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A Survey of the Water Quality and Fishes of Rocky Branch Nature Preserve, Clark County, Illinois

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A Survey of the Water Quality and Fishes of

Rocky Branch Nature Preserve, Clark County, Illinois

(TITLE)

BY

Larry J. Decker

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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THIS PART OF THE GRADUATE DEGREE CITED ABOVE

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The undersigned, appointed by the Head of the Department of Zoology

have examined a thesis entitled

A Survey of the Water Quality and Fishes of Rocky Branch Nature Preserve, Clark County, Illinois

Presented by

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a candidate for the degree of Master of Zoology

and hereby certify that in their opinion it is acceptable.

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Introduction

Water is essential for life as we know it on this planet. Because of this fact the necessity for clean water is obvious. Without clean usable sources of water, life would disappear from the face of the Earth.

Wilbur (1969) estimates that there are 273 liters of water per square centimeter of surface on this planet. He also states that, of this amount, the majority or 269 liters per square centimeter is seawater. The remaining 4 liters exist as freshwater, continental ice, and water vapor. The freshwater is of utmost importance to man for this is the form readily available for his use.

Water is involved in a definite cycle of evaporation and precipitation. This sequence of events is termed the hydrological cycle. During this cycle water is evaporated from large bodies of water and from the land. The sun's energy acts as the driving force which brings about evaporation and purification of the water vapor. It is then condensed or precipitated in the form of rain, dew, and mist. After reaching the ground, a portion of the water returns to the atmosphere via evaporation and transpiration from plants. The remainder either soaks into the soil and becomes ground water or runs off as surface water.

During this cycle the quality of water changes drastically and man plays a very important role in that change. Water from various sources is utilized by man and then continues on through the cycle in the form of sewage or industrial effluent. The next user must realize its condition and attempt to alter it into a usable form by purification. Clean water is essential not only for man but also for a healthy aquatic community.

Many researchers have long been aware of the importance of clean water. Forbes (1893), Kofoid (1898), and Agassiz (1850) were a few of the first authors to conduct serious limnological studies. In recent years the number of lake, river, and stream studies has increased at a rapid rate.

The need for such studies is apparent. Man utilizes water directly, in industry and agriculture. Copious amounts of clean water are necessary to meet such requirements. Water quality criteria have been recommended by the Federal Government in order to establish a base from which to work in maintaining and cleaning our streams and lakes (Anon., 1968). Many states have followed suit and established their own standards which work in conjunction with those set up by the federal government. Such criteria provide the researcher with an index which can be compared with his own results in determining water quality.

Flood control, irrigation, power production, and fish and wildfowl production are a few of the many reasons stream studies are conducted. Kittrell (1969) feels most studies fall into one of two general categories. The first of these are studies designed to determine water quality at a single point or at isolated points. Sampling occurs at varied intervals and at one or more unrelated sampling stations over a protracted period of time. The second general category is designed to determine changing water quality in a stream system as the water moves downstream. This involves a series of related sampling stations which are selected to reflect instantaneous changes in water quality. Water samples are collected at frequent intervals for a limited period of time.

According to Kittrell(1969) there have probably been as many objectives of water quality studies as there have been studies. Among the many objectives listed are:

1) establishment of a base line record of water quality
2) investigation of suitability for propagation of aquatic life
3) surveillance to detect adherence to or violation of water quality standards
4) determination of causes of fish kills or other disasters involving deterioration in water quality
5) research on methods of stream studies.

These represent only a few of the possible objectives of stream studies.

The chemistry of water is of major importance in determining water quality. The effect certain water chemistry parameters have upon aquatic ecosystems warrants that investigators monitor them. Such parameters as phosphate and nitrate levels, temperature, dissolved oxygen, and turbidity are usually components of water chemistry studies. Many other parameters are also monitored depending upon the circumstances and objectives of each individual study. Ellis, Westfall, and Ellis (1948) give a rather complete listing of the more common water chemistry parameters while Standard Methods (Anon., 1971b) outlines the most recent analytical procedures.

Detailed chemical studies of stream systems are quite common. Harmeson and Larson (1969) published a 10 year continuing study which included 33 Illinois streams and rivers.

Inventories of fish species present in a stream system often accompany water chemistry data in determining relative water quality. The earliest censuses of Illinois streams were made by Jordan (1878) and Forbes and Richardson (1920). The early work of these pioneers in their field proved invaluable during later years when Illinois streams were resurveyed. Smith (1971) noted the absence of several species formerly reported in Illinois streams.

Water chemistry and biological indices are major factors in determining water quality of a stream system. It was with these factors in mind that a limnological and ichthyofaunal study of Rocky Branch, Clark County, Illinois was undertaken.

<u>The Study Area</u>

Rocky Branch Nature Preserve is located approximately 9.7 kilometers northwest of Marshall, Illinois (Fig. 1). The Preserve, which is owned by the Illinois Nature Conservancy and administered by Eastern Illinois University, is located in section 29 and 30, T 12 N, R 12 W, of Clark County, Illinois (Anon., 1971c). The Preserve encompasses approximately 300 acres. Hellinga and Ebinger (1970) state that Rocky Branch

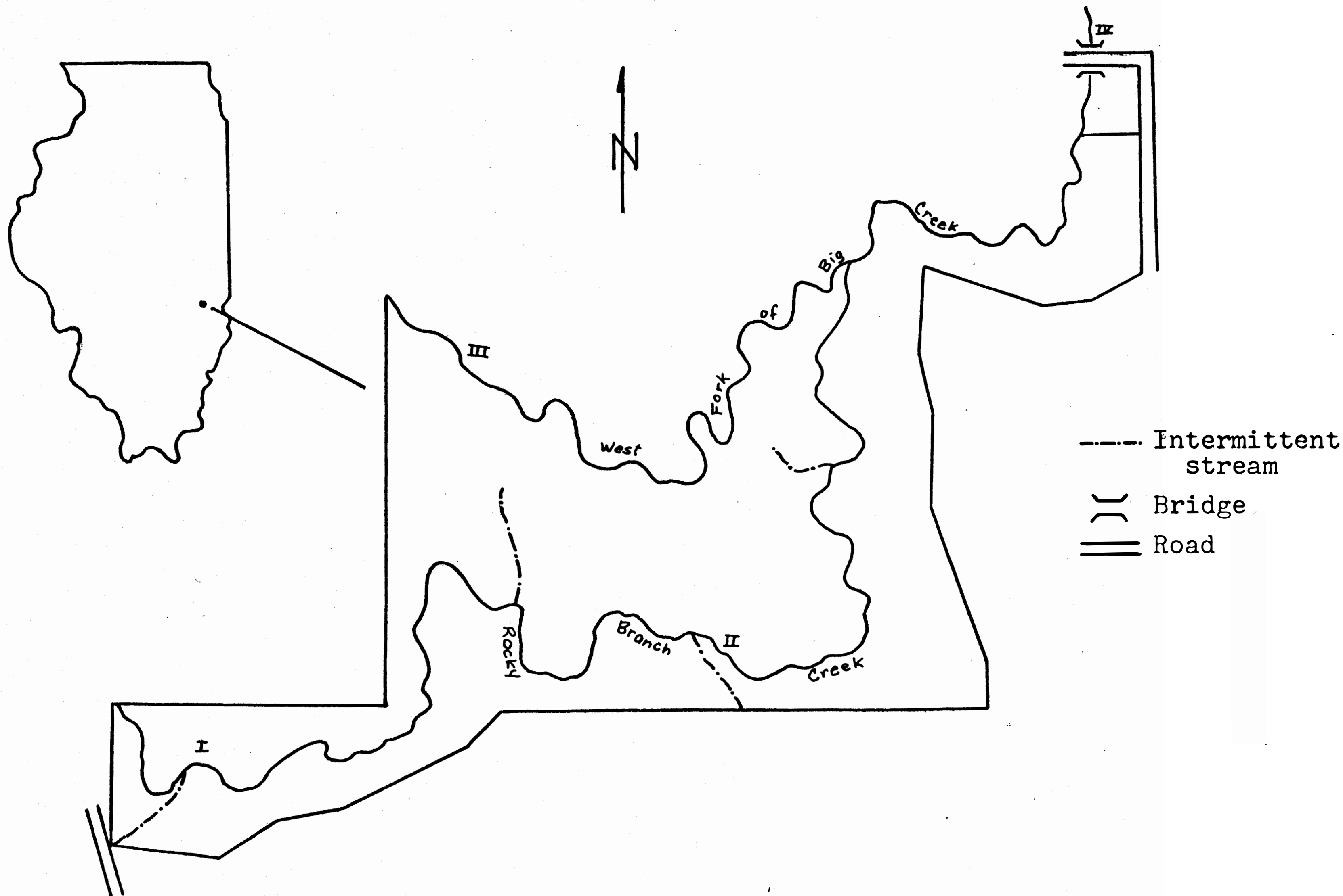

Figure 1. Location of Rocky Branch Preserve, Clark County, Illinois and sampling stations I - IV for the study conducted from September 15, 1972 to May 8, 1973.

is situated on the till of the Illinoian glacier about 16 kilometers south of the Shelbyville Moraine, the terminal moraine of the Wisconsin glacier. The Rocky Branch area is characterized by steep-sided sandstone outcroppings and hillsides, many of which are 15 to 18 meters from base to top. During flood stage Stover (1930) reports that water in Rocky Branch may rise as much as 2.5 meters above its gravel and sandstone bed. This author has observed water levels as high as 1.2 to 1.5 meters above the stream bed. Rocky Branch, the main creek running through the Preserve, and its tributaries have carved the sandstone cliffs into a beautiful gorge covered with mosses and liverworts.

Hellinga and Ebinger (1970) report that the area is a remnant of the typical forest associated with the deep valleys of east-central Illinois located on Illinoian till. They report 445 species of vascular plants in 97 families. Of this number 120 taxa reported had not previously been recorded from Clark County.

Evers (1963) includes Rocky Branch Preserve in a list of unusual and unique sites in Illinois. He describes the area as being chiefly deciduous forest with the upland areas consisting of oak and hickory. The vegetation of the drier ravine slopes is composed of black oak, red oak, and shagbark hickory while the moist ravine slopes sustain a beech, hard maple, and dogwood forest. <u>Conocephalum conicum</u> is a species of liverwort typically abundant on the sandstone cliffs (Evers, 1963).

Rocky Branch has long been considered unique from a botanical standpoint. Stover (1930) published the first floral list for the Preserve. Since that time several other authors have studied the flora of the area. Vaughan (1941) conducted an extensive survey of the area's bryophytes while Wiedman (1971) surveyed the lichen flora. Hellinga and Ebinger (1970) made an extensive survey of the Preserve's vascular plants.

Rocky Branch, the small stream running through the Preserve, is approximately 2.4 kilometers in length. It has its origin in the eastern half of section 30, T 12 N, R 12 W, and empties into the West Fork of Big Creek in section 29 of the same township (Anon., 1971c). The stream is relatively shallow throughout its course, averaging approximately 25 centimeters in depth. The deepest section of the stream is a pool approximately 1.7 meters deep near the west edge of the Preserve. The stream's average width is 1.5 meters with the widest section occurring near its confluence with the West Fork of Big Creek, the Preserve's northwest boundary. The stream's velocity is fairly rapid with many riffles and pools, while the bottom is composed of fine-grained sand and gravel.

The northwest boundary of Rocky Branch is delimited by the West Fork of Big Creek. The West Fork is generally larger than Rocky Branch with an average width of 6 meters and a depth of 42 centimeters. Many small falls and large riffles tend to make the stream's velocity somewhat greater than that of Rocky Branch. The stream bed is composed of fine-grained to course sand, large pebbles, and rock. The West Fork eventually joins with Big Creek which is a tributary of the Wabash River.

The general drainage area, which includes the Wabash River, contains several uncommon species of fish, according to Smith (1971). To the present no studies of water quality nor recent studies of the fish species found in Rocky Branch had been made. It is the author's hope that this study will contribute to the information already collected concerning Rocky Branch Nature Preserve and increase the knowledge necessary to conserve the unique resources of the area.

Methods

Water sampling stations were established at four points within the study area. Two stations were located at 1.2 kilometer intervals on Rocky Branch Creek just below the juncture of small intermittant tributaries. The remaining two stations were located about 1.2 kilometers upstream and downstream from the confluence of Rocky Branch with the West Fork of Big Creek. Water samples were collected at two week intervals from September 9, 1972 to May 8, 1973. During September and May only one sample was taken.

Plastic 1 liter bottles were used to collect water samples at each site. All of the samples were returned to the Eastern Illinois University Water Quality Lab for analysis. Total phosphates, orthophosphates, condensed phosphate, nitrate, total iron, turbidity, and sulfates were determined according to Hach Colormetric Methods (Anon., 1967b). For these parameters a Hach AC-DR Colorimeter was used. Hach (Anon., 1967b) titrametric methods were used to determine total hardness and alkalinity.

A Sargent-Welch Model LS Meter was employed to determine pH of each sample. The conductivity of each sample was recorded by a Hach Model 2200 Conductivity Meter (Anon., 1971a).

Dissolved oxygen for each sampling station was initially determined by the Winkler Method while later in the study a

YSI Model 54 Oxygen Meter and Probe were used. Checks were made periodically to ensure the accuracy of the YSI Meter by running a Winkler dissolved oxygen and comparing the results.

Temperature was recorded at each sampling station by suspending a standard laboratory thermometer in the stream for no less than 15 minutes.

Fish collections were made by trapping and seining. A standard minnow trap containing various baits was left over night in the deeper holes along the stream. Seining was accomplished by a three man team dragging a 2.4 meter by .9 meter, .2 centimeter mesh net upstream. Two men hauled the seine while the third walked toward the seine kicking up the riffles. Due to the length of the creek it was possible to seine the entire stream several times. A total of 10 seining trips was made to the area.

A representative of each species encountered was removed from the stream and preserved in 10% formalin. No attempt was made to preserve the entire catch for later calculations of relative abundance. It was felt that the removal of large numbers of fish from the Nature Preserve was not warranted. However, the author did note the more common species. Fish sampling was conducted only on Rocky Branch and not on the West Fork of Big Creek.

