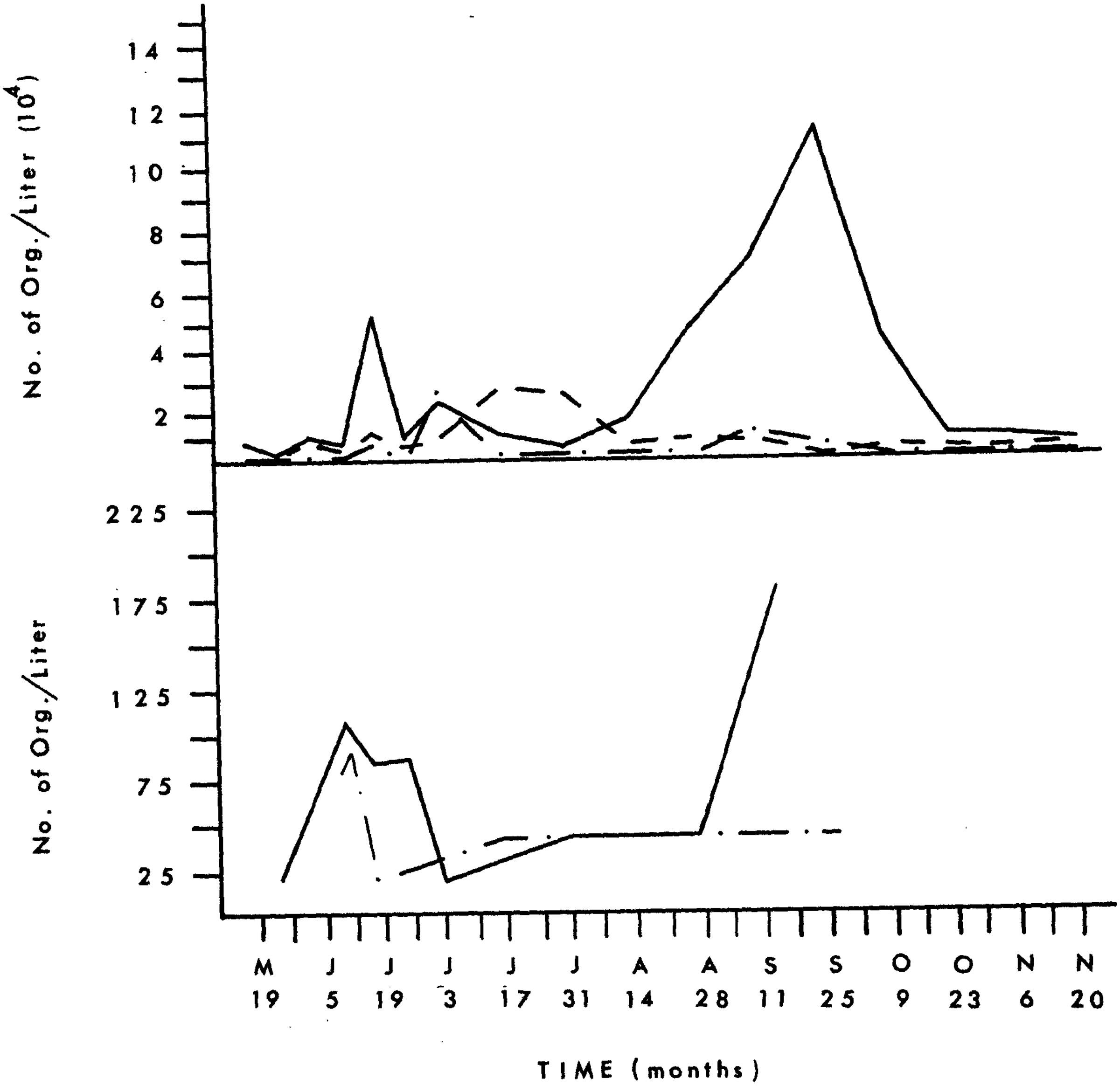

Figure 8: Station 4 LaCrosse River, upper graph; Chlorophyta ——— , Cyanophyta —— · —— , Bacillariophyceae — — — , lower graph; Pyrrophyta ——— , Euglenophyta —— · ——

