A STUDY OF THE PHYCOPERIPHYTON COMMUNITY IN THE BLACK RIVER, LA CROSSE COUNTY, WISCONSIN

A Thesis

Submitted to the Faculty

of

University of Wisconsin - La Crosse

La Crosse, Wisconsin 54601

by

Michael Raymond Strenski

In Partial Fulfillment of the
Requirements for the Degree

of

Master of Science in Biology

December 1977

UNIVERSITY OF WISCONSIN - LA CROSSE

La Crosse, Wisconsin 54601

COLLEGE OF ARTS, LETTERS, AND SCIENCES

Candidate: Michael Raymond Strenski

We recommend acceptance of this thesis to the College of Arts, Letters, and Sciences in partial fulfillment of this candidate's requirements for the degree of Science in Biology. The candidate has completed his oral defense of the thesis.

Thesis Committee Chairperson — 10 November 1977
Date

Thesis Committee Member — 10 November 1977
Date

Thesis Committee Member — 10 November 1977
Date

Thesis Committee Member — 10 November 1977
Date

This thesis is approved for the College of Arts, Letters, and Sciences

Dean, College of Arts, Letters, and Sciences — 11/18/77
Date

ABSTRACT

Phycoperiphyton taxonomic composition, numbers, biomass, and pigments were analyzed from materials gathered from the Black River, La Crosse County, Wisconsin. Phycoperiphyton samples were collected from two stations at each of four sites and water samples were also collected at each of the four sites during the open water season, April through November 1976. Floating samplers fitted with glass slides served as the phycoperiphyton substrate. Station selection was based on current velocity and direct sunlight. The following measurements were made at each side: temperature, dissolved oxygen, pH, alkalinity, calcium and total hardness, ortho-phosphorous, nitrate, and nitrite. River depth and current velocity were measured at each station.

A total of 56 genera and 205 species (29 species were further identified to include 75 varieties) were found. The phycoperiphyton community was dominated greatly by members of the class Bacillariophyceae (ca. 98% of the total community). *Achnanthes lanceolata,* was the dominant species during spring months. *Melosira varians* dominated by mid-June and was succeeded by *Cocconeis placentula euglypta* during July through late September. *Navicula cryptocephala* dominated next in the autumn, and during the final sampling period in November *Diatoma vulgare* was the dominant species.

ACKNOWLEDGEMENTS

I wish to express my sincere graditude to Dr. Ronald G. Rada for his supervision and assistance throughout the study and in the preparation of this manuscript. Thanks are due Dr. Thomas O. Claflin, Dr. D. J. Grimes, Dr. Charles Hosler and Dr. James Warner for their valuable advice and guidance in the preparation of this manuscript. Appreciation is expressed to Bruce Biltgen, Keith Mueller, and William Smith for their assistance during the collection of field data. I would like to acknowledge the River Studies Center and the Biology Department at the University of Wisconsin-La Crosse for use of the equipment and facilities used in the study.

Special thanks go to my mother, Patricia Strenski, for typing this manuscript.

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX
TABLE | PAGE

APPENDIX TABLE		PAGE

LIST OF FIGURES

INTRODUCTION

The Black River is a tributary of the Mississippi River with the confluence located 11.5 km (7 mi) north of La Crosse, Wisconsin. The headwaters of the Black River are located approximately 267 km (160 mi) NNE in Taylor County, Wisconsin. The River serves as a boundary between a portion of La Crosse and Trempealeau counties. This investigation, performed during April through November 1976, was undertaken to establish basic information about the phycoperiphyton community in the Black River. The objectives of the study were:

(1) To determine the taxonomic composition of the phycoperiphyton community;

(2) To quantify taxonomic composition with respect to density, relative density (% of the total community), biomass, and pigmentation; and

(3) To determine the general physical and chemical composition of the Black River.

DESCRIPTION OF THE STUDY AREA

The southern portion of the Black River was studied. It is located between lat. 43° 57" to 44° 03" and long. 91° 12" to 91° 16". This section of the river formed the northern boundary of sections 1 and 2 and the western boundary of sections 10, 16, 21, and 27 of Holland Township, La Crosse County, T. 18 N., R. 8 W. (Fig. 1). The Black River drains 5490 km^2 (2129 mi^2). United States Geological Station 05382000 is located about 50 m upstream from the first set of stations established in this study. The study area covered a distance of 11 km (6.6 mi). Much of the river in the study area meanders through an area known locally as the Black River Bottoms. Dominant tree species include *Ulmus americana* (American Elm), *Acer saccharinum* (Silver Maple), *Betula nigra* (River Birch), and *Salix* spp. (Willows). Agricultural crops and a few grazing areas are found along the Trempealeau County side of the river. Swimming, canoeing, and fishing are popular recreational activities on the Black River.

Two stations were established at each of four sites. At each site, one station was located where current velocity was maximal, and a second station where current velocity was minimal. Direct sunlight was also a criterion in station location because it greatly affects phycoperiphyton distribution. United States Highway 53 spans the Black River at a crossing known as Hunter's Bridge, 3.5 km (2 mi) southeast of Galesville, Wisconsin. This bridge serves as a reference point for site locations (Fig. 1). Site 1, where sampling stations 1-N and 1-S were located, was 0.25 km (0.15 mi) east (upstream) of Hunter's Bridge. Station 1-N was established near the northern bank in an area of deposition where the depth ranged from 0.17 m to

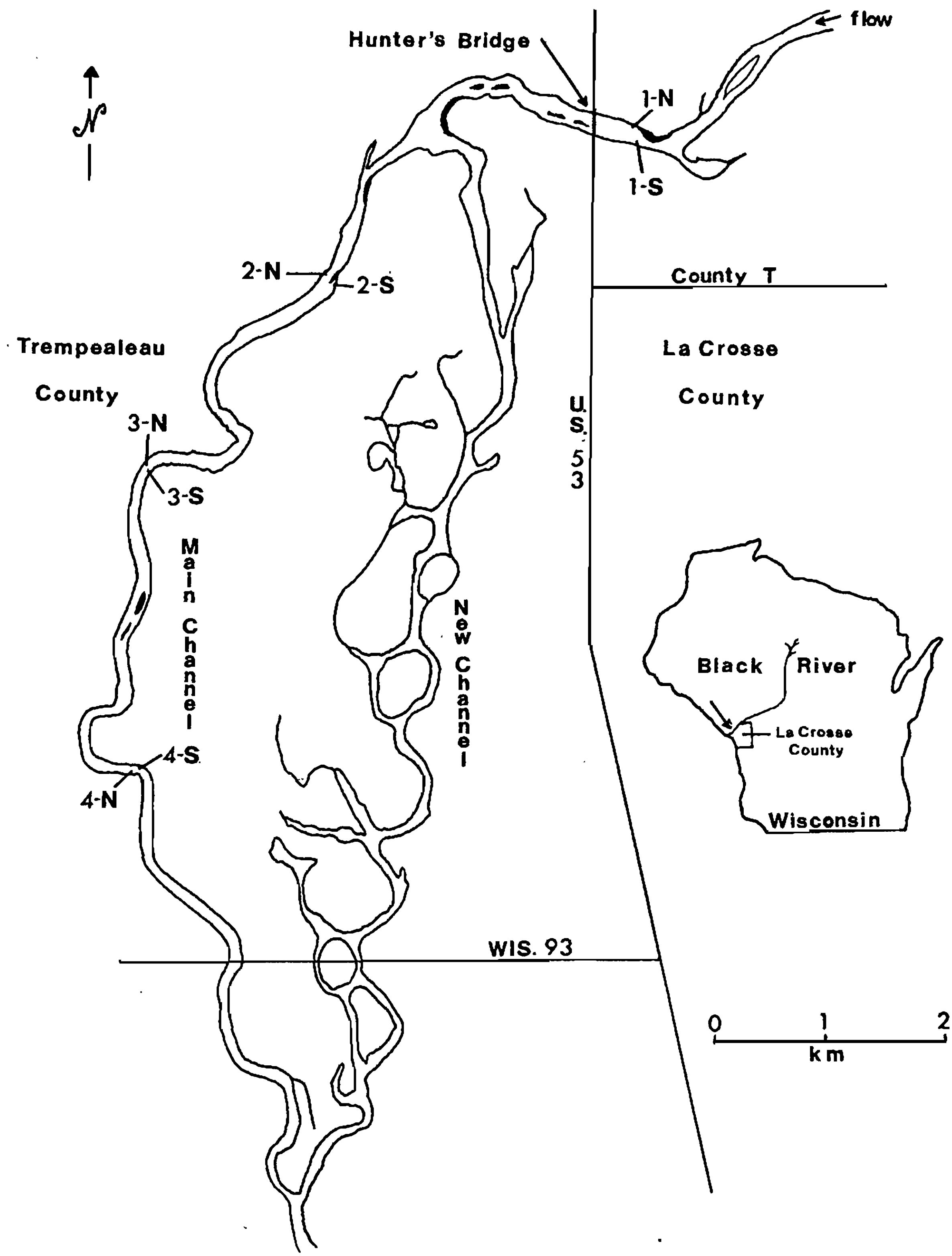

Fig. 1. Map of the study area with locations of sampling stations indicated 1-N, 1-S, etc.

0.50 m. This station was always exposed to direct sunlight and the current velocity did not exceed 0.03 m/sec. Station 1-S, located near the southern bank, ranged in depth from 0.35 m to 1.05 m, and exhibited current velocities of 0.03 m/sec to 0.23 m/sec. This station received considerable shading from overhanging trees; direct sunlight was found only in the evening hours until October when the leaves fell from the trees. Sampling stations 2-N and 2-S were located at a site 3.25 km (1.95 mi) downstream from Hunter's Bridge. Station 2-N was placed near the northern bank by several small *Betula nigra* (River Birch) which remained partially submerged during the entire study. The depth at this station ranged from 0.20 m to 0.70 m; no shading occurred until midafternoon. The current velocity fluctuated between 0.10 m/sec and 0.34 m/sec. Station 2-S was located between the southern bank and a sandbar where the initial current velocity was 0.06 m/sec in April. However, due to the continued reductions in the water level current velocity became negligible by July. Shading began in the afternoon. Site 3 was located 7 km (4.2 mi) downstream from Hunter's Bridge at the end of a large bend in the river. Station 3-N was established near the northern bank where some sloping topsoil had been eroded and several large trees had fallen. Depth ranged from 0.25 m to 1.50 m and current velocity from 0.04 m/sec to 0.39 m/sec. Shading at station 3-N occurred only toward evening. This station and station 3-S remained relatively uniform with respect to current velocity for the entire project. Station 3-S was located near the southern bank. Depth ranged from 0.15 m to 1.00 m; current velocity was 0.11 m/sec to 0.50 m/sec. Shading was similar to that at station 1-S with direct sunlight occurring only in the evening. The fourth and final site was 10.8 km (6.4 mi) downstream from Hunter's Bridge. Station 4-N, near the northern bank, provided the greatest variation in current velocity of all the stations; a range of $\leq$ 0.01 m/sec to 0.42 m/sec was recorded. Depth ranged from 0.15 m to 0.55 m and there was essentially no shading. Station 4-S remained shaded until approximately midmorning. Depth varied from 0.85 m to 1.75 m; current velocity was consistently highest at this station, 0.21 m/sec to 0.48 m/sec (Table 1).

Table 1. A summary of direct sunlight trends, mean and range values for current velocity (m/sec), and depth (m) at each station in the Black River, 10 April through 20 November 1976.

STATION	DIRECT SUNLIGHT[a]	CURRENT VELOCITY	DEPTH
1-N	1	0.01 (<0.01-0.03)	0.27 (0.15-0.50)
1-S	3	0.14 (0.03-0.23)	0.70 (0.35-1.05)
2-N	2	0.23 (0.10-0.36)	0.42 (0.20-0.70)
2-S	2	0.01 (<0.01-0.06)	0.91 (0.50-1.35)
3-N	1	0.28 (0.04-0.39)	0.70 (0.20-1.50)
3-S	3	0.26 (0.11-0.50)	0.44 (0.15-1.00)
4-N	1	0.16 (<0.01-0.42)	0.26 (0.07-0.55)
4-S	2	0.30 (0.21-0.48)	1.17 (0.85-1.75)

[a] DIRECT SUNLIGHT=1 - Direct sunlight at least until early evening.
2 - 6 to 8 hr of direct sunlight daily.
3 - Less than 3 hr of direct sunlight daily.

METHODS AND MATERIALS

Physical Analyses

The water temperature was taken with a glass thermometer. River depth at each station was measured with the use of a sounding pole marked in 0.05-m gradations. A current meter (Kahlsico Co., El Cajon, CA) was employed to measure current velocity at each station. The United States Geological Survey, Water Resource Division, provided the discharge data which was recorded at station 05382000, 305 m upstream from Hunter's Bridge and approximately 50 m upstream from Site 1.

Chemical Analyses

Water samples were collected in acid washed sample bottles rinsed in river water prior to collection. Samples were taken at depths from 5 to 10 cm simultaneously with the collection of live phycoperiphyton material. Alkalinity, pH, and total and calcium hardness were analyzed using unfiltered water. Ortho-phosphorous and nitrogen analyses were made on water previously filtered with glass fiber filters (Gelman Instrument Co., Type A, Ann Arbor, MI). All chemical analyses were routinely performed within 12 hr after sampling. Hydrogen ion concentration was determined in the laboratory with a pH meter (Ionalyzer Digital, model 701, Orion Research Inc., Cambridge, MA). Alkalinity was determined potentiometrically by titration with standard sulfuric acid (APHA 1975). Total hardness and calcium hardness were determined by complexometric methods using standard HexaVer^R as the titrant and ManVer^R and CalVer^R, respectively, as the indicators (Hach Chemical Co., Ames, IA). Ortho-phosphorous was determined using the single reagent method described by the Environmental Protection Agency (1974). The Mullin and Riley reduction method was used in the analyses of nitrate (Barnes 1959). Nitrite was determined using the color-buffer reagent (EPA 1974). The Modified Winkler Technique was used for determining dissolved oxygen (APHA 1975).

Phycoperiphyton Analyses

Sampler

Phycoperiphyton sampling apparatus were constructed from plastic micrscope slide boxes by removing the bottoms so as to leave enough of an edge to retain glass microscope slides. Slides were retained in the box with rubber bands. A 40-mm x 150-mm styrofoam float was attached to one side and a 2-m nylon anchoring line to the other. A brick served as the anchor (Fig. 2). Two samplers were set at each station to ensure adequate amounts of material for analyses. Each sampler contained eight evenly spaced glass slides which were inserted vertically to prevent sedimentation from occurring on the slides. Several investigators have shown that artifical substrates are an effective method of biological sampling and glass is one of the most suitable for periphyton (Beak et al. 1973).

A total of 208 samplers (two sets at each station) were placed at the various stations over the duration of the study. Sampler recovery was > 94% (196 of 208). During the initial sampling period, samplers at four stations were not recovered, probably because of insufficient anchorage. Also, two stations appeared to have been vandalized during the summer.

Biomass

Biomass was determined by removing the phycoperiphyton material from both surfaces of three slides (total surface area of 0.01125 m^2 for each sample). This material was then analyzed for dry and ash-free dry weight (APHA 1975).

Pigment Analyses

Prior to pigment analyses, the algal material was stored, darkened in a freezer. Pigment analyses were performed on material obtained by scraping the surfaces of

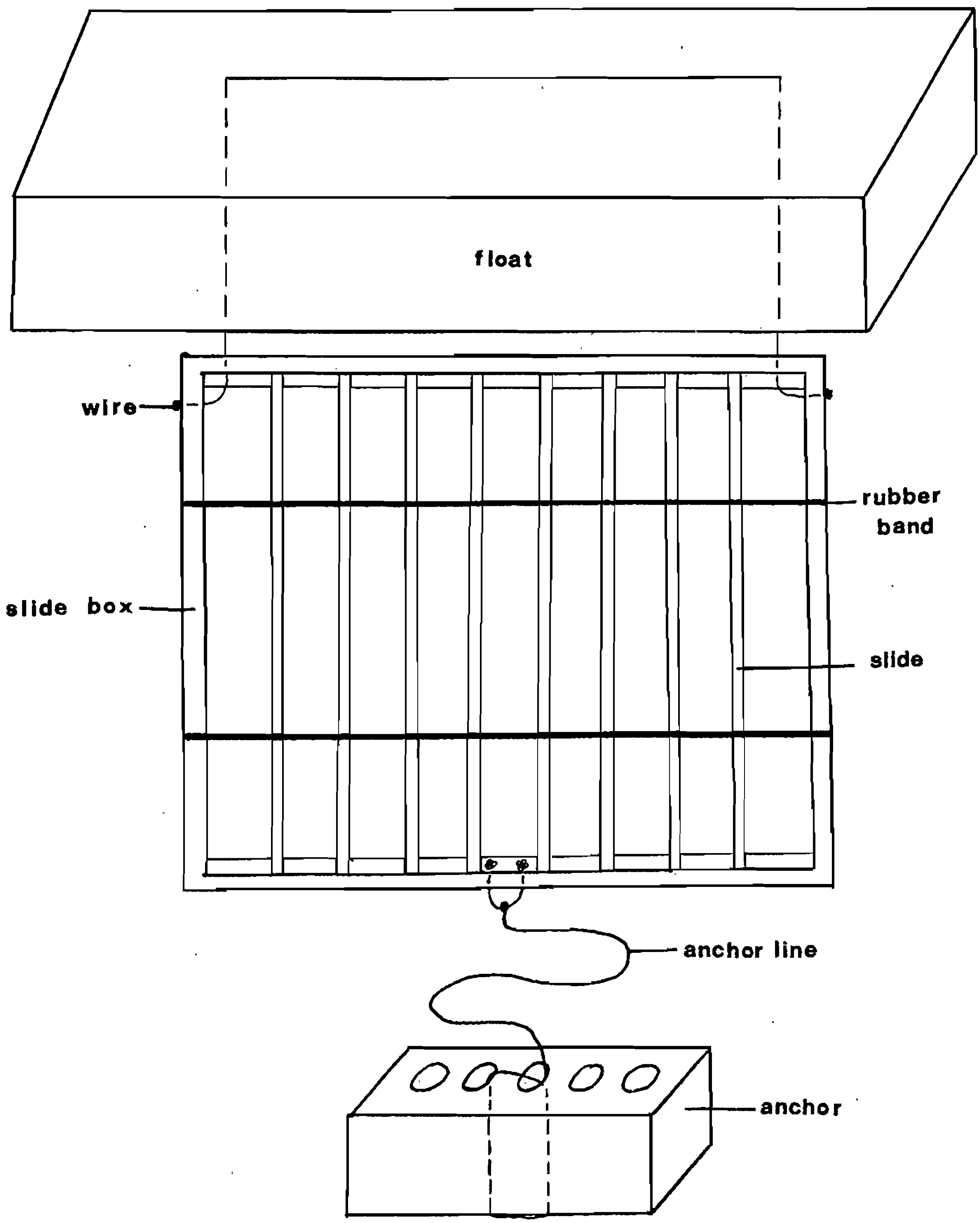

Fig. 2. Phycoperiphyton sampling apparatus design; actual scale is represented (anchor is reduced).