Trautman (1957), Eddy (1969), and Hubbs and Lagler (1958) have published keys which aided in the identification of the fishes from Rocky Branch.

Description of Sampling Stations

Station I

Station I (Fig. 1) was located at the extreme western edge of the Rocky Branch Nature Preserve. Samples were taken on the creek five meters below a small tributary which drained farm and pasture lands located to the southwest. At this location the creek is approximately 2.1 meters in width and usually 20 to 25 centimeters in depth. Stream velocity at the sampling point is fairly rapid due to an upstream riffle area. Bottom sediments are composed of a fine-grained sand and gravel mixture as well as what appeared to be large slabs of slate which were scattered intermittantly. The south bank of the creek is an extremely steep sandstone cliff supporting numerous bryophytes while the north bank is relatively flat and covered with a dense shrub-sapling community. The north bank is an old abandoned field undergoing an early stage of plant succession.

Station II

Station II (Fig. 1) was located approximately 1.2 kilometers downstream from Station I. At this point a small intermittant stream drains a large, steep forested area located on Rocky Branch's south bank. The north bank is a flat, heavily-forested floodplain area. Fine-grained sand and gravel make up the bottom sediment. At this point, the stream is approximately 1.8 meters wide and 12 to 18 centimeters deep. Stream velocity is fairly rapid due to upstream riffle areas.

Station III

Station III (Fig. 1) was located about 1.2 kilometers upstream from the confluence of Rocky Branch with the West Fork of Big Creek. At this station the West Fork is approximately 5.5 meters wide and 45 centimeters deep. The stream bottom is composed of coarse gravel and pebbles as well as fine sand. Due to the absence of riffles near this station, the stream's velocity is rather slow. The southwest bank of the West Fork is a heavily-wooded steep hill while the northeast bank is a gently rolling plowed field. Only a small green belt of grasses and a few sycamores separates the field from the stream.

Station IV

Station IV (Fig. 1) was located approximately 2.4 kilometers downstream form Station III and approximately 1.2 kilometers from the mouth of Rocky Branch. The West Fork of Big Creek is 7.6 to 9 meters wide and 45 to 60 centimeters deep at this station. The creek is crossed by a concrete bridge and road which makes it easily accessible. A large riffle area which is located just upstream from the sampling site causes a marked increase in stream velocity. The bottom is composed of coarse gravel, pebbles, and fine-grained sand. Both stream banks are somewhat steep and lined with various shrubs and grasses. The bank area has the appearance of having been cleared at one time.

Results

The data collected for the various chemical and physical parameters which were considered are presented in Figures 2 through 14.

Mean values and the ranges for the physical and chemical parameters at each sampling station are recorded in Table 1.

Table 2 relates biochemical oxygen demand data collected on six dates. Table 3 lists the dates and results of turbidity readings.

Lists of fishes collected during the course of the Rocky Branch study are presented in Table 4. This table also lists the type of habitat in which they were collected, family, and relative abundance of each.

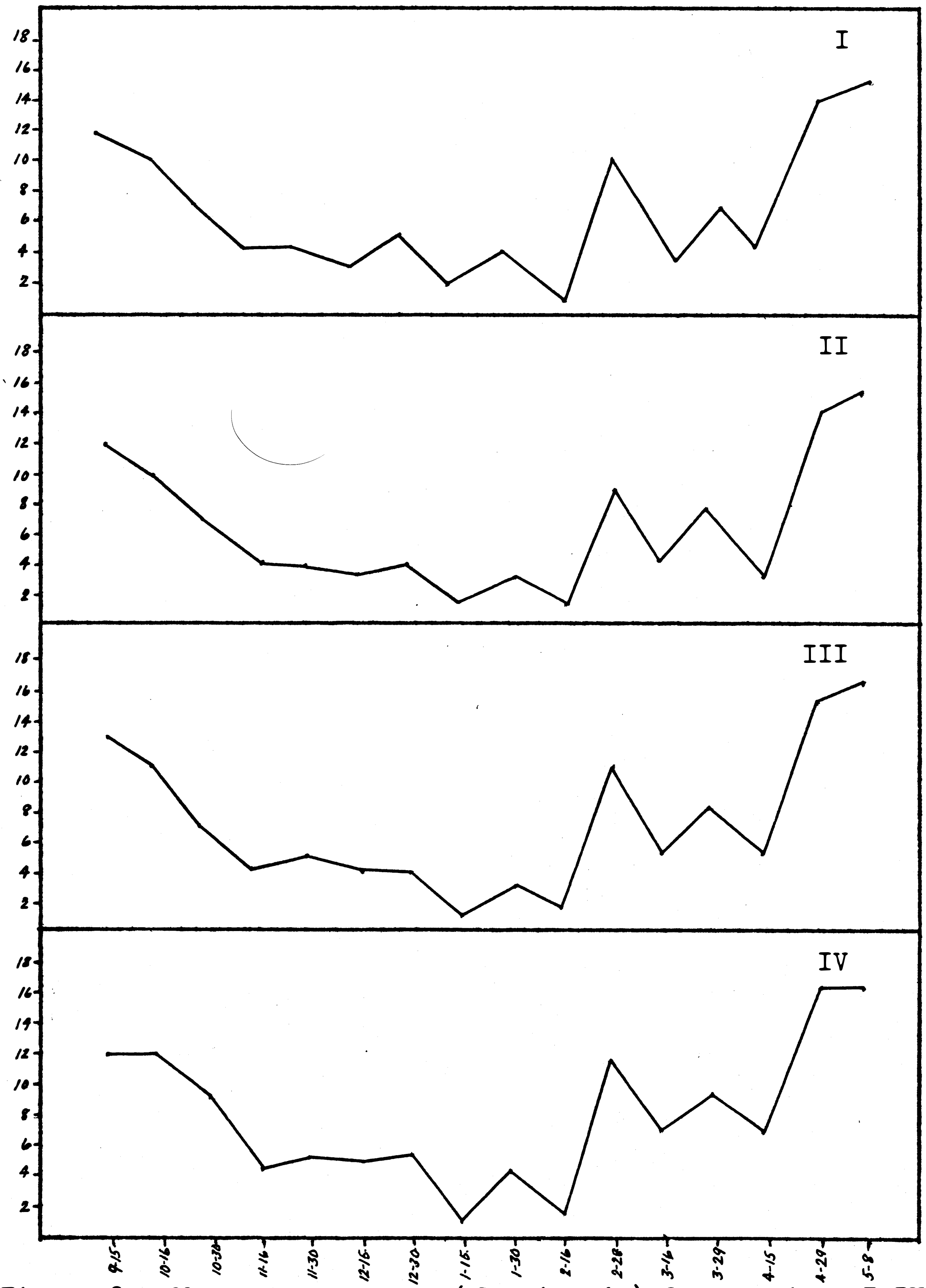

Figure 2. Water temperature (Centigrade) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

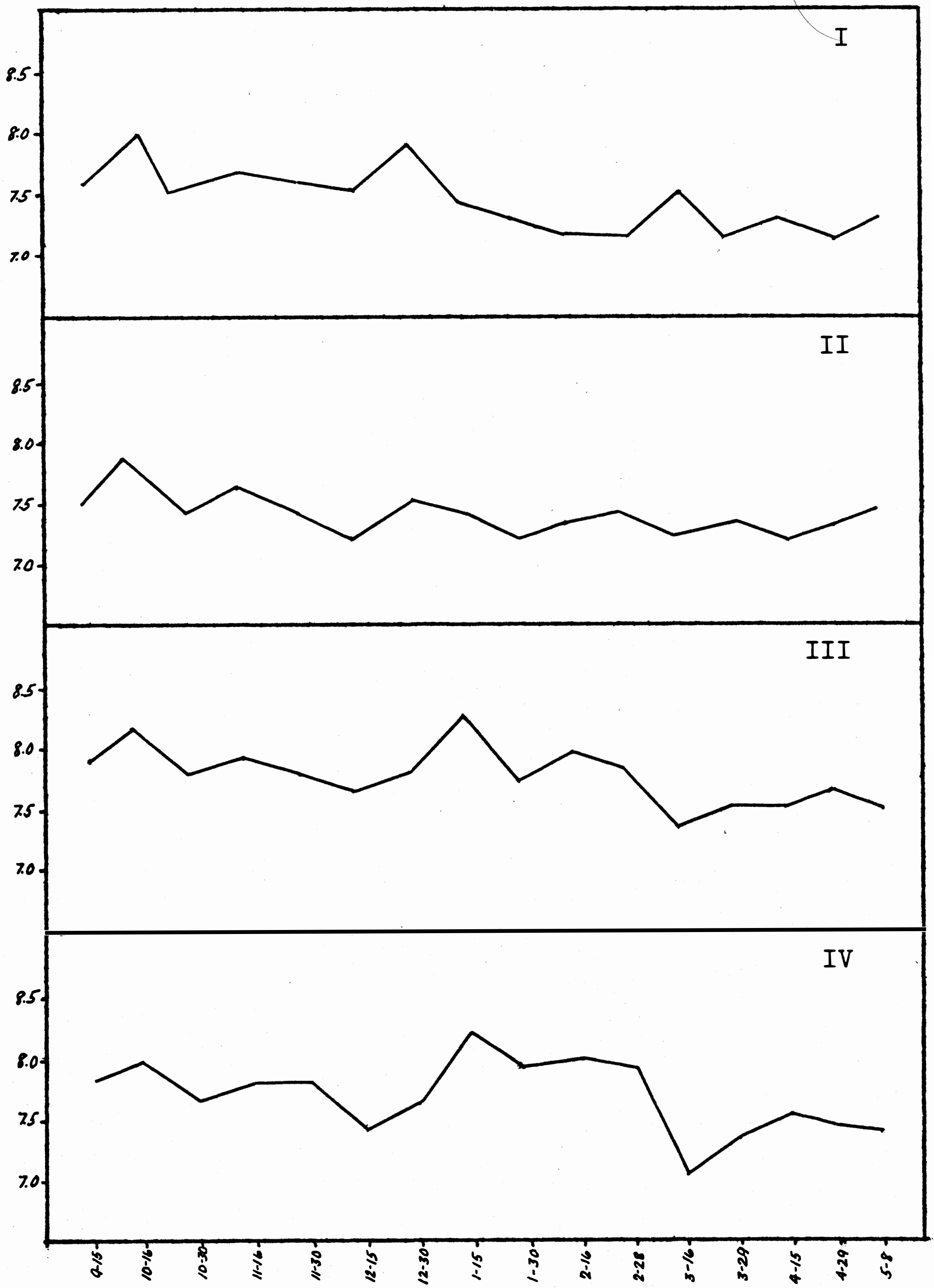

Figure 3. pH levels for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 through May 8, 1973.

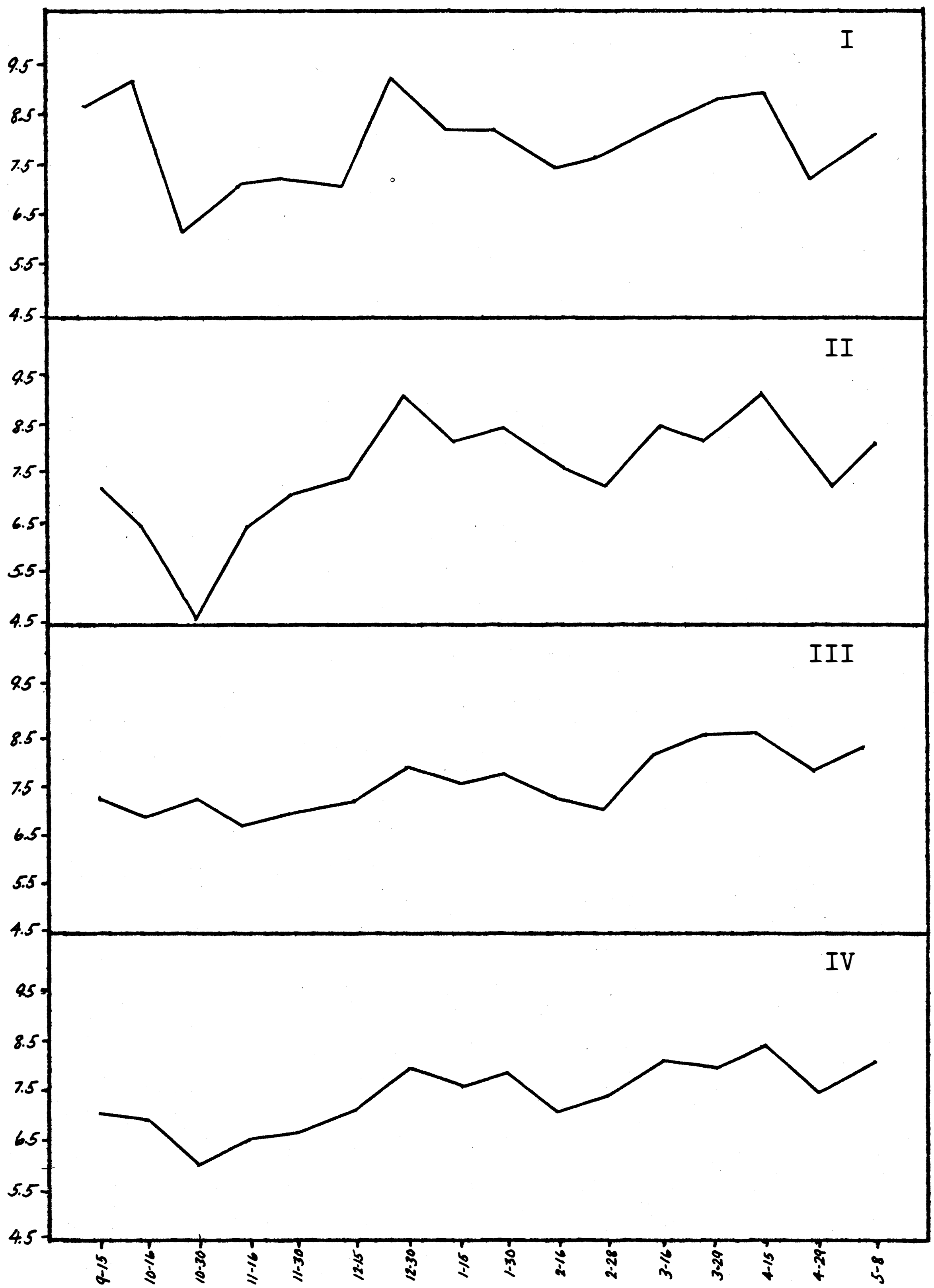

Figure 4. Dissolved oxygen levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