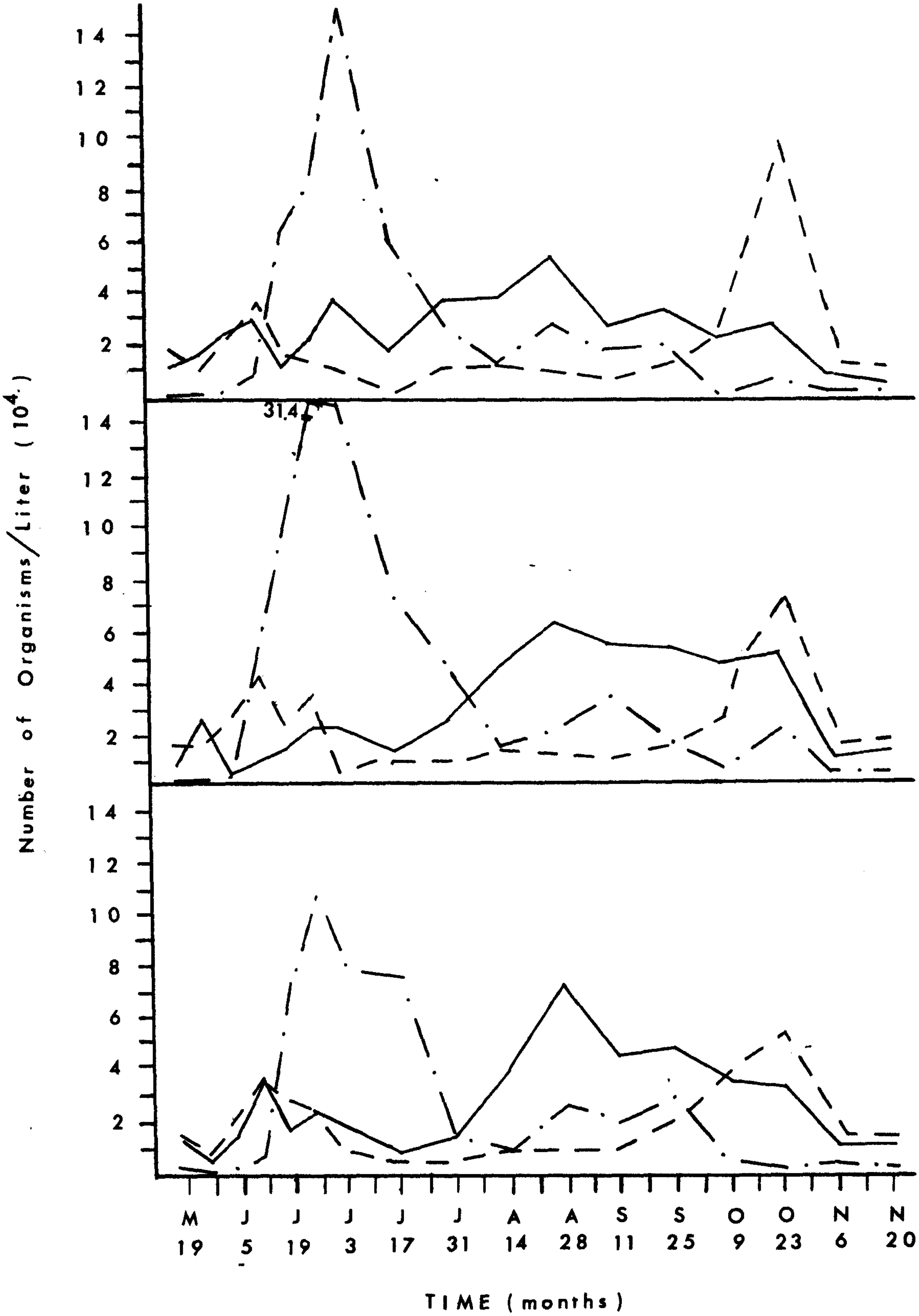

Figure 9: Station 6 juntion of "Black" and Mississippi River, 1m, 2m, & 3m. Chlorophyta ——— , Cyanophyta —— . —— , Bacillariophyceae — — —