three slides (0.01125 m^2) onto glass fiber filters (Gelman Type A), inserted in filtering apparatus. The filters were removed from the apparatus and placed in foil-wrapped 15-ml centrifuge tubes to which 10 ml of 90% spectrophotometric grade acetone (Fisher Scientific Co., Fair Lawn, NJ) were added. The tubes were capped and replaced in a freezer for 24 hr. Glass fiber filters were preferred over membrane filters for several reasons: higher pigment yields, speed in filtration, and lower cost (Long and Cooke 1971). Extracts were clarified by centrifugation at low speed (500 g) for ten minutes. Optical densities of the pigment solutions were determined using a double beam spectrophotometer (Perkin-Elmer model Coleman 124, Hitachi Ltd., Tokyo, Japan). Pigment concentrations were calculated using the trichromatic method with the pheophytin correction (APHA 1975). In addition to calculating the chlorophyll *a* and pheophytin *a* concentrations, the "OD_{663} Before:OD_{663} After" acidification ratios were also determined (EPA 1973). Pheophytin *a* is a degradation product of chlorophyll *a* in which the magnesium is lost from the porphyrin ring structure of the chlorophyll *a* molecule. Acidification quantitatively converts chlorophyll *a* to pheophytin *a*. Pheophytin *a* has a decreased optical density at 663 nm after acidification compared to chlorophyll *a* because pheophytin *a* has a lower specific absorption. Samples producing a chlorophyll *a* before:after acidification ratio of 1.7 contain a population with mostly viable nondecaying organisms (EPA 1973). However, if pheophytin *a* is present in high amounts ratios approach 1.0. In nature both pigments are present and a ratio between 1.0 (all pheophytin *a*) and 1.7 (all chlorophyll *a*) is found. Pigment concentrations were calculated by using the corrected optical densities in the appropriate equations (APHA 1975).

Preservation of Phycoperiphyton Material

Live algal material was scraped from the surfaces of two slides (0.0075 m^2) into a solution of "M^3" preservative (APHA 1975). Permanent mounts of diatom material were made by the nitric acid-potassium dichromate method (Patrick and Reimer 1966). Hyrax[R] (Custom Research and Development Inc., Auburn, CA) was the mounting media used in this procedure.

Identification of Phycoperiphyton

The phycoperiphyton was identified to the lowest taxonomic levels possible with the use of bright-field microscopy (450X - non-diatoms, 1000X - diatoms). The following taxonomic keys were used for identification; Bourrelly (1968), Cleve-Euler (1955), Hansmann (1973), Hohn and Hellerman (1963), Huber-Pestalozzi (1942), Hustedt (1930a, 1930b), Patrick and Reimer (1966), Prescott (1962), Smith (1950), Tiffany and Britton (1952), and Weber (1971).

Enumeration of Phycoperiphyton

A standard Palmer-Maloney cell (Palmer and Maloney) was used to determine the relative density of all living cells (diatoms and non-diatoms) and for identification of non-diatoms. A minimum of 500 organisms per counting cell were tallied. Diatoms were identified from permanent mounts. The relative density within the diatom community was estimated by counting a minimum of 500 cells from random fields (usually 40-50) in the permanent mounts. Diatoms comprised 98% of all algae encountered and never accounted for $<$83% of the total in any sample. Phycoperiphyton density (cells/m^2) was determined using the following equation:

$$\text{cells}/m^2 = \frac{\frac{C}{T} \times \frac{A_{P-M}}{A_t} \times 10 \times V}{\text{area scraped}}$$

Where C = number of cells counted

T = number of transects

A_{P-M} = area of the Palmer-Maloney counted

A_t = area of one transect

10 = equates volume of Palmer-Maloney to 1 ml (Palmer-Maloney volume is 0.1 ml)

V = volume of the concentrated sample

RESULTS

Chemical and Physical Determinations

Sampling was initiated on 10 April 1976. However, complete sets of chemical and some physical measurements were not made until 2 June at which time equipment and materials became available. The values for all data presented refer to means unless otherwise indicated.

Current Velocity and Depth

The mean and range values for current velocity and depth are presented in Table 1. Individual measurements of current velocities varied from <0.01 m/sec at stations 1-N, 2-S, and 4-N to 0.50 m/sec at station 3-S. Stations 1-N and 2-S averaged ≤ 0.01 m/sec and stations 1-S and 4-N had current velocities of 0.14 m/sec and 0.16 m/sec, respectively. The remaining four stations had current velocities from 0.23 m/sec to 0.30 m/sec.

Depth ranged from 0.07 m (8 September, 4-N) to 1.75 m (16 June, 4-S). Seasonally, depth ranged from 0.27 m (1-N) to 1.17 m (4-S). Actual determinations from all dates at all stations are given in the Appendix (Tables 17 and 18).

Discharge

Discharge during each sampling period is presented in Table 2. It must be noted that discharge information is accurate only at stations 1-N and 1-S since the Black River branches into two forks prior to reaching the remaining sites. These forks are locally known as the main channel and the new channel. It is estimated that one-fourth to one-third of the flow is diverted into the new channel. Discharge at site 1 ranged from 120.83 m^3/sec in April to a low of 9.51 m^3/sec during late September and early October 1976.

The range and mean values of the remaining physical

Table 2. Mean seasonal discharge in the Black River above sampling site 1 (USGS 05382000), 10 April through 20 November 1976.

PERIOD	MEAN DISCHARGE (m^3/sec)
10 April-19 May	120.83
19 May-2 June	53.18
2-16 June	23.28
16-30 June	17.61
30 June-14 July	13.88
14-28 July	13.08
28 July-11 August	16.91
11-25 August	11.36
25 August-8 September	10.11
8-22 September	9.80
22 September-12 October	9.51
12 October-2 November	10.87
2-20 November	12.49

and all chemical parameters for each site are presented in Table 3. The range and mean for each sampling period are given in Appendix Table 19.

pH and Alkalinity

The pH decreased slightly from sites 1 to site 4. Seasonal variations ranged from 6.64 (19 May, site 1) to 9.38 (11 August, site 1).

Alkalinity, essestially all bicarbonate at the pH encountered, was consistently higher at site 3 compared to sites 1 and 2. Alkalinity between site 2 and 3 differed by more than 20 mg/L $CaCO_3$. Seasonally, alkalinity ranged from 32.2 mg/L $CaCO_3$ (30 June, site 4) to 99.2 mg/L $CaCO_3$ (20 November, site 3).

Hardness

Calcium hardness and total hardness showed similar patterns of increase at site 3 as compared to sites 1 and 2. A range of 29.2 mg/L $CaCO_3$ (2 June, site 1) to 106.4 mg/L $CaCO_3$ (2 November, site 3) was noted for calcium hardness. Seasonally, calcium hardness varied from 32.8 mg/L $CaCO_3$ (30 June) to 57.9 mg/L $CaCO_3$ (2 November).

Total hardness ranged from 48.8 mg/L $CaCO_3$ (2 June, site 1) to 133.6 mg/L $CaCO_3$ (20 November, site 3). Seasonally, concentrations ranged from 54.8 mg/L $CaCO_3$ (30 June) to 101.0 mg/L $CaCO_3$ (20 November). Higher concentrations were often found at site 3 compared to the other sites.

Nitrogen and Ortho-phosphorous

Marked increases in nitrate-nitrogen and ortho-phosphorous occurred at site 3. Nitrate-nitrogen increased more than two-fold from site 2 to site 3, 0.091 mg/L NO_3-N to 0.209 mg/L NO_3-N, respectively. Nitrite-nitrogen increased only about 12%, 0.017 mg/L NO_2-N to 0.020 mg/L NO_2-N.

Ortho-phosphorous concentrations increased approximately 47% at site 3 compared to site 2, 0.068 mg/L PO_4-P

Table 3. Mean and range values of some chemical and physical parameters in the Black River during 10 April through 20 November 1976.

	SITE 1	SITE 2	SITE 3	SITE 4
pH	(6.74-9.38)	(6.64-9.27)	(6.73-8.94)	(6.71-8.96)
Alkalinity (mg/L $CaCO_3$)	50.6 (37.4-65.5)	50.3 (34.3-73.8)	73.6 (51.0-99.2)	55.7 (32.2-71.8)
Calcium hardness (mg/L $CaCO_3$)	35.5 (29.2-45.6)	34.9 (30.4-40.8)	62.5 (32.8-106.4)	47.0 (35.2-64.8)
Total hardness (mg/L $CaCO_3$)	59.6 (48.8-76.8)	60.5 (51.2-81.6)	102.0 (54.4-133.6)	75.2 (60.8-117.2)
NO_3-N (mg/L)	.096 (.002-.189)	.091 (.002-.197)	.209 (.142-.242)	.127 (.039-.232)
NO_2-N (mg/L)	.016 (.001-.068)	.017 (.001-.071)	.020 (.001-.076)	.020 (.001-.077)
PO_4-P (mg/L)	.068 (.060-.091)	.066 (.046-.090)	.097 (.062-.139)	.079 (.057-.117)
Temperature (°C)	17.3 (0-28)	17.4 (0-28)	17.3 (0-28)	17.3 (0-28)
Dissolved oxygen (mg/L)	8.6 (7.0-10.1)	8.6 (6.7-10.3)	7.9 (6.7-10.6)	8.4 (6.9-10.4)
Discharge (m^3/sec)	24.84 (9.51-120.83)			

to 0.097 mg/L PO_4-P. Nitrate-nitrogen and ortho-phosphorous concentrations at each site are depicted in Fig. 3.

Seasonal changes in nitrate-nitrogen varied from 0.210 mg/L NO_3-N (16 June) to 0.069 mg/L NO_3-N (14 July). Nitrite-nitrogen ranged from 0.067 mg/L NO_2-N (16 June) to a trace (25 August). Ortho-phosphorous concentrations ranging from 0.063 mg/L PO_4-P (30 June) to a high of 0.098 mg/L PO_4-P (28 July) were found.

Temperature

The minimum temperature (0°C) was recorded on 20 November at all four sites and the maximum temperature (28°C) was recorded on 14 July at all sites. The greatest variation on a single sampling date occurred on 8 September when a difference of two degrees (19° to 21°C) was found between sites 1 and 4, respectively (Fig. 4).

Dissolved Oxygen

A minimal dissolved oxygen concentration of 6.7 mg/L was observed on 2 June at sites 2 and 3, while a maximal concentration of 10.6 mg/L was recorded on 20 November at site 3. In general, a slight decrease (0.2 through 0.8 mg/L) was noted farther downstream. Concentrations remained relatively uniform with the onset of cooler weather. Temperatures and dissolved oxygen concentrations for each sampling date are presented in Fig. 4.

Phycoperiphyton Flora

Taxonomic Composition

The taxonomic composition of the phycoperiphyton in the Black River was represented by four classes of algae: Bacillariophyceae (diatoms), Chlorophyceae (green algae), Dinophyceae (dinoflagellates), and Myxophyceae (blue-green algae). A total of 54,905 cells were identified (an average of 560 cells per sample) and yielded 56 genera and 205 species. Twenty-nine of the 205 species were further identified to include 75 varieties.

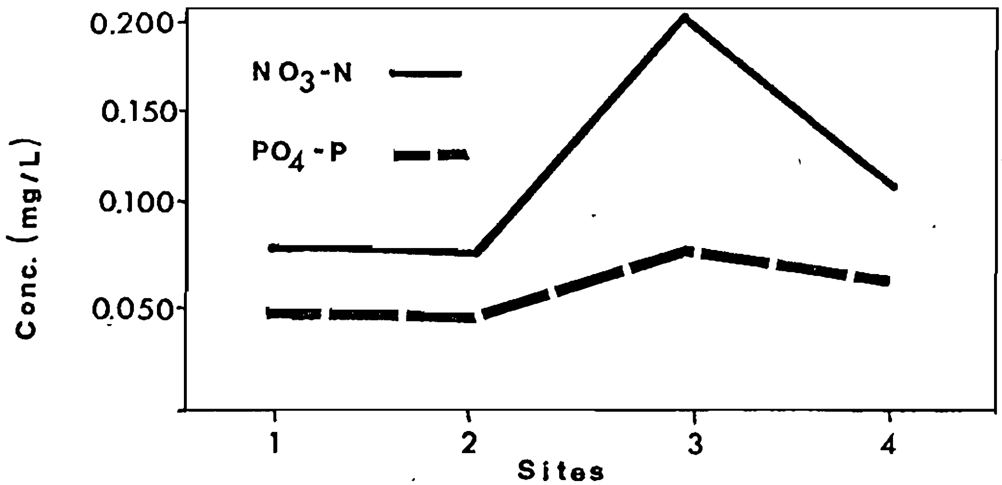

Fig. 3. Mean nitrtate-nitrogen and ortho-phosphorous concentrations at each site in the Black River, 10 April through 20 November 1976.

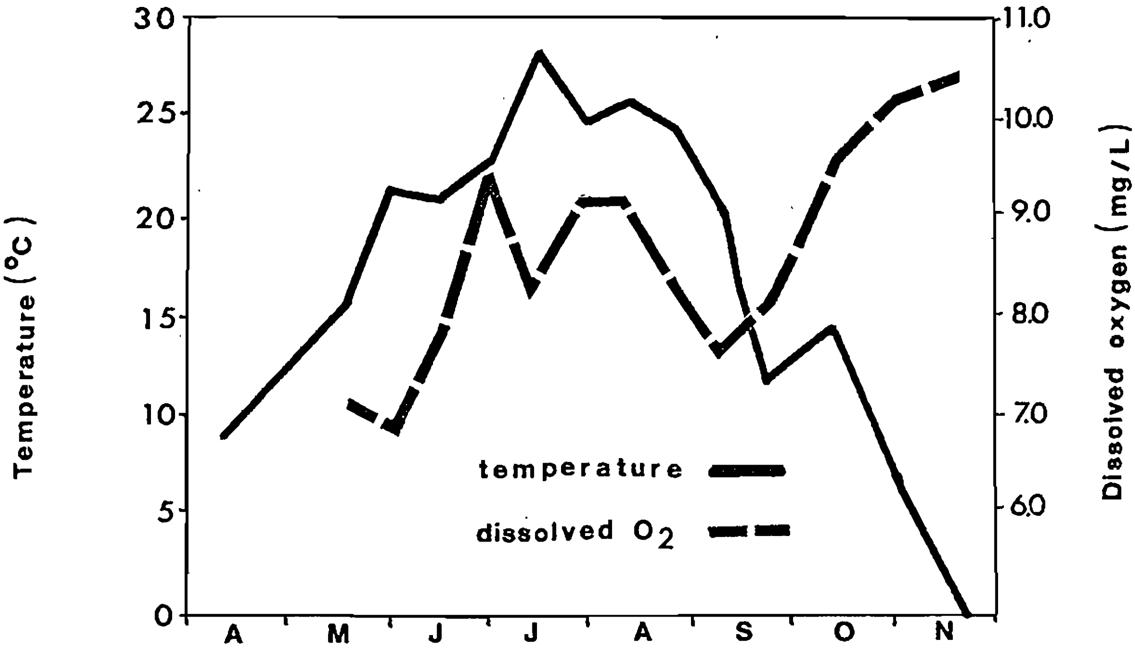

Fig. 4. Mean temperature and dissolved oxygen concentrations in the Black River, 10 April though 20 November 1976.

Members of the class Bacillariophyceae greatly dominated the community. A total of 192 species representing 35 genera were identified from this class which accounted for approximately 98% of the phycoperiphyton community. Diatoms from 28 species primarily belonging to the genera *Fragilaria, Synedra, Achnanthes, Navicula,* and *Pinnularia* were further identified to variety level. Seasonally dominant taxa included *Achnanthes lanceolata, Melosira varians, Cocconeis placentula euglypta, Navicula cryptocephala,* and *Diatoma vulgare*. These five taxa comprised about 44% of the total community. Two species, *Navicula cryptocephala* and *Nitzschia palea*, occurred in each of the 98 samples. Fifteen taxa appeared in at least 93.9% of the samples. *Navicula cryptocephala* ranked first in relative density at 16.72%. *Cocconeis placentula euglypta* and *Melosira varians* ranked second and third with 12.53% and 8.24%, respectively.

Chlorophyceae was represented by 20 genera but was not considered a major component of the community. Members from this class contributed only 2.24% of the algae encountered. Representatives of Chlorophyceae were found in 85.7% of the samples collected. The most frequently encountered green algae were *Scenedesmus quadricauda, Pediastrum duplex,* and *Scenedesmus dimorphus*, which were found in 70, 43, and 42 samples, respectively.

A species of *Merismopedia* and *Oscillatoria* were documented from the class Myxophyceae; each occurred in early autumn at different stations.

Ceratium hirundinella was the sole representative of the class Dinophyceae and was noted only once. Seasonal relative density of each class is provided in Appendix Table 20. The mean and range number of taxa identified (including species and varieties) at each station and during each sampling period are presented in Appendix Tables 21 and 22.