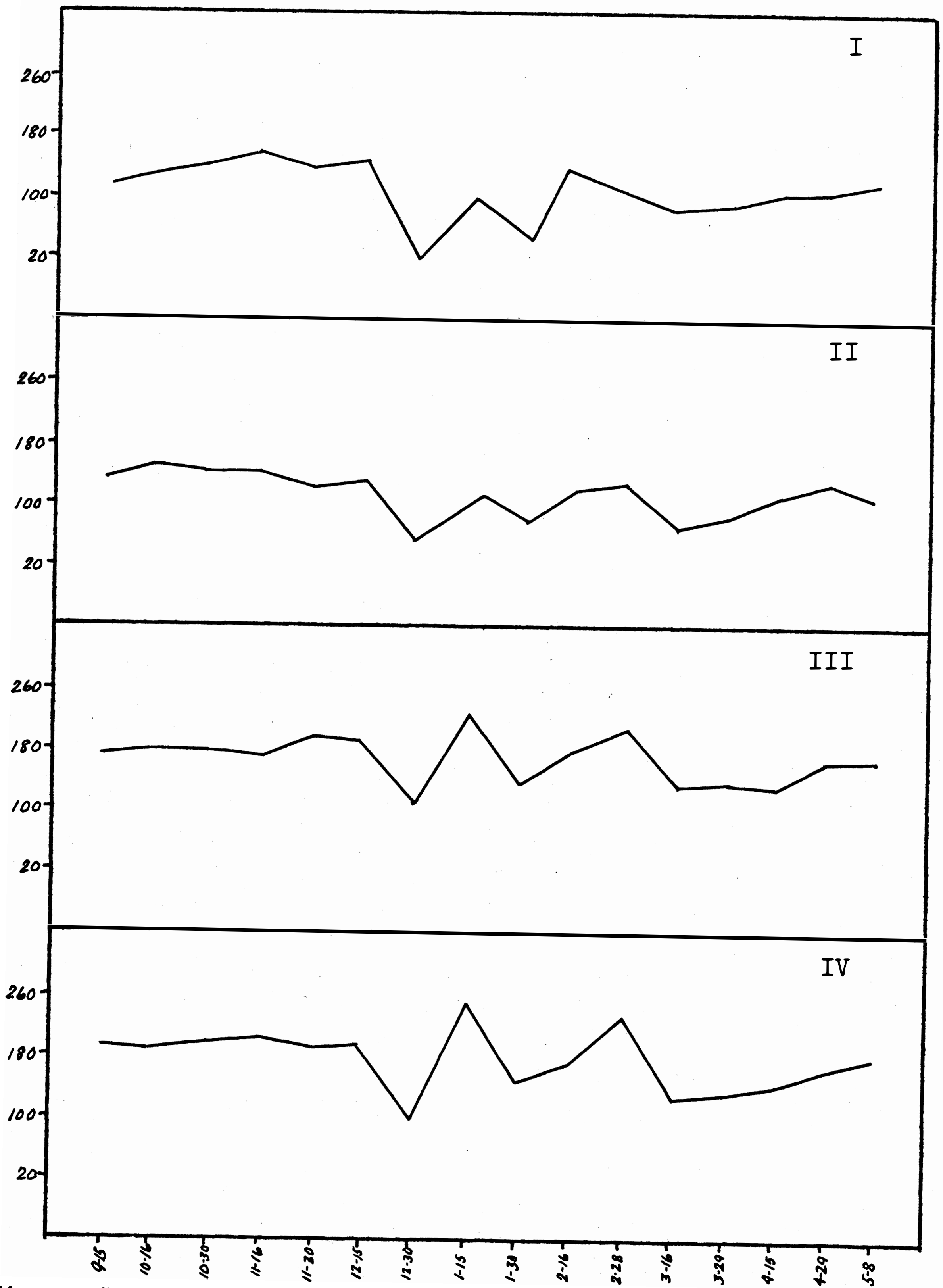

Figure 5. Alkalinity levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

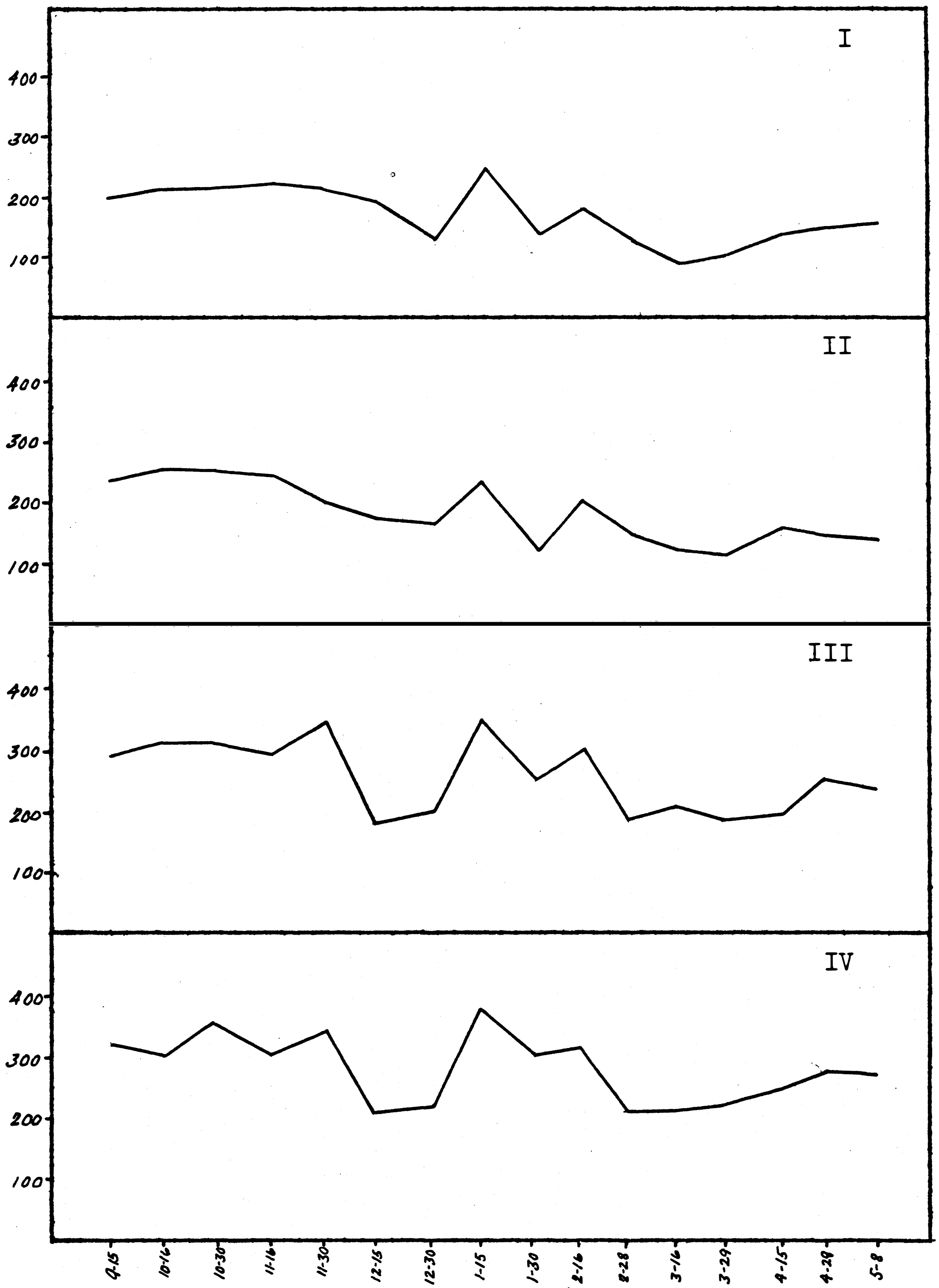

Figure 6. Total hardness levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