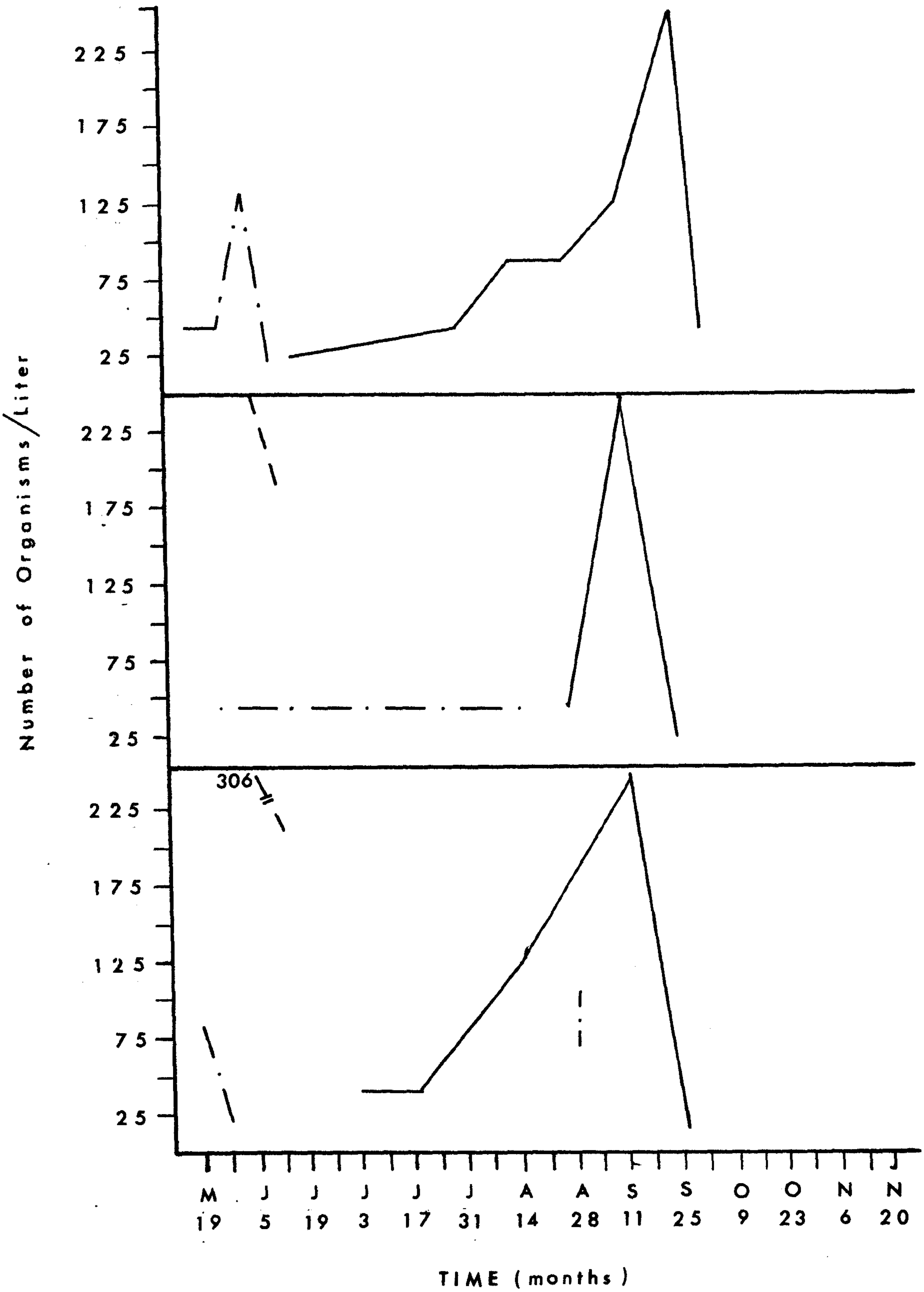

Figure 9A: Station 6 juntion of "Black" and Mississippi Rivers, 1m, 2m, & 3m. Pyrrophyta ——, Euglenophyta —— · ——, Chrysophyceae — — —