Table 4. Phycoperiphyton taxonomic composition and frequency of occurrence for all stations in the Black River, 10 April through 20 November 1976.

TAXON	FREQUENCY OF OCCURRENCE (%)
Division: CHRYSOPHYTA	
Class: Bacillariophyceae	
Order: Centrales	
Suborder: Coscinodiscineae	
Coscinodiscus sp.	4.1
Cyclotella atomus Hust.	74.5
Cyclotella comta (Ehr.) Kutz.	2.0
Cyclotella glomerata Bachmann	6.1
Cyclotella kutzingiana Thwaites	30.6
Cyclotella meneghiniana Kutz.	93.9
Cyclotella stelligera Cl. and Grun.	96.9
Melosira distans (Ehr.) Kutz.	7.1
Melosira granulata (Ehr.) Ralfs	12.2
Melosira islandica O. Muller	1.0
Melosira italica (Ehr.) Kutz.	95.9
Melosira italica tennuissima (Grun.) Muller	72.4
Melosira varians Ag.	97.9
Stephanodiscus astrea (Ehr.) Grun.	1.0
Stephanodiscus hautzschia Grun.	3.1
Stephanodiscus invisitatus Hohn and Hellerman	35.7
Stephanodiscus sp.	3.1
Order: Pennales	
Suborder: Fragilarineae	
Asterionella formosa Hass.	34.7
Asterionella sp.	2.0
Diatoma vulgare Bory	63.3
Eunotia arcus Ehr.	1.0
Eunotia crista galli Cl.	2.0
Eunotia exigua (Breb. ex Kutz.) Rabh.	3.1
Eunotia formica Ehr.	
Eunotia lunaris (Ehr.) Grun.	51.0
Eunotia lunaris subarcuata (Naeg.) Grun.	4.1

Table 4. (cont.)

TAXON	FREQUENCY OF OCCURRENCE (%)
Eunotia maior (W. Sm.) Rabh.	2.0
Eunotia meisteri Hust.	6.1
Eunotia microcephala Krasske	2.0
Eunotia monodon Ehr.	15.3
Eunotia pectinalis (Kutz.) Rabh.	10.2
Eunotia pectinalis minor (Kutz.) Rabh.	43.9
Eunotia pectinalis minor impressa Ehr.	9.2
Eunotia pectinalis minor intermedia Krasske	1.0
Eunotia pectinalis ventralis (Ehr.) Hust.	1.0
Eunotia praerupta Ehr.	5.1
Eunotia robusta tetradon (Ehr.) Ralfs	4.1
Eunotia septentrionelis Oestrup	6.1
Eunotia tenella (Grun.) Hust.	3.1
Eunotia valida Hust.	1.0
Eunotia sp.	32.7
Fragilaria arcus (Ehr.) Patr.	3.1
Fragilaria brevistriata Grun.	3.1
Fragilaria constricta Ehr.	19.4
Fragilaria construens (Ehr.) Grun.	58.2
Fragilaria construens binodis (Ehr.) Grun.	1.0
Fragilaria construens venter (Ehr.) Grun.	1.0
Fragilaria crotonensis Kitton	2.0
Fragilaria inflata (Heid.) Hust.	5.1
Fragilaria leptostauron (Ehr.) Hust.	18.4
Fragilaria leptostauron rhomboides Grun.	58.2
Fragilaria pinnata Ehr.	62.2
Fragilaria pinnata capittula Krieger	2.0
Fragilaria pinnata lancettula (Schum.) Hust.	1.0
Fragilaria virescens Ralfs	32.7
Fragilaria virescens capitata Krasske	1.0
Fragilaria virescens mesolepta Rabh.	1.0
Fragilaria virescens oblongella Grun.	19.4
Fragilaria virescens subsalina Grun.	1.0
Fragilaria spp.	82.7
Meridion circulare (Grev.) Ag.	25.5
Meridion circulare constrictum (Ralfs) V. H.	4.1

Table 4. (cont.)

TAXON	FREQUENCY OF OCCURRENCE (%)
Opephora martyii (Herib.)	80.6
Synedra acus Kutz.	42.9
Synedra affinis fasciculata (Kutz.) Grun.	1.0
Synedra capitata Ehr.	1.0
Synedra nana Meister	1.0
Synedra parisitica (W. Sm.) Hust.	9.2
Synedra parisitica subconstricta Grun.	1.0
Synedra pulchella Ralfs ex Kutz.	11.2
Synedra rumpens Kutz.	61.2
Synedra rumpens familiaris (Kutz.) Hust.	17.3
Synedra rumpens fragilariodes Grun.	2.0
Synedra ulna Ehr.	93.9
Synedra ulna impressa Hust.	11.2
Synedra ulna oxyrhynchus Kutz.	40.8
Synedra ulna oxyrhynchus contracta (Hust.) van Heurck	2.0
Synedra vaucheriae Kutz.	26.5
Synedra vaucheriae capitella Grun.	8.2
Tabellaria fenestrata (Lyngb.) Kutz.	55.1
Tabellaria flocculosa (Roth) Kutz.	40.8
Suborder: Achnanthineae	
Achnanthes delicatula Kutz.	71.4
Achnanthes detha Hohn and Hellerman	78.6
Achnanthes exigua Grun.	1.0
Achnanthes exigua heterovalvata Krasske	53.1
Achnanthes hauckiana Grun.	1.0
Achnanthes hungarica (Grun.) Grun.	14.3
Achnanthes lanceolata (Breb.) Grun.	96.9
Achnanthes lanceolata abbreviata Reim.	1.0
Achnanthes lanceolata apiculata Patr.	8.2
Achnanthes lanceolata capitata Muller	13.3
Achnanthes lanceolata rostrata Hust.	98.0
Achnanthes lanceolata ventricosa Hust.	24.5
Achnanthes laterostrata Hust.	1.0
Achnanthes marginulata Grun.	2.0
Achnanthes minuta (Cl.) A. Cl.	1.0
Achnanthes peragalli Brun. and Herib.	3.1
Cocconeis diminuta (Pant.)	15.3
Cocconeis pediculus Ehr.	66.3

Table 4. (cont.)

TAXON	FREQUENCY OF OCCURRENCE (%)
Cocconeis placentula Ehr.	99.0
Cocconeis placentula euglypta (Ehr.) Cl.	98.0
Rhoicosphenia curvata (Kutz.) Grun ex Rabh.	73.5
Suborder: Naviculineae	
Amphiprora ornata Bailey	4.1
Amphiprora sp.	3.1
Caloneis amphisbaena	
Caloneis bacillum (Grun.) Mereschkowsky	1.0
Caloneis lewisii Patr.	53.1
Caloneis ventricosa (Ehr.) Meister	3.1
Caloneis ventricosa truncatula (Grun.) Meister	30.6
Cymbella cistula (Hemprichi) Grun.	1.0
Cymbella cuspidata Kutz.	11.2
Cymbella lanceolata (Ehr.) van Heurck	45.9
Cymbella naviculiformis Auerswald	54.1
Cymbella prostrata (Berkeley) Cl.	28.6
Cymbella triangulum Grun.	19.4
Cymbella tumida (Breb.) van Heurck	71.4
Cymbella ventricosa Kutz.	55.1
Diploneis elliptica (Kutz.) Cl.	4.1
Diploneis ovalis (Hilse) Cl.	1.0
Diploneis smithii (Breb.) Cl.	1.0
Epithemia turgida (Ehr.) Kutz.	76.5
Epithemia sp.	4.1
Frustulia rhomboides Ehr.	41.8
Frustulia rhomboides amphipleuroides (Grun.) Cl.	1.0
Frustulia vulgaris (Thwaites) Det.	2.0
Gomphoneis herculaneum (Ehr.) Cl.	2.0
Gomphonema acuminatum Ehr.	19.4
Gomphonema angustatum (Kutz.) Rabh.	60.2
Gomphonema angustatum producta Grun.	93.9
Gomphonema angustatum sarcophagus (Gregory) Grun.	8.2

Table 4. (cont.)

TAXON	FREQUENCY OF OCCURRENCE (%)
Gomphonema augar Ehr.	5.1
Gomphonema citera Hohn and Hellerman	1.0
Gomphonema constrictum Ehr.	25.5
Gomphonema helveticum Brun.	1.0
Gomphonema intricatum Kutz.	1.0
Gomphonema olivaceum (Lyngb.) Kutz.	9.2
Gomphonema parvulum Kutz.	10.2
Gomphonema parvulum micropus (Kutz.) Cl.	3.1
Gyrosigma kutzingii (Grun.) Cl.	81.6
Gyrosigma scalproides (Rabh.) Cl.	7.1
Navicula americana Ehr.	3.1
Navicula bacillum Ehr.	1.0
Navicula Bremeyeri Hust.	67.3
Navicula clementis Grun.	2.0
Navicula costulata Grun.	2.0
Navicula crucicula (W. Sm.) Donkin	1.0
Navicula cryptocephala Kutz.	100.0
Navicula cuspidata Kutz.	69.4
Navicula cuspidata ambigua (Ehr.) Cl.	34.7
Navicula dicephala (Ehr.) W. Sm.	1.0
Navicula elginensis (Gregory) Grun.	52.0
Navicula exigua (Gregory) Grun.	
Navicula exigua capitata Patr.	98.0
Navicula gastrum Ehr.	48.0
Navicula halophila (Grun.) Cl.	1.0
Navicula hungarica Grun.	58.2
Navicula hungarica capitata (Ehr.) Cl.	96.9
Navicula imbellis Hohn and Hellerman	2.0
Navicula integra (W. Sm.) Ralfs	12.2
Navicula lacustris Gregory	8.2
Navicula minuscula Grun.	34.7
Navicula mutica Kutz.	25.5
Navicula placenta Ehr.	2.0
Navicula placentula (Ehr.) Grun.	1.0
Navicula punctalata W. Sm.	1.0
Navicula pupula Kutz.	68.4
Navicula pupula capitata Hust.	40.8
Navicula pupula rectangularis (Gregory) Grun.	25.5
Navicula radiosa Kutz.	42.9
Navicula rhynchocephala Kutz.	1.0
Navicula Rotaena (Rabh.) Grun.	5.1
Navicula seminuloides Hust.	1.0

Table 4. (cont.)

TAXON	FREQUENCY OF OCCURRENCE (%)
Navicula seminulum Grun.	1.0
Navicula subfasciata Patr.	1.0
Navicula subtilissima Cl.	1.0
Navicula tripunctata (Muller) Bory	56.1
Navicula viridula Kutz.	81.1
Neidium affine (Ehr.) Cl.	2.0
Neidium dubium (Ehr.) Cl.	20.4
Neidium incurvum (Gregory) Ost.	1.0
Neidium iridis (Ehr.) Cl.	21.4
Neidium iridis amphigomphus (Ehr.) Mayer	23.5
Neidium iridis ampliatum (Ehr.) Cl.	21.4
Neidium productum (W. Sm.) Cl.	1.0
Pinnularia acrosphaeria turgida Grun. ex Cl.	1.0
Pinnularia appendiculata (Ag.) Cl.	1.0
Pinnularia brevicostata Cl.	1.0
Pinnularia borealis Ehr.	5.1
Pinnularia caudata (Boyer) Patr.	1.0
Pinnularia divergens W. Sm.	2.0
Pinnularia fasciata Lagerstedt	1.0
Pinnularia gentilis (Donkin) Cl.	1.0
Pinnularia gibba Ehr.	19.4
Pinnularia gibba linearis Hust.	2.0
Pinnularia gibba mesogongyla (Ehr.) Hust.	1.0
Pinnularia gibba rostrata Patr.	1.0
Pinnularia subundulata (Mayer) Patr.	1.0
Pinnularia globiceps Krookei Grun.	1.0
Pinnularia interrupta W. Sm.	1.0
Pinnularia lata (Breb.) Rabh.	1.0
Pinnularia legumen Ehr.	1.0
Pinnularia microstauron (Ehr.) Cl.	4.1
Pinnularia microstauron Brebissonii (Kutz.) Hust.	1.0
Pinnularia nobilis (Ehr.)	2.0
Pinnularia nodosa (Ehr.) W. Sm.	14.3
Pinnularia pulchra Ostrup	1.0
Pinnularia streptoraphe Cl.	2.0
Pinnularia subcapitata Gregory	42.9
Pinnularia sudetica Hilse	1.0
Pinnularia viridis (Nitzsch.) Ehr.	46.9
Pleurosigma delicatulum W. Sm.	9.2
Rhopalodia gibba (Ehr.) Muller	27.6

Table 4. (cont.)

TAXON	FREQUENCY OF OCCURRENCE (%)
Rhopalodia gibberula (Ehr.) Muller	1.0
Rhopalodia sp.	5.1
Stauroneis anceps Ehr.	42.9
Stauroneis anceps gracilis (Ehr.) Cl.	2.0
Stauroneis anceps hyalina Brun and Per.	1.0
Stauroneis anceps linearis (E.?) Grun.	3.1
Stauroneis crucicula (Grun.) Cl.	76.5
Stauroneis kriegeri Patr.	1.0
Stauroneis parvula Grun.	1.0
Stauroneis phoenicentron Ehr.	22.4
Stauroneis pygmaea Krieger	1.0
Stauroneis smithii Grun.	4.1
Suborder: Surirellineae	
Cymatopleura elliptica (Breb.) W. Sm.	2.0
Cymatopleura solea (Breb.) W. Sm.	71.4
Hantzschia amphioxys (Ehr.) Grun.	37.8
Nitzschia acicilaris W. Sm.	53.1
Nitzschia acuta Hantzsch	3.1
Nitzschia amphibia Grun.	78.6
Nitzschia anugustata (W. Sm.) Grun.	10.2
Nitzschia apiculata (Gregory) Grun.	2.0
Nitzschia dissipata (Kutz.) Grun.	45.9
Nitzschia filiformis (W. Sm.) Hust.	13.3
Nitzschia fonticola Grun.	6.1
Nitzschia gracilis Hantzsch	3.1
Nitzschia hungarica Grun.	6.1
Nitzschia linearis W. Sm.	95.9
Nitzschia obtusa scalpelliformis Grun.	1.0
Nitzschia palea (Kutz.) W. Sm.	100.0
Nitzschia sigmoides (Ehr.) W. Sm.	7.1
Nitzschia thermalis Kutz.	1.0
Nitzschia tryblionella victoriae Grun.	3.1
Surirella angustata Kutz.	53.1
Surirella ovata Kutz.	54.1
Surirella robusta splendida (Ehr.) van Heurck	4.1
Surirella tenera Gregory	84.7

Table 4. (cont.)

TAXON	FREQUENCY OF OCCURRENCE (%)
Division: CHLOROPHYTA (Green Algae)	
Class: Chlorophyceae	
Order: Tetrasporales	
Tetraspora sp.	2.0
Order: Ulothricales	
Ulothrix spp.	6.1
Stigeoclonium spp.	10.2
Order: Cladophorales	
Cladophora sp.	3.1
Order: Chlorococcales	
Ankistrodesmus falcatus (Corda) Ralfs	20.4
Ankistrodesmus falcatus acicularis (A. Braun) G.S. West	1.0
Ankistrodesmus falcatus stipitatus (Chod.) Lemmermann	2.0
Characium limneticum Lemmermann	1.0
Chlorococcum sp.	2.0
Dictyosphaerium sp.	2.0
Golenkinia sp.	1.0
Pediastrum duplex Meyen	43.9
Scenedesmus acuminatus (Lag.) Chodat	1.0
Scenedesmus dimorphus (Turp.) Kutz.	42.9
Scenedesmus longus Meyen	1.0
Scenedesmus obliquus (Turp.) Kutz.	1.0
Scenedesmus quadricauda (Turp.) Kutz.	71.4
Selenastrum Westii G.M. Smith	1.0
Tetraedon hastatum (Reinsch) Hansgirg	1.0

Table 4. (cont.)

TAXON	FREQUENCY OF OCCURRENCE (%)
Order: Zygnematales	
Closterium spp.	14.3
Cosmarium spp.	12.2
Mougeotia spp.	4.1
Spirogyra sp.	1.0
Staurastrum gracilis Ralfs	1.0
Staurastrum hirsutum (Ehr.) Breb.	1.0
Division: CYANOPHYTA (Blue-green Algae)	
Class: Myxophyceae	
Order: Chroococcales	
Merismopedia sp.	1.0
Order: Oscillatoriales	
Oscillatoria sp.	1.0
Division: PYRRHOPHYTA (Dinoflagellates)	
Class: Dinophyceae	
Order: Peridiniales	
Ceratium hirundinella (O.F. Muell.) Dujardin	1.0

Rank of Common Taxa

The rank of the common phycoperiphyton taxa according to mean relative density (% of the total community) is depicted in Table 5. Common is defined in this study as those taxa with a relative density of ≥ 1%. During the study, eighteen taxa were denoted as common. *Navicula cryptocephala* (16.72%), *Cocconeis placentula euglypta* (12.55%), and *Melosira varians* (8.24%) ranked first through third, respectively. These were followed by *Nitzschia palea* (4.44%) and *Navicula exigua capitata* (3.91%). Six taxa had relative densities between 3.72% and 2.74%, while seven other taxa each comprised between 2.31% and 1.19% of the total community.

Rank of common taxa according to frequency of occurrence is shown in Table 6. Frequency of occurrence of a taxon is defined as the percentage of samples within which a taxon was found. In this instance, common denotes those taxa whose frequency of occurrence was at least 50%. This ranking included only one non-diatom taxon, *Scenedesmus quadricauda*. It ranked twenty-eighth along with three diatom taxa. Several taxa including *Cyclotella meneghiniana* (frequency 93.9%), *Synedra ulna* (93.9%), *Amphora ovalis* (89.8%), *Surirella tenera* (84.7%), *Gyrosigma kutzingii* (81.6%), and *Opephora martyii* (80.6%) ranked in the top twenty but were never very abundant in any sample. Therefore, they failed to rank high on the basis of relative density. Only 52 of the 254 taxa occurring in the Black River had a frequency of occurrence ≥ 51%.