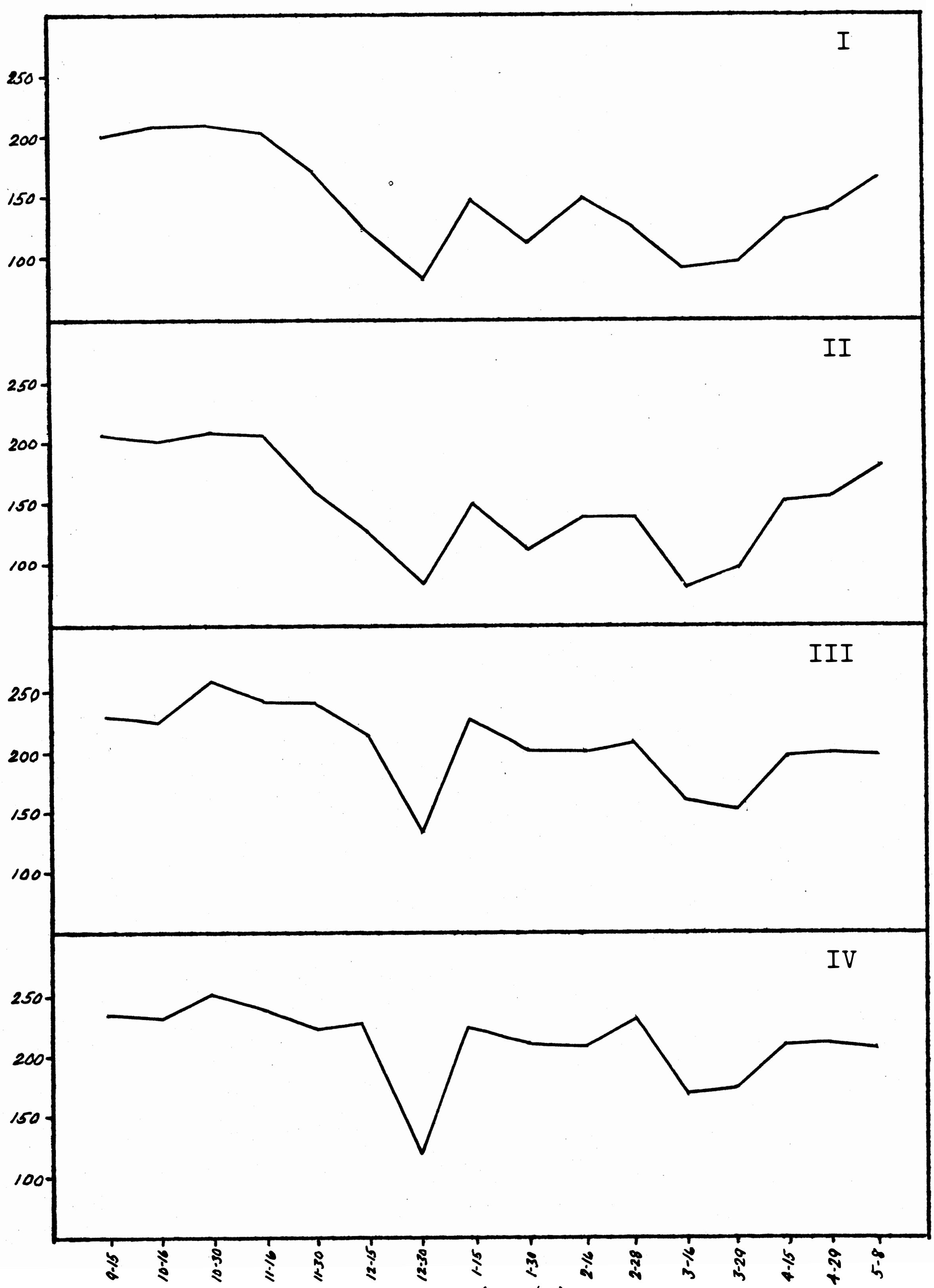

Figure 7. Conductivity levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

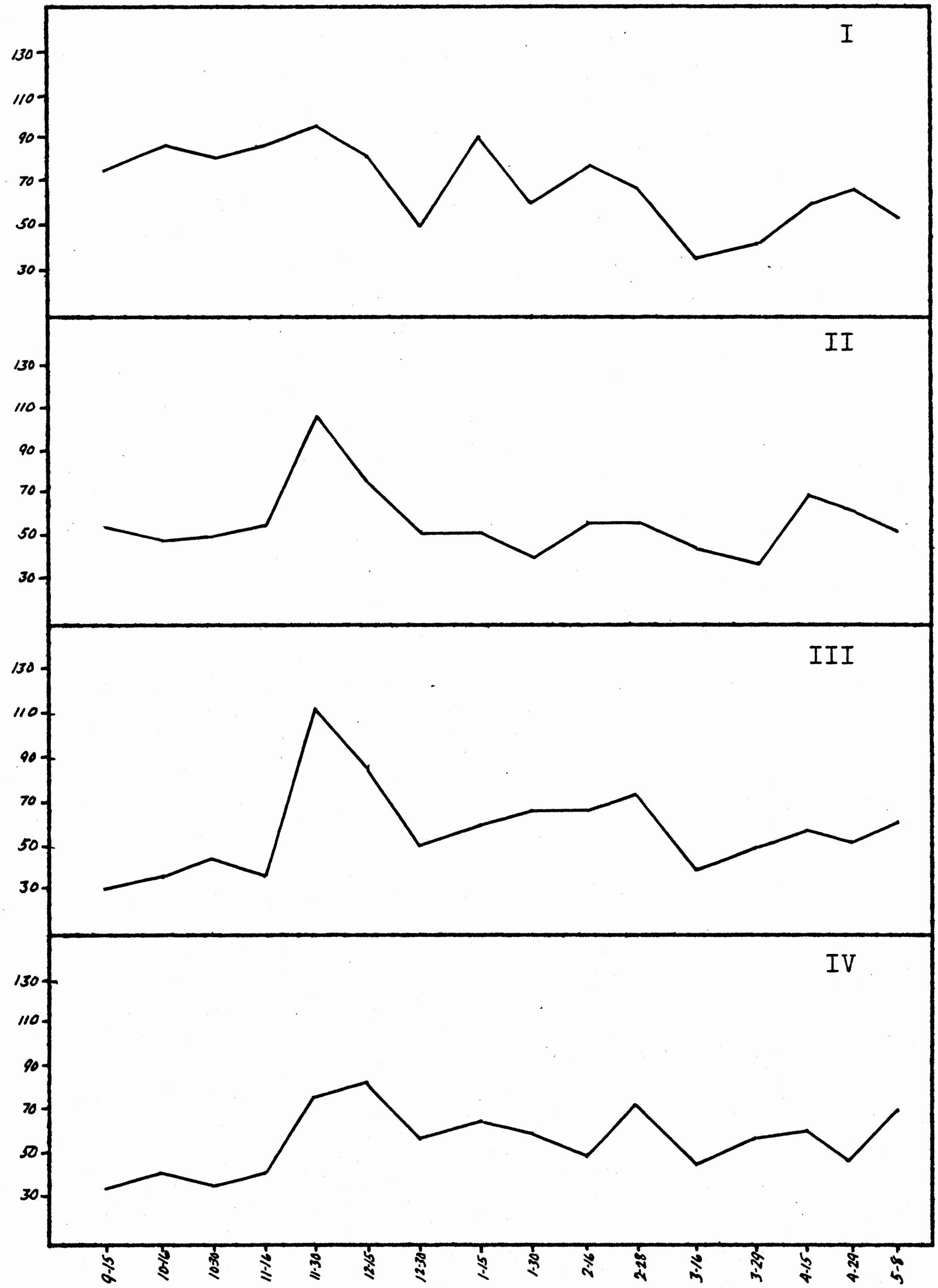

Figure 8. Sulfate levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

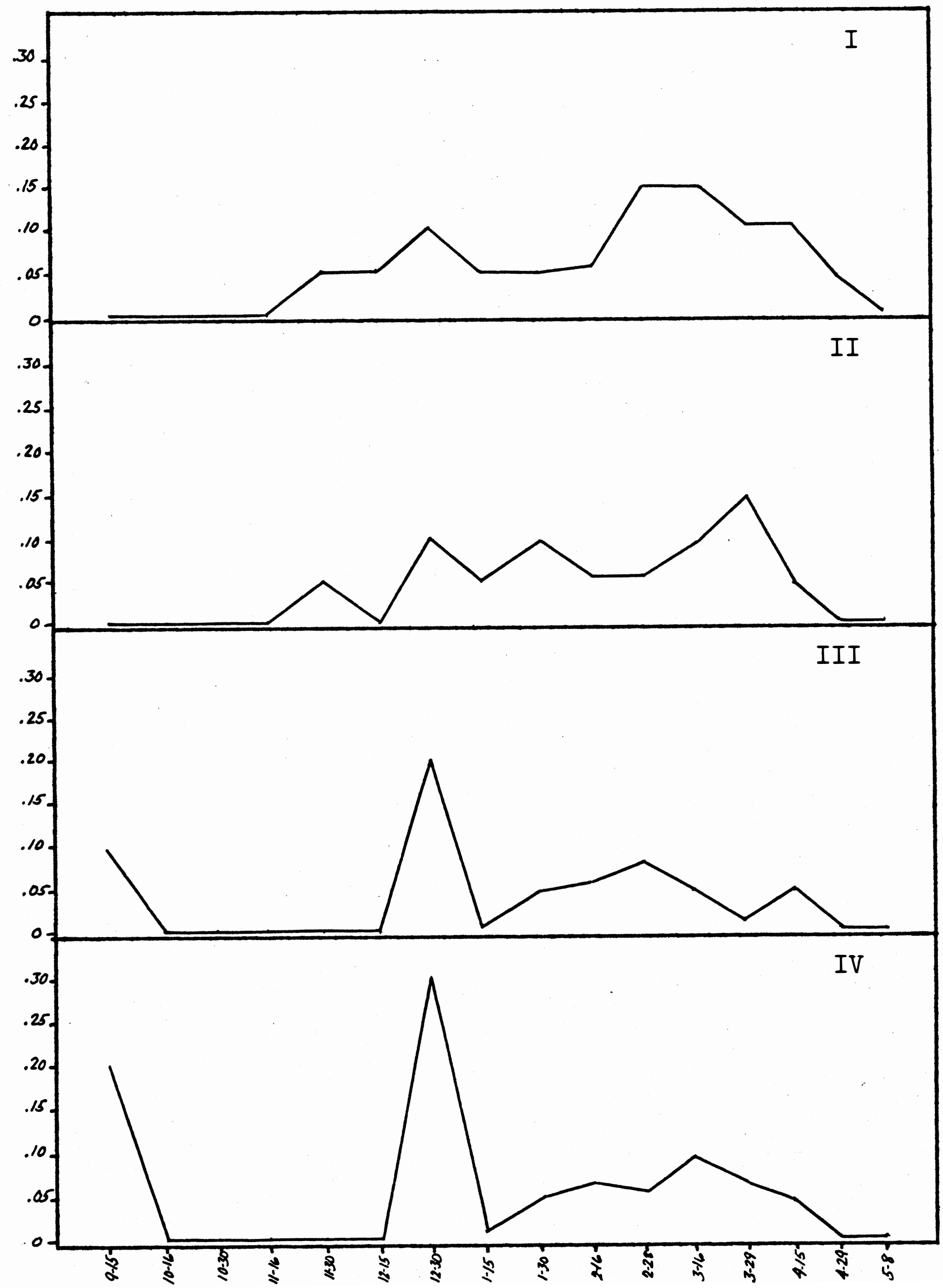

Figure 9. Total iron levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

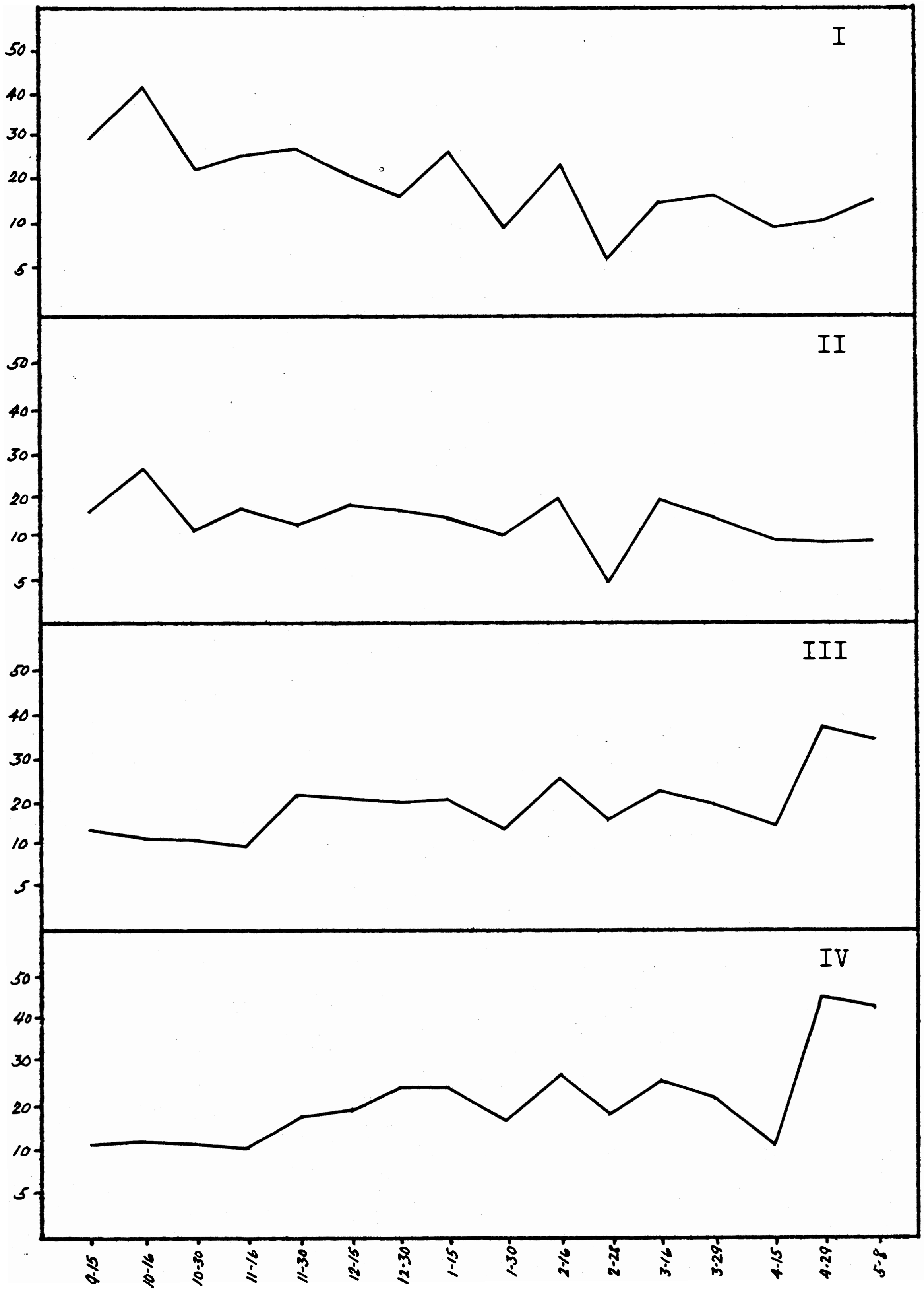

Figure 10. Nitrate levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

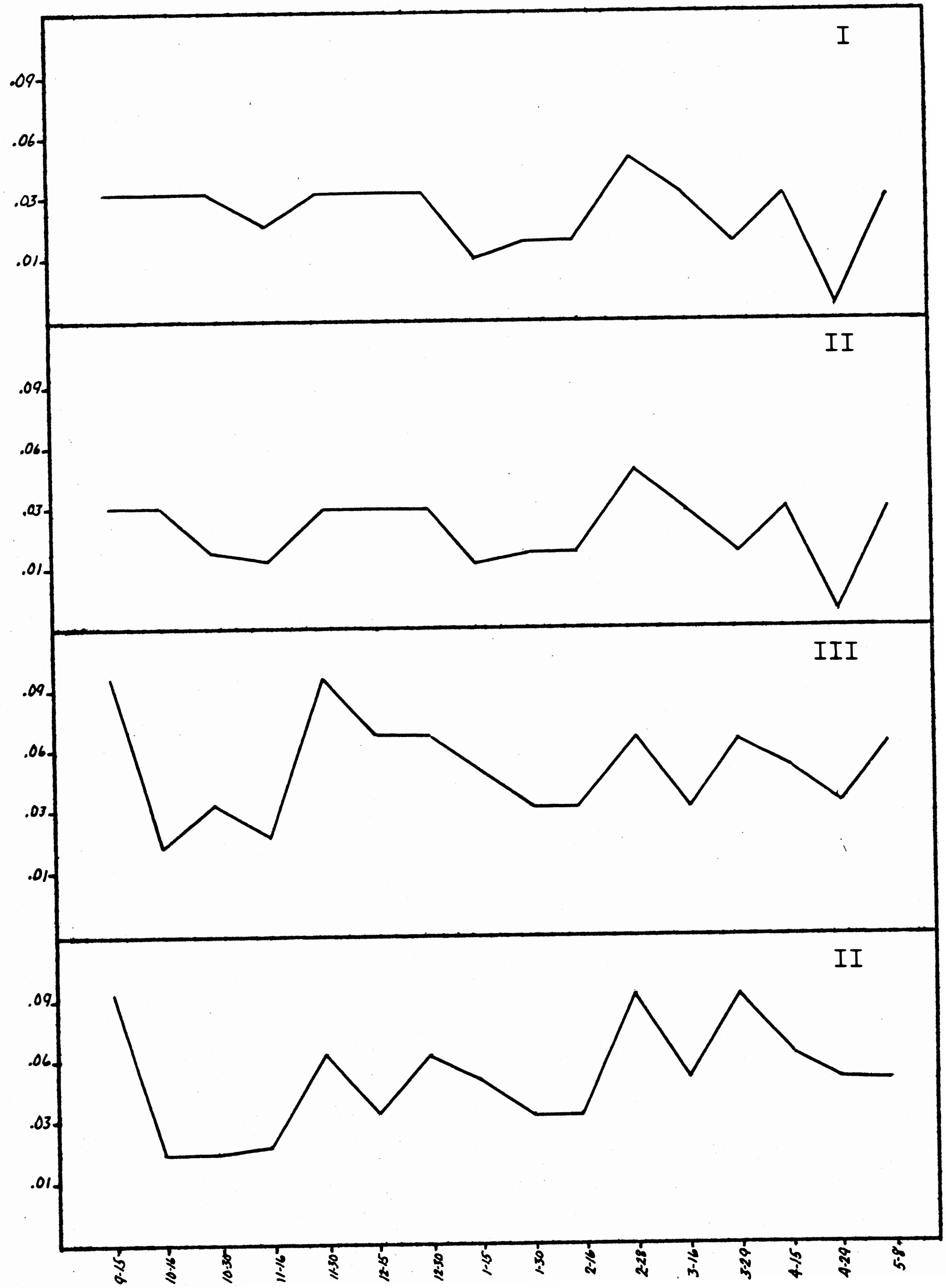

Figure 11. Nitrite levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

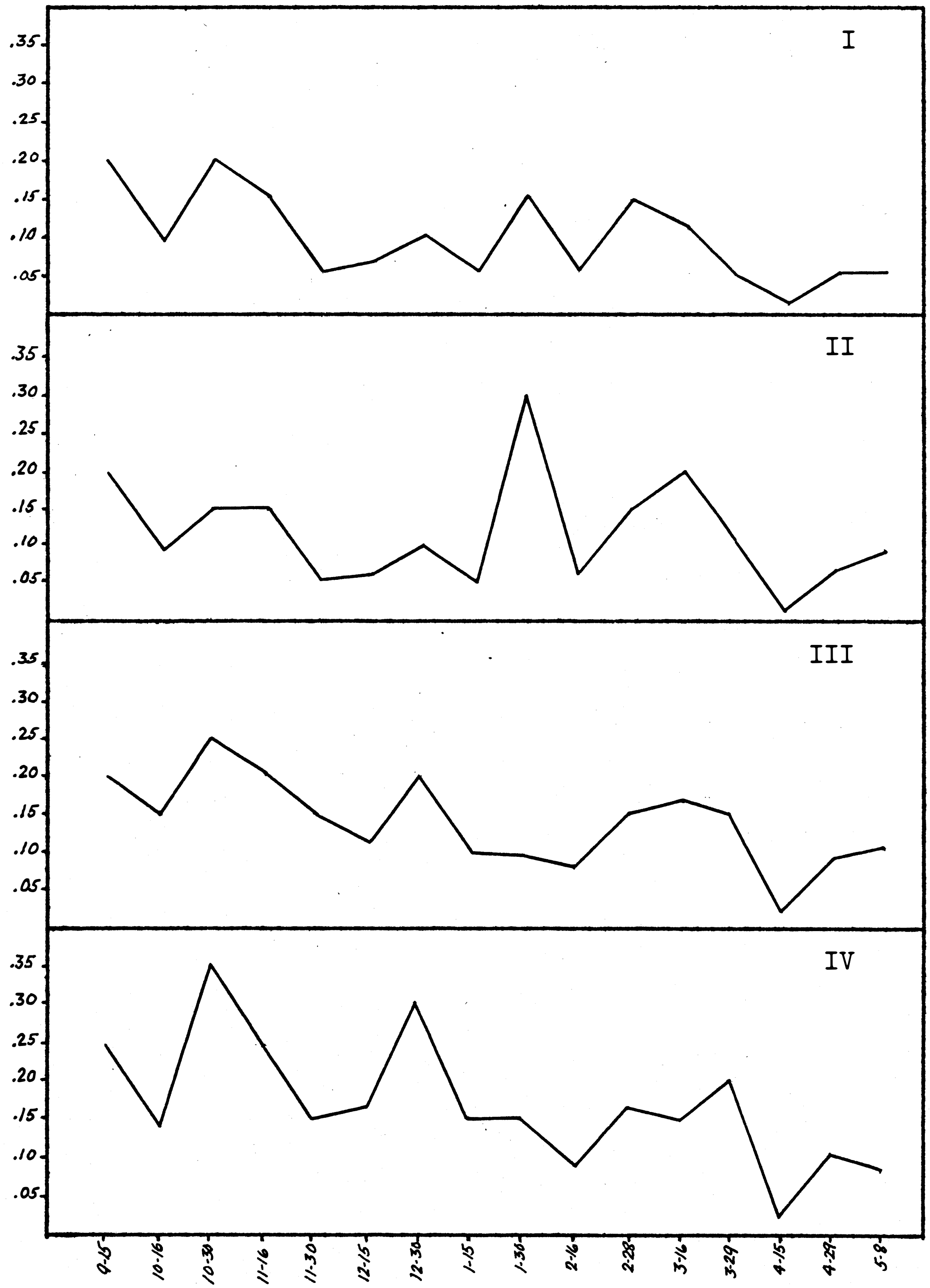

Figure 12. Orthophosphate levels (mg/l) for stations I - IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

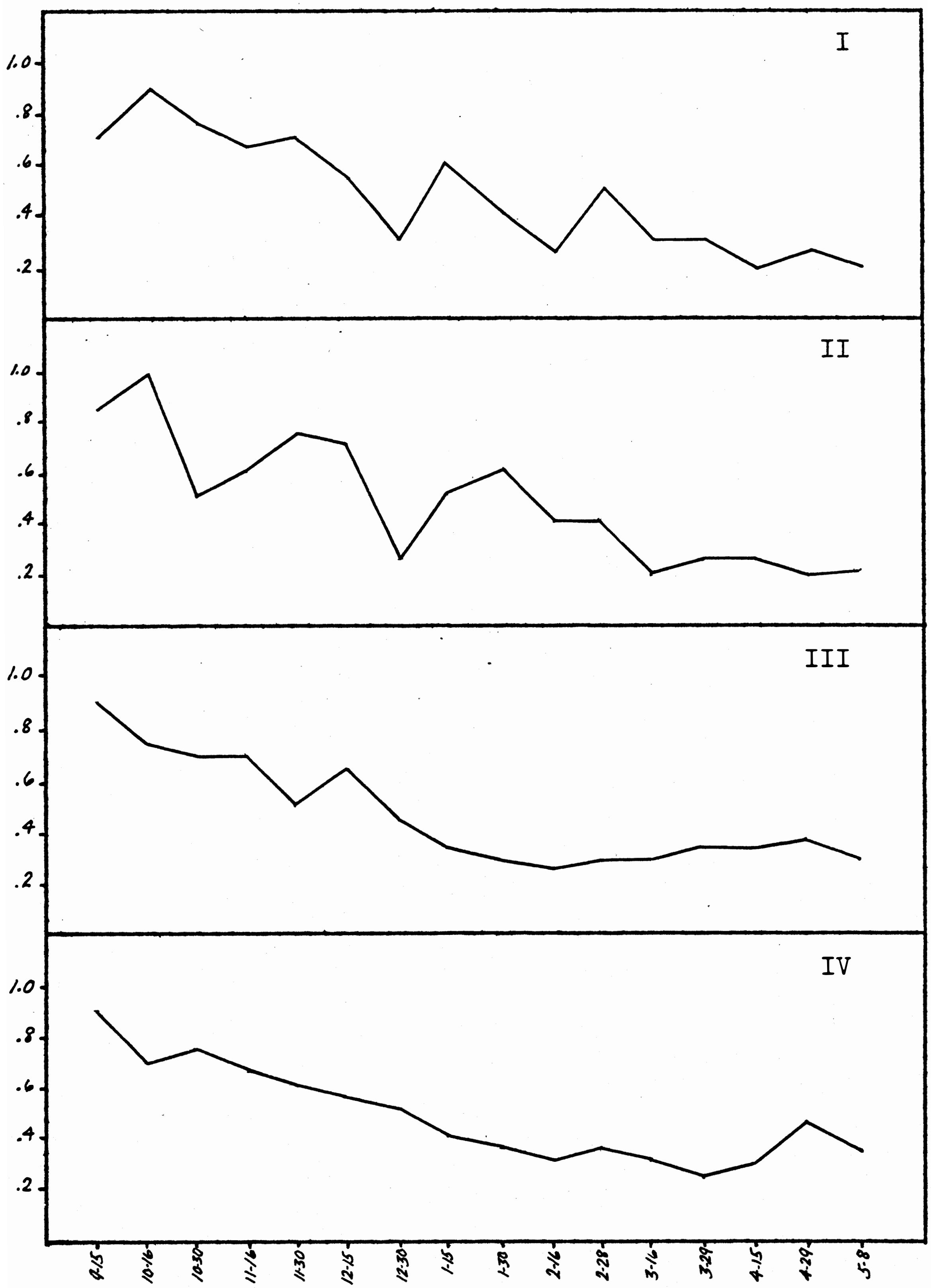

Figure 13. Total phosphate levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

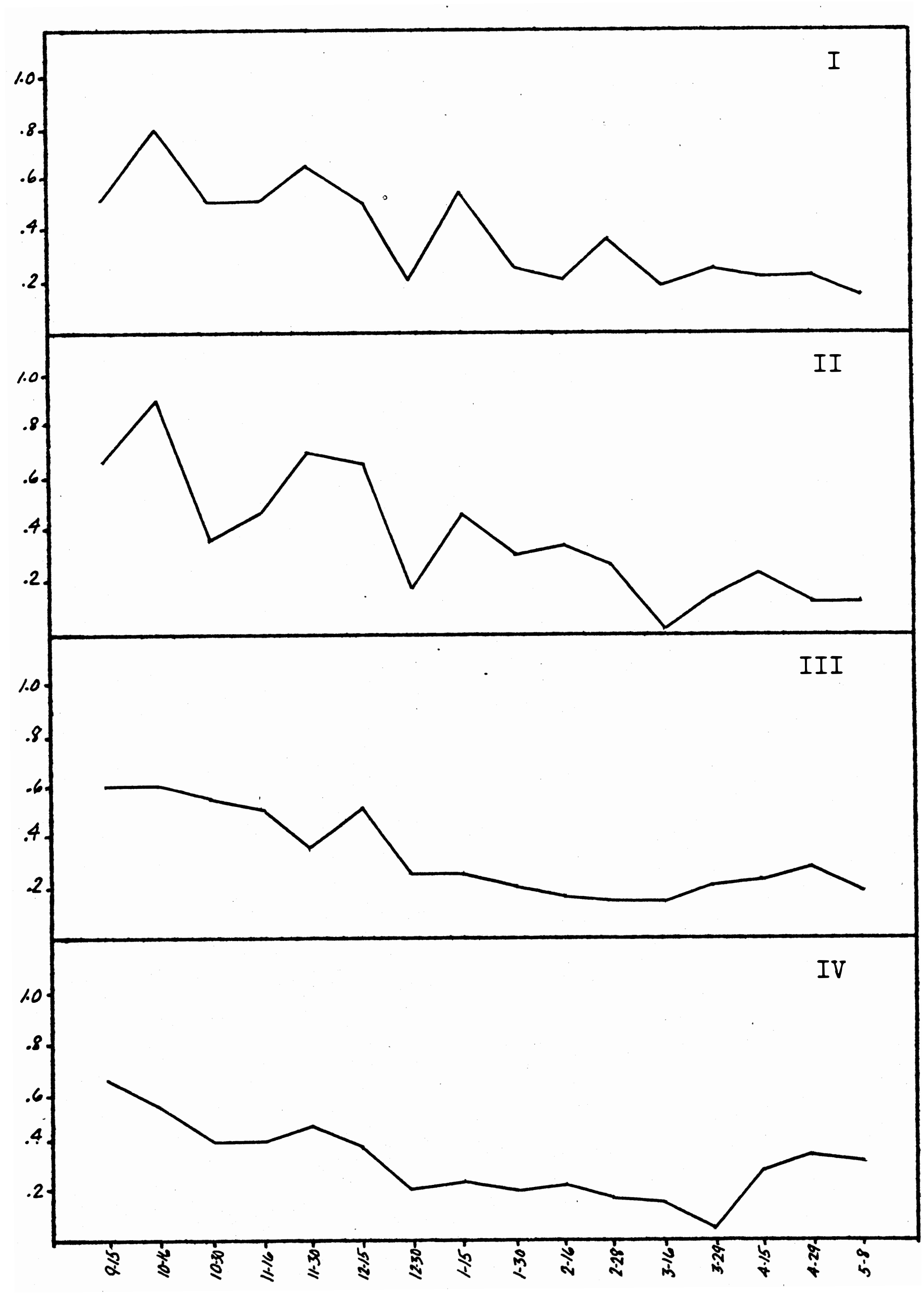

Table 14. Condensed phosphate levels (mg/l) for stations I-IV, Rocky Branch Nature Preserve, September 15, 1972 - May 8, 1973.

Table 1. Ranges for the parameters monitored on the West Fork of Big Creek and Rocky Branch, Clark County, Illinois, between September 15, 1972 and May 8, 1973. The means for each station appear in parenthesis.

Parameter	Station Number			
	I	II	III	IV
pH	7.2-8.0 (7.5)	7.2-7.9 (7.4)	7.3-8.3 (7.8)	7.1-8.2 (7.7)
Dissolved O_2 (mg/l)	6.2-9.2 (8.0)	4.5-9.2 (7.5)	6.6-8.5 (7.5)	6.0-8.6 (7.4)
BOD (mg/l)	1.1-2.6 (2.0)	1.0-2.1 (1.8)	1.9-3.2 (2.0)	1.8-2.5 (2.0)