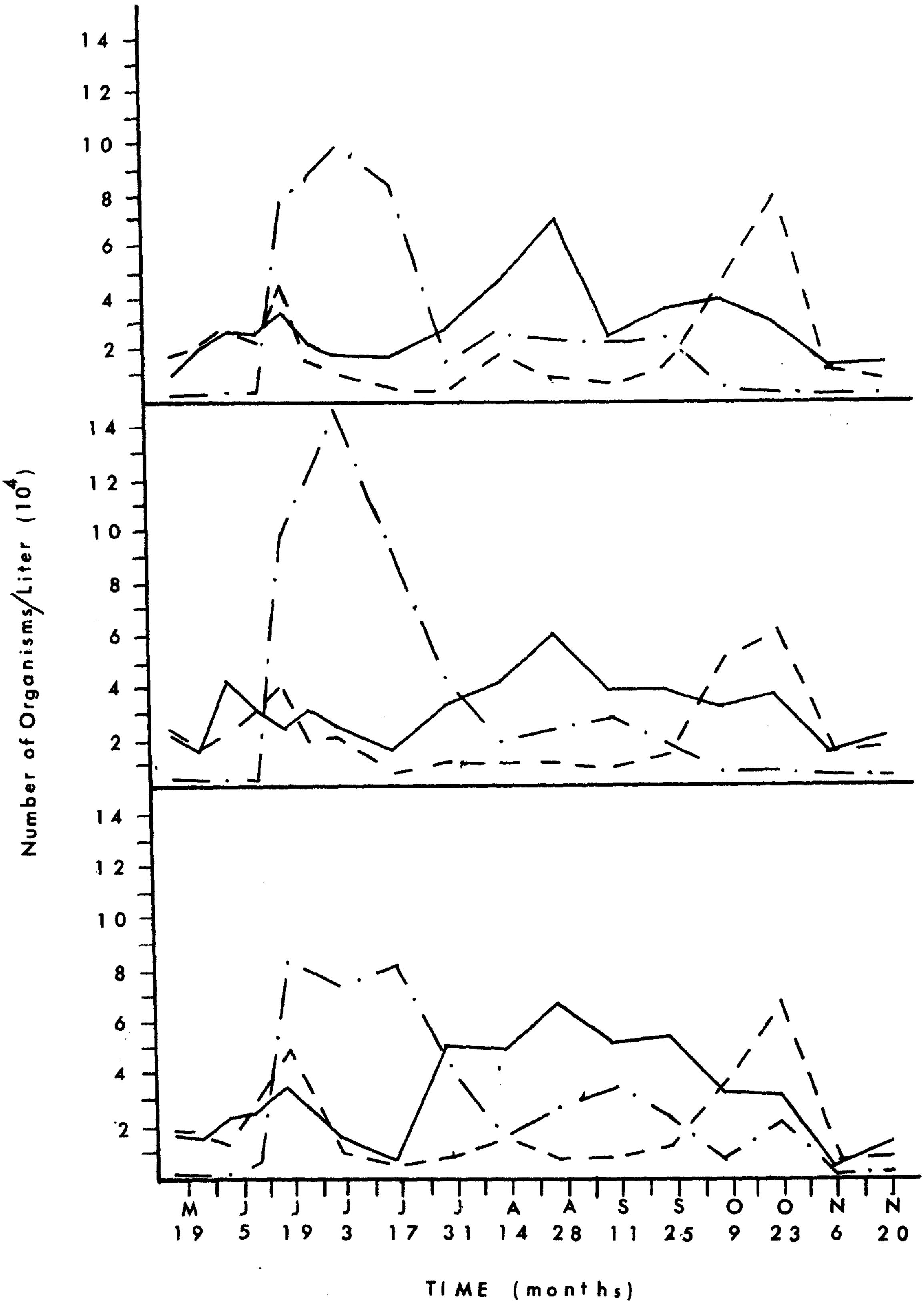

Figure 10: Station 7 Mississippi River, 1m, 2m, & 3m. Chlorophyta _____, Cyanophyta ____ . ____, Bacillariophyceae _ _ _

