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AN ECOLOGICAL STUDY OF THE ALGAL POTAMOPLANKTON COMMUNITIES UPSTREAM AND DOWNSTREAM FROM A SANITARY LANDFILL ON RILEY CREEK, COLES COUNTY, ILLINOIS

(TITLE)

BY

Larry W. Coutant

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

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CHARLESTON, ILLINOIS

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THIS PART OF THE GRADUATE DEGREE CITED ABOVE

4 May 1976
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DEPARTMENT HEAD

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INTRODUCTION

The study of the algal flora of aquatic habitats has been rather extensive in the past. The early studies of stream habitats, however, were less frequent than studies on larger bodies of water such as oceans, lakes, and ponds (Butcher, 1940) and studies on "polluted" streams were even less common than those on "natural" algal stream communities (Blum, 1957).

Due to the addition of an ever-increasing variety of domestic and industrial pollutants to streams (Tarzwell and Gaufin, 1953), the resulting effect on the biotic communities therein has become of increasing concern and, therefore, a cause for intensified scientific investigation.

One tool which has become recognized as important in recent years as a means for evaluating aquatic environments is that of community structure. It has been noted that individual genera or species of algae, when considered alone, are not necessarily reliable indicators of organic enrichment; however, entire algal communities do serve as reliable indicators (Palmer, 1956). It has been stated by Patrick (1965) that "...certain species of blue-green algae, red algae, and diatoms may be useful in qualitatively indicating certain chemical and physical conditions of the water as they are related to pollution and that most of these species are tolerant to various types of pollution rather than indigenous to them."

It is, therefore, the intent of this study to characterize the algal flora of two discrete sites in Riley Creek, located in Coles County, Illinois. The sites were selected in relation to the location of a 40-

acre sanitary landfill along part of the stream (Fig. 1) and the purpose was to determine the effect of the landfill and of the surrounding land on the nature of the stream algal flora.

In this and similar studies, there are numerous physical, chemical, and biological factors which affect the stream communities under consideration. The following introductory discussion, supported, where possible, with literature citations, is intended to provide a background on Riley Creek, the nature of the algal flora of streams in general, and the possible roles of the various factors influencing such communities.

BACKGROUND AND LITERATURE REVIEW

Riley Creek, a stream located in an agricultural area in East-Central Illinois, has been the site of two biological studies in recent years. One such study was undertaken as part of a county-wide stream survey in which numerous biological, physical, and chemical parameters of streams were measured in conjunction with the Water Pollution Control Research Series (Durham and Whitley, 1971). The other study of Riley Creek involved the effluents received by the creek from the Anaconda American Brass Company in Mattoon, Illinois and the toxicity of those effluents to various fish (Conlin, 1970).

In the present study, the site which was selected as the upstream site (hereafter called site 1) characteristically had a depth of approximately 0.2 to 0.3 m throughout most of the study period, although there was considerable variation from this estimate due to the presence of large rocks and some pools in the area. The width of the stream at site 1 was approximately 3 to 4 m although this width was also variable throughout the area. The rate of flow was not precisely determined, but due to the presence of pooling and the absence of any steep gradient,

the flow rate is characterized as "slow-moving". There was vegetation in the area consisting of grass on the banks of the stream, and some trees upstream and downstream from the site, but not in the immediate area. There was no visible attached vegetation (i.e., macrophytes and benthic algae) established in the stream bottom.

The site which was selected as the downstream site (hereafter called site 2) was directly below the landfill and characteristically had a depth of approximately 0.6 m and a width of approximately 4 m. The stream flow rate and the vegetational characteristics described above for site 1 were also typical of site 2.

Sanitary Landfills

The landfill located on Riley Creek (Fig. 1) occupies 40 acres and has been run by several persons since 1967(R.L. Dunn, personal communication). The landfill has been in continual operation since its inception in 1967, and has been the subject of considerable controversy because of wind-borne trash loss to adjacent fields and the accumulation of various tire-piercing objects on the adjacent roadway. To the author's knowledge, there has been little public concern about the accumulation of trash in Riley Creek (some of which appears to have been placed there from the bridge adjacent to site 2, see Fig. 1) or the possible impact of the landfill on the creek.

In general, it appears that sanitary landfills are preferable to open dumps (Anon., 1972; Jeter, 1973). State officials recommend sanitary landfills as an alternative to open dumping (Anon., 1972). The positive attributes of sanitary landfills include low operating cost compared to other methods of solid waste disposal and reclamation of

otherwise unusable land (Anon., 1972).

The composition of the refuse within landfills has been investigated to some degree. According to Fonrie (1972), data studied indicate that landfill refuse is composed of the following: "...rags, leather, and rubber 3.8%, other organic waste 80.5%, metal 8.6%, and glass 7.2%. Paper in various forms amounts to well over 50% of the gross total."

One problem associated with landfills is the water which passes through them; the resulting liquid is termed leachate. This leachate may become highly contaminated due to decomposition of the refuse; the nature of the refuse and certain other factors influence the amount of contamination (Ho, Boyle, and Ham, 1974).

To define precisely the nature of the leachates from solid waste disposal sites is highly difficult. According to Boyle and Ham (1974), the composition of leachates from landfills is so variable that any attempt to describe the typical leachate would include such wide concentration ranges that the description would be virtually meaningless. Variations in leachates are, according to Boyle and Ham (1974), due to "...hydrogeology of the site, climate, season, age of the site, height of refuse, and moisture routing through the refuse. Second... many analytical techniques are in error because of interferences, and results are not necessarily comparable. Finally...the apparent leaching quality may be changed (by)...dilution with ground or surface waters, ponding within the refuse, or removal of contaminants during passage through soils...The quantity of leachate generated...is highly variable and depends on the design;...estimates indicate that from one-quarter to one third of the incident rainfall may percolate through a midwestern landfill site."

Although specific concentrations of certain contaminants in leachate are variable, there are certain characteristics of leachate substances produced by sanitary landfills which may be common to a great majority of landfills. Cursory examination of data on landfill leachates as presented by Boyle and Ham (1974) indicates that leachates which have been analyzed may have high concentrations of such chemicals as sodium, potassium, sulfate, chloride, nitrate, ammonia nitrogen, iron, and organic nitrogen. Data also show that COD (chemical oxygen demand) and BOD (biochemical oxygen demand) values may be high. Certain types of gas production have been associated with landfills and include methane, carbon dioxide, nitrogen, and hydrogen sulfide (Anon., 1972).

At least certain types of landfill leachates were quite successfully treated by biological means (Boyle and Ham, 1974) and while chemical treatment was not as successful, such treatment might well be effectively used as a supplement to biological treatment of the leachate (Ho, Boyle, and Ham, 1974).

The degree to which natural communities of microorganisms in the soil and water surrounding a given landfill might change leachate and decontaminate it has not been studied intensively. Zanoni (1972) stated that leachates are highly pollutional in character but dilution, adsorption, and microbial degradation in the surrounding soil tended to reduce the impact on the underground water supply. Zanoni also stated that little new research on the pollutional characteristics of landfills was underway.

Land Drainage

Land runoff has been cited as a non-point source for additions to

a watercourse and this runoff can contribute such pollutants as organics, sediment, pesticides, and nutrients, among others (Harms, Dornbush, and Anderson, 1974). Agricultural land, in particular, is a source of pollutants such as eroded soil, agricultural fertilizers, animal wastes, and pesticides (e.g., Campbell and Whitley, 1970).

One of the most important losses due to runoff from agricultural land is that of phosphorus. It was stated by Kramer, Herbes, and Allen (1972) that, of the phosphorus used in the U.S., 76% is used in agricultural fertilizers; these workers suggest that the major influx of phosphorus into natural waters is from detergents and agricultural uses. The effects of these additions of phosphorus to waters and its relation to eutrophication of them has been well documented (Kramer, Herbes, and Allen, 1974), particularly since phosphorus has been long known as one of the principal limiting nutrients in aquatic ecosystems (Brezonik, 1972).

The factors which affect the loss of phosphorus from agricultural land to streams are cited by Englebrecht and Morgan (1956) as the "nature and amounts of phosphorus in the soil, mode of drainage, topography, intensity and distribution of rainfall, rates of infiltration and percolation, and probably others." One factor which seems to have major importance in the contribution of nutrients (both nitrogen and phosphorus) to receiving waters studied was snowmelt runoff, a large percentage of which was soluble (Harms, Dornbush, and Andersen, 1974).

Another important feature of the runoff studied by Harms, Dornbush, and Andersen 1974) was soil loss, primarily from cultivated fields. This loss was greatest during short rainstorms of high intensity.

Dissolved oxygen concentration in receiving waters also seems to be affected by runoff from agricultural land; lowered dissolved oxygen concentrations have been observed during periods of high flow (Wallace and Dague, 1973). The importance of runoff in lowering dissolved oxygen concentrations of receiving waters is borne out by the fact that land runoff apparently has had a much greater influence in lowering the dissolved oxygen content in the Iowa River than did wastewater discharges (Wallace and Dague, 1973).

Another matter of concern has been the possible effects of pesticides on the ecosystem since these are pollutants associated with agricultural land runoff. It has been shown that algae are particularly resistant to the effects of DDT, up to concentrations of 100 mg/liter, but there is no appreciable degradation of the pesticide by the algae (Christie, 1969). The resistance of algae to the toxic effects of pesticides has also been noted by Vance and Drummond (1969). The problem of pesticides lies, therefore, not in their effects on algae but in the concentration of these pesticides in tissues of animals higher in the food chain (Vance and Drummond, 1969); these organisms are not as resistant as the algae to their toxic effects (Vance and Drummond, 1969).

Stream Algal Communities

The algal flora of any given stream is well described by Butcher (1932) who divided the algae into two components, those that are floating freely in the water and those algae which are sessile--either attached to the riverbed or to any plant or object in the water. The freely floating algae have been given the name potamoplankton by early investigators (see, e.g., Tiffany, 1958) and the attached algae have been

subdivided according to the various substrates (e.g. epipelic, epilithic, epiphytic, etc.) and according to their growth type (Butcher, 1932).

Certain sessile algae commonly associated with flowing waters are discussed by G. M. Smith (1950) who states that the flow rate of a given stream will determine to a large extent the flora which will be found therein. In swiftly-flowing waters, encrusting algae such as Hildenbrandia, Chamaesiphonaceae, various diatoms, Gongrosira, Fridaea, and Rivularia are typically found. Trailing thallus types such as Lemanea, Audouinella, Batrachospermum, and Hydrurus are also found. In more slowly-moving waters, filamentous algae such as Ulothrix, Stigeoclonium, Draparnaldia, Cladophora, Vaucheria, Zygnemataceae, and Oedogoniaceae are common. Filamentous sessile algae are also discussed by Tiffany (1958) who states that probably the most common green filamentous alga in streams of temperate regions is Cladophora.

Sessile algae of streams are discussed in more detail by Butcher (1932) who cites growth types of sessile algae as follows:

a. The 'thalloid' type comprises those algae that are closely appressed and firmly attach by mucilage or other means along a large part of their surface. They are multicellular or colonial forms, e.g., Ulvella, Stigeoclonium farctum, Oncobyrsa.

b. The 'Cocconeis' type comprises those diatoms, that are attached to the substratum by the whole of one surface, e.g., Cocconeis and possibly some species of Amphora and Cymbella.

c. The 'filamentous' type comprises those filamentous algae that are attached to the substratum by a holdfast, e.g., Ulothrix or by a mucilaginous film, e.g., Phormidium.

d. The 'stalked' diatom type includes many genera of diatoms all of which are loosely attached to the substratum by a branched or unbranched mucilaginous pedicel (e.g., Gomphomema), a mucilaginous 'tube' (e.g., Cymbella & Encyonema) or by a mass of mucilage at one end, (e.g. Synedra and Diatoma).

e. The 'unattached' type comprises a tremendous number of colonial Chlorophyceae and Myxophyceae, desmids and diatoms that have no obvious method of attachment, e.g., Cyclotella, Scenedesmus, Closterium.

f. The 'motile' type includes all those algae that are obviously adapted to a free-swimming existence because they possess cilia (sic) or flagellae (sic).

The relation of sessile algae in streams to potamoplankton is discussed by Butcher (1932), who states that the sessile algae are an important source of the potamoplankton because "The continual movement of the current over these growths will wash away a certain number of individuals or portions of individuals which will float downstream...These sessile algae are thus an important source of supply for the river plankton, and in small streams probably a far more important source than any of those mentioned by Krieger (see below)."

The potamoplankton, or free-floating river algae, is a term originally established by Zacharias (according to Butcher, 1932) and included those free-floating organisms in a river whose nature was determined by the pools, backwaters, and current strength.

The actual sources of potamoplankton were listed by Krieger (1927, according to Butcher, 1932) as follows:

1. The districts adjoining the source.
2. The heleoplankton (i.e., from pools on the system).
3. The limnoplankton (i.e., from lakes on the system).
4. Drains and tributaries.

To those sources Butcher (1932) added a fifth, which has already been discussed to some degree, that of the "algal vegetation on the river-bed". The importance of this source was greatly stressed by Butcher (1932) who, however, (1940) indicates that in other studies,

the potamoplankton have shown considerably less resemblance to the sessile algae.

Apparently the source of potamoplankton was of importance in defining the term originally and because of this Butcher (1932) stated that "Zacharias's conception of the potamoplankton should be enlarged" to contain all those organisms that are "floating freely in the water" (of rivers) evidently disregarding their source.

Tiffany (1958) mentions that "the truly autopotamic planktons are generally diatoms" (in streams). The dominance of diatoms in streams is generally accepted and the green algae and blue-green algae form the remnant major portions of the algal flora (Tiffany, 1958). Tiffany also mentions that these plankters are evidently capable of multiplication en route downstream and, therefore, the slower a stream moves, the greater will be the number of individuals in the stream. This is mentioned by Hynes (1970) who also states that many of the organisms comprising river plankton are truly planktonic and capable of reproduction in the rivers. In relation to this reproductive capability it should be noted that the measurement of production in flowing waters (i.e. streams) had not received much attention until the last twenty years (Odum, 1956). Since then (1956), however, there have been several studies involving production in flowing waters (e.g., Doyle, 1971; Brigham, 1972; Brock, 1967; Cushing, 1964; and many others) using periphyton (attached algae) as the tool.

Use of the planktonic (potamoplankton) algae of streams for measurement of the production has seldom been applicable because "much of the community is benthic and heterogeneous rather than planktonic" (Odum, 1956). It was also stated by Odum (loc. cit.) that "any measurement made without the normal turbulent flow may be questioned on the grounds

that production is a function of the current flow." Some work with the resultant community change within light and dark bottles has been done by Smayda (1957) and by Pratt and Berkson (1959) but these investigations were not undertaken in stream environments.

Potamoplankton is then understood to mean that portion of the stream community which is free-floating, regardless of origin. Because this paper deals only with that portion of the potamoplankton which is algal in nature, algal potamoplankton will therefore be used to mean the free-floating algal community of the stream studied (Riley Creek).

Physical Factors

Light

Light is a basic requirement for the growth of primary producers (including algae and photosynthetic bacteria). Light has been recognized as the energy source used in photosynthesis to move electrons against the thermochemical gradient (from Goldman, 1966). The amount of light which reaches a given depth in aquatic ecosystems is inversely related to turbidity and fluctuates according to the angle of the sun with the water (more light enters the water with an increase in the angle of incidence) (Hynes, 1970). A particular factor important to streams is that the ruffled surfaces of flowing water allow more light to enter than does still water and this tends to offset the effect of the generally higher turbidity associated with flowing water and consequent shallower light penetration (Hynes, 1970). Another factor which influences light intensity in streams and rivers is the vegetation along the banks (e.g.,trees); light available to small unaltered streams for photosynthesis may be considerably less than that available to an open

aquatic habitat due to the stream being "roofed over by branches" (Hynes, 1970).

Temperature

One of the axioms associated with temperature and microorganisms is that of an optimum temperature for growth, with decreases in growth rates associated with temperature fluctuations on either side of the optimum. Therefore, temperature is known to govern not only rates of growth and reproduction (Smith, 1950) but also death rates (Gainey and Lord, 1952).

It is common knowledge that chemical reaction rates are generally increased with an increase in temperature. It is noted by Klein (1962) that the speed of a chemical or biochemical reaction is approximately doubled by an increase in temperature of 10 C according to the van't Hoff rule. Klein (Loc. cit.) also states that the validity of the rule is often limited in biochemical or biological processes to temperatures in the neighborhood of 20 C.

Klein (1962) mentions the effects of stream temperatures on the organisms therein; of importance is the fact that microorganisms responsible for breakdown of organic matter are more active at higher than at lower temperatures, which means that stream self-purification will be much more rapid in the summer than in the winter (if one ignores other factors). It should be emphasized, however, that oxygen solubility in warmer water is much less than that of colder water and, therefore, there would be generally less oxygen available in the summer (and, consequently, lower purification rates); thus a heavy pollutional load could deoxygenate a stream much more easily in the summer (Klein, 1962). Also, anaerobic processes are greatly increased with

increases in temperature; putrefaction is four times as great at 27 C as at 8 C (Klein, 1962).

Another important aspect of temperature in relation to stream communities is that the temperatures of flowing waters fluctuate more dramatically than temperatures within still water of similar depth (Hynes, 1970). These fluctuations may amount to as much as 6 C in the summertime (Hynes, 1970) during the diurnal cycle and this variation could then have a great influence on rates of production and respiration of the communities located in a given stream.

Turbidity

The relationship of turbidity to algal community productivity is, in general, inverse, i.e., higher turbidities allow less light to enter and as a result photosynthesis is reduced (Klein, 1962). In some cases, plant life is made impossible by very high turbidity (Klein, 1962). Streams generally have higher turbidities than still waters but generally have low turbidity when the water level is low (Hynes, 1970). Turbidity can be increased in times of low flow merely by the production of more plankton (Shelomov and Spichak, 1960, according to Hynes, 1970).

It has been suggested that any river with continually turbid water will carry little true plankton and rivers which are known to be seasonally highly turbid (i.e., the Volga) may carry limited amounts of plankton during those seasons (Hynes, 1970).

Chemical Factors

Nitrogen

The primary value of nitrogen in aquatic habitats is as a macronutrient for primary producers (primarily phytoplankton and macrophytes).

Nitrogen is recognized as one of the absolute requirements of phytoplankton (Bostwick, 1954) and in this respect it is often stated that nitrogen is one of the two (the other is phosphorus) most frequent principal limiting nutrients (McCarty, 1970; Brezonik, 1972).

There are many sources of nitrogen which contribute to aquatic ecosystems. The following are sources for lakes (Brezonik, 1972). but these would also probably apply as possible sources for a stream:

1. Airborne: rainwater, aerosols and dust, leaves and miscellaneous debris
2. Surface: agricultural (cropland) and drainage, animal waste runoff, marsh drainage, runoff from uncultivated and forest land, urban storm water runoff, domestic waste effluent
3. Underground: natural groundwater, subsurface agricultural and urban drainage, subsurface drainage from septic tanks near lake shores (near streams)
4. In situ: nitrogen fixation, sediment leaching

The basic forms of nitrogen and their transformations in aquatic ecosystems are best understood (or explained) by the concept of the nitrogen cycle. In this cycle inorganic nitrogen in the environment is incorporated into living systems and then is subsequently released, primarily in inorganic forms, back into the environment (Brezonik, 1972). The operation of the nitrogen cycle is portrayed in detail by Figure 2). It should pointed out that except for ammonia exchange with sediments, all reactions in Fig. 2 are the result of biological processes (Brezonik, 1972).

The basic processes which operate in the nitrogen cycle are as follows (Brezonik, 1972):

1. Assimilation-the change of nitrate and ammonia into organic nitrogen via organisms (primarily phytoplankton and macrophytes)
2. Ammonification-organic nitrogen is changed back into am-

monia by organisms (bacteria, zooplankton, autolysis of plant and animal material; bacteria and fungi in bottom sediments)

3. Nitrification-oxidation of ammonia to nitrite and nitrate (aerobic autotrophic bacteria, actinomycetes, and fungi)

4. Denitrification-reduction of nitrate (via nitrite) to molecular nitrogen (N_2) (facultatively anaerobic and anaerobic bacteria in the absence of oxygen)

5. Nitrogen fixation-use of N_2 as a source for production of organic nitrogen (blue-green algae, photosynthetic bacteria, aerobic bacteria (e.g. Azotobacter), anaerobic bacteria (e.g. Clostridium), and facultatively anaerobic bacteria (only under anoxic conditions)

In a stream, it seems reasonable that many of these processes would occur much as they do in a stratified lake. One difference in a stream would be that since continual mixing generally would occur there would be no hypolimnion. Therefore some conditions present in the hypolimnion would not be present. One of these would be the anaerobic conditions commonly associated with the hypolimnion at certain times of the year. This is supported by Holl's statement (1955, according to Hynes, 1970) that streams normally have an oxygen content at or above saturation; certain stretches of streams, however, may have oxygen concentrations which are very low, due to heavy organic pollution (Bartsch, 1967), which would mean that denitrification could not occur to any significant degree in organically unpolluted streams since denitrification is dependent on anaerobic conditions. Therefore, the means for the return of nitrogen to the atmosphere would be limited in a generally highly aerobic stream. Following this line of reasoning, one can conclude that nitrogen fixed by blue-green algae in a stream would not return to the atmosphere until the stream ran into an impoundment of sufficient depth to allow anaerobic denitrification in the lower layers (unless anaerobic

conditions existed elsewhere en route).

Several workers present the nitrogen requirements for growth of algae. For example, Silver and Moore (1971) list 0.1 mg liter^{-1} as minimal for growth while accelerated growth is possible when concentrations exceed 1.0 mg liter^{-1}. Sawyer (1947, according to Harms, Dornbush, and Anderson, 1974) lists critical nitrogen levels to support algal blooms at 0.30 mg liter^{-1}.

Phosphorus

Like nitrogen, phosphorus is another essential nutrient required for algal growth (see, e.g., Bostwick, 1954) and is the second of the two most frequent principal limiting nutrients (McCarty, 1970; Brezonik, 1972). Phosphorus has been emphasized repeatedly as a critical factor in the eutrophication of lakes (e.g., Kramer, Herbes, and Allen, 1972).

The major supply of phosphorus to natural waters is said to be detergents, agricultural sources, the atmosphere, and industrial effluents (Kramer, Herbes, and Allen, 1972). The importance of agricultural lands as a source for phosphorus to streams is stressed by Engelbrecht and Morgan (1959).

Phosphorus may be present in natural waters in dissolved, colloidal, or particulate forms and may exist as orthophosphate, polyphosphate, or in organic compounds (Kramer, Herbes, and Allen, 1972). The cycling of phosphorus in a lake is shown in Fig. 3. The fact that zooplankton are of limited abundance in flowing water (Hynes, 1970) could affect their importance in the phosphorus cycle in a stream. According to Hayes and Phillips (1958), exchangeable phosphorus present in a lake is dependent upon:

1. The net rate at which phosphorus in solution and in particulate

matter enters the lake.

2. The rate at which phosphorus is lost in inorganic precipitates and undecaying organic matter to the lake bottom.

3. The morphometric properties of the lake which include volume, area, depth, thermal stratification, and photosynthetic zone.

These writers further state that the amounts of precipitated inorganic phosphorus in the sediments, the soluble organic phosphorus in the water, and the soluble inorganic phosphorus in the water are in a ratio of 5:5:1, respectively. This means that almost half of the usable phosphorus is tied up in the sediments, an equal amount in organic phosphorus compounds, and about 9% is available as soluble inorganic phosphorus. This is of primary importance since the ability of higher plants to utilize organic phosphorus, if possible at all, is very limited; phytoplankton are able to utilize organic phosphorus to a certain extent, depending on the organisms and the particular organic phosphate present; bacteria are apparently able to utilize almost all (92%) of certain organic phosphates (Kramer, Herbes, and Allen, 1972).