Turbidity (JTU)	0-35 (13)	0-30 (14)	0-85 (28)	0-90 (28)
Conductivity (mg/l)	55-210 (147)	70-210 (149)	130-260 (207)	125-250 (211)
Total Hardness (mg/l)	100-250 (172)	115-250 (183)	190-350 (260)	200-380 (278)
Alkalinity (mg/l)	20-155 (109)	50-150 (113)	110-230 (170)	100-250 (178)
Sulfates (mg/l)	37-95 (69)	35-105 (55)	30-110 (57)	35-80 (55)
Total Iron (mg/l)	0-.15 (.06)	0-.15 (.04)	0-.20 (.04)	0-.30 (.06)
Nitrate (mg/l)	8.8-41.8 (19.5)	4.4-27.5 (14.3)	9.0-38.5 (19.5)	10.0-44.0 (20.9)
Nitrite (mg/l)	.01-.05 (.03)	.01-.05 (.03)	.02-.09 (.05)	.02-.09 (.05)
Total Phosphate (mg/l)	.20-.90 (.47)	.20-1.0 (.48)	.30-.90 (.47)	.25-.90 (.48)
Orthophosphate (mg/l)	.01-.15 (.10)	.01-.30 (.11)	.02-.25 (.14)	.02-.35 (.17)
Condensed Phosphate (mg/l)	.15-.80 (.38)	.01-.90 (.37)	.15-.60 (.33)	.05-.65 (.31)

Table 2. Biochemical oxygen demand (mg/l BOD) for the sampling stations established on Rocky Branch and the West Fork of Big Creek, Clark County, Illinois between December 30, 1972 and May 8, 1973

Sampling Date	Station Number			
	I	II	III	IV
December 30, 1972	1.1	1.0	1.8	1.9
January 15, 1973	1.6	1.8	2.0	2.3
February 28, 1973	2.0	1.8	2.5	2.1
March 16, 1973	2.1	2.0	2.2	1.8
April 29, 1973	2.6	2.1	3.2	2.5
May 8, 1973	2.4	1.9	2.6	2.0

Table 3. Turbidity readings (in JTUs) for 8 of the 16 sampling dates at all sampling stations on Rocky Branch and the West Fork of Big Creek, Clark County, Illinois between September 15, 1972 and May 8, 1973. The sampling dates not shown recorded zero JTU readings.