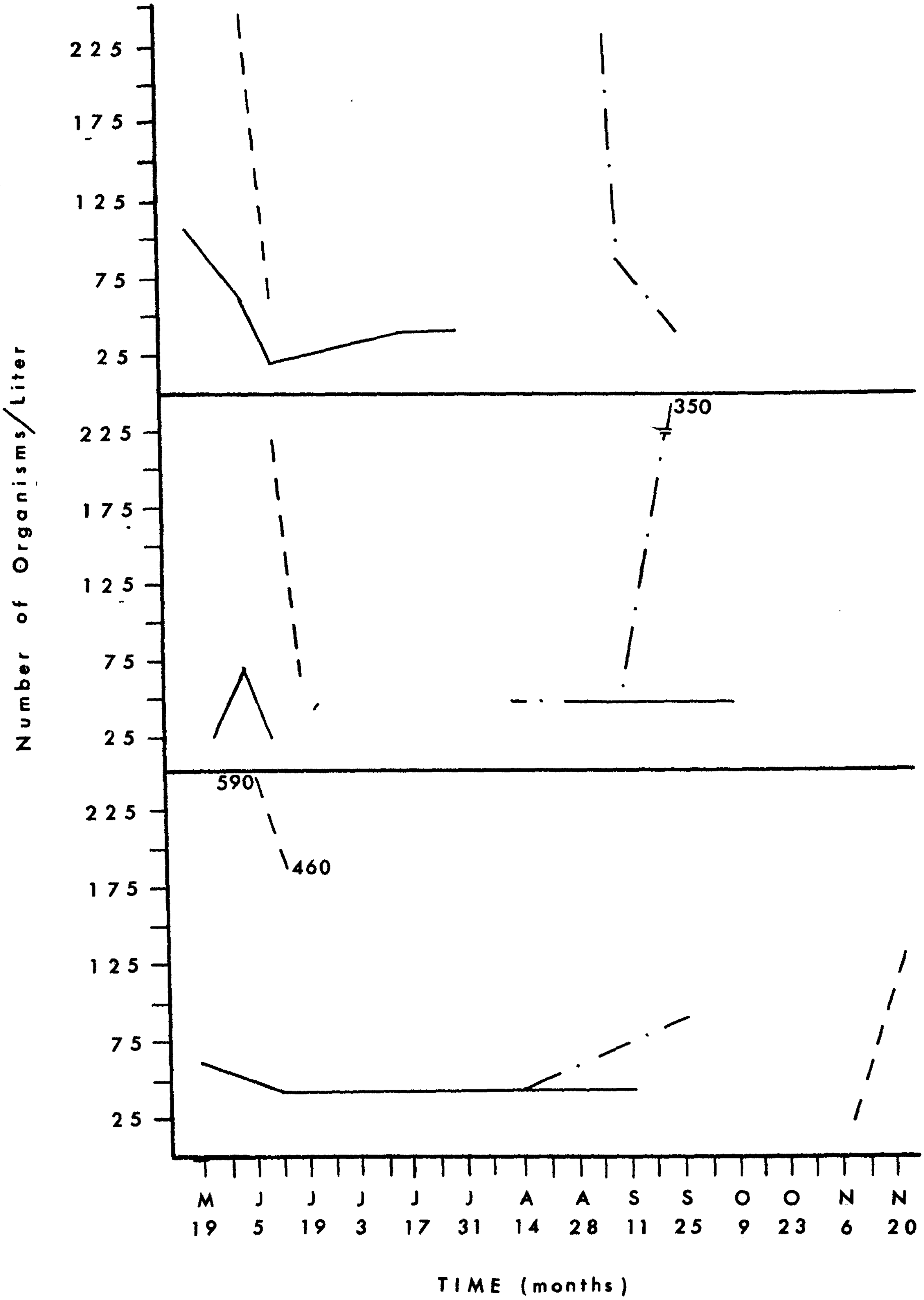

Figure 10A: Station 7 Mississippi River, 1m, 2m, & 3m.
Pyrrophyta ——, Euglenophyta — . —, Chrysophyceae — — — .

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