The rank of common taxa by stations according to relative density is given in Table 7. *Cocconeis placentula euglypta* was dominant at five of the eight stations (1-N, 2-S, 3-N, 4-N, 4-S). It ranked second at station 2-N and third at the two stations which were shaded much of the day (1-S and 3-S). *Navicula cryptocephala* ranked first at

Table 5. Common phycoperiphyton taxa in the Black River ranked according to their mean relative density. The data is based on samples from all stations during 10 April through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%) (mean and range)
1	*Navicula cryptocephala*	16.72 (0.36-60.78)
2	*Cocconeis placentula euglypta*	12.55 (0.00-56.02)
3	*Melosira varians*	8.24 (0.00-54.43)
4	*Nitzschia palea*	4.44 (0.37-12.38)
5	*Navicula exigua capitata*	3.91 (0.00-14.26)
6	*Cocconeis placentula*	3.71 (0.00-18.55)
7	*Achnanthes lanceolata*	3.67 (0.00-34.55)
8	*Melosira italica tennuissima*	2.92 (0.00-12.35)
9	*Diatoma vulgare*	2.87 (0.00-66.60)
10	*Cyclotella stelligera*	2.85 (0.00-14.38)
11	*Cyclotella atomus*	2.74 (0.00-15.30)
12	*Achnanthes lanceolata rostrata*	2.31 (0.00-12.05)
13	*Gomphonema angustatum producta*	2.07 (0.00-29.55)
14	*Melosira italica*	1.56 (0.00-19.93)
15	*Synedra ulna oxyrhynchus*	1.54 (0.00-14.31)
16	*Nitzschia linearis*	1.40 (0.00-10.05)
17	*Navicula viridula*	1.24 (0.00-9.37)
18	*Navicula hungarica captitata*	1.19 (0.00-7.32)

Table 6. Common phycoperiphyton taxa in the Black River ranked according to their frequency of occurrence (%). The data are based on samples from all stations during 10 April through 20 November 1976.

RANK	TAXON	FREQUENCY OF OCCURRENCE (%)
1	*Navicula cryptocephala*	100.0
	Nitzschia palea	100.0
3	*Cocconeis placentula*	99.0
	Navicula exigua capitata	99.0
5	*Achnanthes lanceolata rostrata*	98.0
	Cocconeis placentula euglypta	98.0
	Melosira varians	98.0
8	*Achnanthes lanceolata*	96.9
	Cyclotella stelligera	96.9
	Navicula hungarica capitata	96.9
11	*Melosira italica*	95.9
	Nitzschia linearis	95.9
13	*Cyclotella meneghiniana*	93.9
	Gomphonema angustatum producta	93.9
	Synedra ulna	93.9
16	*Amphora ovalis*	89.8
17	*Surirella tenera*	84.7
18	*Gyrosigma Kutzingii*	81.6
	Navicula viridula	81.6
20	*Opephora martyii*	80.6
21	*Achnanthes detha*	78.6
	Nitzschia amphibia	78.6
23	*Epithemia turgida*	76.5
	Stauroneis crucicula	76.5
25	*Cyclotella atomus*	74.5
26	*Rhiocophenia curvata*	73.5
27	*Melosira italica tennuissima*	72.4
28	*Achnanthes delicatula*	71.4
	Cymatopleura solea	71.4
	Cymbella tumida	71.4
	Scenedesmus quadricauda	71.4
32	*Navicula cuspidata*	69.4
33	*Navicula pupula*	68.4
34	*Navicula Bremeyeri*	67.3
35	*Cocconeis pediculus*	66.3
36	*Diatoma vulgare*	63.3
37	*Fragilaria pinnata*	62.2
38	*Synedra rumpens*	61.2
39	*Gomphonema angustatum*	60.2
40	*Fragilaria construens*	58.2
	Fragilaria leptostauron rhomboides	58.2

Table 6. (cont.)

RANK	TAXON	FREQUENCY OF OCCURRENCE (%)
40	*Navicula hungarica*	58.2
43	*Navicula tripunctata*	56.1
44	*Cymbella ventricosa*	55.1
	Tabellaria fenestrata	55.1
46	*Cymbella naviculiformis*	54.1
	Surirella ovata	54.1
48	*Achnanthes exigua heterovalvata*	53.1
	Caloneis lewisii	53.1
	Surirella angustatum	53.1
51	*Navicula elginensis*	52.0
52	*Eunotia lunaris*	51.0

Table 7. Common[a] phycoperiphyton taxa at each station in the Black River ranked according to their mean relative density (%). The data are based on samples from all stations during 10 April through 20 November 1976.

TAXON	1-N	1-S	2-N	2-S	3-N	3-S	4-N	4-S
Cyclotella atomus	-	12	7	9	-	10	10	11
Cyclotella stelligera	11	7	8	8	9	5	9	8
Melosira italica	16	18	12	16	14	9	12	16
Melosira italica tennuissima	-	15	15	10	-	11	13	12
Melosira varians	3	2	3	3	3	2	3	3
Achnanthes lanceolata	7	5	4	4	5	8	4	6
Achnanthes lanceolata rostrata	15	10	11	11	12	13	11	13
Cocconeis placentula	6	8	10	5	4	12	5	5
Cocconeis placentula euglypta	1	3	2	1	1	3	1	1
Diatoma vulgare	8	9	14	13	8	4	8	4
Gomphonema angustata producta	10	11	9	-	10	-	-	15
Navicula cryptocephala	2	1	1	2	2	1	2	2
Navicula exigua capitata	4	6	6	7	7	6	6	9
Navicula hungarica capitata	14	14	16	17	15	-	-	14
Navicula viridula	13	12	13	14	-	14	15	-
Nitzschia linearis	9	17	17	12	13	16	16	-
Nitzschia palea	5	4	5	6	6	7	7	7
Synedra ulna oxyrhynchus	12	16	18	15	11	15	14	10

[a] Common refers to all taxa of mean relative density ≥ 1%.

both shaded stations as well as at station 2-N. It ranked second at all stations where *Cocconeis placentula euglypta* ranked first. *Melosira varians* generally ranked third in relative density. *Achnanthes lanceolata* ranked fourth at three stations (2-N, 2-S, 4-N) and was fifth through eighth at the rest. *Nitzschia palea* ranged from fourth to seventh, while *Navicula exigua capitata* ranked from fourth to ninth. *Diatoma vulgare* provided the greatest variation ranking fourth to fourteenth. Fifteen to eighteen taxa having a relative density $\geq$ 1% occurred at each station; of those, twelve were commonly present at each of the eight stations.

Common taxa were also ranked for each sampling period to depict seasonal changes (Table 8). This ranking contained sixteen genera including four from the class Chlorophyceae. However, none of the green algae ranked higher than tenth during the study. Thirty-seven taxa were ranked during the study, and nine to fifteen common taxa were found each period. *Melosira varians* and *Nitzschia palea* were the only taxa common enough to be ranked each sampling period. Excluding the initial period *Navicula cryptocephala* and *Navicula exigua capitata* were also ranked each period. Overall, *Navicula* was the most conspicuous genus and was represented by seven species and varieties. *Gomphonema* and *Synedra* followed with four taxa each. *Achnanthes, Melosira, Nitzschia,* and *Cyclotella* each had three taxa. Two varieties of *Cocconeis* were included, whereas *Cymbella, Diatoma, Eunotia,* and *Surirella* were all represented by one species. *Pediastrum duplex* (Chlorophyceae) was the most commonly ranked non-diatom taxon. Other Chlorophyceae taxa included *Cladophora* sp., *Stigeoclonium* sp., and *Ulothrix* sp.

In addition to relative density, the density (cells/m^2) was calculated. Range and mean values at each station are found in Table 9 and Fig. 5. Density was lowest at the

Table 8. Common phycoperiphyton taxa ranked according to mean relative density (%) during each sampling period in the Black River. The data are based on samples from all stations during 10 April through 20 November 1976.

TAXON	10A-19M	19-2J	2-16J	16-30J	30-14J	14-28J	28-11A	11-25A	25-8S	8-22S	22-12O	12-2N	2-20N
Cyclotella atomus	-	-	5	6	11	4	4	7	11	16	-	-	-
Cyclotella meneghiniana	-	-	-	10	-	-	-	-	-	-	-	-	-
Cyclotella stelligera	-	-	7	5	10	9	7	4	6	7	9	-	-
Melosira italica	-	11	13	9	4	11	10	9	-	12	-	-	-
Melosira italica tennuissima	-	-	-	-	9	5	8	8	9	11	-	-	-
Melosira varians	15	10	1	1	5	7	12	13	10	9	2	2	3
Achnanthes lanceolata	1	1	2	7	6	9	9	10	8	8	11	-	-
Achnanthes lanceolata rostrata	8	2	6	-	12	13	11	14	-	13	-	-	-
Achnanthes lanceolata ventricosa	9	6	14	-	-	-	-	-	-	-	-	-	-
Cocconeis placentula	-	13	12	-	3	3	3	3	4	6	-	-	8
Cocconeis placentula euglypta	-	14	3	8	1	1	1	1	1	1	6	-	-
Cymbella tumida	-	-	-	-	-	-	-	-	-	-	8	7	-
Diatoma vulgare	-	-	-	-	-	-	-	-	-	-	-	4	1
Eunotia lunaris	12	-	-	-	-	-	-	-	-	-	-	-	-
Gomphonema angustata	7	-	-	-	-	-	-	-	-	-	-	-	-
Gomphonema angustata producta	2	5	8	-	-	-	-	-	-	-	-	-	-
Gomphonema olivaceum	14	-	-	-	-	-	-	-	-	-	-	-	-

Table 8. (cont.)

TAXON	10A-19M	19-2J	2-16J	16-30J	30-14J	14-28J	28-11A	11-25A	25-8S	8-22S	22-12O	12-2N	2-20N
Gomphonema parvulum	6	-	-	-	-	-	-	-	-	-	-	-	-
Navicula cryptocephala	-	4	4	2	2	2	2	2	2	2	1	1	2
Navicula elginensis	-	-	-	-	-	14	-	-	-	-	-	-	-
Navicula exigua capitata	-	9	10	4	7	6	6	6	3	3	7	8	6
Navicula hungarica	-	7	-	-	-	-	-	-	-	-	-	-	-
Navicula hungarica capitata	-	8	15	11	-	-	-	-	-	14	12	-	-
Navicula Rotaeana	13	-	-	-	-	-	-	-	-	-	-	-	-
Navicula viridula	-	-	-	-	-	-	-	11	7	5	5	-	7
Nitzschia amphibia	-	-	-	-	-	-	-	-	13	15	13	-	9
Nitzschia linearis	-	-	-	-	-	-	-	-	-	9	4	6	-
Nitzschia palea	5	3	9	3	8	8	5	5	5	4	3	5	5
Surirella ovata	-	15	-	-	-	-	-	-	-	-	-	-	-
Synedra rumpens	11	-	-	-	-	-	-	-	-	-	-	-	-
Synedra rumpens familiaris	3	-	-	-	-	-	-	-	-	-	-	-	-
Synedra ulna oxyrhynchus	-	-	-	-	-	-	-	-	-	-	10	3	4
Synedra vaucheriae capitellata	4	-	-	-	-	-	-	-	-	-	-	-	-
Cladophora sp.	-	-	-	-	13	12	-	-	-	-	-	-	-
Pediastrum duplex	-	-	11	-	13	-	12	12	12	-	-	-	-
Stigeoclonium sp.	-	-	-	-	-	-	-	-	14	-	-	-	-
Ulothrix sp.	10	-	-	-	-	-	-	-	-	-	-	-	-

Table 9. Mean and range values for density of phycoperiphyton at each station in the Black River, 10 April through 20 November 1976.

STATION	DENSITY (cells/m^2 X 10^9)
1-N	2.6125 (0.8030-4.5627)
1-S	1.7223 (0.7247-4.6916)
2-N	2.1215 (0.6273-3.3511)
2-S	2.6739 (0.3953-4.6658)
3-N	2.9035 (0.5575-5.1900)
3-S	1.6978 (0.7332-4.0643)
4-N	3.0532 (0.8608-4.7604)
4-S	2.3973 (0.4965-5.9118)

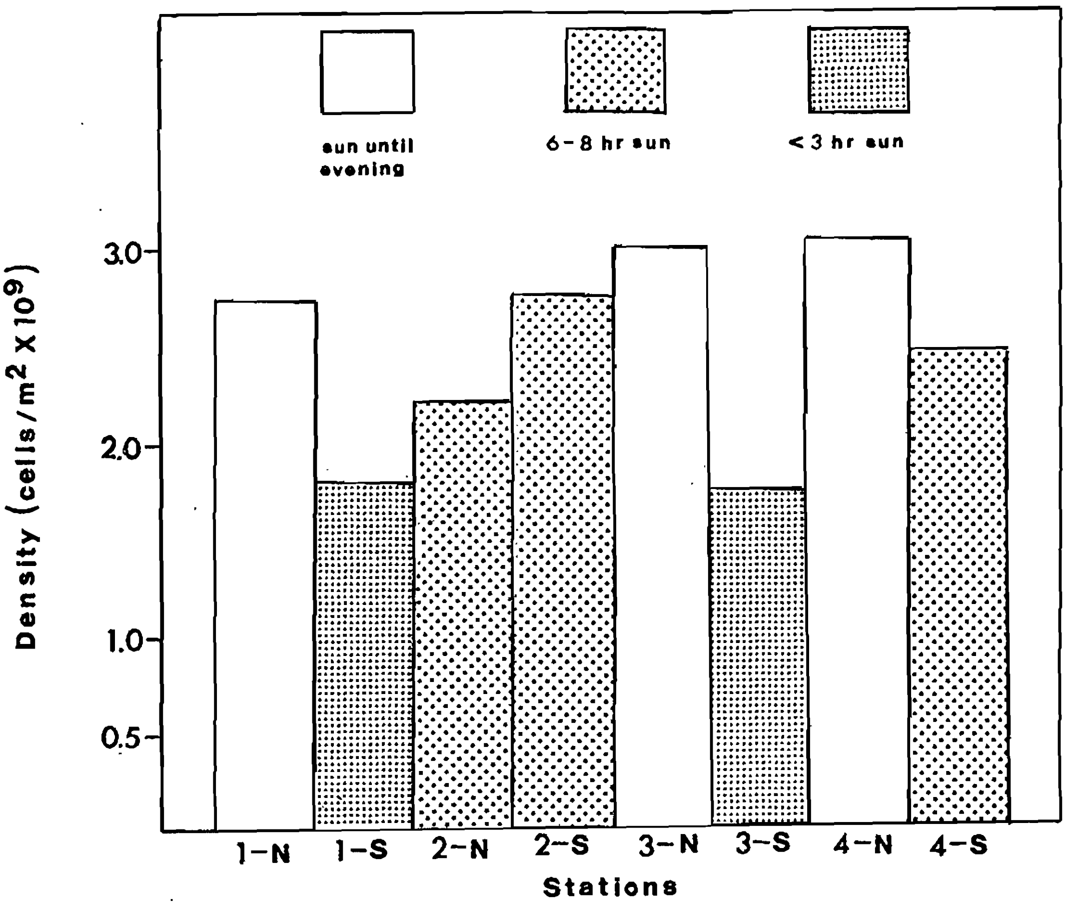

Fig. 5. The mean density of phycoperiphyton with respect to direct daily sunlight at each sampling station in the Black River, 10 April through 20 November 1976.

heavily shaded stations, i.e. 3-S produced an average 1.6978 cells/m^2 X10^9 and 1-S had 1.7223 cells/m^2 X10^9. This contrasted with 4-N (no shade) at 3.0532 cells/m^2 X10^9 and 3-N (shaded only in the evening) 2.9035 cells/m^2 X10^9. The other four stations ranged between 2.1215 cells/m^2 X10^9 and 2.6739 cells/m^2 X10^9. Direct daily sunlight affected the density at each station and was categorized into three groups: those exposed to direct sunlight at least until early evening (1-N, 3-N, 4-N), those exposed to 6 to 8 hr of direct sunlight (2-N, 2-S, 4-S), and those exposed less than 3 hr of direct sunlight (1-S and 3-S). The "Student's" t-distribution was used to test the significance of direct sunlight. The density of algae at those stations receiving direct sunlight at least until evening had significantly greater densities than those at stations which received 6 to 8 hr of direct sunlight (P=0.078). Similarly, the densities at stations with 6 to 8 hr of direct sunlight had significantly greater densities than those receiving less than 3 hr of direct sunlight (P=0.012). Moreover, the densities at stations with direct sunlight until evening showed the most significant differences in densities than those at stations receiving less than 3 hr of daily direct sunlight (P=<0.001).

Seasonal Distribution

Sampling began during April when the high water resulting from the spring thaw began to subside. Low densities were found during the spring sampling periods (8.782 cells/m^2 X10^8, 10 April through 19 May; 8.795 cells/m^2 X10^8, 19 May through 2 June). The low densities were likely resultant of the still high spring discharge which produced a scouring effect on the glass substrate. The greatest densities occurred during September and October when 3.4723 cells/m^2 X10^9 were reached, 22 September through 12 October, followed by 3.2778 cells/m^2 X10^9 during 12 October through 2 November. A spring maximum of 3.3404 cells/m^2 X10^9 was noted during the period 2 through 16 June. Throughout July and August densities ranged from 2.0629 cells/m^2 X10^9 to 3.0725 cells/m^2 X10^9. The lowest density (7.026 cells/m^2 X10^8) was found during the final sampling period (Table 10 and Fig. 6).

Taxonomically, five species reached dominance during the study. Early in the season *Achnanthes lanceolata* was the dominant species (Fig. 7). Its highest relative density was observed during the period 19 May through 2 June when it accounted for 21.00% of the total community. It remained a common taxon until 12 October when it comprised <1% of the total community. During its dominance, other common taxa included *Gomphonema angustatum producta, Achnanthes lanceolata rostrata, Nitzschia palea, Navicula cryptocephala* and *Achnanthes lanceolata ventricosa* (in order of decreasing relative density). Peak density of *Achnanthes lanceolata* (4.274 cells/m^2 X10^8) occurred after *Melosira varians* became dominant (Fig. 8).