The reason many algae are able to utilize some organic phosphorus is that they produce phosphatase enzymes. It should be emphasized that only certain algae are capable of producing such phosphatases; if orthophosphate becomes limiting, those algae capable of producing phosphatases will have a distinct advantage in competition for phosphorus (Kramer, Herbes, and Allen, 1972).

In view of the growing concern regarding eutrophication in natural waters, values of possible eutrophying levels of phosphorus are of significance. Silver and Moore (1971) point out that the minimum phosphate needed for growth is below 0.01 mg liter^{-1} while accelerated growth of various algae may occur at concentrations of 0.1 mg liter^{-1}. Sawyer,(1947,

according to Harms, Dornbush, and Andersen, 1974) listed 0.01 mg liter^{-1} as the critical nutrient level for support of algal blooms by phosphorus. Studies involving laboratory cultures of algae have shown that phosphate may fail to stimulate growth and can in some cases prove inhibitory (Smith and Bold, 1966; Hamilton, 1969).

pH

Hydrogen ion concentration, commonly referred to as pH ($pH = -\log [H^+]$), is interrelated with many physical and chemical factors of an aquatic system and is of considerable importance to all biotic factors, including algae.

The pH variation in lakes with normal calcium content is commonly within the range of 7 to 9 (Ruttner, 1953). The pH of natural waters is variable, depending to a great degree upon the influence of the plant and animal community therein, and may be a useful tool for study of the biotic community.

The relationship of pH to the biotic community is due to the production and uptake of CO_2 by the community. Since the pH is dependent upon the amounts of carbon present in all its inorganic forms (total alkalinity) in the system (see Moore, 1939), and since the biotic community is continually adding CO_2 to the system (respiration of all organisms) and periodically absorbing CO_2 from the system (photosynthesis by phytoplankton), it is evident that pH is directly related to the biological processes of the biotic community.

By using the relationships between pH, CO_2, photosynthesis, and respiration one can, in fact, measure the pH change in water over a period of time, and if the temperature and carbonate alkalinity are known, the amount of CO_2 change within the system is calculable. By applying this concept dur-

ing the daylight hours, one can estimate the primary production (CO_2 uptake) of the system. This method is explained in some detail in a paper by Ryther (1956) who gives some advantages and disadvantages of the procedure.

Oxygen

The majority of living organisms require oxygen for life (Bartsch, 1967), and since stream life is no exception, it is necessary to examine the factors which control oxygen levels in streams.

The importance of oxygen in stream ecosystems often lies in the relationship of the dissolved gas to the self-purification of the stream (Klein, 1962). Oxygen is, therefore, a key link between the oxygen-producing plants of a stream and other microorganisms which are dependent on oxygen for the decomposition and purification process. Because of this fact, it is of primary importance that the rate of photosynthetic production of oxygen exceeds the requirements of bacteria and other microorganisms (as well as other aquatic life) involved in the decomposition of organic materials (Klein, 1962). It has been noted by Bartsch (1967) that when certain streams become organically overloaded (e.g., by sewage effluent), the stream becomes oxygen-depleted due to excessive uptake by microorganisms (e.g., bacteria) which may select against "more desirable animals. It also has been stated that the oxygen content of small turbulent streams is at or above saturation (Holl, according to Hynes, 1970).

Since oxygen is a product of photosynthesis, its presence has been utilized as a quantitative tool for determining primary productivity of aquatic communities (see Ryther, 1956); the procedure is adaptable to the study of stream communities (Odum, 1956).

According to Odum (1956), four main processes occur during a daily

cycle which affect the oxygen concentration of a stream, as follows:

1. There is a release of oxygen into the water as a result of photosynthetic productivity during the day by both benthic plants and phytoplankton.

2. There is an uptake of oxygen from the water as a result of the respiration of benthic organisms, plankton communities, and sometimes chemical oxidation.

3. There is an exchange of oxygen with the air depending upon the saturation gradient.

4. There may be an influx of oxygen with accrual of ground water and surface water along the stretch. In most of the examples discussed, accrual is assumed to be negligible relative to the other influences.

One factor which affects the solubility of oxygen in the water is temperature: the solubility varies inversely with the temperature This would seem to give higher nightly concentrations of oxygen in streams than daylight concentrations. However, due to the photosynthetic production of oxygen during daylight hours and the lack thereof at night, combined with oxygen consumption by respiring organisms, the daily oxygen variation is actually reversed (from Hynes, 1970). The daily curve of oxygen content in a "normal" stream might be like that of Figure 4.

Biological Factors

Primary productivity

Primary production can be defined as the accumulation of certain primary organic compounds of high potential chemical energy by means of external energy, both radiant and chemical (Vollenweider, 1974). Thus primary production not only includes photosynthetic processes but also chemoautotrophic processes.

There are many gaps in the knowledge concerning primary producers. These gaps include such things as the flow of chemicals other than car-

bon in the system, an appropriate theoretical framework of the structure and dynamics of the plant communities, and the inability to measure direct energy flow (Vollenweider, 1974).

The concept of the food pyramid emphasizes the actual importance of the primary producers. The basic idea is that the primary producers (i.e., algae and certain bacteria) synthesize the materials needed for life from certain inorganic chemicals. All other organisms are directly or indirectly dependent upon the primary producers for these synthesized substances; these other organisms cannot synthesize their own organic compounds from inorganic compounds and gain energy in the process; they must utilize energy stored in organic compounds synthesized by the primary producers.

At present, much work with primary production of aquatic environments is centered around photosynthetic primary producers (i.e. phytoplankton, benthic algae, and macrophytes) since they comprise the majority of producers in most aquatic environments; the production by chemosynthetic autotrophs is minimal in comparison (Frey, 1956).

Since the production of organic matter in water is primarily a result of photosynthesis, the measurement of primary production then becomes a matter of measuring the rate of photosynthesis (Ryther, 1956). The measurement of photosynthetic rates may be accomplished by the following means:

1. Oxygen production over time based on the photosynthetic equation in which the oxygen produced approximates the carbon dioxide assimilated.

   $$CO_2 + H_2O \xrightarrow[\text{chloroph.}]{\text{light}} CH_2O + O_2$$

   Methods of measurement include:

   a. Light and dark bottle technique of Gaardner and Gran (1927, according to Pratt and Berksen, 1959)

b. Use of upstream-downstream oxygen measurements and the resultant oxygen (or carbon dioxide) changes (Odum, 1956)

2. Carbon dioxide consumption based on the above equation in which the number of moles of carbon dioxide assimilated is equivalent to the number of moles of carbohydrate synthesized.

Methods of measurement include:

a. Change in pH using equations of Moore (1939) which relate pH, temperature, and total carbonate alkalinity (Ryther, 1956)

b. The uptake of ^{14}C based on the following assumption (Ryther, 1956) (K is the isotope effect)

$$\frac{\text{Activity of plankton}}{\text{Activity of } {}^{14}CO_3^{=} \text{ added}} (K) = \frac{\text{Total C assimilation}}{\text{Total C available}}$$

3. Uptake of phosphorus

Methods include use of ^{32}P and measurement of uptake rates (from Ryther, 1956)

All of the methods mentioned above have advantages and shortcomings. Many are not effective for use in a stream situation because of certain drawbacks.

The light and dark bottle method, first described by Gaardner and Gran (1927, according to Pratt and Berkson, 1959) has the advantage of measuring not only net production of plant matter, but also gross production and respiration. The method is easy to use and the requisite materials are inexpensive and common in laboratories. The limitations of the method are: 1) The accuracy of measurement is reduced by the very result of primary production--that is, the community in the light bottle increases with time and the rate of respiration, therefore, would not be comparable to that in the dark bottle, which is receiving no sunlight--thus no growth (Pratt and Berkson, 1959) 2) The method is not applicable to a stream community because of the reasons submitted by Odum

(1956); the stream community is often benthic and heterogeneous; therefore, a measure of stream productivity based on algal potamoplankton alone (floating plankton) would exclude an important aspect of the primary production; in addition, primary production has been shown to be a function of current (Olinger, 1968). As a result, the measurement of primary production without turbulence would render the data questionable. In addition, since some of the respiration of the light and dark bottles may be due to bacteria, and bacterial growth has been known to be a function of surface area (Zobell and Anderson, 1936 according to Pratt and Berkson, 1959), a measurable growth in the light and/or dark bottles could produce increases in respiration which would not be present in the outside environment (Pratt and Berkson, 1959). This would then result in an overestimation of respiration and an underestimation of net photosynthesis (Pratt and Berkson, 1959).

One further limitation of oxygen use for production estimates is the assumption that oxygen is released in a one-to-one ratio as carbon is assimilated. Due to production of growth products (e.g., fats, proteins) other than carbohydrates the oxygen : carbon dioxide ratio has been shown to vary significantly from unity (Ryther, 1956).

The method of upstream-downstream measurements of oxygen is a method for use in flowing waters discussed by Odum (1956). It has the advantage of measuring the stream community under completely natural conditions. One disadvantage of this technique is that the actual rates of diffusion of oxygen into and out of the stream are needed so that the influence of this factor can be accounted for and subsequently deleted. In order to do this, the diffusion coefficient for the particular stream in question must be experimentally derived if it is unknown. Another disadvantage is

that the methods described assume no accrual of ground water, which might have a different oxygen content than that of the stream and thus be a significant factor.

One advantage of the pH technique is that it also measures primary production under completely natural conditions. The method is also convenient and requires little more equipment than is found in most laboratories (pH meter, thermometer, and chemicals for alkalinity determinations). A disadvantage of the pH technique is that because of the buffering capacities of most fresh waters, a large uptake of CO_2 is necessary for an observable change in pH (Ryther, 1956). With the equipment available to most laboratories, the lower limit of sensitivity of the method might be 0.1 pH unit (Ryther, 1956). This would be equal to an assimilation rate of 0.1 to 0.5 mg CO_2 $liter^{-1}$ depending upon the alkalinity and in many lakes of high alkalinity, and in seawater, this method would be useful only in areas of plankton blooms (Ryther, 1956).

The uptake of ^{14}C is a more recently developed method for measuring primary production. A distinct advantage of this method is that it is the most sensitive (Ryther, 1956). Other advantages are that ^{14}C is a weak Beta emitter and thus hazard and safety problems are minimal and ^{14}C samples can be stored for long periods without a noticeable change in their specific activity because their half-life is very long (4700 years) (from Vollenweider, 1974). One obvious disadvantage would be the cost of equipment for preparation and analysis of the samples (e.g. a sample preparator, sample oxidizer, and liquid scintillation counter). Also, the cost of prepared ampoules containing a measured amount of ^{14}C (e.g., approx. $125 for 100 ampoules in 1975) might be excessive were sampling to be done on a large scale. Another disadvantage is that it is

not known whether ^{14}C methods measure net or gross productivity due to possible loss of photosynthesized ^{14}C through concurrent respiration (Fogg, 1974). A 4% loss in a 4-hour experiment was rather arbitrarily assumed by Steeman Nielsen according to Ryther (1956).

The use of radioactive phosphorus has been cited as of limited value due to the inability to relate ^{32}P assimilation to organic production (Ryther, 1956). This is due to the inconsistency of phosphorus content in various plants which may be due to a large proportion of the phosphorus that may be loosely bound and freely bound (Goldberg, Walker, and Whisenand, 1951 and Rice, 1953 according to Ryther, 1956). Even though the phosphorus assimilated may be measured, these measurements cannot be directly related to specific uptake of various other nutrients (e.g., carbon).

The writer, after considering the possible methods for measurement of primary production, felt that, based on convenience and expense, the light and dark bottle method described by Gaardner and Gran (1927, according to Pratt and Berkson, 1959) would be used in this study. Although the actual values obtained may be questioned on the basis of no current flow within the bottles, the study was designed to give insight into possible differences in photosynthetic capabilities between algal potamoplankton at sites 1 and 2 and not to give results for comparison to other stream environments. Also, this method allowed for enumeration of algal potamoplankton populations within the light bottles after 1 day's growth, which allowed for computation of growth coefficients of the total population, specific groups (divisions), and/or individual taxa. Thus, if any one group of algae were more inhibited or stimulated photosynthetically than the other groups, this result could be measured.

MATERIALS AND METHODS

Water samples were collected from the two sampling sites noted earlier (Fig. 1) according to a schedule of weekly sampling for the first month (i.e., except week 2--no data) and a biweekly schedule for the next 9 sampling periods. Unfiltered water was collected in plastic one-liter bottles which had been washed previously with a 5% solution of "Liqui-Nox" in distilled water and then rinsed with distilled water. The bottles containing the samples were then placed on ice in an insulated chest. Samples of unfiltered water were then taken from the stream and placed in light and darkened bottles (wrapped in black opaque tape) for the measurement of primary production--the dissolved oxygen concentration was then measured using a YSI Model 54 oxygen meter according to the manufacturer's specifications. The bottles were then placed in the stream at the the edge of the water at a depth of approximately 0.1 meter. Air and water temperatures were taken at both sites 1 and 2 with the YSI meter.

The original samples taken and placed on ice were then immediately transported to the laboratory for chemical analyses. The pH was measured with a Fisher Accumet pH meter; subsequently, analyses for ammonia, nitrite, and nitrate nitrogen, and orthophosphate were made with a Hach Kit Model DR-EL 12 spectrophotometer, all within 2 hours after collection. The methods used for these analyses were those described by the manufacturer in the methods book accompanying the Model DR-EL 12 spectrophotometer.

Upon completion of the chemical analyses, 6 ml of Lugol's solution (1 part Iodine, 2 parts potassium iodide, 20 parts water, and 2 parts glacial acetic acid) were added to the remainder of the water sample. These samples were then stored in the dark at 4-8 C for later quantitative and qualitative analysis.

Twenty-four hours after the placement of light and dark bottles in the stream at sites 1 and 2, the bottles were removed and their oxygen concentration was measured. The light bottles were then preserved using 6 ml of Lugol's solution and stored with the original samples in the dark at 4-8 C; the dark bottle samples were discarded and the bottles cleaned for reuse.

Phytoplankton quantification was carried out utilizing the membrane filter method as described by McNabb (1960) and suggested by Weber (1973). (This method was chosen because of its convenience and the semi-permanency of the slides made which allows for quick future reference.) In this method, a known volume of water (usually 25 ml) was filtered through a 0.45 micrometer Millipore filter of 47-mm diameter marked with a grid network. The filter disk was allowed to dry and then a strip was cut such that it would fit under a 22 x 50-mm cover slip; the strip was placed in immersion oil over which was placed the cover slip on a standard glass slide. All such slides were stored horizontally in the dark until analysis.

Upon examination of the slide at a later date, an oil immersion objective (total magnification 1000x) was used to identify and enumerate all algae within a visual strip between two grid markings on the filter disk. Two of these strips were examined on each filter disk and if a total of 200 organisms had not been tallied in the combined total of these two strips, then more strips were examined until either (1) at least 200 organisms were tallied or (2) a total of ten such strips had been examined. The organisms counted by this method were converted to no. liter^{-1} by the following equation:

$$N = \frac{n}{v_f} \quad \frac{100\ (wg)}{wf} \quad \frac{V_i + F}{V_i}$$

where: N = the number of organisms liter^{-1} original sample
n = the number of organisms tallied per strip

v_f = the volume of water filtered in liters
v_i = the volume of water left after chemical analyses were run (before addition of preservative) in ml
100 = the constant for the number of grid squares used for filtering
wg = the distance in microns between two parallel grid markings
wf = the distance in microns across the field of view using the oil immersion objective (total mag. 1000x)
F = the volume of preservative added in ml

The growth coefficients were calculated by the following formula:

$$K = \frac{C_f}{C_i}$$

C_i = the number of algae ml^{-1} in the original water sample
C_f = the number of algae ml^{-1} in the light bottle after 1 day's growth
K = the growth coefficient day^{-1}

RESULTS

The results of the physical, chemical, and biological analyses are presented in Figures 5 through 17 and Tables 1 through 6. All values given are the result of laboratory and field measurements and computations except for those values in Figure 5 which were obtained from another source (see Background and Literature Review).

The trends observed from the results are as follows: The total algal potamoplankton community concentrations at both sites showed a general decrease through time as did gross primary production, growth coefficients, daylength, air temperature, and water temperature (Figs. 5, 6, 7, 15a, 15b, 16, 17, and Table 1). The community composition showed a general dominance at both sites by members of the Bacillariophyta and Chlorophyta throughout the sampling period with a distinct increase in the dominance of members of the Cryptophyceae during week 12 which continued through week 22 (Figs. 18 and 19) at both sites. The growth coefficients computed show that site 1 had higher growth coefficients for the total population than site 2 during the first 3 sampling dates and the last 3 sampling dates while site 2 had higher values for weeks 8 through 14; the values for the last 3 dates at site 2 were negative--those values obtained for site 1 remained positive (Fig. 17 and Table 1). Table 3 shows the growth coefficients for the major groups at sites 1 and 2. Of importance is the high growth coefficient at site 2 for the Chlorophyta during week 6 and the considerably lower overall growth coefficient for site 2 on that date (Tables 1 and 3). Other differences between the overall growth coefficients (Table 1) and growth coefficients of major groups (Table 3) occurred during week 12. General trends for chemical and physical factors (excluding those mentioned above) were not apparent but there appeared to be a close correlation between sites

through time for many of the factors (i.e., nitrite, nitrate, orthophosphate, and dissolved oxygen) (Figs. 10, 11, 12, and 14, Table 1). A close correlation between sites was exhibited by turbidity and by ammonia through time with the exceptions of weeks 6 and 8 (for turbidity) and weeks 6, 12, 14, 20, and 22 (for ammonia) (Figs. 8 and 9, Table 1).

The actual concentrations of the algal potamoplankton populations at sites 1 and 2 varied noticeably in concentration-from 684 organisms ml^{-1} to 22960 organisms ml^{-1}; the highest concentrations occurred generally earlier in the sampling period and the lowest concentrations occurred later in the sampling period; notable exceptions were the low concentrations of organisms found during week 6 and both sites (Figs. 15a and 15b, Table 1).

The results of the primary production and growth coefficients show values of gross primary production to range from 0.1 mg O_2 produced $liter^{-1}$ day^{-1} to 5.2 mg O_2 produced $liter^{-1}$ day^{-1} and growth coefficient values to range from -0.445 to +3.625. The highest growth coefficients for sites 1 and 2 (3.625 and 2.398, respectively) were during week 6 when initial algal potamoplankton populations were low (1277 and 1540 organisms ml^{-1}; sites 1 and 2, respectively) in comparison to other populations of that period (Table 1).

The concentrations of certain of the chemical factors were of importance during the sampling period; the concentration of ammonia on the various sampling dates was at or above 0.40 mg $liter^{-1}$ for both sites on all sampling dates with the exception of week 1 (Fig. 9 and Table 1). Nitrite concentration dropped rather sharply at site 2 during week 6 although during the rest of the sampling period, values ranged from 0.014 mg $liter^{-1}$ to 0.20 mg $liter^{-1}$. Nitrate concentrations never dropped below 0.90 mg li-

ter^{-1} at either site on any sampling date; however, values did reach as high as 6.3 mg liter^{-1} during week 1 at site 2 (Table 1). Orthophosphate levels never dropped below 0.02 mg liter^{-1} at either site during the entire sampling period; values were typically much higher (Table 1).

DISCUSSION

The overall trends of decrease illustrated by daylength, air temperature, water temperature, gross primary production, growth coefficients, and algal potamoplankton population levels illustrate a seasonal variation which would be expected; there was a decrease in the maximum possible intensity of light and the daylength (Fig. 5) with a resultant decrease in temperature (air and water) (Figs. 6 and 7, respectively), gross primary production (Fig. 16), growth coefficients (Fig. 17, Tables 1 and 3), and finally algal potamoplankton concentrations (Figs. 15a and 15b, Table 1). Since it is commonly known that the maximum possible light intensities would decrease from week 1 through week 22 (in this study), the fact that laboratory stream research has shown primary production to be approximately linearly related to light intensity (at certain intensities) (McIntire, et. al., 1964) would explain in part the reduced gross primary productivity rates through time as illustrated in Fig. 16 and Table 1. Also, the angle of the sun with the water would decrease through time; this would mean that less light would be able to enter the water (see Hynes, 1970) and the reduced light intensities in the water would tend to lower photosynthetic rates further. Then too, the reduction in water temperatures by more than 20 C (from the beginning to the end of the sampling period) would theoretically reduce biological reaction rates roughly by more than 75% (using the general biological rate change based on temperature change--see Klein, 1962). These three occurrences could then easily account for the tremendous decrease in primary production seen at both sites (Fig. 16 and Table 1) and for the decrease in growth coefficients at both sites (Fig. 17 and Table 1).

The community composition showed a general dominance of members of the Bacillariophyta and Chlorophyta throughout the sampling period; the

dominance of these two groups in streams is in agreement with the statement by Tiffany (1958) that diatoms (Bacillariophyta) were generally dominant, with greens (Chlorophyta) and bluegreens (Cyanophyta) forming the other major portions of the algal flora. The bluegreen algae (Cyanophyta), however, did not form a major portion of the algal potamoplankton in this study (Figs. 18 and 19). A group not mentioned by Tiffany (1958) which was of considerable importance in the community composition in the latter half of the study was the Cryptophyceae; this group composed a major portion of the algal community from week 12 through week 22 (Figs. 18 and 19, Tables 2 and 4). At least certain members of this group (e.g., Cryptomonas) apparently may be indicative of completion of decomposition of organic matter in water (Brinley, 1942) although certain members of this group may also grow in waters rich in nitrogenous and organic materials (Smith, 1950). According to the values obtained for ammonia, nitrite, and nitrate, Riley Creek might best be characterized as rich in nitrogenous materials; minimum values of nitrogen for accelerated growth by phytoplankton are listed as being 1.0 mg liter^{-1} (Silver and Moore, 1971)--the combined values for nitrogen concentrations in Table 1 show that inorganic nitrogen was in excess of 4.5 mg liter^{-1} at both sites during the appearance of the relatively high concentrations of members of the Cryptophyceae (week 12) and remained in excess of 2.0 mg liter^{-1} throughout the remainder of the sampling period. Members of the Cryptophyceae continued to remain important in the community composition at both sites 1 and 2 throughout the remainder of the sampling period. It is quite possible, however, that an unknown factor or a combination of several factors may be responsible for the appearance and dominance of this group.

Differences between sites 1 and 2 in total numbers of algal potamo-

plankton present are less obvious than those seasonal variations mentioned, but one observable difference is that the total population at station 1 was higher than that found at station 2 in 8 out of 12 sampling weeks (Figs. 15a and 15b). One possible reason for the higher populations at station 1 on the majority of the occasions is that the dilution of the population by incoming ground water en route downstream was greater than the increase in population due to reproduction and additions from the benthic algae. This possibility is partially borne out by the fact that the size of the stream at station 2 was generally larger than at station 1 (see materials and methods) indicating additions of water en route (assuming similar velocities at the two sites and absence of pooling). Other possible explanations for the difference in populations between sites are the settling out of some organisms en route downstream or the disintegration of cells en route by contact with intolerable chemical or physical conditions, or loss by other means. If cell disintegration did occur, then it seems logical that the preferential cell disintegration of certain taxa of algae might occur since not all algae have the same tolerances to environmental conditions; this is in part supported by the fact that the community composition showed that members of the Cryptomonadales comprised a lower percentage of the total population at site 2 than at site 1 on 11 out of 12 sampling dates (Table 2). This may represent an influx of greater numbers of other groups (i.e., diatoms and greens), however, from other sources and/or a greater reproductive capability of the greens and diatoms while en route downstream (which might tend to offset the dilution effect of incoming ground waters--while the Cryptomonadales were inhibited or more limited and could not maintain their percentage of the population).