Sampling Dates	Station Number			
	I	II	III	IV
September 15, 1972	5	8	10	10
October 16, 1972	10	10	10	10
October 30, 1972	10	15	15	15
November 16, 1972	15	10	15	20
November 30, 1972	0	5	5	5
December 30, 1972	12	30	85	90
February 28, 1973	2	0	8	5
March 16, 1973	35	20	45	40

Table 4. Fishes collected, relative abundance, and habitat in Rocky Branch Nature Preserve between September 9, 1972 and May 8, 1973.

Species	Family	Habitat	*Abundance
Catostomus commersoni	Catostomidae	pool	common
Erimyzon oblongus	Catostomidae	pool	rare
Hypentelium nigricans	Catostomidae	pool	rare
Lepomis cyanellus	Centrarchidae	pool	rare
Lepomis macrochirus	Centrarchidae	pool	rare
Ictalurus melas	Ictaluridae	pool	rare
Etheostoma caeruleum	Percidae	riffle	common
Etheostoma flabellare	Percidae	riffle	common
Etheostoma nigrum	Percidae	riffle	common
Campostoma anomalum	Cyprinidae	pool/flow/riffle	abundant
Chrosomus erythrogaster	Cyprinidae	pool/flow	common
Ericymba buccata	Cyprinidae	pool/flow/riffle	abundant
Notropis chrysocephalus	Cyprinidae	pool	common

*rare: only 1-4 specimens seen
common: 60-80 specimens seen
abundant: 80-100 specimens per seine hall

Table 4--Continued.

Species	Family	Habitat	*Abundance
Pimephales notatus	Cyprinidae	pool/flow	common
Rhinichthys atratulus	Cyprinidae	pool/flow	common
Semotilus atromaculatus	Cyprinidae	pool/flow/riffle	abundant

*rare: only 1-4 specimens seen
common: 60-100 specimens seen
abundant: 80-100 specimens per seine haul

Discussion

The Rocky Branch Nature Preserve, located in the northwestern corner of Clark County, has long been considered a unique section of Central Illinois (Evers, 1963). Stover (1930) published the first floral list for the area. Since that time numerous botanical studies have been conducted within the boundaries of the Preserve.

Rocky Branch, the small creek bisecting the Preserve, represents one of the dominant features of the area's terrain. High sandstone cliffs bordering the creek bed testify to the erosional powers of running water.

While many studies concerning the flora of the region have been conducted, no similar studies have been undertaken with regard to the water quality or fish species present in the creek. During the course of this study the stream's fish population and water quality were examined.

Fishes of Rocky Branch

An extensive survey of the fishes of Rocky Branch was conducted. Seining and trapping were the primary means employed to collect specimens from the stream. Due to the narrow width, shallowness, and clarity of the creek it was possible to seine an area with very few fishes escaping.

Rocky Branch Nature Preserve supports a large fish population within its boundaries. No attempt was made during this study to make a statistical analysis of this population. A total of 16 species representing five families was collected (Table 4).

Seven of the 16 species taken were cyprinids with *Ericymba buccata*, *Campostoma anomalum*, and *Semotilus atromaculatus* by far the most frequently encountered. All three were abundant throughout the course of the creek and were collected in pools, flows, and riffle areas. Two unusual species for east-central Illinois proved to occur quite commonly in Rocky Branch. Smith (1965) lists *Chrosomus erythrogaster* and *Rhinichthys atratulus* as occurring sporadically in the extreme eastern part of the state. These two species were quite common at Rocky Branch. A classification of the streams of Illinois (Smith, 1971) lists Big Creek, to which Rocky Branch is a tributary, among east-central Illinois waterways containing unusual fish species. Smith noted four species, *Chrosomus erythrogaster*, *Rhinichthys atratulus*, *Notropis boops*, and *Etheostoma blennoides*, as occurring in the Wabash River- Big Creek drainage area. Two of the four noted can be found in Rocky Branch.

Darters (Percidae) were the second most abundant fish collected. Three species *Etheostoma caeruleum*, *E. flabellare*, and *E. nigrum* were extremely common and collected primarily from riffle areas. Percids generally inhabit relatively clean, fast-moving streams with sandy or gravel bottoms (Hubbs and Lagler, 1958).

Catostomidae, Centrarchidae, and Ictaluridae are the remaining three families found in Rocky Branch. Of these only

Catostomidae was represented in large numbers. Catostomus commersoni was abundant and collected from only the larger pools in the stream. The presence of Hypentelium nigricans, although rare, indicates good water quality. Lepomis cyanellus and L. macrochirus (Centrarchidae) were noted on several occasions but were always rare. Ictalurus melas (Ictaluridae) was collected only one time from a pool area.

Rocky Branch supports a variety of ecological niches which various fish species can occupy. This perhaps accounts for the variety of species found in such a small stream. Lagler, Bardach, and Miller (1962) note that portions of a stream can be divided into distinct areas such as riffles, pools, flows, and flood waters. Collections at Rocky Branch were made in riffles, pools, and flows and yielded fish species characteristic to each. Percids were almost always confined to fast-moving riffles while catostomids were always found in pooled areas. These results are consistant with Lagler et al. (1962).

Water Quality

According to Mackenthun (1969) the constituents of water quality analysis are temperature, dissolved oxygen, pH, light, flow, silt, oil, major nutrients, micronutrients, and toxic substances. The Federal Water Pollution Control Administration, based in Washington, D.C., has set up standards which can be used as guidelines in determining water quality (Anon., 1968). These standards often place limits on the "constituents" for water quality. The limits are set with not only potable water as an objective but also a healthy aquatic community.

In order to analyze the various constituents for water quality, numerous chemical and physical parameters must be considered. Mackenthun (1969), Ellis et al. (1948), Harmeson and Larson (1969), and Kittrell (1969) have done a considerable amount of research concerning water quality. Their various studies include such parameters as water temperature, pH, dissolved oxygen, phosphates, nitrate, nitrite, sulfate, hardness, alkalinity, conductivity, and turbidity. Biological oxygen demand is also frequently referred to in water quality studies. Standard Methods (Anon., 1971b) provides the analytical information necessary while Hach (Anon., 1967b) provides a field kit for conduction of the majority of tests required in water quality studies.

The need for such studies is apparent. Agricultural, industrial, and municipal pollution of waterways is a common occurrence and only through stream monitoring can that pollution be detected and perhaps reversed. A record of a waterway's previous condition can prove invaluable in later years when trying to determine what changes have taken place over a period of time. Such a record is even more important in unique areas, as is the case with Rocky Branch Nature Preserve.

Rocky Branch is the major stream draining the 300 acres of the Preserve. It can best be described as a clear, fast-flowing stream composed of alternating pooled and riffled areas. Several intermittent streams draining surrounding farm land enter Rocky Branch along its course. The Branch eventually joins with the West Fork of Big Creek which flows into

Big Creek and then into the Wabash River. The West Fork delimits Rocky Branch Nature Preserve's northwestern boundary and drains a considerable amount of surrounding farm land. These two streams were sampled and water quality data were gathered over an eight month period.

A tabulation of the data collected appears in Figures 2 through 14 and Tables 1 through 3. The parameters studied will be discussed individually.

Temperature

Mackenthun (1969) lists temperature as one of the most important physical parameters to be measured in an aquatic community. Extremes in temperature can activate, depress, restrict, or kill the organisms present. Indeed, temperature ranges determine the aquatic species present, spawning, hatching, growth, and development rate.

Stream temperature is also critical from the standpoint of dissolved gases. Gas solubility in water, oxygen included, is inversely proportional to the water temperature. In fresh water, the solubility of oxygen is decreased by 55% as the temperature rises from 0 degrees Centigrade to 40 degrees Centigrade (Mackenthun, 1969). Since all aquatic life depends upon oxygen, this fact is of utmost importance. Stream temperature variations are the result of climatic and geologic phenomena.

According to Welch (1952) lotic environments differ from lentic environments by three principle features: lotic waters are uniform in temperature at all depths, there is a tendency for flowing waters to mirror the ambient temperature, and thermal stratification is virtually absent. Where temperature variations are present they are generally slight and due to such things as current velocity, shading, time of day, and to a lesser degree, depth.

Temperature at the sampling stations located on Rocky Branch and Big Creek ranged from 1 degree Centigrade to 16.5 degrees Centigrade and reflected the season of the year when they were recorded (Fig. 2). All of the stations sampled were usually within 1 degree of each other while the West Fork sites (III, IV) were generally warmer. This was probably due to the lack of direct shade provided by the high sandstone cliffs and dense foliage near Rocky Branch (stations I and II).

Water Quality Criteria (Anon., 1968) notes that fixed temperature limits are not feasible because of the variation exhibited by surface water due to geographical location and climatic conditions. However, they do consider a more than 5 degree (Fahrenheit) water temperature increase, in excess of that caused by ambient conditions, to detract from raw water quality. Such conditions could only be caused by thermal pollutants or hot springs. At no time during the study did the four sampling stations exceed this limit.

Turbidity

Duchrow and Everhart (1971) define turbidity as an optical expression of finely divided material suspended in a sample with the standard unit of measurement the Jackson Turbidity Unit (JTU). Their studies have shown that settlable solids are the greatest contributors to light reduction in turbidimetric measurements.

Large quantities of suspended solids are detrimental to aquatic organisms. Rocks, rubble, gravel, and other large particles producing abrasive effects on organisms are found only in swift water, while turbidity exerts indirect harmful effects upon bottom fauna through light exclusion in all types of water. Stroud (1967) notes that heavy sedimentation destroys organisms having holdfast structures, affects sight-feeding fishes, acts as an abrasive on gills, and destroys breeding grounds by siltation. Studies conducted by Buck (1956) note a decrease in fish growth with an increase in turbidity. Excessive siltation of a stream or other body of water can reduce fishing success as well as detract from the aesthetic appearance of the area (Mackenthun, 1969).

The greatest ranges in turbidity, according to Welch (1952), occur in running water. He states that high turbidity is a permanent feature in some stream systems while it is seasonal in others. High precipitation and runoff from surrounding areas usually result in higher turbidity readings.

Rocky Branch and the West Fork of Big Creek are both relatively clear streams which show an increase in turbidity only following heavy rain storms. Of the 16 sampling dates, only seven had a measurable turbidity reading (Table 3). Stations IV and V had high readings of 85 and 90 JTUs following a heavy rainstorm on December 30, 1972. The Rocky Branch sampling stations I and II also showed an increase in turbidity on this date. However, the Branch's high of 35 JTUs was not recorded until March 16, 1973 at station I.

The present standards governing the turbidity of stream systems and lakes are concerned primarily with the water's potability. Standard Methods (Anon., 1971b) states that a maximum of 5 JTUs in treated or delivered water is the level at which this characteristic becomes objectionable to a large number of consumers. Water Quality Criteria (Anon., 1968) establish a maximum discharge of water containing 50 Jackson Units into warm water streams. Discharges into warm and cold water lakes are set at 25 and 10 JTUs, respectively.

Ellis (1936) feels that the increasing loss of surface soil by erosion can be correlated with higher turbidity readings in streams and lakes following periods of heavy precipitation. Poor farming practices and land management increase the amount of erosional silt carried into a stream system by surface runoff. The relatively higher turbidity readings recorded for the West Fork of Big Creek can probably be attributed to higher amounts of erosional silt. The West Fork drains a larger, more heavily farmed area than Rocky Branch and therefore would carry more suspended material. However, Rocky Branch and the West Fork carry less erosional silt and have lower turbidity readings than similar streams studied in neighboring Coles County, Illinois (Durham and Whitley, 1971). Once again this can be attributed to less extensive farming practices in Clark County, Illinois.

pH

The pH of a stream or lake can be critical to the fauna and flora of that body of water. An extremely high or low pH can drastically alter the aquatic community. According to

Standard Methods (Anon., 1971b) the pH of most natural waters falls within a range of 4 to 9. The majority of these waters are slightly alkaline due to the presence of carbonate and bicarbonate. A pH of 7.0 at 25 degrees Centigrade represents exact neutrality on a scale ranging from 0 to 14. The low side of neutral is an acidic reading while the high side is a basic or alkaline reading.

Stroud (1967) states that pH values should not be permitted to fall below 5.0 or exceed 9.5 for any long period of time. He also states that a pH level between 6.5 and 8.5 is necessary for good game fish production. However, extremes well below a pH level of 4.0 and above 10.0 can be tolerated by certain resistant fishes for indefinite periods of time (Mackenthun, 1969).

The drastic alteration of a stream or lake pH level can usually be attributed to the dumping of acidic or basic waste material into it. Minor fluctuations of pH are to be expected and can be traced to a variety of causes. Decomposition and/or respiration tends to reduce pH and increase bicarbonates while the tendency of photosynthesis is to raise pH and reduce bicarbonates (Mackenthun, 1969). Cowles and Schwitolla (1923) state that when water flows rapidly over a clean bed, most notably at falls and riffles, the pH is raised, probably as a result of aeration.

Sampling stations I and II, located on Rocky Branch, and III and IV, located on the West Fork of Big Creek, were always well within the range of pH levels suggested by various authors (Fig. 3). The pH of Rocky Branch ranged from 7.2 to 8.0 while the West Fork ranged from 7.1 to 8.3. These represent levels well within the optimum for the production of game fish as suggested by Stroud (1967).

The West Fork generally had a higher pH than Rocky Branch which could probably be attributed to its larger size and greater velocity. If Cowles and Schwitolla (1923) are correct, the increased aeration of the West Fork would account for its slightly higher pH.

According to Warren (1971) limesone and other forms of calcium carbonate ($CaCO_3$) dissolve readily in water containing carbon dioxide. The carbonic acid in the water reacts with calcium carbonate yielding the highly soluble calcium bicarbonate ($Ca(HCO_3)$), which exists only in solution. Natural waters with an alkaline pH contain a high concentration of bicarbonates while an acid pH lacks the bicarbonates. Soils rich in carbonates and bicarbonates are responsible for the high pH. This accounts for the alkaline pH levels recorded at the four sampling sites.