Melosira varians dominated the community by mid-June (Fig. 7). It attained a peak relative density of 34.14% during the period 16 through 30 June. This was the only species that also exhibited a fall peak, reaching a value of 13.17% during the final sampling period. It remained a common taxon during each sampling period. Its relative density fell to approximately 1.50% during August and September. Peak density during 16 through 30 June was 8.237 cells/m^2 X10^8. A fall peak of 3.998 cells/m^2 X10^8 was observed during 12 October through 2 November (Fig. 8). Other common taxa occurring while *Melosira varians* was dominant were *Navicula cryptocephala, Cocconeis placentula euglypta, Achnanthes lanceolata, Nitzschia palea* and *Navicula exigua capitata*.

July, August, and much of September were dominated by *Cocconeis placentula euglypta* (Fig. 7). During that time

Table 10. Seasonal distribution of phycoperiphyton in the Black River. The data are expressed as mean and range values for densities including all stations, 10 April through 20 November 1976.

PERIOD	DENSITY (cells/m^2 X10^9)
10 April - 19 May	0.8782 (0.4965-1.1128)
19 May - 2 June	0.8795 (0.5146-1.2840)
2 - 16 June	3.3404 (2.2814-5.9118)
16 - 30 June	2.7150 (1.7667-4.2705)
30 June - 14 July	2.3100 (1.6383-4.5198)
14 - 28 July	2.3876 (0.7332-5.1900)
28 July - 11 August	3.0725 (1.8285-4.7604)
11 - 25 August	2.0629 (0.8679-3.5173)
25 August - 8 September	2.9099 (1.2742-4.5627)
8 - 22 September	2.2192 (1.5037-3.5075)
22 September - 12 October	3.4723 (1.7563-4.6658)
12 October - 2 November	3.2778 (1.5467-4.9924)
2 - 20 November	0.7026 (0.3953-0.8954)

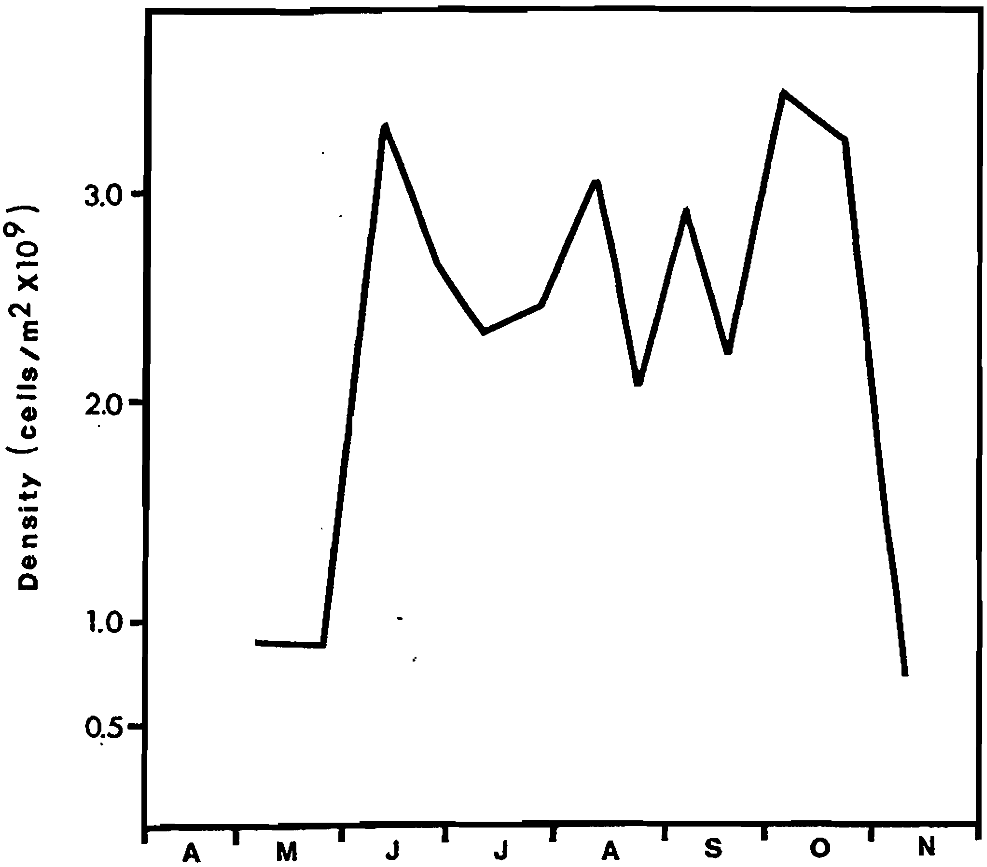

Fig. 6. Seasonal mean density of phycoperiphyton in the Black River, 10 April through 20 November 1976.

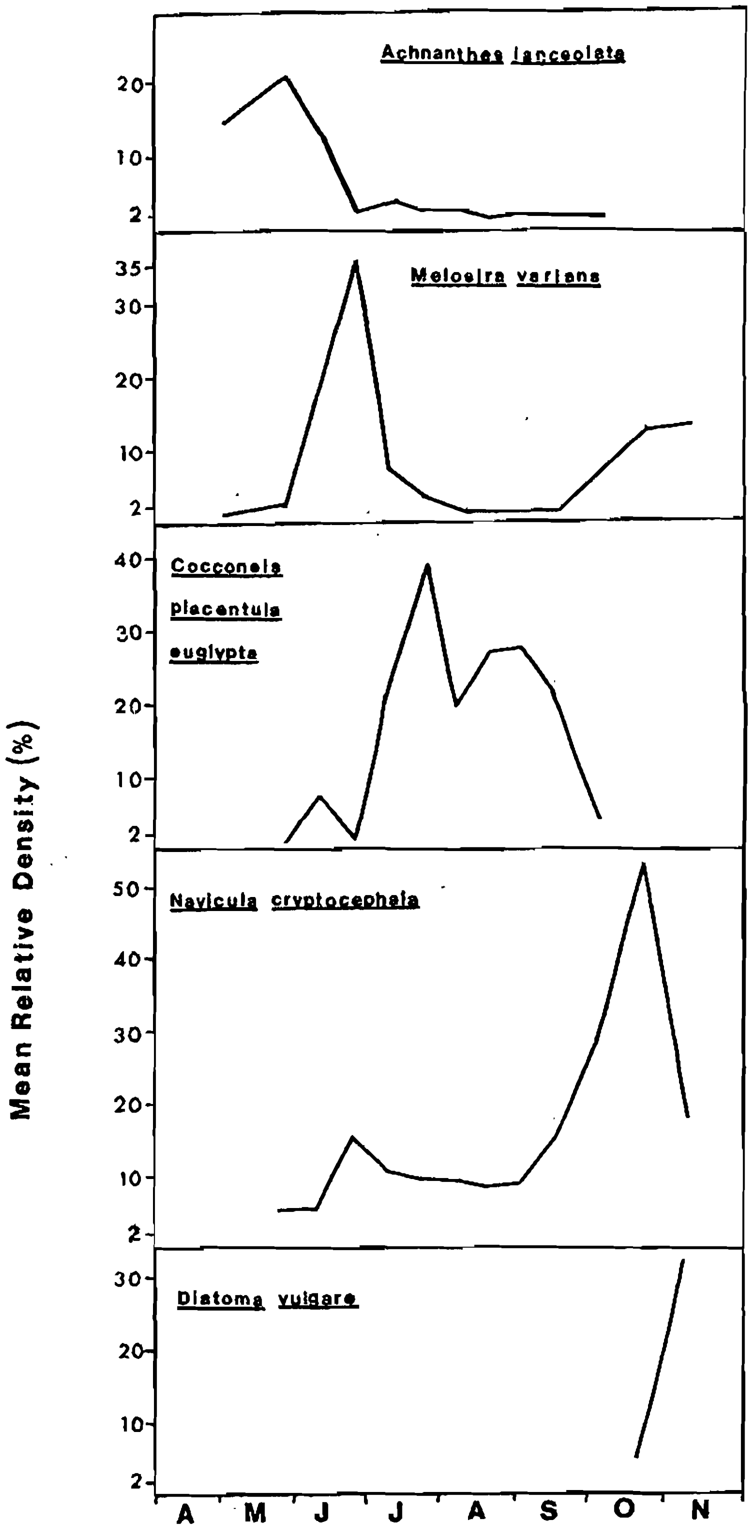

Fig. 7. Seasonal mean relative density of the five dominant phycoperiphyton taxa in the Black River, 10 April through 20 November 1976.

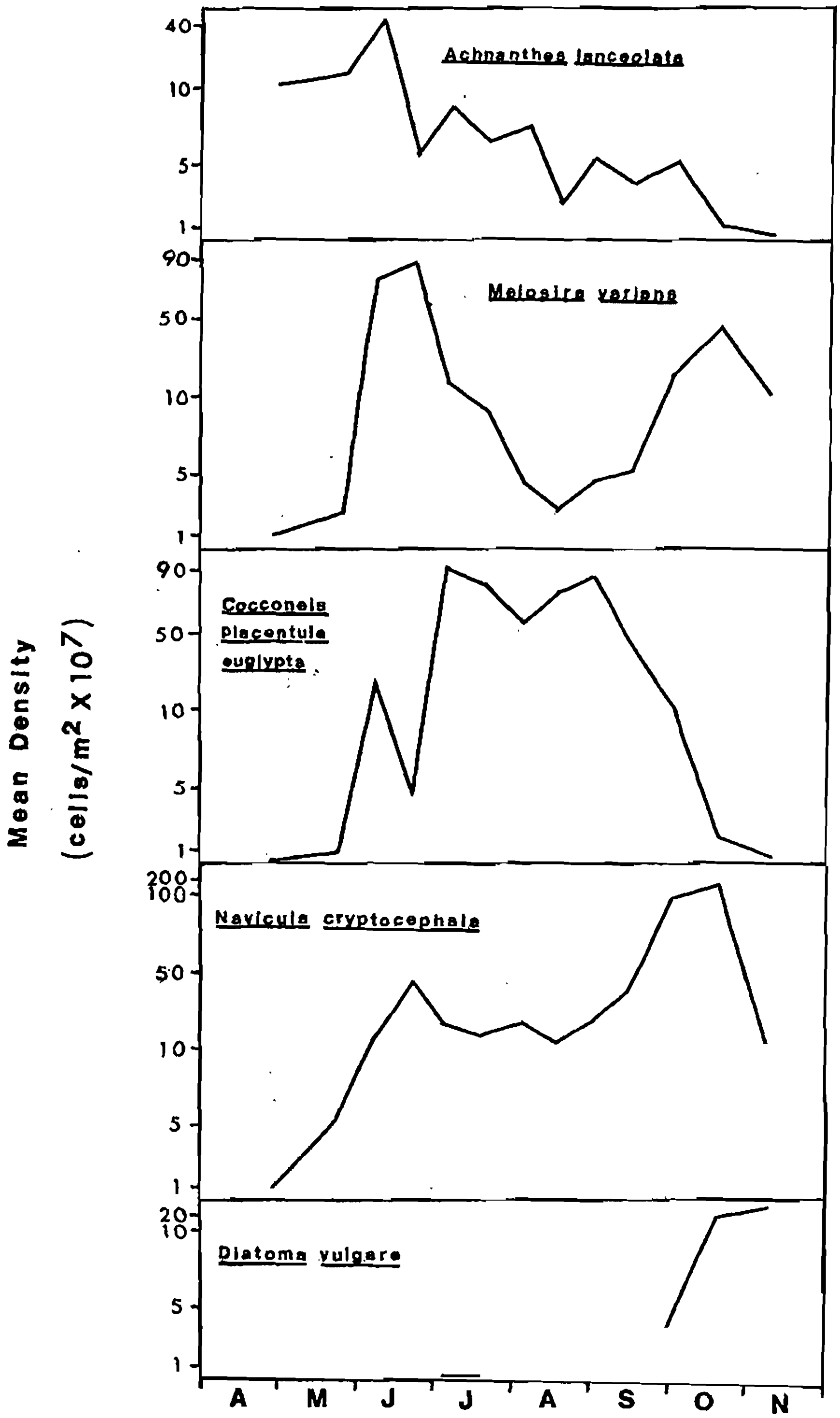

Fig. 8. Seasonal mean density of the five dominant phycoperiphyton taxa in the Black River, 10 April through 20 November 1976.

this taxon ranged in relative density from 19.41% to a high of 39.53% (14 through 28 July). *Achnanthes lanceolata* and *Melosira varians* were found in rather uniform relative densities while they were dominant; however, *Cocconeis placentula euglypta* was conspicuously reduced at the stations where significant shading occurred, i.e., stations 1-S and 3-S. A peak density of 9.178 cells/m^2 X10^8 was noted during the sampling period of 14 through 28 July (Fig. 8). *Navicula cryptocephala, Cocconeis placentula, Navicula exigua capitata, Nitzschia palea,* and *Cyclotella stelligera* were also common throughout the summer months.

A shift in dominance to *Navicula cryptocephala* occurred during the autumn (Fig. 7). This species was found only as a trace during the extended first period (10 April through 19 May), but comprised at least 5.24% of the phycoperiphyton community throughout the remainder of the study. It attained its peak relative density of 53.27%, during the period of 12 October through 2 November. At the same time it reached a peak density of 1.7617 cells/m^2 X10^9 (Fig. 8). *Navicula cryptocephala* was the only taxon to yield a density greater than 10^9 cells/m^2 during any sampling period. Taxa also common at this time were *Melosira varians, Synedra ulna oxyrhynchus, Nitzschia palea, Nitzschia linearia,* and *Diatoma vulgare.*

Throughout much of the study *Diatoma vulgare* appeared only in small numbers; however, near the end of the study, it was the dominant alga (Fig. 7). During the final sampling period it comprised 32.30% of the total community which was nearly twice that of the next species, *Navicula cryptocephala* (18.03%). Its relative density at station 3-S during the final period was 66.60%. This was the greatest dominance exhibited by any taxon during this study. A density of 2.361 cells/m^2 X10^8 was recorded at that time. Other common taxa during that time included *Melosira* *varians, Synedra ulna oxyrhynchus, Nitzschia palea,* and *Navicula exigua capitata.* The relative density of common taxa at each of the eight stations is provided in Appendix Tables 23 through 30, and the mean relative density during each sampling period appear in Appendix Tables 31 through 43.

Abundance-Occurrence Index

This index is calculated as the product of the mean relative density and frequency of occurrence of any taxon. It gives an indication of the commonness of a taxon and it is directly related to the probability of finding a taxon in any sample. The theoretical maximal value is 10,000. This index was calculated for all taxa comprising $\geq$ 1% of the total community. Ranking was identical to the frequency of occurrence for the first seven taxa (Table 11). The final eleven taxa, however, changed in rank with the notable exceptions of *Cyclotella atomus, Melosira italica* and *Navicula viridula.*

Diversity

Diversity indices were calculated for each phycoperiphyton sample. Both spatial (station to station) and seasonal mean diversities were determined using the index of Shannon-Weaver (1963). The machine formula presented by Lloyd, Zar, and Karr (1968) of this index was used to calculate mean diversity and is expressed as

$$\overline{d} = \frac{C}{N} (N \log_{10} N - \Sigma n_i \log_{10} n_i)$$

where C = 3.321928 (converts base 10 log to base 2)

N = total number of individuals

n_i = total number of individuals in the i^{th} species

A range from 3.45 (station 4-S) to 4.19 (station 1-S) occurred over the eight stations (Table 12). Shading appeared to have a marked influence on diversity. Stations 1-S and 3-S with less than 3 hr of direct sunlight daily

Table 11. Common phycoperiphyton taxa in the Black River ranked according to the abundance-occurrence index.

RANK	TAXON	A-O INDEX
1	*Navicula cryptocephala*	1672
2	*Cocconeis placentula euglypta*	1239
3	*Melosira varians*	808
4	*Nitzschia palea*	444
5	*Navicula exigua capitata*	387
6	*Cocconeis placentula*	367
7	*Achnanthes lanceolata*	356
8	*Cyclotella stelligera*	276
9	*Achnanthes lanceolata rostrata*	226
10	*Melosira italica tennuissima*	211
11	*Cyclotella atomus*	204
12	*Gomphonema angustatum producta*	194
13	*Diatoma vulgare*	182
14	*Melosira italica*	150
15	*Nitzschia linearis*	134
16	*Navicula hungarica capitata*	115
17	*Navicula viridula*	101
18	*Synedra ulna oxyrhynchus*	63

Table 12. Mean diversity and equitability at each station in the Black River, 19 May through 20 November 1976.

STATION	MEAN DIVERSITY	EQUITABILITY
1-N	3.85	0.38
1-S	4.19	0.46
2-N	3.91	0.37
2-S	3.75	0.34
3-N	3.75	0.36
3-S	3.91	0.38
4-N	3.51	0.28
4-S	3.45	0.30

had significantly greater indices than stations that received direct sunlight until the evening (P=0.014). Those stations which received less than 3 hr of direct sunlight also had significantly greater diversity indices than stations receiving 6 to 8 hr of direct sunlight daily (P=0.034). The initial sampling period produced inadequate data to be used in the diversity considerations from a spatial standpoint and was therefore omitted.

High mean diversity (>4.36) was observed during the early sampling periods, 10 April through 2 June. Seasonal changes in diversity were most significant in the fall (October and November) when the mean diversity was reduced from 3.93 during the months of July through mid-October to 2.95 for the remainder of the study (Table 13). The overall seasonal mean diversity was 3.89 (10 April through 20 November).

Equitability

Lloyd and Ghelardi proposed the term "equitability" to compare the observed mean diversity with the maximum possible diversity (EPA 1973). Equitability should range from 0 to 1 except in unusual situations. In the Black River this index ranged from 0.28 (4-N) to 0.46 (1-S) with respect to a spatial distribution (Table 12). An overall mean of 0.36 was found. Seasonal changes ranged from 0.19 (12 October through 2 November) to 0.55 (19 May through 2 June) and an overall mean of 0.38 was recorded (Table 13).