The growth coefficients of the Cryptomonadales as well as the other

major groups (Bacillariophyta and Chlorophyta) showed overall similarities between sites 1 and 2 through time but there are noticeable differences. During the first 3 weeks of primary production measurement (weeks 3 through 6), the growth coefficients of the total algal potamoplankton population at site 1 remained higher than those growth coefficients at site 2 (Fig. 17 and Table 1); this trend is not as well supported by the growth coefficients computed for each of the 3 dominant groups of algae encountered (Table 3). In Table 3 it is seen that during week 6, growth coefficients at site 2 for members of the Chlorophyta were considerably higher than any of the values for the major groups at site 1 but the community composition was such that 88% of the population at site 2 was composed of diatoms and their growth coefficient was considerably lower than the Chlorophyta growth coefficient at site 2. Thus, even though the Chlorophyta at site 2 had the highest growth coefficient of any group on that date at either site, the predominance of diatoms in the population (site 2) and their lower reproductive rates brought the growth coefficient for the entire population below that of site 1.

The next 4 weeks (weeks 8 through 14) show that values of growth coefficients at site 2 were higher than those at site 1 (Figure 17 and Table 1); the values in Table 3 for the 3 major groups encountered show that during weeks 8, 10, and 14 the growth coefficients of the major groups were almost unanimously higher at site 2 than at site 1. During week 12, however, the coefficients for the diatoms and greens at site 1 were actually noticeably higher than the values for those groups at site 2; these two groups (diatoms and greens) were, however, overshadowed by the abundance of the Cryptomonadales which showed a negative growth coefficient at site 1 and a distinctly positive growth coefficient at site 2.

The final 3 weeks of data for growth coefficients of the total population showed that those growth coefficient values for site 1 were higher than those values for site 2; the differences in growth coefficients between sites were most dramatic during these last 3 weeks (Fig. 17 and Table 1). Site 1 algal growth was shown to be positive by the growth coefficients while site 2 showed distinctly negative growth coefficients. The growth coefficients for the 3 major groups (Table 3) were generally in agreement with the overall growth coefficients of the total population.

Results of measurement of changes in population within light primary production bottles are available for marine environments (Smayda, 1957; Pratt and Berkson, 1959). The values for growth obtained by Smayda (1957) show that the flagellates present in the light bottles were not able to successfully increase their population during 1-day growth experiments but diatom populations increased significantly over 1-to 2-day experiments (growth coefficients per day ranged from 0.45 to 0.58). The flagellates which were studied by Pratt and Berkson (1959) did show positive growth coefficients but their growth was generally at slower rates than the rates of diatoms. Percent increase day^{-1} of the flagellates studied by Pratt and Berkson (1959) showed a range of -24% to +82% (equivalent to growth coefficients of -0.24 to +0.82) in the light primary production bottles; these values show some similarities to the values obtained in this study for the Cryptomonadales (which are flagellates); the lowest rate was -42%. In this study, however, the highest rates of increase day^{-1} for this group of flagellates was 310% (excluding week 6 at site 2 which was based on low concentrations of organisms), nearly 4 times the maximum value obtained for flagellates by Pratt and Berkson (1959). Percent increase day^{-1} of the diatoms in this study ranged from -63% to +434%; these values compare favor-

ably to those values obtained by Pratt and Berkson (1959) which ranged from -36% to +523%.

The growth capabilities of the algal potamoplankton populations as illustrated by Fig. 17 and Tables 1 and 3 clearly show that these organisms are capable of growth and reproduction. Whether the concentration of these organisms would increase or decrease en route downstream would be dependent upon reproductive rates of the organisms, the additions of organisms from other sources en route, the loss of organisms through settling and predation (and other processes), and the rate of dilution by additions of ground and surface water along the way.

General trends for chemical and physical factors (excluding those discussed above) were not as apparent as those trends of the algal potamoplankton community but there appeared to be a close correlation between sites 1 and 2 through time for several of the factors (i.e., nitrite, nitrate, orthophosphate, and dissolved oxygen) (Figs. 10, 11, 12, and 14, Table 1). The generally close correlation between these factors would be expected since the water which flows through site 1 would flow through site 2 a short time later (see Fig. 1). Of interest is the fact that several factors measured (i.e., orthophosphate, nitrite, and nitrate) showed lower values at site 2 than at site 1 on a large majority of the sampling dates. These values correlate well with the reduced concentrations of algal potamoplankton seen at site 2 on a majority of the dates. Once again, one possible explanation seems to be that a dilution of these factors is occurring by additions of water along the way. A more likely explanation is that the nutrients mentioned are absorbed by algae and macrophytes as they are flowing downstream, thus the concentrations were lowered. Quick absorption of these nutrients by microorganisms in streams is in

fact pointed out by Hynes (1970). The most likely reason for the higher dissolved oxygen concentrations downstream on most of the earlier sampling dates (Fig. 14 and Table 1) is that the oxygen is produced by algae en route downstream and by benthic algae and macrophytes in greater quantities than it is being absorbed through respiration by the algal population and all other organisms in the stream; thus, there would be a net increase in the oxygen content of the stream--this increase in oxygen content downstream is noted by Odum (1956) and can be the basis for estimations of primary production in streams. Other factors which would have an influence on the degree of change in dissolved oxygen en route downstream would be diffusion rates out of or into the stream and the accrual of oxygen through ground water along the stretch of the stream (Odum, 1956). The lower oxygen concentrations observed at site 2 on the last 2 sampling dates would seem to indicate that the respiration of organisms in the stream was exceeding the production of oxygen and the influx of oxygen by diffusion and ground water accrual. It seems likely that there was a negative net rate of primary production (during these last 2 sampling periods) considering the negative growth coefficients of the algal potamoplankton at site 2 during weeks 16 through 20 (Fig. 17 and Table 1). In order that there could occur a lower dissolved oxygen concentration at site 2 than at site 1 during these 2 weeks, the rate of respiration would not necessarily have to exceed the rate of photosynthesis; since the temperature of the water might be rising during the day, the oxygen would be diffusing out of the water due to the lower solubility of oxygen in water at higher temperatures (Hynes, 1970).

The correlation between sites 1 and 2 for ammonia and turbidity was not as distinct as for those nutrients mentioned above but on several dates the values between sites were quite close (Figs. 8 and 9, Table 1).

Turbidity values were quite similar between sites on all of the sampling dates with the exception of weeks 6 and 8; the explanation for the considerably higher values of turbidity seen at site 2 on those dates might be explained by the fact that two rainstorms passed to the south of sampling sites 1 and 2 on the days of sampling for weeks 6 and 8, although no rain occurred at either site; water coming in from the semi-permanent branch of the creek to the south (Fig. 1) could have been the source of the added turbidity on the two dates at site 2. This possibility seems likely since the turbidity is related to the discharge rate (Hynes, 1970) and if the stream flow were increased, there would be a resultant increase in turbidity. The values for turbidity were generally quite low at both sites; only the two occasions mentioned above gave turbidity readings of higher than 25 JTU (Fig. 8 and Table 1). The low turbidity values commonly observed in this study can be contrasted with the statement by Lockart (1971) that the main source of water pollution in slower moving streams is siltation. It is also noted by Smith (1969) that silt is one of the main water pollutants associated with agriculture. Perhaps if Riley Creek had been sampled frequently during rainfall and shortly afterward, more values such as those at site 2 during weeks 6 and 8 would have been observed. Ammonia seemed to give the most erratic results between sites during the sampling period (Fig. 9 and Table 1). In particular, values during weeks 6 and 8 at site 2 showed definite increases over those values found at site 1; the one single event which seems to follow the same pattern during that time is the sudden increase in turbidity at site 2. There may be a relationship between the increase in these two factors (ammonia and turbidity) on those dates--possibly the rainfall to the south brought increased amounts of ammonia into the semi-permanent tributary as well as increased tur-

bidity. Considerable differences in concentration of ammonia were noted between sites during weeks 12, 14, 20, and 22; each time the concentrations at site 2 dropped considerably below those values obtained at site 1 (Fig. 9 and Table 1). These differences could be attributed to the assimilation of ammonia en route downstream by the algae; since ammonia can be directly assimilated by the algae (Brezonik, 1972), this would explain the large drop in ammonia concentration on these 4 dates, although dilution and other factors must be considered also.

The actual concentrations of the algal potamoplankton populations at sites 1 and 2 varied between 684 organisms ml^{-1} and 22960 organisms ml^{-1}; as would be expected, the higher concentrations generally occurred earlier in the sampling period and lower concentrations generally occurred later in the sampling period. One occasion which showed a low population early in the sampling period was week 6 at both sites 1 and 2 (1277 and 1540 organisms ml^{-1}, respectively). These relatively low concentrations of organisms were apparently not due to reduction of the population by toxic effects of any substance or limitation by nutrients since sites 1 and 2 showed their highest values for growth coefficients during the entire sampling period (3.625 and 2.398, respectively) (Figure 17 and Table 1). One possible explanation could be the removal of many of the planktonic population prior to the day of sampling by a spate, thus the algal potamoplankton population was in the process of reestablishing a higher population concentration.

The actual concentrations of the nutrients measured in this study suggest that both sites 1 and 2 were rich in nutrients; minimum values for growth of phytoplankton presented by Silver and Moore (1971) were 0.1 mg $liter^{-1}$ for nitrogen and less than 0.01 mg $liter^{-1}$ for phosphorus while

excessive growth of algae may be observed if values for nitrogen are above 1.0 mg liter^{-1} and phosphorus concentrations are above 0.1 mg liter^{-1}. Data from this study show that nitrogen values were always greater than 1.4 mg liter^{-1} (Figs. 9, 10, and 11, Table 1) and phosphorus values (orthophosphate) were never below 0.02 mg liter^{-1} and were above 0.2 mg liter^{-1} on all sampling dates except weeks 1 and 3 (Fig. 12 and Table 1). These high values for nitrogen and phosphorus might be expected since Riley Creek runs through agricultural land and agricultural uses of phosphorus are cited by Kramer, Herbes, and Allen (1972) as one of the major contributors of phosphorus to natural waters.

The individual taxa identified in this study and listed in Table 6 show the predominance of members of the Bacillariophyta followed by members of the Chlorophyta. Some insight into the water quality at sites 1 and 2 might be gained by an accurate knowledge of the tolerances and specific requirements of the various individual taxa listed. Certain trends were noticed for some of the individual taxa and these are as follows: The various taxa (see Table 4) which showed a definite decrease in concentration and abundance seasonally were green flagellates, Scenedesmus spp., Stichococcus-like organisms, and Cyclotella spp. Seasonal increases in abundance were observable for members of the Euglenophyta, the pennate diatoms, including Navicula spp. and Nitzschia spp., and the Cryptomonadales. There may be a combination of factors which work to cause these seasonal trends; the most obvious factors which might influence the seasonality of these organisms would seem to be daylength, light intensity, and temperature.

Of interest as a final note were certain of the taxa which were found in Riley Creek--Scenedesmus quadricauda, Nitzschia palea, and the algal genera Nitzschia, Navicula, Scenedesmus, and Euglena were found with in this study. These taxa are listed by Palmer (1969) as organisms very tolerant to organic pollution.

SUMMARY AND CONCLUSIONS

There appeared to be a close correlation between seasonal trends exhibited by daylength, air temperature, water temperature, gross primary productivity, growth coefficients, and total algal potamoplankton population. The most obvious controlling factors for these trends seemed to be light and temperature.

The community composition showed a predominance of diatoms, followed by greens; members of the Cryptomonadales became dominant midway through the sampling period and remained of importance through the end of sampling.

Many of the chemical factors did not show apparent seasonal trends but did show a close correlation between sites 1 and 2 (e.g. nitrite, nitrate, orthophosphate, and dissolved oxygen). Nitrite, nitrate, and orthophosphate showed consistently lower values at site 2 than site 1. Possible explanations include dilutions of these chemicals by ground and surface waters and absorption by the algal community while en route downstream; this latter explanation has been known to occur in flowing waters (Hynes, 1970). A close correlation of dissolved oxygen occurred between sites but concentrations at site 2 were consistently higher than those concentrations found at site 1. This agrees with the idea that oxygen is constantly being added to the water by algae while the water is in route downstream (Odum, 1956); in this case, it seems logical that the rates of oxygen production were greater than the rates of respiration by the stream community at the times dissolved oxygen was measured on most sampling dates.

Ammonia concentrations were similar between sites through time with several exceptions. Weeks 6 and 8 showed higher values at site 2; this seems to be due to rainfall on a tributary branch between sites 1 and 2 which increased amounts of ammonia at site 2. The reasons for reduced

ammonia concentrations at site 2 during weeks 12, 14, 20, and 22 could be the direct assimilation of ammonia by algae and macrophytes as the water flows from site 1 to site 2.

Turbidity values were similar between sites 1 and 2 with the exception of weeks 6 and 8 which were presumably higher at site 2 due to rainfall on a tributary of Riley creek located between sites 1 and 2 to the south. The general overall lower turbidity values undoubtedly increased rates of primary production and of reproduction (growth coefficients).

The results of primary production and growth coefficient calculations showed considerable variability with general decreases in values through time, which might be a normal seasonal trend.

The concentrations of certain chemical factors (i.e., nitrogen and phosphorus) were of significance; minimal requirements of nitrogen and phosphorus for growth of algae have been stated to be 0.1 mg liter^{-1} and less than 0.01 mg liter^{-1}, respectively, while accelerated growth may be seen with values of over 1.0 mg liter^{-1} and 0.1 mg liter^{-1}, respectively, (Silver and Moore, 1971). Values for nitrogen and phosphorus obtained for Riley Creek in this study have shown that values of more than 1.4 mg liter^{-1} and 0.2 mg liter^{-1}, respectively, occurred at both sites continuously. Therefore, it is suggested that nitrogen and phosphorus were most likely not limiting throughout most if not all of the sampling period.

The various taxa showed general trends through time (Table 4). The green flagellates showed a definite decrease in concentration and abundance seasonally as did Cyclotella spp., Scenedesmus spp., and to a lesser extent, Stichococcus-like organisms. Increases in abundance were seen for Navicula spp. to a certain degree, Nitzschia spp., members of the Euglenophyta, and the Cryptomonadales. The most evident factors for these trends are, once again, light and temperature.

The differences noticed between sites 1 and 2 on various sampling dates for many of the parameters which were measured cannot conclusively be attributed to the agricultural land surrounding the stream, the stream tributarities and rainfall, or to the sanitary landfill, but this study may have given enough preliminary data to aid future studies of these specific areas and allow a grasp of their roles and a better understanding of their interrelationships with the physical, chemical, and biological factors of Riley Creek.

Fig. 1. Map of the portion of Riley Creek studied and the surrounding area: 1 and 2 represent sampling sites 1 and 2 respectively; SL represents the location of the sanitary landfill located on the creek; solid lines and dotted lines represent permanent and semi-permanent portions of the creek, respectively.

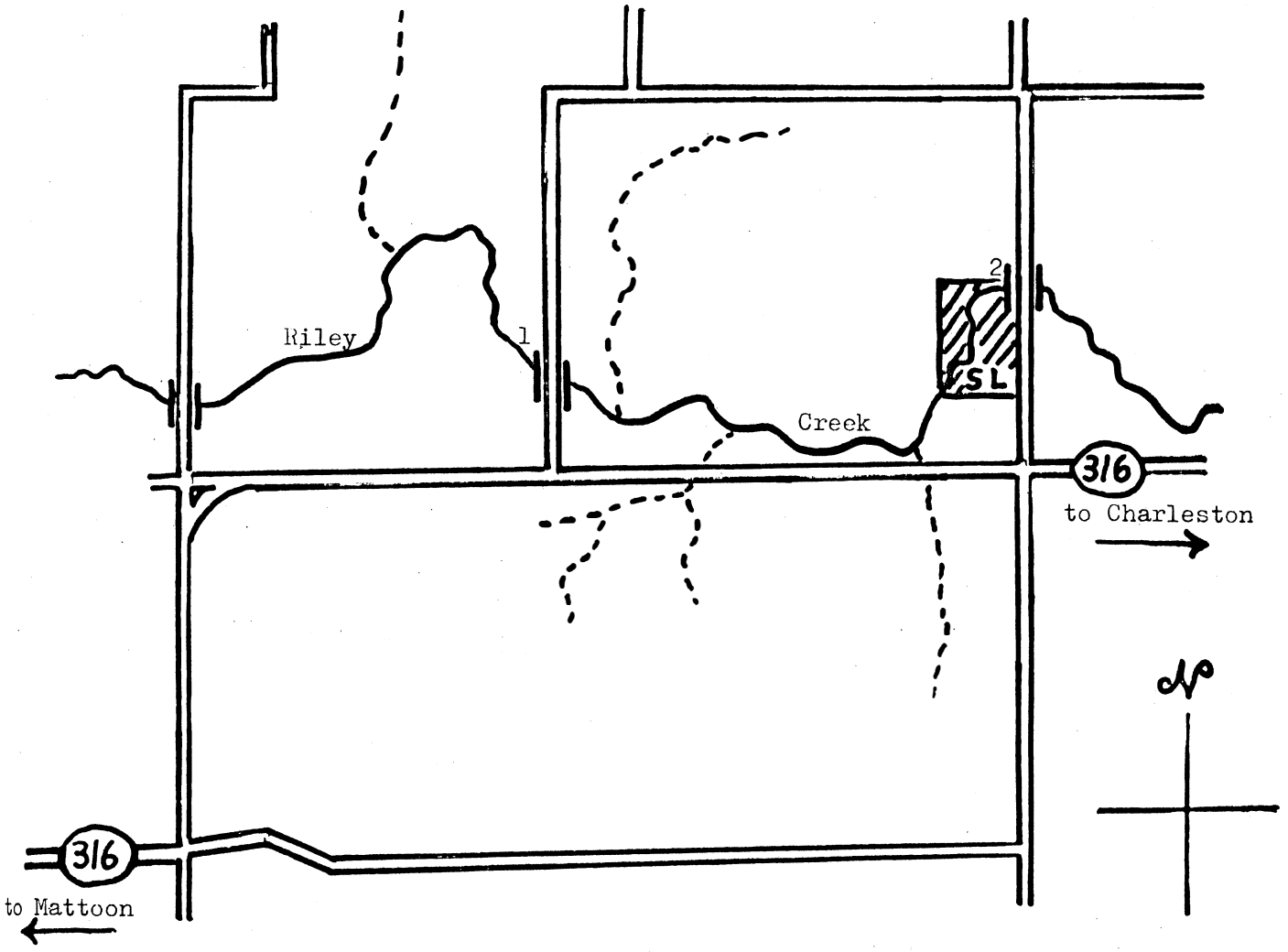
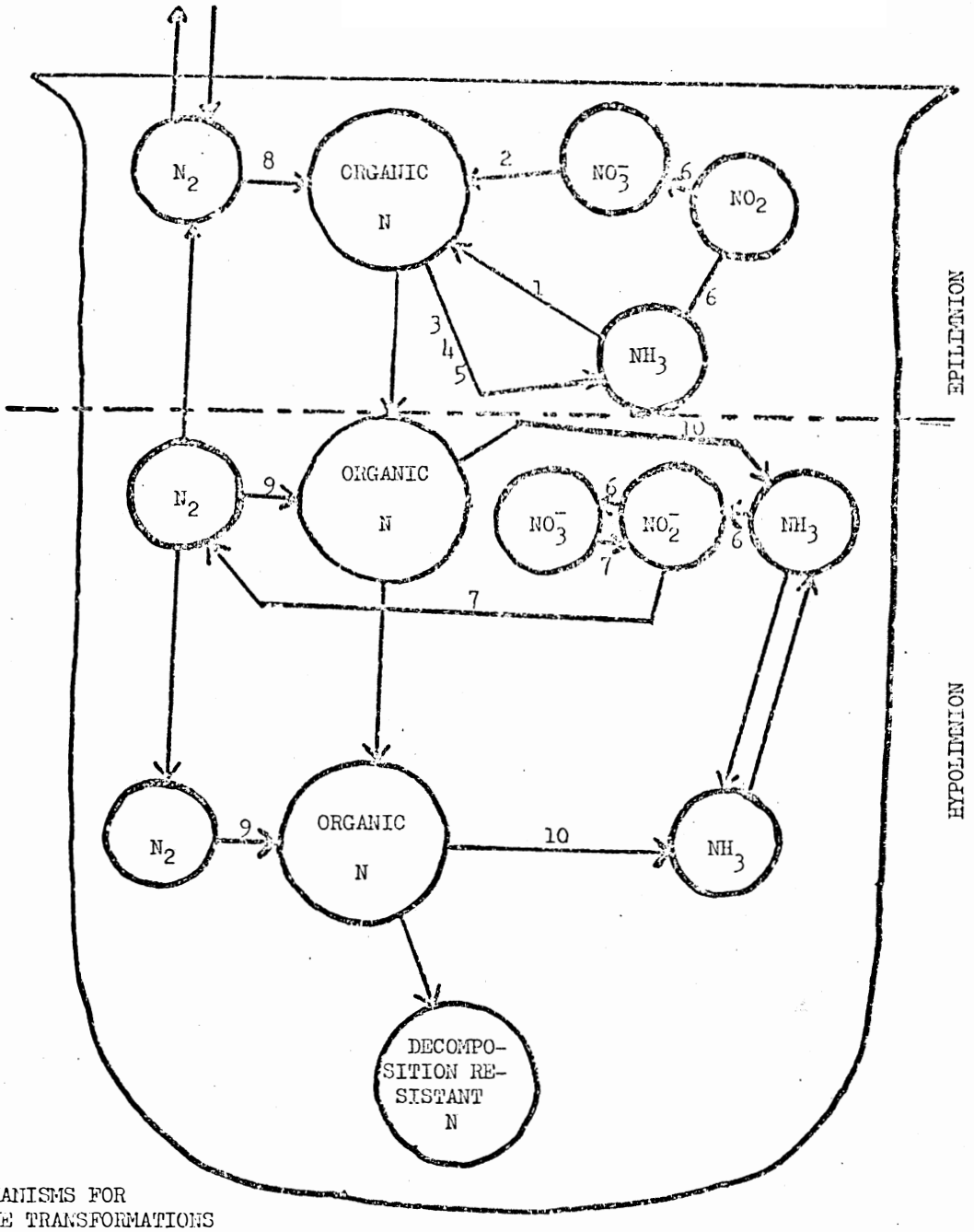

Riley
1
2
SL
Creek
316
to Charleston
316
to Mattoon

Fig. 2. The nitrogen cycle reactions in an idealized stratified lake. Note that both aerobic and anaerobic transformations are shown in the hypolimnion, although in a real lake they would not occur simultaneously. Adapted from Kuznetsov (After Brezonik, P. L. 1972. Nitrogen: sources and transformations in natural waters. In, Nutrients in Natural Waters. J. Wiley and Sons, New York. 457p.).



MECHANISMS FOR ABOVE TRANSFORMATIONS

1. algae
2. algae
3. zooplankton
4. bacteria
5. direct autolysis after death of plant and animal material
6. anaerobic autotrophic bacteria, heterotrophic bacteria, actinomycetes, fungi
7. anaerobic bacteria, facultative bacteria, in absence of oxygen
8. bluegreen algae, photosynthetic bacteria, aerobic bacteria
9. anaerobic and facultative under anoxic conditions only
10. bacteria and fungi

Fig. 3. Phosphorus cycle of a hypothetical lake. Heavy solid lines represent first occurring reactions, time in minutes. All other times in days. Lighter solid lines indicate reactions occurring two to three times more slowly than the initial one. Dashed line represents the inorganic release by mud, slower yet. Top dotted lines are infinitely slow by comparison, too slow to measure. (After Hayes, F. R. and J. E. Phillips. 1958. Lake water and sediment, IV. radiophosphorus equillibrium with mud, plants, and bacteria under oxidized conditions. Limnol. Oceanog. 3:459-475.)