Dissolved Oxygen

According to Ellis et al. (1948) the accurate determination of dissolved oxygen is highly important in water quality studies because oxygen is indispensable to fishes and other aquatic organisms. The knowledge of the exact amount of dissolved oxygen is also essential in solving many problems which confront the aquatic biologist.

Oxygen is one of the essential ingredients for maintaining the metabolic processes which produce energy for growth and reproduction. Oxygen enters the aquatic community by three different means. Oxygen can enter the aquatic ecosystem by absorption directly from the atmosphere, by photosynthesis, or by surface water agitation by wind and waves. Oxygen may be removed from the system by respiration, decomposition, or direct loss back to the atmosphere. Photosynthesis, the process by which plants utilize carbon dioxide and liberate oxygen, accounts for the greatest proportion of oxygen to be found within a body of water (Mackenthun, 1969). Respiration and decomposition, according to Mackenthun (1969), result in just the opposite effect. Animals and plants, either respiring or decomposing, utilize oxygen and liberate carbon dioxide.

Oxygen levels in a body of water vary considerably depending upon factors such as water temperature, atmospheric pressure, rate of flow, depth, decomposition, pollutants, and many others. In Water Quality Criteria (Anon., 1968), the National Technical Advisory Committee suggests that a 5 milligrams per liter (mg/l) oxygen concentration be the lower limit for a diversified warm water biota. The committee further states that oxygen concentrations can drop as low as 4 mg/l for short intervals during any 24 hour period providing other water quality aspects are favorable. For cold water environments, it is desirable that oxygen concentrations be at or near saturation. Doudoroff and Shumway (1967), however, feel that it is difficult to fix definite dissolved oxygen level requirements for a species of fish. While they believe there is a need for definite guidelines, they also feel more research is required. Their studies have shown that successful hatching, prolonged survival, and growth of young salmonids is possible in the laboratory at concentrations near 3 mg/l.

Low concentrations of dissolved oxygen in a body of water alter the faunal makeup of the area. Mills, Starrett, and Bellrose (1966), reporting on the Illinois River, noted a definite zonation of fish species based on oxygen concentrations. They state that carp and buffalo were the only fish found in water with a low dissolved oxygen concentration of 2.5 mg/l while a variety of fishes was found in an area of 4 mg/l.

Dissolved oxygen concentration can affect more than fish location within a body of water. Lagler et al. (1962) report that decreasing oxygen pressure during embryonic development produces an increase in the number of vertebrae in Salmo trutta.

Stream oxygen concentrations are generally high and often near saturation for the existing temperature in unpolluted waterways. According to Welch (1952) this condition is due to the mechanics of stream current. Generally, declines in oxygen concentration can be encountered only in deep holes, slow-moving streams, under heavy ice cover, or during polluted conditions (Welch, 1952). Welch (1952) feels that the main factors influencing the dissolved oxygen concentration in unmodified streams are: character of stream flow, slope of channel, temperature, oxygen released by chlorophyll-bearing plants, oxygen consumed in respiration of biota, and oxygen consumed in the decay of organic deposits on the bottom.

The concentrations of oxygen in Rocky Branch and the West Fork of Big Creek were usually well above the 5 mg/l level (Fig. 4) recommended in Water Quality Criteria (Anon., 1968).

Only on one occasion, October 30, 1972, at station II did the oxygen concentration drop to a level of 4.5 mg/l. On this date an unusual amount of decaying leaf matter had accumulated on the bottom. The decomposition of the leaves probably accounts for the low reading. Throughout the rest of the study period high dissolved oxygen concentrations were recorded at all sampling sites. This is consistant with Welch (1952) who states that unpolluted running waters generally exhibit a high dissolved oxygen concentration.

Biochemical Oxygen Demand

Biochemical oxygen demand is the amount of oxygen required by aerobic microorganisms to stabilize the organic material of wastewater, wastewater treatment plant effluent, polluted water, or industrial waste (Marske and Polkowski, 1972). BOD is in fact an indirect measurement of the oxygen-using microorganisms present in a sample and the rate of decomposition taking place. The BOD test records the decomposability of organic matter and thereby gives a measure of the pollution characteristics of a sample in terms of oxygen demand.

Biochemical oxygen demand data for the Preserve area appear in Table 2. Data were recorded for only six sampling dates. These limited data indicate a very low oxygen demand for all sampling sites. Stations I, III, and IV averaged 2 mg/l BOD while station II had an average of 1.8 mg/l BOD. A low BOD level is to be expected in a relatively clean and fast-moving stream. Such is the case with Rocky Branch and the West Fork of Big Creek.

Hardness

Kemp (1971) and Standard Methods (Anon., 1971b) state that the hardness of a body of water was originally understood to be a measure of the capacity of the water for precipitating soap. Calcium and magnesium are the chief ions found in flowing water which cause this precipitation reaction. Other elements such as aluminum, iron, manganese, strontium, zinc, and hydrogen ions can cause the precipitation of soap. Since they are usually found only as trace elements, they are insignificant (Kemp, 1971). However if these elements are present in sufficient concentrations, they should not be overlooked as possible contributors to hardness values.

Total hardness can be subdivided into two categories. When the amount of hardness is equal to or less than the total carbonate and bicarbonate alkalinity, it is designated as carbonate hardness. If the hardness exceeds that alkalinity, the excess is called non-carbonate hardness (Ellis et al., 1948). These types of hardness are of prime importance in water treatment plants. If a large percentage of the total hardness is non-carbonate hardness, the scale formed within the facility's equipment can be expected to be hard and difficult to remove. The presence of non-carbonate hardness in water requires the use of a more expensive chemical in the lime softening process (Harmeson and Larson, 1969). In general the effects of hard water are economic and not harmful to one's health or an aquatic ecosystem.

The Illinois State Water Survey has classified hardness according to mg/l $CaCO_3$ as follows: 0-75, soft; 75-125, fairly soft; 125-250, moderately hard; 250-400, hard; and over 400, very hard (Harmeson and Larson, 1969). Presently 88.5% of Illinois water supplies have a hardness greater than 200 mg/l, and 26% greater than 400 mg/l (Anon., 1967c).

Only total hardness was considered at Rocky Branch and the West Fork of Big Creek. Water from the two streams is not used for human consumption therefore no economic importance of non-carbonate hardness in a water treatment plant exists. The information was gathered in order to have a record of the present stream condition for future reference.

Figure 6 shows the range of total hardness recorded for the two streams. If the Illinois State Water Survey classification is used, Rocky Branch can be classed as a moderately hard water stream (125-250 mg/l $CaCO_3$) while the West Fork would be considered a moderately hard to hard water stream (125-250 mg/l to 250-400 mg/l $CaCO_3$). A normal fluctuation of hardness readings was noted throughout the study period.

Alkalinity

Alkalinity of surface and ground water, like hardness is important primarily from an economic standpoint. Alkalinity, when related to hardness and pH, is significant to municipal and industrial users and to their choice of water treatment processes. Natural waters rarely contain a total alkalinity so low as to adversely affect an aquatic ecosystem (Ellis et al., 1948). Ellis et al., (1948) describe alkalinity as the kinds and quantities of compounds present in a body of water which collectively shift the pH to the alkaline side of neutrality. Standard Methods (Anon., 1971b) goes one step far-ther by stating that alkalinity of a body of water is the capacity of that water to accept protons. Total alkalinity includes the bicarbonate, carbonate, and hydroxide component of a natural water supply. Of these three forms the calcium carbonate form is by far the most common while the hydroxide form can cause damage to aquatic fauna when introduced as an industrial effluent (Ellis et al., 1948).

Natural water supplies in Illinois have a total alkalinity ranging between 200 to 400 mg/l $CaCO_3$ (Anon., 1967c). Ellis et al. (1948) report that in unpolluted water supporting a good fish fauna the range is from 0 to 350 mg/l $CaCO_3$, with usual expected values between 45 and 200 mg/l. He states that in these values the carbonates and bicarbonates have little direct effect on fishes. However in streams with low carbonate ranges, the natural buffering and neutralizing effect provided by the carbonates against acid from acid pollution is absent. Only low concentrations of carbonates are necessary to sustain an adequate aquatic flora in order to support fish life. This is evident from the excellent fish faunas supported by mountain streams where carbonate levels are extremely low.

Stream alkalinity is a relatively unimportant parameter to be considered in a limnological study unless the water is ultimately to be processed for municipal use. Carbonates are almost always present in sufficient quantities to insure aquatic plant growth. Rocky Branch and the West Fork are not exceptions to this statement. The calcium carbonate alkalinity for station I on Rocky Branch ranged from 20–155 mg/l $CaCO_3$

while station II ranged from 50-150 mg/l $CaCO_3$ (Fig. 5). The West Fork showed a much higher reading for its sampling sites. Station III ranged from 110-230 mg/l $CaCO_3$ while station IV ranged from 100-250 mg/l $CaCO_3$ (Fig. 5). The West Fork drains a larger area and could logically be expected to carry more carbonates from the surrounding terrain into its flow. All of the alkalinity readings recorded for the study period fall well within the range suggested by Ellis et al. (1948).

Conductivity

The conductivity of a solution is an important parameter considered in most limnological studies. Welch (1952) and Ellis et al. (1948) state that the richer a body of water in electrolytes, to a point, the greater its biolgocal productivity. The easily measured electrical conductivity of solutions is closely related to salt content and, therefore, milligrams per liter sodium chloride (NaCl) is the standard unit of measurement (Edmondson, 1956).

In addition to increased biological productivity of a body of water, Williams (1966) suggests that specific conductance is directly related to the amount of total dissolved solids in the waterway. During a study concerning 62 Australian lakes, he found a very close correlation between their conductivity and total dissolved solids.

Total dissolved solids in natural water supplies are usually greatly affected by man's activities. Irrigation, oil field discharges, diversion of streams, and deepening of ship channels are a few of man's activities that alter the dissolved salt content of bodies of water (Warren, 1971). Drastic changes in total dissolved solids can adversely affect the aquatic community. Water Quality Criteria (Anon., 1968) recommend that 500 mg/l NaCl be the upper limit for total dissolved solids.

Rocky Branch and the West Fork of Big Creek were well under the limit recommended by Water Quality Criteria (Anon., 1968) during the study period (Fig. 7). The West Fork, due to its increased drainage area, always had a higher conductivity reading. The higher reading reflects the effect of man's activities on the amount of total dissolved solids carried in solution. The West Fork stations ranged from 125-260 mg/l NaCl while the Rocky Branch stations ranged from 55-210 mg/l NaCl. The higher reading on both streams usually followed rainy periods. Runoff from surrounding farm lots and fields would probably increase the amount of dissolved solids carried in solution under such circumstances.

Sulfates

The sulfate ion, according to Sawyer (1960), is one of the major anions occurring in natural waters. Most sulfates result from the natural decomposition of organic material. Sulfates are found in most natural waters, except some mountain streams near their snow sources and certain spring-fed streams (Ellis et al., 1948). Ellis et al. (1948) also state that sulfates are one of the expected groups of compounds tolerated by fishes in concentrations up to 300 mg/l or more without marked effects. Water Quality Criteria (Anon., 1968) suggest that a limit of 250 mg/l sulfate be placed on all natural water supplies.

Sulfates are found in many industrial effluents such as mine drainage wastes (Anon., 1968). Monitoring areas subjected to such waste material can provide an indication of dumping activities by industry.

Figure 8 shows the range of sulfate concentration for the study area. The sulfate levels for Rocky Branch and the West Fork were always low, never exceeding the 250 mg/l recommended upper limit for the parameter. The highest reading which occurred for all stations was 110 mg/l at station IV. Such a low reading indicates the absence of industrial effluents as well as the lack of large amounts of organic decomposition.

Total Iron

Iron is an important element in plant metabolism. Ruttner (1953) reports that iron can exist as a ferrous or ferric compound depending on environmental conditions. The ferrous iron compounds can only exist in the absence of oxygen while the ferric form is almost completely insoluble. Total iron measures both forms.

Rocky Branch and the West Fork of Big Creek registered minute amounts of total iron at all sampling sites. Because of the presence of dissolved oxygen, the ferrous iron form could not exist and only the ferric form was present. Generally very small amounts of total iron were recorded for all sampled areas (Fig. 9). On several occasions total iron was not present while on many other sampling dates only trace amounts were noted. A high reading of .3 mg/l for all stations was recorded December 30, 1972 at station IV. This level is within the permissible iron level allowed for public water supplies (Anon., 1968). All other samples tested well below this level.

Nitrogen

The earth's atmosphere is the major repository of available nitrogen. Approximately 80% of the atmosphere is composed of the diatomic gas, N_2. Nitrogen is recognized as one of the most important constituents of living matter and for that reason represents a nutrient of outstanding value (Ruttner, 1953).

Inorganic nitrogen compounds, usually as nitric acid, are present in small amounts in rain water. Ruttner (1953) states that these inorganic forms come from the atmosphere as the products of electrical discharges, terrestrial decomposition, and volcanic eruptions. A considerable amount of elemental nitrogen is fixed in the soil by nitrogen-assimilating bacteria and becomes available for use by plants. The chief product of the decomposition of plant and animal proteins is ammonia. In the presence of oxygen the ammonia is quickly transformed by nitrifying bacteria into nitrate. Bacterial oxidation accounts for the transformation of nitrates to nitrites and then back again. These relationships which exist between the various forms of nitrogen compounds and the changes which occur in nature can be considered the nitrogen cycle (Sawyer, 1960).

Tebbutt (1971) lists four main forms of nitrogen important in an aquatic community:

a) organic nitrogen- nitrogen in the form of proteins, amino acids, and urea

b) ammonia nitrogen- nitrogen as ammonium salts, e.g. $(NH_4)_2CO_3$, or as free ammonia

c) nitrite nitrogen (NO_2)- an intermediate oxidation stage not normally present in large amounts

d) nitrate nitrogen (NO_3)- final oxidation product of nitrogen.