Biomass and Pigment Analyses

Biomass

Means and ranges of dry weight and ash-free dry weight determinations for each station are presented in Table 14. Seasonal dry weight ranged from 75.333 g/m^2 (28 July through 11 August) to 0.240 g/m^2 (2 through 20 November). The dry weight ranged from 10.905 g/m^2 (1-N) to 22.909 g/m^2 (4-N) with respect to spatial distribution. The greatest dry weight occurred where current velocities

Table 13. Seasonal mean diversity and equitability of phycoperiphyton in the Black River, 10 April through 20 November 1976.

PERIOD	MEAN DIVERSITY	EQUITABILITY
10 April - 19 May	4.86	0.54
19 May - 2 June	4.36	0.55
2 - 16 June	3.82	0.38
16 - 30 June	3.65	0.30
30 June - 14 July	3.88	0.36
14 - 28 July	4.04	0.40
28 July - 11 August	4.30	0.45
11 - 25 August	3.81	0.33
25 August - 8 September	3.83	0.33
8 - 22 September	3.99	0.39
22 September - 12 October	4.09	0.40
12 October - 2 November	2.71	0.19
2 - 20 November	3.18	0.33

Table 14. Mean and range values for concentrations of phycoperiphyton dry weight, ash-free dry weight, and chlorophyll *a* in the Black River at each station during 10 April through 20 November 1976.

STATION	DRY WEIGHT (g/m^2)	ASH-FREE WEIGHT (g/m^2)	CHLOROPHYLL *a* (g/m^2)
1-N	10.905 (0.293-40.213)	9.475 (0.267-38.289)	0.011 (0.001-0.022)
1-S	12.757 (1.413-32.506)	11.286 (1.200-29.627)	0.005 (0.003-0.011)
2-N	11.257 (0.640-27.653)	9.156 (0.587-23.191)	0.008 (0.002-0.018)
2-S	11.640 (1.013-31.200)	9.873 (0.907-28.667)	0.009 (0.002-0.021)
3-N	15.689 (0.960-46.747)	12.101 (0.924-32.196)	0.012 (0.001-0.022)
3-S	22.255 (0.480-54.880)	15.776 (0.338-47.707)	0.004 (0.001-0.009)
4-N	22.909 (0.827-72.160)	17.806 (0.747-51.397)	0.011 (0.002-0.021)
4-S	22.717 (0.240-75.333)	18.178 (0.204-63.858)	0.011 (0.001-0.025)

were also highest viz. stations 4-N, 4-S, 3-S, and 3-N.

Ash-free dry weight ranged from 0.204 g/m^2 to 63.858 g/m^2 (both extremes occurred at 4-S). Between stations, ash-free dry weight varied from 9.156 g/m^2 (2-N) to 18.178 g/m^2 (4-S). The overall ash-free dry weight was 12.956 g/m^2 with respect to a spatial distribution. Stations 4-S, 4-N, 3-S, and 3-N ranked first through fourth, respectively, with regard to ash-free dry weight. Similarly, high current velocities were also recorded at those stations. Stations 1-N and 2-S exhibited the lowest current velocities and ranked sixth (2-S) and eight (1-N) with respect to dry weight, and sixth (2-S) and seventh (1-N) for ash-free dry weight. Simple correlations indicated that during part of the summer current velocity was perhaps the most significant factor affecting biomass (P=0.024); however, during spring and autumn other factors (e.g. direct sunlight and temperature) appeared to also greatly influence the accumulation of biomass.

<u>Pigment Analyses</u>

Means and ranges for chlorophyll *a* concentrations are presented in Table 14. The quantities of chlorophyll *a* produced appeared to be directly related to the amount of direct sunlight at each station. The concentration of chlorophyll *a* at stations which received direct sunlight until evening had greater concentrations than those at stations receiving 6 to 8 hr of direct sunlight (P=0.015). The concentrations at stations which received 6 to 8 hr of direct sunlight were significantly greater than those at stations receiving less than 3 hr of direct sunlight (P=0.004). Furthermore, chlorophyll *a* concentrations at stations with direct sunlight until evening had significantly greater concentrations than stations which received less than 3 hr of direct sunlight (P=0.003). The greatest chlorophyll *a* concentration was observed at 3-N (0.012 g/m^2). This was only slightly greater than stations

1-N, 4-N, and 4-S (0.011 g/m^2). The higher concentrations at 3-N might have been the result of high nutrient levels and current velocities at this site.

Chlorophyll *a* ranged from a high of 0.025 g/m^2 (11 through 25 August, 4-S) to a low of 0.001 g/m^2 (2 through 20 November, several stations). During the final sampling period, daylight was reduced to approximately ten hours.

Seasonal changes in chlorophyll *a* are presented in Table 15. Concentrations ranged from 0.006 g/m^2 to 0.010 g/m^2 during the spring and summer. During the early autumn months chlorophyll *a* increased to 0.015 g/m^2 and to 0.016 g/m^2 through the end of October. This coincided with the trees loosing their leaves; hence, the shaded stations became exposed to additional direct sunlight. A significant reduction in chlorophyll *a* was found during the last sampling period when ice cover began. The overall concentration for all samples was 0.009 g/m^2.

<u>Chlorophyll *a* / Pheophyton *a*</u>

Mean and range values for chlorophyll *a* before:after ratios at each station are given in Table 16. The highest ratio (1.600) was found at 3-N. Some individual samples indicated values as high as 1.671 and ≥ 1.600 was commonly found throughout the study at various stations. Fig. 9 depicts the seasonal changes in the before:after ratios. Slight decreases occurred as the summer progressed. The ratio fell below 1.500 only during the sampling period 25 August through 8 September.

<u>Autotrophic Index</u>

The biomass (ash-free dry weight) to chlorophyll *a* ratio or autotrophic index was determined for each sample. Mean values for each sampling period are given in Appendix Table 44. The indices appeared abnormally high (>800); however, this can be attributed to the accumulation of tricopteran larval cases on the samplers. The index showed

Table 15. Seasonal means and ranges for concentrations of chlorophyll *a* in the Black River, 10 April through 20 November 1976.

PERIOD	CHLOROPHYLL *a* (g/m^2)
10 April - 19 May	0.008 (0.005-0.015)
19 May - 2 June	0.007 (0.005-0.009)
2 - 16 June	0.010 (0.004-0.022)
16 - 30 June	0.008 (0.004-0.012)
30 June - 14 July	0.010 (0.002-0.022)
14 - 28 July	0.008 (0.003-0.020)
28 July - 11 August	0.009 (0.004-0.016)
11 - 25 August	0.010 (0.002-0.025)
25 August - 8 September	0.006 (0.001-0.014)
8 - 22 September	0.008 (0.003-0.013)
22 September - 12 October	0.015 (0.003-0.021)
12 October - 2 November	0.016 (0.004-0.021)
2 - 20 November	0.002 (0.001-0.004)

Table 16. Means and ranges for chlorophyll *a* / pheophytin *a* ratios at each station in the Black River during 10 April through 20 November 1976.

STATION	RATIO
1-N	1.577 (1.521-1.651)
1-S	1.544 (1.418-1.671)
2-N	1.564 (1.488-1.648)
2-S	1.540 (1.469-1.634)
3-N	1.600 (1.506-1.634)
3-S	1.522 (1.345-1.671)
4-N	1.556 (1.429-1.627)
4-S	1.549 (1.417-1.634)

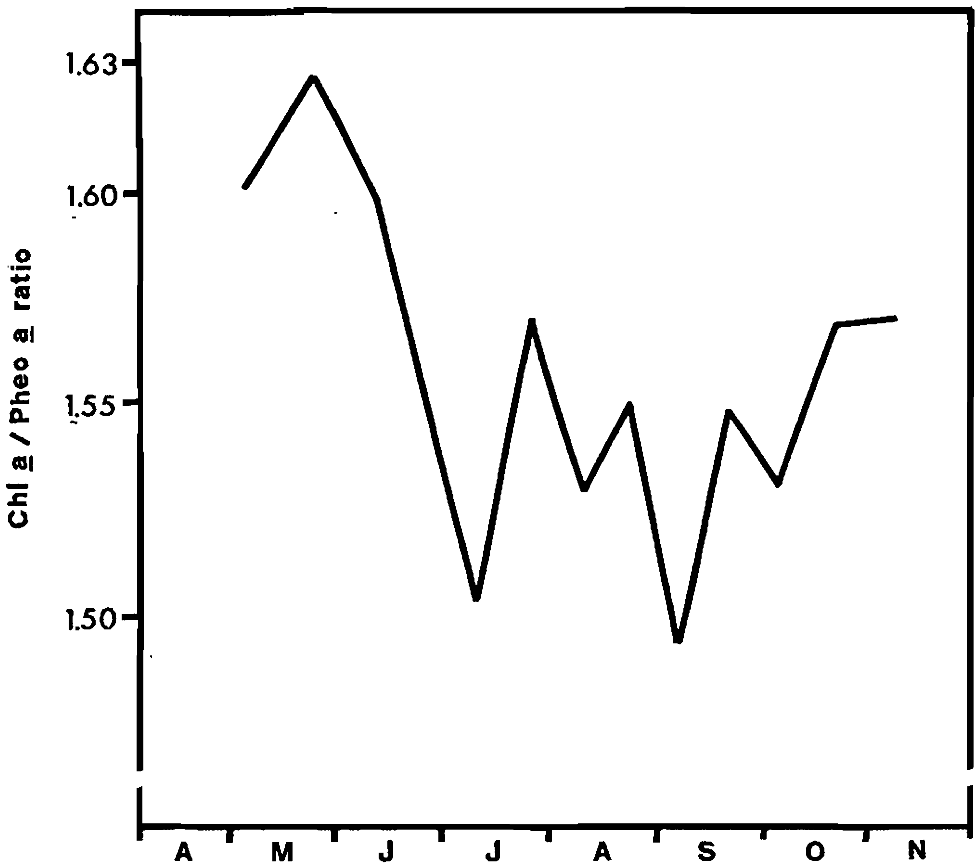

Fig. 9. Seasonal mean chlorophyll *a* / pheophytin *a* ratios in the Black River, 10 April through 20 November 1976.

more favorable results in the latter periods (12 October through 20 November) when temperatures were lower and insect emergence concluded for the season.

DISCUSSION

Higher concentrations of nitrogen and phosphorous were found at site 3 as compared to the other upstream sites. Farm crops were found near the banks at various locations on the Trempealeau County side of the river. A few grazing areas occurred upstream of site 3, and in at least one area cattle were allowed to enter the river. It was this type of localized enrichment that appeared to have been accountable for the increased concentrations of nitrogen and phosphorous at site 3.

Alkalinity and hardness were also at higher levels at site 3. This increase was likely due to the emergance of groundwater. Overall, the Black River appeared to be a soft water system with low alkalinity and high dissolved oxygen. The river bed was predominantly sandy, but was occasionally rocky.

Five taxa attained dominance in the Black River phycoperiphyton community. In the early spring *Achnanthes lanceolata* was observed as the dominant species. Its dominance began in April and continued through mid-June. Whitford and Schumacher (1973) reported this species as being widespread in North Carolina during cool seasons as well as during warm seasons when found in shaded areas. They also stated that high light intensities inhibited the species. Early in the season at heavily shaded areas in the Black River (1-S and 3-S), *Achnanthes lanceolata* had a relative density of 13%. At stations with essentially no shade (1-N and 4-N) this species produced a relative density of about 18%. Therefore, Whitford and Schumacher's findings do not support the data on the Black River.

Melosira varians dominated the community during late June, reaching a peak of approximately 27%. Its relative density decreased about ten-fold during the rest of the summer. A fall peak about one-half that of the June peak was noted. Smith (1950) documented this genus as the most commonly encountered of all fresh-water Centrales. He further stated that *Melosira varians* may dominate during the early spring and late fall months. Similarly, a late spring and early fall dominance occurred in the Black River community. This species was also one of two principal species found during October and November on the Ohio River (Weber and Rascke 1970). In the Black River the distribution of this species appeared to be relatively unaffected by direct sunlight. Relative density of *Melosira varians* at well-shaded stations differed from unshaded stations by only 3%. During the period 2 June through 14 July relative density at 1-N and 4-N (no shade) was 24% while 1-S and 3-S (well-shaded) was 21% for this species.

Throughout the summer months (July through mid-September) *Cocconeis placentula euglypta* dominated the algal community. *Cocconeis placentula* was also a common taxon at this time. Massey (unpublished data) found this species and several varieties of it dominant in Pool 8 of the Mississippi River during midsummer. Weber and Raschke (1970) reported this species as dominant in the Klamath River, Oregon, during August. Direct sunlight appeared to be an important factor with respect to the distribution of this taxon. During the period 30 June through 22 September shading appeared to inhibit *Cocconeis placentula euglypta*. A relative density of about 37% was noted at stations 1-N and 4-N. During the same period the relative density at stations 1-S and 3-S yielded only about 18%.

Navicula cryptocephala was common throughout the study. significant relative densities were observed in May and continued throughout the summer. By mid-September it had reached a state of dominance that continued until the final sampling period when it was succeeded by *Diatoma vulgare*. A variety of *Navicula cryptocephala* was reported by Bahls (1971) as one of the dominant species in the Upper East Gallatin River, Montana. The variety Bahls identified attained a seasonal peak in summer followed by a downward trend in fall and winter. In this study, the species was found in all samples; Bahls also found the variety of *Navicula cryptocephala* in all his collections from natural substrates. Direct sunlight did not appear to significantly affect the relative density of this species. During the period from 8 September through 2 November stations 1-N and 4-N had a relative density of 29%; shaded stations 1-S and 3-S had 28%.

Diatoma vulgare appeared in only small amounts throughout most of the season; however, it became the dominant alga during the cooler autumn months. This taxon was reported by Blum (1957) in the Saline River, Michigan, as characteristic of the fall and winter diatom flora in unpolluted waters. Drum (1964) also found it most abundant during October and November in the Des Moines River, Iowa. Low relative densities were observed in the early sampling periods of this study, thus giving some indication that this species was present throughout the winter months. Apparently direct sunlight was not a significant factor affecting the distribution of this species.

Current velocity was another critical factor taken into consideration when locating the sampling stations. Under experimental stream conditions, McIntire (1966) demonstrated that areas with faster current velocities yielded greater quantities of biomass. Odum (1956) implied that the depleted life requirements needed by the algal flora were renewed and the accumulated by-products were removed by the water flowing over the organisms. Whitford (1960) stated that swift currents rapidly removed the somewhat impoverished water around a community and replenished it with fresh nutrient-rich water. Experiments conducted by Whitford and Schumacher (1961) demonstrated high rates of respiration and phosphorous uptake in species of *Oedogonium* and *Spirogyra* when exposed to currents of 0.15 m/sec as compared to still water. McIntire (1966) investigated the structure of two laboratory stream periphyton communities in which the currents were held at 0.09 m/sec and 0.39 m/sec. Accumulation of biomass on the substrate was much more rapid in faster currents. Distinct differences in biomass (ash-free dry weight) with respect to current velocity were also noted in the Black River. The algal communities found in the two slower current velocities yielded a biomass of 9.674 g/m^2, whereas those present in the faster current velocities produced 15.140 g/m^2; however, current velocity proved to be the primary influencing factor only during a portion of the summer. At different times of the year other factors (e.g. direct sunlight and temperature) also significantly influenced biomass accumulation. The accumulation of biomass, particularly throughout the summer and early autumn in the Black River, was also affected by the presence of tricopteran larval cases on the slides as well as on the samplers and anchor lines. Thus contributing significantly to the total biomass of the samples. Spring biomass measurements were lower and this was thought to be the result of a high discharge due to the spring thaw which tended to produce a scouring affect over the slides. Gumtow (1955) noted scouring action after flooding in May and June in the West Gallatin River, Montana.

McIntire (1966) found that species composition of the two laboratory stream periphyton communities were approximately the same but that the relative densities differed significantly. This was also observed in the Black River with *Achnanthes lanceolata* which had relative densities of 11% and 17% in the slowest and fastest current velocities, respectively. *Melosira varians* comprised a relative density of 17% in the slower currents and 22% in faster current velocities. A difference of 6% was found for *Cocconeis placentula euglypta* with 27% in slower currents and 33% in faster currents. The least amount of difference was found for *Navicula cryptocephala* which comprised 24% in the slower currents and 28% in faster currents. *Diatoma vulgare* was markedly affected with 11% in slower currents in contrast to 24% in faster current velocities.

This study revealed a community comprised of about 98% diatoms. Patrick and Hohn (1959) have found, as a result of many river surveys, that diatoms are one of the most reliable groups of organisms for indicating river conditions. Most nutrients used by diatoms are derived from the dissolved chemicals in the water. Hence, the association of algae in a water system is very useful for indicating the water quality of the system. The approach used in this study was to analyze the natural environment in terms of the community structure and changes in the species composition.

Patrick (1949) remarked that natural or healthy streams were represented by an algal flora high in numbers of species (with most species present in small populations). The effect of unnatural levels of chemicals in a system would reduce the species number, change the population size, and change the species composition. Thus a stream with a pollution load would result in a reduced diversity. The overall mean density in this study was about 3.80; and during all periods but two, a range of 3.65 to 4.86 was found. The diversities encountered in this study indicate a community under little stress from pollution. Based on data from a wide variety of polluted and clean-water streams, Wilhm and Dorris (1968) indicated that diversities well in excess of 3.0 were generally indicative of relatively clean water.

It has been noted that 98% of the phycoperiphyton community was diatoms. An average of 60 taxa per sampling period were observed. This figure is indicative of a diverse community with few representatives of polluted or stressed conditions.