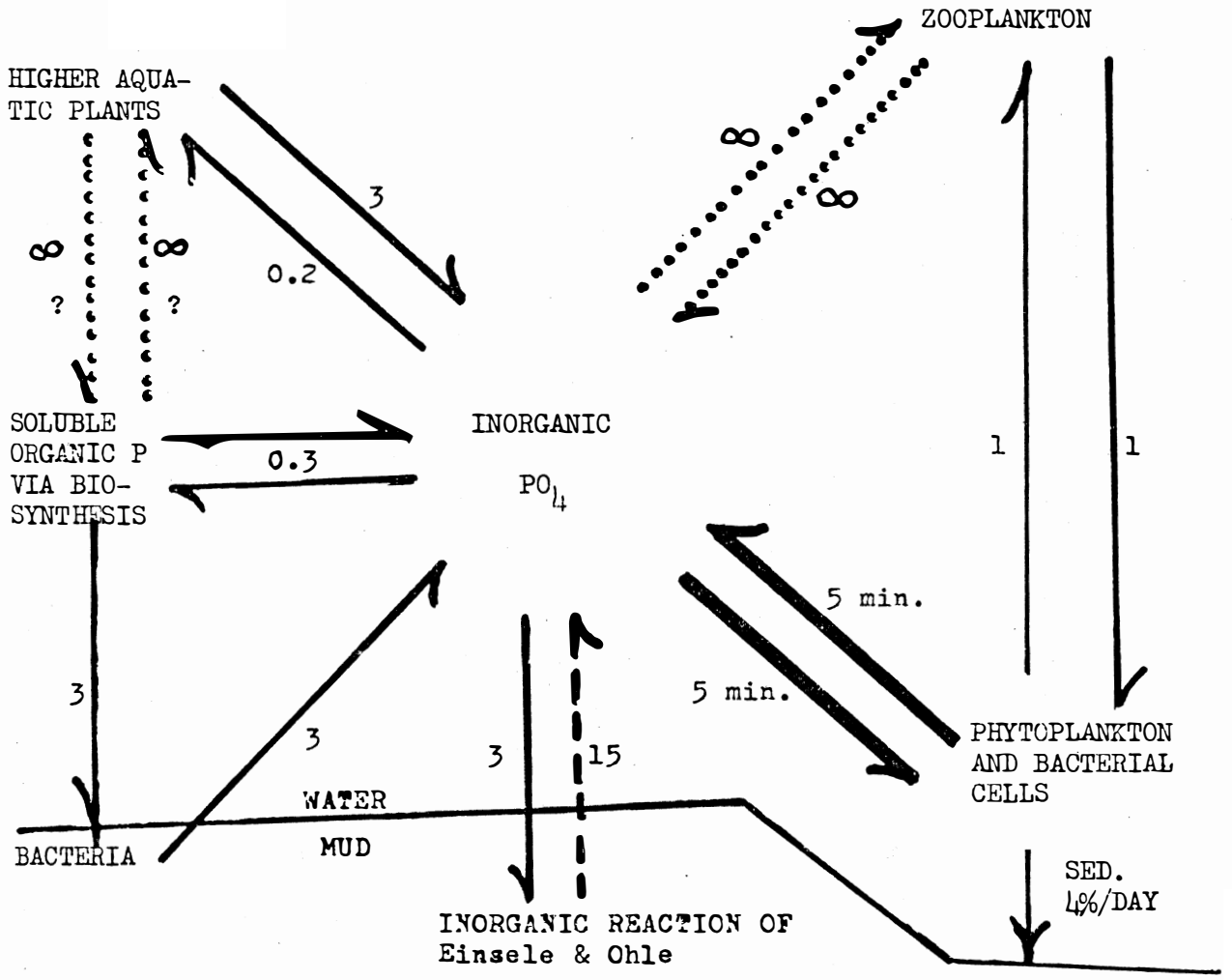

ZOOPLANKTON
HIGHER AQUATIC PLANTS
8
8
?
?
3
0.2
8
8
SOLUBLE ORGANIC P VIA BIOSYNTHESIS
0.3
INORGANIC
PO_4
1
1
5 min.
5 min.
3
3
3
15
PHYTOPLANKTON AND BACTERIAL CELLS
WATER
MUD
BACTERIA
SED. 4%/DAY
INORGANIC REACTION OF Einsele & Ohle

Fig. 4. Typical oxygen curve for a stream with a long homogeneous community. (After Odum, H. T. 1956. Primary production in flowing waters. Limnol. Oceanog. 1:102-117.)

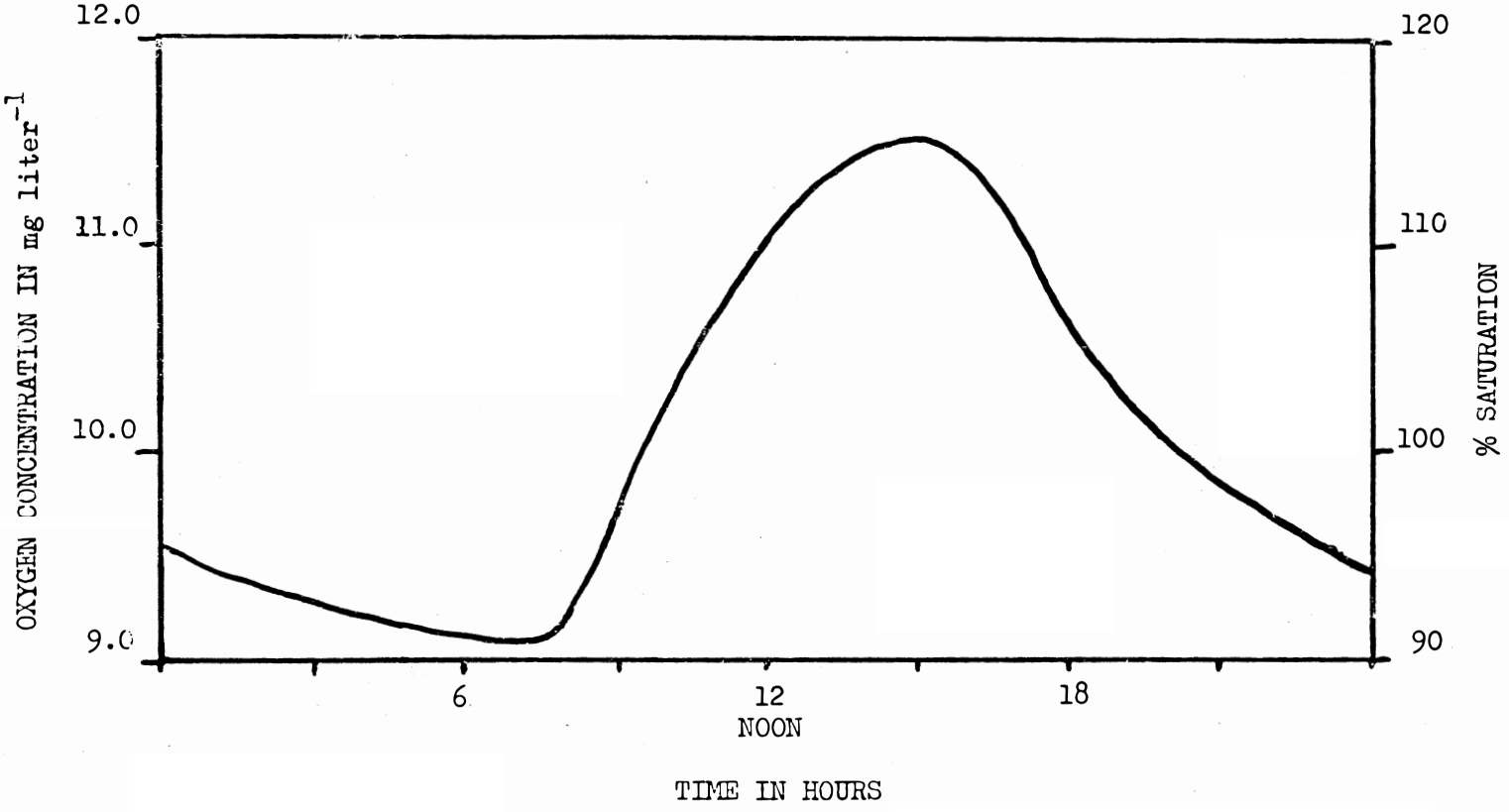

12.0
11.0
10.0
9.0
OXYGEN CONCENTRATION IN mg liter^{-1}
120
110
100
90
% SATURATION
6
12
NOON
18
TIME IN HOURS

Fig. 5. Daylength (hours) for the area of Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 December, 1974. (Daylength estimated from sunrise and sunset times given in Times-Courier newspaper, Charleston, Illinois)

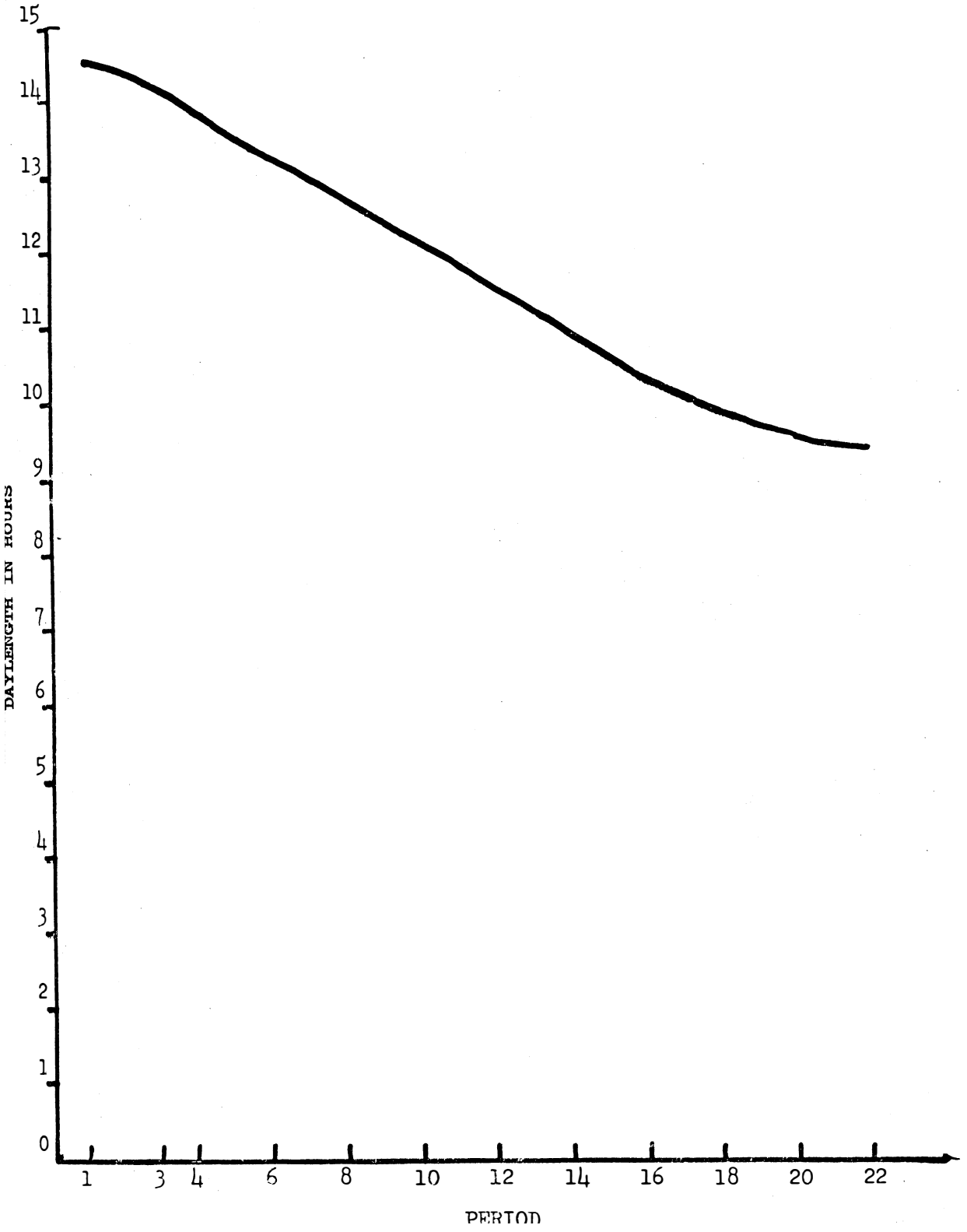

15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
DAYLENGTH IN HOURS
1
3
4
6
8
10
12
14
16
18
20
22
PERIOD

Fig. 6. Air temperature (°C) at sampling sites 1 (dashed line) and 2 (solid line) on Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 December, 1974.

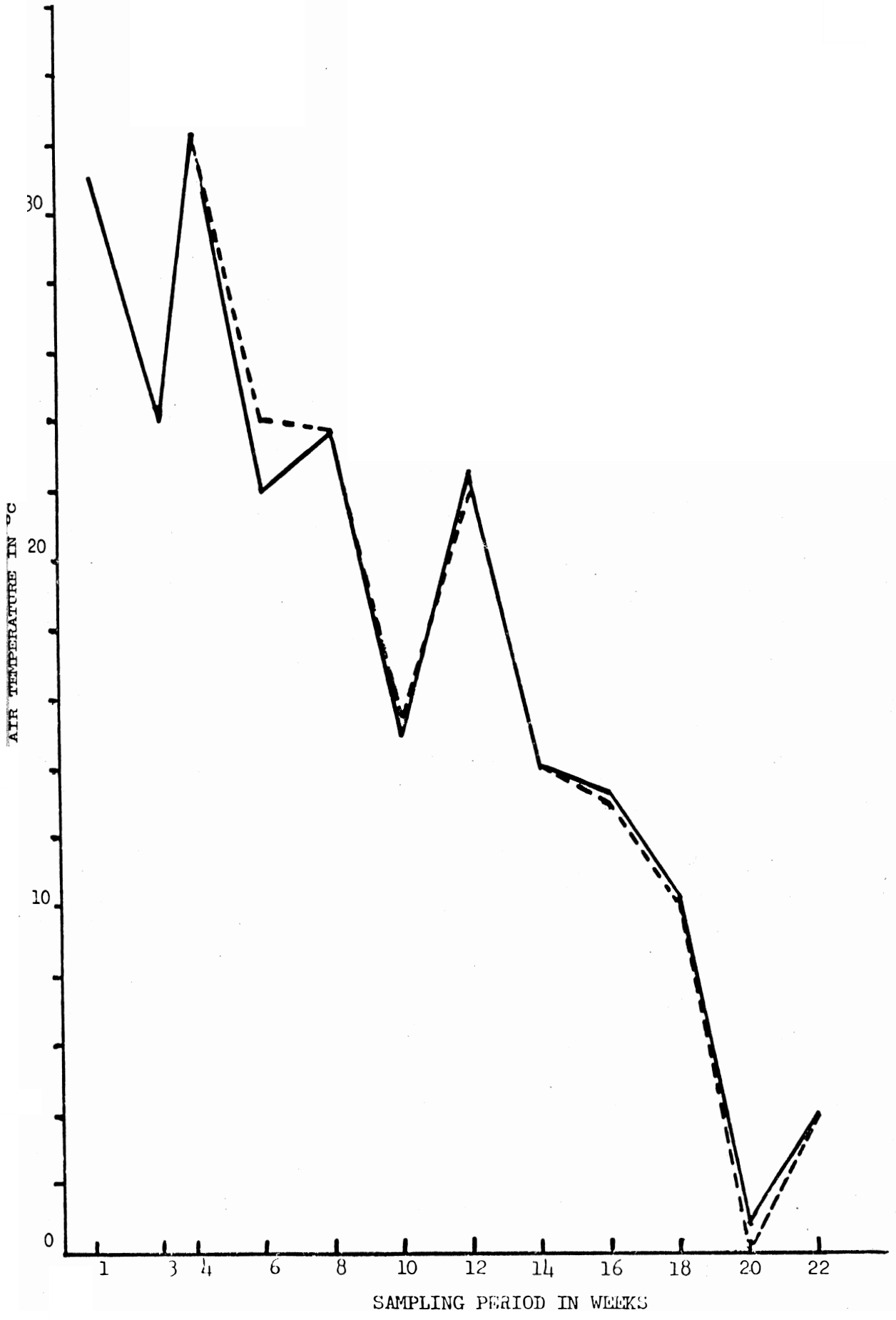

AIR TEMPERATURE IN °C
30
20
10
0
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 7. Water temperature (^{o}C) at sampling sites 1 (dashed line) and 2 (solid line) in Riley Creek from 21 July, 1974 to 15 December, 1974.

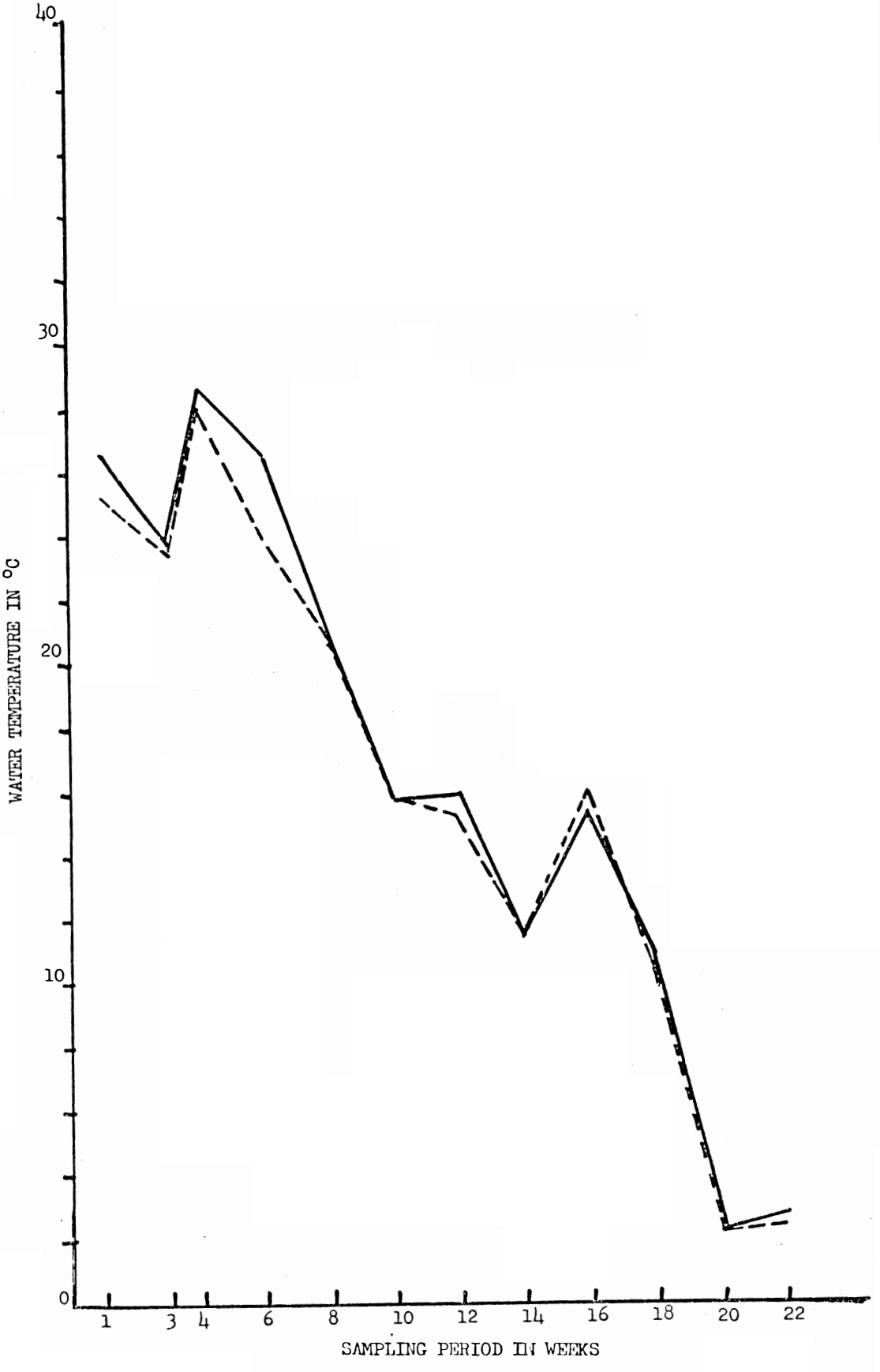

40
30
20
10
0
WATER TEMPERATURE IN °C
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 8. Turbidity (FTU) at sampling sites 1 (dashed line) and 2 (solid line) in Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 December, 1974.

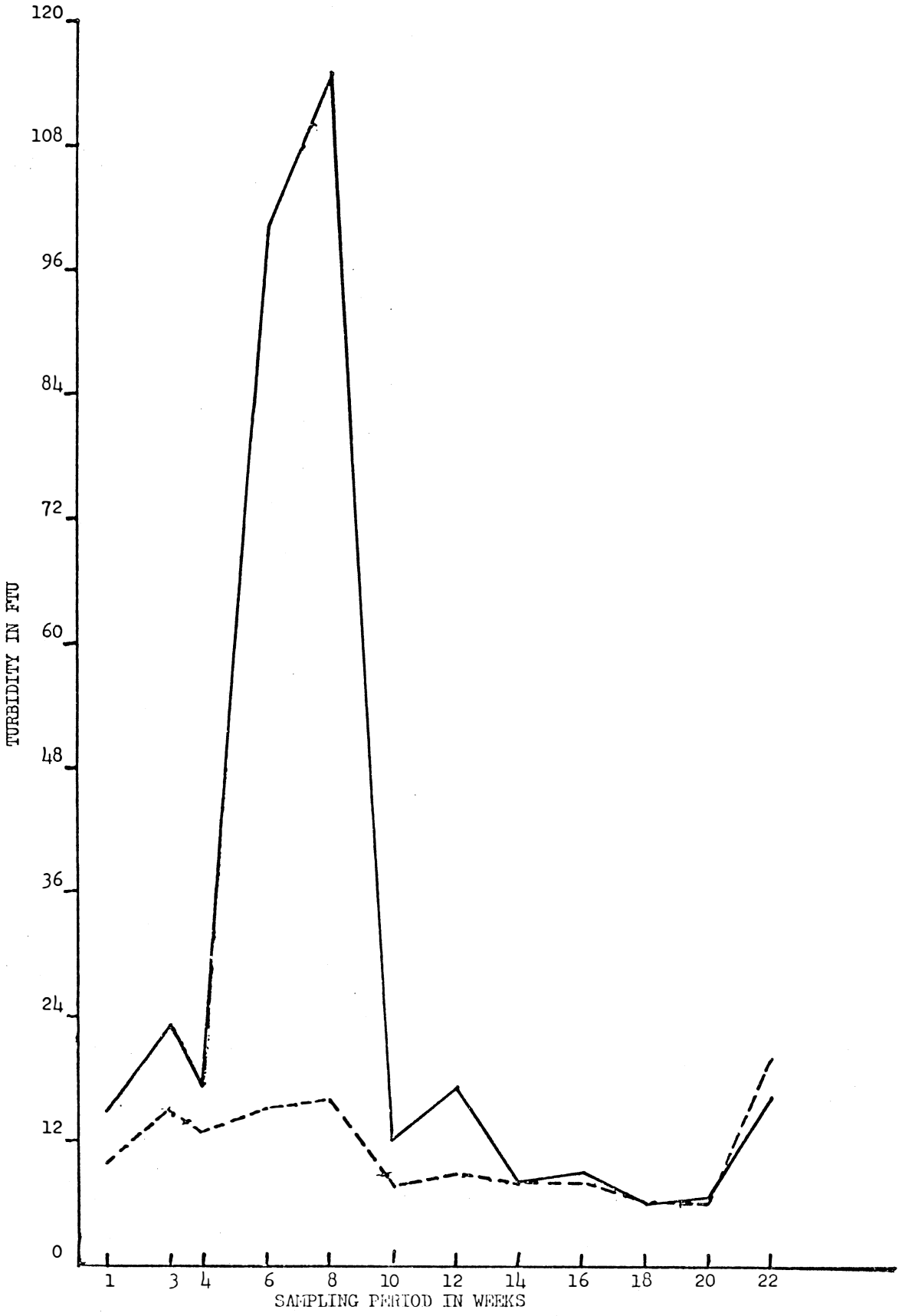

120
108
96
84
72
60
48
36
24
12
0
TURBIDITY IN FTU
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 9. Ammonia concentration (mg liter^{-1}) at sampling sites 1 (dashed line) and 2 (solid line) in Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 December, 1974.