During this study only the nitrate and nitrite levels of the four sampling stations were monitored

Viets (1971) states that nitrate is a storage form of nitrogen in soils, water, or plants. Nitrates in the environment are products of nitrification of the ammonium ion arising from organic matter ammonification, ammonium-containing fertilizers, or animal origin by Nitrosomas spp. and Nitrobacter spp, acting in that order. Nitrate, according to Viets (1971) is the only form of nitrogen that can be leached from the soil. Nitrate, not utilized by the immediate plant community, is eventually carried into drainage systems by percolating ground water.

Nitrate levels in Illinois waterways have drastically increased during the last two decades. Harmeson, Sollo, and Larson (1971) report that before 1956 the nitrate levels in eleven Illinois streams never exceeded the 45 mg/l water quality standard set in Water Quality Criteria (Anon., 1968). Subsequent sampling of the same rivers between 1956 and 1966 showed that the 45 mg/l standard was exceeded in nine of the 11. A recent study in Coles County, Illinois (Durham and Whitley, 1971) showed several sampling stations with nitrate levels above the recommended 45 mg/l limit. One station located on Kickapoo Creek registered a high of 163 mg/l nitrate.

Nichols (1965) reports that one of the greatest dangers of high nitrate levels in a water supply is methemoglobinemia. The actual cause of methemoglobinemia in infants is not the nitrates but the nitrites formed in the intestinal tract by the reduction of the nitrates by bacteria. The nitrites are then absorbed into the bloodstream where they react with hemoglobin. A literature survey made by Walton (1951) reports 278 cases of methemoglobinemia and 39 deaths. His survey showed that there were no cases reported where nitrate levels in public water supplies were less than 45 mg/l.

Nuisance algal blooms and accelerated eutrophication of a water supply is another problem caused by the presence of nitrates. Harmeson et al. (1971) state that there is much disagreement over the role of nitrogen as a nutrient element in a body of water. Certain sources have reported algal blooms in lakes having an average nitrate concentration of 1.3 mg/l (Harmeson et al., 1971). At the present no clear agreement exists concerning the nitrate level/eutrophication question. In fact many authors feel that carbon and phosphorus are the controlling factors causing accelerated aging of a lake or stream.

Nitrates occur naturally in most bodies of water due to the decomposition of organic material. Excessively high levels can generally be attributed to man. Viets (1971) reports that sewage effluents from municipal treatment plants may increase the nitrate level of the receiving body of water depending upon the design and operation of the plants. Many authors feel that the increased use of ammonia fertilizer has been primarily responsible for increased nitrate levels. In 1963 5.6 million tons of ammonia, the precursor of nitrate, were added as fertilizer to the soil in the United States (Nichols, 1965). The nitrate not utilized by the plants would eventually find its way into the streams and lakes of the area. Harmeson et al. (1971) feel that increased field fertilization plus poor farming practices have contributed to the increase in nitrate levels in Illinois streams. They also report that the highest nitrate levels can be found in the streams of areas of high agricultural production during spring and early summer. On the other hand, the fall and winter months show a considerable drop in nitrate levels.

Another source of nitrogen in natural waterways is runoff from feedlots. Prophet (1969) reports that high ammonia and nitrate levels from feedlot runoff resulted in numerous livestock deaths.

Nitrate levels at the Rocky Branch and West Fork sampling stations varied considerably during the study period (Fig. 10). Stations III and IV usually recorded a higher nitrate reading than station I or II. Early in the study period just the opposite was true. All four sampling sites fell below the 45 mg/l standard set by Water Quality Criteria (Anon., 1968). However, station IV recorded levels above 40 mg/l on two occasions while station I went above 40 mg/l on one occasion. Station IV recorded the highest mean nitrate level of the four stations, 20.9 mg/l nitrate, while station II. with a 14.37

mg/l level, was the lowest (Table 1). Harmeson et al. (1971) report that most Illinois surface waters average near 10 mg/l nitrates. The high average for the study sites reflects the farming activity in the area. Higher readings would be expected in the spring and early fall due to runoff from surrounding fertilized fields and feedlots. Late spring and summer results are not available but if Harmeson et al. (1971) are correct, this would be a time of very high nitrate levels at the four sampling stations.

Nitrites were also considered for the Rocky Branch-West Fork study area. Sawyer (1960) states that under anaerobic conditions nitrates are reduced to nitrites. Nitrites may then be further reduced to ammonia by certain bacteria, but most carry the reduction to nitrogen gas which escapes to the atmosphere. Nitrites represent an intermediate stage in the nitrogen cycle and may occur in water as the result of biological decomposition of proteins.

Nitrites represent an unstable nitrogen species which are readily oxidized or reduced by either chemical or biological processes. They are easily oxidized by chlorine in water treatment plants. This results in the removal of most nitrites from public water supplies. Treated water from municipal water treatment plants seldom exceed a nitrite level of .1 mg/l (Anon., 1971b), while natural running waters rarely exceed 1 mg/l nitrite (Anon., 1970). In such low concentration there is little danger of methemoglobinemia. However, Standard Methods (Anon., 1971b) suggest that trace amounts of nitrites could indicate organic pollution.

Trace amounts of nitrites were recorded at the Rocky Branch and West Fork sampling stations (Fig. 11). Stations I and II recorded mean readings of .03 mg/l and .02 mg.l while stations III and IV recorded a mean of .05 mg/l. Standard Methods (1971b) suggest that such trace amounts of nitrites could represent organic pollution of the waterway. However, in the streams studied no visible sign of organic pollution was noted. Other parameters, such as biochemical oxygen demand, showed no indication of pollution. The nitrite level encountered at the four sampling stations probably represents the natural breakdown of nitrates to nitrites by denitrifying bacteria.

Phosphorus

Phosphorus is one of the most abundant elements known to occur on Earth and is estimated to be eleventh among elements found in igneous rock. It can be found with other minerals as orthophosphate (Anon., 1970). Authors suggest that the Earth's sphere contains approximately 160 billion pounds of phosphorus per acre or a total of 10^{19} tons (Anon., 1967a). However only a small fraction of this amount is available for utilization by plants. Many phosphorus-containing minerals are only slightly soluble in water. This tends to limit naturally occurring concentrations of phosphorus in aquatic environments. Only 2% or .07 mg/l phosphorus can be found in solution while the remainder of this naturally occuring element eventually becomes incorporated in ocean sediments. Even in low concentrations, phosphorus with nitrogen is often considered an essential nutrient in the natural aging process of a body of water (Keup, 1968).

Mackenthun (1968) and Sawyer (1968) note that eutrophication of lakes and streams is of rapidly growing interest to scientists. Both authors state that when phosphorus is present in excess of a critical concentration and when other environmental conditions are favorable, nuisance algal blooms, scums, and foul odors can result. Phosphorus, unlike nitrogen, cannot be fixed from the atmosphere by plants. Therefore the amount of soluble phosphorus in an aquatic community can indeed act as a limiting factor in aquatic plant growth. These authors feel that detailed studies of macronutrients such as phosphorus and their effects on the aquatic plant community are essential in understanding man's role in eutrophication.

According to Standard Methods (Anon., 1971b), phosphorus occurs under natural conditions in three forms: orthophosphate, condensed phosphate, and organically bound phosphate. These may occur in soluble form, in particles of detritus, or in the bodies of aquatic organisms.

Large quantities of slightly soluble mineral phosphates make up an almost unlimited reservoir of phosphorus. The weathering of phosphate-bearing rocks and the ultimate solution of the soluble phosphate ion results in the presence of inorganic orthophosphate in an aquatic ecosystem. The phosphate minerals, however, are relatively insoluble and solution rates are slow. These factors tend to keep orthophosphate concentrations at relatively low levels. Orthophosphates are frequently added to farm lands as commercial fertilizers (Barrett, 1953). Smith (1969) reports that 10% of the phosphate fertilizer added to farm land in Canada found its way into the local drainage system within the first year after its application.

Condensed phosphates generally are man-made and are used in detergents and water treatment. Man-made condensed phosphates are produced by dehydration condensation of orthophosphates. Increased usage of detergents containing condensed phosphates has resulted in a marked increase in total phosphorus noted in sewage effluents. Devey and Harkness (1973) report a significant correlation between detergent use and increases in total and orthophosphate levels. They report that the condensed phosphate will slowly hydrolize to orthophosphate under natural conditions while changing rapidly under acidic sewage effluent conditions. Soluble orthophosphate is the form most readily utilized by aquatic plants.

Organic phosphates are formed as a result of biological processes. According to Standard Methods (Anon., 1971b) they are contributed to sewage in body wastes, food residue, or may be formed from orthophosphates in biological treatment processes. Organic phosphates often make up a considerable percentage of the total phosphorus concentration of a stream or lake. Researchers studying the Illinois and Kaskaskia Rivers found that 15% to 30% of the total phosphorus levels were organic phosphates (Anon., 1970). According to Hach (Anon., 1967b) the analysis of organic phosphate constitutes a complex and time-consuming digestion process. Because of this, researchers have often neglected organic phosphates as a parameter to be considered in water quality studies. This has resulted in a definite lack of information concerning organic phosphate as a fraction of natural bodies of water.

Phosphates enter an aquatic community by several means. Weathering and erosion of phosphate-bearing rock constitute the only natural introduction of inorganic phosphorus into a water environment, while decomposition of organic material results in the release of organic phosphorus fractions. Man has increased the amount of total phosphorus in waterways through sewage effluents and commercial fertilizers. It is this extra phosphorus load carried by streams and lakes which accounts for premature eutrophication of our waterways.

Commercial fertilizers enter a waterway through drainage water and eroded soil. In most instances, according to Cook and Williams (1973), these phosphate fertilizers are held tightly by the eroded soil and are not available for use by the plant community. Studies conducted by Gotterman (1973) seem to confirm this. He found that the alga Scenedesmus could not be cultured on phosphate-bearing clays because of the unavailability of this nutrient.

Sawyer (1965) states that vast tonnages of condensed phosphate compounds are used in the formulation of modern detergents. The bulk of this man-made phosphate eventually is expelled into a drainage system by way of sewage treatment plants. This added condensed phosphate has increased the phosphorus level of receiving streams by a factor of two to possibly four times what it would be in its absence. Condensed phosphates eventually degrade to orthophosphate, the form readily available for plant utilization.

Sawyer (1965,1968) and Mackenthun (1968) feel that the excess orthophosphate which results from introduced condensed phosphates is the cause of premature eutrophication.

Studies have shown that phosphorus can be removed from waste water with the correct treatment. Sawyer (1965) states that coagulation with alum, ferric salts, or lime effectively lowers the amount of total phosphorus released in a sewage effluent. However this is an expensive technique and the resulting sludges are voluminous and difficult to dewater. Only a few sewage treatment plants presently remove phosphates from their effluents.

Total phosphate (Fig. 12), orthophosphate (Fig. 13), and condensed phosphate (Fig. 14) were monitored during the course of the Rocky Branch and West Fork survey. Organic phosphates were not considered because of the complex analytical procedures required.

Total phosphate readings at the four sampling stations were very similar. All sampling sites averaged within .01 of each other (Table 1). On September 16, 1972, station II on Rocky Branch recorded 1 mg/l, the high reading for all sites. This high, however, falls well below the 8.5 upper limit set for public water supplies by the U.S. Government (Anon., 1968). Mackenthun (1968) suggests that in order to avoid biological nuisances, total phosphates should not exceed 100 mg/l at any point within a flowing stream or 50 mg/l where the waters enter a lake. The Preserve study area falls well within these limits.

Orthophosphate levels varied somewhat at each sampling site (Fig. 13). Station I was the lowest while station IV averaged the highest with .17 mg/l. Since orthophosphate is the only form of phosphorus readily available for use by aquatic plants, the threat of premature eutrophication in the study area is not significant. The weathering of phosphorus-bearing rocks generally accounts for the greatest proportion of naturally occurring orthophosphate. The larger drainage pattern of the West Fork, along with the increased erosion of phosphate minerals from the area, is probably the reason the West Fork registered a slightly higher orthophosphate level.

Orthophosphates also result from the degradation of condensed phosphates. The rate at which condensed phosphates change to orthophosphates varies with their type, temperature of the water, and its pH. Condensed phosphates are almost always present because of man's actions. During the study period the condensed phosphates at all sampling stations ran approximately twice the level recorded for orthophosphate. However, all of the levels recorded were extremely low. Stations I and II on Rocky Branch recorded higher, although not significantly higher, condensed phosphate levels than stations III and IV on the West Fork (Fig. 14). The presence of condensed phosphates in the two streams can probably be attributed to runoff and seepage from septic tanks on surrounding farms and farming communities. Most condensed phosphates enter stream systems as effluent from substandard sewage treatment plants. This, however, cannot be the case in this area as no treatment plants exist. The levels recorded are minimal and pose no threat to the water quality in the area.

Summary

Rocky Branch, located in the Rocky Branch Nature Preserve, Clark County, Illinois contains a diverse fish population in relation to its size. During the study period 16 species belonging to five families were collected.

Darters (Percidae) were common and collected from fast-flowing riffle areas. Cyprinids (seven species) were the most common family collected while bullheads (Ictaluridae) and sunfish (Centrarchidae) were rare. Certain species of Catostomidae were also common.

Two species of Cyprinidae which were collected are relatively uncommon in east-central Illinois. The red-bellied dace (*Chrosomus erythrogaster*) and the black nosed dace (*Rhinichthys atratulus*) proved to be quite common in Rocky Branch.

Data for 17 water quality parameters were gathered at four sampling sites on Rocky Branch and the West Fork of Big Creek. Water temperature, pH, DO, BOD, turbidity, nitrate, nitrite, total phosphate, orthophosphate, condensed phosphate, total iron, sulfate, total hardness, alkalinity, and conductivity were recorded.

The results indicate that the two streams are well within the limits established for a healthy aquatic community and/or potable water for the majority of parameters studied. However, while nitrate levels did not exceed the recommended 45 mg/l level, they were very close to it. The possibility exists that in the future high nitrate levels might become a problem as a result of agricultural runoff or other influences that would tend to increase the levels of nitrates.

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