In a review of 165 studies, Palmer (1969) listed 80 of the most pollution-tolerant species of algae. Included in his list were greens, blue-greens, diatoms, and flagellates. This listing is useful when organic pollution is present. Twenty-three species that appeared on Palmer's list were identified in the Black River; however, only six were significant (i.e., taxa comprising ≥ 1% of the total community). These species were (Palmer's rank in parenthesis) *Nitzschia palea* (2), *Melosira varians* (13), *Navicula cryptocephala* (17), *Diatoma vulgare* (40), *Navicula viridula* (49), and *Cocconeis placentula euglypta* (58). *Nitzschia palea* was a commonly occurring species; however, in the Black River it never attained a position of dominance and always appeared in rather uniform relative density. It was the only species of the first ten listed by Palmer that was found in the Black River. Similarly, *Navicula viridula* was present often enough to be considered one of the common taxa, but it never comprised a relative density ≤ 5.22%. The remaining four species on the list appeared in significant quantities; however that was due to seasonal changes in the environment and apparently was not related to organic pollution.

High autotrophic indices were observed in the Black River. This was attributed to the accumulation of tricopteran larval cases on the samplers and slides thus increasing the organic content of the periphyton. Bahl's (1971) investigation on the East Gallatin River, Montana, found autotrophic index values of 121 above a sewage discharge. Downstream 23.5 km the mean values was 132 which indicated a recovery from the waste. Weber and McFarland (1969) reported an index of 127 in a self-purified section of a stream receiving domestic waste in Ohio. Each investigation indicated a high autotrophic to heterotrophic production in the community. Weber (1973) reported that autotrophic indices fall in a range of 50 to 100 for periphyton communities in unpolluted waters.

The physiological condition of the algal flora can be estimated by comparing the before:after acidification ratios of chlorophyll *a* (Weber 1973). High before:after ratios were observed at all stations on the Black River at all times of the year, thus indicating an algal community in good physiological condition. The overall ratio in the Black River was 1.577. Samples with ratios approaching 1.7 are considered to be in excellent physiological condition (APHA 1975).

SUMMARY AND CONCLUSIONS

Phycoperiphyton was collected from artificial sampling apparatus at eight stations located on the Black River, Wisconsin. Exposure periods for the accumulation of phycoperiphyton were two weeks until the latter part of September when the exposure periods were extended to three weeks. The study included the open-water season beginning 10 April through 20 November 1976. Physical and chemical determinations were made on the same dates that the phycoperiphyton apparatus were collected. Water samples from each site were analyzed for pH, alkalinity, calcium and total hardness, dissolved oxygen, nitrate and nitrite nitrogen, and ortho-phosphorous. Measurements of temperature, depth and current velocity were also made at each station.

The river was found to be of low alkalinity and hardness. Seasonal changes in dissolved oxygen concentrations ranged from 6.8 mg/L to 10.3 mg/L. Seasonal changes in nitrate-nitrogen ranged from 0.069 mg/L NO_3-N to 0.210 mg/L NO_3-N. Nitrite-nitrogen ranged from <0.001 mg/L NO_2-N to 0.067 mg/L NO_2-N. Ortho-phosphorous concentrations ranged from 0.063 PO_4-P to 0.098 mg/L PO_4-P. Current velocity ranged from 0.01 m/sec to 0.30 m/sec at the eight stations.

A total of 56 genera and 205 species were identified which represented four class of algae. Twenty-nine of the 205 species were identified further to include 75 varieties. Diatoms dominated the community comprising about 98% of the total community. Five taxa dominated during the study, *Achnanthes lanceolata, Melosira varians, Cocconeis placentula euglypta, Navicula cryptocephala,* and *Diatoma vulgare*. Eighteen taxa were commonly encountered ($\geq$ 1%

relative density); fifty-two taxa occurred in at least 51% of the samples. The highest community density (5.9118 cells/m^2 X10^9) was observed during June.

A high diversity of taxa prevailed at all stations throughout the study giving an indication of a healthy natural community. Diversity became slightly reduced with the onset of cooler temperatures.

Dry and ash-free dry weights were greatest at stations with higher current velocities. Dry weight ranged from 10.905 g/m^2 to 22.909 g/m^2 with respect to spatial distribution. Ash-free dry weight ranged from 9.156 g/m^2 to 18.178 g/m^2. The presence of tricopteran larval cases added significantly to the biomass measurements until late in the study when emergence ceased for the season.

Seasonal variations in chlorophyll *a* ranged from 0.025 g/m^2 in the summer to 0.001 g/m^2 during November. Seasonally, chlorophyll *a* before:after acidification ratios were always high, indicating a community in good physiological condition. The analyses of the phycoperiphyton community, including taxonomic composition, density, relative density, biomass and pigments; and the analyses of several physical and chemical parameters indicates that the Black River is characteristic of a mesotrophic or slightly eutrophic waterway.

LITERATURE CITED

American Public Health Association. 1975. Standard methods for the examination of water and wastewater, 14th ed. APHA, New York.

Bahls, L.L. 1971. Ecology of the diatom community of the Upper East Gallatin River, Montana with *in situ* experiments on the effect of current velocity on features of the *Aufwuchs*. Ph.D. Disertation. Montana State University, Bozeman, Montana.

Barnes, H.H. 1959. Inorganic nitrogen-nitrate. pp. 113-125. *in* Apparatus and methods of oceanography. Interscience Publishers, Inc.

Beak, T.W., T.C. Griffing, and A.G. Appleby. 1973. Use of artifical substrate samplers to assess water pollution. pages 227-241. *in* Biological methods for the assessment of water quality. ASTM STP, American Society for Testing and Materials.

Blum, J.L. 1957. An ecological study of the algae of the Saline River, Michigan. Hydrobiol. 9:361-405.

Bourelly, P. 1968. Les algues d'eau diuce. Tome II les algues jaunes et brunes Chrysophycacées, Pheophyycées, Xanthophycées et Diatomées. Boubee and Cie, Paris.

Cleve-Eular, A. 1955. Die diatomeen von Schweden und Finnland, Vol. I-V, Almquist und Wiksells Boktryckeri, Stockholm.

Drum, R.W. 1964. Ecology of diatoms in the Des Moines River. Ph.D. Disertation. Iowa State University of Science and Technology, Ames, Iowa.

Gumtow, R.B. 1955. An investigation of the periphyton in a riffle of the West Gallatin River, Montana. Trans. Am. Microsc. Soc. 74:278-292.

Hansmann, E.W. 1973. Diatoms of the streams of Eastern Connecticut. State Geological and Natural History Survey of Connecticut, Department of Environmental Protection, Bulletin 106.

Hohn, M.H. and J. Hellerman. 1963. The taxonomy and structure of diatom populations from three eastern North American Rivers using three sampling methods. Trans. Amer. Microscop. Soc. Vol. 82(250-329).

Huber-Pestalozzi, G., and F. Hustedt. 1942. Die Kieselalgen. *in* A. Thienemann, ed., Das Phytoplankton des Susswassers, Die Binnengewasser, Band XVI, Teil II, Halfe II. E. Schweizerbant'sche Verlagsbuch-Handlung, Stuttgart.

Hustedt, F. 1930a. Bacillariophyta. *in* A. Pascher, ed., Die Suswasser-Flora Mitteliuropas, Heft 10. Gustav Fischer, Jena.

Hustedt, F. 1930b. Die Kieselalgen. *in* L. Rabenhorst, ed., Kryptogamen-Flora von Deutschland, Osterreich, und der Schweiz. Band VII, Teil 1,2,3, Akademische Verlagsellschaft m.b.h., Leipzig.

Lloyd, M., J.H. Zar, and J.R. Karr. 1968. On the calculation of information-theoretical measures of diversity. Am. Mid. Nat. 79(2):257-272.

Longe, E.B., and G.D. Cooke. 1971. A quantitative comparison of pigment extractions by membrane and glass-fiber filters. Limnol. Oceanogr. 16(6):990-992.

McIntire, C.D. 1966. Some effects of current velocity on periphyton communities in laboratory streams. Hydrobiol. 27:559-570.

Odum, H.T. 1956. Primary production in flowing waters. Limnol. and Oceanogr. 1:102-117.

Palmer, C.M. 1969. A composite rating of algae tolerating organic pollution. J. Phycol. 5:78-82.

Palmer, C.M. and T.E. Maloney. 1954. A new counting slide for nanoplankton. Amer. Soc. Limnol. Oceanogr. Spec. Publ. N. 21, pp. 1-6.

Patrick, R. 1949. Proceedings, Academy of Natural Sciences of Philadelphia, Vol. 101, pp. 277-341.

Patrick, R. and M.H. Hohn. 1956. The diatometer-a method for indicating the condition of aquatic life. Proceedings, American Petroleum Institute, Section III, Refining, Vol. 36, no. 3, pp. 332-339.

Patrick, R. and C.M. Reimer. 1966. The diatoms of the United States. Vol. I. Monograph 13, Philadelphia Acad. Natur. Sci.

Prescott, G.W. 1962. Algae of the Western Great Lakes Area, 2nd ed. W.C. Brown, Dubuque, Iowa.

Shannon, C.E. and W. Weaver. 1963. The mathematical theory of communication. Urbana: University of Illinois Press.

Smith, G.M. 1950. The freshwater algae of the United States, 2nd ed. McGraw-Hill Book Co., New York.

Tiffany, L.H. and M.E. Britton. 1952. The algae of Illinois. University of Chicago Press, Chicago.

United States Department of Interior, Geological Survey, Water Resource Division, Madison, Wisconsin. Black River Basin. Water Year October 1975 to September 1976, and Water Year October to November 1976 (October-November 1976 is provisional data).

United States Environmental Protection Agency. 1973. Plankton. p. 13-20, and Periphyton. p. 1-6 *in* Biological field and laboratory methods for measuring the quality of surface waters and effluents. EPA-670/4-73-001. EPA, Cincinnati.

United States Environmental Protection Agency. 1974. Methods for chenical analysis of water and waste. EPA, Cincinnati.

Weber, C.I. 1971. A guide to the common diatoms at water pollution surveilance system stations. EPA, Cincinnati.

Weber, C.I. 1973. Recent developments in the measurement of the response of plankton and periphyton to changes in their environment. pages 119-138. *in* Glass, ed. Bioassay Techniques and Environmental Chemistry. Ann Arbor Science Publishers, Inc.

Weber, C.I. and B.H. McFarland. 1969. Periphyton biomass-chlorophyll ratio as an index of water quality. Presented at 17th Annual Meeting, Midwest Benthological Society, Gilbertsville, Ky., April, 1969.

Weber, C.I. and R.L. Raschke. 1970. Use of a floating periphyton sampler for water pollution surveilance. U.S.F.W.P.C.A., Cincinnati.

Whitford, L.A. 1960. The current effect and growth of fresh-water alga. Trans. Amer. Micr. Soc. 79:302-309.

Whitford, L.A. and G.J. Schumacher. 1961. Effect of current on mineral uptake and respiration by a freshwater alga. Limnol. Oceanogr. 6:423-425.

Whitford, L.A. and G.J. Schumacher. 1973. A manual of fresh-water algae. p. 111. Sparks Press, Raleigh, North Carolina.

Wilhm, J.L. and T.C. Dorris. 1968. Biological parameters of water quality. Bioscience 18:447-481.

APPENDIX

Table 17. Current velocities (m/sec) at each station for each sampling date in the Black River, 10 April through 20 November 1976.

DATE	1-N	1-S	2-N	2-S	3-N	3-S	4-N	4-S
10 April [a]	--	--	--	--	--	--	--	--
19 May [a]	--	--	--	--	--	--	--	--
2 June	0.03	0.19	--	--	0.39	0.26	0.27	0.48
16 June	0.01	0.08	0.17	0.06	0.04	0.12	0.03	0.32
30 June	t[b]	0.03	0.27	t	0.34	0.36	0.42	0.47
14 July	t	0.03	0.34	t	0.12	0.11	0.22	0.24
28 July [a]	--	--	--	--	--	--	--	--
11 August	t	0.19	0.19	0.02	0.22	0.19	0.19	0.25
25 August	t	0.18	0.29	t	0.32	0.30	0.13	0.21
8 September	t	0.10	0.21	t	0.31	0.50	t	0.28
22 September	t	0.21	0.36	t	0.38	0.32	0.07	0.32
12 October	t	0.13	0.21	t	0.29	0.15	0.09	0.31
2 November	t	0.23	0.18	t	0.39	0.29	0.17	0.24
20 November	t	0.14	0.10	t	0.31	0.22	0.20	0.21

[a] Equipment was unavailable
[b] t represents current velocities <0.01 m/sec

Table 18. Depth (m) measurements at each station on each sampling date in the Black River, 10 April through 20 November 1976.

DATE	1-N	1-S	2-N	2-S	3-N	3-S	4-N	4-S
10 April	0.50	0.60	0.50	1.35	0.25	0.50	0.50	1.20
19 May	0.45	0.60	0.45	0.60	0.35	0.70	0.55	1.50
2 June	0.30	0.50	0.30	0.50	0.20	0.20	0.30	1.50
16 June	0.30	1.00	0.30	1.00	1.50	1.00	0.50	1.75
30 June	0.20	0.50	0.20	0.50	1.25	0.75	0.25	1.50
14 July	0.20	0.50	0.20	0.50	0.85	0.55	0.12	1.10
28 July	0.30	1.05	0.30	1.05	0.80	0.60	0.25	1.10
11 August	0.30	0.80	0.30	0.80	0.80	0.40	0.15	1.10
25 August	0.30	0.35	0.55	0.95	0.80	0.15	0.20	1.05
8 September	0.15	0.75	0.45	0.80	0.65	0.25	0.07	0.85
22 September	0.15	0.75	0.50	0.90	0.60	0.22	0.20	0.90
12 October	0.17	0.70	0.50	0.95	0.55	0.22	0.15	0.93
2 November	0.20	1.00	0.55	0.95	0.55	0.30	0.20	0.95
20 November	0.20	0.75	0.70	0.95	0.65	0.35	0.25	0.95

Table 19. Mean and range for some chemical and physical parameters in the Black River for each sampling date, 10 April through 20 November 1976.

DATE	pH	ALKALINITY (mg/L $CaCO_3$)	CALCIUM HARDNESS (mg/L $CaCO_3$)	TOTAL HARDNESS (mg/L $CaCO_3$)
10 April	--	--	--	--
19 May	(6.74-6.88)	--	--	--
2 June	(7.38-7.67)	50.4 (40.6-60.0)	36.3 (29.2-47.2)	83.0 (48.8-99.2)
16 June	(7.92-8.16)	49.4 (37.4-70.7)	37.7 (30.4-48.8)	64.4 (50.0-89.2)
30 June	(8.35-8.44)	38.7 (32.2-51.0)	32.8 (31.2-35.2)	54.8 (51.2-60.8)
14 July	(8.49-9.09)	73.1 (65.5-83.2)	44.6 (36.0-56.4)	78.7 (58.2-114.0)
28 July	(8.36-8.83)	65.4 (47.8-93.6)	51.6 (33.2-78.8)	80.2 (53.6-128.8)
11 August	(8.94-9.38)	65.5 (47.8-92.6)	49.7 (32.4-74.8)	73.9 (53.2-110.4)
25 August	(8.64-8.84)	58.3 (55.1-61.4)	37.3 (34.0-40.8)	58.4 (54.8-62.8)
8 Sept.	(8.02-8.39)	60.3 (44.7-88.4)	48.0 (36.8-72.4)	73.7 (56.4-116.0)
22 Sept.	(6.64-6.97)	52.7 (47.8-60.0)	37.7 (34.8-44.0)	68.3 (62.0-76.4)
12 Oct.	(6.97-7.85	55.0 (51.7-58.9)	48.3 (37.6-78.4)	84.3 (69.6-119.2)
2 Nov.	(7.91-8.18)	55.8 (45.5-71.3)	57.9 (40.8-106.4)	87.8 (70.0-128.8)
20 Nov.	(6.71-7.07)	66.1 (50.6-99.2)	56.8 (38.8-78.4)	101.0 (71.6-133.6)

Table 19. (cont.)

DATE	NITRATE (mg/L NO_3-N)	NITRITE (mg/L NO_2-N)	ORTHO-PHOSPHOROUS (mg/L PO_4-P)
10 April	--	--	--
19 May	--	--	--
2 June	0.172 (0.135-0.212)	0.026 (0.021-0.033)	0.072 (0.057-0.088)
16 June	0.210 (0.189-0.232)	0.073 (0.068-0.077)	0.069 (0.067-0.073)
30 June	0.154 (0.146-0.158)	0.067 (0.062-0.072)	0.063 (0.061-0.067)
14 July	0.069 (0.003-0.222)	0.005 (0.002-0.010)	0.072 (0.046-0.112)
28 July	0.091 (0.005-0.227)	0.008 (0.004-0.019)	0.098 (0.074-0.139)
11 August	0.071 (0.002-0.239)	0.005 (0.001-0.014)	0.083 (0.068-0.124)
25 August	0.079 (0.005-0.220)	0.001 ((-0.001)	0.093 (0.068-0.117)
8 September	0.138 (0.100-0.186)	0.007 (0.006-0.008)	0.074 (0.058-0.092)
22 September	0.106 (0.073-0.142)	0.006 (0.005-0.006)	0.090 (0.084-0.094)
12 October	0.155 (0.132-0.221)	0.008 (0.006-0.011)	0.077 (0.058-0.103)
2 November	0.169 (0.139-0.242)	0.008 (0.006-0.010)	0.065 (0.060-0.079)
20 November	0.157 (0.129-0.230)	0.007 (0.007-0.008)	0.075 (0.068-0.086)

Table 19. (cont.)

DATE	WATER TEMPERATURE (°C)	DISSOLVED OXYGEN (mg/L)
10 April	8.5 (8.5)	--
19 May	15.8 (15.7-16.0)	7.1 (7.0-7.2)
2 June	21.1 (20.5-21.3)	6.8 (6.7-7.0)
16 June	20.8 (20.5-21.3)	7.8 (7.6-8.2)
30 June	22.8 (22.5-23.0)	9.4 (8.8-10.1)
14 July	28.0 (28.0)	8.2 (7.5-9.1)
28 July	24.6 (24.5-25.0)	9.2 (8.7-9.7)
11 August	25.3 (25.0-25.5)	9.1 (8.7-9.6)
25 August	24.0 (24.0)	8.2 (7.7-8.4)
8 September	20.0 (19.0-21.0)	7.6 (7.3-8.0)
22 September	11.5 (11.0-12.0)	8.0 (7.7-8.4)
12 October	14.0 (14.0)	9.4 (9.0-9.6)
2 November	6.3 (6.0-6.5)	10.1 (10.0-10.3)
20 November	0.0 (0.0)	10.3 (9.9-10.6)

Table 20. Mean relative density (%) for each class of algae represented in the Black River, 10 April through 20 November 1976.