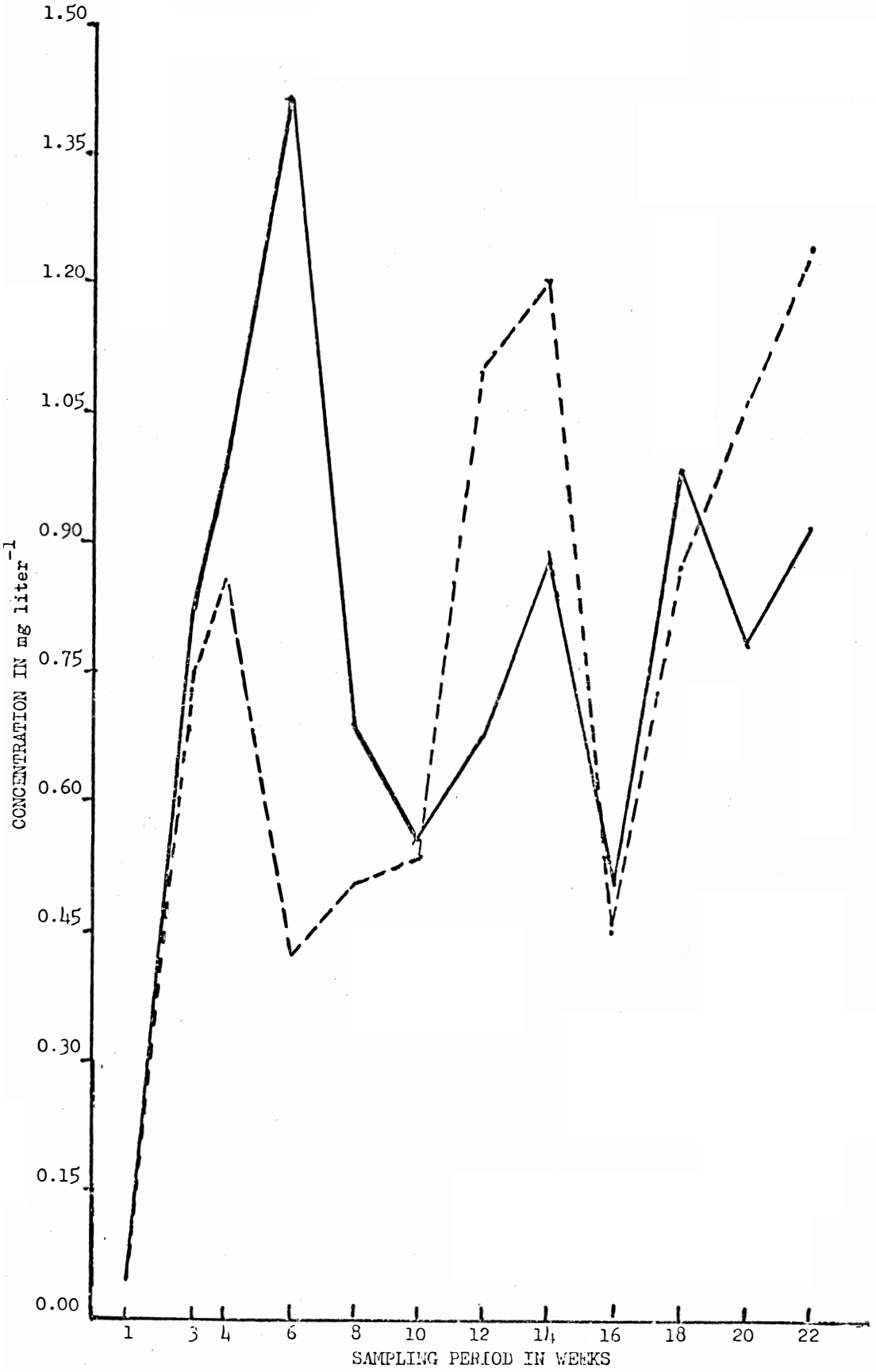

1.50
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
CONCENTRATION IN mg liter^{-1}
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 10. Nitrite concentration (mg $liter^{-1}$) at sampling sites 1 (dotted line) and 2 (solid line) in Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 December, 1974.

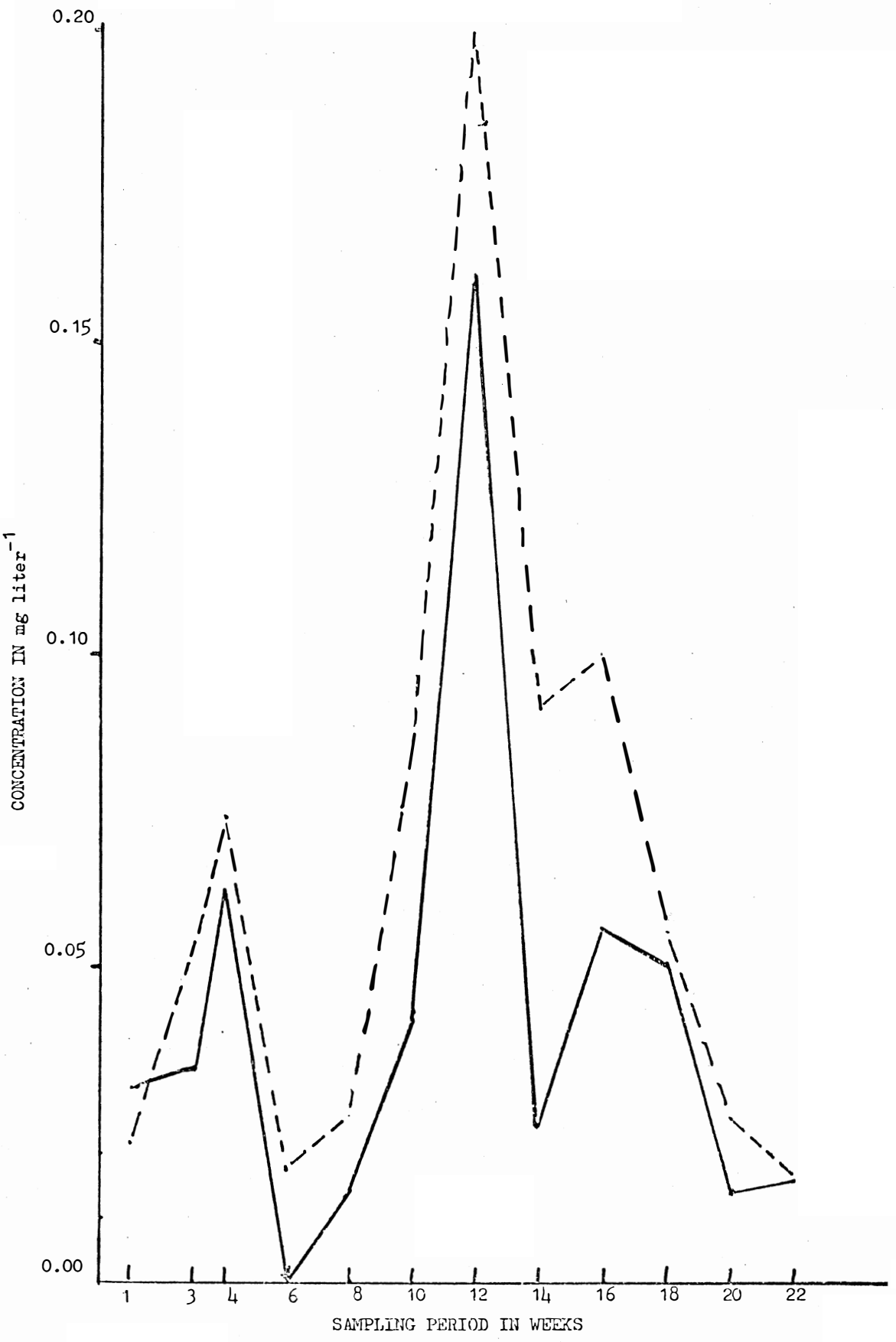

0.20
0.15
0.10
0.05
0.00
CONCENTRATION IN mg liter^{-1}
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 11. Nitrate concentration (mg liter^{-1}) at sampling sites 1 (dashed line) and 2 (solid line) in Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 December, 1974.

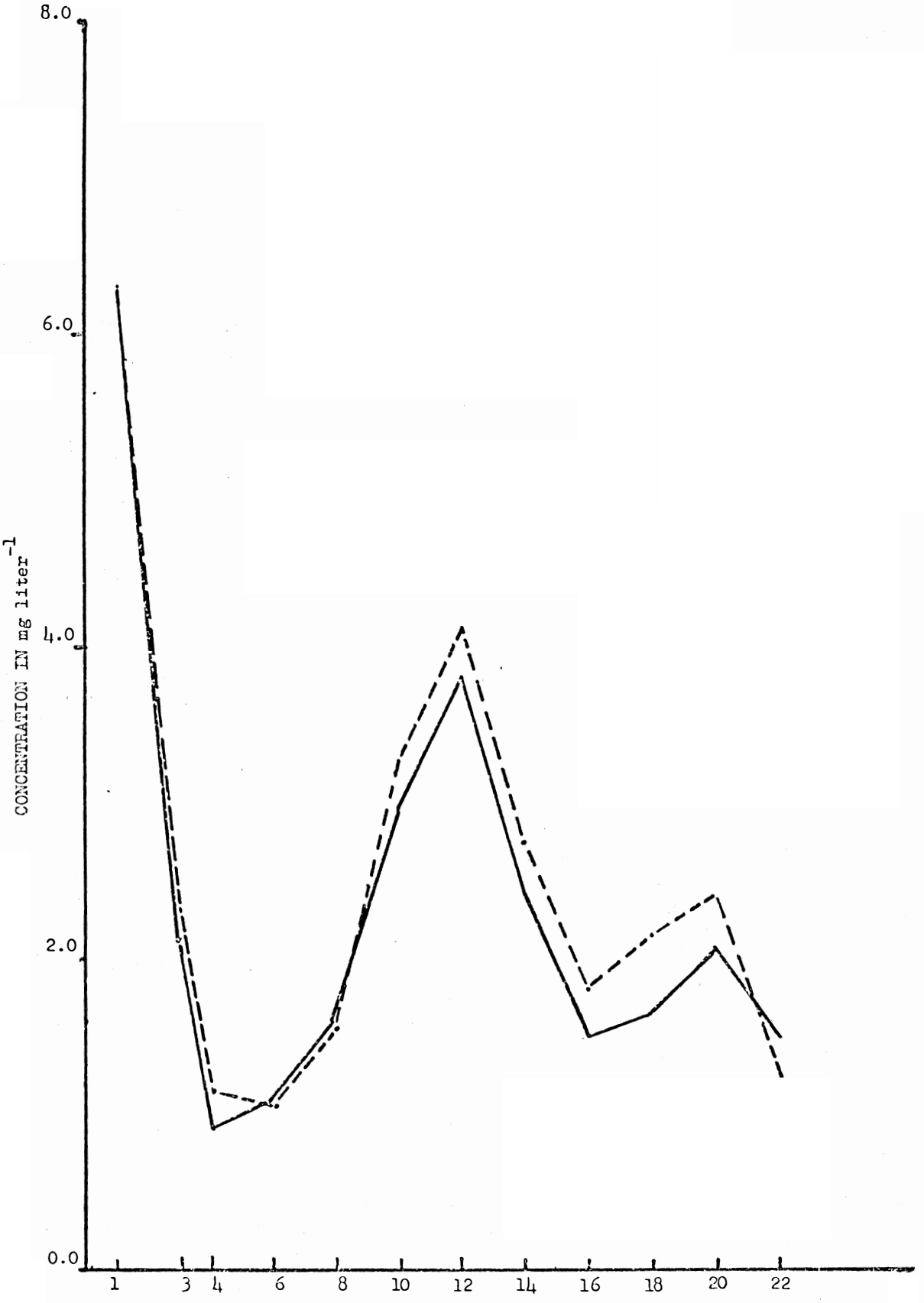

8.0
6.0
4.0
2.0
0.0
CONCENTRATION IN mg liter^{-1}
1
3
4
6
8
10
12
14
16
18
20
22

Fig. 12. Orthophosphate concentration (mg liter^{-1}) at sampling sites 1 (dotted line) and 2 (solid line) in Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 December, 1974.

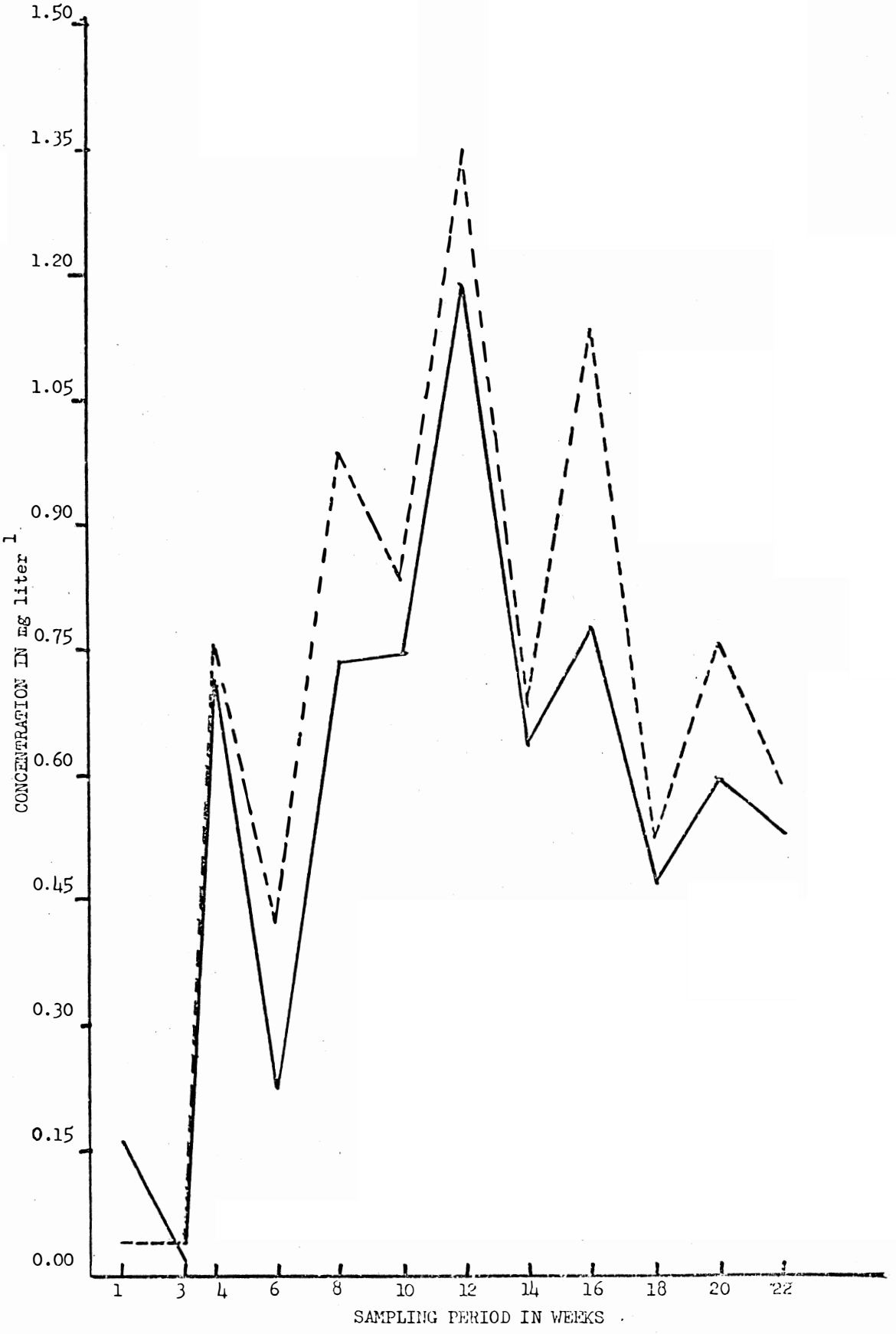

1.50
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
CONCENTRATION IN mg liter $^{-1}$
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 13. Hydrogen ion concentration (in pH units) at sampling sites 1 (dashed line) and 2 (solid line) in Riley Creek from 21 July, 1974 to 15 December, 1974.

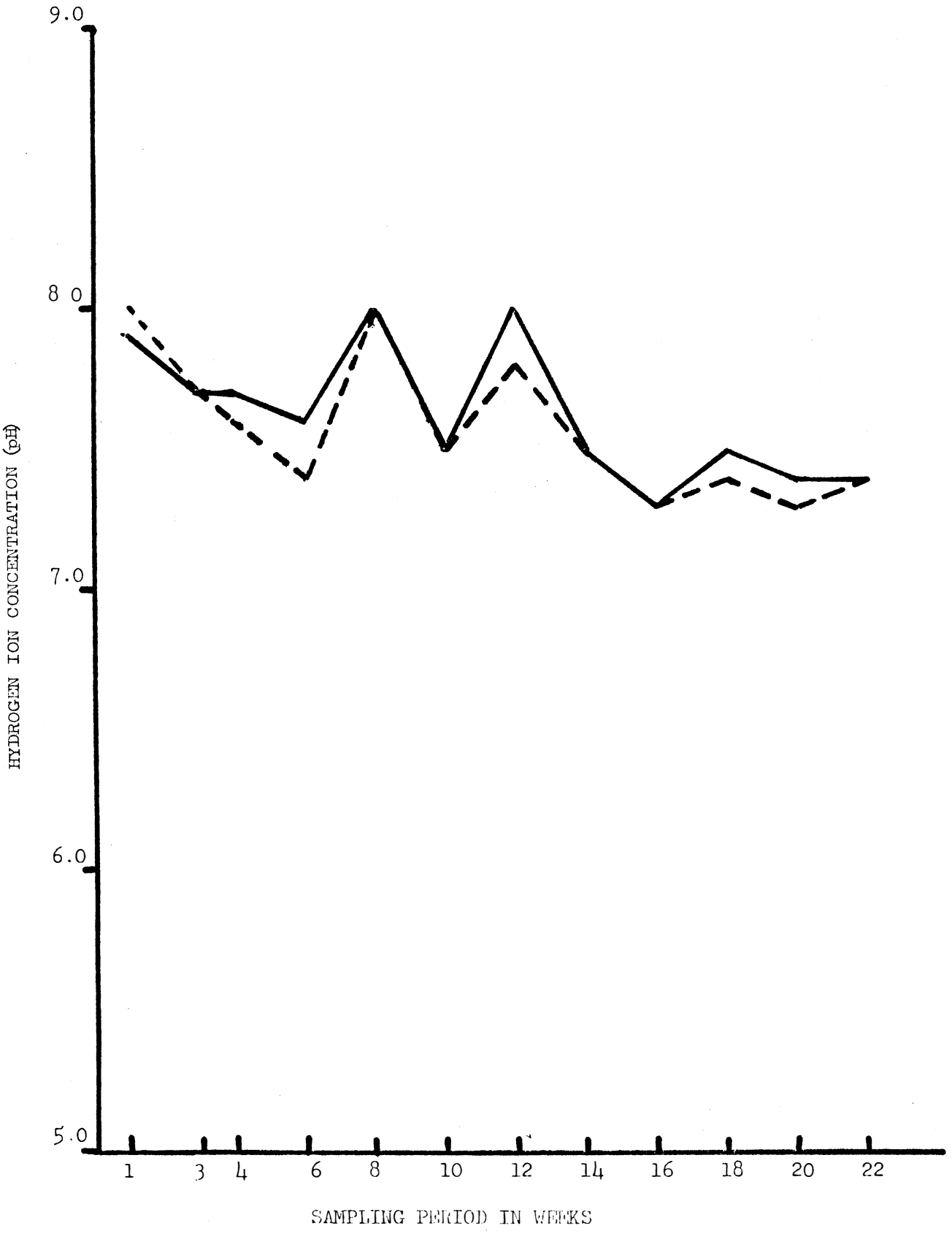

9.0
8 0
7.0
6.0
5.0
HYDROGEN ION CONCENTRATION (pH)
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 14. Dissolved oxygen concentration (mg liter^{-1}) at sampling sites 1 (dashed line) and 2 (solid line) in Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 December, 1974.

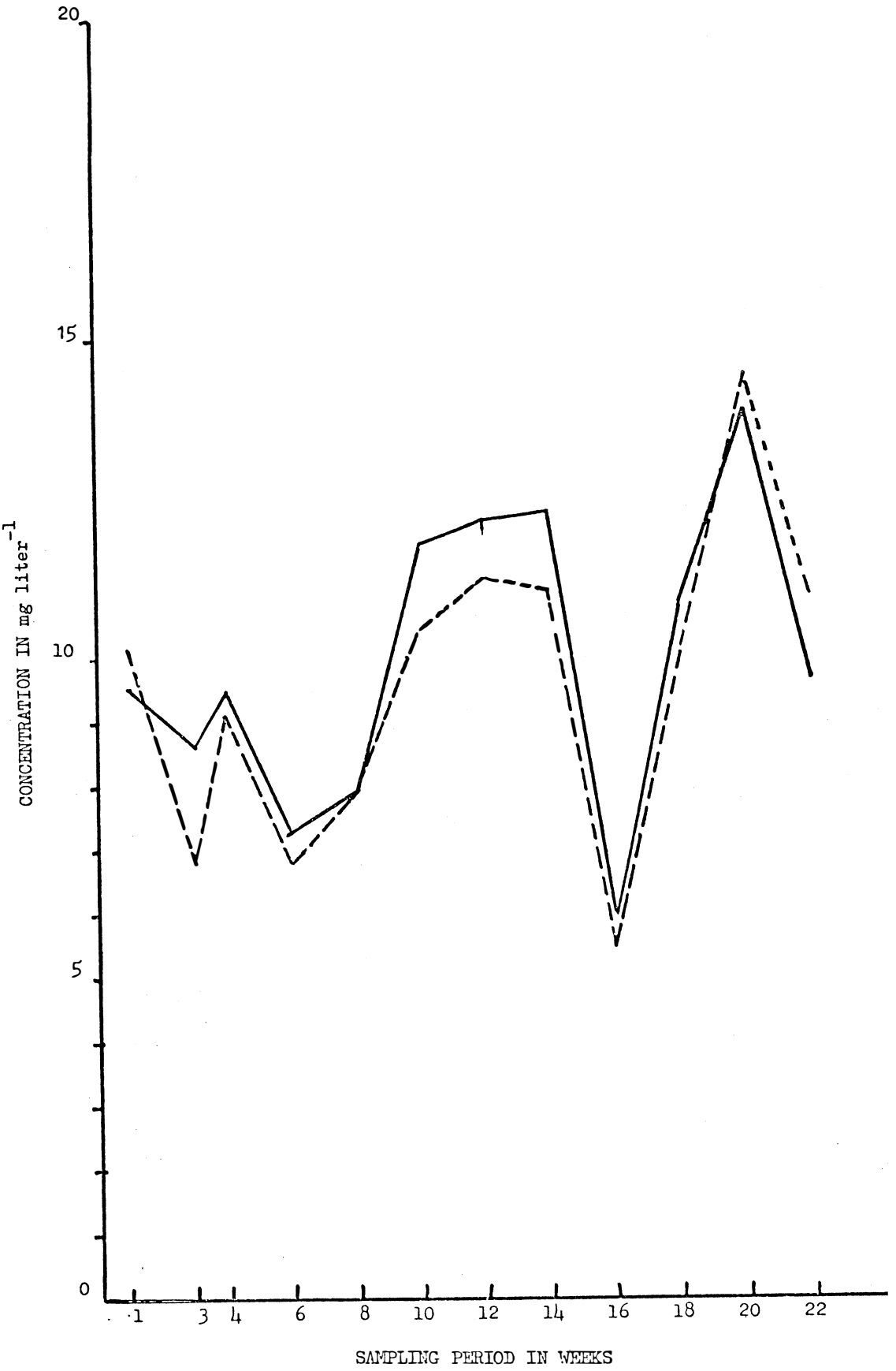

20
15
10
5
0
CONCENTRATION IN mg liter^{-1}
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 15a. Algal potamoplankton concentration (# liter^{-1} x 10^6) at sampling sites 1 (solid bars represent initial concentration, clear bars represent light bottle primary production concentration after 1 day of growth) and 2 (left to right upward diagonal bars represent initial concentration, left to right downward diagonal bars represent concentration after 1 day of growth) in Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 1974.

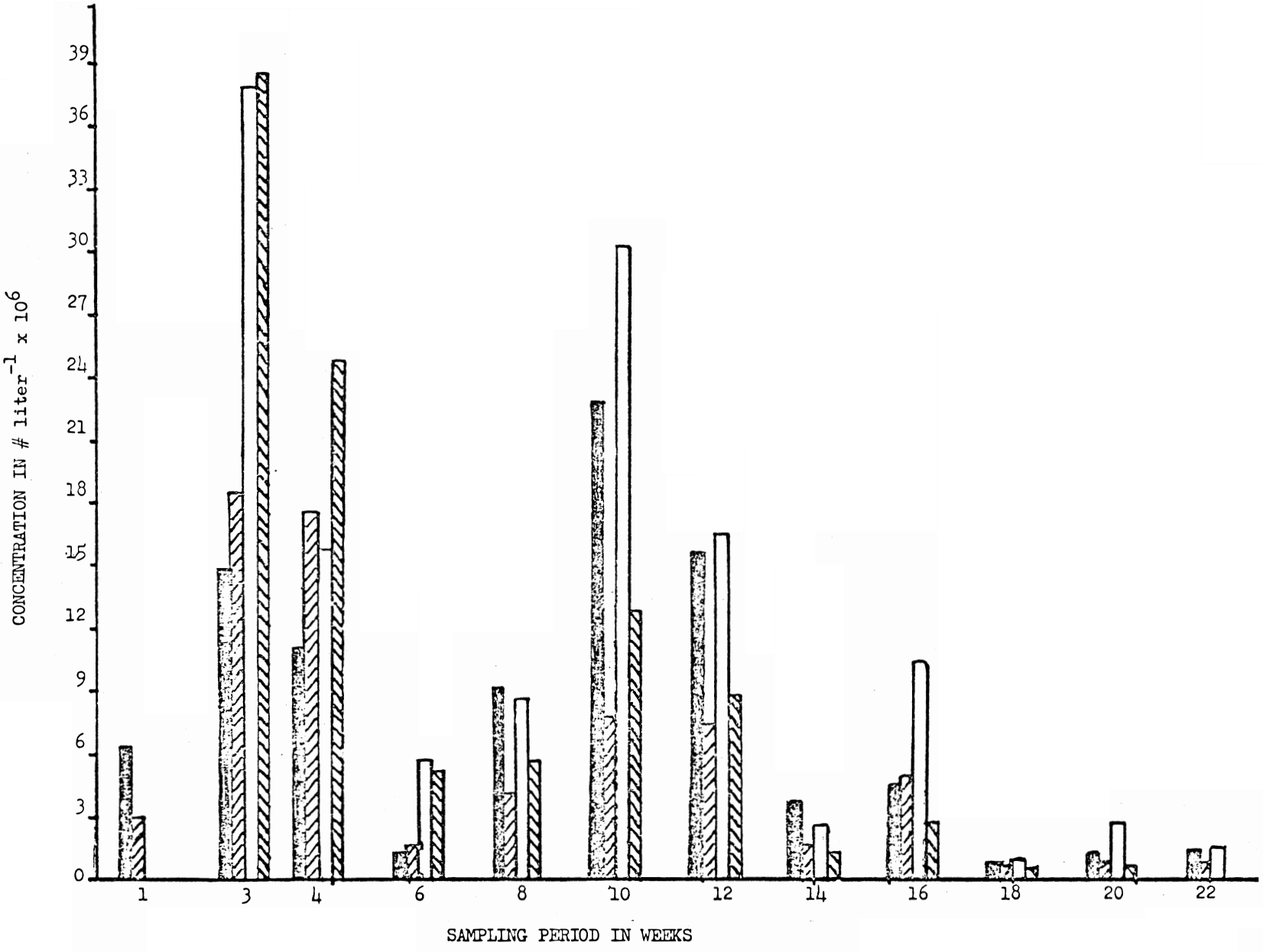
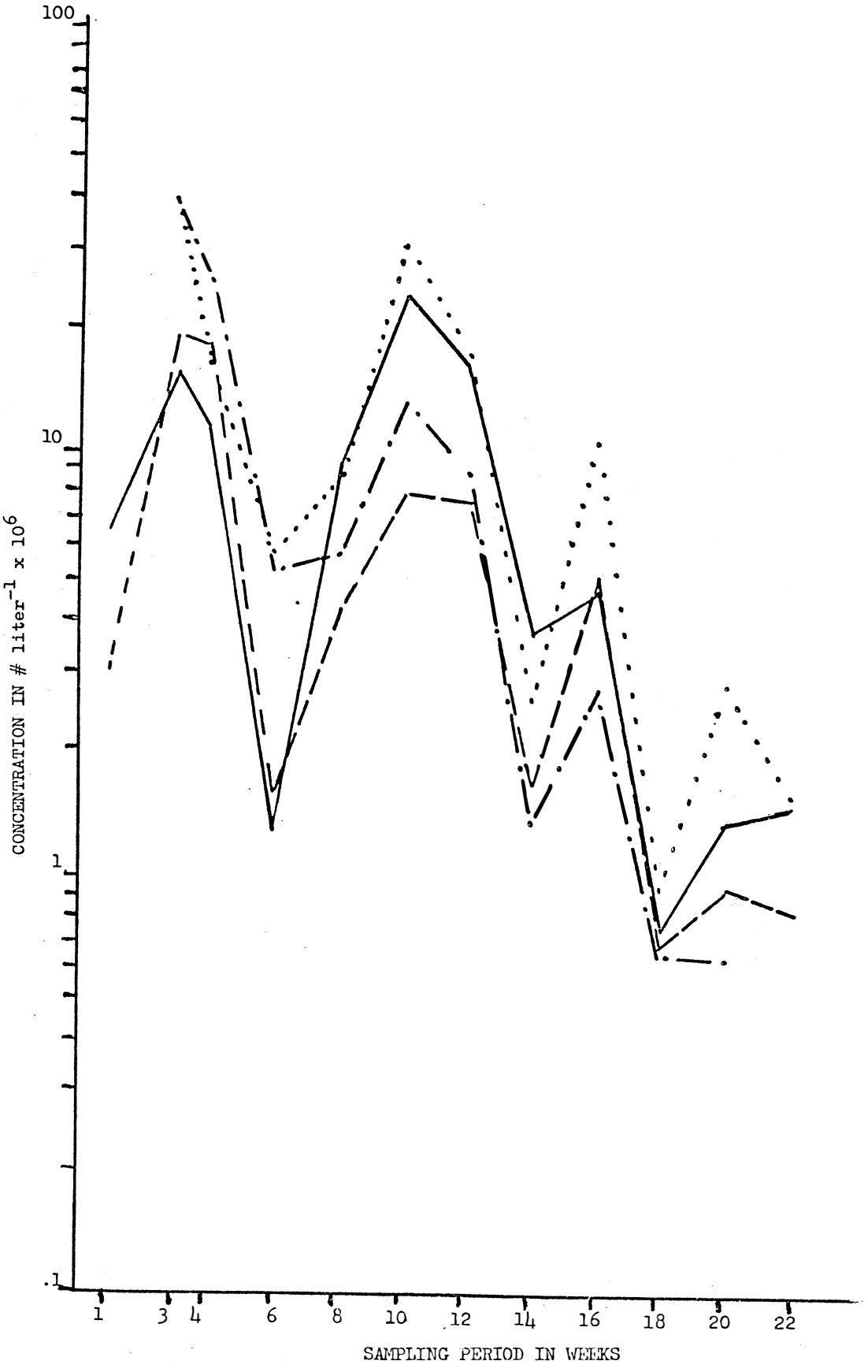

CONCENTRATION IN # liter^{-1} x 10^6
39
36
33
30
27
24
21
18
15
12
9
6
3
0
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 15b. Algal potamoplankton concentration (# liter^{-1} x 10^6) at sampling sites 1 (initial concentration represented by the solid line, concentration after 1 day of growth represented by the dotted line) and 2 (initial c ncentration represented by dashed line, concentration after 1 day of growth represented by dotted dash line) in Riley Creek, Coles County, Illinois from 21 July, 1974 15 December, 1974.


100
10
1
.1
CONCENTRATION IN # liter^{-1} x 10^6
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

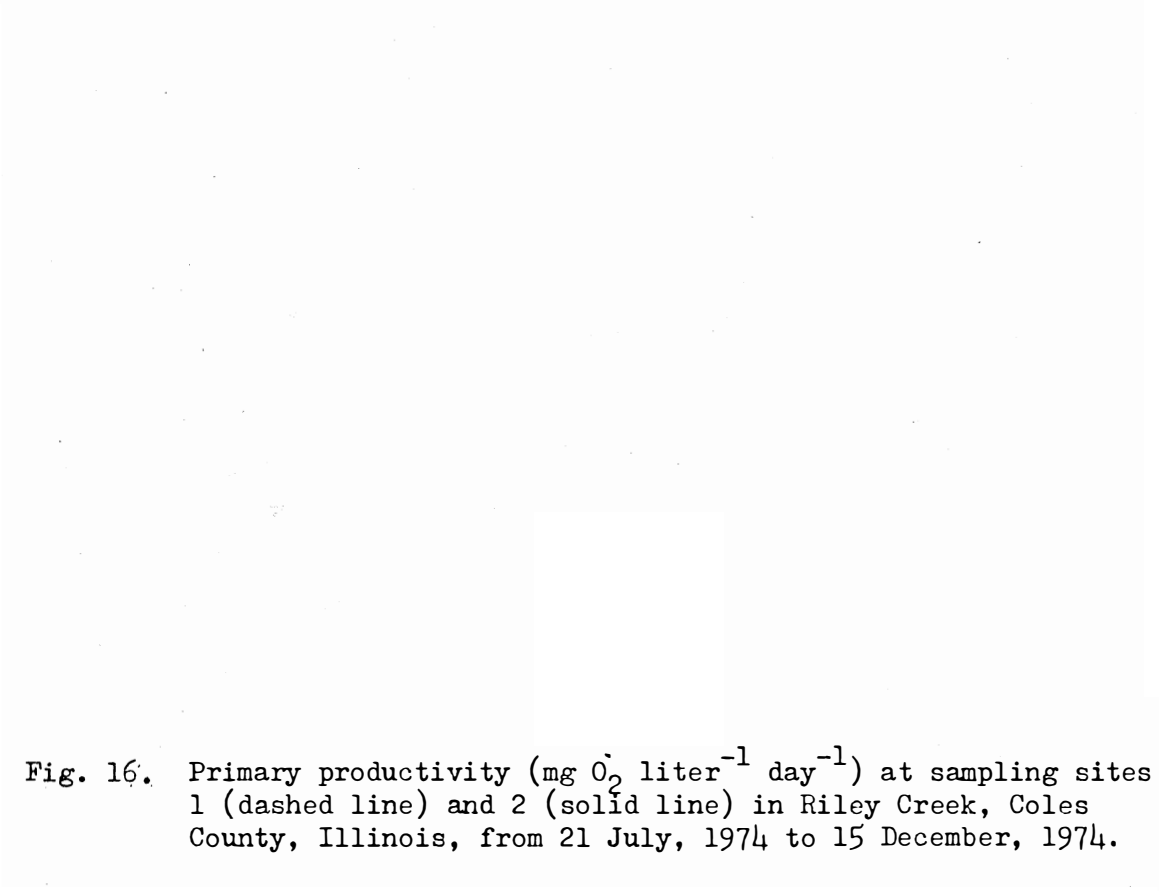


Fig. 16. Primary productivity (mg O_2 $liter^{-1}$ day^{-1}) at sampling sites 1 (dashed line) and 2 (solid line) in Riley Creek, Coles County, Illinois, from 21 July, 1974 to 15 December, 1974.

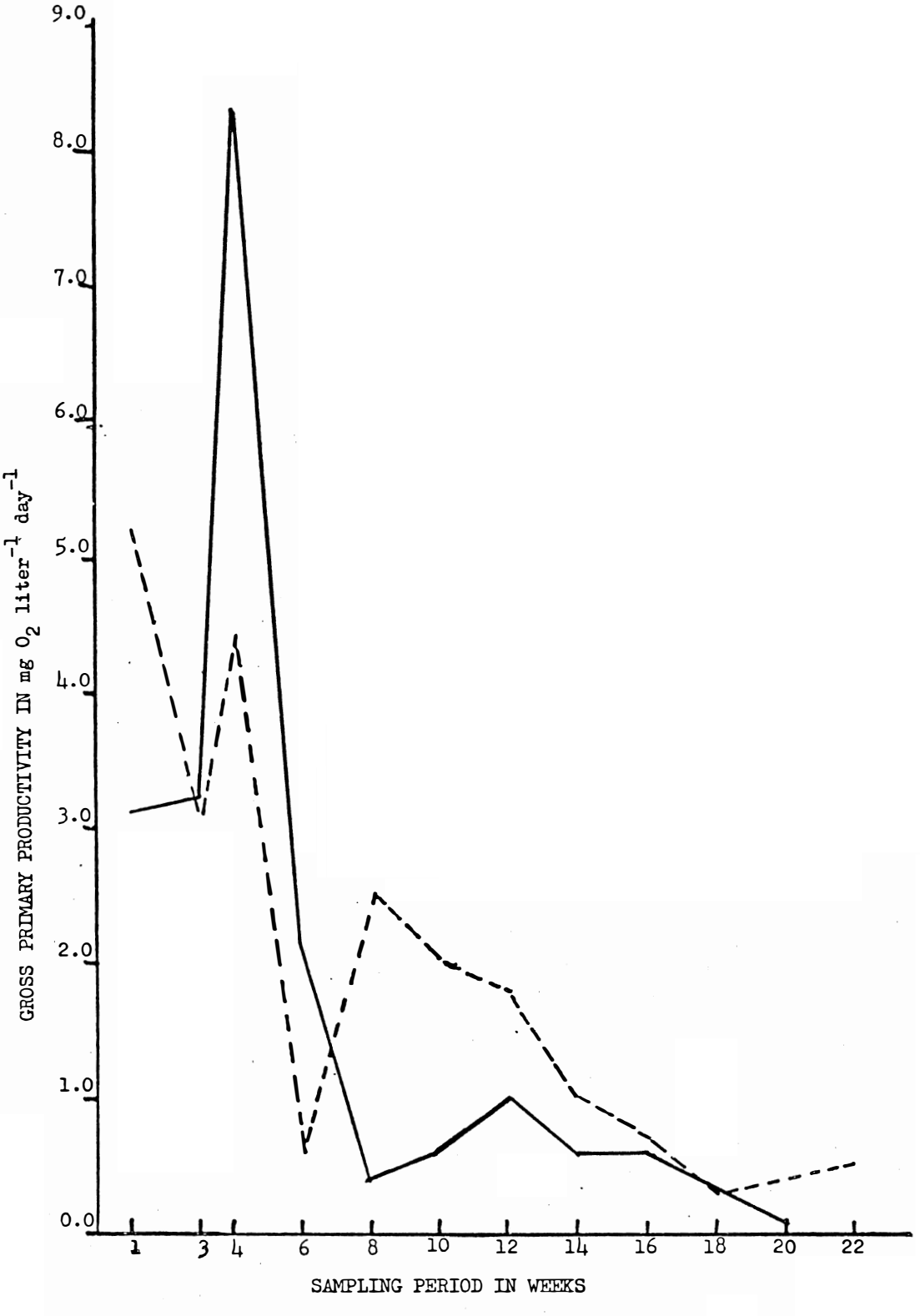

9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
GROSS PRIMARY PRODUCTIVITY IN mg O_2 liter^{-1} day^{-1}
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Fig. 17. Growth coefficients (population increase day^{-1}) at sampling sites 1 (clear bars) and 2 (crossed bars) in Riley Creek, Coles County, Illinois, from 3 August, 1974 to 15 December, 1974.

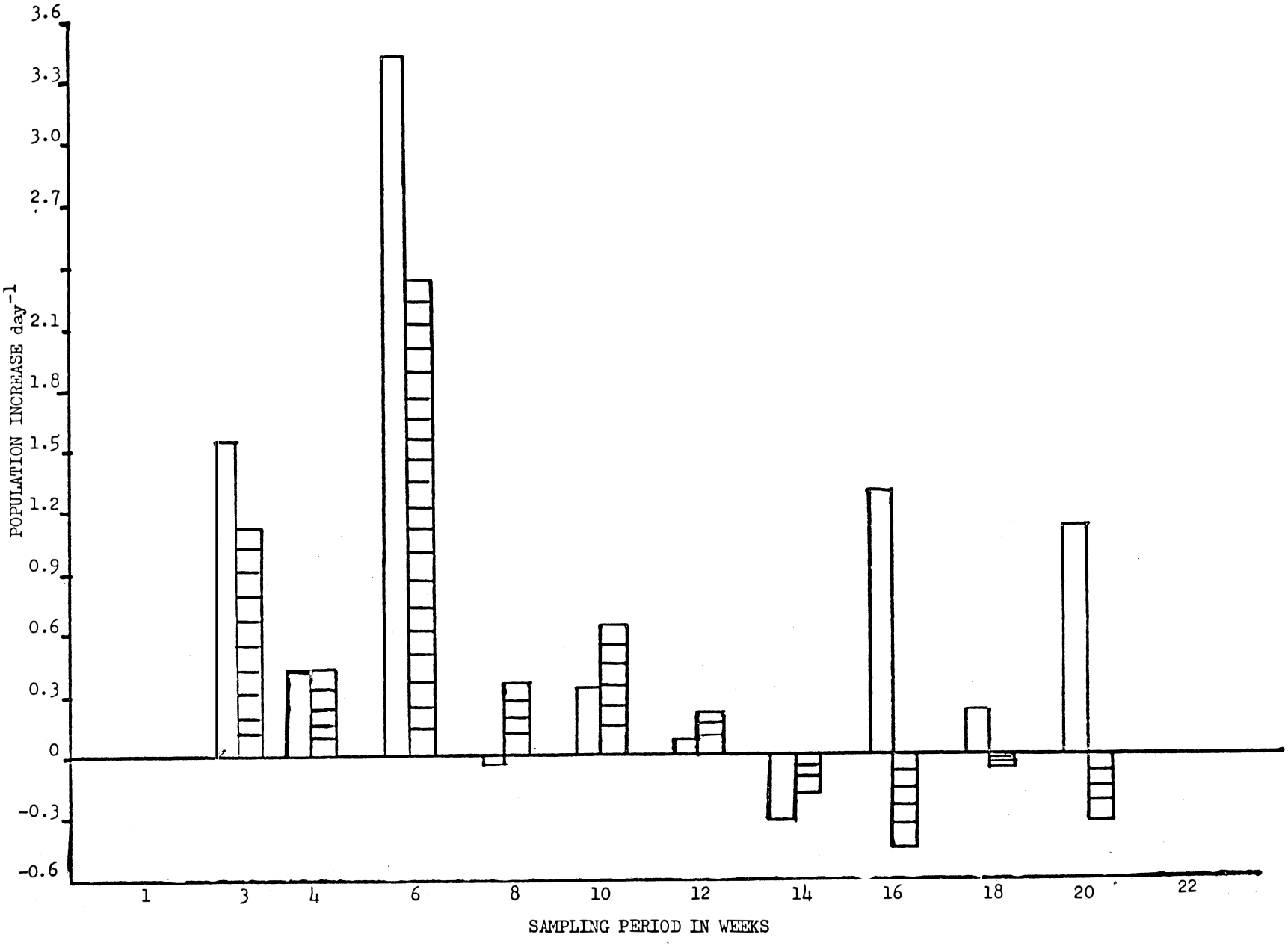

3.6
3.3
3.0
2.7
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
-0.3
-0.6
POPULATION INCREASE day-1
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Figure 18. The percent composition of the major groups of organisms in the algal potamoplankton population encountered at site 1 from 21 July, 1974 through 15 December, 1974 in Riley Creek, Coles County, Illinois.

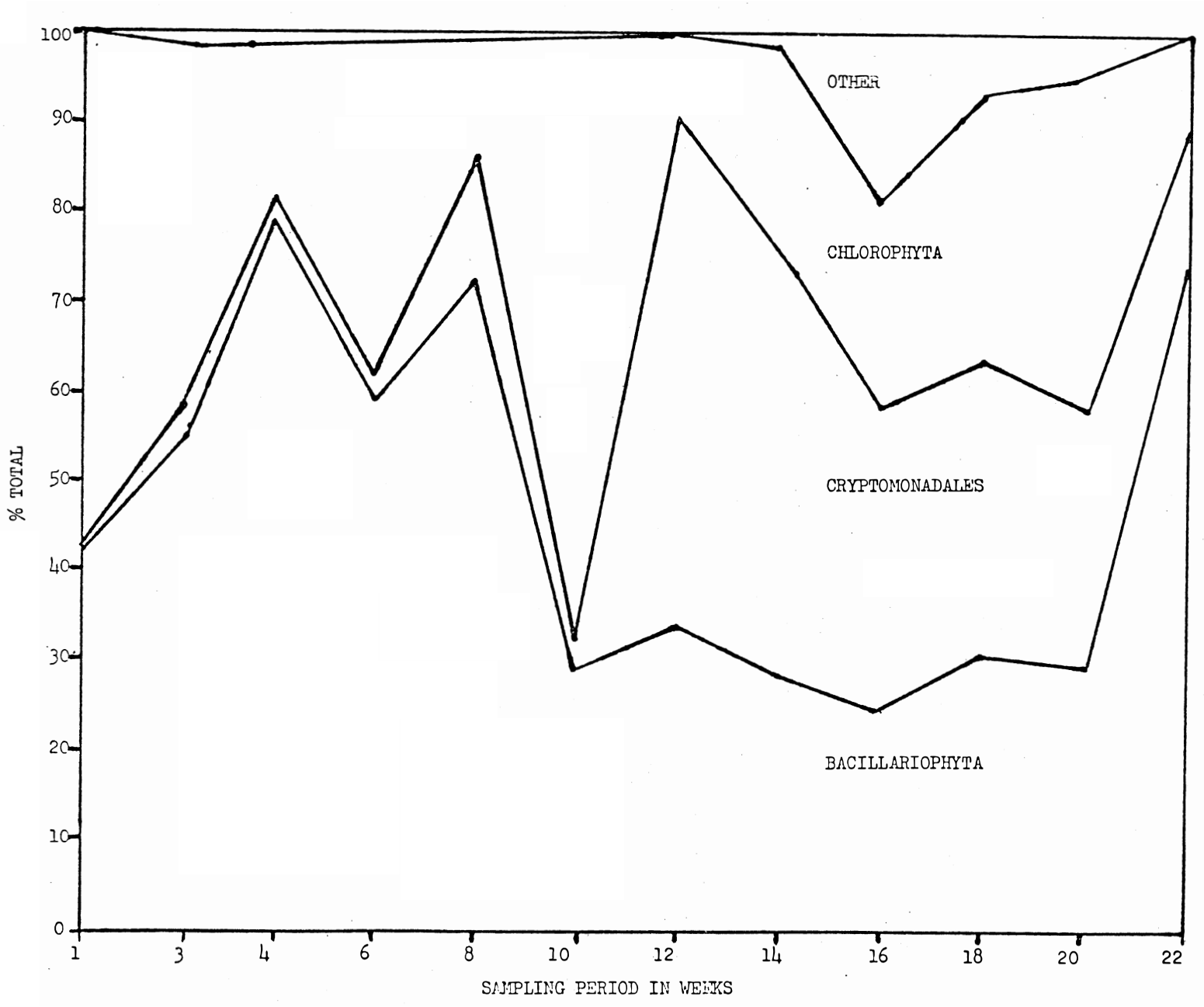

100
90
80
70
60
50
40
30
20
10
0
% TOTAL
OTHER
CHLOROPHYTA
CRYPTOMONADALES
BACILLARIOPHYTA
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Figure 19. Percentage composition of the major groups of organisms in the algal potamoplankton population encountered at site 2 from 21 July, 1974 through 15 December, 1974 in Riley Creek, Coles County, Illinois.