PERIOD	BACILLARIOPHYCEAE	CHLOROPHYCEAE	MYXOPHYCEAE	DINOPHYCEAE
10 April-19 May	97.49	2.51	0	0
19 May-2 June	99.48	0.52	0	0
2-16 June	97.46	2.54	0	0
16-30 June	99.20	0.80	0	0
30 June-14 July	96.96	3.04	0	0
14-28 July	96.91	3.09	0	0
28 July-11 Aug.	96.76	3.24	0	t[a]
11-25 Aug.	96.53	3.47	0	0
25 Aug.-8 Sept.	96.36	3.64	0	0
8-22 Sept.	98.45	1.55	0	0
22 Sept-12 Oct.	97.01	2.99	t	0
12 Oct.-2 Nov.	98.51	1.49	t	0
2-20 Nov.	99.78	0.22	0	0
(mean)	(97.76)	(2.24)	(0)	(0)

[a] t <0.2% of the total

Table 21. Means and ranges for the numbers of identified taxa (species and varieties) at each station, 19 May through 20 November 1976.

STATION	NUMBERS
1-N	56 (45-90)
1-S	59 (33-75)
2-N	59 (42-70)
2-S	59 (48-69)
3-N	55 (47-68)
3-S	58 (21-68)
4-N	61 (42-89)
4-S	54 (22-77)

Table 22. Means and ranges for the numbers of identified taxa (species and varieties) for each sampling period, 10 April through 20 November 1976.

PERIOD	NUMBERS
10 April-19 May	80 (67-90)
19 May-2 June	56 (43-70)
2-16 June	56 (44-72)
16-30 June	61 (53-65)
30 June-14 July	61 (48-77)
14-28 July	60 (50-67)
28 July-11 August	65 (56-77)
11-25 August	63 (52-70)
25 August- 8 Sept.	64 (50-72)
8-22 Sept.	61 (48-69)
22 Sept.-12 Oct.	63 (49-71)
12 Oct.-2 Nov.	48 (33-59)
2-20 Nov.	39 (21-56)

Table 23. Rank and mean relative density of common[a] taxa in the Black River at station 1-N, 10 April through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	20.42
2	*Navicula cryptocephala*	16.49
3	*Melosira varians*	7.36
4	*Navicula exigua capitata*	5.20
5	*Nitzschia palea*	5.03
6	*Cocconeis placentula*	4.41
7	*Achnanthes lanceolata*	3.52
8	*Diatoma vulgare*	1.86
9	*Nitzschia linearis*	1.63
10	*Gomphonema angustatum producta*	1.62
11	*Cyclotella stelligera*	1.56
12	*Synedra ulna oxyrhynchus*	1.55
13	*Navicula viridula*	1.47
14	*Navicula hungarica capitata*	1.43
15	*Achnanthes lanceolata rostrata*	1.28
16	*Melosira italica*	1.04
	(total)	(75.87)

[a] commom refers to taxa with a mean relative density ≥ 1%

Table 24. Rank and mean relative density of common taxa in the Black River at station 1-S, 10 April through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Navicula cryptocephala*	17.49
2	*Melosira varians*	8.74
3	*Cocconeis placentula euglypta*	7.16
4	*Nitzschia palea*	4.82
5	*Achnanthes lanceolata*	4.66
6	*Navicula exigua capitata*	4.47
7	*Cyclotella stelligera*	3.81
8	*Cocconeis placentula*	2.89
9	*Diatoma vulgare*	2.11
10	*Achnanthes lanceolata rostrata*	2.16
11	*Gomphonema angustatum producta*	2.09
12	*Cyclotella atomus*	1.73
	Navicula viridula	1.73
14	*Navicula hungarica capitata*	1.71
15	*Melosira italica tennuissima*	1.55
16	*Synedra ulna oxyrhynchus*	1.42
17	*Nitzschia linearis*	1.34
18	*Melosira italica*	1.03
	(total)	(68.85)

Table 25. Rank and mean relative density of common taxa in the Black River at station 2-N, 10 April through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Navicula cryptocephala*	18.37
2	*Cocconeis placentula euglypta*	9.90
3	*Melosira varians*	6.16
4	*Achnanthes lanceolata*	5.82
5	*Nitzschia palea*	5.48
6	*Navicula exigua capitata*	4.08
7	*Cyclotella atomus*	3.89
8	*Cyclotella stelligera*	3.42
9	*Gomphonema angustatum producta*	2.77
10	*Cocconeis placentula*	2.54
11	*Achnanthes lanceolata rostata*	2.30
12	*Melosira italica*	2.11
13	*Navicula viridula*	2.02
14	*Diatoma vulgare*	2.83
15	*Melosira italica tennuissima*	1.61
16	*Navicula hungarica capitata*	1.23
17	*Nitzschia linearis*	1.14
18	*Synedra ulna oxyrhynchus*	1.08
	(total)	(75.75)

Table 26. Rank and mean relative density of common taxa in the Black River at station 2-S, 10 April through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	13.68
2	*Navicula cryptocephala*	8.66
3	*Melosira varians*	8.23
4	*Achnanthes lanceolata*	5.82
5	*Cocconeis placentula*	4.42
6	*Nitzschia palea*	4.39
7	*Navicula exigua capitata*	3.72
8	*Cyclotella stelligera*	3.25
9	*Cyclotella atomus*	2.41
10	*Melosira italica tennuissima*	1.90
11	*Achnanthes lanceolata rostrata*	1.87
12	*Nitzschia linearis*	1.82
13	*Diatoma vulgare*	1.64
14	*Navicula viridula*	1.54
15	*Synedra ulna oxyrhynchus*	1.37
16	*Melosira italica*	1.17
17	*Navicula hungarica capitata*	1.00
	(total)	(66.89)

Table 27. Rank and mean relative density of common taxa in the Black River at station 3-N, 10 April through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	17.61
2	*Navicula cryptocephala*	16.05
3	*Melosira varians*	7.56
4	*Cocconeis placentula*	5.32
5	*Achnanthes lanceolata*	4.23
6	*Nitzschia palea*	4.00
7	*Navicula exigua capitata*	3.29
8	*Diatoma vulgare*	2.50
9	*Cyclotella stelligera*	2.39
10	*Gomphonema angustatum producta*	2.04
11	*Synedra ulna oxyrhynchus*	1.95
12	*Achnanthes lanceolata rostrata*	1.63
13	*Nitzschia linearis*	1.59
14	*Melosira italica*	1.40
15	*Navicula hungarica capitata*	1.05
	(total)	(72.61)

Table 28. Rank and mean relative density of common taxa in the Black River at station 3-S, 10 April through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Navicula cryptocephala*	16.25
2	*Melosira varians*	10.31
3	*Cocconeis placentula euglypta*	7.18
4	*Diatoma vulgare*	5.96
5	*Cyclotella stelligera*	4.93
6	*Navicula exigua capitata*	4.92
7	*Nitzschia palea*	4.83
8	*Achnanthes lanceolata*	4.46
9	*Melosira italica*	3.11
10	*Cyclotella atomus*	2.51
11	*Melosira italica tennuissima*	1.99
12	*Cocconeis placentula*	1.98
13	*Achnanthes lanceolata rostrata*	1.75
14	*Navicula viridula*	1.39
15	*Synedra ulna oxyrhynchus*	1.23
16	*Nitzschia linearis*	1.02
	(total)	(73.82)

Table 29. Rank and mean relative density of common taxa in the Black River at station 4-N, 10 April through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	17.23
2	*Navicula cryptocephala*	12.71
3	*Melosira varians*	11.39
4	*Achnanthes lanceolata*	5.56
5	*Cocconeis placentula*	4.93
6	*Navicula exigua capitata*	3.32
7	*Nitzschia palea*	3.16
8	*Diatoma vulgare*	3.09
9	*Cyclotella stelligera*	3.08
10	*Cyclotella atomus*	2.52
11	*Achnanthes lanceolata rostrata*	2.30
12	*Melosira italica*	1.82
13	*Melosira italica tennuissima*	1.52
14	*Synedra ulna oxyrhynchus*	1.29
15	*Navicula viridula*	1.09
16	*Nitzschia linearis*	1.02
	(total)	(76.03)

Table 30. Rank and mean relative density of common taxa in the Black River at station 4-S, 10 April through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	14.19
2	*Navicula cryptocephala*	11.61
3	*Melosira varians*	10.40
4	*Diatoma vulgare*	6.52
5	*Cocconeis placentula*	5.34
6	*Achnanthes lanceolata*	4.21
7	*Nitzschia palea*	3.48
8	*Cyclotella stelligera*	2.91
9	*Navicula exigua capitata*	2.85
10	*Synedra ulna oxyrhynchus*	2.48
11	*Cyclotella atomus*	2.47
12	*Melosira italica tennuissima*	2.08
13	*Achnanthes lanceolata rostrata*	1.66
14	*Navicula hungarica capitata*	1.59
15	*Gomphonema angustatum producta*	1.50
16	*Melosira italica*	1.21
	(total)	(74.50)

Table 31. Rank and mean relative density of common taxa in the Black River during 10 April through 19 May 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Achnanthes lancoelata*	14.69
2	*Gomphonema angustata producta*	12.26
3	*Synedra rumpens familiaris*	5.30
4	*Synedra vaucheriae capitellata*	4.83
5	*Nitzschia palea*	3.64
6	*Gomphonema parvulum*	3.17
7	*Gomphonema angustatum*	3.15
8	*Achnanthes lanceolata rostrata*	3.11
9	*Achnanthes lanceolata ventricosa*	2.52
10	*Ulothrix* sp.	2.51
11	*Synedra rumpens*	1.95
12	*Eunotia lunaris*	1.94
13	*Navicula Rotaeana*	1.59
14	*Gomphonema olivaceum*	1.52
15	*Melosira varians*	1.36
	(total)	(63.54)

Table 32. Rank and mean relative density of common taxa in the Black River during 19 May through 2 June 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Achnanthes lanceolata*	21.00
2	*Achnanthes lanceolata rostrata*	7.38
3	*Nitzschia palea*	5.51
4	*Navicula cryptocephala*	5.24
5	*Gomphonema angustatum producta*	4.35
6	*Achnanthes lanceolata ventricosa*	3.52
7	*Navicula hungarica*	3.38
8	*Navicula hungarica capitata*	3.00
9	*Navicula exigua capitata*	2.84
10	*Melosira varians*	2.63
11	*Cyclotella meneghiniana*	2.45
12	*Melosira italica*	2.01
13	*Cocconeis placentula euglypta*	1.28
14	*Cocconeis placentula*	1.27
15	*Surirella ovata*	1.26
	(total)	(67.12)

Table 34. Rank and mean relative density of common taxa in the Black River during 16 through 30 June 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Melosira varians*	34.14
2	*Navicula cryptocephala*	15.69
3	*Nitzschia palea*	4.73
4	*Navicula exigua capitata*	3.40
5	*Cyclotella stelligera*	2.58
6	*Cyclotella atomus*	2.54
7	*Achnanthes lanceolata*	2.34
8	*Cocconeis placentula euglypta*	1.85
9	*Melosira italica*	1.62
10	*Cyclotella meneghiniana*	1.37
11	*Navicula hungarica capitata*	1.12
	(total)	(71.38)

Table 35. Rank and mean relative density of common taxa in the Black River during 30 June through 14 July 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	22.46
2	*Navicula cryptocephala*	10.83
3	*Cocconeis placentula*	7.14
4	*Melosira italica*	6.89
5	*Melosira varians*	6.44
6	*Achnanthes lanceolata*	3.88
7	*Navicula exigua capitata*	3.52
8	*Nitzschia palea*	3.11
9	*Melosira italica tennuissima*	3.03
10	*Cyclotella stelligera*	2.04
11	*Cyclotella atomus*	1.97
12	*Achnanthes lanceolata rostrata*	1.50
13	*Cladophora* sp.	1.26
	Pediastrum duplex	1.26
	(total)	(75.33)

Table 36. Rank and mean relative density of common taxa in the Black River during 14 through 28 July 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	39.53
2	*Navicula cryptocephala*	9.36
3	*Cocconeis placentula*	7.74
4	*Cyclotella atomus*	5.30
5	*Melosira italica tennuissima*	3.93
6	*Navicula exigua capitata*	3.87
7	*Melosira varians*	3.39
8	*Nitzschia palea*	3.22
9	*Cyclotella stelligera*	2.90
	Achnanthes lanceolata	2.90
11	*Melosira italica*	1.71
12	*Cladophora* sp.	1.54
13	*Achnanthes lanceolata rostrata*	1.30
14	*Navicula elginensis*	1.14
	(total)	(87.83)

Table 37. Rank and mean relative density of common taxa in the Black River during 28 July through 11 August 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	19.41
2	*Navicula cryptocephala*	8.75
3	*Cocconeis placentula*	8.14
4	*Cyclotella atomus*	6.36
5	*Nitzschia palea*	5.87
6	*Navicula exigua capitata*	5.67
7	*Cyclotella stelligera*	5.38
8	*Melosira italica tennuissima*	2.76
9	*Achnanthes lanceolata*	2.42
10	*Melosira italica*	2.04
11	*Achnanthes lanceolata rostrata*	1.86
12	*Melosira varians*	1.46
	Pediastrum duplex	1.46
	(Total)	(71.58)

Table 38. Rank and mean relative density of common taxa in the Black River during 11 through 25 August 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	26.33
2	*Navicula cryptocephala*	8.31
3	*Cocconeis placentula*	7.97
4	*Cyclotella stelligera*	7.28
5	*Nitzschia palea*	5.39
6	*Navicula exigua capitata*	5.04
7	*Cyclotella atomus*	3.38
8	*Melosira italica tennuissima*	3.08
9	*Melosira italica*	1.91
10	*Achnanthes lanceolata*	1.81
11	*Navicula viridula*	1.59
12	*Pediastrum duplex*	1.55
13	*Melosira varians*	1.41
14	*Achnanthes lanceolata rostrata*	1.16
	(total)	(76.21)

Table 39. Rank and mean relative density of common taxa in the Black River during 25 August through 8 September 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	27.48
2	*Navicula cryptocephala*	8.47
3	*Navicula exigua capitata*	6.43
4	*Cocconeis placentula*	6.08
5	*Nitzschia palea*	5.05
6	*Cyclotella stelligera*	4.77
7	*Navicula viridula*	2.30
8	*Achnanthes lanceolata*	1.96
9	*Melosira italica tennuissima*	1.91
10	*Melosira varians*	1.45
11	*Cyclotella atomus*	1.13
12	*Pediastrum duplex*	1.11
13	*Nitzschia amphibia*	1.09
14	*Stigeoclonium* sp.	1.04
	(total)	(70.27)

Table 40. Rank and mean relative density of common taxa in the Black River during 8 through 22 September 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Cocconeis placentula euglypta*	21.36
2	*Navicula cryptocephala*	15.71
3	*Navicula exigua capitata*	7.81
4	*Nitzschia palea*	6.18
5	*Navicula viridula*	5.22
6	*Cocconeis placentula*	3.98
7	*Cyclotella stelligera*	3.52
8	*Achnanthes lanceolata*	1.78
9	*Nitzschia linearis*	1.75
	Melosira varians	1.75
11	*Melosira italica tennuissima*	1.39
12	*Melosira italica*	1.33
13	*Achnanthes lanceolata rostrata*	1.31
14	*Navicula hungarica capitata*	1.30
15	*Nitzschia amphibia*	1.11
16	*Cyclotella atomus*	1.05
	(total)	(76.55)

Table 41. Rank and mean relative density of common taxa in the Black River during 22 September through 12 October 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Navicula cryptocephala*	28.41
2	*Melosira varians*	6.75
3	*Nitzschia palea*	5.50
4	*Nitzschia linearis*	5.13
5	*Navicula viridula*	4.18
6	*Cocconeis placentula euglypta*	4.03
7	*Navicula exigua capitata*	3.94
8	*Cymbella tumida*	3.67
9	*Cyclotella stelligera*	3.62
10	*Synedra ulna oxyrhynchus*	2.63
11	*Achnanthes lanceolata*	1.70
12	*Navicula hungarica capitata*	1.19
13	*Nitzschia amphibia*	1.17
	(total)	(75.95)

Table. 42. Rank and mean relative density of common taxa in the Black River during 12 October through 2 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Navicula cryptocephala*	53.26
2	*Melosira varians*	12.26
3	*Synedra ulna oxyrhynchus*	6.71
4	*Diatoma vulgare*	5.22
5	*Nitzschia palea*	2.86
6	*Nitzschia linearis*	2.22
7	*Cymbella tumida*	2.20
8	*Navicula exigua capitata*	1.41
	(total)	(86.14)

Table 43. Rank and mean relative density of common taxa in the Black River during 2 through 20 November 1976.

RANK	TAXON	RELATIVE DENSITY (%)
1	*Diatoma vulgare*	32.30
2	*Navicula cryptocephala*	18.03
3	*Melosira varians*	13.17
4	*Synedra ulna oxyrhynchus*	9.42
5	*Nitzschia palea*	3.12
6	*Navicula exigua capitata*	2.57
7	*Navicula viridula*	1.60
8	*Cocconeis placentula*	1.52
9	*Nitzschia amphibia*	1.23
	(total)	(82.96)

Table 44. Mean autotrophic indices for each sampling period in the Black River, 10 April through 20 November 1976.

PERIOD	AUTOTROPHIC INDEX
10 April-19 May	4592
19 May-2 June	803
2-16 June	1458
16-30 June	1200
30 June-14 July	2662
14-28 July	2553
28 July-11 August	2949
11-25 August	4272
25 August-8 September	5371
8-22 September	1745
22 September-12 October	945
12 October-2 November	254
2-20 November	405