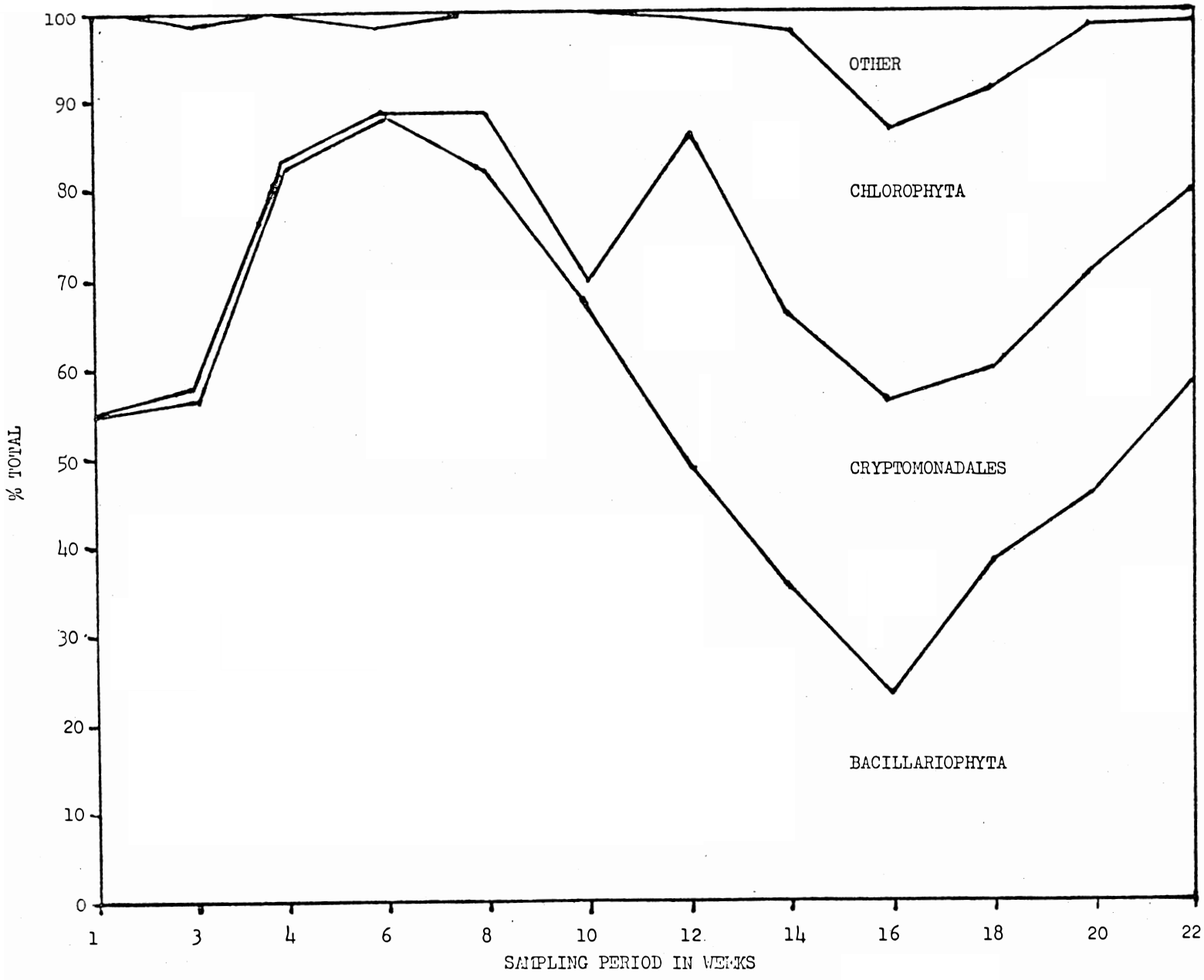

100
90
80
70
60
50
40
30
20
10
0
% TOTAL
OTHER
CHLOROPHYTA
CRYPTOMONADALES
BACILLARIOPHYTA
1
3
4
6
8
10
12
14
16
18
20
22
SAMPLING PERIOD IN WEEKS

Figure 20. The percent composition of the major groups of organisms encountered in the light primary production bottles after 1 day's growth at site 1 from 21 July, 1974 through 15 December, 1974 in Riley Creek, Coles County, Illinois.

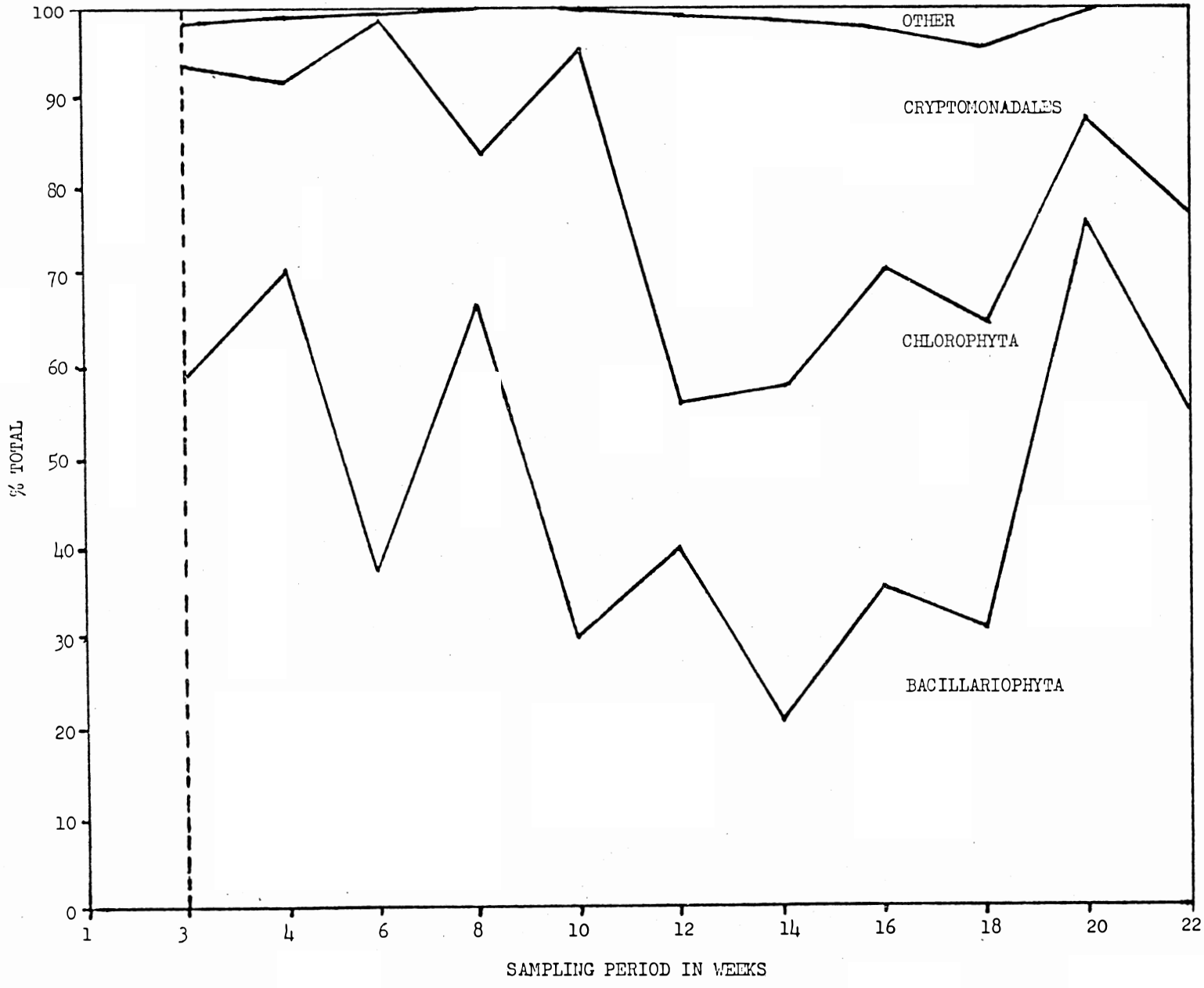

OTHER
CRYPTOMONADALES
CHLOROPHYTA
BACILLARIOPHYTA
% TOTAL
SAMPLING PERIOD IN WEEKS
100
90
80
70
60
50
40
30
20
10
0
1
3
4
6
8
10
12
14
16
18
20
22

Figure 21. The percent composition of the major groups of organisms encountered in the light primary production bottles after 1 day's growth at site 2 from 21 July, 1974 through 15 December, 1974 in Riley Creek, Coles County, Illinois.

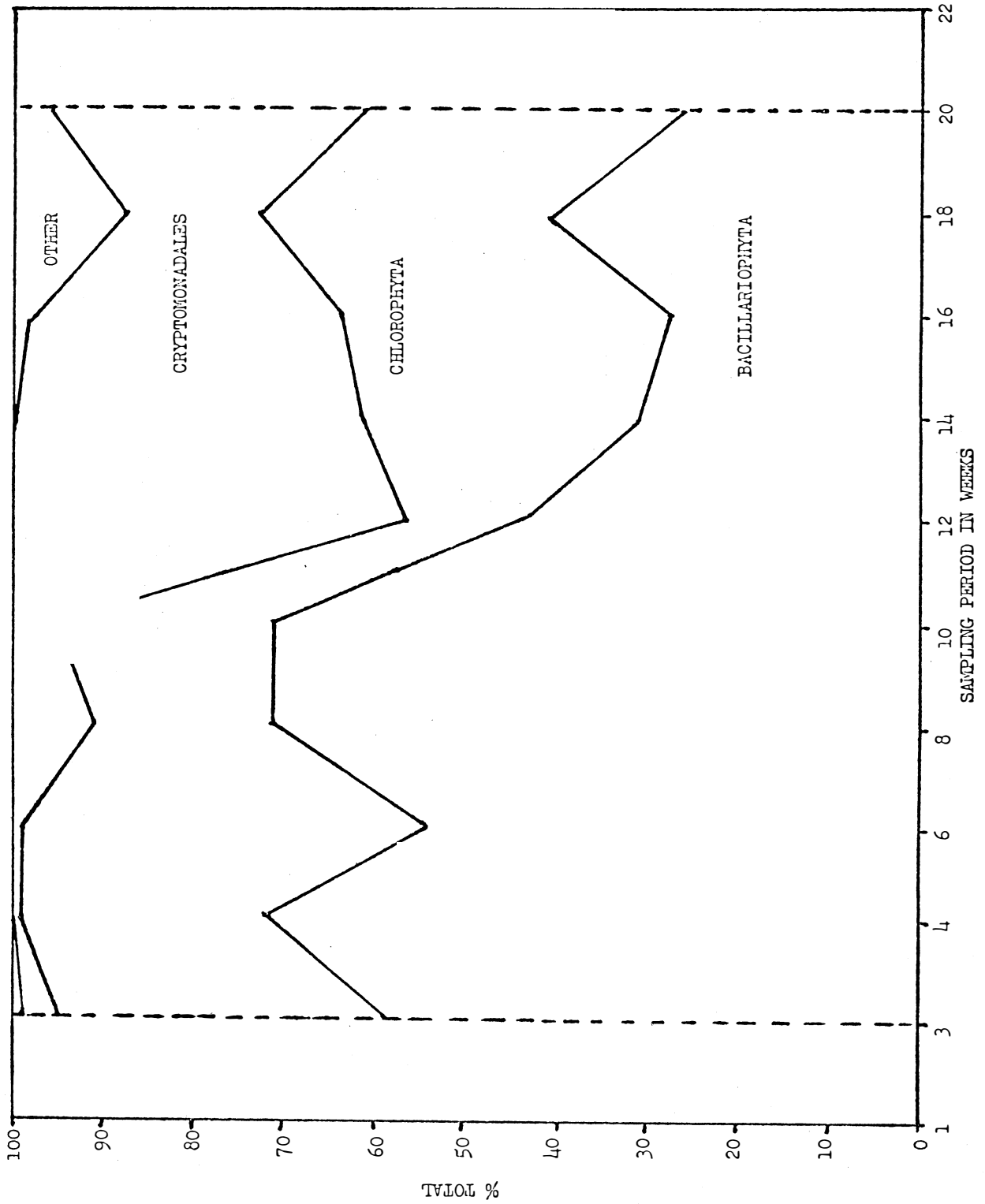

OTHER
CRYPTOMONADALES
CHLOROPHYTA
BACILLARIOPHYTA
% TOTAL
SAMPLING PERIOD IN WEEKS
100
90
80
70
60
50
40
30
20
10
0
1
3
4
6
8
10
12
14
16
18
20
22

Table 1. Chemical, physical, and biological factors measured at sampling sites 1 and 2 in Riley Creek, Coles County, Illinois from 21 July, 1974 to 15 December, 1974. (continued on second page)

DATE	SITE													
	TURBIDITY (FTU)		NITRITE (mg liter^{-1})		AMMONIA (mg liter^{-1})		NITRATE (mg liter^{-1})		ORTHOPHOSPHATE (mg liter^{-1})		AIR TEMP. (°C)		WATER TEMP. (°C)	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2
21 July	10	15	.022	.031	.07	.05	6.20	6.30	.04	.16	31.0	31 0	25.2	26.5
3 Aug.	15	23	.054	.034	.74	.82	2.30	2.10	.04	.02	24.0	24.0	23.4	23.8
11 Aug.	13	17.5	074	.0625	.855	.985	1.15	0.90	.755	.71	32.1	32.3	27.9	28.6
26 Aug.	15	100	.018	.00	.42	1.415	1.05	1.1	.425	.225	24.0	22.0	23.9	26.8
9 Sept.	16	115	.0265	.015	.505	.69	1.55	1.6	.99	.735	23.8	23.8	20.8	20.8
22 Sept.	8	12	.0875	.042	.535	.555	3.25	2.95	.835	.745	15.5	15.0	15.8	15.8
5 Oct.	9	17	.20	.16	1.10	.675	4.1	3.8	1.35	1.19	22.0	22.5	15.3	16.0
19 Oct.	8	8	.092	.0245	1.20	.88	2.75	2.4	.68	.64	14.0	14.0	11.5	11.5
3 Nov.	8	9	.1005	.056	.45	.505	1.8	1.5	1.13	.775	13.0	13.3	16.0	15.4
17 Nov.	6	6	056	.0505	.87	.985	2.15	1.65	.525	.47	10.1	10.2	10.6	10.8
1 Dec.	6	7	026	.014	1.06	.78	2.4	2.05	.76	.595	0.0	0.8	2.2	2.3
15 Dec.	20	16	.0175	.016	1.24	1.07	1.25	1.5	.59	.51	4.0	4.0	2.5	2.8

Table 1. (cont.)

DATE	pH		DAYLENGTH (HOURS)		INITIAL POTAMOPLANKTON CONCENTRATION (# liter^{-1} x10^3)		1 DAY GROWTH POTAMOPLANKTON CONCENTRATION (# liter^{-1} x10^3)		GROWTH COEFFICIENT		GROSS 1° PROD. (mg O_2 l^{-1} day^{-1})		DISSOLVED O_2 (ppm)	
	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2	SITE 1	SITE 2
21 July	8.0	7.9	14:34		6446	2994					5.2	3.1	10.1	9.5
3 Aug.	7.7	7.7	14:13		14882	18444	39605	39320	1.661	1.132	3.1	3.2	6.8	8.6
11 Aug.	7.6	7.7	13:51		11156	17759	16535	25337	0.482	0.427	3.9	8.3	9.1	9.5
26 Aug.	7.4	7.6	13:16		1277	1540	5906	5233	3.625	2.398	0.6	2.1	6.8	7.3
9 Sept.	8.0	8.0	12:43		9126	4173	8736	5699	-.043	0.366	2.5	0.4	7.9	7.9
22 Sept.	7.5	7.5	12:10		22960	7859	30903	12995	0.346	0.654	2.0	0.6	10.4	11.8
5 Oct.	7.8	8.0	11:36		15540	7382	16781	8988	0.080	0.218	1.8	1.0	11.2	12.1
19 Oct.	7.5	7.5	10:59		3715	1630	2576	1351	-.307	-.171	1.00	0.6	11.0	12.3
3 Nov.	7.3	7.3	10:21		4574	4990	10631	2769	1.324	-.445	0.7	0.6	5.5	6.0
17 Nov.	7.4	7.5	9:57		0744	0684	0929	0653	0.249	-.045	0.3	0.3	10.1	10.8
1 Dec.	7.3	7.4	9:35		1338	0924	2826	643	1.112	-.304	0.4	0.1	14.4	13.9
15 Dec.	7.4	7.4	9:25		1511	0862					0.5		11.0	9.7

Table 2. Major algal groups encountered and their percentage of the algal potamoplankton population (both in the initial samples and after 1 day of growth in the light primary production bottle) at sites 1 and 2 in Riley Creek, Coles County, Illinois from 21 July, 1974 to 15 December, 1974.

DATE	INITIAL SAMPLE						LIGHT PRIMARY PRODUCTION BOTTLE (1 day)					
	SITE		SITE		SITE		SITE		SITE		SITE	
	1	2	1	2	1	2	1	2	1	2	1	2
21 July	41.6	54.8	58.0	45.2	0.4	0.0	----	----	----	----	----	----
3 Aug.	55.3	56.3	40.1	39.7	3.6	1.3	59.1	58.7	34.7	35.8	4.9	4.4
11 Aug.	79.0	82.0	18.0	17.2	2.4	0.8	70.8	71.4	21.5	27.7	6.5	0.5
26 Aug.	58.9	88.0	32.6	9.7	3.0	0.5	37.0	54.2	62.0	44.9	0.6	0.9
9 Sept.	72.6	81.7	13.1	11.7	14.0	6.6	66.2	71.0	18.0	19.7	15.8	9.2
22 Sept.	29.0	66.9	67.1	31.0	3.7	2.1	30.5	71.3	64.4	23.3	5.1	5.4
5 Oct.	34.0	49.0	10.1	13.2	55.9	37.4	39.5	43.9	17.1	13.1	43.4	42.8
19 Oct.	28.7	35.5	23.4	31.9	46.7	30.3	20.8	31.0	36.6	30.2	41.2	38.8
3 Nov.	24.4	24.1	22.8	30.1	34.4	32.5	35.5	27.5	35.2	36.2	27.3	34.5
17 Nov.	30.4	38.3	29.6	31.3	33.6	21.7	31.0	40.7	34.1	31.5	31.0	15.7
1 Dec.	29.3	45.9	37.8	28.0	29.3	24.6	76.0	25.0	11.6	35.7	12.4	35.1
15 Dec.	74.0	58.9	10.0	18.8	16.0	21.3	55.4	----	21.6	----	23.0	----
	Bacillario-phyta		Chlorophyta		Cryptomona-dales		Bacillario-phyta		Chlorophyta		Cryptomona-dales	

able 3. Growth coefficients (net increase day^{-1}) for the major groups of algae (Bacillariophyta, Chlorophyta, Cryptomonadales) found at sites 1 and 2 in Riley Creek, Coles County, Illinois from 21 July, 1974 to 15 December, 1974.

DATE	SITE							
	1	2	1	2	1	2	1	2

DATE	SITE					
	1	2	1	2	1	2
21 July	----	----	----	----	----	----
3 Aug.	1.71	1.17	1.19	0.88	2.44	2.62
11 Aug.	0.26	0.21	0.65	1.21	2.87	-0.18*
26 Aug.	1.76	1.04	6.24	14.30	-0.09*	6.38*
9 Sept.	-0.14	0.16	0.29	1.76	0.05	0.86
22 Sept.	0.38	0.72	0.26	0.21	0.79	3.10
5 Oct.	0.22	0.06	0.78	0.18	-0.18	0.36
19 Oct.	-0.51	-0.29	0.06	-0.23	-0.41	0.04
3 Nov.	2.31	-0.38	2.50	-0.35	0.80	-0.42
17 Nov.	0.22	-0.01	0.38	-0.06	0.11	-0.33
1 Dec.	4.34	-0.63	-0.35	-0.14	-0.13	-0.03
15 Dec.	-0.25	----	1.16	----	0.44	----
	Bacillariophyta		Chlorophyta		Cryptomonadales	

*based on less than 1% of the total population

Table 4. Concentrations (# ml^{-1}) and relative abundance (% of the total algal population) of dominant algae in the potamoplankton observed at sampling sites 1 and 2 from 21 July, 1974 to 15 December, 1974 in Riley Creek, Coles County, Illinois.

TAXA		SAMPLING WEEK 1	3	4	6	8	10	12	14	16	18	20	22	
I. Division Chlorophyta														
coccoids	(# ml^{-1})	2180	642	455	149	287	609	322	329	415	190	458	121	site 1
	(% total)	33.8	4.3	4.1	11.7	3.1	2.7	2.1	8.8	9.1	25.6	34.2	8.0	
	(# ml^{-1})	824	214	287	57	227	215	381	273	71	149	183	88	site 2
	(% total)	27.4	1.2	1.6	3.7	5.4	2.7	5.1	16.7	23.2	21.7	19.8	10.1	
flagellates	(# ml^{-1})	503	4211	1078	72	301	14435	179	329	257	12	36	23	site 1
	(% total)	7.8	28.3	9.7	5.6	3.3	62.9	1.1	8.8	5.6	1.6	2.7	1.5	
	(# ml^{-1})	124	5993	2045	36	49	2031	143	182	167	36	36	46	site 2
	(% total)	4.1	32.5	11.5	2.3	1.2	25.8	1.9	11.2	3.3	5.2	3.9	5.3	
Scenedesmus spp.	(# ml^{-1})	48	500	311	227	227	108	143	28	43	6	6	0	site 1
	(% total)	0.7	3.4	2.8	17.8	2.5	0.5	0.9	0.8	0.9	0.8	0.5	0	
	(# ml^{-1})	0	599	323	36	114	119	24	6	48	6	4	0	site 2
	(% total)	0	2.7	1.8	2.3	2.7	1.5	0.3	0.4	1.0	0.9	0.5	0	
Stichococcus-like	(# ml^{-1})	863	143	0	0	100	36	929	143	57	0	0	8	site 1
	(% total)	13.4	1.0	0	0	1.1	0.2	6.0	3.8	1.2	0	0	0.5	
	(# ml^{-1})	361	143	0	0	33	24	405	32	0	0	0	0	site 2
	(% total)	12.0	0.8	0	0	0.8	0.3	5.5	2.0	0	0	0	0	
Subtotal (all Chlorophyta including infrequents)	(# ml^{-1})	3738	5960	2011	480	1191	15402	1572	872	1044	220	494	151	site 1
	(% total)	58.0	40.6	18.0	37.6	13.1	67.1	10.1	23.4	22.8	23.6	37.8	10.0	
	(# ml^{-1})	1353	7313	3049	150	487	2436	976	520	1501	214	259	162	site 2
	(% total)	45.2	39.7	17.2	9.7	11.7	31.0	13.2	31.9	30.1	31.3	28.0	18.8	

Table 4. (continued)

TAXA		SAMPLING WEEK 1	3	4	6	8	10	12	14	16	18	20	22	
II. Division Euglenophyta														
Euglena spp.	(# ml^{-1})	0	36	24	6	0	0	0	28	329	30	30	0	site 1
	(% total)	0	0.2	0.2	0.5	0	0	0	0.8	7.2	4.0	2.3	0	
	(# ml^{-1})	0	36	0	14	0	0	24	32	381	48	9	4	site 2
	(% total)	0	0.2	0	0.9	0	0	0.3	2.0	7.6	7.0	1.0	0.5	
Trachelomonas volvocina	(# ml^{-1})	0	0	48	0	0	0	0	14	500	6	12	0	site 1
	(% total)	0	0	0.4	0	0	0	0	0.4	10.9	0.8	0.9	0	
	(# ml^{-1})	0	0	0	14	0	0	0	0	262	6	4	0	site 2
	(% total)	0	0	0	0.9	0	0	0	0	5.3	0.9	0.5	0	
Subtotal (all Euglenophyta including infrequents)	(# ml^{-1})	0	24	72	6	0	0	0	43	29	36	42	0	site 1
	(% total)	0	0.2	0.6	0.5	0	0	0	1.1	18.1	4.8	3.2	0	
	(# ml^{-1})	0	36	0	26	0	0	24	32	643	54	13	4	site 2
	(% total)	0	0.2	0	1.9	0	0	0.3	2.0	12.9	7.8	1.4	0.5	
III. Division Bacillariophyta														
Cyclotella spp.	(# ml^{-1})	2611	7244	7158	570	5983	6555	5001	614	915	36	24	68	site 1
	(% total)	40.5	48.7	69.5	44.7	65.6	28.5	32.1	16.5	20.0	4.8	1.8	4.5	
	(# ml^{-1})	1597	8669	13454	499	1705	4873	2406	273	1072	131	49	50	site 2
	(% total)	53.0	47.0	75.6	32.4	40.9	62.0	32.6	16.7	21.5	19.1	5.3	5.8	
Navicula cryptocephala	(# ml^{-1})	0	36	120	0	0	0	36	43	28	12	54	144	site 1
	(% total)	0	0.2	1.1	0	0	0	0.2	1.2	0.6	1.6	4.1	9.5	
	(# ml^{-1})	0	143	0	14	0	0	24	46	0	36	125	121	site 2
	(% total)	0	0.8	0	0.9	0	0	0.3	2.8	0	5.2	13.5	14.0	

Table 4. (continued)

TAXA		SAMPLING WEEK 1	3	4	6	8	10	12	14	16	18	20	22	
Navicula rhyncocephala	(# ml^{-1})	0	0	0	0	57	0	0	14	28	0	0	0	site 1
	(% total)	0	0	0	0	0.6	0	0	0.4	0.6	0	0	0	
	(# ml^{-1})	10	0	178	100	325	0	0	13	0	0	0	4	site 2
	(% total)	0.3	0	1.0	6.5	7.8	0	0	0.8	0	0	0	0.5	
Navicula lanceolata-like	(# ml^{-1})	0	0	0	0	0	0	0	0	0	30	72	408	site 1
	(% total)	0	0	0	0	0	0	0	0	0	4.0	5.4	27.0	
	(# ml^{-1})	0	0	0	0	0	48	48	0	12	0	36	83	site 2
	(% total)	0	0	0	0	0	0.6	0.6	0	0.2	0	3.9	9.7	
Navicula symmetrica	(# ml^{-1})	0	0	0	0	0	0	0	0	0	6	0	0	site 1
	(% total)	0	0	0	0	0	0	0	0	0	0.8	0	0	
	(# ml^{-1})	0	250	0	164	0	0	24	0	0	0	0	0	site 2
	(% total)	0	1.4	0	10.6	0	0	0.3	0	0	0	0	0	
Navicula spp. (above plus infrequents)	(# ml^{-1})	24	143	192	19	100	0	143	57	72	71	157	582	site 1
	(% total)	0.4	1.0	1.7	1.5	1.1	0	0.9	1.5	1.6	9.6	11.7	38.5	
	(# ml^{-1})	10	471	287	392	666	119	167	65	36	42	192	237	site 2
	(% total)	0.3	3.1	1.6	25.5	16.0	1.5	2.3	4.0	0.7	6.1	20.8	27.5	
Nitzschia palea	(# ml^{-1})	0	178	168	97	186	36	0	72	29	54	90	128	site 1
	(% total)	0	1.2	1.5	7.6	2.0	0.2	0	1.9	0.6	7.2	6.8	8.5	
	(# ml^{-1})	10	285	36	250	271	72	95	39	12	18	49	25	site 2
	(% total)	0.3	1.5	0.2	16.2	11.3	0.9	1.3	2.4	0.2	2.6	5.3	2.9	
Nitzschia acicularis	(# ml^{-1})	0	0	48	6	43	0	72	229	43	12	12	38	site 1
	(% total)	0	0	0.4	0.5	0.5	0	0.5	6.2	0.9	1.6	0.9	2.5	

Table 4. (concluded)

TAXA		SAMPLING WEEK 1	3	4	6	8	10	12	14	16	18	20	22	
Nitzschia acicularis	(# ml^{-1})	10	107	0	78	16	96	48	65	36	36	13	8	site 2
	(% total)	0.3	0.6	0	5.1	0.4	1.2	0.6	4.0	0.7	5.2	1.4	1.0	
Nitzschia spp. (above plus infrequents)	(# ml^{-1})	48	178	239	114	258	36	107	357	100	89	102	287	site 1
	(% total)	0.7	1.2	2.1	8.1	2.8	0.2	0.7	9.6	2.2	12.0	7.7	19.0	
	(# ml^{-1})	21	392	36	342	536	191	214	149	83	60	94	137	site 2
	(% total)	0.7	2.1	0.2	22.2	12.8	2.4	2.9	9.2	1.7	8.7	10.1	15.9	
Surirella ovalis	(# ml^{-1})	0	0	0	0	0	0	0	28	0	18	72	106	site 1
	(% total)	0	0	0	0	0	0	0	0.8	0	2.4	5.4	7.0	
	(# ml^{-1})	10	0	0	0	16	24	738	84	0	6	80	42	site 2
	(% total)	0.3	0	0	0	0.4	0.3	10.0	5.2	0	0.9	8.7	4.8	
Subtotal (all Bacillariophyta)	(# ml^{-1})	2683	8208	8811	752	6600	6663	5287	1072	1114	226	392	1119	site 1
	(% total)	41.6	55.3	79.0	58.9	72.6	29.0	34.0	28.7	24.4	30.4	29.3	74.0	
IV. Division Pyrrophyta														
unidentified cryptomonadales	(# ml^{-1})	24	535	263	39	1277	860	8681	1743	1572	248	392	242	site 1
	(% total)	0.4	3.6	2.4	3.0	14.0	3.7	55.9	46.9	34.4	33.6	29.3	16.0	
	(# ml^{-1})	0	464	144	7	276	167	4144	494	1619	149	228	183	site 2
	(% total)	0	2.5	0.8	0.5	6.6	2.1	37.4	30.3	32.5	21.7	24.6	21.3	

Table 4. (concluded)

TAXA		SAMPLING WEEK 1	3	4	6	8	10	12	14	16	18	20	22	
Nitzschia acicularis	(# ml^{-1})	10	107	0	78	16	96	48	65	36	36	13	8	site 2
	(% total)	0.3	0.6	0	5.1	0.4	1.2	0.6	4.0	0.7	5.2	1.4	1.0	
Nitzschia spp. (above plus infrequents)	(# ml^{-1})	48	178	239	114	258	36	107	357	100	89	102	287	site 1
	(% total)	0.7	1.2	2.1	8.1	2.8	0.2	0.7	9.6	2.2	12.0	7.7	19.0	
	(# ml^{-1})	21	392	36	342	536	191	214	149	83	60	94	137	site 2
	(% total)	0.7	2.1	0.2	22.2	12.8	2.4	2.9	9.2	1.7	8.7	10.1	15.9	
Surirella ovalis	(# ml^{-1})	0	0	0	0	0	0	0	28	0	18	72	106	site 1
	(% total)	0	0	0	0	0	0	0	0.8	0	2.4	5.4	7.0	
	(# ml^{-1})	10	0	0	0	16	24	738	84	0	6	80	42	site 2
	(% total)	0.3	0	0	0	0.4	0.3	10.0	5.2	0	0.9	8.7	4.8	
Subtotal (all Bacillariophyta)	(# ml^{-1})	2683	8208	8811	752	6600	6663	5287	1072	1114	226	392	1119	site 1
	(% total)	41.6	55.3	79.0	58.9	72.6	29.0	34.0	28.7	24.4	30.4	29.3	74.0	
IV. Division Pyrrophyta														
unidentified cryptomonadales	(# ml^{-1})	24	535	263	39	1277	860	8681	1743	1572	248	392	242	site 1
	(% total)	0.4	3.6	2.4	3.0	14.0	3.7	55.9	46.9	34.4	33.6	29.3	16.0	
	(# ml^{-1})	0	464	144	7	276	167	4144	494	1619	149	228	183	site 2
	(% total)	0	2.5	0.8	0.5	6.6	2.1	37.4	30.3	32.5	21.7	24.6	21.3	

Table 5. Concentrations (# ml^{-1}) and relative abundance (% of the total algal population) of dominant algae in the algal community after one day's growth (light primary productivity bottle) at sampling sites 1 and 2 from 21 July, 1974 to 15 December, 1974 in Riley Creek, Coles County, Illinois.

TAXA		SAMPLING WEEK											
		1	3	4	6	8	10	12	14	16	18	20	22	
I. Division Chlorophyta														
coccoids	(# ml^{-1})	--*	1641	375	2766	387	532	254	444	2286	247	109	218	site 1
	(% total)	--	4.1	2.3	46.8	4.4	1.7	1.5	17.3	21.5	26.6	3.9	14.1	
	(# ml^{-1})	--	847	605	920	345	629	247	100	766	139	188	--	site 2
	(% total)	--	2.2	2.4	17.6	6.1	4.8	2.7	7.4	24.5	21.3	29.2	--	
flagellates	(# ml^{-1})	--	9174	1921	280	532	19384	381	254	581	29	121	7	site 1
	(% total)	--	23.2	11.6	4.7	6.1	62.7	2.3	9.9	5.5	3.1	4.3	0.5	
	(# ml^{-1})	--	10000	3628	315	544	2081	174	223	181	18	27	--	site 2
	(% total)	--	25.4	14.3	6.0	9.6	16.0	1.9	16.5	6.6	2.8	4.2	--	
Scenedesmus spp.	(# ml^{-1})	--	1119	703	467	169	0	145	36	36	29	24	15	site 1
	(% total)	--	2.8	4.2	7.9	1.9	0	0.9	1.4	0.3	3.1	0.9	0.9	
	(# ml^{-1})	--	920	1391	291	145	73	44	11	0	12	8	--	site 2
	(% total)	--	2.3	5.5	5.6	2.5	0.6	0.5	0.8	0	1.9	1.2	--	
Stichococcus-like	(# ml^{-1})	--	373	47	0	194	0	2032	154	181	0	12	7	site 1
	(% total)	--	0.9	0.3	0	2.2	0	12.1	6.0	1.7	0	0.4	0.5	
	(# ml^{-1})	--	751	0	0	54	145	682	56	0	0	0	--	site 2
	(% total)	--	1.9	0	0	1.0	1.1	7.6	4.1	0	0	0	--	
Subtotal (all Chlorophyta including infrequents)	(# ml^{-1})	--	13038	3321	3472	1535	19438	2799	921	3649	305	319	326	site 1
	(% total)	--	34.7	21.5	62.0	18.0	64.4	17.1	36.6	35.2	34.1	11.6	21.6	
	(# ml^{-1})	--	13723	6731	2291	1098	2952	1148	398	980	201	224	--	site 2
	(% total)	--	35.8	27.7	44.9	19.7	23.3	13.1	30.2	36.2	31.5	35.7	--	

* Samples were not available for analysis due to accidental loss

Table 5. (continued)

TAXA		SAMPLING WEEK 1	3	4	6	8	10	12	14	16	18	20	22	
II. Division Euglenophyta														
Euglena spp.	(# ml^{-1})	--	298	0	19	0	0	19	36	145	14	0	0	site 1
	(% total)	--	0.8	0	0.3	0	0	0.1	1.4	1.4	1.6	0	0	
	(# ml^{-1})	--	242	0	0	0	0	0	0	24	42	4	--	site 2
	(% total)	--	0.6	0	0	0	0	0	0	0.9	6.5	0.6	--	
Trachelomonas volvocina	(# ml^{-1})	--	0	94	0	0	0	0	0	0	7	0	0	site 1
	(% total)	--	0	0.6	0	0	0	0	0	0	0.8	0	0	
	(# ml^{-1})	--	0	121	0	0	0	0	0	24	6	0	--	site 2
	(% total)	--	0	0.5	0	0	0	0	0	0.9	0.9	0	--	
Subtotal (all Euglenophyta including infrequents)	(# ml^{-1})	--	283	89	18	0	0	71	35	142	21	0	0	site 1
	(% total)	--	0.8	0.6	0.3	0	0	0.1	1.4	1.4	2.4	0	0	
	(# ml^{-1})	--	236	118	0	0	0	0	0	47	47	4	--	site 2
	(% total)	--	0.6	0.5	0	0	0	0	0	1.7	7.4	0.6	--	
III. Division Bacillariophyta														
Cyclotella spp.	(# ml^{-1})	--	21331	10726	1962	5372	9244	6168	390	3701	73	315	65	site 1
	(% total)	--	53.9	64.9	33.2	6.15	29.9	36.8	15.1	34.8	7.8	11.2	4.2	
	(# ml^{-1})	--	21113	16085	1889	3811	9583	3078	196	387	54	15	--	site 2
	(% total)	--	53.7	63.5	37.0	66.9	70.0	34.2	14.5	14.0		2.4	--	
Navicula cryptocephala	(# ml^{-1})	--	0	0	0	0	0	0	9	0	14	279	36	site 1
	(% total)	--	0	0	0	0	0	0	4.0	0	1.6	9.9	2.3	
	(# ml^{-1})	--	0	60	0	0	0	14	11	36	66	34	--	site 2
	(% total)	--	0	0.2	0	0	0	0.2	0.8	1.3	10.2	5.4	--	

Table 5. (continued)

TAXA		SAMPLING WEEK 1	3	4	6	8	10	12	14	16	18	20	22	
Navicula rhyncocephala	(# ml^{-1})	--	224	312	19	0	0	0	0	0	0	12	7	site 1
	(% total)	--	-.6	1.4	0.3	0	0	0	0	0	0	0.4	0.5	
	(# ml^{-1})	--	73	121	73	0	0	29	6	0	0	0	--	site 2
	(% total)	--	0.2	0.5	1.4	0	0	0.3	0.4	0	0	0	--	
Navicula lanceolata-like	(# ml^{-1})	--	0	0	0	0	0	18	9	0	14	521	153	site 1
	(% total)	--	0	0	0	0	0	0.1	4.0	0	1.6	18.5	9.9	
	(# ml^{-1})	--	0	0	0	0	48	0	11	0	12	19	--	site 2
	(% total)	--	0	0	0	0	0.4	0	0.8	0	1.9	3.0	--	
Navicula symmetrica	(# ml^{-1})	--	75	0	0	0	0	0	0	0	0	0	0	site 1
	(% total)	--	0.2	0	0	0	0	0	0	0	0	0	0	
	(# ml^{-1})	--	48	0	48	0	0	0	0	0	0	0	--	site 2
	(% total)	--	0.1	0	0.9	0	0	0	0	0	0	0	--	
Navicula spp. (all the above plus infrequents)	(# ml^{-1})	--	298	437	75	48	48	18	36	36	80	849	232	site 1
	(% total)	--	0.8	2.0	1.3	0.6	0.2	0.1	1.4	0.3	8.6	30.0	15.0	
	(# ml^{-1})	--	121	302	218	18	145	58	45	73	103	57	--	site 2
	(% total)	--	0.3	1.2	4.2	0.3	1.1	0.6	3.3	2.6	15.7	8.9	--	
Nitzschia acicularis	(# ml^{-1})	--	149	47	56	97	73	54	18	36	36	267	116	site 1
	(% total)	--	0.4	0.3	0.9	1.2	0.2	0.3	0.7	0.3	3.9	9.4	7.5	
	(# ml^{-1})	--	242	242	121	36	0	14	22	24	18	19	--	site 2
	(% total)	--	0.6	1.0	2.3	0.6	0	0.2	1.7	0.9	2.8	3.0	--	
Nitzschia palea	(# ml^{-1})	--	149	47	56	97	73	54	18	36	36	267	116	site 1
	(% total)	--	0.4	0.3	0.9	1.1	0.2	0.3	0.7	0.3	3.9	9.4	7.5	

Table 5. (concluded)

TAXA		SAMPLING WEEK												
		1	3	4	6	8	10	12	14	16	18	20	22	
Nitzschia palea	(# ml^{-1})	--	242	242	121	36	0	14	22	24	18	19	--	
	(% total)	--	0.6	1.0	2.3	0.6	0	0.2	1.7	0.9	2.8	3.0	--	site 2
Nitzschia spp. (all the above plus infrequents)	(# ml^{-1})	--	224	187	75	121	122	200	91	36	109	643	349	
	(% total)	--	0.6	1.1	1.3	1.4	0.4	1.2	3.5	0.3	11.7	22.7	22.5	site 1
	(# ml^{-1})	--	508	363	218	91	0	160	95	73	48	61	--	
	(% total)	--	1.3	1.4	4.2	1.6	0	1.8	7.0	2.6	7.4	9.5	--	site 2
Surirella ovalis	(# ml^{-1})	--	0	0	0	0	0	0	9	0	0	230	80	
	(% total)	--	0	0	0	0	0	0	0.4	0	0	8.2	5.2	site 1
	(# ml^{-1})	--	0	0	0	0	0	566	67	218	36	19	--	
	(% total)	--	0	0	0	0	0	6.3	5.0	7.9	5.6	3.0	--	site 2
Subtotal (all Bacillariophyta including infrequents)	(# ml^{-1})	--	22249	11071	2073	5645	9188	6466	523	3685	276	2090	836	
	(% total)	--	59.1	70.8	37.0	66.2	30.5	39.5	20.8	35.5	31.0	76.0	55.4	site 1
	(# ml^{-1})	--	22509	17655	2763	3950	9046	3855	409	744	260	157	--	
	(% total)	--	58.7	71.4	54.2	71.0	71.3	43.9	31.0	27.5	40.7	25.0	--	site 2
IV. Division Pyrrophyta														
unidentified cryptomonadales	(# ml^{-1})	--	1939	1078	37	1379	1573	7274	1061	2902	283	352	356	
	(% total)	--	4.9	6.5	0.6	15.8	5.1	43.4	41.2	27.3	30.5	12.4	23.0	site 1
	(# ml^{-1})	--	1719	121	48	526	702	3847	525	956	103	226	--	
	(% total)	--	4.4	0.5	0.9	9.2	5.4	42.8	38.8	34.5	15.7	35.1	--	site 2

Table 6. Composite list of algal taxa observed at sampling sites 1 and 2 from 21 July, 1974 to 15 December, 1974 in Riley Creek, Coles County, Illinois showing sites of occurrence (x) and absence (-).

TAXA	SITES 1	2
I. Division Chlorophyta		
unidentified coccoids	x	x
unidentified flagellates	x	x
unidentified fusiform cells	x	x
A. Class Chlorophyceae		
1. Order Chlorococcales		
a. Family Coelastraceae		
Coelastrum spp. Nageli	x	x
b. Family Oocystaceae		
Planktosphaeria sp. G. M. Smith	x	x
c. Family Scenedesmaceae		
Actinastrum hantzschii Lagerheim	x	x
Scenedesmus abundans (Kirch.) Chodat	x	x
Scenedesmus bijuga v. alternans (Rein.)Hans.	x	-
Scenedesmus dimorphus (Turp.) Kuetzing	x	x
Scenedesmus opoliensis (Turp.) Kuetzing	x	x
Scenedesmus quadricauda (Turp.) de Brebisson	x	x
2. Order Zygnematales		
a. Family Desmidiaceae		
Closterium spp. Nitzsch	x	x
Staurastrum spp. Meyen	x	x
Staurastrum cuspidatum	x	x
3. Order Ulotrichales		
a. Family Ulotrichaceae		
Stichococcus-like Nägeli	x	x
II. Division Euglenophyta		
A. Class Euglenophyceae		
1. Order Euglenales		
a. Family Euglenaceae		
Euglena spp. Ehrenberg	x	x
Trachelomonas volvocina Ehrenberg	x	x

TAXA	SITES 1	2
III. Division Bacillariophyta		
Achnanthes lanceolata (Breb.) Grun.	x	x
Achnanthes minutissima Kutz.	x	x
Amphora ovalis Kutz.	x	-
Asterionella formosa Hass.	-	x
Cocconeis diminuta Pant	x	x
Cocconeis pediculus Ehr.	x	x
Cyclotella spp. Kutz.	x	x
Cyclotella atomus Hustedt	x	x
Cyclotella glomerata Bachmann	x	x
Cyclotella kutzingiana-like Thwaites	x	x
Cyclotella meneghiniana Kutz.	x	x
Cyclotella pseudostelligera	x	x
Cyclotella stelligera Cleve and Grun.	x	x
Cymbella cuspidata Kutz.	x	x
Cymbella prostrata (Berkeley) Cleve.	-	x
Cymbella ventricosa Kutz.	-	x
Diploneis sp. Ehr.	-	x
Epithemia sp. Brebisson	x	-
Gomphonema angustatum (Kutz.) Grun.	x	-
Gomphonema olivaceum (Lyngbye) Kutz.	x	-
Gomphonema parvulum (Kutz.) Grun.	x	-
Gomphonema sphaerophorum Ehr.	-	x
Gyrosigma scalproides (Rabenhorst) Cleve	x	x
Hantzschia amphyoxis (Ehr.) Grun.	-	x
Melosira binderana-like Kutz.	x	x
Navicula spp. Bory	x	x
Navicula capitata Ehr.	x	x
Navicula cryptocephala Kutz. var. cryptocephala	x	x
Navicula cryptocephala var. veneta (Kutz.) Grun.	x	x
Navicula exigua-like Greg. ex Grun.	-	x
Navicula gracilis Ehr.	x	x
Navicula heufleri var. leptocephala (Breb. ex Grun.) Patr.	x	x
Navicula lanceolata-like (Ag.) Kutz.	x	x
Navicula notha-like Wallace	-	x
Navicula protracta Grun.	x	x
Navicula rhyncocephala Kutz.	x	x
Navicula symmetrica Patr. var. symmetrica	x	x
Navicula viridula var. rostellata (Kutz.) Cl.	-	x
Neidium sp. Pfitzer	-	x
Nitzschia spp. Hassall	x	x
Nitzschia acicularis (Kutz.) Wm. Smith	x	x
Nitzschia angustata (Wm. Smith) Grun.	x	x
Nitzschia apiculata	x	x
Nitzschia filiformis (Wm. Smith) Hustedt	x	x
Nitzschia hungarica Grun.	x	x

TAXA	SITES 1	2
Nitzschia linearis (Agardh) Wm. Smith	x	x
Nitzschia palea (Kutz.) Wm. Smith	x	x
Nitzschia sigmoidea (Nitzsch) Wm. Smith	x	x
Nitzschia vermicularis (Kutz.) Hantzsch	-	x
Pinnularia brebissonii (Kutz.) Rabenhorst	x	-
Stephanodiscus hantzschii-like Grunow	x	x
Stephanodiscus invisitatus	x	x
Stephanodiscus tenuis Hustedt	-	x
Surirella angustata	x	x
Surirella ovalis Brebisson	x	x
Surirella splendida (Ehr.) Kutz.	x	-
Synedra sp. Ehrenberg	x	x
Synedra fasiculata (Ag.) Kutz.	x	x
IV. Division Cryptophyta		
A. Class Cryptophyceae		
1. Order Cryptomonadales		
unidentified cryptomonads	x	x
a. Family Cryptochrysidaceae		
Chroomonas-like Hansgirg	x	x
b. Family Cryptomonadaceae		
Cryptomonas spp. Ehrenberg	x	x
Cryptomonas ovata Ehrenberg	x	x
V. Division Cyanophyta		
unidentified coccoids	x	x
unidentified filaments	x	x
VI. Unclassified algae		
non-green flagellates	x	x
non-green coccoids	x	x

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